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Adaptation planning for climate change: An application of the advanced bibliometric analytical framework

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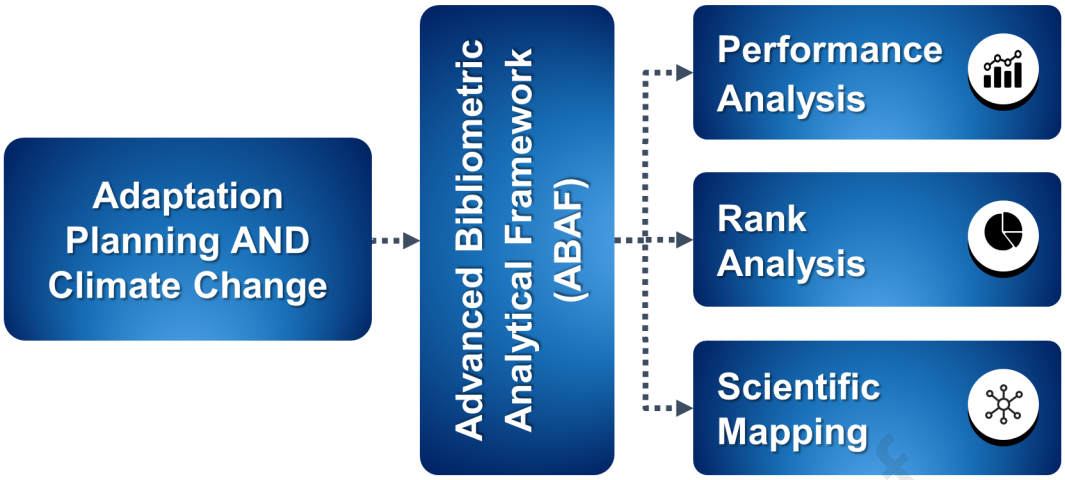


Adaptation planning for climate change: An application of the advanced bibliometric analytical framework

Abstract

There has been a surge in research on adaptation planning to address climate change and its effects. This study conducted a bibliometric analysis of the keywords "adaptation planning" and "climate change" to determine the level of research being undertaken using a proposed Advanced Bibliometric Analytical Framework (ABAF). ABAF intends to overcome the inconsistency and vagueness surrounding the existing bibliometric analytical frameworks. Three types of analyses, namely performance analysis, rank analysis, and scientific mapping, were carried out on a dataset of 1087 research articles retrieved from the Web of Science database. The study found contributions from 1515 institutions and 116 countries. Most studies were published in English and Chinese languages only. An upward trend was observed in the number of publications per year, with 135 being the highest number recorded in 2021, emphasizing SDG13: Climate Action, followed by SDGs 6, 15, and 14. Findings show adaptation planning as a trending discourse in the impact reduction of climate extreme events. The results of this study can serve as a foundation for future research on adaptation planning for climate change. Additionally, ABAF can be applied in any bibliometric analytical study, and the framework could be expanded to include additional analysis typologies and metrics to enhance its comprehensiveness.

Keywords: Adaptation Planning; Climate Change; Advanced Bibliometric Analytical Framework (ABAF); Urban Adaptation Planning; Scientific Knowledge

1. Introduction

Climate change has become one of the major concerns of this century. The current patterns will continue to worsen throughout the 21st century, as the rate of climate change is directly influenced by factors such as greenhouse gas emissions, deforestation, and the destruction of natural habitats. Global greenhouse gas emissions have alarmingly increased by 30% since 2000, and a 5.8% hike in emissions has been observed for the first time in human history in only 2010 (Carter et al., 2015). Climate change is a serious threat and challenge to urban

sustainability (Wamsler, Brink, & Rivera, 2013). According to the estimations, an increase in precipitation of 2% globally for every 1°C of warming is likely to occur (Ukkola, De Kauwe, Roderick, Abramowitz, & Pitman, 2020). The Intergovernmental Panel on Climate Change (IPCC) also estimated a complex succession of secondary impacts on local and global economies, communities, and ecosystems due to rapid climate change (Carter et al., 2015). The most vulnerable segments of society are also the ones most heavily impacted by climate change, as their access to the facilities, livelihoods, and services necessary to maintain their wellness are heavily affected (Linda Shi et al., 2016).

Research studies and literature on adaptation planning have increased dramatically in developed nations. Countries have accelerated their efforts to adapt as an essential, supportive, and merely natural reaction to climate change (Baker, Peterson, Brown, & McAlpine, 2012; Woodruff, 2018). These emerging adaptation policies have become a common approach to tackling climate risk under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol that ensures the number of adaptation finance mechanisms on a global scale (Zhang, Chen, Liang, Tian, & Yang, 2020). Various other bilateral and multilateral agreements for financing adaptation are added to these channels (Preston, Westaway, & Yuen, 2010). Apart from a viable solution to climate change, adaptation planning is the only way forward for three main reasons. First, it will reduce carbon footprint as well as current climate-sensitive risks. Second, it can be implemented locally or nationally (Khanal, Wilson, Hoang, & Lee, 2018). This factor of application also makes it less dependent on the actions of others, enhancing its efficacy. Third, results can be seen quickly, which helps secure crucial funds for its successful execution (Füssel, 2007). Studies on adaptation planning for climate change have been published in the areas of agriculture (Khatri-Chhetri, Aggarwal, Joshi, & Vyas, 2017), computer sciences, and artificial intelligence (Dugord, Lauf, Schuster, & Kleinschmit, 2014), disaster risk reduction (Rana et al., 2023; Zia, Rana, Arshad, Khalid, & Nawaz, 2023), development studies (Sovacool, 2018), environmental sciences (Cradock-Henry et al., 2020), geography (Hardy, Milligan, & Heynen, 2017), geosciences (Ukkola et al., 2020), water resources (Souvignet et al., 2014), transportation (Ford, Dawson, Blythe, & Barr, 2018), urban studies (Birchall & Bonnett, 2021), urban and regional planning (Butler, Deyle, & Mutnansky, 2016), meteorological and atmospheric sciences (Elijah & Odiyo, 2020), and sustainability (Nakhaei Ashtari & Correia, 2022).

This paper examines literature through bibliometric analysis, a method to evaluate large-scale data that provides a comprehensive overview of large amounts of scholarly literature (Rana, 2020). It determines the most current advancements, research orientations, and trends in a given field of study and assesses the productivity and research patterns of authors, journals, countries, and institutions (Merigó & Yang, 2017). This research addresses the questions: What is the current state of knowledge in the context of adaptation planning and climate change?, and how to ensure complete, comprehensive, and critical bibliometric analysis? Advanced Bibliometric Analytical Framework (ABAF) is proposed to provide complete, comprehensive, and critical analysis. The proposed framework includes metrics related to publication, citation, and publication-and-citation that give information regarding citations and authorship of articles. The statistical analysis provides information on top publishing authors, institutions, countries, journals, research areas, languages, and publication trends. It also explains the Sustainable Development Goals (SDGs) targeted by these studies. Lastly, scientific mapping reveals connections among keywords, publications, and citations and represents global research collaboration on adaptation planning and climate change.

2. Conceptualizing adaptation planning for climate change

The development of contemporary ideas of sustainable development in the 20th century has conflicted between expanding resource management practices and prosperity in the long run. In the wake of climate change, sustainable development has emerged with major problems, particularly in metropolitan regions with high growth intensity (Kauffman & Hill, 2021). Climate change mitigation and adaptation are used to lessen its risks and impacts on society and nature. Mitigation aims to reduce carbon (CO, CO_2) or greenhouse gas (GHG) emissions (IPCC, 2018). Adaptation means efforts or actions toward the most vulnerable population or system in response to actual or expected climate stimuli causing harm or exploiting beneficial opportunities. It heightened the need for climate adaptation, considered a primary area of interest for urban and regional planners worldwide (Kauffman & Hill, 2021).

According to IPCC, adaptation is defined as “the process of adjustment to actual or expected climate and its effect, to moderate harm or exploit beneficial opportunities” (IPCC, 2018). Whereas climate change is defined as “a change in the state of the climate that can be identified by changes in the mean and/or variability of its properties and that persists for an

extended period, typically decades or longer (IPCC, 2018). Adaptation can be incremental or transformational, depending upon the scale of transition caused by the measures or actions implemented (Pachauri, 2014). Adaptation differs from adaptive capacity as the former is a process involving adjustment to climatic changes, and the latter is defined as the ability or potential of a system to get adjusted to potential climatic changes (IPCC, 2018). Due to the diverse applications of the concept, defining the meaning and scope of adaptation has proven to be a significant obstacle in the literature (Khanal et al., 2018). It is defined based on planning horizon (short/long term), actions nature (reactive/preventive), dimension (technical, institutional, legal, psychological, educational), actors involved (public/private), policy nature (autonomous/planned) (Khanal et al., 2018; Smit & Wandel, 2006).

Much research has already been carried out that covers and explains climate change adaptation from different perspectives (Ahmed et al., 2023; Zia et al., 2023). A concept of adaptation that specifically addresses climatic risk was developed from an "endpoint" framework of vulnerability and has been widely adopted by the UNFCCC and urban climate change research (UNDP, 2015). This described that actions are only regarded as climate change adaptation if they are specifically created to address the climate change-induced hazards. The process becomes planned adaptation when current and planned projects, policies, and infrastructure are critically evaluated under present and future climate trends. Adaptation planning seeks to establish the difference between climatic and non-climatic conditions of the past and the future; determine the influence of projected climatic conditions on current policy decisions; define and strike to achieve the balance between acting pre-and-post-adaptation (Füssel, 2007). An effective adaptation planning practice requires problem identification, availability and knowledge of effective adaptation measures, resource inventory for implementation, social acceptability of measures, and incentivization to support implementation on a larger scale. Climate change adaptation planning can be conceptualized as a holistic and interdisciplinary concept that intends to reduce the risks and vulnerabilities of extreme events by applying sound measures or actions at the community and institutional levels.

Since the implication of the concept leads to the pathways of sustainable and climate-resilient development, adaptation has been emphasized and promoted by international bodies. The IPCC has highlighted and recognized adaptation planning as a key factor in reducing exposure

and vulnerability to climate change (Pörtner, D.C., & Simpson N. P., 2022). The recent report (AR6) of IPCC has highlighted that progress in adaptation planning and implementation is observed across all sectors and regions, generating multiple benefits. The progress is associated with increasing awareness of climate impacts and risks, resulting in the successful integration of adaptation planning in the climate policies and planning processes of at least 170 countries (IPCC, 2023).

Many academia and government institutions consider adaptation similar to the conventional infrastructure or public development programs aimed at susceptibility reduction without a prime focus on climate resilience. From a climate change perspective, some adaptation planning frameworks were also found in the literature. Evidence from developed countries identified the capacity building of institutions, predefined roles and responsibilities of stakeholders, and urban fabric as the core elements influencing decisions on climate change adaptation (Lehmann, Brenck, Gebhardt, Schaller, & Süßbauer, 2013). Another study identified participation, curtailing challenges, and effective execution as key pillars for effective integration of adaptation planning for climate change adaptation (C40 Cities Climate Leadership Group. & Global Platform for Sustainable Cities (GPSC), 2020). However, adaptation planning from a climate change perspective has not been discussed at length. As a result, most adaptation responses to climate change are still fragmented, incremental, sector-specific, and unequally distributed across regions with increasing adaptation gaps (IPCC, 2023). This study provides a comprehensive insight into the level of research being carried out and the intellectual landscape of adaptation planning research from the climate change perspective.

3. A review of existing bibliometric analytical frameworks

Bibliometric analysis is a well-known and systematic technique to evaluate extensive scientific literature datasets (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021). The technique is useful in performing an objective-oriented analysis to interpret and chart the scientific knowledge and evolutionary nuances of queries by precisely making sense of extracted data. It is also known for managing and categorizing scientific datasets with more entries and producing high research impact. The technique assists and encourages researchers to have a comprehensive outlook of literature, identify research gaps, develop novel ideas and future research

directions, and rank their intended contributions to the field—bibliometric analysis methodology or bibliometrics dates back to the 1950s. The first bibliometric analysis was indexed in 1972 to the Web of Science (WoS) database. Since then, an increasing trend has been observed in publications using the bibliometric analysis technique. The efficiency in performing bibliometric analysis has dramatically increased due to the scientific databases and repositories, such as Web of Science (WoS) and Scopus, and other software like Gephi, Leximancer, and VOSviewer. Such scientific databases help authors get the desired dataset with a few clicks and allow them to validate their results by providing the "Analyze Results" option. On the other hand, graphical tools help to develop bibliographic linkages among keywords, studies, and authors.

Bibliometric analysis is being applied in geography and geographical information systems (GIS) (Wu, Dong, Wu, & Liu, 2023), gender studies (Mongeon, Brown, Dhaliwal, Hill, & Matthews, 2021), business and marketing (Donthu et al., 2021), social sciences (Wang, Song, & Su, 2022), public relations (Castillo-Esparcia, Carreton-Ballester, & Pineda-Martinez, 2020), medical sciences (Salvador-Olivan, Marco-Cuenca, & Arquero-Aviles, 2021), IT (L. Shi, Mai, & Wu, 2022), urban and environmental studies (Marques, Martins, Fernandes, Silva, & Freires, 2020), journalism and media sciences (Singh, Arora, & Kapur, 2022), public administration and governance (Roziqin, Kismartini, Fajrina, Salahudin, & Sulistyaningsih, 2022). Due to its vast application in different disciplines, several analytical frameworks and analytical methods have been adopted by researchers. Glänzel (2012) described the bibliometric analysis as comprised of discipline, emerging topics, and network analysis. To explain the extent of bibliometric analysis's impact, indicators like article classification, number of indexing, number of citations, number of citing journals, citing articles per journal, publication over the years, regression analysis for year-wise publications and citation impact, and normalized citation impact have been used. Country analysis, subject analysis, subject categories, and keyword analysis were also considered for bibliometric analysis (Ellegaard & Wallin, 2015). The application of advanced statistical techniques to identify specific segments with similar growth rates in the history of science was also found (Bornmann & Mutz, 2015). The analytical framework of Derviş (2020) covers aspects like the summary of the dataset, most productive authors, most productive papers based on collaboration publications, most published articles, annual scientific production, co-citation network, and conceptual structure were analyzed. While

conducting bibliometric analysis on financing innovations, Padilla-Ospina, Medina-Vásquez, and Rivera-Godoy (2018) opted for h-index, impact factor, number of citations, number of co-citations per article, number of bibliographic coupling, intra-corpus strategy (to get articles with most references) and extra-corpus strategy (to get articles with more references originated from within the corpus). Another bibliometric study used annual publication trends, word cloud, popular subject areas, active authors, active institutions, popular research areas, international collaborations, top countries, industry-academia collaborations, most cited papers, and citation analysis to get the results (Garousi, 2015). Language and publishing medium, top 20 publishers, top academic journals, documents by subject area, most relevant articles, keywords analysis, and co-citation analysis using VOSviewer were also found to be applied in the bibliometric analytical framework (Magadán-Díaz & Rivas-García, 2022). Another bibliometric toolbox was developed by Donthu et al. (2021), incorporating the methods and tools suited to their understanding and expertise. In the context of systematic literature reviews, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model is a well-known method that is widely used to conduct systematic literature reviews (Moher, Liberati, Tetzlaff, Altman, & Group, 2009). The PRISMA model comprises a 27-item checklist divided into four phases. The application of the PRISMA model has standardized and improved the reporting of systematic reviews as the model provides a roadmap to help authors best describe what was done, what was found, and what they need to add further. However, in the case of bibliometric studies, it was observed that different bibliometric analytical frameworks were used in different studies. The major shortcoming in the existing set of bibliometric methods or frameworks is that each author(s) understood bibliometric analysis as per their scope of interest and understanding. As a result, some studies applied many tests, whereas some limited their bibliometric analysis to just a few tests. Thus, a gap was observed in identifying the criteria or number of analyses required to make a bibliometric analysis complete, comprehensive, and critical. To fill this gap, this study took inspiration from the PRISMA model and proposed an Advanced Bibliometric Analytical Framework (ABAF) that covers almost all tests, matrices, and scientific mapping techniques being used globally in conducting bibliometric analysis studies. The application of ABAF in bibliometric studies contributes to the scientific body by standardizing, improving, and expanding the horizon of bibliometric analysis reporting that will eventually assist the researchers in understanding the

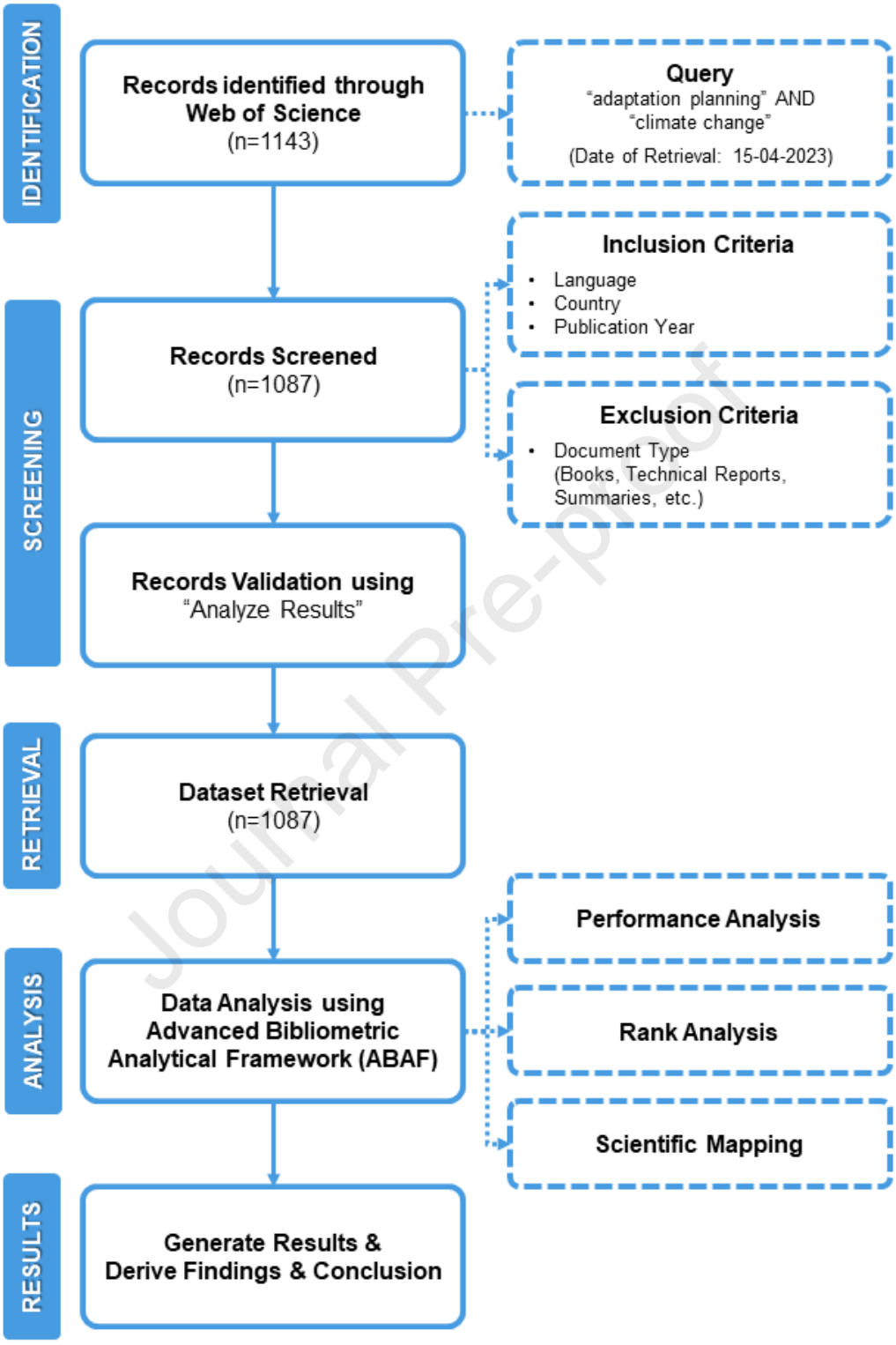
existing work done and highlighting the core aspects of the topic to be covered in future studies.

4. Methods

This section includes a brief regarding the method and process of data collection, justification and limitations of the selected query, the opted analytical methods, tools and techniques used to generate results, and the variety of analyses involved.

4.1. Data collection

The data collection or data retrieval is the first phase of the proposed framework. A systematic search of query, i.e., *"adaptation planning" AND "climate change,"* was performed on the Web of Science (WoS) database on the 15th of April 2023. The terminologies have opted to procure maximum search results and all possible publications based on climate change and adaptation planning. The scope of the query was further expanded by the usage of inverted commas around keywords to consider them as a single word, and the database be searched accordingly. Whereas applying the AND operator helps retrieve all articles related to the topic. The results gave 1087 research articles. The applied inclusion criteria were not restricted to language, country, or publication year constraints to avoid and limit bias in search results as much as possible. However, only one exclusion criterion, i.e., document type, was applied as the study only focused on published research articles. Lastly, results validation and cross-verification were carried out by comparison of generated results with the "Analyze Results" tool available on the WoS website to ensure data authenticity and quality. The research process flow diagram is illustrated in **Figure 1**.



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236 **Figure 1: Research methodology**

4.2. Operationalizing Advanced Bibliometric Analytical Framework (ABAF)

The advanced bibliometric analysis comprises performance analysis, rank analysis, and scientific mapping **(Figure 2)**. Performance analysis includes publication-related metrics having insights regarding overall publications (TP), publication distribution in terms of academia, industry, and their collaborations (TP, TP-A, TP-I, and TP-AI), details of authors (NCA), publication distribution in terms of single author and co-authors (SA and CA), publication active years and its productivity (NAY and PAY). Citation-related metrics include the number of citations and their average (TC and AC). Citation-and-publication-related metrics include details regarding collaboration index and coefficient (CI and CC), number of citations, their proportion, and citations per cited publications (NCP, PCP, and CCP). This study extends the comprehensiveness of performance analysis explained by Donthu et al. (2021) by adding some new matrices, including publications per author (PAU), authors per publication (AUP), author's keywords (AK), total journals (TJ), total publishers (TPUB), total institutions (TI), and total countries (TC). Indexes of scientific databases and repositories are another important indicator to determine the impact and citation connections of publication on the selected topic. The proposed framework also covers this aspect by including the Web of Science indexes, including Science Citation Index Expanded (SCI), Social Sciences Citation Index (SSCI), Emerging Sources Citation Index (ESCI), Conference Proceedings Citation Index-Science (CPCI-S), Arts & Humanities Citation Index (AHCI), and Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SS&H). Ranking analysis was carried out to determine the most frequent and top 10 languages (T_{10}L), research areas (T_{10}RA), countries/regions (T_{10}CO), journals (T_{10}J), affiliations (T_{10}A), authors (T_{10}AU), and publication trends over the years (PTY). It also introduces SDG analysis (SDGA) that is computed using the data obtained from WoS on published articles targeting specific and/or multiple SDGs. It helps identify the major sustainable development goals (SDGs) targeted by the selected topic (in this case, adaptation planning and climate change). Lastly, the scientific mapping includes keyword analysis, co-citation analysis using VOSviewer, and global research collaboration analysis using ArcGIS. The analysis involved and the description or computation method of associated metrics are tabulated in the supplementary material of the paper.

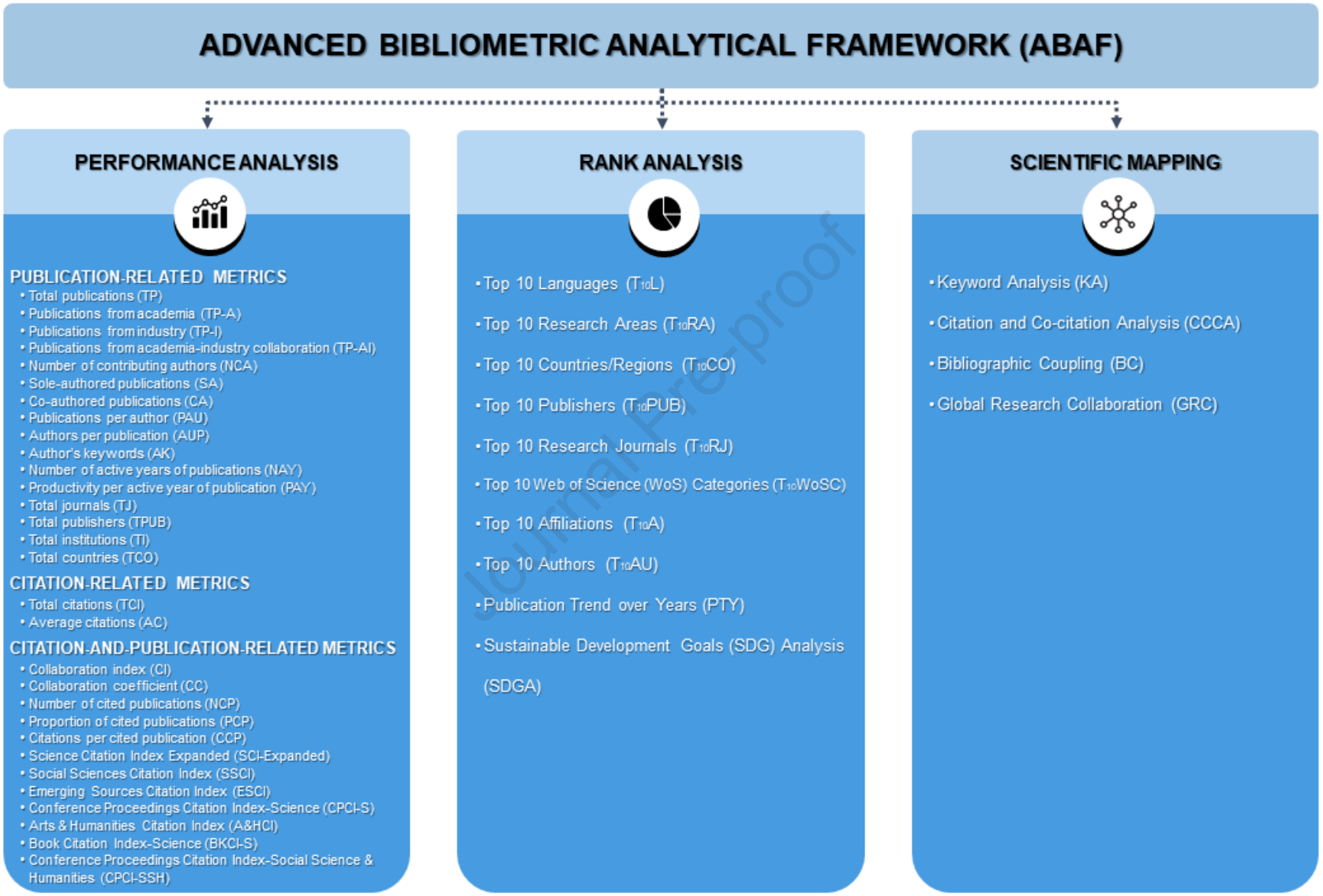

Figure 2: ABAF conceptual framework

5. Results and discussion

5.1. Performance Analysis

Findings from publication-related metrics show that the query “adaptation planning” AND “climate change” retrieved 1087 research articles. 718 studies were contributed by academia, and 91 were published by industries, mainly research organizations, and departments. As inter-departmental coordination is being emphasized globally, 246 articles were found published through academia-industry linkages. The contribution of 4058 authors belonging to 1515 different institutions located in 116 countries was published in 334 different research journals. 86 authors published their papers solely, whereas 3972 papers were found to be co-authored. Publication per author and authors per publication rates were low, i.e., 0.26 and 3.73, respectively. The authors used 2367 different keywords. Findings also showed adaptation planning and climate change studies being published in the last 17 years, wherein productivity per active year of publication was found to be 64.

Citation matrices showed 27214 citations and an average citation rate of 25. The collaboration index was rated low (0.0034), expressing a lesser extent of research collaboration. The number of time total publications cited was 69128, with an average proportion of each publication counting to 63.59. The citations per cited publication rate was 2.58. Whereas the scores of Web of Science indexes were SCI-Expanded (827), SSCI (655), ESCI (51), CPCI-S (11), A&HCI (8), CPCI-SSH (4), and BKCI-S (1), respectively **(Table 1)**.

343 **Table 1: Performance analysis**

Metrics	Symbol	"adaptation planning" AND "climate change"
Publication-related metrics		
Total publications	TP	1087
Publications from academia	TP-A	718
Publications from industry	TP-I	91
Publications from academia-industry collaboration	TP-AI	246
Number of contributing authors	NCA	4058
Sole-authored publications	SA	86
Co-authored publications	CA	3972
Publications per author	PAU	0.26
Authors per publication	AUP	3.73
Author's keywords	AK	2367
Number of active years of publications	NAY	17
Productivity per active year of publication	PAY	64
Total journals	TJ	334
Total publishers	TPUB	77
Total institutions	TI	1515
Total countries	TCO	116
Citation-related metrics		
Total citations	TCI	27214
Average citations	AC	25
Citation-and-publication-related metrics		
Collaboration index	CI	0.0034
Collaboration coefficient	CC	0.99
Number of cited publications	NCP	69128
Proportion of cited publications	PCP	63.59
Citations per cited publication	CCP	2.54
Science Citation Index Expanded	SCI-Expanded	827
Social Sciences Citation Index	SSCI	655
Emerging Sources Citation Index	ESCI	51
Conference Proceedings Citation Index-Science	CPCI-S	11
Arts & Humanities Citation Index	A&HCI	8
Conference Proceedings Citation Index-Social Science & Humanities	CPCI-SSH	4
Book Citation Index-Science	BKCI-S	1

344 ### 5.2. Rank analysis

345 The ranks analysis results include top languages, research areas, countries/regions, journals,
346 affiliations, authors, and publication trends. Results of rank analysis were validated and cross-
347 verified by comparing the results with the WoS "Analyze Results" tool. The data validation
348 shows that both results were identical and complemented each other with no
349 errors/omissions.

5.2.1. Top languages (T_{10}L), research areas (T_{10}RA), and countries/regions (T_{10}CO)

The top languages category in rank analysis aims to identify the number of languages wherein adaptation planning and climate change studies have been published globally. Using the keywords "adaptation planning" and "climate change" in the WoS database, publications were found in English and Chinese languages. English was most prominent, having 1084 publications out of 1087, whereas only three studies were in Chinese **(Figure 3a)**. The language results were validated by **Figure 3c,** showing the USA as the country with the most publications counting 382, followed by Australia (217), England (183), Canada (117), and Germany (89). 688 studies fall under the research area of environmental sciences ecology, followed by meteorology atmospheric sciences (246), and science technology other options (124) **(Figure 3b)**. Studies on adaptation planning were also found in Asian countries, wherein China had the highest number of publications, counting 65, followed by India (28), Bangladesh (21), Vietnam (11), Malaysia (10), Nepal (7), Pakistan (6), and Sri Lanka (2). As climate change adaptation is closely linked to water-related hazards, such as floods, GLOF, intense rainfall, tsunami, etc., and strives for coordination among policymaking, institutional reforms, and engineering approaches, studies were also found related to the research areas of water resources (92), and public administration (72), and geography (59).

5.2.2. Top research journals (T_{10}J), affiliations (T_{10}A), and authors (T_{10}AU)

Springer's Climatic Change had the maximum number of publications counting 54, followed by Regional Environmental Change (44), Elsevier's Environmental Science & Policy (38), Springer's Mitigation & Adaptation for Global Change (38), and MDPI's Sustainability (35) **(Figure 3d)**. A total of 72 studies were affiliated with the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Other major affiliations were the University of London (33), the University of California System (32), and the Bureau of Meteorology Australia (31) **(Figure 3e)**. Dr. Christine Wamsler, a professor at the Lund University Centre for Sustainability Studies (LUCSUS), has the highest publications on adaptation planning and climate change, counting to 12, followed by Seekamp, E. (10), Brown, J.R. (9), and Ford, J.D. (9) **(Figure 3f)**.

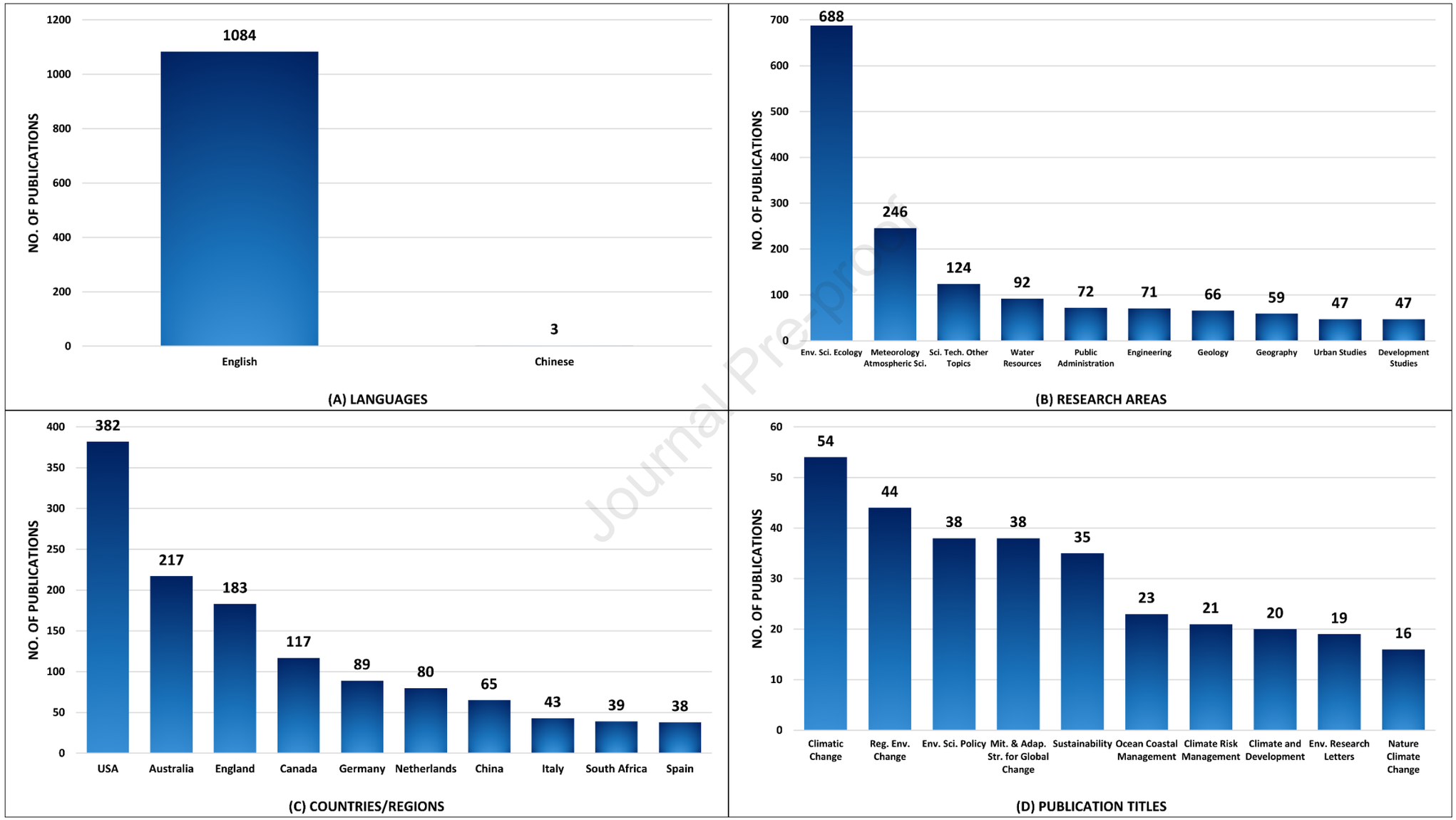

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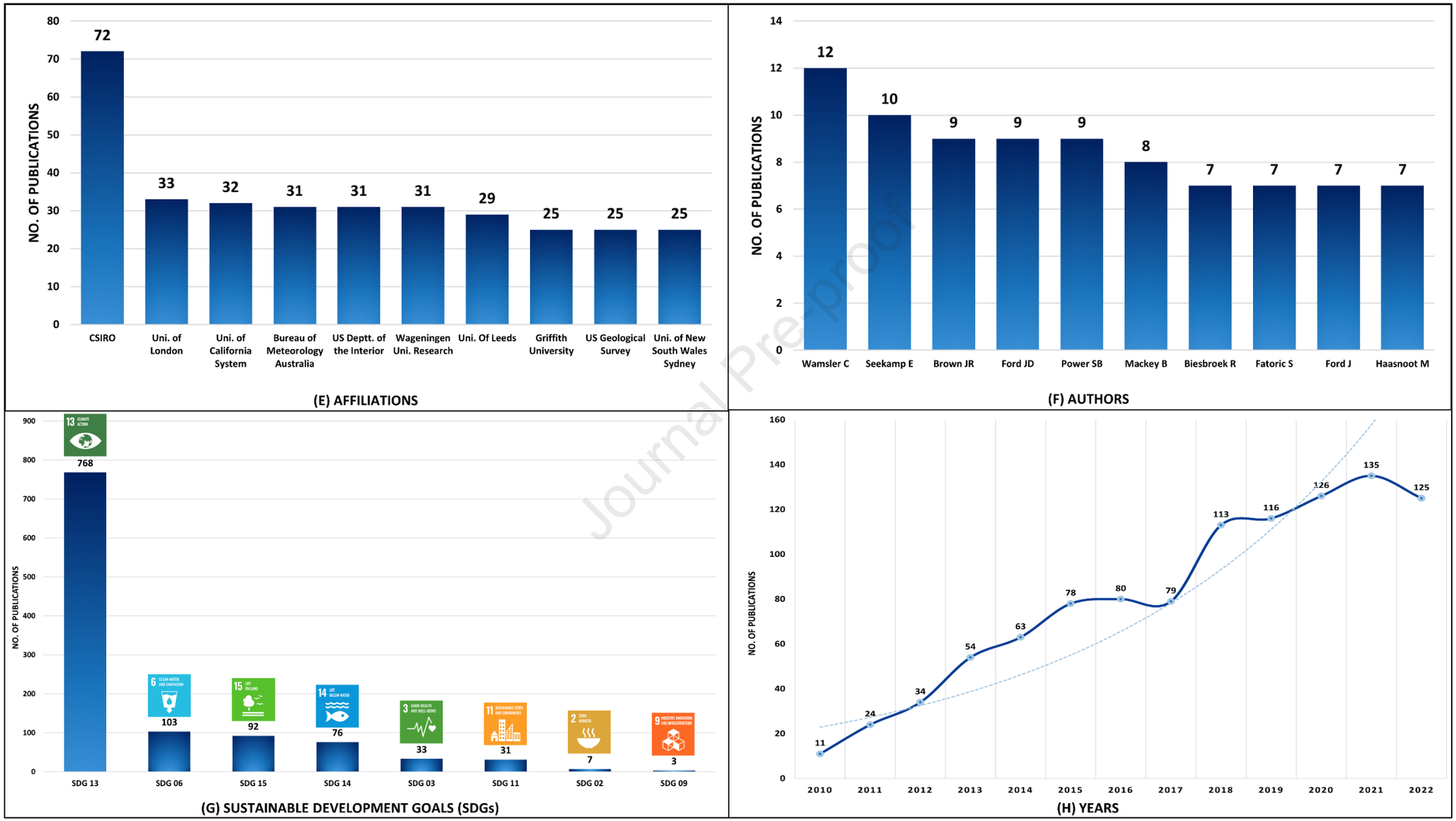
Figure 3: Rank analysis



380 **Figure 3: Rank analysis (cont.)**

5.2.3. Publication trends over the years (PTY)

In the last decade, an increasing trend in research publishing on adaptation planning and climate change has been observed **(Figure 3h)**. In 2010, only 11 studies were found related to the topic, whereas the number reached 126 in 2020, 135 in 2021 (highest till date), and 135 in 2022. Up till now, 39 studies have been published in the current year, and based on the trendline, it can be inferred that the existing year's publications will cross the previous year's records.

5.3. Sustainable Development Goals (SDG) Analysis (SDGA)

Climate change adaptation is at the heart of the United Nation's agenda for sustainable development and their sustainable development goals (SDGs). Each goal and its associated targets are so framed that they contribute directly or indirectly to lessening the adverse climate change effects and encouraging practices for adaptation planning. To perform SDGA, publications data classified into SDGs by the Web of Science (WoS) database is used and presented in a graphical format. Results show 768 out of 1087 studies published in adaptation planning and climate change were targeted toward SDG13: Climate Action **(Figure 3g)**. Other major SDGs include SDG6: Clean Water and Sanitation, with 103 publications, SDG15: Life on Land, with 92 publications, and SDG14: Life below Water, with 76 publications. Since innovation and technology also have a role to play in implementing climate change adaptation measures, three studies were also found targeted towards SDG9: Industry, Innovation, and Infrastructure.

5.4. Scientific mapping

This section includes an analysis related to the authors' keywords. Most cited publications, co-citation analysis, bibliographic coupling, and global research collaboration among countries publishing on adaptation planning and climate change help to understand and explore relationships between research constituents.

5.4.1. Keyword Analysis (KA)

A keyword analysis is used to identify the exact theme or subject of the selected topic. Results found a total of 2367 keywords used in 1087 studies. To further understand the association among keywords, visualization maps were prepared using VOSviewer. The circle depicts a keyword, and the respective size of a circle (keyword) represents its degree of interconnectedness with other keywords. The line segment between two keywords represents the number of times both are cited and mentioned together. **Figure 4** shows the keywords mentioned in adaptation planning and climate change studies with a minimum co-occurrence of 3 keywords in extracted publications. After excluding the searched keywords, the keywords vulnerability, resilience, and adaptive capacity were found to have the highest number of occurrences. This shows a strong association among vulnerability, resilience, adaptive capacity, and adaptation concepts to achieve climate change adaptation **(Table 2).** The concept of planning, precisely urban planning, has also been much emphasized in the literature as fruitful results cannot be obtained without integrating disaster risk reduction and climate change adaptation concepts in the planning and development of cities. Furthermore, urban planning provides an implementation ground for the strategies and policies designed to achieve sustainability and resilience. Thus, a profound role of urban planning was observed in the context of climate change adaptation. Also, adaptation planning was revealed as a holistic umbrella concept that covers aspects of disaster risk reduction and vulnerability, resilience, adaptive capacities, and climate change adaptation.

Table 2: Top ten author's keywords

Keyword	No. of occurrences
Vulnerability	73
Resilience	46
Adaptive capacity	41
Planning	32
Uncertainty	28
Urban planning	26
Agriculture	23
Sea level rise	17
Vulnerability assessment	15
Climate variability	14

Note: Results are extracted by excluding searched keywords

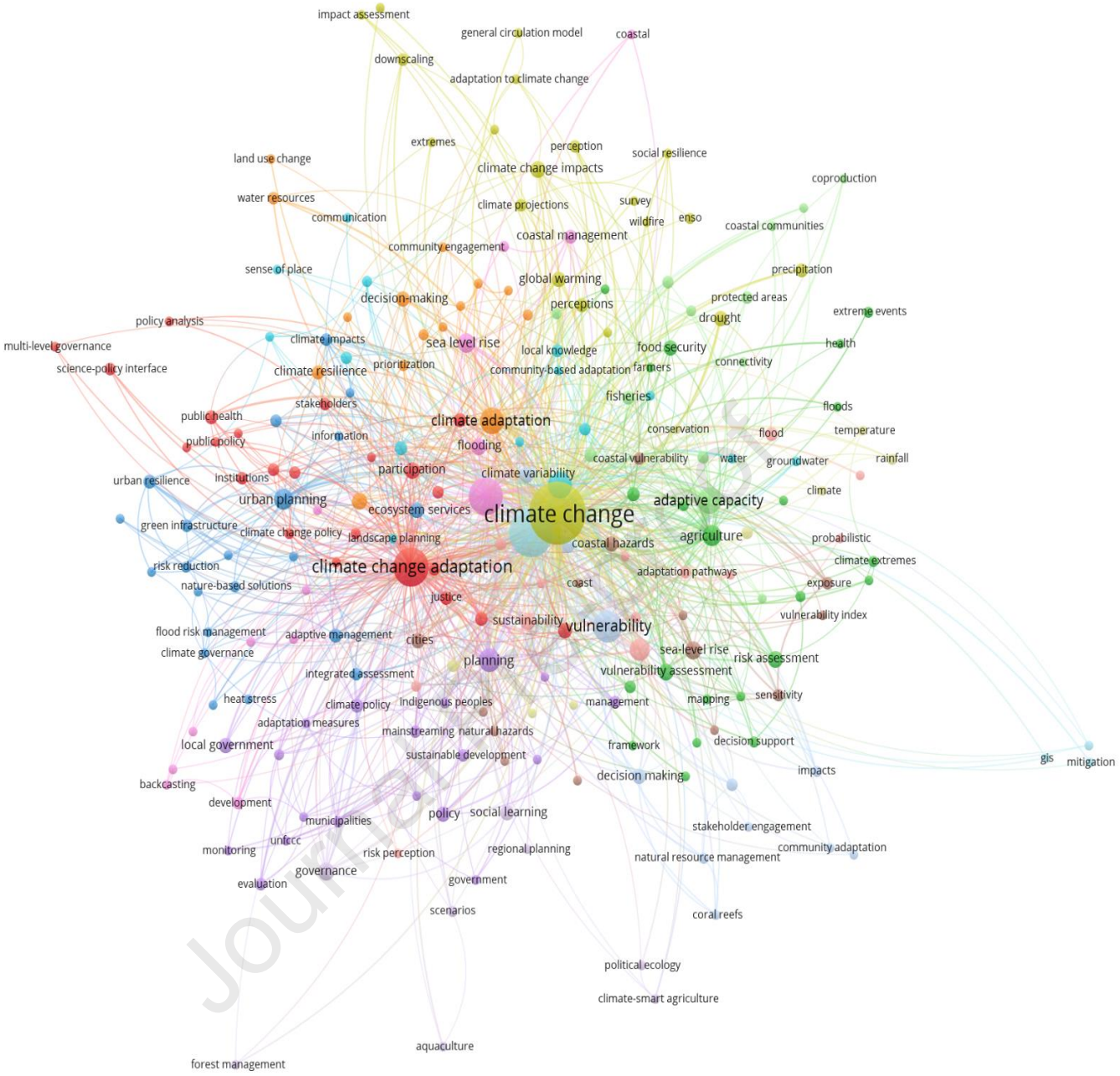


Figure 4: Keyword analysis with minimum co-occurrence of 3 keywords

5.4.2. Citation and co-citation analysis (CCCA)

Citation analysis is carried out to determine the most impactful publication based on the number of citations each publication contains. Based on the results generated from the dataset retrieved from the Web of Science database on the 15th of April 2023, the work of Moser and Ekstrom (2010) had the highest number of 90 citations. The article presents a systematic framework identifying impediments and bottlenecks to adapt to climate change impacts. Smit and Wandel (2006) reviewed the concept of adaptation and its association with the notions of adaptive capacity and vulnerability, which had 81 citations. The third highest-

cited paper was by Neil Adger, Arnell, and Tompkins (2005), which explains pathways for successful climate change adaptation across various levels **(Table 3).**

Co-citation analysis is a scientific mapping method based on the inference that the publications cited by each other belong to identical themes (Donthu et al., 2021). The method aims to identify the intellectual structure of a research field. **Figure 5** shows a co-citation network map of the most-cited references used in adaptation planning and climate change studies constructed using VOSviewer with a minimum co-occurrence of 20 citations. The network consists of 4 clusters having major themes: climate change adaptation (yellow), climate policy (green), adaptation governance (red), and institutional (blue).

Table 3: Top ten most cited publications

Publications	No. of citations
Moser and Ekstrom (2010)	90
Smit and Wandel (2006)	81
Neil Adger et al. (2005)	80
Measham et al. (2011)	77
Adger et al. (2008)	72
Pörtner et al. (2022)	67
Preston et al. (2010)	55
Pachauri (2014)	53
Füssel (2007)	52
Taylor, Stouffer, and Meehl (2012)	52

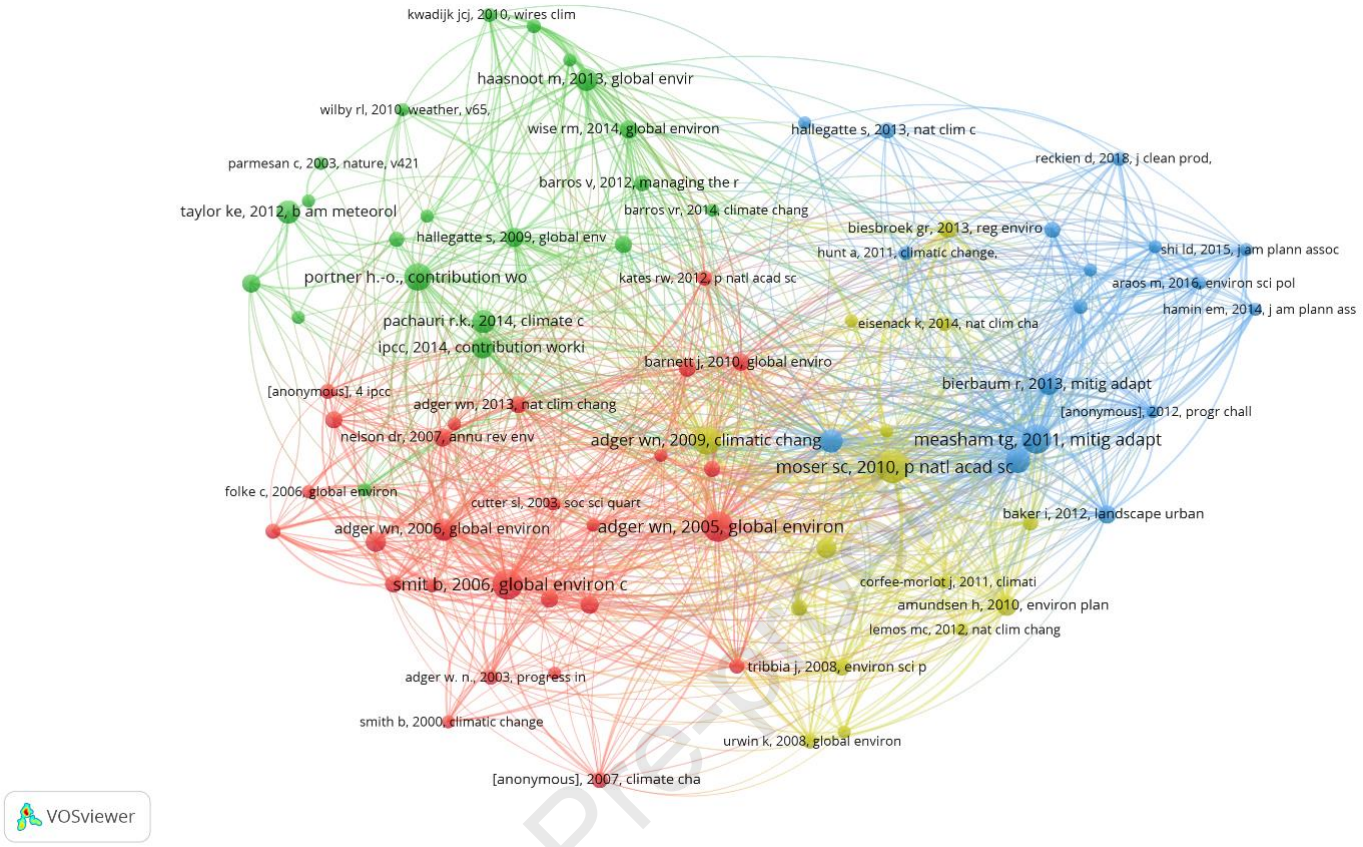


Figure 5: Co-citation analysis of most-cited references used in adaptation planning and climate change (with a minimum of 20 citations)

5.4.3. Bibliographic coupling (BC)

Bibliographic coupling is another scientific mapping method based on the narrative that the publications with common citations are contextually identical (Donthu et al., 2021). The map revealed the intellectual structure of the research field, which also entails recently published and most popular publications in adaptation planning and climate change fields. **Figure 6** shows a bibliographic coupling network map of the most-cited references used in adaptation planning and climate change studies constructed using VOSviewer, having 80 citations at least. The results developed 6 clusters having studies falling under the research areas of environmental management (blue), adaptation planning (yellow), climate change in cities (turquoise), climate change projections (red), climate governance (green), and urban climate adaptation (orange).

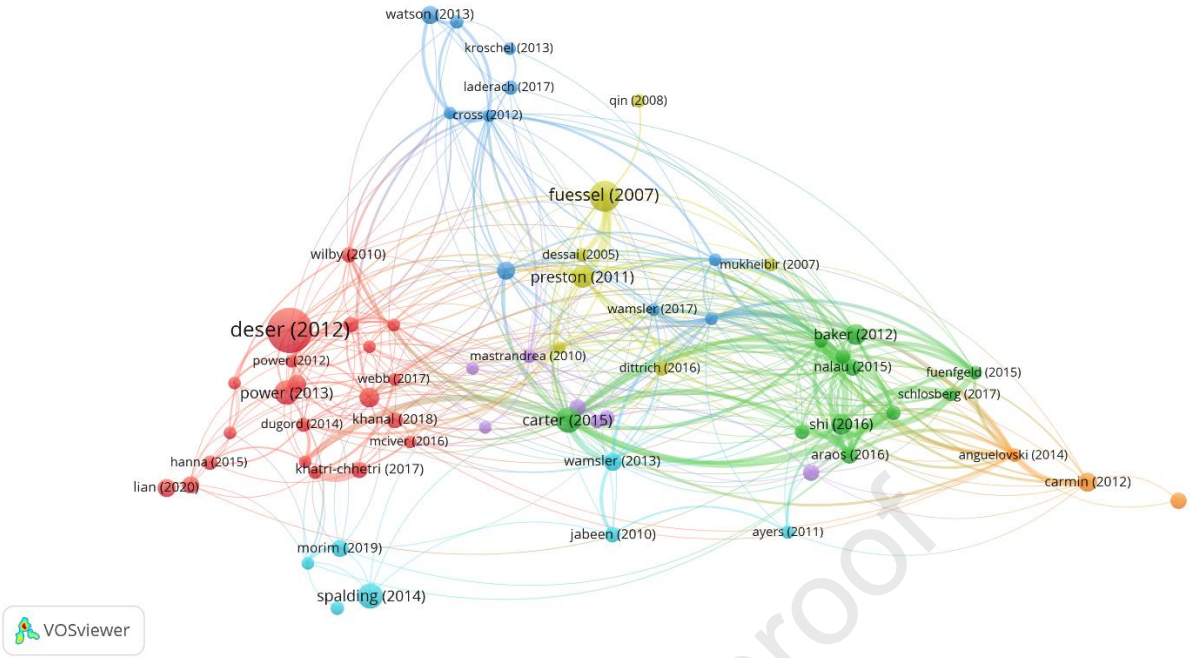


Figure 6: Bibliographic coupling of most-cited references used in adaptation planning and climate change (with a minimum of 80 citations)

5.4.4. Global research collaboration (GRC)

Since climate change is a global issue and countries, whether developed or developing, face its severe and recurring impact, global research is being carried out on climate change. Adaptation planning is being deliberated and discussed as an optimum solution to lessen the climate change impacts on vulnerable populations. As shown in **Figure 7**, the developed countries having relatively higher human and financial capital are contributing more, led by the USA, Australia, United Kingdom, Canada, Germany, and the Netherlands. The developed countries are observed to have close cooperation in adaptation planning and climate change. Studies are also being carried out in developing countries, particularly South Asian countries, namely India and Bangladesh. The international research collaboration will help the targeted countries and the neighboring countries with similar conditions to adapt to the detrimental impacts of climate change.

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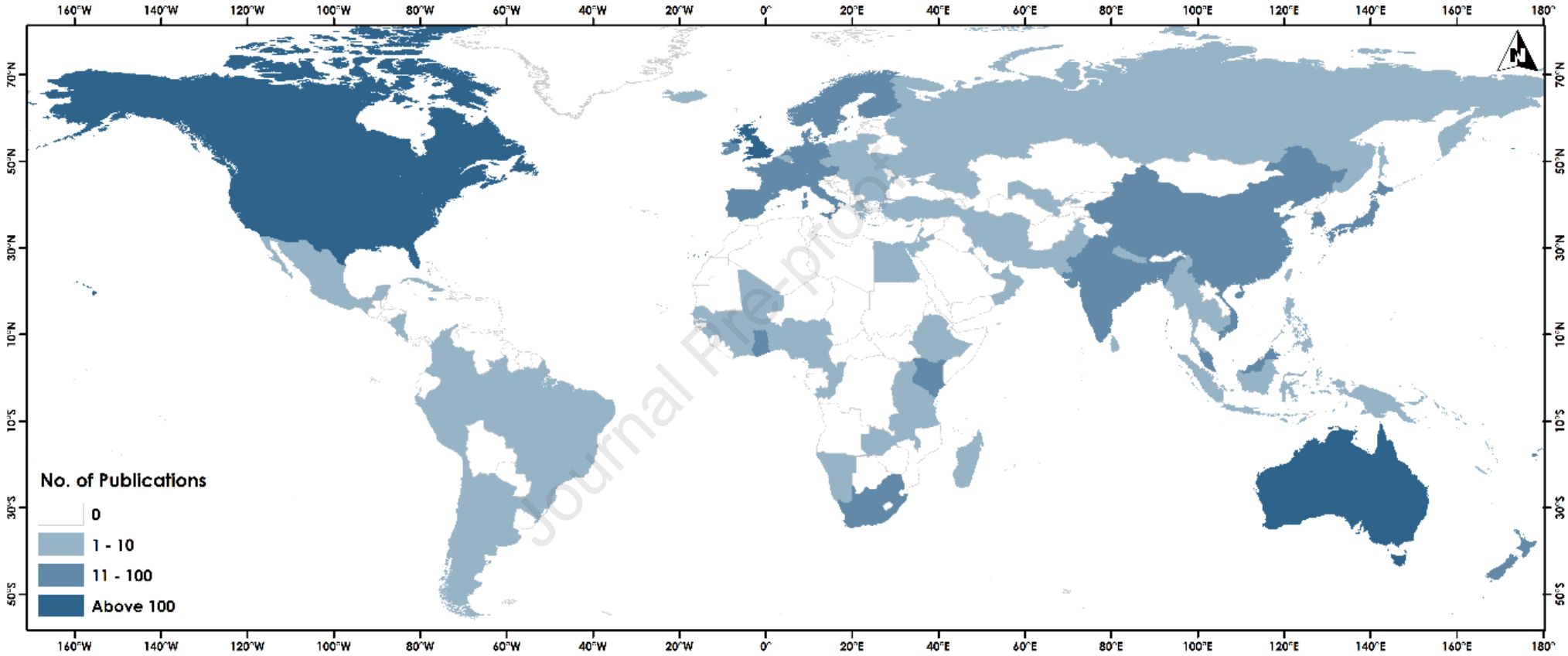

479
480 **Figure 7: Global research collaboration**

6. Discussion

Adaptation strategies are being integrated into disaster risk management and urban/rural development plans to lessen the impacts of extreme climate events. This study conducted a bibliometric analysis using an Advanced Bibliometric Analytical Framework (ABAF) to get a complete, comprehensive, and critical insight into the existing body of literature regarding adaptation planning and climate change. Results found 1087 studies published on the selected topic with major contributions from academia and a surprisingly higher frequency of publications by academia-industry collaboration with an upward publication trend. The study found that planned adaptation in the context of climate change is being studied more in developed or technologically advanced countries. However, a substantial contribution of developing countries was also observed. Adaptation planning directly and positively relates to climate action (SDG13). Apart from other factors, the community has a major role in adopting and implementing adaptation measures. In other words, climate change adaptation planning is closely intertwined with various interdisciplinary terms, e.g., social capital. Social capital is defined by its function, i.e., in the form of trust, social norms, participation, and network (Coleman, 1988, 1993; Putnam, 1993). The adaptation planning process needs local indigenous information and context, specifically on socioeconomic issues and social dynamics analysis, to understand community characteristics and link them with the adaptation policies and plans (Nakagawa & Shaw, 2004). As extreme climate events have the potential to create social divisions within communities, mostly in post-disaster situations, it is essential to incorporate the social capital dimension in the adaptation actions or measures to enable them to ensure community mobilization in the form of collective action. Besides, social networks tend to influence and are influenced by extreme climate events. Empirical evidence has found that better social networks in a community can enhance social support in the form of resource sharing and mobilization that can assist people in reducing risks (preparedness) and effectively respond (response) and withstand (recover) the disaster impacts (Ananda Y. Karunarathne, 2021; A.Y. Karunarathne & Lee, 2020). The above discussion is complemented by keyword analysis results whereby vulnerability, resilience, and adaptive capacity were found to be the most recurrent keywords in studies on climate change adaptation planning. Thus, social capital can be inferred as a missing link to ensure climate change adaptation in the communities, and efforts in this research area must be undertaken. Other aspects of the

adaptation planning process in the context of climate change include risk and vulnerability assessment and evaluation of physical form, street pattern, and micro-climatic conditions so that hazard-specific adaptation measures suitable to the physical and socioeconomic character can be outlined and implemented with enhanced willingness to adopt. Integrating these aspects requires formulating an integrated framework, and that gap should be considered in future studies associated with adaptation planning and climate change.

7. Conclusion

In the wake of climate change-induced extreme events, like floods, drought, GLOF, and heat waves, the concept of adaptation planning is emerging and gaining attention. The concept aims to reduce the risks and vulnerabilities by applying sound measures or actions and has linkages with sustainability sciences and climate-resilient development. Various studies have applied the notion of adaptation planning in different areas; however, a dearth of knowledge has been observed from a climate change perspective. This study has conducted a bibliometric analysis of adaptation planning and climate change to get an understanding of the current level of research. Advanced Bibliometric Analytical Framework (ABAF) is proposed to ensure a complete, comprehensive, and bibliometric review. ABAF is based on three core components, i.e. performance analysis, rank analysis, and scientific mapping. The findings of the study suggested an increasing publication trend, particularly in the areas of environmental sciences, ecological sciences, meteorological and atmospheric sciences, and urban climate. Climate policy, climate, and adaptation governance were major themes or categories. Most studies were targeted at SDG13: Climate Action and SDG6: Clean Water and Sanitation. Moreover, the observed connections between publications on the selected topic with vulnerability, resilience, and capacity show conceptual linkages between them. The study caters to limitations of language, publication year, and country, but it is limited by the duration of dataset retrieval as it does not cover the articles published after the date of retrieval (i.e., the 15th of April 2023).

The proposed framework can be replicated in other studies in its current state but is limited in terms of indicators of exclusion/inclusion criteria and the quantity of analysis to be performed. Future studies may add more criteria and analysis components to expand the

horizon of the proposed framework to enhance the bibliometric analytical studies. In this context, identifying the relationship between the countries and research themes can be added as another metric in rank analysis. Exploring the role of social capital in adaptation planning and integrating adaptation planning processes with disaster risk reduction and urban/rural planning are suggested as future research directions so that climate change impacts in susceptible communities can be reduced. Furthermore, country-specific gaps and their effects must be identified in the context of adaptation planning and climate change.

Declarations

Ethics approval: Not applicable.
Consent to Participate: Not applicable.
Consult to publish: Not applicable.
Conflicts of interest/Competing interests: The authors declare no conflicts of interest
Availability of data and material: Data available on reasonable request
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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: