Revista
GEOCIÊNCIAS

ISSN: 1980-900X (online)

# SOIL LOSS ESTIMATION IN A WATERSHED OF THE PARANÁ RIVER WITH DYSTROPHIC RED LATOSOL

*ESTIMATIVA DA PERDA DE SOLO DA BACIA HIDROGRÁFICA CÓRREGO SANTA VERA SOBRE LATOSSOLO VERMELHO DISTRÓFICO*

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**ABSTRACT -** The hydroelectric power plants (HPP) in Ilha Solteira and Jupiá are part of the Urubupungá Hydroelectric Complex, which is the sixth most important hydroelectric complex in the world. However, their reservoirs are undergoing an intense siltation process. We evaluated the erosive potential of the Santa Vera Stream Watershed (SVSW), located on the banks of the Jupiá HPP reservoir. Soil use and occupation maps, and field analysis, enhanced by Geographic Information Systems (GIS), were used to obtain important parameters for the creation of RUSLE factors for the entire watershed. It was confirmed that areas dominated by degraded pastures that lacked conservation practices, such as contour lines, together with the increase in steepness of slopes toward areas near the drainage networks, resulted in higher estimates of soil loss. We concluded that the predominant values for soil loss estimates in the SVSW were low or close to zero. Nevertheless, values classified as being above soil recovery capacity were found in the reservoir banks, which lack riparian vegetation. Therefore, projects aiming at replenishing the vegetation of the reservoir banks are extremely important for their maintenance and for the conservation of native species in the region.
**Keywords:** Conservation. Soil erosion. Riparian vegetation.

**RESUMO -** As usinas hidrelétricas (UHE) de Ilha Solteira e Jupiá compõem o complexo hidrelétrico denominado Urubupungá, o sexto complexo mais importante mundialmente, porém os reservatórios dessas usinas vêm sofrendo um processo intenso de assoreamento. Neste contexto, estre trabalho tem como objetivo avaliar o potencial erosivo da Bacia Hidrográfica Córrego Santa Vera (BCSV), localizada as margens do reservatório da UHE de Jupiá. Por meio do uso de mapas de uso e ocupação dos solos e análises de campo, associada à utilização de Sistemas de Informações Geográficas (SIGs) pôde-se obter parâmetros importantes para a confecção dos fatores pertencentes a RUSLE para toda bacia. Verificou-se a predominância de áreas com pastagens degradadas e sem uso de boas práticas conservacionistas, como curvas de nível, que associados ao aumento da declividade nas áreas próximas as redes de drenagem, resultaram em maiores estimativas de perdas de solo. Concluiu-se que os valores predominantes de estimativa de perda de solo na BCSV foram baixos ou próximos de zero, porém, valores classificados como acima da capacidade de recuperação do solo foram encontrados nas margens do reservatório, que não possuem mata ciliar. Neste âmbito, projetos que visem a revegetação das margens do reservatório são de extrema importância para a manutenção do reservatório bem como a conservação de espécies nativas da região.
**Palavras-chave:** Conservação. Erosão do solo. Vegetação. Erosão do solo. Vegetação ripária.

## INTRODUCTION

The hydroelectric power plants (HPP) in Ilha Solteira and Jupiá are part of the Urubupungá Hydroelectric Complex, which is the sixth most important hydroelectric complex in the world (Lima, 2013). Despite their strategic importance in the production of national electric power, the reservoirs of these plants have been undergoing intense siltation processes due to landslides on their corresponding banks. This is caused by the impacts of rainfall and reservoir waves and is aggravated by the lack of riparian vegetation.

In tropical countries, specifically in Brazil, water erosion generates several problems with respect to soil fertility, agricultural production, and the quantity and quality of water resources. Water erosion is considered to be a major environmental problem, which results in decreased crop yields and increased production costs, thereby decreasing the profitability of agricultural activities. In addition, it causes the siltation of rivers, degrading the water quality of the local watershed (Santos et al., 2015).

Considering the importance that erosional processes have on tropical soils, management of ground cover, and the production system, become important factors with direct influence on the intensity of superficial drainage and water erosion.

As such, understanding the processes that contribute to water erosion, as well as their relation to soil and water loss in different systems, are extremely important in order to identify and choose adequate measures for better planning and sustainable productivity (Barbosa et al., 2015). Candido et al. (2014), while studying water erosion in eucalyptus forests, observed that contour farming with continuous coverage of an organic residue on the soil resulted in lower values for water and soil loss, similar to losses in areas with native vegetation. The authors also observed that soil type and the different management and planting systems used for the crop result in different amounts of soil loss, further reinforcing the importance of an appropriate and integrated production system.

Simulation models, as well as the mathematical models used for predicting erosion, are useful tools both for research and agricultural practices, given that they help to determine the most appropriate conservation practices and management for each specific scenario (Chaves, 1996). These models were initially created to estimate soil loss on slopes, but with the invention of Geographic Information Systems (GIS), these models started being applied to larger surfaces, such as watersheds and large properties.

Erosion estimation through the Universal Soil Loss Equation, proposed by Wischmeier & Smith (1978) and Renard et al. (1991), seeks to reproduce what occurs naturally in a given area based on the main factors that act in water erosion. An adjustment of this model is the Revised Universal Soil Loss Equation (RUSLE), which makes it possible to estimate erosion potential by taking into account the interaction between rainfall energy, soil, and relief characteristics, and the use and management of the area of study. The integration of the model with GIS allows for more efficient methods of data input and output (Alatorre & Bequíra, 2009). The objective of this work was to evaluate the erosive potential of the Santa Vera Stream Watershed (SVSW), with the banks of the Jupiá HPP reservoir being located using a combination of GIS and the RUSLE mathematical model.

## MATERIALS AND METHODS

The study area, named Talude 227, is located in the watershed of the Santa Vera stream, in the municipality of Três Lagoas – Mato Grosso do Sul (MS) (Figure 1), and covers 3 555 ha. The climate classification, as per Köppen and Geiger, is Aw (humid tropical climate, with rainy season during the summer and dry during the winter). Annually, the approximate average rainfall is 1 250 mm. The average annual temperature is 24.2 °C. The terrain is mostly flat/smooth wavy and the most common soil type in the area is dystrophic Red Latosol, mostly of a light sandy texture (Albuquerque & Sakamoto, 2015).

The erosion estimate through the Universal Soil Loss Equation was obtained using the following equation:

$$A = R \,.\, K \,.\, LS \,.\, C \,.\, P \quad (1)$$

in which:

A = annual soil loss in Mg ha -1 year -1;

R = rainfall erosivity factor in MJ mm ha -1 h -1 year -1;

K = soil erodibility factor in Mg h MJ - 1 mm - 1;

LS = topographic factor (dimensionless);

C = crop coverage and management factor (dimensionless);

P = practical management factor (dimensionless).

The rainfall erosivity factor (R) was calculated based on the methodology described by Wischmeier & Smith (1978), as shown in equation 2, using the average meteorological data from the last 20 years for the municipality of Ilha Solteira – SP (Table 1).

$$R = \sum_{i}^{12} 1.735 \times 10^{1.5 \log_{10}(P_i^2/P) - 0.008188} \quad (2$$

in which

R = Rainfall erosivity (MJ.mm/ha.h.year).

Pi = average monthly rainfall in month i (mm).

P = average annual rainfall (mm).

The value associated with the K factor was 0.017 Mg h MJ-1 mm-1 (Bertoni & Lombardi Neto, 2017).

This value was directly used for the final calculations of the erosive potential of the SVSW. It was possible to generate a digital terrain model using an altimetric grid, with each pixel corresponding to 30 m, provided by the Shuttle Radar Topography Mission (SRTM) satellite. The methodology used was described by Zhang et al. (2013) for the construction of raster maps, using the values from the LS factor and a slope map, which together with the creation of a map of soil conservation management practices, were used in the formulation of the P factor raster map. Additionally, a map of land use and occupation was generated using SPRING GIS to associate the factor C values by means of an image obtained from Sentinel-2 (orbit point 22KDC) on May 26, 2019, thereby generating a raster map of this factor. Factor A was calculated, using Qgis GIS, by multiplying all of the other factors and consequently generating a raster map with the values for the erosive potential of the SVSW.

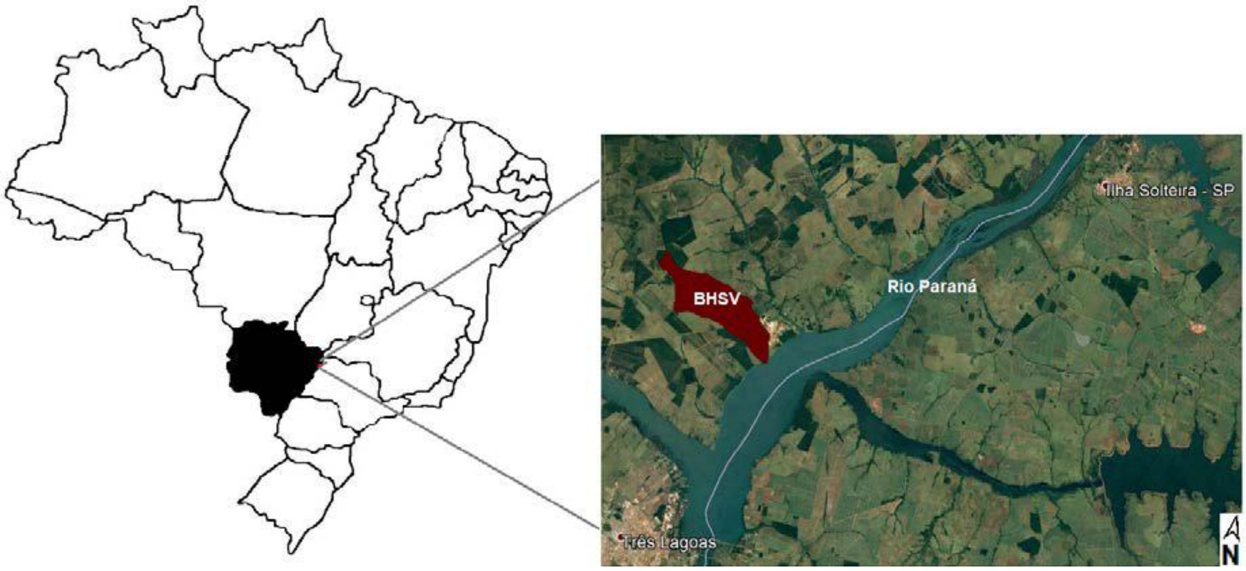


**Figure 1 -** Location of the Santa Vera Stream Watershed (SVSW).

## RESULTS AND DISCUSSION

The erosivity value obtained was 1 214.9 MJ mm/ha h year, which is consistent with data from Coutinho & Antunes (2013).

The values for the ramp length factor ranged from 0 to 6.5, with predominantly lower values, tending to 0 (Figure 2). These values may be related to the predominance of the types of slopes; flat and smooth wavy, in the SVSW area. Carvalho et al. (2014) obtained similar LS values when studying the influence of ground coverage variation and rainfall erosivity on the RUSLE; their values ranged from 0 to 10.83 in various types of soil, including Red Latosol.

In order to obtain factor C, a mapping of land use and occupation in the basin area was performed, resulting in a land use and occupation map (Figure 3).

This map allowed for identifying the following 9 types of land use and occupation: degraded pasture (44.22%), conserved pasture (28.91%), natural vegetation (17.59%), dirty pasture (4.45%), constructed area (2.37%), water bodies (1.13%), exposed soil (0.93%), sugarcane (0.22%), and reforestation (0.18%).

**Table 1 -** Rainfall values (average of 20 years) and rain erosivity in the municipality of Ilha Solteira.

| Date (month) | Rainfall (mm) | Erosivity (MJ mm ha -1 h -1 year -1) |
|---|---|---|
| January | 260.82 | 517.2209 |
| February | 177.02 | 161.7039 |
| March | 171.84 | 147.9198 |
| April | 71 545 | 10.67557 |
| May | 62 615 | 7.1563 |
| June | 29 595 | 0.755629 |
| July | 19 905 | 0.229901 |
| August | 28 895 | 0.703269 |
| September | 66.44 | 8.54953 |
| October | 100 435 | 29.53307 |
| November | 166.58 | 134.7479 |
| December | 188 655 | 195.7304 |
| **Total** | **1344.345** | **1214.926** |

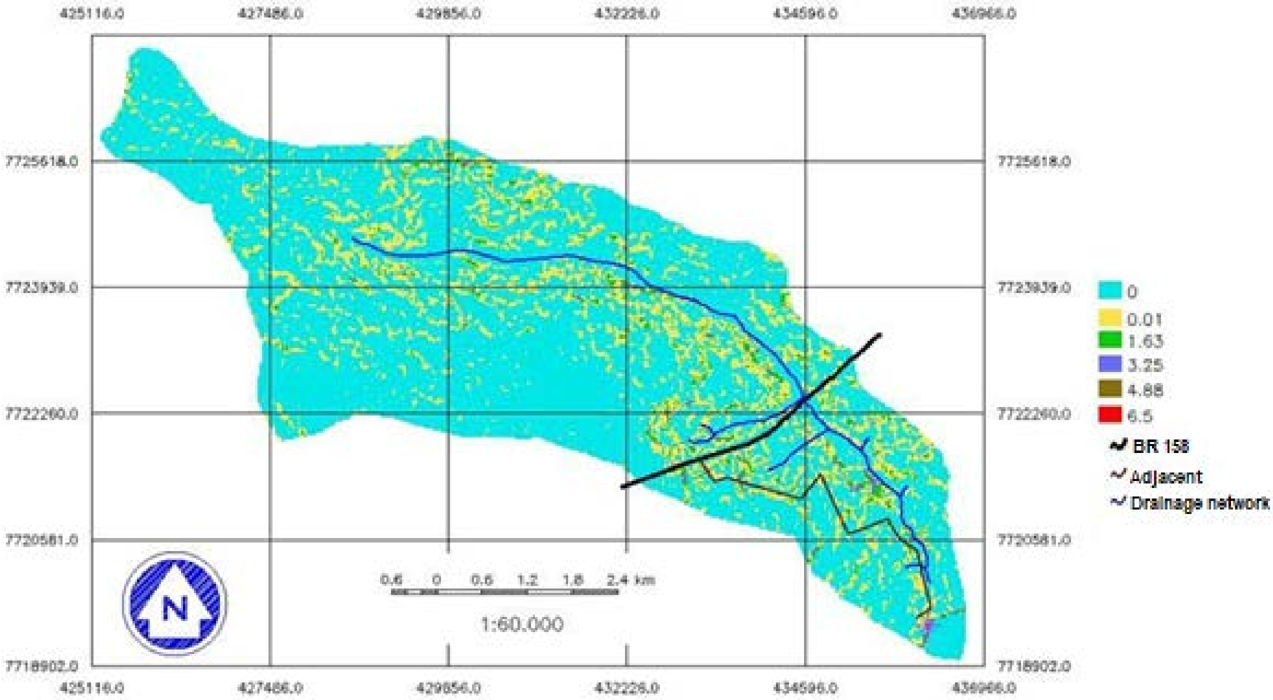


**Figure 2 -** Values for the ramp length factor (dimensionless) in the SVSW.

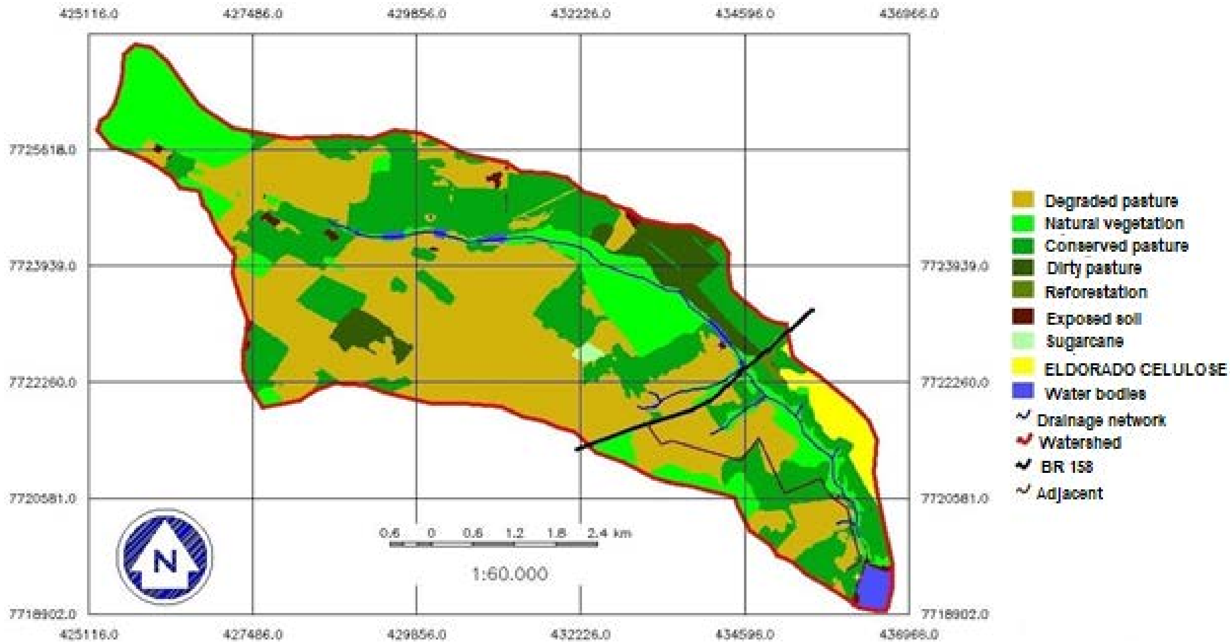


**Figure 3 -** Soil use and occupation map for SVSW.

Based on this map, it was possible to confirm the predominance of degraded pastures in this basin. Factor C is extremely important, given that the vegetation type has a direct influence on the damage caused by rain drops.

Areas with denser vegetation protect the soil by decreasing the water erosion common to areas with lower vegetation coverage (Correa et al., 2016).

Factor P was obtained by classifying the study area and dividing it into three classes, namely: “terracing”, “planting downhill” and “absent” (where no management practice is used). The classes “planting downhill” and “absent” were identified by the same value (1), and "terracing" was divided according to 4 slopes, which were associated with different values.

Factor A in the SVSW ranges from 0 to 134 Mg $ha^{-1}$ $year^{-1}$, with most soil losses ranging from 0 to 2 Mg $ha^{-1}$ $year^{-1}$ (Figure 4). Nonetheless, the highest values were observed along the banks of the reservoir, especially within the first few meters. Barbosa et al. (2015) obtained similar results in the region of Paraíso das Águas (MS). When studying soil loss in this municipality, the losses ranged from 0 to 1 307.32 Mg $ha^{-1}$ $year^{-1}$, with most areas (96%) displaying losses below 50 Mg ha$^{-1}$ year$^{-1}$.

According to Bertoni & Lombardi Neto (2017), the value for soil loss tolerance used for the studied soil type ranges from 11.5 to 13.3 Mg ha$^{-1}$ year$^{-1}$. As such, it is clear that most of the basin (99.7%) has soil loss values below these tolerance thresholds.

However, there are critical areas in the basin, along the basin reservoir banks, ranging predominantly from 10 to 100 Mg ha$^{-1}$ year$^{-1}$ over a range of 30 to 60 meters.

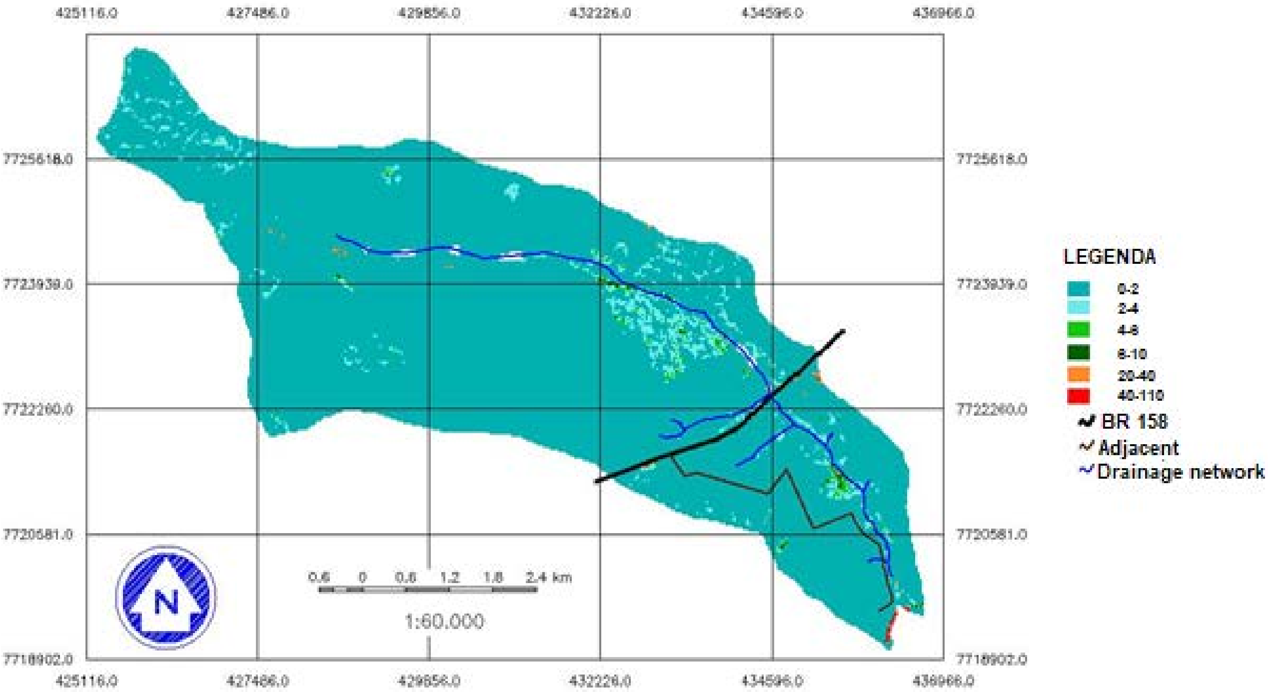


**Figure 4 -** The values for the estimates of soil loss in the SVSW are in Mg ha -1 year -1.

## CONCLUSIONS

The use of GIS and RUSLE techniques enabled the physical characterization (relief, type of soil, soil use, and occupation) of the Santa Vera Stream Watershed and it proved efficient for quantifying soil losses, making it satisfactory and adequate for this work.

It proved to be a complete tool with a great deal of potential, especially given how easy it was to visualize and integrate data and how fast it executed the results. Even though the main values were within a tolerant range of soil loss (<13.3 Mg ha$^{-1}$ year$^{-1}$), the importance of maintaining riparian vegetation, which is essential to avoid siltation of water bodies, should not be underestimated.

This relationship was shown by the high loss values in these areas, which exceeded 60 Mg ha$^{-1}$ year$^{-1}$ at some points.

## ACKNOWLEDGEMENTS

We would like to thank China Three Gorges Brasil (CTG Brasil) for financing this research.

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*Submetido em 6 de novembro de 2018*
*Aceito para publicação em 25 de maio de 2021*