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Scientific Mapping of the Knowledge Base on Biosphere Reserves

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Abstract: Biosphere Reserves (BRs), designated by UNESCO, are spaces that promote biodiversity conservation and sustainable development. This study provides a comprehensive overview of the current state of research on BRs through a bibliometric analysis of publications indexed in Scopus between 1977 and 2024. The main objective was to analyse the evolution of research in this field, identifying trends in scientific output, types of papers, most influential countries and universities, highest impact journals, prominent authors and established collaborative networks. In addition, the predominant research topics were identified, highlighting emerging areas of study and challenges yet to be addressed. The results provide a global perspective on the scientific development of BRs and serve as a reference for future work aimed at the sustainable management of these areas. Integrating scientific research with traditional knowledge enhances adaptive management, ensuring that strategies remain relevant and effective over time.

Keywords: biosphere reserves; natural protected areas; sustainable development; bibliometrics

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1. Introduction

Biosphere Reserves (BRs) are internationally recognised areas of the planet, which remain under the sovereignty of their respective countries, selected for their scientific interest in ecological, biological and cultural aspects, and where the inhabitants of these territories develop socio-economic, human and conservation activities, seeking sustainability [1]. BRs act as a bridge between the environment and development, and are intended to ensure compatibility between long-term conservation and rational land and water management [2].

The concept of 'BR' emerged from the Man and the Biosphere Programme (MAB). MAB was initiated through a resolution passed by the 'Biosphere Conference' convened in Paris by UNESCO in 1968 as an intergovernmental programme of research, aiming to develop an interdisciplinary scientific basis for the rational use and conservation of the resources of the biosphere. The first official definition of 'BRs' was given in 1970, in the plan proposed to the UNESCO General Conference for the launching of MAB [2]. It was in 1976 that the MAB office designated the first BRs; today, there are 748. The countries with the largest number of BRs in their territory are Spain (53), Russian Federation (48), Mexico (41), China (34), Indonesia (20) and Italy (20) [3]. Figure 1 shows how the number of "BR" designations increased over time and worldwide. The information is grouped into five-year periods for better visualization and understanding.

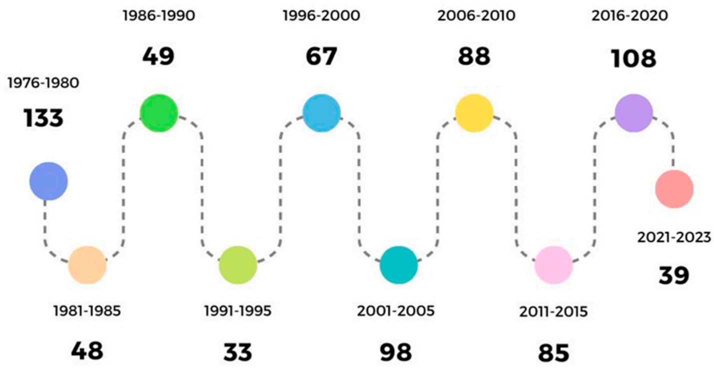

Figure 1. Timeline. Source: own elaboration based on UNESCO [3].

BRs represent a mechanism within UNESCO's MAB Programme, which seeks to promote a land management approach that balances human-environment interactions [4]. They are also learning sites for sustainable development, where interdisciplinary approaches to understanding and managing change and interactions between social and ecological systems, including conflict prevention and biodiversity management, are pursued. In addition, they provide local solutions to global problems [3]. Basically, BRs represent a holistic approach to land management, in which biodiversity conservation and progress in human well-being are achieved in a harmonious and balanced way. This is achieved through three main objectives [3]: (1) conservation of biological and cultural diversity, (2) socio-culturally and environmentally sustainable economic development, (3) logistical support to sustain development through research, monitoring, education and training.

BRs may offer a unique opportunity to understand pathways for more sustainable social-ecological systems. Their ambitious goals match the huge challenges we currently face, including halting biodiversity loss and ending poverty [5]. BRs have a key role in research and in the co-production of knowledge for sustainable development, which implies that they should serve as spaces where science, policy and education are integrated [6]. The aforementioned shows that BRs provide a promising framework for moving towards a more sustainable future.

These three functions are carried out in the three main BR areas [3]:

1. Core or central zone. It has a strict protection area that contributes to the conservation of landscapes, ecosystems, species and genetic variation [3]. In this zone, human activities are very limited so as to protect natural resources [6].
2. Buffer zones. Surrounding or adjacent to the core zone, and where shared activities with ecological practices that reinforce scientific research, monitoring, training and education take place [3]. These zones allow for the sustainable use of natural resources, while contributing to conservation [7].
3. Transition zone. In this zone, communities promote different economic and human activities that are socio-culturally and ecologically sustainable [3]. In these areas, a balance is sought between conservation and the use of natural resources by local communities [6].

Research and development in the BR context are interdependent subjects, requiring a range of scientific approaches and close interdisciplinary collaboration. With the exponential growth of scientific output in all disciplines, especially in recent decades, there is an urgent need to quantify specific elements of the resulting literature, allowing for a comparative, measurable and objective assessment of the activity under consideration. In response to this need, bibliometrics has emerged as a useful tool [8]. Bibliometric analysis of the behaviour of publications is important to establish what the current topics are and where the trends in the field are heading [9]. This analysis also makes it possible to identify the evolving aspects of a field of study and to shed light on emerging areas of research [10]. In addition, bibliometric studies can help visualise knowledge structures, identify influential researchers and institutions, assess research impact, detect knowledge gaps, prioritise research areas and optimise resource allocation. By providing quantitative data on research activities, bibliometrics offers a solid basis for evidence-based decision-making in academia, industry and government. On the other hand, the knowledge gained enables optimisation of resources. Thus, funding agencies and universities can focus their resources on strategic areas, maximising the impact of investment in scientific research.

Bibliometric research in the BR context is scarce and with a significant time gap. Kratzer [6] provided an overview, based on bibliometric data on the main publications and research topics on BRs; this study considered publications from 1970 to 2016, indexed in the Web of Science database. Kratzer's work represents the first systematic review of the literature on the subject; he also points out the need to carry out a bibliometric analysis based on another database to compare and verify the results he obtained. Ferreira et al. [5,11] developed a couple of studies in which a review of the scientific literature related to the management and governance of BRs was provided. Their selection criteria considered work published between 1996 and 2017, indexed in Scopus in English and of the 'article' document type, the full text of which was available and in which the case study was mainly on a single reserve; this led them to carry out their analysis and classification using 66 articles. These two papers provided insights into factors related to the effectiveness of BR management. More specifically, Rawat & Rawal [12] conducted a bibliometric analysis of Himalayan BRs, with an emphasis on the Nanda Devi BR, covering publications from 1990–2010.

In this context, the aim of this research paper is to provide an overview of the state of the art of research carried out in the context of BRs, based on a bibliometric analysis of information published in Scopus from 1977 to 2024 (15 July). This research presents a broader time frame compared to previous works that exist on the subject, as these had only covered up to 2017. It identifies the following:

1. Assessment of growth and knowledge. It shows how scientific interest in BRs has evolved since their creation, identifying periods of increased academic production, as well as temporary gaps or stagnation in research, which is crucial for understanding the development of knowledge in key areas such as conservation, biodiversity and sustainable development.
2. Assessment of the impact and quality of research. It allows measurement of the influence of publications through indicators such as number of citations, most influential journals and key authors. This type of assessment is important to identify research that has been particularly relevant for the development and management of BRs, providing a basis for guiding public policy and decision-making for the management of these areas.
3. The main topics within the field of study, as well as identifying emerging issues and priority areas. This is essential for targeting future studies towards areas of research that require further attention or unexplored areas.
4. Identification of collaboration networks between countries. In this regard, BRs are territories managed with a global approach, where international cooperation is crucial. Therefore, by using bibliometrics, it is possible to map collaboration networks between authors, institutions and countries, which helps to visualise global research dynamics

and fosters cooperation between key stakeholders. This analysis facilitates the creation of strategic alliances to address common global problems.

Although BRs have been the subject of numerous studies in areas such as conservation, sustainable development and governance, the current literature lacks a comprehensive bibliometric analysis covering a period as extensive as the one considered in this work (1977–2024). This approach not only allows for the identification of general trends and patterns of scientific collaboration, but also highlights emerging areas and gaps in research. In this way, this study provides a global perspective that contributes to a better understanding of the scientific development around BRs, serving as a reference for future research and for strategic decision-making in their management.

This article is structured in five main sections. First, the methodology describes the bibliometric process used, including the search, selection and analysis criteria. Next, the results section presents the key findings, such as the evolution of publications, the main research topics and the dynamics of collaboration between countries and institutions. Subsequently, the discussion analyses the implications of these findings and highlights gaps in current research. Finally, the conclusions summarize the most relevant points of the study, suggest future lines of research and address the limitations of the work.

2. Methodology

In order to achieve the objective of this research, a bibliometric analysis was conducted. A bibliometric analysis allows a large amount of information to be analysed in a very detailed way, based on global data as well as data from a variety of specific fields [13]. Analysing the literature through a systematic review of the last few decades has many advantages, including the opportunity to observe changes over time in an area of knowledge [14]. Bibliometric studies help to build a solid foundation for advancing a research area in a meaningful way and allow researchers to (1) get an overview, (2) investigate knowledge gaps, (3) design innovative ideas for research and (4) position their intended contributions to the field [15]. This type of analysis requires a search protocol that provides confidence and validity to the studies in which it is applied [16]. In summary, bibliometric analysis is a research tool that enables the quantitative and qualitative study of scientific production in a given area and provides a solid base of empirical evidence to identify trends and patterns, detect knowledge gaps, assess the impact of research [17–19], inform decision-making [20] and visualise the structure of a field of knowledge [21].

The steps that were followed in the present bibliometric analysis are shown in Figure 2 [19,22–24], with the aim of ensuring that the analysis is conducted in a rigorous and scientific manner, providing valid and useful results to understand the evolution and trends in research on BRs. First, the objectives were defined in terms of what we want to analyse. Next, the Scopus database was selected to collect the data, which is a reliable database with wide coverage in the study area. Atienza-Barba et al. [25] and Álvarez-García et al. [26] point out that for any bibliometric query, the choice of databases plays a key role, requiring platforms of high reliability and comprehensive coverage. The Scopus database is considered an important source of documentation for researchers' work [27] and in terms of its scope of coverage, it is slightly broader than Web of Science [28]. Furthermore, by using the Scopus database in this study, an analysis of the subject is achieved using the two most important databases worldwide; all this considering the research previously conducted by Kratzer, published in 2018.

Figure 2. Steps of bibliometric analysis. Source: own elaboration.

Next, several criteria were established for the search and follow-up of the information for the development of the review as established by Del Río-Rama et al. [29]; the search was conducted on 15 July 2024 and the search criterion was ARTICLE TITLE (biosphere reserv* OR reserv* de la biosfera), which was defined from the work of Kratzer [6]. In the next step, the data were collected and refined (duplicates and irrelevant or low-quality publications were removed). The search yielded 2830 results from the years 1977 to 2024. All the results returned by the criteria were included, without discriminating by language, type of document, country or any other factor. Following the process, metrics and indicators were chosen (productivity in number of publications, impact through citation, collaboration between authors and co-occurrence analysis—keywords and predominant subjects) and the data were analysed and downloaded in CSV format for processing by using Excel, VOSViewer 1.6.20, Leiden University, The Netherlands (visualises co-authorship networks, collaboration between institutions and keywords) and Microsoft PowerBI. The last two programmes allowed for the analysis of trends and networks. Finally, the data were interpreted (observing emerging trends, well-covered areas and gaps in research) to conclude with recommendations and pointing out future areas of research. In other words, to point out the practical implications and recommendations for the scientific community and BR managers.

To ensure the clarity and reproducibility of the process, the steps established in the PRISMA guidelines were followed (Figure 2). In the initial stage, documents on the topic were identified in the Scopus database. Duplicates were subsequently eliminated and irrelevant documents were discarded through a preliminary review based on titles and abstracts (PRISMA eligibility criteria). The exclusion criteria applied included documents not directly related to the concept of Biosphere Reserves, incomplete abstracts or publications with fewer than two pages.

For data analysis and visualization, the information was downloaded in CSV format and processed using Excel, VOSViewer and PowerBI.

3. Results and Discussion

3.1. Evolution of the Number of Publications

Figure 3 shows the evolution of publications related to BRs, excluding data from 2024 because the search was carried out in mid-July of that year. Figure 3 shows that in the early years (1977–1990), which could be considered the first period, the number of publications remained relatively low and with little variation, indicating an initial and exploratory interest in the subject and the conceptual framework of BRs being partially developed. This period can be considered as an initial consolidation of the BR idea, probably driven by the global environmental debates of the 1970s and 1980s on conservation, sustainable development and the role of local communities. These debates influenced the consolidation of BRs and the development of their conceptual frameworks. Among them, the Stockholm Conference in 1972 marked the beginning of international awareness of environmental issues and highlighted the need for coordinated action to preserve the environment at the global level. The Brundtland Report [30] is also noteworthy, as it popularised the concept of sustainable development and the creation of UNESCO's Man and the Biosphere (MAB)

Programme [31], which, as mentioned previously, sought to address the interrelationship between people and the environment, focusing on ecological research, sustainable use of resources and improving the relationship between local communities and their natural environments. Finally, it is also worth highlighting the 1992 Convention on Biological Diversity (United Nations, 1992) [32] and the 1971 Ramsar Convention on Wetlands (UNESCO, 1971) [31], the latter being a precursor to the creation of international protected areas and helping to foster the focus on the protection of critical ecosystems, which would later influence the designation of BRs in biologically diverse areas and fragile ecosystems.

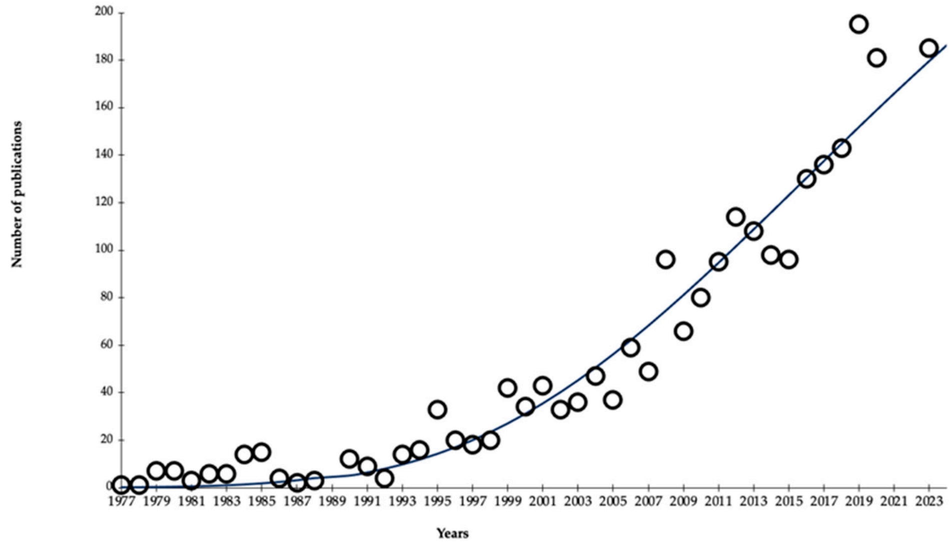

Figure 3. Evolution of publications in the Scopus database on the topic of BRs. The circles indicate Scopus data, and the solid line indicates data fitting by the Gompertz model (0.055 years−1 rate; 0.95 coefficient of determination (R2)). Source: own elaboration.

The second period corresponds to the years 1990 to 2015. It shows that from the mid-1990s onwards, there was an accelerated growth in publications. One of the factors that may be related to this increase is the Convention on Biological Diversity (CBD), proclaimed by the United Nations in 1992 and which came into force in 1993. This global agreement is aimed at the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from the use of genetic resources [32]. The emergence of other important international initiatives, such as the Aichi Biodiversity Targets set in 2010 [33], which could have further encouraged research on BRs, should also be mentioned. Furthermore, by 1990, 213 BRs had already been designated, which corresponds to 28.5% of the total number of BRs in existence today.

The third period corresponds to 2015–2023. From 2015 to date, there has been an even greater acceleration, possibly due to factors such as climate change, biodiversity loss and growing awareness of the importance of ecosystems. In this sense, this growth may be influenced by the 2015 Paris Agreements [34]. These agreements generated greater scientific engagement around ecosystems and biodiversity, promoting a significant increase in the amount of research related to BRs, as they are natural laboratories for studying the effects of climate change. The Paris Agreement established global commitments and targets to reduce greenhouse gas emissions (committing countries to keep global temperature rise below 2 °C and striving to limit it to 1.5 °C), and to addresses adaptation to the impacts of climate change, with an emphasis on finance, technology and capacity building.

In general, there is a sustained upward trend over the period 1977 to 2023, which is consistent with Kratzer's [6] analysis of the Web of Science database.

3.2. Publications by Type of Document

Figure 4 shows the percentage of publications by document type. There is a clear bias towards articles. The result is also consistent with that reported by Kratzer [6] in his study. Some other prominent formats are Book Chapter, Conference paper, Review and Note. The bar labelled Others encompasses less-used formats such as Erratum, Editorial, Letter, Book, Data paper, Short survey and Conference Review.

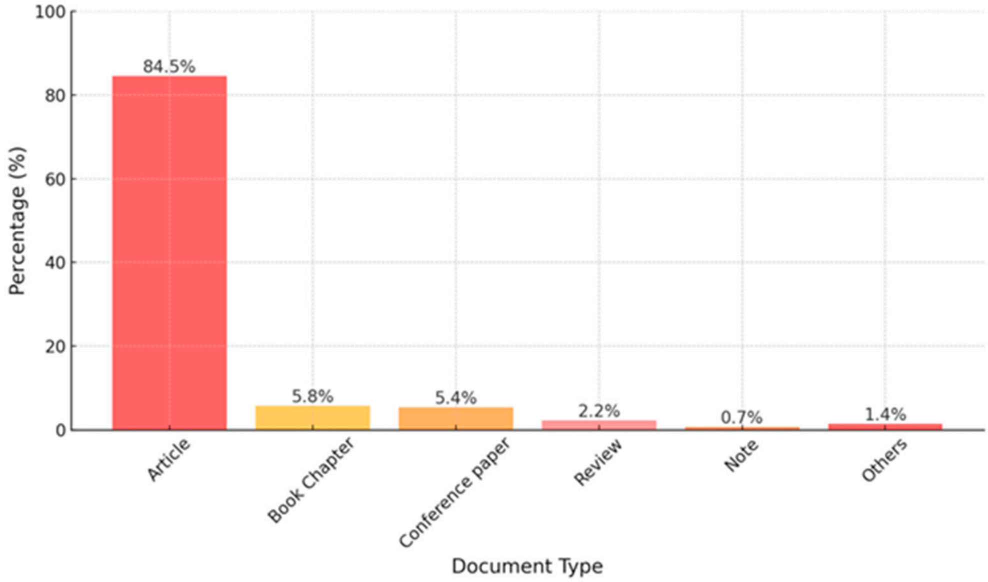

Figure 4. Percentage of publications by type of document. Source: own elaboration.

3.3. Countries, Universities and Key Authors

Table 1 shows the Top 10 countries, universities and authors with the highest number of publications on the topic. In the case of authors, the total number of citations that their publications on the subject have accumulated to date was also added, as well as the TC/TP ratio to determine the impact. It can be seen that Mexico leads the ranking of countries with a total of 463 publications; in the case of universities, it is a Mexican university that leads the ranking, the National Autonomous University of Mexico with 168 publications, and among the authors, the ranking is led by Rozzi, Ricardo with 24 publications, who is a professor in the Department of Philosophy at the University of North Texas in the United States.

The geographical distribution of publications reflects the regional interest in BRs. Mexico leads the ranking of countries with the highest number of publications, being a country with a large number of BRs designated by UNESCO, namely 42, which include a great diversity of ecosystems ranging from deserts to tropical rainforests. This can be explained, on the one hand, by its commitment to conservation and its network of BRs, and on the other hand, by the impact of research initiatives supported by the government or international cooperation. In addition, Mexico has implemented conservation policies, which have encouraged scientific research in its reserves, with influential academic institutions, such as the National Autonomous University of Mexico (UNAM), leading key projects in the management and conservation of natural protected areas. There are many projects, and it is not possible to mention them all. The Institute of Biology of the UNAM has studied the migratory and habitat patterns of the monarch butterfly, as well as the implications of deforestation and climate change on its life cycle, which is a study carried out in the Monarch Butterfly BR. The Biodiversity and Climate Change Research Programme, which involves various UNAM faculties and research centres, also seeks to understand how climate change affects biodiversity in Mexico's BRs, key results for the formulation of adaptation and mitigation policies in the field of conservation. UNAM has ecology and ecosystem restoration laboratories and actively participates as a university in UNESCO's Man and Biosphere Programme, organising conferences and symposia that bring together scientists, managers and local communities to discuss the conservation and management of BRs.

Table 1. Key countries, universities and authors in the research field of BRs from 1976 to 2024 in the Scopus database.

Ranking	Country		Ranking	University		Ranking	Authors			
	Name	TP		Name	TP		Name	TP	TC	TC/TP
1	Mexico	463	1	Universidad Nacional Autónoma de México	168	1	Rozzi, R.	24	409	17.04
2	India	434	2	El Colegio de la Frontera Sur	76	2	Maikhuri, R.K.	22	900	40.91
3	United States	303	3	Russian Academy of Sciences	57	3	Sinsin, B.	18	299	16.61
4	Spain	200	4	Instituto de Ecología, A.C.	49	4	Sivaperuman, C.	18	6	0.33
5	Germany	198	5	Chinese Academy of Sciences	46	5	Gavio, B.	16	162	10.13
6	Russian Federation	158	6	Zoological Survey of India	45	6	Rao, K.S.	16	826	51.63
7	France	110	7	Centro de Investigaciones Biologicas del Noroeste	44	7	Stoll-Kleemann, S.	14	377	26.93
8	China	106	8	G.B. Pant National Institute of Himalayan Environment	40	8	Saxena, K.G.	13	773	59.46
9	United Kingdom	93	9	University of Abomey-Calavi	37	9	Nautiyal, S.	13	719	55.31
10	Canada	85	10	Universidad del Pais Vasco	36	10	Reed, M.G.	13	280	21.54

TP = total publications, TC = total citations, TC/TP = average impact per publication. Source: own elaboration.

The second position is held by India, with 12 BRs, featuring unique ecosystems such as the Himalayan mountains and tropical forests. The interest of its researchers is due to the need to manage large natural areas with human populations that depend on these resources for their subsistence [35]. In this regard, Singh & Borthakur [36] state that BRs in India not only focus on biodiversity conservation, but are also of great importance in terms of sustainable human development, a key issue in a country with a high population density and dependence on natural resources. The third position is held by the United States, with 28 BRs. It is a leading country in environmental research and conservation, highlighting the role of the National Park Service or NASA, which participate in research on climate change, ecosystem conservation and biodiversity. The fourth position is held by Spain, followed by Germany (5th position), France (7th) and the United Kingdom (9th). All of them are European Union countries, showing the European interest in environmental sustainability, which is reflected in their leadership in the creation of biodiversity conservation policies. With regard to BRs, Spain has 53, making it the country with the most BRs in the world, which shows its commitment to conservation and sustainability; Germany has 17, France 18, and the United Kingdom 7.

In Kratzer's analysis [6], Mexico is also shown as the country that leads the publications on the topic of BRs, but in that case, the second position was held by the United States and the third by India, roles that were reversed in the results of the present study.

Regarding the number of authors, the most influential authors are Saxena, K.G. and Nautiyal, S., with the highest citation rates per publication (59.46 and 55.31, respectively). Despite not being the most prolific authors, their research has a high impact on the scientific community. On the contrary, Sivaperuman, C., with 18 published papers, has the lowest impact with only 0.33 citations per publication, which could suggest a lower relevance or visibility of his research. The most productive author is Rozzi, R., with 24 publications, but his impact per publication is moderate compared to other authors. Finally, it is observed that Maikhuri, R.K. (40.91 citations) and Rao, K.S. (51.63) show a balance between productivity (prolific) and impact (very influential).

Figure 5 shows the journals in which the 10 countries that make up the Top 10 publications have obtained the greatest number of citations. Figure 5 shows that in terms of the number of accumulated citations, the main journals are as follows: Biological Conservation with papers from Canada, China, Spain, the United States and Mexico; Forest Ecology and Management with papers from Canada, China, Germany, Russia and the United States; Economic Botany with papers from the United States and Mexico. Note: this Figure is based on the five journals with the highest number of citations for each country.

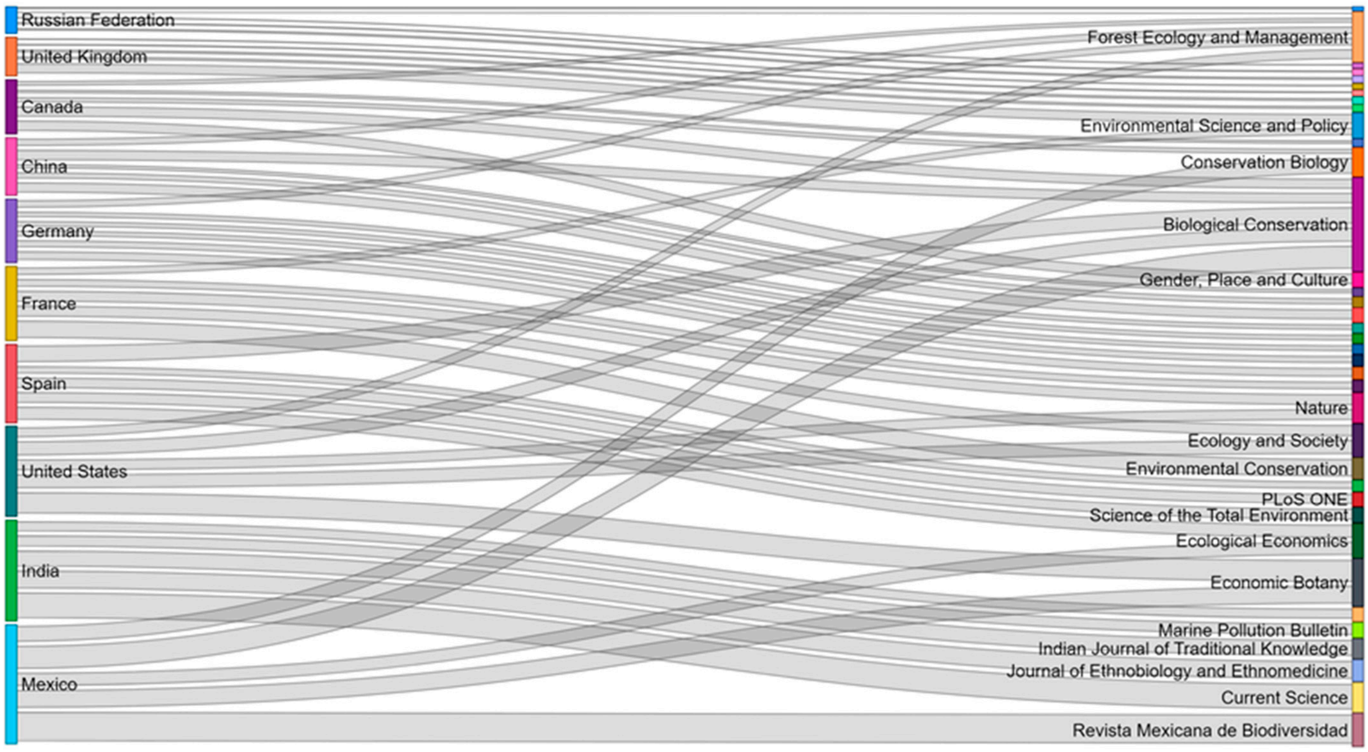

Figure 5. Top 10 countries with the most publications and the journals where they have achieved the most citations. Source: own elaboration. Note: The height of each bar indicates the number of country-to-journal citation relationships. A higher bar height means a higher number of cited works from the country and journals to which the bar is linked. Colours were automatically assigned to differentiate countries and journals in this case.

Figure 6 shows the indices of the journals in which the Top 10 countries have the highest number of citations. Figure 6 shows that the Top 10 countries have publications and citations in journals classified as Q1, which is also the quartile that accumulates the most citations. At the other extreme are those journals that do not yet have a quartile (NYAQ), but which stand out for the number of citations accumulated by the publications found there. Note: the information in this Figure was obtained by considering the 20 most cited journals of the countries in the Top 10 publications.

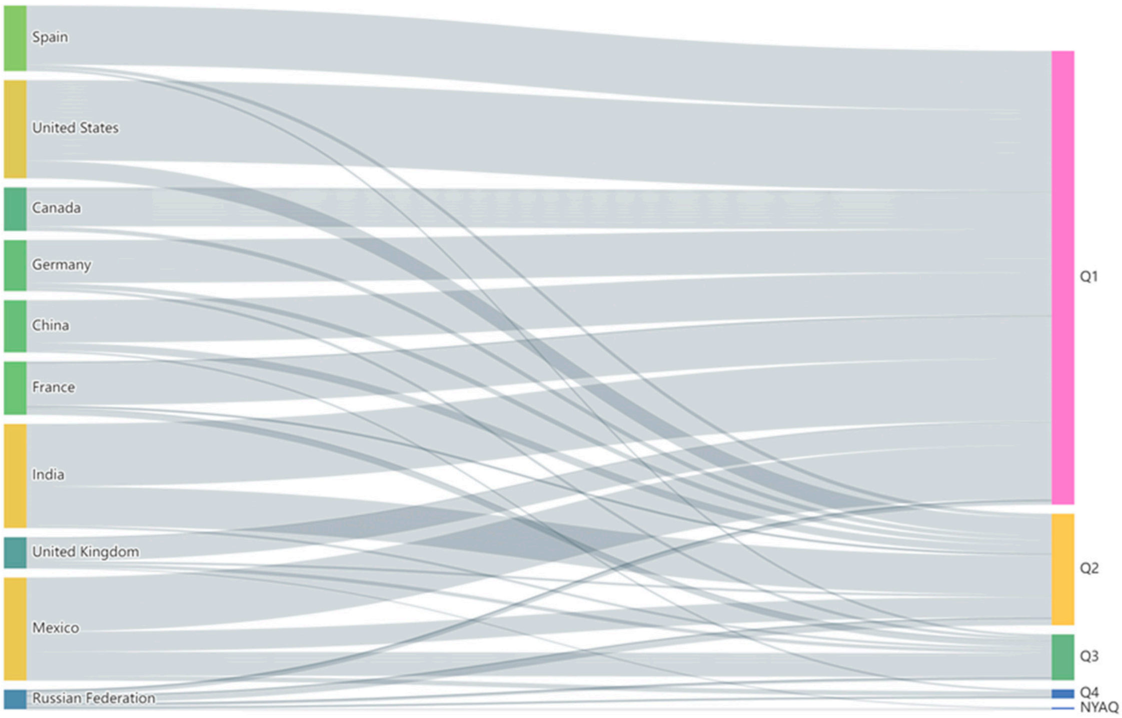

Figure 6. Top 10 countries with the most publications and the indexes of the journals where they have received the most citations. Source: own elaboration. Note: The height of each bar indicates the number of country-to-journal citation relationships. A higher bar height means a higher number of cited works from the country and journals to which the bar is linked. Colours were automatically assigned to differentiate countries and journals in this case.

3.4. Most Cited Articles

The first article published on the subject of BRs was "The BR program in the United States" by the author Franklin, Jerry F. The article was published one year after the designation of the first BRs and has been cited 32 times to date. This research analyses BRs as the programme to select key sites for environmental research and monitoring [37]. This work laid the foundation for the study of BRs as natural laboratories for environmental exploration and monitoring.

Table 2 shows the Top 10 most cited articles. It can be seen that the paper by Olsson et al. in 2007, entitled "Enhancing the fit through adaptive co-management: Creating and maintaining bridging functions for matching scales in the Kristianstads Vattenrike BR, Sweden" has had the greatest impact on the field, with 358 citations to date, with an average of 21.06 citations per year. This paper addressed the adaptive governance of social–ecological systems, highlighting the importance of social factors in improving the relationship between governance systems and ecosystems. This work was carried out in the Kristianstads Vattenrike BR, Sweden.

Table 2. Articles most cited.

Ranking	Title Article	Author(s)	Year	TC	TC/Year	Source Title
1	Enhancing the fit through adaptive co-management: Creating and maintaining bridging functions for matching scales in the Kristianstads Vattenrike BR, Sweden	Olsson P.; Folke C.; Galaz V.; Hahn T.; Schultz L. [38]	2007	358	21.06	Ecology and Society
2	Losing knowledge about plant use in the Sierra de Manantlan BR, Mexico	Benz B.F.; Cevallos J.E.; Santana F.M.; Rosales J.A.; Graf S.M. [39]	2000	216	9.00	Economic Botany
3	Herpetofauna diversity and microenvironment correlates across a pasture-edge-interior ecotone in tropical rainforest fragments in the Los Tuxtlas BR of Veracruz, Mexico	Urbina-Cardona J.N.; Olivares-Pérez M.; Reynoso V.H. [40]	2006	191	10.61	Biological Conservation
4	The BR: A Tool for Environmental Conservation and Management	Batisse M. [2]	1982	169	4.02	Environmental Conservation
5	Identities in the making: Conservation, gender and race in the Maya BR, Guatemala	Sundberg J. [41]	2004	160	8.00	Gender, Place and Culture
6	Local people's perceptions as decision support for protected area management in Wolong BR, China	Xu J.; Chen L.; Lu Y.; Fu B. [42]	2006	155	8.61	Journal of Environmental Management
7	Participation, Adaptive Co-management, and Management Performance in the World Network of BRs	Schultz L.; Duit A.; Folke C. [7]	2011	154	11.85	World Development
8	Ethnomedicinal plant use by Lepcha tribe of Dzongu valley, bordering Khangchendzonga BR, in North Sikkim, India	Pradhan B.K.; Badola H.K. [43]	2008	148	9.25	Journal of Ethnobiology and Ethnomedicine
9	Application of geoaccumulation index and enrichment factor for assessing metal contamination in the sediments of Hara BR, Iran	Nowrouzi M.; Pourkhabbaz A. [44]	2014	139	13.90	Chemical Speciation and Bioavailability
10	Roadkills of vertebrate species on two highways through the Atlantic Forest Biosphere Reserve, southern Brazil	Coelho I.P.; Kindel A.; Coelho A.V.P. [45]	2008	133	8.31	European Journal of Wildlife Research
	Bovine tuberculosis in Doñana Biosphere Reserve: The role of wild ungulates as disease reservoirs in the last Iberian lynx strongholds	Gortázar C.; Torres M.J.; Vicente J.; Acevedo P.; Reglero M.; de la Fuente J.; Negro J.J.; Aznar-Martín J. [46]	2008	133	8.31	PLoS ONE

Source: own elaboration. Abbreviation: TC = Total citations.

Five of the ten articles shown in Table 2 were also mentioned by Kratzer [6] in his work. However, here it can be seen that the number of citations has increased and has moved some of these articles to a different position; the exception being the paper by Olsson et al. [38], which in both cases occupies the first position.

3.5. Key Journals

Table 3 shows the Top 10 journals with the most articles on the topic "BRs". The ranking is led by the journal Eco.mont, published by The Austrian Academy of Sciences

Press. Seven of the ten journals listed in Table 3 are published in European countries and the other three are published in American countries, two of them developing countries: Mexico and Costa Rica.

Table 3. Journals with most articles.

R	Source Title	TP	Country	Publisher	Best Quartile	SJR 2023	Subject Area	Category
1	Eco.mont	54	Austria	The Austrian Academy of Sciences Press	Q3	0.2	Environmental Science	Ecology
								Management, Monitoring, Policy and Law
								Nature and Landscape Conservation
2	Revista Mexicana de Biodiversidad	47	Mexico	Universidad Nacional Autónoma de México	Q3	0.29	Agricultural and Biological Sciences	Ecology, Evolution, Behavior and Systematics
3	Sustainability	39	Switzerland	Multidisciplinary Digital Publishing Institute (MDPI)	Q1	0.67	Computer Science	Computer Networks and Communications
								Hardware and Architecture
							Energy	Energy Engineering and Power Technology
								Renewable Energy, Sustainability and the Environment
							Environmental Science	Environmental Science (miscellaneous)
								Management, Monitoring, Policy and Law
							Social Sciences	Geography, Planning and Development
4	Iop Conference Series: Earth And Environmental Science	33	United Kingdom	IOP Publishing Ltd.	NYAQ	0.2	Earth and Planetary Sciences	Earth and Planetary Sciences (miscellaneous)
							Environmental Science	Environmental Science (miscellaneous)
							Physics and Astronomy	Physics and Astronomy (miscellaneous)
5	Environmental Conservation	29	United Kingdom	Cambridge University Press	Q1	0.73	Environmental Science	Health, Toxicology and Mutagenesis
								Management, Monitoring, Policy and Law
								Nature and Landscape Conservation
								Pollution
								Water Science and Technology
6	Biodiversity And Conservation	27	Netherlands	Springer Netherlands	Q1	0.95	Agricultural and Biological Sciences	Ecology, Evolution, Behavior and Systematics
							Environmental Science	Ecology
								Nature and Landscape Conservation
7	Ekologia Bratislava	25	Slovakia	-	Q3	0.3	Environmental Science	Ecology
8	Revista De Biologia Tropical	21	Costa Rica	Universidad de Costa Rica	Q2	0.27	Agricultural and Biological Sciences	Agricultural and Biological Sciences (miscellaneous)

Table 3. *Cont.*

R	Source Title	TP	Country	Publisher	Best Quartile	SJR 2023	Subject Area	Category
9	Environmental Monitoring And Assessment	21	Germany	Springer Science and Business Media Deutschland GmbH	Q2	0.64	Environmental Science	Environmental Science (miscellaneous)
								Management, Monitoring, Policy and Law
								Pollution
							Medicine	Medicine (miscellaneous)
10	Ecology And Society	19	Canada	The Resilience Alliance	Q1	1.07	Environmental Science	Ecology

TP = Total publications, NYAQ = Not Yet Assigned Quartile; Source: own elaboration.

Two areas of knowledge predominate in these journals: (1) Environmental Science and (2) Agricultural and Biological Sciences; although there are also areas of knowledge such as Computer Science, Social Science, Energy, to mention a few, which reflect the multidisciplinary nature that research on BRs can have. The journals that make up the Top 10 generally have a high impact factor, which indicates that the publications found in them receive a high number of citations and are recognised by the scientific community.

Figure 7 shows the countries of authors that have published in the Top 10 journals and particularly those whose publications have achieved the highest number of citations for their papers. In this figure, it can be seen that authors from countries such as Slovakia, Argentina, Australia and Sweden have a great impact on the field of BRs due to the number of citations their papers have achieved. Other countries such as Mexico, India, the United States, Spain, Germany, France, China, and Canada stand out both for the number of publications and the number of citations.

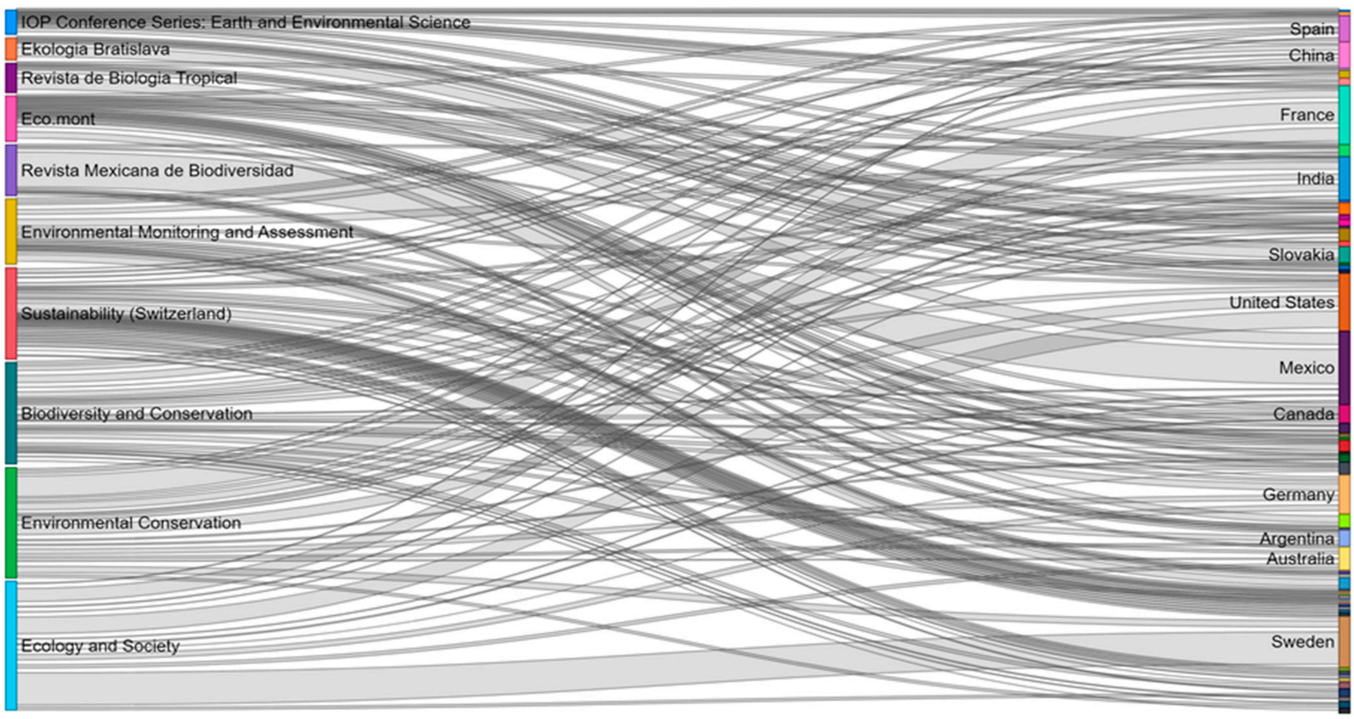

Figure 7. Top 10 journals with the most publications and the main countries that publish in them. Source: own elaboration. Note: The height of each bar indicates the number of country-to-journal citation relationships. A higher bar height means a higher number of cited works from the country and journals to which the bar is linked. Colours were automatically assigned to differentiate countries and journals in this case.

3.6. Main Topics in the Field of Study

A co-occurrence of words was performed considering the following criteria: all keywords (including author keywords and index keywords), the counting method was Full Counting, and the minimum number of occurrences per word was 25. The words 'biosphere', 'biosphere reserve(s)', 'article', 'biospherics' were excluded due to their obvious repetitiveness and in order to clearly visualise the main topics in this field of study. Figure 8 shows the co-occurrence of words. It can be observed that five word clusters are formed, identified by the colours red, green, blue, yellow and purple.

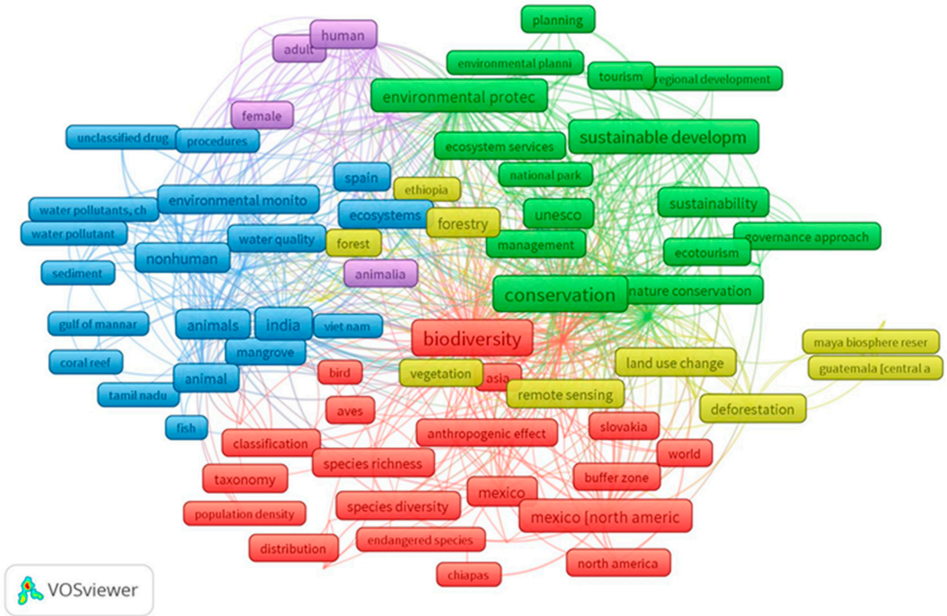

Figure 8. Co-occurrence of words. Source: own elaboration.

The red cluster is made up of 42 items, where the word 'biodiversity' stands out as a core concept, suggesting that most of the studies included in the group focus on aspects related to biological diversity; how species are distributed, the factors that affect them, and how they vary according to the geographical region. This cluster reflects the interest in understanding the natural diversity found in BRs, as well as the interest in the preservation and management of these environments. The presence of countries such as North America, Asia, Mexico and Slovakia within the cluster indicates a specific geographic interest in the biodiversity of these areas. In the first three cases, given that they are leaders in BRs, their predominant presence in the cluster is explained, since as identified previously, there is a correlation between research and countries with BRs. In the case of Slovakia, it would be important to investigate the interest of the scientific community in this environment.

The green cluster, made up of 31 items, highlights the term 'sustainable development', which positions itself as the main theme of the cluster. Topics include: (1) sustainable tourism, which is established as an economic activity that can benefit local communities, but only if it is properly managed, being a recurring theme to achieve a balance between tourism and the preservation of ecosystems; (2) environmental planning, which is essential to ensure that development projects within the BR do not harm ecosystems; (3) governance, which can involve numerous stakeholders in decision-making (local administrations, governments, indigenous communities, NGOs); (4) regional development, in the sense that BRs can facilitate the economic development of the area in which they are located; and (5) environmental conservation. The latter connects the concept of sustainable development with the other clusters, showing that conservation is crucial for long-term sustainable development.

The blue cluster is made up of 28 items, highlighting the words 'ecosystem' and 'water'. This cluster is focused on aquatic ecosystems and problems related to water quality and pollution. Geographically, this cluster includes the countries of Vietnam, Spain and India, which implies a strong interest of these countries in studying aquatic ecosystems and water management in these regions. In the case of Vietnam, the studies show interest in water management in tropical protected areas, where the abundance of water resources plays a key role for wildlife and human communities that depend on water for agriculture. Spain is a country with important BRs in areas where water resources are limited or threatened, which explains Spanish researchers' interest in water quality and pollution. In the case of India, studies are influenced by the high dependence of the population on water resources, aggravated by a high population density. In the yellow cluster, consisting of 22 items, the words 'forestry', 'deforestation' and 'land use change' are highlighted. Geographically, the countries of Guatemala and Ethiopia stand out as very important countries in terms of these problems. In the case of Guatemala, this country has extensive tropical forests threatened on the one hand by illegal deforestation and, on the other hand, by agricultural expansion, and in Ethiopia the impact of climate change significantly affects BRs, as well as the expansion of agriculture in these protected areas. Finally, in the purple cluster made up of 10 items, the words 'human', 'female', and 'adult' stand out. This cluster focuses on humans as central stakeholders within BRs, which suggests a focus on human interaction with ecosystems and on the socioeconomic aspects of BRs. It groups together studies on the social and economic impact of activities within BRs, community management of these areas, and the role of women in the management of resources such as water, agriculture, and soil conservation.

Mexico appears to be an important geographic focus for BR research among the countries shown in Figure 8.

Figure 9 also shows the co-occurrence of words, but from a time horizon, so it is possible to observe those words that have prevailed over time (e.g., 'Eurasia', 'Germany') and those words that have emerged in recent years (e.g., 'Sundarbans biosphere reserve'), thus showing interest in the research topic from different perspectives.

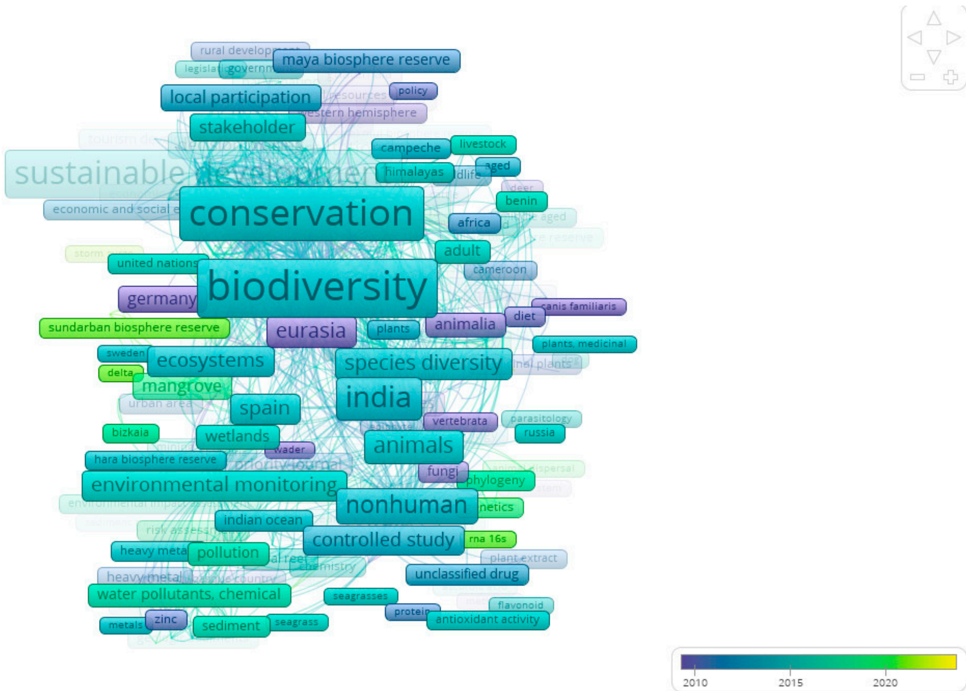

Figure 9. Co-occurrence of words by temporal horizon. Source: own elaboration.

3.7. Collaboration Networks Between Countries

An analysis of co-authorships between countries was also conducted, considering at least five documents per country. Nine clusters were formed, identified by the colours red, green, blue, sky blue, purple, brown, orange, yellow and pink (see Figure 10). It can be seen that countries such as Mexico (sky blue cluster), the United States (brown cluster), India (blue cluster), Germany (purple cluster), Spain (green cluster) and the Russian Federation (red cluster) are those that perform the most collaborative work. This figure provides a better understanding of how knowledge is co-produced and shared across borders; it shows the structure of collaboration between countries, highlighting key research networks and groups.

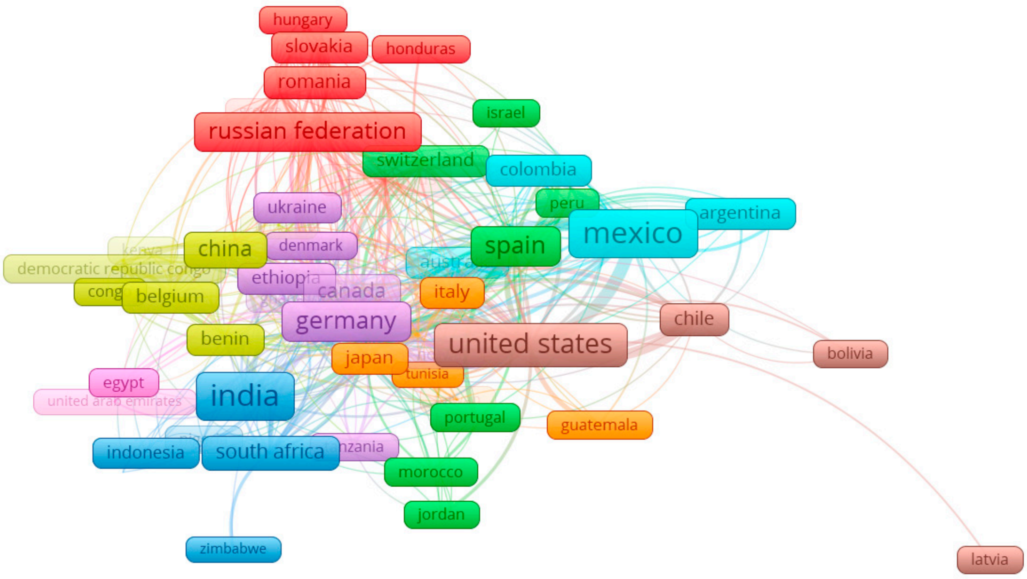

Figure 10. Collaboration networks between countries. Source: own elaboration.

The influence in the number of studies from North America (including Mexico and the USA) has increased since the mid-1990s, which possibly makes that region have a higher visibility of publications over time with respect to the number of publications from Europe, Asia and South America, which all increased their publications after the 2000s [47]. New scientific linkages are vital for peripheral countries such as Mexico and the USA to integrate into global knowledge networks. The establishment and dissolution of these linkages are influenced by both cognitive and cultural proximities [48].

In Mexico, the National Commission of Natural Protected Areas (CONANP) administers and supports the Biosphere Reserve Network, safeguarding more than 12% of the national territory. In India, government agencies such as the Ministry of Environment, Forest and Climate Change and the National Biodiversity Authority support scientific research and conservation projects. The high effectiveness of research in Mexico and India may also be linked to foreign funding [47].

4. Conclusions

This work was based on the objective of providing an overview of the state of the art regarding BRs. It was inspired by the research conducted by Kratzer, published in 2018 [6], so it focused on (1) showing up-to-date information in an area that has experienced significant changes in recent years and (2) addressing analyses not previously conducted, which allow new perspectives to be addressed.

Main finding

One of the main contributions is the identification of the predominant research topics from which BRs have been studied. This information is key to researchers' decision-making regarding the planning of future research, with the aim of addressing emerging or under-explored areas. This research revealed some issues that have been addressed when studying BRs; among them are issues related to biodiversity (main research focus), tourism (focus is mainly on sustainability and local economic impact), sustainable development (many studies have investigated how to achieve a balance between conservation and economic development), conservation and environmental protection.

The information obtained in this study provides a comprehensive overview of the scientific development around Biosphere Reserves, highlighting key trends, collaborative dynamics and emerging areas in research. The findings of this work can serve as a guide for researchers, managers and policy makers in their search for innovative strategies that foster sustainable management and resilience of these territories in the face of global challenges such as climate change and biodiversity loss. By identifying both advances and gaps in knowledge, this analysis contributes significantly to the global understanding of these protected areas as models for sustainability. Biosphere Reserves not only represent crucial spaces for biodiversity conservation and sustainable development, but also living laboratories that integrate science, policy and local communities, facilitating interdisciplinary approaches that effectively address the challenges of our time.

Future lines of research

There is still work to be done regarding the effects of climate change on biodiversity and ecosystem services, as well as on identifying what strategies are being implemented in reserves to deal with these changes. In terms of governance and community participation, it would be interesting to address how participatory governance mechanisms can be strengthened in BRs to ensure more equitable and sustainable management, and the role of local communities in decision-making and the implementation of conservation strategies. With regard to sustainable tourism and local development, an unanswered question is how to minimise the negative impacts of tourism on biodiversity and local communities, or in other words, how to promote sustainable tourism in BRs to benefit both conservation and local economic development.

It could be interesting to analyse how the connections between BRs and other protected natural areas are strengthened, in terms of research and environmental preservation. For example, Pérez et al. [49] pointed out the importance of global geo-parks in the conservation of the planet by having a geological heritage that has been recognised and used rationally to promote life in harmony with the earth; in the same sense, BRs have a relevant role due to the natural resources and ecosystems they have. In relation to research, it would be interesting to explore the benefits of greater collaboration between BRs and other protected areas, both nationally and internationally, to share better practices, environmental monitoring data and shared management strategies.

In summary, policies should be aligned with the principles of sustainable development, emphasizing the balance between conservation and economic growth. The identification of under-explored areas in BR research suggests that policies should encourage studies on the effects of climate change on biodiversity and ecosystem services. In addition, partnerships and collaborative networks should be fostered for knowledge sharing, education programs, and training of local communities for effective BR management.

Limitations

Although bibliometric analysis is a powerful tool for exploring scientific production and research patterns in a specific field, in this case in BRs, its limitations should also be mentioned. The first of these refers to coverage bias, since the analysis is based on data obtained from a single database, Scopus. Even though this is one of the main international bibliographic databases, it does not include all publications on the subject. A second limitation is temporal: recent publications, although indexed, may not have accumulated enough citations (the number of citations of an author or article can be highly dependent on the time elapsed since its publication), which affects the assessment of the impact of recent authors, articles or topics. Another limitation found in this study is the large number of results obtained from the search criteria, since it only allows for general analyses and leaves out more specific analyses. In future studies, these limitations could be mitigated by performing bibliometrics using two or more databases and using indicators to make comparisons between them, for example, overlap and uniqueness. With respect to the temporal limitation, it would be worthwhile to analyse trends over time to identify patterns of growth and evolution in BR research.

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