



MODELING OF WATER EROSION IN A SUB-BASIN IN RIO GRANDE DO SUL USING THE RUSLE MODEL

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ABSTRACT

The intense use of farming land has caused many consequences to the environment, among them, water erosion. The scale study of river basins through modeling allows the identification and estimation of soil losses, aiming at the conservationist planning of the site. The objective of this work was to predict soil loss in the Micaela sub-basin, with an area of 37 km² located in the municipality of Pelotas, Rio Grande do Sul. For the prediction of soil loss, the Revised Universal Soil Loss Equation (RUSLE) was used. Erosivity was obtained from data from the literature and erodibility was estimated by means of the inherent soil attributes and the topographic factor calculated according to the accumulated flow and declivity in each pixel. For the cover factor, data from the literature were used, according to use recommendation and existing soil cover. The study area shows a strong erosivity, which ranged from 8,045 to 8,833 MJ mm ha⁻¹ h⁻¹ year⁻¹. The Argissolos occupy 81.31% of the sub-basin and present high erodibility, varying from 0.0369 to 0.0422 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹. The sites with the largest vegetation cover were those with the lowest soil losses. However, in more than 36% of the area, the soil losses are above the tolerable threshold, indicating that they are more prone to degradation and, therefore, the systems of land use and adopted management should be reviewed.

Palavras-chave:

fator topográfico
perda de solo
susceptibilidade à erosão

MODELAGEM DA EROSIÃO HÍDRICA EM UMA SUB BACIA DO RIO GRANDE DO SUL

RESUMO

O intenso uso das terras agrícolas tem ocasionado consequências ao ambiente, dentre elas, a erosão hídrica. O estudo em escala de bacias hidrográficas por meio da modelagem permite a identificação e a estimativa das perdas de solo, visando o planejamento conservacionista. O objetivo desta pesquisa foi prever a perda de solo na sub-bacia Micaela, com 37 km², situada no município de Pelotas, Rio Grande do Sul. Para a previsão da perda de solo foi utilizada a Equação Universal de Perda de Solo Revisada (RUSLE). A erosividade foi obtida a partir de dados de literatura, a erodibilidade estimada por meio de atributos intrínsecos do solo e o fator topográfico calculado de acordo com o fluxo acumulado e a declividade em cada pixel. Para o fator cobertura foram utilizados dados da literatura, conforme a identificação do uso e cobertura existentes. A região de estudo apresenta uma erosividade considerada como forte, a qual variou de 8.045 a 8.833 MJ mm ha⁻¹ h⁻¹ ano⁻¹. Os Argissolos ocupam 81,31% da sub bacia e apresentam alta erodibilidade, variando de 0,0369 a 0,0422 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹. Os locais com maior cobertura vegetal foram os que apresentaram as menores perdas de solo. Em mais de 36% da área as perdas de solo estão acima do limite tolerável, indicando que são mais propensas à degradação e, portanto, devem rever os sistemas de uso e manejo do solo adotados.

INTRODUCTION

The increasing need for food production has intensified the use of agricultural land, which has generated undesirable impacts on the agricultural landscape and the environment. This scenario has compromised the quality of the soils due to the formation of erosion, compaction, salinization, loss of carbon and structure, which results in unproductive soil and irreversible degradation (DAVIES, 2017).

Among the countless factors related to soil degradation, water erosion significantly contributes to the depletion of farming land (CHEN *et al.*, 2020). This theme has been studied by several authors, due to the problems resulting from the process, such as the loss of soil and water, reduction in fertility and productivity of crops, sedimentation and eutrophication of water courses (WU *et al.*, 2012; DOTTERWEICH, 2013; YUE *et al.*, 2020).

The study of the erosion focuses mainly on where disaggregation, transport and deposition of soil particles occurs. The study in scales of hydrographic basins allows for a better understanding of these processes in view of the great existing variability. In the last decades, several researchers have used techniques for monitoring and modeling erosion on a hydrographic basin scale (BATISTA *et al.*, 2017; YAN *et al.*, 2018).

To estimate soil loss, it has been developed mathematical models that contribute substantially to the integration of information, given the spatial and temporal variability inherent to river basins. The model proposed by Renard *et al.* (1997), the Revised Universal Soil Loss Equation (RUSLE), Renard *et al.* (1997), besides easily providing data is also one of the most used models. This model considers the potential of rainfall to cause erosion, the susceptibility of the soil to be eroded, the topography, the use and management of the soil and the implemented conservationist practices (CHADLI, 2016; NAPOLI *et al.*, 2016; HAO, OGUCHI e PAN, 2017; ZERIHUN *et al.*, 2018).

The Micaela sub-basin, inserted in the Arroio Fragata Hydrographic Basin accounts for a large part of the water supplied to the the municipality of Pelotas and region. According to Cunha and Silveira (1996), this area presents serious problems related to water erosion. Thus, because of the environmental vulnerability and the socioeconomic importance of the southern region of the State of Rio Grande do Sul, the study and survey of data

from the sub-basin is explained with the objective of maintaining soil quality, avoiding the silting of adjacent water bodies, as well as sponsoring conservationist policies. The knowledge of the factors that affect water erosion can help in the prediction of soil losses.

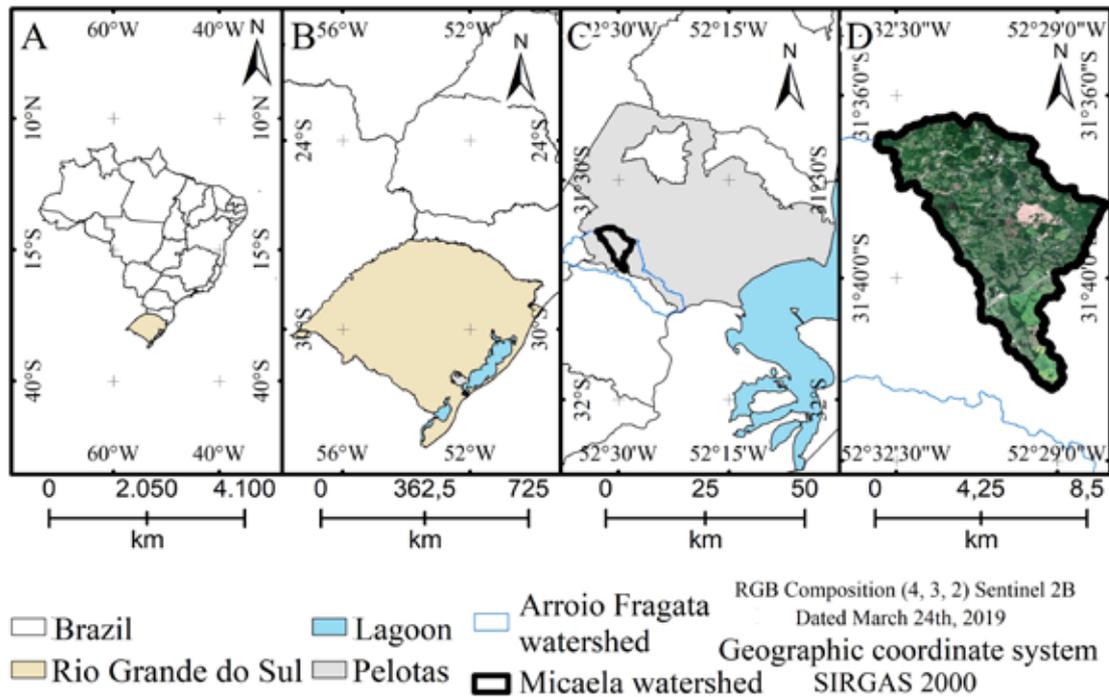
Thus, the objective of this study was to estimate soil erodibility using empirical equations and to estimate soil losses caused by water erosion in the Micaela sub-basin by means of the RUSLE model.

MATERIALS AND METHODS

The study covers an area of approximately 37 km², corresponding to the Micaela sub-basin located between 52°28'30"W and 52°33'00" W and latitudes 31°36'00"S and 31°44'00"S, belonging to the Fragata hydrographic basin located in the municipality of Pelotas, State of Rio Grande do Sul (Figure 1), accounting for most of the water supply of the region. According to Köppen, the climatic classification of the region is the humid subtropical type (Cfa), with abundant and well distributed rainfall throughout the year. In the north of the sub-basin, at higher altitudes (up to 259 m), the springs are located at the lower altitudes (33 m), and hydromorphic soils are present. The sub-basin was delimited using SPRING software version 5.3 (CÂMARA *et al.*, 1996), by means of the Digital Elevation Model of the area. All maps were elaborated using SPRING.

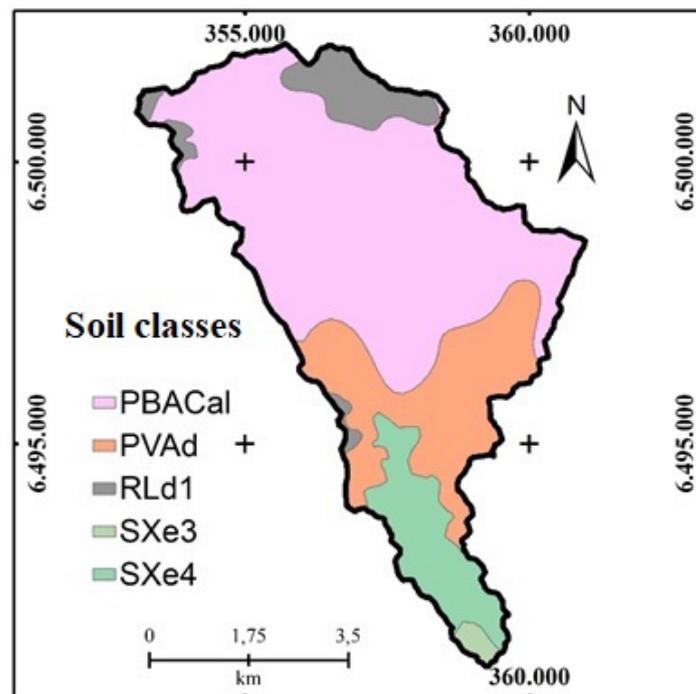
The sub-basin is characterized by different uses and types of soil. The soils were classified according to the Brazilian Soil Classification System – SiBCS.

The sub-basin has different land uses with more than 80% of the area covered with native forest or silviculture, spontaneous vegetation and pasture. The rest is used by urban areas, water courses and farming, including soybean, peach and corn crops, in particular. Figure 2 shows that in the areas located in the north of the sub-basin, deeper soils such as Bruno-Acinzentado (PBACal) e o Argissolo Vermelho-Amarelo (PVAd), corresponding to 81.31% of the area. In the most inclined areas, associations between Neossolo Regolítico e Litólico e Argissolo Bruno-Acinzentado (RLd1) are found, and in the lowlands, there is an association of Planossolo Háplico Distrófico e Gleissolo Háplico (SXE3) and an association between Planossolo Háplico e Argissolo Vermelho-Amarelo e Acinzentado (SXE4) (CUNHA; SILVEIRA, 1996).



Source: the author (2019)

Figure 1. Micaela basin location. A) Position of Rio Grande do Sul State (RS) in Brazil; B) Municipality of Pelotas in RS; C) Details of Arroio Fragata HB and Micaela SB in the municipality of Pelotas; D) Micaela sub-basin with 2B Sentinel image details



Source: the author (2019)

Figure 2. Distribution of soil classes in the Micaela sub-basin, RS, Brazil. PBACal: PBACal: Argissolo Bruno-Acinzentado; PVAd: Argissolo Vermelho-Amarelo; RLd1: Associação entre Neossolo Regolítico e Litólico e Argissolo Bruno-Acinzentado; SXe3: Associação entre Planossolo Háplico Distrófico e Gleissolo Háplico; SXe4: Associação entre Planossolo Háplico e Argissolo Vermelho-Amarelo e Acinzentado

Table 1 shows that the soils and soil associations in the sub-basin have high levels of sand and low levels of clay, which can promote soil losses due to water erosion.

To estimate the soil loss in the Micaela sub-basin, it was used the Revised Universal Soil Loss Equation (RUSLE) proposed by Renard *et al.* (1997), according to Equation 1:

$$A = R \times K \times SL \times C \times P \tag{1}$$

Where: A is the average annual loss of soil per unit area (Mg ha⁻¹ year⁻¹); R, rainfall erosivity (MJ mm ha⁻¹ h⁻¹ year⁻¹); K, soil erodibility, which is the rate of soil loss per unit of erosivity index (Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹); SL, topographic factor, corresponding to the slope degree and the ramp length (dimensionless); C, land use factor and cover management (dimensionless); P, factor related to the impact of conservationist practices (dimensionless).

To calculate the R factor, the daily rainfall disaggregation technique was used. Data on the rainfall from the Climatological Station of Pelotas, RS (INMET-EMBRAPA-UFPel) were used, from a series of 17 years, corresponding to the period from 1982 to 1998 (SANTOS, 2013). Erosivity is classified according to the adapted version of Carvalho (2008), considering: R <250 MJ mm ha⁻¹ h⁻¹ year⁻¹ as weak; between 250 and 500 MJ mm ha⁻¹ h⁻¹ year⁻¹, moderate; between 500 and 750 MJ mm ha⁻¹ h⁻¹ year⁻¹ moderately strong; between 750 and 1000 MJ mm ha⁻¹ h⁻¹ year⁻¹, strong and above

1000 MJ mm ha⁻¹ h⁻¹ year⁻¹, very Strong.

The K factor was calculated using Equation 2, proposed by Denardin (1990), for temperate and tropical soils. Thirty-three samples of non-preserved structure were collected, georeferenced during a transection (Figure 1), on the 0.00 to 0.10 m layer. For the calculation, the organic matter content was determined, according to Tedesco (1995), and the particle size according to Equation 2, proposed by Gee and Bauder (1986):

Where: K is the value to be estimated for the soil erodibility factor (Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹); M (%), variable calculated from granulometric values, according to Equation 3:

$$M = (\text{new silt}) \times (\text{new silte} + \text{new sand}) \tag{3}$$

Where: K is the value to be estimated for the soil erodibility factor (Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹); M (%), variable calculated from granulometric values, according to Equation 3:

$$M = (\text{new silt}) \times (\text{new silt} + \text{new sand})$$

The new silt is the sum of the silt and very fine sand content and the new sand, is the subtraction of the total sand content and very fine sand.

P is the permeability of the soil profile which was coded according to Wischmeier, Johnson and Cross (1971); DMP is the weighted average diameter of particles smaller than 2.00 mm (coarse sand from 1.00 to 0.50 mm; fine sand from 0.25 to 0.10 mm; silt from 0.05 to 0.02 mm and clay less than 0.002 mm), determined by Equation 4:

Table 1. Particle size distribution of the main soils and associations present in the Micaela sub-basin, RS

Soil	Sand	Silt (g kg ⁻¹)	Clay
Planossolo Háplico Distrófico + Gleissolo Háplico (SXE3)	618.76	226.42	154.81
Argissolo Vermelho-Amarelo + Planossolo Háplico Eutrófico solódico (SXE4)	581.13	253.10	165.77
Argissolo Vermelho-Amarelo Distrófico (PVAd)	638.36	198.68	162.96
Argissolo Bruno-Acinzentado (PBACal)	580.80	216.09	203.11
Neossolo Regolítico + Neossolo Litólico + Argissolo Bruno-Acinzentado (RLd1)	564.19	262.69	173.11

Source: the author (2019)

$$K = 0.00000748 \times M + 0.00448059 \times P - 0.0631175 \times DMP + 0.01039567 \times R \tag{2}$$

$$DMP = \frac{[(0.65 \times \text{coarse sand}) + (0.15 \times \text{fine sand}) + (0.0117 \times \text{silt}) + (0.00024 \times \text{clay})]}{100} \tag{4}$$

R is the relationship between organic matter content (%) and the new sand content.

Erodibility was attributed according to the classification proposed by Mannigel *et al.* (2002), which has six classes: extremely high, for K greater than 0.060 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹; very high, for K between 0.045 and 0.060 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹; high, for K between 0.030 and 0.045 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹; intermediate, for K between 0.015 and 0.030 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹; low, for K between 0.009 and 0.015 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹; and very low, for K less than 0.009 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹.

The LS factor was computationally calculated from the Digital Elevation Model (DEM), derived from the Shuttle 2236 mission, Radar Topography Mission (SRTM), developed by the National Aeronautics and Space Administration (NASA), using SPRING software version 5.3 (CHAMBER *et al.*, 1996). The value L was estimated using Equation 5 developed by Desmet and Govers (1996):

$$L = \left[\frac{(A+D^2)^{m+1} - (A)^{m+1}}{D^{m+2} \times X^m \times (22.13)^m} \right] \quad (5)$$

Where: L is the slope length factor for each cell; A is the contribution area of each cell (m²); D is the size of the cell grid (m); X is the value of the flow direction of each cell; M is the coefficient according to the slope of each cell, which assumes the values: 0.5, if s ≥ 5%; 0.4 if 3% ≤ s < 5%; 0.3 if 1% ≤ s < 3%; and 0.2 if s < 1% (s is the slope degree).

Table 2. Factor C for the different uses of soil in Micalea sub-basin, RS, Brazil, according to the bibliographic references. Source: the author (2019)

Soil use	C factor	Reference
Farming	0.156	DE MARIA and LOMBARDI NETO (1997)
Pasture	0.025	DEDECEK, RESCK and De FREITAS (1986)
Native Forest	0.012	SILVA (2004)
Spontaneous vegetation	0.042	SILVA (2004)
Exposed Soil	1.000	WISCHMEIER and SMITH (1978)
Water	0.000	SILVA (2004)
Urban areas	0.004	FU, CHEN and MCCOOL (2006)

Table 3. Loss tolerance for soil classes in the Micaela sub-basin, RS, Brazil. Source: the author (2019)

Soil Class	MANNIGEL <i>et al.</i> (2002)	OLIVEIRA <i>et al.</i> (2008)	Mean
	Mg ha ⁻¹ ano ⁻¹		
Argissolos	9.06	7.03	8.05
Gleissolos	5.82	-	5.82
Neossolos	5.28	5.21	5.25
Planossolos	5.74	4.80	5.27

The S factor was developed from the slope obtained with the DEM, using Equation 6, proposed by Wischmeier and Smith (1978):

$$S = 0.00654 * s^2 + 0.0456 * s + 0.065 \quad (6)$$

Where s is the angle average declivity (%).

In relation to factor C, data from bibliographic references that showed similar land uses to those found in the study basin were considered (Table 2). The uses were identified by means of satellite images on December 12, 2016, using the Landsat8 /OLI sensor, with bands 2 to 8, with spatial resolution of 30 meters and 15 meters for band 8 (band panchromatic). The images were classified with a mixer classifier with 100% acceptance threshold and checked in the field later.

For factor P, considering that there is no implementation of conservationist practices for erosion control in the region, a value of 1 was attributed (LEE, 2004).

Once all the factors that affect the water erosion process were identified and calculated, soil loss was estimated using RUSLE, based on the algorithm executed in LEGAL (Spatial Language for Algebraic Geoprocessing), with the aid of the SPRING software (CÂMARA *et al.*, 1996). The classification by Batista *et al.* (2017) for soil losses was used, which were compared with the average loss tolerance, for each soil class (Table 3), according to bibliographic references.

RESULTS AND DISCUSSION

Rainfall erosivity ranged from 8,045 to 8,833 MJ mm ha⁻¹ h⁻¹ year⁻¹, which is considered as strong, according to Carvalho (2008). For Evangelista, Carvalho and Bernardino (2015), the characteristics of rainfall in a region largely determine the effects of erosion, where the intensity of rainfall is one of its main characteristics. In Rio Grande do Sul, the hydrological patterns of rainfall were characterized as an advanced pattern (BAZZANO, ELTZ and CASSOL, 2010), which presents rainfall with high intensity peaks, resulting in greater losses of soil and water than the constant-intensity rainfall.

The mean value of soil erodibility (0,0398 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹) in the Micaela sub-basin is classified as high, due to the presence of soils more susceptible to water erosion. Table 4 shows that the mean erodibility value for the Argissolo Vermelho-Amarelo (PVAd) e o Argissolo Bruno-Acinzentado (PBACal), which together represent 81.31% of the sub-basin, is 0.0369 and 0.0422 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹, respectively. In a study carried out by Didoné (2013), for a Argissolo Vermelho-Amarelo, in Santa Maria, RS, and using the equation of Roloff and Denardin (1994), an erodibility of 0.0370 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹ was verified, which is a value close to that value.

According to Streck *et al.* (2008), the Argisol in the a-eluvial horizon, a characteristic of a coarse texture and generally sandier, which favors water erosion due to its fragile structure and weak aggregation. In addition, when subject to more intense rainfall events, the water flow reaches the textural (illuvial) B horizon, which is less

permeable, resulting in the loss of large amounts of soil and water, due to the profile saturation and a consequent surface runoff. Cassol *et al.* (2018) evaluated losses caused by water erosion in a Argissolo Vermelho-Amarelo in the field, for 13 years in Eldorado do Sul, RS, and obtained an erodibility of 0.0338 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹. The authors also estimated erodibility using the nomogram by Wischmeier, Johnson and Cross (1971), obtaining a K value equal to 0.0325 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹, which is very close to the value determined in the field.

The association between Planossolo and Argissolo (SXE4), which represent 10.41% of the sub-basin area, resulted in a greater erodibility (0.0434 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹), when compared with the others soils. The association between Planossolo and Gleissolo (SXE3), typical soils of the lowland areas, resulted in a mean value of 0.0394 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹ and represents 0.98% of the study area. In Lino (2010), the estimated erodibility for soils in Rio Grande do Sul was 0.0371 and 0.0410 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹ for Gleissolo and Planossolo, respectively, not differing much from the values found in that study. The high K value found in Planossolo may be due to the fact that horizon A is sandier and, therefore, less cohesive, in addition to presenting a planic B horizon, which restricts subsurface permeability. In the Argissolo Bruno-Acinzentado, the sand content reaches 57.6% (CUNHA; SILVEIRA, 1996) which may have provided the high erodibility value of this soil class.

The association of Neosol and Argissolo Bruno-Acinzentado (RLd1) showed the lowest erodibility value (0.0372 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹), when compared with the other soils. Silva, Andrade and Campos Filho (1986) evaluated the

Table 4. Representative area and erodibility (K) of each soil class, in the Micaela sub-basin, RS, Brazil

Soils	Area (%)	K (Mg ha h ha ⁻¹ MJ ⁻¹ mm ⁻¹)
Planossolo Háplico Distrófico + Gleissolo Háplico (SXE3)	0.98	0.0394
Planossolo e Argissolo Vermelho-Amarelo + Planossolo Háplico Eutrófico solódico (SXE4)	10.41	0.0434
Argissolo Vermelho-Amarelo Distrófico (PVAd)	21.13	0.0369
Neossolo Regolítico + Neossolo Litólico + Argissolo Bruno-Acinzentado (RLd1)	7.31	0.0372
Argissolo Bruno-Acinzentado (PBACal)	60.18	0.0422

Source: the author (2019)

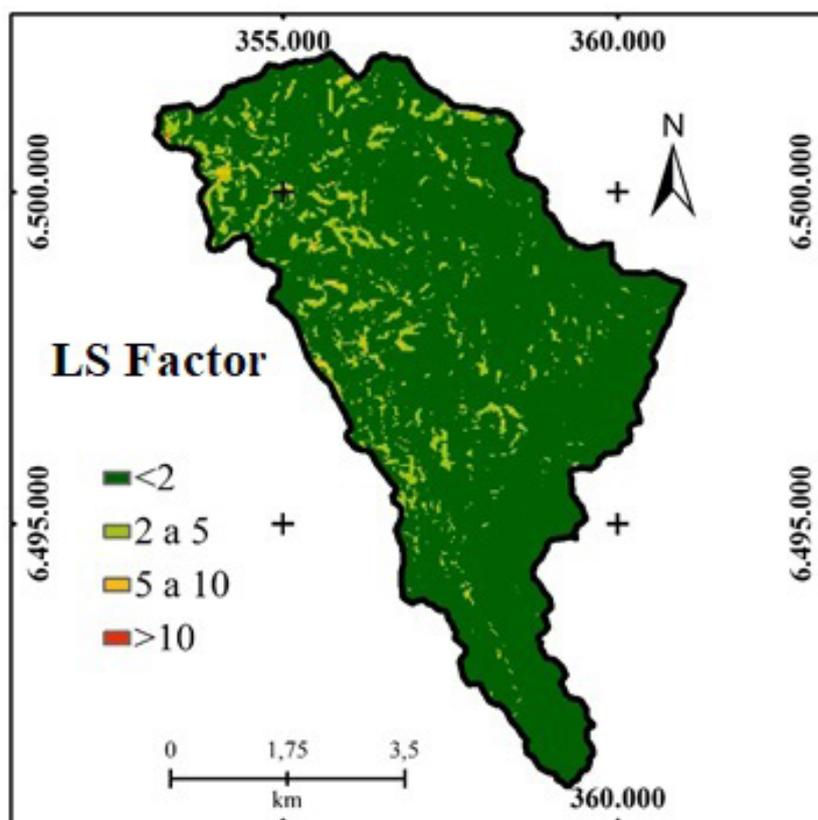
erodibility of six soils in the semi-arid region in the Paraíba State, with a field rainfall simulator, and also obtained low K values for the Neossolos Litólicos. According to the authors, this behavior was associated with the presence of gravels and pebbles on the soil surface, which intercepted part of the rain drops, reducing their erosive effect and soil transport. These authors also found higher K values for Argissolo, in relation to Neossolo and found that the nomogram method by Wischmeier, Johnson and Cross (1971) was not adequate to represent the erodibility of the studied Neossolo.

From the results obtained in this study, it can be seen that the Neossolos, which are poorly pedogenetically developed, did not present the highest erodibility values, probably due to the common presence of superficial stoniness (CUNHA, SILVEIRA and SEVERO, 2006), which may increase the resistance to the impact of raindrop (RENARD *et al.*, 1997), reduce the disintegration of particles and prevent the formation of the surface crust, influencing the infiltration and formation of surface runoff. This

is because the traditional methods of determining granulometry, used to calculate K, exclude particles larger than 2.00 mm, failing to represent the effect of stoniness, both on the surface and on the soil profile. Thus, the need for further works is highlighted, with methods applied to more stony soils, aiming to better understand the behavior of the Neosols, in particular, regarding resistance to erosion processes. Also, it should be observed the large lack of studies on erosive processes also in Planossolos, Gleissolos and Neossolos both in the study region and in Brazil, as well.

The LS factor varied from 0, in the lower areas, where the slope angle is zero, to 14.22, in the steepest slopes. It is observed that 91% of the SL factor is between 0 and 2, which is probably due to the predominance of the low-declivity classes. Only 1% of the sub-basin is greater than 5 (Figure 3).

When analyzing the sensitivity of the LS factor when calculated through different equations, Zanin, Bonumá and Minella (2017) observed a significant difference between the values



Source: the author (2019)

Figure 3. Indicative map of topographic factor (LS factor) in Micaela sub-basin RS, Brazil

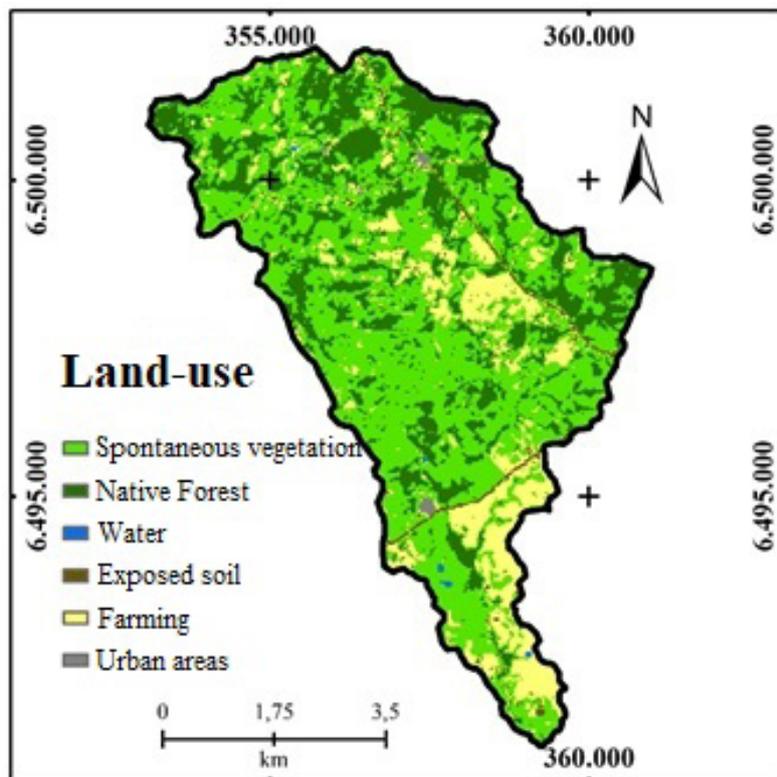
calculated using the three equations, where that of Desmet and Govers (1996) showed the lowest LS values in comparison to the others. Minella, Merten and Ruhoff (2010) after carrying out a topographic survey in four hydrographic sub-basins, also found variation in the values of SL, with the equation of Desmet and Govers (1996) which presented the highest values.

The C-factor ranged from 0 to 1. Values close to 0 are indicative of an adequate protection by cover and crop management systems and, in contrast, values close to 1 indicate very weak protection, or uncovered soils, as it could be observed in 2.46 % of the sub-basin area. In the areas of farming production, high values of factor C (0.156) were observed, representing 15.5% of the area. The lowest values of factor C (<0.042) are found in areas under spontaneous vegetation, native forest, forests and pasture, representing 82.04% of the sub-basin (Figure 4). These areas tend to have less loss of soil, due to the fact that they maintain the surface covered throughout the year, especially during periods of heavy rainfall. In addition to providing a greater increase in

organic matter, resulting in a more structured soil, the canopies of the trees intercept part of the rain, which reduces the kinetic energy of the drops and prevents the degradation of the soil particles (MARTINS *et al.*, 2010).

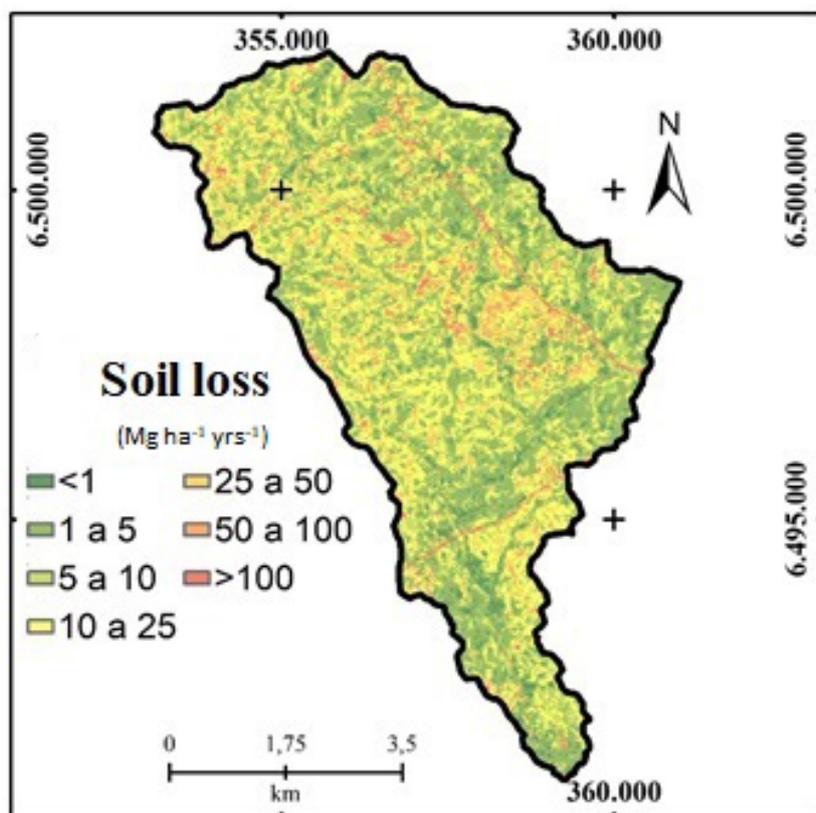
The estimate for soil loss for the Micaela sub-basin ranged from 0 to 4,843.81 Mg ha⁻¹ year⁻¹ (Figure 5). It should be seen that this model estimates only the soil loss rates, which indicate the intensity of the erosion processes. This loss corresponds to the superficial removal of soil particles, which does not mean that they will actually reach the drainage network. The calculation of the soil loss allows to observe that the largest extension of the sub-basin presents a loss less than 10 Mg ha⁻¹ year⁻¹. This result is due to the association of the topographic factor and the use and management of the soil, as the study area has a low LS factor and a predominance of areas under pasture, spontaneous vegetation, native forest and forestry, which keep the soil covered, reducing the degradation and transport of the particles and, consequently, soil loss.

Considering the soils in the basin, the loss



Source: the author (2019)

Figure 4. Indicative map of soil use and management in Micaela sub-basin, RS, Brazil



Source: the author (2019)

Figure 5. Soil loss map in the Micaela sub-basin, RS, Brazil

tolerance varies from 5.25 to 8.05 Mg ha⁻¹ year⁻¹ (MANNIGEL *et al.*, 2002; OLIVEIRA *et al.*, 2008). Thus, over 36% of the basin area has soil losses above what is considered tolerable (<10 Mg ha⁻¹ year⁻¹).

The largest losses may be associated with areas that present a steeper slope, under inadequate agricultural cultivation, the presence of more susceptible soils and the high erosivity existing in the sub-basin, which are factors that intensify the erosion process.

A small extension of the sub-basin (2%) has a loss of soil greater than 100 Mg ha⁻¹ year⁻¹, where the soil is uncovered, in which there is a tendency to occur a greater desegregation and transport of particles, combined with the high potential of the rainfall in causing erosion. AYER *et al.* (2015) observed that the greatest losses in the basin occurred in areas of exposed soil, combined with the high erosivity of the region.

The results obtained demonstrate the importance of estimating soil losses, in order to identify areas more susceptible to the erosion process, as well

as the use and proper management, aiming to avoid water erosion problems, especially in highly erodible soils and subject to erosive rainfall. The low loss of soil in almost the entire area is probably due to the adequate use of the soil, composed mainly of fields, native forest, forestry and pastures. However, it is considered the adoption of complementary conservation practices important for the reduction of erosion processes in areas that present soil losses above the tolerable threshold.

CONCLUSIONS

- The prediction of soil losses through the RUSLE model allowed the identification of areas susceptible to erosion on a hydrographic basin scale, therefore contributing to further conservation planning.
- Argissolos occupy 81.31% of the sub-basin and have high erodibility, ranging from 0.0369 to 0.0422 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹. Neossolos

did not present the highest erodibility values (0.0372 Mg ha h ha⁻¹ MJ⁻¹ mm⁻¹)

- The sites with the largest vegetation cover were those with the lowest soil losses caused by water erosion. More than 36% of the soil losses are above the tolerable threshold, therefore it is necessary to implement practices that aim to minimize the effect of the erosion process.

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