GEODIVERSITY AND BIODIVERSITY FOR CONCEPTUAL SYNTHESIS

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ABSTRACT

The earth changes by various physical, chemical, climatic, and geological factors. These processes have allowed for diversity in both geological and biological environments on the planet. Geological diversity allowed life and its diversity in different environments and ecosystems. This study aims to analyse geodiversity and biodiversity using informetric tools to know their relationship and interaction and research trends in this area. The systematic methodology is four steps: (i) topic and information preparation in Scopus and WoS; (ii) data processing in Bibliometrix-RStudio and VOSviewer; (iii) visualisation of results; and (iv) interpretation of results. The results show that geodiversity enabled different ecosystems and life. Therefore, the main conclusion of this study is that biodiversity is on geodiversity, allowing for diverse ecosystems around the world, promoting geo-eco-tourism development under nature conservation criteria.

Keywords: natural heritage, natural systems, geotourism, Scopus, WoS, informetrics.

1 INTRODUCTION

The planet earth, from its origin, remains in constant change; the changes caused by physical, chemical, climatic and geological conditions allowed the natural heritage [1]. UNESCO defines natural heritage as "geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science or conservation" [2]. It also means everything included in the natural environment for its preservation. In other words, natural heritage includes geodiversity and biodiversity [3].

Geodiversity corresponds to various geological, geomorphological, hydrological and soil characteristics [4]. This term also includes landscapes and processes such as erosion, sedimentation and soil formation [5]. Geodiversity importance focuses on materials used for the well-being of humanity since its beginnings and benefits for economic development [6], [7]. On the other hand, biodiversity means the variety of living things that interact with their environment [8], i.e. it includes the different plants, animals, micro-organisms, fungi, ecosystems and ecological processes [9]. The importance of biodiversity is directly related to human health, such as medicinal plants, or the loss of biodiversity causing disease transmission between animals and even to humans [10]. It also provides resilience to different environments [11]. In addition, many species help in water purification, pollination, and pest control [12].

The conservation of natural heritage is important because of significant global challenges, e.g. climate change mitigation and adaptation [13]. Natural heritage links geosystem services (GS) and ecosystem services (ES). Geosystem services are constituted by geodiversity (natural abiotic factors), i.e. GS have low biological activity [14]. In comparison, ES refers to natural biological factors that include biotic and abiotic nature and their interaction [15]. In addition, the protection and conservation of natural heritage contribute to sustainable

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tourism and development (geo-ecotourism) in a locality [16], [17]. Some natural heritage conservation strategies are initiated by creating World Heritage Sites (WHS) and Global Geoparks (UGGp), both promoted by UNESCO. WHS allow for the recognition and protection of natural, cultural or mixed heritage in a specific site [18], whereas UGGp are large areas of sites of international geological significance [19], within geodiversity is geological heritage (geoheritage), differing in that it includes scientific values [20]. Both mixed WHS and UGGp are megadiverse areas because these areas include geo-biodiversity and cultural diversity. Fig. 1 relates the concepts of megadiversity, Mixed WHS, UGGp, natural heritage, geo-biodiversity, cultural diversity, GS and ES.

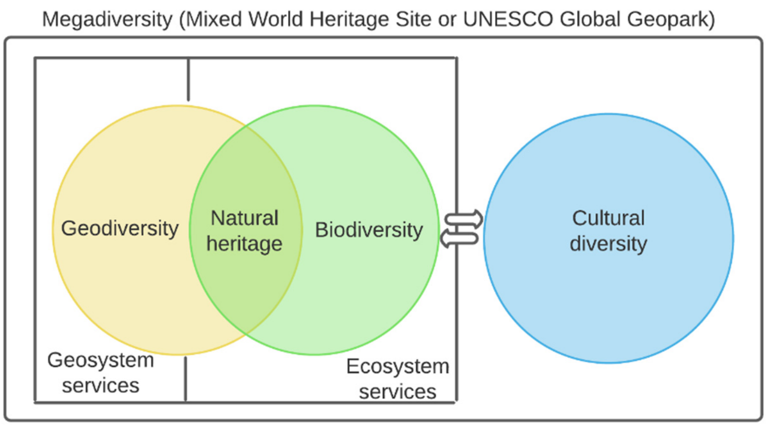

Figure 1: Framework of the relationship between concepts, based on [15], [20], [21].

This study aims to analyse geodiversity and biodiversity using informetric tools to know their relationship and interaction and research trends in this area. Bibliometric studies analyse information indexed in databases, allowing to know the evolution of a research field, topics, research trends through efficiency analysis and mapping science; for example, geosciences [22].

2 METHOD

Fig. 2 shows the systematic approach of this work, which consists of four phases, phase 1 consists of topic and information preparation in Scopus and Web of Science (WoS); phase 2 consists of data processing in Bibliometrix-RStudio and VOSviewer; phase 3 consists of visualisation of results; and phase 4 corresponds to the interpretation of results.

2.1 Topic and data preparation

The preparation of the subject and information is essential for informetric studies. The Scopus and WoS databases were selected for the search due to the extensive information indexed by both databases [23]. The following terms and Boolean operators were used: “biodiversity” or “biological diversity” AND “geodiversity” or “geological diversity”. The search resulted in 407 documents in Scopus and 245 in WoS. Combining the databases and deleting duplicates results in a global database with 462 documents.

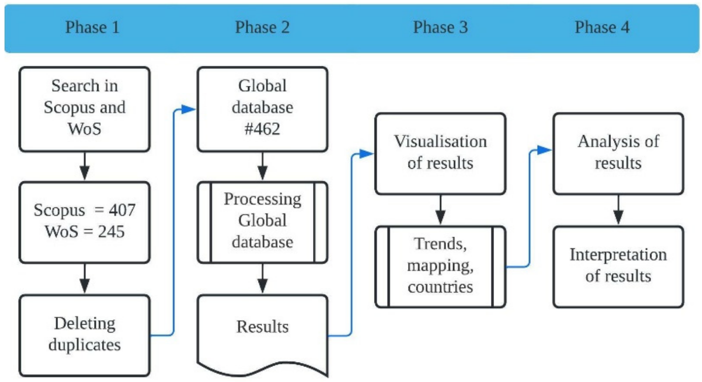

Figure 2: Diagram of the systematic method.

2.2 Global database processing

The global database is processed to obtain the results using Bibliometrix in RStudio [24]: trend in time, national contribution, and research trends. Bibliometrix is an open tool designed for analysis through bibliographic data.

2.3 Visualisation of results

The software (Bibliometrix and VOSviewer) allows thesaurus to merge synonyms into a single word for keyword analysis to obtain a more accurate visualisation. VOSviewer was used to generate a bibliometric map [25].

2.4 Analysis of results

For each result, further analysis is carried out, mainly considering the number of citations of each document, the number of documents per country, the frequency and interaction of authors' keywords.

3 RESULTS

3.1 Trend in time

Fig. 3 shows the trend curve covering the studies in the global database. It shows a constant trend up to 2009, and from there, the exponential shape emerges.

Analysis between 1998 to 2009 (steady trend, n = 44), this initial period, highlights studies that biodiversity depends on geodiversity, i.e. the higher the geodiversity allows higher the biodiversity [26]. It also considers the importance of soil for both geodiversity and biodiversity, studied in terms of materials, landscapes, flora and fauna [27]. Furthermore, it shows the importance of geodiversity for biodiversity in rivers, and so begins the promotion of ecosystem preservation in both research and policy [28]. In addition, it describes the origin of the terms "biological diversity" (1988), "biodiversity" (Earth Summit held in Rio de Janeiro 1992), "geodiversities" (geographic diversity 1940s) and "geodiversity" (1990s) [29]. Geodiversity is classified by intrinsic, cultural, aesthetic, functional and scientific values, and

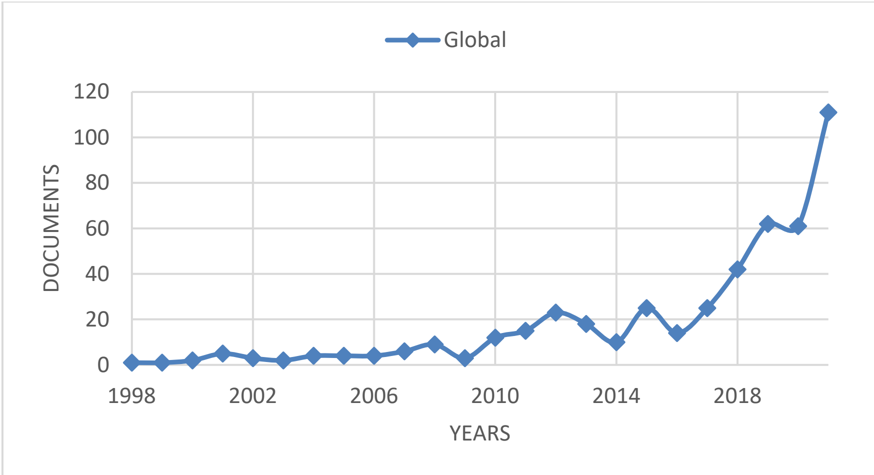

Figure 3: Trend of publications (global database, n = 462).

the importance of geo-resources to humanity throughout history is also recognised [30]. Finally, the sum of geodiversity and biodiversity is natural heritage, comprising vegetation, fauna, climate, soils, relief, geology, water and topography [31].

Between 2010 and 2021 (exponential trend, n = 418), this period of increase, studies highlight climate change threats to geodiversity and biodiversity (e.g. loss of soil and species) [32]. In addition, the high degree of geodiversity indicates high heterogeneity in biodiversity, showing that both interact with each other [33]. Therefore, conservation of geo-biodiversity enhances adaptation to climate change through ES and GS [34]. it includes the importance of geodiversity in preserving exotic and unique biological species, which contributes to sustainability [35]. Finally, it highlights how climate change affects mountain systems and their plants [36].

3.2 National contribution

Table 1 shows the five countries with the most contributions in the subject area and their significant contributions considering the number of citations (n indicates the number of documents and the percentage relative to the number of documents in the global database).

3.3 Bibliometric map using authors' keywords

Fig. 4 shows the conceptual structure of the thematic. The nodes represent the themes. Each group of colours is a cluster, which allows the knowledge generated by areas. In addition, the visualisation of the relationship between clusters and nodes. Four clusters are recognised, the first cluster is geodiversity, the second cluster is biodiversity, the third is geoheritage, and the fourth is natural conservation.

The first cluster, "Geodiversity" (yellow colour), is the most central cluster, with seven nodes and 99 occurrences. While it is the centre of the whole map, it represents the importance of geodiversity for geoheritage and biodiversity. Nodes such as landscape and mapping also stand out. An example is where ignorance of geodiversity distribution affects biodiversity, landscapes, and conservation [33].

Table 1: Countries and their contributions.

Country	Contribution
United States (n = 110 – 24.6%)	• van Riper et al. studied the geo-biodiversity relationship at different Channel Island National Park locations and found that biodiversity varies from location to location [37]. • Restoration and conservation of habitats enable and enhance biodiversity in different environments [38].
Germany (n = 98 – 21.1%)	• Kühn et al. show that high plant species richness depends on geodiversity [39]. • High geodiversity worldwide is related to high plant diversity due to different abiotic conditions [40] (e.g. climate and soil).
United Kingdom (n = 90 – 19.4%)	• Geodiversity and biodiversity conservation strategies enable adaptation to climate change in different environments [32]. • Gray highlighted strategies for nature conservation based on international and UNESCO policies such as WHS and UGGp [41].
Brazil (n = 78 – 16.9%)	• Pellitero et al. designed a tool to assess geodiversity in terms of biodiversity at regional scales [42]. • Santos et al. related urban growth and geodiversity through a geodiversity index map [43].
Spain (n = 51 – 11%)	• Serrano and Ruiz-Flaño proposed an equation for the geodiversity index that relates elements of geodiversity per km^2 [29]. • Lobo and Martín-Piera related geo-biodiversity to species richness in beetles and their geological environment [44].

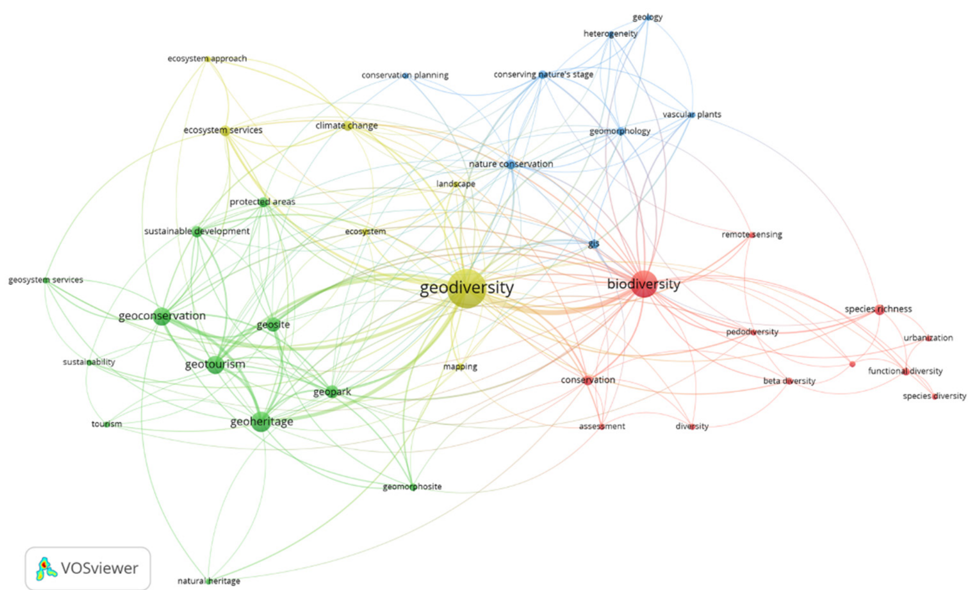

Figure 4: Cluster network using author keywords (four clusters, 39 nodes, 215 links).

The second cluster, “Biodiversity” (red colour), has 12 nodes with 227 occurrences. Nodes such as urbanisation and species richness stand out. One study reveals that urbanisation affects the settlement of species [45].

The third cluster, “Geoheritage and geoconservation” (green colour), has 12 nodes with 294 occurrences. Nodes such as geotourism, geopark and sustainable development stand out. A study indicates how geo and bio-conservation opportunities help in climate change adaptation [46].

The fourth cluster, “Nature conservation” (blue colour), has eight nodes with 160 occurrences. In addition, nodes conservation planning, heterogeneity and geology stand out. For example, it is necessary to know the species under threat for their conservation and proper management of natural areas [47].

3.4 Research trends

Fig. 5 shows the research trends over time, indicating the frequency for each keyword and its interaction each year. This figure was exported from Bibliometrix.

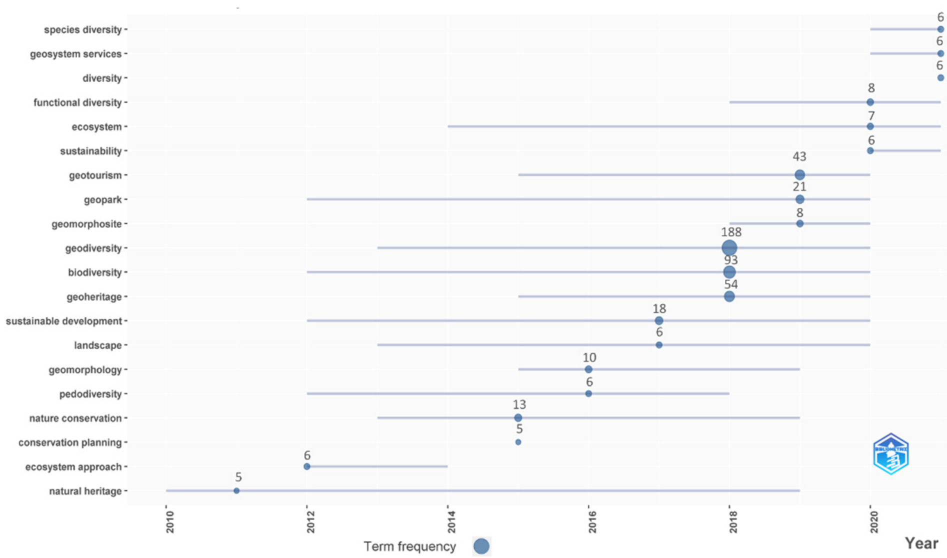

Figure 5: Research trends in time over the last ten years.

Natural heritage shows a study period from 2010 to 2019. In comparison, conservation planning was only studied in 2015. On the other hand, the most used words are geodiversity (188), biodiversity (93) and geoheritage (54); these words interact with each other in 2018. Although a topic that has been studied since 2014 is ecosystems, the current trends are sustainability, geosystem services and species diversity, which can be the basis for future research trends. Gray’s study highlights that geodiversity offers biodiversity, nature conservation, and sustainability for geomaterials [48].

4 INTERPRETATION AND DISCUSSION

The information analysed in the global database corresponds to 462 documents, indexed in 254 sources (e.g., journals, books, conferences), contributed by 1,659 authors, and a study period between 1998 and 2021. The contributions correspond to 66 countries, which the United States, Germany, the United Kingdom, Brazil, and Spain are the countries with the highest number of contributions (Table 1). Where the United States has contributed significantly to the study of geodiversity and biodiversity in national parks; however, it does not have geoparks. While Germany, the United Kingdom, Brazil and Spain have 7, 8, 1 and 15 UGGp [19], respectively, which indicates that the five countries have protection in their megadiverse areas.

The bibliometric map shows geodiversity as the central node, which contributes to biodiversity, geoheritage and geotourism, and nature conservation, thus revealing that it is essential for sustainable development and nature conservation. On the other hand, research trends highlight topics according to time of study and frequency of the theme, whereby the most studied themes according to their time are natural heritage and sustainable development. Furthermore, considering the frequency of keywords, the most studied topics are geodiversity, biodiversity and geoheritage. Current trends are species diversity, geosystem services and functional diversity, which are the basis for future trends.

A comparison of different studies shows that high biodiversity directly depends on geodiversity [33], [37], [44], [47], which highlights in Fig. 4. When comparing the production trend with the article "geodiversity and geoheritage" [49], both studies show an exponential trend from 2009 onwards, with countries such as Spain and Germany also standing out.

5 CONCLUSIONS

Geo-biodiversity and its interaction conform to natural heritage. These diversities provide benefits to humans through their resources such as water and food and global problems (e.g., adaptation to climate change). Therefore, it is also essential to conserve them through strategies such as WHS or UGGp (protection of megadiverse areas) and sustainable tourism, where the aim is to preserve these services and resources (GS/ES) and provide sustainability for future generations.

Finally, high or low geodiversity translates into high or low biodiversity, respectively, i.e., geodiversity supports biodiversity allowing for heterogeneity of ecosystems worldwide. On the other hand, current trends focus on species diversity, GS, functional diversity, diversity, ecosystem and sustainability, which are the basis for future research trends.

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