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Prediction of soil losses and agrotechnological seizure in the Sertão Alagoano

Predição de perdas de solo e apreensão agrotecnológica no Sertão Alagoano

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Abstract: Accelerated soil erosion is an environmental problem related to land occupation and use and compromises production, biotic and climate regulatory functions. In the semi-arid region, the loss of productivity and the expansion of the desertification phenomenon is little associated with erosion processes and related to drought by farmers. The evaluation of erosion in the municipality of Poço das Trincheira-AL through the Universal Soil Loss Equation, relates its impact to loss of productivity and changes in use, correlating the results with data from the IBGE agricultural sense and deforestation from MapBiomas from 2010 to 2021. The predicted erosion map had an accuracy of 52% and Kappa of 35%. Laminar erosion predominates and is intensified by the inappropriate use of technologies. There is an advance in agricultural activity to the detriment of areas in the Caatinga Biome. Human activities and climate change, which may be associated, do not favor revegetation, and may lead to irreversible soil degradation and expansion of the desertification phenomenon. The perception of the soil erosion rate can help in the development of knowledge strategies for the establishment of management practices that reduce soil losses.

Keywords: Caatinga; Soil degradation; Semiarid.

Resumo: A erosão acelerada do solo é um problema ambiental relacionado a forma de ocupação e uso das terras e compromete as funções de produção, biótica e reguladora do clima. No semiárido, a perda de produtividade e a expansão do fenômeno de desertificação é pouco associada aos processos erosivos e relacionada a seca pelos agricultores. A avaliação da erosão no município de Poço das Trincheira-AL através da Equação Universal de Perdas de Solo, relaciona seu impacto a perda de produtividade e mudanças de uso correlacionando os resultados com dados do censo agropecuário IBGE e de desmatamento do MapBiomas de 2010 a 2021. O mapa de erosão predito teve acurácia de 52% e Kappa de 35%. A erosão laminar predomina e é intensificada pelo uso inadequado de tecnologias. Há avanço da atividade agropecuária em detrimento de áreas do Bioma Caatinga. As atividades humanas e a mudança climática, que podem estar associadas, não favorecem a revegetação, e podem implicar na degradação irreversível do solo e expansão do fenômeno de desertificação. A percepção da taxa de erosão do solo pode ajudar no desenvolvimento de estratégias de conscientização para o estabelecimento de práticas de manejo que reduzam as perdas de solo na região.

Palavras-chave: Caatinga; Degradação de solo; Semiárido.

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1. Introduction

The increase in drought severity and duration are an indicative of changes in the Brazilian semi-arid region and of a greater vulnerability of this region, associated with climate change, lies in the localities' ability to respond to the occurrence of long drought periods (MARENGO, et al., 2020). In the state of Alagoas, spatial and temporal irregularities in the rainfall regime are typical of the Agreste and Sertão mesoregions. Climate studies indicate that phenomena such as El Niño - Southern Oscillation (ENSO), and the general circulation of the atmosphere would be responsible for the occurrence of low rainfall (MOLION; BERNARDO, 2002). However, the erosivity of rainfall, concentrated in 3 to 4 months of the year, leads to soil degradation and is a factor that worsens the effects of these phenomena.

Accelerated soil erosion is an environmental problem related to the form of occupation and land use, compromising production, biotic and climate regulatory functions, among others. By progressively reducing the ecological memory of the soil (seeds, spores, organisms), erosion contributes to increasing its susceptibility to degradation to the extent that it compromises the vegetation capacity for regeneration (NUNES, et al., 2020). This process, in the semi-arid region, contributes to the expansion of desertification, as soil functions only remain effective as long as its properties and natural balance are preserved (MCBRATNEY et al, 2014).

The Caatinga Biome in the region is used in agricultural activities. The preserved areas constitute refuges where farmed animals can be gathered when the dry period is longer. However, the loss of land yield and the demand to meet food production for a constantly growing population has intensified the expansion of agricultural areas to the detriment of Caatinga areas.

The productive sustainability of crop-livestock integration depends on the interaction between climatic factors and soil and animal management. However, when carried out with technological apprehension dissociated from soil and animal management practices, the activity is identified as a cause of soil erosion and degradation (OLIVEIRA et al., 2021; CARVALHO, et al., 2020; BRITO et al., 2020; SILVA et al., 2018; TORRES et al., 2018). In the Sertão Alagoano, the expansion of this process has resulted in the expansion of desertification (UFAL, 2019).

The municipality of Poço das Trincheiras has around 90% of its territory within the Caiçara Environmental Protection Area (APA). Agricultural properties within this APA have shown yield and soil losses over time through erosion (EMBRAPA, 2012). Yield loss, little associated by farmers with erosion processes, is constantly related to drought, a cyclical phenomenon in the region.

Water erosion is related to the interaction between relief characteristics, soil attributes, land use and occupation, besides local rainfall. To demonstrate the impact of erosion on yield loss and intensification of soil degradation processes in rural areas of the Sertão Alagoano, an erosion analysis was carried out based on the Universal Soil Loss Equation – USLE (RENARD et al., 1997; adapted from WISCHMEIER and SMITH, 1978) and on data from the IBGE 2010-2021 agricultural census and MapBiomas 2010/2021. The estimate of annual soil loss in the area included in APA Caiçara, municipality of Poço das Trincheiras - AL in 2023, was based on Geographic Information System (GIS) tools.

2. Methodology

2.1 Area characterization

The studied area covers 18.21 km² around the Guarí village, located in the Sertão Alagoano mesoregion (Figure 1). In the region, according to Thornthwaite, the climate is semiarid (DdA’a’), with an average temperature of 24.2°C (EMBRAPA, 2012), and average annual rainfall of 1,040.6 mm. The area is inserted in the Caatinga biome and presents vegetation cover marked by the presence of hypoxerophilic caatinga fragments and deciduous forest amidst a matrix of anthropic dynamics with areas in regeneration, capoeiras, pastures and various temporary crops. The local geology is represented by lithotypes that make up the Granitic Migmatite Complex, represented by intrusive syenite and monzonite rocks, rich in quartz (GOIS et al, 2023). Relief surfaces developed on these rocks that gave rise to residual massifs were, such as the Serra dos Poços and Serra dos Bois, comprising the predominantly wavy relief to strongly wavy relief, with strong structural control, altitudes ranging between 425 and 720 m, differential dissection, dissymmetrical valleys, and inselbergs that stand out on pediplain surfaces with gently undulating relief (EMBRAPA, 2010).

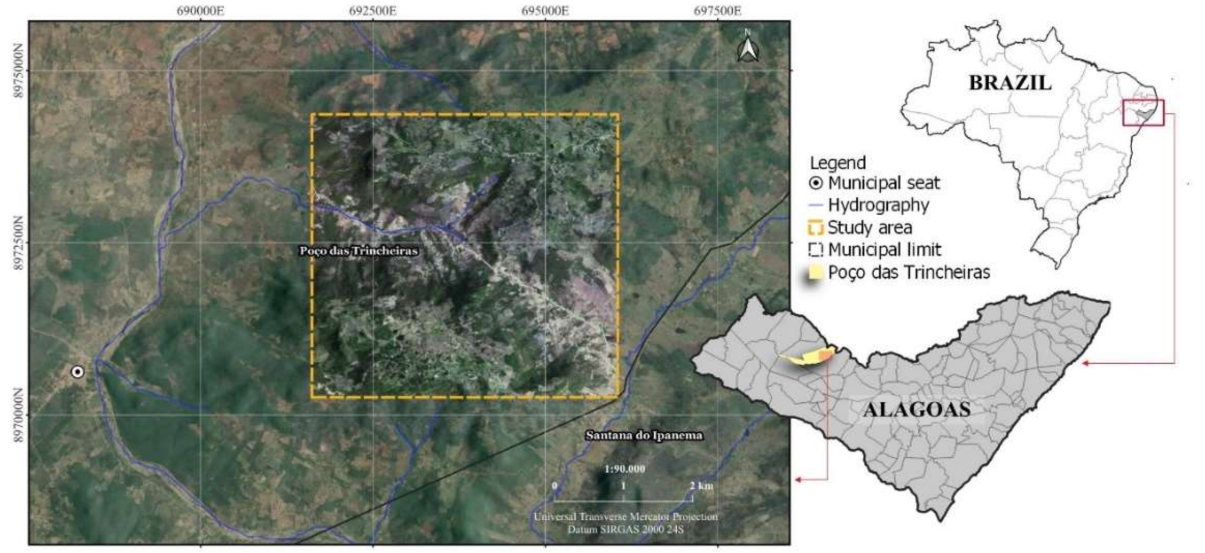

Figure 1- Location of the study area.
Source: Prepared by the authors based on Planet Team images (2023), Google Satellite and the IBGE cartographic base, 2023.

The local economic activity is based on livestock farming and subsistence agriculture conducted extensively, both using intermediate technological standards with low yield, resulting from food shortage during dry periods (EMBRAPA, 2012), which have intensified with soil degradation in the region.

2.2 Modeling in a GIS environment

Quantitative modeling in a GIS environment allows the processing and use of information in different media, scales and periods of time. To estimate soil loss, data integration and analysis was performed in QGIS (version 3.28 Firenze), applying the Universal Soil Loss Equation - USLE (RENARD et al., 1997; adapted from WISCHMEIER and SMITH, 1978).

The USLE correlates six factors that directly influence soil erosion: rainfall erosivity (R), soil erodibility (K), slope length (L), slope steepness (S), vegetation cover (C) and conservation practices (P). The K factor was derived indirectly through association with the Poço das Trincheiras soil map (EMBRAPA, 2012); erodibility values for soil classes were obtained through a bibliographic survey (Table 1).

Table 1- Soil classes and erodibility in the study area.

Soil class (EMBRAPA, 2012)	Area (km²)	K	Source
Haplic Cambisols	11.30	0.0355	Silva et al. (2009)
Argisols Ver Amar	3.48	0.0577	Morais e Sales (2017)
Lithosols	2.60	0.0460	Silva et al., (2009)
Haplic Planosols	0.45	0.0570	Silva et al., (2009)
Regosols	0.38	0.0520	Silva et al., (2009)

Source: Prepared by the authors (2023).

For the analysis of rain erosivity, factor R, the impact energy of rain on uncovered soil areas, was calculated using a historical series with data from 34 years (1988-2022) from the rainfall station of the Community Seed Bank in Povoado Guarí, Poço das Trincheiras-AL.

The Topographic Factor (LS Factor) is the product between the S Factor (slope) and the L Factor (ramp length). The runoff rate increases with the slope and slope length, as it increases the volume of runoff, directly interfering with soil erosion (BERTOL; CASSOL; BARBOSA, 2019). These terrain attributes (elevation, slope and ramp length) were derived from the Digital Elevation Model-DEM of images from the Shuttle Radar Topography Mission (SRTM), with a spatial resolution of 1 arc (~30m), obtained from Project Topodata (INPE) and processed in QGIS, GRASS GIS and SAGA (CONRAD et al., 2015; FARR et al., 2007; JASIEWICZ & METZ, 2011; NETELER, et al., 2012; VALERIANO, 2008).

Factors C and P, soil use and management and conservation practices are variables directly related to human actions. The type of vegetation cover is a key factor and interferes in increasing or reducing soil protection against disintegration/erosion. The use and coverage classes were determined through the analysis of images from 01/26/2023 from Planet Team, with surface reflectance ready for analysis (PlanetScope AnalyticMS Level 3B), spatial resolution of 3 m, blue (464-517 nm), green (547-585 nm), red (650-682 nm) and NIR (846-888 nm) bands.

The land use and cover classes were identified through a field visit and, after image analysis, supervised classification was carried out using the Minimum Distance (MD) classifier, run in QGIS with the Semi-Automatic Classification Plug-in – SCP (CONGEDO, 2021). In the classification, land use classes and coverage were considered: water, pasture/agriculture, capoeira, exposed soil, hypoxerophilic caatinga and deciduous forest (Figure 2).

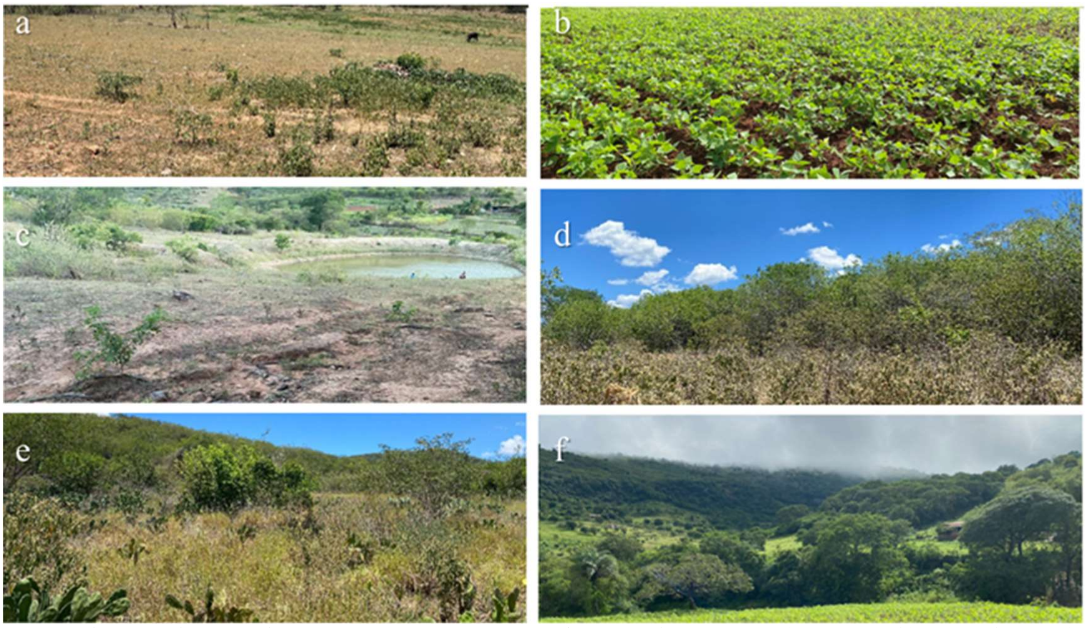

Figure 2- Soil use and cover classes in Sítio Guari - Poço das Trincheiras-AL: a) pasture; b) agriculture; c) water and exposed soil; d) hypoxerophilic caatinga, e) capoeira f) deciduous forest. Source: The authors (2023).

For areas with exposed soil, a maximum erodibility index 1 was adopted. This value was reduced due to the increased soil protection provided by the various natural or anthropogenic vegetation covers. The assigned erodibility values for each land use and cover class were established through a bibliographic survey (Table 2).

Table 2 - CP values used in this study.

Use class and cover	Erodibility	Source
Water	0.00	Barbosa et al., (2015)
Pasture/Agriculture	0.25	Barbosa et al., (2015)
Exposed soil	1.00	Barbosa et al., (2015)
Capoeira	0.01	Santos et al., (2014)
Hypoxerophilic Caatinga	0.0085	Santos et al., (2014)
Deciduous Forest	0.0004	Barbosa et al., (2015)

Source: Prepared by the authors (2023).

The equation of soil loss due to erosion is based on short-term data; therefore, it disregards soil erosion over time and may underestimate its assessment. To evaluate the accuracy of the predicted erosion map, the confusion matrix and the PABAK coefficient associated with the Kappa index were applied, which can be expressed as total agreement or for individual classes (COHEN,1960).

The parameters adopted to qualify the degree of erosion in the field were: no or slight erosion, when around 25% of horizon A was removed; moderate, when more than 50% of horizon A was removed and horizon B emerged; strong, when associated with moderate erosion, there were frequent furrows less than 30 m apart, occupying an area of less than 75% and could be crossed and undone by agricultural machinery, and very strong, when there were deep furrows less than 30 m apart, occupying an area greater than 75% that cannot be crossed by agricultural machinery and have already reached horizon C or the parent material.

3. Results and Discussion

The pedological cover of the area is made up of Haplic Cambisols (25.6%), followed by Haplic Planosols (21.9%); an undifferentiated group of Regosols + Red Argisols (20.5%); Lithosols (13.8%); small areas with undifferentiated groups of Haplic Cambisols + Red-Yellow Argisols (8.8%) and Red Argisols (0.4%). The Embrapa mapping (2012) shows that Haplic Cambisols are sandy and shallow, Haplic Planosols have a sandy/clayey texture with gravel, sandy Regosols, Red Yellow Argisols have a sandy/clayey texture with gravel and Lithosols are sandy and all are eutrophic. These soils are very susceptible to erosion, as they bring together an intrinsic set of morphological characteristics (sandy texture, low effective depth, superficial horizon with low levels of organic matter (weak A), textural gradient and columnar structure (planosols) which, associated with climate, relief and use, can influence the magnitude of erosion processes. The macroporosity characteristic of sandy textures favors rapid infiltration and runoff of water and soil in conditions of concentrated rainfall; this fact, associated with relief characteristics, intensifies the erosion process in uncovered areas with downhill soil.

The average annual rainfall for the village of Guarí in the municipality of Poço das Trincheiras – AL was 1,040.6 mm. It can be observed in Figure 3 that the historical series shows 17 years with values above the rainfall average and 18 years with values below average.

2022 was the year with the highest rainfall record, 2,049 mm, while 2016 was the year with the lowest rainfall, recording 482 mm. The monthly average (86.7 mm) shows that rainfall occurs concentrated in May to August (159.3 - 170.1 – 182.1 and 101.3 mm), corresponding to 58.86% of total annual rainfall, a condition that favors the action of erosive processes. According to Bertol, Cassol and Barbosa (2019), in bare soils, the intensity of rainfall in itself is already a factor that influences soil disintegration, while surface water runoff has a greater effect on disaggregation and transport in covered and discovered soils.

There is also a tendency towards a reduction in total annual rainfall. Costa et al. (2020), analyzing extreme climate indices in the Northeast of Brazil between 1961 and 2014, observed a reduction in total annual rainfall and the frequency of rainy days in the region. The authors did not relate this reduction to human activities. However, it is undoubted that urban advancement and agricultural expansion influence the hydrological cycle and, consequently, regional climatic conditions.

The monthly average erosivity showed a variation from 403.9 to 10,213.4 MJ mm $year^{-1}$ ha^{-1} h^{-1} (Figure 4). From May to July, erosivity was classified as very strong and in March, April and August, as moderate (Carvalho, 2008). Analysis of the water balance in the region (Figure 5) shows that there are 3 months of surplus in contrast to 8 months of water deficit.

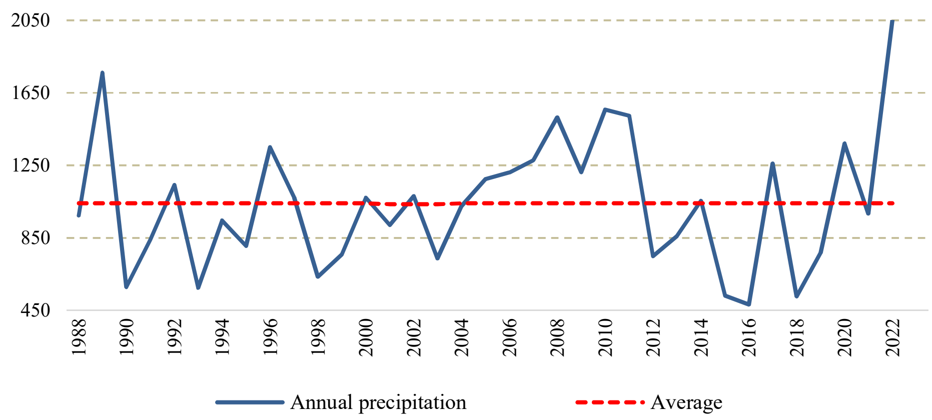

Figure 3- Distribution of average annual rainfall from 1988 to 2022 in Poço das Trincheiras – AL.
Source:Prepared by the authors (2023).

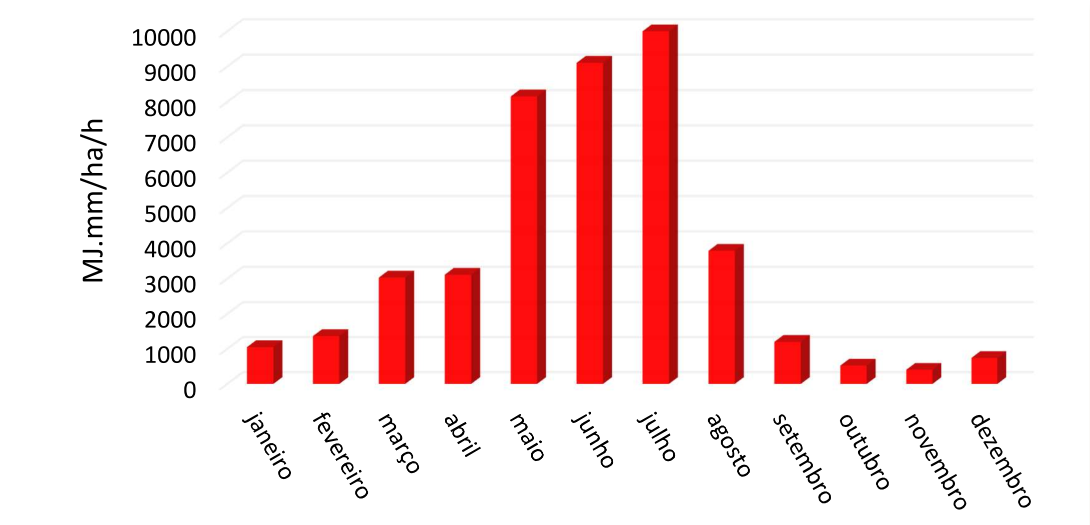

Figure 4- Average monthly erosivity in Poço das Trincheiras – AL: model proposed by Lombardi Neto and Moldenhauer (1992).
Source: Prepared by the authors (2023).

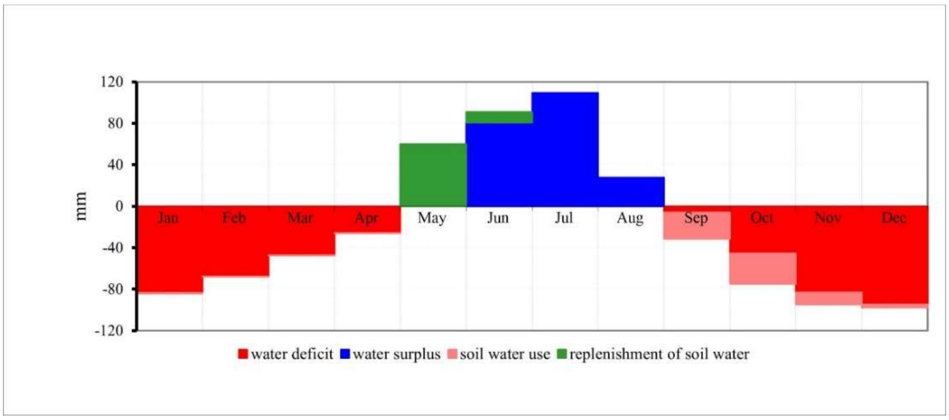

Figure 5 - Normal water balance Thornthwaite & Mather (1955) of Poço das Trincheiras – AL (1988 to 2022).*
*INMET temperature data.
Source: Prepared by the authors (2023)

Considering that the pedological cover in the region is predominantly made up of soils that are very susceptible to erosion, it appears that both agricultural production and the natural regeneration process of the vegetation cover are compromised. It is also possible to observe the continuity of the expansion model of agricultural frontiers, with deforestation that advances over the Caatinga Biome, changing the type of land use, related to impoverishment or soil degradation that determine productive loss or loss of agricultural profitability.

In the relief, the predominant steep slope classes are: strongly wavy relief (849.3 ha), wavy relief (633.2 ha) and mountainous relief (242 ha), geomorphologies that naturally favor surface runoff. The flat (88.8 ha) and gently undulating (3.8 ha) areas represent 5.1% and make up the valleys and plateaus of the intermediate surfaces between the highest and lowest relief compartments (Figure 6), where dragged sediments accumulate.

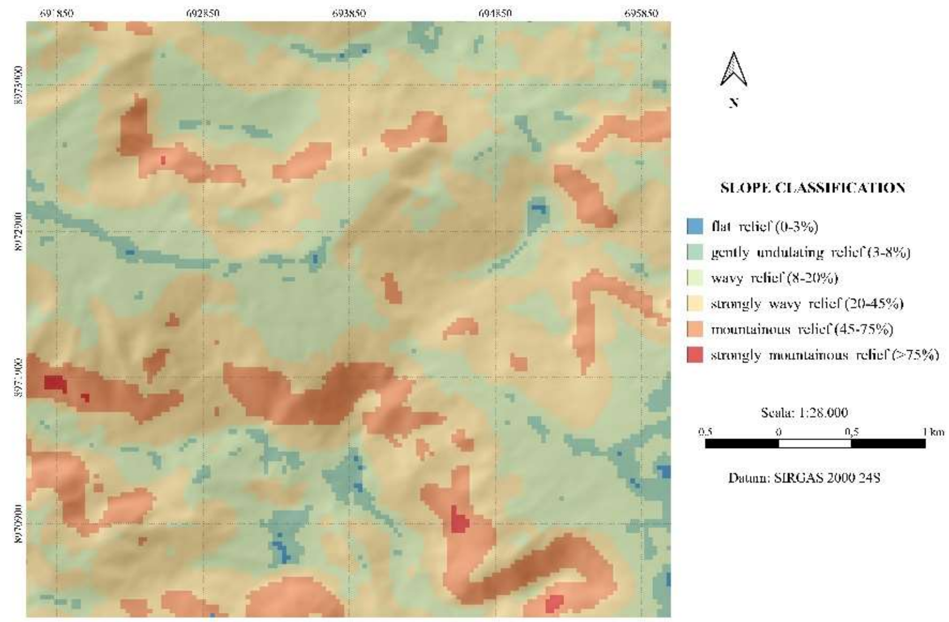

Figure 6 - Slope map of the Guari Village, Poço das Trincheiras - AL.
Source: The authors (2023).

Agricultural mechanization in the region imposes a simplification level that weakens the environmental balance. Soil mobilization for preparation and cultivation in areas with slopes above 20% increases susceptibility to erosion. Management with agricultural practices dissociated from conservation techniques results in losses of soil, water and nutrients, in addition to the degradation of the agroecosystem.

Medeiros and Silva (2014) highlighted the direct influence of the phytophysiognomy of the Caatinga biome on hydrosedimentological processes, its role in intercepting rainwater and controlling water and sediment losses through surface runoff. Its role is even more important when considering the irregularity and low rainfall in the semi-arid Northeast.

Figure 7 shows the map with the prediction of soil losses. It was evaluated by comparing the identification of erosion classes defined by the EUPS, with field observations collected in January 2023.

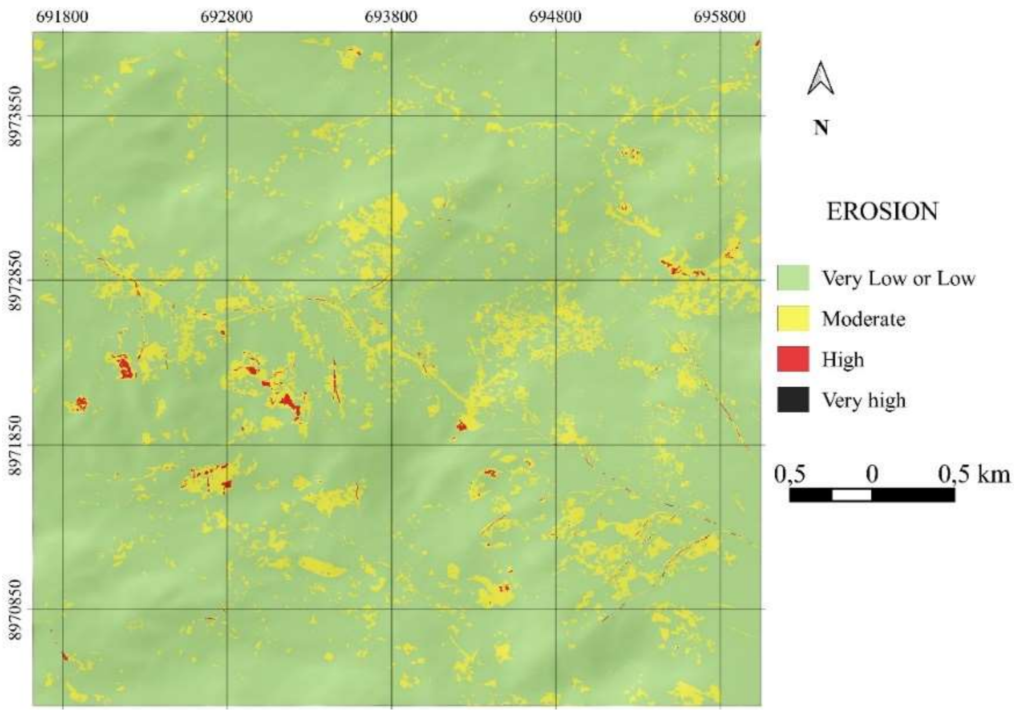

Figure 7 - Prediction of soil losses – Guari Village, Poço das Trincheiras - AL.
Source: The authors (2023)

The methodology does not evaluate the absolute values of soil loss. Therefore, Table 3 presents an estimate of the erosion potential for the class intervals outlined in the predicted map. A very low erosion potential is related to the areas of vegetation cover where deciduous forest, capoeira and hypoxerophilic Caatinga occur, which comprise around 1007.5 ha. Moderate, high and very high soil losses occur predominantly in strongly wavy and wavy relief, where agricultural activities are carried out. In this study, the mobilization and exposure of soil for planting is a factor that proved to be preponderant in the intensification of erosion processes.

Table 3-Distribution of erosion potential.

Erosion range (t.ha^{-1}.year^{-1})	Erosion Potential Condition	Area (%)	Area (t/ há)
0 – 10	Low	88.702	1603.5376
10 – 50	Moderate	10.969	198.2905
50 – 200	High	0.327	5.9096
> 200	Very high	0.002	0.0423

Source: The authors (2023)

The accuracy of the predicted map in relation to Global Accuracy (GA) was 52%, considered reasonable. However, the Kappa Index of 35%, which verifies the agreement level, was minimal in general (Table 4). The evaluation portrays how correct the generated map is in relation to the class labels observed in the field. Nonetheless, it also allows increasing the quality of the information generated, as it indicates the limitations inherent to modeling.

Table 4- Confusion matrix: correlation between the erosion class map and field observations.

		Predicted						
		L	Mod	H	V H	Total	Com	UA
Field	L	32	7	-	-	39	0.18	0.82
	Mod	-	21	-	-	21	0	1
	H	2	35	-	-	37	-	-
	V H	1	4	-	-	5	-	-
Total		35	67	-	-	102		
Om		0.09	0.69	-	-	GA	0.52	
ME		0.91	0.31	-	-	KI	0.35	

L= Low ; Mod= Moderate; H = Hight; V Str= Very Hight; Com= Comission; UA= User Accuracy; Om=Omission; GA= Global Accuracy; ME= Mapper Accuracy; KI= Kappa Index.

Source: Prepared by the authors.

According to the confusion matrix, 69% of moderate erosion was included in classes to which it does not belong. It is known that in digital cartography, the smallest mappable feature (Nyquist sampling theorem) corresponds to an area of 2 x 2 pixels, a standard size that has been designated nominal spatial resolution (MCBRATNEY et al., 2003). The median accuracy values can be explained based on this concept, as they are related to non-representation and the discrepancies detected for areas with strong and very strong erosion.

In the PlanetScope image (spatial resolution of 3 m), mappable features must have minimum dimensions of 6 m. Therefore, grooves and gullies with smaller dimensions were aggregated and incorporated into the moderate erosion class, or were not identified due to the dimensions and frequency of spatial distribution. However, we also emphasize that this equation has results limited to data temporality and this fact ends up underestimating the expansion of the erosive process, as it disregards, in the long term, the cumulative effects of processes that are classified based on features (presence, frequency and distribution of furrows and gullies, horizon decapitation, etc.). This also explains the high performance in relation to low or very low erosion, with 82% user accuracy, that is, the type of erosion and its distribution favor the classifier, so the probability of erosion class actually occurring is high in the areas outlined on the map.

The study was carried out in a year of atypical rainfall in the region, which favored the development of vegetation and "masked" part of the furrows and some gullies, affecting the classification estimate. However, it is possible to visualize on the soil loss map the delineation of linear areas with moderate erosion surrounded by areas with mild erosion and linear areas with hight erosion surrounded by moderate erosion. In the field, we found that they were related to more advanced erosion processes and that they were camouflaged by the vegetation growth stage, which can, depending on the time of year, reduce the visibility of furrows/gullies in the satellite image and interfere with identification and measurement of the extent of the erosion process.

Laminar (mild) erosion is predominant and corresponds to 89.82% of the area. However, on gentler slopes, there is erosion in furrows and gullies (moderate and hight) that expose the underlying rock. On intermediate surfaces, which make up levels between the highest parts and the base of the local relief, erosion in furrows was observed in some areas and, in others, the deposition of sediments burying soils and, in valleys, silting up streams (Figure 8).

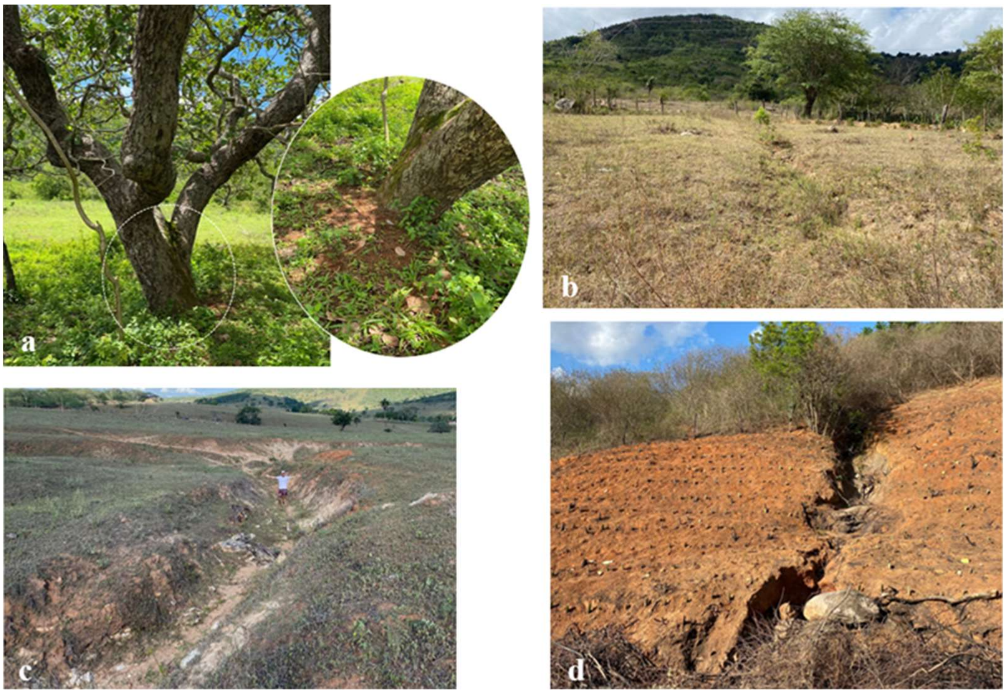

*Figure 8***-** *a) partial burial of cashew tree; b) furrow erosion; c) rocks exposed in gully and d) moderate erosion and ravine, Poço das Trincheiras-AL.*
Source: The authors (2023)

Within the areas delineated with no or mild erosion are the most preserved lands, still covered by forests and caatinga or thinned by them. In Paraíba, Medeiros and Silva (2014) found that areas with the lowest sediment production values are characterized by the presence of shrubs and shrub-tree vegetation, proving the importance of preserving caatinga vegetation in soil protection.

Areas with strong erosion are related to agriculture developed in strongly wavy and mountainous relief. In 2010, the municipality had 500 ha planted with maize. However, there was an expansion due to the yield competition established by the municipality's agriculture department and, in 2021, according to the IBGE, this area increased to 2,250 ha. Land use data from MapBiomas shows that there is an advance in crop-livestock integration in caatinga areas. In the period between 2010/2021, 158.25 ha of the caatinga area were transformed into pasture/agriculture areas. The expansion of agriculture into the caatinga and forest areas is the result of the progressive yield loss in cultivated areas due to erosion.

The expansion of erosion processes in areas where crop-livestock integration is practiced is significant. According to Paiva and Sá (2019), not only does the transformation and suppression of natural ecosystems with the progressive worsening of environmental degradation reduce resources, but also destroys local productive bases.

Downhill planting of subsistence crops (maize, beans and cassava) is frequently practiced, after harvesting animals graze the stubble, native grass and herbs (Figure 9). According to Data from the Municipal Livestock and Agricultural Survey-PPM / IBGE, the number of cattle remained constant. However, between 2010 and 2021, the sheep herd increased from 4,235 to 7,060 heads and the goat herd from 713 to 1,200 heads in the municipality. Cassava production, which was 8,000 kg/ha, fell to 7,000 kg/ha, but without parallel with the cultivated area in the region which, from 2010 to 2021, increased from 10 to 35 ha, that is, 350%. The data reflects not only the consequences of the erosion process on the region's economy, but also the pressing need to raise awareness among producers, regarding the severity of the soil degradation scenario that has been taking shape.

Figure 9 - Downhill planting in areas participating in yield awards: a) beans and b) maize - Poço das Trincheiras-AL. Source: The authors (2023).

For Rastgoo and Hasanfar (2021), excessive agricultural exploitation disturbs the ecological balance of arid and semi-arid regions, leading to adverse environmental changes that can result in a reduction in food production, water resources and desertification. In the region, the seizure of technologies (mechanization and inputs) is used in a way that is dissociated from technical assistance, which prevents the understanding of processes and the adoption of animal management and soil conservation practices.

In the region, the use of pesticides that are potentially dangerous to humans and the environment is common (Figure 10). Studies have shown that pesticides can also unbalance ecosystems, reducing the population of plant and animal species such as birds, frogs and bees, as well as soil resilience and coverage, as they reduce its biological "memory", as a seed cradle and reserve (NUNES, et al., 2020; LOPES; ALBUQUERQUE, 2018).

Figure 10 - Application of insecticides in maize crops downhill.
Source: The authors (2023)

There is a gap between the diffusion and apprehension and correct use of agrotechnologies. This dissociation does not allow the producer to relate the incorrect use of these practices to soil and yield losses. Therefore, there is a pressing need for qualified and active rural extension with rural communities to build new cognitive structures that direct the producer to apply innovations as an instrument that provides more balanced production within the region's agroecosystem.

This misunderstanding explains the dominant laminar erosion in crop-livestock areas, the replacement of livestock by native pastures, as producers are unable to obtain good harvest, and the subsequent advance over remnants of native vegetation with subsistence crops. Identifying and understanding these processes intrinsically associated with soil degradation is essential to avoid limit situations that are commonly irreversible (SÁ; PAIVA, 2019).

Although more adapted to the region's climate, small ruminants have natural grazing behavior that involves walking in a more concentrated and repetitive pattern (LEITE E CAVALCANTE, 2005), especially in restricted pasture areas (BARROS-JUNIOR et al, 2020). They have the habit of selecting legumes for their diet, the "ramoneio" (HINCH, 2017), in addition to consuming species considered as "invasive herbs" and shrub species from the caatinga, which have a higher crude protein content than grasses (BARROS-JUNIOR et al, 2020). Being more demanding, considering the body weight ratio, these small ruminants proportionally eat more forage than other ruminants (LEITE E CAVALCANTE, 2005).

The behavior, lack of control over stocking and the time animals spend grazing (BARROS-JUNIOR et al, 2020), associated with the anatomy of the goat-sheep paw (relatively small and compact compared to other large animals), mean greater pressure exerted and concentrated on a smaller soil area and greater forage consumption, both in cultivated and caatinga areas. Another specificity of these animals is that they avoid humid, muddy areas or areas with softer soil (HINCH, 2017). As a result, they tend to concentrate and trample drier areas, increasing soil density.

This continuous movement in limited areas and with reduced vegetation cover results in greater soil compaction (COLLARES et al, 2011), degradation of pastures, infestation by pests and weeds, increased surface runoff, increased laminar and furrow erosion, burial of levels in the middle and lower thirds of slopes and silting of streams.

The situation has worsened, as added to these facts is the lack of conservation practices for soil preparation when implementing crops. This inappropriately conducted combination of uses intensifies laminar erosion and establishes the dynamics of furrow formation and soil degradation in the region (OLIVEIRA et al, 2021; SILVA and CARVALHO, 2019).

In areas with gently undulating relief, where there are currently only native pastures, the presence of gullies is common (Figure 11a). In the field, gullies were recorded in argisols cultivated with palm, beans and maize (Figure 11b), and some were hidden by larger secondary vegetation (very strong erosion).

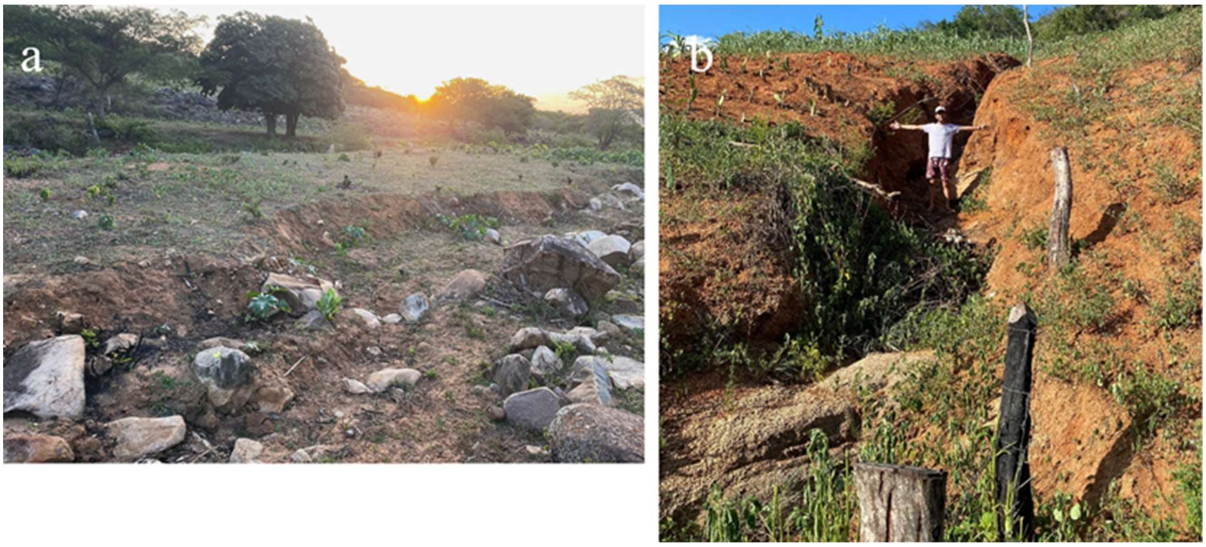

Figure 11 - Very strong erosion in: a) maize and palm cultivation on a hillside; b) pasture. Poço das Trincheiras - AL. Source: The authors (2023)

4. Final considerations

The accuracy for the predicted erosion map was 52%, considered reasonable, but the Kappa of 35% was minimal. In the studied area, laminar erosion (slight) predominates, with high classification accuracy. There is also a tendency to decapitation of the soil surface layer and more advanced erosion stages (furrows, ravines and gullies) in areas with strongly wavy and wavy relief, where crop-livestock integration with inadequate adoption of technologies is developed on soils naturally susceptible to this process. However, the analysis at a drier time of the year, with less interference from vegetation cover, may change and expand the framework to more severe erosion classes than those observed.

The reduction in agricultural yield, driven by erosion processes in the area, favors the advancement of agricultural activity to the detriment of areas with natural physiognomies in the Caatinga Biome. This means that human activities and climate change, which may be associated, compromise revegetation, and may result in irreversible soil degradation and expansion of desertification. In this context, the perception of the area soil erosion rate can help in implementing awareness strategies and establishing agricultural management practices that reduce soil losses.

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