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Review Article

UNESCO Global Geoparks and Geomorphology: A Bibliometric Analysis of Global and Brazilian Scientific Production

Geoparques Mundiais da UNESCO e Geomorfologia: Uma Análise Bibliométrica da Produção Científica Global e Brasileira

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Abstract: UNESCO Global Geoparks play a strategic role in the conservation of geological heritage, the promotion of geoscience education, and sustainable territorial development. This article presents a bibliometric analysis of international and Brazilian scientific production on geoparks, with a focus on the presence of geomorphology between 2007 and 2024. A total of 172 articles from Scopus and Web of Science databases were analyzed, revealing exponential growth in publications, particularly in countries such as China, Portugal, Spain, and Italy. In Brazil, scientific output remains recent and thematically narrow, concentrated in a few geoparks. The thematic analysis revealed that, although geomorphology is crucial for understanding and interpreting landscapes, its application remains limited and unsystematic, particularly in national studies. This gap underscores the need to integrate geomorphological knowledge more effectively into geopark management, conservation, and territorial planning strategies. The study reinforces the importance of technical training, research networks, and the inclusion of geomorphology as an analytical tool for geoconservation and landscape interpretation.

Keywords: UNESCO Global Geoparks; Geomorphology; Geodiversity; Scientific production;

Resumo: Os Geoparques Mundiais da UNESCO desempenham papel estratégico na conservação do patrimônio geológico, na promoção da educação em geociências e no desenvolvimento territorial sustentável. Este artigo apresenta uma análise bibliométrica da produção científica internacional e brasileira sobre geoparques, com ênfase na presença da geomorfologia entre 2007 e 2024. Foram analisados 172 artigos extraídos das bases Scopus e Web of Science, evidenciando o crescimento exponencial das publicações, especialmente em países como China, Portugal, Espanha e Itália. No Brasil, a produção é recente e concentrada em poucos geoparques, com baixa diversificação temática. A análise temática revelou que, embora a geomorfologia seja fundamental para a leitura e interpretação da paisagem, sua abordagem ainda é limitada e pouco sistematizada, sobretudo nos estudos nacionais. Essa lacuna aponta para a necessidade de maior integração entre os saberes geomorfológicos e as estratégias de gestão, conservação e valorização dos geoparques. O estudo reforça a importância de

fortalecer a formação técnica, ampliar redes de pesquisa e integrar a geomorfologia como ferramenta analítica nos planos de gestão territorial e geoconservação.

Palavras-chave: Geoparques Mundiais da UNESCO; Geomorfologia; Geodiversidade; Produção científica;

1. Introduction

UNESCO (United Nations Educational, Scientific, and Cultural Organization) Global Geoparks are geographically delimited areas, encompassing one or more municipalities, that preserve and manage sites and landscapes of global geological significance (UNESCO, 2024). These places are driven by an integrated concept of protection, education, and sustainable development, combined with the involvement and benefits of the population directly linked to the Geoparks (GODOY *et al.*, 2013). In addition to geological conservation, geoparks promote geotourism, education, and value other forms of heritage, such as cultural, architectural, ethnographic, and gastronomic (KUHN *et al.*, 2022).

The geopark concept has gained global recognition in less than 20 years, as evidenced by the growing number of sites designated as UNESCO Global Geoparks. Although the formal proposal to create a UNESCO Geoparks Programme was not approved during the 161st Session of the Executive Board in 2001, the organization made significant progress that same year by signing, in April, a cooperation agreement with the European Geoparks Network (EGN). The EGN had been created in 2000 with four pioneering geoparks: the Gerolstein/Vulkaneifel District Geopark (Germany, 1989), the Haute-Provence Geological Reserve (France), the Maestrazgo Cultural Park (Spain), and the Petrified Forest of Lesbos (Greece) (HERRERA-FRANCO *et al.*, 2021; PÉREZ-ROMERO *et al.*, 2023).

In February 2004, the Madonie Declaration formalized the creation of the Global Geoparks Network (GGN), with the EGN recognized as the entity responsible for regulating GGN adhesions (HERRERA-FRANCO *et al.*, 2021). With the support of UNESCO and the International Union of Geological Sciences (IUGS), the network was expanded in 2004 to include not only 17 European geoparks but also eight Chinese national geoparks, demonstrating its global reach (PÉREZ-ROMERO *et al.*, 2023).

Subsequently, in 2015, UNESCO launched the International Geosciences and Geoparks Programme (IGGP) and established the 'UNESCO Global Geoparks' (UGGp) label (HERRERA-FRANCO *et al.*, 2021; WANG *et al.*, 2022). This program has consolidated geoparks as essential tools for sustainable development, promoting the conservation of natural and cultural resources, while also contributing to the eradication of poverty and educational equity (WANG *et al.*, 2022). In 2024, 213 geoparks were identified in 48 countries (UNESCO, 2024; GLOBAL GEOPARKS NETWORK, 2024), with 108 recognized by 2014 and 105 between 2015 and 2024.[1] Figure 1 illustrates the location and concentration of geoparks, highlighting density and creation dates.

Initially concentrated in Europe, with 109 geoparks, and in Asia, with 83, geoparks have expanded significantly in recent years on the American continent. This expansion has leveraged the continent's ethnic, cultural, geographic, climatic, and, primarily, geological diversity (HERRERA-FRANCO *et al.*, 2021). Currently, North America has 7, Central America has 1, and South America has 10 geoparks, totaling 18. In Brazil, six geoparks were recognized due to their geodiversity and scientific, pedagogical, historical, and cultural values:

1. Araripe Geopark (2006) – Ceará: With an area of 3,789 km², it includes six municipalities and has 9 geosites.
2. Seridó Geopark (2022) – Rio Grande do Norte: It covers 2,802 km² and encompasses 21 geosites distributed across six municipalities.
3. Southern Canyons Paths Geopark (2022) – Rio Grande do Sul and Santa Catarina: It covers an area of 2,830.80 km², including seven municipalities, and has 30 official geosites and 18 proposed geosites.
4. Caçapava Geopark (2023) – Rio Grande do Sul: It covers an area of 3,047 km² within the territorial limits of the municipality and has 23 geosites.

[1] In April 2025, UNESCO announced the inclusion of 16 new geoparks in the Global Geoparks Network, bringing the total to 229 sites spread across 50 countries and covering an area of approximately 855,000 km². Highlights include the creation of the first geopark in the Democratic People's Republic of Korea and the first two in Saudi Arabia (UNESCO, 2025).

5. Fourth Colony Geopark (2023) – Rio Grande do Sul: It covers an area of 2,923 km², distributed across nine municipalities, and includes 54 points of interest, of which 31 are geosites and 23 are sites of complementary interest.

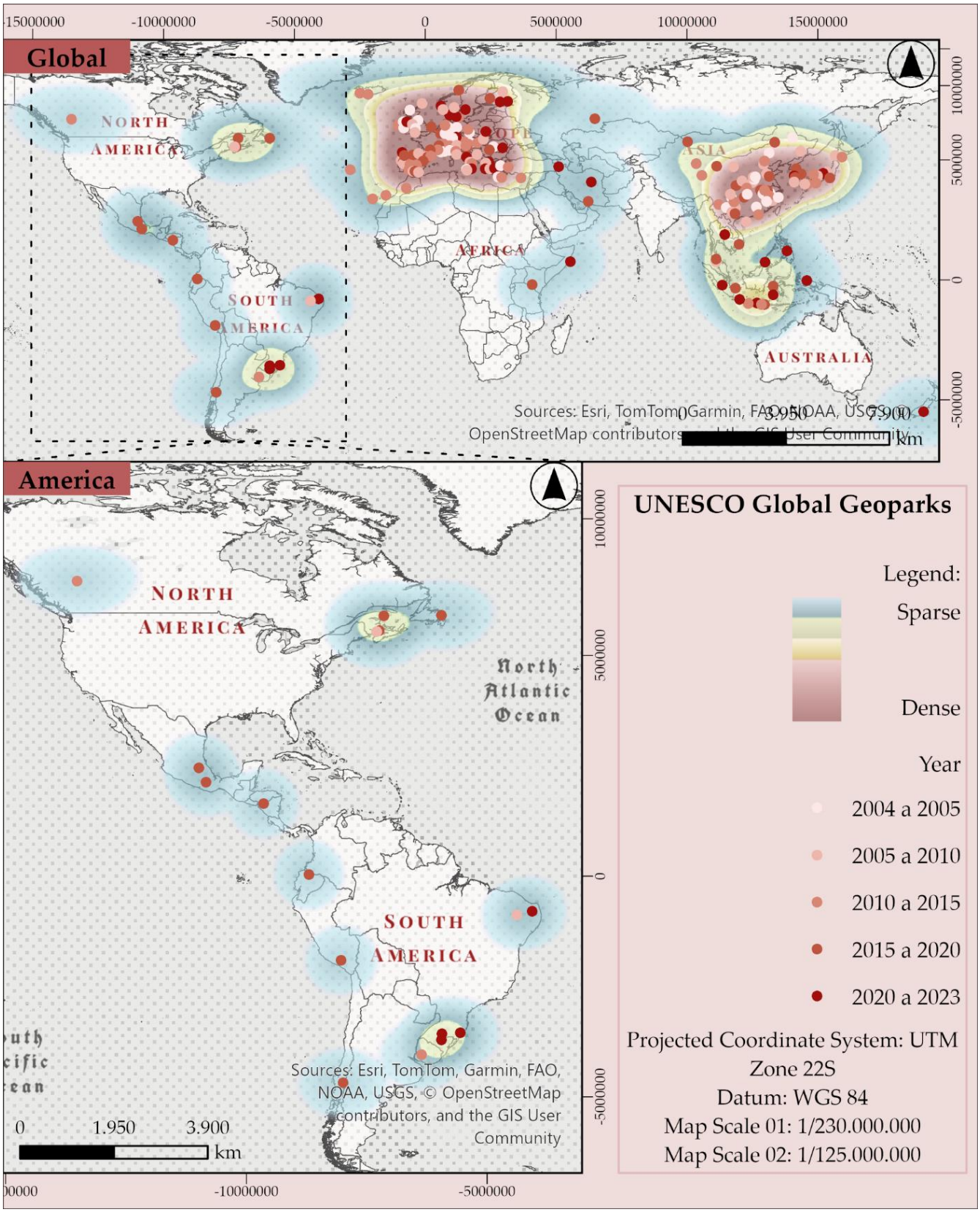

Figure 1. Spatial and temporal distribution of UNESCO Global Geoparks. Source: Prepared by the authors with geographic information provided by the Global Geoparks Network (2024), 2024. The 18 geoparks approved in 2024 and the 16 approved in 2025 were not georeferenced due to the lack of available spatial data.

6. Uberaba Geopark (2024) – Minas Gerais: It occupies an area of 4,540.51 km² within the municipal limits and contains 7 geosites.

In addition to these, several geopark projects are under development in Brazil, such as those in Chapada da Diamantina (BA) and Chapada dos Guimarães (MT), among others (KUHN *et al.*, 2022). This development is driven by the country's vast geological potential, given its continental extension and rich geodiversity.

Geosites are places with geological, paleontological, geomorphological, lithological, or hydrogeological relevance, which have scientific, educational, and/or tourist potential. Sites of complementary interest (or geodiversity, according to Brilha et al., 2018) refer to areas with archaeological, historical-cultural, scenic, or ecological value, which, although not strictly geological, contribute to the integrated appreciation of the landscape and territory.

Geoparks, which encompass geosites—many of which are internationally important for their contributions to understanding the Earth's geological history—have aroused growing interest in the scientific community. This interest has driven a significant increase in publications in different areas of knowledge.

In this context, the role of Geomorphology stands out as an essential science for the integrated reading of the landscape, based on interdisciplinary, systemic, and methodologically plural approaches (MOTA *et al.*, 2025). Because it integrates geodiversity, Geomorphology frequently appears in studies on geoparks, especially in the characterization of geosites and in the analysis of natural landscapes. However, its presence is not always evident or systematized, and is often used implicitly, as descriptive or contextual support.

This panorama highlights the need for investigations that analyze not only the incidence of Geomorphology in publications on geoparks, but also the nature of its incorporation — that is, to what extent its concepts, methods, and approaches have been applied superficially or in-depth. This application can range from basic morphological descriptions to analyses aimed at understanding dynamic processes, landscape modeling, scientific, and aesthetic valuation of geosites, or their articulation with cultural, educational, and land-use planning dimensions.

To this end, bibliometric methods prove to be effective tools in measuring scientific production, allowing us to assess impact, map trends, identify gaps, and observe relationship patterns between themes, authors, and institutions (HERRERA-FRANCO *et al.*, 2021). Using data such as citations, keywords, years of publication, and co-occurrence networks, it is possible to build a comprehensive view of the thematic evolution around geoparks (MARTÍNEZ-MARTÍN *et al.*, 2023).

Therefore, this study proposes an integrated approach to scientific production related to UNESCO Global Geoparks, with two central objectives: (i) to conduct a bibliometric analysis of national and international literature published between 2007 and 2024, in the Scopus and Web of Science databases, identifying publication patterns, most productive authors, recurring terms, and countries with greater representation; and (ii) to develop a thematic reading aimed at identifying and qualifying the presence of Geomorphology in research on geoparks.

Unlike previous studies dealing with geoheritage, geosites (HERRERA-FRANCO *et al.*, 2022), methodological approaches in geoconservation, geotourism, and geoheritage (QUESADA-VALVERDE e QUESADA-ROMÁN, 2023), or bibliometric analyses focused on the theme of Global Geoparks (PÉREZ-ROMERO *et al.*, 2023; HERRERA-FRANCO *et al.*, 2021), this work is distinguished by adding a specific interpretative perspective on the role of Geomorphology in the field.

It is understood that, although it is not a mandatory component, Geomorphology constitutes one of the possible dimensions for the study of geoparks, especially due to its capacity to integrate the reading of relief, natural processes, and interfaces with scientific, educational, and landscape values. Rather than pointing out its absence as a flaw, we seek to understand the contexts, purposes, and strategies that motivate its adoption, whether as a conceptual tool, descriptive language, or methodological resource.

By combining bibliometric analysis with a qualitative thematic approach, the study not only enables mapping of quantitative patterns but also interprets the degree of depth and how Geomorphology has been mobilized. This perspective helps to highlight the connections between geodiversity, geoparks, and geomorphological approaches, deepening the reflection on their implications for research, management, and valorization of geoparked territories.

2. Materials and methods

The literature review is fundamental for knowledge management in a research area, as it maps and evaluates the scientific production of a specific field, the results of which are used for decision-making (HERRERA-FRANCO *et al.*, 2020; PÉREZ-ROMERO *et al.*, 2023). This process requires a formal and rigorous methodological procedure that must be reproducible and include an exhaustive analysis with clear contextual relationships, thereby characterizing a systematic literature review (HERRERA-FRANCO *et al.*, 2021). Methodological precision is equally crucial for bibliometric analyses, ensuring the quality of the information used (HERRERA-FRANCO *et al.*, 2020).

Bibliometric analysis, a field within scientometrics, employs statistical and mathematical methods to examine scientific production, including its characteristics, evolution, and monitoring. As highlighted by Herrera-Franco *et al.* (2021), there are two main procedures: (1) analysis of the performance of scientific production, which assesses the impact of the field of study and its stakeholders (such as countries, universities, and authors), and (2) bibliometric mapping combined with clustering techniques, which reveals the cognitive structure and behavior of the scientific field through the analysis of its themes, disciplines, and research areas.

To meet the two proposed methods, this study adopts a methodology structured in four stages: (1) selection of databases and definition of search criteria; (2) extraction and manipulation of data; (3) analysis and interpretation of results; and (4) complementary thematic analysis, with a specific focus on geomorphology. This process is developed in two spheres: international and national, allowing an articulated comparison between different scales of approach.

2.1 Step 01 – Databases and search criteria

The choice of databases is a fundamental step in bibliometric studies, as it directly influences the scope and representativeness of the results. In this research, bibliographic materials from the international databases SCOPUS and Web of Science (WoS) were used. Both are widely recognized globally for bringing together articles published in high-quality scientific journals, providing citation data, facilitating the download of information, and offering excellent coverage of journals in the field of geosciences, contributing significantly to bibliometric analysis.

Data collection was conducted on June 12, 2024. The term "geopark" in English was used, with four spelling variations, combined with Boolean operators (AND, NEAR, and W) to associate it with terms related to the "geo" theme and UNESCO. Table 1 presents the search strategy used in both databases.

The initial collection in the two databases generated 455 articles. However, after filtering only articles in English, ensuring the possibility of access or download, and removing duplicates identified by DOI using Mendeley software, the number of articles was reduced to 172. It is essential to note that the duplication check was also conducted by the Start software and RStudio (version 2023.12.1+402). However, this check presented discrepancies and did not completely eliminate all duplicates, due to errors in comparing metadata characters, especially in cases of accentuation, which caused some data to be inconsistent. Table 2 shows the quantitative relationship between the search and the reduction resulting from the application of the criteria.

Table 1. Search strategy in SCOPUS and Web of Science databases.

Search combinations: OPERATORS: **(W – SCOPUS** **(NEAR – Web of Science)**	*TITLE* (geopark ***OR*** *geoparks* ***OR*** *geo-park* ***OR*** *geo-parks)* ***AND*** *KEYWORDS (geopark* ***OR*** *geoparks* ***OR*** *geo-park* ***OR*** *geo-parks)* ***AND*** *ABSTRACT (geopark* ***OR*** *geoparks* ***OR*** *geo-park* ***OR*** *geo-parks)* ***AND*** *ARTICLE TITLE, ABSTRACT, KEYWORDS (geo** ***W-NEAR/10*** *geo*)* ***AND*** *ARTICLE TITLE, ABSTRACT, KEYWORDS* (UNESCO)

Table 2. Quantitative results of the search in SCOPUS and Web of Science databases after applying filters.

Process/Database	SCOPUS	Web of Science	Total
		International scope	
Search	259	196	455
Articles	195	159	354
English	163	147	310
Acessible	150	129	279
Duplicates		107	172
		National scope (Brazil)	
Restricted to Brazil	10	8	18
Accessible	9	8	17
Duplicates		7	10

In contrast to other reviews that integrated several databases (HERRERA-FRANCO *et al.*, 2021) or focused on just one (PÉREZ-ROMERO *et al.*, 2023), this study chose to work with the databases both separately and combined. The decision was based on the understanding that each base presents variations in terms of production volume, research, classification, global involvement, and thematic composition for different countries. Furthermore, it is recognized that the results of bibliometric analyses may vary depending on the database used (SINGH *et al.*, 2021; MONGEON, PAUL-HUS, 2016). Therefore, the analysis will be conducted individually for each base, allowing comparisons in performance and also combinations of these bases in scientific mapping related to the Geoparks theme.

This analysis presents some methodological limitations that must be considered. Firstly, the scope was restricted to academic articles, excluding other types of documents, such as books, book chapters, and proceedings of scientific events, which may have resulted in the omission of relevant contributions on the topic. Furthermore, we chose to analyze only publications in English, the language with the greatest international circulation, which may have resulted in the underrepresentation of relevant studies published in other languages, such as Portuguese, Spanish, French, or Chinese. It is also possible that certain articles were not retrieved due to the specific indexing criteria of the SCOPUS and Web of Science databases, or their limited availability via institutional access (CAPES).

Despite these limitations, the research adopts a systematic approach and uses widely recognized databases in the scientific community. The careful selection of keywords, the defined time frame, and the volume of documents analyzed lend reliability to the results, allowing this study to serve as a solid basis for future investigations. Future studies could broaden the scope of the analysis by including other databases, languages, and document types, contributing to a more comprehensive view of the scientific production on UNESCO Global Geoparks.

2.2. Step 2 – Data extraction and manipulation

The collected data were reviewed and examined for their relevance to the research topic. To this end, the bibliographic information from the 150 documents in the SCOPUS database and the 129 documents in the WoS database was exported in BibTex format, a text file format used to organize bibliographic listings. Data manipulation was performed using RStudio (version) and Bibliometrix (ARIA and CUCCURULLO, 2017)) software, which were used to combine the databases, review, debug, and statistical analysis of the three data sets (individual and combined), together with Excel. Extracted metadata included authors, affiliations, titles, publication years, cited publications, abstracts, author keywords, index keywords, references, and other relevant bibliographic information. There was no need to delete any records because the metadata was absent. For intellectual structure mapping, VOSviewer was used due to its graphic quality.

2.3. Step 3 – Data analysis and interpretation

For the analysis and interpretation of information, two bibliometric review approaches were used: (1) analysis of the performance of scientific production and (2) scientific mapping.

In the first approach, the performance of scientific production is analyzed through annual publications and citations, productivity by country, author productivity, affiliations, and journals, as well as frequently cited documents. In scientific mapping, the co-occurrence of authors' keywords is analyzed in nodes and clusters.

2.4. Step 4 – Complementary thematic analysis: focus on geomorphology

In addition to the general bibliometric analysis on geoparks, this study conducted a qualitative thematic analysis to identify and characterize the presence of geomorphology in the scientific production on UNESCO Global Geoparks. This stage aims to understand how this component of geodiversity has been addressed in the scientific literature on geoparks, exploring not only its frequency but also the methodological, contextual, and interpretative approaches attributed to the theme.

The screening was conducted on the 172 articles included in the final sample by checking for explicit mentions of the term "geomorphology" in the titles, keywords, abstracts, and subsequently in excerpts from the text. The articles that were directly related to the topic were read in full and organized into a qualitative analysis spreadsheet.

The classification of studies followed five main criteria: 1) Geomorphological approach: whether the theme appears as a central focus, as analytical support, or only as a specific mention; 2) Instruments and methods: geomorphological cartography, landform analysis, use of digital elevation models (DEM), geosite inventories, among others; 3) Landscape focus: degree of integration between relief and natural, cultural, or geotourism landscape; 4) Type of insertion: explicit and methodological presence of geomorphology or only implicit and descriptive use; 5) Analytical contributions: implications for the management, conservation, or interpretation of the landscape in the context of geoparks.

Additionally, a qualitative classification of thematic affinity between the studies and Geomorphology was established, adapted from the proposal by Mota *et al.* (2025). The articles were categorized into four levels: low affinity, when geomorphology is mentioned in a specific way and disconnected from the main objective; moderate affinity, when there is a related methodological or descriptive application, but without conceptual depth or contextual integration; high affinity, when the geomorphological theme structures the methods and objectives of the study in an articulated way; and very high affinity, when the geomorphological approach constitutes the central axis of the research, explicitly articulating with the landscape and with aspects of management, conservation and/or geotourism in the context of geoparks. This classification was assigned based on a full reading of the articles and supported the construction of the comparative table presented in the results section.

The systematization of the results of this thematic analysis is presented in the results section, supported by a comparative table that illustrates the different levels of geomorphology approach and the degrees of thematic affinity in studies on geoparks. This stage reinforces the articulation between quantitative and qualitative analyses, as proposed in the objectives of this study.

3. International Results

The 172 articles obtained cover the period from 2007 to 2024. Table 3 presents the main information related to the sets of articles from the two individual databases and their combined dataset.

Table 3. Search combination for databases.

Main information	SCOPUS	Web of Science	SCOPUS e WoS
Articles	150	129	172
Time span	2007 a 2024	2011 a 2024	2007 a 2024
Authors	549	538	671
Co-authors per document	4.22	4.67	4.49
Authors' keywords	503	489	607
References	8993	6465	8886
Average citations per document	11.26	8.023	9.465

The SCOPUS database spans a longer period than the Web of Science, with a four-year difference. Although there is a duplication of 107 articles, SCOPUS stands out for the number of references in the 150 articles and the average number of citations per document. The oldest article available in the SCOPUS database, dated 2007, is "*Multi-designated geoparks face challenges in China's heritage conservation.*" *The* most recent, from June 2024, is *Geological and mining heritages in the Seridó UNESCO Global Geopark: Ediacaran to Cambrian mineral deposits revealed by historical mines in Northeast Brazil.*" On the Web of Science, the oldest article is from 2011, titled *The Langkawi Global Geopark: local community's perspectives on public education,*" and the most recent is "*Objective or subjective adjectives? A case study on UNESCO Global Geopark tourism texts.*

3.1. Analysis of the performance of scientific production

3.1.1. Analysis of publications by year and citations

Among the measures used to analyze the performance of an area of knowledge, the most prominent is the number of publications and citations per year. The number of publications is an indicator of productivity, while the number of citations measures impact.

The analysis of scientific production was conducted through the number of publications per year, allowing the evaluation of scientific literary evolution through bibliometric productivity indicators, specifically Price's Law (HERRERA-FRANCO *et al.*, 2021; MONTERO *et al.*, 2016). This bibliometric indicator is used to determine whether the increase in scientific production follows an exponential or linear growth law. For the study, linear and exponential adjustments were made to the data obtained from SCOPUS and Web of Science, resulting in the following equations, as shown in Figures 2 and 3.

The R^2 values (coefficient of determination) were higher for linear regression (0.645 and 0.582, respectively) than for the exponential curve (0.589 and 0.493), indicating that the linear fit was superior. This is because a higher R^2 suggests that linear regression can explain a greater proportion of the variability in the data around the mean, implying that the relationship between the variables is better represented by a linear pattern than by an exponential pattern.

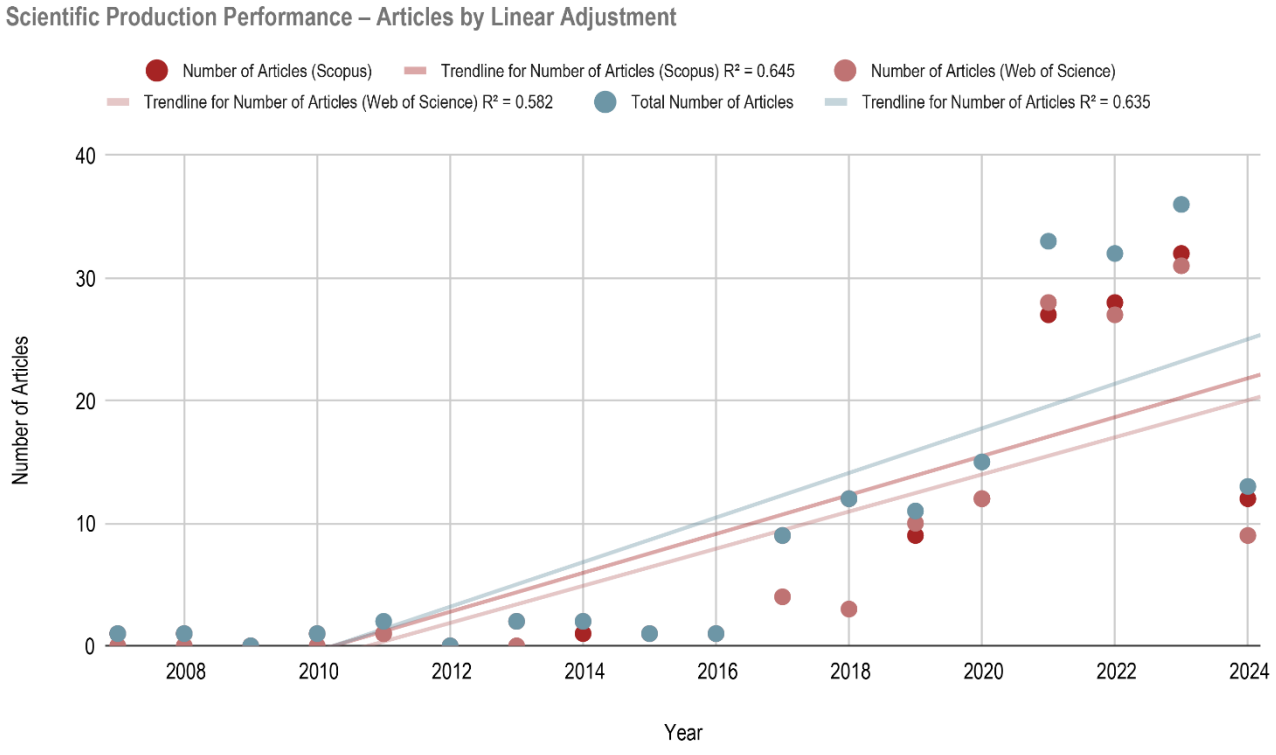

Figure 2. Graph on the performance of scientific production with linear adjustment. Source: prepared by the authors, 2024.

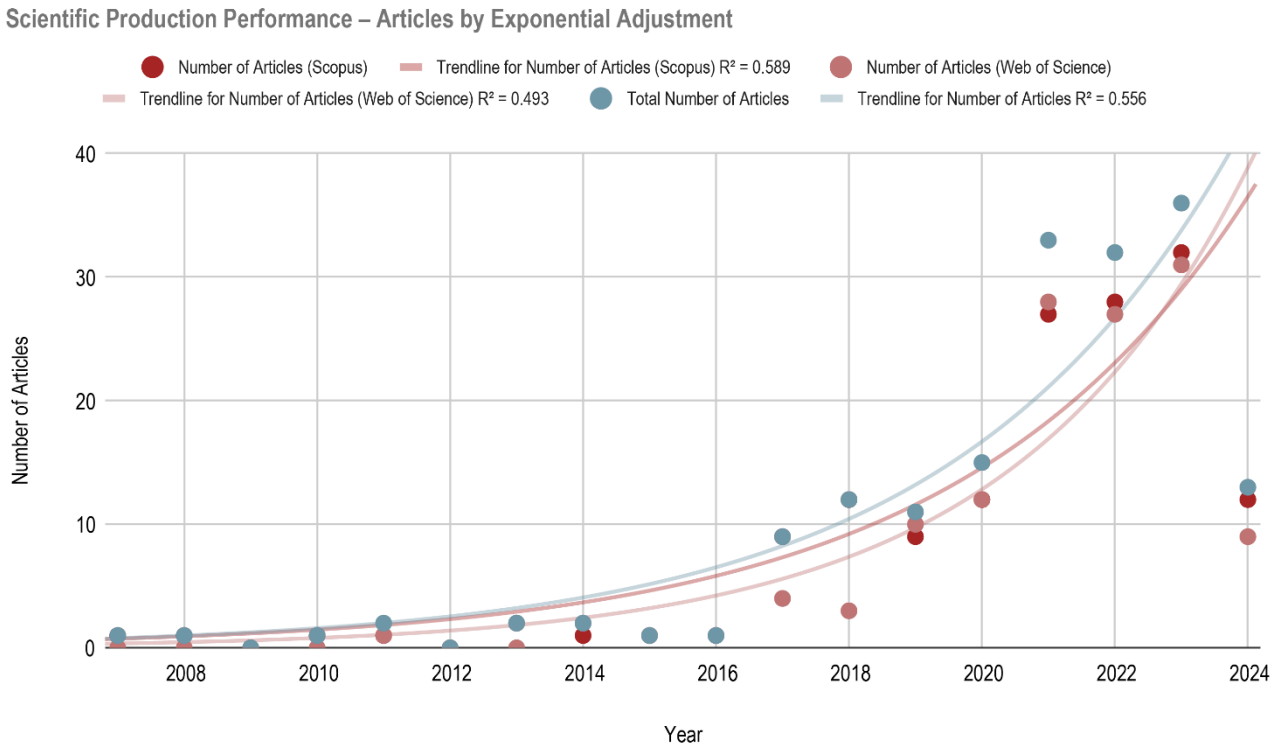

Figure 3. Graph on the performance of scientific production with exponential adjustment. Source: prepared by the authors, 2024.

However, the data presents inconsistencies. An analysis up to 2023, discounting 21 articles already published by mid-2024, suggests a panorama of exponential growth in publications on geoparks. The R^2 values are 0.933 and 0.927 for the exponential curve in SCOPUS and Web of Science, respectively, and 0.707 and 0.662 for linear regression. It is worth noting that growth has accelerated since 2017, making exploration of the topic relatively recent.

The most productive years (without duplicate articles) were 2023, with 36 articles in total; followed by 2021, with 33 publications; and 2022, with 32 articles. These three years together represent almost 60% of the total articles. This indicates that the topic is a trend in the scientific community, suggesting that geoparks are effectively contributing to their objectives and have great potential. The average annual growth rate during the study period is 15.74% (SCOPUS) and 18.41% (Web of Science), according to data obtained through Bibliometrix.

The considerations made can validate the logarithmic regression curve of citations presented in Figure 4, which evidences a significant number of citations reflecting the high influence of publications over the years, especially from 2018 onwards. Notably, 2023 reached 825 citations, the highest to date. It is worth noting that the search was conducted before the middle of 2024, which indicates that the significant numbers already recorded in the current year may exceed those of 2023, confirming the growth trend of the topic.

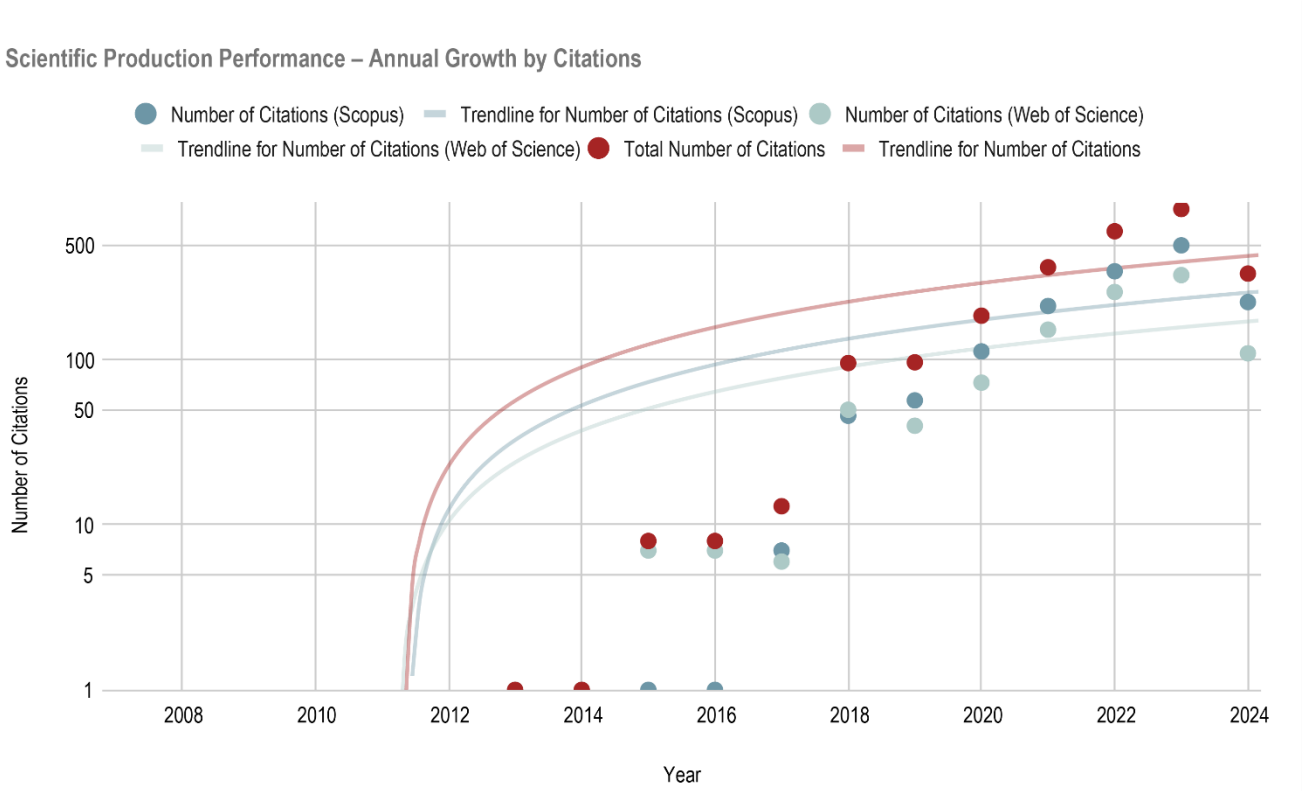

Figure 4. Graph showing the performance of scientific production in relation to citations. Source: prepared by the authors, 2024.

Due to the asymmetric distribution of citations, it is observed that, although publications began in 2007, citations began to appear in 2013, corroborating a recent trend.

3.1.2. Productivity analysis by country

Given that Geoparks are a global initiative, it is important to conduct a detailed analysis of production in each country. The global contribution includes 43 countries, 8 in Latin America, 20 in Europe, 1 in Oceania, 3 in Africa, and 11 in Asia. Among these, Portugal, China, Spain, Italy, and Brazil stand out as the main contributors. The distribution of the other countries is illustrated in Figure 5, where they are represented based on the data and symbolized by the number of production. It is worth noting that China (41 + 6 approved in 2024) and Spain (16) rank first and second, respectively, in the number of Geoparks, while Portugal has 5 plus 1 approved in 2024, Italy has 11, and Brazil has 5 plus 1 approved in 2024.

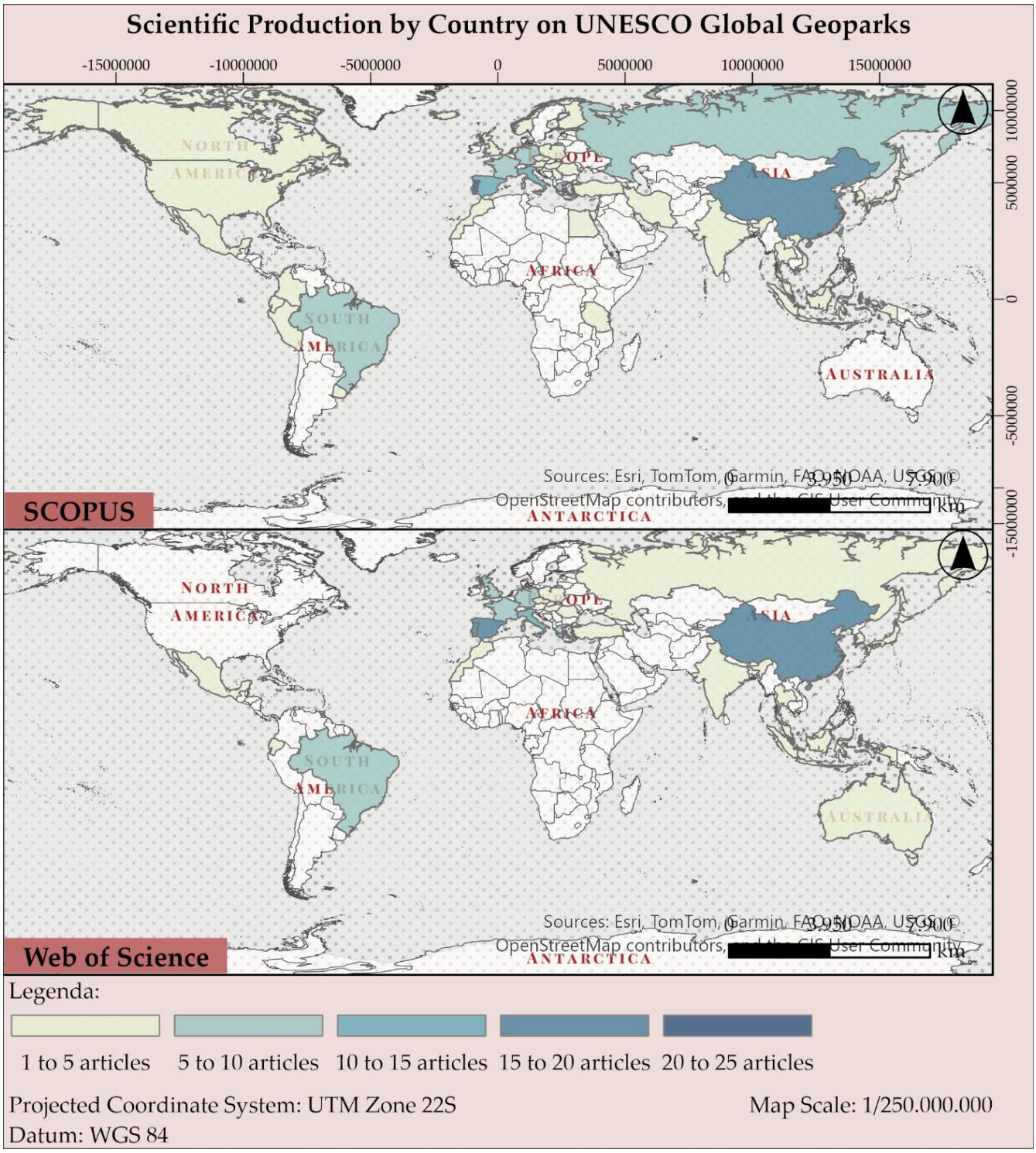

Figure 5. Spatial distribution of scientific productivity. Source: prepared by the authors, 2024.

Interestingly, countries such as Colombia, Egypt, the United States, Luxembourg, and India do not have Geoparks, yet they have still made significant contributions to the field. In contrast, countries such as Chile (1), Cyprus (1), Croatia (2), Ireland (2), Nicaragua (1), New Zealand (1), the Philippines (1), and Sweden (1), despite having at least one Geopark in their territory, did not record scientific contributions.

Considering the countries that produced the most scientific work, highlighted above, Table 4 presents the number of contributions, as well as the most recurring keywords, the authors with the most publications, an analysis of bigrams (a sequence of two consecutive elements in a text) and trigrams (three elements in sequence) of the article abstracts, in addition to the predominant areas of study and research, to highlight the topics most

covered in the publications of these countries. This set of information is helpful for a study of geoparks, providing a more specific vocabulary for textual analysis and future academic research in geopark-related areas.

Table 4. Main contributions from countries and main topics, authors, and areas of study related to these countries.

Country Contributions	Topics, main authors, and fields of study		
	Keywords and main authors	**Bigrams and trigrams from abstracts**	**Fields of study/research**
Portugal (Europe) SCOPUS = 23 (15.33%) WoS = 19 (14.72%) Duplicates = 13	Geoparks Geotourism Geoconservation Geoheritage UNESCO Global Geopark	Global Geopark(s) Geoparks UGGps UNESCO Global Geological Heritage	(SCOPUS) Earth and Planetary Sciences Social Sciences Environmental Sciences
	SÁ, Artur A.; BRILHA, José B. R.; HENRIQUES, Maria H.	UNESCO Global Geopark(s) Global Geoparks UGGps	(WoS) Geology Geography Paleontology
China (Asia) SCOPUS = 19 (12.66%) WoS = 19 (14.72%) Duplicates = 17	Geotourism Geopark Geoconservation Geodiversity Geoheritage	Ecological quality Popular science Global geoparks Sustainable development National Geopark	Earth and Planetary Sciences Environmental Sciences Social Sciences
	WU, Fadong; HAN, Jin-fang; LI, Xiuming; CAI, Yinlu; WANG, Yanjie.	UNESCO Global Geoparks Organization UNESCO Global Nations Educational Scientific Cultural Organization UNESCO UNESCO Global Geopark	Geology Environmental Sciences – Ecology Paleontology
Spain (Europe) SCOPUS = 15 (10%) WoS = 19 (14.72%) Duplicates = 13	Geopark Geoconservation Geoparks Geotourism Geoheritage	UNESCO global Global geopark Geological heritage Global geoparks	Earth and Planetary Sciences Social Sciences Environmental Sciences
	GUTIERREZ-MARCO, Juan C.; SÁ, Artur A.; MARINOSO, Pilar E.; MARTÍNEZ-MARTÍN, Jesús E.; ROSADO-GONZÁLEZ, Emmaline M.	UNESCO Global Geopark(s)	Geology Geography Paleontology Environmental Sciences – Ecology
Italy (Europe) SCOPUS = 13 (8.66%) WoS = 14 (10.85%) Duplicates =4	Geotourism Geoparks Geodiversity Geoturism Sustainable development	UNESCO global Sustainable development Cultural heritage Sesia Val Grande UNESCO Global Geopark	Environmental Sciences Earth and Planetary Sciences Social Sciences
	GIARDINO, Marco; PEROTTI, Luigi; FIRPO, Marco; VIANI, Cristina.		Environmental Sciences – Ecology Technology Sciences Geology
Brazil (America) SCOPUS = 9 (6%) WoS = 8 (6.20%)	Geoheritage Geopark Geodiversity Geosites Brazil	Global Geoparks Geological heritage Unesco Global Unesco Global Geopark	Earth and Planetary Sciences Social Sciences Environmental Sciences
	COSTA, Silas Samuel dos Santos		Geology

The table reveals a diversity of approaches to geoparks, highlighting themes such as “Geotourism," “Geoconservation," and “Geoheritage," with a focus on the conservation of geological heritage. The most productive countries address these issues globally, with an emphasis on UNESCO policies and Sustainable Development. The areas of study are interdisciplinary, involving Earth Sciences, Environmental Sciences, and Social Sciences, indicating the need for integrated approaches to the management and promotion of geoparks, which also require contributions from Ecology, Sustainability, and Cultural Heritage.

3.1.3. Analysis of the productivity level of authors, affiliations, and journals

The authors were classified into groups based on their productivity level (PL), resulting in six groups for the 671 authors from the combined SCOPUS and Web of Science databases, as shown in Table 5. The PL=01 group includes authors with a single scientific contribution, which is the vast majority. In contrast, the PL=06 group has only one author, with six published documents. Regarding documents with single authorship, there are 21 documents and 18 authors in this situation.

Table 5: List of written documents and authorship.

Written documents	Number of authors	Proportion of authors
1	603	0.899
2	48	0.072
3	11	0.016
4	6	0.009
5	2	0.003
6	1	0.001

Of the 307 affiliations with contributions, the University of Coimbra (Portugal), Chinese University of Geosciences, University of Trás-os-Montes (Portugal), Federal University of Rio Grande do Norte (Brazil), University of Estremadura (Spain), and Federal University of Rio de Janeiro (Brazil) stand out, with respective contribution quantities of 18, 15, 14, 11, 8, and 7. Portugal, a country already known for its great contributions, has two outstanding universities. Brazil's presence in scientific production, particularly through two universities, is noteworthy, especially in collaborations with Portugal.

Regarding the journals that disseminate these scientific contributions, the selection encompasses 53 journals for the 172 articles analyzed (using SCOPUS and Web of Science). Table 6 presents three groups: journals with up to two articles, which represent the majority and account for around 30% of publications; a second category comprising six journals that published between three and ten articles; and, finally, four journals with more than ten articles published. There is a significant concentration of articles in journals such as Geoheritage, Geosciences, Land and Geoconservation Research, which together account for 52.33% of publications. This pattern may indicate both the thematic specialization of these journals in geosciences and geoconservation, as well as a limitation in the number of journals specifically focused on the topic of geoparks. It is worth noting that, although some of these journals are recognized in the field, not all have a high impact factor in traditional rankings, which reinforces the importance of also considering their thematic relevance and adherence to the research scope, primarily since they represent a significant percentage in the general context of publications on the topic.

Table 6. List of written documents and authorship.

Publication groups	Journals	Percentage of journals	Number of articles	Percentage of publications
Up to 2 articles	43 journals	81.15%	48	27.91%
3 to 10 articles	6 journals	11.32%	34	19.77%
More than 10 articles	Geosciences (Switzerland)	1.88%	11	6.40%
	Land (Switzerland)	1.88%	13	7.56%
	Geoconservation Research (Iran)	1.88%	23	13.37%
	Geoheritage (United Kingdom)	1.88%	43	25.00%

Total:	53 journals	100%	172	100%

This panorama showcases the diversity and scope of scientific production in geoparks, highlighting both the concentration of efforts in a few prominent institutions and the dissemination of knowledge through a diverse range of journals. Collaboration between countries, as observed in the case of Brazil and Portugal, highlights the importance of international partnerships in expanding and deepening research in this area. With a quarter of publications concentrated in a single journal, the importance of specialized vehicles in disseminating specific knowledge is also evident, which significantly contributes to the visibility and impact of the research developed.

3.1.4. Analysis of frequently cited documents

When evaluating a research area, it is essential to consider articles based on the citations they receive, as this allows one to identify the most influential publications in a specific scientific field. Citations indicate connections between publications. Based on the number of citations and the year of publication of the article, it is possible to calculate the Annual Citation Index (ACI) and understand whether a recent publication already has a great influence. Among the 172 articles analyzed, Table 7 presents the 10 most cited articles and their respective values, as well as the Annual Citation Index for each database considered individually.

Table 7. The 10 most cited and influential articles.

	Classification, title, authors, journal, and year	Citations	ACI
1	Worldwide Research on Geoparks through Bibliometric Analysis Gricelda Herrera-Franco, Néstor Montalván-Burbano, Paúl Carrión-Mero, María Jaya-Montalvo e Miguel Gurumendi-Noriega (Sustainability, 2021)	99 S 80 W	20,00
2	Geodiversity as a precious national resource: A note on the role of geoparks Dmitry A. Ruban (Resources Policy, 2017)	72 S 62 W	7,75
3	The Role of UNESCO Global Geoparks in Promoting Geosciences Education for Sustainability Maria Manuela Catana e José B. Brilha (Geoheritage, 2020)	59 S 48 W	9,60
4	From Geopark to Sustainable Development: Heritage Conservation and Geotourism Promotion in the Huangshan UNESCO Global Geopark (China) Jinfang Han, Fadong Wu, Mingzhong Tian e Wei Li (Geoheritage, 2018)	51 S 42 W	6,00
5	UNESCO Global Geoparks, Geotourism and Communication of the Earth Sciences: A Case Study in the Chablais UNESCO Global Geopark, France Sophie Catherine Justice (Geosciences, 2018)	45 S	6,50
	Using Tourism Carrying Capacity to Strengthen UNESCO Global Geopark Management in Hong Kong Wei Guo e Shanshan Chung (Geoheritage, 2019)	41 W	6,80
6	Geoproducts – Innovative development strategies in UNESCO Geoparks: Concept, implementation methodology, and case studies from Naturtejo Global Geopark, Portugal Joana Rodrigues, Carlos Neto de Carvalho, Mário Ramos, Raquel Ramos, Ana Vinagre e Helena Vinagre (International Journal of Geoheritage and Parks, 2021)	39 S	9,75
	Analysis of Network Activities in Geoparks as Geotourism Destinations Neda T. Farsani, Celeste O. A. Coelho, Carlos M. M. Costa (International Journal of Tourism Research, 2014)	30 W	2,70
7	Economic impact of UNESCO Global Geoparks on local communities: Comparative analysis of three UNESCO Global Geoparks in Asia Yu Jin Lee, Ramasamy Jayakumar	33 S	8,25

	(International Journal of Geoheritage and Parks, 2021)		
8	Geotourism, geoconservation, and geodiversity along the belt and road: A case study of Dunhuang UNESCO Global Geopark in China Yanjie Wang, Fadong Wu, Xiuming Li, Lihong Chen (Proceedings of the Geologists' Association, 2019)	28 W 32 S	4,65
	Geodiversity evaluation and water resources in the Sesia Val Grande UNESCO Geopark (Italy) Luigi Perotti, Gilda Carraro, Marco Giardino, Domenico A. de Luca, Manuela Lasanha (Water - Água, 2019)	27 W	4,50
9	Fieldtrips and Virtual Tours as Geotourism Resources: Examples from the Sesia Val Grande UNESCO Global Geopark (NW Italy) Luigi Perotti, Irene Maria Bollati, Cristina Viani, Enrico Zanoletti, Valeria Caironi, Manuela Pelfini e Maco Giardino (Resources, 2020)	31 S 26 W	5,20
	Geodiversity evaluation and water resources in the Sesia Val Grande UNESCO Geopark (Italy)		
10	Promoting sustainability in a low density territory through geoheritage: Casa da Pedra case-study (Araripe Geopark, NE Brazil) M. H. Henriques, A. R. S. F. Castro, Y. R. Félix, I. S. Carvalho (Resources Policy, 2020)	25 W	5,00

S Number of citations in the SCOPUS database.

W Number of citations in the Web of Science database.

The article "*Worldwide Research on Geoparks through Bibliometric Analysis*", published in 2021 by Gricelda Herrera-Franco, Néstor Montalván-Burbano, Paúl Carrión-Mero, María Jaya-Montalvo, and Miguel Gurumendi-Noriega, leads the number of citations in the SCOPUS (99) and Web of Science (80) databases. The study analyzed the academic production on geoparks between 2002 and 2020 in the SCOPUS database, using the search strategy terms (*TITLE-ABS-KEY (Geopark) OR TITLE-ABS-KEY (Geoparks) OR TITLE-ABS-KEY (geo-park) OR TITLE-ABS-KEY (geo-park)*), resulting in 1032 documents (including articles, reviews, and other types of publications). Already at that time, the authors highlighted the growth of the area and the consolidation of geoparks as an emerging scientific discipline. The thematic concentration on discussions about geomorphological heritage and geotourism stands out, with an emphasis on methodologies aimed at identifying, evaluating, and valuing geosites/geomorphosites, to reduce subjectivities and reinforce the role of geoparks in sustainable territorial development.

It is worth noting that this type of bibliometric study tends to achieve a high number of citations due to its usefulness as a structuring reference for researchers in the field, serving as a starting point for new work, identifying gaps, and building theoretical and methodological frameworks. In addition to contributing to the advancement of the field, this type of approach also enhances the journals in which it is published, thereby increasing their impact factor and relevance within the scientific community.

The second most influential is the article "*Geodiversity as a Precious National Resource: A Note on the Role of Geoparks* ", published in 2017 by Dmitry A. Ruban. In this article, the author addresses geodiversity as a set of geological phenomena in a given area, considering it a geological resource of national importance. In this context, geoparks are crucial for the exploration of these resources; however, as an international initiative, they often exclude geological heritage sites that are relevant in national contexts, which is a limitation. The author recommends that countries develop their policies for the efficient exploitation of geodiversity resources through the creation of geoparks, highlighting that "geoparks should be established to reflect the diversity of geological phenomena in the country" (RUBAN, 2017).

Third, the article "*The Role of UNESCO Global Geoparks in Promoting Geosciences Education for Sustainability*", published in 2020 by Maria Manuela Catana and José B. Brilha, explores the role played by geoparks in promoting geoscience education for sustainability, based on educational programs based on data obtained through a questionnaire answered by seventy-three UNESCO Global Geoparks from thirty-five countries. The results were used to propose resources for application in geoparks, promoting education, one of the pillars of the certification. Some recommendations include: (i) Educational program staff should have specific training in geology; (ii)

Programs should complement formal education; (iii) They should focus on national curriculum topics and be adapted to different school levels; (iv) Collaboration with partners such as schools, universities, training centers, museums, and adventure companies can be beneficial.

Analysis of the most cited articles highlights not only the influence of these publications on the field of study, but also emerging trends and focuses within geopark research. The recommendations and conclusions of these studies are valuable for guiding future research and policies related to the conservation and sustainable use of geological resources.

3.2. Scientific Mapping

3.2.1. Author keyword co-occurrence network

The author keyword co-occurrence network in scientific mapping reveals the most frequently occurring keywords and their connections within the field of study. This enables the identification of concepts (keywords) and topics (sets of related concepts), highlighting the areas of greatest relevance and search frequency. The analysis was performed using VOSviewer, which allows a multidimensional and visual representation. The software was configured to maintain a minimum of five co-occurrences, resulting in 39 nodes and four clusters. Figures 6 and 7 present four clusters, with 39 nodes, 458 links, and a total link strength of 1290, also spatialized by time. The terms 'UNESCO' and 'geotourism' appear 70 times each, being the most relevant words, while the terms 'geopark' and 'geoparks' appear, respectively, 50 and 27 times, being the fifth and seventh most relevant words, as shown in Table 8.

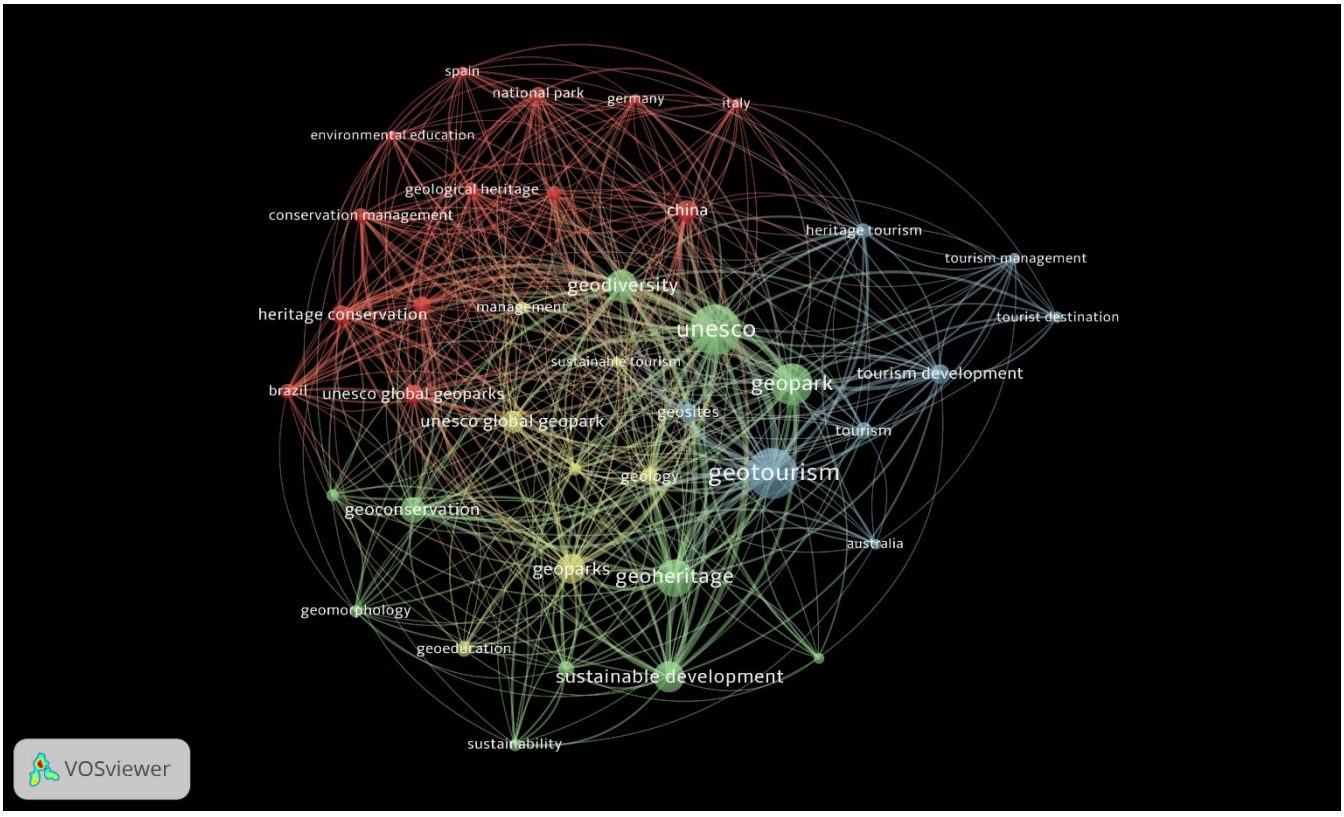

Figure 6. Clustered co-occurrence network of databases at the international level. Source: prepared by the authors, 2024.

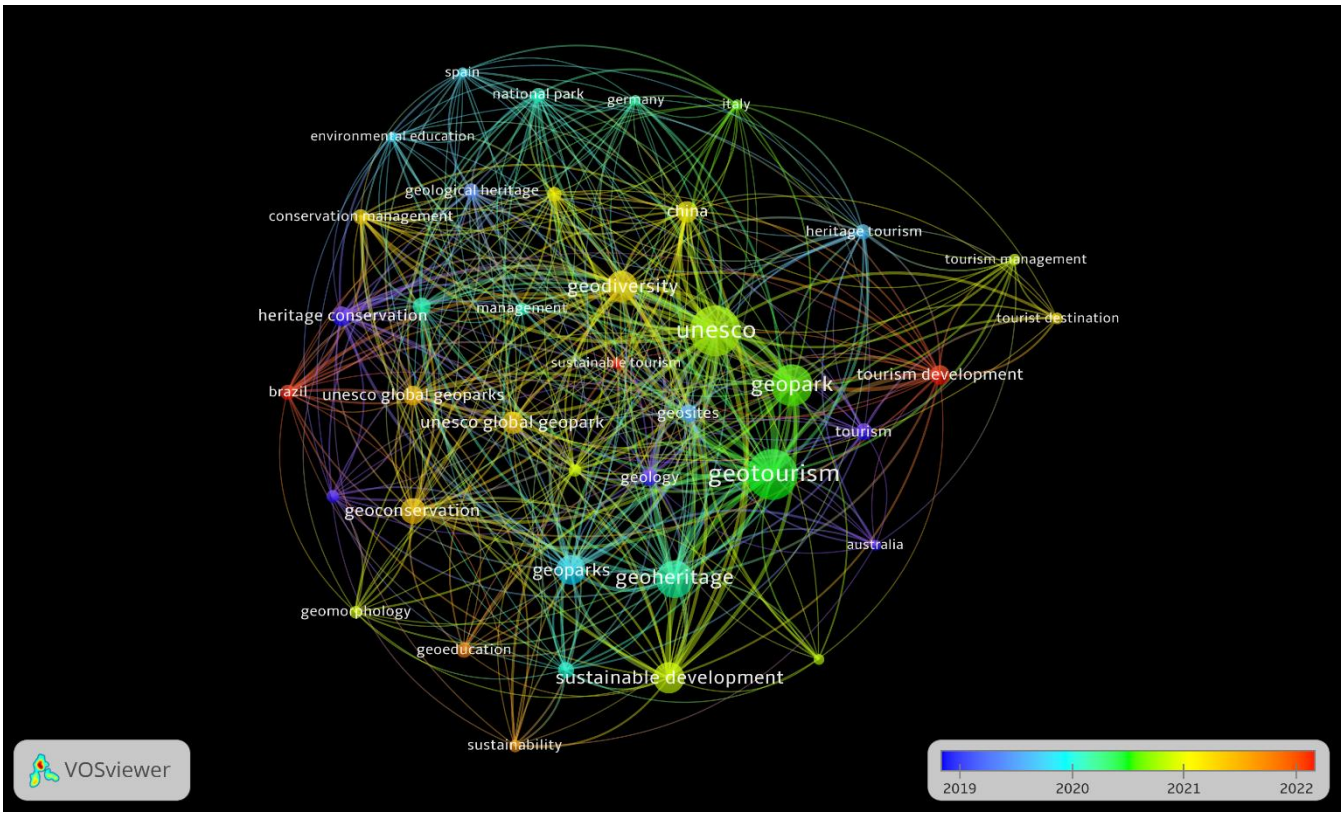

Figure 7. Clustered co-occurrence network and temporality of databases at the international level. Source: prepared by the authors, 2024.

Table 8. Author keyword co-occurrence network results for international results.

Cluster	Co-occurrences	Links	Total Link Strength	Author Keywords
Cluster 1 13 nodes (red)	9	22	50	Brazil
	16	32	86	China
	9	24	59	conservation management
	12	27	61	cultural heritage
	5	19	26	environmental education
	9	26	52	geological heritage
	5	20	31	Germany
	14	31	76	heritage conservation
	5	22	34	Italy
	8	26	55	national park
	8	27	50	Portugal
	5	21	35	Spain
	14	27	60	Unesco Global Geoparks
Cluster 2 11 nodes (green)	5	13	21	assessment method
	7	18	30	conservation
	10	22	40	education
	22	27	76	geoconservation
	30	32	140	geodiversity
	42	33	151	geoheritage
	7	17	25	geomorphology
	50	31	137	geoparque
	7	14	27	sustainability

	31	28	125	sustainable development
	70	38	316	Unesco
Cluster 3 8 nodes (blue)	5	13	22	Australia
	12	21	48	geosites
	70	36	245	geoturism
	9	24	46	heritage tourism
	11	22	39	tourism
	14	26	68	tourism development
	6	13	24	tourism management
	6	10	24	tourist destination
Cluster 4 7 nodes (yellow)	9	13	24	geoeducation
	11	28	47	geology
	27	31	99	geoparks
	7	15	24	management
	7	24	38	park management
	5	16	22	sustainable tourism
	18	26	47	Unesco Global Geopark

Cluster 1 has the term "China" as the most prominent, with 16 co-occurrences. In this same cluster, other countries, such as Brazil, Germany, Italy, Portugal, and Spain, are also related to conservation, cultural heritage, geology, and UNESCO Global Geoparks. In cluster 2, the strongest word is "UNESCO" with 70 co-occurrences, associated with other thematic terms, generally reflecting the topics/themes of the articles. Cluster 3 highlights the term "geotourism" as the most relevant, complemented by words such as "tourism" and focusing on "geosites". Cluster 4 features "geoparks" as its primary term, linked to geoeducation, geology, and management.

These results underscore the significance of specific keywords in developing knowledge about geoparks and geotourism. Bibliometric analysis not only identifies the main areas of interest and study but also reveals the relationships between different concepts and geographic regions. This contributes to a deeper understanding of trends and future directions in geopark research, highlighting the relevance of global and local initiatives in the conservation and enhancement of geological heritage.

4. National Results

The national results, compiled in 10 articles, span the period from 2018 to 2024, with the involvement of 40 authors and publication in 5 international journals, as shown in Table 9.

Table 9. Main bibliometric information of Brazilian scientific production.

Main information	SCOPUS e WoS
Time span	2018 a 2024
Authors	40
Co-authors per document	5.2
Authors' keywords	41
References	685
Average citations per document	6.2

4.1. Annual analysis of scientific performance and productivity level of authors and journals

Brazilian scientific production has shown a more recent improvement since 2018, with a slight decline in 2019. Figure 8 illustrates the annual scientific performance, comparing the number of authors per article, with no occurrences of single authorship, and the relationship with the journals, with only one article published on each occasion. Table 10 highlights the 10 Brazilian articles, along with their corresponding numbers of citations and the Annual Citation Index (ACI).

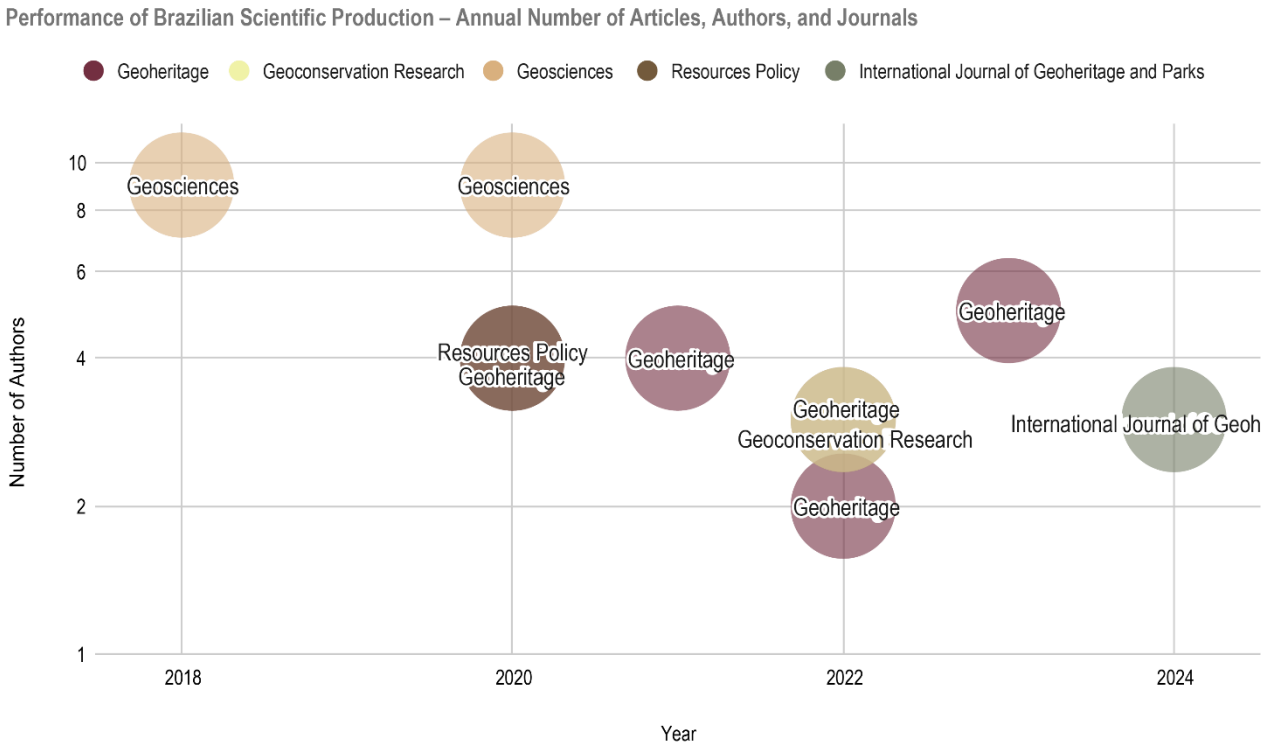

Figure 8. Graph on the performance of national scientific production. Source: prepared by the authors, 2024.

Table 10. Author keyword co-occurrence network results for international results.

Title, authors, jornal and year	Citations	ACI
Land Use and Land Cover in the Territory of Seridó UNESCO Global Geopark, Northeast Brazil Diego Santos de Medeiros Bernardino, Edson Helder Silva de Menezes, José Yure Gomes dos Santos, Marco Túlio Mendonça Diniz, Marcos Antonio Leite do Nascimento (Geoheritage, 2023)	No citations	0
Ecosystem Services Assessment of Geosites in the Seridó Aspiring UNESCO Geopark Area, Northeast Brazil Matheus Lisboa Nobre da Silva, Kátia Leite Mansur, Marcos Antonio Leite do Nascimento (Geoconservation Research, 2022)	4 S 2 W	0,65
The Guaritas, Serra do Segredo, and Minas do Camaquã geosites of the 'Caçapava UNESCO Aspiring Geopark' (southernmost Brazil): world-class sites for Gondwanan sedimentation, tectonics, copper mining, and cavernous weathering research André Weissheimer de Borba, Felipe Guadagnin (Geoheritage, 2022)	3 S	0,6
Geoheritage of a Brazilian Semi-Arid Environment: the Seridó Aspiring UNESCO Geopark Matheus Lisboa Nobre da Silva, Marcos A. Leite do Nascimento, Silas S. dos Santos Costa (Geoheritage, 2022)	3 S 1 W	0,33
Evaluation of Typologies, Use Values, Degradation Risk, and Relevance of the Seridó Aspiring UNESCO Geopark Geosites, Northeast Brazil Marcos Antonio Leite do Nascimento, Matheus Lisboa Nobre da Silva, Matheus Carlos de Almeida, Silas Samuel dos Santos Costa (Geoheritage, 2021)	13 S 7 W	1,75
A Network Perspective of the Ecosystem's Health Provision Spectrum in the Tourist Trails of UNESCO Global Geoparks: Santo Sepulcro and Riacho do Meio Trails, Araripe UGG (NE of Brazil) Eduardo S. Guimarães, Ronaldo C. D. Gabriel, Artur A. Sá, Rafael C. Soares, Paulo Felipe R. Bandeira, Isabella H. S. Torquato, Helena Moreira, Michel M. Marques, Jaqueliny R. S. Guimarães (Geosciences, 2021)	No citations	0

Promoting sustainability in a low density territory through geoheritage: Casa da Pedra case-study (Araripe Geopark, NE Brazil) M. H. Henriques, A. R. S. F. Castro, Y. R. Félix, I. S. Carvalho (Resources Policy, 2020)	26 [S] 25 [W]	5,0
Promotion of the Geological Heritage of Araripe Unesco Global Geopark, Brazil: the Casa da Pedra Reference Center I. S. Carvalho, M.H. Henriques, A.R.S.F. Castro, Y.R. Félix (Geoheritage, 2020)	14 [S] 14 [W]	2,80
Geological and mining heritages in the Seridó UNESCO Global Geopark: Ediacaran to Cambrian mineral deposits revealed by historical mines in Northeast Brazil Silas Samuel dos Santos Costa, Marcos A. Leite do Nascimento, Matheus Lisboa Nobre da Silva (International Jorunal of Geoheritage and Parks, 2024)	No citations	0
Matrix of Priorities for the Management of Visitation Impacts on the Geosites of Araripe UNESCO Global Geopark (NE Brazil) Eduardo S. Guimarães, Artur Sá, Ronaldo Gabriel, Helena Moreira, Jaqueliny R. S. Guimarães, Paulo Felipe R. Bandeira, João Marcos F. de Lima Silva, Rafael C. Soares, José Patrício P. Melo (Geosciences, 2018)	8 [S]	1,15

[S] Number of citations in the SCOPUS database.

[W] Number of citations in the Web of Science database.

It is worth mentioning that there is a significant emphasis on the Araripe UNESCO Global Geopark and Seridó UNESCO Global Geopark, which were the first three geoparks in Brazil to join the global network, together with Southern Canyons Paths (2022). Of the 10 articles analyzed, 05 refer to Seridó, 4 to Araripe (Rio Grande do Norte), and 1 to Caçapava UNESCO Global Geopark, in Rio Grande do Sul.

The most influential article in this context is "*Promoting Sustainability in a Low Density Territory through Geoheritage: Casa da Pedra Case Study (Araripe Geopark, NE Brazil)"* published in 2020. The authors, M. H. Henriques, A. R. S. F. Castro, Y. R. Félix, and I. S. Carvalho, highlight that the geopark recognizes the geological heritage of international relevance present in Araripe, located in the arid backlands of northeastern Brazil, a region of low population density due to its climatic conditions. The study describes and qualitatively evaluates an experience developed at the Casa da Pedra Reference Center, which meets the social needs of the local community. The project's results provide positive social impacts and promote global sustainability, and can serve as inspiration for other geoparks in low-density regions with relevant geological heritage.

In this same context, the second article, "Promotion of the Geological Heritage of Araripe UNESCO Global Geopark, Brazil: The Casa da Pedra Reference Center," also published in 2020, complements the previous article. The authors I.S. Carvalho, M.H. Henriques, A.R.S.F. Castro, and Y.R. Félix address in this article the implementation and qualitative evaluation of a project conducted by the Institute of Geosciences of the Federal University of Rio de Janeiro in the geopark and the Casa da Pedra Reference Center, located in the strategic Araripe Basin. This center is ideal for those wishing to develop research and training activities in geosciences, filling the previous lack of basic logistical facilities in the region. The authors highlight that Casa da Pedra "offers accommodation for 60 people, mainly university students from Brazil and abroad, but is open to local communities for other activities, whether of a cultural or religious nature" (CARVALHO et al., 2020).

The third article, "*Evaluation of Typologies, Use Values, Degradation Risk, and Relevance of the Seridó Aspiring UNESCO Geopark Geosites, Northeast Brazil*", published in 2021, in which the authors Marcos Antonio Leite do Nascimento, Matheus Lisboa Nobre da Silva, Matheus Carlos de Almeida, Silas Samuel dos Santos Costa present the Seridó region, located in an interstate region of the northeastern backlands of Brazil, which has a remarkable geological heritage. With the development of the geopark proposal since 2010 and its official acceptance as an aspirant in 2019, this article conducts an assessment of the 21 geosites within the geopark, considering their scientific value, educational and tourist uses, and the associated degradation risk. The research identifies the types of interest and relevance of geosites, providing solid information for decision-making and establishing action priorities to promote the protection of geosites and develop effective geoconservation strategies.

The analysis of the articles highlights the growing importance of research on geoparks in Brazil, highlighting the fundamental role of these areas in the conservation of geological heritage, education, and sustainable

development. The reviewed studies highlight the relevance of the Araripe and Seridó geoparks, but also reveal a significant gap in terms of awareness and social engagement, both in established geoparks and in geopark projects under development.

There is an urgent need to expand the dissemination and publicity of initiatives conducted in these territories, not only among local communities but also in academic circles. It is particularly concerning that only three Brazilian geoparks were mentioned in the analysis and that no geopark projects received significant attention. Visibility and recognition are essential elements for achieving aspirant status, obtaining the UNESCO Geopark label, and maintaining it.

This scenario highlights the importance of strategies aimed at valuing and promoting geoparks, as well as the integration between social stakeholders, educational, and scientific institutions. Outreach and awareness initiatives should target both the local public and researchers, consolidating geoparks as drivers of sustainable development and models for the conservation and responsible use of natural resources.

Strengthening dialogue between geopark managers, universities, and society is essential for these spaces to be recognized and valued, both in Brazil and internationally. This will enable the country to fully leverage its geological abundance and promote sustainable development, grounded in geoconservation, education, and collective engagement.

4.2. Brazilian Scientific Mapping – Author keyword co-occurrence network

The Brazilian scientific mapping, in which the software was configured to maintain a minimum of three co-occurrences, resulted in 7 nodes and 2 clusters. Table 11 and Figure 9 present these two clusters, comprising 7 nodes, 20 links, and a total link strength of 50, which are also spatialized by time.

Table 11. Author keyword co-occurrence network results for international results.

Cluster	Co-occurrences	Links	Total Link Strength	Author keywords
Cluster 1 4 nodes (red)	7	6	22	Brazil
	4	6	14	geoheritage
	4	5	12	heritage conservation
	7	6	21	Unesco
Cluster 2 3 nodes (green)	4	6	9	Geodiversity
	3	6	12	geosites
	3	5	10	Rio Grande do Norte

In cluster 1, the terms “Brazil” and “UNESCO” stand out, linked to geoheritage and heritage conservation, which are topics/themes of most articles. Cluster 2 presents the term “geodiversity” as the strongest, connected to geosites and the state of Rio Grande do Norte, which has areas of its context represented in 9 articles. However, the term “geopark” or its derivatives do not appear in the authors’ keyword co-occurrence network, indicating a possible limitation in bibliometric or bibliographic review research protocols.

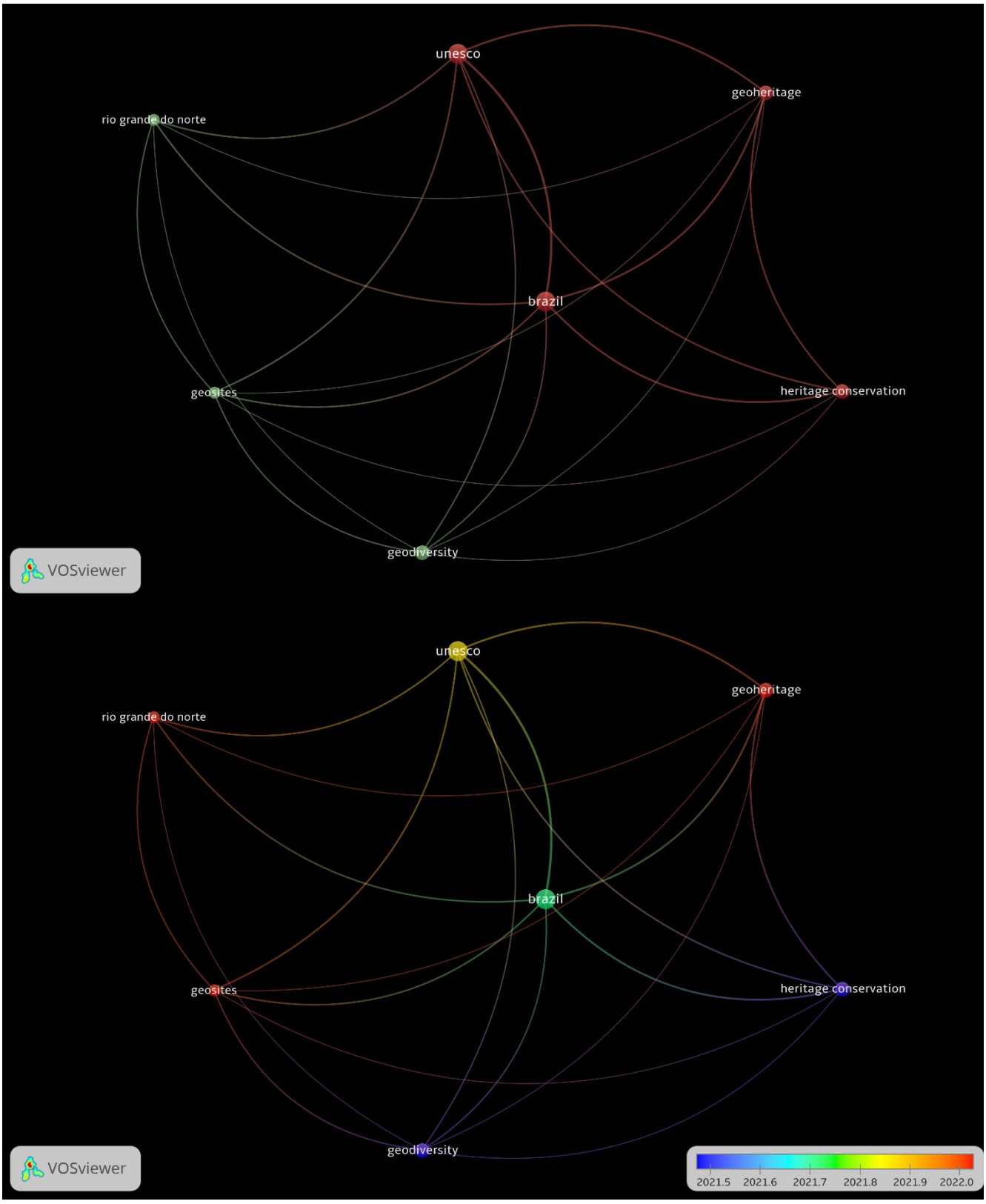

Figure 9. Clustered co-occurrence network and temporality of databases at the national level. Source: prepared by the authors, 2024.

5. Geomorphology in Geopark Research: Frequency, Depth, and Implications

Having overcome the quantitative analysis, we sought to deepen the reading of the corpus in light of the presence of geomorphology, structuring a thematic analysis that would allow us to evaluate not only the frequency, but also the degree of centrality and instrumentalization of this area in studies on geoparks.

5.1. Presence of Geomorphology in International Scientific Production

When analyzing the results obtained in the international context related to the term "Geomorphology," a discrepancy in the indexing of keywords between the main scientific databases, SCOPUS and WoS, is evident. In SCOPUS, six articles indexed with keywords related to the term "geomorphology" were identified. In contrast, in the WoS database, the term "geomorphology" does not appear among the main categories nor in the meso and micro citation topics, characteristic of this database.

However, when performing a specific search in the list of 129 articles found in WoS using the term "geomorphology," seven articles were identified. Of these, three are also present in SCOPUS due to the database's indexing characteristics. The other four articles mention the term geomorphology secondarily, but still contribute significantly to the study of the interaction with geology, geomorphology, and other abiotic and socioeconomic territorial aspects.

Of the six articles identified in the SCOPUS database and the three present in WoS, some mention geomorphology only as indexed keywords, meaning terms added by the database to facilitate the organization and retrieval of articles. However, only one study addresses geomorphology as a central theme in its proposal by the authors: *Geomorphology of the Courel Mountains UNESCO Global Geopark* (PEREZ-ALBERTI, GOMEZ-PAZO, 2023), which also appears in the WoS database. This article highlights the importance of geomorphology in the context of geoparks, focusing on the geological and geomorphological diversity of the Courel Mountains Geopark, situated in Galicia, Spain. It utilizes geomorphological cartography to map reliefs and deposits within the geopark, thereby promoting the conservation and sustainable use of natural resources. The detailed description of glacial, periglacial, karst, and alluvial reliefs reflects a comprehensive approach that values geomorphological formations as fundamental elements for education and sustainable tourism.

Among the studies that include indexed keywords is the work of Tukiainen et al. (2024), titled "A framework for quantifying geodiversity at the local scale: a case study from the Rokua UNESCO Global Geopark." This paper proposes a methodology for quantifying geodiversity at local scales using data derived from digital elevation models (DEMs) in the Rokua Global Geopark. The presented approach offers a valuable quantitative perspective, assessing geodiversity based on different landforms and their topographic and geomorphological variations. The analysis suggests that topographic variability can serve as an indicator of geodiversity, providing essential information for management and geoconservation, particularly in areas that are difficult to access or have limited geospatial data.

In turn, the study by Polman et al. (2024), entitled *Global geodiversity components are not equally represented in UNESCO Global Geoparks*, reveals that, although UNESCO geoparks play a fundamental role in protecting geodiversity, not all components of this geodiversity, such as geomorphology, soils, and hydrology, are equally represented. The work highlights that lithological and topographic diversity is more represented in geoparks than outside them. At the same time, components related to soil and hydrology are underrepresented, indicating a need for a more balanced approach in the conservation and management of geodiversity.

The research by Veiga-Pires et al. (2024) on *The Escarpão Plateau (South of Portugal) —a Study Case of Nested Geosites from the Aspiring Algarvensis Geopark*, also offers valuable contributions to the understanding of geomorphological geosites. The structure of the plateau, shaped by karst, fluvial, and tectonic processes, is described in detail, highlighting the importance of these reliefs for conservation and scientific dissemination. The integration of cultural and historical aspects into geomorphological points of interest, as evident in the geopark's interpretive trail, is a practice that significantly contributes to education and the engagement of the local community with geological heritage.

In the Brazilian context, the study on the *Geoheritage of a Brazilian Semi-Arid Environment: the Seridó Aspiring UNESCO Geopark*, described by Silva et al. (2022), highlights the geomorphological complexity of a semi-arid region, characterized by a diversity of geosites of different relevance. The research examines the interaction between geodiversity and sociocultural factors, including agriculture and mining, which have a direct impact on

the conservation and utilization of natural resources. Geoconservation in Seridó is also a sustainable development strategy that integrates local communities into the active conservation of geological heritage, promoting a balance between environmental protection and local economic activities.

Finally, the work of Deng and Zou (2021), entitled *"Orogenic belt landforms of Huanggang Dabieshan UNESCO Global Geopark (China) from geoheritage, geoconservation, geotourism, and sustainable development perspectives," contributes a broader approach, addressing not only the geomorphological aspects* but also the perspectives of geotourism and sustainable development. The SWOT analysis applied to the relief of the orogenic belt reveals that education and geotourism are central aspects for promoting geoconservation and valorizing geosites.

These studies, although addressing different geographic and methodological contexts, converge on the idea that geomorphology, when integrated with geoconservation and geotourism, has the potential to promote sustainable development in regions with abundant geodiversity. Effective management of geoparks depends on equitable representation of all components of geodiversity and the integration of these resources with local, cultural, and socioeconomic needs.

5.1.1. Author keyword co-occurrence network and Geomorphology

The analysis of the author's keyword co-occurrence network, based on international studies on geoparks, indicates that the term geomorphology is predominantly inserted in cluster 2 (green), grouped with keywords such as geodiversity, geoheritage, geoconservation, and sustainable development. This positioning demonstrates that geomorphology is fundamentally linked to geodiversity, a key concept in studies on geoparks.

However, it is observed that geomorphology does not appear among the central themes of the other clusters, especially those involving *cultural heritage, environmental education, heritage conservation* (cluster 1, red), and *geotourism and tourism management* (cluster 3, blue) (Figure 7). This distribution suggests that geomorphology remains mainly on the margins of broader discussions related to heritage management, environmental education, and sustainable tourism, despite its clear potential to make significant contributions to these fields.

The network shows that the connections between geomorphology and topics related to education, management, and tourism are fewer and have less relational strength compared to its strong articulation with geodiversity and geoconservation. This gap reveals not only a challenge, but also a strategic opportunity to strengthen the interdisciplinary approach and to expand the role of geomorphology in the valorization, planning, and sustainable use of geoheritage territories.

This peripheral position is even more pronounced in the Brazilian context, where the term does not appear as a relevant keyword in the co-citation network, highlighting the underutilized potential of geomorphology as an integrative tool for territorial management, environmental education, and the valorization of geosites for tourism.

5.2. Geomorphology in Brazilian Scientific Production: Advances and Weaknesses

An analysis of national scientific production on geoparks reveals a reduced presence of the explicit approach to the term *geomorphology* in published articles, especially in databases such as WoS. While a single reference indexed with the term was found in SCOPUS, it was not part of the keywords assigned by the authors, as previously presented in the international context: "Geoheritage of a Brazilian Semi-Arid Environment: the Seridó Aspiring UNESCO Geopark" (SILVA *et al.,* 2022).

Despite this, a more in-depth analysis of the articles revealed that geomorphological aspects are frequently addressed, albeit implicitly or without the direct use of the term, resulting in 3 more articles. These works demonstrate the fundamental role of geomorphology in the characterization and valorization of geoparks, as described: The *Guaritas, Serra do Segredo, and Minas do Camaquã Geosites of the 'Caçapava UNESCO Aspiring Geopark'* (BORBA and GUADAGNIN, 2022), this study highlights the international scientific relevance of the Camaquã Basin and its geosites, recognized for exceptional geomorphological characteristics, such as ruiniform landforms, stress-controlled arcades, and tafoni; *Promotion of the Geological Heritage of Araripe Unesco Global Geopark, Brazil: the Casa da Pedra Reference Center* (CARVALHO *et al.,* 2020), this article emphasizes the contribution of the geomorphodiversity of the Araripe Geopark to the understanding of the morphotectonic evolution of northeastern Brazil; *Land Use and Land Cover in the Territory of Seridó UNESCO Global Geopark, Northeast Brazil* (BERNARDINO *et al.*, 2023), focused on the relationship between land use and land cover and the geodiversity of the Seridó Geopark, the study addresses geomorphological characteristics such as inselbergs and pediplaned surfaces.

These examples demonstrate that, despite the absence of the term 'geomorphology' as a keyword in the databases researched, the theme is present in studies on geoparks. The explicit inclusion of the term could increase the visibility of the contribution of geomorphology in the field of geoparks, facilitating its integration with international and national debates, and strengthening the role of geomorphological science in the planning and management of these territories. This gap highlights the need for greater attention from authors and reviewers in selecting keywords that accurately reflect the content and contributions of their work.

Despite the recognized relevance of geomorphology for characterizing geosites and natural landscapes, its presence in the analyzed Brazilian articles is discrete and often implicit. Such invisibility may result from the prevalence of biogeographical or heritage approaches, the lack of specific technical training among authors, or the absence of more robust guidelines in the geopark nomination and management processes. This situation does not necessarily characterize a failure, but reveals a relevant opportunity for strengthening integrated geoconservation approaches in Brazil.

5.3. Between Scientific Relevance and Applied Invisibility

To deepen the thematic reading of the presence of geomorphology in studies on geoparks, five representative articles were selected, given their approach to the theme with different levels of centrality, methodologies, and geographic contexts. Tables 12 and 13 present a summary of these studies, highlighting the variations in methodological and conceptual approaches.

It should be noted that this selection is not intended to be exhaustive, but rather to illustrate significant examples that highlight the diversity of ways in which geomorphology is integrated into studies on geoparks, both nationally and internationally.

Approaches vary between detailed technical mapping, qualitative description, and quantification of geodiversity, demonstrating that the presence of geomorphology in studies is diverse in form and depth. It is observed that, when central, geomorphology contributes directly to the reading of the landscape and its management. In secondary approaches, their role tends to be descriptive or indirect, which can still generate educational and tourist value.

Table 12. Geomorphology Approach in Geopark Studies.

Author(s) and year	Silva *et al.* (2022)	Pérez-Alberti e Gómez-Pazo (2023)	Borba e Guadagnin (2022)	Tukiainen *et al.* (2024)
Geopark/Location	Seridó (Brazil)	Courel (Spain)	Caçapava do Sul (Brazil)	Rokua (Finland)
Geomorphological Approach	Identification of landforms and their interactions with the semi-arid environment	Detailed geomorphological mapping: glacial, periglacial, karstic features	Morphological description: tafoni, ruiniform relief, and tectonic structure	Quantification of geodiversity with emphasis on relief and landforms
Instruments/ Methods	Geosite inventory + qualitative description	Geomorphological cartography + interpretation of landforms	Qualitative morphological analysis + geological review	Statistical analysis with DEM data + geodiversity
Landscape Focus	Partial – appreciation of the natural and cultural context	Strong – integrated reading of the geological landscape	Implicit – visual recognition and aesthetic potential	Medium – measures morphological variations as an indicator
Type of Insertion	Secondary	Central	Secondary	Technical and integrated
Analytical Commentary	Integrates geomorphological aspects in relation to	One of the few studies with an exclusive focus on geomorphology,	Evident landscape value, but lacking conceptual	Innovative methodological proposal for

	geological heritage and local identity	highlighting its practical application	articulation with landscape	quantitative landscape assessment
Thematic Affinity	Moderate to high	High	Medium to low	High
Geomorphological Contribution	Identification of inselbergs and pediplanation plains with value for conservation and education	Conservation zoning and basis for educational interpretation of glacial forms	Recognition of forms with aesthetic and heritage value without deeper methodological integration	Quantitative assessment of geodiversity as a tool for territorial management
Use of Specific Methods	Moderate	High	Low	High
Articulation with Mnagement Policies	Partial	Yes	No	Partial
Impact on Geoconservation	Moderate	High	Partial	Moderate

Table 13. Geomorphology Approach in Geopark Studies.

Author(s) and year	**Veiga-Pires *et al.* (2024)**	**Deng, Zou (2021)**	**Carvalho *et al.* (2020)**	**Bernardino *et al.* (2023)**
Geopark/Location	Algravensis (Portugal)	Huanggang Dabieshan (China)	Araripe (Brazil)	Seridó (Brazil)
Geomorphological Approach	Analysis of plateau and slope geomorphological structures	Integrated analysis of orogenic landforms for conservation, tourism, and education	Morphotectonic interpretation and geomorphodiversity value of the territory	Interaction between landforms and land use
Instruments/ Methods	Geosite inventory + interpretive trails	SWOT + landform description + geotourism analysis	Qualitative interpretation + reference center	Thematic mapping of land use and cover + geosites
Landscape Focus	High – landscape as an educational and cultural narrative	Medium – oriented toward practical application across multiple dimensions	Partial – focused on heritage appreciation and educational use	Moderate – highlights anthropic impact on relevant landforms
Type of Insertion	Central	Technical	Secondary	Secondary
Analytical Commentary	Integrates geomorphology with cultural heritage and tourism use	Articulates geodiversity and geotourism with morphostructural landscape	Links geomorphology with heritage for purposes of local appreciation	Highlights inselbergs and pediplanation surfaces in the context of land use and conservation
Thematic Affinity	High	High	Moderate	Moderate
Geomorphological Contribution	Integrates geomorphological landscape with tourism, education, and local historical narratives	Practical application in tourism planning and geoscience education	Connection between geomorphology and heritage for local valorization	Emphasis on inselbergs and pediplanation surfaces in anthropic contexts
Use of Specific Methods	Moderate	Moderate	Low	Moderate
Articulation with Mnagement Policies	Yes	Partial	Partial	Partial

Impact on Geoconservation	High	Moderate	Moderate	Moderate

The analysis of Tables 12 and 13 highlights a crucial methodological difference between national and international studies. While international studies tend to use specific geomorphological tools—such as geomorphological cartography, digital elevation models (DEMs), and formal typologies—national studies still mostly explore descriptive or associative aspects, without geomorphology being fully integrated into the planning or territorial management of geoparks.

This differentiation is directly reflected in the degree of thematic affinity attributed to each study, demonstrating that centered and methodologically structured approaches tend to exhibit a high degree of affinity. In contrast, studies of a more descriptive or exploratory nature tend to remain at moderate to low levels. This categorization, adapted from the methodology of Mota et al. (2025), enables us to highlight not only the quantitative presence of geomorphology in studies on geoparks but also how this component is integrated into strategies for valuing and managing the geological landscape.

When speaking of "form of incorporation," we refer to the degree of conceptual and methodological systematization, the articulation between geomorphology and the objectives of analysis or territorial planning, as well as the extent to which it is used to support management recommendations and practices. Thus, although geomorphology is present in a significant portion of scientific production on geoparks, its potential as an analytical tool and support for territorial planning is more consistently and comprehensively demonstrated in international studies.

The thematic analysis shows that, although geomorphology is intrinsically related to the structure and evolution of the landscape — central elements in geoparks —, its presence in the literature is fragmented and often implicit. This invisibility does not reflect an absence of application, but rather a limitation in the methodological and conceptual explanation of its presence. Such a scenario may limit the recognition of geomorphology as a strategic tool in geoconservation, planning, and scientific communication.

More than increasing the frequency of the term, it is urgent to qualify its presence as a structuring axis of integrated landscape analyses, strengthening the dialogue between geosciences, public policies, and educational strategies in geoparked territories.

6. Discussions

The discussion is then organized according to the central dimensions explored in the article: the evolution of scientific production, keyword co-occurrence networks, the role of geomorphology in the context of geoparks, and the thematic contribution of publications to the pillars defined by UNESCO.

The bibliometric analysis conducted in this study aimed to map the scientific production on geoparks, with a focus on the approach to geomorphology within the scope of national and international studies. The research results indicate a growing and diversified production, with contributions from several countries throughout the study period (2007-2024). Below, the discussion is organized according to the different dimensions explored in the article.

The data obtained indicate a growing trend in scientific production on geoparks, particularly since 2017, reflecting the increasing interest in these territories and their relationship with geotourism, geoconservation, and sustainability. Countries such as Portugal, China, Spain, Italy, and Brazil are among the largest producers of articles, with a significant presence in major databases like SCOPUS and Web of Science. This growth can be attributed to the global recognition of geoparks as crucial instruments for conserving geological heritage and promoting the sustainable development of the regions in which they are located.

The predominance of certain countries reflects both the implementation of geoparks as a model of territorial management and the role of these countries as leaders in scientific research in this area. The study confirms that the internationalization of the topic is an increasingly prevalent phenomenon, characterized by increased collaborations between researchers from different countries and a growing exchange of knowledge and practices related to the sustainable management of geoparks.

Keyword co-occurrence network analysis revealed a growing connection between the terms "conservation," "geoconservation," "geodiversity," "UNESCO," "geopark," "geoheritage," and "sustainable development." These findings reflect a growing trend to integrate geological heritage conservation with local and regional development

needs. Scientific research on geoparks is increasingly connected to the debate on sustainability and the importance of environmental education, promoting greater awareness of the natural and cultural values of geoparks.

Although education is one of the institutional pillars of UNESCO Global Geoparks, the bibliometric analysis revealed that the approach to environmental education is presented in a specific and limited manner in the analyzed publications. The term environmental education appears with little frequency and limited connections compared to other more established themes, such as geotourism and geoheritage. This result reflects the concentration of studies on technical and territorial management aspects, suggesting that environmental education, although relevant, has not figured as a thematic priority in recent international scientific literature on geoparks. This finding does not compromise the results of the present study. Still, it highlights an opportunity for further investigation in future studies, especially in the Brazilian context, given the socio-environmental diversity and the demands for social and environmental inclusion in these territories.

The growing interconnection between these concepts in geopark studies demonstrates that the field is evolving toward a more integrated approach, which recognizes not only the conservation of geological heritage but also the role of geoparks in the social and economic development of the regions where they are located. Scientific production is thus contributing to a greater understanding of the potential of geoparks as instruments for sustainable development and the promotion of responsible tourism, aligned with conservation practices.

A key point of the analysis was the difference observed in keyword indexing between the SCOPUS and Web of Science databases. While SCOPUS explicitly indexes the term "geomorphology" as one of its main keywords, WoS does not consistently highlight it. This discrepancy can be attributed to different approaches in article curation and keyword selection, which may reflect a limitation in categorizing topics within scientific publications. Although geomorphology is an essential aspect in the evaluation of geoparks, its visibility in the main databases could be increased, which would allow for greater awareness of the importance of this area in the context of geoconservation.

Geomorphology is one of the essential components of geodiversity and frequently appears in studies on geoparks, although not always explicitly or as a central axis. Its presence may vary depending on the geological context of the area studied, the objectives of the management project, or the approaches adopted by the research. Although geomorphology is recurrent, it is essential to remember that geodiversity also encompasses other elements—such as soils, water resources, minerals, and fossils—which, as Polman et al. (2024) point out, do not always receive the same attention. Thus, excessive emphasis on certain components, such as geomorphology itself, can limit a broad and integrated understanding of the value of geoparks. It is therefore essential to promote geoconservation and management strategies that consider, in a balanced manner, all aspects of geodiversity, aiming at the effective conservation and sustainable use of these territories.

Among the international studies analyzed, the research by Perez-Alberti and Gomez-Pazo (2023) on the Courel Mountains stands out, which exemplifies the application of detailed geomorphological methods to map and conserve the geological diversity of a territory. The use of geomorphological cartography in this study highlights the importance of a detailed approach in identifying areas of high geoconservation value. The research by Tukiainen et al. (2024) exemplifies the use of technological tools, such as digital elevation models, to quantify geodiversity and map reliefs of interest, demonstrating how these tools can be applied for more effective management of geoparks.

These examples demonstrate that, internationally, there is a strong tendency to integrate geomorphology with other dimensions of geodiversity, in addition to exploring new technological approaches to enhance the management and conservation of geoparks. Furthermore, the growing focus on sustainable development within geoparks is becoming increasingly evident, with research emphasizing not only conservation but also the importance of environmental education and sustainable tourism. The balanced integration of all components of geodiversity, as suggested by Polman et al. (2024), is essential to ensure the effectiveness of geopark management and its contribution to the conservation and sustainable use of geological heritage.

In Brazil, although scientific production on geoparks has increased, the analysis revealed a still reduced presence of geomorphology explicitly in academic studies. The Araripe Geopark exemplifies this reality. Although geodiversity and sustainability are frequently addressed, geomorphology, despite being one of the pillars of the geopark, is not always treated in detail. This can be attributed to the emphasis on aspects such as geotourism, which, despite being fundamental for local development, has prioritized other thematic dimensions to the detriment of more in-depth geomorphological analyses.

In the case of the Seridó Geopark, there is a greater emphasis on cultural and tourist aspects, with geomorphology taking a secondary role. This pattern is also repeated in other national studies analyzed, suggesting that, in indexed Brazilian publications, the geomorphological approach does not yet occupy a central position. This observation, however, should be interpreted with caution, considering the limited number of national publications available in the analyzed databases, which restricts the possibility of generalizations about the stages of development of geoconservation and geopark management in the country.

It is essential to note that the classification by thematic affinity, adapted from Mota et al. (2025), proved effective in not only highlighting the frequency but also the depth and centrality of geomorphology in publications. This tool allowed us to qualitatively identify the methodological and conceptual asymmetries between national and international productions, highlighting the gaps and potential still underexplored in Brazil.

It is also worth noting that the linguistic scope and the exclusive focus on articles indexed in the SCOPUS and Web of Science databases impose limitations on the scope of the analysis, especially in the Brazilian context. Therefore, for future research, it is recommended to incorporate regional databases and include publications in Portuguese and Spanish, as well as consider other types of documents, such as book chapters and conference proceedings, to better assess national and Latin American scientific production on geoparks and their interface with geomorphology.

Given the growing international appreciation of geodiversity as a basis for integrated territorial management, the Brazilian case still presents significant opportunities for advancement. The clearer inclusion of geomorphology—not as an imposition, but as an epistemological possibility—can broaden the scope of studies and strengthen conservation, education, and land use planning strategies, especially when combined with other components of natural heritage. Its unique contribution lies in its ability to interpret the landscape systematically, assess natural risks, support tourist routes, and develop educational materials on relief evolution, collaborating directly with UNESCO's pillars for geoparks. Table 14 clearly and objectively shows how geomorphology directly contributes to the three fundamental pillars of UNESCO geoparks: conservation, education, and sustainable development. Cases such as conservation zoning in Courel or the use of geomorphological mapping in Seridó demonstrate how geomorphology can support public policies for conservation, education, and tourism in geoparks.

Table 14. Contributions of Geomorphology to the Pillars of UNESCO Geoparks.

UNESCO Pillar	Potential Contributions of Geomorphology	Applied Examples
Conservation	Mapping of risk areas (erosion, landslides, instability) Inventory of relevant landforms (inselbergs, plains, glacial forms) Support for zoning and environmental planning	Seridó: identification of inselbergs and susceptible areas Courel: zoning based on glacial landforms
Education	Development of didactic materials on landform evolution and geomorphological processes Landscape interpretation as a pedagogical tool	Courel: educational use of glacial and periglacial landforms Araripe: reference centers based on landforms
Sustainable Development	Planning of geotourism routes based on landforms Aesthetic and cultural valorization of geomorphological features Support for territorial identity	Algarvensis: tourism linked to karst features and plateaus Caçapava: ruiniform relief and tafoni as attractions

In summary, the discussion demonstrates that geoparks constitute a promising platform for interdisciplinary scientific production, although challenges still persist regarding the visibility of certain fields of knowledge, such as geomorphology. It is therefore not a matter of centralizing geomorphology, but of recognizing its contribution as a strategic ally in the articulation between science, territory, and society. Their more effective presence can favor integrated approaches that strengthen the role of geoparks as territories of sustainability, memory, and innovation.

7. Conclusions

This study conducted a bibliometric analysis of scientific production on UNESCO Global Geoparks between 2007 and 2024, integrating a quantitative and thematic approach. In addition to mapping the international and national research panorama, we sought to qualify the presence and role of geomorphology in the publications analyzed.

The results demonstrate significant growth in global scientific production, particularly in countries such as China, Spain, Portugal, and Italy—nations that not only have a high number of geoparks but also stand out for the density and diversity of their research. In Brazil, despite recent progress in the recognition of new geoparks, scientific production remains incipient and is mostly concentrated in the Araripe and Seridó geoparks, with limited thematic diversification.

The thematic analysis revealed that, although present in a significant portion of the studies, geomorphology is applied with different levels of depth and systematization, being less frequent in methodological analyses in the Brazilian context. This deficiency goes beyond the absence of terminology, revealing a structural weakness in the articulation between geomorphological knowledge, planning strategies, and territorial valorization practices.

The low inclusion of geomorphology in studies on Brazilian geoparks is not only due to limited scientific or methodological appreciation, but also to operational obstacles, such as the scarcity of detailed data, the complexity of geomorphological analyses, and the lack of infrastructure for monitoring physical landscape processes. Such challenges make it difficult to consolidate integrated and robust empirically based approaches.

Given this scenario, the urgency of investing in specialized training, strengthening interdisciplinary research networks, and accessing geospatial databases and territorial analysis technologies becomes evident. Furthermore, the importance of stimulating the internationalization of scientific production and the articulation between academia, public policies, and local communities is highlighted.

It is concluded that strengthening the presence of geomorphology in studies on geoparks is strategic for the consolidation of geoconservation and for the recognition of geoparks as instruments of sustainable territorial development. By highlighting this gap, this study provides support for further research to deepen the interfaces between geodiversity, geomorphology, and natural heritage, promoting a critical, integrated approach applicable to different geographic contexts.

Finally, it is recommended that future geopark management plans in Brazil incorporate geomorphological cartography as a tool for landscape conservation and interpretation, in addition to encouraging the indexing of terms such as geomorphology in scientific databases, increasing the visibility of the topic. Geomorphology, in this context, reaffirms itself as an articulating link between the scientific, educational, and tourist values that support the mission of geoparks.

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