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EVALUATION OF VULNERABILITY TO SOIL LOSS IN THE ESPINHO STREAM SUB-BASIN, MUNICIPALITY OF MORRINHOS, CEARÁ, BRAZIL

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ABSTRACT
The present work aims to identify the different degrees of vulnerability to soil loss in the Espinho stream sub-basin, municipality of Morrinhos, Ceará, Brazil. For this, it was used as a methodology the construction of a geographic database with the help of the QGIS software version 3.16-Hanover, from the criteria Geology (G), Slope (D), Pedology (S), Use and Coverage (U) and Climate (C). Four classes of vulnerability to erosive processes were identified in the sub-basin. The results showed that the classes with predominance of pedogenetic processes accounted for 34% of the sub-basin area. The one whose processes represent balance between pedogenesis and morphogenesis was 64%. The class where morphogenetic processes prevail totaled 2% of the studied area.

ANÁLISE DE VULNERABILIDADE À PERDA DE SOLO NA SUB-BACIA HIDROGRÁFICA DO RIACHO ESPINHO, MUNICÍPIO DE MORRINHOS, CEARÁ, BRASIL

RESUMO
O presente trabalho tem como objetivo identificar os diferentes níveis de vulnerabilidade à perda de solo na sub-bacia hidrográfica do riacho Espinho, município de Morrinhos, Ceará, Brasil. Para isto, usou-se como metodologia a construção de um banco de dados geográficos com auxílio do software QGIS versão 3.16-Hanover, a partir dos critérios Geologia (G), Declividade (D), Pedologia (S), Uso e Cobertura (U) e Clima (C). Foram identificadas na sub-bacia quatro classes de vulnerabilidade a processos erosivos. Os resultados mostraram que as classes com predominância de processos pedogenéticos somaram 34% da área da sub-bacia. Aquela cujos processos representam equilíbrio entre a pedogênese e a morfogênese foi 64%. A classe onde prevalecem processos morfogenéticos totalizaram 2% da área estudada.
Palavras-chave: Geotecnologias. Análise ambiental. Sub-bacia Hidrográfica.

INTRODUCTION

The environmental vulnerability of environments with Potential Natural Fragility is provided for in Decree No. 4,297/2002 (BRASIL, 2002), which regulates the National Environmental Policy, Law No. 6,938/1981 (BRAZIL, 1981). The decree brings the nomenclature of Ecological- Economic Zoning (ZEE) and in the National Environmental Policy it is called environmental zoning.

The System Theory assumes that in nature the exchanges of energy and matter are processed through dynamic equilibrium relationships, sometimes altered by human actions, sometimes becoming a state of disequilibrium (TRICART, 1977). Continuing, Lima (2014) mentions that the interpretation of the processes that act in the different geoenvironmental features of the semi-arid context facilitate territorial planning minimizing the negative effects resulting from the continuous and disorderly exploitation of natural resources.

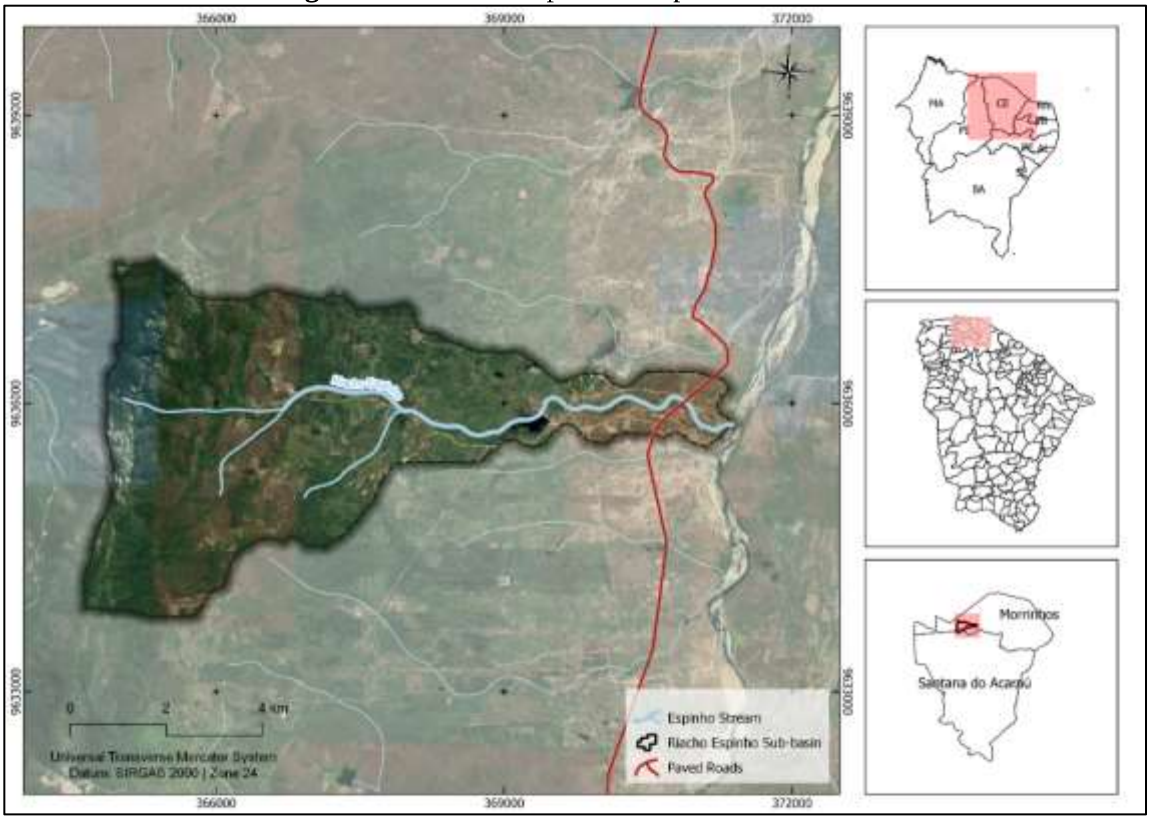
When studying soil loss, it's necessary to consider the influence of the variation of landforms on the formation of the pedological cover, the gradient of slopes which can generate a higher speed of surface runoff, where consequently there is a greater displacement, dragging of materials and the degree of of soil development, also related to the slope of the ramp. On the other hand, Kawakubo (2005) mentions that the fragility of the soil is closely related to its vulnerability to erosion, as well as the type of use and vegetation cover, besides the differences in its physical and chemical attributes.

Considering the methodology proposed by Crepani et al. (2001), which has been widely used in Brazil for soil loss assessments and development of environmental zoning, and considering the above, it is proposed with the present work to evaluate the vulnerability to soil loss of the Espinho stream sub-basin, located in the municipality of Morrinhos/CE. It is a contribution to zoning, planning and environmental management work in the Espinho stream sub-basin. Besides providing support to those responsible for state and municipal environmental management, it is a tool that can support territorial planning through preventive actions (zoning, master plans, prioritization of areas, creation of protected areas, etc.) and environmental licensing.

Characterization of the Study Area

The study area comprises the Espinho stream sub-basin (ERSB) located in the municipality of Morrinhos, state of Ceará (Figure 1). The ERSB is located between the geographic coordinates 3°16'41.07"S to 3°18'44.47"S and 40°13'6.23"W to 40° 9'23.02"W, with area of 11.45 km². The Espinho stream goes through a total course of 10 km, developing in a west-east direction until it flows into the Acaraú River.

Figure 1: Location map of the Espinho stream sub-basin.



Source: Authors, 2022.

According to IPECE (2017), the climate of the region where the sub-basin is located is a hot tropical semi-arid climate, with average annual temperatures between 26ºC and 28ºC. The average annual rainfall is around 1,066.6 mm. The sub-basin altitudes vary from 89 to 725 meters. The geological pattern is predominantly composed of crystalline basement rocks, with different gneisses and migmatites. Sandy and clayey sediments rest on this substrate, which may include tertiary carbonaceous levels. The lithology is composed of Litholic Neosols, Fluvic Neosols, Haplic Planosols, Dystrophic Solodic Planosols and Argisols (IBGE, 2019). The vegetation classes are composed by dense shrubby caatinga, open shrubby caatinga and riparian forest with carnaubas and dicots.

METHODOLOGY (Data Acquisition)

To carry out the present work, it was used ALOS-PALSAR images from the Japanese Aerospace Exploration Agency (JAXA) with a spatial resolution of 12.5 meters. The limits of the sub-basin were obtained from the website of the National Water Agency – ANA (ANA, 2015).

Land Use and Land Cover raster data were acquired from Mapbiomas Project Platform, which aims to map the soil surface annually at a national level, with a spatial resolution of 30 meters, whose pixel values comprise coverage and use classes for the year 2020 (MAPBIOMAS, 2020).

Soil and lithology vector data were acquired at the Brazilian Institute of Geography and Statistics website (IBGE, 2019) at a scale of 1:250,000.

Precipitation data was acquired from the National Aeronautics and Space Administration (NASA) Langley World Energy Resources Forecasting Project (POWER) Research Center (LaRC), funded by NASA's Earth Sciences/Applied Sciences Program (STACKHOUSE, 2022).

The acquired data were standardized by reprojection to SIRGAS 2000 (Geodetic Reference System for the Americas 2000), UTM zone 24 South. The files were converted to raster format, with a spatial resolution of 12.5 meters, row and column dimensions of 698 and 454, respectively. According to Francisco et al. (2019), these procedures allow simplifying metric calculations and standardizing parameters for performing the analysis.

Analysis of Vulnerability to Soil Loss

The vulnerability of landscape units was established through a scale of values (21 classes from 1.0 to 3.0) based on Crepani et al. (2001), according to the morphogenesis/pedogenesis relationship, analyzing the criteria Geology (G), Slope (D), Pedology (S), Use and Coverage (U) and Climate (C).

Initially the data were acquired in the respective databases. Then, vectorization, insertion of weights in attribute tables and conversion to raster format were carried out. For this, the software QGIS 3.16.13-Hannover was used and the arithmetic mean of the criteria was calculated, according to equation 1:

$$V = \frac{(G + D + S + U + D)}{5} \tag{1}$$

Where V = Vulnerability to soil loss; G = Vulnerability for the Lithology theme; D = Vulnerability attributed to the Slope theme; S = Vulnerability attributed to the topic Soil; U = Vulnerability attributed to the Land Use and Land Cover theme; and C = Vulnerability attributed to the Climate theme.

Then, after obtaining the V factor, reclassification was carried out based on the values shown in table 1.

Table 1: Representation of values and stability/vulnerability classes.

DEGREE OF VULNERABILITY	VALUES
Stable	$1.0 \leq V \leq 1.3$
Moderately Stable	$1.4 \leq V \leq 1.7$
Moderately Stable/Vulnerable	$1.8 \leq V \leq 2.2$
Moderately Vulnerable	$2.3 \leq V \leq 2.6$
Vulnerable	$2.7 \leq V \leq 3.0$

Source: Adapted from Crepani et al. (2001).

RESULTS AND DISCUSSION

Based on the adopted procedures, vulnerability data were obtained for each of the criteria used to obtain the vulnerability map to soil loss in the studied area. The results are shown in table 2:

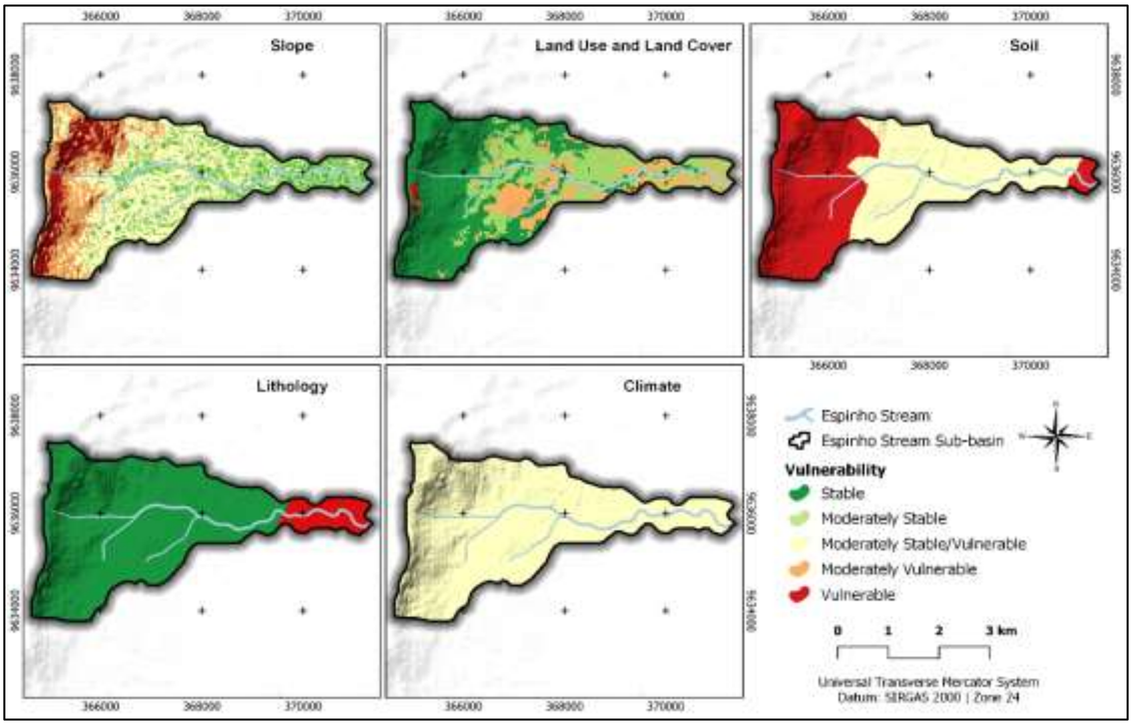
Table 2: Vulnerability classes and areas (km²) in ERSB.

Vulnerability Classes	D*	U*	S*	G*	Ç*
Stable	0.61	6.44	-	10.39	-
Moderately Stable	3.10	3.20	-	-	-
Moderately Stable/Vulnerable	4.09	0.01	5.46	-	11.45
Moderately Vulnerable	2.37	1.71	-	-	-
Vulnerable	1.28	0.10	5.99	1.06	-
TOTAL			***11.45***		

*Slope (D), Land Use and Land Cover (U), Pedology (S), Geology (G) and Climate (C).

As can be seen in Table 2, most of Land Use and Land Cover criterion was classified as a stable class, in which pedogenetic processes predominate. The Slope and Climate criteria were more representative in the Moderately Stable/Vulnerable vulnerability class, denoting, for such criteria, a balance between pedogenetic and morphogenetic processes. The vulnerable class predominated in the pedology criterion, thus occurring processes with a tendency to morphogenesis. Figure 2 shows the specialized criteria individually with the representation of vulnerability classes in order to verify the disposition of the areas along the studied area.

Figure 2: Spatialization of vulnerability for slope, use and cover, pedology, geology and climate criteria.



Source: Authors, 2022.

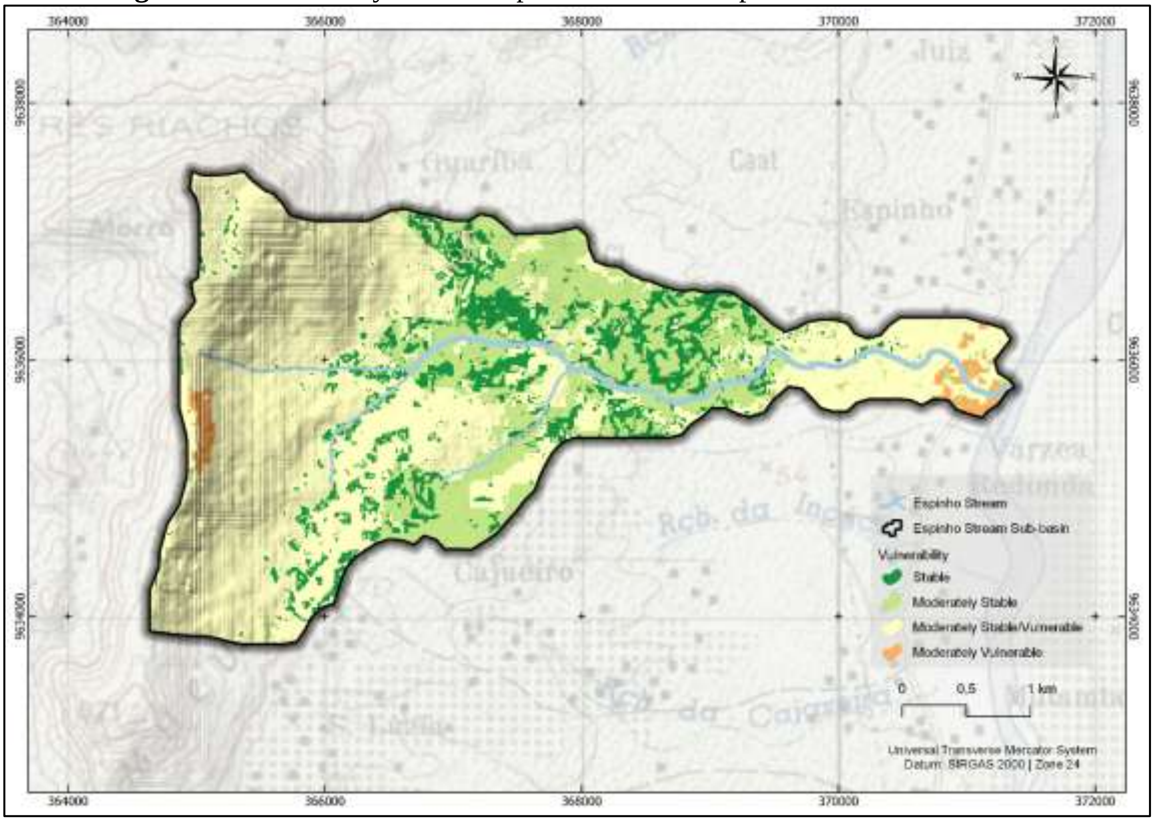
Figure 3 shows the spatial distribution of vulnerability classes in the studied area. The Moderately Stable/Vulnerable class prevailed in the area with 731.73 hectares (64%).

This class is distributed along the entire basin. The Moderately Stable class with 245.33 hectares (21%) prevailed in the central portion of the area.

Stable class (149.56 hectares or 13%) occurs mostly in the central portion of the basin. The Moderately Vulnerable class (18.77 hectares or 2%) prevailed in the lower course of the Riacho Espinho.

Therefore, the Riacho Espinho sub-basin can be classified as Moderately Stable/Vulnerable to soil loss, which corresponds to the transition between the most stable and the most vulnerable units, with a balance between the pedogenetic processes and morphogenetics.

Figure 3: Vulnerability to erosive processes in the Espinho Stream Sub-basin.



Source: Authors, 2022.

CONCLUSION

The use of remote sensing data and GIS techniques allied to the integrated analysis of criteria related to Soil, Lithology, Slope, Climate and Land Use and Land Cover resulted in the map of vulnerability to erosion processes. Therefore, the synthesis map was generated, which allowed the identification and analysis of vulnerability based on the concepts of ecodynamics, based on the relationship between morphogenesis and pedogenesis.

The vulnerability of the basin showed predominance in the moderately stable/vulnerable degree in the scale of vulnerability to soil loss. We emphasize the importance of remote sensing and geoprocessing techniques in the elaboration of environmental studies, facilitating the collection and crossing of data, combined with theoretical knowledge and the study area, as well as the systemic view which allowed us to understand the landscape of the study area.

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