ISSN 2359-6562 (ONLINE) 2359-6562 (CD-ROM)

Edição especial – 9º INOVAGRI International Meeting

SUSCEPTIBILIDADE EROSIVA DOS SOLOS EM BACIAS HIDROGRAFICAS NO CERRADO GOIANO

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RESUMO: O uso e ocupação do solo e as atividades econômicas representam grandes fatores de exploração do solo, podendo preservar ou comprometer a qualidade do mesmo e dos recursos hídricos. Os principais problemas associados à degradação do solo e do ambiente estão relacionados ao aumento da compactação dos solos, redução da infiltração da água e favorecimento do escoamento superficial. As origens do processo erosivo podem ser agravadas por esses elementos, sendo desencadeadas por meio da ação antrópica, tornando os solos suscetíveis à erosão. O objetivo do trabalho concentrou-se em elaborar mapas de suscetibilidade erosiva antrópica e natural, através de banco de dados espaciais, tratamento de bases existentes e confecção de mapas temáticos, trabalhadas a partir da metodologia de análise de multicritério, cruzando as informações referentes aos componentes geomorfológicos da área de estudo. Através dos resultados foi possível concluir que apesar de ter apresentado suscetibilidade natural média na maior parte da área causada pela declividade e vegetação, a suscetibilidade à erosão por ação antrópica também remete a fatores de degradação, provocada pela urbanização e pastagem.

Palavras-chaves: Erosão do solo, NDVI, SIG, Aptidão ao uso do solo

EROSIVE SUSCEPTIBILITY OF SOILS THE WATERSHEDS IN THE CERRADO OF GOIÁS

ABSTRACT: Land use and occupation, along with economic activities, are major factors in soil exploitation and can either preserve or compromise soil quality or water resources. The main problems associated with soil and environmental degradation are related to increased soil compaction, reduced water infiltration, and increased surface runoff. The origins of the erosion process can be worsened by these factors and are often triggered by anthropogenic activity, increasing the susceptibility of soils to erosion. The objective of this study was to develop maps of anthropogenic and natural erosion susceptibility using spatial databases, process existing data, and create thematic maps. This was carried out through a multicriteria analysis methodology, integrating information related to the geomorphological components of the study area. On the basis of the results, it was concluded that although the area mostly showed moderate natural susceptibility due

Recebido em 05/11/2025 e aprovado para publicação em 10/12/2025
DOI: http://dx.doi.org/10.17224/EnergAgric.2025v40p55-63

to slope and vegetation, erosion susceptibility caused by anthropogenic activity is also linked to degradation factors such as urbanization and pasture use.

Keywords: Soil erosion, NDVI, SIG, Land use suitability.

1 INTRODUCTION

The erosive susceptibility of an area depends on a series of conditioning variables, among which vegetation, soil, slope, rainfall, land use, and lithology stand out. These are factors that, depending on their current situation, can influence susceptibility more or less (Santos; Nascimento, 2019).

Considering the multicriteria analysis, weights (0–100%) are defined for each variable to differentiate the degree of importance and correlation with the phenomenon in question (erosive susceptibility), and scores (1 to 5) are assigned to each legend component such that the higher the score is, the greater the erosive susceptibility (1: very low; 2: low; 3: medium; 4: high; 5: very high). The final maps are created from the intersection of the parameters established for the variables.

Despite the importance and necessity of analyzing the factors in an integrated way, the application of the multicriteria analysis methodology should be considered in isolation for each item. The relationship between the variables results from the application of the model, which necessarily crosses all the components (Moura, 2007).

The erosive susceptibility of an area depends on a series of conditioning variables, among which vegetation, soil, slope, rainfall, land use, and lithology stand out. These factors, depending on their current situation, can influence susceptibility more or less (Santos; Nascimento, 2019). Geographic information systems (GISs) have proven to be essential tools for the integrated spatial analysis of variables, allowing for the understanding and containment of soil degradation (Assis *et al.,* 2017).

The use of GIS associated with remote sensing products reinforces data acquisition and processing for product generation; from this perspective, the use of indices such as *the normalized difference vegetation index (NDVI) is crucial. Difference The vegetation index (*NDVI) complements data analysis by indicating areas with degraded vegetation, which is frequently associated with more intense erosive processes (Barros *et al.,* 2018). The NDVI is an indicator of the presence and photosynthetic activity of vegetation cover; through the use of mathematical formulas and spectral bands, it allows the identification and evaluation of the presence or absence of vegetation cover (Sousa; Giongo, 2022) or even the greenness and activity of that vegetation cover (Silva *et al*. 2023).

On the basis of the above, the objective of this study was to obtain a map of the natural and anthropogenic erosion susceptibility of watersheds in the municipality of Santa Helena de Goiás.

2 MATERIALS AND METHODS

The study was conducted in river basins located in the southwest of the state of Goiás within the Cerrado biome. Four river basins were analyzed across the municipalities of Santa Helena de Goiás, Rio Verde, and Santo Antônio da Barra, with the area locations shown in Figure 1.

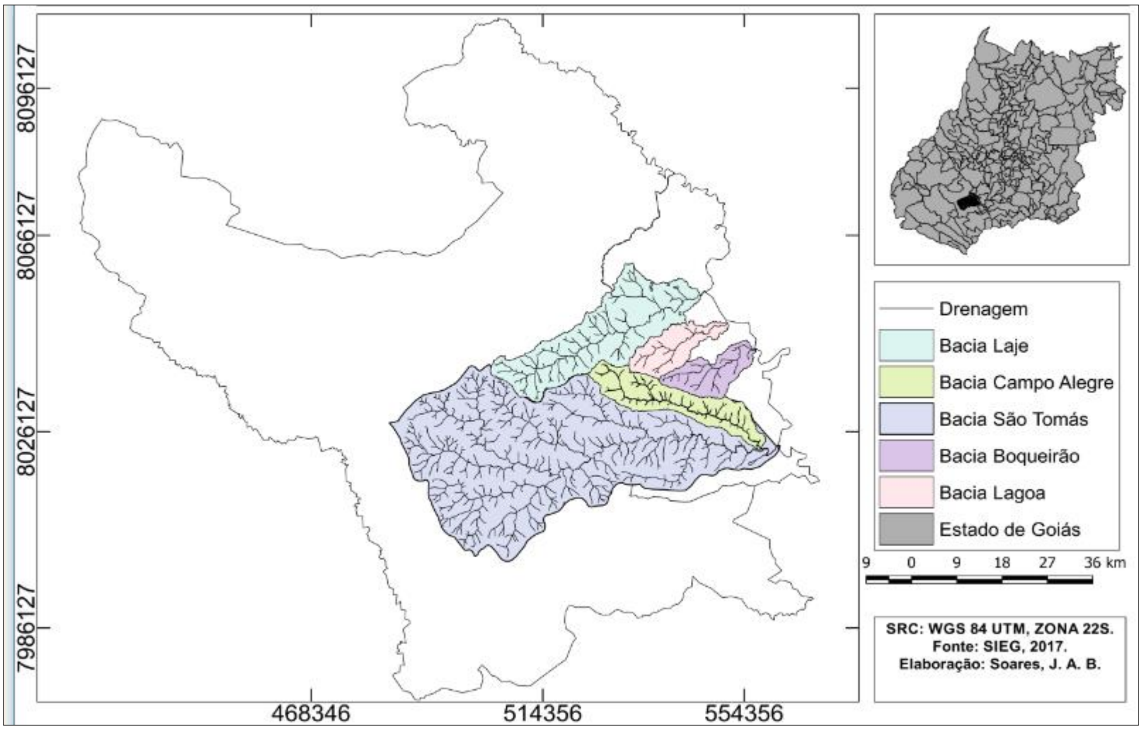
For the delimitation of the microbasins, the 17S51 and 18S51 matrix products from the Shuttle Radar Topography Mission (SRTM) carried out by NASA were used; the data were acquired from the Geomorphometric Database of Brazil (INPE, 2017). The delimitation was performed using QGIS 3.18 software. The microbasins selected for the study were Campo Alegre, Boqueirão, Lagoa, and Laje, as shown in Figure 1. The altimetry data were used with the digital elevation model tools in QGIS software to create the slope maps.

For land use and land cover characterization, an image from the CBERS 4 satellite, MUX sensor, orbit/point 160/120, passed on 07/17/2017, with a spatial resolution of 20 meters and spectral bands of blue, green, red, and near-infrared, was used. To create the vegetation index (NDVI) map, the CBERS 4 image was used, through the difference between the reflectances of the near-infrared and red bands.

The cartographic base, lithology, and soil class at a scale of 1:50,000 were provided by the State Geoinformation System (SIGA, 2025). The information was cropped to the study area. The road proximity layer was created using the buffer tool, with distances of 5, 10, 25, and 50 meters, referencing road data from the state of Goiás (SIGA, 2025).

The multicriteria analysis was based on the methodology of Silva and Machado (2014), which considers weights and percentages for each input variable. Weights were established according to erosive susceptibility by natural and anthropogenic means, as shown in Table 1. While each variable had scores between 1 and 5, the classes within it are described in Table 2.

Figure 1. Geographic location of the hydrographic subbasins in the municipality of Santa Helena de Goiás, Goiás.



Source: Municipal boundaries - SIGA; river basins – Delineation based on SRTM data.

Table 1. Weights and variables represented by thematic maps for identifying areas susceptible to erosion.

Maps	**Susceptibility to erosion by natural means**	**Susceptibility to erosion due to human activities**
	Weight (0 to 100%)	**Weights (0 to 100%)**
Lithology	10	6
Soil classes	25	13
Slope	25	13
Rainfall intensity	15	8
Vegetation index	25	13
Proximity to roads	-	12
Land use	-	35
Total	100	100

Source: Adapted from Silva and Machado (2014).

Table 2. Scores established for the components of the variables for susceptibility to erosion.

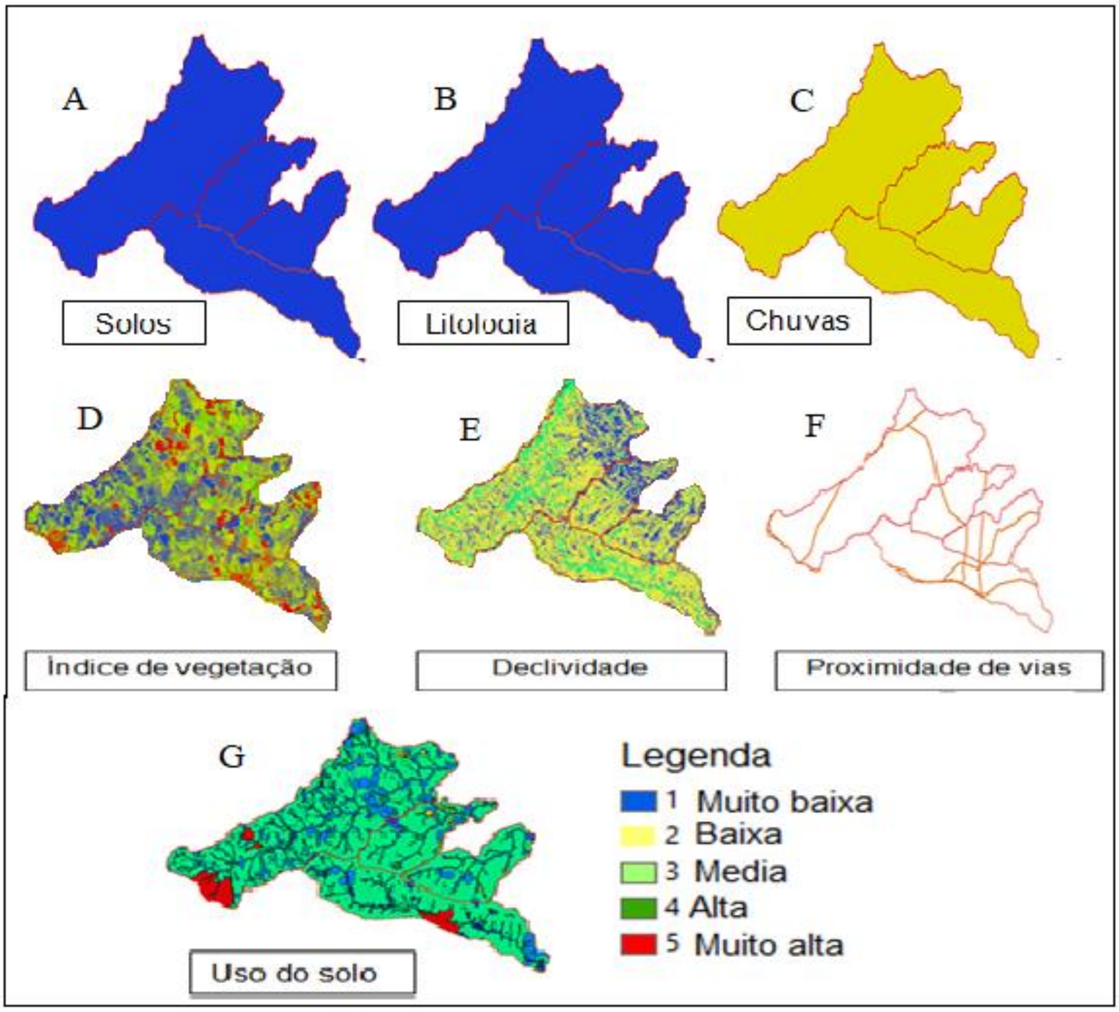
VARIABLE	CAPTION COMPONENT	NOTE (1 - 5)
Lithology	Canga, Iron oxide concentrations, Hematite ore bodies, Diabase, Iron formation, Itabirite, Hematite lenses, Quartzite, Quartz	1
	Metabasalt , Sericite , Serpentinite	
	Phyllite, Shale, Detrital-Lateritic Cover	2
	Polymict Conglomerate, Talc	3
	Alluvium, Colluvium, Dolomite	4
		5
Soil class	Latosol	1
	Unclassified area	2
	Canga Exhibition	3
	Cambisol	4
	Neosol/Degraded area	5
Slope (%)	0 – 2	1
	2 - 6	2
	6 - 20	3
	20 - 50	4
	>50	5
Rainfall intensity	Low	2
	High	4
Vegetation vigor (NDVI)	High Vigor (0.490 – 1)	1
	Medium Vigor (0.341 - 0.490)	2
	Low Vigor (0.215 - 0.34)	3
	Very Low Vigor/Absence (0.066 - 0.215)	4
	Absence of Vegetation (-1 - 0.066)	5
Proximity to roads	above 50 meters	1
	from 25 to 50 meters	2
	from 10 to 25 meters	3
	5 to 10 meters	4
	up to 5 meters	5
Land use	Forest/Natural	1
	Grassland (pasture)	2
	Cultures	3
	Exposed soil	4
	Urbanized area	5

Source: Adapted from Silva and Machado (2014).

3. RESULTS AND DISCUSSION

The soil in the study region is characterized as Latosol, a class that presents a high concentration of clay and, therefore, is classified as having very low susceptibility (Figure 2A). The soils in these locations are well developed, with great depth, good structure, and high water permeability (Crepani). *et al.,* 2001). These soils generally exhibit very low susceptibility, except in situations of high slopes and intensive agricultural use.

Figure 2. Reclassification of variables for susceptibility to soil class (A), lithology (B), rainfall intensity (C), vegetation index (D), slope (E), proximity to roads (F) and land use (G).



The region receives an average annual rainfall of 1300 mm, with a good temporal distribution, which indicates that it is characterized as having low susceptibility to erosive processes. Notably, rainfall in the region is of low intensity and rarely exceeds the soil's water infiltration capacity (Silva *et al.,* 2021). However, variations in rainfall near the watershed directly influence vegetation resistance, water body flow, water quality and availability, directly affecting long-term production (Giongo *et al.,* 2022).

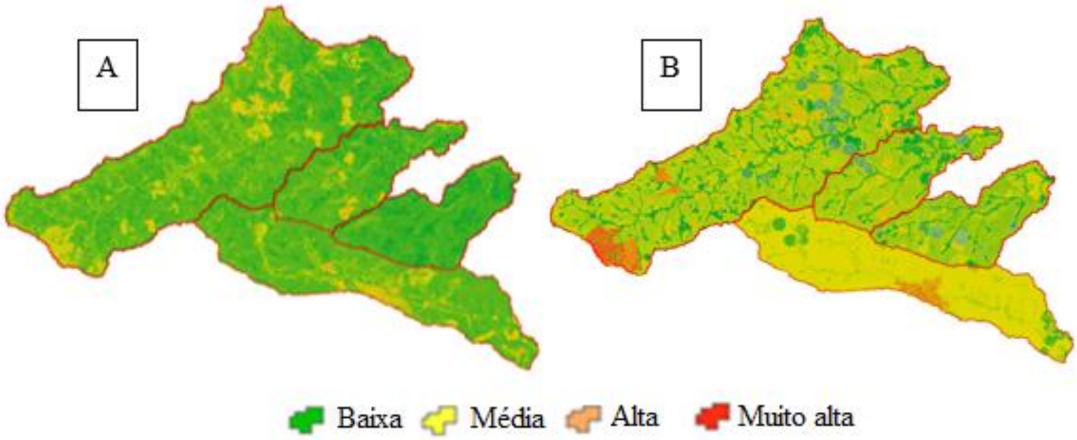
The NDVI is an indicator of the presence and photosynthetic activity of vegetation cover in the soil. Mathematical formulas and spectral bands can be used to analyze and evaluate vegetation cover (Sousa; Giongo, 2022). Thus, it helps intercept raindrops, reducing the impact and disruption of the soil, which mainly causes surface sealing by clay. There is great variation in the area, both in vegetation cover and in cultivated species, such as annual crops (soybeans and corn), as well as other semiperennial and perennial crops (sugarcane and pasture). Therefore, the NDVI is more highly classified in the eastern and northern portions, whereas lower susceptibility is predominant in the southwestern and western portions (Figure 2D).

With respect to natural erosion susceptibility, small regions, such as the northern region, exhibit a low degree of erosion (Figure 3A).

Areas with medium to high susceptibility to erosion occur in almost all the basins and are influenced mainly by Latosol-type soils and their intensive land use. These soils exhibit high permeability to rainwater and aggregation between particles (Salomão, 2005; Crepani). *et al.,* 2001).

Slope and the NDVI have greater impacts on erosion, and when combined, they influence the occurrence of fragments with very high susceptibility, which are distributed in the center and extend southward through the basin. Areas with abundant vegetation cover (high NDVI), such as grasslands, can reduce the intensity of erosion processes. The parameters that contributed most to the increased erosive susceptibility in this area are the NDVI and slope, as shown in Figure 3, which represents the natural (A) and anthropogenic (B) susceptibility maps of the Campo Alegre, Boqueirão, Lagoa, and Lage basins.

Figure 3. Maps of natural (A) and anthropogenic (B) erosive susceptibility of the Campo Alegre, Boqueirão, Lagoa and Lage basins in the municipality of Santa Helena de Goiás, GO.

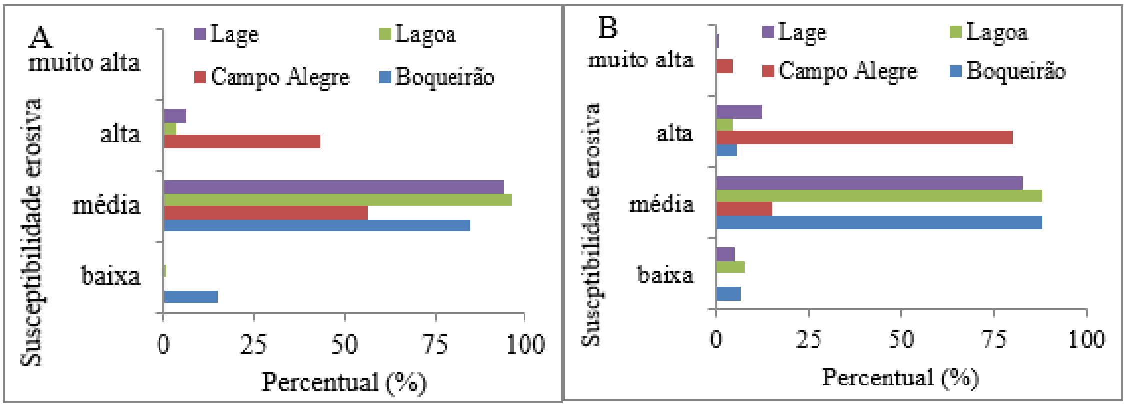


The anthropogenic erosion susceptibility map shows the transformations in the natural landscape. The Campo Alegre, Boqueirão, Lagoa, and Lage basins are largely influenced by anthropogenic activity, as they are potentially arable areas.

Areas exhibiting high to very high anthropogenic susceptibility include urbanized areas such as industrial parks, airports, residential development, and sugar and ethanol plants, among others. These areas correspond to intensive land use. Pastured and agricultural areas are also highly susceptible to erosion processes. The process of humanization has a greater impact on susceptibility to erosion, as it is a process capable of modifying the natural environment (Assis *et al.,* 2017). Alves *et al.* (2015) reported soil loss in areas cultivated with monocultures in the Ribeirão da Picada Basin in southwestern Goiás.

As shown in Figure 4, the percentages of areas with natural and anthropogenic susceptibility in the Campo Alegre stream are mostly medium and high susceptibility, with values of 56.63% (natural) and 80.15% (anthropogenic), respectively; in the Lagoa stream, these areas are mostly medium susceptibility, with values of 96.45% (natural) and 87.97% (anthropogenic), respectively; in the Lage stream, these areas are mostly medium susceptibility, with values of 93.94% (natural) and 82.67% (anthropogenic), respectively; and in the Boqueirão stream, these areas are mostly medium susceptibility, with values of 85% (natural) and 88.06% (anthropogenic), respectively.

Figure 1 Percentages of areas in the natural (A) and anthropogenic (B) erosive susceptibility classes of the Campo Alegre, Boqueirão, Lagoa and Laje stream microbasins.



Source: The authors.

4 CONCLUSIONS

Under natural cover conditions, erosion susceptibility is more concentrated across all the basins in the middle class, whereas under anthropogenic conditions, there is an increased risk for all the basins, with a greater proportion in the Campo Alegre Basin.

Land cover and slope increase the risk of erosion in watersheds.

The use of multicriteria analysis is relevant because these tools allow for the combination of variables and the creation of summary maps, enabling both qualitative and quantitative assessments of erosion susceptibility.

The application of GIS tools contributes to the generation of information capable of demonstrating the vulnerability of areas susceptible to erosion, which is essential for carrying out this study.

5 ACKNOWLEDGEMENTS

The authors acknowledge the institutional support of the State University of Goiás through the acquisition of equipment and funding of the following grants: UEG Notice No. 05/2021 Pro-projects 2021 (SEI 202100020013910), UEG Notice No. 22/2022 Pro-projects 2022 (SEI 202200020022752); UEG Notice No. 52/2023, External Commission Project (SEI 202300023055); UEG Notice No. 20/2023, Pro-projects 2023 Water Security (SEI 202300020023352).

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