Application of the Soil and Water Assessment Tool (SWAT) for sediment transport simulation at a headwater watershed in Minas Gerais State, Brazil

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Introduction

Natural resources are essential to life and irreplaceable in various human activities and, in addition, they are the foundation of the environmental equilibrium. Due to a rapid population growth observed during the last decades, the need for natural resources has increased significantly because of food production and water supply for population and industry.

Hydrological modeling has been widely used as a tool for evaluation of hydrological processes, thus allowing prediction of: (i) sediment accumulation in rivers and reservoirs; (ii) soil degradation and water erosion; and (iii) water quality for water supply and electric energy generation. Therefore, hydrological modeling makes possible to estimate the impact of land-use scenarios on water and sediment yield. It should be highlighted that the use of modeling for analysis of different land-use and management scenarios can support a rational use of water resources and implementation of adequate conservation practices for the desirable sustainable development.

Objectives

To calibrate and to validate the SWAT model for hydrology and sediment transportation simulation in an experimental headwater watershed located in the Mantiqueira Range region (Minas Gerais State, Brazil).

Materials and Methods

Study area

This research was carried out at Lavrinha Creek Watershed (LCW) which is located in the Mantiqueira Range region, Minas Gerais – Brazil (Figure 1). The drainage area is about 8.69 km² with altitudes ranging from 1,159 m to 1,704 m (mean value of 1,364 m) and mean slope equal to 39.9%. The climate is classified as Cwb (Koppen’s classification), characterized as meso-thermal with mean annual precipitation of 1,860 mm and mean annual temperature around 19°C.

SWAT model

The SWAT model is composed of a command structure to route runoff, sediments and agrochemicals within a watershed. Its main components are associated with hydrology, climate, sediments, soil temperature, observed hydrological series; SWAT makes use of the Shuffled Complex Evolution (SCE) method (Duan et al., 1992) for automatic parameter selection.

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Figure 1. Location of the Lavrinha Creek Watershed (LCW).

SWAT model

The SWAT model is composed of a command structure to route runoff, sediments and agrochemicals within a given watershed. Its main components are associated with hydrology, climate, sediments, soil temperature, crop growth, nutrients, pesticides and agricultural management. The hydrological component includes subroutines of surface runoff, percolation, lateral subsurface flow, return flow from shallow aquifers and evapotranspiration. It requires daily data related to precipitation, maximum and minimum air temperature, solar radiation and relative humidity (Neitsch et al., 2005).

To calibrate and to validate the SWAT model for hydrology and sediment transportation simulation in an experimental headwater watershed located in the Mantiqueira Range region (Minas Gerais State, Brazil).

Table 1. Parameters, ranges and calibrated values used or obtained in simulations.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Initial Value</th>
<th>Variation Method</th>
<th>Calibrated Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha_bf</td>
<td>0 – 1</td>
<td></td>
<td>0.048</td>
<td>Replace by value</td>
<td>0.021116</td>
</tr>
<tr>
<td>Ch_N2</td>
<td>0 – 1150 mm</td>
<td></td>
<td>0</td>
<td>Replace by value</td>
<td>28.133</td>
</tr>
<tr>
<td>CN2</td>
<td>-25% – 25%</td>
<td></td>
<td></td>
<td>Multiply by (%)</td>
<td>-24.065</td>
</tr>
<tr>
<td>S burst</td>
<td>0 – 10 days</td>
<td></td>
<td>4</td>
<td>Replace by value</td>
<td>1.325</td>
</tr>
<tr>
<td>Sia</td>
<td>-10% – 150%</td>
<td></td>
<td>1</td>
<td>Multiply by (%)</td>
<td>0.991</td>
</tr>
<tr>
<td>Ch_N2</td>
<td>0 – 1</td>
<td></td>
<td>0</td>
<td>Replace by value</td>
<td>0.0472</td>
</tr>
<tr>
<td>GWQmn</td>
<td>-1000 – 0</td>
<td></td>
<td>0</td>
<td>Add to value</td>
<td>-910.07</td>
</tr>
<tr>
<td>S_slope</td>
<td>-100% – 100%</td>
<td></td>
<td>0.95</td>
<td>Replace by value</td>
<td>0.8474</td>
</tr>
<tr>
<td>Slope</td>
<td>-25% – 25%</td>
<td></td>
<td></td>
<td>Multiply by (%)</td>
<td>-24.91%</td>
</tr>
<tr>
<td>GW_Delay</td>
<td>-10 days – 10 days</td>
<td>31</td>
<td>Add to value</td>
<td>9.056</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. (a) Digital elevation model (DEM); and (b) land-use map of the Lavrinha Creek Watershed.

Figure 3. (a) Soil map; and (b) location of the soil samples in the Lavrinha Creek Watershed.

Sediment and Water Assessment Tool

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Figure 4. Observed hydrograph and simulated hydrograph for (a) calibration period; (b) validation period in the Lavrinha Creek Watershed.

Figure 5. Observed and simulated values of suspended sediment concentration at the LCW’s outlet for the (a) calibration period; and (b) validation period.

Conclusions

Due to the COE results found during calibration and validation of the SWAT model it was concluded that such model was capable of simulating adequately both stream flow and suspended sediment concentration at the Lavrinha Creek Watershed’s outlet.

Acknowledgements: