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URBAN HEAT ISLAND AND MITIGATION INITIATIVE IN GLOBAL PERSPECTIVE: A BIBLIOMETRIC ANALYSIS FROM 2002 TO 2024

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Abstract

The urban heat island has a significant influence on urban resilience, given the increasing temperatures that cities face because of climate change. Previous studies have extensively examined urban heat islands worldwide, but the exploration of research topics and the assessment of key trends in performance within this area remain insufficiently developed and ambiguous in bibliometric analysis context. Hence, a bibliometric analysis was undertaken to investigate the research trends on the urban heat island and initiatives aimed at its mitigation from a global perspective. The publication output data was obtained from research articles available in the Web of Science (WoS) database from 2002 to 2024. The analysis of collaboration networks among authors, countries, institutions and co- citations among authors and sources was conducted using VOSviewer in this study. A total of 777 papers on urban heat island and mitigation initiative research were identified. The findings identified the main factors contributing to urban heat islands and research on initiatives to mitigate their impact, highlighted influential studies and tracked the patterns in publishing within this area. Miah et al. [1] stood as one of the most cited works with 468 citations followed by Hagmann et al. [2] which has been cited 353 times. The analysis showed that China has been in a top position in urban heat island and mitigation initiative research followed by the United States out of 88 countries involved. The most impactful insight from this analysis highlights significant thematic clusters, such as the impact of urban heat island on public health, energy consumption and air quality including various mitigation initiatives such as green roofs, urban forests and cooling technologies related to Sustainable Development Goals (SDGs) in themes 11 (sustainable cities and communities) and theme 13 (climate action). The important findings from this research can assist academics in gaining a deeper insight into the current trends in urban heat island research and mitigation efforts, as well as guide future research directions.

Keywords: Bibliometric analysis, Development trends, Urban heat islands, Urban resilience, VOSviewer.

1. Introduction

The urban heat island (UHI) spectacles describe the increased temperatures observed in urban areas relative to their surrounding rural regions. This topic has been the focus of extensive research for several decades. The phenomenon of the urban heat island has been a topic of considerable interest and study within the domain of urban climate change [3]. The proliferation of urban areas has led to substantial challenges associated with the urban heat island effect and its implications for climate change [4].

As cities expand, they often trap and hold more heat from the widespread use of materials like concrete and asphalt, which have lower reflective properties than natural landscapes [5]. This results in urban areas experiencing elevated temperatures when compared to the neighbouring countryside, worsening heat-related health problems and raising energy usage for cooling. The United Nations highlighted that urban areas are projected to house 70% of the global population by 2050, intensifying the UHI effect as more people migrate to cities [6]. The increased demand for energy and resources in these densely populated areas further contributes to greenhouse gas emissions, the critical drivers of climate change.

Comprehensive research has been carried out globally regarding the reasons and significant implications of the urban heat island phenomenon, affecting developed and developing countries alike [7]. E. Torres Molina et al. [8] investigated the impact of urban heat islands in tropical regions, finding that urban areas can experience air and surface temperatures ranging from 1.8-5.4 °C, higher than those found in surrounding rural areas, with variations potentially reaching as much as 22 °C in more severe instances. This is because urban areas tend to exhibit higher temperatures compared to their neighbouring rural regions [9].

Notwithstanding, to the best of the authors' understanding, there has been no previous research that investigated global trends in urban heat islands and associated mitigation initiatives for the period between 2002 and 2024 utilising bibliometric analysis. Based on statistical data from the World Bank, there has been a substantial surge in urban expansion and urban population from 2002 to 2024 [10]. This significant growth is closely linked to the effects of climate change and the emergence of urban heat islands. Moreover, the mitigation strategies for urban heat islands remain inadequately researched in tropical and developing countries [11].

Universally, researchers have broadly studied urban heat islands and mitigation. However, analyses of the development of international scientific studies on urban heat island mitigation through bibliometric evaluation remain inadequate and ambiguous. This current study also employs social network analysis to comprehensively understand research performance trends in this study area.

Furthermore, bibliometric analysis is utilised to comprehensively evaluate the studies and current trends in the field of urban heat islands and mitigation initiatives from a global perspective. Mitigation strategies for future research areas are also important; for example, urban vegetation, cool materials, water bodies and urban design and geometry [12-14]. This analysis provides a thorough examination of the scientific literature to identify science mapping and the most significant topics in the field.

2. Materials and Methods

2.1. Data sources and searches approach

Bibliometric analysis serves as a useful instrument for academics to illustrate and encapsulate the research output and development patterns of the worldwide scientific literature within a particular field or subject. It also thoroughly examines significant academic literature, encompassing prominent authors, esteemed journals, renowned institutions, and distinguished countries. Using bibliometric analysis, researchers can evaluate and assess the growth patterns of research quantitatively and qualitatively [15]. In addition, they can utilise science mapping techniques to gain a deeper understanding of a particular field of study [16]. Thomson Reuters created the Web of Science (WoS) database, which serves as the most comprehensive scientific search engine and primary source for retrieving bibliometric data [17].

In contrast to other databases like PubMed, Scopus, and Google Scholar, which are widely recognised as high-quality sources of scientific literature, WoS stands out as a leading resource for retrieving multidisciplinary research across various fields. It is known for providing a more consistent and standardised record of scientific literature, making it the preferred choice for researchers seeking comprehensive and reliable information. The WoS database provides a wide range of vital metadata for conducting bibliometric and network analyses [18]. This includes abstracts, document types, timelines, citation counts, lists of scholars, information on countries, universities, and the journal impact factor.

This comprehensive set of metadata enables researchers to gain insights into the scholarly landscape, track the influence of publications and identify key trends and connections within the academic community. In this study, the WoS was selected as the scientific data source for carrying out bibliometric analysis. The dataset utilised in this research includes a diverse set of indexes, such as the Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Book Citation Index-Science, Emerging Sources Citation Index (ESCI), Conference Proceedings Citation Index-Science (CPCI-S), Book Citation Index-Social Sciences and Humanities (BKCI-SSH) and the Arts and Humanities Citation Index (A&HCI).

The WoS Core Collection database was employed to perform advanced search for publications on urban heat islands and mitigation initiatives over 22 years during the preliminary phase. This study identified appropriate search keywords by reviewing highly cited literature on urban heat island research. The search terms encompassed the title, abstract and keywords as follows: TS= ((“urban heat island” OR “anthropogenic heat” OR “land use change” OR “temperature differential” OR “thermal capacity”) AND (“urban heat mitigation” OR “green space” OR “permeable surfaces” OR “urban climate change” OR “urban resilience”)). The Boolean operators were utilised as a crucial element in selecting the final dataset to prevent the omission of pertinent research articles. The main research focus for this study is defined within the period from 2002 to 2024.

The quest for pertinent articles on urban heat islands and mitigation initiatives from a global perspective was implemented on 18 September 2024. The search for the requisite articles was conducted on a single day to mitigate any potential bias arising from the daily updates of the WoS database. In addition, this study

specifically focused on articles written in the English language, as it is widely used in scholarly research. Research articles were accepted, excluding review papers, proceedings, and other document types such as meeting abstracts, early access, editorials, data papers and letters. A total of 777 articles from a file containing "Full Record and Cited References" were downloaded using the "save for other file formats" export function with "Tab- delimited (window)" and analysed with VOSviewer software. These were all the primary data sources in this paper for further bibliometric analysis, as shown in Fig. 1.

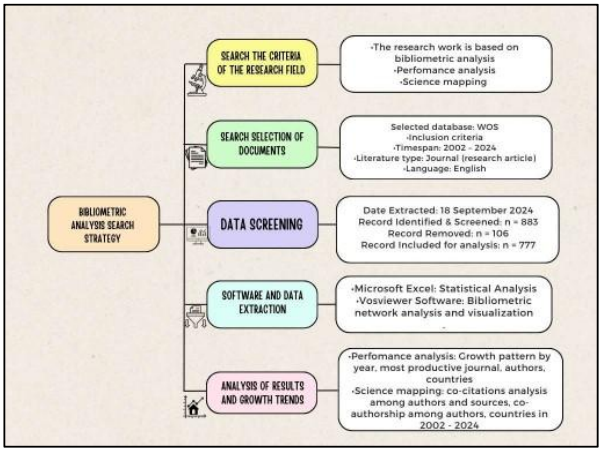

Fig. 1. Research procedure.

2.2. Statistical analysis

Initially, this study investigated the number of publications in connection with trends in research growth, the output by subject area and the types of journals focusing on the relationship between urban heat islands and mitigation initiatives. Also, it assessed the impact factors of these journals and the H-index. The research assessment conducted in this study encompassed the following components: (1) publication output, (2) subject categories as classified by the WoS database from 2002 to 2024 and (3) an analysis of the most influential journals among the top 10 in the field. The impact factors were computed using the 2024 edition of the Journal Citation Reports (JCR). The assessment of publication performance and subject categories was conducted utilising Microsoft Excel 2022.

Moreover, the data set was limited to articles published in the English language. Next, a co-citation analysis was performed to investigate the overall relationship between authors and the sources of their jointly authored publications, as well as to determine the evolution of research topics. Analysing the frequency of co-citations among authors and sources helped the researchers understand the interconnectedness between urban heat islands and mitigation initiatives, fostering connections within multidisciplinary research networks. Third, co-authorship analysis was conducted to delineate the connections among the most productive authors and nations pertaining to the research topic through VOS Viewer software.

This analytical approach continues to be a widely recognised method for acquiring insights into the dynamics of scientific collaboration among authors and

countries. It also fosters a deeper understanding of research partnerships and highlights the interconnectedness of knowledge production on a global scale. Also, a bibliometric analysis of keywords was performed to identify the main cluster of research trends regarding urban heat islands and mitigation initiatives. Table 1 provides a more detailed breakdown of the analysed variables and their corresponding methods, enhancing clarity and demonstrating the statistical analysis process.

Table 1. Summary of the examined variables and their corresponding methods of analyses.

No.	Analysed Variables	Method of Analysis
1	Articles on digital transformation research by publication year	Microsoft Excel
2	Number of articles by journals and authors	Microsoft Excel
3	Co-citations among cited authors	VOS viewer
4	Co-citations among cited sources	VOS viewer
5	Articles counted by countries	Microsoft Excel and mapchart net
6	Co-authorship among countries	VOS viewer

3. Results and Discussion

3.1. Features of publications outputs and trends

3.1.1. The number of articles

According to the evaluation of subject classifications in Journal Citation Reports (JCR), there have been notable advancements in the study of urban heat islands and mitigation initiatives, encompassing 53 wide-ranging disciplines. The top 10 subject categories were environmental science (432 articles), environmental studies (220 articles), green sustainable science (150 articles), meteorology atmospheric (135 articles), construction buildings (121 articles), urban studies (109 articles), ecology (100 articles), geosciences multidisciplinary (97 articles), remote sensing (93 articles) and energy fuels (87 articles).

Figure 2 illustrates the subject area based on urban heat islands and mitigation initiatives from 2002-2024. The figure shows research on urban heat islands and mitigation as a multidisciplinary field, drawn from a wide range of subject areas. Environmental sciences and environmental studies are the dominant areas of research, but other relevant fields such as green sustainable science and technology, meteorology atmospheric sciences, construction building and architecture, as well as urban studies are also contributing to the knowledge base. The increasing focus on urban heat islands and associated mitigation strategies among researchers stems from their substantial impact on urban resilience and climate change.

This emphasis is driven by the growing recognition of the urgent need to address urban heat island effects. Urban areas have gained increasing significance, affecting a substantial proportion of the global population. This situation underscores the necessity for scholars and stakeholders to comprehend the local and global implications of addressing urban heat islands in the context of climate change. To effectively tackle this issue, interdisciplinary collaboration is required among researchers from various fields, including management, climatology, and technology. A multidisciplinary approach can yield comprehensive solutions to urban heat island challenges.

For instance, management disciplines can contribute strategies for the implementation and oversight of mitigation efforts. Climatologists can provide insights into the complex interactions between urban environments and climate systems. Meanwhile, technological experts can develop innovative solutions for heat reduction and energy efficiency in urban settings. By fostering connections among these diverse fields, researchers can develop more holistic and effective approaches to mitigating urban heat islands. This collaborative effort is crucial for enhancing urban resilience and addressing the broader challenges of climate change in densely populated areas.

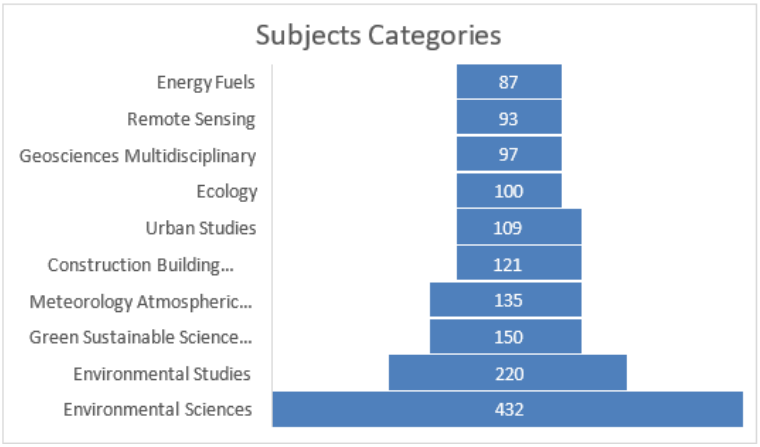

Fig. 2. Subject area output based on urban heat islands and mitigation initiatives during 2002-2024.

3.1.2. Total count of articles released by the journal

Table 2 lists the 10 most productive journals that published the highest volume of research on urban heat islands and mitigation initiatives from 2002 until 2024. The leading 10 journals accounted for more than 42.8% (333 research articles) of total publications. This study revealed that a total of 229 distinct journals published an average of 777 articles. The Journal of Sustainable Cities and Society published the greatest number of research articles on urban heat islands and mitigation initiatives with an entire of 52 publications (h-Index of 130, impact factor of 10.5) with a focus on energy & fuels (Q1), construction & building technology (Q1), green & sustainable science and technology (Q1).

Among the 10 journals presented in Table 1, these specific journals demonstrated the highest impact factor, reflecting their prominent influence and citation frequency within the academic community. The second most impactful publication was Sustainability, which released 46 papers with an impact factor of 3.3; it has an h-index of 169, and its primary categories include environmental sciences (Q2), environmental studies (Q2), and green & sustainable science and technology (Q3). Remote Sensing secured the third position for the most publications, offering 41 papers with an impact factor of 4.2 and an h-index of 193, with categories more aligned to imaging science & photographic technology (Q2/10/36), environmental science (Q2), geosciences, multidisciplinary (Q1) and remote sensing (Q2).

This was followed by Urban Forestry & Urban Greening with 38 publications and Science of the Total Environment with 35 publications. The journal Urban Forestry & Urban Greening has a 6.0 impact factor and an h-Index of 117. The main interests of this journal were environmental studies (Q1), urban studies (Q1) and forestry (Q1), while the Science of the Total Environment with an 8.2 impact factor and 353 h-Index focuses on environmental sciences (Q1). The Journal of Urban Climate has 27 publications with a 6.0 impact factor and a 75 h-Index, which focuses on environmental sciences (Q1) and meteorology & atmospheric sciences (Q1) ranked seventh highest.

This was followed by the Journal of Building and Environment with a total of 27 publications and a 7.1 impact factor, 205 of h-index and the articles related to environmental engineering (Q1), civil engineering (Q1), as well as construction & building technology (Q1). Additionally, it is worth noting that several less-represented journals have contributed significantly to the publication of research papers (refer to Table 2 for details). Also, the impact factor (IF) cited in Table 2 was for the journal ranking of impact factor, which is very important to reflect current trends in the research focus of urban heat islands such as mitigation strategies and citation patterns. In addition, journals with high impact factors often encourage interdisciplinary research and are vital for addressing complex issues in urban heat islands.

Table 2. The 10 journals publishing the maximum urban heat island and mitigation initiatives.

Journals	Publisher	Country	TP	IF	H-Index	Subject categories
Sustainable Cities and Society	Elsevier	Netherlands	52	10.5	130	Energy& Fuels (Q1/18/170), Construction & Building Technology (Q1/3/91, Green & Sustainable Science & Technology (Q1/10/91)
Sustainability	MDPI	Switzerland	46	3.3	169	Environmental Sciences (O2/159/358), Environmental Studies (0266/182), Green & Sustainable Science & Technology (O3/58/91)
Remote Sensing	MDPI	Switzerland	41	4.2	193	lmaging Science & Photographic Technology (Q2/10/36), Environmental Science (02/110358), Geosciences, Multidisciplinary (Q1/34/253), Remote Sensing (Q2/16/62)
Urban Forestry & Urban Greening	Elsevier GMBH	Germany	38	6.0	117	Environmental Studies (O1/25/182), Urban Studies (Q15/77), Forestry (Q1289)
Science of the Total Environment	Elsevier	Netherlands	35	8.2	353	Environmental Sciences (Q1/28/359)
Urban Climate	Elsevier	USA	28	6.0	75	Environmental Sciences (O1/58358), Meteorology & Atmospheric Sciences(01/12/110)
Building and Environment	Pergamon Elsevier Science Ltd	England	27	7.1	205	Engineering, Environmental (Q1/1481), Engineering, Civil (018/181), Construction &/ Building Technology (Q17/91)
Landscape and Urban Planning	Elsevier	Netherlands	25	7.9	211	Ecology (Q1/7/195), Geography, Physical (O1/3/65), Regional & Urban Planning (O13/54), Environmental Studies (Q1/15/182), Urban Studies (Q1/2/77), Geography(013/171)
Land	MDPI	Switzerland	23	3.2	54	Environmental Studies (Q2/68/182)
International Journal of Environment Research and Public Health	MDPI	Switzerland	18	4.6	198	Environmental Studies (Q1/28/359)

3.2. Authors publishing performance

3.2.1. Co-citations among cited authors

Figure 3 demonstrates the relationship between co-citations and cited authors, emphasizing thematic areas and their influence on the academic community. Analysis VOSviewer showed that from 19695 authors, 321 met the threshold. Based on the co-citations analysis, the network map primarily involved five clusters. In addition, the nodes displayed that each circle represented an author or a group of authors while the edges showed the lines connecting the nodes that indicate the co-citation frequency, which was a thicker line signifying more frequent co-citations. Cluster 1 (red colour) was centred by “oke tr”, “akbari h” and “steward id”, connected closely to Cluster 2 (green colour), Cluster 3 (blue colour) and Cluster 4 (yellow colour).

Meanwhile, Cluster 5 (purple colour) centred by "santamouris, m", "takebayashi, h," and “wang yp” were linked closely with Cluster 1 (red colour) and Cluster 3 (blue colour). The network map indicates the most active research network groups and the co-citation relations among the cited authors involved in urban heat island and mitigation initiatives research, while co- citations can indicate the flow of ideas and knowledge between researchers. Moreover, the dense connections between certain authors or clusters suggest strong collaborative relationships or shared research interests and authors who have recently emerged in the network or formed new connections might be working on innovative or emerging topics within the field. Furthermore, in this study (Figs. 3 and 4), a cluster analysis of keywords was conducted to identify the main cluster related to urban heat island effects and mitigation strategies in research from 2002 to 2024.

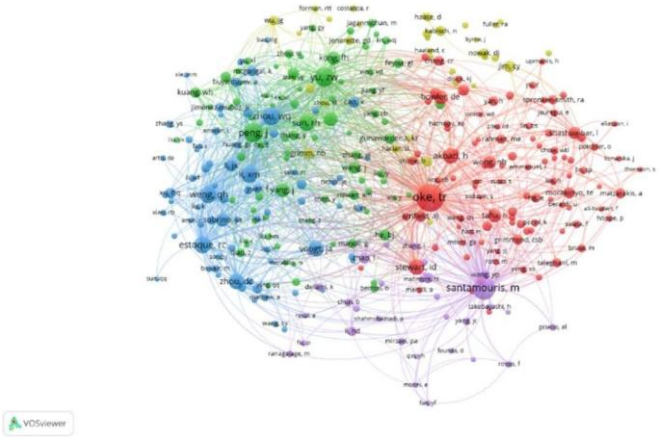

Fig. 3. Network visualisation of co-citations analysis by cited authors.

3.2.2. Co-citations among cited sources

The illustration presents a comprehensive co-citations network analysis of cited sources related to urban heat islands and mitigation initiatives research (Fig. 4). VOSviewer analysis showed that from 10062 sources, 251 items met the threshold. Based on the co-citations analysis, the network map primarily involved six clusters. Cluster 1 (red colour) was represented by “landscape urban plan” with 2532 citations, Cluster 2 (green colour) was represented by “remote sense environ” with

1645 citations, Cluster 3 (blue colour) was represented by "build environ" with 1630 citations, Cluster 4 (yellow colour) was represented by "sci total environ" with 1625 citations, Cluster 5 (purple colour) was represented by "nat commun" with 167 citations and Cluster 6 (turquoise colour) was represented by "j environ sci" with 79 citations.

Additionally, Cluster 1 (red colour) was associated closely with Cluster 2 (green colour), Cluster 3 (blue colour) and Cluster 4 (yellow colour). The relationship between co-citations and cited sources elucidates the transmission of concepts and information. Sources that are frequently cited in conjunction may indicate shared ideas, methodologies, or findings among scholars. This thematic grouping aids in recognising different fields of study and the relationships between them.

Furthermore, newly established, or recently integrated nodes within the network may be investigating emerging or nascent areas of inquiry within the discipline of urban heat island and mitigation initiatives research. This study conducted a comprehensive analysis of keyword clusters to systematically identify and assess the predominant research trends by examining the connections and frequency of co-citations and cited sources regarded as important strategies for gaining a comprehensive insight into the progression of the research topic and proposing potential areas for future study.

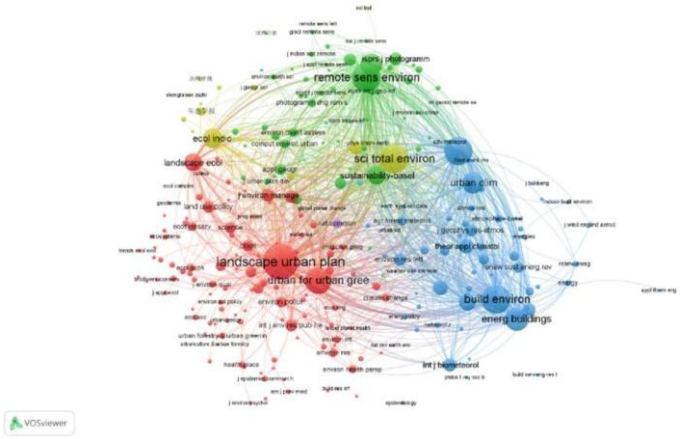

Fig. 4. Network visualisation of co-citations analysis by cited sources.

3.3. Analysis of the author's countries

3.3.1. Articles counted by country

A recent study emphasised 88 nations based on the 777 published works on urban heat island and mitigation initiatives research. Figure 5 distinctly illustrates the categorisation of published articles by different countries or regions worldwide. The countries that demonstrate the highest levels of productivity in terms of academic and research publications included China, the United States, Australia, Germany, Italy, Netherlands, England, Japan, India, and Canada. These 10 nations have consistently produced the largest volume of scholarly work, reflecting their significant contributions to global research and knowledge dissemination of urban heat island and mitigation initiatives research articles over the last 25 years. More

than 30% of the total number of research articles were published in China (432 publications), which was found with the highest number of urban heat island and mitigation initiatives publications.

According to Tian et al. [19], China has emerged as a leading contributor to UHI research. This trend reflects a growing recognition of the UHI effect's impact on urban environments, including increased energy consumption, health risks and environmental degradation. The focus on mitigation strategies is critical as cities continue to expand and face rising temperatures. Notably, the United States came as the second most productive country, which produced 260 urban heat island and mitigation initiatives publications. This considerable output reflects a growing awareness and response to the challenges posed by UHIs, which are characterized by significantly higher temperatures in urban areas compared to their rural surroundings.

Also, the United States researchers are exploring various strategies to mitigate UHI effects, including the use of reflective pavements, green roofs, and urban forestry. These initiatives aim to reduce surface temperatures and improve overall urban liveability [20]. This was followed by five other countries with a huge number of papers: Australia (77 articles), Germany (74 articles), Italy (65 articles), Netherlands (59 articles) and England (51 articles). Other countries also appeared with significant numbers of publications, such as Japan (48 articles), India (40 articles) and Canada (39 articles).

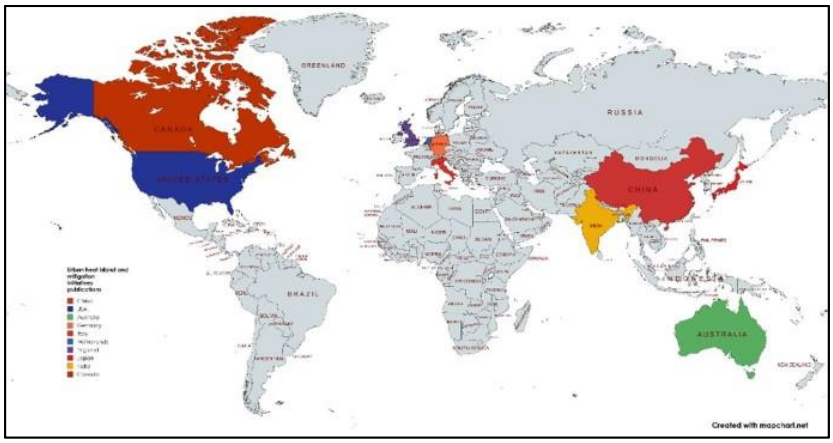

Fig. 5. The map generated using the web link: https://mapchart.net/world.html.

3.3.2. Co-authorship among countries

Research papers produced in various nations can, to a certain degree, indicate the significance and demonstrate the impact of a country in studies related to urban heat island and mitigation initiatives. Figure 6 shows the main structure of the cooperation network among the authors from different countries or regions in the world. Each node (circle) represents a country and the lines connecting the nodes indicate the frequency of co-authored publications, which is a thicker line that signifies more frequent collaborations. VOSviewer analysis showed that from 88 countries, 35 items met the threshold. Based on the co-authorship analysis, the

network map primarily involved eight clusters; within this network were eight different groups that actively collaborated among themselves (Fig. 6).

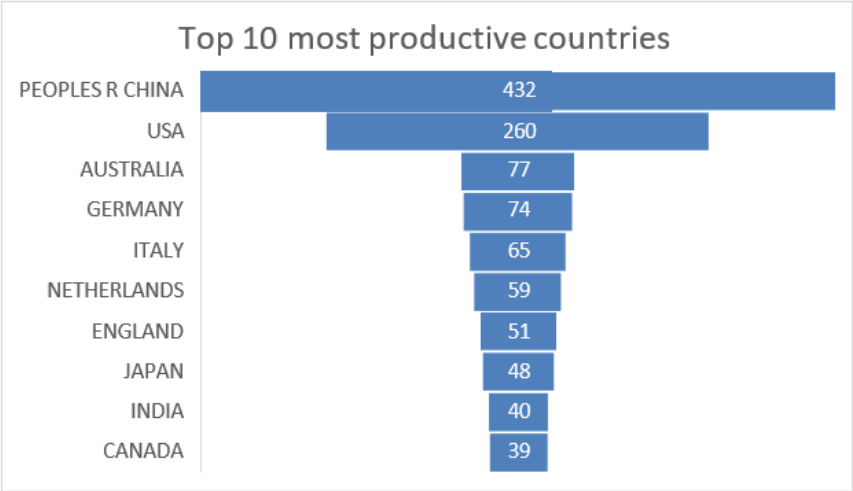

Fig. 6. Top 10 most productive countries according to the total number of publications on urban heat island and mitigation initiatives.

The bibliometric map provides a comprehensive visual representation of international research collaboration, offering insights into the global scientific landscape. The colour-coding system groups nations with similar research profiles or collaborative patterns, allowing for quick identification of research clusters or regional partnerships. China's prominence, indicated by its large node size, underscores its significant contributions to the global research output. The intricate network of lines connecting various countries illustrated the complex web of international collaborations, with thicker lines denoting stronger partnerships.

This visualisation tool not only highlights the quantity of research output but also reveals the quality and extent of international cooperation. For example, the strong connection between China and the United States suggests a mutually beneficial exchange of knowledge and resources between these two scientific powerhouses. This is because the primary organisations engaged in research on urban heat islands and their mitigation efforts included the US Environmental Protection Agency (EPA) [2] and National Centre for Atmospheric Research (NCAR), Southwest Research Institute (SwRI) and Arizona State University (ASU) [21].

Furthermore, China's diverse collaborative links with countries like Australia, Japan, India, and the Netherlands demonstrated its strategic approach to international research partnerships, spanning different continents and research traditions. This global engagement contributes to the cross-pollination of ideas, methodologies, and expertise, potentially leading to more innovative and impactful research outcomes. The map thus serves as a valuable tool for policymakers, researchers, and institutions to identify potential collaborators, assess the strength of existing partnerships and develop strategies for enhancing international scientific cooperation. Research cooperation network among authors from different countries as shown in Fig. 7.

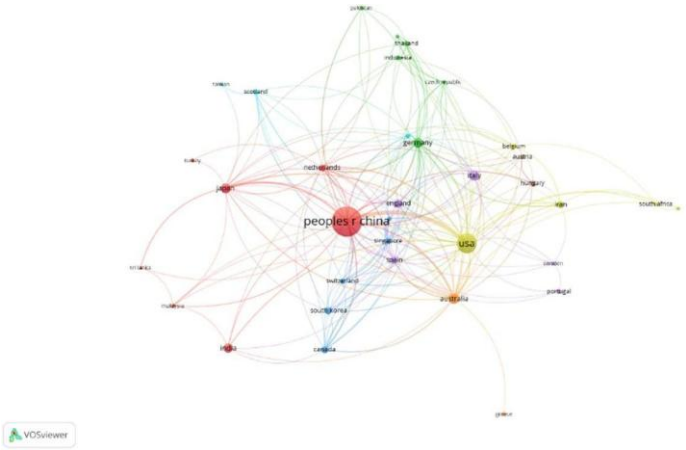

Fig. 7. Research cooperation network among authors from different countries.

3.4. Discussions

The UHI effect poses a major environmental issue, especially as urban development increases around the world. This phenomenon happens when cities have higher temperatures compared to nearby rural regions, mainly as a result of human activities and changes in land use [3, 18]. The analysis of subject matter related to the UHI effect from selected papers between 2002 and 2024 revealed several trending issues and mitigation initiatives. For example, Miah et al. [1] contributed valuable knowledge that can inform policymakers and urban planners in developing effective adaptation strategies to improve environmental quality and public health in rapidly urbanising areas like Chittagong.

Also, a significant focus has been on the spatiotemporal dynamics of UHI, as evidenced by studies that utilised remote sensing data to quantify surface urban heat island intensity [22]. Their research highlights the effectiveness of satellite imagery in assessing land surface temperatures (LST) and understanding the spatial distribution of UHI across urban landscapes. Their findings underscore the critical role of remote sensing in identifying not only the extent of SUHI but also its temporal dynamics, thereby providing essential data that can inform urban planning and mitigation strategies aimed at reducing heat-related impacts in metropolitan regions.

This research contributes to the broader discourse on sustainable urban development by emphasising the need for effective monitoring and management of urban heat phenomena. Furthermore, mitigation initiatives have also emerged as a critical area of discussion in recent literature. Studies have emphasised the role of green infrastructure, such as parks, green roofs, and urban forestry [23, 24] as effective strategies to combat urban heat islands. Research showed that increasing vegetation cover can significantly reduce surface temperatures and improve urban microclimates.

For example, cross-country assessments indicate that cities implementing green infrastructure not only mitigate urban heat island effects but also enhance biodiversity and improve overall urban resilience [25]. Additionally, innovative approaches like land-surface modelling have been employed to understand the synergies between UHI and heat waves, further informing policy decisions in creating sustainable urban

[3, 24]. These insights collectively underscore a growing awareness of urban heat islands as a complex challenge that necessitates comprehensive solutions integrating both environmental design and urban planning.

4. Future Research Direction

This study offers valuable insights for guiding future research in urban heat island and mitigation initiatives. Through bibliometric analysis, it identified significant research trends and perspectives in urban heat island and mitigation initiatives, providing a potential roadmap for future investigations. The collaboration among scholars should undertake research to advance the SDGs in Theme 11 (sustainable cities and communities) and Theme 13 (climate action). This effort aims to foster inclusive, safe, resilient, and sustainable cities while emphasising the imperative prompt action to address climate change and its repercussions. These endeavours not only mitigate the UHI effect but also contribute to overarching sustainability objectives by enhancing the quality of life in urban areas.

The issue of climate change is a pressing global concern that has garnered attention from stakeholders across the world. Efforts are being made to mitigate the impact of climate change on biodiversity, particularly in urban and rural communities. This issue has far- reaching implications, including but not limited to severe flooding, prolonged droughts, and increased occurrences of landslides. Recent research emphasised the need for integrated strategies that simultaneously address climate change and biodiversity loss. Conservation actions aimed at halting or reversing biodiversity decline can also contribute significantly to climate change mitigation. For instance, protecting high-carbon ecosystems like forests and wetlands is critical, as they play a vital role in carbon sequestration [26].

Additionally, the relationship between climate change and biodiversity is complex but critically important. Addressing one without the other risks exacerbating both crises. Therefore, a holistic approach that combines conservation efforts with climate action is essential for fostering resilient ecosystems capable of withstanding the impacts of climate change while providing vital services to humanity. By prioritising integrated strategies that recognise the interdependencies between biodiversity and climate health, stakeholders can work towards sustainable solutions that benefit the people and the planet.

5. Conclusions

Extensive bibliometric analysis has been conducted using the WoS database, encompassing 777 articles published between 2002 and 2024. The results of this bibliometric study carry important implications and provide valuable insights for guiding future research in urban heat island and mitigation initiatives. The use of bibliometric analysis can serve as a valuable tool for new scholars and researchers seeking to establish and foster connections within the global research community. By analysing the volume of articles, notable scholars, contributing institutions and leading countries, this approach can facilitate networking and collaboration opportunities.

The findings of bibliometrics can support scholars in collaborating on research endeavours, exchanging ideas, and engaging in discussions with various stakeholders, including industries, governments, non-governmental organisations (NGOs) and research centres. This collaboration aims to elucidate the interplay

between urban heat islands, mitigation efforts and climate change, thereby informing future urban planning and development initiatives. Furthermore, the significance of establishing inclusive, safe, resilient, and sustainable urban and rural communities is paramount in addressing the challenges posed by climate change.

As global urbanisation accelerates, with projections indicating that 70% of the world's population will reside in urban areas by 2050, the necessity for effective strategies to mitigate climate impacts becomes increasingly critical. Strategies such as expanding green spaces, implementing cool roofs, and enhancing urban vegetation contribute to reducing heat absorption and improving air quality in cities. Additionally, sustainable urban planning is vital for mitigating climate impacts. This involves integrating green spaces, promoting public transportation, and ensuring access to affordable housing. Sustainable cities prioritise resource efficiency, which can lead to reduced environmental impacts while enhancing quality of life.

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