Water Erosion

Overview of Water Erosion

The Agricultural Research Service (ARS) has primary responsibility for erosion prediction research within the U.S. Department of Agriculture (USDA). ARS is the lead agency for developing erosion prediction technology, including the Revised Universal Soil Loss Equation (RUSLE). The technology in RUSLE is documented to the publication Predicting Soil Erosion by Water: A Guide to Conservation Planning With Revised Universal Soil Loss Equation, U.S. Department of Agriculture Handbook 703, hereafter referred to as Agriculture Handbook 703.

Forms of water erosion

Forms of soil erosion by water include sheet and rill, ephemeral gully, classical gully, and streambank. Each succeeding type is associated with the progressive concentration of runoff water into channels as it moves downslope. Sheet erosion, sometimes referred to as interrill erosion, is the detachment of soil particles by raindrop impact and the removal of thin layers of soil from the land surface by the action of rainfall and runoff. Rill erosion is the formation of small, generally parallel channels formed by runoff water. Rills usually do not re-occur in the same place. Ephemeral gullies are concentrated flow channels formed when rills converge to form shallow channels. They are alternately filled with soil by tillage operations and re-formed in the same general location by subsequent runoff events. Classical gullies are also concentrated flow channels formed when rills converge. These are well defined, permanent incised drainageways that cannot be crossed by ordinary farming operations.

Other forms of erosion that are related to soil erosion by water include stream channel and geologic. Stream channel erosion refers to the degradation of channels and waterways. Geologic erosion refers to long-term erosion effects, as opposed to accelerated erosion events discussed in this Subpart.

No reliable methods exist for predicting the rate of ephemeral gully, classical gully, stream channel, or geologic erosion. The remainder of this part deals only with prediction and control of sheet and rill erosion.

The water erosion process

The processes of sheet and rill erosion are detachment, transport and deposition of soil particles caused by raindrop impact and surface runoff. Detachment is the removal of particles from the soil mass and is expressed in units, such as tons per acre. When soil particles are removed from the mass, they are referred to as sediment.

The movement of sediment downslope is sediment transport. A measure of sediment transport is sediment load. Sediment load on a slope increases with distance downslope as long as detachment is occurring. That is, detachment adds to the sediment load.

Where runoff is slowed at the base of a slope or by dense vegetation, deposition occurs, which is the transfer of sediment from the sediment load to the soil mass. That is, deposition removes sediment from the sediment load, and accumulates on the soil surface.

Two types of deposition, remote and local occur. Remote deposition occurs some distance away from the origin of the sediment. Deposition at the toe of a concave slope, on the uphill side of vegetative strips, and in terrace channels are examples of remote deposition. Local deposition is where sediment is deposited near, within several inches, of where it is detached. Deposition in microdepressions and in low gradient furrows are examples of local deposition.

Estimating sheet and rill erosion

How, why, and by whom water erosion is estimated

NRCS estimates soil erosion by water as part of its technical assistance to land users. In conservation planning, erosion estimates are made for an existing management system and compared with alternative systems and with soil loss tolerance, T, values.

In addition, soil loss estimates are used to inventory natural resources, evaluate the effectiveness of conservation programs and land treatment, and estimate sediment production from fields that might become sediment yield in watersheds.

In March 1995, NRCS adopted RUSLE as the official tool for predicting soil erosion by water. NRCS continues to use USLE for certain provisions of Farm Bill programs and for the NRCS National Resources Inventory (NRI).

Methods of estimating sheet and rill erosion

Efforts to predict soil erosion by water started in the 1930's. Cook (1936) identified the major variables that affect erosion by water. Zingg (1940) published the first equation for calculating field soil loss. Smith and Whitt (1947) presented an erosion-estimating equation that included most of the factors present in modern soil loss equations. The Musgrave equation (Musgrave 1947) was a soil loss equation developed for farm planning. Finally, an effort was initiated to develop a national equation from the various state and regional equations that existed in the 1950's. In 1954, the Agricultural Research Service established the National Runoff and Soil Loss Data Center at Purdue University in West Lafayette, Indiana, to consolidate all available erosion data. Using the data assembled at the Data Center, Wischmeier and Smith (1965) developed the Universal Soil Loss Equation (USLE).

The USLE was a consolidation of several regional soil loss equations, and was based on summarizing and statistical analyses of more than 10,000 plot-years of basic runoff and soil loss data from 49 U.S. locations (Agriculture Handbook 703, 1997; Wischmeier and Smith 1965, 1978).

The USLE was designed to provide a convenient working tool for conservationists. It quantifies soil erosion as a product of six factors representing rainfall and runoff erosiveness, soil erodibility, slope length, slope steepness, cover-management practices, and supporting practices.

The Revised Universal Soil Loss Equation

Since March 1995, the Revised Universal Soil Loss Equation (RUSLE) has been used by NRCS to estimate soil loss by water (Agriculture Handbook 703.).

RUSLE predicts long-term average annual soil loss from sheet and rill erosion. RUSLE is an update of the Universal Soil Loss Equation (USLE) as described in Agriculture Handbook 537(Wischmeier and Smith 1978). RUSLE utilizes a computer program to facilitate the calculations and the analysis of research data that were unavailable when Agricultural Handbook 282 (Wischmeier and Smith 1965) and Agriculture Handbook 537 were completed.

Limitations of the equation

The term *Universal* distinguishes the USLE and RUSLE from State and regionally based models that preceded them. However, the use of the USLE and RUSLE is limited to situations where factors can be accurately evaluated and to conditions for which they can be reliably applied (Wischmeier 1978; Agriculture Handbook 703, 1997).

RUSLE predicts long-term average annual soil loss carried by runoff from specific field slopes under specified cover and management systems. It is substantially less accurate for the prediction of specific erosion events associated with single storms and short-term random fluctuations.

RUSLE also estimates sediment yield for the amount of eroded soil leaving the end of a slope with certain support practices. It does not predict sediment yield for the amount of sediment that is delivered to a point in a watershed, such as the edge of a field, that is remote from the origin of the detached soil particles. Nor does RUSLE predict erosion that occurs in concentrated flow channels.

Alternative methods of applying RUSLE

ARS released RUSLE in 1992 as a computer program in the DOS environment. The model calculates soil loss from a field slope using values for each factor and using data elements from climate, plant, and field operation databases.

Since 1996, RUSLE has been implemented in Texas NRCS field offices in hardcopy form in the Field Office Technical Guide (FOTG). State and area agronomists have developed tables and charts containing values for each of the RUSLE factors. NRCS will continue to implement RUSLE technology using charts and tables in the FOTG.

Data needed to support RUSLE

RUSLE uses soil erodibility, K, values from the NASIS Soils Database. Climatic data is obtained from National Weather Service weather stations with reliable long-term data. State and area agronomists have developed cover and management factor, C, values for common cropping systems.

The crop database in the DOS RUSLE program contains plant growth and residue production parameters. These variables for key crops are listed in chapter 7 of Agriculture Handbook 703. Values for many of these parameters are available in a database for a wide variety of plants. A user interface, the Crop Parameter Intelligent Data System (CPIDS) (Deer-Ascough et al. 1995), allows the user to search the data base. The USDA, ARS, National Soil Erosion Research Laboratory, West Lafayette, Indiana, maintains CPIDS.

Development and maintenance of data bases used by NRCS in erosion prediction models are the responsibility of NRCS agronomists at the State and national levels. The national agronomist maintains a data base management plan that identifies the process of developing and maintaining data bases needed to support RUSLE.

Tools for using RUSLE

Maps of rainfall and runoff factors, R and R_{eq} for the continental United States plus Hawaii are available in Agriculture Handbook 703, figures 2-1 to 2-5 and figures 2-15 and 2-16. Additional climate-related data and inputs are available in this chapter. Most states and Basin Areas have developed county-based climatic maps for their areas. These contain the greater detail that is desired when applying RUSLE to specific field situations, and are available in NRCS State offices.

Soil erodibility factor, K, values for RUSLE are available in the NASIS Soils Database and in other soils databases and tables. In areas of the United States where K values are adjusted to account for seasonal variability, (Agriculture Handbook 703) tables are available in State offices that show how the values are rounded to the nearest class and subclass.

Four slope length and steepness, L and S, table options are available in RUSLE. LS values can be obtained from tables 4-1 to 4-4 in Agriculture Handbook 703. The RUSLE computer program also calculates LS factor values for both uniform and complex slopes.

Cover and management factor, C, values are available in the local county Field Office Technical Guide. Hardcopy tables are also available in the Texas State office.

Support practice factor, P, values are calculated using tables available in the FOTG in Texas. Copies, where available, can be obtained from the local county field office and the State office.

RUSLE factors

The average annual soil loss estimate, A

The long time average annual soil loss, A, is the computed spatial average soil loss and temporal average soil loss per unit of area, expressed in the units for K and for the period selected for R.

As applied by NRCS, the units for K and the period for R are selected so that A is expressed in tons per acre per year. RUSLE predicts the soil loss carried by runoff from specific field slopes in specified cover and management systems.

The rainfall and runoff erosivity factor, R

The rainfall and runoff erosivity factor, R, is the product of total storm energy times the maximum 30-minute intensity. Stated another way, the average annual total of the storm energy and intensity values in a given location is the rainfall erosion index, R, for the locality. The R factor represents the long-term average annual summation of the Erosivity Index (EI) for an extended period of record.

The soil erodibility factor, K

The soil erodibility factor, K, is a measure of erodibility for a standard condition. This standard condition is the unit plot, which is an erosion plot 72.6 feet (22.1 m)long on a 9percent slope, maintained in continuous fallow, tilled up and down hill periodically to control weeds and break crusts that form on the soil surface. The erodibility factor K represents the combined effect of susceptibility of soil to detachment, transport of sediment and the amount and rate of runoff caused by a particular rainfall event. Soil properties that affect soil erodibility include texture, structure, permeability and organic matter content. Values for K should be selected from those given in the NRCS soil survey database in NASIS or in published reports. The RUSLE soil erodibility nomograph can also be used to estimate K values for most soils. Soil erodibility K varies by season. It tends to be high in early spring during and immediately following thawing, and other periods when the soil is wet.

Rock fragments in the soil profile affect the soil erodibility factor 1/ . The K value is adjusted upwards to account for rock fragments in the soil profile of sandy soils that reduce infiltration. No adjustment to the K value is recommended by NRCS for rocks in the pro-file of medium and heavy textured soils.

The slope length and steepness factors, L and S

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

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

In erosion prediction as used by NRCS, the factors L and S are evaluated together, and LS values for uniform slopes can be selected from tables 4-1, 4-2, 4-3, and 4-4 in Agriculture Handbook 703.

The slope length is defined as the horizontal distance from the origin of overland flow to the location of either concentrated flow or deposition. Slope lengths normally do not exceed 400 feet because sheet and rill flows will almost always coalesce into concentrated flow paths within that distance. Lengths longer than 1,000 feet should not be used in RUSLE.

Slope length and steepness determinations are best made in the field. In conservation planning, the hillslope profile representing a significant portion of the field having the most severe erosion is often chosen. Slope lengths are best determined by pacing out flow paths and making measurements directly on the ground. Steep slopes should be converted to horizontal distances. Slope steepness determinations are best (1/ Rock fragments on the soil surface are accounted for in the C factor.) made in the field using a clinometer, Abney level or similar device. Chapter 4, Agriculture Handbook 703 contains additional guides for choosing and measuring slopes.

Most naturally occurring hillslope profiles are irregular in shape. When the slope profile is significantly curved (convex or concave, or sigmoid.convex at the shoulder and concave at the toe), the conservationist should represent it as a series of slope segments, using the irregular slope procedure in the RUSLE computer program.

The cover-management factor, C

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

The C factor is used most often to compare the relative impacts of management options on conservation plans. The impacts of cover and management on soil losses are divided into a series of subfactors in RUSLE. These include the impacts of previous vegetative cover and management, canopy cover, surface roughness and in some cases the impact of soil moisture.

In RUSLE, these subfactors are assigned values, and when multiplied together yield a soil loss ratio (SLR). Individual SLR values are calculated for each period over which the important parameters are assumed to remain constant. Each SLR value is then weighted by the fraction of rainfall and runoff erosivity, EI, associated with the corresponding period, and these weighted values are combined (summed) into an overall C factor value.

The source of the list of individual C factors for specific areas of Texas is the local NRCS field office.

The support practice factor, P

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

The contour P subfactor accounts for the beneficial effects of redirected runoff that then modifies flow pattern because of ridges or oriented roughness that are partially or completely oriented along the contour.

The contour P subfactor includes the effects of storm severity, ridge height, off-grade contouring, slope length and steepness, infiltration, and soil cover and roughness.

The stripcropping P subfactor is a support practice where strips of clean-tilled or nearly clean-tilled crops are alternated with strips of close growing vegetation, or strips with relatively smooth tilled soil surfaces are alternated with strips with rough tilled surfaces.

The stripcropping P subfactor evaluates what are variously described as contour stripcropping, cross-slope stripcropping, field stripcropping, buffer strips and vegetated filter strips.

Terraces in RUSLE are support practices where high and large ridges of soil are constructed across the slope at intervals. These ridges and their accompanying channels intercept runoff and divert it around the slope or into a closed outlet. Terraces can affect sheet and rill erosion by reducing slope length and cause deposition in the terrace channel.

Tile drainage, under optimum conditions, can reduce erosion by reducing runoff. Because of a lack of support data, NRCS does not use the tile drainage subfactor in RUSLE, except in the Willamette Valley in the Oregon and Puget Sound basin in Washington.

In addition to the support practice factor, P, used in conservation planning, RUSLE estimates sediment yield for contour strips and terraces. The sediment yield, or delivery ratio, used in RUSLE is the ratio to the amount of sediment leaving the end of the slope length to the amount of sediment produced on the slope length.

Principles of water erosion control

Overview of principles

The principle factors that influence soil erosion by water are climate, soil properties, topography, vegetative cover, and conservation practices. Climate and soil properties are conditions of the site and are not modified by ordinary management measures. Conservation treatment primarily involves manipulation of vegetative cover, modification of topography, and manipulation of soil conditions in the tillage zone.

The greatest deterrent to soil erosion by water is vegetative cover, living or dead, on the soil surface. Cover and cultural practices influence both the detachment of soil particles and their transport. Growing plants and plant residue absorb the energy of rain-drops, decrease the velocity of runoff water, and help create soil conditions that resist erosion. Cultural practices that affect vegetative cover include crop rotations, cover crops, management of crop residue, and tillage practices.

Relation of control to RUSLE factors

In conservation planning, the cover and management factor, C, and the support practices factor, P, can be manipulated in RUSLE to develop alternatives for erosion reduction. In addition, where slope length is reduced with some terrace and diversion systems, the slope length and steepness factor, LS, will be reduced.

Using RUSLE technology, estimates of erosion reduction are illustrated in the subfactors of factor C. Benefits to erosion control are achieved in the:

- prior land use subfactor by increasing the mass of roots and buried residue and increasing periods since soil disturbance,
- canopy cover subfactor by increasing the canopy cover of the field area and low raindrop fall height from the canopy,
- surface cover subfactor by increasing the ground cover of plant residue, and by permanent cover such as rock fragments,
- surface roughness subfactor by increasing the random surface roughness that ponds water, and thereby reduces the erosive effect of raindrops and traps sediment.

When support practices are applied, they become integral parts of a resource management system for controlling soil erosion by water. Contour farming, contour stripcropping, and conservation buffers form ridges on or near the contour that slow runoff and trap sediment. Terraces and diversions intercept concentrated runoff flows and, in many cases, shorten the length of slope.

Some erosion control practices, such as grassed waterways and water control structures, do not substantially reduce sheet and rill erosion. While these can be effective erosion control practices in a resource management system, they are not a part of the soil loss reduction that is estimated by RUSLE.

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