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SUSCEPTIBILITY TO LAMINAR EROSION BETWEEN THE DRY AGRESTE AND THE MATA ÚMIDA ZONE: A CASE STUDY OF THE CANHOTO RIVER BASIN (PE/AL).

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RESUMO

A erosão laminar é um dos principais processos de degradação do solo, principalmente por ser dificilmente perceptível. Ao tratar sobre erosão é importante frisar que se trata de um processo ambiental natural, mas que pode ser acelerado por meio de ações antrópicas. Nesse sentido, o objetivo desse trabalho é avaliar a susceptibilidade natural dos solos à erosão laminar em bacias hidrográficas inseridas entre o Agreste e a Zona da Mata, por meio do estudo de caso da bacia do rio Canhoto (PE/AL). A metodologia adotada utilizou dados sobre erodibilidade dos solos e a declividade para a identificação das áreas susceptíveis a erosão laminar, na escala 1:100.000. Os resultados demonstraram que mais de 75% da área da bacia encontrou-se distribuída entre as classes de maior susceptibilidade, inseridas no trecho semiárido, apresentando fragilidades do ponto de vista da geração de processos erosivos. Ocorreram porcentagens elevadas de solos com altos índices de erodibilidade e grande variabilidade de na declividade, resultando em áreas susceptíveis a erosão, tornando-se assim um importante objeto de estudo, visto a necessidade de pesquisas com essa temática na região.

Palavras-Chave: Processos erosivos; Erodibilidade; Declividade; SIG.

ABSTRACT

Laminar erosion is one of the main processes of soil degradation, mainly because it is hardly noticeable. When dealing with erosion, it is important to emphasize that it is a natural environmental process, but it can be accelerated through human actions. In this sense, the aim of this work is to evaluate the natural susceptibility of soils to laminar erosion in hydrographic basins between the Agreste and Zona da Mata, through the case study of the Canhoto river basin (PE/AL). The methodology adopted used data on soil erodibility and slope to identify areas susceptible to laminar erosion, on a scale of 1:100,000. The results showed that more than 75% of the basin area was distributed between classes I and II, which are in the semi-arid area, presenting weaknesses from the point of view of the generation of erosive processes. There are high percentages of soils with high rates of erodibility and a great variability in the percentage of slope, resulting in areas susceptible to erosion, thus becoming an important object of study, given the need for research on this topic in the region.

Key words: Erosive processes; Erodibility; slope; GIS

INTRODUCTION

Soil degradation affects both naturally vegetated agricultural lands and urbanized environments and can be considered one of the most serious environmental problems in contemporary times. Water induces soil erosion, for example, is responsible for 56% of soil degradation in the world (GUERRA; SILVA; BOTELHO, 2014). According to FAO and ITPS (2015) erosion eliminates 25 to 40 billion tons of soil per year on the planet, significantly reducing crop productivity and the capacity to storage carbon, nutrients, and water.

Among the various types of erosion, laminar erosion stands out. This occurs from the runoff formation during rainfall events that removes thin layers of theoretically homogeneous soil (BAPTISTA, 2003), causing a loss in the quality of the environment (soil and water). It is responsible for a hidden erosion, which can occur in a relatively continuous way, without, however, leaving empirically observable marks on the slope. According to Eduardo et al. (2013), the susceptibility to laminar erosion represents the susceptibility of the soil to the erosive process and can be determined directly, by the ratio between soil losses and rainfall erosivity, that is, it is the capacity of a soil to be eroded by rainfall factors. To establish the soil erodibility index, its physical properties and topography must be considered, whose slope and slope length directly interfere with the flow velocity (SALOMÃO, 2014).

In the Northeast of Brazil, watersheds with areas in humid and dry climate sectors are recurrent, as in the basins with the high stream in the Agreste and the lower stream in the Zona da Mata. Thus, the susceptibility of soils to erosion can vary in the sectors of the basin, depending on the different combinations of the geological, geomorphological, climatic variables, the slope of the terrain and the types of soil. In this sense, the purpose of this work is to evaluate the susceptibility of soils to laminar erosion in watershed between the Agreste and Zona da Mata, as a way of contributing to conservation, planning and environmental management actions in drainage basins with such characteristics. For this, a case study was developed in the Canhoto river basin (PE/AL).

METHODOLOGY

Characterization of the study area

The Canhoto river basin has an area of 1,198 km², being considered the main sub-basin of the Mundaú River (Figure 1). Due to its location, it is situated between the Agreste Pernambucano (84.24% of the area) and the Zona da Mata Alagoana (15.75% of the area).

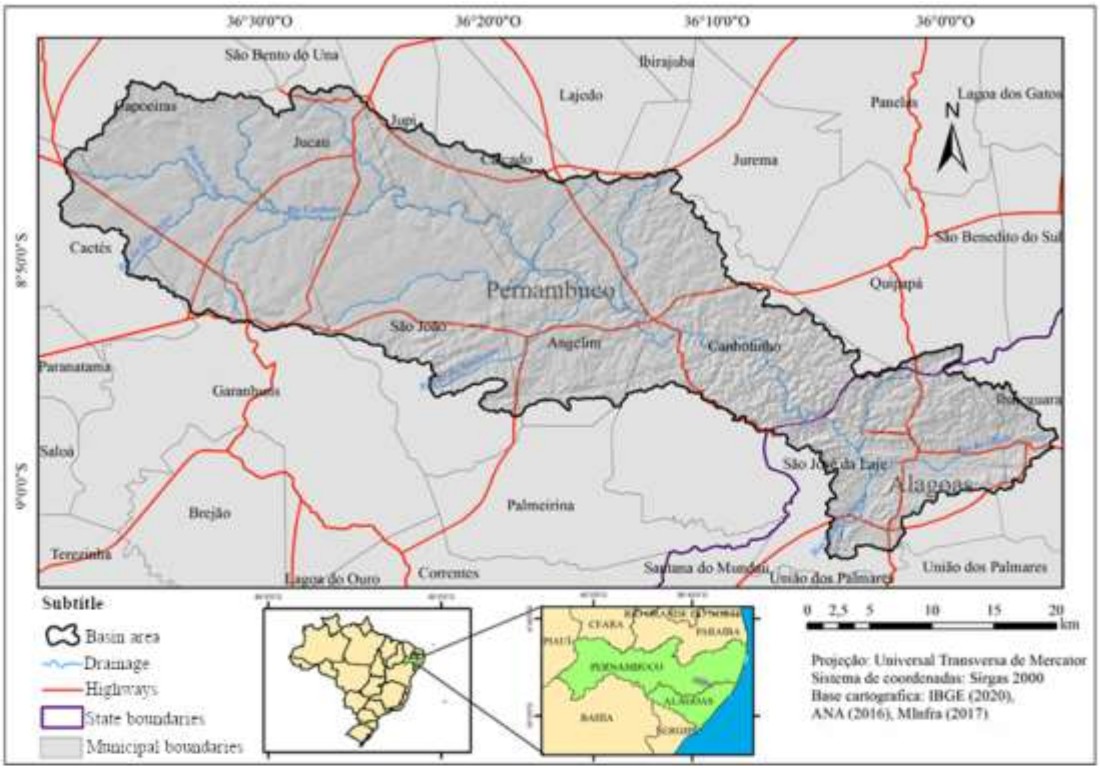

Figure 1: Location map of the Canhoto river basin (PE/AL)
Source: Own authorship.

The basin area is in the southern portion of the Borborema plateau on the activated orogenetic belt at the end of the Proterozoic, between the Pernambuco and Patos lineaments. From the lithological point of view, rocks formed by regional metamorphism predominate, grouped in the Belém do São Francisco Complex, in the Cabrobó Complex and in granitoid intrusions and peraluminous leucocratic suites (SILVA, 1993). According to Gomes (2015), on these lithologies and structural features, two morphosculptural units belonging to the Borborema Plateau were developed regionally.

The morpho-sculptural unit Cimeira da Borborema, also called Structural Summit Pernambuco-Alagoas by Corrêa et al. (2010), corresponds to a planning surface located between 600 and 1018 meters above, whose morphological units include plateaus, plateaus and low plateaus, covered by Litolic Neosol (Entisol Lithic/Leptosols), Regolith (Entisol Psamments/Regosols), and Haplic Planosol (Alfisols/Planosols); and the Garanhuns erosive threshold, covered by Yellow Latosol (Oxisols/Ferralsols) (ARAÚJO FILHO et al., 2000; ARAÚJO FILHO et al., 2012; SOIL SURVEY STAFF, 2014; IUSS WRB, 2015).

The morphosculptural unit of Residual Surfaces corresponds to a dissected surface positioned between 210 and 600 meters above. In the transition stretch with the summit surface, scarps vertically dissected predominantly by fluvial action. In the sector corresponding to the lower Canhoto river, there are hills and mounts dissected by differential erosion, in addition to alluvial plains (COSTA, 2018). Associated with the dissection models, there are more developed soils in the depth of the basin, such as Yellow Latosol (Oxisols/Ferralsols), Red-Yellow Latosol (Oxisols/Ferralsols), Yellow Argisol (Ultisols/Alisols) and Red-Yellow Argisol (Ultisols/Alisols) (ARAÚJO FILHO et al., 2000; ARAÚJO FILHO et al., 2012; SOIL SURVEY STAFF, 2014; IUSS WRB, 2015).

From a climatic point of view, the AS (dry tropical) and BSh (wet tropical) climates occur in the basin, according to the Köppen classification (COSTA, 2018). The average rainfall in this area is 900 mm per year in the humid tropical and about 650 mm in the dry tropical, with the highest rainfall occurring from February to July, which corresponds to about 73% of all annual precipitation (GOMES, 2015). This rainy period occurs due to disturbances from the east, which, coupled with the trade union systems and land breezes, intensify precipitation, especially at night.

Materials and methods

For the development of the research, the methodological recommendations presented in IPT (1990), Salomão (2014) and Silva and Mendes (2019) were followed, which suggest the combined use of slope data and the degree of soil erodibility to know the natural susceptibility to erosion of a given area. The digital data extraction procedures were performed in a GIS environment with the help of the Qgis 3.10.2-A Coruña software, considering the 1:100,000 working scale.

The slope was elaborated from the Digital Elevation Model (DEM) of the Alos satellite, Palsar sensor, with a spatial resolution of 12.5m. The slope was grouped into four classes with percentage values, according to Salomão (2014). Thus, the following intervals were recognized: Class I (> 20%), Class II (12├ 20%), Class III (6├ 12%) and Class IV (0├ 6%). After classification, still in raster format, the data were converted to vector format (shapefile).

To obtain the degree of erodibility, the pedological cartographic bases developed by Araújo Filho et al. (2000) and Araújo Filho et al. (2012). Soils were grouped into four of the five erodibility classes proposed by Salomão (2014), in which values were assigned to the index, according to the properties of each soil type, their associations, proportions and relief situation (Table 1).

Table 1: Erodibility classes associated with pedological units.

Erodibility classes	Relative erodibility indices	Pedological units*
I	10,0 a 8,1	SX20, RR11, RL1
II	8,0 a 6,1	LA19, PA35, PVA19, PVA18
III	6,0 a 4,1	PA’10, PA’17, PA’16
IV	4,0 a 2,1	LA12a, LA18, LVA3
V	2,0 a 0	-

*SX20: Ass.: Haplic Planosol (Alfisols/Planosols) + Litholic Neosols (Lithic Entisols/Leptosols). RR11: Ass.: Regolithic Neosol (Psamments Entisols/Regosols) + Quartz Sands. RL1: Ass.: Litholic Neosol (Lithic Entisols/Leptosols) + Haplic Cambisol (Inceptisols/Cambisols) + Red-Yellow Ultisol. LA19: Ass.: Yellow Latosol (Oxisols/Ferralsols), + Red Argisol (Ultisols/Alisols) + Red-Yellow Argisol (Ultisols/Alisols). PA35: Ass.: Yellow Argisol (Ultisols/Alisols) + Red-Yellow Argisol (Ultisols/Alisols) and Yellow Latosol (Oxisols/Ferralsols). PVA19 and PVA18: Red-Yellow Argisol (Ultisols/Alisols). PA'10, PA'17, PA,16: Ass.: Yellow Argisol (Ultisols/Alisols). + Red-Yellow Argisol (Ultisols/Alisols) and Yellow Latosol (Oxisols/Ferralsols). LA12a: Ass.: Yellow Latosol (Oxisols/Ferralsols) + Yellow Argisol (Ultisols/Alisols) and Red-Yellow Argisol (Ultisols/Alisols). LA18: Ass.: Yellow Latosol (Oxisols/Ferralsols) + Yellow Argisol (Ultisols/Alisols) and Red-Yellow Argisol (Ultisols/Alisols) + Haplic Gleissol (Entisols/Gleysols) and Haplic Cambisol (Inceptisols/Cambisols). LVA3: Ass.: Red-Yellow Latosol (Oxisols/Ferralsols) + Red-Yellow Argisol (Ultisols/Alisols) + Haplic Gleyssol (Entisols/Gleysols).

Source: Adapted from Salomão (2014).

Subsequently, the laminar erosion susceptibility map was obtained from the intersection between the erodibility classes and the slope classes, through the map algebra operator (SILVA; MENDES, 2019). Map algebra serves to indicate the set of spatial analysis procedures in Geoprocessing that produce new data, from manipulation functions applied to one or more maps (TOMLIN, 1990). This method conceives spatial analysis as a set of mathematical operations on maps, in analogy to traditional algebra and statistics environments, presenting three classes of map algebra: point, neighborhood and zonal.

Among the three map algebra classes, Punctual was applied in this work, where the output of the operation is a map, whose values are only a function of the values of the input maps in each corresponding location, performing intersections between spatial sets. Using the "Intersection" tool, the combination between the slope and soil erodibility classes was performed and, through the conditional operators of the attribute table, the property "susceptibility to laminar erosion" was created with five classes (Table 2). 265

Table 2: Criteria adopted in the definition of susceptibility classes to laminar erosion through the erodibility X slope relationship.

		Slop (%)				Laminar Erosion Susceptibility Classes
		I (>20%)	II (12 ├ 20%)	III (6 ├ 12%)	IV (0 ├ 6%)	
Erodibility	1	I	I	II	II	I - Extremely susceptible
	2	I	II	II	III	II - Very susceptible
	3	II	III	III	IV	III - Moderately susceptible
	4	II	IV	IV	V	IV - Slightly susceptible
	5	-	-	-	V	V - Little to not susceptible

Source: Adapted from Salomão (2014).

Thus, the final map indicated the areas that are naturally susceptible to erosion, that is, when human activities are not considered as a factor that can potentiate erosive processes. The classes were described as follows:

Class I - extremely susceptible: they present complex conservation problems. These are generally very steep, eroded areas that must be used with extreme care; Class II - very susceptible: they present complex conservation problems, partially favorable to pasture occupation, being more suitable for reforestation; Class III: moderately susceptible: they present complex conservation problems, being more suitable for pasture and permanent crops that favor the protection of the ground; Class IV: little susceptible: they present complex conservation problems, being more suitable for pasture and permanent crops and, eventually, annual crops. However, these areas require intensive mechanized erosion control practices; Class V: little to not susceptible: they present simple conservation problems and can also be used with any type of culture, however requiring non-mechanized erosion control practices or requiring special cultivation techniques, when located in waterlogged soils.

RESULTS AND DISCUSSIONS

The spatial distribution of slope classes in the Canhoto river basin showed a pattern resulting from the topographic characteristics of the area (Figure 2). Lands with up to 12% slope (classes III and IV) occupied a few more than a half of the area (Table 3) and are predominantly distributed in the highest sector of the basin, the area corresponding to the Borborema Summit, and in the alluvial plains of the Eastern Slopes. Class II is mainly distributed in the residual elevations and in the transition scarps between the two geomorphological units, while class I occurs predominantly in the dissected sector and in the structural level of Garanhuns.

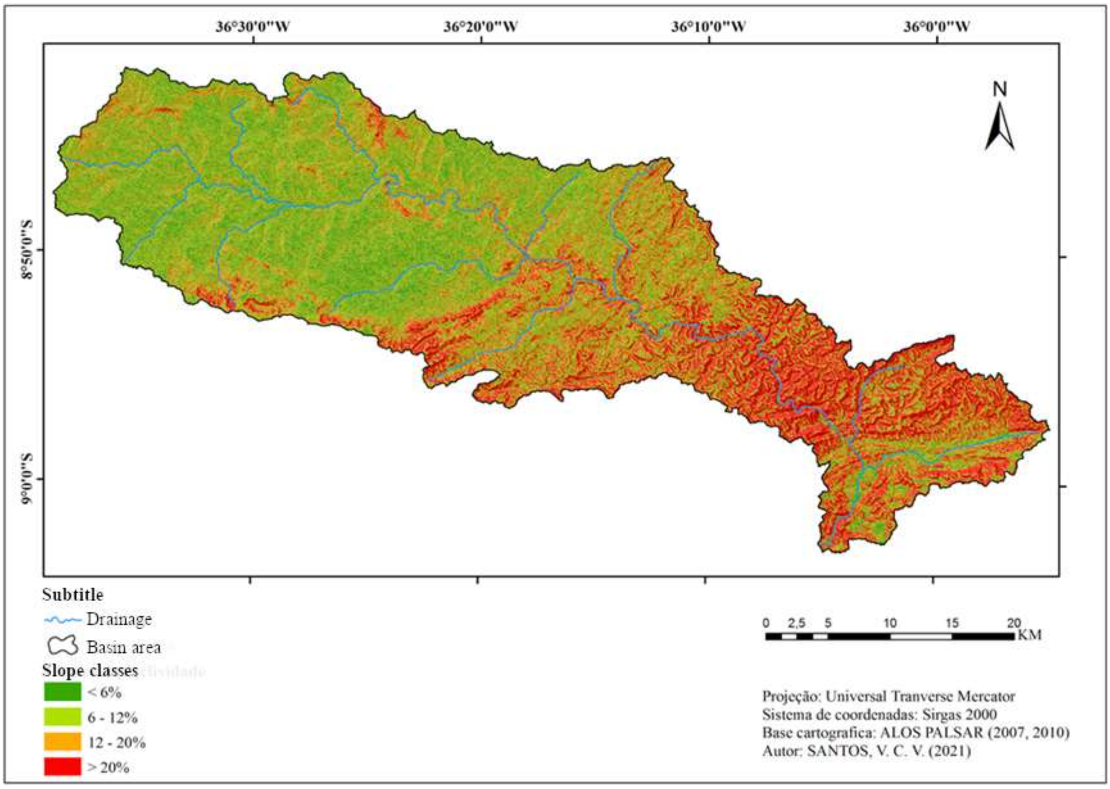

Figure 2: Map with slope classes of the Canhoto river basin (PE/AL).
Source: Own authorship.

Table 3: Representativeness of slope classes in the Canhoto river basin.

Classes	Area (km²)	(%)
I (>20%)	278.477	23,24
II (12 ├ 20%)	282.911	23,61
III (6 ├ 12%)	352.171	29,39
IV (0 ├ 6%)	280.514	23,41

Source: Own authorship.

As for soil erodibility classes, 4 of the 5 classes proposed by the methodology used occurred in the basin (Figure 3), whose areal representation can be seen in Table 4.

Class I, due to its physical, chemical, and mineralogical characteristics, presented the highest erodibility rate. This class represented 49.41% of the analyzed area, being the most representative, being associated with the younger soil classes with associations of Litholic Neosols (Entisols/Leptosols). Class II represented 28.29%, and pedological units that stand out for their medium/clayey texture, such as Argisols (Ultisols/Alisols) and non-abrupt Latosols (Oxisols/Ferralsols), are present in this class. In class III, which represented only 5% of the area, Ultisols with a large percentage of clay in their composition stood out. Finally, class IV was represented by the classes of Latosols (Oxisols/Ferralsols), in this case Yellow Latosols (Oxisols/Ferralsols) and Red-Yellow Latosols (Oxisols/Ferralsols), representing 17.28% of the study area.

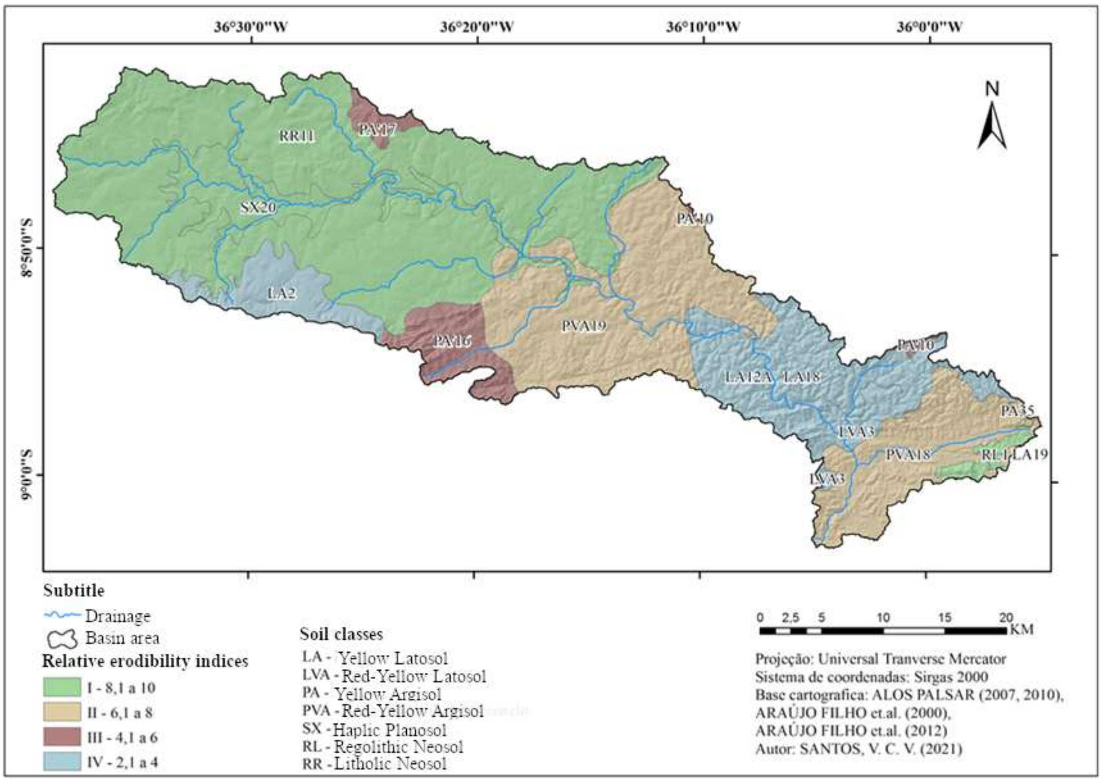

Figure 3: Map with soil erodibility classes in the Canhoto river basin (PE/AL).
Source: Own authorship.

Table 4: Areal representation of erodibility classes in the Canhoto river basin.

Classes	Area (km²)	(%)
I	592,125	49, 415
II	339,014	28,292
III	59,9943	5,006
IV	207,135	17,286

Source: Own authorship.

After crossing the erodibility classes with the slope classes, the five susceptibility classes found in the Canhoto river basin were generated (Figure 4). The sand representation of the erodibility classes can be found in Table 5.

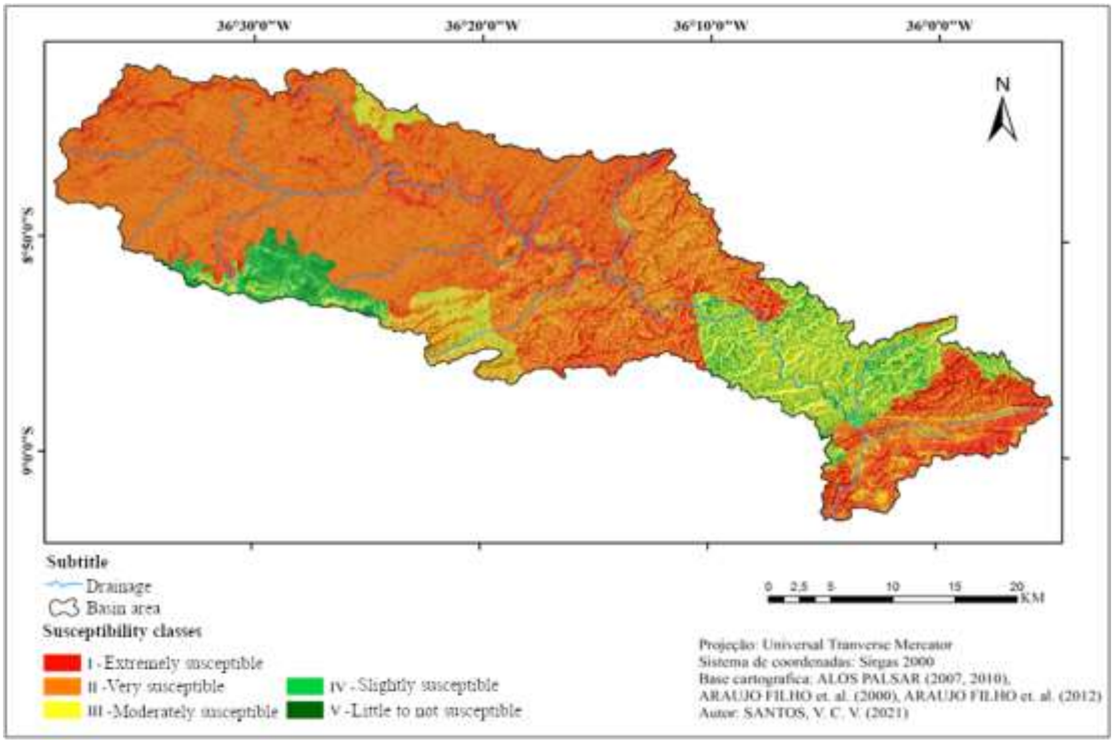

Figure 4: Map with the classes of susceptibility to laminar erosion of the Canhoto river basin (PE/AL). Source: Own authorship.

Table 5: Representativeness of susceptibility classes in the Canhoto river basin.

Classes	Area (km²)	(%)
I	269,231	22,46
II	640,568	53,45
III	180,111	15,03
IV	85,752	7,15
V	22,572	1,88

Source: Own authorship.

From the mapping of the natural susceptibility to laminar erosion, it was observed that more than 75% of the basin area was found to be distributed between classes I and II, that is, they presented weaknesses from the point of view of the generation of erosive processes. It can be said, therefore, that in the Canhoto river basin, this susceptibility is mainly associated with the textural characteristics of the soils that occur in the semi-arid area. This was verified in the sectors with the lowest slopes of the terrain, located at the Borborema Summit, where Haplic Planosols (Alfisols/Planols) occur more frequently.

This demonstrates that, if agricultural activities in these sectors are incompatible with the natural fragility of the soils, erosive processes may occur from laminar erosion, in addition to furrows, ravines and even gullies. The sediment load resulting from these processes may reach regional water resources, causing their silting, in addition to soil degradation through infertility (ARAGÃO *et al.*, 2011).

In this way, several mitigation actions for soil conservation can be carried out to prevent soil conditions from being exhausted to the point of becoming unproductive and degraded, considering the controlled adoption with appropriate conservation practices for each type of soil.

Class III, although presenting complex conservation problems, represented a smaller percentage. If associated with incompatible uses, mitigation and conservation measures have a simpler applicability. The classes with low susceptibility (IV and V) represented very little of the basin area, not presenting special conservation problems or, when they do, they are simple and easy to solve, and can be used with different types of culture, requiring non-mechanized practices to control the water. erosion.

In general, the results are alarming, considering that this region has been highly demanded from the point of view of its use, as shown by the mapping of land use and occupation by Costa (2018). Therefore, it is observable that the use is being incompatible with its potential for laminar erosion in some areas. Presumably, the proper conservation techniques have not been applied to the basin, so a soil conservation and management plan is necessary to adapt land use to the preservation of natural resources, soil and water.

However, future studies should better detail the different forms of soil use along this area, demonstrating its potential for laminar erosion, since areas with the same level of susceptibility, occupied in different ways, may present different potentialities for the development of erosive processes.

FINAL REMARKS

Taking in consideration that it is distributed in an area of environmental transition, in the Canhoto river basin, high percentages of soils with high erodibility indices and a great variability of slope percentage occur, resulting in susceptible areas to erosion, thus becoming an important object of study, given the lack of research of this type in the region. Considering the data obtained, it was found that the basin has a predominance of susceptible and extremely susceptible areas, being the result mainly of pedological units with low performance of pedogenetic processes and poorly drained, which has its genesis related to lower pluviometric indexes of the semi-arid climate and geological materials of the Precambrian with acidic plutonic rocks.

Despite the predominance of high slopes in the southern region with its dissected hills, the susceptibility results were reasonably average or even low. The factor that balanced these results were the physical properties of the pedological units, being well developed, deep and with good drainage. Both environmental characteristics (geomorphological and pedological) are closely related to the high rainfall in the region, contributing to the good development of pedogenetic processes.

The need for conservationist practices in the basin is undeniable, as more than 75% of the area has the highest levels of susceptibility to laminar erosion, since these are lands that present complex conservation problems. The moderately and less susceptible areas are more suitable for pastures, planting of perennial crops, however, with erosion control practices, such as planting in contour lines, contributing to better drainage of rainwater, facilitating infiltration into the soil. On the other hand, sectors classified as low to non-susceptible do not present special conservation problems, and simple conservation techniques should be adopted.

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