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Geoheritage and Geosites: A Bibliometric Analysis and Literature Review

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Abstract: Geological heritage represents and brings together geological elements of great local and global relevance. It also promotes conservation and sustainable use. This study aims to perform a bibliometric analysis of the contributions that address the topics of geological heritage and geosites, using the Scopus and Web of Science databases for the knowledge of trends and research focuses in this area. The methodology consists of: (i) the preparation of the idea and gathering information from a search on the subjects of interest (geoheritage and geosites); (ii) the merging of the databases and applying automated conversions; and (iii) the analysis of the results and the literature review. The first phase of the work identified 2409 and 1635 documents indexed in Scopus and WoS, respectively. The merged global database (2565 documents) identified the following words as analysis topics: geoconservation, geotourism, geopark, and geodiversity. The analysis also revealed the top five countries in scientific contributions as Italy (12.1%), Spain (8.77%), China (5.67%), Portugal (5.35%), and Brazil (5.31%). Finally, most of the publications focus on the characterisation, assessment, and development of geosite initiatives. The main lines of action and contributions to the topics (7.91%) highlight the fact that geoscientists worldwide value geosites for geoconservation and geotourism strategies.

Keywords: geotourism; geoconservation; Scopus; Web of Science; research trends; scientometric analysis

1. Introduction

Geodiversity is a term that is considered analogous to the term biodiversity [1,2]. According to Nieto [3], geodiversity is "the number and variety of structures sedimentary, tectonic, geological materials, minerals, rocks, fossils, and soils, that constitute the substratum in a region, above which the organic activity is settled, the anthropic included". On the other hand, other definitions indicate that geodiversity refers to the different objects and places with particular geological, geomorphological, and soil characteristics [4–7]. The geological heritage, "geoheritage", according to Mata-Perelló et al. and Carrión-Mero et al. [8,9], is defined as the group of geological elements or geological sites (geosites) with outstanding scientific, cultural and educational values. Geosites are geological sites or points of aesthetic, scientific, and educational uniqueness [10,11]. Moreover, geosites include "geomorphosites" (geomorphological features) [12,13]. Both have unique qualities for science, education, and tourism. According to Brilha [14], geosites such as glacial cirques, cliffs, deserts, or volcanoes are part of geodiversity with scientific value “in-situ”. Moreover, geoheritage elements as museums where geoheritage is collected, exhibited, and preserved are also part of the geodiversity with scientific value “ex-situ”. Therefore, both types are important for tourism development [15–17]. In addition, their description is of interest to tourists and for geodiversity protection [18–20]. Quantitative methodologies exist that allow the assessment, selection, and classification of geosites. Among the main methods are The Spanish Inventory of Places of Geological Interest method (IELIG-acronym in Spanish) [11], Quantitative Assessment of Geosites and Geodiversity Sites [14], Geosites Assessment Model (GAM) [10], and Modified-GAM (M-GAM) [21]. Additionally, it is important to highlight the Earth Science Comparative Matrix, focused on geomorphological processes [22], and the “Quantification of geodiversity and its loss” method [23], which calculates damage in geosites.

Geological conservation, “geoconservation”, is an initiative that aims to preserve geodiversity through protection strategies [24]. According to Brilha [14], only a small fraction of geodiversity is considered a relevant value that justifies the implementation of geoconservation strategies, regardless of whether this fraction are considered geoheritage and geodiversity (with intrinsic values). A protection strategy in areas with high geoheritage has been expanded in recent years, declaring them United Nations Educational, Scientific and Cultural Organization (UNESCO) Global Geoparks (UGGs) [25–29].

The definition of the main terms related to geodiversity is appropriate for understanding their degree of interrelation. For example, according to Carcavilla et al. [30], in cases where a territory has a wide geodiversity, the relationship between geodiversity and geoheritage will focus more on geosites needed to represent the geology of that territory, than in would in a less geologically varied one. Along the same lines, a highly geodiverse region does not necessarily have relevant geosites or a more relevant geoheritage than areas with lower geodiversity. Therefore, it is essential to understand the orientation of the works that deal with the subject studied. A simplified conceptual framework that explains and correlates geodiversity and its main components within the domain of natural diversity (geosites, geoheritage elements, geodiversity sites and geodiversity elements) [14].

The economic exploitation of unique geoheritage features is the basis of geotourism [31–34]. In general, geotourism is a type of sustainable tourism that promotes the protection of natural areas at local and international levels [5,35]. Geotourism was introduced by Hose [36], referring to a form tourism that facilitates learning about the geology and geomorphology of a site for the tourists, promoting geoconservation. In addition, governments seek to protect both geodiversity and geoheritage through geoconservation strategies [37]. Finally, geotourism and geoconservation initiatives promote and protect geodiversity through inventories [38], geoparks [39], and protection policies [35], leading to the sustainability of geodiversity, geoheritage, and geosites. The care and conservation of geoheritage lead to the promotion of geoparks proposals [40], which are integrally implicit in geotourism, geoconservation, and sustainability. Currently, geoheritage and geotourism are considered fields of study [41].

Bibliometrics study academic information through different methods, such as efficiency analysis, which relates authors, journals, citations, countries, and mapping sciences that allow the visualization of cognitive and intellectual structures in various areas of knowledge [42–44]. Its applicability is important for the study of different disciplines such as tourism [45], environmental sciences [46], education [47], sustainability [48,49], and geosciences [50,51]. In addition, bibliometric analyses contribute to understanding an academic area from its inception, evolution, and future research trends through bibliographic information.

This study aims to perform a bibliometric analysis of the contributions that address the topics of geoheritage and geosites, using the Scopus and Web of Science (WoS) databases for the knowledge of trends and research focuses in this area. It also aims to describe the research trends on the theme of geoheritage and geosites from the determination of its activity, problems, importance, and the analysis of results based on bibliometric methods.

2. Materials and Methods

The methodological process (Figure 1) comprises three main phases in this work. The first phase includes conceptualizing the geoscience idea and data preparation. The second phase focuses on merging the databases used and extracting the parameters to be analysed. Finally, the third phase involves analysing the results and reviewing the most representative literature.

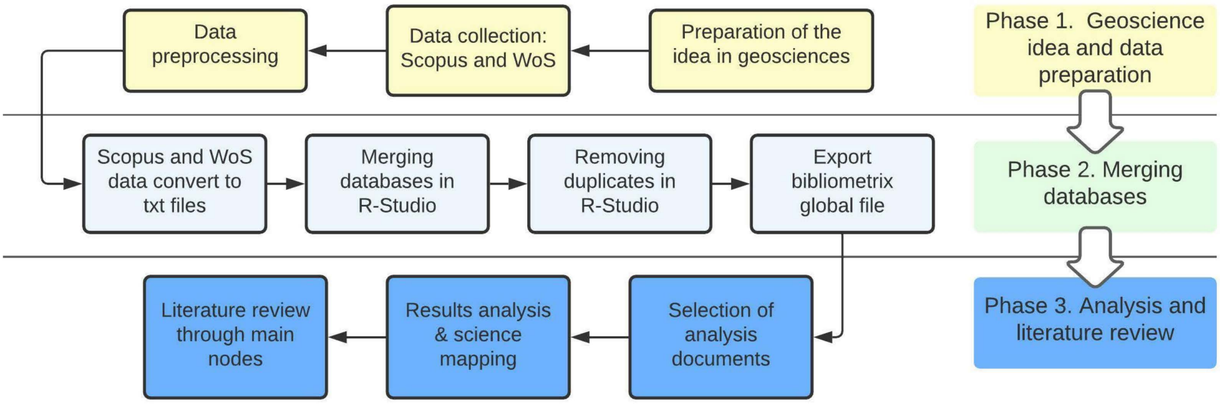

Figure 1. Diagram of the method used in this work. Based on the Echchakoui process for merging databases [52].

2.1. Phase 1—Preparation of the Geoscience Idea and Information

It is important to define the study idea and prepare information so as to cover many subjects and contribute to the body of knowledge [53]. To that end, this study obtained information from two major databases known in the academic world: Scopus and WoS. These databases have a large amount of scientific information across various disciplines of knowledge [54,55]. Moreover, both databases are used as main sources for bibliometric analyses [56,57].

Once the databases were defined, the search topics selected were "geological heritage or geo-heritage or geoheritage" or "geological site or geo-site or geosite". These topic keywords were searched for in the following fields: title, abstract, and keywords [58]. The search included all document types (e.g., articles, conference papers, editorial, comments, book chapters). Furthermore, all languages of the contributions were included in the search (e.g., English, Spanish, French) [59–62]. The search was performed in the second week of December 2021, resulting in 2409 documents from Scopus and 1635 from WoS. The records were collected from each database and exported to the following format (".xls"), which allowed them to be processed through Microsoft Excel (version 2201) [63].

In this step, after saving the databases, the databases were prepared individually. Specifically, records from 2022 were excluded because the year is presently in effect. The proposed analysis was set to recognise a study period from 1949 to 2021.

2.2. Phase 2—Merging Databases

This study merged as many records as possible from both databases to develop general analyses (e.g., the trend of publications in time). Bibliometrix 3.1 tool in RStudio (version 4.1.2) was used as it allows merging of both databases [64], and is compatible for use with the Windows 10 operating system. Bibliometrix is an open-source tool that analyses authors, keywords, and co-occurrences of the bibliographic information exported from Scopus, WoS, Dimensions, PubMed, and Cochrane [65–67]. In addition, this tool converts files to have the same labelling format in columns, obtaining a merged database [52]. For duplicate documents, this study prioritised WoS due to the quality of journals indexed in that particular database [68]. Figure 2 shows the process of merging databases using the covert2df, mergeDbSources, and export functions from Bibliometrix.

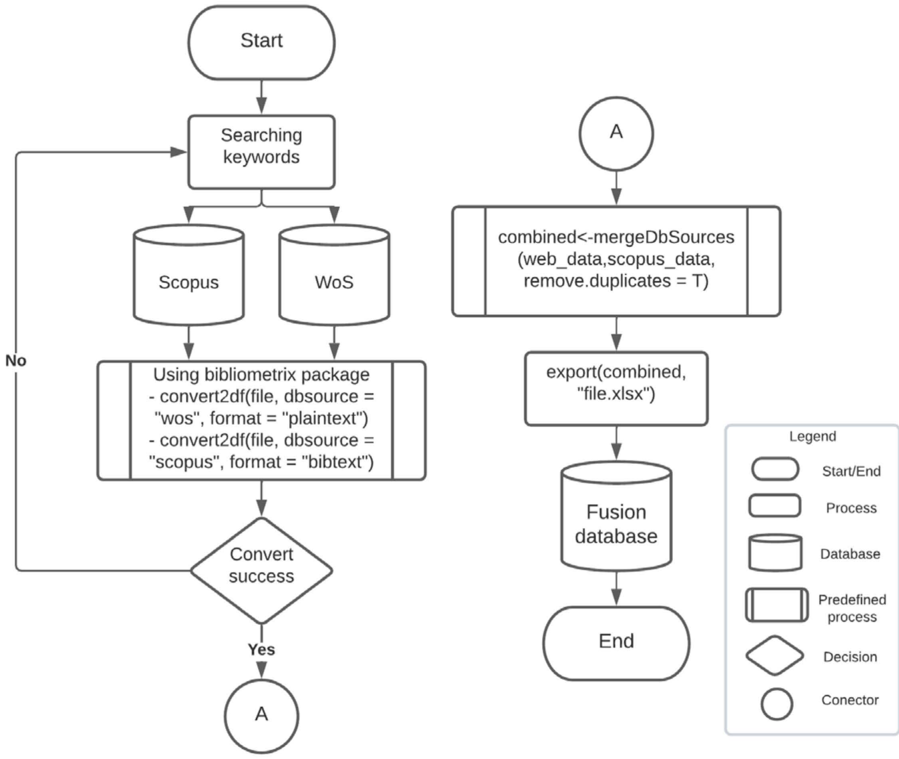

Figure 2. The flowchart of Bibliometrix (RStudio) instructions for merging WoS and Scopus databases.

In the construction and graphic representation of intellectual structures, VOSviewer software (VOSviewer version 1.6.18 for Microsoft Windows systems), developed by Leiden University, has been used to construct two-dimensional distance-based maps with a capacity greater than 10,000 items [69,70].

2.3. Phase 3—Analysis and Literature Review

This phase corresponds with processing results, efficiency analysis, and mapping science through bibliometrics to obtain a bibliometric map. Consequently, the literature review results from the bibliometric map, emphasising the main nodes (geoheritage and geosites) and their relationships with the secondary ones (geoconservation, geotourism, and geoparks).

3. Results

3.1. Selection of Analysis Documents

Exclusion criteria were applied to documents from 2022 in both Scopus (11) and WoS (9). In addition, this study eliminated records with incomplete fields. In pre-processing, nine articles (without author information) were excluded from the Scopus database, resulting in 2389 documents from Scopus and 1626 from WoS. The sum of the documents in both databases was a total of 4014 documents. The fusion database eliminated 1280 duplicates (31.9%), resulting in a total of 2735 documents (where 1109 and 346 were exclusive to Scopus and WoS, respectively). The final global database contained 2565 documents (including documents only in the study context), as shown in Figure 3. In this step, the global database was exported from RStudio, Bibliometrix and VOSviewer processed the global database to obtain the results of the efficiency analysis and intellectual structure of the subject.

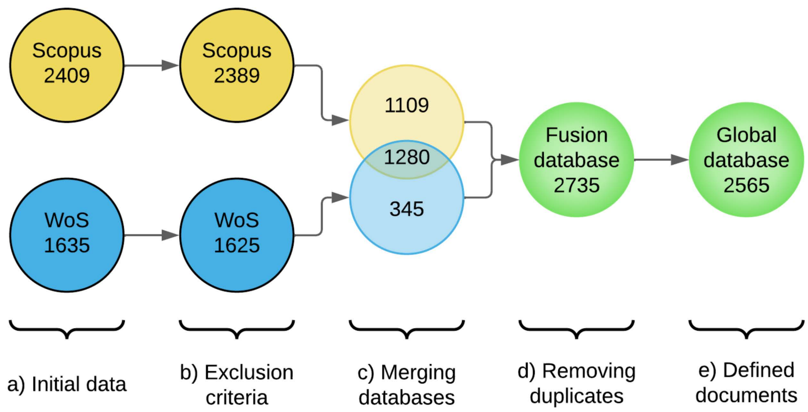

Figure 3. The systematic process of merging the databases with their respective number of documents.

In sum, the total documents (2565) were published in 724 journals and books, were written by 5540 authors and the study period covers a time span from 1949 to 2021. The analysis also allows us to recognise that the characterisation, assessment, and development of initiatives for geosites are the main lines of action in the contributions (7.91%, relative to the global database). The results of the efficiency analysis and mapping science were publication trends, countries' contributions, authors, topics, bibliometric maps, literature reviews, and research trends.

3.2. Performance Analysis

3.2.1. Publication Trend

Figure 4 shows the trend of publications over time inventoried in Scopus, WoS and the global database. There is a constant trend in scientific output between 1949 and 1994 (steady trend). From 1994 onwards, the evolution shows an exponential growth (increasing and exponential trend), coinciding with specific studies on geoheritage and geosites.

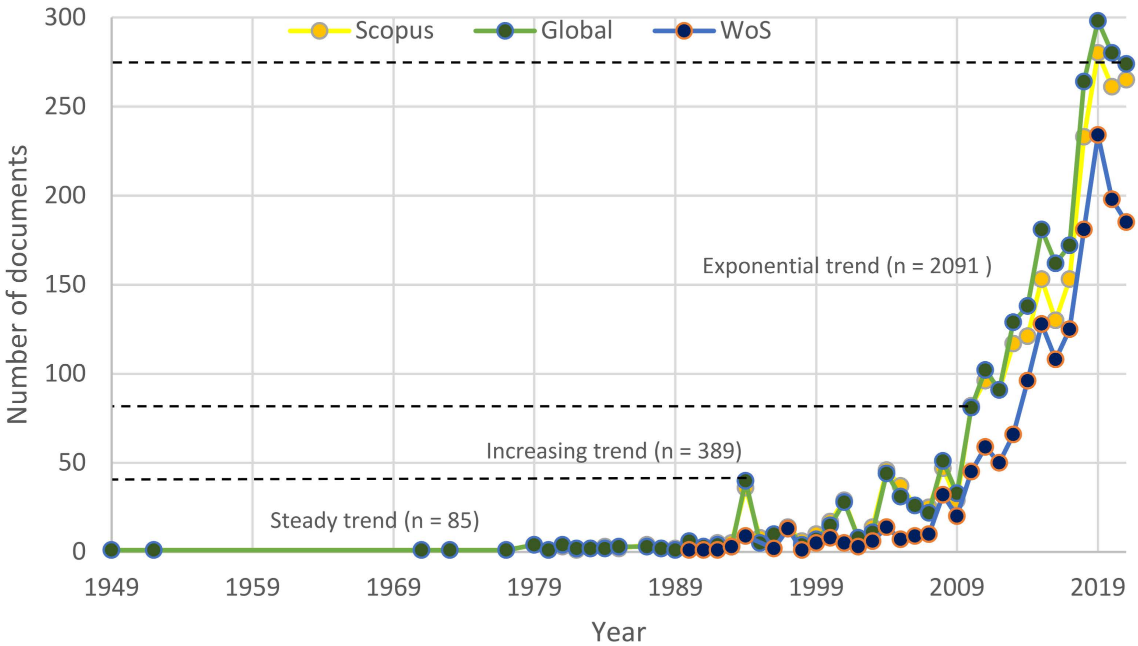

Figure 4. Trend of publications between geoheritage and geosites, using data from Scopus (n = 2389 documents), WoS (n = 1626), and Global database (n = 2565).

Between 1949 and 1994 (steady trend, n = 85), the first studies on the topics of geoheritage and geosites were conducted. The first document collected in the global database corresponds to 1949 [71], which involves locating geosites using geographic coordinates. The International Geological Congress in Great Britain recognised the importance of preserving geosites for their scientific and educational values [72]. This period highlighted fossil and mineral conservation [73] and the threat of commercial exploitation–development of resources [74]. In the late 1970s, Australia created procedures and legislation to identify and manage geoheritage sites [75]. In 1991, the protection of the natural environment at the international level included geoheritage [76], highlighting its attractiveness for geologists and geoscientists [77]. In other cases, they mapped geosites in Alaska [78]. In 1994, Thomas A. Hose presented his doctoral thesis developing the term "geotourism", and from then on, geoheritage and geosites became topics of interest for geoscientists [79].

Between 1995 and 2010 (increasing trend, n = 389), technical proposals for geoconservation emerged [80]. In 1995, UNESCO supported "GEOSITES" for the inventory, conservation, and promotion of geosites [81]. Since the late 19th century, geologists have valued geoheritage by describing and photographing geosites [82]. Moreover, methods for evaluating geomorphosites—considering the scientific and conservation value of geosites—are appearing [83]. The geoheritage assessment considers geosites, relevance, and scientific value at national and international levels [84]. Furthermore, the geoheritage evaluation considers its level of significance and abstract perceptiveness [85], with the importance of protecting it through legislation [86].

Between 2011 and 2021 (exponential trend, n = 2091), the role of geoparks for the protection of geoheritage as a sustainable source began to appear [25]. The geoheritage has become key to the development of geotourism in UGGs [87], considering the growth in geoconservation criteria [88]. Additionally, several authors have highlighted the evolution of geotourism worldwide [5,34,87,89,90]. Several methodologies are emerging for the inventory and management of geomorphosites, considering their potential, type of use, and the evaluation of the stakeholders [91]. For example, Brilha proposes evaluating geosites with consideration of educational, touristic, and scientific values [14]. Furthermore, the role of geoheritage conservation involves sustainable development in protected areas [92].

3.2.2. National Contribution, Authors, and Topics Analysis

The worldwide contribution is 96 countries, 38 belong in Europe, 21 in Asia, 17 in Africa, 15 in America and five to Oceania. Table 1 links the top ten countries, authors, and topics. The ranking of countries and authors corresponds to the number of documents in the global database. Moreover, the selection of contributions was made based on the author and the number of citations of the documents.

Table 1. Contribution of countries and main authors.

Contributions of Countries	Topics and Main Authors
Italy (n = 544/12.1%)	• Coratza and De Waele [93], some geomorphosites may have occurrences of natural disasters such as landslides and mudflows. • Giordano et al. represented Italian geoheritage through virtual reality [94]. Furthermore, a geopark was proposed for educational and recreational purposes during evaluation of the Susa Valley [95].
Spain (n = 393/8.77%)	• Carcavilla et al. [86], Spain's geoheritage, its history, and study are highlighted. • Fuertes-Gutiérrez and Fernández-Martínez presented an inventory of 97 geosites in Leon Province [96]. • Canesin et al. compared the establishment process and management of two UGGs [97].
China (n = 254/5.67%)	• Chen et al. [98], determined that the importance of the Huangnitang Geopark is due to its uniqueness in biostratigraphy. • Han et al. described its ecological and cultural characteristics [99]. • Cai et al. [100], geotourism increased rapidly in this territory due to UGGs.
Portugal (n = 240/5.35%)	• Brilha contributed to the use of local nature protection legislation for geoconservation [101]. Another important contribution is the conceptualisation of geodiversity, geoheritage, geosites, and their differences [102]. • Farsani et al. showed the importance of geotourism and geoparks as sources of development in rural areas [25].

Table 1. *Cont.*

Contributions of Countries	Topics and Main Authors
Brazil (*n* = 238/5.31%)	• Garcia et al. developed an inventory of 142 geosites for geoconservation strategies on a regional scale [103]. • Mansur et al. [104], geoconservation started through legislation and geoethics. • Mucivuna et al. compared methods for geomorphosite assessment [105].
Poland (*n* = 218/4.86%)	• Różycka and Migoń assessed geodiversity in volcanic environments using M-GAM [106]. • Mocior and Kruse showed the educational, scientific, geological importance of valuing geosites and valuation methodologies [107]. • Migoń et al. developed a synthesis of information on rocks, landscapes, forms, and processes from a geomorphological point of view [108].
United Kingdom (*n* = 199/4.44%)	• Prosser et al. indicated an effective conservation of geosites for more than 60 years [109]. • Kenrick and Strullu-Derrien described the importance of geosites due to their fossils by the evolution of roots [110]. • Gordon et al. emphasised the importance of geoconservation in protected sites [111].
Russia (*n* = 182/4.06%)	• Ruban worked on the aesthetic properties of the Lagonaki Highland geoheritage by relating the local significance and its appearance [112]. • Bruno et al. developed a method for classifying palaeogeographical geosites [113]. • Sallam et al. assessed ten geosites in Egypt for their relevance, uniqueness, and geotourism potential [114].
Australia (*n* = 153/3.41%)	• Brocx and Semeniuk proposed a Geoheritage Tool-kit, which facilitates the compilation of a geological and geomorphological features inventory [115]. • Migoń and Pijet-Migoń selected and assessed geosites in volcanic environments [116]. • Also, Brocx and Semeniuk [117] stated the worldwide importance of the Australian paleontological heritage for its uniqueness.
France (*n* = 149/3.32%)	• De Wever et al. [118] used secondary information sources to present an inventory of 611 geosites nationwide. • Reynard et al. developed an inventory of geomorphosites using an integrated approach [91]. • Odin worked on the study of a geosite that was important for its macro and microfossils [119].

Figure 5 (Sankey diagram) links the top ten countries—authors and topics. Bar size depends on the author's contributions to the research topics. It was exported from Bibliometrix.

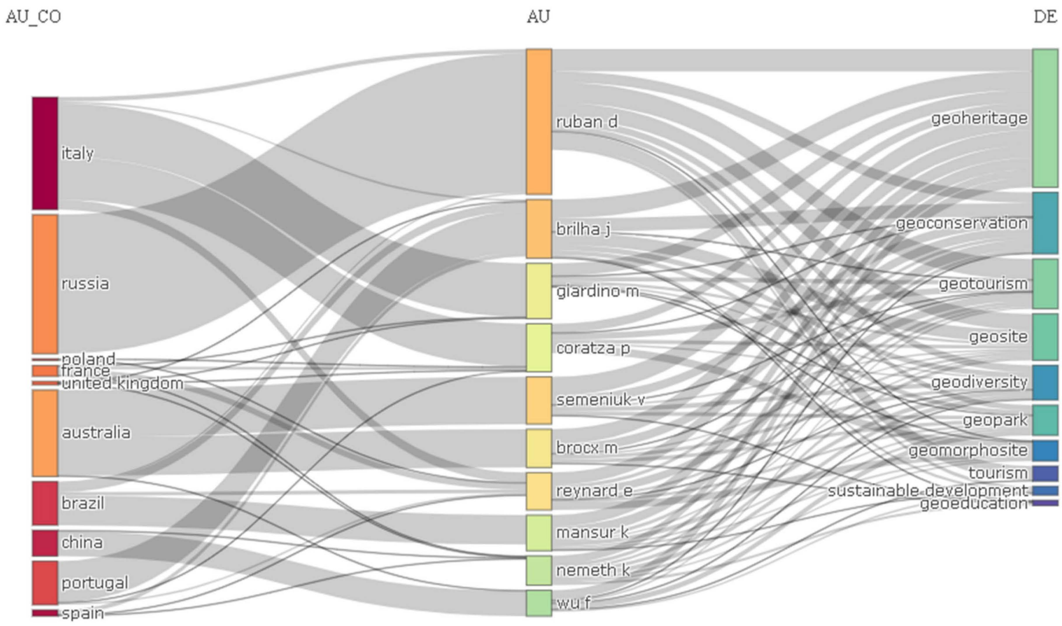

Figure 5. Sankey diagram showing the list of countries (AU_CO), authors (AU), and research topics (DE) from global data base.

3.3. Mapping Science

Cluster Network through Author Keywords

Figure 6 shows the conceptual structure that allows an overview of the knowledge topics in the main subject [120]. VOSviewer processed the author keywords for the generation of the network map. There are six clusters due to the most frequent author keywords: geoheritage, geosite, geotourism, geodiversity, geoconservation, tourism, and national geopark (Threshold of 10 co-occurrences, displaying 67 keywords, minimum cluster size of 5).

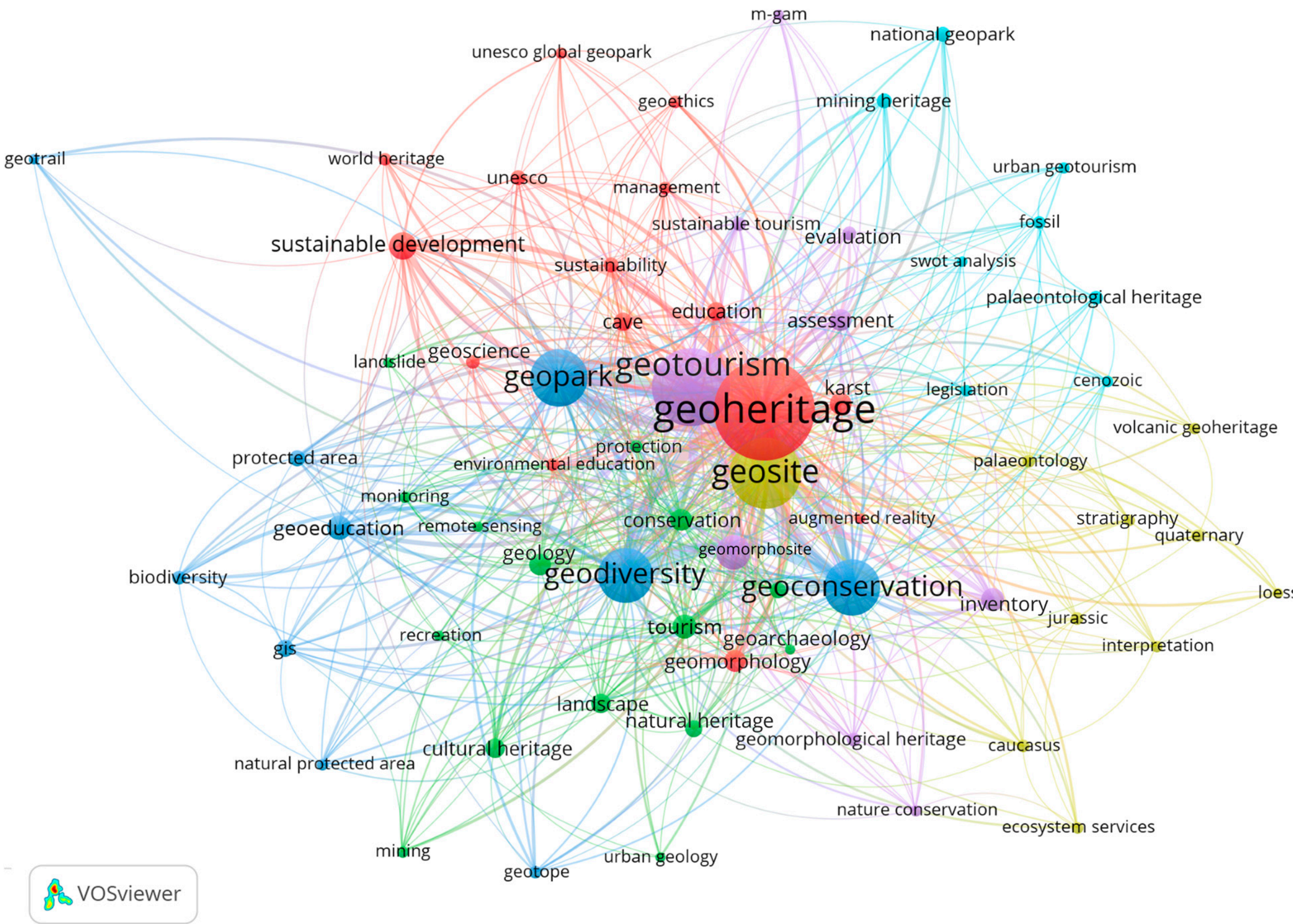

Figure 6. Map of co-occurrence of author keywords, with six clusters, 67 nodes, and 620 links.

Cluster 1 (red colour), "*Geoheritage*", comprises 15 nodes with 1171 occurrences. The main keyword is Geoheritage. Its main connections are sustainable development, education, and world heritage. Moreover, UNESCO is important for the preservation of natural and cultural heritage sites [121]. Sustainability is related to geoethics due to behaviour and practices in the field [104]. The characteristics of UGGs offer long-term, sustainable development [122,123].

Cluster 2 (yellow colour), "*Geosite*", consists of ten nodes with 538 occurrences. The conservation of geosites through their attractiveness, scientific, cultural, and anthropological values [124]. Studies indicate that the geo-palaeontological sites present information and fossils that are attractive [125]. For example, dinosaur fossils are present in some geosites, including Jurassic geomorphology [126]. Moreover, the loess geosites represented the Quaternary period and were studied by lithology and morphology [127].

Cluster 3 (purple colour), "*Geotourism*", consists of nine nodes with 758 occurrences. Geotourism preserves and promotes nature conservation in geoparks [99]. Furthermore, the valuation of geosites strengthens geotourism proposals and strategies [128,129].

Cluster 4 (blue colour), "*Geoconservation, geopark and geodiversity*", consists of ten nodes with 935 occurrences. The legal protection and consideration of natural or anthropogenic threats allow geoconservation in geoparks [130]. Some geoparks have complex landscapes, linking tectonics, volcanism, and sedimentary events [131]. Geo and biodiversity are related because their importance allows for life's richness and conservation [132]. Geoconservation must be ensured in protected areas at local, regional, and global levels for development that is compatible with nature [133].

Cluster 5 (green colour), "*Tourism and conservation*", consists of 15 nodes with 345 occurrences. It describes the importance of geoheritage as a basis for tourism and education [134,135]. Furthermore, tourism is an avenue for economic development based on geoheritage and cultural heritage [136]. It also highlights the tangible and intangible conservation of natural heritage [137]. In addition, geoarchaeology sites increase the local economy that is directly involved in tourism [138].

Cluster 6 (turquoise colour), "*National geopark, mining heritage and palaeontological heritage*", consists of eight nodes with 114 occurrences. Illegally exploited mining heritage leads to environmental problems. On the other hand, mining sites with safe infrastructure are mining geosites [139,140]. Palaeontological heritage represents biodiversity during geological time. Its geoconservation and protection are necessary [141,142]. In addition, the importance of the Cenozoic successions for the fossils of macro and microspecies present in some formations [143].

3.4. Literature Review

The literature review through the main nodes in the co-occurrence map allows for the analysis and synthesis of information, as shown in Figure 7.

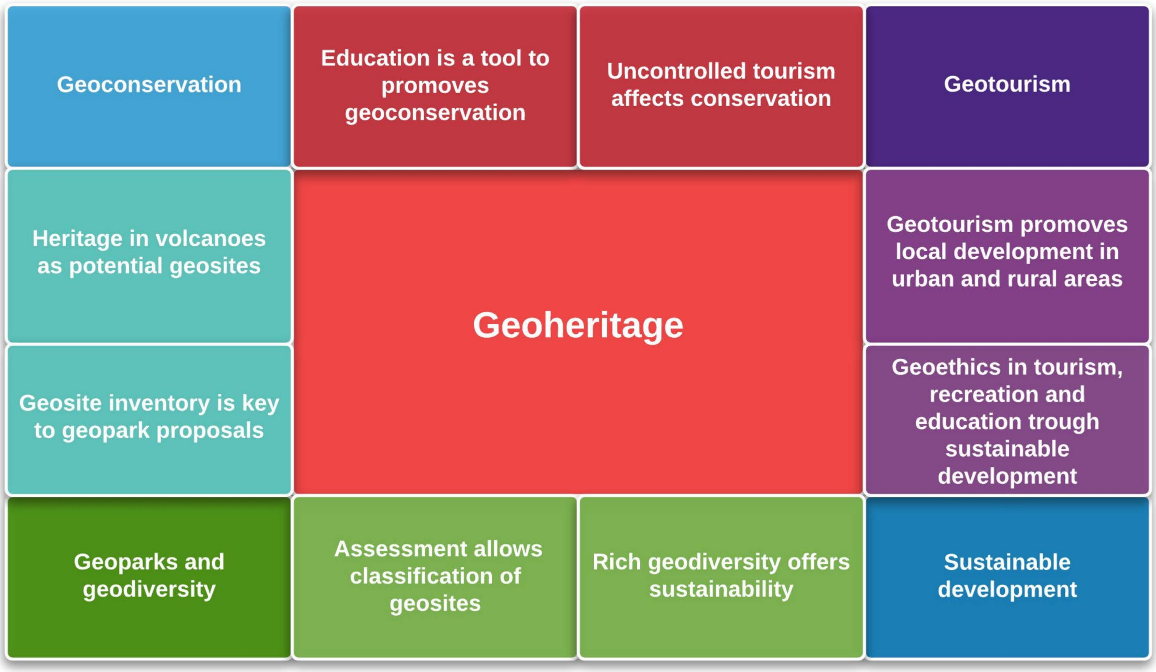

Figure 7. Synthesis of information found in the literature review.

Table 2 indicates the 90 selected documents by their relation to the main keywords, such as geoheritage and geosites with geoconservation, geotourism, and geopark. As mentioned in Section 2.3, secondary nodes are terms that are close to geoheritage and geosites.

Table 2. The literature review according to the interaction of the main nodes with the secondary nodes.

Geoheritage and Geosite
Geoconservation
• The combination of protection, mining, and tourism helps in the geoconservation of some of the geosites [144]. A balance between mining and conservation is needed [145]. The protection of geotopes is needed for the sustainable use of georesources. On the other hand, urbanisation and exploitation lead to a reduction in biodiversity [146]. There is a link between geological and mining heritage through the resources used in construction, materials, energy, and water [147]. Quarries present the significance of connecting people to their geoheritage, achieving successful geoconservation by understanding its importance [148]. It also provides infrastructure and jobs [149]. • The organisation of geoheritage information for geoconservation and tourism purposes for research and publication [150]. • The lack of knowledge and technical information on geoheritage in local and national authorities hinders legislation and legal mechanisms for its protection [151]. Geoconservation needs to be compatible with other legislation [152]. Geoheritage is vulnerable to climatic conditions and human activities [153,154], and legislation helps conserve it [155,156]. Geoheritage inventory, characterisation, and assessment support policies for nature conservation [157]. • Application of digital technologies for geoheritage conservation and management can be achieved using geographic information systems (GIS) [158]. GIS allows the modelling and mapping of protected areas as a tool that relates landscape variables [159]. In addition, mapping geomorphosites is necessary for their conservation [160]. Moreover, these technologies provide the appropriate management of geoheritage [161]. • The essential role of geotourists and local communities in geoheritage conservation and economic development [162]. • The protection of geoheritage begins with geosite assessments and their inventory according to their type. It can be geomorphological, hydrological, palaeontological, natural resource, stratigraphic, sedimentological, and tectonic [118]. The inventory of geomorphological elements of landscapes favours conservation and geotourism [163]. It also helps the sustainable use of geoheritage [4]. The valuation of geoheritage is related to scientific, educational, cultural, and tourism values and enables its successful management [164,165]. Furthermore, it promotes sustainable development due to its regional relevance [166]. • Geoconservation promotes sustainable development and human well-being, and even promotes nature-based solutions to global problems [167]. It is also important for nature, man, and sustainability [111]. Therefore, a balance between nature, man, and sustainable development is needed to understand the earth's history and protect its resources [168]. • Knowledge of geoheritage, by accepting responsibility for geosites through plans to protect and conserve natural heritage, is important [137,169]. • Education as a geoheritage conservation and learning tool that demonstrates knowledge of the planet's changes over time [170,171]. Management of protected sites involves cooperation between local stakeholders and geotourists through raising awareness so that the resources enjoyed now will endure for future generations [172]. • The protection of ecological and geoscientific sites achieves natural conservation [20]. • Geoheritage provides recreation and needs protection in its biodiversity, rarity, and geological features [173]. • Environmental education is related to geoheritage because of climate change, geohazards, pollution, and sustainability [174]. In addition, geoscience research through field trips and data collection enables education, promotion, and popularisation of geoheritage [175].
Geotourism and geopark
• The geoheritage of volcanoes is widely visited globally and are considered potential geosites because of their attractiveness [176]. Therefore, the use of notices in different languages and the accompaniment of tour guides trained in volcanology are necessary [177]. • Geosite interpretation panels should contain figures, illustrations, or photographs for proper communication with tourists [178]. In addition, the use of panels, interactive tools, laboratories, and trekking tours encourages the promotion of geoheritage and tourism [179]. • Geoheritage relates to cultural diversity through cultural activities at geosites [180,181]. For example, art through literature and poetry links to the culture and landscape by mediating cultural heritage and aesthetic values [182]. • The network of georoutes between geosites and cultural sites promotes socioeconomic activities and increases the local economy [183]. In addition, geotourism offers natural and geological resource conservation [89]. Urban geotourism is related to palaeontological, historical, and cultural features present in urban constructions [184]. • The combination of geological and geomorphological phenomena as well as climate, contributes to the formation of waterfalls and geotourism [185]. Underwater geosites are included in the inventory due to their uniqueness and representativeness for underwater geotourism activities [180]. Accessibility to the geosites varies, with some using conventional transport and others resorting to activities such as climbing [186]. • Generation of networks of national geoparks with the objective of sustainable development [187]. • Methodological proposal for the inventory of geosites at national levels through their uniqueness and their geoheritage values [188]. Semi-qualitative methods were proposed for assessing coastal geotourism potential and its protection [189]. Qualitative methods for identifying geosites and valuing geoheritage through educational and geotourism values were presented [131]. A method that relates scientific, additional, and potential values also considers their fragility and vulnerability [190].

Table 2. *Cont.*

Geoheritage and Geosite
• The assessment of geoheritage and geosites is fundamental for developing geopark proposals [191–193]. Classification of geosites by geomorphological, palaeogeographical and structural type—used for geotourism and to generate knowledge at the local and international level [194]. Furthermore, geomorphological landscapes, geological processes with natural or cultural heritage need to be considered, which contribute to the planning and development of geotourism [128], using SWOT analysis [195]. Some geosites have cultural, historical, and socio-economic values, and their assessment defines management priorities [176]. The conservation of geomorphosites is the basis and importance of abiotic factors [196]. M-GAM allows for geosite assessment and sustainable tourism, allowing for visitor feedback [197]. Using GAM and M-GAM, the results are more accurate in evaluating geosites, mainly for their relevance and making decisions when visiting them [198]. For the proper functioning of a geopark, the opinions of experts in geoheritage, nature conservation, and geotourism development are necessary [199]. Interpretation of geosites provides their history and preservation [200], and assessing them allows for their classification depending on scientific, educational, tourism, and degradation criteria [201]. The rich geodiversity and cultural heritage provide a fundamental basis for geotourism and development [202].
• Geoparks achieve geoheritage protection, sustainable development, research, conservation, and geotourism [203,204]. The use of the Digital Earth Tool helps in geoconservation [205]. Geoparks also provide sustainable development through natural and cultural conservation [206]. Due to overexploitation, rock desertification, and uncontrolled tourism, monitoring systems for disasters help with sustainable development [207]. Communities in geoparks have an important role to play in the development of geotourism activities [208]. Geoparks synthesise geological histories of a region and lead to public attention, which promotes geological interpretation [209].
• Countries should implement laws for exploiting georesources by creating geoparks [210]. The absence of national legislation for geoheritage protection is compensated for by geopark initiatives [28].
• Binational cooperation creates a geopark through landscapes, mining activities, ecosystems, and geoheritage objects [211].
• Abandoned quarries can be high impact geotourism hotspots, and restoration helps exploit their potential [212,213]. In addition, the assessment of mining sites through their geoheritage values, potential risks, and environmental impact promotes cultural and tourist routes [140]. Characterising and evaluating historic monuments and quarries enhance geological interest of them, allowing for georouting [214]. The development of a complex mining network, history, and culture, and its relationship with geoheritage can also promote geotourism [207].
• Quarries and geological units link urban geoheritage with architecture [215]. In these sites, geoheritage interacts with mining heritage, where they also show the richness in biodiversity, culture, and history of the territory as a source of sustainable development [216]. Some urban geosites are in geologically evolving cities, reflected in natural and anthropogenic events [179]. Abandoned quarries and natural outcrops at public sites contribute to urban geotourism [217].
• Hydrocarbon reservoirs are energy and geoheritage resources due to their geological complexity [218]. The use of geoheritage energy resources such as geothermal energy contributes to sustainable development [124].
• Technological tools can be used for searching and visualising geoheritage on websites [219]. They also allow education and tourism through augmented reality, including image, video, and sound [161,220].
• Viewpoint geosites require management strategies that focus on clearing vegetation to balance facilities, scenic value, and ensuring visitor safety [221]. In addition, landslides may occur on some geosites and require risk analysis [222].

3.5. Research Trends

This analysis indicates trends in researched topics. If the term has at least ten occurrences in a year, its evolution is shown in Figure 8 (exported from Bibliometrix in R-Studio). The node shows the used frequency of the keyword during its respective period (line), and the alignment of the different nodes indicates their interaction.

The most extended period corresponds to palaeontology and stratigraphy, while the shortest to geotope. In addition, the most frequent keywords are geoheritage (837), geotourism (504), geosite (426), geopark (274), and geoconservation (266). Finally, current trends are geoeducation (49), geoethics (13), and sustainability (20), which can serve as a basis for future research trends. For example, some studies highlight that land-use planning and protection strategies are necessary for sustainability in geosites affected by urbanisation [223]. Moreover, geoeducational values include learning experiences and interaction in the geosite environment for local communities and tourists [224].

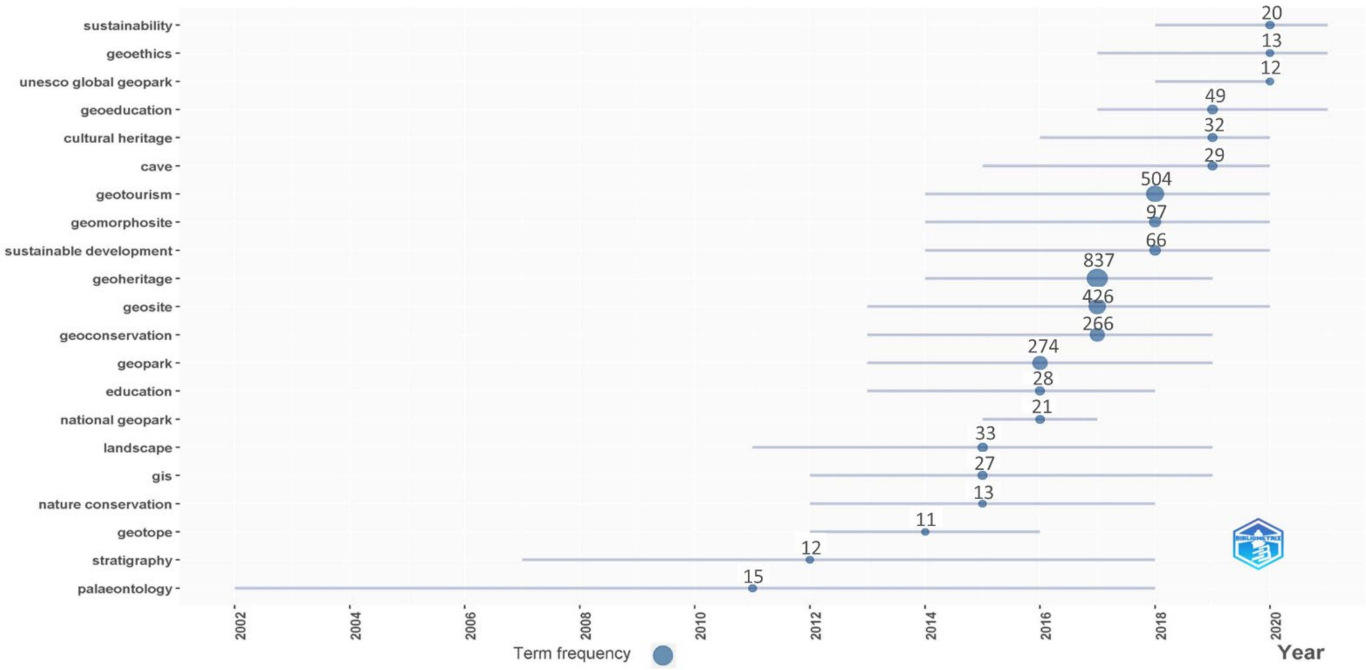

Figure 8. Trending topics during the geoheritage study period.

4. Interpretation and Discussion

Bibliometric studies depend on the bibliographic data collected and preserved in the reference databases. In this work, the use of Scopus and WoS is due to their rigorous process in collecting scientific contributions [55,225]. In the case in question, the aim of developing the merged databases was to have the largest possible number of records and cover more samples in the overall analysis. The analysis included publication trend, author details, and the correlations between keywords. However, merging can lead to conflicts in analysis when each database has its own counting system (e.g., citations for each contribution) [226].

4.1. Contribution Statistics

As for the results obtained, this study collected 2565 documents from 724 sources (journals, books), and the contributions corresponded to 5540 authors. The research trend analysis indicated that the most studied topics were geoheritage (837, 32.6%), geotourism (504, 19.6%), geosite (426, 16.6%), geopark (274, 10.6%), and geoconservation (266, 10.3%). A general analysis of the selection of works in the thematic area of interest indicated that: (i) geoheritage is paramount for the development of geoparks because it is related to a community's cultural, social, and historical values [165,227–229]; (ii) geopark proposals need to make inventories of geoheritage and geosites for their identification, selection, and conservation [191,193,206]; (iii) geotourism contributes to the sustainable development of geoheritage, but there are cases where tourism damages it [154,190,230]; (iv) the protection of geoheritage and its resources through legislation is necessary for sustainable development. In some countries there is no legislation but conservation is initiated through geopark projects [28,155].

4.2. Author Contributions

Researchers such as Dimitri Ruban, Jose Brilha, Margaret Brocx, Vic Semeniuk, and Emmanuel Reynard stand out in this field of study. Ruban has contributed both as a lead author and as an international collaborator. He has published studies about the geoheritage of Russia and Egypt [204,231,232]. He has also contributed to the development of methodologies for cases of geodiversity loss [23], geotourism growth [5], and geodiversity in geoparks worldwide [210]. Brilha has contributed to large-scale geosite assessments in

Portugal and Brazil [103,163,233], developing a methodology for valuation, selection, and construction of inventories of geosites [14], as well as conceptualising geoheritage [102]. Semeniuk and Brocx have focused on Australian palaeontology, the global importance and relevance of stratigraphy [75,117,234], the history of geoheritage and geoconservation [75], and the development of a systematic methodology for constructing geosite inventories [115]. Finally, Reynard has presented contributions mainly on geomorphosites [13,91,105]. Its main contribution is to inventory geomorphological heritage at regional scales [91] and assess urban geomorphological heritage [235]. The above researchers have contributed to geotourism, geoconservation, and sustainable development, and they have presented different methods for the inventory and assessment of geoheritage, geosites, and geodiversity. Furthermore, the bibliometric mapping identified that M-GAM (introduced by Tomić and Božić [21]) as a novel approach due to its wide usage applications, as it considers tourists' views and market segment preferences in the assessment process [106,197].

The bibliometric analysis identified these five researchers according to the number of publications. In addition, researchers such as Hose, Newsome, and Dowling contributed to the origin and development of geotourism at different scales, promoting conservation strategies at international levels [37,41,79]. As shown in Figure 4, the key year identified in this study is 1994, when the trend in global production changed due to the developed concept of "geotourism" by Thomas Hose in his doctoral thesis [79]. Consequently, international geoheritage protection projects, the conservation and promotion of geosites, as well as the development of conservation techniques, were initiated [76,80,82,102].

4.3. Informetric vs. Bibliometric

When comparing the trend of publications in time with other articles, for example, the one relating to geodiversity and geoheritage [236], the form of the curve is similar in general, having an exponential shape. Some of the most frequent keywords have similarities with "geoheritage conservation" [237] in its word cloud: geodiversity, UNESCO, conservation, cultural heritage, and sustainable development (Figures 6 and 8). Furthermore, both studies show the connections between geoheritage and geosite, geopark and geotourism, and geodiversity and geoconservation. The maps show that, when comparing bibliometric maps of articles in geoparks and geotourism [89,238]—such as the relationship between geodiversity and geoconservation, and the links between geoheritage and geosites and geoparks—these are the main keywords. It also shows that sustainable development is an important node in each study.

There are studies that use informetrics in a systematic literature review, using the topic of "geoheritage conservation", offering a conceptual synthesis [237]. Using bibliometric analyses with "geodiversity and geoheritage", other studies highlight the main differences and relationships between biodiversity, geodiversity, and pedodiversity [238]. Moreover, they emphasise the importance of conserving geoheritage through proposals for UGGs and protected areas [239]. The "geoheritage and cultural heritage" [240] as they relate to "geotourism" are combined to describe conservation contributions, interactions with territorial development, and effective management with local communities [32,89,241]. There are also articles on "geoparks", which support conceptual and intellectual visualisation, along with their relationship to communities [238,242].

4.4. Strengths and Weaknesses

This study has identified six strengths in the analysis: (i) in the late 19th century, geologists valued geoheritage [82], finding it attractive for tourism [77]. (ii) The surge of geoheritage preservation initiatives led to geoconservation and geotourism through the inventory of geosites at regional, country, and international scales [91,103,192,211]. (iii) The emphasis of the importance of geoheritage concerning the territory is paramount for the initiation and creation of geoparks [243], local community development [8,206,208,244], community knowledge for geoconservation, sustainable development in geoparks [245–247], and sustainable tourism potential [136,248]. (iv) The relevant interest in studying these topics is evidence of the increase in contributions in the last ten years. (v) The increase of initiatives related to the proposed creation of UGGs, geotourism routes or itineraries, with the participation of the community. (vi) The development of private or public geotourism projects focused on creating alternative employment and protecting the sites.

In addition, beyond identifying research trends in geoheritage and geosites, this study identified two notable weaknesses during the analyses. The first is in the context of the applicability of the proposed initiatives. Specifically, the absence of national legislation explicitly promoting the conservation and protection of these resources (e.g., [28,156]). The second is more specific to conceptualising the terms that define the topic under study. Specifically, the lack of unified definitions, sometimes resulting in the inappropriate use of these terms in developed works in the field (e.g., [14]).

5. Conclusions

This study on geoheritage and geosites analysed research contributions by year, efficiency analysis, bibliometric mapping, literature review, and research trends. The study focused on lines of research such as geoconservation, geoparks, geotourism, and intrinsically sustainable development. The subjects of geoheritage and geosites first emerged in scientific publications in 1949. The trend in time reached its apogee in 1995, then grew rapidly through different research trends, such as stratigraphy and palaeontology of global relevance, initiatives for geopark proposals, geotourism, and geoconservation. Current trends focus on geological processes, geoethics, and geoeducation to strengthen the path towards sustainability. Therefore, one of the most developed topics in the 21st century is geoparks that combine territory, geodiversity, and biodiversity, generating a connection with sustainability.

Geoheritage contributes to the economy by exploiting its resources for tourism; protection is necessary through geoparks or national legislation that allows preservation and sustainability over time. Therefore, inventories of geoheritage and geosites are essential to identify, describe, and evaluate their relevance for protection and geotourism purposes. However, the study also highlights some problems in this area. From the point of view of initiatives to protect and exploit these resources, there is a lack of specific national legislation on geoconservation in some countries. Therefore, standardised local and international policies on geoconservation are also recommended. Furthermore, from a conceptual point of view, there is a lack of standardised definitions and uses for terms in the different initiatives addressed. These weaknesses should be considered in future research.

Finally, education is a tool to raise awareness to local communities and tourists regarding the importance of geoheritage, its objects, and resources, thus enabling its conservation for future generations. Therefore, trends highlight the importance of geoethics and are linked to sustainable development and cultural heritage, establishing a developed sensitivity to the care of natural heritage.

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