

Article

Groundwater and Tourism: Analysis of Research Topics and Trends

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Abstract: Recent years have seen an increase in the popularity of exploring the correlation between groundwater and tourism as a research topic. Although previous studies have touched on certain aspects of this relationship, none has yet plunged to the heart of the matter. This Bibliometric study examines the literature on the relationship between tourism and groundwater in the overall context of economic development. The bibliometric tools VOS Viewer version 1.6.19 and R Bibliometrix were employed to analyze 104 publications selected via the Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram. The results suggest a growing interest in the subject and the need for broader and collaborative research, to fully understand these dynamics. Major contributions come from Spanish, American, Chinese, and Mexican authors, focusing on sustainability, anthropogenic impact, physical characteristics, and groundwater quality. In conclusion, this study provides an overview of the current research landscape, identifies trends and gaps, and encourages international collaboration for a better understanding of groundwater issues in the tourism context. Although our work provides very important knowledge, it should be recognized that the analysis is made only based on the Scopus-indexed literature. This restriction highlights the necessity for future research to do a more comprehensive and integrated bibliometric analysis. The array of research sources will thus definitely enhance the joint academic knowledge on that subject and lead to more inclusive and, therefore, higher-quality academic discourse.

Keywords: groundwater; tourism; bibliometric study; VOS viewer and R Bibliometrix



Citation: Lamhour, O.; El Bouazzaoui, I.; Perkumienė, D.; Safaa, L.; Aleinikovas, M.; Škėma, M. Groundwater and Tourism: Analysis of Research Topics and Trends. *Sustainability* **2024**, *16*, 3723. <https://doi.org/10.3390/su16093723>

Academic Editors: Yun Pan, Yuyan Zhou, Yicheng Gong, Jina Yin and Ya Huang

Received: 25 February 2024

Revised: 8 April 2024

Accepted: 19 April 2024

Published: 29 April 2024



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1. Introduction

Frequently, the tourism industry relies on the use of resources that are free or inherent to the destination, such as weather and natural resources, as well as cultural and social heritage [1]. As an integral part of a region's natural and cultural landscape, water forms the initial core of the original tourism offer (beaches, waterfalls, lakes, snow, etc.), providing tourists with a wide choice of activities and attractions [2]. Alongside these resources, support services and new infrastructures are being developed, making water a crucial element of the derived offer as well (swimming pools, skating rinks, spas, etc.) [3]. Therefore, water's fundamental attribute lies in its essential contribution to both original and derived supplies, putting great pressure on the existing water resources, which are sometimes exposed to irreversible impacts, particularly when they are vulnerable to human activity, as is the case for groundwater [4,5].

Stored in the saturated zone of an aquifer [6], groundwater is a vital resource for ecosystems, agriculture, and human consumption [7]. They are also particularly attractive

to tourists because of their uniqueness [8]. Caves, underground rivers, hot springs, and artesian wells are all examples of groundwater-related places that attract the attention of nature lovers and tourists from all over the world.

As a vital natural resource, groundwater is often used to meet the needs of several economic and social sectors [8]. For the tourism industry, considered a booming economic activity, groundwater can be used to supply drinking water [9], golf course irrigation, swimming pool supply, and water-based recreational activities [10–12]. However, over-exploitation and mismanagement of this resource can have harmful consequences, such as lowering groundwater levels, saltwater intrusion, degradation of water quality, and disruption of local ecosystems [8,13–15].

Most of the major studies carried out by researchers to explore the relationship between tourism demand and natural resources, and more specifically groundwater, are case studies [15–19]. One of the aims of these studies is to propose solutions to the ongoing overexploitation of coastal aquifers by Mallorca's tourist industry and its impact on water quality [15], exploring the impact of tourism development on water demand and beach degradation in the same destination [20], assessment of the dangers of exploiting groundwater for tourism in the Egyptian city of Aswan [21], the development of specific optical property index mapping using remote sensing products on Mexico's Yucatán Peninsula, known for its marine wildlife tourism, to enable long-term monitoring and ecosystem-based management of phytoplankton blooms resulting from underwater groundwater discharges and having adverse effects on local tourist attractions, such as fish mortality and reduced water transparency [22], as well as examining the increased demand on limited water resources following the rapid growth of the tourism sector at Gigante Beach, Nicaragua [23].

While tourism is often closely linked to the use and management of water resources, and despite the water table's ecological importance and tourist appeal, The relationship between groundwater and tourism is a complex and under-researched area, with few studies addressing this issue. Review articles in this field are rare and do not take a holistic view of the impact of tourism on groundwater and vice versa.

To better understand the current state of research and identify emerging trends in this field, a bibliometric study of published articles on tourism and groundwater is essential. Bibliometric analysis provides a quantitative analysis of research articles on a specific topic using mathematical methods [16]. It can be used to determine the most important areas of research, to assess the quality of studies [17], and to identify the characteristics as well as the patterns of articles published in any scientific discipline [18]. In addition, this popular method provides insight into schools of thought in a specific field of study and allows the researcher to summarize scientific production in terms of quantity and quality [19].

The number of bibliometric analyses of groundwater-related research is limited [20–24]. In the examined bibliometrics studies, a range of methodological techniques was applied to explore the nuances of groundwater-related research. In the study by Zhou et al. (2020), a bibliometric analysis on karst groundwater pollution was conducted using CiteSpace software version 5.7.R2, shedding light on the increasing trend of research in this domain, with the identification and protection of karst aquifers and modeling of groundwater flow and pollutant migration as central themes. The use of water chemical analysis, tracer experiments, and numerical modeling emerged as predominant research methods [22]. Priyanka Lal et al. (2023) adopted a multidisciplinary bibliometric analysis using Dimensions.ai to investigate groundwater access and management, focusing on Sustainable Development Goal 6 which underscores the necessity of clean water access and sanitation [20]. In a study conducted by de Gricel et al. (2022), a bibliometric analysis underpinned by the Scopus and Web of Science databases scrutinizes groundwater's Life Cycle Assessment (LCA).

These methodological forays into the depths of groundwater study shed light on the multifaceted impacts of human activity and natural processes on this vital resource. Despite these advances, there remains a lacuna in the literature when it comes to a consolidated bibliometric review that bridges "tourism" and "groundwater". Our study embarks on

this uncharted journey, employing a bibliometric lens to dissect the evolution of research at this intersection. With this in mind, the main aim of this article is to review the current state of research in this specific field and to understand the trends, gaps, and advances in the scientific literature, while highlighting the main authors, the most cited sources, the most common research topics, and the current gaps in the scientific literature. By analyzing the trends and the themes addressed in articles on tourism and groundwater, we hope to contribute to a better understanding of this field and generate new research perspectives. To this end, this study aims to answer the following research questions:

- How have scientific production and global collaboration in this field of research fared?
- What are the relevant emerging sources that reflect trends in this subject?
- Which authors have made significant contributions in this field?
- What emerging keywords or sub-themes are most relevant to the study?
- What research directions can be recommended?

To answer these questions, a selection of 104 articles published between 1989 and 27 July 2023 was obtained from the Scopus database and analyzed using the Bibliometrix R Studio and VOS viewer tools.

2. Materials and Methods

The Scopus database was adopted as the data extraction platform for our bibliometric study. This recognized and inclusive database is one of the largest and most comprehensive scientific data platforms in terms of bibliographies, abstracts, and citations currently available [25]. Due to its comprehensive multidisciplinary scope, this invaluable resource serves as an indispensable asset for conducting bibliometric analyses across a diverse array of disciplines [26]. We also chose this database because of its wider coverage of tourism journals than the Web of Science [16,27]. To conduct this study, we followed the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to ensure objective and clear data filtering [28]. This method was published in 2009 to provide authors of systematic reviews with a transparent guide for reporting the objectives, methods, and results of their studies in a clear and consistent manner [16,28–30]. We conducted a search using the keywords “groundwater” and “tourism”, selecting only those documents that included these two terms in the title and keywords to ensure that we considered articles that were closely related to our topic.

Language (English) and document type (article, journal, and conference paper) were chosen as inclusion criteria, and the search period covered articles published up to the date of extraction from our database (27 July 2023). The justification for the English publication criterion is based on our decision to standardize the language of the keywords. Publications in English account for over 92% of online documents between 1989 and the date of data retrieval. In order to improve the quality of our dataset, a manual filtering process was undertaken. This involved carefully eliminating irrelevant or duplicate data points, ensuring that only the most relevant information was retained for analysis. The criterion for this manual filtering was relevant to the purpose of the study, which is to explore the relationship between groundwater and tourism. It is important to note that this filtering process was implemented by reading the abstract of each publication to eliminate potential biases or inaccuracies in the dataset and to improve the overall robustness of our results (Figure 1).

After sorting, the data were exported in Excel Common Separated Value (CSV) format and analyzed using two bibliometric tools, Bibliometrix R Studio and VOS viewer, to generate the results.

Bibliometrix R Studio is an R studio package, offering specialized parameters for bibliometric data analysis [31,32]. We used this tool to create graphical representations related to the number of publications per year, the most significant journals and publications, the most cited authors with their affiliated institutions and countries, as well as a thematic map. VOS viewer is a bibliometric tool developed by van Eck and Waltman [33]. It focuses on the graphical representation of bibliometric maps, using specific labeling algorithms,

zoom, or density metaphors to generate maps of authors, keywords, or countries based on co-occurrence data [34,35]. In our case, we used the VOS viewer to map the network of emerging themes related to the impact of tourism on groundwater.

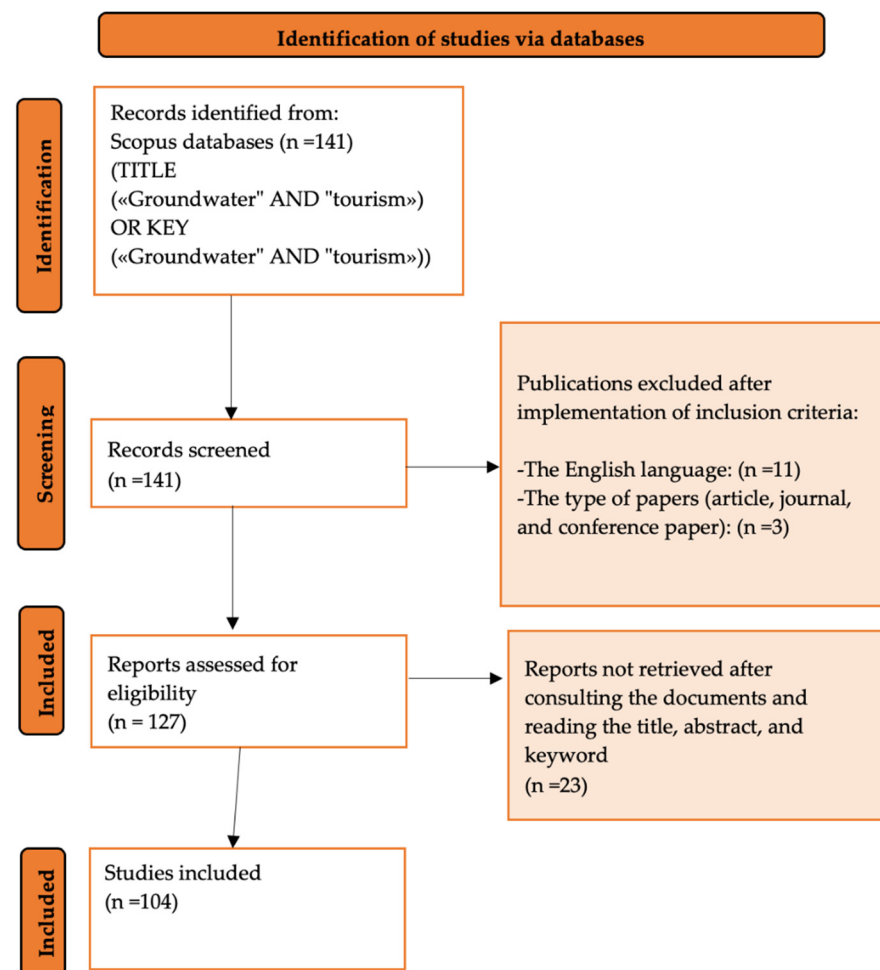


Figure 1. Filtering flowchart using the PRISMA method.

3. Results

3.1. Summary Information

Table 1 shows the main information relating to the 104 documents published between 1998 and 27 July 2023 in the Scopus database about tourism and ground water. These documents were published in 60 sources, mainly journals. “Author keywords” refers to the basic concepts identified by the authors, representing 356 keywords. In addition, “keywords plus” refers to the keywords frequently used in article titles, estimated at 1720 keywords.

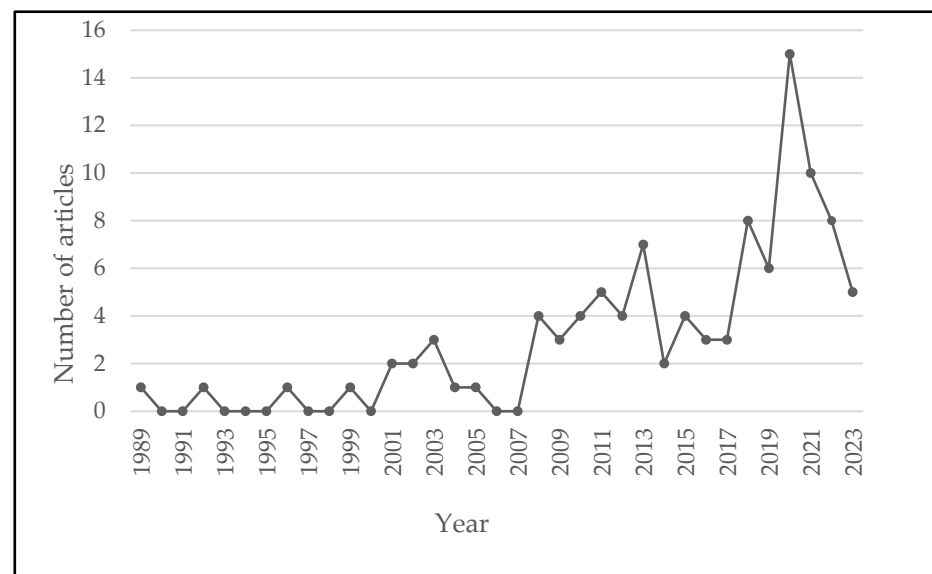
Among the selected papers, 12 were written and published by a single author, while the majority were written by an average of four authors (3.91). The “International co-authorships%” index, which measures the degree of international collaboration between authors in our research corpus, stands at 30.77%. This index specifically indicates the percentage of scientific publications involving authors of different nationalities in the fields of “Groundwater” and “Tourism”. This result suggests that while some publications involve researchers from different parts of the world, a notable proportion of articles were probably written in collaboration with authors belonging to the same nation or institution. Several factors may contribute to this observation.

Table 1. Introductory information of the database generated with the Bibliometrix R Studio tool.

Description	Results
Period	From 1989 to 27 July 2023
Sources	60
Documents	104
Annual Growth Rate %	4.85
Document Average Age	8.2
Average citations per doc	17.03
References	4319
Keywords Plus (ID)	1720
Author's Keywords (DE)	356
Authors	387
Authors of single-authored docs	11
Single-authored docs	12
Co-Authors per Doc	3.91
International co-authorships %	30.77

Articles account for 73% of published papers, while conference papers and reviews represent only 26% and 1%, respectively. The number of literature review articles on the relationship between groundwater and tourism is insufficient, and they do not provide a holistic view of this area of research.

Over the last 14 years, there has been a general upward trend in the number of publications, with an annual growth rate of 4.85%. Figure 2 shows the annual distribution of the 104 publications included in this study.

**Figure 2.** Annual scientific production.

From the data in Figure 3, it was found that the Environmental Sciences field had the highest number of publications dealing with the relationship between groundwater and tourism, with 43.4%. The Earth and Planetary Sciences field came in second with 17%.

Research on the intersection between tourism and groundwater research extends beyond the specific field of hydrology to encompass diverse disciplines such as environmental science, economics, and sociology. In the field of environmental science, the relationship between tourism and groundwater is crucial, as tourism activities can have a significant impact on groundwater quality and aquatic ecosystems. Environmental considerations, such as sustainable water resource management, are essential to preserving ecosystems and ensuring the sustainability of tourism. From an economic perspective, the research

explores how tourism activities influence water resource management, the costs associated with water use, and how these factors can in turn shape local economic policies. In sociology, the impact of tourism on local communities and their relationship with water resources is an important dimension. Interactions between tourists and locals, social changes linked to tourism, and issues of equity in access to water are key aspects that require in-depth exploration.

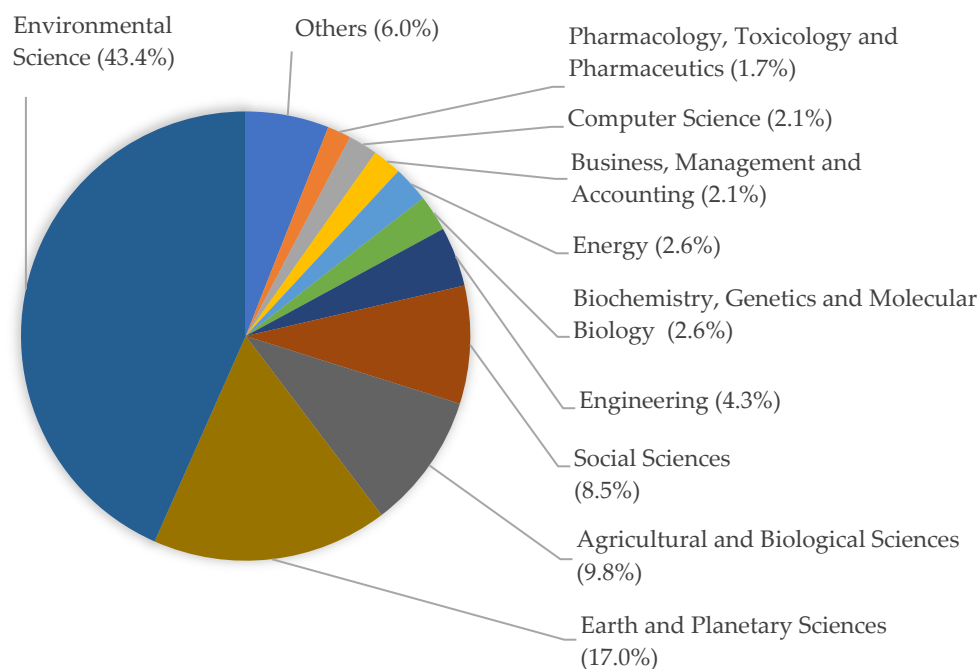


Figure 3. Disciplinary anchoring generated by Scopus.

3.2. Analysis of Contributing Journals, Authors and Countries

The growth of groundwater and tourism research is presented in 60 scientific journals. *Science Of The Total Environment* occupied first place with the highest number of publications ($n = 15$), published by Elsevier with a research focus on the in-depth study of the environmental and socio-economic impacts of water resource use, particularly in areas affected by tourism and agriculture, followed by *Iop Conference Series: Earth And Environmental Science* ($n = 8$), published by Iop Publishing. The papers published in this journal reflect an interest in interdisciplinary studies on the interactions between tourism development and environmental management, particularly water resource management in karst regions, urban watersheds and mountain areas. Third place goes to *Environmental Earth Sciences*, published by Springer ($n = 5$). Articles published in “*Environmental Earth Sciences*” highlight the challenges of managing groundwater resources in the face of rapid urbanization, tourism development, and agricultural and industrial activity.

Fourth place is shared between *Water (MDPI)*, *Environmental Monitoring And Assessment (Springer)*, and *Water Science and Technology (Editions IWA)* with four articles each (Table 2). The analysis of research on the intersection of groundwater and tourism reveals a landscape characterized by regional research hubs, notably led by Spain, with significant contributions from China, Mexico, and the USA, reflecting not only a strong academic interest but also regional environmental challenges that necessitate this focus (Table 3). Collaborative efforts, particularly between the USA and Mexico, as well as the USA and China, signify active partnerships, possibly driven by shared ecological and tourism-related concerns, while collaboration between Spain and Portugal may be bolstered by cultural and linguistic. Despite these partnerships, the overall network of researchers indicates a need for more extensive international cooperation, suggesting that the full potential of global collaborative insights into sustainable water management and tourism practices has yet to

be fully realized (Figure 4). Figure 4 depicts international collaboration on groundwater and tourism research based on bibliometric data. The countries in blue represent those that have contributed to the research field, with the intensity of the color indicating the volume of contributions. The red lines signify collaborative research efforts between countries, with the thickness of the line correlating to the number of co-authored studies.

Table 2. Journals with the highest number (N.) of documents in the field of study provided by Bibliometric.

Journals	Articles
Science Of The Total Environment	15
Iop Conference Series: Earth And Environmental Science	8
Environmental Earth Sciences	5
Environmental Monitoring And Assessment	4
Water (Switzerland)	4
Water Science And Technology	4
12th International Multidisciplinary Scientific Geoconference And Expo—Modern Management Of Mine Producing, Geology And	2
Environmental Protection, Sgem 2012	2
Bulletin Of Environmental Contamination And Toxicology	2
Environmental Geology	2
Environmental Pollution	2

Table 3. The most contributing countries on the theme of groundwater and tourism.

Countries	Articles
SPAIN	12
CHINA	9
MEXICO	6
USA	6
GREECE	3
INDIA	3
BRAZIL	2
FRANCE	2
GERMANY	2
INDONESIA	2

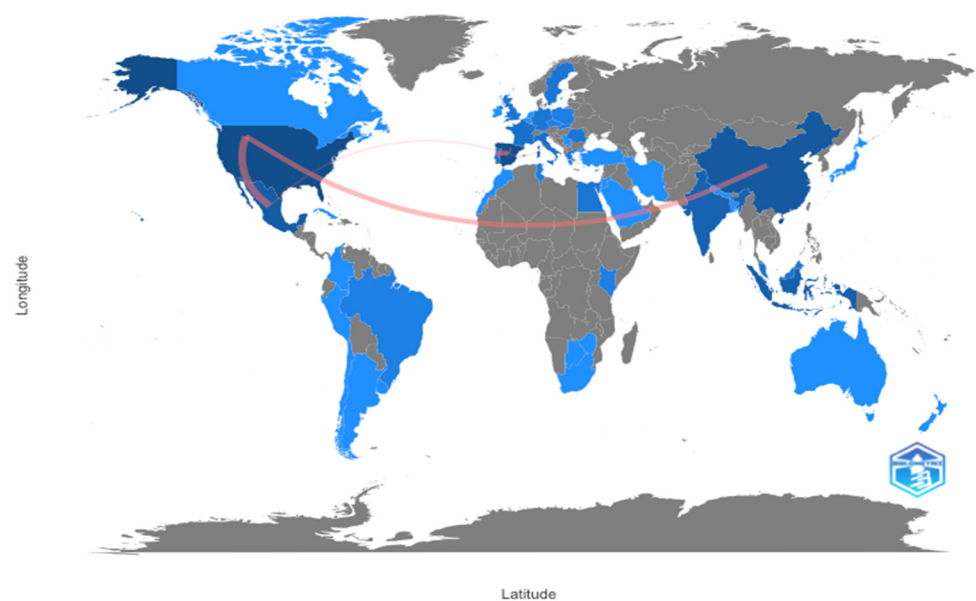


Figure 4. Geographic map of international cooperation generated by Bibliometrix R Studio.

This disparity in global research efforts could potentially influence the direction and applicability of policy-making, as insights from predominant research contributors shape global strategies. The current research network offers opportunities for broadening collaborative frameworks, incorporating underrepresented regions, and integrating diverse disciplinary perspectives to develop more comprehensive and universally relevant environmental solutions within the nexus of groundwater management and tourism development. The Bibliometrix or Biblioshiny program offers researchers the possibility of extracting a three-field graph of their choice from a Scopus database. For our study, we preferred to analyze the relationship between authors, countries, and keywords to obtain a clear view of the scientific community working on this subject [36].

As illustrated in Figure 5, there is an interaction between authors (left), countries (right), and keywords (middle) in the analysis of the relationship between groundwater and tourism.

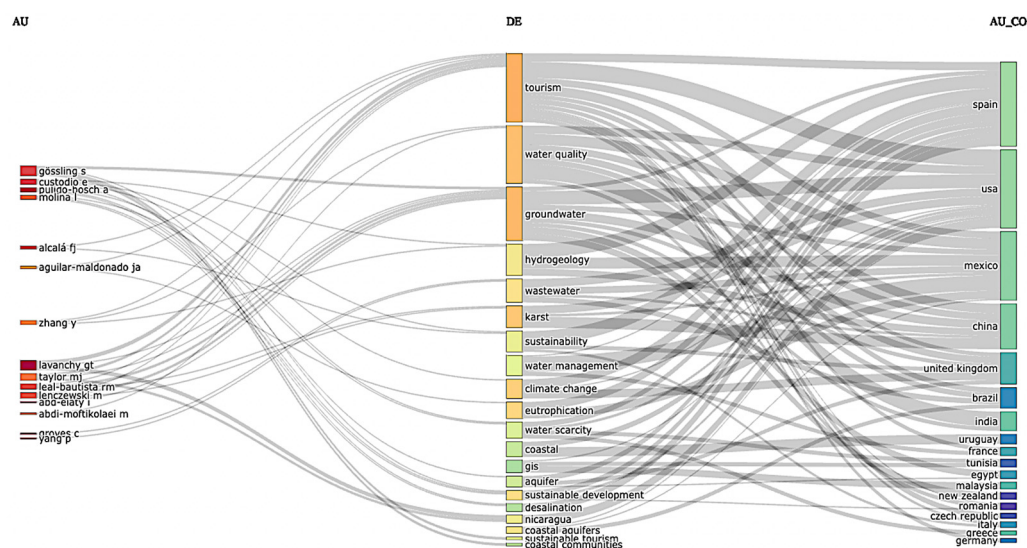


Figure 5. A three-field plot or Sankey diagram generated by Bibliometrix R Studio.

The research landscape highlights different orientations within different national communities regarding the complex relationship between groundwater and tourism. For example, Spanish researchers focus mainly on the use of hydrological models to study the sustainable management of groundwater resources in arid regions. Their work highlights the significant anthropogenic impact of tourism, in particular its effect on water consumption and the overall groundwater balance. In addition, they propose practical, low-tech solutions to mitigate the degradation of groundwater quality.

In contrast, the American research community is focusing more on the dynamic processes affecting water quality within karst flow systems influenced by tourism activities. Their focus underlines the crucial importance of understanding how tourism-related factors influence complex karst landscapes, in particular the delicate balance of groundwater systems.

Chinese researchers, meanwhile, are focusing on a range of issues related to groundwater in tourist destinations. These include the investigation of physical characteristics, quantity assessment, and careful analysis of groundwater quality. Their multi-dimensional approach aims to provide a comprehensive understanding of groundwater dynamics within these crucial tourist areas.

In parallel, the Mexican research community is directing its efforts toward understanding the complex dynamics of water quality within karst systems. Their particular focus lies in the study of nitrate migration and transformation, recognizing the potential environmental consequences of groundwater contamination in karst landscapes.

3.3. Analysis of the Most Cited Publications

Table 4 shows the ten most influential articles on the relationship between groundwater and tourism, ranked by total number of citations, indicating their significant impact within the scientific community.

Table 4. Top 10 scientific papers in the field.

Publication (Type of Publication)	Title of the Journal	Year of Publication	Citations	Citations per Year	Total Normalized Citations	Reference
The consequences of tourism for sustainable water use on a tropical island: Zanzibar, Tanzania (article)	Journal of Environmental Management	2001	184	8	1.56	[36]
Major Ion Chemistry and Quality Assessment of Groundwater in and Around a Mountainous Tourist Town of China (article)	Exposure and Health	2016	126	15.75	1.75	[37]
Contaminants in the coastal karst aquifer system along the Caribbean coast of the Yucatan Peninsula, Mexico (article)	Environmental Pollution	2011	124	9.54	3.02	[38]
Tourism and sustainable water supply in Mallorca: a geographical analysis (article)	Applied Geography	2002	114	5.18	1.85	[39]
Impacts of tourism development on water demand and beach degradation on the island of Mallorca (Spain) (article)	Geografiska Annaler: Série A, Géographie physique	2003	111	5.29	2.50	[40]
Groundwater vulnerability assessment in the Melaka State of Malaysia using DRASTIC and GIS techniques (article)	Environmental Earth Sciences	2013	102	9.27	3.32	[41]
Groundwater intensive use and mining in south-eastern peninsular Spain: Hydrogeological, economic and social aspects (article)	Science of the Total Environment	2016	77	9.63	1.07	[42]
Hydrogeochemistry and geochemical simulations to assess water–rock interactions in complex carbonate aquifers: The case of Agüedulce (SE Spain) (article)	Current Issues in Tourism	2013	57	5.18	1.86	[43]
Kenya (article)	Marine Pollution Bulletin	2001	52	2.26	0.44	[44]
Groundwater quality of porous aquifers in Greece: a synoptic review (conference paper)	Géologie environnementale	2008	48	3.00	3.56	[45]

The first study, cited 184 times, explores the dire consequences of unchecked tourism on Zanzibar’s water resources, employing hydrogeological assessments and surveys to grasp the full extent of water use within the tourism sector. The second, with 126 citations, conducts a detailed hydrochemical investigation into the water quality surrounding a mountainous tourist town in China, using major ion analysis to determine the water’s suitability for various uses. The third article, cited 124 times, delves into the contamination of the Yucatan Peninsula’s karst aquifer system, applying passive samplers in cave systems to identify pollutants from tourism. The article titled “Groundwater quality in porous aquifers in Greece: a synoptic review”, which had received the fewest total citations ($n = 48$) among the top ten in this selection, sets out to synthesize the hydrochemical state of porous aquifers across Greece. The methodology involves a comprehensive chemical analysis of water samples collected from various Greek aquifers, with the study aiming to diagnose issues of salinization and nitrate pollution. The objective is to offer a broad overview of groundwater quality, assess the impact of factors like agricultural fertilization and septic

tank leakage, and provide data-driven insights for better aquifer management. Each study's objective is closely tied to its methodology, offering nuanced insights into the sustainability of groundwater in tourism-intensive regions.

3.4. Analysis of Keyword Occurrences

The main objective of a bibliometric study is to examine research themes and trends in a specific field in order to identify the most common terms and the relationships that link them together, based on the analysis of keyword occurrences [37–46]. The aim of this analysis is to identify the links between the ideas present in the themes covered in the text corpus. This approach has enabled the creation of a strategic diagram highlighting the relative relevance of topics related to the relationship between tourism and groundwater [47–59]. VOS viewer is the software used to map the network of the most frequent keywords in our selection of articles [60–72].

A selection of 108 keywords with a frequency of ≥ 5 co-occurrences was selected from 1868 keywords.

Figure 6 shows a network representation of these keywords. The most frequent terms are represented by circles, whose size varies according to their frequency of occurrence. Links indicate associations between words, and nodes of the same color form groups of keywords. The thickness of the links reflects the strength of the associations; the greater the thickness, the greater the strength of the association between words and their frequency of appearance in the same publication. The distance between the two nodes is a negative function of the number of occurrences between the keywords.

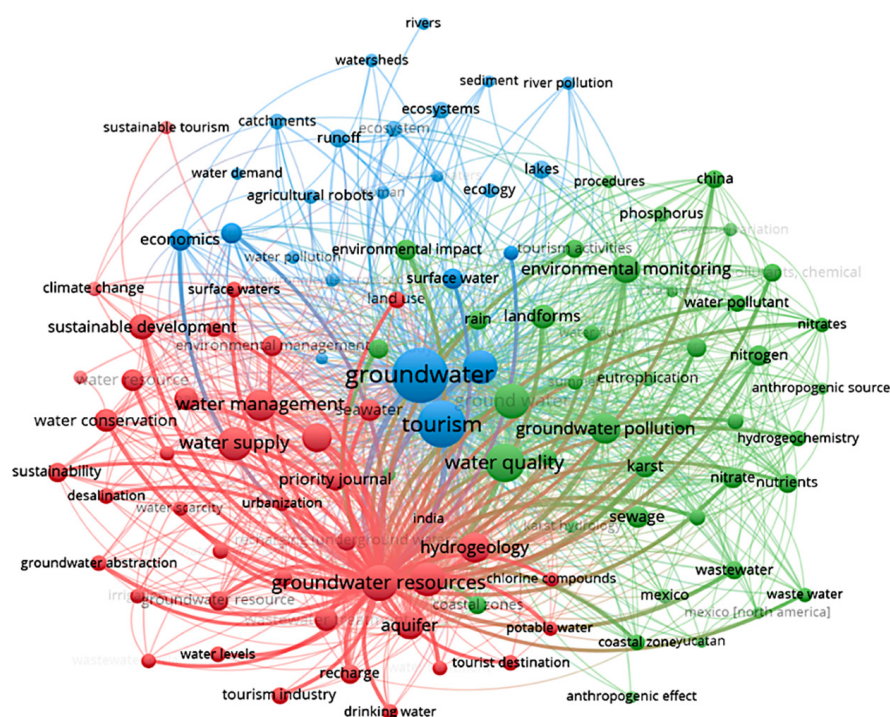


Figure 6. Network analysis illustrating the co-occurrence of keyword on relation between groundwater and tourism generated by the VOS viewer software.

Our keyword network comprises three clusters with 3446 links and 8583 in terms of link strength, namely cluster 1 (42 keywords), cluster 2 (42 keywords), and cluster 3 (24 keywords). Analysis of this network enabled us to define three hot topics in research on the relationship between tourism and groundwater (Table 5). After reading the articles and getting an idea of the purpose of each document, we classified each article into its corresponding theme and cluster.

Table 5. Themes around the senses in the dataset.

Cluster	Theme	Articles Included
Cluster 1: Red	Sustainability and management of groundwater resources in tourist destinations	[39,48–66]
Cluster 2: Green	Groundwater resources in tourist destinations	[7,37,41–45,67–96]
Cluster 3: Blue	Assessing the environmental impact of tourism activities on groundwater	[8,36,38,40,65,97–135]

Cluster 1, in red, includes keywords such as “groundwater resources”, “water management”, “water supply”, “sustainability”, “sustainable development” and “aquifer”. Consequently, this cluster concerns the sustainability and efficient management of water resources to minimize the adverse effects of tourism on groundwater. The keywords “water quality”, “groundwater pollution”, landforms”, and “environmental monitoring” are the dominant ones in cluster 2. This cluster therefore focuses on groundwater resources in tourist destinations. This research theme encompasses the physical characteristics, quantity, and quality of groundwater in a tourist destination. Cluster 3 in blue is the smallest group in the network in terms of number of keywords but the largest in terms of number of articles. The word “groundwater”, with the highest number of occurrences, is linked to other keywords such as “tourism”, “water demand” and “water pollution”. This group of words represents the theme of the specific environmental impacts of tourism on groundwater, such as chemical pollution, wastewater from tourism activities, plastic waste, and overexploitation of groundwater resources.

4. Discussion

Tourism is one of the world’s most important and fastest-growing economic sectors [73–82]. It is a major driver of economic and social development [83–95], and plays a crucial role in job creation, income generation and the promotion of cultural heritage [99]. However, like many human activities, tourism relies on an essential and often underestimated resource: groundwater [96–122]. The use of groundwater in tourism goes far beyond basic needs such as hygiene and food consumption. It is vital for a variety of leisure, water sports, landscaping, and wellness activities in tourist destinations [123–148].

However, in the last few years, the complex relationship between tourism and groundwater has become an increasingly important topic, mainly due to the growing impact of climate change and the increasing scarcity of water resources, particularly in arid and semi-arid regions [115]. The increasing trend in publications from 1989 to 2023 in the field of tourism and groundwater research highlights a growing interest in the impact of tourism on water resources. The noticeable acceleration from 2011 onwards may suggest a growing awareness of the vulnerability of aquatic ecosystems to the pressures of tourism development and climate change, the latter becoming a matter of global concern. The peak observed in 2013 may correspond to increased recognition of the need for innovative management methodologies, while the exceptional peak in 2021 coincides with the COVID-19 pandemic, which not only revealed the fragility of tourism infrastructures but also prompted the scientific community to look into the resilience and sustainable management of water resources in circumstances of global crisis. The COVID-19 pandemic has had a significant impact on tourism, with the focus shifting to coastal and marine destinations [143]. This has led to a reduction in water consumption in the tourism sector, making it possible to assess and manage water resources [115]. However, the pandemic has also highlighted the vulnerability of some regions to water crises, which can be exacerbated by urbanization and industrial reconfiguration [149]. The upheaval caused by the pandemic has served as a wake-up call [150–152], prompting a reassessment of the principles of resilience and sustainability that underpin the tourism sector’s use of natural resources [147,148,153]. This period of global upheaval therefore appears to be a critical inflection point, offering valuable insights into the need for a strategic shift towards more resilient and sustainable practices, capable of withstanding the unpredictability of global crises [144,154,155]. Despite the crucial importance of the relationship between groundwa-

ter and tourism, the subject has historically received limited attention in scientific research, as evidenced by the relatively low number of publications. Our study, which analyzed the data available in SCOPUS, found only 104 relevant publications on the subject. This finding highlights an area of research which, although essential for the long-term sustainability of tourism and the preservation of natural resources, is perhaps under-represented in the scientific literature. This suggests a significant opportunity for future academic research and discussion to fill knowledge gaps in understanding tourism–groundwater interactions.

This study highlights a predominant trend towards specific case studies, often focused on a single tourist destination, highlighting a major gap in the literature: a lack of large-scale comparative or synthesis studies. This focus on isolated contexts can hamper the ability to generalize results and apply groundwater management solutions to a variety of geographical and tourism situations. It is imperative to encourage more holistic research that addresses groundwater issues in tourism across a broader spectrum of conditions and practices, to broaden our understanding and strengthen the resilience of tourism destinations in the face of global environmental challenges. The 43% proportion of Open Access articles in our selection may reflect research funding policies that encourage or require open dissemination to improve the visibility and impact of discoveries. It may also reflect a growing commitment to open and collaborative science, essential in dynamic and interdependent fields such as the environment, where rapid and universal access to knowledge is crucial for innovation and global action. In our analysis, it appears that co-authorship networks and international partnerships are fragmented and lack cohesion, with researchers and countries often preferring to operate independently, revealing a preference for individual research projects rather than large-scale collaborative initiatives. However, there are exceptions where a small number of researchers have established cooperative ventures, involving two to eight colleagues, to make joint progress in exploring the dynamics between tourism and groundwater management, hence the need for greater collaboration between authors and countries in this field. International research collaboration is crucial for advancing knowledge and solving global problems [149]. It offers opportunities for networking, learning, and problem-solving, and can lead to greater impact and applicability of research findings [150,151,156,157]. The journal “Science of The Total Environment” stands out as the leading contributor in the field of research on the relationship between tourism and groundwater, thanks to its interdisciplinary approach and international reach. It provides an essential platform for environmental studies, attracting cutting-edge research that sheds light on the significant impact of tourism on the world’s aquatic ecosystems. Southwest University, Universidad Nacional Autónoma De México And Kapodistrian University Of Athens stand out in groundwater and tourism research, reflecting their strategic positioning in regions where tourism and water resources are intimately linked. Their significant presence in scientific publications testifies to their leading role in the advancement of knowledge and the development of sustainable water management practices in tourist destinations.

5. Research Topics with the Highest Acuity Research

As the relationship between tourism and groundwater is complex and multifaceted [152–154], our principal aim is to discern and map the prevailing scholarly dialogues that shape our understanding of this dynamic interplay. Through a meticulous bibliometric analysis, we have pinpointed key research themes that are central to conceptualizing the sustainable interplay between tourism and groundwater resources. The outcomes of our study delineate three principal themes that have garnered considerable academic attention. In subsequent sections, we will dissect these themes meticulously, offering a comprehensive analysis of the underpinnings of each theme as illustrated in Figure 7, thereby elucidating the broader implications they hold for environmental policy and management practices within tourism-centric locales. Figure 7 clearly illustrates the distribution of research themes in the study of groundwater and tourism. The largest segment, accounting for 45% of the literature, concerns the assessment of the environmental impact of tourism activities on

groundwater. This indicates that academics are trying to understand how tourism activities influence the quality and availability of groundwater. The next theme, accounting for 36%, is groundwater resources in tourist destinations, indicating a significant interest in the characterisation and management of groundwater resources in tourist areas. The theme of sustainability and management of groundwater resources in tourist destinations is much less important (19%). This highlights an essential, but less explored, area of research that links the principles of sustainability with the practical management of groundwater. The disparity in thematic distribution highlights the need for a more balanced research approach that not only assesses impacts but also develops sustainable management strategies to safeguard groundwater resources in tourism-dependent regions.

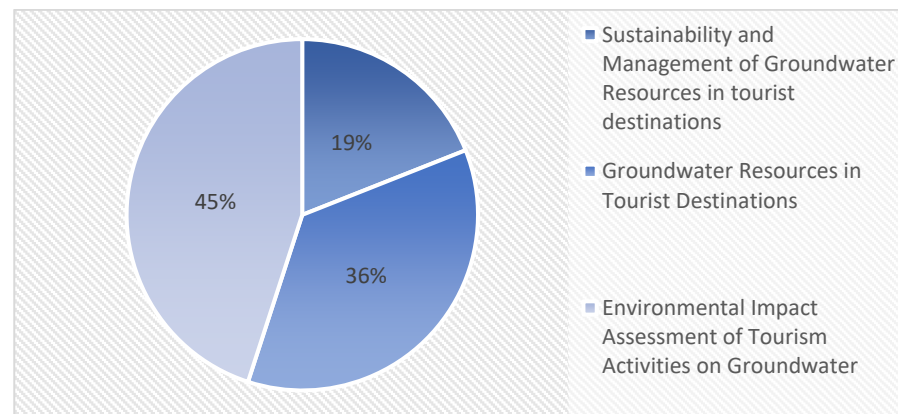


Figure 7. Distribution of the most emerging themes in research into the interaction between tourism and groundwater.

5.1. Sustainability and Management of Groundwater Resources in Tourist Destinations

The sustainability of groundwater supplies in tourist resorts has become an issue of growing concern and importance in the fields of applied geography and environmental management [39,66]. Researchers in applied geography and environmental management are increasingly interested in studying sustainability issues related to groundwater in tourist destinations. They have analyzed in detail the problems of water supply in these areas, taking into account the increasing demand for water due to tourist activity, the potential risks associated with overexploitation of aquifers, and the pressures exerted by climate change on water availability. They also studied the solutions implemented to solve these problems, such as the use of sustainable water management technologies, the implementation of conservation policies, and the commitment of stakeholders to the responsible use of groundwater resources. Alcalá et al. present a hydrological-economic model to ensure the sustainable use of groundwater in arid zones, focusing on the Amtoudi Oasis, an attractive region for rural tourism in southern Morocco, showing indications of groundwater degradation. The model analyzes the impact of tourism on reducing emigration and the introduction of new social habits linked to water consumption. Low-tech actions are proposed to mitigate groundwater degradation, including wastewater treatment for irrigation and rainwater harvesting [53]. Kent et al. examine the growing problems of water supply sustainability in tourist resorts on the island of Mallorca, highlighting the relationship between tourism and water, and proposing measures to address this issue in the context of the climate change and overexploitation of coastal aquifers [39,133]. Pulido-Bosch et al. examined groundwater sustainable strategies in the Sierra de Gador-Campo de Dalias system in southeastern Spain, taking into account the challenges imposed by climate variability, increasing rainfall scarcity, and growing demand for water resources from agriculture and tourism [66].

By exploring methods for sustainable groundwater management in tourist areas, new research perspectives are opening up. This will enable the creation of sustainable, life-

supporting local environments throughout the world while taking into account different local contexts involving different stakeholders.

5.2. Groundwater Resources in Tourist Destinations

The development of a tourist destination depends mainly on the availability of groundwater resources, as well as the “health” of these resources, largely related to their physical characteristics, quantity, and quality [7,156,157]. In order to guarantee a sustainable destination without the risk of growing short of water, it is important to implement strategic solutions with low environmental impact, including conservation, recycling, and their reuse. This may help prevent groundwater depletion by limiting its consumption and preserve its quality, particularly in areas with high vulnerability to pollutants from tourism, agricultural, and industrial activities.

Researchers in this field have focused on analyzing the physico-chemical characteristics of groundwater, which they have compared with national and international standards for different uses, including domestic, agricultural, and tourism. Chang et al. investigated the fate of nitrates in the karst aquifers of a rural basin in Southwest China. This was done using hydrochemistry and double nitrate isotopes to understand decadal changes in contamination, as well as the effects of improved rural tourism activities and land use changes on groundwater pollution [68]. Daniele et al. have used classical geochemical tools and simulations combined with GIS software to delineate, identify, and locate the physicochemical processes acting at groundwater level in the Aguadulce hydrogeological unit (Campo de Dalas Aquifers, SE Spain). This was done to better understand groundwater quantity and quality problems induced by increasing demand from intensive agriculture and tourism [43,53,157]. Peiyue et al. assessed the quality of groundwater used for domestic and agricultural purposes in a mountainous tourist town in China, analyzing concentrations of major ions as well as physicochemical parameters, and discussing the sources of major ions through correlation analyses and bivariate plots [37,147]. Shirazi et al. interpreted groundwater vulnerability in Melaka State, Peninsular Malaysia, using the DRASTIC model combined with remote sensing and geographic information systems (GIS) to map areas of high, moderate, and low vulnerability, based on seven parameters: depth to water level, net recharge, aquifer environments, soil environments, topography, vadose zone impact and hydraulic conductivity [41,42,125]. Assessing the physicochemical characteristics of groundwater has been a fertile research topic for several decades, providing insights into the quality of groundwater resources, including in tourist areas with high vulnerability to anthropogenic pollution.

5.3. Assessing the Environmental Impact of Tourism Activities on Groundwater

Like any other industry, tourism has a significant impact on many aspects of the environment, mainly water resources, air, soil, biodiversity, etc. [15,40,155]. In particular, environmentally sensitive areas, such as coastal zones and islands, are adversely affected by the massive influx of tourists [130,154,155]. Researchers have focused on several aspects of this impact, including the overexploitation of water resources, the contamination of groundwater by tourist activities, and changes in the hydrological balance of coastal ecosystems due to the large influx of visitors. For example, Metcalfe et al. assessed contaminant concentrations in groundwater resources in the “Riviera Maya” region of Mexico’s Yucatan Peninsula, affected by intensive land development resulting from the rapid growth of the tourism industry. Metcalfe et al. also identified potential sources of contamination, including domestic sewage, runoff from highways and other impervious surfaces, as well as pesticide applications on golf courses. This may help to put in place prevention and mitigation measures to protect Caribbean coastal ecosystems and human health, and thus preserve the region’s tourism-based economy [38]. Gössling also examined the unsustainable use of freshwater resources on the Zanzibar coast due to the rapid growth of tourism, which is endangering the ecosystem and local living conditions.

5.4. Model Framework That Connects the Themes That Can Be Tested in Further Research

Based on the keyword analysis, we present a conceptual model re-grouping the three themes: “Sustainability and management of groundwater resources in tourism destinations», “Groundwater resources in tourism destinations”, and “Assessment of the environmental impact of tourism activities on groundwater”. This proposed conceptual framework highlights the interconnections between three critical themes related to the sustainable management of groundwater resources in tourism destinations. These three themes are closely linked and play a crucial role in the preservation and responsible management of groundwater resources in the context of tourism (Figure 8).



Figure 8. A model framework that connects the themes that can be tested in further research.

To articulate a conceptual framework addressing the complex relationship between tourism and groundwater sustainability, we consider a model that encapsulates the interdependence and collective impact of sustainable management, resource characterisation and environmental assessment. This framework recognises the dynamic balance required between the water demands of tourism and the intrinsic regenerative capacities of aquifers. It promotes adaptable management strategies that integrate technological innovation, conservation initiatives and anticipatory governance to reduce the risks of overexploitation. In addition, it calls for comprehensive and predictive assessments of the environmental footprint of tourism on groundwater systems, highlighting the need for adaptive measures that reflect both current and anticipated impacts of climate change. By integrating these elements into a coherent narrative, the proposed model highlights the need for a multi-faceted approach that embraces ecological stewardship, economic pragmatism and community engagement, laying the foundations for transformative research and policy development that will safeguard and sustain groundwater resources in the evolving tourism landscape.

6. Conclusions, Limitations, and Perspectives for Further Research

This article aims to provide a bibliometric analysis of 104 articles belonging to the Scopus database. It addresses the relationship between tourism and groundwater by using the two bibliometric tools: Bibliometrix R Studio and VOS viewer. Analysis of the publications reveals that the majority of articles are based on case studies, reflecting the researchers’ desire to focus on in-depth analyses of specific situations associated with the interaction between tourism and groundwater. The multidisciplinary nature of this field, encompassing geological, ecological, and tourism-related aspects, adds complexity to the conduct of comprehensive literature reviews. Scholars may lean towards empirical

studies, emphasizing tangible outcomes for immediate problem-solving, contributing to the observed scarcity of literature review articles. Moreover, the challenges inherent in conducting exhaustive analyses in this domain are notable, ranging from the diversity of research methodologies to the absence of standardized norms. This diversity might contribute to the preference for empirical studies, where the application of specific methodologies is often more straightforward. Additionally, the relative novelty of the field might explain the limited presence of literature reviews, as researchers may initially prioritize establishing empirical foundations before engaging in more abstract synthesis endeavors. Recognizing these factors, we aim to explore them in-depth in the subsequent section to offer a comprehensive understanding of the dynamics influencing the research landscape in tourism and groundwater interaction.

Geographically, Spain stands out as the main contributor to tourism-related groundwater research, followed by China, Mexico, and the USA. Despite some international collaboration, there is still some untapped potential for strengthening the cooperation between active researchers in this field.

To foster international collaboration in this field, the research community can consider several strategies. Firstly, initiatives that promote linguistic inclusion, such as translation services or standardized communication protocols, can facilitate smoother collaboration. Establishing international funding mechanisms and encouraging joint research proposals could help overcome financial constraints. In addition, fostering a culture of knowledge exchange through conferences, workshops and collaborative platforms can encourage researchers to share their views and overcome differences in research priorities and methodologies.

The conceptual framework highlights the interconnections between the themes of sustainability and management of groundwater resources in tourism destinations, and the assessment of the environmental impact of tourism activities on groundwater. It provides a basis for future research by emphasizing the importance of responsible management of groundwater resources in the context of tourism development. The results of environmental assessments can be used to support the development of policies and mitigation measures aimed at preserving groundwater and ensuring its long-term availability for the needs of tourism and local environments. The framework also encourages collaboration between stakeholders, including local authorities, tourism businesses, and researchers, to foster a holistic approach to sustainable groundwater management in tourism destinations. Taking these interconnections into account is crucial to ensure a sustainable and prosperous future for tourism destinations while preserving groundwater resources for future generations.

This bibliometric study serves as a pivotal contribution to the scientific literature, providing a comprehensive analysis of current trends, identifying gaps, and presenting challenges. Beyond serving as an informative resource, its primary significance lies in its substantial contribution to the existing body of knowledge. By critically engaging with and synthesizing existing literature, our study seeks to add depth and nuance to the discourse surrounding the impact of tourism on groundwater. Rather than merely identifying key research areas and active researchers, our objective is to enrich the current understanding, placing our findings within the broader context of ongoing scientific conversations. This emphasis on contribution extends beyond theoretical insights; it has practical implications for water management in the tourism sector. The integration of cutting-edge scientific knowledge into water management practices within the tourism sector is imperative for fostering sustainable policies and effective mitigation measures. This strategic integration not only contributes to the ongoing discourse on water resource management but also actively informs the development of targeted policies. By leveraging scientific insights, we aim to delineate actionable strategies that mitigate the environmental impact of tourism on water resources. This approach serves as a robust foundation for maintaining the sustainability of water resources while concurrently promoting responsible and environmentally friendly tourism practices. Our goal is to translate scientific findings into practical solutions, ensuring a harmonious balance between the burgeoning tourism industry and the preservation

of vital natural resources Our study is limited by the choice of a single database. Therefore, it is recommended that future research combine several databases, including Scopus, Web of Science, Google Scholar, and PubMed, to ensure more in-depth results.

In conclusion, this work presents a comprehensive review of research on the nexus between tourism and groundwater, which could be a relevant source for future research.

Author Contributions: Conceptualization, O.L., L.S. and I.E.B.; methodology, O.L., D.P., M.Š. and M.A.; software, O.L.; validation, M.Š., M.A., L.S. and D.P.; formal analysis, O.L. and L.S.; investigation, D.P., I.E.B., M.Š. and M.A.; resources, M.Š. and M.A.; data curation, O.L., D.P., M.Š. and M.A.; writing—original draft preparation, O.L., M.Š., M.A. and L.S.; writing—review and editing, L.S. and I.E.B.; visualization, O.L. and I.E.B.; supervision, L.S.; project administration, D.P.; funding acquisition, M.Š., M.A. and D.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

Conflicts of Interest: The authors declare no conflicts of interest.

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