https://rbgeomorfologia.org.br/
*ISSN 2236-5664*

**Revista Brasileira de Geomorfologia**

v. 25, nº 4 (2024)

http://dx.doi.org/10.20502/rbgeomorfologia.v25i4.2596

*Artigo de Revisão*

# Linear Water Erosion Incisions in the Central-West Region of Brazil: A Bibliometric Analysis

## *Incisões erosivas hídricas lineares no Centro-Oeste do Brasil: uma análise bibliométrica*

**Kássio Samay Ribeiro Tavares [1], Selma Simões de Castro[2]**

[1] Universidade Estadual de Campinas, Instituto de Geociências, Campinas, Brazil. kassiosamayribeiro@gmail.com
ORCID: https://orcid.org/0000-0003-3248-5236

[2] Universidade Estadual de Campinas, Instituto de Geociências, Campinas, Brazil. scastro@unicamp.br
ORCID: https://orcid.org/0000-0002-5401-5852

Received: 02/07/2024; Accepted: 19/10/2024; Published: 02/12/2024

**Abstract:** This study presents the results of a comprehensive bibliometric analysis of research on linear water erosion incisions in the Central-West region of Brazil. A total of 91 documents, including scientific articles, dissertations and academic theses, were analyzed to map the research trends and patterns in this field. The results indicate a predominance of geospatial and geodynamic studies. A multidisciplinary methodological approach is evident in 71% of the studies that combine multiple procedures to obtain more robust results. Most studies are multifactorial, using indicators of vegetation, land use and management, and geomorphology, reflecting the complexity of the processes involved. The main research focuses include modeling, mapping, and prediction indices. The results show that multiscale approaches are essential for integrating local and regional knowledge, offering a comprehensive understanding of the challenges and solutions for the erosive phenomenon. In addition, the geographical distribution of the studies reveals a greater concentration in the states of Goiás and Mato Grosso, associated with the intense agricultural and livestock activity in these areas. It is concluded that interdisciplinary approaches and the use of advanced technologies to address the challenges of linear water erosion should be intensified to promote sustainable land use and management practices.

**Keywords:** Linear water erosion; Cerrado; Geotechnologies; Sustainability; Land use and management.

**Resumo**: Este estudo apresenta o resultado de uma análise bibliométrica abrangente das pesquisas sobre incisões erosivas hídricas lineares na região Centro-Oeste do Brasil. Foram analisados 91 documentos, incluindo artigos científicos dissertações e teses acadêmicas, para mapear as tendências e padrões das pesquisas na área. Os resultados indicam uma predominância de estudos geoespaciais e geodinâmicos. A abordagem metodológica multidisciplinar é evidente em 71% dos estudos que combinam múltiplos procedimentos para obter resultados mais robustos. A maioria dos estudos é multifatorial, utilizando indicadores de vegetação, uso e manejo do solo e geomorfologia, refletindo a complexidade dos processos envolvidos. Os principais focos de pesquisa incluem modelagem, mapeamento e índices de predição. Os resultados mostram que as abordagens multiescalares se destacam como essenciais para integrar conhecimentos locais e regionais, oferecendo uma compreensão completa dos desafios e soluções para o fenômeno erosivo. E ainda que a distribuição geográfica dos estudos revela maior concentração nos estados de Goiás e Mato Grosso, associada à intensa atividade agrícola e pecuária nessas áreas. Conclui-se que estudos com abordagens interdisciplinares e o uso de tecnologias avançadas para enfrentar os desafios da erosão hídrica linear devem ser intensificados, de modo a promover práticas sustentáveis de uso e manejo do solo.

**Palavras-chave:** Erosão hídrica linear; Cerrado; Geotecnologias; Sustentabilidade; Uso e manejo do solo.

## 1. Introduction

In the last two decades, there has been increasing interest in bibliometric studies in different areas of knowledge. Such studies map scientific progress, evaluate the impact of and trends in scientific knowledge, and direct future investigations, promoting more efficient management of the resources available for research and development (TURMUZI et al., 2023; TAVARES & CASTRO, 2023).

According to Zhuang et al. (2015), bibliometrics on major categories of soil erosion increased greatly in North America and Spain, in addition to China and Australia. However, there is little bibliometric research on water erosion, particularly linear erosion (grooves, ravines, and gullies), which is a phenomenon that can compromise food security and is generally derived from poor land use and management, especially in relation to agricultural activities (SELLAMI & TERRIBILE, 2023). Both Batista et al. (2019) and Tavares and Castro (2021) discuss the low number of publications on linear erosion and emphasize its importance in the scientific and technical arena in terms of land use and occupation and its consequences, and for enabling the spatialization of the most impacted areas based on the publications.

Certain publications in Brazil can be highlighted, such as that of Barreto, Barros and Sparoveck (2008), which undertook two bibliometrics, one on the history and the other on the geography of Brazilian research on accelerated soil erosion, verifying a preference for studies on laminar water erosion. Likewise, Tavares and Castro (2021), who carried out a survey on the modelling of hydraulic soil erosion, found the main focus of the studies to be laminar water erosion and they emphasized the scarcity of studies on linear water erosion.

Historically, linear erosion has been identified as a relevant process to soil degradation, being frequently associated with unsustainable land management practices (GUERRA & LOUREIRO, 2023; POESEN, 2011). This phenomenon corresponds to erosive incisions in soils classified as grooves, ravines, and gullies, which motivated the elaboration of various proposals for their differentiation (CASTILLO & GÓMEZ, 2016).

In a recent bibliometric study, Tavares and Castro (2023) found a concentration of studies in areas subject to intensive agricultural activities, which accentuate the susceptibility to and risk of erosion, revealing a trend in the investigation of mitigation strategies and sustainable soil management practices. The authors also emphasized the importance of interdisciplinary approaches to the phenomenon, as they integrate geological, geomorphological, pedological, hydrological, and agronomic knowledge, and they observed significant evolution in the knowledge on linear erosion in the Cerrado biome.

The Central-West region, which is almost entirely covered by the Cerrado biome, includes Goiás, Mato Grosso, Mato Grosso do Sul, and the Distrito Federal (Federal District). According to Tavares and Castro (2023), these states present the phenomenon of linear erosion, the distribution and conditioning of which are not sufficiently known in geospatial and geodynamic terms. The Cerrado is crucial for intensive farming production, driven by deforestation since the 1970s and specialized in crop and livestock commodities. Nunes and Castro (2023) and Rodrigues and Castro (2023) indicate that this dynamic may increase susceptibility to linear water erosion in little known areas.

This study uses bibliometrics to survey and critically analyze the academic production on linear erosion in the Central-West region of Brazil. The aim is to quantify and qualify Brazilian academic production, clarifying the trends in and the direction of research on linear erosion in the Central-West region, with the aim of providing support to the advancement of scientific knowledge, guiding future research and promoting more efficient and sustainable land management in the region.

## 2. Methodology

The study methodology was structured into three main phases: pre-processing, processing, and final data analysis (Figure 1). Books and congress annals were not considered, as the focus of this study was the analysis of scientific production of greater impact, such as articles in peer-reviewed periodicals, theses, and dissertations, which have greater methodological rigor and consolidated research results. Although books and congress annals also contain valuable information, the inclusion of these documents could lead to data heterogeneity that could compromise the consistency of the bibliometric analysis, considering that these types of publication do not always pass through peer review processes with the same level of rigor and frequency as articles and dissertations. On the other hand, books and congress annals merit a separate study, since they may address the theme more broadly, which would not meet the criteria of rigor and delimitation adopted in this study. In contrast, theses and

dissertations were included as they represent a significant body of detailed academic research, which are often published before being adapted for articles in periodicals. Therefore, their inclusion is relevant for mapping the current state of academic research and its trends.

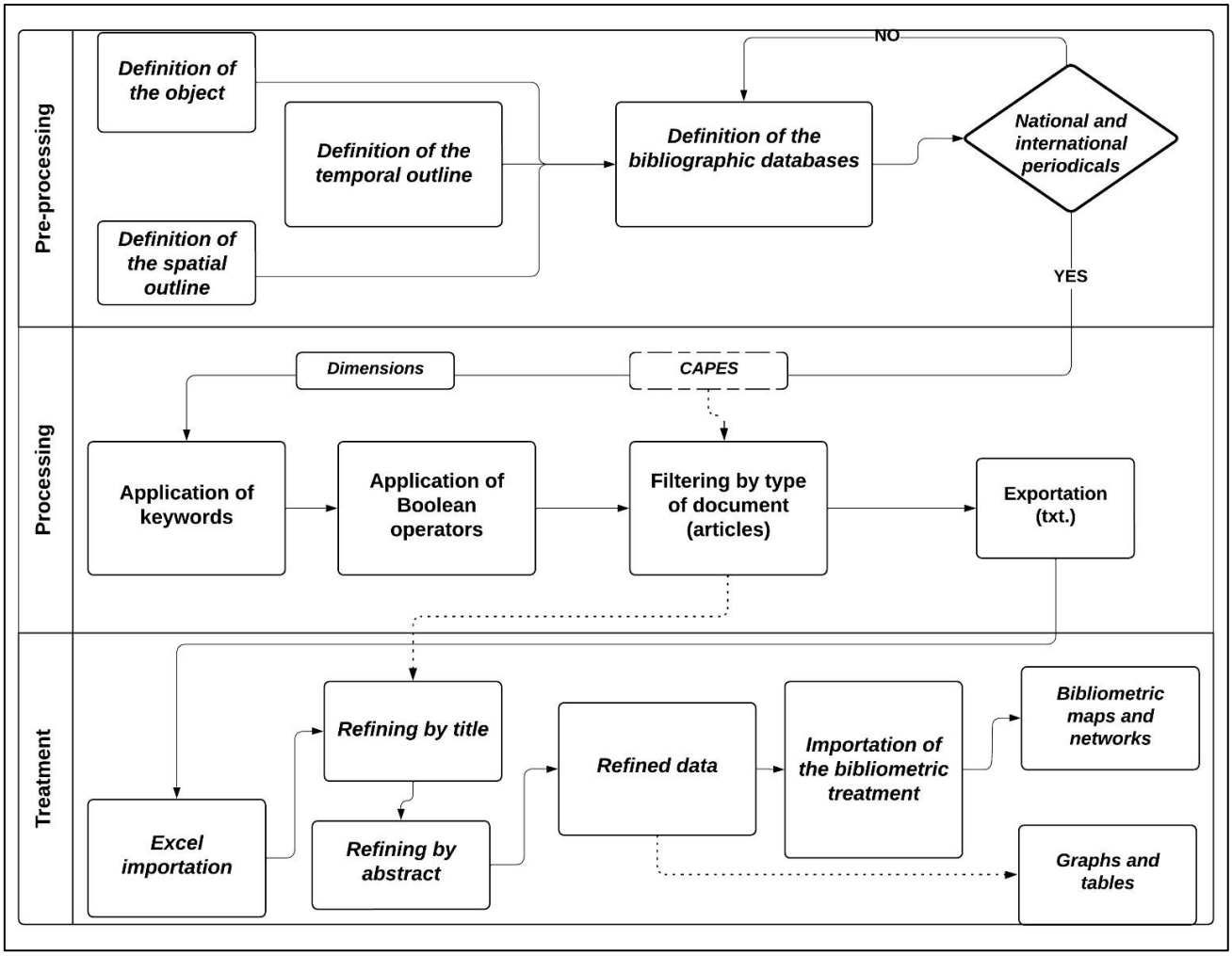


**Figure 1.** Illustrative flowchart of the methodological procedures of the study.

The first phase of pre-processing began with the definition of the bibliographic databases of scientific articles and academic studies, including theses and dissertations. The search for bibliographic databases focused on national and international periodicals with a spatial outline in the Central-West region. The (free access) Dimensions database, created in 2018 by Digital Science and containing 11 million publications, was used to collect scientific articles.

The choice of the Dimensions platform was made because it has broad coverage of national periodicals, which is appropriate for the aim of this study in the scope of Brazilian scientific production. It had a strong connection with data from Brazilian institutions, including funding agencies such as the Conselho Nacional de Desenvolvimento Científico e Tecnológico (National Council for Scientific and Technological Development) (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Coordination for the Improvement of Higher Education Personnel) (CAPES), Fundação de Amparo à Pesquisa do Estado de São Paulo (Research Support Foundation of the State of São Paulo) (FAPESP), and Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (Carlos Chagas Filho Foundation for Research Support of the State of Rio de Janeiro) (FAPERJ) (SILVA, SENA & ARAÚJO, 2023), which guarantees the inclusion of a robust database of national publications. Although other databases such as Web of Science, Scopus, and Google Scholar are also widely used in bibliometric studies, Dimensions was chosen for its focus on national publications, in line with the proposal to identify the research trends on linear erosion in Brazil.

For the theses and dissertations dataset, those available on CAPES were prioritized, as it is a platform that has thousands of theses and dissertations defended in Brazil in its collection, covering the most diverse areas of knowledge and research. Moreover, this database is free access and allows detailed searches with filters by author, title, institution, and year defended, facilitating the identification of significant research throughout national territory (FARIA, PESSOA & SILVA, 2020).

In the second phase, that of data processing, a set of keywords and Boolean operators were used to work together to direct and refine the scientific data research ensuring precise alignment with the study aims (TAVARES & CASTRO, 2021, 2023). The set of keywords used on the Dimensions platform included terms that refer to the essence of the object of study and the geographical context of the research, in addition to terms representative of the states of the Brazilian Central-West, specifically: "*soil erosion AND gully AND cerrado AND Brazil AND go AND df AND mt AND ms*", which resulted in 48 relevant scientific documents, from the period from 1962 to 2023. The search was conducted considering the entire content of the documents, including title, abstract, keywords, and the complete body of the text, when available. The resulting dataset was then exported in the *CSV* format for analysis and more detailed treatment.

The search on the CAPES database began with data acquisition in the table model for data referring to theses and dissertations published between 1987 and 2022, treated using Excel software. This document contains complete information with titles, abstracts, authors, date of defense, state of publication, and tutor(s), among other information items. Subsequently, the file was subjected to filtering by locating words in the titles and abstracts of each file, which were defined as "erosão linear" (linear erosion), "voçoroca" (gully), "ravinas" (ravines), "sulcos" (grooves) and "cerrado", that is, all the publications that contained the defined keywords in their titles or abstracts were selected. The focus on the word "Cerrado" is justified by the fact that the Cerrado biome covers most of the Central-West region, being the predominant environment where the studied erosive processes occur. Furthermore, a refinement in the place of publication was also carried out, whereby only documents linked to graduate programs in the states of Goiás, Distrito Federal, Mato Grosso, and Mato Grosso do Sul were selected. After refinement, 8 theses and 35 dissertations were selected.

Regarding the choice to filter only for documents linked to graduate programs in the states of Goiás, Distrito Federal, Mato Grosso, and Mato Grosso do Sul, this decision was taken to ensure that the studies had been conducted within the specific area of geographic interest of this study. Although research carried out in other graduate programs may address linear erosive processes, the focus was on publications directly associated with institutions located in the Central-West region, as they tend to have greater proximity and more detailed knowledge of local conditions, such as land use, agricultural practices, and environmental characteristics.

The bibliometric approach was carried out on the Biblioshiny platform, which is an interactive tool that serves as a graphic interface for the bibliometrix package on R (free software). This package is widely recognized for its capacity to conduct deep bibliometric and scientometric analyses, allowing researchers to efficiently extract, process, and analyze the bibliographic data (MOREIRA, GUIMARÃES & TSUNODA, 2020). The dataset of each group (articles and theses/dissertations) was individually evaluated using statistical analysis tools on R 4.1.3 and Studio 4.1.3 software and on Excel (Microsoft Office 365).

## 3. Results and Discussion

### *3.1. Dimensions dtabase*

In the analysis period, it was found that the first publication dates from 1962, with the article by William (1962), entitled "South Brazil: Its vegetation, natural resources, research centers, and other economic aspects", which broadly addresses the vegetation and natural resources, including mentions of the linear erosive process at certain locations. This study establishes a starting point for the theme of this study, despite not concentrating specifically on linear erosion.

The mean number of citations per identified document was approximately 7.38, for a total of 128 distinct authors contributing to the body of research. A division between individual (19) and group (28) authored studies was observed, indicating a preference for collaboration among researchers in this field.

Analysis of the temporal distribution of the publications showed a significant increase in the last two decades, with 20 publications recorded in both the 2010s and the 2020s, demonstrating a growing interest in the theme since

2004. Specifically, the years 2005, 2011, 2014, 2017, 2020, 2021, 2022, and 2023 stand out for the volume of published studies (Figure 2).

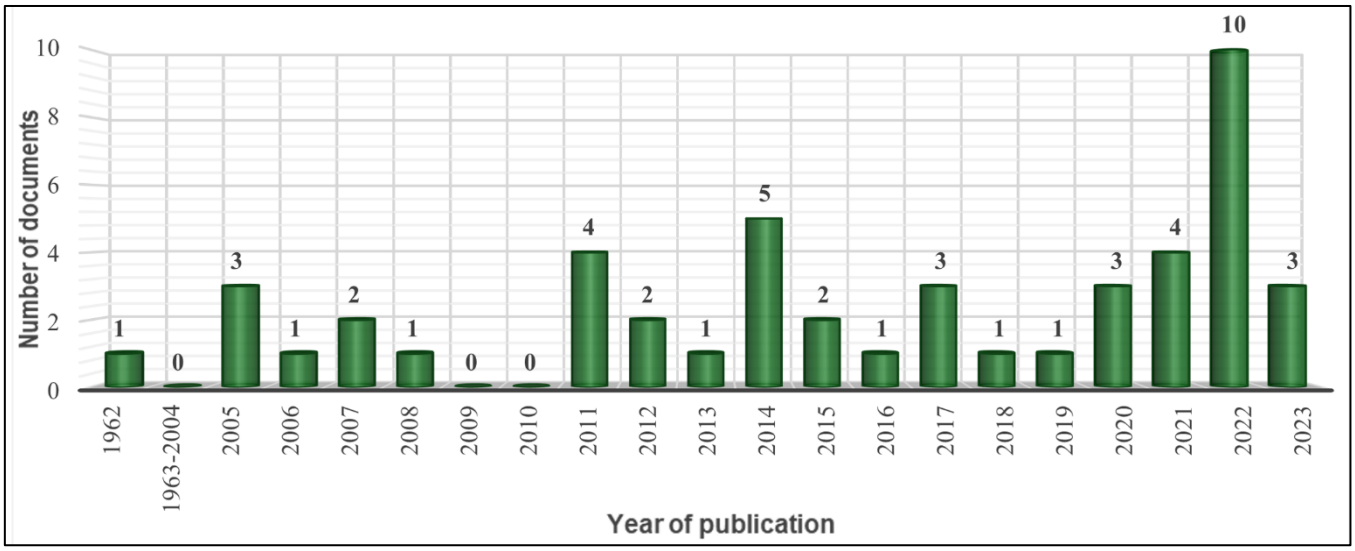


**Figure 2.** Annual scientific production.

Analysis of the dataset indicates that the period with the most activity was between 2004 and 2023, suggesting the direct influence of growing contemporary environmental concerns, which are often induced by the increasing number of exceptional rain events and the consequences of soil degradation (Nunes & Castro, 2023). Moreover, the focus on critical themes such as soil conservation, scarcity of water resources/water crisis, and food security reflects an urgent academic and scientific response to the demands for studies on sustainable land use and management. This trend in the scientific literature may also be associated with the recognition of the Cerrado not only as the second largest biome in Brazil, but also as a vital area for the agricultural production of commodities and, above all, for being one of the world's main biodiversity hotspots, as it is home to a rich variety of endemic species and unique ecosystems that are under constant threat of habitat loss and even species extinction (HOGAN et al., 2002; KAJEYIAMA, 2008; SILVA & MIZIARA, 2011; MITTERMEIER et al., 2011; MELLO, MACHADO & NOGUEIRA, 2015).

In the bibliometric analysis concentrated on periodicals, whose articles are indexed, a total of 27 distinct periodicals were found, among which, only one has published more than 5 articles on its platform, demonstrating a diversity of publication vehicles used by researchers in the dissemination of their work. Thus, the periodicals with the largest number of publications in the dataset are *Geoderma*, with 11 articles, *Catena*, with 5 articles, and *Sociedade & Natureza* (Society & Nature) and *Revista Brasileira de Geografia Física* (Brazilian Journal of Physical Geography) with 4 articles each (Table 1).

**Table 1.** Main periodicals that have published articles on linear erosion in the Central-West.

| Periodical | No. publications |
|---|---|
| Geoderma | 11 |
| Catena | 5 |
| Revista Brasileira de Geografia Física | 4 |
| Sociedade & Natureza | 4 |
| Revista Brasileira de Geomorfologia | 2 |
| Ambiente & Sociedade | 1 |
| Aquatic Conservation Marine and Freshwater Ecosystems | 1 |
| Ciência e Agrotecnologia | 1 |

The fact that *Geoderma* and *Catena* are at the top of the list corroborates previous bibliometric studies (TAVARES & CASTRO, 2021; 2023) that had already indicated these journals as important for the publication of research related to specific themes of the physical-natural environment, including linear water erosion. Maintaining this position throughout the analysis period suggests that the relevance of these journals is not only as a means of scientific divulgation, but also as a consecrated preference of researchers in environmental and geoscience studies in Brazil.

Furthermore, *Geoderma* and *Catena* stand out for their comprehensive scope, which includes themes mainly related to soil science, erosion, geomorphology, and sustainable land management. *Geoderma*, for example, is an internationally recognized periodical for publishing studies on soils and degradation processes, with a focus on management and recuperation techniques. *Catena*, in turn, is widely cited in studies on geomorphology and erosive processes, addressing both soil degradation and environmental recovery, which makes these journals a natural choice for researchers working in the field of geosciences.

Other periodicals such as the *Revista Brasileira de Geografia Física* (Brazilian Journal of Physical Geography) and *Sociedade & Natureza* (Society and Nature) have a broader scope that covers both physical geography studies and analyses of environmental impacts and the management of natural resources. This may explain their relevance in the dissemination of studies related to linear erosion and land management in the Brazilian context.

Well-known periodicals such as *Earth Surface Processes and Landforms*, *Land Degradation*, and *Geomorphology* are also extremely pertinent to the theme. However, their absence from the results may be related to the limitations of the Dimensions platform used for the bibliometric search, which does not necessarily index all the international periodicals.

The most relevant authors in terms of academic production, considering authorship and co-authorship, are Selma Simões de Castro, Derick Martins Borges de Moura, and Wellmo dos Santos Alves, with the first author standing out with four publications (Figure 3). These researchers have made significant contributions to the scientific literature, focusing on relevant themes for the understanding and management of ecosystems such as erosive processes and the sustainable management of natural resources.

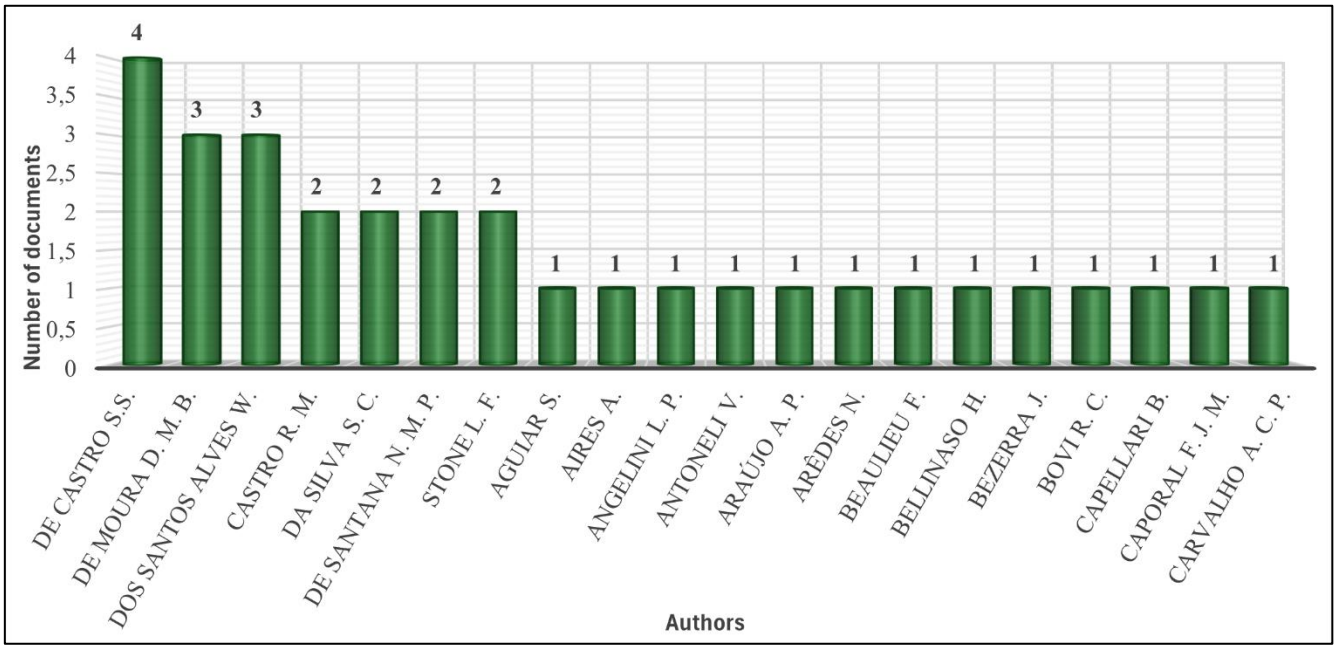


**Figure 3.** Most relevant authors – Number of publications.

Other authors with notable contributions include Silvando Carlos da Silva and Luís Fernando Stone, each with two publications. These researchers also participate in significant collaborations, reinforcing the importance of scientific partnerships in the production of qualified knowledge on critical environmental themes such as soil management and conservation, the mitigation of linear water erosion, and the impacts of intensive agriculture in the Cerrado biome. These themes involve the analysis of agriculture and livestock practices, the degradation of water resources, and biodiversity loss, which are directly related to the sustainability of ecosystems and food security in the Central-West region of Brazil.

The bibliometric analysis of the affiliations of the authors in the selected articles reveals a significantly varied scenario of scientific collaboration and production, demonstrated by the participation of a broad range of academic and research institutions. The Universidade Federal de Goiás (Federal University of Goiás) (UFG) and the Universidade de São Paulo (University of São Paulo) (USP) stand out as the most cited institutions, each with six mentions, reinforcing their role of leadership in the conducting of research relevant to the addressed theme (Figure 4). Institutions such as the Universidade Federal de Santa Maria (Federal University of Santa Maria) (UFSM), Universidade Federal de Mato Grosso (Federal University of Mato Grosso) (UFMT), and the Instituto Federal Goiano (Federal Institute of Goiás) (IFG) follow with three mentions each, along with the Universidade Federal do Mato Grosso do Sul (Federal University of Mato Grosso do Sul) with two mentions, and the Instituto Nacional de Pesquisas Espaciais (National Institute for Spatial Research) (INPE) and the Empresa Brasileira de Pesquisa Agropecuária (Brazilian Corporation of Agricultural Research) (EMBRAPA), both with one mention.

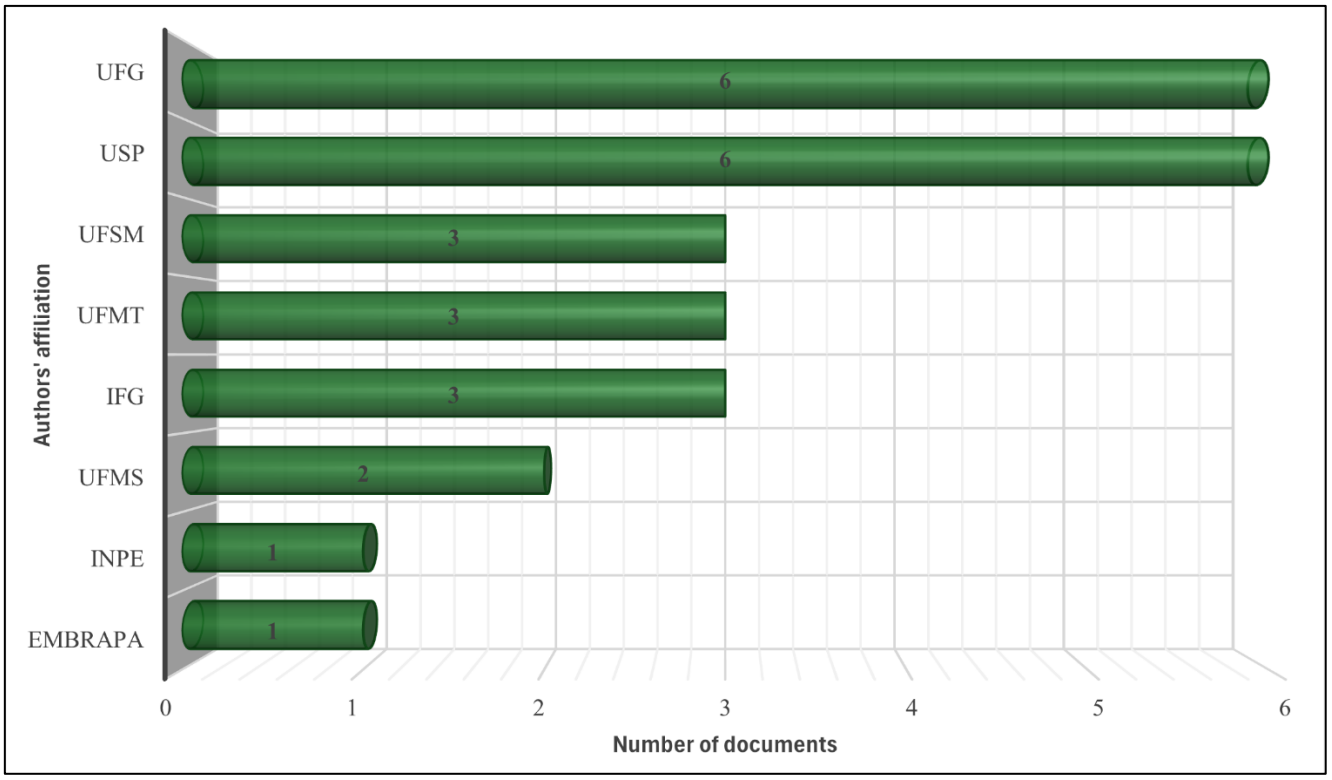


**Figure 4.** Author affiliations.

It should be noted that, with the exception of UFSM, the institutions are located in environments of the Cerrado and constitute a diverse group of affiliations. The predominance of Brazilian federal universities among the most mentioned affiliations highlights the importance of investment and support for national academic research, in addition to the significant role these institutions play in the production of scientific knowledge relevant to society.

Regarding the keywords used in the analyzed studies, these were grouped into clusters indicating focus areas and recurrent themes in the publications (Figure 5). The blue cluster highlights terms related to environmental and geological processes and characteristics, with “Erosion” and “Soil” as central concepts, suggesting a strong focus on studies on erosion and its implications for soil. Words such as “Cerrado”, “Study”, “Natural”, “Land”, “Management”, and “Conservation” indicate an integrated approach that encompasses case studies, land management, and conservation efforts.

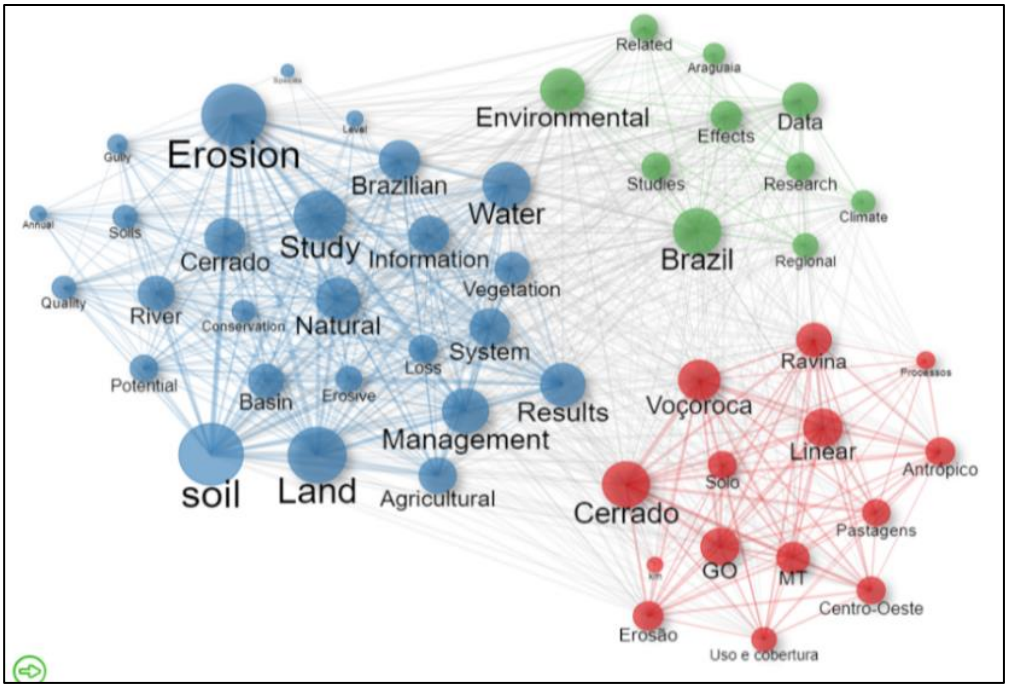


**Figure 5.** Occurrence of keywords.

The green cluster emphasizes the geographical and climatic dimension of the studies, with "Brazil" and "Water" standing out, reflecting research that is concentrated on Brazil's water resources and associated environmental issues. Terms such as "Environmental", "Studies", "Data", "Effects", and "Research" indicate a broader analysis of environmental impacts and the importance of data collection and analysis in regional climate research.

In the red cluster, "Cerrado" appears again, reaffirming the relevance of this biome in the studies, together with words such as "Linear", "Ravina" (Ravine), and "Voçoroca" (Gully), which refer to specific types of linear water erosion. "Solo" (Soil) and terms related to geographical locations, such as "GO" (Goiás), "MT" (Mato Grosso) and "Central-West" (Central-West) suggest a specific focus on erosive processes and land use in the central areas of Brazil, where such phenomena are noteworthy.

The keywords analysis, visualized through the bibliometric map, reveals a panorama of multidisciplinary research covering everything from soil erosion and the management of natural resources to environmental and climate studies. The marked presence of specific erosion terms, such as "Ravina" (Ravine) and "Voçoroca" (Gully), together with the mention of specific locations, indicates that the research is highly contextualized from the geographical point of view, while the connections between the keywords in different clusters demonstrate the interdisciplinarity of the studies.

### *3.2. Capes database*

A total of 43 studies were identified (1994 – 2022), distributed among prominent institutions in the states of the Brazilian Central-West. Quantitative analysis of these publications over time shows a pattern of fluctuating interest in the study of linear erosion, indicating variations in the priority given to this theme despite it being crucial to environmental conservation in Brazil.

The academic studies are distributed over various years, and most are dissertations, with a total of 35, while 8 are theses, indicating a greater focus on the theme in master's level research. This difference may be related to the nature of master's dissertations, which tend to have a shorter period for their development and a more focused and specific approach. In contrast, doctorate theses demand greater depth and a more comprehensive scope, which may limit the academic production on this theme at doctorate level.

Furthermore, the difference in the quantity of dissertations in comparison to theses may reflect the structure of the graduate programs of the region's institutions, which may offer more places and resources to master's programs than to doctorate programs. It is also possible that the study of linear water erosion is considered an adequate theme for more specific approaches, characteristic of master's dissertations, whereas doctorate studies

tend to demand a broader but more complex and deeper approach to the phenomenon. The theses are distributed over the years 2003 (1), 2010 (2), 2011 (1), 2013 (1), 2015 (1), 2020 (1), and 2021 (1). The years 2001 and 2022 have the highest number of studies with 5 publications each (Figure 6).

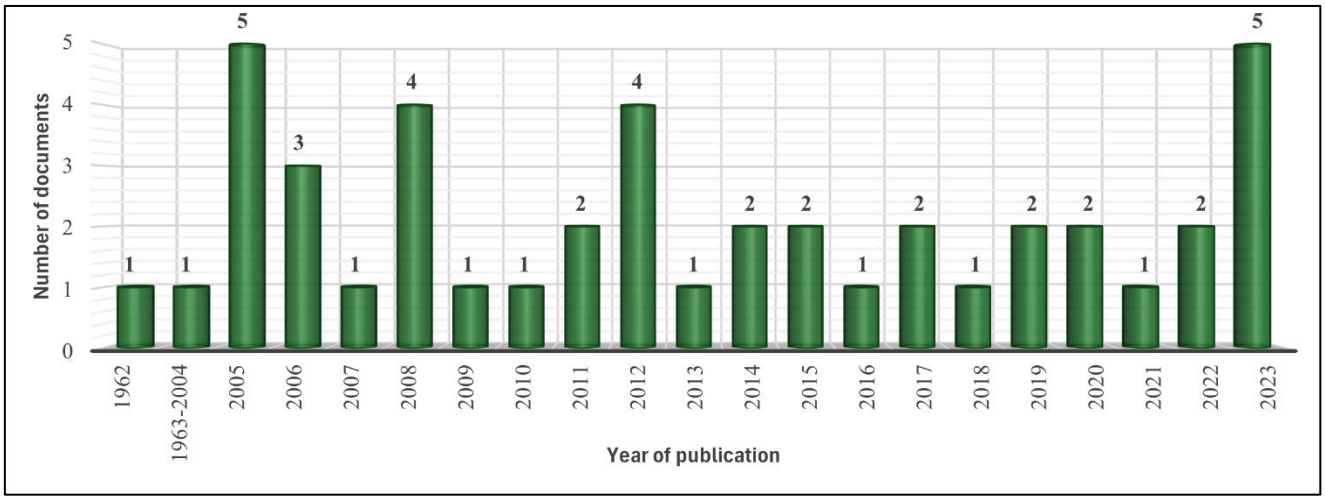


**Figure 6**. Temporal distribution of the publications by year.

Most of the studies are concentrated in Goiás (GO), with 21 studies distributed between the Universidade Federal de Goiás (federal University of Goiás) (UFG), Universidade Estadual de Goiás (State University of Goiàs) (UEG), and the Universidade Federal de Jataí (Federal University of Jataí) (UFJ). This is followed by Mato Grosso (MT) with 14 studies from the Universidade Federal do Mato Grosso (Federal University of Mato Grosso) (UFMT) and the Universidade do Estado do Mato Grosso (State University of Mato Grosso) (UNEMAT), the Distrito Federal (Federal District) (DF) with 4 studies from a single institution, the Universidade de Brasília (University of Brasília) (UNB), and Mato Grosso do Sul (MS), with 4 studies from two universities, the Universidade Estadual do Mato Grosso do Sul (State University of Mato Grosso do Sul) (UEMS) and the Universidade Federal da Grande Dourados (federal University of Grande Dourados) (UFGD) (Figure 7). Analysis of the geographical distribution of the publications demonstrates how the different study areas contribute to the data set.

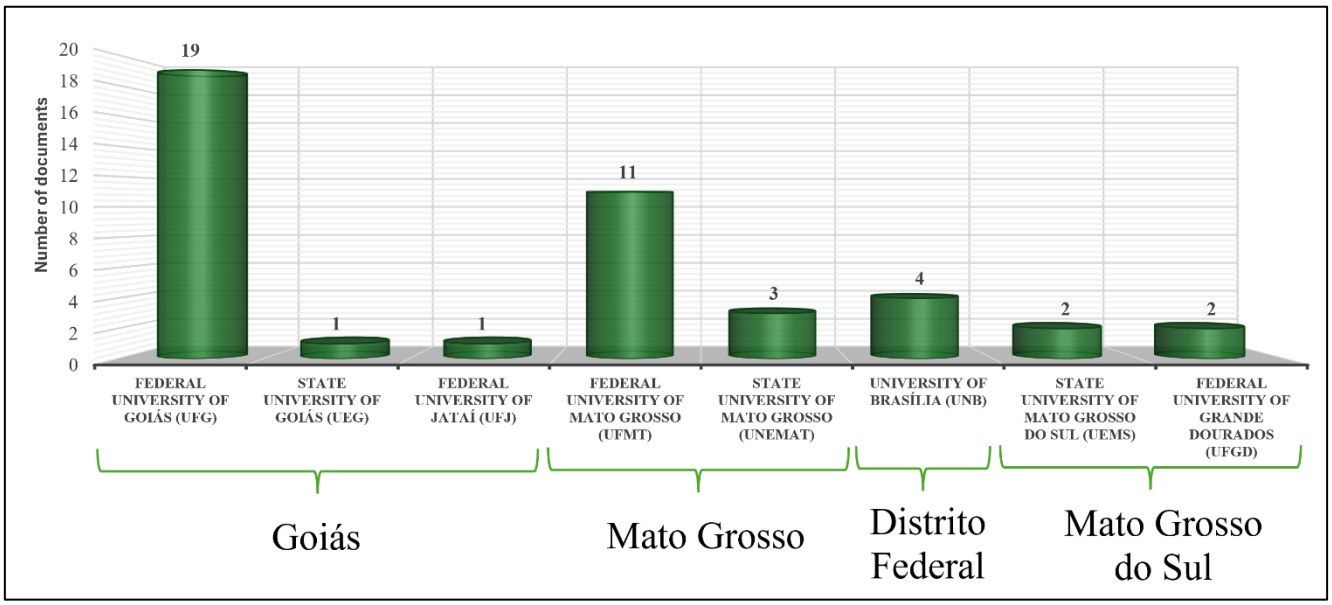


**Figure 7**. State distribution of the publications between 1994 and 2020.

Goiás stands out with a total of 21 studies, demonstrating its central role in the academic research on linear erosion. This focus can be attributed to the distinct characteristics of the region, which attract academic interest due to the environmental, social, and economic nuances connected to the relevance of the agricultural and livestock activities and their environmental impacts. In this state, the studies are predominantly concentrated in three thematic areas: 1) methodological analyses and environmental contexts related to the phenomenon; 2) the development of mitigation techniques to alleviate piping and soil preservation problems; and 3) soil management practices that influence environmental conservation.

The themes of these studies cover from the distribution of linear water erosion and its main conditioners (SANTANA, 2007; NUNES, 2011, 2015; RODRIGUES, 2020) to soil management, environmental conservation, and the implementation of corrective strategies to reduce adverse ecological impacts. There is a predominance of an inclination towards applied studies aimed at sustainability and agricultural techniques. These studies mostly have co-authors such as Selma Simões de Castro and Vládia Correchel.

Mato Grosso contributed 14 publications, highlighting the importance of the region as a center of interest due to the diversity of ecosystems and the significant agricultural activity that drive the research (PASCOTTO et al., 2022). The studies focus on analyses of hydrographic sub-basins and aquatic ecosystems; evaluations of affected soils, including their composition, use, and management; and approaches to the conservation and protection of natural resources. Authors such as Elder de Lucena Madruga, Joaquim Corrêa Ribeiro, and Lineu Petersen Fett bring contributions that vary from the understanding of ecological processes and the conservation of biodiversity to agricultural management practices and geographical studies, with the aim of spatialization of the phenomenon and the causal factors. Their studies reflect concerns regarding the sustainable use of the region's natural resources.

Mato Grosso do Sul, with 4 publications, presents a focus concentrated on themes related to environmental management and conservation. The main study topics address the impact of vegetation cover and the use of simulated data for environmental modeling; the soil and water loss dynamics and their effects on erosion; and the management of sediment runoff and its implications for soil conservation. Researchers such as Claudia Gonçalves Vianna Bacchi and Pedro Luiz Nagel contribute significantly with important studies on biodiversity conservation, erosion mitigation strategies, and the sustainability of water resources. Their approaches reflect the integration of environmental sciences and agronomy, emphasizing management practices with the aim of preserving the unique ecosystems of Mato Grosso do Sul, such as the Pantanal.

In the Distrito Federal, 4 publications highlight the role of the region as a field for urban environmental studies, which are most likely driven by its political importance as the federal capital and the presence of conservation areas/units. The predominant topics include geotechnical studies and analyses of the flow of water; research focused on soil characterization and the evaluation of erosive processes; and the influence of environmental factors on urban and rural soils. Among the relevant authors are Diogenes Mortari and Leonardo Figueiredo de Freitas, whose studies contribute to the understanding of the environmental challenges faced by the Distrito Federal, addressing from soil stability to the implications of erosion in urbanized areas. These studies are essential for developing territorial management and soil conservation strategies in the country's capital, reflecting a multidisciplinary approach that integrates environmental science, urbanism, and geotechnics.

Regarding the most frequent keywords, the words "Erosão" (Erosion), "Ravinas" (Ravines), and "Voçorocas" (Gullies) lead the ranking (Table 2). This suggests a significant focus on studies of erosive processes and their impacts. Other keywords are associated with these, such as "Compartimentação Morfopedológica" (Morphopedological Compartmentation), "Uso do solo" (Land Use), and "Erodibilidade" (Erodibility).

The keywords show a concentration on the word "Erosão" (Erosion) with 10 occurrences, indicating the marked concern of the studies with soil degradation processes, their conditioners, and the environmental consequences, emphasizing erosion as paramount in environmental and agronomic studies and highlighting the necessity to develop mitigation methods.

**Table 2.** Frequent keywords.

| Keyword | Number of Occurrences |
|---|---|
| Erosão (Erosion) | 10 |
| Voçorocas (Gullies) | 7 |
| Uso do solo (Land Use) | 7 |
| Ravinas (Ravines) | 6 |
| Medidas Corretivas (Corrective Measures) | 6 |
| Erodibilidade (Erodibility). | 4 |
| Compartimentação Morfopedológica (Morphopedological Compartmentation) | 3 |
| Precipitação Pluvial (Rainfall) | 2 |
| Fragilidade Ambiental (Environmental Fragility) | 2 |
| Sandy Soil | 2 |

With 7 occurrences each, "Voçorocas" (Gullies) and "Uso do Solo" (Land Use) highlight the importance of investigating intense forms of erosion and the impacts of land use practices on environmental sustainability. "Ravinas" (Raqvines) and "Medidas Corretivas" (Corrective Measures), with 6 mentions each, indicate interest in specific forms of erosion and remediation strategies. "Erodibilidade" (Erodibility), mentioned 4 times, reflects interest in the susceptibility of soil to erosion. "Compartimentação Morfopedológica" (Morphopedological Compartmentation), cited 3 times, indicates an analysis of the geospatial configuration of the land and whether or not it favors the erosive phenomenon. "Precipitação Pluvial" (Rainfall), "Fragilidade Ambiental" (Environmental fragility), and "Sandy Soil", with 2 occurrences each, indicate interest in the effects of rainfall, the sensibility of ecosystems, and sandy soils, which are recognized for their high levels of erodibility.

### *3.2. General trends in the research*

The data presented below summarize various dimensions of the studies on linear erosion in the Central-West region, involving the set of articles, theses and dissertations used in the previously executed bibliometric analysis. Through the combination of these data, it was possible to visualize general trends in the research on the theme and demonstrate the pathways that are being followed in the study of this phenomenon, the main types of study, and the variety in the scale employed, among others. Each study was individually reviewed and the key information on the methodological approach, the research topics, and the study area were extracted and grouped. This process ensured a detailed analysis of the research trends, as shown in Figure 8.

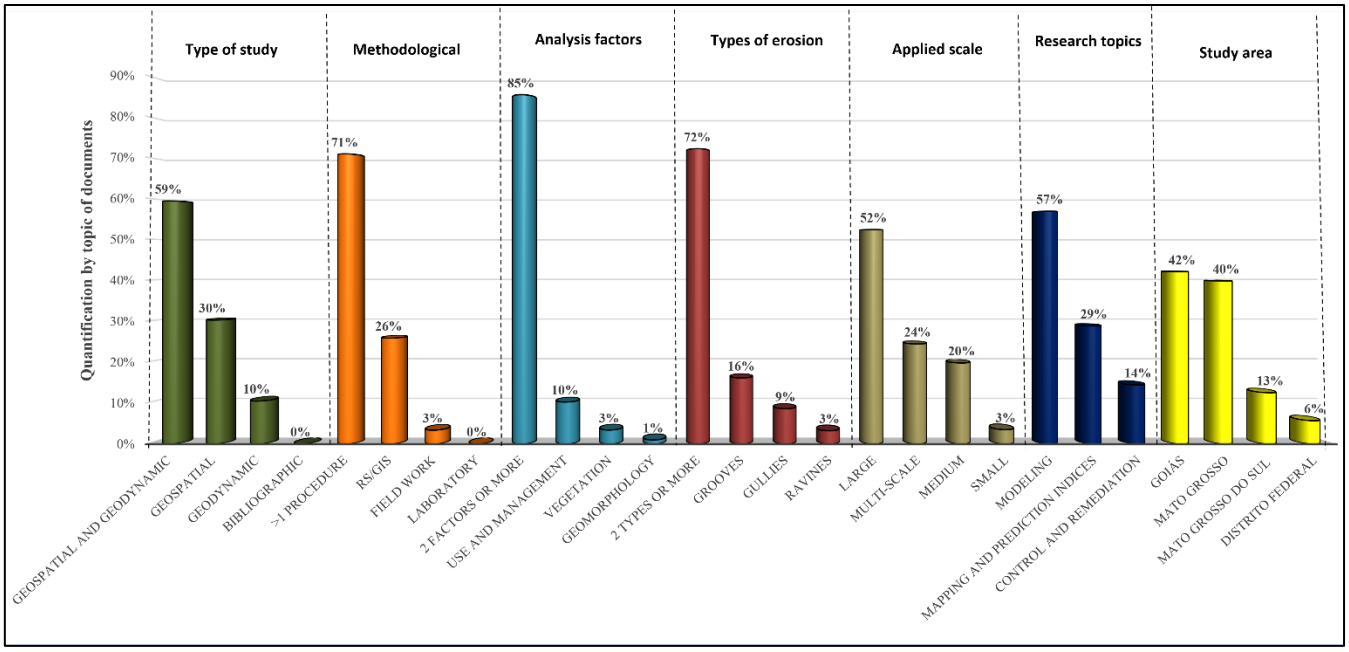


**Figure 8.** Quantification by theme of the documents.

The studies were classified into four main categories: geospatial (31%), geodynamic (10%), geospatial and geodynamic (59%), and bibliographic (0%). Geospatial studies involve analyses of spatial data using remote sensing and geoprocessing techniques, with particular emphasis on the mapping of susceptible areas and areas at risk. Geodynamic studies focus on the dynamic of the erosive processes, considering factors such as water flow behavior resulting from the interaction between soil, relief, water, and vegetation. There were no exclusively bibliometric studies, indicating a preference for empirical and practical approaches, combining spatial and dynamic analyses of the erosive processes. It is important to recognize that the absence of exclusively bibliographic studies in this survey results from the delimitation of the types of documents considered in the research, although the relevance of bibliographic and bibliometric review studies for comprehending the general panorama of scientific research on linear erosion should be recognized.

Regarding the methodological procedures, 26% of the studies used remote sensing and geoprocessing, 3% involved field work, and 71% combined multiple procedures. The combination of various methodological approaches suggests a tendency towards multidisciplinary research applying various techniques to obtain robust, comprehensive results. Among the most used procedures are the analysis of satellite images, hydrological modeling, the use of Geographic Information Systems (GIS), the supervised classification of land use and coverage, and field measurements for data collection on soil characteristics, surface runoff, and vegetation. It can be observed that the combination of two or more of these methods enables an integrated evaluation of the erosive dynamics and their interactions with the physical environment and human activities.

The analyzed factors were varied, with 3% of the studies focused on vegetation, 10% on land use and management, 2% on geomorphology, and 85% analyzed multiple factors simultaneously. This integration is defended as fundamental to understanding the complexity of the erosive phenomenon, which involves multiple factors simultaneously, such as land use and management, vegetal coverage, geomorphology, soil characteristics, and the hydric regime.

It is acknowledged in the studies that geomorphological knowledge contributes to the understanding of the relief forms and the erosive processes, enabling identification of areas with greater susceptibility to erosion. Hydrological knowledge is essential to analyzing the behavior of water flows and their impact on soil removal, especially in periods of intense rainfall. Pedological knowledge, in turn, deals with soil characteristics such as texture, composition, and permeability, as they influence the resistance of soil to erosion. Agronomic knowledge, particularly that referring to land use and management, is fundamental to understanding how agricultural practices such as planting, harvesting, and soil compaction can increase or mitigate the risk of erosion.

The predominance of multifactorial studies (85%) reflects this complexity, demonstrating the interconnection between the environmental elements and those of management. These studies frequently integrate the analysis of

soil coverage with the water dynamic in surface runoff, the relationship between different types of vegetation and their influence on reducing erosion, in addition to the impact of agricultural activities and mechanization on soil stability. It is evident that this multidisciplinary approach enables a more complete vision of the erosive processes, facilitating the development of effective strategies for the prevention and mitigation of linear water erosion.

The types of erosion studied include grooves (16%), ravines (3%), gullies (9%), and combinations of two or more types (72%). Most of the studies addressed multiple types of erosion, highlighting the need for integrated approaches for complete understanding of the phenomenon. In relation to the applied scales, 52% of the studies used large scales (local, from 1:10.000 to 1:50.000), 21% used intermediate or medium scales (municipal or state, from 1:50.000 to 1:250.000), 3% applied small scales (national or less detailed, above 1:250.000), and 24% integrated multiple scales of analysis. As such, the local scales, followed by medium and multiscale approaches stand out. Thus, large scales enable a detailed understanding of the erosive processes in specific areas, while intermediate and small scales cover larger areas such as the sub-regional and regional. The multiscale approach, which integrates different scales of analysis, enables a more complete vision of the erosive processes, considering spatial variability in different regions and at different levels of detail.

The studies on linear erosion in the Central-West of Brazil address three main research topics: modeling (57%), control and remediation (14%), and mapping and prediction indices (29%). In terms of geographical distribution, the studies are concentrated in Goiás (43%) and Mato Grosso (40%), followed well behind by Mato Grosso do Sul (13%) and the Distrito Federal (6%).

The analysis of the results and documents offers a comprehensive view of the current trends in research on linear erosion in the Brazilian Central-West. The main focus of the studies shows a growing trend in sustainable land management practices, demonstrated by recent studies (SCHIAVON et al., 2015; SOUSA et al., 2019, for example), reflecting a standardized change in agricultural and environmental management aiming at geographical sustainability, as proposed by Sachs (2009). Strategies such as conservationist or agroecological and sustainable agriculture, agroforestry systems, and the recovery of degraded landscapes are some of the solutions mentioned by the authors with the aim of promoting the combat of linear erosion, especially through preventative measures, in addition to improving soil health, increasing biodiversity, and contributing to climate resilience (GOMES et al., 2019; SCHIAVON et al., 2015).

It should be clarified that the geographic sustainability proposed by Sachs (2009) is understood as a holistic approach that considers the equilibrium between the environmental, social, and economic dimensions in a specific area, be it state, municipal, region, or river basin. The objective is to guarantee the well-being of both present and future generations, promoting development that does not compromise the capacity of the coming generations to meet their own needs.

This concept is broadly reflected in several studies, such as that of Petsch et al. (2022), which evaluates the relationship between land use, rainfall seasonality, and erosion, highlighting the importance of planning in land use and management to mitigate erosive processes. Alves et al. (2021) and Gomes et al. (2019) focus on the impacts of changes in land use and inadequate management practices as causes. Gouveia et al. (2022) emphasize the importance of integrated land and water management in the dynamic between land use and water quality, highlighting sustainable practices. In this context, Wantzen (2006) and Gutierrez et al. (2023) address the conservation of fluvial valleys and the monitoring of gullies, demonstrating the severe consequences of erosion and highlighting the need for effective prevention and mitigation strategies.

The multifactorial approach, in turn, is complemented by studies focused on forest recuperation and the rehabilitation of areas affected by gullies, using plants native to the Cerrado biome (ALVES et al., 2016; MARCELO, PAIXÃO & RAMOS, 2019; OLIVEIRA et al., 2020; SOUZA & FELFILI, 2006). The analysis of study scales in research on linear erosion in the Central-West of Brazil reveals a multiscale and interdisciplinary approach to the understanding of the linear water erosion process. The preference for large cartographic scales (local or detailed) reflects the need to understand erosive processes at a more detailed level, which is essential for grasping the complexity and variability of linear water erosion processes, enabling identification of specific conditioners and the unique dynamic of each studied area, considering from soil composition and attributes, topography, and vegetation to the impact of human activities. This focus is corroborated by studies such as that of Thaler et al. (2022), in which the authors emphasize the importance of larger scales to understanding the socioeconomic implications of erosion. Studies on a more detailed scale, such as that carried out by Gomes et al. (2021), are crucial

to analyzing the development of management techniques adapted to local conditions and to testing and refining erosion models.

The medium scale approach, adopted in studies such as those of Alves et al. (2022) and Gouveia et al. (2022), focus on entire river basins or specific regions of the Cerrado, integrating data from different locations to understand erosion and sedimentation patterns, impacts on water resources, and interactions with land use and changes in vegetal coverage. On a small and medium scale (macroregional, national), the studies are focused on environmental models such as that applied by Gomes et al. (2021), which involves climate modeling and global analyses of land use with the aim of anticipating future changes and their impacts on erosion and evaluating how climate change and socioeconomic transformations will influence erosion patterns in the Central-West.

Multiscale approaches, as highlighted by Ofstehage and Nehring (2021) and emphasized by Rodrigues and Castro (2023), reflect the recognition that erosive processes are influenced by factors operating simultaneously at multiple scales. These approaches are particularly effective for integrating specific local knowledge with regional patterns and global trends, offering a more complete understanding of the challenges faced and their potential solutions. The adoption of multiscale approaches has intensified in the analysis of various objects of study, becoming particularly valuable in the context of linear erosion. Driven by the evolution of computational and environmental models, this strategy makes increasingly precise and comprehensive results viable.

The main foci of the research, which include modeling, mapping and forecast indices, in addition to control and remediation, indicate a clear direction towards erosion prevention and mitigation. This corroborates the affirmations of studies such as that of Vanmaercke et al. (2021), which emphasizes modeling as an essential tool for predicting and managing the impacts of erosion in the long term, and that of Lal (1998), which highlights the importance of control and remediation to improve soil resilience and mitigate the effects of soil degradation.

Methodologically, the advance in the use of geotechnology such as remote sensing, geospatial modeling, and geoprocessing has marked recent research on linear erosion in the Brazilian Central-West. Such tools are innovative for enabling precise mapping, dynamic modeling, and the prediction of erosive processes with high temporal and spatial resolution, contributing to radically transforming how soil erosion is studied and understood, especially in geoenvironmental terms (LIMA, 2014; PISANI, DEMARCHI & RIEDEL, 2020). The emphasis on geospatial (mapping) and geodynamic (processes and mechanisms) models suggests that modeling the dynamic of the affected or potentially affected landscape is a central concern for researchers. Studies by Lima (2014) and Pisani, Demarchi, and Riedel (2020) highlight the importance of remote sensing to understanding changes in land use and their effects on erosion. The prevalence of multiple methodological procedures and multiproxy analysis reinforces this tendency, showing that the complexity of linear erosion demands a robust set of analytical tools to be duly investigated, understood, and controlled.

Studies such as that of Castro et al. (2022) intensively use geotechnology, including remote sensing and Geographic Information Systems (GIS) to map and estimate factors of the Universal Soil Loss Equation (USLE) and evaluate the relationship between potential and real erosion. This capacity to integrate data from diverse sources and scales highlights the importance of these technologies for environmental monitoring and land use planning, demonstrating how the erosivity of rain, the erodibility of soil, topographic factors, land use and management, and support practices contribute to soil losses. Similarly, Alves et al. (2022) extensively used geotechnology to model soil erosion. Wantzen et al. (2006) applied geotechnology, such as the interpretation of satellite images (Landsat-7), to map streams and areas affected by linear erosion. Gutierres et al. (2023) mentioned the use of Unmanned Aerial Vehicles (UAV) to photographically record and identify areas with gullying, demonstrating the applicability of modern geotechnology in the monitoring and evaluation of erosive processes.

Pilatti et al. (2022) exemplified the effective use of geotechnology to morphometrically analyze and map land use, emphasizing the need to align anthropic actions with soil conservation practices to mitigate negative impacts. Rodrigues and Castro (2023) used remote sensing techniques and high spatial resolution satellite images to map linear erosion foci, and Pereira (2021) used geotechnology to map gullies, evaluate land use, and identify areas susceptible to erosion.

Multifactorial analysis, which is being increasingly adopted, incorporates a large part of the information derived from geotechnology, enabling the integrated consideration of various factors. Land use and management, vegetation, and geomorphology reflect a systemic approach to soil erosion aligned with the literature that recognizes the interaction between biotic and abiotic factors in the determination of erosion rates (BOARDMAN, 2006; ELHAG et al., 2023).

On the other hand, upon specifically analyzing the object of study, erosion, the combination of more than one type of linear erosion, predominantly ravines and gullies, suggests an effort to understand erosion in its various contexts, which is an approach also recommended by Poesen and Hooke (1997), Singh, Barman and Tirkey (2021), and Alberico et al. (2022) to understand the spatial and temporal variability of soil erosion.

The geographic distribution of the studies with a greater focus on Goiás and Mato Grosso is linked to the extensive agricultural activity in these areas and the challenge of conciliating intensive land use for the production of food, fibers, and fuels with soil and water conservation. The research in these states may be responding to the challenges imposed by the intensification of agricultural use caused by the arrival of the agricultural frontier and its advance towards the central north of the biome, and by the need for sustainable land use practices, as seen in the discussions raised by authors such as Motta Silva and Loureiro (2021) and Russell-Smith et al. (2021), which explore the sustainable management of lands in the Cerrado to combat erosion.

The lower proportion of studies in the Distrito Federal, especially urban studies, and in Mato Grosso do Sul, rural studies, may suggest that these regions face linear erosion with less intensity or that other research priorities are being addressed. However, considering the graduate programs and the institutions of learning present in these regions, it is possible that the lower quantity of studies is also related to the lower availability of academic programs specialized in geosciences and related areas, in addition to the possible limitations of financing for research projects. Moreover, the logistics of conducting field studies in more remote areas, in addition to the smaller territorial dimension of the Distrito Federal, may represent other challenges. The distribution of Cerrado biome remnants in these areas may also influence the number of studies focused on linear water erosion, given that more preserved areas or those with a lower intensity of agricultural use tend to present lower degradation indices, which may reduce the priority of studies on the theme.

It is also important to consider the heterogeneity within the Cerrado biome, with its different phytophysiognomies and sub-regions facing distinct challenges. Nunes and Castro (2021) discuss the variations in soil degradation in different phytophysiognomies of the Cerrado and highlight the impacts of linear water erosion processes in the southwest of Goiás, an area of intense agricultural activity. In this context, "sub-regions" refer to the divisions within the Cerrado with unique geographical and environmental characteristics, which directly influence erosion processes and the focus of research.

The complexity of erosive processes and their multiple trigger factors, such as changes in land use, inadequate agricultural practices, and extreme climate events demand an interdisciplinary approach. Thus, recent research in the Cerrado of the Central-West has promoted collaboration between geologists, agronomists, biologists, geographers, ecologists, and social scientists, among others, to develop integrated mitigation strategies that consider ecological, economic, and social aspects (MARTINS et al., 2023; SANTOS et al., 2021).

In summary, linear erosion in the Central-West is an object of multidisciplinary research driven by the need to understand complex, multifactorial processes on scales relevant to environmental sustainability and agricultural management. The trends highlighted by the data reflect a field of study that is adapting to new technologies and integrated approaches to confronting contemporary environmental challenges, with a clear focus on predictive modeling and the application of management practices aimed at long-term sustainability.

## 5. Conclusions

This article presented a panorama of the scientific production on linear water erosion in the Central-West region through the analysis of 91 documents consisting of 48 articles extracted from the Dimensions platform and 43 dissertations and theses from the Capes database. All the documents were subjected to bibliometric analysis, which enabled mapping of the main trends and patterns in research on the theme. The results offer a comprehensive view of the historical development of and the methodological approaches used in the studies, in addition to highlighting the areas with the highest concentration of publications and the topics of greatest relevance. This panorama contributes to a better understanding of the research gaps and of the main approaches adopted, providing a basis for future investigations in the field of linear erosion.

The results presented and discussed herein highlight a recent increase in the academic production, emphasizing a multi- and interdisciplinary approach that integrates geomorphological, hydrological, pedological, and agronomic (land use and management) knowledge and multiscale analysis, with a predominance of detailed scales. The bibliometric analysis emphasizes the urgent need to address the challenges represented by linear erosion in the Brazilian Central-West region.

The concentration of studies in the states of Goiás and Mato Grosso reflects the accentuated environmental concerns associated with intensive agricultural activity, characterized by the arrival and advance of the agricultural frontier since the 1970s, with intensive, indiscriminate deforestation practices followed by livestock and crop conversion. Meanwhile, smaller quantitative studies, such as those carried out in the Distrito Federal and Mato Grosso do Sul, suggest regional variations in the research priorities or in the intensity of erosion phenomena, although this is yet to be clarified.

The bibliometric tool used here, *Biblioshiny*, proved to be effective for understanding trends, themes, and collaborative networks within the field of study. As such, the documents extracted from the databases not only quantify the academic contributions, but also enable demonstration of the evolution of the research focused on the sustainable management of soil resources in the Cerrado.

In summary, the trajectory of the research on linear erosion in the Central-West region of Brazil is increasingly aimed at developing practical solutions and management strategies that can be applied in the region. For this, the interdisciplinarity of the studies and the adoption of advanced technology are fundamental to confronting contemporary environmental challenges, with a clear focus on predictive modeling and the implementation of sustainable land management practices for long-term sustainability.

**Contributions of the authors**, TAVARES, K. R. S., CASTRO, S. S.; methodology, TAVARES, K. R. S.; software, TAVARES, K. R. S.; validation, TAVARES, K. R. S.; analysis form, TAVARES, K. R. S., CASTRO, S. S.; article writing, TAVARES, K. R. S., CASTRO, S. S.; revision, TAVARES, K. R. S., CASTRO, S. S.; supervision, CASTRO, S. S. All of the authors have read and are in agreement with the published version of the manuscript.

**Acknowledgements:** We would like to thank the Fundação de Amparo à Pesquisa do Estado de São Paulo (Research Support Foundation of the State of São Paulo) (FAPESP) for the doctorate grant – Process number: 2022/12891-6.

**Conflict of Interest:** The authors hereby declare that there is no conflict of interest.

## References

1. ALBERICO, I.; CASALBORE, D.; PELOSI, N.; TONIELLI, R.; CALIDONNA, C.; DOMINICI, R.; DE ROSA, R. Remote Sensing and Field Survey Data Integration to Investigate on the Evolution of the Coastal Area: The Case Study of Bagnara Calabra (Southern Italy). **Remote Sensing**, vol. 14, nº 10, 2022. DOI: 10.3390/rs14102459.
2. ALVES, D. DE S., SILVA, M. M. DE S., SILVA, J. M. DOS S., SKRAPEC, M. V. C., SILVA, D. F. DOS S., DE QUEIROZ, D. B., CARDOSO, M. V. DE O. A Importância das Medidas de Mitigação e Adaptação Frente às Mudanças Climáticas na Agropecuária Brazil eira. **Brazilian Journal of Development**, 7(11), 2021. DOI: 10.34117/bjdv7n11-460.
3. ALVES, L. R.; OLIVEIRA, R. J. de; COIMBRA, R. R.; FERREIRA, W. de M. Crescimento Inicial De Parkia Platycephala (Benth.) E Enterolobium Timbouva (Mart.) Sob Condições De Campo Numa Área De Cerrado. **Revista Ceres**, 2016. DOI: 10.1590/0034-737x201663020006.
4. ARIA, M.; CUCCURULLO, C. Bibliometrix: an R-tool for comprehensive science mapping analysis. **Journal of Informetrics**, v. 11, n. 4, p. 959-975, 2017. DOI: 10.1016/j.joi.2017.08.007.
5. BIBLIOMETRIX.ORG. Disponível em: https://www.bibliometrix.org/. Acesso em: 24 jun. 2022.
6. BARRETTO, A. G. de O. P.; BARROS, M. G. E.; SPAROVEK, G. Bibliometria, história e geografia da pesquisa Brazil eira em erosão acelerada do solo. **Revista Brazil eira de Ciência do Solo**, vol. 32, nº 6, 2008. DOI: 10.1590/s0100-06832008000600022.
7. BATISTA, P. V. G.; DAVIES, J.; SILVA, M. L. N.; QUINTON, J. N. On the evaluation of soil erosion models: Are we doing enough? **Earth-Science Reviews**, vol. 197, 2019. DOI: 10.1016/j.earscirev.2019.102898.
8. BOARDMAN, J. Soil erosion science: Reflections on the limitations of current approaches. **Catena**, vol. 68, nº 2–3, 2006. DOI: 10.1016/j.catena.2006.03.007.
9. CASTRO, R. M., SANTOS A., W., DE OLIVEIRA M, S. M. L., DE MOURA, D. M. B., DA SILVA O. D. M. Soil losses related to land use and rainfall seasonality in a watershed in the Brazilian Cerrado. Journal of South American Earth Sciences, 119, 104020, 2022. DOI: 10.1016/j.jsames.2022.104020
10. DE FARIA, K. M. S.; PESSOA, M. A.; DA SILVA, E. V. Geoecologia das Paisagens: uma análise cienciométrica da sua produção científica no Brazil (1990 - 2019). **Geography Department University of Sao Paulo**, vol. 41, 2021. DOI: 10.11606/eissn.2236-2878.rdg.2021.178138.

11. ELHAG, M.; BAHRAWI, J.; ZHANG, L.; EJAZ, N. Assessment and quantification of sediment retention and dam management in arid environments using remote sensing techniques. **Arabian Journal of Geosciences**, vol. 16, nº 10, 2023. DOI: 10.1007/s12517-023-11661-1.
12. GOMES, L.; SIMÕES, S.; DALLA NORA, E.; DE SOUSA-NETO, E.; FORTI, M.; OMETTO, J. Agricultural Expansion in the Brazilian Cerrado: Increased Soil and Nutrient Losses and Decreased Agricultural Productivity. **Land**, vol. 8, nº 1, p. 12, 8 jan. 2019. DOI 10.3390/land8010012. Disponível em: https://www.mdpi.com/2073-445X/8/1/12.
13. GOMES, W. W. E., LEITE-FILHO, A. T., SOARES-FILHO, B. S. Simulação dos impactos das mudanças climáticas globais na evapotranspiração de referência da bacia amazônica Brazil eira. **Revista Brazil eira de Climatologia**, 28, 2021. DOI: 10.5380/rbclima.v28i0.74046.
14. GOUVEIA, R. G. L., PEREIRA, G. T., PISSARRA, T. C., VIEIRA MARTINS FILHO, M. V., SILVA, M. A. P .M., JUNIOR, R. Influência do uso e cobertura da terra na qualidade da água da bacia hidrográfica do Rio Uberabinha – MG. **Revista Geonorte**, 13(41), 2022. DOI: 10.21170/geonorte.2022.v.13.n.41.167.190.
15. GUERRA, A.; LOUREIRO, H A. S. **Erosão em Áreas Tropicais**. 1. ed. Rio de Janeiro, 2023.
16. GUTIÉRREZ, F., SEVIL, J., MIGOŃ, P. Landslides in the Remolinos gypsum escarpment (NE Spain): controls imposed by stratigraphy, fluvial erosion, and interstratal salt dissolution. **Landslides**, 20(10), 2023. DOI: 10.1007/s10346-023-02090-y.
17. HOGAN, D. J.; CUNHA, J. M. C.; CARMO, R. L. **Uso do solo e mudança de sua cobertura no Central-West do Brazil : consequências demográficas, sociais e ambientais**. In: HOGAN, D. J.; HOGAN, D. J.; CARMO, R. L.; CUNHA, J. M. P.; BAENINGER, R. (org.). Migração e ambiente no Central-West. Campinas, NEPO/UNICAMP: PRONEX, 2002, p. 149-174.
18. KAGEYAMA, A. **Desenvolvimento Rural: Conceitos e Aplicações ao Caso Brazil eiro**. Porto Alegre: Editora da UFRGS: Programa de Pós-graduação em Desenvolvimento Rural, 112 f., 2008.
19. LAL, R. Soil erosion impact on agronomic productivity and environment quality. **Critical Reviews in Plant Sciences**, vol. 17, nº 4, 1998. DOI: 10.1016/S0735-2689(98)00363-3.
20. LIMA, T. C. **Modelagem dos vetores de mudança na paisagem no bioma Cerrado**. Programa de Pós-Graduação em Geografia, Dissertação de mestrado. Universidade Federal de Minas Gerais - Instituto de Geociências, 68 f., 2014.
21. MARCELO, V. G.; PAIXÃO, C. F. C. da; RAMOS, M. Uso De Plantas Do Domínio Cerrado Com Fins Medicinais Em Urutaí, Go, Brazil . **Multi-Science Journal**, 2019. DOI: 10.33837/msj.v2i1.958.
22. MARTINS, T.; FREITAS, S. R.; SEMENSATTO, D. L.; HARDT, E. A Influência Da Proximidade Com as Matas Ciliares E a Distância Das Áreas Urbanas Nos Atropelamentos De Vertebrados Em Uma Área Fragmentada Do Cerrado Brazil eiro. **Austral Ecology**, 2023. DOI: 10.1111/aec.13415.
23. MELLO, P. L. H, MACHADO R. B., NOGUEIRA C. D. C. Conserving Biogeography: Habitat Loss and Vicariant Patterns in Endemic Squamates of the Cerrado Hotspot. PLoS ONE 10(8): e0133995. DOI: https://doi.org/10.1371/journal.pone.0133995
24. MITTERMEIER, R.A., TURNER, W.R., LARSEN, F.W., BROOKS, T.M., GASCON, C. Global Biodiversity Conservation: The Critical Role of Hotspots. In: Zachos, F., Habel, J. (eds) **Biodiversity Hotspots**. Springer, Berlin, Heidelberg. DOI: https://doi.org/10.1007/978-3-642-20992-5_1
25. MOREIRA, P. S. da C.; GUIMARÃES, A. J. R.; TSUNODA, D. F. QUAL FERRAMENTA BIBLIOMÉTRICA ESCOLHER? um estudo comparativo entre softwares. **P2P E INOVAÇÃO**, vol. 6, 2020. DOI: 10.21721/p2p.2020v6n2.p140-158.
26. MOTTA SILVA, J. G. da; LOUREIRO, A. C. NOVO SER TÃO VAZIO: avaliação da gestão do plano de manejo da APA DE POUSO ALTO, GOIAS. **Tecnologia e Ambiente**, vol. 27, 2021. DOI: 10.18616/ta.v27i0.6701.
27. NUNES, E. D. **Ensaio sobre modelagem de bacia hidrográfica no contexto dos sistemas dinâmicos - Ribeirão Lajeado - Goiânia** - GO. 2011. 134 f. Programa de Pós-Graduação em Geografia. Dissertação de Mestrado – Universidade Federal de Goiás, 2011.
28. NUNES, E. D. **Modelagem de processos erosivos hídricos lineares no município de Mineiros** - GO. Programa de Pós-Graduação em Geografia Tese – Universidade Federal de Goiás, 236 f., 2015.
29. NUNES, E. D.; CASTRO, S. S. de. Análise Multiescalar Aplicada À Avaliação De Erosão Hídrica Linear Para Área Tropical Subúmida Situada Na Região Sudoeste Do Estado De Goiás - Brazil . **Revista Brazil eira De Geomorfologia**, 2023. DOI: 10.20502/rbgeomorfologia.v24i00.2368.
30. NUNES, E. D.; CASTRO, S. S. Degradação de fitofisionomias do Cerrado e impactos erosivos hídricos lineares no sudoeste de Goiás – Brazil . **Sociedade & Natureza,** vol. 33, nº 1, p. 1–14, 2021.
31. OFSTEHAGE, A., NEHRING, R. No-till agriculture and the deception of sustainability in Brazil. **International Journal of Agricultural Sustainability**, 19(3–4), 2021. DOI: 10.1080/14735903.2021.1910419.
32. OLIVEIRA, A. M. E. de; WENDLING, B.; ERICSSON, D. B. de C.; XAVIER, M. A. de S.; XAVIER, A. R. E. de O. Métodos De Propagação E Fatores Que Interferem Na Germinação Das Principais Gramíneas Nativas De Cerrado. **Caderno De Ciências Agrárias**, 2020. DOI: 10.35699/2447-6218.2020.15845.

33. PASCOTTO, L., SILVA, S., MARQUES, G., SCALOPPE, L. Análise do impacto na rentabilidade de usuários e do potencial financiador da cobrança pelo uso da água subterrânea no sistema aquífero Parecis. **Revista de Gestão de Água Da América Latina**, 19(1), 2022. DOI: 10.21168/rega.v19e8.
34. PEREIRA, J. S. **Mapeamento das voçorocas e análise da susceptibilidade erosiva no município de Uberlândia, MG**. Tese (Doutorado em Geografia) - Universidade Federal de Uberlândia, Uberlândia, 197 f, 2021. DOI: 10.14393/ufu.te.2021.5529.
35. PETSCH, C., SCCOTI, A. A. V., DE SOUZA ROBAINA, L. E., TRENTIN, R.Controlling factors and mapping of linear erosive features in Santa Maria river watershed–RS. **Revista Brazil eira de Geomorfologia**, 23(4), 1876-1892, 2022.
36. PILATTI, H. DA S. C., ALVES, W. D. S., OLIVEIRA, L. D., PEREIRA, M. A. B., MORAIS, W. A., DE MOURA, D. M. B. Analysis of the transition of the land use and cover: subsidy to public policies of soil use in the Brazilian Savannah. **Revista Brazil eira de Geografia Fisica,** 15(3), 2022. DOI: 10.26848/rbgf.v15.3.p1587-1609.
37. PISANI, R. J.; DEMARCHI, J. C.; RIEDEL, P. S. Simulação de cenário prospectivo de mudanças no uso e cobertura da terra na sub-bacia do Rio Capivara, Botucatu - SP, por meio de modelagem espacial dinâmica. **Revista Cerrados**, vol. 14, nº 02, 2020. DOI: 10.22238/rc24482692v14n22016p03a29.
38. POESEN, J. Challenges in gully erosion research. **Landform Analysis**, vol. 17, 2011.
39. POESEN, J. W. A.; HOOKE, J. M. Erosion, flooding and channel management in Mediterranean environments of southern Europe. **Progress in Physical Geography**, vol. 21, nº 2, 1997. DOI: 10.1177/030913339702100201.
40. RODRIGUES, H. S. M. C. **Análise geoespacial do processo erosivo hídrico linear no estado de goiás e distrito federal**. 2020. 194 f. tese – Universidade Federal de Goiás, 2020.
41. RODRIGUES, H. S. M. D. C.; CASTRO, S. S. De. Mapeamento e identificação de áreas críticas à erosão hídrica linear : o exemplo do bioma Cerrado no estado de Goiás , Brazil Mapping and identification of areas critical to linear water erosion : the case of the Cerrado Biome in the State of Goiás , Braz. **Revista Brazil eira de Geomorfologia**, vol. 24, p. 30, 2023.
42. RUSSELL-SMITH, J.; MOURA, L. C.; YATES, C.; BEATTY, R.; MAFOKO, J.; JOHNSTON, S. Oportunidades de Mercado para Apoiar o Manejo Sustentável do Fogo em Paisagens com Remanescentes de Cerrado (savana) Pirofíticos. **Biodiversidade Brazil eira - BioBrazil** , nº 2, 2021. DOI: 10.37002/bioBrazil .v11i2.1725.
43. SANTANA, N. M. P. **Chuva, erodibilidade, uso das terras e erosão hídrica na Alta Bacia do Rio Araguaia**. 2007. 162 f. Dissertação de Mestrado – Universidade Federal de Goiás, 2007.
44. SANTOS, S. A. D. dos; MOMM, S.; TRAVASSOS, L.; FERNANDES, B. de S. As Áreas Protegidas Do Sistema Produtor Do Alto Tietê: A Governança E O Planejamento Em Cenários De Mudanças Climáticas. **Revista De Gestão Social E Ambiental**, 2021. DOI: 10.24857/rgsa.v15.2794.
45. SCHIAVON, G. de A.; LIMA, A. C. R. de; SCHIEDECK, G.; SCHWENGBER, J. E.; SCHUBERT, R. N.; PEREIRA, C. V. O Conhecimento Local Sobre a Fauna Edáfica E Suas Relações Com O Solo Em Agroecossistema Familiar De Base Ecológica: Um Estudo De Caso. **Ciência Rural**, 2015. DOI: 10.1590/0103-8478cr20121185.
46. SELLAMI, M. H.; TERRIBILE, F. Research Evolution on the Impact of Agronomic Practices on Soil Health from 1996 to 2021: A Bibliometric Analysis. **Soil Systems**, vol. 7, nº 3, 2023. DOI: 10.3390/soilsystems7030078.
47. SILVA, Z. C. G. da; SENA, P. M. B.; ARAUJO, R. F. de. A pesquisa sobre Ecossistema de Inovação: uma análise bibliométrica na base Dimensions. 2023. [*S. l.*: *s. n.*], 2023. DOI: 10.22477/vi.widat.49.
48. SILVA, A. A., MIZIARA, F. Avanço do setor sucroalcooleiro e expansão da fronteira agrícola em Goiás. **Pesquisa Agropecuária Tropical,** 41, 399-407, 2011.
49. SINGH, W. R.; BARMAN, S.; TIRKEY, G. Morphometric analysis and watershed prioritization in relation to soil erosion in Dudhnai Watershed. **Applied Water Science**, vol. 11, nº 9, 2021. DOI: 10.1007/s13201-021-01483-5.
50. SOUSA, R. M. de; PEREIRA, R. R.; ARAÚJO, D. R. de; SOARES, F. Sustentabilidade Ambiental De Agroecossistemas Familiares Na Amazônia Maranhense. **Acta Tecnológica**, 2019. DOI: 10.35818/acta.v13i2.670.
51. SOUZA, C. D. de; FELFILI, J. M. Uso De Plantas Medicinais Na Região De Alto Paraíso De Goiás, GO, Brazil . **Acta Botanica Brazil ica**, 2006. DOI: 10.1590/s0102-33062006000100013.
52. TAVARES, K. S. R.; CASTRO, S. S. Bibliometria dos estudos de erosão linear no Cerrado. **XIX Simpósio BrasieliroBrazil eiro de Geografia Física Aplicada**, , p. 61–65, 2023.
53. TAVARES, K. S. R.; CASTRO, S. S. Bibliométrica das Modelagens de Erosão do Solo: Panorama Geral. **XIII SINAGEO - geomorfologia: complexidade e interescalaridade da paisagem análise**, , p. 1184–1198, 2021.
54. THALER, E. A., KWANG, J. S., QUIRK, B. J., QUARRIER, C. L., LARSEN, I. J. Rates of Historical Anthropogenic Soil Erosion in the Midwestern United States. Earth's Future, 10(3), 2022. DOI: 10.1029/2021EF002396.
55. TURMUZI, M.; SUHARTA, I. G. P.; ASTAWA, I. W. P.; SUPARTA, I. N. Mapping of Mobile Learning Research Directions and Trends in Scopus-Indexed Journals: A Bibliometric Analysis. **International Journal of Interactive Mobile Technologies**, vol. 17, nº 3, 2023. DOI: 0.3991/ijim.v17i03.36461.

56. VANMAERCKE, M. *et al*. Measuring, modelling and managing gully erosion at large scales: A state of the art. **Earth-Science Reviews**, vol. 218, nº April, p. 103637, jul. 2021. DOI 10.1016/j.earscirev.2021.103637. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0012825221001379.
57. WANTZEN, K. M. Physical pollution: Effects of gully erosion on benthic invertebrates in a tropical clear-water stream. **Aquatic Conservation: Marine and Freshwater Ecosystems**, 16(7), 2006. DOI: 10.1002/aqc.813.
58. WILLIAM, L. South Brazil: Its vegetation, natural resources, research centers, and other economic aspects. **Economic Botany**, vol. 16, no 3, 1962. DOI: 10.1007/BF02860032.
59. ZHUANG, Y.; DU, C.; ZHANG, L.; DU, Y.; LI, S. Research trends and hotspots in soil erosion from 1932 to 2013: a literature review. **Scientometrics**, vol. 105, nº 2, 2015. DOI: 10.1007/s11192-015-1706-3.