APPLICATION OF REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE) TO MISSISSIPPI

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INTRODUCTION

Sheet and rill erosion of soil caused by rainfall and associated surface runoff is a major problem throughout Mississippi. The climate is very erosive because of the amount and intensity of rainfall, the soils tend to be highly erodible, and the major crops of cotton and soybeans provide inadequate cover to protect against excessive erosion. Average annual soil loss on the moderately steep slopes in the upland areas of Mississippi can be as high as 88 tons/acre-year under fallow conditions (McGregor et al. 1969). Average annual soil loss can be as high as 41 tons/acre-year with cotton, using no special conservation measures (Mutchler et al. 1985). Even when corn residues are left on the ground after harvest, average annual soil loss with corn grown up-and-downhill on these moderately steep slopes can be as high as 11 tons/acre-year (McGregor et al. 1969; McGregor et al. 1982). On the very gentle slopes in the Mississippi Delta, average annual soil loss from cotton land can be as high as 8 tons/acre-year (Murphree et al. 1976). These rates of soil loss are much in excess of established soil loss tolerance limits that range from 3 to 5 tons/acre-year.

Federal legislation, passed in 1985 and 1990, requires erosion control on lands susceptible to high erosion in order to maintain eligibility for participation in certain federal agricultural support programs. Erosion is not easily measured and varies greatly depending on the cropping-management system, climate, soil, and topography. Thus erosion prediction is a valuable tool for conservationists and farmers in identifying sites where erosion potential is excessive. Erosion prediction also is valuable for designing an erosion control system that especially is tailored to the conditions of specific sites. The Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) has long been used by the Natural Resources Conservation Service (NRCS) and soil and water conservation districts for these purposes in conservation planning.

The USLE recently was revised and released as the Revised Universal Soil Loss Equation (RUSLE) by the USDA-Agricultural Research Service (ARS), NRCS, and cooperators through the Soil and Water Conservation Society (Renard et al. 1995a). RUSLE is a significant advancement and improvement over the USLE. This paper describes some of these improvements and gives some example applications for Mississippi.

BACKGROUND ON RUSLE

The equation form of RUSLE is the same as that of the USLE, and is:

$$A = R\ K\ L\ S\ C\ P \qquad [1]$$

where: A is the average annual soil loss by sheet and rill erosion (tons/acre-year); R is the rainfall erosivity factor; K is the soil erodibility factor; LS is the combined slope length and steepness factors; C is the cover-management factor; and P is the support practices factor. Soil loss is computed by assigning a value to each of the factors based on site-specific conditions. RUSLE is empirically based, having been derived from a large data-base collected at more than 50 locations across the United States. The factors in RUSLE represent the influence of the four major factors that affect sheet and rill erosion: climate, soil, topography, and land use. The influence of land use is most important because it is the one that can be modified in farming operations to reduce erosion to acceptable levels.

R - Rainfall Erosivity

The two most important variables affecting the erosivity of a rainstorm are amount and intensity of rainfall. The R factor in RUSLE is a measure of these two effects on an average annual basis. The erosivity of a single storm is the product of the total kinetic energy (E) of the storm, which is a function of rainfall amounts and rainfall intensities throughout each storm as well as the storm's maximum 30-

minute rainfall intensity (I_{30}). Erosivity values in Mississippi range from a low of 300 in the north to a high of 600 in the south. If the product of other factors in RUSLE is the same for these locations, soil loss at a southern location is about two times the soil loss at a northern location because of erosivity differences.

Another important component of R is the distribution of erosivity during the year. The interaction of the distribution of erosivity during the year with the distribution of cover during the year can have a great effect on erosion. For example, erosion is much greater with corn in Ohio on a relative basis than with wheat because rainfall is concentrated in the late spring and early summer when cover is sparse with corn but is dense for maturing wheat. This interaction effect between erosivity and cover distributions is much less important in Mississippi than in other regions because erosivity in Mississippi is relatively uniform.

Before development of RUSLE was initiated in 1985, very little data on rainfall erosivity existed for the western United States. Rainfall data from more than 1000 stations were analyzed to develop erosivity maps for this region (Renard et al. 1995b). No similar analysis was carried out for the eastern United States because developers of RUSLE judged that erosivity values computed using rainfall data collected between about 1935 and 1955 for the USLE would not differ much from values computed with more recent data. That assumption may have been incorrect because analysis of data at the Mississippi locations of Oxford, Batesville, and Holly Springs showed that erosivity values are about 30 percent larger than values computed with the early data (McGregor and Mutchler 1977; McGregor et al. 1980; and McGregor et al. 1993). These results indicate that a comprehensive effort, comparable to that used to develop erosivity values for the western United States, should be made for the eastern United States.

An improvement in RUSLE of particular significance in Mississippi is the reduction of the R factor for very small slopes, like those in the Delta. Erosivity is reduced as a function of slope steepness and severity of the 10-year-return storm. The concept is that flow is much deeper on nearly flat slopes and more "ponded" in comparison to flow on steep slopes (Mutchler and McGregor 1983). Ponded water acts as a "cushion," dramatically reducing the erosivity of impacting raindrops. The effect in RUSLE is that erosivity at Yazoo City for a slope of 0.2 percent is about 64 percent of the erosivity for a six percent slope, a slope so steep that no adjustment would be made. For cropping management systems involving high beds, RUSLE does not use this reduction in erosivity because much of the soil is directly exposed to raindrop impact.

K - Soil Erodibility Factor

The soil erodibility factor is a measure of soil erodibility under the standard test conditions of a unit plot, which is 72.6 ft long on a 9 percent slope, maintained in continuous fallow, and periodically tilled up and down hill to break the crust and to control weeds. No changes were made between the USLE and RUSLE in defining K or the base values for K. However, Mutchler and Carter (1983) used data from Holly Springs, Mississippi, and Morris, Minnesota, to show that soil erodibility can vary greatly during the year. Erodibility tends to be greatest when soil moisture is high in the spring and lowest in late summer and early fall when soil moisture is low and microbial activity during the warm months has produced organic compounds that decrease soil detachability.

RUSLE computes an adjustment in the base K value to account for seasonal variability in erodibility. This adjustment is made by combining variable erodibility and erosivity distributions. This adjustment is not as great in Mississippi as in many other regions. For example, percent erosivity around Holly Springs, Mississippi, ranges from only 2 to 6 percent of the annual erosivity during any two week period during the year, whereas percent of annual erosivity at St. Louis, Missouri, ranges from 1 to 11 percent. The erodibilty for a silty clay loam soil in Mississippi may range from 0.22 in July to 0.54 in January as compared to a minimum of 0.16 in September and a maximum value of 0.76 in Missouri. Because of the uniform rainfall, the adjustment in the base K value in Mississippi for the silty clay loam soil would only decrease by about 5 percent as compared to an 18 percent decrease in Missouri.

LS - Topographic Factor

The LS factor represents the influence of topography on soil erosion, primarily as represented through the effect of slope length and steepness. RUSLE applies to a hillslope profile, which is defined as the length between the origin of overland flow and the location where the runoff enters concentrated flow or where deposition begins. Obviously many different profiles exist in a field. A representative profile or one where erosion is especially severe is used to develop a conservation plan. An alternative is to use several profiles over the field, which can be done in conjunction with different farming techniques used within a field.

For RUSLE, major improvements were made in the LS relationships. One is that the relation of soil loss to slope steepness is linear in comparison with the quadratic relationship in the USLE, which gave a much too large soil loss for slopes steeper than 30 percent (McCool et al.

1987). Another is that the linear relationship breaks at 9 percent. The slope effect for these steepnesses less than 9 percent is lower and corresponds to data collected in the Mississippi Delta by Murphree and Mutchler (1981).

The slope length factor is a function of the ratio of rill to interrill erosion (Foster et al. 1977). Rill erosion is erosion primarily caused by flow. Interrill erosion is erosion primarily caused by raindrop impact. On steep slopes, erosion increases much more rapidly with increased slope length than on very small slopes like those in the Delta and upland flood plains. On slopes less than one percent, erosion is hardly affected by slope length because most of the erosion is by raindrop impact rather than by flow. Research in Mississippi on 0.2 percent slopes confirmed the small effect of slope length on erosion of low slopes (Mutchler and Greer 1980). As a result, not much concern needs to be given to slope length on nearly flat slopes.

Although an analysis procedure for irregular slopes (varying steepness throughout the slope length) has been available for 20 years (Wischmeier and Smith 1978), it was seldom used. The computerized RUSLE makes this procedure useable for field office locations. Use of the irregular slope procedure is of particular importance on convex slopes that have a very steep section near the end of the slope.

C - Cover-Management Factor

Some C factor improvements in RUSLE include the use of subfactors to evaluate the effects of various parameters; the capability to compute the effects of multiple crops, weeds and tillage implements; and the ability to be more representative of no-till conservation systems utilizing a larger data base including more information on crop canopy, root biomass, and plant characteristics. The C factor, which represents the influence of cover and management, is perhaps the single most important factor in RUSLE because it is the main factor that can be varied to represent alternative land use systems that affect erosion. The P factor, which represents support practices, also can be varied, but it has fewer alternative variations to consider than with the C factor. Because RUSLE is a highly empirical equation, a large data base is required to develop C factor values. Although erosion data are extensive for the major crops, data often are not available for minor field crops or for vegetable crops.

Current USDA regulations require application of erosion predictions to much broader conditions than when conservation programs were voluntary. Obtaining experimental data for all cases where RUSLE would be applied is not feasible. Thus a method was needed that would allow users to apply RUSLE to a much broader range of conditions than was represented by the bulk of existing experimental data.

Separate subfactors of the C factor are used in RUSLE to account for the effects of canopy, ground cover, surface roughness, below ground biomass, soil consolidation, and soil moisture. This approach was first used by Wischmeier (1975) to apply the USLE to undisturbed land. Mutchler et al. (1982) developed a subfactor method to compute C factor values for cotton in Mississippi. The subfactor method has been adapted in RUSLE to apply to many land uses, including cropland, rangeland, construction sites, and disturbed forest land.

The subfactor approach allows RUSLE to compute the effect of a wide variety of tillage implements on soil loss. Many different implements are now being sold specifically to help farmers meet conservation requirements. Different implements leave different amounts of residue on the surface, different degrees of surface roughness and pulverization, and residue roots from last year's crop buried at different depths.

RUSLE provides the capability of analyzing the effect of multiple crops or cover systems during the year. In Mississippi, this capability is an important improvement of RUSLE over the USLE, allowing representation of the effect of winter plant growth, double-cropping of soybeans following wheat, and the prevalent growth of weeds. Winter weeds act as a cover crop, significantly reducing erosion during erosive rain events during the winter months (McGregor and Mutchler 1983).

No-till has become an important conservation practice for meeting the compliance requirements of federal legislation. The USLE has been strongly criticized for over-estimating soil loss from no-till cropping. As a part of the development of RUSLE, an extensive data base for conservation tillage was assembled and analyzed. Much of the data came from studies at Holly Springs, Mississippi (McGregor 1978; McGregor et al. 1975; McGregor and Mutchler 1983; Mutchler and Greer 1984; Mutchler et al. 1985; Mutchler and McDowell 1990; and McGregor and Mutchler 1992). RUSLE computes soil loss for no-till that is about 50 percent of that estimated by the USLE. When the effect of winter annuals is included in the computations, RUSLE no-till soil loss computations can be as much as 80 percent less than USLE computations. This improved accuracy in RUSLE may allow farmers to avoid having to install much more extensive and expensive conservation practices.

RUSLE can compute the effect of different plant communities by considering protection of the surface cover by canopy and the amount and distribution of root biomass in the soil. The main plant characteristic affecting soil loss is residue ground cover, which RUSLE estimates from crop yield and loss of residue by decomposition as a function of rainfall, temperature, and plant residue characteristics. Plant characteristics are available for the major field crops (SWCS 1993), but characteristic data for other crops are limited. Where data are limited, plant characteristic values are inferred by comparison between crops. Alcorn State University has a major project in cooperation with NRCS and ARS to collect these data for vegetable crops. Similar studies are underway in Alabama and North Carolina.

P - Support Practices Factor

Contouring, terracing, and strip-cropping are effective erosion control practices. These practices also are used to support cultural practices like crop rotations and conservation tillage. Although use of crop residues effectively reduce erosion, crops like soybeans and cotton without a cover crop do not always produce sufficient residue to control erosion in Mississippi (Mutchler and McDowell 1990). A support practice, when used in conjunction with a conservation tillage system, may be sufficient to maintain soil losses below tolerance limits.

The most frequently used support practice is contouring. Contour tillage usually is not exactly on the contour because of inconvenience to farming operations and because irregular topography often makes exact contours impossible. RUSLE, based on data collected at Holly Springs, Mississippi (McGregor et al. 1969; Mutchler et al. 1994), computes the loss of effectiveness of contouring as contour tillage deviations increase. In addition, RUSLE computes effectiveness of contouring as a function of ridge height, expected storm severity, and cover-management condition. RUSLE also computes the critical slope length where contouring loses its effectiveness as a function of these same variables. This capability did not exist with the USLE. Thus RUSLE computes less effectiveness in general for contouring in Mississippi than did the USLE because of the severity of erosive rains. Offsetting this loss is the capability to show greater effectiveness of the ridge tillage system with RUSLE than was possible with the USLE.

Buffer strips are being tried in northern Mississippi to eliminate every other terrace in terrace-type conservation systems. If this system performs satisfactorily, cost of terrace systems can be significantly reduced. Also, narrow grass hedges are being evaluated as an alternative to terraces (McGregor and Dabney 1993). RUSLE uses a method based on fundamental erosion mechanics to compute the effectiveness of strip-type systems. A major benefit of strip systems involving a strip of grass is that significant amounts of coarser sediment being transported by the runoff is deposited in the ponded water on the upper side of the strip.

Nearly all data on strip crop systems were collected in the 1930-1950s before modern conservation tillage systems became available. One of the key questions that can be answered by existing data is whether strips are as effective with no-till and low erosion rates as with conventional tillage that allows high erosion. Research is underway at Holly Springs by the National Sedimentation Laboratory to answer this specific question (McGregor et al. 1995). Thus, a process-based approach was used in RUSLE to ensure that it could be applied to a wide range of strip systems even though experimental data were not available for them.

AVAILABILITY AND IMPLEMENTATION OF RUSLE

The RUSLE computer program, background documentation, and user guides (Renard et al. 1995) are available for purchase from the Soil and Water Conservation Society (SWCS) in Ankeny, Iowa. RUSLE is being distributed by the SWCS under the authority of a Cooperative Research and Development Agreement with the USDA-Agricultural Research Service.

The USDA-Natural Resources Conservation Service (NRCS) is in the process of implementing a "paper version" of RUSLE in the field offices. This version will be used much as the USLE was used, but with new factor values based on RUSLE. In addition, the NRCS is including RUSLE in computer systems that are currently being developed for use in field offices and which should be in common use in 1996.

The RUSLE computer system has three major components: (1) the computer program that uses input data and the governing equations to compute soil loss; (2) data files that describe weather, plant and soil disturbing operations, and plant characteristics; and (3) user-developed input files that describe site specific conditions such as location, soil topography, and a sequence of operations and plant communities. The user files can be used by multiple clients in a particular field office.

The computer program will run best on a 386 or more powerful personal computer with a math co-processor and a DOS operating system. The program is easy to use and has an extensive help system that minimizes the need to consult user guides. The background documentation describes the equations used in RUSLE and how they are used to compute soil loss.

Large data files representing climate, operations, and crops are required to effectively use RUSLE. Core data (SWCS 1993) have been developed that can be used as a starter or to adjust an existing data base. These data files are provided when RUSLE is purchased. However, since the NRCS has developed extensive data bases for its national and state implementation of RUSLE, users of RUSLE should first contact an NRCS office before developing their own data files. A data file probably has already been developed and checked for accuracy for such applications.

EXAMPLE APPLICATION FOR MISSISSIPPI

Problem - A farmer wants to grow cotton in Marshall County on hill land. He has fields that range from 3 to 6 percent slope with soils of Providence or Grenada type. For this example, we will assume that 150 feet is the longest slope length in his fields.

RUSLE is entered and R = 320 is found for Holly Springs, which is located in Marshall County. The ponding adjustment for low slopes is not applicable for the slopes in his fields. The K factor is computed from RUSLE using the nomograph option. We entered 70% very fine sand and silt, 28% clay, and 1.5% organic matter which resulted in an annual K = 0.37. RUSLE gave a LS value of 0.44 for conventional-till on 3% and 150 ft slope and 0.93 for 6% and 150 ft slope. The LS value was reduced for no-till to 0.40 for 3% and 0.83 for 6% to account for soil consolidation with no-till.

A computation for conventional tillage resulted in 12.5 tons/acre-year on the 3 percent slope. Obviously, tillage cannot be used on a slope of 3 percent without drastic erosion control, so only soil loss values for the no-till system were used for further illustration.

For the 3-percent slopes, no-till cotton resulted in 3.5 tons/acre-year soil loss, which is too much for Providence soil. The addition of contouring (P factor of 0.72) reduced the erosion estimate to 2.5 tons/acre-year, which is acceptable.

For the 6-percent slopes, 7.2 tons/acre-year soil loss was predicted for no-till for up-and-down hill farming. Using contouring would reduce the loss to 4.8 tons/acre-year, which is still excessive. Grassed buffer strips or terraces might solve this problem. The point is that cotton can be grown on a 6 percent slope without excessive erosion only with great difficulty.

Summary of RUSLE Values

First case, up-and-down hill rows:

	R	**K**	**LS**	**C**	**P**	**A** tons/acre-year
Cotton, NT, 3%	320	0.37	0.40	0.073	1	5
Cotton, NT, 6%	320	0.37	0.83	0.073	1	7.2
Cotton, conv, 3%	320	0.37	0.44	0.240	1	12.5

Second case, contoured rows:

	R	**K**	**LS**	**C**	**P**	**A** tons/acre-year
Cotton, NT, 3%	320	0.37	0.40	0.073	0.72	2.5
Cotton, NT, 6%	320	0.37	0.83	0.073	0.67	4.8
Cotton, conv, 3%	320	0.37	0.44	0.240	0.72	9.0

SUMMARY

The Revised Universal Soil Loss Equation (RUSLE) is a significant improvement over the widely used Universal Soil Loss Equation. Many of the new features in RUSLE are based on research conducted by the National Sedimentation Laboratory of the USDA-Agricultural Research Service in cooperation with the Mississippi Agricultural and Forestry Experiment Station.

Improvements in RUSLE of particular importance to applications in Mississippi include a reduction in the R factor for ponded water on flat slopes; an improved slope steepness relationship for low slopes; a subfactor method to compute the effect of cover and management for a wide range of conditions; the consideration of the effect of winter weeds; much improved accuracy for no-till; a method to compute the effect of contouring as a function of storm erosivity, row grade, and ridge height; and a method to compute the effect of a wide variety of cropping systems that involve strips.

RUSLE is available for purchase from the Soil and Water Conservation Society. It is also being implemented by the Natural Resources Conservation Service (NRCS) in its field offices, and data needed to use RUSLE are available from NRCS. This technology represents a dramatic improvement over past erosion prediction technology, which is an important consideration in choosing cost-effective systems to comply with federal legislation to participate in key government agricultural support programs.

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