

Research

The trends of major issues connecting climate change and the sustainable development goals

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Abstract

This study aims to explore the research trends and patterns of major issues connecting climate change and the Sustainable Development Goals (SDGs) by employing a bibliometric analysis. The study has found that there is an increasing number of research and policies in various countries committed to finding and implementing strategies to solve climate change issues. The countries with the most research in this field are China, India, the United States, the United Kingdom, and Australia, with Environmental Sciences & Ecology being the most published domain. The study has identified 19 clusters intersecting with climate change and SDGs, with the top five clusters in terms of proportion related to agricultural and food systems, water and soil resources, energy, economy, ecosystem, and sustainable management. This study also presents the trend changes of research topics intersecting climate change and SDGs every 2–3 years. Especially in the recent two years, with the convening of COP26 and COP27 and the advocacy of Net Zero and CBAM (Carbon Border Adjustment Mechanism) of the EU, important topics include renewable energy, protection of ecosystem services, life cycle assessment, food security, agriculture in Africa, sustainable management, synergies of various policies, remote sensing technology, and desertification among others. This shows an increasingly diversified range of important topics being discussed in relation to climate change and sustainable development goals.

Keywords SDGs · Climate change · Bibliometric analysis · CATAR · VOSviewer

1 Introduction

1.1 Background

Climate change has emerged as a pressing global issue that poses significant challenges to human societies and the environment [1–3]. Climate change is primarily due to human activities, particularly the extensive combustion of fossil fuels such as coal, oil, and natural gas. These human activities generate a substantial amount of carbon dioxide and other greenhouse gases, leading to global warming.

Global warming, a persistent increase in Earth's average temperature, is the most significant manifestation of climate change. This change in climate has led to numerous severe effects, including an increase in extreme weather events [2] (such as storms, floods, and droughts), the melting of glaciers and ice caps, a rise in sea levels, and changes to ecosystems [4] and agriculture [5, 6]. If left these impacts unchecked, these impacts could have disastrous consequences for human societies and the natural environment.

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In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was signed at the Earth Summit in Rio de Janeiro, Brazil. The goal was "to prevent dangerous human interference with the climate system," and it required countries to reduce greenhouse gas emissions in accordance with their responsibilities, abilities, and specific circumstances. The first substantive agreement of the UNFCCC, the Kyoto Protocol [7], was signed in 1997, requiring industrialized countries to reduce their greenhouse gas emissions to below 5% of 1990 levels between 2008 and 2012. In 2009, the UN hosted a climate change conference in Copenhagen in an attempt to reach a new global agreement; however, the meeting ended without a clear agreement and was considered a failure [8]. The Paris Agreement [9] was signed at the UN Climate Change Conference in 2015, with the goal of keeping global warming to well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius. To achieve this, countries agreed to submit nationally determined contributions (NDCs) to reduce emissions and to review these goals every five years. These agreements and meetings highlight the challenges of combating climate change, including in science, policy, economics, and justice. A key issue is how to ensure economic development and poverty reduction while reducing greenhouse gas emissions. These challenges and issues are intimately related to sustainable human development.

The Brundtland Report, "Our Common Future [10]," was released by the United Nations World Commission on Environment and Development in 1987. The report first introduced the concept of "sustainable development," defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." The Rio Declaration [11] and Agenda 21 [12] were both signed at the Earth Summit in 1992. The Rio Declaration included 27 principles on sustainable development, while Agenda 21 was a global action plan aimed at achieving a balance between the environment and development. In 2000, the United Nations established eight development goals to be achieved by 2015, known as the United Nations Millennium Development Goals (MDGs), which included reducing extreme poverty and hunger, improving levels of education, health, and gender equality, and ensuring environmental sustainability. The United Nations General Assembly adopted the 2030 Agenda for Sustainable Development in 2015, which outlines 17 Sustainable Development Goals (SDGs) as a blueprint for achieving a more sustainable future for all [13].

Among them, SDG13 (Climate Action) is directly related to climate change, with the aim to "take urgent action to combat climate change and its impacts". SDG13 encourages all countries to respond to climate change, strengthen their resilience and adaptability to its impacts, and integrate climate change measures into national policies, strategies, and plans. The goal also emphasizes enhancing education, raising people's awareness of the threats posed by climate change, and increasing institutional capacities to handle climate change. It also refers to global participation and cooperation in addressing these issues. This includes development assistance to help developing countries enhance their capacities to deal with climate change.

The goal of sustainable development is to achieve balance in social, economic, and environmental dimensions, a principle also known as the "triple bottom line [14]." Under this framework, it is not only necessary to ensure economic growth and social justice but also to ensure the health and sustainability of the Earth's ecosystems and resources. Therefore, addressing climate change is an integral part of achieving sustainable development. On the other hand, accomplishing one or more sustainable development goals is also a way to address climate change issues.

1.2 Research frontier

Addressing the issue of climate change faces many challenges and obstacles, including political challenges, economic factors, technological challenges, social and cultural barriers, and issues of inequality. Firstly, policy makers need to strike a balance between short-term economic benefits and long-term environmental sustainability. Political disagreements and national interests can also hinder the achievement and implementation of global climate agreements [15, 16]. Secondly, transitioning to a low-carbon economy requires a significant amount of funding and investment. Many economically backward countries may lack resources to implement necessary changes [17]. Thirdly, although renewable energy technologies have made significant progress, these technologies still can't completely replace fossil fuels in many cases [18]. Fourthly, human lifestyles and consumption patterns need to undergo major changes, which may face resistance in many societies and cultures [19]. Lastly, the impacts of climate change are not equal globally. Some of the poorest and most vulnerable countries and communities are often the most affected, yet they lack the resources and capacity to cope with these changes [20].

There are numerous studies related to climate change, and these studies encompass a wide range of issues. Issues related to climate change and sustainable development goals [21], for example, the water-energy-food (nexus), has been extensively studied in relation to climate change in the past [22]. In this issue, systematic analyses, comparisons,

interpretations, and governance recommendations have been proposed, along with in-depth exploration of sustainable development goals and appropriate management models [23–25].

The connection between climate change and the SDGs is evident, as the impacts of climate change have the potential to undermine the progress made towards achieving these goals [166, 167]. For instance, climate change has direct implications for SDGs [26–32] related to poverty reduction (SDG1: NO Poverty), food security (SDG2: No Hunger) [33–39], energy (SDG7: Affordable and clean energy) [40–43], clean water and sanitation (SDG6: Clean water and sanitation), and sustainable cities [44–46] and communities (SDG11 Sustainable cities and communities). People must take urgent action to combat climate change and its impacts, including enhancing the resilience and adaptive capacity of nations to climate-related disasters, and integrating climate change measures into national policies and planning (SDG13: Climate action). Therefore, understanding the trends and patterns of research on the interlinkages between climate change and the SDGs is crucial for policymakers, researchers, and practitioners to identify gaps and prioritize efforts in addressing these challenges [47–49].

However, many topics still require systematic research to formulate sustainable management strategies. For instance, key decisions from the COP26 held in 2021 included the formulation of long-term low-carbon development strategies, strengthening actions to reduce non-CO2 greenhouse gases (such as methane), and enhancing the intensity of nationally determined contributions (NDC) targets for 2030 [50–53]. Comprehensive assessments are needed on how countries can gradually reduce coal burning and phase out fossil fuel subsidies, as well as establish rules for the international carbon market [54].

In order to follow these resolutions, the majority of countries around the world are currently formulating net-zero emission management strategies. Net-zero emissions mean that the greenhouse gas emissions produced by an organization, city, region, or country are balanced by the amount they offset, thereby contributing zero to global warming [55].

When systematically formulating net-zero management strategies, there are several important topics that need to be considered, such as energy transition (requiring investment and policy promotion to replace fossil fuels with renewable energy) [56, 57], green infrastructure (constructing low-carbon, green infrastructure, such as green buildings and public transportation systems) [58], green finance (encouraging and guiding financial institutions to invest in low-carbon technologies and industries, and incorporating climate risks into their risk management frameworks) [59], carbon pricing (establishing and implementing carbon pricing systems, such as carbon taxes or carbon trading markets, to reflect their true environmental costs), and international cooperation (climate change is a global issue that requires cooperation among countries to share resources and technology).

It involves multiple Sustainable Development Goals (SDGs). These strategies need to take into account trade-offs or synergistic effects, including the balance between economy and environment (energy transition may lead to job loss in certain industries, but it may also create new job opportunities. Appropriate policies are needed to mitigate the impact of this transition) [60–62], fairness (wealthier countries have more resources to reduce emissions, while poorer countries may rely more on fossil fuels. To resolve this inequality, international aid or other mechanisms may be needed) [63, 64], cross-sector collaboration (many solutions will require cooperative work between different sectors or industries, such as energy, transportation, construction, finance, etc.) [65, 66], technological innovation and application (from improving energy efficiency to developing clean energy, and designing and implementing carbon capture and storage (CCS) technologies, technological innovation plays a key role in achieving net-zero. Of course, this also requires resource input and a suitable policy environment to incentivize and support) [67–69], behavioral and cultural change (to successfully achieve net-zero, it may be necessary to change public behavior and values, from dietary habits to travel methods, and attitudes towards energy use. This may involve education, policy guidance, and public participation) [70, 71], and ecological restoration and protection (forests, oceans, and other natural ecosystems are important carbon sinks of the planet. Protecting and restoring these ecosystems can provide important offset strategies, while also helping to protect biodiversity and enhance ecological resilience) [72].

Strategies to address climate change include mitigation and adaptation. The aforementioned net zero is a mitigation strategy, while the formulation of adaptation strategies to manage and respond to climate change also requires systematic consideration. This includes disaster prevention and post-disaster recovery, water resource management, adjustments to farming and livestock practices, urban planning and design, protection and restoration of ecosystems, and policy and legislation among other topics. Additionally, research suggests that enhancing the ability to manage extreme weather events can reduce economic, social, and human losses, and ultimately decrease borrowing from lending institutions. The vulnerability to extreme weather events, disaster management, and adaptation must become part of the long-term sustainable development planning for developing countries [73–76].

In this process, there indeed exist many challenges, echoing the previously mentioned obstacles faced in tackling the issue of climate change. These include technical, policy-related, economic, social, and cultural aspects. Therefore, people must take a systemic and holistic approach, implementing solutions to climate change from the framework of sustainable development.

Currently, there are over ten thousand academic papers discussing the relevance of climate change or one or more Sustainable Development Goals (SDGs). There are numerous ways to summarize, integrate, or categorize these research perspectives. Common methods include convening expert meetings [77, 168] or using literature mining software [73, 74, 78, 169, 170] such as VOSviewer, Microsoft Excel, and Biblioshiny, to conduct structured reviews of the interrelationships between Climate Change (CC) and SDGs.

The discussions at the expert meeting revealed the synergies and trade-offs between climate change and Sustainable Development Goals (SDGs), as well as the impact of climate change (CC) on the achievement of the SDGs [77]. Using literature software, the bibliometrix package, and R library, it was found that precipitation, drought, and evapotranspiration are the main climate terms most focused on under the topic of climate change [79]. Moreover, an analysis using Microsoft Excel on published journal articles found that gender equality, climate action, and global health are the key words most focused on in studies related to the Sustainable Development Goals. Some researchers also presented the evolution of themes over the years, and the co-occurrence maps of key words in the context of climate change and sustainable development practice, and found that there have been many research studies in these areas, but there is still a need for more in-depth study [80].

However, as highlighted in the background, after the 2015 Paris Agreement and the United Nations' Sustainable Development Goals were proposed, researchers worldwide are called upon to perform comprehensive and systematic analyses, categorizations, and discussions of the results presented by these literature analysis tools. These efforts aim to aid researchers and policymakers in addressing climate change and its related problems, as well as formulating suitable strategies for these issues, all from a perspective of sustainable development. These areas continue to require further in-depth research, and bibliometric analysis can serve as one effective method in this regard.

1.3 Research questions

The research question of this study is to examine the trends of major issues connecting climate change and the SDGs, as reflected in the literature [81, 82]. In particular, the study aims to identify the most prominent Clusters and sub-Clusters related to this intersection and to understand the evolution of research in this area over time. This examination will help uncover potential gaps in knowledge, as well as highlight areas in need of further investigation or policy intervention.

Additionally, when systematically analyzing the issues and sub-issues of climate change within the framework of sustainable development, we still do not have a clear understanding of how many important issues related to climate change have emerged since the United Nations announced the Sustainable Development Goals in 2015, as well as the proportion of these issues in the research or which fields is leading in these areas [75, 77, 83]. The policy-making and research processes have not had sufficient literature to help understand the varying degrees of correlation between these issues to aid policy-makers or researchers in making appropriate strategies. Moreover, one indicator of the current situation in various countries is the development status of how researchers or research institutions in these countries view climate change within the framework of the Sustainable Development Goals, but there is limited academic research on the issues connecting climate change and the sustainable development goals [84].

This study poses four questions:

- Q1: What are the main research topics at the intersection of climate change and sustainable development goals?
- Q2: How have the research trends at the intersection of climate change and sustainable development goals developed?
- Q3: What are the main research countries at the intersection of climate change and sustainable development goals?
- Q4: What are the main research fields at the intersection of climate change and sustainable development goals?

1.4 Methodological approach

This study employs a bibliometric analysis to systematically review and analyze the body of literature on the connection between climate change and the SDGs. Bibliometric analysis is a quantitative method that employs statistical techniques to analyze and classify large volumes of academic publications. This method has the advantage of providing a comprehensive and objective overview of the research landscape [85], as compared to traditional literature reviews and other classification methods, which may be subject to biases and limited in scope [80, 86, 87].

1.5 Significance of the study

The findings of this study will provide valuable insights into the trends and patterns of research on the interlinkages between climate change and the SDGs, helping to inform future research agendas and policy interventions. By identifying the most prominent Clusters and potential knowledge gaps in this area, this study can contribute to a better understanding of how climate change and the SDGs are interconnected, thereby supporting the development of more effective strategies to address these pressing global challenges.

1.6 Potential applications

The results of this study can be applied in various ways. For instance, the findings can be used by researchers to identify research gaps and opportunities, guiding the direction of future studies. Policymakers and practitioners can also use the insights gained from this study to prioritize efforts and allocate resources more effectively in addressing the challenges posed by climate change and achieving the SDGs. Furthermore, the study can contribute to the development of interdisciplinary research, as understanding the complex interconnections between climate change and the SDGs requires the integration of knowledge from multiple fields and disciplines.

In conclusion, this study aims to explore the research trends and patterns of major issues connecting climate change and the SDGs using a bibliometric analysis. The findings will provide valuable insights for researchers, policymakers, and practitioners.

2 Methodology

2.1 Literature mining tools

This study analyzes and categorizes literature using the two tools. The first one is called Content Analysis Toolkit for Academic Research (CATAR), the other one is called VOSviewer.

2.1.1 The benefits of using CATAR for literature analysis

CATAR is designed to help researchers analyze scholarly literature with academic value. CATAR is particularly effective in multidimensional scaling (MDS) and hierarchical agglomerative clustering (HAC) [88], which can be used as one of the presentation directions for research outcomes. MDS is a technique that presents n documents on a map according to their similarity [89], where documents with high similarity cluster in close proximity to each other, while those with low similarity are located further apart. HAC is a type of document clustering [90] that does not require users to specify the number of categories and can iteratively group the most similar documents or categories into larger groups, gradually organizing all documents from the bottom up. In particular, the complete linkage method can group files that are highly similar to each other into the same group. Therefore, if two files cite common bibliography, they will generate a coupling relationship, and the more bibliography they share, the higher the correlation will be, and the more likely they will be classified into the same category.

The topic map of this study was generated by CATAR using multidimensional scaling (MDS) technique to calculate the relative relationships between categories in a two-dimensional space and draw the topic map accordingly. In the map, circles represent a group of documents classified into the same cluster, with the size of the circle indicating the number of documents in the group, and the distance between circles representing the strength of the relationship between the groups. The closer the circles, the higher the relevance between the topics. The color of the circle represents the classification result in the next higher level, and if the circle is composed of dashed lines, it indicates that it cannot be clustered in the next level [91].

2.1.2 The benefits of using VOSviewer for literature analysis

The second tool used in this study is VOSviewer, which is a visualization tool characterized by its technical robustness and relatively simple usage. It allows for a detailed examination of bibliometric maps. In the network visualization maps produced by VOSviewer, each label is represented by a colored node, with node size determined by the frequency of use of the item. The higher the usage frequency of an item, the larger its label. In addition, the thickness of the nodes and connecting lines indicates the co-occurrence frequency of the labels. Nodes with the same color have stronger connections [74, 84, 85, 92].

As keyword co-occurrence network analysis is one of the most effective methods, a large number of studies have used VOSviewer for topics such as climate change or sustainable energy [91, 93, 94], helping researchers quantify trends in research Clusters and future research directions. This study use keyword co-occurrence network analysis in Vosviewer.

2.2 Explanation of data background

2.2.1 The selection of the database

The data source for this study is the Web of Science (WoS) academic database by Thomson Reuters. Analysis of citation data in WoS has shown greater consistency and accuracy than other databases such as Scopus and Google Scholar, [95] thus this study only analyzed journals included in WoS.

2.2.2 Boolean operators

The background setting for downloading data from WoS was as follows: TS = (climate change) AND AB = ("sustainable development goal" OR "sustainable development goals" OR SDG OR SDGs). These documents are focused on the Cluster of climate change, and the mention of SDGs in the abstract refers to the United Nations' Sustainable Development Goals. The SDGs aim to address major global issues, including poverty, hunger, inequality, and climate change. Therefore, if a document related to climate change also involves SDGs, it may explore how to link climate change with sustainable development goals to achieve a more sustainable future. Such research may investigate the impact of climate change on sustainable development goals or how to address issues related to climate change by achieving sustainable development goals.

2.2.3 The status of literature download

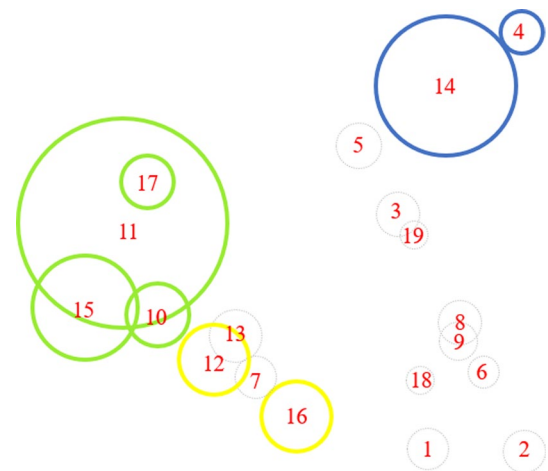
In order to understand the research trends up to December 31, 2022, a total of 2533 articles were downloaded for analysis. On the other hand, when downloading data from the WOS database, it was found that the closer it was to 2022, the more literature discussed CC and SDGs. In order to understand the research trends every 2–3 years and appropriately distribute the number of articles for analysis, research from 2015 to 2017, 2018 to 2022, and 2021 to 2022 was also downloaded. A total of 177 articles were from the first three years, 955 articles were from the middle three years, and 1401 articles were from the last two years.

3 Results and discussion

The research results are presented using the analysis results of two tools, CATAR and VOSviewer. The two research tools are distinguished by date. The data analyzed by the CATAR tool dates from 2015 to 2022, and this tool carries out a comprehensive analysis of the literature. The data analyzed by the VOSviewer tool is divided into three parts: 2015–2017 (the first three years), 2018–2020 (the middle three years), and 2021–2022 (the most recent two years), to understand the development trends of the research field. In addition, CATAR also specifically presents the main research fields and research countries of the literature as academic references.

Table 1 CATAR categorizes linkages between CC and SDGs (2015–2022)

Cluster N.O	Number of documents	Proportion (%)	Key words
A-1	416	34	Sustainable development goal, food, system, soil, agriculture
A-2	70	6	Water, security, resource, management, water resource
A-3	139	11	Energy, renewable energy, emission, country, economic
A-4	97	8	Ecosystem, land, grassland, degradation
A-5	66	5	Entrepreneurship, resilience, ethic, development, goal
A-6	40	3	Forest, landscape, redd, plu, lesson
A-7	55	5	Biodiversity, land, implication, mitigation, ecosystem
A-8	41	3	Co-benefits, clean, air quality, energy, cook
A-9	26	2	Cover, surface, city, surface water, amur
A-10	17	1	Health, mental health, climate change, planetary health, guideline
A-11	20	2	Coastal, knowledge integration, knowledge integration in sustainability governance through science-based actor, climate-change-related, city-university
A-12	60	5	Ocean, marine, reef, coral, biodiversity
A-13	32	3	Tourism, sustainable tourism, clean development mechanism, park, antimicrobial
A-14	19	2	City, urban, infrastructure, government
A-15	20	2	Local and global, defecation, ndc, mega-urban, green and blue infrastructure
A-16	31	3	Sustainable development, corporate, company, cultural, sustainability
A-17	19	2	Survey, carbon balance, renewable, energy, carbon neutrality
A-18	30	2	Circular, circular economy, waste, global research, waste management
A-19	22	2	Farmer, adaptation, landslide, vulnerability, social

Fig. 1 Maps of the clusters (2015–2022)

3.1 Results and discussion of bibliographic coupling analysis by using CATAR (2015–2022)

Using CATAR for bibliographic coupling analysis and multiple hierarchical agglomerative clustering, 19 clusters (A-1 to A-19) were obtained at the fourth level, with 1220 documents participating in clustering. The characteristic vocabulary of each cluster is shown in Table 1 (with a default threshold of 0.01), and the degree of association is shown in Fig. 1, (with a threshold set to 0.02). Furthermore, the top five clusters in terms of proportion are related to agricultural and food systems, water and soil resources, energy, economy, ecosystem, and sustainable management, with a proportion of 53% of the documents in this level. The first cluster has the highest proportion of 34%.

Table 2 The topic of clusters (2015–2022)

Cluster N.O	Topic	Circle color
A-1	Sustainable Agriculture and Food Systems	None
A-2	Water Security and Resource Management	None
A-3	Renewable Energy and Economic Impact	None
A-4	Ecosystems and Land Degradation	Blue
A-5	Entrepreneurship and Ethical Development	None
A-6	Forest Conservation and Lessons from REDD+	None
A-7	Biodiversity and Ecosystem Mitigation	None
A-8	Clean Energy and Air Quality Co-benefits	None
A-9	Global Land Cover Change and Urban Heat Island Effect	None
A-10	Climate Change and Global Health Guidelines	Green
A-11	Knowledge Integration for Climate Resilience	Green
A-12	Ocean Conservation and Coral Reef Biodiversity	Yellow
A-13	Sustainable Tourism and Clean Development	None
A-14	Urban Infrastructure and Governance	Blue
A-15	Integrated climate change adaptation strategies from sanitation facilities to green–blue infrastructure	Green
A-16	Corporate Cultural Sustainability	Yellow
A-17	Carbon Neutrality and Renewable Energy Survey	Green
A-18	Circular Economy and Global Waste Management	None
A-19	Social Vulnerability and Farmer Adaptation	None

In Fig. 1, clusters 10, 11, 15, and 17 are in green, clusters 4 and 14 are in blue, and clusters 12, and 16 are in yellow. These colors indicate that they can continue to form clusters in the next level and suggest that these topics are worth exploring as they are related to each other. Dashed circles represent clusters that cannot be agglomerated in the next level.

Referring to Table 1 for the keywords condensed in each cluster, appropriate names for the clusters are assigned. The results are shown in Table 2.

Through the research results of Fig. 1, since the circles represent the knowledge content contained in the cluster, considering factors such as circle color, circle size, and the intersection and union of circles, a systematic discussion is conducted below.

3.1.1 The relationship about A-10, A-11, A15 and A17 (color green)

In the green circle, A-10, A-11, A-15, and A-17 are four significant topics. The critical issues intersecting these four topics, this study discovered, include "Adaptation and mitigation strategies", "Integration of knowledge and collaboration", and "Urban and community context".

The four Clusters collectively highlight the importance of both adaptation and mitigation strategies in response to climate change. Cluster 10 emphasizes the need to understand and address the health impacts of climate change as an adaptation measure [88, 89, 96]. Cluster 11 focuses on building resilience in coastal areas, which is another form of adaptation [97]. Cluster 15 covers various aspects of climate change adaptation strategies, including public health, particularly sanitation issues, large urban environments, and the application of green and blue infrastructure. It emphasizes the importance of considering these issues from both local and global perspectives [98–102]. Cluster 17 centers on mitigation strategies such as achieving carbon neutrality through renewable energy sources [95, 97, 103–105].

Clusters 11 and 17 highlight the importance of integrating knowledge from various sources and fostering collaboration between different stakeholders. Cluster 11 emphasizes the role of knowledge integration in sustainability governance, while Cluster 17 involves surveys and research on carbon balance and renewable energy, which require collaboration among experts from various fields.

Cluster 10, 11 and 17 explore the impacts of climate change and sustainable development within urban or community settings. Cluster 10 investigates the relationship between climate change and health in the context of planetary health. Cluster 15 addresses the role of green and blue infrastructure in promoting sustainable development

within mega-urban areas. Cluster 17 focuses on achieving carbon neutrality in cities or countries, which has direct implications for urban and community sustainability.

3.1.2 The relationship between “ocean conservation and coral reef biodiversity” (A-12) and “corporate cultural sustainability” (A-16) (color yellow)

The relationship between "Ocean Conservation and Coral Reef Biodiversity" and "Corporate Cultural Sustainability" is closely connected to climate change and ongoing sustainable development [106–108]. Many companies recognize the importance of environmental sustainability, particularly in the context of climate change and sustainable development. They incorporate this into their business strategies, which includes supporting ocean conservation and preserving coral reef biodiversity through environmentally-friendly practices, philanthropy, or partnerships with non-profit organizations. Examples of this include adopting sustainable practices and reducing greenhouse gas emissions, promoting innovation in products, services, and technologies that contribute to ocean conservation and coral reef biodiversity protection, and collaborating with various stakeholders, including customers, employees, investors, and local communities, to address the challenges of climate change and support ocean conservation and coral reef biodiversity preservation [109–111].

3.1.3 The relationship between “ecosystems and land degradation” (A-4) and “urban infrastructure and governance” (A-14) (color blue)

First, Climate change poses threats to ecosystems and land, including extreme weather events and unstable rainfall patterns. Ecosystems play a crucial role in land conservation, water resource management, and biodiversity protection. Disrupting ecosystems increases the risk of land degradation, adversely affecting agriculture and ecological environments. Protecting and restoring ecosystems are key to achieving sustainable development goals [171, 172].

Second, rapid urbanization necessitates large-scale infrastructure development. The expansion and management of urban infrastructure are directly linked to land use. Poor urban planning and management can lead to improper land use, overdevelopment, and environmental deterioration. Effective urban governance should emphasize the sustainability of land use, including land planning and environmental regulation. Sustainable urban infrastructure and governance help reduce the risk of land degradation while achieving sustainable development goals [173–176].

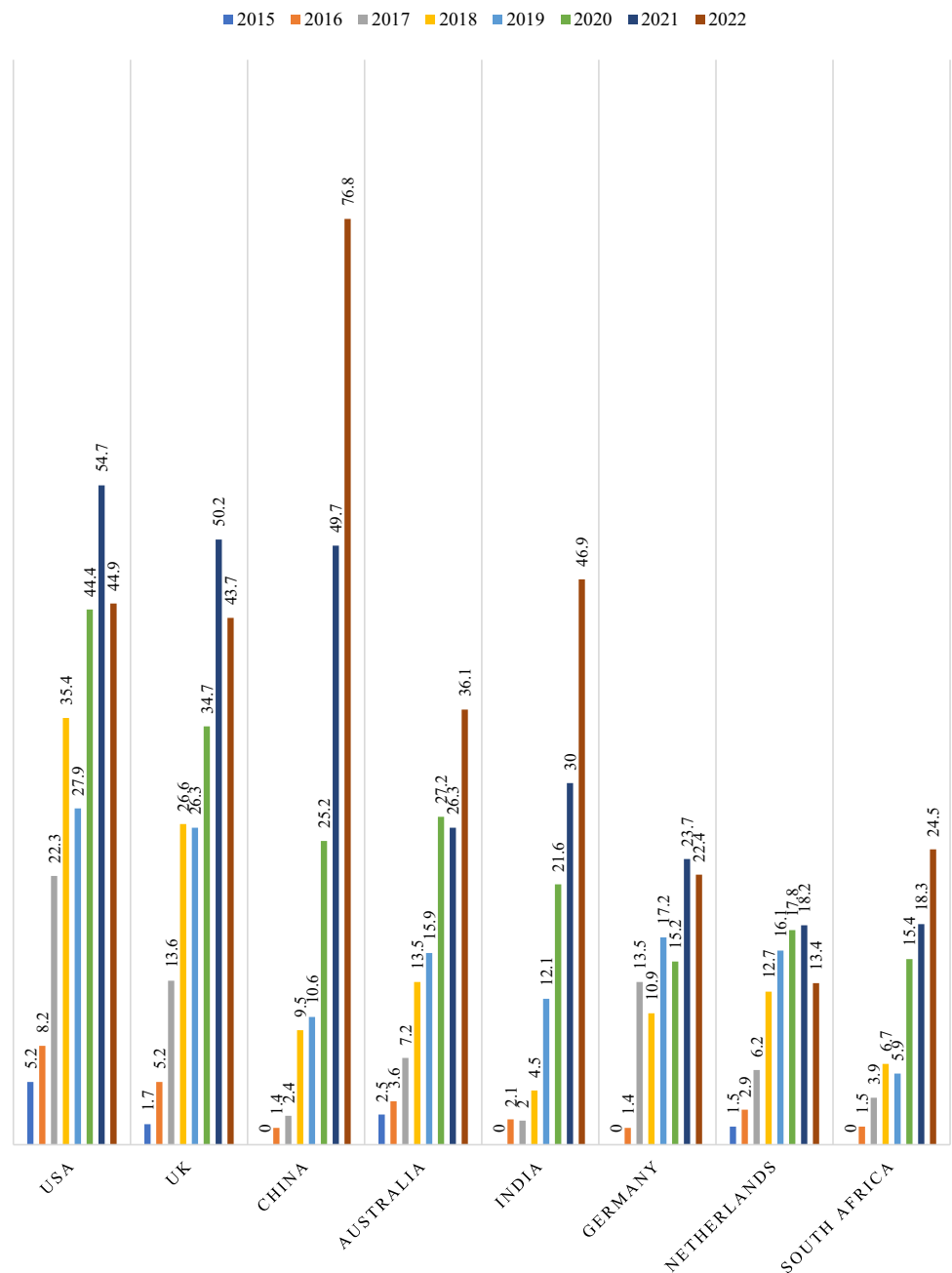
Therefore, the relationship between ecosystems and land degradation and urban infrastructure and governance should be viewed comprehensively. The expansion and management of urban infrastructure should fully consider ecosystem protection and land degradation prevention. For instance, urban planning may include the preservation of green spaces and natural conservation areas to promote ecosystem health. Moreover, urban governance should emphasize the involvement of multiple stakeholders to ensure that land use and infrastructure development align with the principles of sustainable development. This necessitates interdisciplinary research and policy formulation to ensure effective management of land resources during the urbanization process while safeguarding ecosystems to address climate change and achieve sustainable development goals.

3.2 Ranking of countries by the number of published papers, citation count, and publication year

The overview analysis through CATAR is used to present the top eight countries in terms of the number of published papers. Considering that each piece of literature might be co-authored by multiple individuals, the analysis results are presented using Fractional Count (FC). FC means that all the co-authors are counted as a single author. For instance, a paper co-authored by two individuals is counted as one, and the contribution of each author to the paper count is 0.5 and 0.5, respectively.

The results of the FC statistics are shown in Figs. 2 and 3. We can observe that within the defined scope, the number of papers has significantly increased since 2015. The top eight countries in terms of the number of published papers, from most to least, are the United States, the United Kingdom, China, Australia, India, Germany, the Netherlands, and South Africa. If we only look at 2022, the top eight countries from most to least are China, India, the United States, the United Kingdom, Australia, Spain, Germany, and Canada.

Fig. 2 Statistical analysis of the top eight countries in terms of the number of papers published, and their publication years, using Fractional Count



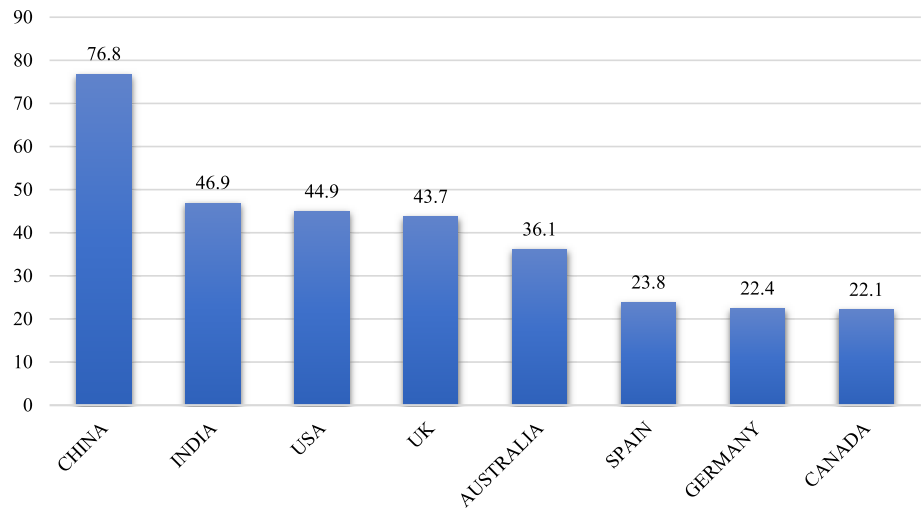
3.2.1 The number of articles interpreting climate change issues from the perspective of sustainable development goals

By observing the results presented in Fig. 2, two pieces of information can be identified. The first piece of information is that, whether the data time is from 2015 to 2022 or only looking at 2022, China, India, the United States, the United Kingdom, and Australia are all in the top five. The reasons for this include several factors:

The first factor is economic influence. These countries are significant pillars of the global economy, and their policies and investment decisions have massive impacts on the global economy. For instance, China is the world’s largest manufacturer and largest emitter of carbon dioxide, while the United States, as the world’s largest economy, holds significant sway in driving global climate action.

The second factor is population size. India and China are the two most populous countries globally, and their decisions will have monumental impacts on global climate change. In countries with large populations, the need for sustainable development is particularly pressing [112–121].

Fig. 3 Statistical analysis of the top eight countries in terms of the number of papers published in 2022, using Fractional Count



The third factor is influence in science and technology. The United States, the United Kingdom, and Australia hold leadership positions in the field of science and technology, including research and development in climate science and environmental technologies. Their innovations and solutions can have significant impacts on the global climate change issue [115–117].

The fourth factor is policy and international leadership. These countries play critical roles in global policy and international affairs [122–125]. For instance, the United Kingdom was the host of the 2021 United Nations Climate Change Conference (COP26), and the United States also plays a leading role in driving the global climate agenda.

3.2.2 The increase and decrease of the number of papers published by each country

The second piece of information is that regardless of the country, the number of publications generally shows a growing trend from 2015 to 2021. The sharp increase in relevant literature published by China and India in 2022 indicates that addressing the challenges brought about by climate change and achieving sustainable development goals are issues of concern to these countries [126–128].

Fig. 4 Number of publications on the relationship between CC and SDGs by field

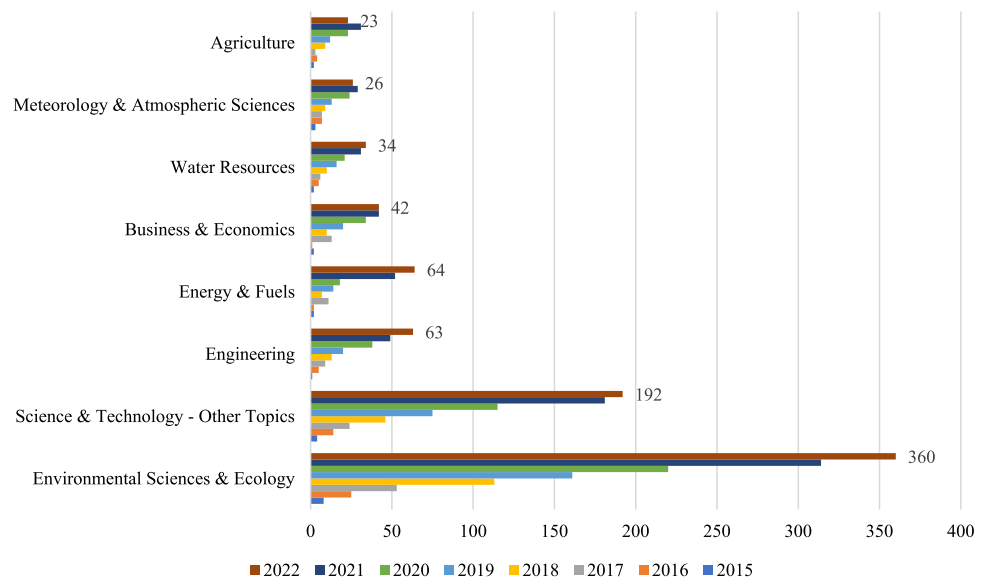


Fig. 5 Keyword relationship diagram for climate change and sustainable development goals from 2015 to 2017

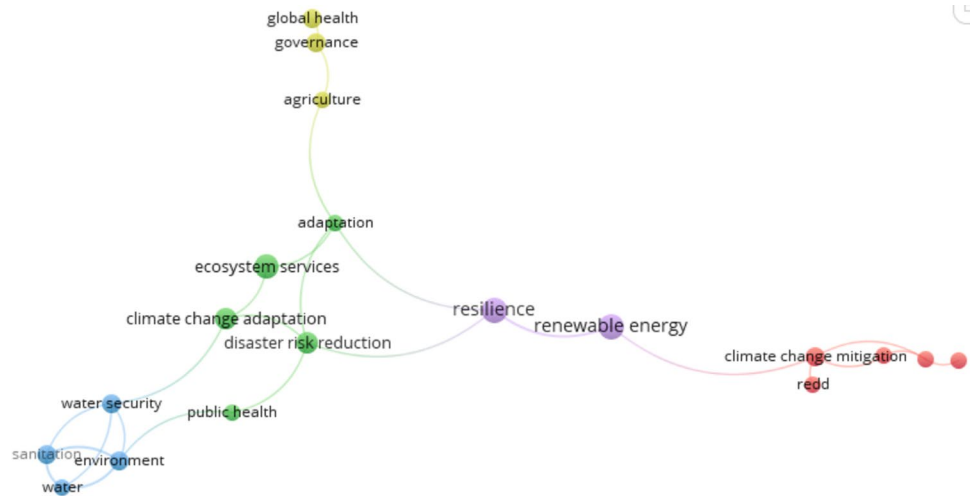
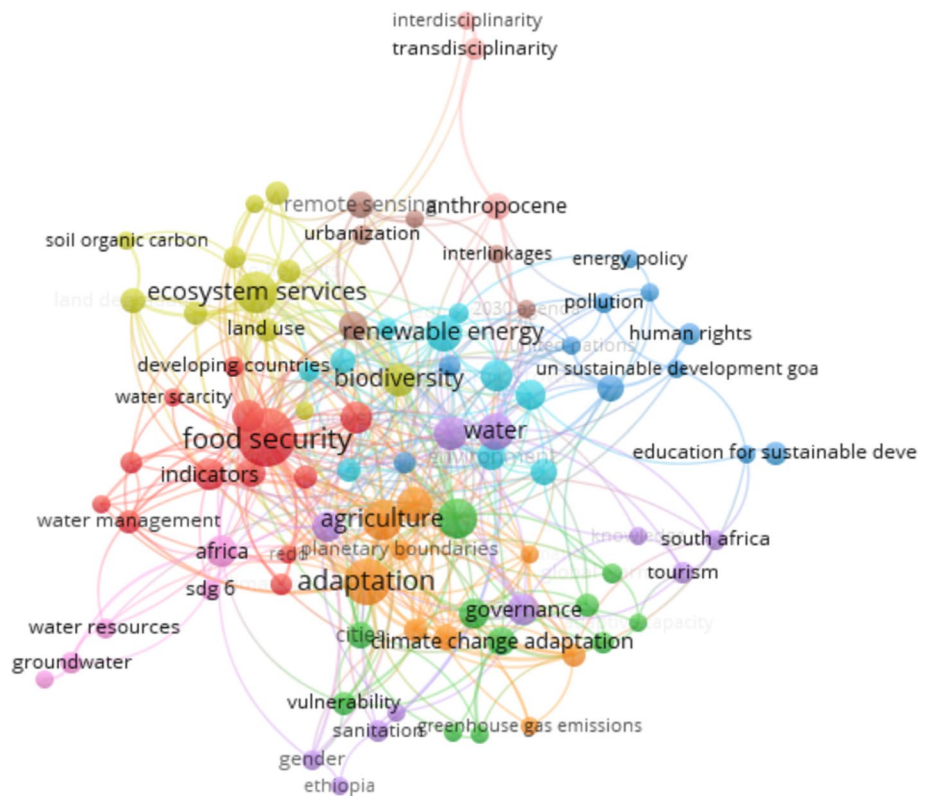


Fig. 6 Keyword relationship diagram for climate change and sustainable development goals from 2018 to 2020



3.3 Number of publications on the relationship between CC and SDGs by field

As shown in Fig. 4, the top eight fields and years in terms of the number of publications can be seen. We can observe that since 2015, there has been a significant increase in literature discussing the relationship between CC and SDGs. The field of Environmental Sciences & Ecology has consistently had the most published documents every year, followed by the field of Science & Technology—Other Topics.

four: "Efficient use and management of food supply to water resources", "Sustainable ecosystem management and land use under climate change", "Adaptation strategies and sustainable development strategies for agriculture under climate change", and "Development of renewable energy" [134–139].

3.4.3 Keywords and topics related to climate change and the implementation of sustainable development goals during 2021–2022

By 2021–2022, the research trend showed that some keywords regarding climate change and the implementation of sustainable development goals continued from the previous stage, and the number of keywords also increased. During this time period, 'renewable energy' (marked in red) has become the most emphasized keyword against the backdrop of hot advocacy topics such as 'Net Zero' and 'CBAM' (carbon border adjustment mechanism). It particularly emphasizes how, in the process of pursuing economic growth, we can reduce carbon dioxide emissions and achieve sustainable development by improving energy efficiency and using renewable energy [140]. This also echoes the resolutions of COP26 and COP27, which call for an increased proportion of clean energy, including renewable and low-carbon energy sources, acceleration in the research and development, deployment, and dissemination of low-carbon technologies, and emphasis on the importance of natural carbon sinks [133, 141–145].

Other important keywords are resilience (in orange), ecosystem services; life cycle assessment (in blue), Africa; agriculture (in dark green), policy; adaptation; education (in purple), and Agenda 2030; Paris Agreement; synergy; bibliometric analysis; remote sensing; desertification (in light green).

These keywords are all related to the clusters of climate change and sustainable development, encompassing topics such as the protection of ecosystem services [140, 146–148], life cycle assessment, agriculture in Africa, policy; adaptation, education [149–154], the global sustainable development goals (Agenda 2030), the Paris Agreement, the synergistic effects of various policies [155–158], bibliometric analysis, remote sensing technology [159–161], and desertification [162–165].

4 Conclusion

This study, through bibliometric analysis tools CATAR and VOSviewer, presents multiple research findings. First, both tools indicate an increasing number of links between climate change and sustainable development goals in research across countries. There is a growing body of research and policy dedicated to finding and implementing strategies to solve climate change issues. These strategies are often linked to sustainable development goals, highlighting the intersection between climate action and sustainable development.

Secondly, through CATAR, this study identified 19 clusters intersecting with climate change and SDGs (as shown in Table 2), among which the top five clusters in terms of proportion are related to agricultural and food systems, water and soil resources, energy, economy, ecosystem, and sustainable management, accounting for 53% of the documents. On the other hand, Fig. 1 also shows that some clusters are highly related (same color). Combined with Table 2 for further explanation, the key topics in the green block include adaptation and mitigation strategies, integration of knowledge and collaboration, and the urban and community context. The important topics in the yellow block are corporate sustainable development and biodiversity investment (especially focusing on the ocean). The important topics in the blue block include urban planning, sustainable governance, due to land degradation and the increased frequency of extreme weather events (such as droughts and floods) damaging ecosystems.

Thirdly, whether the data period is from 2015 to 2022 or just in 2022, China, India, the United States, the United Kingdom, and Australia are the countries with the most research on the link between climate change and sustainable development goals. This is due to their economic influence, population size, influence in science and technology, and policy and international leadership. Specifically, in 2022, the number of publications in China and India grew at the fastest rate, while the growth trend in the UK and the US was slightly slower. Furthermore, Environmental Sciences & Ecology is the field with the most publications.

Fourthly, by observing Figs. 5, 6, and 7, we can see the continuation and transformation of key topics in literature discussing the link between climate change and sustainable development goals. In the early period (2015–2017), the focus was on 'the impact of climate change on public health and its adaptation strategies'. By the mid-term (2018–2020), topics expanded to include 'efficient use and management of food supply to water resources', 'sustainable ecosystem

management and sustainable land use under climate change', 'agricultural adaptation strategies and sustainable development strategies under climate change', and 'development of renewable energy'.

In the later period (2021–2022), under the context of popular initiatives like net zero and CBAM (Carbon Border Adjustment Mechanism), there was increased emphasis on renewable energy, as well as protection of ecosystem services, life cycle assessment, food security, agriculture in Africa, sustainable management, synergies of various policies, remote sensing technology, and desertification among others. This shows an increasingly diversified range of important topics being discussed in relation to climate change and sustainable development goals.

The interconnections among the identified Clusters highlight the complex and interrelated nature of climate change and the 17 SDGs. Understanding these interconnections can help researchers, policymakers, and practitioners develop integrated and interdisciplinary approaches to address climate change and achieve the SDGs. For example, policies promoting agroforestry and sustainable agriculture can contribute to climate change mitigation, food security, and biodiversity conservation, thereby advancing multiple SDGs simultaneously.

Lastly, it is worth mentioning that the clusters that have not been part of the coalescence (as shown in the dashed circles in Fig. 1) do not imply that these topics are unimportant. On the contrary, these topics could potentially become the focus of emerging research in the future, serving as a reference for future researchers to conduct in-depth studies.

Author contributions SCY wrote the main manuscript text and prepared Figs. 1–3. YLH and SCY drafted the work. SCY and YLH made substantial contributions to the conception or design of the work. All authors reviewed the manuscript.

Data availability The literature data used in this study were sourced from the Web of Science database.

Declarations

Competing interests The authors declare no competing interests.

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