Diversitas Journal
ISSN 2525-5215
Volume 11, Issue 4 (Oct../Dec.. 2026) p. 001 - 014
https://diversitasjournal.com.br/diversitas_journal

Analysis of the evolution of an erosive process: The case of the gully in the Clima Bom neighborhood, Maceió, Brazil

VIANA, Melquisedeque da Silva[1]; SILVA, João Pedro Luiz Santos da[2]; JUNIOR, Jeilson Rodrigues da Silva[3]; FILHO, Antonio Rodrigues de Oliveira[4]; SILVA, Ana Paula Lopes da[5]

[1] 0009-0001-0852-3370; Master's student in the Postgraduate Program in Geography at the Institute of Geography, Development and Environment (*Instituto de Geografia, Desenvolvimento e Meio Ambiente* - IGDEMA) of the Federal University of Alagoas (*Universidade Federal de Alagoas*). Maceió, Alagoas (AL), Brazil.
Corresponding Author - Email: melquisedeque.viana@igdema.ufal.br.

[2] 0000-0002-4905-7468; Master's degree from the Postgraduate Program in Geography at the Institute of Geography, Development and Environment (*Instituto de Geografia, Desenvolvimento e Meio Ambiente* - IGDEMA) at the Federal University of Alagoas (*Universidade Federal de Alagoas*). Maceió, Alagoas (AL), Brazil. Email: joaopedro.luiiz@gmail.com.

[3] 0000-0002-1557-2250; Master's degree from the Postgraduate Program in Geography at the Institute of Geography, Development and Environment (*Instituto de Geografia, Desenvolvimento e Meio Ambiente* - IGDEMA) at the Federal University of Alagoas (*Universidade Federal de Alagoas*). Maceió, Alagoas (AL), Brazil. Email: jeilsonrodriguesdasilva@gmail.com.

[4] 0009-0006-1939-1795; Specialist from the Postgraduate Program in Geography at the Institute of Geography, Development and Environment (*Instituto de Geografia, Desenvolvimento e Meio Ambiente* - IGDEMA) at the Federal University of Alagoas (*Universidade Federal de Alagoas*). Maceió, Alagoas (AL), Brazil. Email: antoniordof@hotmail.com.

[5] 0000-0002-7263-7671; PhD. Teacher at the Institute of Geography, Development and Environment (*Instituto de Geografia, Desenvolvimento e Meio Ambiente* - IGDEMA) at the Federal University of Alagoas (*Universidade Federal de Alagoas*). Maceió, Alagoas (AL), Brazil. Email: ana.lopes@igdema.ufal.br.

The content expressed in this article is the sole responsibility of its authors.

ABSTRACT

Erosive processes are common and are natural elements of landscape dynamics in various environments around the world. Still, when they affect humans, they start being labeled as disasters, as defined by the Brazilian Classification and Coding of Disasters (*Classificação e Codificação Brasileira de Desastres* - COBRADE). In this sense, the present work represents a preliminary effort to map the evolution of an erosive feature (gully) that has been developing for a few years in the Clima Bom neighborhood in Maceió, Alagoas. For this, a low-cost methodology was used, based on freely available images and open-source software. It was possible to see that the erosive feature studied has been growing progressively since it was first recorded in the landscape and is approaching the BR-316 at an average rate of 2.5 m/year. BR-316 is one of the main roads connecting the state capital to some of the main municipalities in its metropolitan area. In this sense, it can be concluded that the methodology used proved to be effective when applied for an initial assessment, allowing for the collection of general data about the feature studied, such as area growth, evolutionary trend, and how close it is to threatening the highway, serving as a basis for monitoring and planning actions.

RESUMO

Processos erosivos são comuns e constituem elementos naturais da dinâmica da paisagem nos diversos ambientes do planeta. Ainda assim, no momento em que atingem o ser humano, passam a receber o rótulo de desastres, tipificados pela Classificação e Codificação Brasileira de Desastres (COBRADE). Nesse sentido, o presente trabalho compreende um esforço preliminar de mapeamento evolutivo de uma feição erosiva (voçoroca) que, há alguns anos, vem se desenvolvendo no bairro Clima Bom, em Maceió, Alagoas. Para tal, foi empregada uma metodologia de baixo custo, baseada no uso de imagens disponibilizadas gratuitamente e em *softwares open source*. Foi possível verificar que a feição erosiva estudada cresce progressivamente desde seu primeiro registro de ocorrência na paisagem e aproxima-se, a uma média de 2,5 m/ano, da BR-316, uma das principais vias de conexão entre a capital do estado e alguns dos principais municípios de sua região metropolitana. Nesse sentido, pode-se concluir que a metodologia empregada se mostrou efetiva quando utilizada para um diagnóstico inicial, tornando possível a obtenção de dados gerais do elemento estudado, como crescimento da área, tendência evolutiva e proximidade de sua ameaça à rodovia, servindo de base para ações de monitoramento e planejamento.

ARTICLE INFORMATION

Article Process:
Submitted: 01/24/2026
Approved: 10/15/2026
Published: 11/04/2026

CC BY

Keywords:
Erosion, Gully mapping, Remote sensing, Urban planning, environment.

Palavras-Chave:
Erosão, Mapeamento de voçorocas, Sensoriamento remoto, Planejamento urbano, Meio Ambiente.

DOI: 10.48017/dj.v11i4.3884

Introduction

Geomorphology plays a key role in interpreting landforms and the various phenomena and processes that take place on them. By understanding relief as the result of complex interactions between surface materials and geodynamic processes occurring over space and time, geomorphology allows us to decipher landform features in an integrated way, through an analysis that provides important information about their current configuration (CHRISTOFOLETTI, 1980).

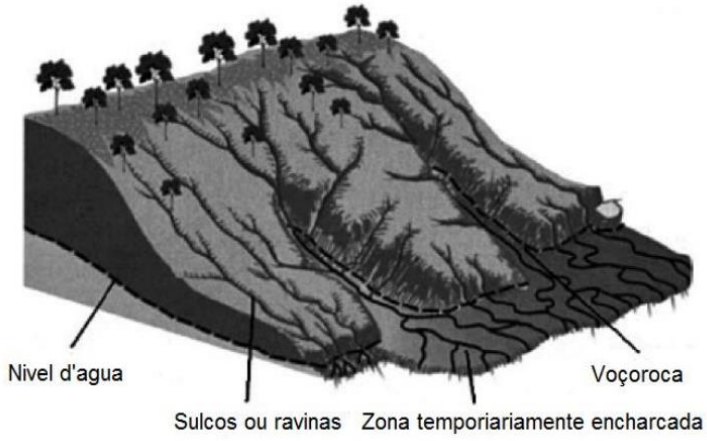
In this sense, it is understood that the relief is the result of the interaction between geological, biological, climatic, and tectonic processes over millions of years, and studying it makes it possible to identify environmental patterns and evolutionary trends of the landscape, which contributes to understanding the environmental history of a region (SANTOS, 2024). Given its ability to influence the process of territorial occupation, condition the development of economic activities, engineering projects, and its inherent susceptibility to disasters when activity management takes place without considering the limits of its stability constraints, the study of relief, forms, and features has broad relevance, especially for planning sectors, as it allows the collection of data that become a basis for understanding its behavior and its implications for the environment (FROTA AND SILVA, 2019).

Ab'Saber (2003) and Christofoletti (1980) highlight the importance of understanding the dynamics of physiographic processes, both past and present, that are responsible for shaping landscapes, especially when analyzed in light of human interventions. In this sense, erosive processes are a natural phenomenon with global reach, playing a key role in transforming landscapes over time (SANTOS, 2021), and although they are inherent to the functioning of environmental systems, occurring mainly through the action of rainwater and wind, specialized literature shows that uncontrolled human interventions significantly increase their intensity and frequency (OLIVEIRA, 2012; GUERRA, 1996; VIEIRA, 2015; HAUSCHILD, 2024).

In this way, the Brazilian Classification and Coding of Disasters (*Classificação e Codificação Brasileira de Desastres* - COBRADE) frames erosion, and consequently erosive processes, as a specific subgroup within the category of geological disasters, mainly linking its occurrence to the removal of vegetation cover, improper land use, and uncontrolled urbanization. Among the recognized types, continental erosion stands out, which COBRADE subdivides into sheet erosion, gullies, and ravines (or large gullies), considered the most common and those with significant potential to generate socio-environmental impacts.

Figure 1.

Illustration of continental erosive processes (Grooves, Gullies, and Badlands).



Source: Silva et al. (2022).

Gullies are characterized by well-defined incisions in the land surface that can reach tens of meters in width, depth, and length (SOIL SCIENCE SOCIETY OF AMERICA, 2020), representing the final stage in the evolution of an erosional incision that typically begins as a small rill resulting from sheet erosion. COBRADE defines them as the "Evolution of the ravine formation process in size and depth, in which the detachment and removal of soil particles are caused by concentrated surface and subsurface water flow (groundwater flow)." As the final stage of an erosional process, with considerable potential to trigger emergency and disaster alerts, their impacts have been extensively documented, particularly their ability to affect the natural, social, and economic dynamics of the areas in which they develop (SANTOS, 2024; RIBEIRO, 2023; SILVA, 2022; MONTE, 2022; JORGE; CAMAPUM, 2006; IMENSO; KWAAD, 1980).

In this regard, understanding and applying methodologies for monitoring this phenomenon are essential not only for developing effective conservation strategies for degraded areas but also for monitoring and managing the risks associated with them (GUTIERRES, 2023; CAPRA, 2013; NIÉDJA, 2005). In recent decades, advances in geotechnologies and remote sensing analysis methods, particularly through the use of satellite imagery and Geographic Information Systems (GIS), have significantly improved approaches to analyzing erosional features. These methods have reduced researchers' exclusive reliance on *in loco* activities and costly field surveys, allowing some analyses to be conducted remotely, with greater efficiency and lower costs. In this context, the use of geotechnologies in the analysis of erosional processes has become essential, particularly when integrated with field surveys and interventions, since combining data from different sources facilitates the analysis, modeling, and understanding of these phenomena (Santos, 2024).

Against this background, the occurrence of soil erosion-related disasters in the urban area of Maceió deserves particular attention. In the city, these erosional processes are common and are primarily associated with slope instability, intense rainfall events, and unplanned land occupation and interventions. Maceió has an extensive history of informal settlements and the expansion of favelas on the slopes of valleys carved into the coastal plateaus (OLIVEIRA, 2023). Considering the city's continued urban expansion, which for many years occurred in the absence of adequate land-use planning, the potential of geomorphological processes to cause disasters in Maceió is particularly significant.

Thus, this study aims to map the growth and progression of an erosional feature located in the Clima Bom neighborhood of Maceió, the capital of the state of Alagoas, which is advancing toward BR-316, an important highway connecting Maceió to municipalities in its metropolitan region. The study employs a low-cost, easily replicable methodology based on the hypothesis that historical imagery obtained through Google Earth Pro, combined with geoprocessing in a GIS environment using QGIS, provides an effective approach for the preliminary assessment and monitoring of gully evolution, enabling the analysis of growth trends and associated risks.

Development

Characterization of the study area

Maceió is the main urban center of the state of Alagoas, featuring a landscape marked by intense urbanization and a high population density, with residential, commercial, and industrial areas all coexisting. Since the 1990s, the city has seen significant population growth, currently reaching close to one million inhabitants, making it the most populous and also the most densely populated city in the state.

Table 1.

Population contingent of Maceió, by demographic census.

Municipality	Resident Population 1991	Resident Population 2000	Resident Population 2010	Resident Population 2022
Maceió	692,041	797,759	932,748	957,916

Source: Prepared with data from IBGE (2022).

The study area has its reference point located at coordinates 09°34'8.26"S, 35°47'41.95"W, in the Clima Bom neighborhood, in Maceió. With a population of 50,486 inhabitants and a population density of 10,812 inhabitants/km² (IBGE, 2022), it is one of the

city's main neighborhoods, with the greatest lack of basic sanitation in the city, having a large population in a situation of socio-environmental vulnerability and an economy based on small businesses and informal work. In addition, the neighborhood, along with its surrounding areas, is located on the edges of the Tabuleiro dos Martins endorheic basin, an urban basin that, in recent decades, has been the target of a large-scale drainage project aimed at managing surface water runoff, with the goal of reducing flooding in the area.

The erosive feature studied, in turn, is associated with the drainage system of the Braço Frio stream, one of the components of the Mundaú River watershed. The region is characterized by sedimentary lands from the Barreiras Formation, composed mainly of sandstones and claystones, which are unconsolidated and friable, creating a concave and convergent slope (PANTA, NASCIMENTO, AND CORREA, 2023). The local climate, according to Köppen's classification, is Aw type (tropical with a dry winter season), with an average annual precipitation ranging between 1,400 and 1,500 mm.

Figure 2.

Location Map of the Study Area.



Source: Prepared by the authors (2026).

Methodological Procedures

The process of analyzing the growth and progression of the gully located in the Clima Bom neighborhood started with the creation of a database of images of the area where the erosion process occurs. This database was created using Google Earth Pro software, through

the "historical images" tool, which allows access to the time-lapse record of images provided by the platform.

As a basic selection criterion, the visual quality of the images, the continuity of the mosaic, and the absence of interferences, such as cloud cover or shadows, were considered. In this way, images that did not meet the minimum requirements for analysis were discarded, and a total of 16 images were selected, distributed between the years 2002 and 2024 (Table 2).

Table 2.

Images collected per year.

Year	***Number of Images***
2002	*01*
2008	*01*
2013	*02*
2016	*01*
2017	*03*
2018	*02*
2019	*01*
2020	*04*
2024	*01*

Source: Prepared by the authors (2025).

The next step involved importing the selected images into a Geographic Information System (GIS) environment, where the spatial analyses would be carried out. For this, the image database was georeferenced using QGIS software (version 3.28.2 Long Term Release). At this stage, the methodological approach was based on the procedures adopted by Vieira and Frota Filho (2023) and Batista, Vieira, and Marinho (2018), who used similar techniques in studies on erosive processes in the city of Manaus, Amazonas.

With the image database properly georeferenced, the final step involved vectorizing the eroded area using the on-screen digitizing method, referencing the boundary between exposed soil areas and adjacent elements susceptible to erosion. Afterwards, an analysis was carried out to measure the spatial evolution of the erosive feature over time, as well as to create the cartographic products.

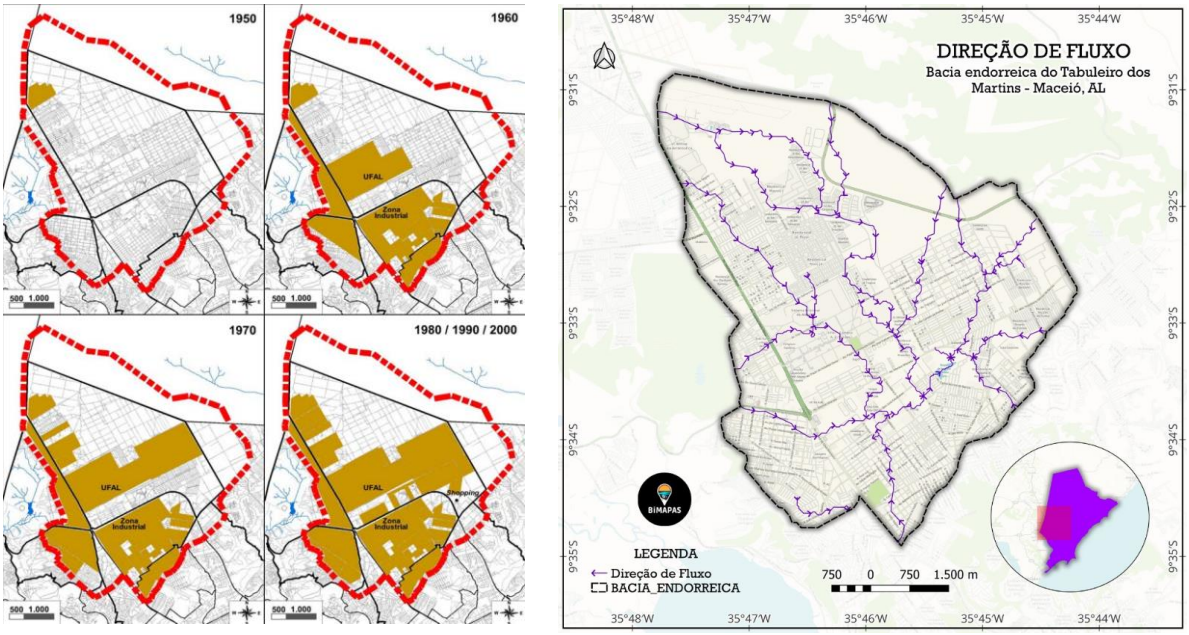
Results and Discussion

The gully area develops between BR-316, which connects Maceió to some of the main municipalities in its metropolitan region, and the limits of the endorheic basin of Tabuleiro dos Martins. Carvalho (2012) focused on studying the urbanization process in this area and highlighted the rapid process of occupation and densification, associated with the progressive

growth of the urban sprawl (Figure 3). The author points out how the increase in impermeable surfaces, caused by the construction of several housing complexes, disrupted the local hydrological cycle, harming water infiltration and increasing flooding.

Figure 3.

Urbanization process of the endorheic basin over the decades (left) and flow direction in the basin area (right).



Source: Carvalho (2012) and Silva (2024).

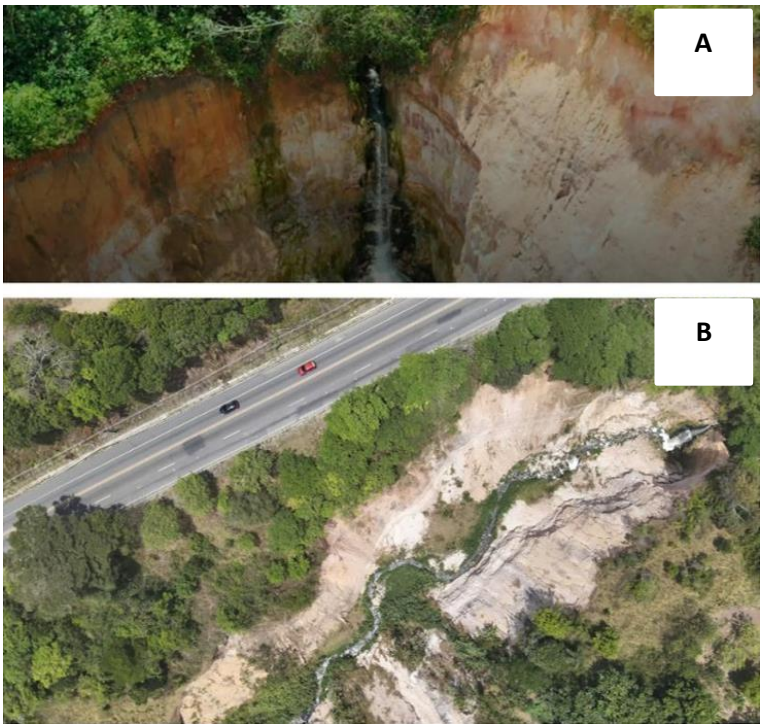
As a result, it can be seen, within its limits, that there is a broad and structured macrodrainage system, whose operation is mainly based on detention ponds and channels intended for stormwater drainage. This system was designed to capture and control the excess water flow generated by heavy rains, preventing surface water from causing floods and damage to urban infrastructure. The detention ponds act as temporary reservoirs, storing the excess water and releasing it in a controlled manner, while the channels and pipes direct the flow to strategic points in the Pratagy, Jacarecica, and Mundaú river basins, integrating the urban system with the natural drainage networks (CARVALHO, 2012).

This context proves to be particularly relevant, since it allows us to infer that the origin of the erosive feature analyzed is, at least in part, associated with the urban drainage channeling project in the neighborhood. As observed, the drainage is directed toward the Braço Frio stream, one of the tributaries of the Mundaú river basin. This concentrated direction of surface runoff may have contributed to an increase in hydraulic energy, favoring soil instability and triggering the erosion process. Added to this factor is the negative human interaction observed in the gully area, since, as noted in on-site activities, there is continuous dumping of water and, additionally, several contributing factors have been identified, such as the irregular

disposal of solid waste, rubble, and domestic sewage, which contribute to environmental degradation, partial obstruction of drainage, and increased slope instability.

Figure 4.

End Point of the Drainage with Water being Dumped (A); Recent Image of the Study Area (B).



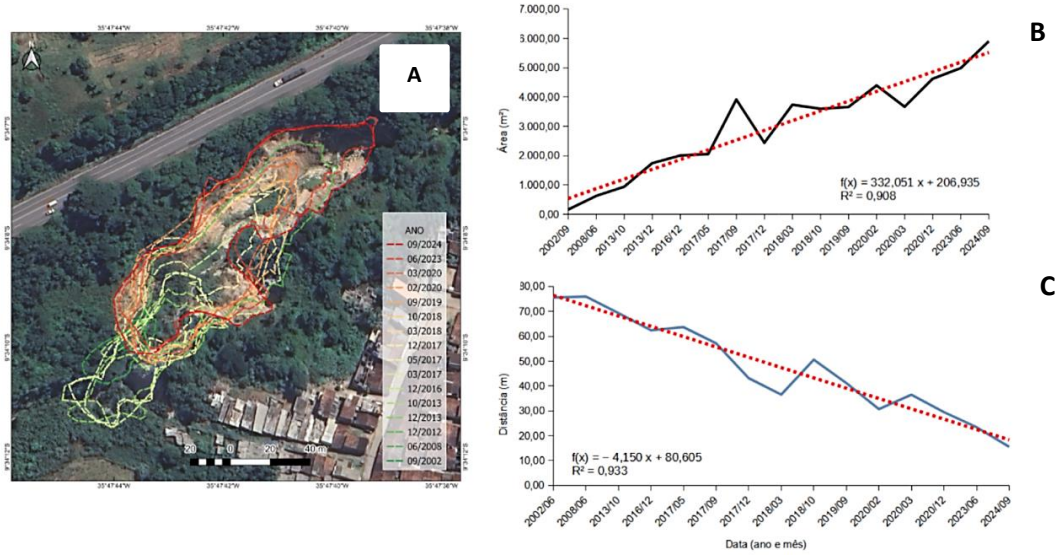
Source: Authors' personal collection (2026).

Through analyses of the collected and georeferenced images, it was possible to understand the dynamics of the ongoing erosion process in the gullied area, allowing the identification of the gradual growth stage of the erosive feature (Figure 5 A). It was observed that initially the erosion developed as a small crater to the south, recorded in 2002, in the portion with the lowest elevation of the channel, and as the cut deepened, there was a progressive advance of the erosive feature upstream, eventually turning into a gully and, in less than 10 years, into a large ravine.

Based on the methodology used, it was found that the eroded area of the channel showed rapid growth over the period analyzed, with this advance seeming to be mainly associated with block-fall erosion processes along the edges of the erosive feature, indicating significant instability of the banks. In the first measurement taken, the studied feature had an approximate area of 161 m², while in 2024 its extent was estimated at around 5,781 m² (Figure 5 B). In this context, the standout year is 2017, when part of the channel collapsed, which resulted in the expansion of the ravine area by more than 1,500 m² of visibly eroded surface.

Figure 5.

Mapping of the gullies' evolution (A); Recorded area (B); Distance from the outermost vertex of the gully to BR-316 (C).



Source: Prepared by the authors (2026).

Another relevant aspect identified was the continuous advancement of erosion upstream of the channel, which is adjacent to BR-316, the highway that connects the city of Maceió to several municipalities in its metropolitan area, such as Satuba, Pilar, Santa Luzia do Norte, and Coqueiro Seco. Figure 5 C illustrates the distance between the outermost vertex of the mapped ravine polygon and the highway centerline. Based on the metrics obtained, an average advancement of approximately 2.5 meters per year of the erosive feature toward BR-316 was observed, showing a growing risk scenario for one of the state's main roads, which carries a high volume of traffic and plays a strategic role in the transportation of people and goods (BARROS, 2024).

This data points to a high-risk disaster scenario if the erosive feature grows to the point of reaching the highway, since the advance of the gully not only poses a threat to the integrity of the road infrastructure and the production and circulation chain that depends on it, but also represents a critical safety risk to the local population. Given the seriousness of the potential socio-environmental impacts associated with this erosive process, it becomes essential to adopt systematic monitoring actions, as well as implement structural and non-structural containment and mitigation measures, aiming to reduce vulnerability and prevent a possible disaster scenario.

Final Considerations

The results show that the eroded area is growing at an accelerated pace. Over a 20-year period, the studied gully grew more than 30 times, being a process that occurs continuously and through abrupt events related to the collapse of specific sections of the channel. In this context, it threatens one of the main highways in the state of Alagoas, BR 316, which connects Maceió with a significant portion of the municipalities in its metropolitan area.

In this sense, the techniques of georeferencing and vectorization of the erosion feature proved to be effective in obtaining consistent information about the growth of the gully located in the Clima Bom neighborhood, in Maceió - AL. It was possible to identify the spatial dynamics of its growth over time, as well as estimate basic rates related to the behavior of the analyzed feature, using a low-cost and easy-to-apply methodology.

Regarding the study's limitations, it's worth noting that they are mainly linked to the elements that make up the database, especially the temporal inconsistency of the available images, variations in the composition of the mosaics created by the tool used, and possible shifts in the images. Because of this, it's recommended that future research use higher spatial resolution images, combined with a larger number of on-site surveys and continuous temporal monitoring, potentially using drones and Unmanned Aerial Vehicles (UAVs), to improve the accuracy and detail of the analyses of erosion processes.

Even so, it is understood that the approach used serves as an important support for future investigations, both for the continuous monitoring of the element analyzed here and for the study of other erosive features with similar characteristics, and it can be replicated as needed by the researcher in different locations.

Ethical statement

This study was conducted in accordance with the ethical principles applicable to scientific research. Participation was voluntary, based on free and informed consent; anonymity and data confidentiality were guaranteed, as was the right to withdraw at any time. All sources used have been duly cited, ensuring academic integrity and adherence to research ethics standards.

Funding agency

The authors didn't disclose any funding sources or acknowledgments.

Conflict of interest statement: The authors state that they have no financial, commercial, personal, or academic interests that could have influenced the results or interpretation of this manuscript.

Declaration of Artificial Intelligence use: Generative Artificial Intelligence tools were used exclusively for language editing tasks, reference standardization, and improving textual clarity. The tools were not used to generate ideas, hypotheses, interpretations, analyses, results, or scientific conclusions. The authors confirm that the manuscript does not contain content fabricated, manipulated, or fully produced by AI, and that all information was manually verified. The authors take full ethical and scientific responsibility for the final content.

REFERENCES

Ab'Sáber, A. N. (2003). Os domínios de natureza do Brasil: potencialidades paisagísticas [The natural domains of Brazil: Landscape potentialities]. Ateliê Editorial.

Barros, J. P. C. C. (2024). Implantação do trecho: ENTR. BR-316/AL-145 [Implementation of the highway section: BR-316 junction/AL-145] [Trabalho de conclusão de curso, Universidade Federal de Alagoas]. Repositório Institucional da UFAL. https://www.repositorio.ufal.br/handle/123456789/14667

Batista, D. C. L., Vieira, A. F. S. G., & Marinho, R. R. (2018). Uso do Google Earth Pro no mapeamento de voçorocas na área urbana de Manaus (AM), Brasil [Use of Google Earth Pro for gully mapping in the urban area of Manaus (AM), Brazil]. Revista Geosaberes, 10(20), 1-12. https://repositorio.ufc.br/handle/riufc/54737

BIMAPS [@bimapas_]. (2024, February 14). Direção de fluxo: bacia endorreica do Tabuleiro dos Martins, Maceió-BR [Flow direction: Endorheic basin of Tabuleiro dos Martins, Maceió, Brazil] [Instagram post]. Instagram. https://www.instagram.com/p/C3SWsfoOEFu/

Camapum, J. C. C., Sales, M. M., Souza, N. M., & Melo, M. T. S. (2006). Processos erosivos no Centro-Oeste Brasileiro [Erosive processes in Central-Western Brazil]. Editora FINATEC.

Capra, A. (2013). Ephemeral gully and gully erosion in cultivated land: A review. In E. C. Lannon (Ed.), Drainage basins and catchment management: Classification, modelling and environmental assessment (pp. 109-141). Nova Science Publishers.

Carvalho, L. M. (2012). Processo de urbanização em área de bacia endorreica: caracterização dos padrões de ocupação dos espaços construídos e dos espaços livres de construção em Maceió-AL [Urbanization process in an endorheic basin area: Characterization of occupation patterns of built spaces and open spaces in Maceió, AL] [Dissertação de mestrado, Universidade Federal de Alagoas]. Repositório Institucional da UFAL. https://www.repositorio.ufal.br/jspui/handle/riufal/735

Dos Santos, F. A. (2024). Geomorphological features of the Jenipapo River Water Basin, located between the states of Ceará and Piauí, Brazil. Margarida Penteado Revista de Geomorfologia, 1(1), 1-16.

Frota, J. C. O., & Silva, M. dos S. (2019). Caracterização das feições geomorfológicas do município de Buriti dos Lopes-PI: subsídio ao ordenamento territorial [Characterization of the geomorphological features of Buriti dos Lopes, PI: Support for territorial planning]. Geosaberes, 10(20), 1-14. https://www.redalyc.org/journal/5528/552857648006/html/

Guerra, A. J. T., & Botelho, R. G. M. (1996). Características e propriedades dos solos relevantes para os estudos pedológicos e análise dos processos erosivos [Soil characteristics and properties relevant to pedological studies and erosion-process analysis]. Anuário do Instituto de Geociências, 19, 93-114. https://revistas.ufrj.br/index.php/aigeo/article/view/6168

Gutierres, H. E. P., Girão, O., Silva, C. S., & Guerra, A. J. T. (2023). Monitoramento de voçorocas na barragem Serro Azul, Mata Sul do estado de Pernambuco [Gully monitoring in the Serro Azul Dam, southern forest zone of Pernambuco State]. Revista Brasileira de Geomorfologia, 24(2). https://rbgeomorfologia.org.br/rbg/article/view/2158

Hauschild, M. C. (2024). Recuperação de Área de Preservação Permanente afetada por voçorocas na Fazenda Cedro do Líbano em São Carlos (SP) [Recovery of a Permanent Preservation Area affected by gullies at Cedro do Líbano Farm in São Carlos, SP] [Trabalho de conclusão de curso, Universidade Estadual Paulista Júlio de Mesquita Filho]. Repositório Institucional UNESP. https://repositorio.unesp.br/entities/publication/2b2039bd-098b-4db3-b445-36672363a264

Imeson, A. C., & Kwaad, F. J. P. M. (1980). Gully types and gully prediction. Geografisch Tijdschrift, 14(5), 430-441.

Jorge, M. C. O., & Guerra, A. J. T. (2013). Erosão dos solos e movimentos de massa: recuperação de áreas degradadas com técnicas de bioengenharia e prevenção de acidentes [Soil erosion and mass movements: Recovery of degraded areas using bioengineering techniques and accident prevention]. In M. C. O. Jorge & A. J. T. Guerra (Orgs.), Processos erosivos e recuperação de áreas degradadas [Erosive processes and recovery of degraded areas] (pp. 7-30). Oficina de Textos.

Marcuzzo, F. F. N., Romero, V., & Cardoso, M. R. D. (2011). Detalhamento hidromorfológico da bacia do rio Mundaú [Hydromorphological characterization of the Mundaú River basin]. Repositório Institucional de Geociências (RIGEO). https://rigeo.sgb.gov.br/items/1dbef6f7-a1b2-4359-83a2-f290d0e074cb

Monte, M. J. M. (2022). Avanço da urbanização e impacto nos fluxos de água e energia à superfície na cidade de Manaus: estudo de modelagem [Urban expansion and its impacts on surface water and energy fluxes in the city of Manaus: A modelling study] [Dissertação de mestrado, Instituto Nacional de Pesquisas da Amazônia]. Repositório Institucional do INPA.

Niédja, M. G. A., Carvalho, J. A. R., & Junior, E. F. S. (2005). Riscos geológicos nas colinas do muniicípio de Camaragibe-PE [Geological hazards on the hills of Camaragibe, Pernambuco]. Mercator, 4(8). https://periodicos.ufc.br/mercator/article/view/99843

Oliveira, B. E. N. (2011). Mapeamento, identificação e análise dos fatores relacionados aos processos erosivos no Distrito Federal (DF): ênfase nas voçorocas [Mapping, identification and analysis of factors related to erosive processes in the Federal District: Emphasis on gullies] [Dissertação de mestrado, Universidade de Brasília]. Repositório Institucional da UnB.

Oliveira, H. B. (2023). Análise de susceptibilidade a movimento de massas em talude na Avenida Pierre Chalita, Maceió/AL [Landslide susceptibility analysis on a slope along Pierre Chalita Avenue, Maceió, AL] [Trabalho de conclusão de curso, Universidade Federal de Alagoas]. Repositório Institucional da UFAL. https://www.repositorio.ufal.br/handle/123456789/12690

Panta, G., Nascimento, J. P. da H., Corrêa, A. C. de B., & Monteiro, K. A. (2023). Processos erosivos no córrego Braço Frio: aspectos da erosão em ambientes urbanos na costa oriental do Nordeste do Brasil [Erosive processes in the Braço Frio stream: Aspects of erosion in urban environments on the eastern coast of Northeastern Brazil]. GeoPUC, 15(29). https://geopuc.emnuvens.com.br/revista/article/view/16

Ribeiro, J. C., Tocantins, N., & De T. S., F. X. (2023). Abordagem morfopedológica aplicada à prevenção de voçorocas: estudo de caso na bacia do Rio Itiquira-Alto Pantanal-Mato Grosso [Morphopedological approach applied to gully prevention: A case study in the Itiquira River basin, Upper Pantanal, Mato Grosso]. Revista Brasileira de Geomorfologia, 24. https://rbgeomorfologia.org.br/rbg/article/view/2349/386386840

Santos, A. A. dos. (2024). Potencial de escoamento superficial em três unidades de gerenciamento de recursos hídricos do Oeste Paulista e sua relação com as mudanças no uso e cobertura da terra [Surface runoff potential in three water-resource management units in western São Paulo State and its relationship with land-use and land-cover changes] [Tese de doutorado, Universidade Estadual Paulista]. Repositório Institucional UNESP. https://repositorio.unesp.br/entities/publication/12ddeb34-27b7-4801-a362-74f649597b75

Santos, R. I. C., & Guerra, A. J. T. (2021). Avaliação da erosão dos solos na bacia hidrográfica do rio Pequeno, Paraty-RJ [Assessment of soil erosion in the Pequeno River watershed, Paraty, Rio de Janeiro]. Geosaberes: Revista de Estudos Geoeducacionais, 12(1), 23-43. https://periodicos.ufc.br/geosaberes/article/view/98243

Silva, B. A., De L. G., A. J., & Dos Santos Gomes, J. L. (2022). Erosão hídrica e antropogênica na formação de voçorocas na cidade de Teófilo Otoni [Water-induced and anthropogenic erosion in the formation of gullies in the city of Teófilo Otoni]. Research, Society and Development, 11(9).

Silva, J. E. C. F. da, Pons, N. A. D., Azevedo, S. C., & Lacerda, C. S. A. (2022). Delimitação de voçorocas por meio de GEOBIA (Geographic Object Based Image Analysis) e mineração de dados, utilizando produtos cartográficos de aeronaves remotamente pilotadas (ARP) [Gully delineation using GEOBIA (Geographic Object Based Image Analysis) and data mining based on cartographic products obtained from remotely piloted aircraft]. Boletim Paranaense de Geociências, 80(2). https://doi.org/10.5380/geo.v80i2.87075

Soil Science Society of America. (2008). Glossary of Soil Science Terms. https://www.soils.org/publications/soils-glossary#

Vieira, A. F. S. G., & Frota Filho, A. B. da. (2023). Avaliação das técnicas de monitoramento de voçorocas: o exemplo da Região Metropolitana de Manaus-AM, na região amazônica [Evaluation of gully monitoring techniques: The example of the Metropolitan Region of Manaus, Amazonas, in the Amazon region]. Revista Brasileira de Geomorfologia, 24. https://rbgeomorfologia.org.br/rbg/article/view/2302

Vieira, C. L., & Verdum, R. (2015). Arenização e erosão hídrica no Sudoeste do Rio Grande do Sul: análise dos agentes condicionantes e considerações básicas para intervenções mecânico-vegetativas [Sandization and water erosion in southwestern Rio Grande do Sul: Analysis of conditioning factors and basic considerations for mechanical and vegetative interventions]. Revista de Geografia, 32(1), 41-65.

Data availability

The data underlying the research are reported in the article.

Responsible editors

Cirlene Jeane Santos e Santos.

Dr. José Crisólogo de Sales Silva.