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The Future of Arid Grasslands:

Identifying Issues, Seeking Solutions

Tucson, Arizona and
Selected Ranches in Southern Arizona,
Southwestern New Mexico, and Northern Sonora

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Using RUSLE for Erosion Control and Grassland Management

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ABSTRACT

Overgrazing over the years has contributed to soil erosion in many areas. The method described in this paper was developed to calculate the rate and type of soil loss and environmental degradation. The Revised Universal Soil Loss Equation (RUSLE) provides a very useful tool for land managers.

Alan Paton (1948) in Cry, the Beloved Country states:

"Where you stand the grass is rich and matted you cannot see the soil. But the rich green hills break down. They fall to the valley below, and falling, change their nature. For they grow red and bare; they cannot hold the rain and mist, and the streams are dry in the kloofs. Too many cattle feed upon the grass, and too many fires have burned it. Stand shod upon it, for it is coarse and sharp, and the stones cut under the feet. It is not kept, guarded, or cared for, it no longer keeps men, guards men, cares for men. The tithoya does not cry here any more."

Although this passage describes conditions in southern Africa, it might well have been about grasslands in the United States.

Some of the earliest water erosion research started in the Western U.S. (e.g. the work by Sampson and Weyl (1912) on the overgrazed rangelands in Central Utah). Such research languished until the latter part of the 1970's (Renard, 1985). Thus, current technology for controlling water erosion on rangelands has evolved primarily from research performed on cultivated croplands and transferred with minimal validation to rangeland and grasslands (especially on the drier climate that dominate the western U.S.).

The National Research Council, Board of Agriculture's Committee on Long-Range Soil and Water Conservation (1993) published an assessment of Soil and Water Quality: An Agenda for Agriculture which enumerated the nation's resource problems on agricultural land. A considerable portion of this major undertaking involved a discussion of "soil degradation" and the physical-chemical-biological facets of the problem. Soil degradation and the associated phenomenon of compaction, fertility depletion, soil organic matter decline, loss of moisture holding capacity (through profile depth decreases), and loss of seedbed attributes, all result in environmental deterioration as well as the downstream consequences of water erosion.

The Universal Soil Loss Equation (USLE)(Wischmeier and Smith, 1978) and its predecessor versions has been widely used for conservation planning. The technology as presented in the 1978

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handbook includes many limitations for problems encountered in the later part of the 20th century. At a 1985 workshop of researchers and users of the USLE technology, it was decided that erosion prediction technology needed to be revised and new technology developed to eventually replace the regression based USLE. The results are RUSLE, the Revised Universal Soil Loss Equation (Renard et al., 1991; 1994; 1996) and the WEPP model (Laflen et al., 1991).

One of the most significant decisions associated with RUSLE development was to computerize the technology. The software produced is available from the Soil & Water Conservation Society in Ankeny, Iowa. The software package includes data bases for application to conditions encountered in the USA and a User's Manual. The society also has a video which assists with training new users.

RUSLE: THE REVISED UNIVERSAL SOIL LOSS EQUATION

RUSLE is based on the same regression equation as the USLE (Wischmeier and Smith, 1978). The USLE and RUSLE (compute sheet and rill erosion using terms representing the major factors affecting erosion) are given as:

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

where A is the computed soil loss, R is the rainfall-runoff erosivity factor, K is a soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is a cover management factor, and P is a supporting practices factor. The empirically based equation, is derived from a large mass of field data.

DATABASES

A major difference between the USLE and RUSLE is the development of databases that permit easy and repetitive solutions with RUSLE. Three databases are included: CITY, CROP, and OPERATIONS.

The CITY DATABASE includes the basic climate information necessary for a soil loss estimate. In addition to an estimate of the annual rainfall erosivity ® = $\sum$ KE*I where KE is the rainfall kinetic energy and I is the maximum 30 minute intensity), the data base includes monthly precipitation, temperature, frost free period, % of the annual erosivity occurring by the first and fifteenth of each month, and 10-year frequency maximum daily EI. These data are available for many locations in the USA and a procedure has been developed for estimating R and the 10-year EI from precipitation data where it is available (Renard and Freimund, 1994).

The CROP DATABASE, as the name implies, includes fundamental information about those features of the crop that might affect erosion. Features include residue at harvest time, residue decomposition rate (both above and below ground are requested although lack of data may lead to a single value for both), and the amount of residue cover (weight per unit area) at 30, 60, and 90% cover. In addition, the amount of root mass in the top 100 mm (4 inches), the canopy cover (%), and the fall height of raindrops intercepted by the canopy are needed at 15 day intervals throughout the growing season. The computer software includes estimates of these data files for most major crops along with a procedure for estimating the values for various crop yields.

The OPERATION DATABASE reflects soil disturbing activities resulting from land use operations. Again the software contains examples of most operations used in the USA. The information needed includes up to five effects with each effect drawn from a list of nine possible scenarios. The information for each effect includes the percent of the surface area disturbed, the initial and final roughness associated with an operation (expressed as the standard deviation of the random roughness), the percent of the original cover left after the operation, and an estimate of the depth of disturbance. Efficient storing of such information permits rapid recovery for a location specific simulation.

RUSLE FACTOR VALUES

RUSLE (as with the USLE) was developed as a tool to assist soil conservationists in farm/resource conservation planning. The conservationist used the USLE to estimate soil loss on specific slopes in specific fields. If the estimated soil loss exceeded acceptable limits, the technology was used to guide choosing a practice or practices that would control erosion while meeting the needs and wishes of the farmer/land owner. As concerns for national inventories and concerns for pollution control in general increased, the technology was used for policy implementation and for the planning of conservation programs to control soil erosion by water. These conservation activities are then reflected in the regression equation defined above.

Discussion of specifics associated with the RUSLE factor values follows.

R factor. Information for this factor is readily obtained from the CITY DATABASE or can be developed by the user for a specific location.

The K factor. The K factor is a measure of the inherent erodibility of a given soil under standard conditions of the unit USLE plot maintained in continuous fallow. Values for K typically range from about 0.10 to 0.45 (customary English units). The erodibility nomograph (Renard et al., 1996) is the most common tool for estimating K values but additional material is needed for some soils. The RUSLE computer software assists with evaluation of the value.

RUSLE also permits varying K seasonally with the highest values occurring in the spring with soil fluffing from freeze-thaw actions. Correspondingly, lowest values occur in mid-fall and winter following rainfall compaction or frozen soil. Seasonal variability of K is not permitted by the software for conditions encountered west of 1050 Latitude (Renard et al., 1991). An additional important change involves accounting for rock fragments on and in the soil. Rock on the soil surface is part of the C factor while assumed to be a part of the K factor.

L and S Factor. The significant changes in the treatment of the topographic effects on erosion are given in McCool et al., 1993 and Renard et al., 1996. The most significant change has involved the ability, with the software program, to segment a hillslope into a number of more or less uniform slopes in contrast to the single plane or uniform slope which was the dominant topography of the USLE. This difference can both increase or decrease the predicted topographic effect on a soil loss estimate. Finally, the RUSLE technology requires estimating whether rill or interrill processes dominate the erosion. Guidelines are given in the compute software to assist with making correct decisions.

C Factor. The cover-management factor is extremely important in calculating soil loss. This is the one term that can be managed to reduce erosion. Values of C are a weighted average of soil loss ratios (SLRs) that represent the soil loss at a given time to the size of the unit plot. Thus, SLRs vary during the year as soil an cover conditions change. To compute C, SLRs are weighted according to the erosivity distribution during a year (from City Database).

RUSLE computes a C factor using a subfactor relationship given as:

$$C = PLU * CC * SC * SR * SM \qquad (2)$$

where PLU is a prior land-use subfactor, CC is the canopy subfactor, SC is the surface cover subfactor, SR is the surface roughness subfactor, and SM is a soil moisture subfactor used in the Pacific Northwest small-grain farming areas.

The subfactor approach in RUSLE permits application/development of SLRs when values are not available from experimental plot data. For example, erosion data do not exist for many vegetable and fruit crops. Developing SLRs using the subfactor method is easier and more accurate than making comparisons with values for other crop C in the 1978 USLE handbook (Wischmeier and Smith, 1978).

The *RUSLE computer program* includes many data files as mentioned earlier. In other instances, the user must input new data. For crops not available in the software, data are needed to reflect canopy characteristics, residue, and root mass in the upper 4 inches (100 mm) of the soil profile, and crop yield and residue characteristics. In making a soil loss estimate, the user must specify the crops in a rotation and the dates of operations. The~ software then calculates SLRs and the average annual C-factor.

P Factor. P-factor values, the least reliable of the RUSLE factors, represent how surface conditions affect flow paths, flow hydraulics, and thus erosion. For example, with contouring, tillage marks are credited with directing runoff around the slope at reduced grades. However slight changes in grade can significantly change runoff erosivity. Considerable scatter in field measured data result in P-factor values that represent broad, general effects or such practices as contouring and stripcropping. The extensive data analyzed in RUSLE using some fundamental hydraulic principles and such known characteristics as ridge height, furrow grade, and climatic erosivity assist in accounting for the affects of terraces, buffer strips, and stripcropping on soil loss. The conservation practices used on rangelands require estimates of surface roughness and runoff reduction.

CREDITS

Numerous USDA and University employees have assisted in the development of the RUSLE document and the computer software. Individual chapter authors including their affiliation are given in Renard et al. (1996).

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