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# Application of RUSLE2 to Pasturelands

**S.M. Dabney, *USDA-ARS Oxford, MS, US, sdabney@ars.usda.gov;***
**D.C Yoder, *Univ. of TN, Knoxville, TN, US, dyoder@utk.edu;***
**G.R. Foster, *USDA-ARS (retired), Oxford, MS, USA, gfoster@iolbv.com;***
**M.A. Nearing, *USDA-ARS, Tuscon, AZ, US, mnearing@tucson.ars.ag.gov***

Abstract

The RUSLE2 erosion model can realistically predict average annual soil loss from perennial pasturelands but care must be taken to properly describe variation in living above- and below-ground biomass and to include residue additions during periods with net canopy increases.

## Introduction

The Revised Universal Soil Loss Equation Version 2 (RUSLE2) estimates rill-interrill soil erosion caused by raindrop impact and Hortonian overland flow (Foster et al., 2003). RUSLE2 is a hybrid model that uses both empirical and process-based equations to estimate long-term average daily soil erosion. RUSLE2 is land use independent and computes the effect of land use and management by computing erosion as a function of the major variables that describe how cover-management affects soil erosion on overland flow areas of a landscape. These variables include canopy cover, effective fall height from canopy cover, ground cover in direct contact with the soil surface, soil surface roughness, live and dead root biomass, incorporated plant residue and other organic material, time since the last mechanical soil disturbance, and antecedent soil moisture (USDA-ARS, 2004, 2005).

The RUSLE2 cover-management equations were calibrated by fitting them to empirical data (USDA-ARS, 2005) including the soil loss ratio values in Agriculture Handbook 537 (Wischmeier and Smith, 1978). Although the soil erosion database for tilled cropland is far more extensive than the soil erosion database for pasture and similar lands where erosion rates tend to be low and highly variable in both space and time, the cover-management subfactor approach allows RUSLE2 to be extrapolated and applied to such conditions.

RUSLE2 computes daily erosion using long term averages of daily precipitation, temperature, and erosivity with a user-entered description of cover-management variables. A RUSLE2 cover-management description is a list of operations, the dates on which the operations occur, and the amounts and characteristics of vegetation and residue involved at a specific site. An operation is an event that affects vegetation, residue, and/or soil at the site. Cover-management operation and vegetation descriptions are developed by the user following a set of definitions, rules, and procedures specific to RUSLE2 (USDA, 2004).

RUSLE2 is not a simulation model except for using climatic and residue variables to compute the accumulation of a surface litter layer and the accumulation of soil biomass. RUSLE2 does not compute how vegetation production varies with climatic, soil, and management conditions. The user must ensure that entered vegetation descriptions are consistent with plant, climate, soil, and management conditions at the site.

An important feature of RUSLE2 is that it takes into account daily temporal variations in cover-management and how these variations interact with daily variations in climatic variables to affect average daily erosion rates. A RUSLE2 cover-management description includes a set of operations that describe how events affect cover-management conditions through time. Vegetation descriptions quantify how the vegetative canopy varies temporally and also provide additional information that RUSLE2 uses to determine related parameters including live ground cover, live above ground biomass, and live root biomass. For example, the following relationship is used to determine above-ground biomass from canopy cover:

$$B_l = B_{mn} + (B_{mx} - B_{mn})[(C - C_{mn})/(C_{mx} - C_{mn})]^{1.5} \qquad [1]$$

where: $B_l$ = live above ground biomass at time t, C = canopy cover at time t, $B_{mx}$ is live above-ground biomass at maximum canopy cover, $C_{mx}$, and $B_{mn}$ is minimum live above-ground biomass at minimum live canopy cover, $C_{mn}$.

A RUSLE2 cover-management description can be either a rotation or a no-rotation type. A rotation-type cover-management description is one where the list of operations in the cover-management description represents a cycle that is indefinitely repeated and where the ending point is the same as the starting point. For example, a one-year rotation cover-management description is used to represent a mature pasture where the same events are assumed to occur on the same date each year. A five-year rotation cover-management description is used to represent a pasture system that is mechanically renovated once every five years. RUSLE2 computes how the mechanical renovation immediately affects erosion and how erosion changes over time after the. Initial conditions are not important for rotation cover-management descriptions because RUSLE2 processes the list of operation in the rotation cover-management description multiple times until the computed erosion values stabilize.

A RUSLE2 no-rotation cover-management description is one where RUSLE2 processes the list of operations in the cover-management description only a single time. The first few operations in a no-rotation cover-management description are used to set initial conditions, which can have a major effect on computed result. An example of a no-rotation RUSLE2 cover-management description is where a brushy, unmanaged site is cleared and seeded in a permanent grass cover that is periodically mowed, hayed, or grazed. RUSLE2 then computes erosion for the before-disturbance condition, erosion during disturbance period (when erosion can be very high), and erosion from the beginning of vegetation establishment until a mature plant community evolves, which may be 20 years in some situations.

It is important for the user to understand the following conventions that govern the way RUSLE2 computes changes in surface residue, buried residue, and soil biomass. When canopy cover declines, the decrease in above ground biomass is converted to surface residue. When root biomass declines, the decrease is added to the dead root biomass pool. When a crop is killed, the above ground biomass is converted to the standing biomass pool and the live root biomass is transferred into the dead root biomass pool. The standing biomass pool is gradually converted into surface residue as a function of time, temperature, and precipitation. As plant litter and crop residue decompose on the soil surface, up to 25 percent of the amount lost by decomposition each day is arbitrarily placed in the buried residue pool in the upper 2 inch (50 mm) of soil so that organic matter can accumulate at the soil surface on pastureland, rangeland, no-till cropland, and other lands not regularly tilled or mechanically disturbed. Surface and subsurface residues decay at the same rate. Residue decay rates depend on residue characteristics, precipitation, and temperature. Soil consolidation takes place with time since last disturbance. Soil consolidation, buried residue, and root biomass interact to determine the soil biomass factor and influence the curve number used to estimate runoff.

## Methods

The application of RUSLE2 to pasture was illustrated with six cover-management systems applied to a 46 m long 6 percent steepness slope with silt loam soil and the climate of Columbia, MO, USA (Table 1). The first system, for references, was a 7 Mg/ha (112 bu/ac) spring plowed conventionally tilled maize crop as described in the core RUSLE2 database. The second and third systems represent continuously grazed mature pasture with 3400 kg/ha above-ground biomass at a maximum canopy cover of 90 percent on July 1, and 340 kg/ha at the minimum live canopy cover of 20 percent on March 15. Live roots in the upper 100 mm soil layer are assumed to be 1.5 times the live above ground biomass. In system 2 no litter was added to the soil surface during periods when the canopy was increasing. The third system was the same as system 2 but was more realistic in that residue equal to approximately 1 percent per day of live above ground biomass was added to the surface litter pool during periods when canopy cover was increasing (Dubeux et al. 2006). To approximate this effect in the current version of RUSLE2, vegetation descriptions were created reflecting portions of the pasture growth curve such that when combined with operations involving “remove live biomass” and “begin growth” processes on 29 April, 29 May, 28 June, and 28 July the canopy cover time series matched that of the second system.

The fourth, fifth, and sixth systems represent a rotational grazing pattern where three brief periods of intense grazing were followed by recovery periods. A sequence of vegetation files was created in which there was a decrease in canopy (and therefore above-ground biomass and roots) between the end of one vegetation and the start of the next, reflecting canopy reductions due to intense grazing. In system 4, no surface litter was added either with grazing operations or during periods of increasing canopy. In system 5, litter equal to approximately 1 percent of average daily above ground biomass was added during grazing operations on 28 May and 19 July. The sixth system was like the fifth system except that the pasture was mechanically renovated once every five years. This renovation disturbed 50 percent of the soil surface and buried 30 percent of the litter cover that existed at time of the disturbance.

## Results, Discussion, and Conclusions

RUSLE2 computed soil losses for the five pasture systems were much lower than the soil loss computed for the conventionally tilled maize system (Table 1). Erosion from pastures was small, but pasture estimates vary by a factor of ten. The reasons for the differences can be seen in the subfactors that RUSLE2 used to compute the effects of cover-management on soil loss. Neither the canopy and surface roughness subfactors varied greatly between pasture and maize cropland. In contrast, the factors with the largest influence in reducing soil loss from pastures were the surface (ground) cover subfactor and the prior land use subfactor, the latter being the product of the soil consolidation and soil biomass subfactors.

Litter addition reduced the surface cover and the soil biomass subfactors, either when added during periods of increasing canopy (e.g., compare system 3 with 2 and 5 with 4) or when larger amounts of litter were available because grazing pressure was reduced (e.g., compare system 3 with system 5). In system 2, calculated surface residue cover under the pasture canopy dropped below 10 percent in October due to residue decomposition without addition.

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With steady litter addition (system 3) residue cover stayed above 50 percent all year long, which is more realistic. The larger canopy subfactor values for pasture systems with litter addition (e.g., compare system 3 with 2 and 5 with 4), reflect RUSLE2's assumption that canopy above surface residue has less effect in reducing erosion than canopy over bare soil. RUSLE2 computes a major effect of a single mechanical soil disturbance as shown by the differences in soil loss between systems 5 and 6, largely due to increasing the prior land use effect where a significant portion soil biomass benefits was lost.

The net subfactor values are averages of daily values weighted by daily erosivity values. Note that the product of those values does not equal the net C factor values which are the daily average product of the subfactor values weighted by the erosivity distribution. Similarly, the computed soil loss values are not necessarily proportional to the net C factor values. These difference illustrate the strong nonlinearity of the relationships used in RUSLE2 and how the fundamental mathematics of RUSLE2 computing a daily erosion differs from the mathematical structure of the USLE and RUSLE1 (Foster et al., 2003).

Table 1. Results of RUSLE 2 computations for selected cropping and pasture systems

| | subfactors | | | | | | |
|---|---|---|---|---|---|---|---|
| System† | prior land use | surface cover | canopy cover | surface roughness | net C factor | net subfactor product | average annual soil loss (Mg/ha) |
| 1 | 0.67 | 0.79 | 0.63 | 0.92 | 0.27 | 0.31 | 52. |
| 2 | 0.048 | 0.138 | 0.55 | 0.81 | 0.0026 | 0.0030 | 0.33 |
| 3 | 0.025 | 0.055 | 0.77 | 0.81 | 0.0009 | 0.0009 | 0.11 |
| 4 | 0.076 | 0.262 | 0.53 | 0.81 | 0.0079 | 0.0086 | 1.10 |
| 5 | 0.049 | 0.088 | 0.70 | 0.81 | 0.0025 | 0.0024 | 0.32 |
| 6 | 0.085 | 0.106 | 0.70 | 0.87 | 0.0067 | 0.0055 | 0.87 |

†System values: (1) conventionally tilled 112 bu/ac maize; (2) pasture without litter addition; (3) pasture with litter addition; (4) short term intense rotational grazing without litter addition; (5) rotational grazing with litter addition; (6) rotational grazing with litter addition and renovation 1 in 5 years [soil loss varies from 1.64 Mg/ha (1st yr) to 0.44 Mg/ha (5th yr)].

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