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Recent Developments in the Science of the Revised Universal Soil Loss Equation, version RUSLE2

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ABSTRACT

Prediction tools for estimating soil erosion are of utmost importance for conservation planning. The most widely used prediction tool is the Universal Soil Loss Equation (USLE) and its revised versions. This paper summarizes some of the scientific improvements of the most recently updated version of this soil loss equation, commonly referred to as RUSLE2.

Introduction

Ever since its formulation in the late 1950s, and its updated versions of 1965 and 1978, the Universal Soil Loss Equation (USLE) has been the most widely used soil erosion prediction and soil conservation management tool for the scientific community, government action agencies, consultants and erosion control practitioners. The precursors to the USLE consisted of regression relationships of soil loss to topographic factors. A key development for the formulation, what became known to be the USLE, was the discovery that storm-to-storm variations in soil loss was highly correlated to the product of total rainfall energy and the maximum 30-minutes intensity of a storm. Structurally, the USLE is a factor relationship, that included the principal factors affecting soil loss – weather, soil and soil profiles, topography, cropping and soil management, and erosion control practices. Since the last update (1978) this equation and the underlying factor relationships, more and improved data sets for a wider range of conditions have been obtained and more in-depth analyses of the data sets have lead to significant improvements of the USLE. These collective improvements lead to the formulation of the Revised Universal Soil Loss Equation (RUSLE) of 1997. The improvements consisted of: revised iso-erodent maps (R); time-varying soil erodibility factors (K); subfactor approach for evaluating the cover-management factor (C) of cropland, rangeland, and disturbed areas, new conservation practice values (P) for both cropland and rangeland; and new relationships for the topographic factors (S and L) based on new ratio of rill and interrill concepts. Since 1997, additional improvements were made, based on more data sets, and revisits of old data sets using improved methods of analyses and/or a better conceptional understanding of the physical soil erosion processes involved. These improvements lead to the formulation of the RUSLE2 erosion prediction version (2005), which development has recently been concluded. This presentation summarizes the principal new science developments of RUSLE2. RUSLE2 is a land-use independent, hybrid model that is to serve as a conservation planning tool.

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Methods

RUSLE2 computes erosion based on three fundamental processes of soil detachment, transport, and deposition. The empirical form of the USLE is used to calculate soil detachment, while process-based equations are used to calculate transport and deposition. RUSLE2's governing equation is the conservation of mass relationship for sediment in overland flow. This equation is numerically solved. The common occurrence of non-uniform soil, steepness, and cover-management characteristics on natural slopes require that the overland flow path be divided into segments. Each segment has within itself uniform values for these characteristics. Stepwise changes in the value of these variables are allowed for detachment computations at points where adjoining segments meet, while runoff and sediment load are continuous at segment modes. RUSLE2 requires both spatial and temporal integration using daily time steps which yield spatially distributed erosion, deposition, and sediment load values along the overland flow paths.

RUSLE2 erosion is viewed as a two-component process: interrill erosion due to raindrop impact and rill erosion due to overland flow. The former component is slope-position independent, while the latter process varies with slope length. The slope length parameter m is, in turn, a function of the ratio of rill to interrill erosion and has been assigned an experimentally determined approximate value of 0.5. An important aspect of RUSLE2 is the inclusion of sediment deposition, which occurs when the transport capacity is exceeded. Deposition occurs selectively and is based on the sediment density. Evaluation of the sediment transport capacity is based on the discharge rate at a given point on the overland flow path, which in turn is determined by the slope position and the excess rainfall rate. The latter value is obtained by the NRCS curve number method.

Science Improvements

Some 75 major aspects were considered in the RUSLE2 erosion prediction model. They are partly in the science and partly in the interface of this computer model. Some of the major science related changes will be mentioned in this paper.

Climate Variables: RUSLE2 uses 4 input weather variables: monthly erosivity, precipitation, temperature, and the 10 year-24 hour precipitation amount. Erosivity is a major variable to compute detachment. Precipitation and temperature influence the loss of biomass on and in the soil and how this loss varies among locations. Precipitation and temperature affect the temporal distribution of soil erodibility and how the distribution varies by location. The 10 year-24 hour precipitation amount is an index storm that is representative of the effect of ponding on erosivity, deposition on concave overland flow path, deposition by dense vegetation strips, and the efficiencies of contouring. RUSLE2 uses disaggregation procedures to convert monthly erosivity, precipitation, temperature, and soil erodibility values into daily values which, in turn, are used to compute erosion. These values and calculation procedures assume that daily values vary linearly within each month, such that the average daily value in a month equals the input monthly value. A significant improvement in arriving at more consistent and geographically smoothly varying erosivity values needed for conservation planning is the erosivity density concept. Erosivity density is defined as the average monthly erosivity, calculated from monthly EI_{30} values, divided by the average monthly precipitation values obtained from 15 min. precipitation data. Since the daily precipitation data sets are far more numerous than the 15-min. precipitation data sets, calculations of the erosivity densities could be improved with the daily precipitation data sets through correlations. Another significant departure from past practices is the use of the 10 year-24 hour (P_{10y24h}) precipitation amount as an index of storm severity.

Soil Erodibility Factor. The soil erodibility factor is a measure of soil to erode under standard natural runoff plot conditions. While, in practice, it is often estimated from intrinsic soil property values (soil erodibiity nomograph), it also has some dependence on the nature of the precipitation regime. RUSLE2 offers more features on how the soil erodibility factor can be obtained from standard soil properties, profile and rainstorm characteristics, such as improved expressions for the very fine sand fractions, structure subfactor, and permeability subfactor. It also provides a relationship for the rill/interrill soil erodibility ratio based on soil texture parameters, which reflects to a higher degree the process oriented aspects of RUSLE2 soil erosion predictions. Likewise, the temporal dependence of soil erodibility has been addressed in relation to the precipitation and temperature regime, as has been the time to consolidation dependence on precipitation. Other features concern an improved account of the rock cover effect on erosion and the erodibility factor and relating subsurface drainage to the hydrologic soil group.

Cover Management Factor. Cover and management are the most important ways by which soil detachment can be controlled in land use practices and is defined by the product of several subfactors. RUSLE2 has substantially improved the subfactor approach in assigning values to the cover management factor for calculating daily soil loss ratios. The canopy subfactor accounts for the reduction in the soil detachment energy of impacting raindrops and is a function of the effective canopy cover and effective fall height. The ground cover subfactor accounts for the detachment protection of material directly in contact with the soil surface and includes subfactors for ground cover percentage, the soil surface roughness, and a parameter b (0.025-0.1) that accounts for the relative effectiveness of the ground surface cover. This parameter also reflects differences in the rill and interrill erosion protective effect of ground cover and is, in turn, dependent on many other plant and soil factors. It should be noted that the slope length exponent m and the ground cover parameter b make erosion predictions through cover-management operations land use independent. The soil surface roughness subfactor represents the effect of mechanical soil disturbance on rill-interrill erosion and is expressed as an exponential decay factor with an adjusted roughness value for the day since mechanical disturbance. The surface roughness subfactor is affected by the level of biomass products, by soil texture, and by the existing roughness at the time and intensity of operations. Likewise, roughness decay is determined by the soil water content, the precipitation amount, the daily erosivity, and the interrill ground cover factor.

Considerable attention in the development of science related components of RUSLE2 concern the effect of the soil consolidation subfactor on rill-interrill erosion immediately after mechanical soil disturbance. This factor is based on a comparison or erosion in unit plot conditions to erosion of the same soil that was not mechanically disturbed. This factor affects the rill-interrill erosion and is a function of soil texture. Likewise, the rill-interrill erosion ratio is highly sensitive to the soil water content, especially in soils with freezing/thawing cycles. Another area of major concern is the effect of decomposing residue on rill-interrill erosion. Much work needs to be done yet.

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Summary

This article disucced selected scientific aspects of RUSLE2 erosion prediction technology. It presented a brief summary of the evolution of RUSLE2 prediction technology, followed by a discussion of the principal methodology of erosion mechanics on sloping land. Of particular interest were new scientific approaches in the evaluation of the soil erodibility factor, weather related relationships, and the cover management factor.

Literature

Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool, and D. C. Yoder (coordinators). 1997. Predicting Soil Erosion by Water. A Guide to Conservation Palnning with the Revised Universal Soil Loss Equation (RUSLE). Agricultural Handbook 703. U. S. Department of Agriculture, Washington, DC.