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SOIL EROSION RESEARCH FOR THE 21ST CENTURY

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Comparing Soil Erosion Estimates from RUSLE and USLE on Natural Runoff Plots

John F. Rapp, Vicente L. Lopes, Kenneth G. Renard[1]

Abstract

Data from 206 natural runoff plots representing a broad range of conditions and not used in the development of the Revised Universal Soil Loss Equation (RUSLE) were used to compare soil loss estimates from RUSLE and the Universal Soil Loss Equation (USLE). Soil loss estimates from RUSLE were consistent with those from USLE for both annual and average annual values for the entire period represented by each individual plot. Like the USLE, RUSLE tended to over estimate soil losses on plots with low erosion rates and under estimate soil losses on plots with high erosion rates. The cover and management factor in RUSLE is the most significant factor affecting soil loss estimates. While there seems to be no improvement in the accuracy of soil loss estimates from RUSLE over USLE, there is an improvement in the use and formulation of land use strategies when RUSLE is used in more complex situations than those found in the data set used in this study.

Keywords. Soil erosion prediction, Runoff plots, USLE, RUSLE, Land use planning.

Introduction

With the increasing amount of land devoted to agriculture worldwide in the last century, erosion research has focused on the prediction and mitigation of soil loss from agricultural lands (Lal, 1994). Laboratory and field plot studies have been conducted in order to improve understanding of the factors that control soil erosion (Mutchler et al., 1994). Efforts to estimate soil losses by flowing water go back a half century. The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) has been widely used for erosion prediction and conservation planning in the United Sates and abroad. The USLE has been subjected to many modifications over the last three decades. In 1985 the U.S. Department of Agriculture decided that the USLE should be revised to incorporate additional research, new data sets and improved computer technology that allows users to easily input, update and store the necessary data for assessing soil loss. The new technology is called the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1994). The purpose of this paper is to present the results of a test performed to compare soil loss estimates from RUSLE with the Universal Soil Loss Equation (USLE). The test was conducted using data from 206 natural runoff plots representing a broad range of conditions and not used in the development of USLE. Soil loss estimates from RUSLE were compared with estimates made by the USLE for each plot year and the average for each plot duration.

Methodology

The RUSLE Computer Program

The development of RUSLE was instigated partly due to the increase in computer processing power as well as the addition of new research data (Renard et al., 1994). The computer program is divided into five user interface components. These are the main screen, function line, header line, suggestion line and the command line. The main screen displayed contains a list of questions and comments. This is where inputs are entered and results displayed. The function line is where the user controls the programs utility functions (e.g., saving and deleting files). The header line presents the program version's title. The suggestion line directs the user to the next logical step in making calculations and the command line allows the user to manipulate the data inputs (e.g., calculate factor values).

[1]John F. Rapp, Hydrogeologist, URS Greiner Woodward Clyde, Seattle Washington 98101; Vicente L. Lopes, Associate Professor, School of Renewable Natural Resources, 325 Bio Sciences East, University of Arizona, Tucson, Arizona 85721; Kenneth G. Renard, Hydraulic Engineer, USDA-ARS Southwest Watershed Research Center, 2000 E. Allen Road, Tucson, Arizona 85719; **Corresponding author**: John F. Rapp, URS Greiner Woodward Clyde, 1501 Fourth Avenue Suite 1500, Seattle Washington 98101; e-mail: <John_Rapp@urscorp.com>.

The program accesses, uses and saves information for each equation factor value. It can get that information from one of three sources: values that the user enters directly, data stored in the program databases, or information that the user entered at a previous time and stored. There are three databases in the program. The CROP database contains all information on the growth and residue characteristics for various crop types, crop stages and other plant characteristics. The OPERATIONS database includes information from research studies for the effect that common soil disturbing operations have on the soil, crop, and residue, and through those, the erosion rates. The CITY database contains all necessary meteorological data and associated EI distributions for specific locations.

The default values in the CROP and OPERATIONS databases are for specific combinations of site location, crop type, potential yields, row spacing, planting density, tillage practices, equipment speed, soil conditions, etc. Most of the values in these databases were used in this study due to the general nature of the data. However, database files were edited when site-specific data (e.g., crop yields, grazing periods) were available. More information on using the RUSLE program software with specific examples and question/answers can be found in the RUSLE reference manual (Renard et al., 1997).

Data Inputs

The data set for this study was supplied by the USDA-ARS Southwest Watershed Research Center in Tucson, Arizona. It contains year-by-year information for individual plots for 21 sites. This information includes previously determined USLE factors, crop types and yields, rotation sequences for each year and the dimensions of each plot. The time frames and crop types range from 26 years of continuous fallow to 4 years of corn-wheat-ryegrass strip crops with an average of 7.9 years per plot for all 21 sites. Most all of the sites have duplication plots in order to account for the natural variability of the recorded soil losses. From each site, unique plot files (all plots except duplicates) were developed in the RUSLE program for each separate year, to express yearly differences and effects of EI distributions and management operations.

The R factor was determined using the supplied year-by-year EI values. Meteorological data for 30-year periods was taken when available, from the U.S. Weather Bureau long-term records to create the appropriate database files. The K factor was computed using an initial estimated K value for the site, the hydrological soil class, the computed LS factor, and the meteorological data for the site taken from the CITY database. The LS factor was computed as a function of slope length and slope steepness and a moderate rill-to-interrill erosion ratio (see Renard et al., 1997). Calculations of the C factor on a year-to-year basis required that previous conditions were accurately represented. With plots that had more than 1 year in the crop rotation, preceding years were maintained in the specific years C factor calculation to account for residue incorporation and decomposition. Situations in which strip cropping was used, values were determined for each different type of strip and a weighted average was calculated based on information regarding the percentage of crop type or plant cover. The P factor was taken from previous USLE calculations due to the lack of information regarding the methods used to create supporting practices.

Model Evaluation

The success of a model is based on how well the model meets the objective of predicting a specific natural phenomenon. Model efficiency is explored by comparing predicted with measured values and expressing the result in graphical form and assessing the model accuracy with a goodness-of-fit statistic or hypothesis testing. One commonly used method of comparing model predictions to recorded values is a dimensionless coefficient (ME) proposed by Nash and Sutcliffe (1970):

$$ME = 1 - \frac{\sum_{i=1}^{n} (Qmi - Qsi)^2}{\sum_{i=1}^{n} (Qmi - Qm)^2} \qquad (1)$$

where ME = model efficiency, Qmi = measured value, Qsi = computed value, Qm = mean of measured values, n = number of observations. An appealing aspect of this coefficient lies in its simplicity, with its value increasing toward unit as the fit of predicted versus measured values progressively improves (Green and Stephenson, 1986).

Results and Discussion

Estimates of soil loss with RUSLE were made for both annual and average annual values and the results were compared with annual and average annual measured soil losses for the entire period of records represented by each plot. Individual plot conditions for all sites and summary statistics are found in Rapp (1994). Scatter diagrams for RUSLE and USLE are shown in Figs. 1 and 2, respectively. It can be seen that like the USLE, RUSLE tended to over estimate soil losses on plots with low erosion rates and under estimate soil losses on plots with high erosion rates. By comparing Figs 1a with 1b and Figs. 2a with 2b, it can be seen also that both the USLE and RUSLE are more efficient at predicting average annual soil losses (average ME = 0.73) than predicting on an individual-year basis (average ME = 0.58). These results are consistent with a previous study that applied USLE to the same plots (Risse et al., 1992).

Model efficiency was also used to assess how much each RUSLE parameter might affect the total error in RUSLE predictions. First, each factor was averaged over the entire data set. Second, each separate factor was held at its average value while the other factors varied according to the individual year's condition (like removing the importance of the parameter in question on the calculations) and model efficiencies were calculated. The cover/management factor was the most influential factor being responsible for an average decrease in model efficiency from 0.54 to 0.19 when its value was held constant.

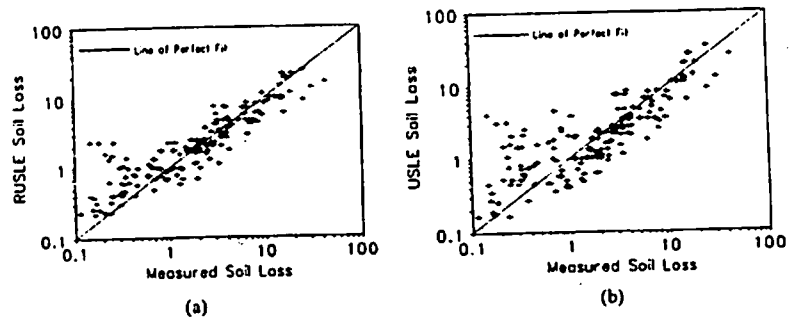

Figure 1. (a) Soil loss on an annual average basis measured and predicted by RUSLE; (b) Soil loss on an annual average basis measured and predicted by USLE. All values in kgm^{-2} for 206 observations.

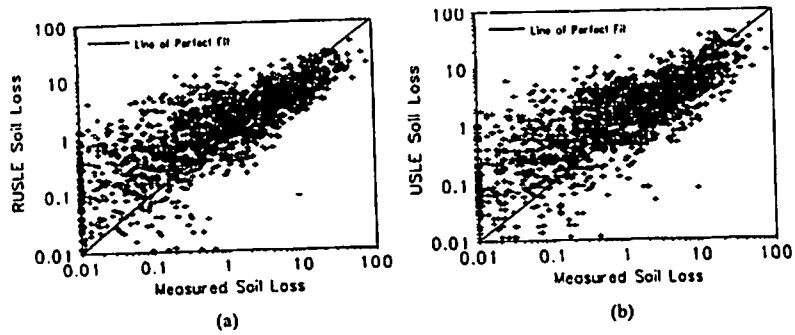

Figure 2. (a) Soil loss on an annual basis measured and predicted by RUSLE; (b) Soil loss on an annual basis measured and predicted by USLE. All values in kgm^{-2} for 1638 observations.

Conclusions

1) The RUSLE applied to 206 natural annual runoff plots with an average of 7.9 years per plot had an average model efficiency (ME) of 0.73 with an average magnitude of error of 1.17 kg/m2. Prediction of 1638 individual annual soil loss events had an average model efficiency of 0.58 with an average magnitude of error of 2.08 kg/m2.

2) The RUSLE results were consistent with those from previous studies with the USLE in that it tended to over predict soil loss on plots with low soil erosion rates and under predict on plots with high soil erosion rates.

3) The C factor is the most significant factor affecting the overall model efficiency. This indicates that further research should improve estimates of this factor.

4) While there seems to be no improvement in the accuracy of RUSLE over USLE for the model efficiencies there is an improvement in the use and formulation of land use strategies when the RUSLE technology is employed as a predictive tool. This is especially true in more complex situations than those found in the data set used in this study.

5) RUSLE technology permits assessing soil erosion rates for plots with complex slopes and for crops without soil loss ratio data as used in the USLE.

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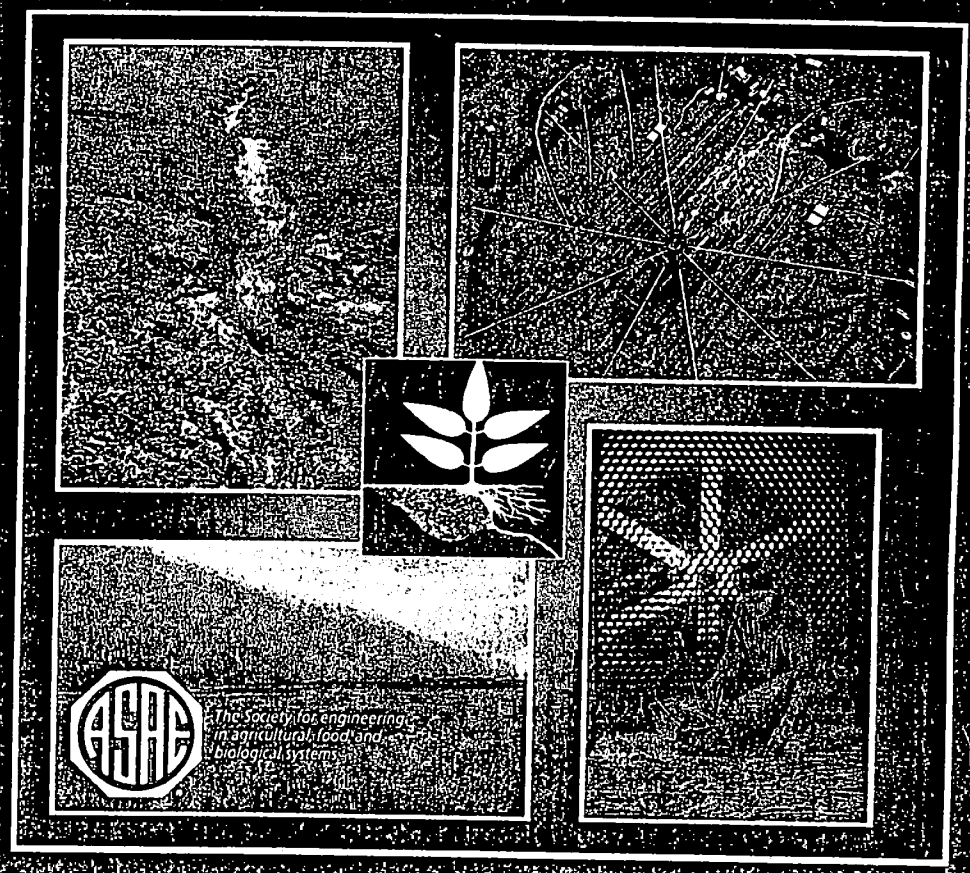

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