This article is presented in Portuguese and English with "resumen" in Spanish.
Brazilian Journal of Applied Technology for Agricultural Science, Guarapuava-PR, v.4, n.2, p.30 – 47, 2011.

Scientific paper

Application the geographic information system for the determination of topographic factor in a watershed

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Abstract

The topographical factor represents the influence of the length and steepness of the slope in the intensity of hydric erosion in the soil. The aim of this study is to test the use of the Geographic Information System (GIS) in the determination of the topographical factor (LS) of the universal equation of soil losses, USLE in the Córrego Tijuco watershed, São Paulo State, Brazil. The study area, which covers 8007.4 ha, has gently undulating relief and two classes of soil (Latossolo Vermelho e Argissolo Vermelho Amarelo). The work was carried out based on geographic information system for calculating the topographic factor. The results showed a predominance of areas with low to moderate values of topographic factor. Although the watershed relief is predominantly gently undulating to strong undulating, the factor (LS) exerted a major influence on erosion mainly to the amount of the watershed where the terrain has a gently relief. High values of slope length (L) and the highest values of the topographic factor were verified in downstream of the watershed.

Keywords: Geoprocessing, slope, length.

Introduction

The universal soil loss equation, USLE, is one of the most used models for estimate the hydric erosion of soil. Its analysis results from the product of the several factors which influence the erosive process, either they are factor rainfall erosivity (R); factor soil erosion (K); factor use and management (C); factor conservationist practices (P) and topographic factor (LS), represented by the joint effect of the ramp length (L) and slope (S) (WISCHMEIER and SMITH, 1978).

For these authors the ramp length (L) in meters is referred as the distance from the point of origin of the water fall to a defined channel. The slope degree of the hillside (S) expressed in percentage is characterized as tangent of an angle or index of the land inclination.

These two factors have been researched separately, however, for practical application, it is more convenient to consider them together as a topographic factor (LS).

The factor ramp length (L) may be obtained from direct measure in topographic maps or through the ratio between the area of the watershed in m² and the sum of all water courses of the river basin in meters, according to the methodology of the equivalent triangle modified by VILELA and MATTOS (1975).

The factor slope (S), in percentage, may be estimated trough the Digital Elevation Model (DEM).

Considering the difficulties found for the

Received in: 17/04/2011 Accepted for publication: 14/08/2011

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calculation of the topographic factor, SILVA (2003) aimed to determine it, using it for the calculation of the length of the slope (L), the algorithm of DESMET and GOVERS (1996) and for the calculation of the hillside slope and the methodology of WISCHMEIER and SMITH (1978).

Other authors, as ROCHA et al. (1996), developed a methodological sequence of application in GIS about DEM, resulting in a plan of information (PI) of ramp length in polygonal structure. Meanwhile, CASTRO and VALÉRIO FILHO (1997), when applying another automatic procedure over the DEM for the determination of the PI ramp length, indicate the use of the crossing between the PI of orientation of the hillsides and the distance relative to drainage channels.

Since all the factors of this equation may be spatialized, it has been common the use of Geographic Information System (GIS) in the evaluation of the soil losses. GIS are one of the most modern and promising tools of storage and thematic manipulation and even in substitution to the maps printed (FORMAGGIO et al., 1992). The thematic maps of slope and ramp length, expressed, respectively, by factors S and L, which were made manually before, may be generated automatically trough the geographic information.

Applications of the GIS and cartographic data for analysis and prediction of the LS are registered in literature. VALERIANO (2002) verified the occurrence of errors in the determinations of the ramp length, and these errors prevailed in areas of uneven relief with high slopes and short ramps, which indicates the necessity to establish more sophisticated procedures of adjustments for the results of the GIS. WEILL and SPAROVEK (2008), also using GIS for the calculation of the factor LS observed that in most part of the studied area, the LS factor was equal or inferior to 1.599, and this value may be associated with the ramp length at approximately 35 m and slope of approximately 10%.

In this scenario, the spatial discretization of the topographic factor (LS) is one of the major challenges for the mathematical modeling of the erosion. Its calculation still follows mathematical models proposed by BERTONI and LOMBARDI NETO (1999), used by the authors UENO and STEIN (2004), SILVA et al. (2005) and FREITAS et al. (2007), who observed that the topographic factor was the one which influenced the most in the erosive process.

Several studies for the calculation of the topographic factor are trough manual methods, in which it is used sampled points, with the results extrapolating for all the studied area. Although the slope is relatively easier to be measured trough planialtimetric maps, measuring the ramp length becomes an obstacle due to the difficulty of the operation, and may obtain different results (SILVA, 2003).

The digital techniques have operational advantages, enabling the map of the ramp length in high resolution, which compensate partially the errors of numeric accuracy of the estimative. VALERIANO (2002) concluded that the estimative of the ramp length trough GIS was affected by the local conformation of relief, with better estimates in areas of smooth relief and more frequent errors around hillsides with high slopes and small ramp length.

The present work has as objective to test the use of the Geographic Information System (GIS) in the determination of the topographic factor (LS) of the universal soil loss equation, USLE.

Material and methods

The study area comprehends the watershed Córrego do Tijuco, which belong to the watershed of Córrego Rico in the management unit of the Rio Mogi Guaçu, which belong to the Municipalities of Jaboticabal and Monte Alto, state of São Paulo. This area is located between the geographic coordinates 45º 19′ 50″ to 48º 27′ 26″ longitude WGr and 21º 18′ 10″ a 21º 12′ 53″ of S latitude, horizontal Datum Córrego Alegre, MG., with approximately 8007.4 ha (Figure 1).

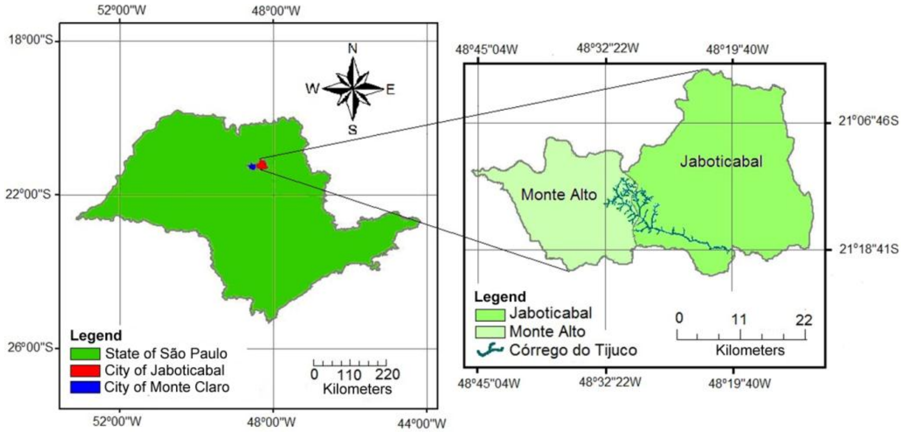

Figure 1. Localization of the watershed Córrego do Tijuco, SP.

The climate, by the classification of Köppen, is mesothermic with dry winter (Cwa), with annual average temperature of 22°C and annual average rainfall of 1400 mm. The local relief is predominantly light wavy, with altitude ranging between 488 and 700 m, Datum vertical, Mareógrafo de Imbituba, SC.

Sugar cane crop, the main use, occurred in 83% of the study area followed by less intensive uses, pasture (8%), forest (0.5%), riparian area (8%) and annual crops (0.5%) of the study area, geologically constituted by sandstones of the formation Adamantina and Marília, both from the Grupo Bauru.

In the area, two classes of soil prevail: Latossolos Vermelhos Distróficos (LVd), moderate "A" horizon, medium texture, plain and soft wavy relief with 2700 ha and Argissolos Vermelho-Amarelos Eutrófico (PVAe), abrupt, with sandy/medium texture, light wavy relief with 5300 ha of the study area.

The cartographic base of the Watershed Córrego do Tijuco used for the plans of information (PI) relative to the contour of the area, to the level curves and the hydrography was elaborated from the Cartas do Brasil, planialtimetric, from the Instituto Brasileiro Geografia e Estatística (IBGE – Brazilian Institute of Geography and Statistics), scale 1:50000, sheets of Jaboticabal (SF 22-Z-B-III-3) and Taiúva (SF 22-X-D-III-2), image of the satellite CBERS – 2/CCD multispectral module with 3 bands, resolution 20m.

The Base Map was elaborated from the Carta do Brasil, IBGE, which has the drainage net of the Watershed of the Córrego do Tijuco, SP. The Carta do Brasil (Taiuva and Jaboticabal), scale 1:50.000, was scanned in 300 DPI and, later, introduced in IDRISI for georeference, adopting the reference system UTM 22 Córrego Alegre, center meridian 45° WGr and ellipsoid South American 1969-SAD69. The digitalization was performed using the program CARTALINX.

The ramp length (L), and the slope degree (S) were grouped in a single factor, named topographic factor (LS) and calculated according to the equation (1), proposed by BERTONI and LOMBARDI NETO (1999).

$$LS = 0.00984 \times C^{0.63} \times D^{1x18} \quad (1)$$

In which: LS = topographic factor (adimensional); C = average length of the ramp, in meters; D=declivity (%).

In order to calculate the ramp length from the method of the equivalent triangle, it was used equation 2:

$$C = A / 4.L \quad (2)$$

In which: C = average length of ramp, in (m); A = area of hidric contribution of the watershed (m^2); L = sum of the length of all the water courses of the watershed.

The method of the equivalent rectangle consists in the determination of the value of C (VILLELA and MATTOS, 1975). This length is comprehended as the average distance of the hillside, which the rainfall water, by superficial drifting, achieves the river beds. This distance considers the area of the basin in study as a rectangle, in which in its center there is a river with length l, correspondent to the sum of the length of all the water courses which compound the drainage net of the basin. This length is performed for each area of water contribution determined from the elaboration of one PI containing hydrographic networks.

In order to determine the area of water contribution of the watershed (A), it was used the module area of the menu Analysis of IDRISI. The sum of the total length of the water coursed (L) was estimated in CARTALINX using a database generated in the moment of vectorizing of the water courses.

To obtain the values Average ramp length (C) for each area of water contribution, it was generated a database in the file format .AVL (value files), for the 31 areas of water contribution and the command Assign to add the values created in the database (Figure 2).

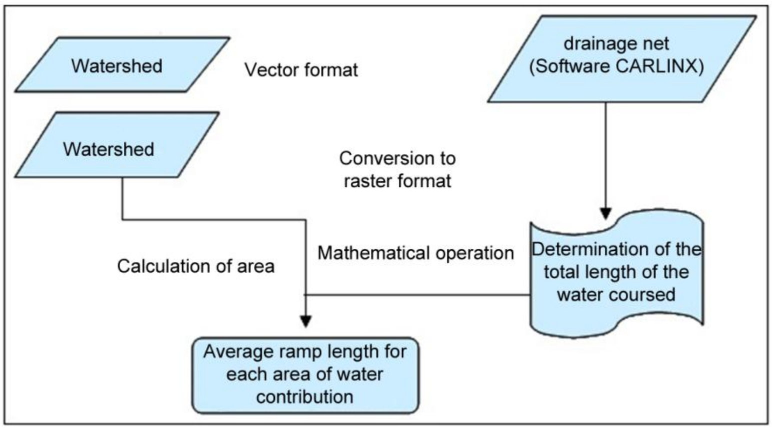

Figure 2. Flowchart for the elaboration of the map mean ramp length (C) for each area of water contribution.

The values of slope (S) of the topographic factor were obtained from the numeric model of the terrain (NMT), with IDRISI from the vectorization of the curve levels from Jaboticabal and Taiuva leaves, from Cartas of Brasil, using menu Gis Analysis>Surface Analysis>Interpolation>Tin Interpolation and in the end the command Tin. After the generation of the triangular grid (TIN), it was executed the comment Surface, choosing the option of output in percentage (Figure 3).

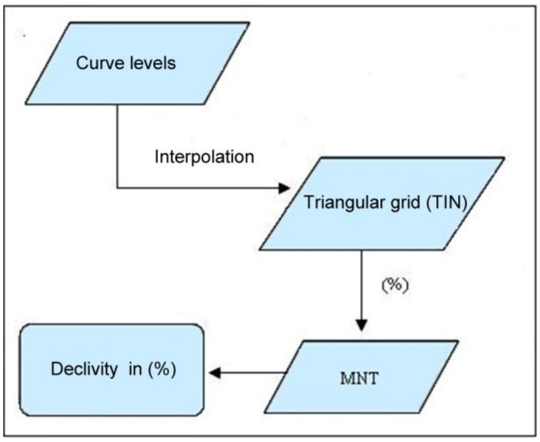

Figure 3. Flowchart for the elaboration of the map of declivity (D) in percentage.

In order to obtain the values of Topographic value (LS) it was necessary to generate the maps of ramp average length (C) for each area of water contribution (L), and declivity (S). For that, it was used the module *Image Calculator* from IDRISI and it was processed an execution of the adequately mathematic expression. The result was generated from the junction of the maps of average length of ramp for each area of water contribution and the map of declivity, according (Figure 4).

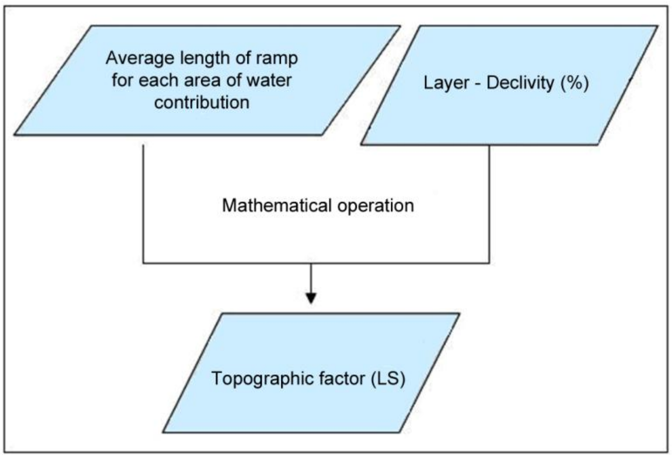

Figure 4. Flowchart to obtain the topographic factor (LS).

For the classification of the values obtained from the topographic factor, it was adopted the classes developed by BERTONI and LOMBARDI NETO (1999): very low (< 1), low (1 to 5), moderated (5 to 10), high (10 to 20) and very high (> 20).

Results and Discussion

In the evaluation of the potential of erosion, the characteristics of the predominant slopes (declivity and length) enables to verify that the declivity and the distance covered, will be directly related to the increase of the energy produced by the rainfall which accumulates and higher will be the resulting erosion.

The classes which prevail in the declivity map (Table 1 and Figure 5) show downstream a predominance of plain areas and light wavy slope (3 to 8%) with very slow superficial drift, which do not favor the water erosion; and areas upstream, with relief moderately wavy (8 to 13%), in which the superficial drift for most part of soils is medium or fast, already occurring erosion.

Table 1. Declivity classes of Watershed Córrego do Tijuco, SP.

Classification	Defined class	Area	
	(%)	(ha)	(%)
Plain	0 – 3	1108.4	13.8
Lightly wavy	3 – 8	4240.2	52.9
Moderately wavy	8 -13	1945.7	24.2
Wavy	13 – 20	604.6	7.5
Strongly wavy	> 20	109.5	1.3

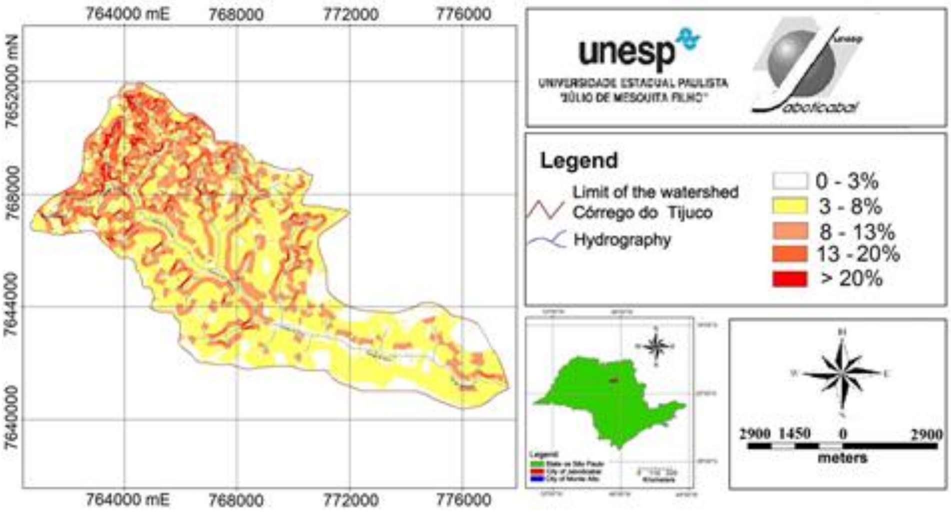

Figure 5. Declivity map for the watershed Córrego do Tijuco, SP.

In several regional studies of evaluation of erosion (CASTRO and VALÉRIO FILHO, 1997; BUENO and GARCIA, 2003; SILVA et al., 2005), the authors observed higher influence over the factor ramp length in the erosive process. However, even though the watershed did not present and accented relief, the factor ramp length presented influence in the erosive process in intensity and quantity of transported material, in accordance with the results obtained by SILVA et al. (2003).

Downstream the watershed, areas in which the water contribution was higher obtained a higher mean ramp length (3195 m), which contribute for a higher value of the topographic factor (Figure 6).

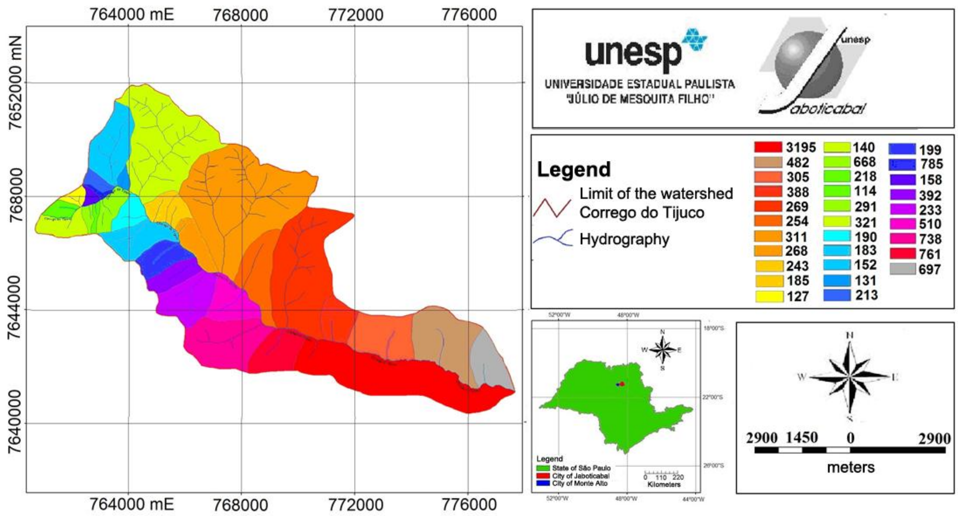

Figure 6. Map of the average ramp length of each area of water contribution, for the Watershed Córrego do Tijuco, SP.

For the topographic factor of the study area, it can be observed the predominance of areas between values of 1 to 5, followed by areas with values from 5 to 10 (Table 2 and Figure 7). Meanwhile, WEILL and SPAROVEK (2008) found mean value of the LS factor measured for its study area of 1.8.

The mapping of the LS factor has been used as one of the parameters for the annual soil loss and it is of extreme importance to demonstrate the area of highest or lowest ramp length, which can have higher speed of rainfall superficial drift corresponding to the highest erosive process. These results are in accordance with the values estimated by BATISTA et al. (1998), who used the method of the equivalent triangle for the calculation of average ramp length in watershed and by WEILL and SPAROVEK (2008) who concluded that the LS factor was the one which influenced the most the range observed in the estimated rates of erosion.

Table 2. Classes of occurrence of the topographic factor defined by BERTONI and LOMBARDI NETO (2008) and their respective areas for the watershed Microbacia Córrego do Tijuco, SP.

Classification	Defined class	Area	
	(Adimensional)	(ha)	(%)
Very low	< 1	446.4	5.5
Low	1 a 5	5323.4	66.4
Moderated	5 a 10	1789.0	22.3
High	10 a 20	423.0	5.2
Very high	> 20	26.5	0.3

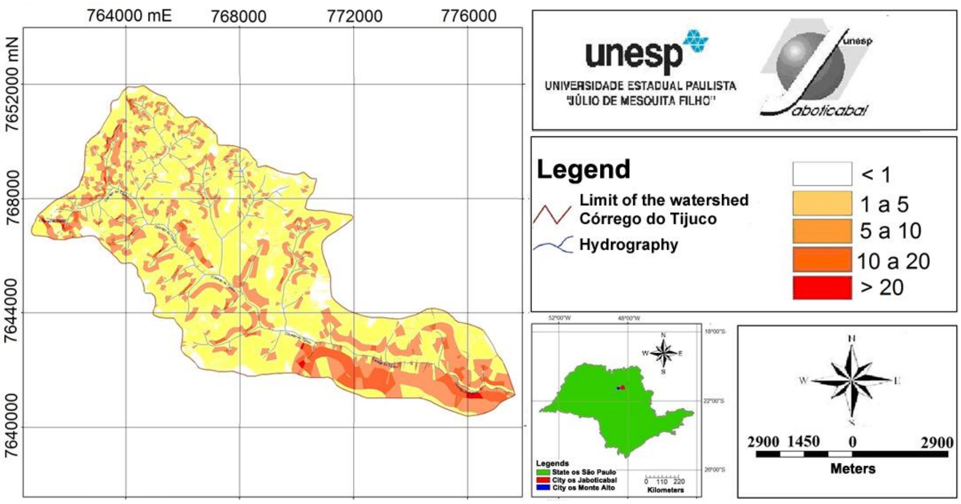

Figure 7. Map of the topographic factor for the watershed Córrego do Tijuco, SP.

Conclusions

- GIS was capable to generate images necessary for the analysis of the LS factor

- The estimate of the topographic factor showed areas with higher probability of occurrence of water erosion.

-Downstream the watershed with predominance of plain areas and soft wavy slope (3 to 8%) and very low superficial drift did not favor the water erosion.

Acknowledge

We acknowledge FUNDUNESP by the financial support.

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