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REVIEW ARTICLE

Geoheritage Research Trends: A Comparative Bibliometric Analysis of Global and Türkiye Perspectives Using R Programming

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Abstract
Geoheritage refers to the scientific, aesthetic and cultural value of geological formations and is closely related to the concepts of geotourism, geosite, geopark, geodiversity and geoconservation. All these concepts work together to protect the scientific, educational and economic value of geoheritage and to use it sustainably. In this study, the findings of a bibliometric analysis that comparatively examines geoheritage literature in the international and Turkish context are presented. The analysis was carried out using the Biblioshiny package of the R program. The methodology of the study is as follows: determining the boundaries of the research, collecting data, analyzing data, creating and interpreting bibliometric maps. In the first stage of the research, studies conducted between 1994–2024 were determined using the databases Web of Science, Scopus, Google Scholar, Researcgate, Dergipark Academic, YökTez. The studies were analyzed within certain limitations and the results were visualized with bibliometric maps. The results indicate that the topic of geoheritage is explored through an interdisciplinary approach in the international literature, while the literature in Türkiye remains underdeveloped in this field at the global level. Despite the geological and geomorphological advantages provided by its geographical location, Türkiye has not been able to fully utilize its existing geoheritage potential. Establishing stronger connections between studies conducted in Türkiye and the international literature is of great importance.

Keywords Geoheritage · Geotourism · Türkiye's Geoheritage · R Programming · Bibliometric Analysis · Biblioshiny Package

Introduction

Geoheritage, geodiversity, geoconservation, geosites, geoparks, and geotourism have recently gained prominence in geosciences research (Sadry 2020; Vlachopoulos and Voudouris 2022). These concepts hold a significant place in the conservation of natural heritage, tourism, and local development processes (Brilha and Reynard 2018). Geoheritage refers to the value of geological elements found in a specific geography in terms of their scientific, educational, aesthetic, and cultural significance (Erikstad 2013). This concept emphasizes that nature conservation approaches should not be limited solely to biological elements (Pijet-Migoń and Migoń 2022). Geoheritage highlights the value of the geological elements a region possesses, while geodiversity refers to the variety of geological processes, rocks, fossils, minerals, and landforms that form the foundation of these elements (Gray 2008). The geodiversity concept is comparatively young; however, it seems essential in understanding and maintaining all kinds of geological processes and formational diversities. Gray (2013) defined geodiversity as the abiotic counterpart of biodiversity, highlighting its crucial role in ensuring the sustainability of natural systems. In this context, geodiversity not only promotes the conservation and understanding of specific regions but also contributes to the preservation of Earth's overall geological heritage (Gray 2008; Ruban 2010). Geoconservation plays a key role in the physical preservation and sustainable management of existing geodiversity (Burek and Prosser 2008). It aims to protect geosites the fundamental components of geological heritage through inventory, assessment, conservation, and monitoring processes (Gray 2005; Henriques et al. 2011). In this context, geoparks serve as fundamental pillars of

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geoconservation. United Nations Educational, Scientific and Cultural Organization defines these areas as geographical regions with sites and landscapes of international significance managed under a holistic concept of protection, education, and sustainable development (Patzak and Eder 1998; Du and Girault 2019). UNESCO Global Geoparks had raised many recent interests in this area and come up with a sustainable conservationist utilization approach. Geoheritage studies have recently occupied a prominent place within the literature, and most of the different focal points had been assessed within various geographical areas until today. Hose (1994, 1995) discussed for the first time basic principles from the geoheritage concept and how these might be assessed in relation to perceptions of tourism within the area of Hunstanton (Norfolk, England). Hose's work served as a significant starting point in integrating geoheritage with public awareness and tourism value. The conceptualization of geoheritage, particularly its definition and classification, was further advanced by Dowling (2008) and Gray (2008), who also explored the relationship between geoheritage sites and tourism on an international scale. Within this framework, Dowling focused on geoheritage sites in Western Australia, while Gray emphasized the role of geological processes and geodiversity in the management of geoheritage. Kazancı (2010) underlined particularly the geoheritage potential of Neogene sedimentary basins in Anatolia during the studies conducted in Türkiye. Çiftçi and Güngör (2014) assessed the karstic geoheritage sites in the Western Taurus region of Türkiye. Kazancı and Gürbüz (2014), on the other hand, analyzed the possible potential of fossil beds that belonged to different ages in regard to Türkiye's geoheritage. In rather recent studies, Brilha (2016) presented the methodological methodologies for conservation in respect of geoheritage. On the other side, Dowling and Newsome (2016) comprehensively reviewed the inter-relationship of geotourism and geoheritage in their studies. Gümüş (2019) examined volcanic rocks as a kind of geoheritage regarding the value and their touristic uses in Türkiye. In the case of volcanic areas in New Zealand, Nemeth et al. (2021) underlined the need for geoheritage to be managed in a sustainable way. Other works have mapped geoheritage sites and identified their potential in different regions of Türkiye, such as Karadeniz et al. (2022), Aytaç and Demir (2023) and Şengün et al. (2023a, b). Finally, Migoń and Pijet-Migoń (2024) highlighted the geoheritage value of granite topographies in Poland, while Zorlu et al. (2024) analyzed the geoheritage value of paleo-geological formations in eastern Türkiye.

A comprehensive analysis of the geoheritage literature is essential for understanding its historical evolution and identifying global research trends. In this situation, Herrera-Franco et al. (2020); Herrera-Franco et al. (2022) executed studies on works related to geoheritage; geotourism, respective contributions made to the subject, productivity analyses, bibliometry mapping, literature reviews together with trends in research of the studied subject. The above-mentioned comprehensive studies played a significant role in contributing to the understanding of diverse worldwide phenomena involved with the broad areas of geoheritage and geotourism, as well as in visualizing scientific progresses undertaken under those studies. The present research searches to comment on the national and international trends regarding the concept of geoheritage from a comparative point of view, besides assessing comprehensively the status and contribution that Türkiye has attained in geoheritage sciences in general.

In the study, the geoheritage studies conducted in Türkiye was correlated with its representation in international literature, and scientific outputs in this field were analyzed based on parameters such as authors, journals of publication, relevant countries, and interdisciplinary connections. The study was conducted using systematic literature reviews and bibliometric methods. Systematic literature reviews are an effective method to develop, in an academic environment, an evidence-based and structured understanding of topics of interest. According to Nightingale (2009), Aromataris and Pearson (2014), and Pati and Lorusso (2018), bibliometric analysis provides a valuable tool for visualizing geoheritage studies and examining their interrelationships. This research employs bibliometric analysis, efficiency metrics, impact assessments, and relational techniques. Accordingly, relational methodologies were applied to examine elements such as author networks, citations, and keyword relationships within the literature using impact-oriented evaluation techniques (Benckendorff and Zehrer 2013; Atabay et al. 2019; Çizel et al. 2020). The data extracted from Scopus, Web of Science, Google Scholar, ResearchGate, Dergipark Academic, and YÖK Thesis databases have been analyzed by using the R programming software.

Methodology

A bibliometric analysis is usually treated as a quantitative approach focused on the analysis of documents, according to bibliographic data involved in describing, assessing, and monitoring the established published research. Regarding related studies, one may refer to Garfield (1964), Pudy, and Skinner, who explained it back in 1964. White and McCain added new perspectives in 1989. The analysis implemented here for this paper followed, basically, the R bibliometrix library, proposed by Aria and Cuccurullo in 2017 based on the biblioshiny package introduced by Huang, Wenchao, Hai, and Liu in 2016. Bibliometrix is a bibliometric analysis library developed in the R programming language. It is an open-source tool applied to the bibliographic analysis of studies, graphical visualization, and interpretation of results.

Biblioshiny is a package in R applied within the bibliometrix library. This application makes it easy to conduct analyses without the need for coding. This is as shown by (Zupic and Čater 2015; Aria and Cuccurullo 2017; Donthu et al. 2021; Bhat et al. 2023). The R program was preferred in the study because it had allowed users to visualize analyses with flexibility and it had an extended capacity to conduct analyses. Besides, it is open-source. The methodological framework of this study encompasses five interrelated phases: study design, data collection, data analysis, data visualization, and interpretation, as shown by Aria and Cuccurullo (2017). Each phase systematically integrates bibliographic data in order to ensure a comprehensive and structured approach to the research objectives (Fig. 1).

Research Design

In the research design phase, the analysis framework was defined, including the time frame and relevant keywords. The selected time frame for the analysis was 1994–2024. This time frame was chosen because the earliest studies related to the topic in the Web of Science (WoS) and Scopus databases were published in 1994. Since the year 2024 is still ongoing, only the first seven months of the year (January–July) were included in the analysis. Especially in the analyses for Türkiye, data were compiled manually due to the fact that it was not possible to download data in R format from some databases, and this affected the scope of the analysis. In the selection of keywords, terms commonly used in geoheritage literature were taken into consideration and the aim was to keep the scope of the analysis wide. The keywords used in this context include the following concepts:

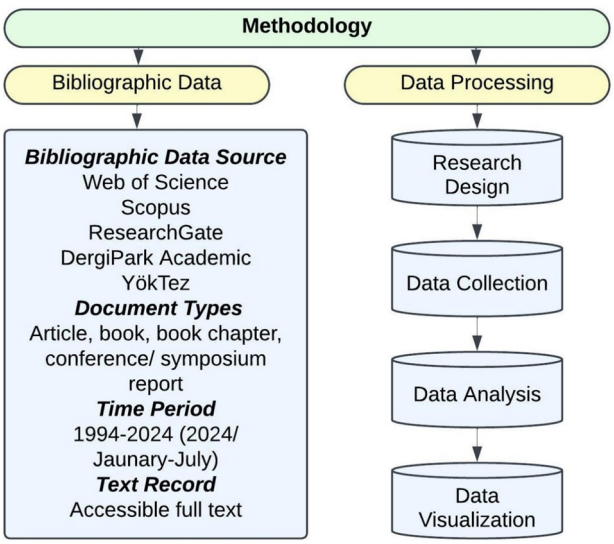

Fig. 1 Methodological framework of the study

geoheritage, geopark, geosite, geoconcervation, geodiversity and geotourism.

Data Collection Process

In the methodology phase of this research, specific databases were utilized to comprehensively review and systematically analyze the relevant literature. In line with the main objective of the research, the Scopus, Web of Science, Google Scholar, ResearchGate, Dergipark Academic, and YÖKTez databases were selected. The data collection process was conducted using predefined keywords to enable a comprehensive examination of the literature. During the literature review; the title, abstract, and keyword sections were analyzed and the following keywords were employed: geoheritage, geopark, geosite, geoconservation, geodiversity, and geotourism. In the search process, queries were constructed using the"OR"operator between these keywords, and the same method was systematically applied across all selected databases (Fig. 2).

At the end of this process, a total of 7,861 scientific studies were identified. When evaluated in detail, 3,592 documents were found in the WoS database, and 3,031 documents were found in the Scopus database. The data downloaded from these two databases were coded and merged using the R program. The studies common to both databases were also filtered out using the R program. A total of 4,441 documents were included in the analysis. In the examination of the literature in the context of Türkiye, additional databases such as Google Scholar, ResearchGate, Dergipark Akademik, and YÖKTez were utilized. 960 studies were identified in Google Scholar, 137 in ResearchGate, 112 in Dergipark Academic, and 29 in YÖKTez. A total of 300 documents were prepared for analysis by sorting out the duplicate documents obtained from these databases. Accessibility of the full texts of these documents was another important step in the research. The studies whose full text could be accessed were selected and included in the analysis process. The selected studies in the Turkish context were organized and analyzed using Microsoft Excel within a table-based approach. During the research process, the entire process was carried out with great care in order to systematically process the data obtained and make it suitable for analysis. The R program was utilized during the stages of merging, filtering, and verifying the accuracy of the data, ensuring both the accuracy and integrity of the dataset. This process was a critical step in eliminating duplicates from the literature and selecting data relevant to the research questions.

Data Analysis

Firstly, the basic characteristics of the sources in the literature were examined with the descriptive analysis method

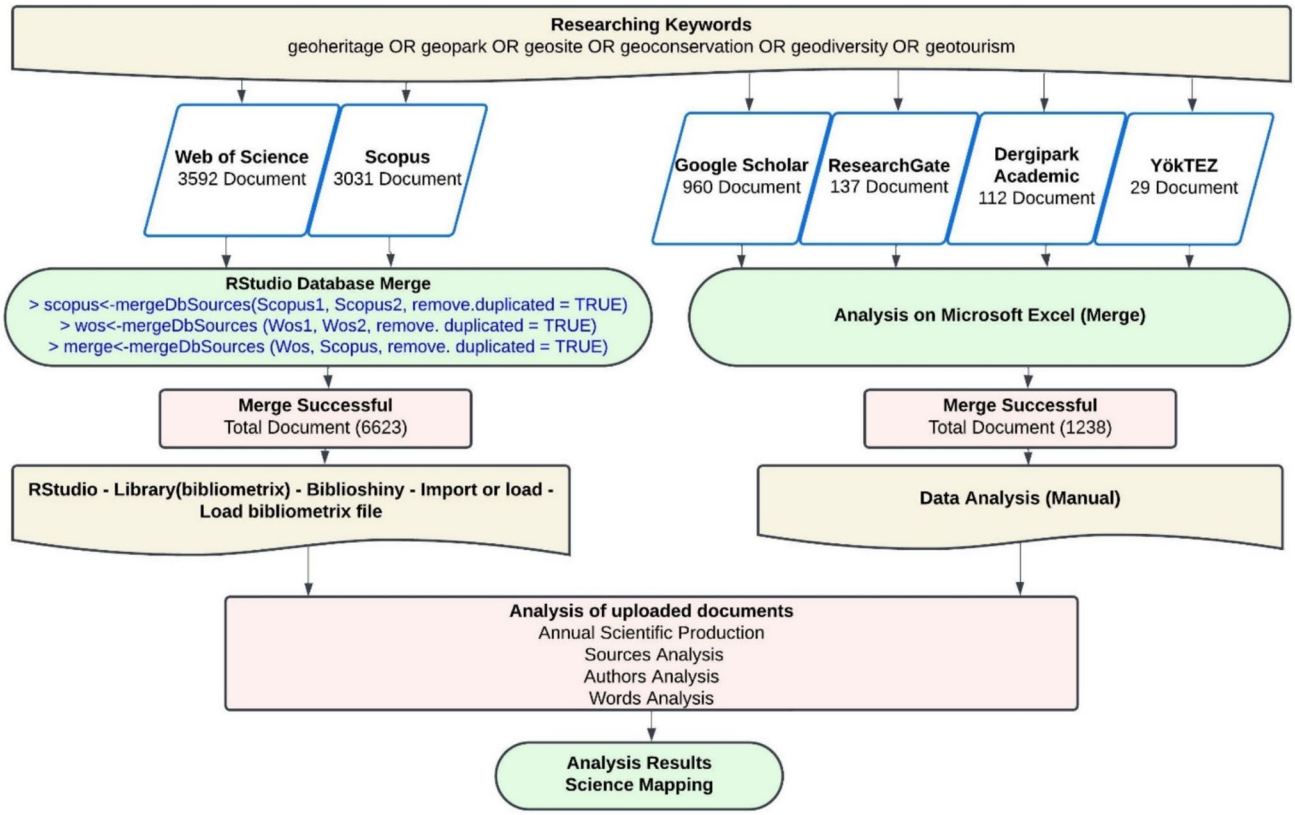

Fig. 2 Systematic integration of databases and data analysis

and their distribution by years was evaluated. In this process, document types (article, conference paper, book chapter, etc.) and the increase rates of the resources over the years were analyzed. Authors'productivity, collaboration networks and preferred publication outlets were determined. In particular, the distinctive characteristics of author contributions were analyzed in detail regarding the difference between Türkiye and international literature. Keyword analysis allows for the identification of the most used terms in the literature and the establishment of the relationships of those terms. The centrality, density, and co-occurrences of keywords have been analyzed to identify the main themes in the research field and their interconnections. Co-word networks were created, visualizing the relationships among frequently used keywords in the literature. These analyses have provided valuable data for predicting future trends in the literature (Aria and Cuccurullo 2017; Farooq et al. 2023; Passas 2024).

Data Visualization and Interpretation

Bibliometric maps help visualize research themes and provide insights into the literature's overall structure. These maps highlight the density of themes in the literature, revealing the levels of exploration for specific research topics. Visualization tools enhance the clarity and comprehensibility of keyword networks and thematic maps. This methodological approach offers a comprehensive evaluation of the current state and future trends of the research field, contributing to the identification of gaps in the literature and opportunities for interdisciplinary collaboration.

Results

International Literature

Key Information and Descriptive Statistics

A total of 4,441 documents were analyzed in the study covering data from 1994 to 2024. These documents were limited to articles, conference papers, books, and book chapters. A total of 1137 different sources were included in this analysis, indicating that the data were compiled from a wide variety of sources. The annual document increase rate was calculated as 21.19%; this rate reveals that the studies carried out in the relevant field have increased rapidly over the years. The total of 4,441 documents was contributed by 11,450 authors. This indicates that the field has a wide scientific participation. While the number of single-authored documents is 466, the

Table 1 Descriptive statistics and key metadata for the analyzed dataset

Descriptive Statistics and Key Metadata	
Timespan	1994–2024
Sources (Journal, Books, etc.)	1137
Documents	4441
Annual Growth Rate %	21,19
Authos	11,450
Authors of Single-Authored Doc	466
Document Average Age	4,93
Average Citations Per Doc	10,21

number of publications produced through collaboration is 3,975 (Table 1).

An average of 4.12 authors per document highlights that research in the field is largely collaborative. These studies, 18.42% of which were produced through international collaboration, validate the field's involvement in global scientific interaction. Additionally, the average age of the documents is 4.93 years, indicating that studies in this field are relatively recent. These data reveal that the field has a dynamic structure in terms of scientific productivity, international collaboration, and impact (Table 1).

Annual Trends in Scientific Output (1994–2023)

When the time series of scientific production between 1994 and 2023 is examined, a significant upward trend in scientific studies is observed. The number of scientific publications, which remained at relatively low levels during the 1990 s, has shown a remarkable increase, particularly from the mid- 2010 s onward. For instance, this upward trend began with 452 documents in 2019 and peaked at 654 documents in 2021. This uphill trend could also be related, in particular, to the historic sequence and growth of the movements of nature conservation. The modern concept of conservation first acquired focus through a national movement in the United States, where during the mid-century, the parks idea initiated natural safeguarding efforts to take real roots. It was further advanced with the establishment of Yellowstone in 1872, the world's first true national park, marking the beginning of a worldwide, broader-reaching nature preservation movement. Following these developments, the Digne Declaration, published in France in 1991, outlined the framework and basic principles of the geopark concept. In 2000, the European Geoparks Network was established, and in 2004, the UNESCO Global Geoparks Network was officially declared. Further to this, the Asia–Pacific Geoparks Network was established in 2007, followed by the African Geoparks Network in 2009 (Göktaş 2023).

The direct implication of scientific production, establishing geopark networks brings about more opportunities for the scientifically active parts of the sites to reach a focal point they deserve within the circles of these geosites. Noticeably, the status change regarding Geoparks, after their international registration during UNESCO's 38 th General Conference in 2015, developed the weight this area takes in scientific interest. This change reflects the fact that geoparks, since the establishment of the International Geosciences and Geoparks Programme, are no longer just areas of interest to local or regional level but have become a focus of international conservation and research. These developments have led to a significant increase in scientific publications related to geoparks since 2015. The decline following the peak in scientific production in 2021 is due to the negative impact of the pandemic on global research and field studies. The pandemic period led to restrictions on physical fieldwork and disruptions in international collaboration and research projects. This explains the fluctuation and temporary decline in scientific production (Table 2).

Most Relevant Publications and Sources

In the figure, the most important scientific resources on geoheritage are ranked according to the number of articles published and which journals have contributed the most to the literature in this field are highlighted (Fig. 3). At the core of the geoheritage literature, the journal *Geoheritage* stands out as the primary source of comprehensive academic studies in this field, with 797 articles. It is by far the leader in scientific production in the field. The journal published by the International Association for the Conservation of Geological Heritage (ProGeo) since 2009 has significantly enhanced the knowledge base in the field by comprehensively presenting research on the conservation, management, and sustainable use of geological heritage (ProGeo 2024). Another

Table 2 Annual Distribution of Scientific Publications (1994–2023)

Year	Documents	Year	Documents	Year	Documents
1994	1	2004	7	2014	139
1995	0	2005	10	25,015	183
1996	0	2006	7	2016	201
1997	1	2007	16	2017	179
1998	2	2008	31	2018	327
1999	2	2009	28	2019	452
2000	1	2010	62	2020	407
2001	3	2011	107	2021	654
2002	4	2012	98	2022	577
2003	4	2013	89	2023	530

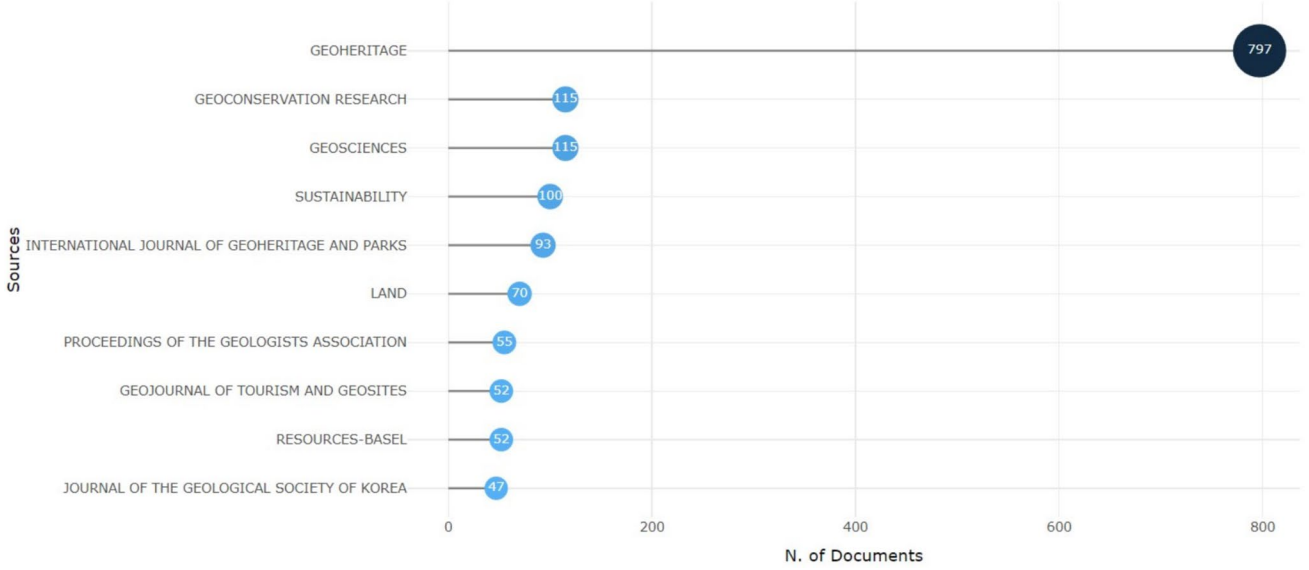

Fig. 3 Most Relevant Sources

prominent journal in which geoheritage studies have found a place within the scientific community is *Geoconservation Research*, ranking second with 115 articles. It particularly contributes to studies focused on nature conservation and the preservation of geological sites. Established in late 2018, this journal aims to publish articles within the framework of geoconservation and geoheritage concepts (Oxford International Collaboration Centre (OICC Press) 2024). The journal *Geosciences* ranks third with 115 articles, approaching geoheritage studies from a broad perspective within the context of geological sciences.

Another characteristic that reflects the interdisciplinary nature of the geoheritage literature involves the 100 articles published in the journal Sustainability. The concept of sustainability emerges as a fundamental principle in geoheritage conservation, playing a vital role in ensuring the long-term preservation of natural heritage (Şengün et al. 2023a, b). Sustainability is an international, scientific, peer-reviewed, open-access journal that aims to support the United Nations'2030 Agenda for Sustainable Development by emphasizing the importance of sustainability and sustainable development for humanity (Sustainability Journal, 2024). In this context, the journal publishes significant studies that highlight the intersection of geological heritage with multidisciplinary fields such as sustainable tourism, ecological balances, and the protection of natural resources. As a result, studies on the concept of geoheritage provide multidimensional contributions to fields such as environmental sustainability, protection, land management, and local development through an interdisciplinary approach. The articles published in the aforementioned journals demonstrate that the conservation and sustainability of geoheritage have transcended being merely a topic of scientific debate, becoming an integral part of environmental policies and sustainable development goals at both local and global levels (Fig. 3).

The Fig. 4 illustrates the cumulative changes in scientific production over the years for various journals contributing to the geoheritage literature. Geoheritage journal has shown a rapid rise since the 2010 s, becoming the most influential source in the field, particularly in the post- 2020 period. This indicates that the topic of geoheritage has been receiving increasing attention in academia, and that the Geoheritage journal serving as a central platform for these studies. Other significant journals, including *Geoconservation Research, Geosciences, International Journal of Geoheritage and Parks,* and *Sustainability*, have shown a more gradual increase, gaining notable momentum in the post- 2020 period (Fig. 4).

Leading Authors and Productivity Trends

The authors in the Fig. 5 represent the academics who have contributed the most to the geoheritage literature and plays an important role in directing scientific studies in this field (Fig. 5). Leading researchers such *as Ruban, Migon, Nemeth,* and *Brilha* have made significant theoretical and practical contributions to the conservation of geological heritage, its integration with tourism, and the development of management strategies. *Dmitriy A. Ruban*, ranked first with 92 publications, stands out as the most prolific author in the field of geoheritage. Ruban's extensive studies on the protection, management and geotourism of geological heritage have formed the cornerstones of the literature in this field and

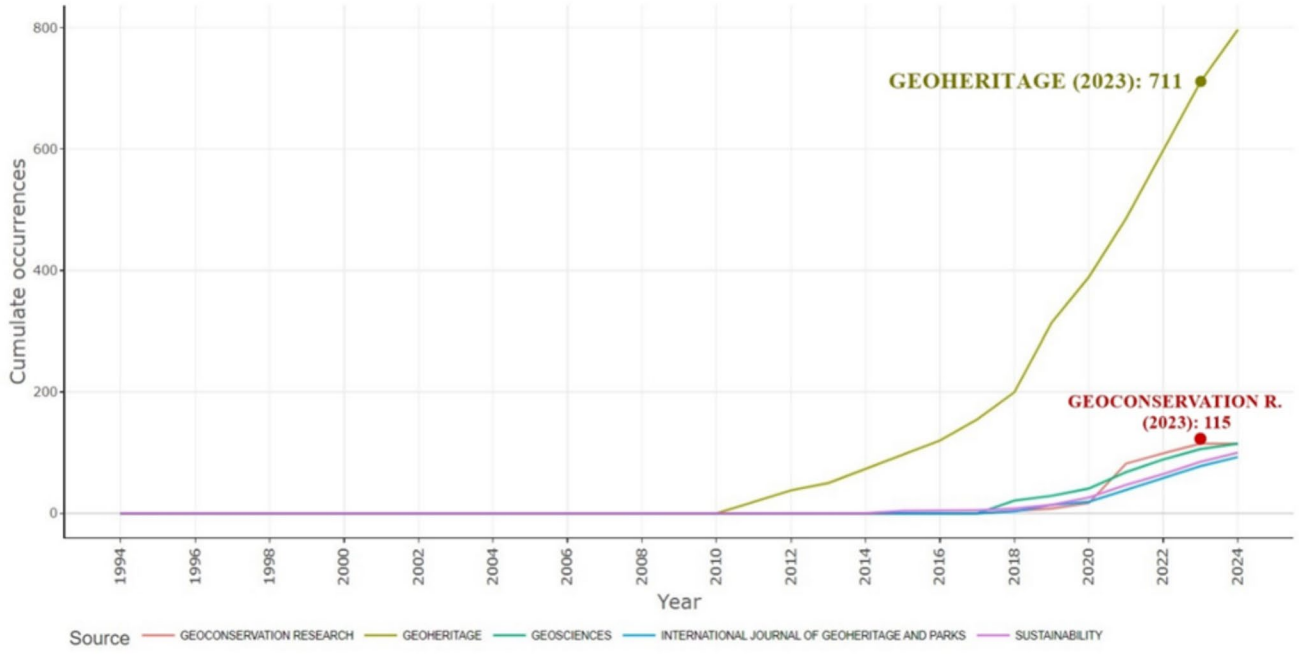

Fig. 4 Sources Production over Time

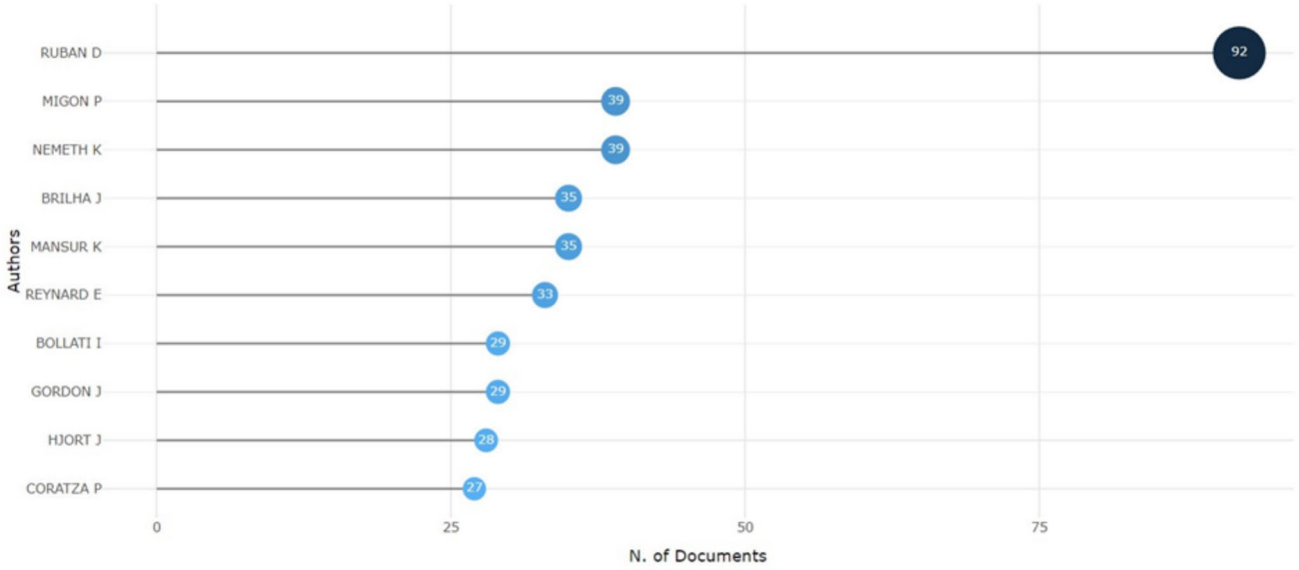

Fig. 5 Most Relevant Authors

determined the direction of scientific discussions (Ruban 2010, 2015; Bruno et al. 2014; Ruban, et al. 2022).

Piotr Migon and Karoly Nemeth rank second with 39 publications each, excelling in critical areas such as the conservation of geological landscapes and the integration of volcanic heritage into tourism. Migon is renowned for his work on the conservation and assessment of geomorphological heritage (Migoń and Pijet-Migoń, 2017, 2019; Migoń, 2018), while Nemeth has pioneered innovative approaches in volcanology and geotourism (Moufti and Németh 2016; Németh et al. 2017, 2021). Both authors have made significant contributions to the conservation of geoheritage and its sustainable management through tourism, playing a leading role in advancing the field.

José Brilha, with 35 publications, ranks fourth and is recognized as an authority for his work on the conservation of

geological heritage and the assessment of geosites (Brilha 2005, 2016, 2018; Henriques et al. 2011). Brilha's studies have provided critical recommendations on the scientific and systematic preservation of geoheritage and have led the development of standards in the field.

Authors' Production over Time

The Fig. 6 illustrates the academic productivity of the key authors in the field of geoheritage over the years. This distribution figure indicates during which year each author was more productive and how their academic contributions have been modified over time. From the figure, the academic productivity of the authors represented has greatly increased over the years. Indeed, since 2008, *Dmitriy A. Ruban* has regularly issued a number of papers on the subject. His contributions to the geoheritage literature increased significantly in the 2020 s. *Piotr Migon* and *Karoly Nemeth* began publishing regularly from 2010 onward, with notable increases in productivity particularly in 2012, 2014, and 2020. *José Brilha* reached his peak number of publications in 2016 and maintained this level of productivity in the following years. *Katia Leite Mansur* and *Reynard Emmanuel* have demonstrated increasing academic productivity since 2012, and have particularly increased their contributions in 2020 and beyond. *Irene Maria Bollati*, *John E Gordon*, *Jan Hjort* and *Paola Coratza* started publishing more from the 2010 s onwards and showed a significant increase in production in the 2020 s (Fig. 6).

The increases in academic production observed in the figure show that the scientific importance and interest of the field of geoheritage has grown rapidly in recent years. Especially since 2010, many authors have started to publish more regularly, indicating that the subject of geoheritage has gained widespread acceptance in the academic community and that research in this field has gained momentum.

Keyword Analysis and Thematic Networks

Figure 7 reveals that the most emphasized themes in the geoheritage literature are *geotourism* (1006 uses), *geoheritage* (833 uses) and *geological heritage* (162 uses). *Geotourism* has a broad scope where not only the physical environment but also the socio-economic and cultural contexts are taken into account (Dowling and Newsome 2016; Ólafsdóttir and Tverijonait 2018). When Fig. 7 is examined, it becomes evident that geotourism emerges as a key theme in the integration of geological heritage with sustainable tourism and in assessing the economic, social, and cultural dimensions of these areas.

The concept of "*geoheritage"* refers to natural and geological formations, either on the Earth's surface or underground, that hold scientific, aesthetic, cultural, or educational value and are preserved and promoted for these purposes. Geoheritage is not limited to the transmission of geological and geomorphological knowledge; it also sheds light on the scientific development of human history, cultural heritage, and interactions with the natural environment (Reynard and Brilha 2017; Pijet-Migoń and Migoń, 2022). When figure is examined, it is clear that the concept of geoheritage has become a focal point for studies on the conservation, management, and promotion of geological heritage. The fact that the term "geoheritage" ranks second among the most

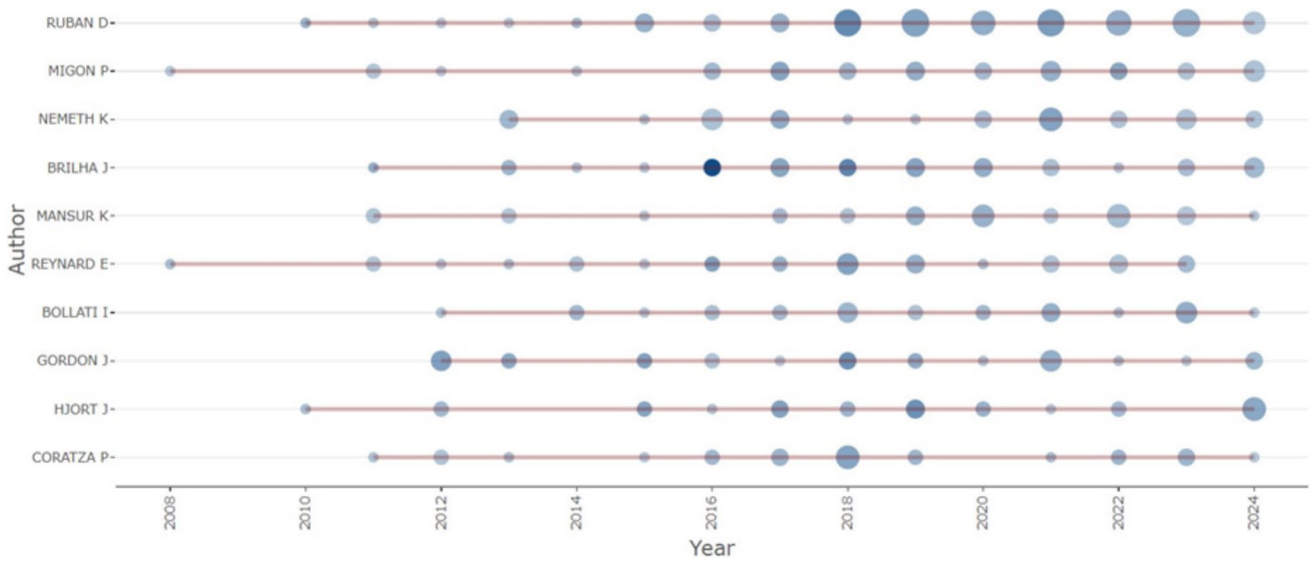

Fig. 6 Authors' Production over Time

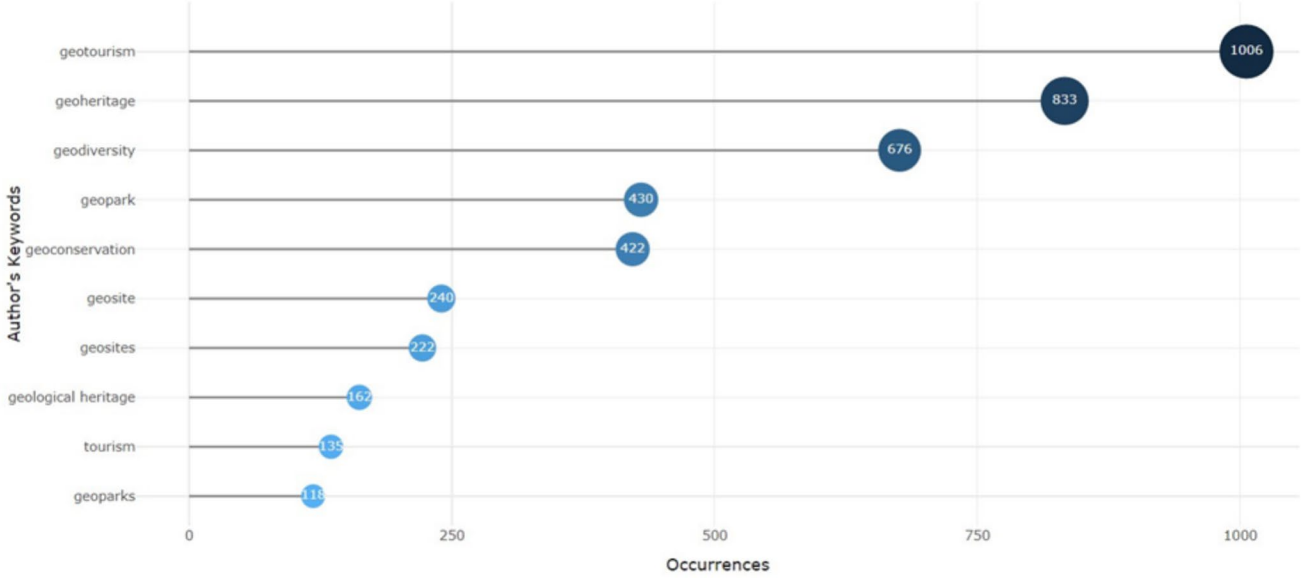

Fig. 7 Most Frequent Words

frequently used words, with 833 uses, highlights the growing attention toward studies in this field (Fig. 7).

The term "geodiversity," ranking third with 676 occurrences in the literature, is a foundational concept in geoheritage studies, providing an essential framework for understanding the field. Gray (2013) defines geodiversity as the natural diversity of geological (rocks, minerals, fossils), geomorphological (landforms and processes), and soil features. Furthermore, Serrano and Ruiz-Flano (2007) emphasize that geodiversity represents a holistic approach, encompassing both natural and human-induced processes. This concept thus addresses not only the conservation of geological elements but also their relationship with human activities, reinforcing the multidisciplinary nature of the field. The frequent appearance of "geodiversity" in the figure underlines its significance as a widely studied and highly valued topic in geoheritage studies (Serrano and Ruiz-Flano 2007; Gray 2008).

The analysis shows that the terms "geopark" (430 occurrences) and "geoparks" (118 occurrences) appear a total of 548 times, ranking fourth in geoheritage studies (Fig. 7). This emphasizes the critical role of geoparks in the protection, promotion, and sustainable management of geological heritage. Geoparks play a significant role in raising awareness by educating the public about the importance of geological heritage. These areas serve not only as sites for conserving and promoting scientifically significant geological formations but also as hubs for sustainable tourism, contributing to economic development (Azman et al. 2010). The frequent appearance of the term "geotourism" in the figure further reflects the integration of conservation efforts with public engagement. As a result, geoparks occupy a vital position in the literature, bridging scientific research with societal perspectives.

Similarly, the terms "geosite" and "geosites," used a combined 462 times, underscore their importance in geoheritage literature. Geosites, which are natural formations of geological, geomorphological, or paleontological significance, provide scientific, aesthetic, cultural, or educational value. Protecting geosites is crucial for geotourism and the sustainable utilization of natural heritage. According to Reynard and Panizza (2005) and Gray (2013), the conservation of geosites supports scientific research while enhancing public understanding of geological processes. Hose (2012) adds that geosites contribute to sustainable development by fostering environmental awareness. The frequency of these terms in the figure highlights their significant role in geoheritage studies, where they are recognized for their scientific, educational, and touristic value.

The term "geoconservation," appearing 422 times in Fig. 7, further illustrates its critical role in geoheritage literature. As defined by Gray (2013) and Prosser (2013), geoconservation involves practices and management strategies aimed at preserving geological and geomorphological heritage for future generations. Burek and Prosser (2008) emphasize that geoconservation contributes to sustainable development at both local and global levels. Geoconservation activities enhance the value of geological heritage by ensuring that these areas remain accessible for scientific research, education, aesthetics, and tourism. The frequent mention of "geoconservation" in the figure reflects the high level of academic interest in preserving geoheritage and

addressing threats to it. In this context, geoconservation plays a pivotal role in identifying, protecting, and managing geological heritage, ensuring its contribution to sustainable natural resource management.

In conclusion, the term geotourism emerges as the most frequently used keyword with a 21% usage rate. This is followed by geoheritage at 18%, emphasizing the importance of conserving geological and geomorphological features and promoting their sustainable use. Geodiversity (14%) addresses the presence of geomorphological and geological diversity and is a crucial concept for the field. Geopark (9%) and geoconservation (9%) are frequently used in studies on the preservation and management of geological structures.

Geosite (5%) and geosites (5%), with a combined 10% usage rate, reflect efforts to identify geological structures that hold aesthetic, scientific, and educational value. Additionally, terms such as geological heritage (3%), tourism (3%), biodiversity (2%), sustainable development (2%), geoeducation (2%), and geomorphology (2%) are used less frequently, as illustrated in Fig. 8. These terms highlight the diverse dimensions of geoheritage and its interdisciplinary nature.

Figure 9 shows how the keywords used in the research are used by countries and researchers. The keywords around which the research has developed are the most frequently used in the field of geoheritage. The most commonly used keywords by the leading countries in publications related to the topic (Italy, Spain, China, Brazil) are displayed in Fig. 4. In studies conducted in Italy, Spain, and Poland, the primary keywords used are *"geoheritage"* and *"geotourism."* In Brazil, this situation has changed to "*geodiversity* and *geoconservation.*" In China, the most frequently used keywords are *"geopark* and *geoheritage."* The words used less by countries compared to other keywords were "*geopark* and *geosite*". The most frequently used keywords by the leading researchers (Ruban D., Migon P., Nemeth K., Brilha J., Mansur K., and Reynard E.). Figure 5 are identified as *"geotourism," "geoheritage,"* and *"geodiversity,"* respectively. The figure shows that the keywords used by researchers are directly proportional to the topics they focus on in their studies (Fig. 9).

Three-Field Plot

Co-occurrence Network

Figure 10 represents each keyword as a node, with the size of the nodes indicating the frequency of the keyword's usage in the literature. The lines between the nodes represent the frequency of co-occurrence of these terms. The largest node, geotourism, indicates that this term is central to the geoheritage literature and is the most used keyword by researchers. The terms geoheritage and geodiversity appear as other prominent nodes strongly associated with geotourism. This indicates that these three terms are frequently addressed together in geoheritage studies.

Other nodes in the network such as geoconservation and geopark are also worth noting; although these terms are shown as relatively smaller nodes, they have significant connections with geotourism, geoheritage, and geodiversity. This analysis highlights that geoprotection and geoparks hold a significant, though less frequently emphasized, position in geotourism studies. The thickness of the connecting lines in the network represents the frequency of co-occurrence of two keywords within the same studies. Thick lines indicate a strong relationship between terms, while thin lines suggest weaker connections. Notably, there are very thick lines between "geotourism" and "geoheritage" as well as "geodiversity," demonstrating that these terms are often used

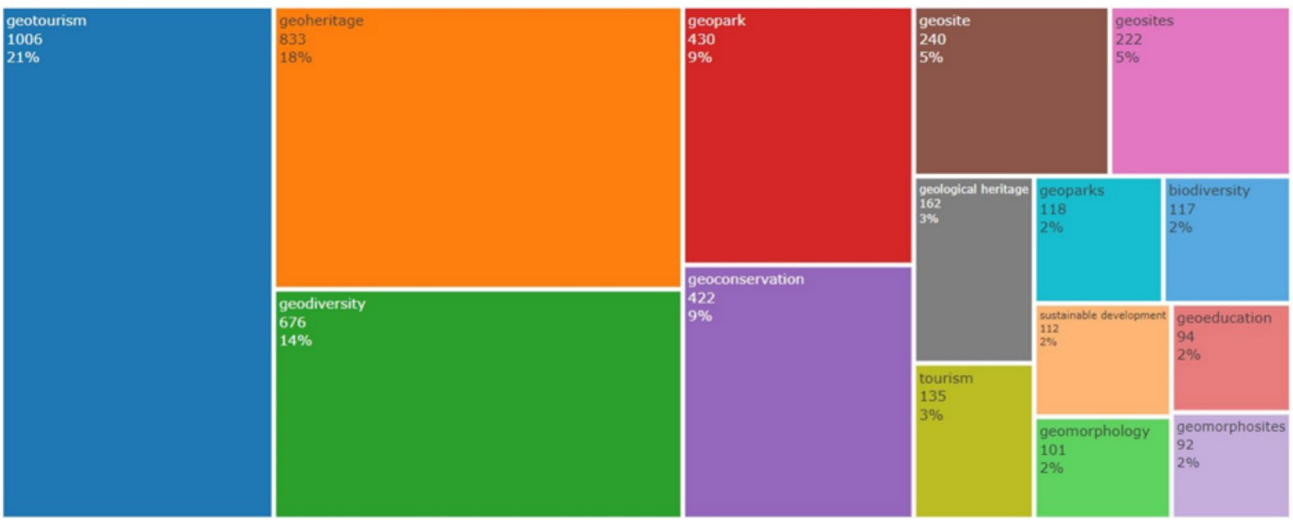

Fig. 8 TreeMap

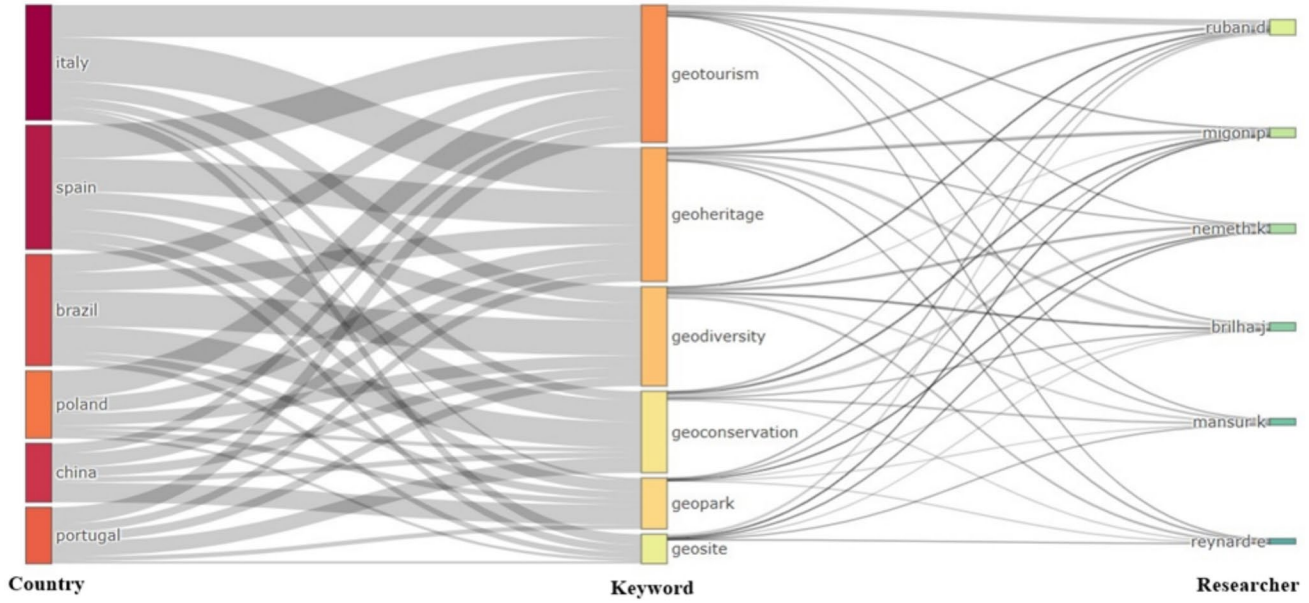

Fig. 9 Three-Field Plot

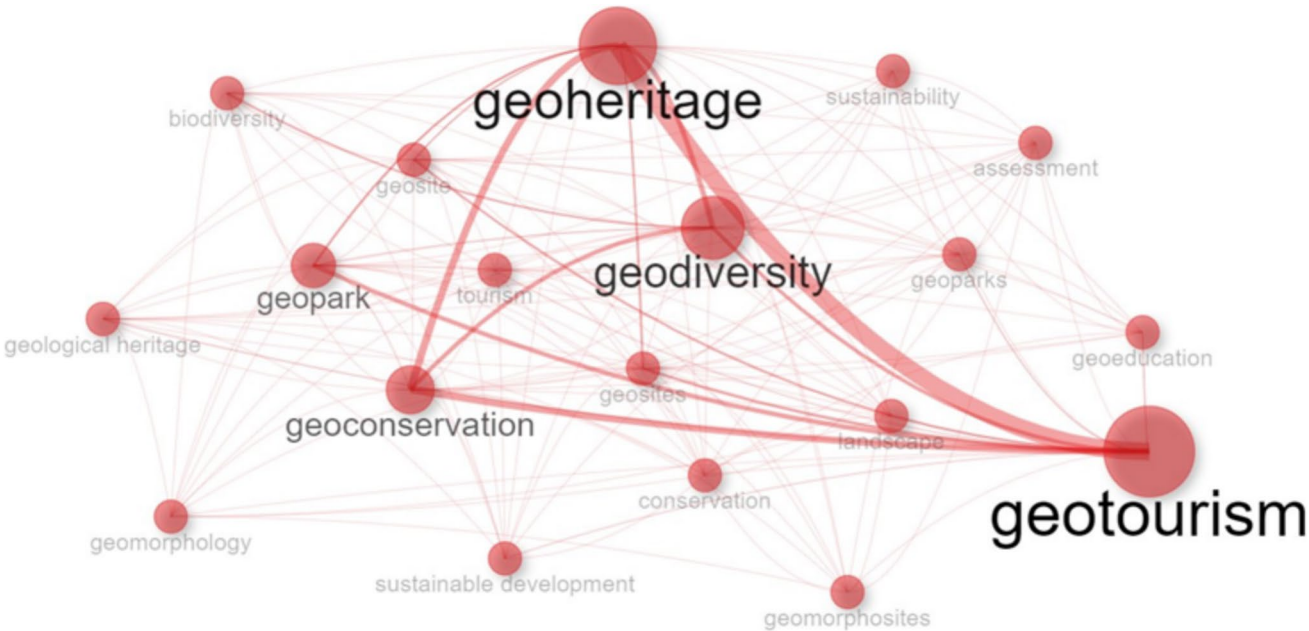

Fig. 10 Co-occurrence Network

together in the literature. Conversely, terms such as "biodiversity," "sustainable development," and "geomorphology," represented by smaller nodes, exhibit weaker connections to geotourism and appear as secondary topics in specific studies. The overall structure of this keyword network is vital for understanding the co-occurrence of terms in the literature and identifying the primary themes that researchers prioritize.

Thematic Map

The Thematic Map analysis categorizes keywords into four thematic groups: Motor Themes, Basic Themes, Niche Themes, and Emerging or Declining Themes. The keywords on the map are evaluated along two dimensions:

- Relevance Degree (Centrality): Indicates how central and important a term is within the research field.
- Development Degree (Density): Reflects how developed or extensively studied a term is.

This framework helps in understanding the thematic structure of the research area and identifying the role and significance of each keyword in the literature.

1. **Motor Themes**: This quadrant features key terms with both high centrality and density, including *Geotourism*, *Geoheritage*, and *Geopark*. These terms are the main driving forces in geoheritage studies, frequently addressed in the literature. Acting as foundational and advanced research pillars, they play a crucial role in shaping the field's development and guiding its direction. Their prominence highlights their importance in both theoretical and applied studies.
2. **Basic Themes**: Found in the bottom-right quadrant of the figure, terms such as *Geodiversity*, *Geomorphology*, and *Landscape* demonstrate high centrality, indicating that they are fundamental and widely referenced in the literature. However, their lower density suggests that, despite their central importance, they have not been extensively explored or developed. Terms like *Tourism*, *Conservation*, and *Sustainability* also fall into this category. While these concepts are relevant and prevalent, they require further research and in-depth investigation to unlock their full potential and advance their understanding within the field.
3. **Niche Themes**: Keywords like *Development* and *Sustainable* are located in this region, characterized by high density but low centrality. These terms are deeply studied within specific subfields, marking them as niche themes. However, their limited centrality indicates that their relevance is confined to particular contexts, and they do not play a significant role in the broader geoheritage studies landscape. Despite their narrower focus, these terms contribute valuable insights to specialized areas of study.
4. **Emerging or Declining Themes**: Terms like *Diversity*, located near this quadrant, show both low centrality and low density. These keywords represent research topics that may either be emerging, with the potential to gain prominence in the future, or declining, gradually losing relevance in the literature. Emerging themes hold potential for growth and offer opportunities for innovative research. Alternatively, as declining topics, they reflect shifts in research priorities and the evolving focus of geoheritage studies.

As a result, terms such as Geotourism, Geoheritage and Geopark have a strong relationship with other terms as motor themes of the field. On the other hand, terms such as Geodiversity, Geomorphology and Landscape are frequently included as basic topics, but they need to be studied in more depth (Fig. 11).

Literature in Türkiye

Distribution of Scientific Publications in Türkiye by Year

According to Fig. 12, the number of publications, which ranged between 2 and 6 from 2004 to 2010, increased after 2010, reaching 15 publications in 2012. Kula-Salihli Geopark, Türkiye's UNESCO-registered geopark, made its first official

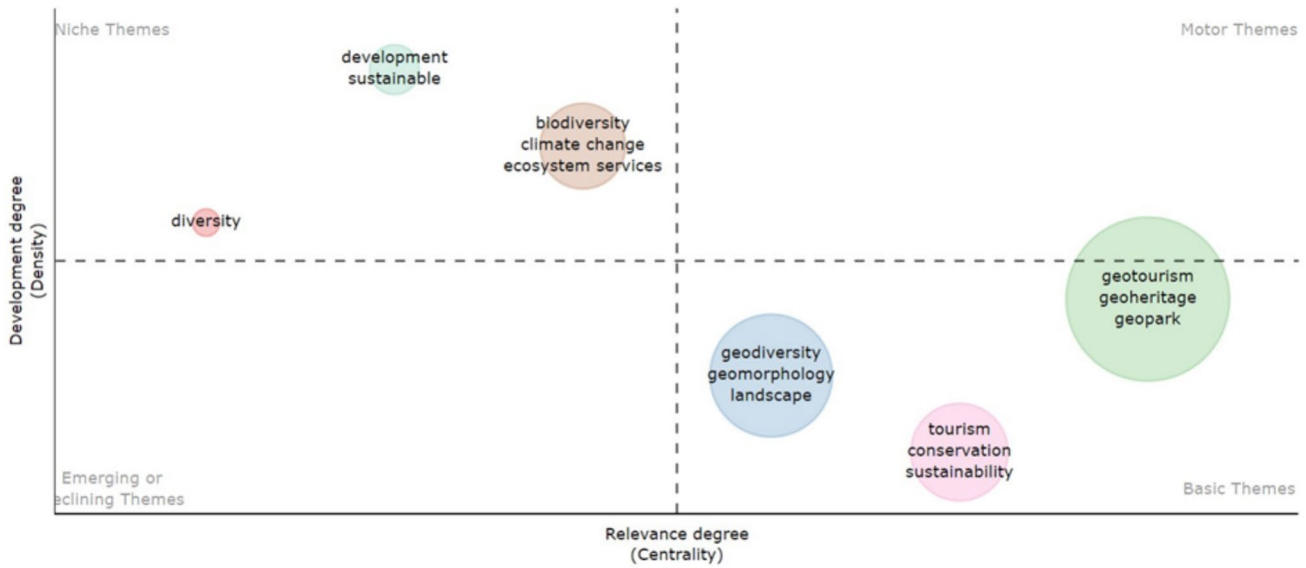

Fig. 11 Thematic Map

application to the Global Geopark Network (GGN) in 2012. In 2013, it was officially recognized by the Global Geoparks Network (GGN), becoming Türkiye's first geopark. With the European Geoparks Network joining the UNESCO Global Geoparks Network in 2015, the status of"Kula Global Geopark"was updated to"UNESCO Kula Global Geopark"(Demir and Aytaç, 2018; Göktaş, 2023). This status has encouraged studies on the geopark and it is observed in the figure that it has caused an increase in the number of publications. From 2014 onward, the number of publications fluctuated between 15 and 38, reaching its peak with 38 studies in 2017. The increase in publications in 2017 can be explained by the 70 th Geological Congress of Türkiye, organized by the Chamber of Geological Engineers of the Union of Chambers of Turkish Engineers and Architects (TMMOB), where the research theme was"Cultural Geology and Geological Heritage."After 2017, the fluctuating increase in the number of publications continued. When the general situation is evaluated, it is observed that the interest in the subject has increased and intensive work has begun (Fig. 12).

Most Referenced Journals and Sources in National Literature

The analysis was conducted within the framework of articles, books, book chapters, conference proceedings, and theses. Within this scope, institutional sources, including 202 different journals, books, and theses, were examined in detail. As a result of the examinations made in the context of journals, it was seen that the Turkish Geological Bulletin Journal published the most studies on the subject with 18 studies. The Journal of Geomorphological Research ranks second with 8 studies, the Blue Planet Journal ranks third with 4 studies, and the Fırat University Journal of Social Sciences ranks fourth with 3 studies. In the proceedings of various years of the Turkish Geological Congress, a total of 41 studies were identified. The analysis revealed a total of 29 master's and doctoral theses from 24 different universities (Fig. 13).

Keyword Distribution and Thematic Analysis in National Studies

The figure illustrates the academic productivity and research areas of the most prolific authors. One of the outcomes of the analysis is that authors from diverse fields show interest in the subject. The data in the figure reveal that writers such as Yıldırım Güngör, Ahmet Serdar Aytaç and Yahya Çiftçi stand out in the fields of geology and geography. The high number of publications by these authors indicates that they provide a significant amount of knowledge and activity in their relevant fields. It is associated in the table that Yıldırım

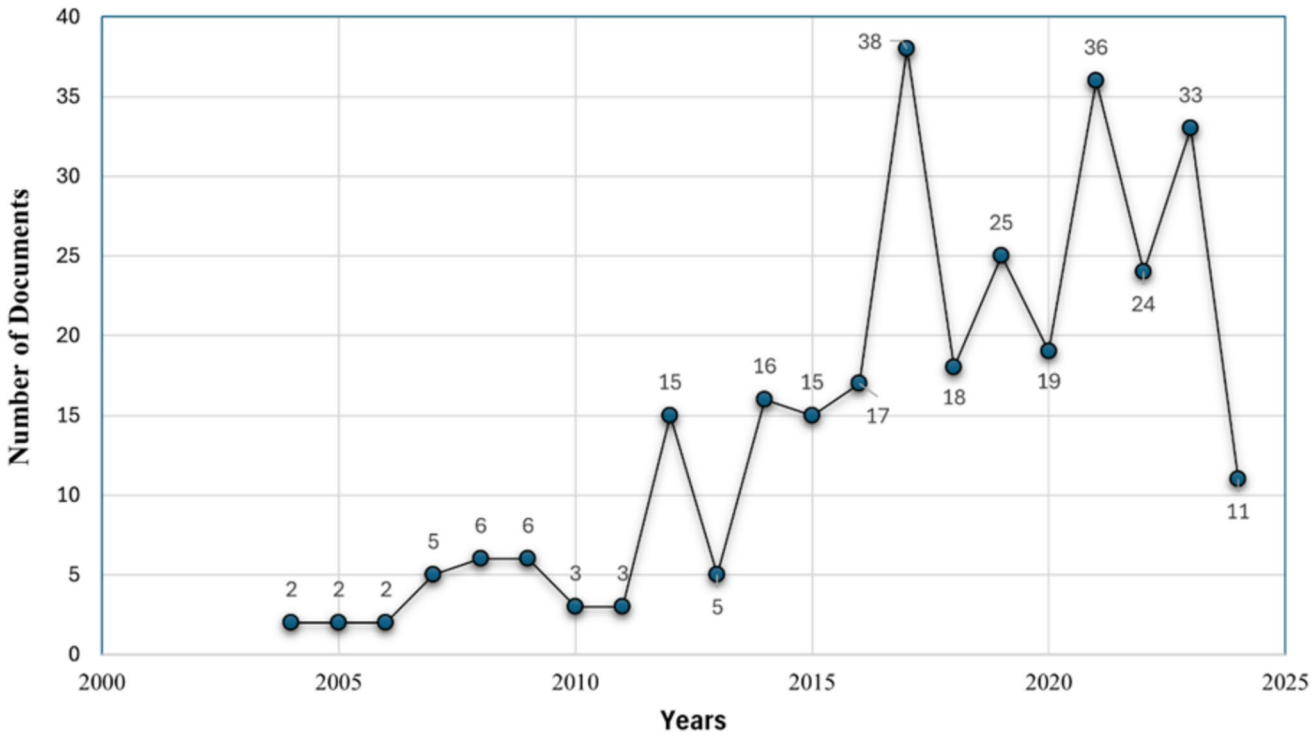

Fig. 12 Annual distribution of scientific publications in Türkiye

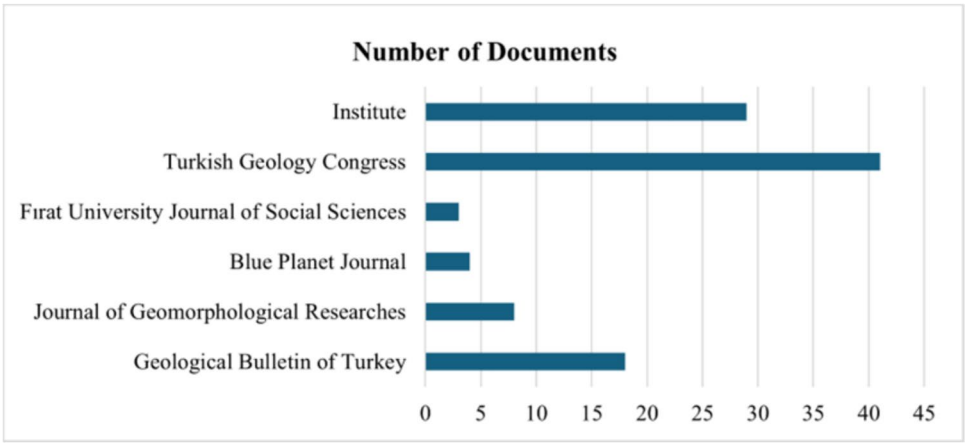

Fig.13 Journal Analysis

Güngör was active in the field of geology and Ahmet Serdar Aytaç was active in the field of geography. This indicates that studies in the context of geology and geography disciplines are dominant among this group of authors (Fig. 14).

Yıldırım Güngör ranks first with 32 studies conducted on the topic. The author has primarily focused on geopark projects, geological heritage inventory studies, and geosite assessment topics (Güngör, 2003; Güngör et al. 2012; Çiftçi and Güngör, 2014, 2016, 2021). Ahmet Serdar Aytaç ranks as the second most prolific author with 25 studies. Aytaç has conducted studies on geopark-geoheritage potential, geopark projects, and geotourism (Demir and Aytaç, 2018; Aytaç and Demir 2019; Aytaç et al. 2023; Pellıcer et al. 2024). The figure also highlights the contributions of authors such as Nizamettin Kazancı, Fuat Şaroğlu, and Tuncer Demir to the field (Kazancı and Şaroğlu 2007; Kazancı, 2010; Kazancı et al. 2015; Demir and Aytaç, 2018). In addition, Nurhan Koçan's work in the field of landscape architecture reveals interdisciplinary interaction and richness by offering diversity in figure (Yıldırım and Koçan 2008; Koçan 2011, 2012).

There is a notable relationship among the research areas of the authors. Geology and geography stand out as two main fields that stand out in the works of many authors. This facilitates interdisciplinary knowledge exchange and collaboration among the authors.Collaboration and joint thematic studies among authors play a vital role in enhancing academic productivity. Additionally, it is evident that interdisciplinary collaboration and scientific dissemination jointly contribute to academic impact.

Most Used Keywords

The analysis reveals that the most frequently used keywords include Geotourism, Geopark, Geosite, Geoheritage, and Geological Heritage. This confirms that the keywords used in research are among the most frequently utilized terms

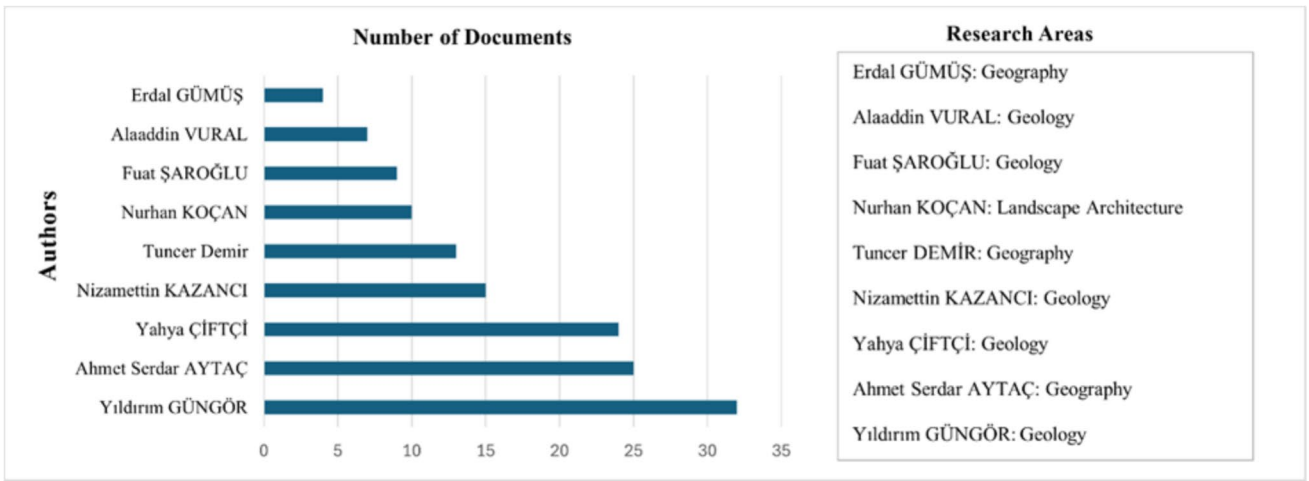

Fig. 14 Author and Field of Study Analysis

(Fig. 15). Another result of the analysis is that there is a parallelism between the keywords used in the literature in Türkiye and the words used in the national literature (Fig. 7). The concept of geotourism addresses the relationship between the human environment and the natural environment in geopark studies. Geotourism contributes to the preservation of both cultural and natural heritage by focusing on the conservation of geological structures, perspectives of societal and sustainable development, and benefits to local communities. From this perspective, the prevalence of the term geotourism as the most frequently used keyword in both national and international indices highlight the critical importance of human impact in geopark studies. The frequent use of the terms Geoheritage, Geosite, and Geopark as key keywords in Turkish literature can be linked to the focus of the research field. Studies related to the field at the national level focus on identifying geosites and geoheritage, revealing geopark potential, and supporting sustainable geotourism. The distribution of the most frequently used keywords in the manner depicted in the figure is a natural outcome of the analysis, given the topics addressed (Fig. 15).

Discussion and Conclusion

The analysis based on international and Turkish literature reviews has revealed the current state of geoheritage studies. A total of 4,441 studies from the international literature and 1,238 studies from the national literature in Türkiye were reviewed, with 300 publicly accessible works subjected to detailed analysis. In terms of content, the national literature predominantly focuses on Türkiye's geoparks, local geological resources, and their contributions to local development. In contrast, the international literature addresses geoheritage on a global scale, offering a rich scientific foundation through its multidisciplinary approaches. The international literature has produced a diverse range of studies using methods such as inventory creation, evaluation models, fieldwork, and geographic information systems (GIS), and has examined numerous geoparks from various countries. An examination of studies conducted in Türkiye reveals that they address various sites on regional and local scales. These studies generally aim to reveal existing potential and support geotourism. An analysis of scientific production over the years reveals a steady increase in the annual number of publications in the international literature. A notable surge was observed, particularly following UNESCO's international recognition of geoparks in 2015. This surge is associated with the effective expansion of international collaboration networks and the growing global significance of geoparks. The number of scientific documents produced by countries with UNESCO geoparks is directly linked to the presence of these geoparks. Countries such as Italy, Spain, China, and Brazil host numerous UNESCO geoparks, providing significant research sites for geoheritage studies (International Geoscience and Geoparks Programme – UNESCO 2024). Geoparks encourage scientific research focused on the conservation of geological heritage, contributing to these countries ranking high in document production. In contrast, a similar upward trend is observed in the national literature, though this growth is primarily

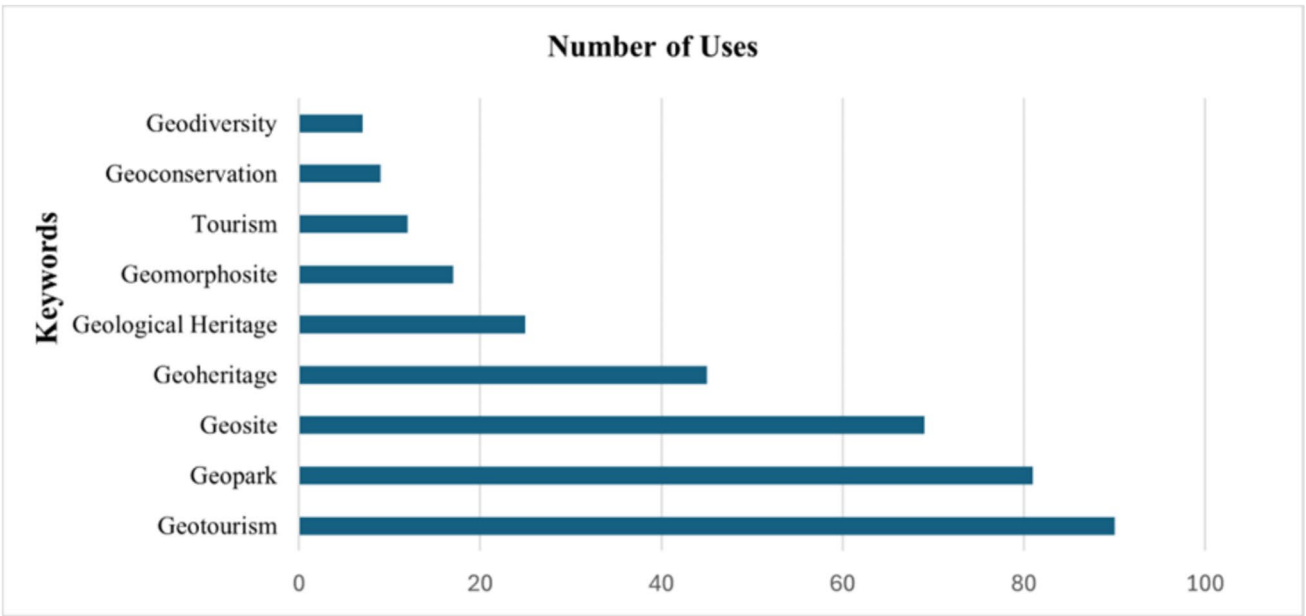

Fig. 15 Keyword Analysis

shaped by events specific to Türkiye and local dynamics. In countries like Türkiye, which have a limited number of geoparks, the number of scientific documents is relatively lower. However, increasing the number of geoparks has the potential to enhance scientific production in this field. The certification of Türkiye's first UNESCO geopark, Kula-Salihli Geopark, in 2013 significantly accelerated scientific production in the national literature. Additionally, periodic national congresses, symposiums, and workshops have supported scientific activities related to geoheritage in Türkiye. Türkiye's location corresponds to the intersection of the Eurasian, Arabian, and African tectonic plates. Being situated at the collision zone of these tectonic plates has led to various geological and geomorphological processes. This has endowed Türkiye with unique and fascinating landforms, making it a country rich in geoheritage diversity. Türkiye's unique landforms, including volcanic mountains, valleys formed along fault lines, karstic areas, fairy chimneys, as well as its geological diversity with various rock types, fossil sites, and mineral diversity, highlight the country's geoheritage potential. However, the existing potential has not been adequately studied or evaluated. Although geoheritage studies have not yet reached the desired level on an international scale, Türkiye has significant potential due to its geomorphological and geological diversity. This is primarily attributed to the lack of international cooperation, limited interdisciplinary approaches, the low number of geoparks, and the insufficient state-supported projects. To enhance geoheritage research, it is essential to promote the establishment of more UNESCO registered geoparks, encourage the integration of GIS and artificial intelligence-based analyses, and incorporate disciplines such as tourism, economics, and sustainable development into geoheritage studies. Additionally, involving local governments and the public in these processes, raising geoheritage awareness through educational programs, and strengthening the connection between academic research and international literature will contribute significantly to the advancement of geoheritage studies in Türkiye. The gaps identified through the analyses will serve as a guide for future research efforts. Keyword analysis reflects the differences and similarities between the two bodies of literature.

The most notable commonality between the national and international literature is the prominence of terms such as geotourism, geopark, geological heritage, and geosite as key themes in both. These concepts connect the two bodies of literature through shared objectives, such as the preservation of geological, biological, and cultural heritage; the development of conservation policies; achieving sustainable development; fostering environmental awareness; establishing local, regional, and international collaborations; and promoting the economic development of local communities. The use of identical keywords in both national and international literature during database searches enhances the accuracy and reliability of the analysis. In the international literature, terms such as geoheritage, geotourism, and geodiversity are widely used, while in the national literature, more specific terms like j geotourism, geopark, and geological heritage take prominence. In the international literature, these keywords are enriched through interdisciplinary connections, whereas in the national literature, they are addressed within a more locally focused framework. Additionally, strong links with areas such as biodiversity, sustainable development, and education in both literatures provide a global context to geoheritage studies. An analysis of both national and international literature reveals that the most frequently used keyword is geotourism. This highlights the shared interest in geotourism across both literatures.

When evaluated in terms of sources and journals, interdisciplinary journals such as Geoheritage, Sustainability, and Geoconservation Research dominate the international literature. These journals approach geoheritage studies from a broad perspective. They cover multifaceted topics such as the sustainable management of natural heritage, ecological balance, and integration with tourism. In contrast, the national literature is dominated by local journals such as Bulletin of the Geological Society of Türkiye, Journal of Geomorphological Research, and Blue Planet. These journals primarily focus on topics such as identifying local geoheritage sites, conserving them, promoting them for tourism, and exploring their geopark potential. The presence of numerous studies across a variety of journals indicates a growing interest in the field in Türkiye. However, the source diversity and interdisciplinary interaction observed in the international literature remain limited in the national literature, which tends to adopt a narrower, locally focused approach.

In conclusion, the national literature in Türkiye provides valuable insights at the local level, focusing on the country’s geological heritage and geoparks. Country-specific studies propose geopark recommendations, reveal geotourism potential, and aim to promote a conservation-utilization approach within the framework of sustainability. Numerous studies have been conducted in the increasingly important field of geoheritage, with geography and geology emerging as the two leading disciplines in this area. Beyond these disciplines, contributions from fields such as landscape architecture, tourism, and urban and regional planning are also evident. However, these contributions remain relatively limited in number. In this context, it can be stated that bringing together different disciplines at the national level is necessary. Interdisciplinary studies in Türkiye will enhance the diversity of resources and provide opportunities for the country's contributions to be recognized in the international literature. The international literature approaches the subject

from a broader perspective, incorporating interdisciplinary connections and enriching geoheritage studies with a global outlook. To make Türkiye's geoheritage and geotourism research more inclusive and impactful on the international stage, enhancing collaboration between national and international literature is essential. Such collaboration, by integrating local and global dynamics, can provide multifaceted and sustainable solutions at both scientific and practical levels. Developing a coordinated approach at both national and international levels for the preservation and promotion of geological heritage will enhance scientific productivity and effectiveness in this field.

Author Contributions Göktaş, (70%) was responsible for conceptualization, methodology design, data analysis, and writing the original draft of the manuscript. Boyraz, (30%) provided supervision throughout the research process. Both authors have reviewed and approved the final version of the manuscript.

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Data Availability All data referring to this study are available with the corresponding author and will be made available upon request by email.

Declarations

Conflict of interest The authors declare no competing interests.

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