Geoprocessing techniques in the study of the soil erosion potential on agricultural lands

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INTRODUCCIÓN

Areas of different soil erosion potentials can be analysed based on the runoff, through statistical models which represent the use of variables of the physical and anthropic environment.

The characterization and spatialization of the potential and erosional risks on soils, due to rainfall can be studied using remote sensing techniques and GIS. The data integration through GIS can be done, for example, using predictive models as the Universal Soil Loss Equation - USLE (Wischmeier and Smith, 1978) and its modified version MUSLE (Modified USLE), according to Williams (1975). In Brazil some studies were developed applying the MUSLE model by Donzeli et al (1994) and Pinto (1996). They are used in this study as methodological support.

The main goal of this study was to provide the characterization of the soil erosion potential by rainfall process in a small watershed using geoprocessing techniques and the MUSLE model for two scenarios (1980 and 2000).

METHODOLOGICAL APPROACH

The area studied is part of the Jacaré-Pepeira river basin (180 km²) and is located at the northeast of the São Paulo State, Brazil (22°12’35” – 22°21’30”
Figura 1. Localization of the study area.
Lat S; 48°08’50” Long W) (Figure 1). The relief is gently undulated. The climate is subtropical humid type CWa according to the Köppen system. The highest temperature is in December ($m = 25.1^{\circ}$C) and the lowest in June ($m = 6.8^{\circ}$C). Annual average precipitation is 1517 mm and the average precipitation in August is 34 mm and in December 259 mm. The most important soils are: Quartzipsammentsic Haporthox (Red Yellow Latosols) 80% of the total area, Typic Quartzipsamment (Regosols) 10%, Typic Eutrorthox (Dark Red Latosols) 5%, Hydromorphic soils 3%, Typic Palendult (Red Yellow Podzols) 2%, (Giometti, 1993).

The cartographic base was prepared by using 1:50,000 topo sheets. Soils and geology thematic maps were also available (1:100,000) as well as LANDSAT digital data (1978 and 1998). These data were processed in a GIS system –SPRING– developed by INPE (Brazilian National Institute for Space Research).

The land use maps were produced considering the following classes: annual crops, sugar cane, citrus, pasture, forestry, dense savannah (cerrado), open savannah (campo cerrado), residual areas of tropical forest, swamp vegetation and urban areas. For the two scenarios the Landsat data were processed using contrast enhancement and IHS transformation techniques as shown in Garcia and Pinto (1998). The land use/land cover overlays were adjusted to the cartographic base for the scale 1:50,000 and the input in the GIS system environment was done through a digitizing table.

To characterize the soil erosion potential (EP) was used the MUSLE model (Williams, 1975), adapted by Donzelli et al (1994).

$$\text{EP} = R_{\text{unoff}} \cdot K \cdot L^{0.63} \cdot S^{1.18},$$

where:

- **EP** = Soil Erosion Potential (t/ha);
- **R_{unoff}** = Runoff (m$^3$. m$^3$/sec);
- **K** = Soil erodibility factor;
- **L** = Slope length factor;
- **S** = Slope steepness factor

According to the MUSLE model the following data were acquired: Erodibility of soils, from the soil map by Almeida et al (1981) and adjusted by Bertoni & Lombardi Neto (1990) and Donzeli et al. (1992); Slope length and steepness from 1:50,000 topo sheets. The model is implement by two additional variables. The C factor which is derived from land use/cover maps and the P factor which represents the degree of conservation practices measurements. In this study the P factor was considered as 1.0 (without conservation practices).

The term $R_{\text{unoff}}$ was used in the equation as adopted and specified by Donzelli et al (1994) and Pinto (1996), as follows:

$$R_{\text{unoff}} = 89.6 \cdot (Q \cdot qp)^{0.56},$$

where

- **Q** = Surface flow volume (m$^3$)
- **qp** = Maximum flow of discharge (m$^3$/sec)

To determine the equation, the following data were obtained:

- **Surface flow volume (Q):**
  - Determination of the hydrological classes of soils, considering their types, according to the USDA-SCS (1972) and Lombardi Neto et al (1993).
  - By overlaying the temporal land use (1980-2000) and the hydrological classes of soils were obtained the values of Curve Number (CN), as proposed by the USDA-SCS (1972) for both years. The CN values were transformed in surface flow estimation (Q) using a specific chart as shown in Figure 2. In this study the maximum rainfall intensity used was 115 mm/24 hs, for a return period of 10 years.

- **To calculate qp was used the equation adopted and specified by Pinto (1996):**

$$Q_p = 0.278 \cdot (C_x) \cdot I \cdot A^0.9 \cdot K,$$

where

- **Cx** = Runoff coefficient
- **I** = Intensity of rainfall
- **A** = Area of the study
- **K** = Coefficient of the rainfall distribution

The values of $R_{\text{unoff}}$ coefficient were spatialized for the 1980 and 2000 scenarios, considering the following classes of data: land use/land cover, hydrological classes of soils and relief classes (as defined through geomorphological and slope maps).

All information were integrated with the aid of the GIS system and maps of soil erosion potential classes (EP) were established for 1980 and 2000, according to the MUSLE model (Donzelli et al, 1994).

To characterize the dynamics of the erosion potential an overlaying of the EP80 and EP00 was performed in the GIS environment. The result was a layer of information showing changes on the classes in the context of the two selected scenarios. This overlaying was applied structuring a file of rules to cross the thematic classes.
RESULTS

Using the proposed methodology, the following results were obtained:


   The soil erosion potential (EP) according to the MUSLE model was characterized for 1980 and 2000 as an indicator of the expectation of the erosion process which could result in a soil erosion by the rainfall over the slope surface.

   The EP can be defined by the USLE model as well as by the MUSLE model (Pinto, 1996). The difference between the two models refers to the erosivity of rainfall (R) in the USLE model which is obtained through a rainfall average in a determined time series. In the MUSLE model the R variable is replaced by the runoff factor which is obtained considering a specific rainfall, hydrologic characteristics of soils, classes of slope and status of vegetation cover of the slope.

   Using the GIS system, the data of the MUSLE model were integrated, using the methodological sequence discussed above. From the processed data were obtained matrices which were classified resulting in two thematic maps (2000-2002). The classes were defined using the automatic option of the GIS, considering the distribution of values and respective frequencies. Four categorized classes were adopted: EP low, EP medium; EP high and EP very high (Table 1).

   Figures 3 and 4 show the spatial distribution of classes of erosion potential for 1980 and 2000. The data analysis show that the spatial arrangement of classes of erosion potential are closely related with the relief characteristics, mainly slope percent and degree of dissection. These areas are also mostly associated with soils presenting higher erodibility values.

<table>
<thead>
<tr>
<th>CLASSES</th>
<th>EP</th>
<th>QUALITATIVE CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 200</td>
<td>Low</td>
</tr>
<tr>
<td>2</td>
<td>200 - 1000</td>
<td>Medium</td>
</tr>
<tr>
<td>3</td>
<td>1000 - 2500</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>2500 - 32400*</td>
<td>35000**</td>
</tr>
</tbody>
</table>

* Maximum value for 1980
** Maximum value for 2000


2. Temporal Analysis of the Soil Erosion Potential

   Overlaying both maps of soil erosion potential the changes in the spatial distribution in the study area were obtained. Table 2 shows the percentage of classes distribution for both scenarios.

   In 1980 the EP low is predominant, while in 2000 the predominance is for the EP medium. The EP high increased from 9.0 % to 12.4 %; the percentage of EP low was significantly reduced and the EP medium shows an important increase. These alterations are due to the changes on the land use and vegetative cover since they have great influence on the determination of the Runoff factor.

   The overlaying of the erosion potential maps, in the GIS system allowed to establish seven classes (Figure 5), where areas in the original condition (1980) were remained in 2000 and the changes were toward a more favorable situation or toward a worst situation in terms of soil erosion risk.

Table 3 shows the overlayed classes of the soil erosion potential for the two scenarios and the areas in percentage.

Table 3 shows that the area of first class of intersection remained stable for the two conditions of analysis, i.e., there were no alteration of land use cover for this class. Classes 2, 4 and 6 changed toward more restrictions classes, while for the classes 3, 5 and 7 the change were in the direction of less restrictions.

As erodibility of soils, length of slope and slope percent in the MUSLE model are constants for both scenarios, the differences in the classes of erosion potential are explained by the Runoff factor of the model which aggregates land use data, highly dynamic in time and space.

**FINAL CONSIDERATIONS**

The methodological approach in this study considered geoprocessing techniques (remote sensing and GIS) and a predictive model (MUSLE) to characterize the erosion potential, for two different periods, in an agricultural watershed. The data integration in the MUSLE model through a GIS allowed the characterization of the erosion potential in the same scenario spaced by 20 years.

On the context of these two scenarios, significant changes were observed in the classes of soil erosion potential with an increase on the restrictions for 2000 mainly due to the development of the agriculture areas.

<table>
<thead>
<tr>
<th>CLASSES</th>
<th>EP80 x EP00 CLASSES</th>
<th>ÁREA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 - 1</td>
<td>27.1</td>
</tr>
<tr>
<td>2</td>
<td>1 - 2 / 3/ 4</td>
<td>25.2</td>
</tr>
<tr>
<td>3</td>
<td>2 - 1 / 2</td>
<td>25.6</td>
</tr>
<tr>
<td>4</td>
<td>2 - 3 / 4</td>
<td>5.3</td>
</tr>
<tr>
<td>5</td>
<td>3 - 1 / 2 / 3</td>
<td>8.2</td>
</tr>
<tr>
<td>6</td>
<td>3 - 4</td>
<td>1.1</td>
</tr>
<tr>
<td>7</td>
<td>4 - 1 / 2 / 3 / 4</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Tabla 3. Overlay of the erosion potential classes in 1980 and 2000 (EP80 x EP00) - Percentage of existing classes.

**BIBLIOGRAPHY**


Figura 5. Intersection of EP 80 x EP 00.