Article

Bibliometric Analysis on Wildfires and Protected Areas

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Abstract: Wildfire are increasingly frequent events on a planet undergoing climate change. With more favourable climate conditions for their occurrence, like prolonged periods of drought, the frequency and intensity of these catastrophes continue to increase. Protected areas are important territories for conserving ecosystems and biodiversity around the world and serve as a key management tool in national environmental policies. Many studies have been developed around the world to assess the conditions, frequency, and intensity of fires, and, on the other hand, protected areas are intensively studied to understand whether conservation actions are effective in keeping the ecosystem balanced. However, there are few studies that contemplate these two themes together. Consequently, this study offers a bibliometric analysis of the wildfires and its occurrence in protected areas, aiming to understand the spatial and temporal relation between them, characteristics of the research studies, and trending issues to be worked on. We used the Bibliometrix package in R language, which provides the option of different methods for analysing bibliometric data to understand the temporal evolution of the published documents about wildfires and protected areas. In total, 1116 publications were analysed, ranging from 1970 to 2022. The findings show that the terms "fires" (185 occurrences), "fire" (117), "wildfire" (101), and "forest fire" (92) are more frequently used and associated with studies on topics including biodiversity (304), conservation (221), environmental protection (188), deforestation (148), ecosystems (138), forestry (133), and climate change (126) as well as protected areas (399). The highest growth of research has been registered since 2002. The majority of the publications were published by authors from universities in the USA (77), South Africa (72), the United Kingdom (22), and Brazil (19). The USA leads all other countries with 7 of the top 10 international collaborations, followed by Brazil, Australia, and South Africa. However, only the United Kingdom continues to maintain an increased number of external (inter-country) collaborations, whereas the other nine continue to maintain an increased number of internal (intra-country). Considering the top 10 authors in terms of production, only 1 was active from 1999 to 2019, and the other 9 only have been active since 2009. The topics that stand out were subjected to a coupling analysis, which revealed that environmental protection is a motor theme, endangered species, Australia, and savannah are niche themes, and protected area, biodiversity, and fire management are basic themes.

Keywords: forest fires; protected areas; bibliometric analysis; Bibliometrix; conservation

1. Introduction

In the second half of the 20th century, the United Nations (UN) promoted and coordinated the United Nations Conferences on the Human Environment. Through these global forums, such as the Stockholm 1972, Rio 1992, and Rio 2012 Conferences, the UN brought together countries with the aim of understanding the human impact on Earth and how to preserve the environment [1].

One possibility of environmental protection is the delimitation of protected areas (PAs), which promotes ecosystem preservation, contributing to the conservation of species and reducing the risk of extinction [2–4].

The implementation of this type of nature conservation initiatives dates back to the second half of the 19th century, with the creation of national parks such as the Yellowstone National Park in the United States in 1872, recognised as the first national park in the world. The early 20th century would see the proliferation of PA across the continents and other nature conservation strategies, a movement that would intensify, particularly in the post-World War II period [5].

Although they are nature conservation areas and subject to constraints regarding the development of anthropic activities (in some cases imposing a prohibition of anthropic activities), PAs have been significantly affected by climate change and subsequent impacts, such as the increase in wildfires, the process of deforestation, and loss of biodiversity [2,3,6–8].

Nevertheless, the total protected land area in the world has grown significantly since the 1970s, from 4.1 million km^2 in 1972 [9] to 22.4 million km^2 in 2021 [10]. Therefore, we consider the beginning of the 1970s up until 2022 as the adequate time frame for the analysis we propose in this bibliometric research.

In addition to the PAs, we also considered the articulation with the topic of wildfires in this study. The frequency and severity of these events are increasing today [11–13]. Moreover, climate change is a relevant topic and a factor capable of altering ecosystems [14], and affecting the behaviour of wildfires and their regimes worldwide [15].

To understand if there are study trends and research gaps on wildfires in PAs, we performed a bibliometric analysis using the Bibliometrix package of the R language [16,17]. We are aware that, so far, research has been developed linking wildfires to tropical rainforests [18], remote sensing [19], and wildland–urban interfaces [20], but we have not come across a thorough research study done on PAs and wildfires.

A better understanding of the field of study in which we work and the development of research in this field, as well as being able to spot future research gaps, are all benefits of bibliometric analysis, which is a quantitative and qualitative analysis of research to evaluate the impact of a researcher, institution, countries, and journals [21,22].

This analysis is based on the metadata of published works, that is, information from publications that can be quantified, such as keywords, citations, references, evaluation indexes such as the H-index, and ranking of institutions, among others, providing a quantitative view of the publications in a certain theme [23]. It is an analysis that is increasingly used to synthesise the scientific production that is constantly growing, making it impossible to follow every publication on a given topic [17].

The aims of the research were to analyse the leading scientists, nations, and research organizations who have published on the topics of wildfire and protected areas to understand what themes are covered by the studies.

2. Materials and Methods

One of the first methodological decisions to consider was the definition of timeframe for the research. Thus, we tried to identify the frequency of major catastrophic events related to wildfires worldwide and the affectation of PAs.

The 1970–2022 period is marked by the occurrence of tremendous and devastating wildfire events in different parts of the globe [24], frequently affecting PAs. In 1988, massive fires raged in the Yellowstone National Park [25,26]. The years 1998 and 1999 were dry and resulted in large wildfires in California, reaching the Los Padres National Forest, located close to Los Angeles and San Diego, which may have affected an important part of the population due to air contamination after the fires [27–29].

Australia also registered astounding megafires in the last decades: the 1974–1975 bushfires, the 2003 Canberra bushfires, the 2008–2009 Australian bushfire season and the Black Saturday bushfires. or the 2019–2020 Australian bushfire season [30,31]; on the other hand, 2012 witnessed a record of deforestation in Amazonia [32]. In 2016, large fires hit the boreal forests of Fort McMurray, Alberta, Canada [33], and 2017 saw major fires in Northern California [34] and Portugal [35,36]. In 2018, large forest fires occurred in Greece [37]. The year 2019 saw a significant increase in forest fires in Amazonia with its maximum exponent

registered on the so-called "day of fire" (10 and 11 August 2019), when rural producers in the region of Pará mobilised to set fire to the Amazonia rainforest [38–40]. All these wildfires were subject to intensive research and analysis, promoting an important effort from the academia to contribute to a better knowledge of the different aspects related to wildfires, in order to help society to be prepared to fight this problem.

The first task of the study was devoted to the definition of the research questions. During this step it was necessary to carry out the keyword selection, and the definition of the structure of the database. The data were acquired from the Scopus database, using the keywords "protected area" AND "fire" OR "wildfire" OR "megafire" OR "forest fire" OR "wildland fire" OR "bushfire" OR "large forest fire" OR "extreme fire" OR "gigafire", searched within the article title, abstract, and keywords. The Scopus database was selected because provides more comprehensive coverage than WoS on topics that may not yet have been reported on [41].

On 8 February 2023, these terms were searched in the titles, abstracts, and keywords of every journal that published between 1991 and 2022. The BibTeX (.bib) file was loaded and the bibliometric analysis was performed in the Bibliometrix package in R language [17]. The Bibliometrix enables the assessment of three key groups: group (1) authors, which includes authorship, affiliation, and country analyses; group (2) sources of publications, which enables the assessment of the influence of the sources and the verification of productivity; and group (3) documents, which includes citation data and references. The main information regarding the data is presented in Table 1.

Table 1. Statistic description. Source: Scopus and Bibliometrix.

Description	Results
Timespan	1970–2022
Sources	527
Documents	1116
Annual Growth Rate %	9.36
Average age of document	8.58
Average citations per doc	26.53
DOCUMENT CONTENTS	
Keywords Plus (ID)	4905
Author's keywords (DE)	3266
AUTHORS	
Authors	4419
Authors of single-authored documents	116
AUTHORS' COLLABORATION	
Single-authored docs	128
Co-authors per doc	4.65
International co-authorships %	33.15
DOCUMENT TYPES	
Article	933
Book	1
Book chapter	52
Conference paper	62
Conference review	5
Editorial	1
Letter	3
Note	3
Review	54
Short survey	2

A total of 1116 publications from the 1970–2022 period were analysed, and of these 933 were journal articles. For our sample of only 1116 publications, and considering the topics of fires and PAs within the context of environmental studies and climate change, we thought it was important to include the different type of publications, described in Table 1. As a result, early publications, like conference papers, are a crucial example of

comprehending the development of publications. The Supplementary Materials contain all of the bibliometric analysis data.

Initially, a temporal analysis of the documents was developed, using the options *annual scientific production*, which presents an evolution of the annual scientific production, and *average citation per year*, which presents the average number of citations per year for each document.

This was followed by an analysis of the social structure, which reveals the networks of cooperation between institutions and nations and enables the identification of the authors and networks that publish the most on a given topic. At this stage, collaborations between institutions and countries were analysed, creating a table containing the citations per country and the average citation per article, calculating the intra-country (SCP) and inter-country (MCP) collaboration index, which indicates whether the research is developed mostly by internal institutions (SCP) in the country or supported by international collaboration (MCP). The most relevant affiliations quantify the frequency of the distribution of all authors' affiliations to document and present the countries where the institutions are located. Finally, the country collaboration map was created, identifying the collaboration networks between the countries.

Next, we identified the top *authors' production over time*, the authors' h-index, and Lotka's law. The top authors' metric was calculated considering the number of publications and total citations per year. The *authors' h-index* is based on the set of the most cited works and the number of citations the authors received in other publications. *Lotka's Law* describes the publication frequency of authors in any field as an inverse square law, where the number of authors publishing a given number of articles is a fixed proportion compared to the number of authors publishing a single article [17,42].

In conceptual structure, the *co-words network* was organised for words that appear together in a document, forming a network. It presents the formation of networks of words most representative of a given theme, according to the network of authors, and their connection with other networks of words. In the *word frequency over time*, the most used words over time are indicated.

Then, the *coupling analysis* was developed, identifying the thematic networks and defining clusters of terms most used to refer to a given topic and its relationship with other terms. It is displayed on a matrix with two dimensions. The X-axis measures the cluster centrality (by Callon's Centrality index), or the importance of themes across the field of research. The Y-axis measures density, or the measure of the theme's development [43].

3. Results

As stated previously, a total of 1116 publications were analysed in this work. The papers recorded an average citation per doc of 26.53, with an average age of 8.46 during the period. These publications were written by 4419 authors, with 116 authors of a single-authored document. The average number of authors per document was 4.65, calculated as the ratio between the total number of authors and the total number of papers.
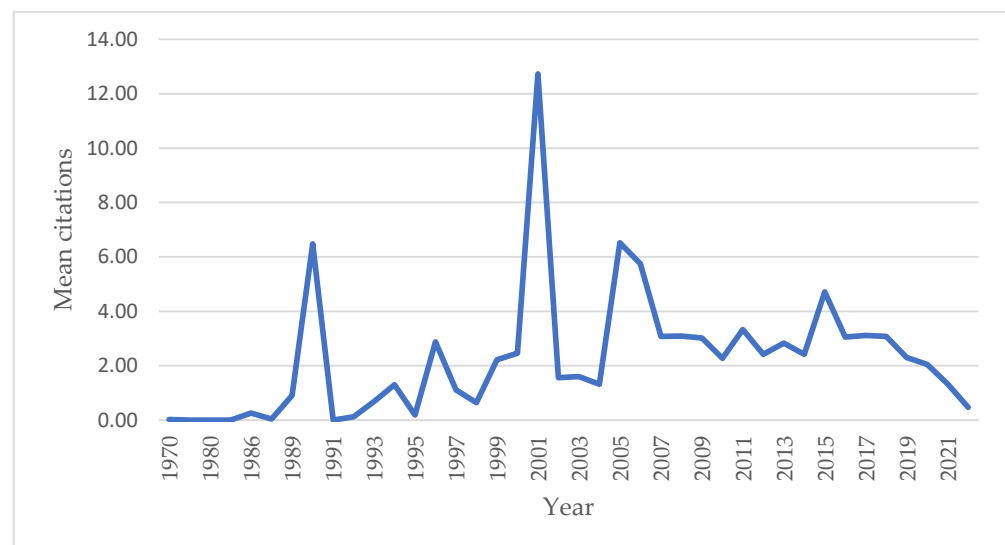
3.1. Documents

The production of scientific articles on the topics was stable between 1970 and 2001, with a maximum of 15 works published in 1999, when catastrophic megafires affected California. Between 2002 and 2005, the scientific production registered a slight increment, between 10 and 17. The number of documents increased steadily from 24 to 60 between 2006 and 2013, dropping to 36 in 2014 before increasing again between 2015 (47) and 2016 (73), years that registered fires in Canada. The number dropped to 65 in 2017 and then increased between 2018 (72) and 2022. The year 2018 was the next year after fires in Portugal and California (USA) (105). Although simplified in this graph, the frequency of megafires across the world and their catastrophic impacts, both in terms of area affected and in human and material losses, have increased significantly, justifying the consequent interest and production of research and scientific publications (Figure 1).
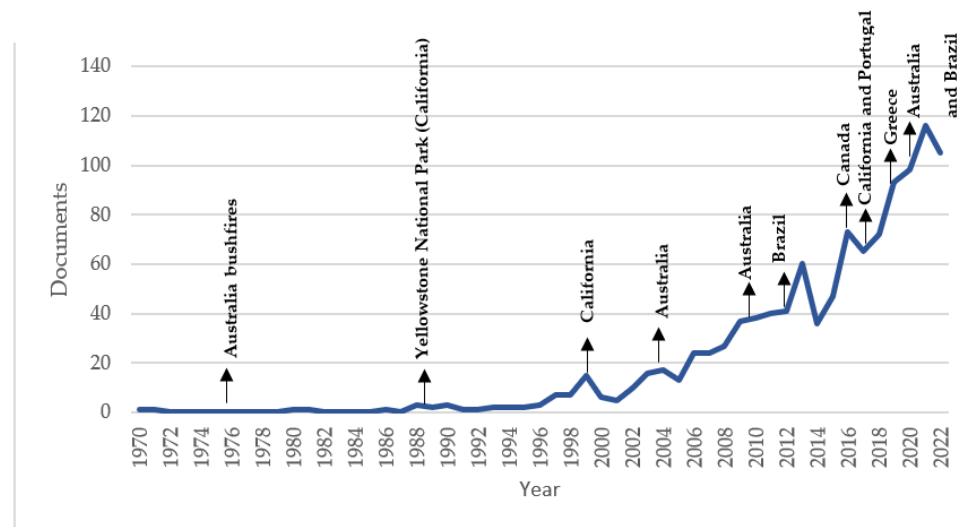
Figure 1. Annual scientific production. Source: Scopus.

Over the considered period (1970–2022), there was no pattern of increase in the mean number of citations. Less than one citation each year was stable between 1970 and 1998, but increased to 6.48 in 1990. The average number of citations varies between 1991 and 2000, but only to a maximum of 2.88 in 1996. In 2001, we observe a significant peak of citations, reaching 12.73. The mean was above two citations in most years from 2002 to 2020, with a decline between 2021 and 2022 (Figure 2).

Figure 2. Mean citations of documents per year. Source: Scopus.

3.2. Social Structure

This section analyses the production quantities concerning the country where the research was developed, and which countries are most important in the production of this theme, considering the citations and analysis of collaborations between countries that identify the internationalisation of academic production. The first way to measure the importance of scientific production is through citations (Table 2)

Table 2. Total number of citations per country and average number of citations per article. TC = Total citation. Source: Scopus.

Country	TC	Average Article Citations
USA	7419	44.69
Brazil	3189	27.49
United Kingdom	2411	57.40
Australia	2054	30.21
South Africa	1908	34.07
Canada	1060	22.55
Spain	1032	25.17
Germany	640	26.67
Finland	607	50.58
Tanzania	583	83.29

The USA ranks first in the total number of citations (7419). However, even with a lower total number of citations than the USA, countries like the United Kingdom and Tanzania have higher average article citations than the USA. The United Kingdom's total citations represent 32.49% of the USA's total citations, but they have an average article citation of 57.40; Tanzania represents 7.85% with 83.29 average article citations. The higher values of average article citations of these countries in comparison to the USA indicate a greater impact of their research.

Collaboration between countries is analysed using an index that assesses whether publications are produced intra-country (SCP) or inter-country (MCP) (Figure 3).

SCP: Single Country Publications, MCP: Multiple Country Publications
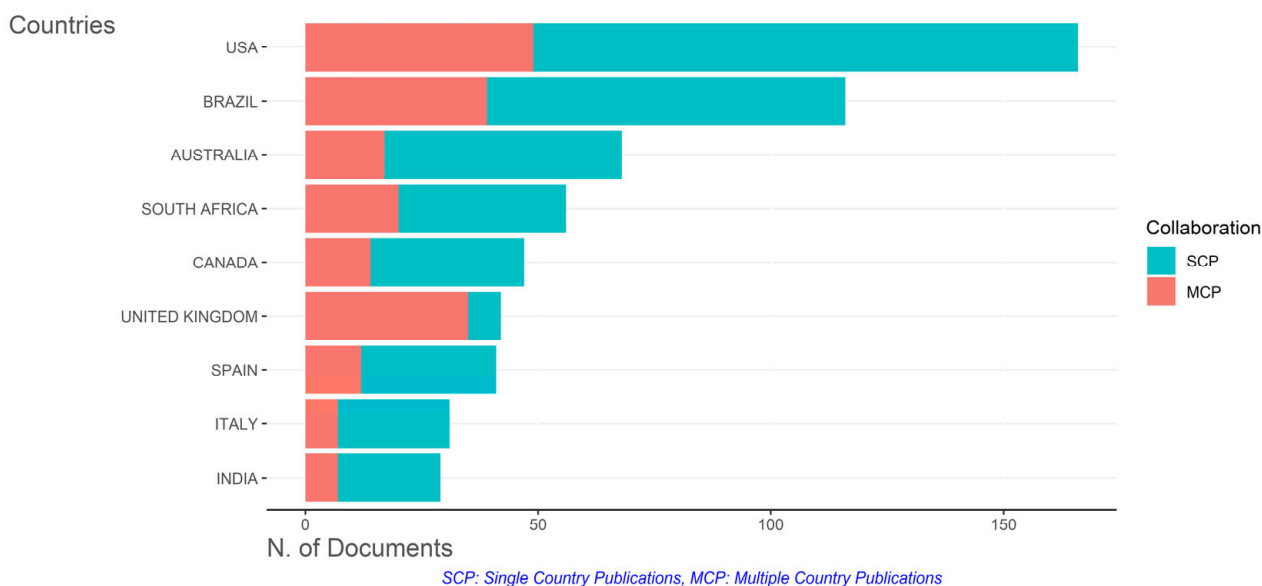
Figure 3. Corresponding author's country. Source: Scopus. Complete data in Supplementary Materials.

Among the first 10 countries, scientific production is concentrated in the SCP in 9 countries, which means that academic relations predominantly occur between internal institutions of the countries. Only four countries maintain higher MCP values compared to the SCP: the United Kingdom (SCP = 7, MCP = 35), indicating that the internationalisation of research in the analysed subject is greater in this country. At the level of institutions, the 10 most relevant are as follows (Table 3):

Table 3. Institution affiliations. Source: Scopus.

Affiliation	Articles
Stellenbosch University (South Africa)	30
University of the Witwatersrand (South Africa)	25
University of California (USA)	22
Scientific Services (United Kingdom)	22
University of Florida (USA)	21
University of Brasília (Brazil)	19
James Cook University (Australia)	18
Oregon State University (USA)	17
University of Pretoria (South Africa)	17
USDA Forest Service (USA)	17

Among the 10 most important institutions, 4 are from the USA, 3 from South Africa, 1 from Australia, 1 from the United Kingdom, and 1 from Brazil. This table helps to complement the analysis of the intra-country (SCP) and inter-country (MCP) collaboration indexes, demonstrating the predominance of American institutions as the most productive in this area of research. The reasons behind this behaviour may be related with the traditional institutional relations and scientific connections existing among English-speaking countries, facilitating cooperation between those universities and researchers.

Another analysis that helps in understanding collaboration networks between countries is provided in Figure 4 and Table 4.
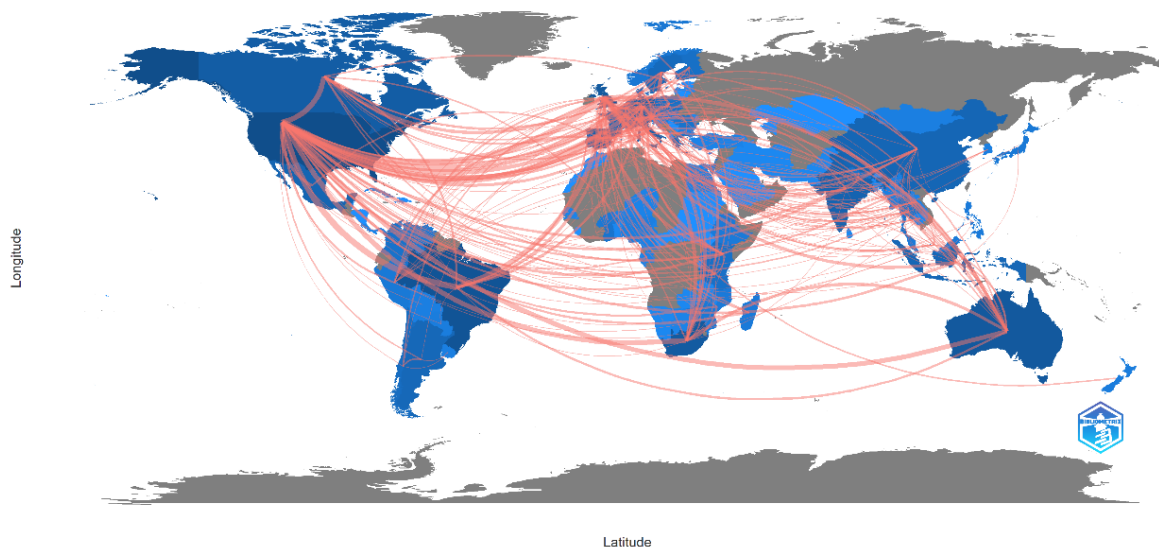
Figure 4. Country collaboration map. Source: Scopus.

Table 4. Country collaboration. Source: Scopus.

From	To	Frequency
USA	United Kingdom	32
USA	Brazil	30
USA	Canada	22
USA	South Africa	21
Brazil	United Kingdom	17
USA	Australia	17
USA	Germany	14
Australia	United Kingdom	12
South Africa	United Kingdom	12
USA	France	11

The country with the highest number of collaborations is the USA, with seven collaborations maintained with countries from all continents. It is important to note that the first four collaborations are maintained by the USA, demonstrating quantitative dominance in the number of collaborations it maintains with countries in Europe, Africa, and South America. The first 10 collaborations are still going strong amongst nations in North America, South America, Europe, Africa, and Oceania, with the USA, the United Kingdom, and South Africa, which have multiple collaborations, dominating the relations.

3.3. Authors and Documents

Scientific production in the 1970–2022 period was developed by 4419 authors, with a concentration of this production, in terms of quantity and quality, in some authors. In this section, we will analyse the main authors who work with the theme (Figure 5).
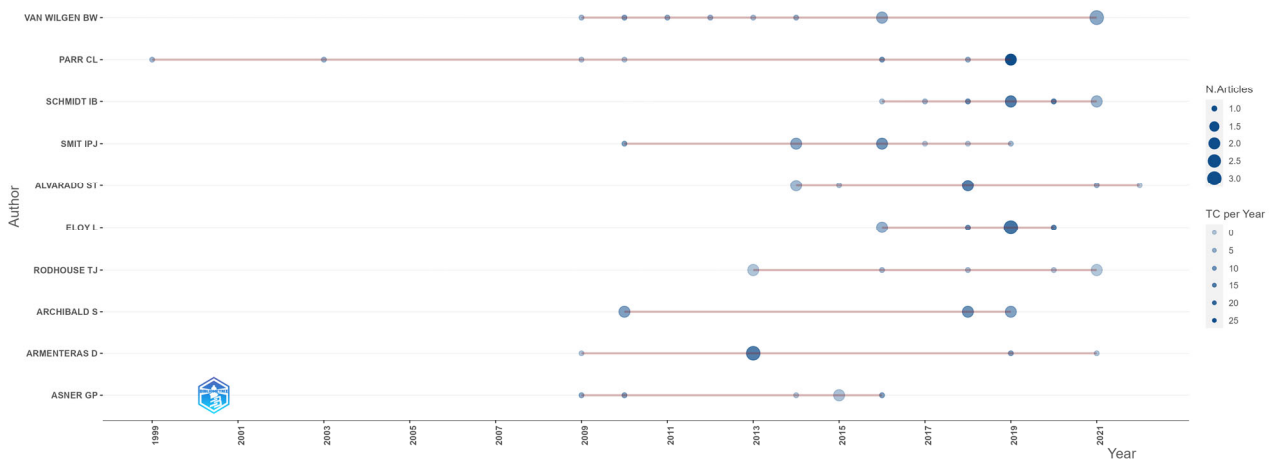

Figure 5. Top authors' production over time. Source: Scopus.

The first 10 authors produced a total of 74 works. Despite the fact that the data series being examined spans from 1970 to 2022, the activity of the most productive authors begins in 1999. Parr C.L. only published one work each year between 1999 and 2003, after which there was a production pause until 2009, when authors van Wilgen B.W., Asner G. P. and Armenteras D. joined him. In addition to the three authors previously mentioned, 22 published papers were also written by Archibald S., Smit I. P. J., Rodhouse T. J. and Alvarado S. T. between 2009 and 2015. The authors Alvarado S. T., O., Archibald S., Armenteras D., Asner G.P., Eloy L., Parr C. L., Rodhouse T. J., Schmidt I. B., Smit I. P. J. and van Wilgen B. W. published 32 publications during the peak output years between 2016 and 2019. Thirteen works have already been published by the authors Alvarado S. T., Armenteras D., Eloy L., Rodhouse T. J., Schmidt I. B. and van Wilgen B. W., between 2020 and 2022. This is less than half of the period between 2016 and 2019, indicating a decrease in the amount of published works.

The most relevant authors, that is, the authors who published the most on the subject, are van Wilgen B. W. with 11 documents. Three authors, each with eight documents, are listed below: Parr C. L., Schmidt I. B. and Smit I. P. J. There are three authors with seven documents each—Alvarado, S. T., Eloy L. and Rodhouse T. J.—and with six documents there are two authors—Archibald S. and Armenteras D.

Regarding the impact measured by the H-index, the most important authors are as follows (Figure 6):
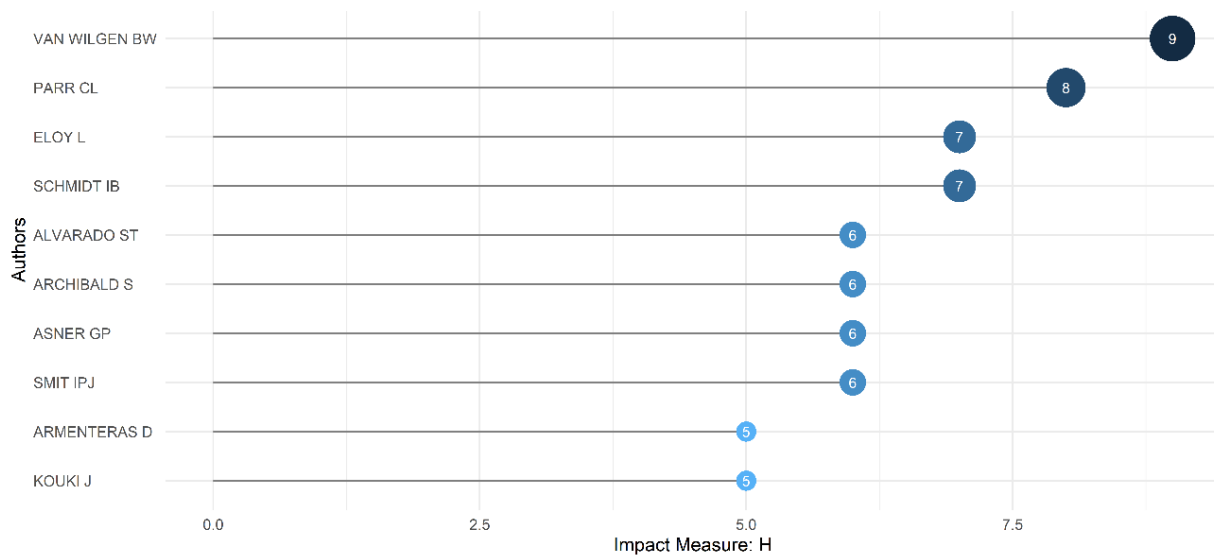
Figure 6. Author local impact by H-index. Source: Scopus.

The author with the highest H-index (9) is van Wilgen B. W. and the author with the next highest H-index (8) is Parr C. L. The H-index of seven is shared by two authors: Eloy L. and Schmidt I. B. The H-index of six is shared by four authors: Alvarado S. T., Archibald S., Asner G. P. and Smit I. P. J. The H-index of five is shared by two authors, Armenteras D. and J. Kouki.

The author productivity through Lotka's Law is presented in Figure 7.
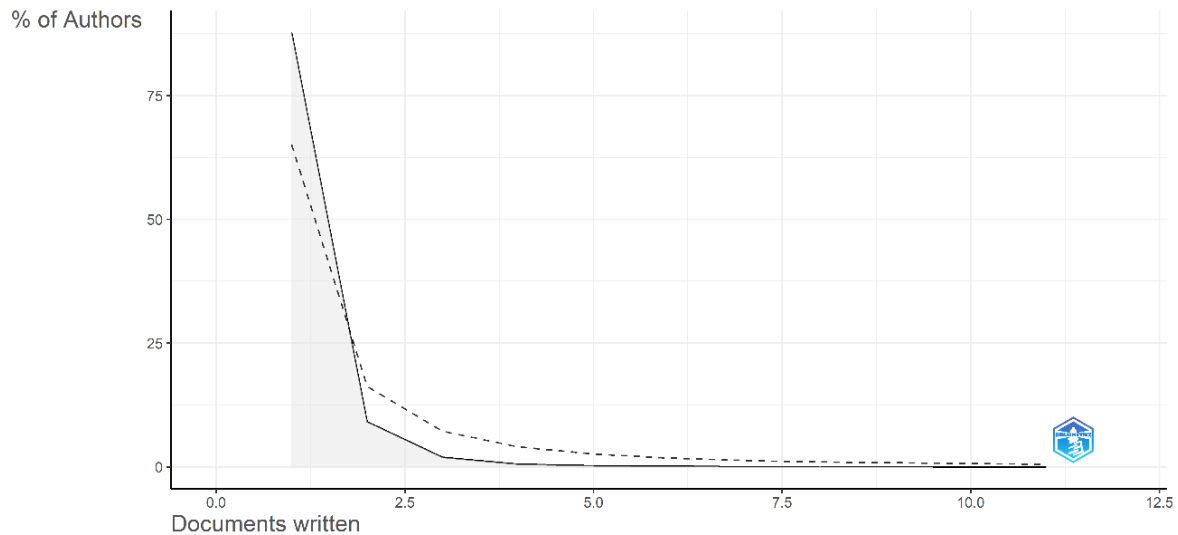
Figure 7. Author productivity through Lotka's Law. Source: Scopus.

The graph shows that 3883 authors, or 87% of the authors, published just one document each, while just 9% of authors—401—published more than two documents. Only 4% of the authors published more than three papers, and Wilgen B.W. was the only author to publish 11 documents, making him the author with the most publications overall.

The top 10 authors' production over time who produce the most work on wildfires and PAs is focused on the Cerrado and Amazonia biomes in Brazil, Amazonia biomes of Colombia, the African savannah, and the United States.

The works of Asner G.P. are essentially focused on the effects of fire on vegetation structure in African savannah [44,45]. In the study by Fisher et al. [46], the authors' works are focused on management practices using fire in private and national reserves.

Armenteras D. conducts research on fire and PAs in the Colombian Amazonia. The majority of his research focuses on PAs and the effects of fire, as well as issues like participatory mapping and socioeconomic variables that contribute to fires breaking out in PAs [47–49].

The author Archibald S. developed his studies predominantly in the savanna biome in Africa and Brazil (Cerrado). His studies on fire in PAs occur in co-authorship with Alvarado et al. [50]. The study of Beale et al. [51] focuses on the control of local fire characteristics (pyrodiversity) and how these variations impact biodiversity in PAs. Archibald et al. [52] conducts an analysis of climate and interannual fire variability in PAs in southern Africa.

Eloy L. conducts research on how traditional livestock practices can manage fires in the Cerrado biome (Brazil) and how this activity can affect PAs [53–56]. Schmidt I. B. has eight works published on this subject, five of which are co-authored with Eloy L. His studies aim to understand the behaviour of fire intensity, with PAs being a complementary research topic [57–59]

The author Alvarado S. T. focuses his publications on themes related to the fire regime in PAs of the Cerrado biome (Brazil). He also has comparative works between PA in Africa and Brazil [50]. In his most cited work as co-author, the research topic is megafires in PA of the Cerrado biome (Brazil), comparing the total burned area and the number of fire scars between PAs [60].

Regarding PAs in the African savanna, the author Parr C.L. has research topics related to the impacts resulting from human activity with the use of fire in PAs and the consequences for wildlife [61–64]. In turn, Smit I. P. J. develops studies on the spatial and temporal patterns of fire and herbivores, in addition to the development of fire management policy in PAs in Africa [65,66]. Finally, van Wilgen B. W. develops his research on fire management in PAs, adaptive management of ecosystems, and control of invasive plants [67–69]

Rodhouse T. J. conducts studies in the USA and focuses on the interaction between fire in PAs in the context of resilience, resistance to invasive species, and impacts of fire on vegetation [70–72].

3.4. Conceptual Structure

A mapping of the co-occurrence network is shown in Figure 8.

Figure 8. Co-occurrence network. Source: Scopus.

The co-occurrence network analysis generated six clusters that divide the dataset according to their occurrence and relationship to other keywords. The word ecosystem is

the main keyword in cluster 1, formed by nine more keywords. In cluster 2, conservation is the main keyword, and this cluster is formed by eight more keywords. In cluster 3, the main keyword is environmental protection, which together with four other keywords forms the cluster. The keyword protected area is the main keyword in cluster 4, which is formed by 10 more keywords. In cluster 5, the main keyword is biodiversity, which together with 10 others form the cluster. Finally, cluster 6 has the keyword South Africa as the main word, which together with two others forms the cluster. Keywords can also be analysed temporally in Figure 9.
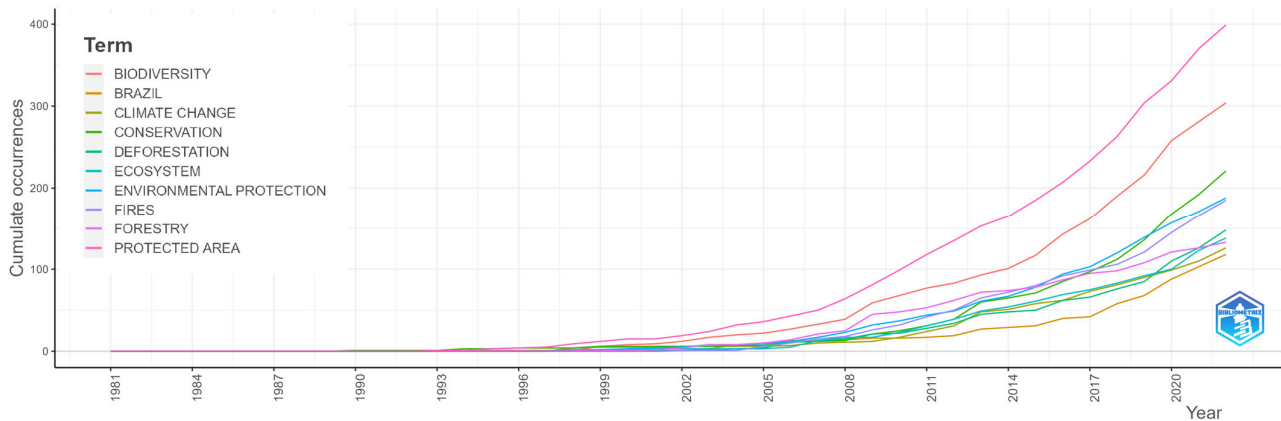
Figure 9. Word frequency over time. Source: Scopus.

Since 1999, the word protected area began to be used more frequently, followed by the words biodiversity, conservation, environmental protection, fires, deforestation, ecosystem, forestry, climate change, and Brazil. One way to visualise the frequency of the use of words is through the Treemap (Figure 10).
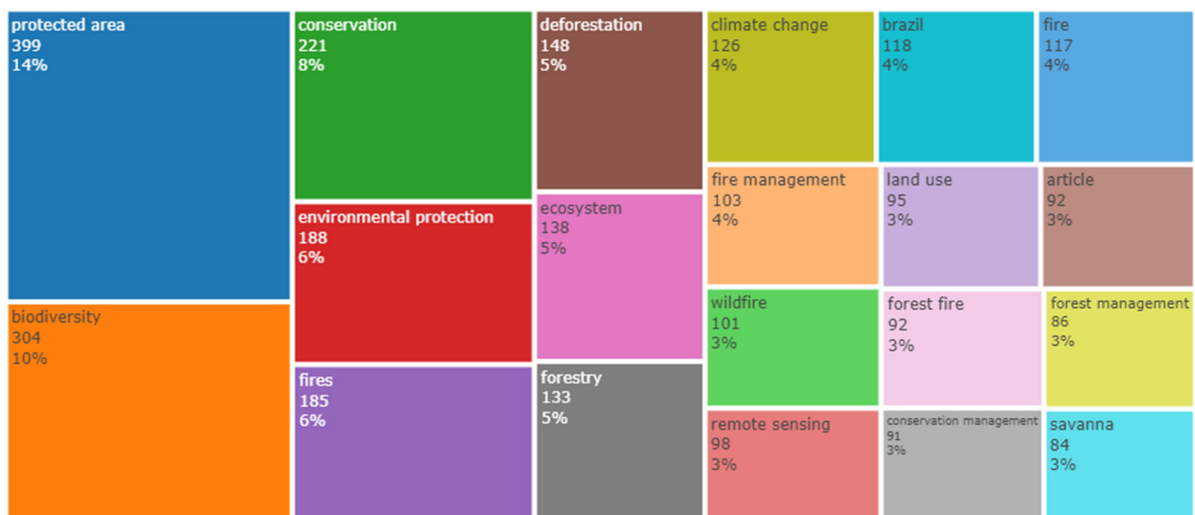
Figure 10. Treemap. Source: Scopus.

The keywords protected area, biodiversity, conservation, environmental protection, and ecosystem, in addition to being among the 10 most frequently used, are also the most important in the clusters of the co-occurrence network analysis. There is an increase in the use of these words from 1997 onwards, with an important change from 2008 onwards, when these keywords become more frequent in the analysed documents.

The coupling analysis of the clusters formed by the keywords classifies them according to the degree of development (density) and the degree of relevance (centrality) (Figure 11 and Table 5).
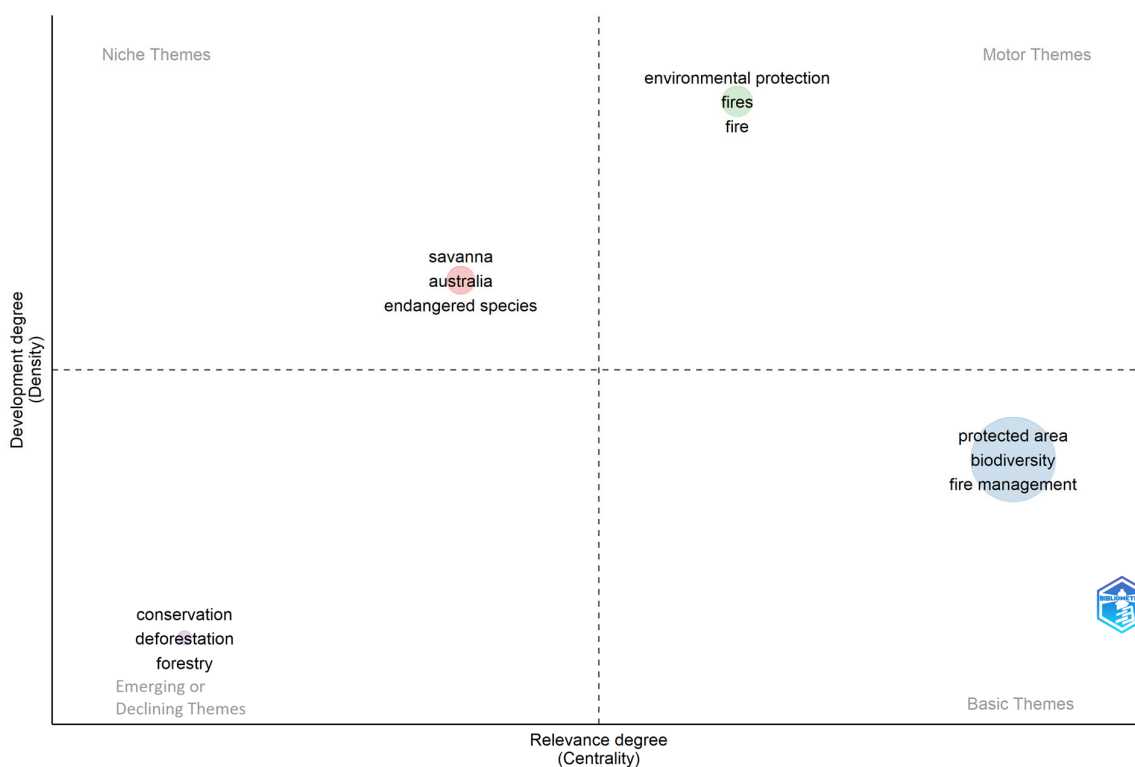
Figure 11. Coupling analysis. Source: Scopus.

Table 5. Callon's index values. Source: Scopus.

Cluster	Callon's Centrality	Callon's Density	Rank Centrality	Rank Density	Cluster Frequency
savanna	7.095	14.044	2	3	1559
protected area	10.493	13.652	4	2	3014
environmental protection	8.186	16.146	3	4	1610
conservation	5.342	12.374	1	1	1332

The coupling analysis shows that the basic themes are related to protected area, biodiversity, and fire management with major centrality and medium density. In turn, the motor themes are environmental protection, fires, and fire, with medium centrality and higher density. Niche themes are savanna, Australia, and endangered species with medium centrality and density. In turn, conservation, deforestation, and forestry are emerging or declining themes with low centrality and density.

4. Discussion

The bibliometric analysis provided an important point for an initial discussion, as the analysis of wildfires in PAs is a field that has not yet been explored much in academic research. Additionally, between 2021 and 2022, fewer documents were published on this theme. The annual trend in document production demonstrates a rise in production after years with a high number of fires, such as California in 1998, Sweden in 2018, and Australia and Brazil in 2020, all of which saw an increase in publications.

The Scopus database provided an overview of the main scientific publishers, and, in this way, it is possible to identify a gap in the scientific production related to PAs and wildfires, becoming a potential area of study that considers the management of these areas in firefighting, contributing to a broader discussion on climate changes.

Regarding the search terms, the keywords "fire" (120 occurrences), "wildfire" (103 occurrences), "forest fire" (96 occurrences), and "bushfire" (4 occurrences) are associated with PAs. In contrast, there have been no instances of "megafire", "wildland fire", "large forest

fire", "extreme fire", or "gigafire", indicating that the topic of large fires and PAs is not directly worked on as a line of research. However, it does suggest a potential subject of study in a scenario of climate change, and, for example, the application of a conservation agenda focused on landscape restoration, rainforest conservation, and ecosystem services. PAs are important sites for maintaining the stability of ecosystems, ensuring, for example, the provision of ecosystem services like water and carbon sequestration.

In PAs, it is possible to institute strategic plans for the management of the territory, creating instruments to combat and control fires that preserve the ecological values and the balance of ecosystems [73,74]. To this end, in addition to improving fire forecasting, it is necessary to include the different social, economic, and political actors in planning [75–77], elaborating a plan that considers, in addition to the territorial management of the PAs, the landscape in an integrated way [78–80].

According to the results, a synthesis of the first top 10 authors' document production over time indicates that production is concentrated on PAs in Brazil, South Africa, and the USA, with the development of joint studies, mainly between Brazil and South Africa when analysing PAs of the savanna/Cerrado biome. The studies focused on conducting an analysis of the impacts of fire on biodiversity resulting from human activity and what management practices can be used to decrease the effects of fire in these areas.

In these regions, there are suitable environmental conditions for fires to occur, such as Brazil, where fires are a widely used instrument to advance the occupation of land in Amazonia [81–83], or fire management practices implemented in South Africa [84].

The top 10 authors are also based in the nations with the most collaborations; however, it is observed that in this regard, the USA has more collaborations than Brazil and South Africa, where some of the top 10 authors are originally from. The UK appears to be a significant collaborator in the production of studies as well.

Regarding the keywords fires, PAs, and other terms indicating the aim of the studies developed—such as biodiversity, conservation, environmental protection, deforestation, and ecosystem—have higher recurrence rates. Thus, we can assume that the analysis of the fire itself provides a support for analyses on the preservation and protection of PAs and the ecosystems they are related to. Additionally, the coupling analysis demonstrated this.

PAs should be further explored by academia and decision makers. It is an important point that relates to international environmental agreements to propose mechanisms for the conservation of ecosystems. Discussion of an integrated landscape management is essential to minimise the effects of climate change on ecosystems and should be considered in the national and local environmental policies of countries.

The academic production on the subject addressed in this article is centred on a few countries that demonstrate good institutional relations. We recognise that researchers from all over the world play a significant role in developing studies on fires and PAs, despite the fact that the total number of published works is still quite small, there is an urgency of developing studies on nature conservation on a planet where climate change affects the dynamics of ecosystems and a need to develop academic studies to support conservation and preservation actions.

5. Conclusions

The bibliometric analysis of wildfires in protected areas showed that this theme does not have a large volume of published papers. Nevertheless, it proves to be an active and important field of study in a context of climate change and the pressing need for ecosystem conservation.

Considering authors, such as Juarez-Orozco et al. [18], Santos et al. [19], Duan et al. [85], and Xue et al. [86], it was possible to observe that the bibliometric analysis focused on themes involving wildfires, remote sensing, and related topics are predominant, with protected areas being secondary themes in this type of work.

The current study makes a contribution in this regard by developing an analysis that takes into account other crucial management issues for these areas, such as fire management, biodiversity conservation, endangered species protection, and environmental protection, in

addition to the application of remote sensing and other methodologies to the study of fire in protected areas. These are significant themes that establish the focus of research on the subject of fires in protected areas.

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