ANALYSIS OF THE RUSLE AND WEPP MODELS FOR A SMALL WATERSHED LOCATED IN VIÇOSA, MINAS GERAIS STATE, BRAZIL

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Abstract
The objective of this paper was to compare runoff and soil loss amounts observed in an experimental watershed with those values simulated by RUSLE and WEPP models. The watershed has sandy-clay-loam soil covered with pasture. Runoff and soil loss measured were very low, due to high infiltration rate and vegetable covering conditions. In WEPP simulations two values were used for the hydraulic conductivity (K_0): a measured in field (scenario A) and another calculated using WEPP internal procedures (scenario B). The runoff calculated by WEPP in scenario A was very close to measured value. In scenario B the annual runoff amount was over-predicted. RUSLE model simulated a very low value of soil loss and, therefore, close to the field observed. WEPP, in scenario B, also simulated a small soil loss, although greater than that one simulated by RUSLE. In scenario A, WEPP simulated soil loss equal to zero, that is close to the observed value. Both models satisfactorily estimated soil loss for the analyzed conditions, although RUSLE performed better. In WEPP, the water loss was simulated better using measured K_0, suggesting that WEPP internal procedures should be carefully used for Brazilian conditions.

Additional Keywords: soil erosion, hydrologic modeling, hydraulic conductivity, runoff, watershed

Introduction
Soil erosion is one of the most important agricultural problems in the world. It is a primary source of sediments that pollutes streams and fills reservoirs. Erosion also adds to the removal of valuable plant nutrients lost with the runoff (Schwab et al. 1981).

That soil erosion is a serious problem is widely recognized. What is difficult to assess reliably and precisely, however, are the dimensions – the extent, magnitude, and rate – of soil erosion and its economic and environmental consequences (Lal 1994).

Modeling soil erosion is the process of mathematically describing soil particle detachment, transport, and deposition on land surfaces. There are at least three reasons for modeling erosion: (a) erosion models can be used as predictive tools for assessing soil loss for conservation planning, project planning, soil erosion inventories, and for regulation; (b) physically-based mathematical models can predict where and when erosion is occurring, thus helping the conservation planner target efforts to reduce erosion; (c) models can be used as tools for understanding erosion processes and their interactions and for setting research priorities (Nearing et al. 1990).

The influence of all the factors that controls soil erosion should be considered in the modeling of the erosive process. Due to the complexity soil erosion process, several propositions have been elaborated intending to find its appropriate modeling (Pruski 1996). The Revised Universal Soil Loss Equation (RUSLE) and the Water Erosion Prediction Project (WEPP) are two of the widely used computer-based models in the world, but few researches has been done to evaluate its application to tropical climate and soil conditions.

In agreement with the exposed, this paper had as objectives: (a) to evaluate the prediction of water loss by runoff made by WEPP, comparing its value with the runoff amount measurd in a experimental watershed located in Minas Gerais State (Brazil); and (b) to evaluate the soil loss predicted by RUSLE and WEPP models, comparing with the amount measured in the same watershed.

Materials and Methods
Watershed description
The experimental watershed is located in the district of Palmital, near Viçosa city, Minas Gerais (Brazil) and its area is about 4.0 ha. The watershed´s surface was all covered with pasture (about 100% of surface covering) during the period soil and water loss data were taken. A gauging station, located on the bank of a drainage ditch, measured surface water leaving the watershed by runoff. No subsurface water movement occurs in the experimental watershed. A raingauge station was also located in the watershed's area.

Only four rainfall events provides surface runoff during the hydrologic year of 2001/2002. (about 4 hectares). The runoff amount measured in that period was 62 m^3. The soil loss measured in the period was about 200 kg ha^{-1}. This soil loss is considered smaller than the average soil loss observed in the Brazilian pasture areas (400 kg ha^{-1}) (Bertoni and Lombardi Neto 1999).

Physical and chemical analysis accomplished to superficial layers of the watershed´s soil (0 – 0.20 m) are presented in Tables 1 and 2. The infiltration rate after long time of wetting (T_{ie}) was determinate by the use of the ring infiltrometers and was equals to 60 mm h^{-1}, a very high value.

Intending optimize the models simulations, the experimental watershed´s area was divided in six different areas with different representative hillslopes (Figure 1). The simulations were done to each one of the different areas.

Table 1. Textural classification of the watershed's soil

Depth	Coarse sand	Very fine sand	Silt	Clay	Textural classification
0 – 10 cm	40 %	14 %	21 %	25 %	Sandy-clay-loam
10 – 20 cm	48 %	15 %	15 %	22 %	Sandy-clay-loam

Table 2. Chemical analysis of the watershed's soil

Depth	pH	P (mg/dm^3)	K (mg/dm^3)	CEC ($cmol/dm^3$)	Organic matter (dag/kg)
0 – 10 cm	5.43	1.4	101	3.74	3.23
10 – 20 cm	6.01	0.7	100	4.42	3.21

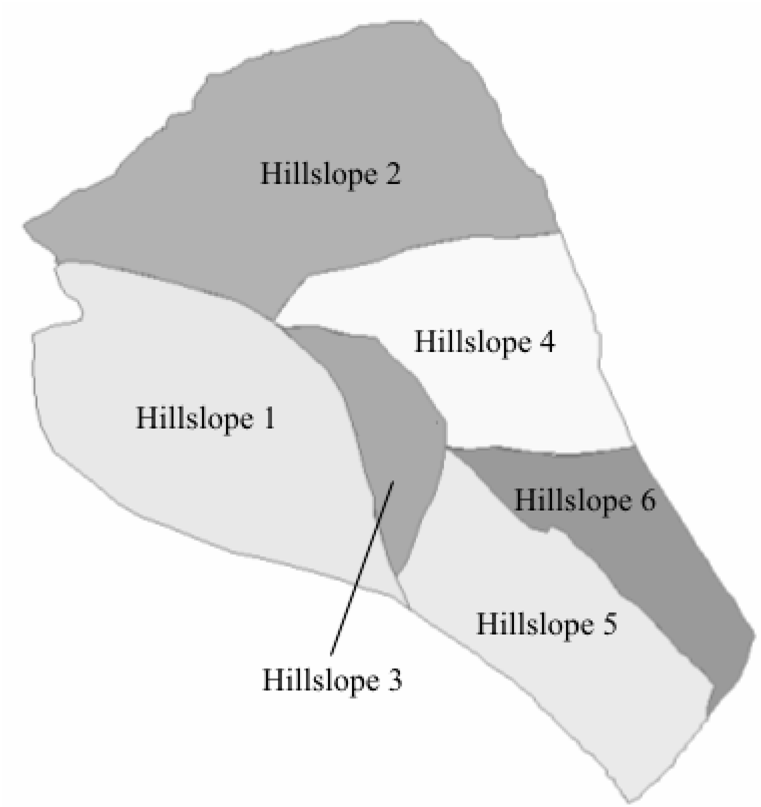

Figure 1. Division of the experimental watershed in hillslopes.

RUSLE model

The revised universal soil loss equation (RUSLE) expresses the soil loss per unit of area. The equation is

$$A = R\,K\,L\,S\,C\,P \tag{1}$$

where

A = soil loss per unit of area, t ha^{-1};
R = rainfall-runoff erosivity factor, MJ ha^{-1} mm h^{-1};
K = soil erodibility factor (t ha^{-1})/(MJ ha^{-1} mm h^{-1});
L = slope length factor, unit-plot conditions;
S = slope factor, unit-plot conditions;
C = cover-management factor unit-plot conditions; and
P = conservation practice factor, unit-plot conditions.

The R factor, calculated using precipitation data of Viçosa´s pluviometric station, was equal to 6769.5 MJ mm ha^{-1} h^{-1}. The value of soil erodibility (K) was taken equal to 0.017 (t ha^{-1})/(MJ ha^{-1} mm h^{-1}) (Bertoni and Lombardi Neto 1999). The factors L and S were calculated directly by the RUSLE software, being used the slope lengths and slopes. The C factor was calcuated considering the original covering of the soil as "bluegrass" (RUSLE database), with 100% of surface covering during all the year. As no conservation practices were adopted in the area of the experimental watershed, the value associated to the factor P was equal to one. The factors R, K, C and P didn't vary in all the six hillslopes of the experimental watershed.

WEPP model

The WEPP watershed computer model requires a minimum of four input data files, including climate, slope, plant/management, and soil.

The climate input data required by the WEPP model was generated by CLIGEN computer model. Based on long-term statistics from historical climate data of Viçosa city, the CLIGEN model generated daily values of precipitation amount, duration, maximum intensity, time to peak intensity, maximum and minimum temperature, solar radiation, dew point temperature, wind speed and direction for the experimental watershed area.

The slope input file includes physical features such as slope length, slope steepness, and profile aspect. As in the application of RUSLE model, six different representative hillslopes were considered in the watershed area. The watershed configuration and watershed channels are presented in Figure 1.

The plant/management file requires land use (agriculture, range, or forest) and information about the specific plants present and management practices used. In the simulations were used pasture covering (“bluegrass” variety) for all the watershed’s area.

Soils input files include soil parameters presented in Tables 1 and 2 and Green-Ampt effective hydraulic conductivity (K_0). Two different simulations were conduced considering different K_0 values, being kept constant all the other soil, slope and climate input data. In the first simulation (scenario A), the K_0 value was used as the infiltration rate after long time of wetting (T_{ie}), in agreement with recommendations of Cecílio et al. (2003) for Brazilian soils. In the second simulation (scenario B), the K_0 value was calculated by the software WEPP taking account to the physical and chemical characteristics of the soil.

Results and Discussion

Table 3 presents the annual soil loss and runoff values obtained by the simulation made with WEPP an RUSLE.

Table 3. Annual soil loss and runoff measured and calculated by simulation made with RUSLE and WEPP

	Field-measured	RUSLE	WEPP (Scenario A)	WEPP (Scenario B)
Runoff	62.0 m^3	-	63.4 m^3	275.4 m^3
Soil loss	200 kg ha^{-1}	140 kg ha^{-1}	0 kg ha^{-1}	300 kg ha^{-1}

In WEPP simulations, scenarios A and B predicted soil loss values close to the field-measured value. Scenario A simulation predicted soil loss lower than the real value due to the high hydraulic conductivity considered. The soil loss values calculated by this scenario under-predicted the real value, as found by Zeleke (1999) in Ethiopian Highlands. Scenario B simulation over-predicted soil loss due to a very low mean hydraulic conductivity calculated by WEPP model (about 12 mm h^{-1}). Scenario B simulation result is in agreement with the trend showed by Zhang et al. (1996) that found that small annual soil erosion values tended to be over-predicted by WEPP model.

RUSLE predicted annual soil loss equals to 140 kg ha^{-1}, a little lower than the field-measured value. This result is in agreement with those described by Spaeth et al. (2003) that found a consistent trend of RUSLE to under-predict soil loss. However, the predicted soil loss was very close to the field observed value, what reveals that RUSLE predicted well the soil loss in the analysed soil and surface covering conditions. The analysis of these values showed that RUSLE predicted soil loss better then WEPP model, what was also observed by Tiwari et al. (2000).

In the simulation made to scenario A of WEPP, it was observed that annual runoff volume was well predicted. The percentile difference between the annual field-observed runoff and the one simulate by WEPP scenario A was only 2.3%, a very small difference. In this simulation, it was observed that the hillsides didn't contribute with runoff. All the lost water comes from the channels of preferential flow. These channels are only supplied in rain times by water that infiltrate in the soil. Finally, scenario A simulation over-predicted runoff, as also found by Zeleke (1999).

In the simulation of WEPP´s scenario B the runoff amount was 275.4 m^3, what differs of that measured in 344%. The trend of WEPP model to over-predict runoff on the small events was observed by Risse et al. (1994) and is due to the low value of hydraulic conductivity calculated by the model.

The annual soil loss and runoff values predicted in scenario B simulation shows that WEPP must be used with extreme precaution in soil conditions that differs from those where the model equations were developed, what was also observed by Yu et al. (2000) in a subtropical Australian area and by Zeleke (1999) in Ethiopian Highlands. The physical and chemical differences between Brazilian and United States´ soils are considerable (for a same soil textural class), being necessary the determination of the Brazilian soils characteristics for the use of WEPP model.

Conclusions

The obtained results allowed us to conclude that:

a) both RUSLE and WEPP models satisfactorily predicted soil loss for the analyzed conditions, and RUSLE performance better than WEPP;

b) the WEPP model had better performance in the prediction of annual runoff using the T_{ie} value of the Green-Ampt hydraulic conductivity;

c) the use of WEPP outside its United States database requires calibration with locally obtained data.

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