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# Scientific Mapping on the Impact of Climate Change on Cultural and Natural Heritage: A Systematic Scientometric Analysis

**Claudia Patricia Maldonado-Erazo** [1] **, José Álvarez-García** [2] **, María de la Cruz del Río-Rama** [3,*] **and Amador Durán-Sánchez** [2]

1 Facultad de Recursos Naturales, Escuela de Ecoturismo de la Superior Politécnica de Chimborazo—ESPOCH, Riobamba 060155, Ecuador; claudia.maldonado@espoch.edu.ec
2 Financial Economy and Accounting Department, Faculty of Business, Finance and Tourism, University of Extremadura, 10071 Cáceres, Spain; pepealvarez@unex.es (J.Á.-G.); amduransan@unex.es (A.D.-S.)
3 Business Management and Marketing Department, Faculty of Business Sciences and Tourism, University of Vigo, 32004 Ourense, Spain
* Correspondence: delrio@uvigo.es

**Abstract:** The world's cultural and natural heritage has been gradually affected by climate change, and although the research agendas of many countries have included this reality since 2003, there is still an incipient approach to it, with analysis techniques used being limited. In addition, there are very few case studies that describe in detail the adaptation processes of spaces to these new conditions. The aim of this research is to identify the scientific production related to the impact of climate change on cultural and natural heritage indexed in the international databases Scopus and Web of Science (WoS), which will enable to establish maturity of the research on this subject. The methodology used for the analysis of the data obtained is bibliometric analysis; evaluative and relational measures are applied to a set of 78 articles (45 in Scopus and 33 in WoS) and to a joint base of 47 articles after deleting those articles that overlap in both databases. The result is a scientific mapping that enables observing of the evolution of knowledge generation in this field of study. The main findings show that research is incipient, with a large presence of transient authors with a single publication, the research is limited to the geographical scope of Europe and North America, neglecting many other areas, the impact which is measured by the citation of articles is very low, the relational measures corroborate that the thematic approach is new by identifying a high presence of isolated relationships among authors. The results obtained will be very useful for researchers working in this scientific area, as they can find a synthesis of scientific production in this document, allowing them to draw their own conclusions regarding the current gaps in research; constituting the starting point of their research, with the aim of filling these gaps.

**Keywords:** climate change; cultural heritage; natural heritage; scientific production; bibliometric analysis

## 1. Introduction

Climate change (CC) is a phenomenon that is reflected by an increase in the planet's average temperature and constitutes a constant challenge that society faces due to its negative effects on the environment at a global level (changes in ecosystems and desertification, rise in sea level as a consequence of the melting of the poles, ocean acidification, etc.), on the economy, health and society. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "any change in climate over time either due to natural variability or as a result of human activity". In addition, the Framework Convention on Climate Change (FCCC) defines climate change by focusing on human activity as "a

change of climate that is attributed directly or indirectly to human activity, which alters the composition of the global atmosphere and in addition to natural climate variability over comparable time periods". There is 95% certainty that society is the cause and precursor of the current global warming, being the main source of contribution of greenhouse gas emissions [1].

The impact of CC has been addressed from natural sciences and social and political sciences [2]. However, there is less research on the implications of CC on cultural and natural heritage, being necessary to understand the risks related to climate change [3] in this area [4–16].

Understanding the effects that climate has on the different types of cultural and natural heritage leads to a consensus in recognizing that CC elements could damage certain characteristics of cultural and natural heritage, if adaptation and mitigation measures are not used [17]. Thus, in 2005, the World Heritage Committee broadened the objectives of cultural and natural heritage protection by integrating the threats generated by CC. Understanding the vulnerability that heritage has regarding CC is essential [17], since the "deterioration or disappearance of any cultural or natural heritage element constitutes a harmful impoverishment of the heritage of all the nations of the world" [18]. Therefore, Rajčić et al. [19] states that evaluating the present and future impact is one of the greatest challenges for heritage management, since as the study of heritage and climate change is studied more in depth, it contributes to the formulation of appropriate adaptation strategies and mitigation, which are increasingly necessary [20].

However, at present, according to Carroll and Aarrevaara [21], there is still no standardized list of all the climate elements that affect cultural or natural heritage, since there are elements for each type that intensify their vulnerability on a smaller or larger scale. The following elements are the most accepted as threats to cultural heritage: rain, floods, relative humidity, wind, rising sea levels, changes in climatic zones, temperature, changes in vegetation, as well as pests and diseases derived from the previous elements [3,19,22,23]. All these elements, according to UNESCO [24], generate detrimental effects such as increased migration processes of plant and animal species due to the difficulty of adapting to current environmental conditions, making it difficult to preserve the biodiversity found in natural heritage sites; degradation processes or disappearance of archaeological heritage lying on the ground, underwater or of immovable heritage located in coastal areas due to an increase in water levels; increase in sea temperatures causing marine biodiversity degradation, including many others.

In this context, in which climate change poses serious threats to the protection, conservation and transmission of cultural and natural heritage to future generations [13], the aim of this research is to identify scientific production regarding the impact of climate change on cultural and natural heritage. A scientific mapping is obtained, which allows observing of the evolution of knowledge generation (evolution of publications by years, impact of publications (citations), author productivity by country and institution, existence of research groups, preferred journals for publishing, cooperation networks). The results obtained will be very useful for researchers working in this scientific area, as they can find a synthesis of scientific production in this document, allowing these researchers to draw their own conclusions regarding the existing gaps in research; constituting the starting point of their research, with the aim of filling these gaps.

Although there is already a relevant bibliometric analysis in Web of Science (WoS) on the subject, which is carried out by Fatorić and Seekamp [25] and covers up to 2015, the contribution of this work is important and novel. The study is justified by: (1) the analysis of production up to 2020, which is 5 years more than in the bibliometrics by Fatorić and Seekamp [25], which are observed to be very productive years; (2) the search is carried out in the two main international databases, WoS and Scopus, which will allow for an overlap and singularity analysis between them; and (3) the subject matter of study will include tangible and intangible cultural heritage, as well as natural heritage.

In order to lay the foundations of the research, before continuing with the scientific production analysis, which is the object of this research, it is considered important to define what is considered tangible and intangible cultural heritage, as well as natural heritage. In this regard, UNESCO [17] (p. 132) defines tangible and intangible cultural heritage and natural heritage following the Convention Concerning the Protection of World Cultural and Natural Heritage [18]; the Convention for the Safeguarding of Intangible Cultural Heritage [26].

"Cultural Heritage: (a) monuments: architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and combinations of features which are of outstanding value from the point of view of history, art or science; (b) groups of buildings: groups of separate or connected buildings, which because of their architecture, their homogeneity or their place in the landscape, are of outstanding value from the point of view of history, art or science; (c) sites: works of man or the combined works of nature and man, and areas including archaeological sites, which are of outstanding value from the historical, aesthetic, ethnological or anthropological point of view" [17] (p. 132).

Natural Heritage: (a) natural features consisting of physical and biological formations or groups of such formations, which are of outstanding value from the aesthetic or scientific point of view; (b) geological and physiographical formations and precisely delineated areas, which constitute the habitat of threatened species of animals and plants of outstanding value from the point of view of science or conservation; (c) natural sites or precisely delineated natural areas of outstanding value from the point of view of science, conservation or natural beauty [17] (p. 32).

Intangible cultural heritage: refers to those practices, representations, expressions, knowledge, skills—as well as the instruments, objects, artifacts and cultural spaces associated therewith—that communities, groups and, in some cases, individuals recognize as part of their cultural heritage. These are manifested in the following domains: (a) oral traditions and expressions, including language as a vehicle of the intangible cultural heritage; (b) performing arts; (c) social practices, rituals and festive events; (d) knowledge and practices concerning nature and the universe; and (e) traditional craftsmanship [17] (p. 33).

This article is structured in four sections. In the introduction, the subject of study is contextualized and the aim of the research is stated. In the second section, the methodology is introduced and in the third section, the results obtained are discussed. Finally, in the last section, the conclusions are discussed, as well as the research limitations.

## 2. Materials and Methods

To meet the proposed objective, a bibliometric analysis is carried out, which according to Pellegrini et al. [27] allows analyzing a large amount of information in a very detailed way, based on global data, as well as from a variety of specific fields. The starting point is the development of a systematic and thorough search for publications in various formats or support, within the same subject under study [28]. This type of analysis requires a search protocol that provides confidence and validity to the studies in which it is applied. The protocol specifies criteria such as: study range, databases in use, coverage of sources to be used, quality of the metadata under analysis, including other aspects, which will give the required precision and will influence the degree of consistency and replicability that the studies may have [28–30].

### 2.1. Search Criteria

The search for scientific documents is carried out in the two most important multi-disciplinary databases worldwide, Scopus and Web of Science (WoS). This will extend the coverage of documents within the study, since each one covers different periods of time [31–33]. Other characteristics that justify their choice are: indexing of high-impact journals, access and downloading of the metadata of the identified articles and quality

control through relative quality indices (RQI); in Scopus, Scimago Journal Rank (SJR) and in WoS, Journal Citation Reports (JCR) [34].

After selecting the databases, the next step is to establish the search criteria. The validity of the results will be marked by the decisions made. Therefore, the search criteria in this research are:

(a) Time-coverage: as of closing January 2020, in order to recover the maximum number of publications and to have information published for full years.
(b) Documentary unit of analysis: the scientific article. It is a resource that shows organized, synthesized and quickly obtainable information, in addition to having visibility and impact at different levels (local, national and international) [35–37]. These are the advantages over other publication formats that are excluded, which both databases contain (book chapters, conferences, etc.).
(c) Thematic approach: to identify studies that address "the impact of climate change on natural and cultural heritage"; theoretical approaches, description of the processes of affectation or actions for either the adaptation, mitigation of the identified impacts or both, etc.
(d) Tracking process, the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method were used.

## 2.2. PRISMA Method

In the first place, advanced search equations (Table 1) were established, one for each base, that is, the query terms that accurately represent the thematic approach studied were defined [38].

**Table 1.** Search equations by database.

| Data Base | Equation |
| --- | --- |
| Scopus | (TITLE ("climat * chang * "OR" climat * effect * "OR"climat * varia * " OR "global climat * " OR "climat * warn * ") ANDTITLE ("cultural resource * "OR" cultural heritage * " OR "heritage * site"OR"urban heritage * " OR "artistic * heritage * " OR "monument * heritage * " OR "historic * heritage * " OR "historic * preservat * " OR "heritage * conservat * " OR "world heritage * " OR "natural heritage * " OR " coastal heritg * " OR "natural site" OR "natural reserve * ")) AND (EXCLUDE (PUBYEAR, 2020)) AND (LIMIT-O (LANGUAGE, "English")) |
| WoS | TITLE:("climat * chang * " OR " climat* effect * " OR "climat * varia * " OR "global climat * " OR "climat * warn * ") ANDTITLE: ("cultural resource * " OR "cultural heritage * " OR "heritage * site" OR "urban heritage * " OR "artistic * heritage * " OR "monument * heritage * " OR "historic * heritage * " OR "historic * preservat * " OR "heritage * conservat * " OR "world heritage * " OR "natural heritage * " OR "coastal heritg * " OR "natural site" OR "natural reserve * ") Refined by: LANGUAGE: (ENGLISH) |

Source: Own elaboration.

In Scopus, 49 articles were identified and a further 40 in WoS (89 articles in total). Following the PRISMA method, exclusion criteria were applied that allow refining and standardizing of the metadata by deleting duplicate documents, then eligibility was evaluated by discarding those with unidentified bibliometrics and those unrelated to the thematic approach of the study. Finally, the number of articles to be included in the study was 78 articles (Figure 1).
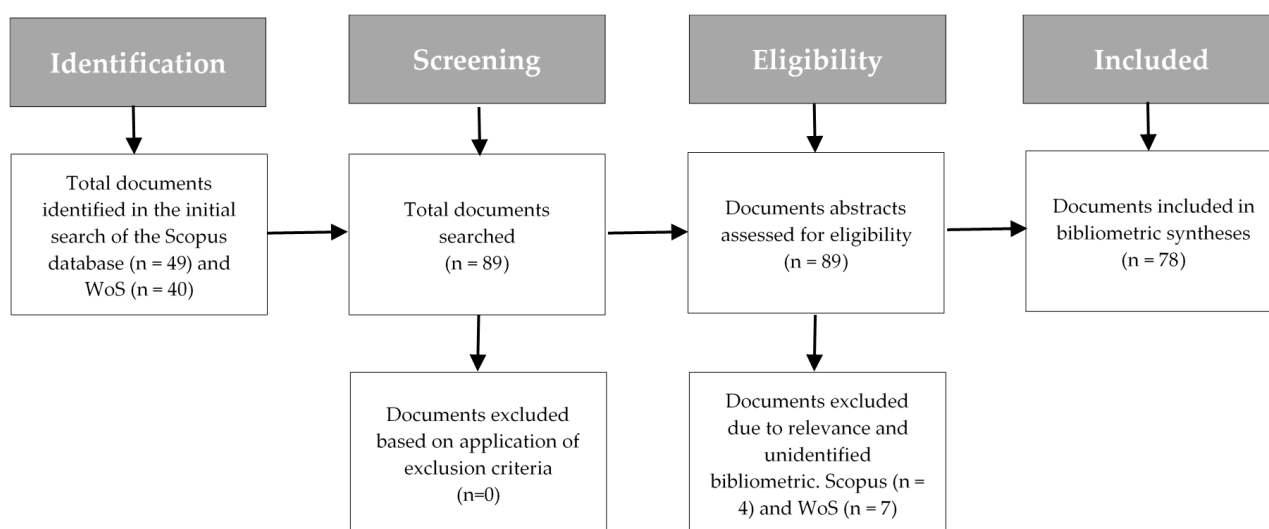
**Figure 1.** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method procedure that details the steps in the identification and selection of documentary units.

### 2.3. Data Extraction

Both the Scopus and WoS articles were downloaded in *.ris (research information systems) format. The metadata download included all the information required for the application of the selected bibliometric indicators. Microsoft-Office Excel software (evaluative analysis measures) and the bibliometric analysis software VOSviewer for the application of relational measures or scientific mapping were used for the analysis [39–44]. Finally, the management of bibliographic references was developed through the Mendeley program.

### 2.4. Data Analysis

Data analysis was structured in three phases. In the first one, production overlapping in the databases used is studied. Three mathematical calculations were applied to determine the level of overlap between the articles indexed in both databases [45–47]: (1) Meyer's index, to determine the degree of coverage that each database has on the scientific production of a specific subject [48]; (2) traditional overlapping (TO), to determine the similarity that base A has within base B [49]; and (3) relative overlapping (RO), to obtain the percentage of overlap that base A has on base B [50]. The development of this type of analysis has been more widely applied in the last decade, although its development emerged more than 50 years ago [46].

In the second and third phases, the most widely accepted evaluative analysis measures and relationships were applied within bibliometric studies [51–53] to minimize the subjectivity of these studies [54], highlighting that these measures arise from mathematical models to establish the relationship between two or more variables [55].

The evaluative measures that were applied to the total set of metadata of the identified articles enabled establishing of the achieved scope, as well as to classify or rate the authors, journals and institutions within the thematic approach [56]. These evaluative measures are classified into: (1) production and productivity measures that show the performance and contributions of articles per year, author, journal or institution; (2) impact measures that determine the average use of published articles, that is, they detail the number of total citations per year, author or journal, and (3) hybrid measures, which combine productivity and impact on a single analysis datum [56,57].

Regarding relational measures, they allowed for a more in-depth analysis of social and intellectual interactions existing between research fields, research clusters or reference institutions, consolidated thematic areas or the emergence of new lines, research methods and co-occurrence analysis [58,59]. The latter can be: analysis of co-citations, co-words,

co-authorship and bibliographic coupling [60–64]. These types of analysis emerged in 2008, but they have a low application within bibliometric studies, being necessary to specify that they are a very useful method for researchers who are starting in new fields of research because from a relational structure graph it is possible to get an overview of the field of knowledge analyzed [65–67].

## 3. Results

### 3.1. Overlap in Databases

The linear correlation coefficient between Scopus and WoS is 0.97, indicating a very high and direct correlation. Of the 78 articles (45 in Scopus and 33 in WoS), 31 are indexed in both databases, which represents 68.89% of articles in Scopus and 93.94% in WoS. Therefore, 14 articles in Scopus and 2 in WoS are classified as single documents, as they are present in a single database. For further analysis, a joint database of 47 articles is developed (duplicates in both databases are removed).

Meyer´s index (MI), which determines the singularity of articles by base, is 0.66 for Scopus and 0.53 for WoS. A similar distribution occurs in the singularity by journals with MI = 0.67 for Scopus and MI = 0.56 in WoS (Table 2). The traditional overlapping (TO) % between Scopus and WoS establishes a similarity of 65.96% between bases, which in other words means that there is only 34.04% disparity between them.

$$\%\text{TO} = 100 \left( \frac{|\text{Scopus} \cap \text{WoS}|}{|\text{Scopus} \cap \text{WoS}|} \right) => \%\text{TO} = 100 \ \times \ \left( \frac{31}{45 + 33 - 31} \right) = 65.96\% \quad (1)$$

**Table 2.** Distribution of citations by articles.

| Distribution. | Cites Scopus | % | Cites WoS | % |
|---|---|---|---|---|
| Less than 1 | 9 | 20.00 | 8 | 24.00 |
| 1–25 | 35 | 78.00 | 25 | 76.00 |
| 26–50 | 1 | 2.00 | 0 | 0.00 |
| | 45 | 100.00 | 33 | 100.00 |

Source: own elaboration.

As a complement to the previous calculation, the percentage of coverage that Scopus has in relation to WoS and vice versa (Gluck, 1990) is determined by means of relative overlapping (RO):

$$\%\text{RO}_{\text{Scopus}} = 100 \left( \frac{|\text{Scopus} \cap \text{WoS}|}{|\text{Scopus}|} \right) => \%\text{RO}_{\text{Scopus}} = 100 \ \times \ \left( \frac{31}{45} \right) = 68.89\%$$
$$\%\text{RO}_{\text{WoS}} = 93.94\% \quad (2)$$

The resulting percentages establish that 68.89% of Scopus is overlapped by WoS, while 93.94% of WoS is covered by Scopus. These data indicate that Scopus has a greater overlap on WoS, which may be a consequence of the levels and time period of indexing the databases, since not all the resources that are published are common between them.

### 3.2. Analysis with Evaluative Measures

#### 3.2.1. Productivity per Years

The 47 articles on the subject were published in the 1999–2019 period, which is over the last 21 years (Figure 2). The first indexed document is by Rowland [68], entitled Accelerated climate change and Australia's cultural heritage, indexed only in Scopus. While Climate change: How should the world heritage convention respond? by Terrill [69] is the first document to be indexed in both databases. Furthermore, 2018 was the most productive year, as it concentrates a quarter of the total number of articles (Figure 2), demonstrating the exponential growth that this approach has been experiencing, as established by Price's Law [70].
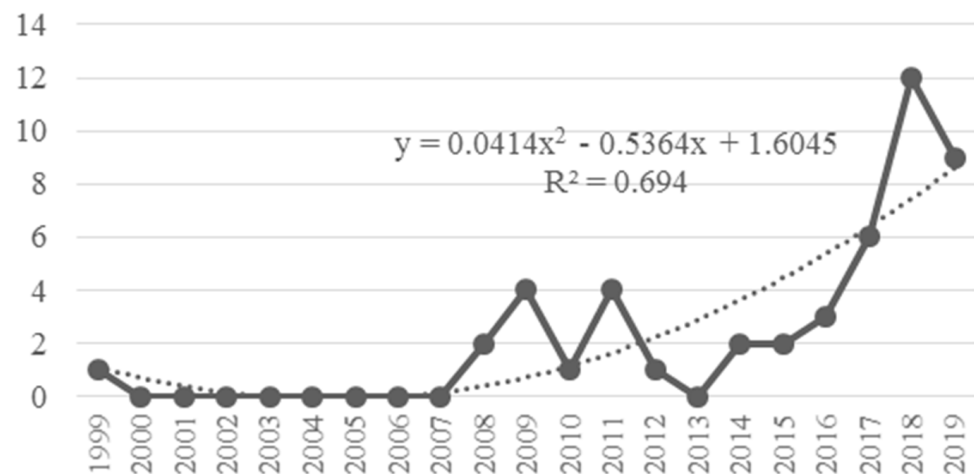
**Figure 2.** Trend of publications in Scopus ∪ WoS. Source: own elaboration.

In the last five years, there has been a significant increase in production (6.40 articles/y), a period in which the number of authors per document has also increased to two or more authors. This change is closely related to the publication of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) of 2014. The report concludes that climate change is a reality and that anthropic activities are its main causes, adding that it is not limited to the melting of the poles, but is affecting various elements of the planet, many of which are part of various asset declarations.

### 3.2.2. Citations

The documents identified have a total of 300 citations (45 articles) in Scopus, with 6.66 citations/articles and an H index = 0, whereas WoS registers 144 citations (33 articles), 4.36 citations/articles and an h-index = 7. The year with the highest number of citations in Scopus is 2017, with 69 citations, while in WoS it is 2018, with 30 citations. None of the articles obtained more than 100 citations. Most of the articles, 78% of Scopus and 76% of WoS reached a maximum of between 1 and 25 citations (Table 2). The only document with 31 citations is by Fatorić and Seekamp [25] (Table 3). A common trend within this type of analysis is the low number of citations within the publications of the last two years, a condition that originates from the short dissemination time that they have within the academic community [71].

The most cited articles are only indexed in Scopus, which are: Are cultural heritage and resources threatened by climate change? A systematic literature review by Fatorić and Seekamp [25]; The capacity to adapt to climate change at heritage sites—The development of a conceptual framework by Phillips [11] and International approaches to climate change and cultural heritage by Hambrecht and Rockman [72], with 31, 23 and 21 citations, respectively. The approach used by the two most cited articles mainly focuses on the theoretical foundation; while the third one proposes an applicative work with the production of a tool to evaluate CC in heritage sites, but of a global nature, being the approach reduced to undeclared local heritage or resources.

**Table 3.** Ranking of the most cited articles.

| R | Authors | Year | Scopus | | WoS | | Main Results |
|---|---|---|---|---|---|---|---|
| | | | C | C/Y | C | C/Y | |
| 1 | Fatorić and Seekamp<br>Are cultural heritage and resources threatened by climate change? A systematic literature review | 2017 [25] | 31 | 15.50 | - | - | High theoretical production<br>Limitation of study areas worldwide<br>Limited production on the benefits of adaptation to CC |
| 2 | Phillips<br>The capacity to adapt to climate change at heritage sites-The development of a conceptual framework | 2015 [11] | 23 | 5.75 | - | - | Determine a conceptual framework for understanding adaptive capacity<br>There is a significant gap in the knowledge of adaptation to climate change and the management of cultural heritage |
| 3 | Hambrecht and Rockman<br>International Approaches to Climate Change and Cultural Heritage | 2017 [72] | 21 | 10.50 | - | - | Theoretical analysis of response experiences to CC with respect to cultural and archaeological heritage<br>It proposes the development of joint efforts to face CC threats supported by the exchange of experiences, increased interaction with visitors and other audiences, generation of local management tools and allocation of resources from different areas for study. |
| 4 | Blankholm<br>Long-Term Research and Cultural Resource Management Strategies in Light of Climate Change and Human Impact | 2009 [73] | 21 | 2.10 | 18 | 1.80 | Deficiency in the adaptation of archaeological research to CC<br>Generation and strengthening of the legal basis for CC mitigation in polar zones |
| 5 | Perry<br>World Heritage hot spots: a global model identifies the 16 natural heritage properties on the World Heritage List most at risk from climate change | 2011 [10] | 20 | 2.50 | 14 | 1.75 | It develops the World Heritage Vulnerability Index (WHVI), as a tool for making informed decisions about natural or mixed heritage.<br>Identifies adaptation strategies and steps to proactively adapt to climate change in 16 natural heritage properties on the World Heritage List that are most at risk. |
| 6 | Terrill<br>Climate Change: How Should the World Heritage Convention Respond? | 2008 [69] | 14 | 1.27 | 10 | 0.90 | It argues that CC is not by itself the only element causing the degradation of heritage.<br>Identify the need to develop CC adaptation plans, with short-term actions. |
| 7 | Forino, et al.<br>A proposed assessment index for climate change-related risk for cultural heritage protection in Newcastle (Australia) | 2016 [3] | 13 | 4.33 | 11 | 3.66 | Develops the Cultural Heritage Risk Index (CHRI).<br>Make a first approach to exploring the relationships between risks linked to climate change and cultural heritage. |
| 8 | Haugen and Mattsson<br>Preparations for climate change's influences on cultural heritage | 2011 [6] | 16 | 2.00 | 12 | 1.50 | Development of a methodology to address the problem of CC and cultural heritage through the use of digital media, details content that increases the knowledge of owners and responsible authorities so that they can prepare for climate change on a practical level. |

R = ranking; C = number of citations received; C/Y= average number of citations received per article per year. Source: own elaboration.

### 3.2.3. Authors

A total of 110 authors are identified with a production index per author of 1.10 articles and a transience index of 94%. The authors with the most publications are Seekamp, E. from North Carolina State University, United States (total author production: 59; h-index = 12) and Fatorić, S. from Delft University if Technology, Netherlands (total author production:

18; h index = 8) with 3 articles. Both authors have an average of 12.67 citations/articles in Scopus and 2.00 in WoS.

On the other hand, it is observed that 40.4% of the articles have been produced by a single author, while 59.6% are signed by two or more authors. In 62.7% of the documents, the signatories are affiliated to the same country, and in 53% of the documents, the members belong to different institutions.

Regarding the production of multiple collaborations, it is established that 19% (9) have been developed between two authors, followed by 17% (8) of articles done by three authors, 11% (5) by four authors, while, 13% (6) have been developed by five or more authors. Based on this, the collaboration distribution enables establishing a co-authorship index of 2.57 authors/article, a value that confirms authors' preferences for collaborating in pairs.

### 3.2.4. Productivity by Type of Institutions and Country

Considering the geographical production by continent, it is observed that the leader is Europe, followed by America and Oceania. At country level, the United States stands out with 17 articles.

Productivity by country of affiliation (Table 4) confirms that the United States is the largest producer, reaching 22 authors, 25 authorships and 17 centers, followed by Australia with 19 authors, 20 authors and 13 centers. Regarding citation accumulation by country, the United States continues as the leader with 144 citations, followed by Norway (77) in Scopus. By contrast, Norway is the leader in WoS, with 56 citations, followed by Australia (45).

**Table 4.** Number of centers, authors and authorships by their country of affiliation.

| R | Country | Scopus ∪ WoS | | | | Cites Scopus | | | Cites WoS | | | |
|---|---------|---|---|----|---|------|----|---------|---|------|----|---------|
| | | C | A | As | f | hi% | TC | h-Index | f | hi% | TC | h-Index |
| 1 | United States | 17 | 22 | 25 | 24 | 18.60 | 144 | 6 | 18 | 17.14 | 35 | 4 |
| 2 | Australia | 13 | 19 | 20 | 22 | 17.05 | 13 | 6 | 16 | 15.24 | 45 | 4 |
| 3 | United Kingdom | 8 | 11 | 12 | 11 | 8.53 | 55 | 5 | 6 | 5.71 | 23 | 3 |
| 4 | Norway | 7 | 8 | 8 | 8 | 6.20 | 77 | 6 | 8 | 7.62 | 56 | 4 |
| 5 | Canada | 5 | 8 | 11 | 11 | 8.53 | 12 | 3 | 11 | 10.48 | 12 | 3 |
| 6 | Italy | 5 | 10 | 10 | 10 | 7.75 | 17 | 3 | 9 | 8.57 | 6 | 2 |
| 7 | New Zealand | 3 | 6 | 6 | 6 | 4.65 | 18 | 2 | 6 | 5.71 | 12 | 2 |
| 8 | Finland | 2 | 3 | 3 | 3 | 2.33 | 16 | 2 | 3 | 2.86 | 10 | 2 |
| 9 | France | 2 | 2 | 2 | 2 | 1.55 | 10 | 2 | 1 | 0.95 | 3 | 1 |
| 10 | Germany | 2 | 3 | 3 | 3 | 2.33 | 9 | 1 | 3 | 2.86 | 7 | 1 |
| 11 | Greece | 2 | 5 | 5 | 5 | 3.88 | 0 | 0 | 5 | 4.76 | 0 | 0 |
| 12 | Israel | 2 | 3 | 3 | 3 | 2.33 | 16 | 2 | 1 | 0.95 | 8 | 1 |
| 13 | Japan | 2 | 2 | 2 | 2 | 1.55 | 10 | 2 | 2 | 1.90 | 8 | 2 |
| 14 | Portugal | 2 | 4 | 4 | 4 | 3.10 | 0 | 0 | 4 | 3.81 | 0 | 0 |
| 15 | South Africa | 2 | 2 | 3 | 3 | 2.33 | 14 | 1 | 1 | 0.95 | 8 | 1 |
| 16 | Austria | 1 | 2 | 2 | 2 | 1.55 | 0 | 0 | 2 | 1.90 | 0 | 0 |
| 17 | China | 1 | 1 | 1 | 1 | 0.78 | 1 | 1 | 1 | 0.95 | 1 | 1 |
| 18 | Croatia | 1 | 3 | 3 | 3 | 2.33 | 7 | 1 | 3 | 2.86 | 7 | 1 |
| 19 | Cyprus | 1 | 1 | 1 | 1 | 0.78 | 0 | 0 | 1 | 0.95 | 0 | 0 |
| 20 | Iceland | 1 | 1 | 1 | 1 | 0.78 | 3 | 1 | 1 | 0.95 | 2 | 1 |
| 21 | Netherlands | 1 | 1 | 3 | 3 | 2.33 | 1 | 1 | 2 | 1.90 | 4 | 1 |
| 22 | Sweden | 1 | 1 | 1 | 1 | 0.78 | 14 | 1 | 1 | 0.95 | 8 | 1 |

R= ranking; C = centers; A = authors; As = authorships; f = frequency; hi% = relative frequency; TC = total number of citations received for published articles; h-index = Hirsch's index. Source: own elaboration.

The analysis of productivity by institution allows for the identification of 81 affiliation centers. University institutions concentrate the highest share of affiliations, with 77%.

Table 5 shows the ranking of the most productive institutions, led by the Italian National Research Council, which is a public sector institution. The rest of the listed institutions (2 from the public sector and 8 universities) have the same number of affiliations.

**Table 5.** Most productive institutions with authors and authorships.

| R | Institution | Country | Scopus ∪ WoS | |
|---|---|---|---|---|
| | | | A | As |
| 1 | Italian National Research Council | Italy | 4 | 4 |
| 2 | Department of Primary Industries, Parks, Water and Environment | Australia | 3 | 3 |
| 3 | IMS–FORTH (Institute for Mediterranean Studies–Foundation for Research and Technology) | Greece | 3 | 3 |
| 4 | The University of Queensland | Australia | 3 | 3 |
| 5 | Universidade NOVA de Lisboa | Portugal | 3 | 3 |
| 6 | University of Camerino | Italy | 3 | 3 |
| 7 | University of Newcastle | Australia | 3 | 3 |
| 8 | University of Otago | New Zealand | 3 | 3 |
| 9 | University of Ottawa | Canada | 3 | 4 |
| 10 | University of the West of Scotland | United Kingdom | 3 | 3 |
| 11 | University of Zagreb | Croatia | 3 | 3 |

R = ranking; A = authors; As = authorships. Source: own elaboration.

### 3.2.5. Journals

The documents were published in 39 journals, showing a great dispersion and it was observed that more than half of the total production (70%) was published in journals that had not published any other article on the subject. The core of journals that publish more than one article on the subject is made up of 6, showing a Dispersion Index of 1.21 articles/journals. *Geosciences* stands out for the publication of 4 articles (indexed in both databases), but accumulates only 18 citations (6%) in Scopus and 14 (10%) in WoS. However, in terms of number of citations, the International Journal of Heritage Studies stands out by accumulating 11% of the total citations in Scopus on the subject and 17% in WoS (Table 6).

Another analysis measure that is applied to journals/authors/institutions is the h-index, which shows that the journals that accumulate the highest number of citations in this study are not the ones with the highest h-index In Scopus, Climatic Change (h = 162) is the leader, followed by ICES Journal of Marine Science (h = 105). In WoS, ICES Journal of Marine Science (h = 115) leads the ranking, followed by Land Use Policy (h = 99).

The United Kingdom is the country that publishes 41% (16) of the total resources identified, followed by the United States with 21% and Switzerland with 10%. The quartile analysis shows that 51.4% of Scopus and 18.5% of WoS are Q1 journals; although it is necessary to point out 29.6% of WoS journals do not have a quartile.

Finally, the concentration core generated in relation to scientific production is identified. For this purpose, Bradford's law [74] is applied and Bradford's minimum zone (MBZ) is established, which takes a value of 17. The Bradford core is made up of 9 (23%) journals (Figure 3). The absence of a concentration core is observed, since it accounts for 36% of production. The distribution by areas of knowledge shows a predominance of Social Sciences with 46%, followed by Earth and Planetary Sciences with 19% in Scopus; however, in WoS, Environmental Sciences & Ecology predominates with 22%, followed by Social Sciences with 19%.

**Table 6.** Ranking of the most productive journals.

| R | Title | Country | f | hi% | Scopus | | | | | WoS | | | | |
|---|-------|---------|---|-----|--------|----|---------|---|------|-----|----|---------|---|-----|
| | | | | | f | TC | h-Index | Q | SJR | f | TC | h-Index | Q | JCR |
| 1 | Geosciences (Switzerland) | Switzerland | 4 | 8.51 | 4 | 18 | 14 | 2 | 0.39 | 4 | 14 | 16 | 0 | 0 |
| 2 | Land Use Policy | Netherlands | 2 | 4.26 | 2 | 7 | 93 | 1 | 1.41 | 2 | 4 | 99 | 1 | 3.57 |
| 3 | Journal of Cultural Heritage | France | 2 | 4.26 | 2 | 10 | 53 | 1 | 0.61 | 2 | 8 | 56 | 3 | 1.95 |
| 4 | International Journal of Heritage Studies | United Kingdom | 2 | 4.26 | 2 | 34 | 36 | 1 | 0.48 | 2 | 24 | 30 | 2 | 1.36 |
| 5 | Australasian Journal of Environmental Management | United Kingdom | 2 | 4.26 | 2 | 9 | 19 | 2 | 0.43 | 1 | 0 | 17 | 4 | 1.19 |
| 6 | African Journal of Hospitality, Tourism and Leisure | South Africa | 2 | 4.26 | 2 | 0 | 3 | 4 | 0.14 | - | – | – | – | – |

f = frequency; hi% = relative frequency; TC = total number of citations received for published articles; h-index = Hirsch's index; Q = Quartile; SJR = Scimago Journal & Country Rank; JCR = Journal Citation Reports. Source: own elaboration.
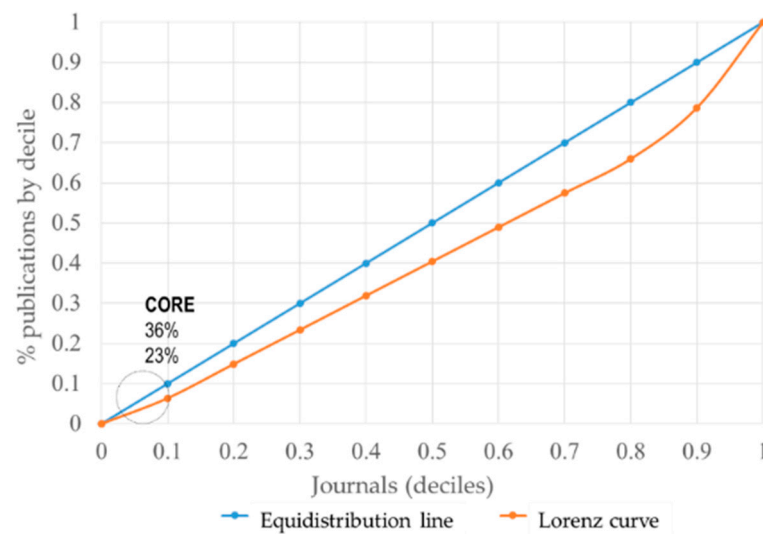


**Figure 3.** Lorenz curve-Bradford core of the most productive journals. Source: own elaboration.

### 3.2.6. Keywords

Keywords are the most widely used mechanism for identifying documents by the scientific community; although they still have usage errors. Nine documents from Scopus and three from WoS, which do not have metadata regarding authors' keywords were registered. Furthermore, 128 keywords are identified within the entire production, with climate change being the central descriptor. Conservation is the term that has been emerging as a descriptor for this thematic approach in the last two years (Figure 4).
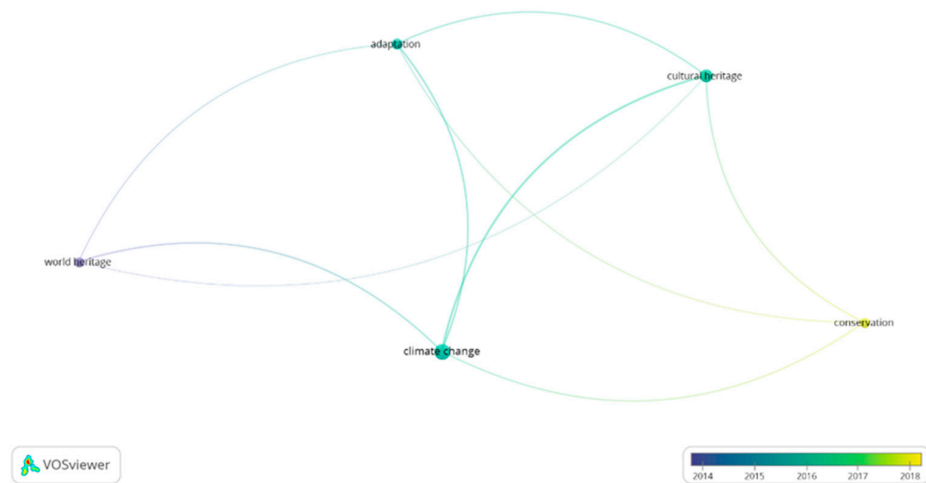
**Figure 4.** Network of co-occurrence of author keywords in the last 5 years. Source: own elaboration.

*3.3. Analysis with Relational Measures (of Networks)*

The network analysis shows that the majority of academics are not related to each other; they are isolated, generating 40 endogamy networks (Figure 5). However, three work clusters of higher relevance are identified for productivity and extension (Figures 6 and 7). The first cluster, formed by the two most productive authors (blue), in which there is no predominance of one over the other and with the total link strength (TLS) = 3. The second cluster (red) is made up of three aspiring authors and it does not have a predominant author either, although they do have the highest TLS of the three clusters, which is 4 (Figure 6). The third cluster is made up of 10 authors, which is the largest network in the study, although most of them are transient (green); it reaches two citations per author and the TLS remains at 1, as in the other networks (Figure 7).
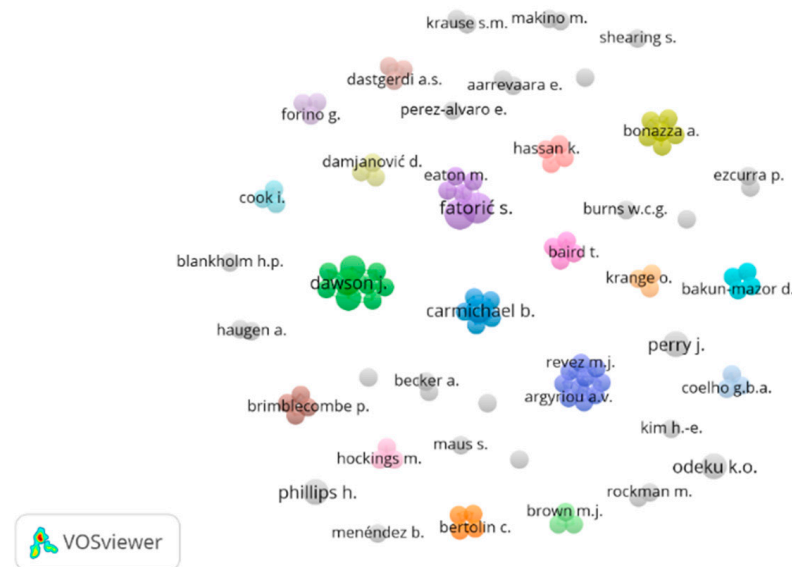


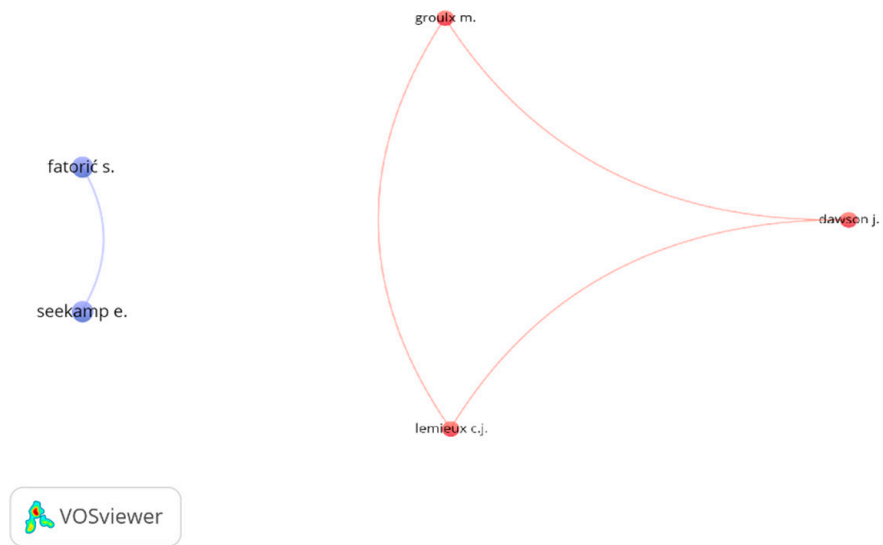**Figure 5.** Co-author networks. Source: own elaboration.

**Figure 6.** Most productive co-author network. Source: own elaboration.
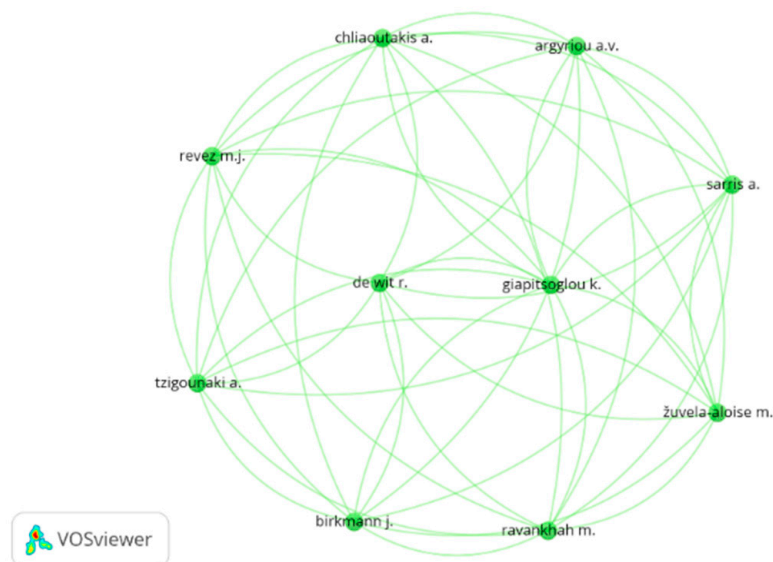


**Figure 7.** Less productive co-author network. Source: own elaboration.

The author co-citation analysis (ACA) visualizes the frequency with which authors from different generations are cited together; the larger the size of the knot, the greater the number of articles that has been published (Figure 8). Furthermore, the closer the authors are, the higher the frequency of citation between them [53]. Thus, 3406 authors were identified, of which 29 reached a minimum of 10 citations, grouped into 4 clusters. The central nodes of each cluster are: Brimblecombe, P. (47 co-citations, 26 links and TLS = 1046), Cassar, M. (48 co-citations, 26 links and TLS = 706), Hall. C. M. (24 co-citations, 22 links and TLS = 622) and Jacob, D. (13 co-citations, 23 links and TLS = 270).
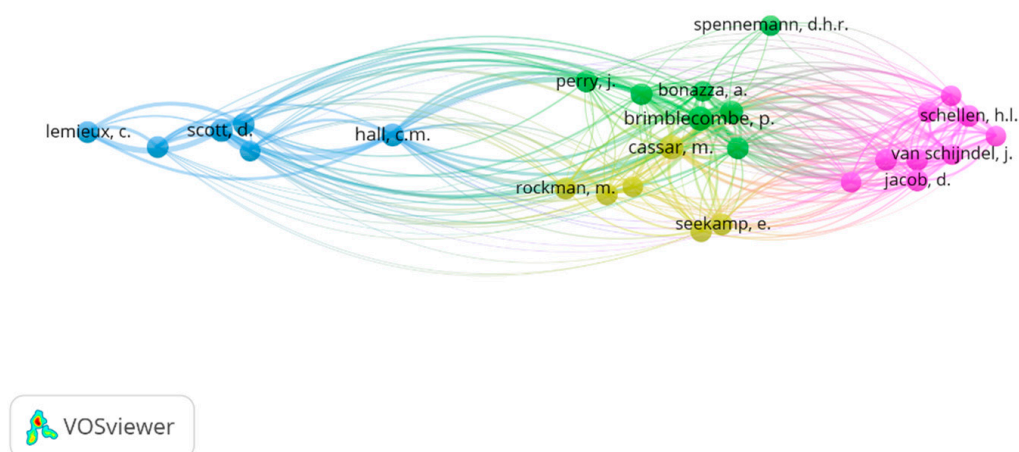
**Figure 8.** Author co-citation analysis (ACA). Source: own elaboration.

Cluster 1, which is green, is made up of seven authors, among whom are several of the most productive, with Brimblecombe, P. (TLS = 1046) and Sabbioni, C. (581) standing out. Both authors carried out the first studies that link climate change science with the potential damage to cultural heritage, not only on tangible or archaeological assets, but also from a cultural landscape approach, mainly focused on Europe. In addition, much more specific contributions are observed in the identification of climatic parameters that can be crucial for the conservation of architectural structures and which are not considered within climatic modeling [5].

In cluster 2 (yellow), planning for adaptability and climate change is addressed; six authors participate, of which Cassar, M. (TLS = 706), Seekamp, E. (237), Fatorić, S. (218), and Adger, W.N. (203) stand out. This group of authors points out the need to initiate planning processes for the adaptation to climate change of different spaces such as: historic districts, buildings, coastal spaces, and archaeological sites on land or underwater [15,25].

In cluster 3 (blue), which is made up of six authors, the line of work is the relationship between tourism and climate change; these authors conceptualize tourism as an opportunity to develop awareness within the different parts of the tourism system (it includes the tourist´s perception) [75,76], as well as to strengthen the development of strategies and policies that allow observing the impact that climate change produces on the management of cultural heritage tourist spaces [13], as well as natural ones [77,78]. Hall, C. M. (TLS = 622), Scott, D. (573), Gössling, S. (333), and Lemieux, C. (242) are highlighted.

The last cluster (purple) is made up of nine authors, and is highlighted by Leissner, J. (309), Schellen, H. (308), Kilian, R. (298), Jacob, D. (270), and Huijbregts, Z. (252). The main theme is the development of simulation models that enable predicting the changes or risks of the climatic conditions that will arise [16,79–81].

Journal co-citation analysis (JCA) identifies the presence of 1571 publication resources that are grouped into 16 clusters. In a more specific analysis, those resources that reach at least 10 citations are examined, generating two clusters, both made up of four resources each (Figure 9). The most cited journal in the purple cluster is Global Environmental Change with 22 co-citations, followed by Journal of Sustainable Tourism with 11 co-citations, both with a TLS = 66. Climatic Change with 14 co-citations and a TLS = 80 is the leader in the green cluster, followed by Current Issues in Tourism with 11 co-citations and TLS = 107, the latter being the highest link strength in the analysis.
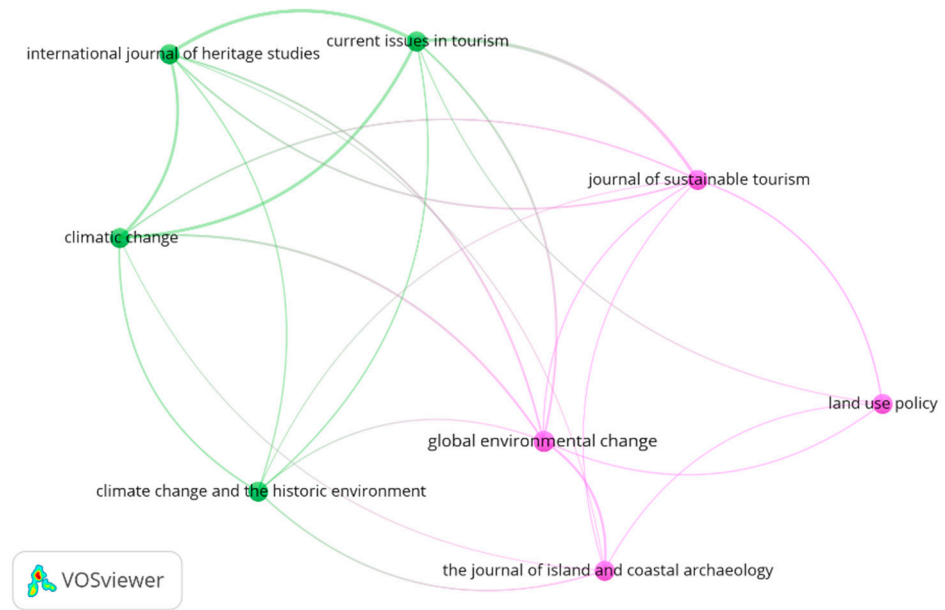
**Figure 9.** Journal co-citation analysis (JCA) in Scopus. Source: own elaboration.

Regarding the bibliographic coupling analysis, it shows the number of references that a group of documents has in common. Figure 10 shows that there are no prominent authors, regardless of the 11 clusters generated, which is based on the low number of documents in common (max. 3 within the clusters). Regarding the TLS, Dawson, J., Groulx, M., and Lemieux, C., stand out with a total strength of 884 each. The main cluster is the purple one, which is composed of 18 items, highlighting Baird, T. with TLS = 462. The second cluster, which is green, has 15 items and Bonazza, A. (TLS = 433) stands out. The last most representative cluster is the blue one, composed of 14 items, with Seekamp, E. and Fatorić, S. being the most representative with TLS = 747 each.
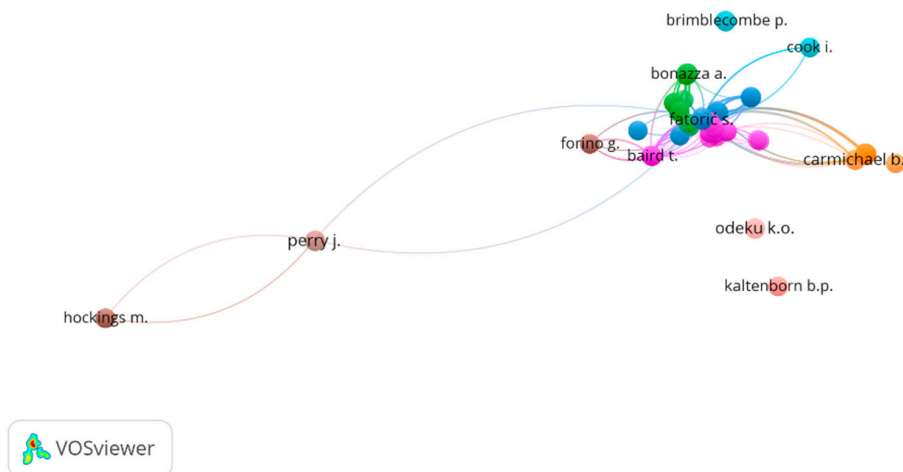


**Figure 10.** Author bibliographic coupling. Source: own elaboration.

## 4. Conclusions

Rajčić et al. [19] state that, although CC can cause damage to natural and cultural heritage, it occurs slowly, resulting in it being easily ignored, hence the slow approach by researchers of this thematic approach. In order to characterize the current reality of the "impact of climate change on the cultural and natural heritage" approach, a comprehensive analysis is carried out in which two different bibliometric analyses techniques are applied; analysis with evaluative measures and analysis with relational measures or scientific

mapping. Document tracking was carried out in the two main databases, WoS and Scopus, identifying 47 documents that were published over a period of 21 years. The overlap analysis between the two databases allowed us to observe that Scopus has a higher indexing of documents, with 94% overlap of information on WoS.

The production of authors is classified as "transient", 94% of the authors appear as signatories of a single study. The collaboration trend is established in pairs, and developed mainly between authors from the same country, but with different institutional affiliations. Production is concentrated in Europe and North America, corroborating the findings made by Fatorić and Seekamp [25]. Institutional affiliation shows that scientific production is concentrated in authors affiliated to university centers.

Regarding the relevance and dissemination of information (measured by the number of citations), it is low; the most cited article has 31 citations and the rest of the documents have less than 25 citations. This may be due to the fact that the high volume of publications has been found in recent years, which limits positioning, which is measured by the number of citations.

The dispersion of articles between journals almost has an equal distribution, because 36% of documents have been published in 23% of the journals. The journal with the highest production is Geosciences with 4 articles, although the International Journal of Heritage Studies accumulates the highest number of citations of the thematic approach. The knowledge areas in which the resources are indexed show that both in Scopus and WoS, there is a trend of association with environmental sciences and social sciences for the publication of articles. Most of the positioning of these resources is within Q1 of the relative quality indices of the databases.

The relational measures corroborate that the thematic approach is new, by identifying a high presence of isolated relationships among the authors. Not even the most productive generate a single cluster, but are instead divided into two working groups. The ACA analysis identifies four clusters with a minimum threshold of 10 citations, which approach the relationship from different perspectives. Cluster 1 establishes the theoretical base and the first elements of characterization of the approach; cluster 2 emphasizes the need for planning for adaptability to climate change. Cluster 3 links production to the analysis of climate change and tourist use that is given to cultural and natural heritage. Finally, cluster 4 groups authors who carry out studies in which they propose simulations that can facilitate the understanding of the damages that will be seen in the future, as long as mitigation processes are not applied. It can be seen that 59% of the co-cited authors are external to the study base.

The JCA analysis identifies that 8 journals are co-cited with the highest frequency. Cluster 1 shows that there is a trend of co-citation between Global Environmental Change and The Journal of Island and Coastal Archeology, and in cluster 2, the citation frequency relationship is observed between International Journal of Heritage Studies and Current Issues in Tourism.

The main limitation is related to the document tracking process carried out in the two main international databases. However, taking into account the level of maturity of the subject under study, which is very low, a large number of publications may be indexed in databases of regional or local relevance. This fact is also shown by the failure to identify scientific production that addresses studies carried out in Africa, Asia, Central and South America. A second limitation is the chosen documentary unit (article), highlighting that the incorporation of other documentary units such as conference communications will help to consolidate the reality of this thematic approach [82].

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