Wildfires In Australia: A Bibliometric Analysis and A Glimpse On 'Black Summer' (2019/20) Disaster

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Abstract

A wildfire, an unplanned fire that is largely uncontrolled and originates in combustible vegetation in rural or urban settings, is one of the most pervasive natural catastrophes in some areas, such as Siberia, California, and Australia. Many studies, such as standard reviews, have been undertaken to look into the works of literature on wildfires or forest fires and their effects on aquatic and terrestrial ecosystems. Regrettably, conventional literature reviews failed to identify the important researchers, evolving complexities, emerging research hotspots, trends, and opportunities for further research on the ground of wildfire study. The present study employs bibliometric analysis to investigate this study area qualitatively and quantitatively. The Scopus database systems and Web of Science Core Collection yielded 78 qualifying papers, which were then evaluated using Biblioshiny (A bibliometrix tool of R-studio). According to the statistics, the discipline is expanding at a pace that is 13.68 percent faster than average. So far, three key periods of transformation have been documented: preliminary evolution (8 articles; 1999–2005), gentle evolution (14 articles; 2006–2013), and quick evolution (56 articles; 2014 to 2021). FOREST ECOLOGY AND MANAGEMENT and SCIENCE journals have the highest number of publications, accounting for 7.70% of total wildfire-related articles published from 1999 to 2021. However, recent data indicate that investigators are shifting their focus to wildfires, with the term AUSTRALIA having the highest frequency (91) and WILDFIRE having the second highest (58) as the most appeared keywords. The present study will provide a foundation for future research on wildfire incidence and management by receiving information by synthesising previously published literature in Australia and around the world.

1 Introduction

Since its widespread distribution began 400–350 million years ago, fire has played a significant role in the dynamics of the global atmosphere and the evolution of biomes (Roach 2020; Haque et al. 2021). In fire-prone ecosystems, fire in the landscape (commonly termed wildfire, wildland fire or bushfire) has been considered as a ‘disaster’ when it engulfs the environmental components at a larger scale beyond control. Wildfires are a worldwide phenomenon that plays an important role in the terrestrial and atmospheric environments (Bowman et al. 2009). It has been around from the beginning of time, and rhyniophyte plant fossils that were preserved as charcoal caused the first known wildfire around 420 million years ago, during the Silurian epoch.(Glasspool et al. 2004). Yearly, around 30–46 million km^2 (approximately 4% of the total land surface) is burned (Randerson et al. 2012). Longer fire seasons are caused by changes of the environmental situation, which influence the frequency and intensity of wildfires (Westerling et al. 2006; Flannigan et al. 2013; Settele et al. 2015) and the wider area covered (Gillett et al. 2004). It all starts with a little site, which might have been caused by a lightning strike or human neglect. It spreads over a vast area of forested areas and locality and has adverse impacts on the environment, ecology, properties, and human health. The abiotic and biotic constituents of the forest ecosystem are destroyed by wildfire (Godfree et al. 2021). At present, climate change and other associated factors are influencing more frequent and intense fires worldwide on a larger scale (Ward et al. 2020). Catastrophic fires have erupted in Australia, USA, Brazil, and Russia in recent years, damaging on a larger scale (Fig. 1).

Like USA, Russia, Brazil, Turkey, Italy and Canada, wildfire is typical in Australia almost yearly (Table 1). In Australia, there are a number of wildfire occurrences have been recorded till now i.e.: Gippsland fires and Black Sunday in 1926, Black Friday in 1939, the Australian Bushfire Season from 1974 to 1975, the Waterfall bushfire in 1980, recent Canberra bushfires in 2003, and the Black Saturday wildfire in 2009 are some examples of devastating wildfires that have occurred in recent history (Weber et al. 2019). The 2019–2020 'Black Summer' wildfires were exceptional among others in terms of burned area, fatalities and ecosystem damages. This mega fire was 50 times more damaging than the historical worst wildfires in California and 5 times more extensive than the Amazon wildfires in 2019 (Ward et al. 2020). More than 15,000 fires occurred across all states of Australia, resulting in a catastrophe for aquatic and terrestrial ecosystems (Filkov et al. 2020). This mega-fire destroyed a large number of flora, fauna and human habitats (Roach 2020). It killed 429 people due to smoke (Johnston et al. 2021), burned over 18 million hectares and damaged 3113 dwellings (Filkov et al. 2020), and destroyed 3 billion animals (Van Eeden et al. 2020). Table 2 shows the overall impacts of Australia's 'Black Summer' bushfire on air, water, soil, biodiversity, food, and human health. The 'Black Summer' culminated in December–January, with significant wildfires consuming around double the total land area of preceding fire seasons throughout numerous states (Morgan et al. 2010), with 2019 being Australia's warmest and driest year on history (Bureau of Meteorology (BoM) 2019). As a result, the cost of Black Summer crossed $110 billion, topped the $4.4 billion cost of the 2009 Black Saturday wildfires, leading to Australia's maximum number of wildfire fatalities (Ell 2020). Large parts of eastern Australia were engulfed in smoke as a result of the Black Summer fires. A quarter of participants in a January 2020 survey in the worst-affected state of New South Wales (NSW) said wildfire smoke had harmed their health (The Australian Institute 2020). Emissions of fine particulate matter have been connected to negative health effects due to wildfire (Cascio 2018), with fatality rates rising on fire days with bad air quality (Morgan et al. 2010; Johnston et al. 2011). Table 3 shows the damages and fatalities caused by 'Black Summer' across Australia.

Australia is habitat to 620,000 species, contributing to 7–10% of all species on the planet (Box 2020). Most of Australia's species and ecosystems are found nowhere else on the planet. The Black Summer fires were termed by the Royal Commission into National Natural Disaster Arrangements (RCNNDA) as an "ecological calamity," with "the most catastrophic habitat destruction for vulnerable species and damage of ecosystems in the postcolonial period" (Wintle et al. 2020). More than 330 biological communities that were severely endangered and 37 biological communities that were threatened were destroyed by the fires; these communities are all protected under national environmental legislation. (RCNNDA 2020; Box 2020). The 2019/2020 bushfires also caused significant damage to vital ecosystems such as clean water supplies. After a fire, the loss of plants and grasses, in addition to changes in the physicochemical properties of the soil, may greatly increase both the amount of surface runoff and the soil's erodibility (Robichaud 2000; Shakesby and Doerr 2006; Shakesby 2011). Following rainfall, soil that has been eroded and ash provide a significant risk of contamination to aquatic systems as well as aquifers (Smith et al. 2011). Algal blooms can be aided by nutrients found in ash and degraded soil that release toxins may induce carcinogenic and non-carcinogenic substances (Hohner et al. 2019).

1.1 Why ‘Black Summer’ Was So Terrible?

According to the 2019 annual climate statement, the 2019/20 Australian wildfire season was the hottest in recorded history, with a maximum temperature of + 2.09°C and an average temperature of + 1.52°C. It surpassed the previous average and maximum temperature records of + 1.33°C and + 1.59°C, respectively, in 2013. The mean minimum temperature change in the 2019/20 bushfire season for Australia was 0.95°C, the sixth-warmest recorded value. Figure 2 shows variations in states' maximum, minimum and mean temperatures. It illustrates that New South Wales, South Australia and Western Australia faced record-breaking maximum and average temperatures.

In addition, between the years 1999 and 2020, the average temperature over the whole of Australia exhibited a large range of variance. The temperature variation ranged from − 1.52 degrees Celsius to 1.52 degrees Celsius above normal during the course of the whole time (Fig. 3). The year 2000 had an average temperature of -0.04 degrees Celsius, while the year 2019 saw an average temperature of + 1.52 degrees Celsius. The lowest average temperature ever recorded occurred in the year 2000, when it fell to -0.04 degrees Celsius. Before the year 2005, the temperature was never higher than + 1°C. However, in 2005, it became the first year when it exceeded + 1°C, and after 2012 the mean temperature was higher than 1°C till 2020, except in 2015 and 2016. These high temperatures in Australia may have a favourable impact on the occurrence of bushfires.

Along with temperature escalation, rainfall pattern was also an influencing factor of recent mega-fires. The rainfall data of Australia was collected from the Special Statement published by the Bureau of Meteorology for 1999–2020-time span. Rainfall data has been represented in this study as every 2 years interval. Rainfall was 578.8 millimetres at the start of the time period, and it continued to climb steadily until it reached its all-time high of 710.6 millimetres in the year 2000.. The rainfall pattern showed a sharp decrease after 2000 and a fluctuating trend until 2009. Then, again, there was a rising trend reaching 683.7 mm in 2010 and 696.7 mm in 2011 (ACS 2020). The lowest rainfall in Australian history was observed in 2019 (Fig. 4). Such a dry season with minimum rainfall ignited 2019/20 bushfires in Australia as a disaster (Filkov et al. 2020). The 2019-20 bushfire seasons began with a lack of rainfall in large swaths of eastern Australia. The unexpectedly low rainfall in 2019 resulted in significant moisture shortages year-round (Bureau of Meteorology (BoM) 2019). The low moisture content is experienced in the Murray–Darling Basin (Filkov et al. 2020). The average annual soil moisture record in five of the Basin's 26 river catchments was the lowest for the year 2019, and after 2018 and 2002, it was the third-lowest on record value for the Basin as a whole. The year 2019 was also the driest year on record for the Basin (ACS 2020). The below-average precipitation that fell throughout the reserving season also had an effect on coastal New South Wales, eastern South Australia, eastern Victoria, northwestern Victoria, the east coast and north coast of Tasmania, and the south west region of Western Australia. Rainfalls in New South Wales, Victoria, and South Australia were the lowest in their history in the 2019/20 season, while Western Australia and Northern Territory faced 2nd most poor rainfall records in history (ACS 2020; Filkov et al. 2020).

Wildfire causes damage to almost every environmental component in a way that is irreplaceable to some extent. Considering the aforementioned wildfire incidence and incurred damages, we aimed to perform a bibliometric analysis for Australia. Bibliometric analysis is the most typical non-traditional review tool. It's a collection of mathematical and statistical techniques for displaying current and ongoing knowledge on a study topic. This tool allows for the collection of reliable quality indicators. It can detect research trends based on country/region publishing outputs, author profiles, and research institutes to create an overall research perspective on a subject of interest. The distribution of words in the article's headline and the keywords can also be used to compare research patterns across time. The current study's conceptual design is depicted in Fig. 5.

2 Methodology

We gathered all of the available data about the number of fires, areas under fire disaster, lives lost, and homes lost from a large compilation of news stories, survey reports, media releases from responsible authorities of the Australian Government, and a few published papers taken from two reliable scientific databases, Scopus and Web of Science. Our goal was to understand the severity of Australian bushfires over the past two decades.. In addition, this research aimed to understand the impacts of several fires on burned areas and homes loss to lives lost in the most affected New South Wales and Victoria states during ‘Black Summer’ and to assess the strength and direction of the relationship between the number of the fire, fired up area, homes and lives losses.

2.1 Data Sources

Several databases offer indexed journal articles, including Google Scholar, Scopus, WoS, and others. Google Scholar has been criticised for admitting works from predatory journals that do not validate their originality or follow basic editorial norms (Ibba et al. 2017; Chapman and Ellinger 2019). Moreover, due to its lack of quality assurance and irregular citation counts, Google Scholar is unsuitable for use as a bibliometric tool (Aguillo 2012). Web of Science (WoS) was the first collection to offer and permit bibliometrics study, covering 1900 to the present (Mingers and Leydesdorff 2015). When compared to Google Scholar and Scopus, WoS asserts that their collection is the most comprehensive and includes papers that have high impact factors (Aghaei Chadegani et al. 2013). The WoS database is distinctive, contains all sorts of articles, and recognises their contributors and bibliographic citations (Mongeon and Paul-Hus 2016). On the other side, Scopus is the world's most comprehensive reference and abstract repository for the peer-reviewed study of science, engineering, pharmacy, and sociology. Elsevier, Springer, Emerald, Interscience, and Taylor & Francis are among the publishers having over 20000 peer-reviewed journals (Fahimnia et al. 2015). Scopus is a well-known scholarly repository for literature and research findings, with both WoS and Scopus-indexed scholarly publications (Falagas et al. 2008; Oakleaf 2009). We decided to explore key terms and keywords in Scopus and WoS repositories in this study, based on the recommendations of (Fernández et al. 2010; Mongeon and Paul-Hus 2016) by combining Scopus and WoS records.

Topic Search, Data Capture and Mining Methods

WoS and Scopus were utilised between January 1 and January 15 2022, to locate all essential papers regarding bushfires/wildfires published between 1999 and 2021. Before 1999, our preferred databases found no published works on wildfires. Because 2022 was not available at the time of the study, articles listed in both repositories following December 31, 2021, were excluded. The following search string was used to conduct the queries: TOPIC keywords: ("bushfire" OR "wildfire" OR "forestfire") AND ("env* impacts" OR "ecolog* impacts" OR "human health* impacts") AND ("australia"). A topic keyword search includes the title of the article, buzzwords, and summary. It was important to verify that the search would be conducted using the correct search word, therefore we utilised quotation marks. Boolean operators were used in order to guarantee that each and every document was gathered.. The Boolean operators used were 'OR' and 'AND,' with the former ensuring that any relevant keywords are detected. The terms in the first set of brackets, however, are only pertinent to the terms in the text.

Both databases have been updated to incorporate citations for English-language research publications, literature reviews, and conference/paper proceedings.After that, researchers manually eliminated documents that didn't fit our criteria and those that didn't have the authors' names, abstracts, or complete text. The revised papers were collected from WoS and Scopus as.txt and.bib files, respectively. Both files were combined using Rcodes in Rstudio, and six duplicate records were detected and eliminated. Finally, 78 records were gathered to conduct the bibliometric analysis (additional information can be found in the supplementary files).

2.2 Data Analysis

A bibliometric analysis can be performed using various advanced tools and software. The most commonly used software includes Gephi, BibExcel, VOSviewer, Histcite, Pajek, Citespace, and Biblioshiny (the bibliometrix package in Rstudio). For Scopus data, Histcite does not provide bibliometric analysis (Fahimnia et al. 2015). BibExcel operates in a complicated environment that necessitates knowledge and expertise to do a simple analysis (Fahimnia et al. 2015). We also discovered that accurately using the merged data in Citespace was impossible. For these reasons, we used the well-known statistical computing software R (Biblioshiny in this case) to do the bibliometric analysis in this work. R is open-source and free software that includes a number of packages for bibliometric analysis (Firdaus et al. 2019).

The bibliometrix tool in R, Biblioshiny, is particularly user-friendly for those unfamiliar with coding (Aria and Cuccurullo 2017). The program yielded data on the most productive authors, countries/regions, institutions, conceptual structure, research hotspots, social structure, and intellectual structure in wildfire research. In addition, the authors' co-citation network was extracted as a Pajek file from Biblioshiny and displayed with VOSviewer for enhanced visualisation.

2.3 Measure of Influence

In 2005, Hirsch devised objective criteria for evaluating a person's scientific productivity (Hirsch 2005). An individual is associated with publications in this context, including an author, country/region, institution, journal, and so on. The h-index measures how many times h of a person's publications have been cited at least h times over a given period (Braun et al. 2006). For example, an author's h-index is 20 if he or she has 20 articles with at least 20 citations. This metric was used in addition to the usual cumulative number of citations and published articles in the current study. Eugene Garfield invented the impact factor (IF) in 1972 as a complement to the h-index. This is a special kind of efficiency measure that appears only in scholarly publications. It's a measure used by journals that shows how often their articles are cited on average over a two-year period. Since the impact factor is strongly correlated with the calibre of the research published in a certain journal, it is often used as a measure of both the quality of the research and the relevance of the study itself (Mao et al. 2015).

3 Results And Discussion

3.1 Summary Information

The data set that was studied in the literature is summarised along with some basic statistics. In order to provide a comprehensive overview of wildfires in Australian literature, it is required to provide such a picture. Table 4 summarises the key findings from 78 publications between 1999 and 2021. The literature entries in the dataset come from 49 distinct sources, including various journals, conference papers, editorials, letters, reviews, and brief surveys, to name a few. There are 297 authors in the dataset, 10 of whom single-authored 12 pieces of literature and 287 among whom co-authored articles with others. The document indicates that, on average, there were 3.81 writers and 4.22 co-authors The dataset contains a total of 262 identified author keywords and 970 keywords Plus entries. The latter part of this article delves more into the academic development of the research area over the course of the last two decades.

3.2 RQ1: How Long Has the Landscape of Wildfire Research in Australia Evolved?

Despite occasional fluctuations over the study timeframe, the cumulative number of publications climbed steadily, as seen in Fig. 6. There was a steady state from 2002 to 2007 with only one publication each year. In 2001 and 2012, there were no publications and the highest number of articles published in 2021 (13 articles). It is conspicuous that from 2015, the interest in wildfire-related research has increased. The research field is rapidly expanding by 13.68 per cent every year. So far, three distinct evolutionary phases have been identified: early evolution (8 articles from 1999 to 2005), sluggish evolution (from 2006 to 2013, there were 14 publications), and rapid evolution (56 publications from 2014 to 2021). When comparing articles from the beginning of evolution to those from the slow and rapid evolution periods, the cumulative growth rates are 75% and 600%, respectively. It is unsurprising that after 2015, the number of articles has increased dramatically, as some major wildfires occurred and 2019/2020 ‘Black Summer’ megafires got considerable attention among researchers. The mean total citations per article (MeanTCperArt) pinnacled in 2007 (80), followed by 76 in 2006, and no citations were counted in 2001 and 2012. Since 2018, there has been a considerable reduction in citations, owing to the fact that it takes many years for recently published works to obtain significant citations. This section's trend shows how communication and investigation in this area of science are inciting the scientific community's interest. This is a positive step toward wildfire research and fire management.

3.3 RQ2: How Are the Scientific Studies on Wildfire Distributed Among the Core and Other Scientific Journals in This Research?

The source of the articles was investigated in order to establish which journals had the greatest number of publishing. The top ten highest prolific journals are listed in Table 5. The journals FOREST ECOLOGY AND MANAGEMENT and SCIENCE have the most publications, accounting for 7.70% of all wildfire-related papers from 1999 – to 2021. For journals that publish articles on the study's topic, it's useful to look at the number of publications as well as other indices like impact factor, total citations (TC), and h-index. Despite having low number of publications (NP = 2) in CLIMATIC CHANGE, in terms of TC, it has garnered considerable attention (116) after FOREST ECOLOGY AND MANAGEMENT (NP = 6, TC = 214) and PLOS ONE (NP = 5, TC = 143). This could be attributed to the fact that FOREST ECOLOGY AND MANAGEMENT is the journal with the earliest publication year (PY = 2004) while CLIMATIC CHANGE started its publications in 2016 and PLOS ONE in 2011. The correlation among NP, h-index and TC is pretty significant and positive. Regarding the impact factor (IF), SCIENCE (41.84), THE LANCET PLANETARY HEALTH (19.173), SCIENCE OF THE TOTAL ENVIRONMENT (7.963) and JOURNAL OF ENVIRONMENTAL

MANAGEMENT (6.789) established as the publications that include high-quality scientific writings that have been peer-reviewed. The top six journals' progression throughout time is depicted in Fig. 7. There were little scholarly efforts on the issue in these journals from 2000 to 2004. FOREST ECOLOGY AND MANAGEMENT was the most widely published journal on this subject from 2004 to 2014, when it was temporarily surpassed by PLOS ONE. However, FOREST ECOLOGY AND MANAGEMENT reclaimed its status as the premier publication in this field from 2020 to 2021. In the 2020–2021 period, FOREST ECOLOGY AND MANAGEMENT, SCIENCE, PLOS ONE and SCIENCE OF THE TOTAL ENVIRONMENT were the leading journals in terms of productivity.

3.4 RQ3: What Organizations and People Have Done the Most to Advance Knowledge in This Field?

Furthermore, from 1999–2021, on the topic of wildfire research, a total of 124 research institutions contributed. About 8.06% of all organisations have published at least three publications. This shows that only a few Australian organisations are actively driving this field of research. Figure 8 depicts the outputs of the top ten organisations in this study displays the contributions of the most relevant institutions in wildfire research in Australia. With 18.97% of the publications produced by these ten institutions, the UNIVERSITY OF TASMANIA has been the most prolific, followed by the UNIVERSITY OF NEW SOUTH WALES (17.24%). The third most productive institutions were found CHARLES DARWIN UNIVERSITY (12.07%) and THE AUSTRALIAN NATIONAL UNIVESITY (12.07%) with a similar number of articles. According to the information gathered, 297 authors have written at least one article about wildfires between 1999 and 2021. 7.41% of these authors have at least two publications, and others produced single publications. Table 6 lists the top ten authors on the subject of wildfire research. These ten authors have combined produced 54 of the 329 documents retrieved (16.41%). It is seen that LINDENMAYER D from The Australian National University (ANU) is the writer with the largest publication and multiple performance indicators are implemented in the field; it is found to be the most productive. He has the maximum overall citations as well as the highest h-index. As a result, We endeavoured to figure out what it was about this author that made them so successful in their area. The author has four publications, the highest in wildfire research from 2011 to 2019. In addition, he is working as an Ecology and Conservation

Biology professor at ANU, having long experience in his sector. These factors may account for the author's greater interest and dominance in the field.

Figure 9 shows the annual scientific output of the 10 most important researchers. The larger circles imply that there were more publications during that time. The darker the hue of the circles, the more citations of the published articles there are. The first and most recent publications of the most productive writer, LINDENMAYER D, were published in 2011 and 2019, respectively, as shown in Fig. 9. The authors with the most significant contributions in this discipline are N BURROWS and T PENMAN. It's worth noting that only BURROWS N was among the first to contribute to the field (from 2000). Figure 10 shows the research collaboration of authors from same/different institutions. There are four clusters found consists of 49 authors. The largest cluster (green) consists of 17 authors, the red cluster have 17 authors, 12 authors from blue and the fewest authors (three) were in yellow clusters. Figure 11 shows the density visualisation based on the author's collaboration network with the color spectrum. It shows that two clusters are highly dense, composed of authors “price”, “bowman” and “bond” and another is “pausas”, “gill” and “williams”. There are also six light yellow-colored dense clusters as seen in Fig. 11 centred by “clarke”, “burrows”, “penman”, “noble”, “lindenmayer” and “mccarthy”. Authors who have more collaborations with others are visualised as red marked clusters followed by green and blue. It can also be seen with a more dense color spectrum in density visualisation analysis for more productive authors with higher collaboration. To increase the research outcomes on the topic of wildfire research in Australia, researchers should be encouraged to join international and national collaborations.

3.5 RQ4 Where Is the Current Wildfire Research in Australia Focusing, and What Are the Emerging Trends?

Keywords Plus is used in this part to find research hotspots and trends in wildfire studies. Words or phrases that occur often in the titles of citations inside an article but not in the titles themselves or as Author Keywords are considered Keywords Plus.Garfield (1990) claimed that Keywords Plus terms may represent the contents of the article at a deeper level and with more diversity, whereasZhang et al. (2016) suggested that Keywords Plus should be used in scientific disciplines' bibliometric analysis.

Figure 12 highlights the fifty most regularly mentioned phrases in the research field. The most often occurring phrases are AUSTRALIA and WILDFIRE, followed by ENVIRONMENTAL IMPACT and FIRES. The frequency of top 10 Keywords Plus is found at least 16 times, and the observation suggests that all of them have mainly centred on the fire, smoke, and environmental impacts of wildfire. It is unsurprising that the term AUSTRALIA got the highest frequency (91), and WILDFIRE got the second highest (58) because most research articles focused on fire or bushfires. Authors are assessing ecological or environmental impacts after the occurrence of wildfires in Australia. This trend is presently escalating with the increasing interest of researchers. Figure 13 shows the top six Keyword Plus growth from 2000 to 2021. AUSTRALIA, WILDFIRE, ENVIRONMENTAL IMPACT, FIRES, CLIMATE CHANGE and SMOKE are mostly abundant and have the highest growth in between the study timespan. AUSTRALIA is most frequent and has maximum growth followed by WILDFIRE and FIRES. From 2000 to 2015, the growth was slow, but from 2016, the word growth escalated significantly till 2019, and after that period, research intensity was maximum and got the highest frequency. It shows that research interest in wildfires or fires has increased dramatically in recent times in Australia.

4 Wildfire Management In Australia

Wildfires, including droughts, have long been a part of Australia's natural climate. Wildfires are now a significant environmental and socioeconomic threat, with government agencies in Australia and New Zealand spending millions per year to combat them. An increasing number of people are settling in the rural-urban transition zone, which is very vulnerable to bushfires, thanks to expanding capital and regional cities and a better lifestyle. Wildfire-related disasters have made them victims. The basic components for every potential wildfire include fuel such as grass, leaves, and twigs, oxygen from the surrounding air, and heat or outright flame.. The fuel type and size, moisture content and degree of compaction of the fuel, climate, and geography are only some of the environmental elements that might influence how far a wildfire that has been started using these materials will go..

However, Australia should concentrate on wildfire reduction by reducing the likelihood of a fire and limiting the fire's spread. The four key types of fire prevention techniques are as follows.

- Land or Soil Management
- The building or House Management
- Community or Mass Education
- Fire Risk or Danger Warnings

4.1 Land or Soil Management

Land management techniques could be one of Australia's significant options for fire risk management. Land management is crucial to minimise the losses and intensity of fires during and after fire incidents. It might be effective in:

- Reducing forest or grassland fuel presence;
- Slowing and often stopping bushfires spread; and
- Offering firefighters with better access routes to reach the blazing locations easily

A community-based approach is also needed for land management strategies for firefighting across Australia. For example, rural people or people who live near the bushland in urban areas have their neighbours and the broader community responsible for land management and fire prevention.

4.2 The building or House Management

Strong building codes and regulations should be established for each Australian state to make buildings or houses more resistant to fire hazards. Local government authorities in some Australian bushfire-prone states have rules governing home siting, layout, and the use of construction materials. The authority should keep an eye on implementing all building design and planning requirements. These measures can be effective in minimising damage to houses and reducing fire losses, and preventing and spreading bushfires.

4.3 Community or Mass Education

Unstable flames from devices like welding equipment, a bonfire, or outdoor cooking facilities may easily ignite a fire. Most bushfires in Australia are caused by human activity, such as careless or reckless burning or flames that spread from trash fires.

In Australia, community education is especially important because of the high bushfire incidence rate due to the callous activities of citizens. Education campaigns aim to inform the public about the dangers posed by wildfires and the preventative measures that may be taken. However, community education could be effective if it can provide answers to the following three questions to the inhabitants:

- What should be the preparation measures before the bushfire season?
- What to do if a bushfire approaches?
- When choosing a home site?

4.4 Fire Risk or Danger Warnings

Television and radio programs could help inform the general public about their duties in terms of fire prevention. These fire safety and prevention campaigns could be aired annually, especially for fire-prone states across Australia. These programs should deliver advice on campfire prevention, the management of fuel burn-offs, the combustion of trash in outdoor fires, and the proper disposal of cigarette butts. Moreover, they can inform citizens about the category of impending danger to adopt necessary measures. Besides, responsible authorities of different states should focus on the following actions and strongly implement the guidelines.

- The entrance should be restricted into the forest land
- Boosting microbial soil activity may help stop soil erosion.
- Use fuel that is good for the environment to cool down.
- Create wildlife Sanctuary to protect endangered species
- Planning for a development project that is good for the environment

However, researchers and policymakers are confronting several challenges in understanding fire threats' magnitude and designing effective management approaches. There is a lack of data and trustworthy research articles, preliminary fire impact assessment studies and inadequate study on the cause-effect relationship of fires are some challenges for researchers to forecast before fire seasons. Bushfires also present several additional management challenges. The challenge is to provide stakeholders with reliable information on the rate of fire spread and the location of the forefront so that they can plan secure preparation time in their specific circumstances. Another challenge is predicting the effects of fires on various flora and fauna species composition. These challenges, however, should be addressed by responsible authorities in Australia with the goal of “long-term improvements rather than short-term fixes of the system.”

5 Research Gaps

There are a few gaps in the field's existing literature, according to the titles and abstracts of the 78 publications recovered and the conclusions of the current study. The first research gap is the scarcity of studies on management policies and regulatory systems to limit wildfires' size. Most of the published articles were based on wildfire causes and consequences. Second, most research focuses solely on fires' ecological and environmental effects but does not significantly discuss human health impacts. According to (Wintle et al. 2020), the megafires in Australia during 2019–2020 resulted in the devastating loss of human life, the worst destruction of habitats for endangered species and damage to ecological communities in postcolonial history. They studied to protect impacted species from extinction and showed how to avoid repeating the impacts of such devastating bushfires. (Munawar et al. 2021) A holistic bushfire evaluation and mitigation model based on a mixed-method approach of Geographical Information systems (GIS), remote sensing, and Unmanned Aerial Vehicles (UAV). Merely these studies are the most recent notable investigations about fire management after the study conducted by (Kanowski et al. 2005). These studies will be necessary for responsible authorities to adopt the proper fire impacts mitigation and management policies. Another research gap is the small amount of study done in this area. Though our study in section 3.1 (RQ1) indicates that the research field is expanding, the annual growth rate is not encouraging. Finally, there is still potential for development in Australia regarding inter-institution/author joint research.

6 Limitations Of The Study

It is worth mentioning that the current study is not spared from limitations. This literature review and bibliographic analysis was solely performed by focusing on wildfires in Australia and didn’t compare with other occurrences elsewhere. Therefore, future research opportunities exist to comprehend the situation in Australia and other nations impacted by wildfires. Furthermore, the search phrases were used at the authors' discretion to reduce excessive contamination in the database as much as possible. However, if more relevant search phrases were included, different results might have been obtained. Nevertheless, we do not expect a considerable departure from the current study's conclusions. By integrating numerous databases, timespan, and relevant search phrases, a future study could supplement the present study to find other minor but relevant studies.

7 Conclusion

Wildfires are a common and frequent occurrence in Australia, and they have played a key role in altering the continent's landscape for millions of years. Research related to wildfires has been growing in Australia for the last two decades. A bibliographic analysis is effective in this context to know the research status and research gaps. Bibliometric analysis successfully distinguishes and maps the accumulated scientific knowledge and subtleties of evolution in well-known domains by making sense of huge amounts of unstructured data in a systematic way. So, a well-done bibliometric study can help academics get a more complete picture of the research area, find gaps in knowledge, come up with new research ideas, and figure out how they want to contribute to the field, laying the groundwork for the field to move forwards in new and important ways. This study gives a list of signs that can be put together to make a useful picture for advancing wildfire research. The key data of 78 different kinds of literature published between 1999 and 2021 was obtained using bibliometric approaches from 49 sources based on the Web of Science Core Collection (SCI and SSCI) and Scopus databases. Since 2016, the research industry has grown a lot, at an average rate of 13.68% per year. This study also showed that six core journals namely SCIENCE, SCIENCE OF THE TOTAL ENVIRONMENT, JOURNAL OF ENVIRONMENTAL MANAGEMENT, FOREST ECOLOGY AND MANAGEMENT, THE LANCET PLANETARY HEALTH and PLOS ONE on wildfires research in Australia. From 1999 through 2021, a total of 124 research organisations contributed to wildfire studies. Only 8.06% of all institutions have produced at least three publications. From 1999 through 2021, a total of 297 authors have published at least one paper about wildfires. 7.41 per cent of these authors have at least two publications, while others have only one. To handle this topic, more tremendous efforts are needed to foster more cooperation among academics from the same/different institutions. International collaboration can also aid capacity building and technology transfer for wildfire research. This could be especially advantageous for countries that are most affected by wildfires. The current study's findings may aid in clarifying the existing state of research and future directions for public officials and academia.

Declarations

The authors do not have existing conflict of Interest.

-Ethical Approval- Not applicable
-Consent to Participate- Agreed by all authors
-Consent to Publish- Agreed by all authors
-Authors Contributions- See below table (Name in order, contribution):

KH	conception, design of the work, interpretation of data, have drafted the work, substantively revised it
MU	conception, design of the work, the acquisition, analysis, interpretation of data, have drafted the work
JA	design of the work, interpretation of data, substantively revised it
MHa	interpretation of data
MSH	interpretation of data
MR	interpretation of data
MYH	interpretation of data
MSH	interpretation of data
MZR	conception, the acquisition, analysis, have drafted the work, substantively revised it

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Tables

Table 1
Wildfire occurrences in different Australian states

Year	Wildfires	States	Burned Area (ha)	Fatalities	Destroyed Homes	References
1994	Eastern seaboard fires	New South Wales	400000	4	225	(BoM 2022)
1997	Dandenong bushfire	Victoria	400	3	41	(CNN 1997)
1997	Perth and South-West Region bushfires	Western Australia	23000	2	1	(CNN 1997)
2002	Black Christmas bushfires	New South Wales	753314	0	121	(NSW Government 2007)
2003	Canberra bushfires	Australian Capital Territory	160000	4	500	(BoM 2022)
2003	Eastern Victorian alpine bushfires	Victoria	1300000	0	41	(AIDR 2003)
2005	Eyre Peninsula bushfire	South Australia	77964	9	93	(Manton 2012)
2006	Jail Break Inn Fire	New South Wales	30000	0	7	(SMH 2006)
2006	Victorian bushfires	Victoria	160000	4	57	(The Courier 2007)
2007	2006–07 Australian bushfire season	New South Wales, Victoria, Tasmania	1360000	5	83	(Kennedy et al. 2006; Morton et al. 2006)
2007	Kangaroo Island bushfires	South Australia	95000	1	0	(Peace and Mills 2012)
2009	Black Saturday bushfires	Victoria	450000	173	2029	(CFA 2019)
2013	Warrumbungle bushfire	New South Wales	54000	0	53	(Van de Wetering 2013)
2013	New South Wales bushfires	New South Wales	100000	1	208	(RFS 2022)
2015	Esperance bushfires	Western Australia	200000	4	10	(Beattie and Baker 2015)
2015	Pinery bushfire	South Australia	85000	2	91	(AIDR 2016)

Year	Wildfires	States	Burned Area (ha)	Fatalities	Destroyed Homes	References
2016	Waroona Fire	Western Australia	69165	2	181	(BoM 2022)
2017	New South Wales bushfires	New South Wales	52000	0	41	(SBS News 2017)
2019	Tingha bushfire	New South Wales	23419	0	19	(BoM 2022)
2020	Black Summer bushfires	Nationwide	18636079	34	3051	(Brulliard and Fears 2020; Noble 2020)

Table 2
Bushfire impacts after 2019-20 season in Australia.

Affected components	Impacts
Air	o Air quality has been destroyed in fire affected states (Glover and Jessup 1999; Sastry 2002; Sapkota et al. 2005) and the Air Quality Index (AQI) have been escalated (Zhou 2019). o A NASA survey conducted in mid-December 2019 confirmed that the New South Wales and Queensland wild fires produced 250 million tonnes of CO_2 since 1 August. NASA later reported that 306 million tonnes of CO_2 had been released as of January 2, 2020 (Readfearn 2019) o The fine particles in Sydney recognized worldwide as $PM_{2.5}$ were measured at 734 μg (0.01133 gm) which is the equivalent of 37 cigarettes (BBC News 2020) and Smoke created a brown tint to the snow and the sky in Auckland turned into orange (Haque et al. 2021)
Soil	o The bushfires in 2019/2010 seriously destroyed millions of ha of Australia's land, damaging both above ground vegetation and lower ground root masses as well as soil (AAS 2020) o The stored carbon in lower ground soils and vegetation (terrestrial carbon sinks) has been disturbed due to damage of above ground vegetation (AAS 2020) o The 2019/20 bush fire was strong enough to radiate heat to the underlying soil layers that disintegrated soil aggregates and soil organic matter, many essential nutrients and soil microorganisms are lost from soil (Maunder 2019; AAS 2020)
Water	o Cyanobacterial blooms and subsequent imbalanced aquatic ecosystem observed across Australia (DAWE 2021) o Organic matter, salts, trace metals from ash of burned vegetation into water bodies reduced dissolved oxygen resulting in fish killing was observed in Australia after 2019/20 bushfire season (AAS 2020) o A downpour following the 2019 bushfires, significant amount of ash was introduced into surface water in NSW resulting in increased chlorine level (Ward et al. 2020)
Biodiversity	o Around 143 million mammals, 2.46 billion reptiles, 181 million birds, 51 million frogs were affected and at least 3 billion terrestrial vertebrates were displaced or destroyed (Van Eeden et al. 2020) o About 33% Kangaroo Island Forest area was damaged which is the last habitat of Kangaroo Island dunnarts and Kangaroo Island glossy black cockatoos (DEW 2018; Brulliard and Fears 2020) o NASA reported that the number of dead koalas on the Kangaroo Island might be 25,000 or about 50% of the species' total population (Dvorsky 2020) o One quarter of Ligurian honey bee hives was ravaged that lived in the Kangaroo Island (Khalil 2020) o After the megafires, the Kangaroo Island assassin spider and the Kangaroo Island micro-trapdoor spider have not been found till the study findings was circulated and it was believed that they might be fully destroyed or displaced (Marsh 2020; Haque et al. 2021)

Affected components	Impacts
Food safety	o Agricultural production and average farm incomes have been recorded to have dropped by 8% in 2019/20; about 4% below the 10-year average across Australia (ABARES 2020) o Australia's total agricultural exports are projected to drop by 11% to 43 billion USD in 2019-20 (Dvorsky 2020)
Human health	o The most frequent complaints after black summer bushfire season were eye and throat pain, coughing, and headaches (Borchers Arriagada et al. 2019) o According to a recent study, the bushfires smoke caused 2,027 people to be admitted to hospitals with respiratory issues and 1,305 people with asthma-related conditions (Borchers Arriagada et al. 2019) o Approximately 1,100 people were hospitalized with cardiovascular complications caused by the fires (Duckett et al. 2020) o People suffered more than twice from post-traumatic stress disorder (PTSD), depression, mental anxiety in ‘highly impacted' communities where people died or properties were damaged (Duckett et al. 2020)

Table 3

Fire and related losses of ‘Black Summer’ fires erupted in different states of Australia (Filkov et al. 2020; Noble 2020; Wuth 2020)

State	Number of fires	Fatalities	Homes lost	Burned area (ha)
Victoria	3500	5	396	1500000
New South Wales	10520	26	2448	5500000
Queensland	N/A	0	48	2500000
Tasmania	N/A	0	2	36000
Western Australia	N/A	0	1	2200000
South Australia	1324	3	151	490000
Northern Territory	N/A	0	5	6800000
Australian Capital Territory	N/A	0	0	86464

Note: N/A = No data available

Table 4
Main information about the final and merged dataset

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1990:2021
Sources (Journals, Books, etc.)	49
Documents	78
Average years from publication	6.83
Average citations per documents	23.83
Average citations per year per doc	3.461
References	4404
DOCUMENT TYPES	
article	63
conference paper	3
editorial	3
letter	1
note	2
review	4
short survey	2
DOCUMENT CONTENTS	
Keywords Plus (ID)	970
Author's Keywords (DE)	262
AUTHORS	
Authors	297
Author Appearances	329
Authors of single-authored documents	10
Authors of multi-authored documents	287
AUTHORS COLLABORATION	
Single-authored documents	12
Documents per Author	0.263

Description	Results
Authors per Document	3.81
Co-Authors per Documents	4.22
Collaboration Index	4.35

Table 5
Performance of top 10 most productive journals

Element	IF	h-index	TC	NP	PY-start
FOREST ECOLOGY AND MANAGEMENT	3.558	4	214	6	2004
SCIENCE	41.84	5	60	6	2018
PLOS ONE	3.24	4	143	5	2011
SCIENCE OF THE TOTAL ENVIRONMENT	7.963	4	96	4	2016
JOURNAL OF ENVIRONMENTAL MANAGEMENT	6.789	3	82	3	2018
THE LANCET PLANETRAY HEALTH	19.173	1	8	1	2020
AUSTRALIAN FORESTRY	1.9	2	38	2	1999
CLIMATIC CHANGE	4.743	2	116	2	2016
FIRE	N/A	1	9	2	2021
INTERNATIONAL JOURNAL OF WILDLAND FIRE	2.627	2	17	2	2018

Note-NP: Number of publications; TC: Total citations; IF: Impact factor; PY: Publication year; N/A: Not available

Table 6
Authors productivity

Author	Affiliation	h-index	TC	NP	PY-start
LINDENMAYER D	The Australian National University	4	167	4	2011
BANKS S	Charles Darwin University	3	138	3	2011
BLAIR D	The Australian National University	3	126	3	2011
BURROWS N	Department of Conservation & Land Management	2	24	3	2000
DIXON K	Curtin University	3	129	3	2006
MCBURNEY L	The Australian National University	3	126	3	2011
PENMAN T	University of Melbourne	2	130	3	2007
SHARPLES J	University of New South Wales	2	102	3	2015
BINNS D	University of New South Wales	2	129	2	2007
EVANS J	Charles Darwin University	2	116	2	2016

Figures

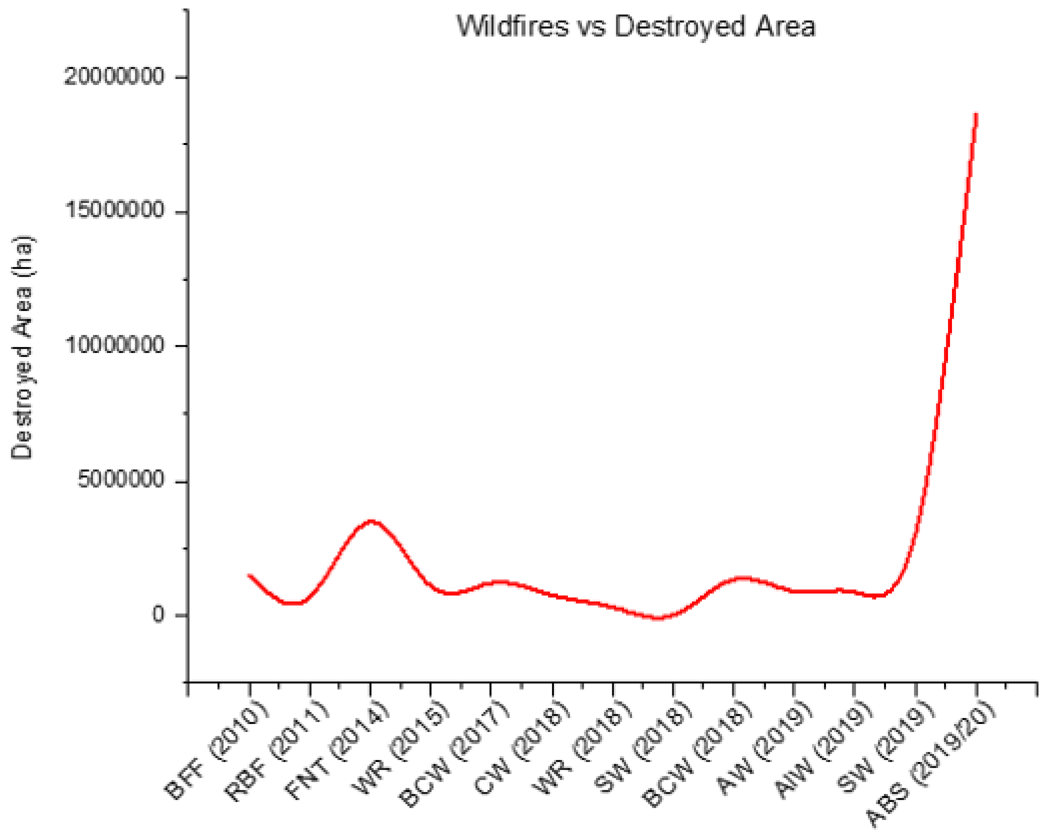

Figure 1

Global wildfires and damaged areas (Filkov *et al.* 2020; Ward *et al.* 2020)

Note: BFF = Bolivia Forest Fires; RBF = Richardson Backcountry Fire, Canada; FNT = Fires in Northwest Territories, Canada; WR = Wildfires of Russia; BCW = British Columbia Wildfires, Canada; CW = California Wildfires, USA; SW = Sweden Wildfires; BCW = British Columbia Wildfires, Canada; AW = Amazon Wildfires; AlW = Alberta Wildfires, Canada; SW = Siberian Wildfires, Russia; ABS = Australian Bushfire Season

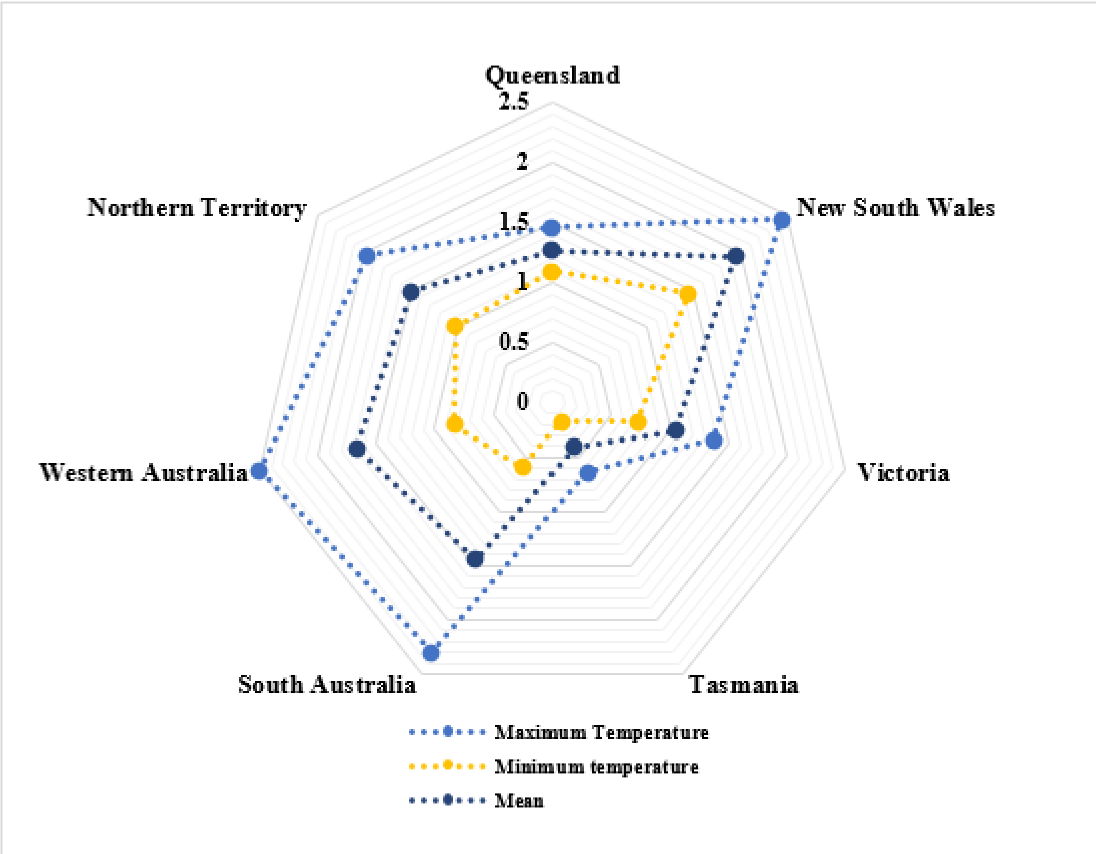

Figure 2

Temperature (°C) upsurge in Australian states in 2019-20 bushfire season (ACS 2020)

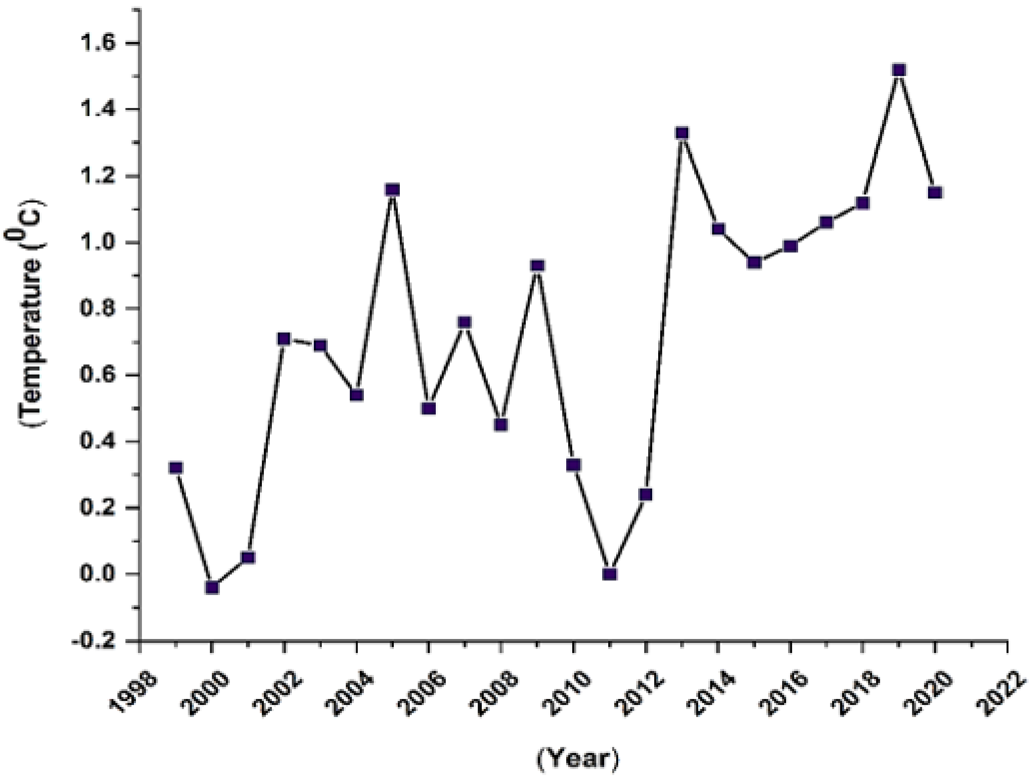

Figure 3

Inconsistency of the average temperature (^{0}C) during 1999-2021 (ACS 2020)

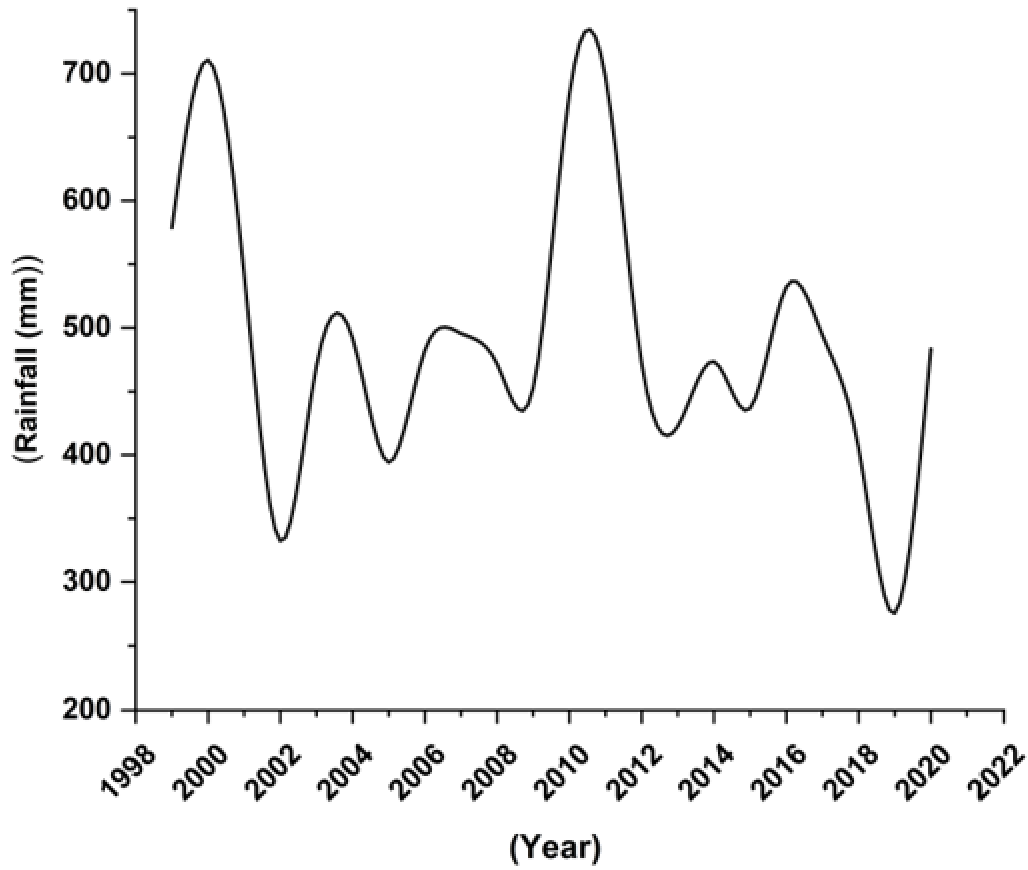

Figure 4

Average rainfall (mm) pattern of the last few years (ACS 2020)

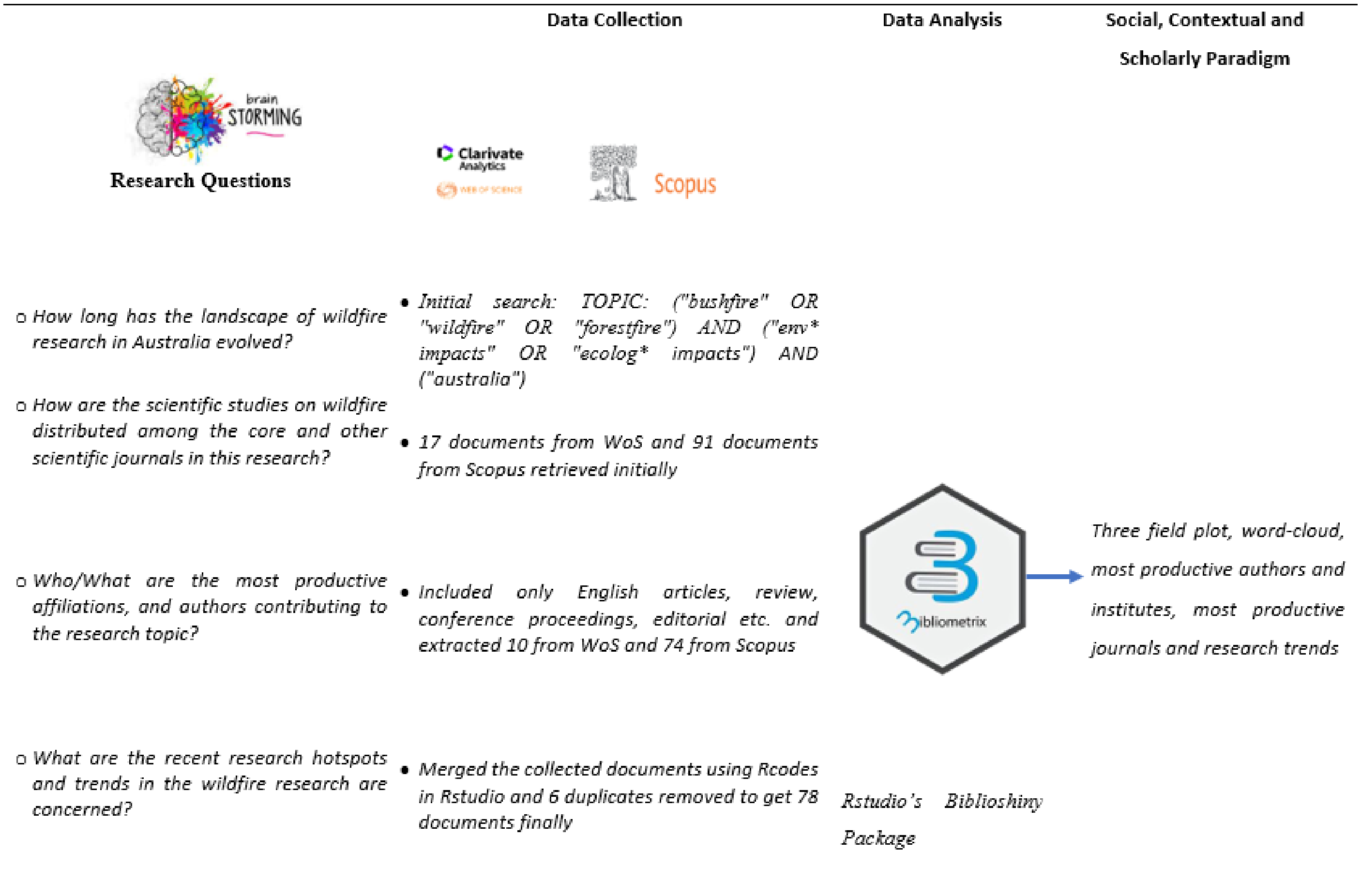

Figure 5

Conceptual design of the current bibliographic study

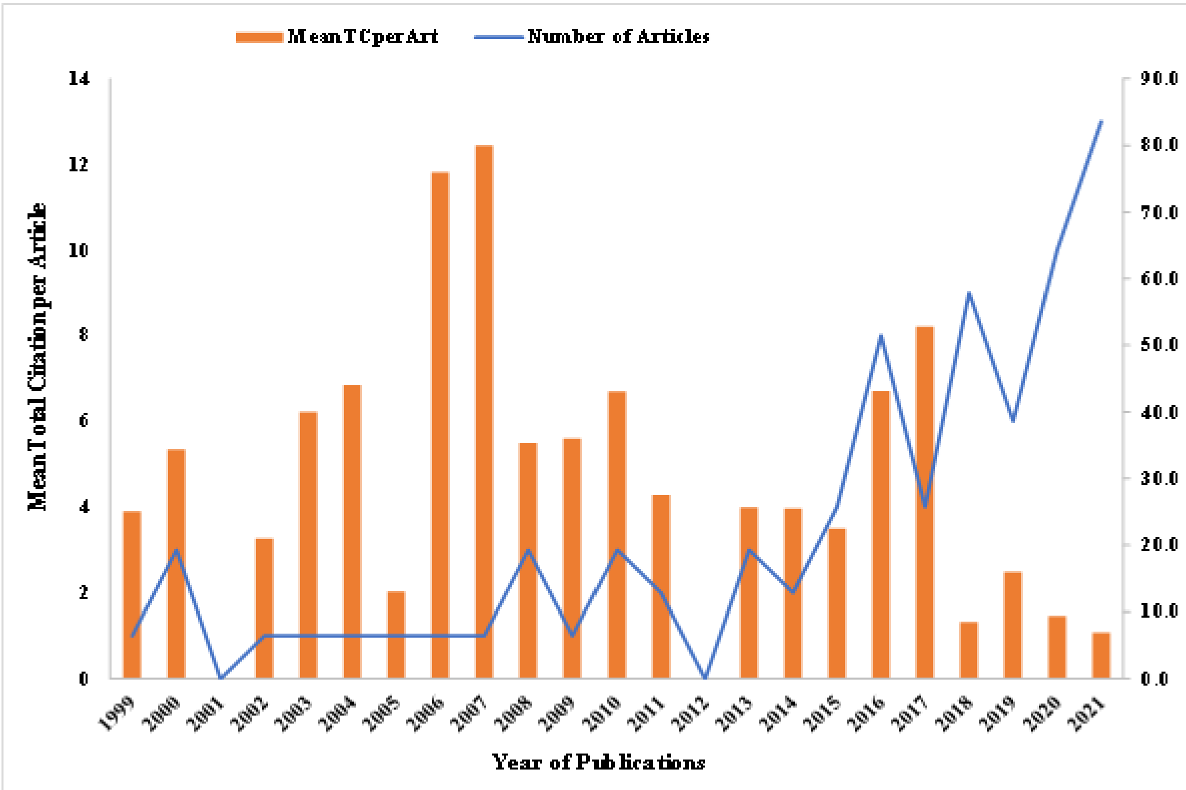

Figure 6

Evolution of wildfire research from 1999 to 2021

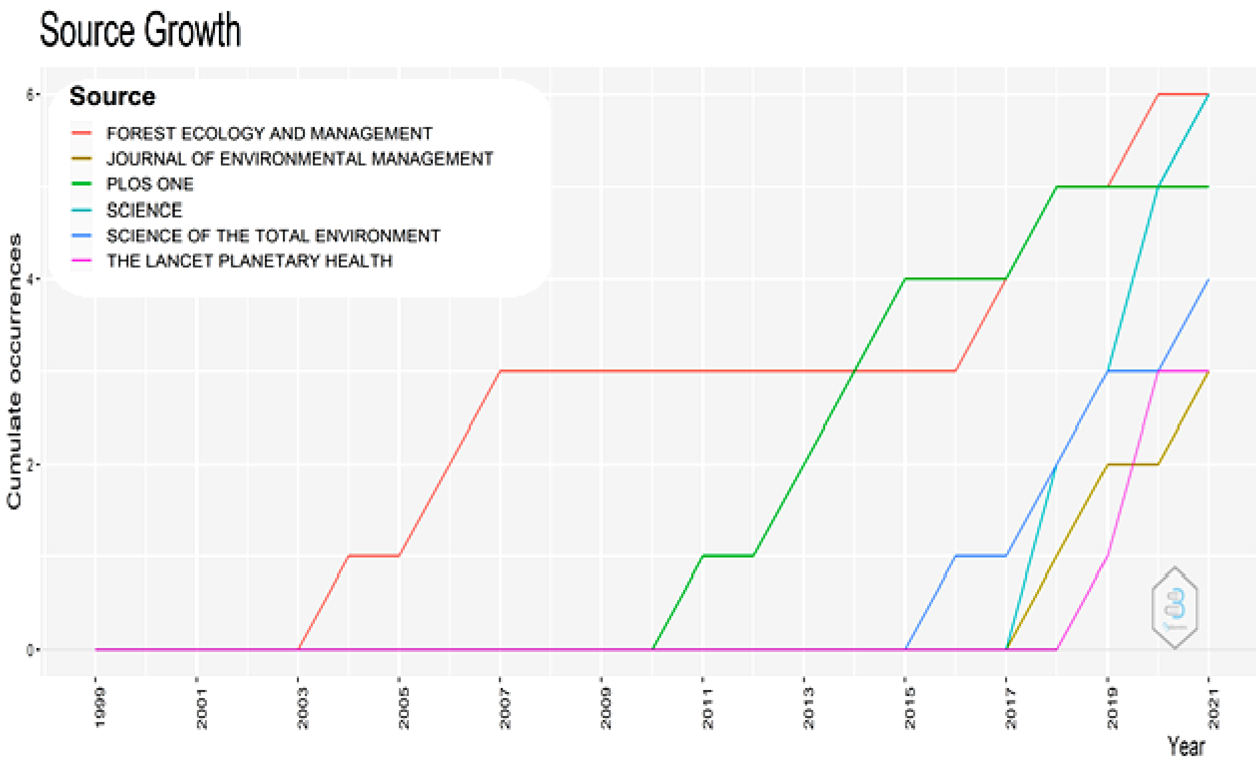

Figure 7

Distribution of publications on wildfires across the top six journals

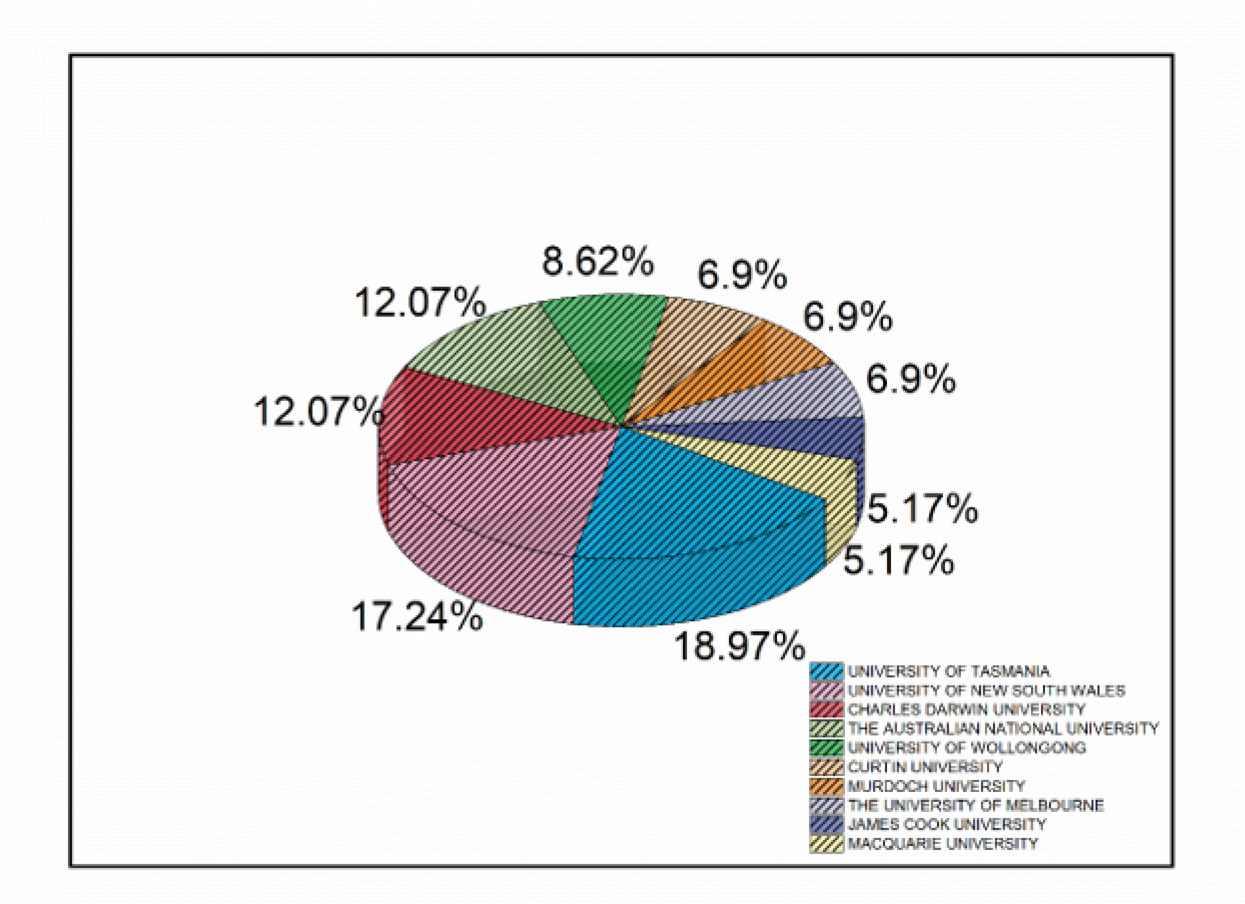

Figure 8

Top 10 Australian institutions according to number of published articles

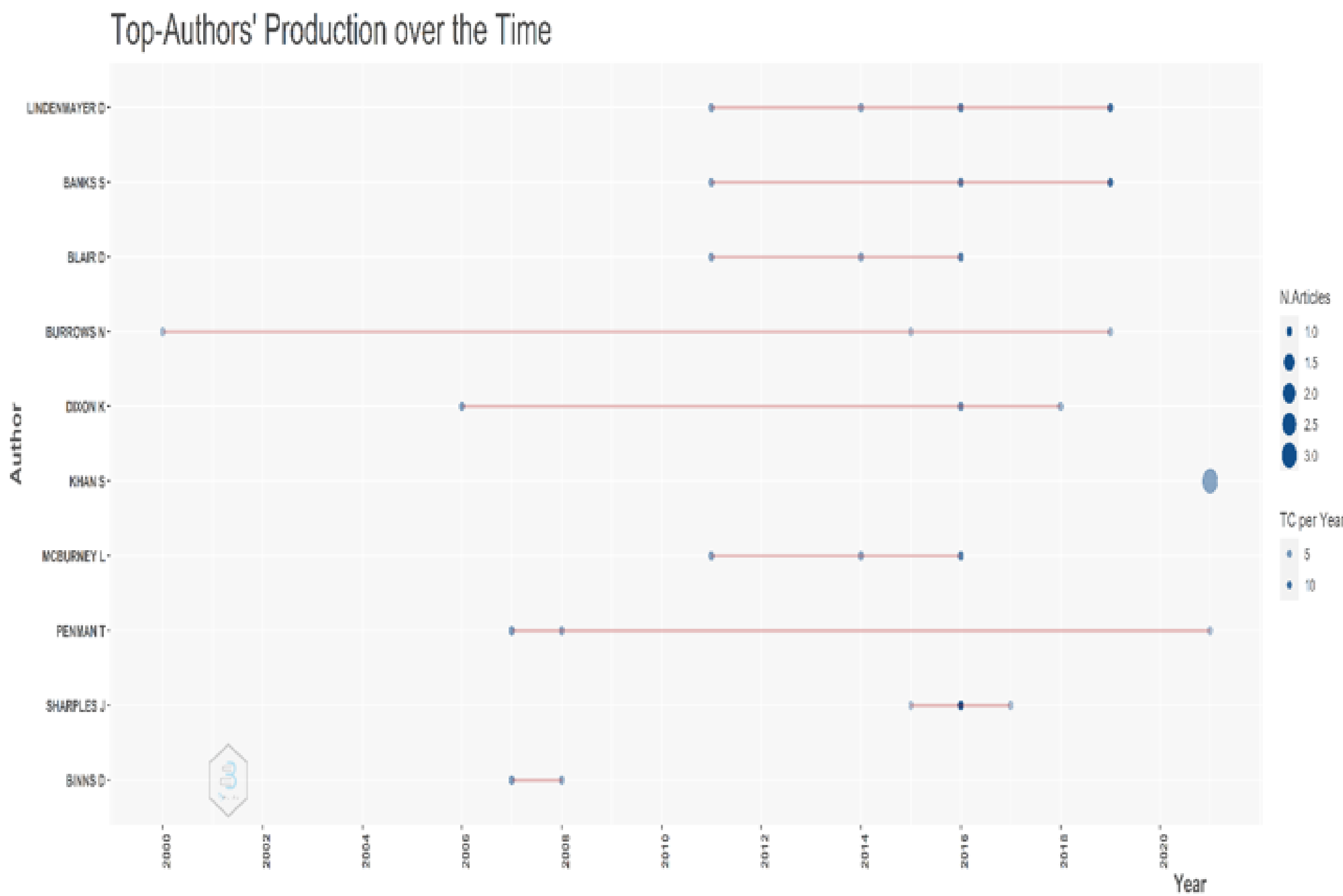

Figure 9

Authors’ scientific production over time

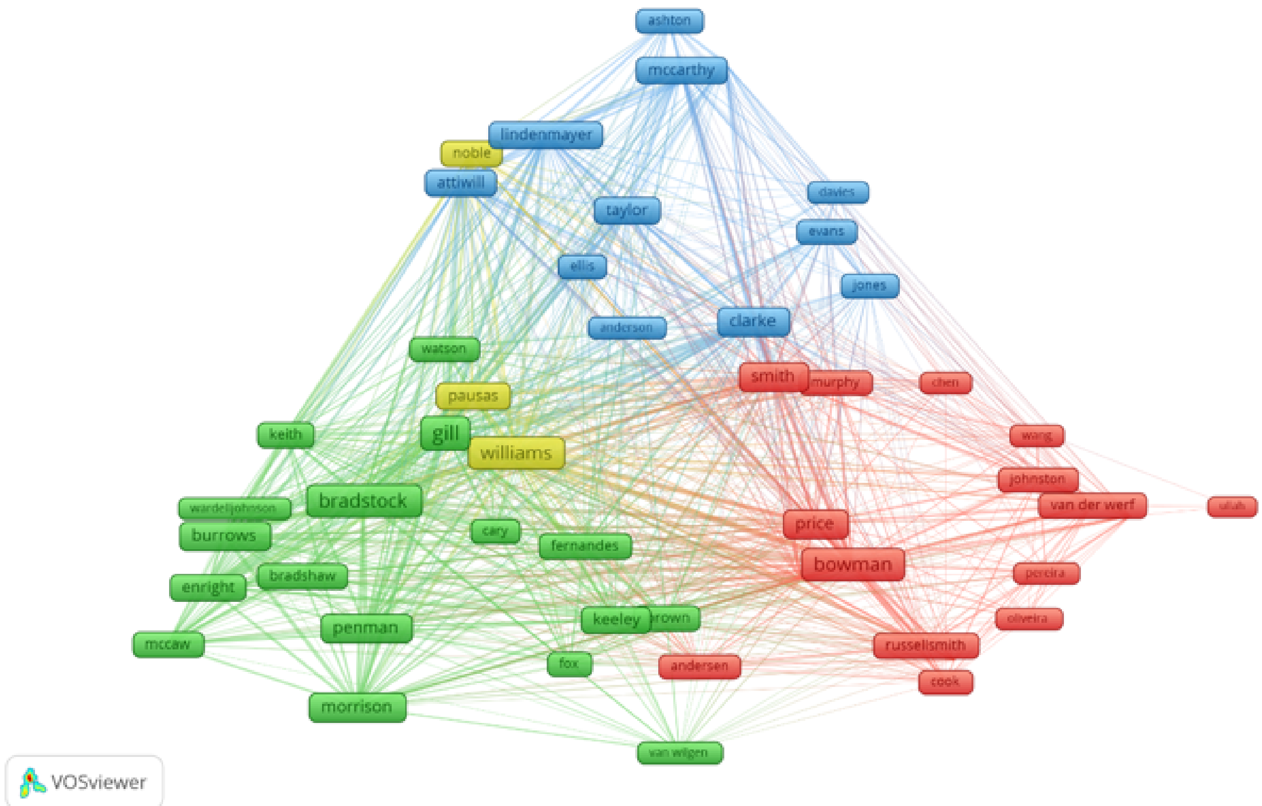

Figure 10

Authors' collaboration network analysis

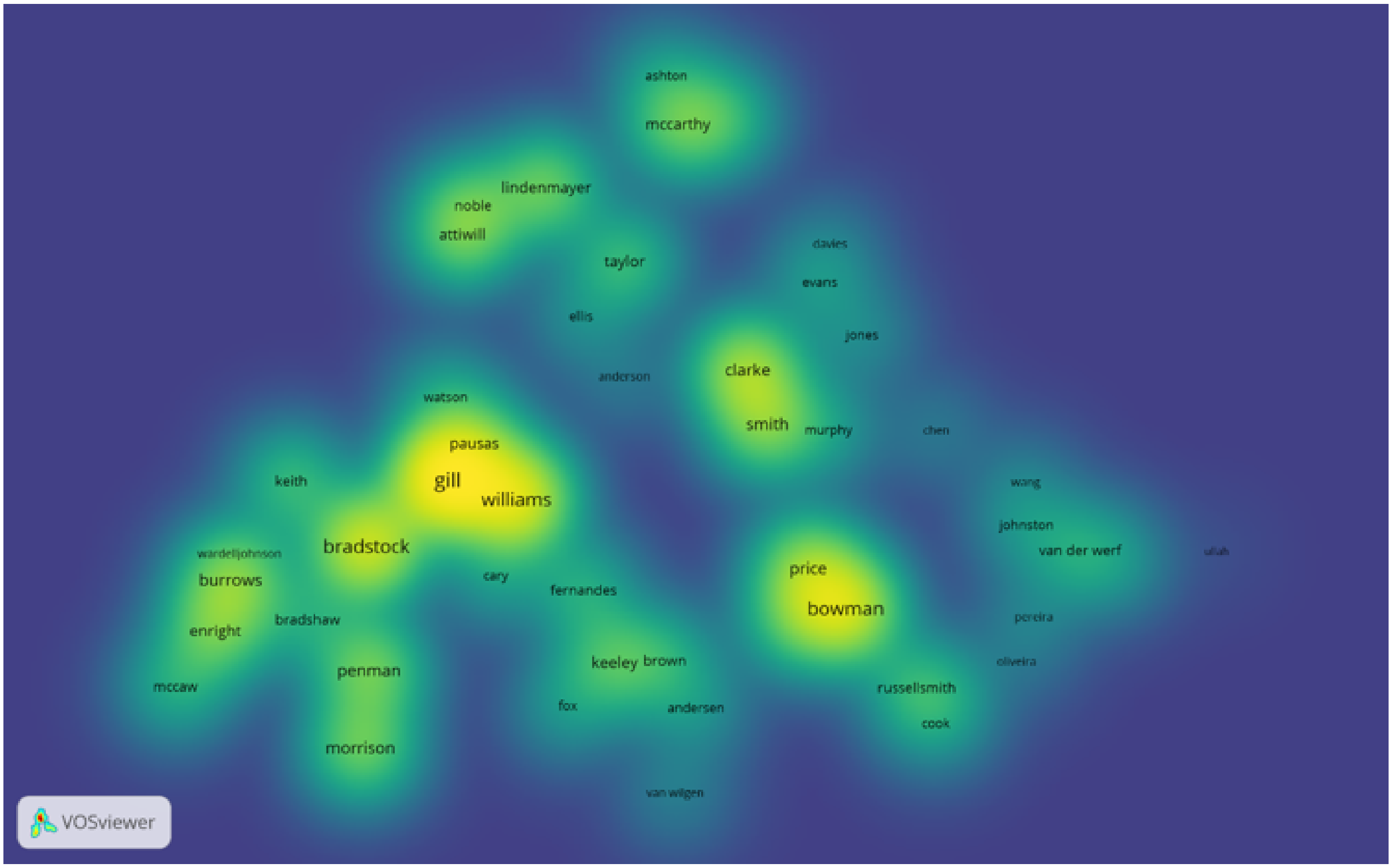

Figure 11

Density visualization of authors collaboration network

Ranks	Terms	Frequency
1	Australia	91
2	wildfire	58
3	environmental impact	35
4	fires	35
5	climate change	29
6	article	20
7	smoke	20
8	biodiversity	17
9	ecological impact	16
10	fire	16

Figure 12

Top 50 keywords on wildfire research from 1999 to 2021

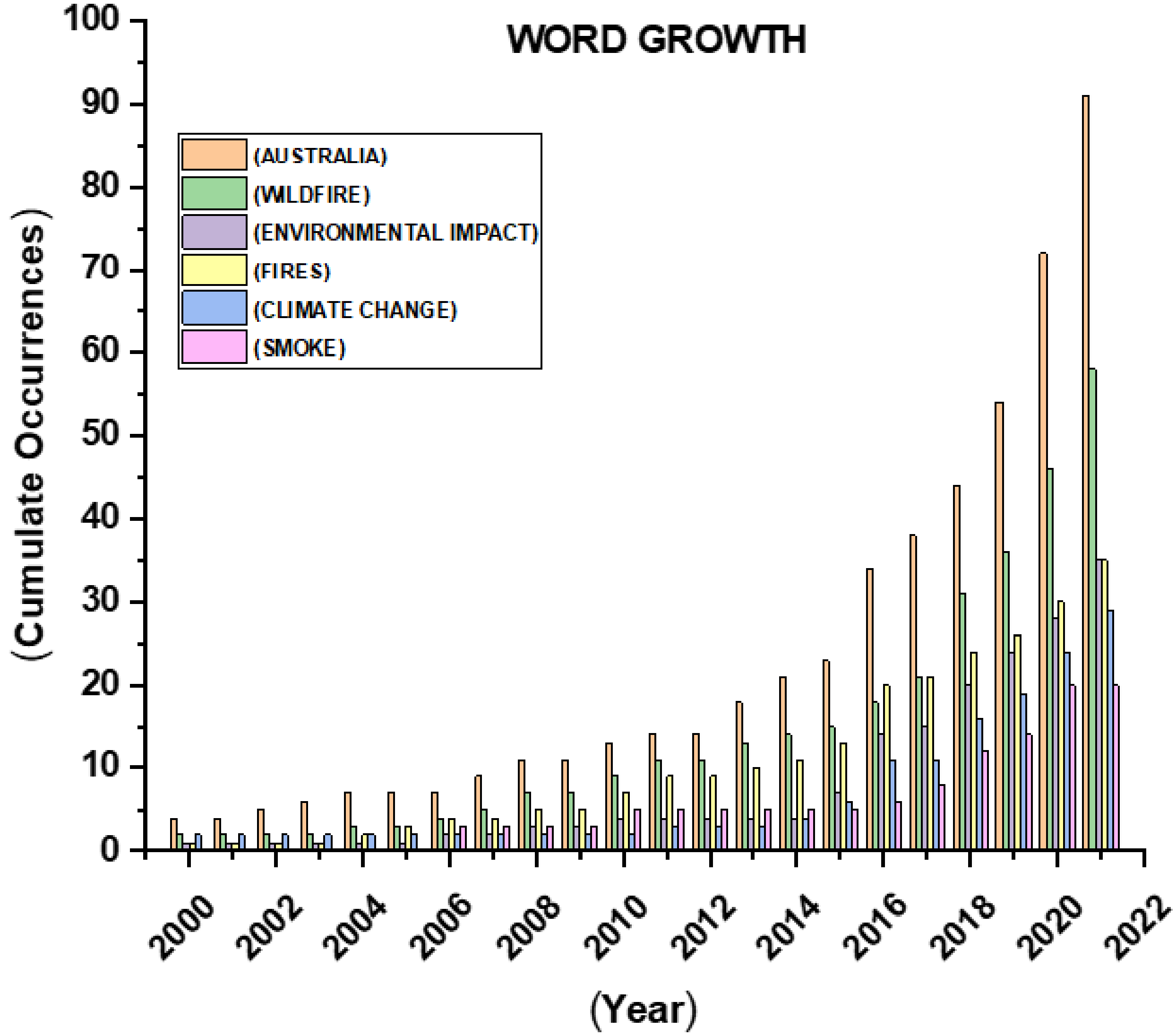

Figure 13

Top six Keyword Plus growth from 2000 to 2021