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Review

Mapping and visualizing global knowledge on planetary health in the climate change context: a comprehensive exploration of insights, trends, and research priorities

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Abstract
Climate change presents a substantial global threat to human health and wellbeing. Planetary health, an emerging field, provides a comprehensive framework to comprehend the intricate interplay between ecological stability, human health, and ecosystems, particularly within the context of climate change. This study investigates the planetary health perspective on climate change by exploring global knowledge. The Scopus database is used as the source of data. The analysis encompassed a performance evaluation aimed at scrutinizing both quantitative and qualitative indicators. Visualization techniques utilizing VOSviewer software were deployed to analyze collaboration patterns, co-citation links among prominent knowledge-sharing platforms, and key topics derived from keyword co-occurrence matrices. Additionally, using SciMAT software, the study conducted thematic evolution and intellectual analyses to identify both driving and emerging themes, while also examining coherence among different themes across various periods. The study also explores policy implications, and the relevance of COVID-19 in the context of planetary health and climate change. Through this analysis, 261 relevant publications are identified, with the United States being the leading contributor (90 documents; 34.5% of publications). At the institutional level, the Australian National University secured the top position, representing 4.6% of the total with 12 documents. The Lancet Planetary Health journal was the most prolific source, contributing 15 documents (5.7%). In terms of impact, The Lancet journal held a central position as the most cited source. The primary funding organization was the Wellcome Trust, based in the United Kingdom. Motor themes shaping the future of this field include vector-borne diseases, human demographics, informal settlements, air pollution, carbon footprint of animal-based foods, and pro-environmental attitudes and behaviors. The study underscores the significance of leveraging the momentum surrounding infectious diseases like COVID-19 and the impacts of climate change to advance planetary health concepts. Integration of the social sciences and enhanced multidisciplinary cooperation are crucial for progress. Additionally, increased funding for developing countries, and legislative empowerment are essential to foster further research.

Article Highlights

- Planetary health and climate change global knowledge is analyzed using performance analysis and visualization mapping.

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- Stimulating collaboration to advance the principles of planetary health is fundamental for effectively combating climate change.
- Managing the socioeconomic determinants of equity and health deserves to be the top priority of climate change initiatives.

Keywords Co-benefits · Sustainability · Climate forcing · Health behaviors · COVID-19 · Carbon footprint

1 Introduction

The impacts of anthropogenic activities on Earth's natural systems have been significant, going beyond what is safe for human societies and ecosystems to continue to function [1–4]. Loss of biodiversity and human-caused climate change have already reportedly reached unsafe levels [2]. Most global assessments, including the Millennium Ecosystem Assessment (MEA), the Global Environment Outlook (GEO), and the Intergovernmental Panel on Climate Change (IPCC) reports, have warned that the rapid alteration of the Earth's natural systems poses a serious threat to human health and ecosystems [5]. Climate change, owing to extra global greenhouse emissions, poses risks to biodiversity and causes severe disturbance of ecosystem functions and services [6]. One in six species might become extinct if climatic changes progress as predicted [7, 8]. Opportunities for viral sharing will arise because of changes in the climate and land use [9]. This will promote zoonotic spillover—a mechanism linking environmental change around the globe to the transmission of diseases [10, 11].

According to the World Health Organization, the warming and precipitation trends resulting from anthropogenic climate change over the past 30 years have already led to an estimated annual loss of over 150,000 lives [12], highlighting the core threat of climate change on human health [13, 14]. Many prevalent diseases among humans are linked to fluctuations in the climate including cardiovascular mortality, malnutrition, and respiratory problems brought on by agricultural failures, and heatwaves [12, 15–17]. Climate change has the potential to exacerbate the impacts on human health by increasing the frequency and duration of meteorological conditions that lead to greater exposure to air pollution. For example, China alone as a result of a rise in exposure to air pollution has nearly over a million deaths annually [18]. In a study assessing the potential health effects of ambient ozone and PM2.5 concentrations impacted by climate change across the United States, Tagaris, Liao [19] concluded that climate change impacts on PM2.5 were linked to about 4000 extra premature deaths annually, compared to 300 deaths linked to ozone changes caused by climate change.

In conclusion, climatic changes and air pollution from fossil fuels have significant negative consequences on both human and planetary health, resulting in an urgent public health concern [20]. These consequences encompass a surge in heat-related diseases and mortalities, diseases transmitted by vectors, respiratory disorders, insecure food supplies, famine, and physically and mental damages from wildfires and extreme weathers [21], and antibiotic resistance [22]. The extent, rate and severity of such repercussions would grow in an absence of proactive measures, unfairly harming exposed communities and aggravating already existing health disparities [21].

Concerns over human health, civilization's sustainability, and human-made and natural systems have all played a significant role in the emergence of the planetary health movement [23, 24]. This emerging field seeks to promote public health initiatives collectively and at various socioeconomic levels [23, 25, 26]. The primary concepts of planetary health have been well established, for several decades, in different disciplines, including conservation medicine, global health, EcoHealth, and One Health [27, 28]. Furthermore, the planetary health concepts display comparable dynamics in the emerging field of health and climate change giving these fundamental concepts more coherence [27]. The perfect example is related to the establishment of The Rockefeller Foundation-Lancet Commission on Planetary Health. This commission builds on previous significant initiatives (e.g., the Brundtland Commission, the IPCC, the MEA, the Convention on Biological Diversity (CBD), and Tony McMichael's insightful book "Planetary Overload") and have been designed to tackle and solve contemporary global challenges [5]. The Commission is devoted to evaluating the risks associated with Anthropocene era's environmental shifts to development and health, identifying persistent and evidenced gaps, and suggesting research agendas and practical strategies [5]. By that it supplements the Lancet Commission on Climate Change duty, which concentrates on the potential opportunities of climate change policies for sustainable development and health [29].

As an emerging field, planetary health introduces an inclusive methodology to address and solve most of today's critical challenges within the climate change context. By adopting such an approach, it is feasible to establish, design,

and apply practical and effective strategies that conserve the wellbeing and health of the planet's human beings, securing a resilient and sustainable future. The comprehensive understanding of the inherent links between climate change, the environment, and human health is what makes this feasible. The planetary health field is characterized by plentiful knowledge platforms, educational programs, academic courses, institutions, and national, regional, and international initiatives. This prevalence of resources has led to rapid growing within planetary health discipline [30].

While recognition of planetary health concepts in the context of climate change is growing, the extent and status of research in this domain remain uncertain. There is also a lack of detailed understanding regarding the key focal topics, body of knowledge, characteristics, and dynamics. This knowledge gap confirms the need for a comprehensive investigation in the subject at hand, which inspired the initiation of this study. This analysis draws on bibliometric and visualization mapping methods, frequently applied for qualitative and quantitative assessments in a wide range of research fields. Its principal objective is to recognize, for the first time, key contributors at regional and international levels, along with the most active institutions, sources, and funding agencies. Likewise, it will address and analyze key themes and fundamental concepts that will drive the long-term trajectory of planetary health in the context of climate change. The study's outcomes will advance our knowledge of this vital topic and deliver guidance for further investigations, investments, and legislative actions that foster sustainable development, benefiting practitioners and scholars with interests in this field. Specifically, the article aims to investigate the following research questions:

RQ1: What is the extent of planetary health in the context of climate change, and which regions of the world are particularly focused on it?
RQ2: Who are the prominent contributors to planetary health in the context of climate change at the levels of countries, institutions, sources, and funding agencies?
RQ3: What are the major collaboration trends among countries and institutions?
RQ4: What are the intellectual structures and primary thematic evolution trajectories observed in planetary health research concerning climate change?
RQ5: What are the major policy implications and future research directions on this topic?

2 Methods

2.1 Data source

The Scopus database was selected as the main data source for several reasons, and on July 8, 2023, the data needed for the current study was successfully obtained and gathered from the database [31]. (1), Access to the Scopus database is provided by the "Research4Life" library. (2), The Scopus database is known for its comprehensive coverage of scholarly works and plenty of insightful information and data. (3), In contrast to comparable literature databases (e.g. PubMed or Web of Science), the Scopus database affords broader content inclusion adaptability. (4), The comprehensive searching and analytical features of the Scopus database enable exhaustive examination as well as offering insightful information on an array of scholarly research topics. (5), Moreover, this database has been frequently utilized across various scientific disciplines for analyzing research trends and frontiers [32–35].

2.2 Search strategy and data acquisition

All subject fields (health, physical, biological, and social fields) within the Scopus database were thoroughly searched to retrieve all research works concerning planetary health in the climate change context. The entire procedure of data retrieval and exportation was concluded in just one single day on July 8, 2023, to reduce any possible bias emerging from the standard updates delivered to the Scopus database. The data concerning the present analysis was acquired following the strategies outlined below:

Step 1: The most often used term "planetary health" was added to the Scopus database in order to fulfill the study's objectives [36]. Other often used phrases related to climate change, such as "climate change," "climate changes," "climatic change," and "climatic changes," were subjected to the same process [37, 38].
Step 2: In the advanced search query provided by the Scopus database, the terms of "planetary health" and "climate change" were added specifically in the "Title-Abstract" section. The underlying assumption was that publications

investigating planetary health and climate change (conceptually, methodologically, and/or empirically) would, at the very least, reference these terms in the title and/or abstract.
Step 3: The expressions of either "planetary health" or "climate change" were combined using the OR operator. Additionally, the terms of "planetary health" and "climate change" were linked using the AND operator to retrieve all relevant publications.
Step 4: The final search string used was as follows: ((TITLE-ABS ("Planetary Health")) AND (TITLE-ABS ("Climate Change") OR TITLE-ABS ("Climate Changes") OR TITLE-ABS ("Climatic Change") OR TITLE-ABS ("Climatic Changes"))).
Step 5: For further analysis, the gathered information was extracted and saved in Excel files. This data included document classifications, as well as details on countries, institutions, authors, and sources that contributed to research on planetary health and climate change.

2.3 Visualization and bibliometric analysis

In this analysis, particular emphasis was placed on identifying the most productive countries, institutions, and sources (including journals, conferences, books, proceedings, etc.), as well as highly cited publications [39–41]. To objectively assess the productivity of countries, an adjustment index (AI) was utilized, which considers population size, nominal gross domestic product (GDP), and publication volume. The AI is calculated using the following formula: AI = [Total number of publications of the country/GDP per capita of the country] * 100. Here, the GDP per capita of a country is determined by dividing its GDP by its population [42]. The data pertains to the population count, and the GDP was extracted from the World Bank portal [43]. While country classification and global region details were sourced from the SCImago Journal & Country Rank portal, integrating journal and country scientific indicators derived from Scopus information [44]. The utilization of VOSviewer, an application for mapping, networking, and visualization developed by the Center for Science and Technology Studies at Leiden University in the Netherlands, serves to showcase global collaboration and generate a co-occurrence matrix that identifies research hotspots based on published data [45, 46]. By linking related words or countries together, visualizations or clusters were generated. These clusters can be identified based on their distinctiveness and similar coloration. The VOSviewer application employs grouping and similarity mapping algorithms to display the contributions of different countries, sources, organizations, and more [46]. Utilizing VOSviewer, a two-dimensional bibliometric mapping depicting international research partnerships and interactions is projected [46]. On this map, the distance between any two collaborated countries reveals how closely or interconnected they are. Countries with the highest level of research collaboration will appear closer on the map.

Throughout the co-occurrence matrix, the terms are depicted by frames. The size of each frame is in proportion with the number of documents where a specific term is available [47]. The terms were considered from article titles and abstracts to highlight the relevant themes within the topic under examination. This strategy facilitates an organized analysis of themes that are pertinent to the topic of investigation. Using this technique, co-occurrence analysis determines the likelihood at which two terms emerge simultaneously across research works to figure out how comparable they are [48]. It highlights key concepts concerning planetary health and climate change, thereby promoting a scrutiny of the state of knowledge in the subject matter. In contrast, co-citation analysis which analyzes comparable citations amongst different sources was employed to inquire links between research works while gaining essential insights regarding the intellectual links and impacts among the scope of planetary health and climate change. Such kind of analysis contributes in the visualization of the research landscapes, the recognition of crucial trends across the subject matter, and the grasp of the primary resources in the field in question [34].

2.4 Intellectual analysis of data using strategic diagram and thematic evolution

To explore major themes and thematic evolution of planetary health and climate change research works, the SciMAT software, an open-source software for science mapping analysis developed by the Soft Computing and Intelligent Information Systems research group at University of the Granada in Spain, was employed [49–51]. This approach uses co-word analysis based on sophisticated text mining technologies to assess and analyze the conceptual, social, and intellectual frameworks of research works [52]. The outcomes were presented utilizing a strategic diagram that displays the primary themes of interest [52]. The methodology followed four steps outlined by Cobo, López-Herrera [49] as follows:

Step 1 involved collecting raw data and extracting relevant details, such as keyword co-occurrence.

Step 2 assessed the similarity rates between elements based on keyword co-occurrence frequency, using an equivalent index to measure association strength.
Step 3 utilized clustering techniques to identify sub-clusters of correlated keywords, revealing significant research themes. The simple center algorithm was employed for this purpose.
Step 4 involved mapping the output onto a 2D space known as a strategic diagram, Figure 1, adopted after Zyoud [35].

The diagram organized major themes according to centrality and density criteria. Four zones were recognized: upper right represented well-developed driving themes with strong centrality and high density, upper left indicated specialized topics of secondary importance, lower right depicted fundamental topics still under development, and lower left represented emerging or disappearing themes with weak development and marginality.

Figure 2 illustrates the methodological approach employed to establish the inclusion criteria and search methods for retrieving research publications directly relevant to planetary health and climate change. In addition to providing a visual representation of the roadmap of the analysis process, which encompasses data collection, bibliometric evaluation, visualization mapping, and noteworthy findings. Figure 2 also provides a concise summary of the entire analysis procedure.

3 Results

3.1 An overview of the publications retrieved for planetary health-climate change

Between 2009 and July 2023, a total of 261 papers were published that included both "planetary health" and "climate change" in their titles and/or abstracts. These papers were obtained through the Scopus advanced search query. The distribution of these documents was as follows: 138 articles (52.9%), 73 reviews (28.0%), and 50 (19.2%) categorized as other types, including book chapters, editorials, letters, conference papers, books, notes, errata, and short surveys.

Most studies conducted on the topic of planetary health and climate change were in the field of medicine, accounting for 150 documents (57.5%). Environmental science had the second-highest number of publications with 67 documents (25.7%), followed by social sciences with 65 documents (24.9%). Other fields of study included nursing (41 documents; 15.7%), agricultural and biological sciences (17 documents; 6.5%), biochemistry, genetics, and molecular biology (11 documents; 4.2%), energy (10 documents; 3.8%), engineering (10 documents; 3.8%), and earth and planetary sciences (9 documents; 3.4%).

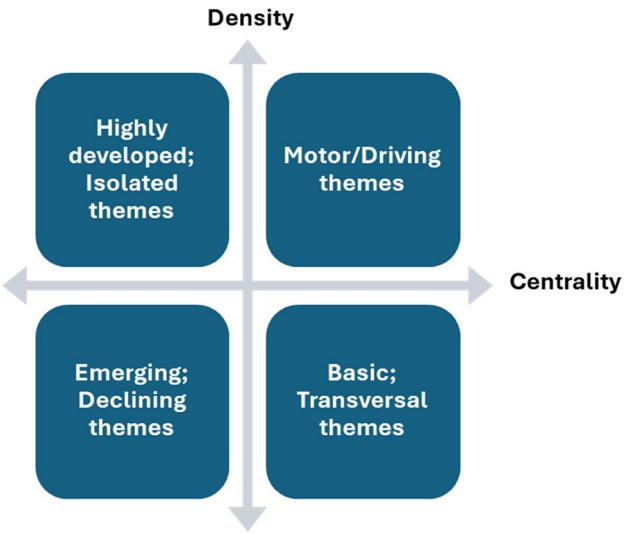

Fig. 1 The strategic diagram displays the various types of themes based on their centrality and density

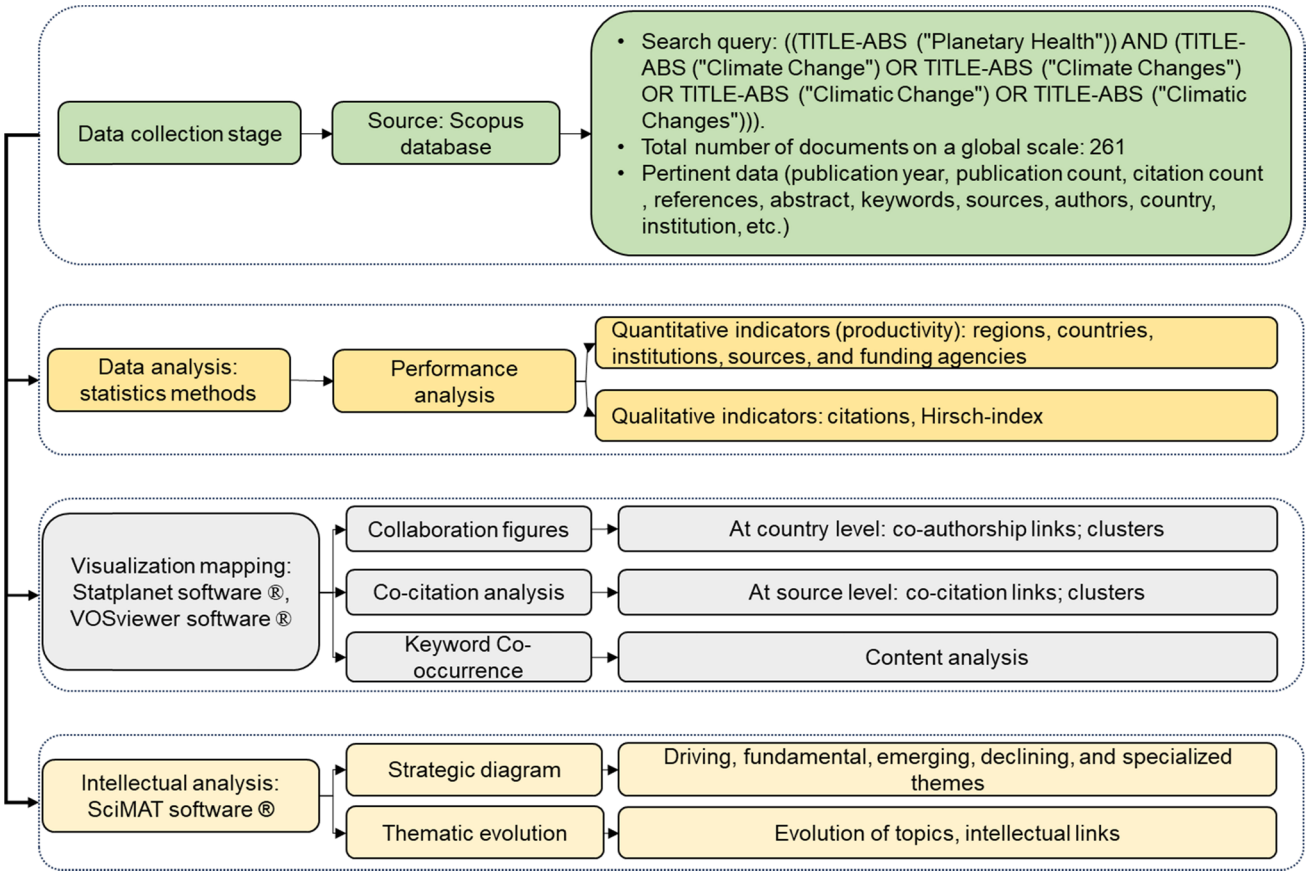

Fig. 2 The roadmap outlines the entire analysis procedure of global research and knowledge on planetary health and climate change including data collection, bibliometric analysis, visualization mapping, intellectual analysis, thematic evolution, and major outcomes

3.2 Publications timeline for planetary health-climate change

Figure 3 illustrates the chronological development of publications focusing on planetary health and the intersection of planetary health with climate change. The publication journey of planetary health began in 1997 with a single document. Overall, significant growth was observed after 2015, with a notable surge coinciding with the emergence of the COVID-19 pandemic after 2019. On the other hand, research on planetary health in the context of climate change started in 2009 with a solitary publication. It experienced a modest growth rate until 2019, with certain years recording no publications. Subsequently, a substantial increase occurred after 2019, aligning with the surge in planetary health research amid the bulk of studies on COVID-19. Research productivity reached its peak in 2022 with 78 documents (30.0% out of total publications). Generally, publications focusing on planetary health -climate change constituted approximately 20% of all planetary health documents. In conclusion, the intersection of planetary health with climate change continues to garner significant attention within the broader scope of research conducted on planetary health.

3.3 Global productivity and international collaboration

A comprehensive overview of the research output on planetary health-climate change is presented in Figure 4. Currently, 65 countries are actively supporting research on planetary health and its relationship with climate change in various capacities. At the regional level, Western Europe stands out as the most productive region with 208 documents (79.7%). Following Western Europe, Northern America has contributed 123 documents (47.1%), while both the Pacific region and Asiatic region have each produced 49 documents (18.8%). The Africa region accounts for 31 documents (11.9% of the total), while Latin America has produced 25 documents (9.6%). Additionally, the Middle East has contributed 6 documents (2.2%), and Eastern Europe has produced 5 documents (1.9%). Western Europe

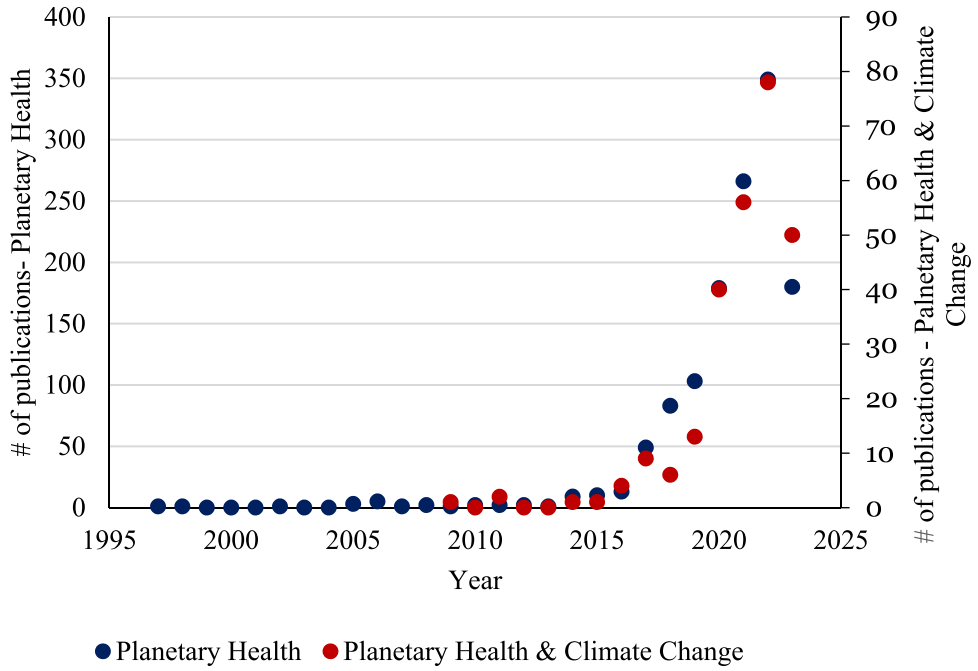

Fig. 3 The evolution of publications related to planetary health and the intersection of planetary health with climate change

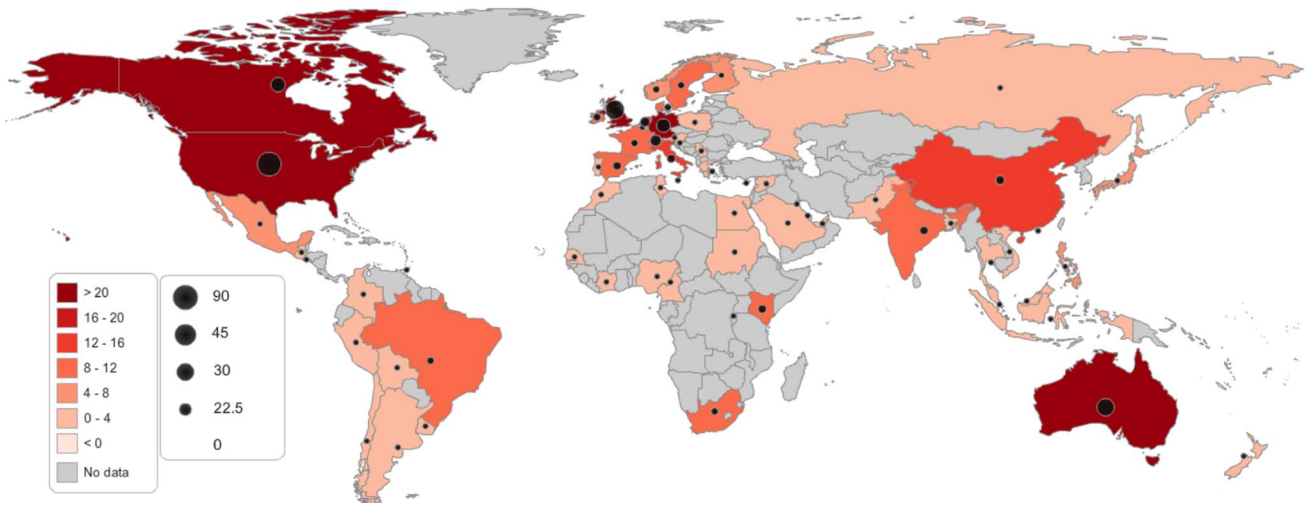

Fig. 4 Nation–level production on planetary health-climate change; a worldwide perspective of research productivity at the country level. The intensity of colors elucidates the number of published works. The size of black circles represents the output of each country (i.e., the larger the circle, the higher the performance of the country with respect to the number of publications). The global map was created using Statplanet Interactive Mapping and Visualization Software, www.statsilk.com, free license

has the highest number of contributing countries (18), followed by the Asiatic region (12), Latin America (11), Africa (10), the Middle East (6), Eastern Europe (4), and both the Pacific region and Northern America with 2 countries each.

When considering individual countries, the United States with 90 documents (34.5%) leads the way as the primary contributor in terms of the number of publications on planetary health-climate change, Table 1. Following closely, the United Kingdom and Australia claim the second and third positions, respectively, with 59 documents (22.6%) and 48 documents (18.4%). Among the 21 countries listed in Table 1 as the most prolific contributors, the majority, precisely 16 countries, are developed nations known for their robust scientific capabilities and extensive research in health and environmental domains. Based on an AI analysis that considers GDP per capita and the number of publications, Kenya and India have secured the top two positions among the ranked countries.

Table 1 Top 20 countries with prolific contributions on planetary health-climate change research

Rank	Country	Number of publications	%	Population (Thousands)	GDP (Millions-US$)	AI	AI Rank
1st	United States	90	34.5	331,893.74	23,315,080.56	128.1	3rd
2nd	United Kingdom	59	22.6	67,326.57	3,131,377.76	126.9	4th
3rd	Australia	48	18.4	25,688.08	1,552,667.36	79.4	8th
4th	Canada	33	12.6	38,246.11	1,988,336.33	63.5	9th
5th	Germany	31	11.9	83,196.08	4,259,934.91	60.5	10th
6th	Switzerland	20	7.7	8,703.41	800,640.16	21.7	14th
7th	Netherlands	15	5.7	17,533.04	1,012,846.76	26.0	13th
8th	China	13	5.0	1,412,360.00	17,734,062.65	103.5	7th
9th	Italy	12	4.6	59,109.67	2,107,702.84	33.7	12th
10th	India	11	4.2	1,407,563.84	3,176,295.07	487.5	2nd
10th	Kenya	11	4.2	54,027.49	113,420.01	524.0	1st
10th	Spain	11	4.2	47,415.75	1,427,380.68	36.5	11th
13th	Ireland	10	3.8	5,086.99	529,244.87	9.6	20th
14th	Brazil	9	3.4	214,326.22	1,608,981.46	119.9	5th
14th	France	9	3.4	67,749.63	2,957,879.76	20.6	15th
16th	Denmark	8	3.1	5,903.04	395,403.91	11.9	18th
16th	South Africa	8	3.1	59,392.25	419,015.02	113.4	6th
16th	Sweden	8	3.1	10,415.81	635,663.80	13.1	16th
19th	Norway	7	2.7	5,457.13	579,267.37	6.6	21st
20th	Belgium	5	1.9	11,592.95	594,104.18	9.8	19th
20th	Japan	5	1.9	125,681.59	4,940,877.78	12.7	17th

The following formula was used to calculate an adjustment index (AI): AI = [Total number of publications for the country / GDP per capita of the country] × 100, where GDP per capita is the country's GDP divided by its population

AI adjustment index, *GDP* gross domestic product

Figure 5 provides a visual representation of the global network of collaborative research on planetary health-climate change. Each country in the visualization has contributed a minimum of 5 documents. The map presents the co-authorship relationships among 21 nations, illustrating the close ties between them. Among these countries, the United States, United Kingdom, and Australia emerge as the top three in terms of collaboration, as indicated by the highest number of links on the visualization map. Notably, the strongest co-authorship links are observed between the United States and the United Kingdom, followed by links between the United States and Australia. The visualization also highlights the most frequently collaborated countries, represented by three distinct clusters. Cluster 1, depicted in red, consists of 9 countries primarily from Western Europe, with the United Kingdom at its core. Cluster 2, depicted in green, comprises 8 countries with Australia as the central node. The final cluster, cluster 3, represented in blue, encompasses 4 countries with the United States at its core.

3.4 Institutions that are most productive in the field of planetary health-climate change

In the field of planetary health-climate change, a collective of 995 institutions has made a significant contribution, totaling 261 documents. Table 2 displays the top 20 institutions based on their contributions in this area. The Australian National University in Australia secures the first position with 12 documents (4.6%), closely followed by the Harvard T.H. Chan School of Public Health in the United States with 9 documents (3.4%). Additionally, both the University of Washington and the University of Melbourne, located in the United States and Australia respectively, have contributed 8 documents each (3.1%). The most productive institutions are predominantly located in developed countries, with the United States and Canada hosting a significant number of these institutions. Figure 6 displays a density visualization network depicting collaboration among institutions. Most institutions with the highest number of co-authorship links are based in Canada, accounting for four out of five institutions, while one institution is from the United States. The total number of co-authorship links amounts to 10. Each institution on the map has four co-authorship links connecting it to the other four institutions.

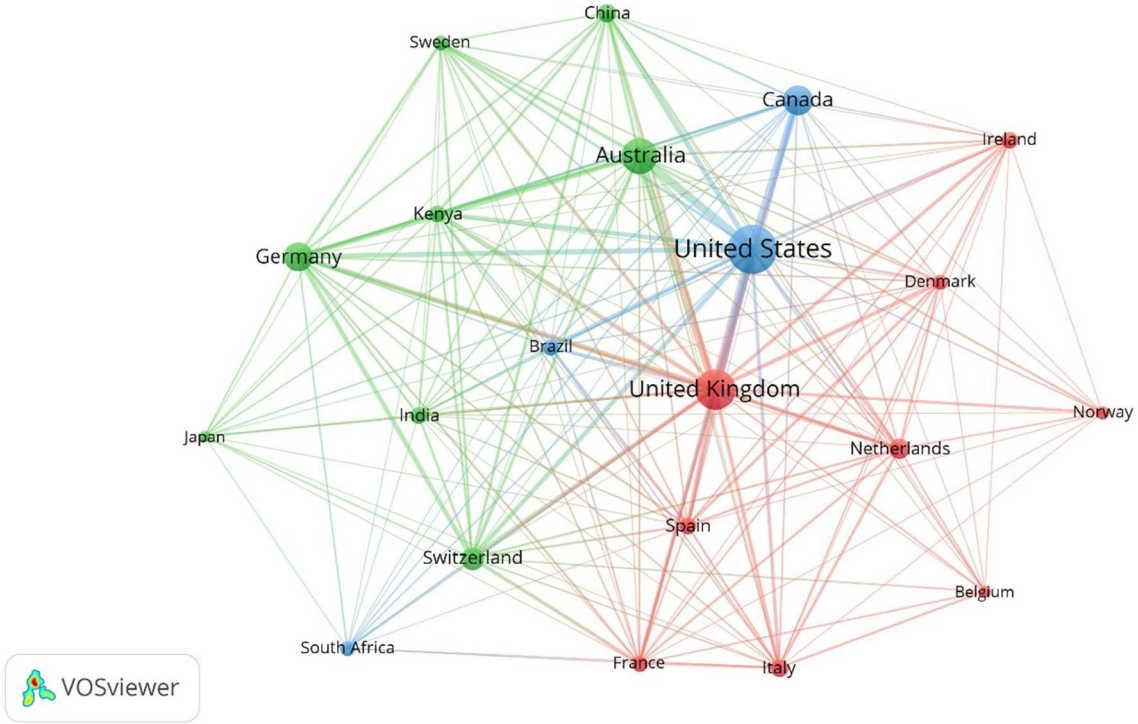

Fig. 5 Network visualization map of international research collaboration among countries with a minimum research output of 5 documents on planetary health-climate change. Full counting is employed, where each co-authorship link is assigned equal weight. Twenty-one countries out of 65 countries met the threshold. For each of 21 countries, the total strength of the co-authorship links with other countries was calculated. The countries with the greatest total link strength were selected. The map was created using VOSviewer software version 1.6.19

Table 2 Top 20 productive institutions on planetary health-climate change

Rank	Institution	Country	Number of publications	%
1st	The Australian national university	Australia	12	4.6
2nd	Harvard T.H. Chan school of public health	United States	9	3.4
3rd	University of Washington	United States	8	3.1
3rd	University of Melbourne	Australia	8	3.1
5th	Johns Hopkins Bloomberg School of Public Health	United States	7	2.7
5th	Stanford University	United States	7	2.7
5th	London School of Hygiene & Tropical Medicine	United Kingdom	7	2.7
8th	Harvard University	United States	6	2.3
8th	The University of British Columbia	Canada	6	2.3
8th	Queen's University	Canada	6	2.3
8th	University of Toronto	Canada	6	2.3
8th	Deakin University	Australia	6	2.3
8th	University College London	United Kingdom	6	2.3
8th	York University	Canada	6	2.3
15th	Université de Lausanne UNIL	Switzerland	5	1.9
15th	Universiteit Utrecht	Netherlands	5	1.9
15th	Trinity College Dublin	Ireland	5	1.9
15th	University of Waterloo	Canada	5	1.9
15th	Queen Mary University of London	United Kingdom	5	1.9
15th	University of Canberra	Australia	5	1.9
15th	Charité—Universitätsmedizin Berlin	Germany	5	1.9
15th	Institute for Advanced Sustainability Studies	Germany	5	1.9

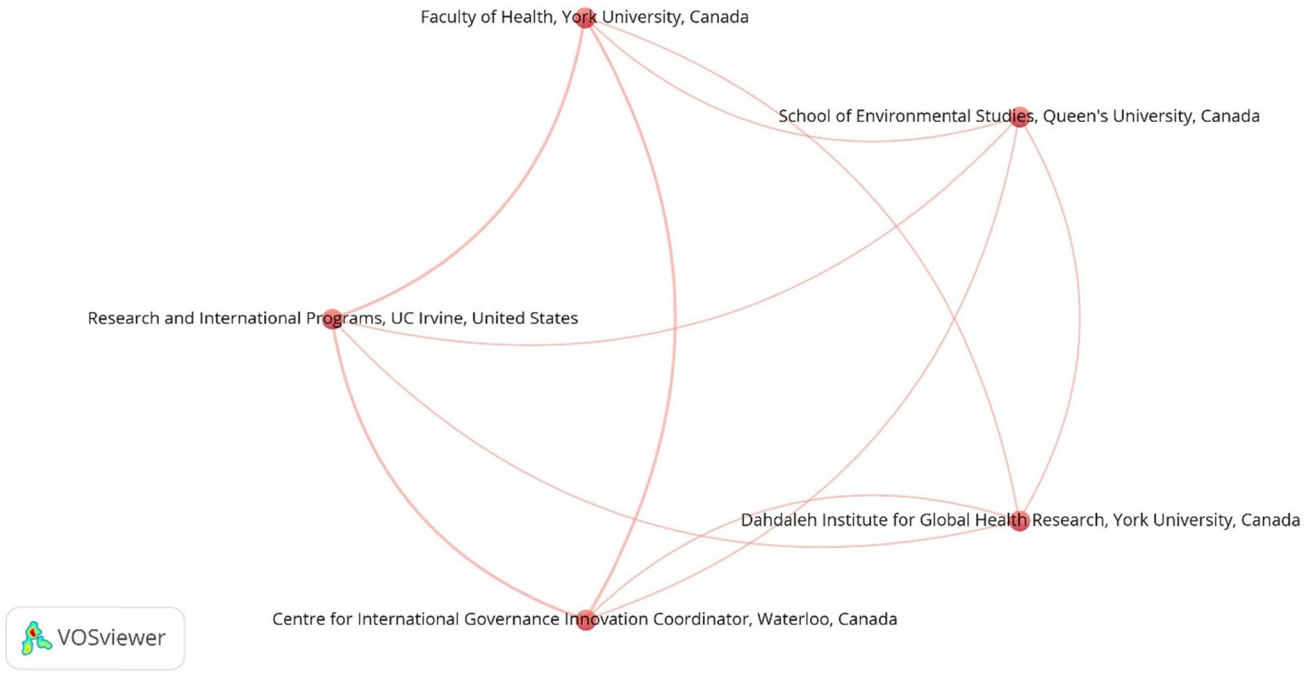

Fig. 6 Network visualization map of international research collaboration among institutions with a minimum research output of 2 documents on planetary health-climate change. Full counting is employed, where each co-authorship link is assigned equal weight. Five institutions out of 995 institutions met the threshold. For each of 5 institutions, the total strength of the co-authorship links with other institutions was calculated. The institutions with the greatest total link strength were selected. The map was created using VOSviewer software version 1.6.19

3.5 The most productive journals and sources

Table 3 presents the top ten peer-reviewed journals and sources among the 179 contributors to research on planetary health-climate change. These ten sources account for approximately 28.0% of all publications in this field. Topping the

Table 3 Top 10 most productive sources on planetary health-climate change

Rank	Source	Number of publications	%	IF
1st	Lancet planetary health	15	5.7	25.7
2nd	Frontiers in public health	11	4.2	5.2
3rd	International journal of environmental research and public health	10	3.8	NA
4th	Medical teacher	6	2.3	4.7
5th	Climate change management*	5	1.9	NA
6th	Current opinion in environmental sustainability	4	1.5	7.2
6th	Proceedings of the nutrition society	4	1.5	7
6th	Sustainability Switzerland	4	1.5	3.9
9th	Creative nursing	3	1.1	NA
9th	Foods	3	1.1	5.2
9th	Frontiers in nutrition	3	1.1	5
9th	Journal of cleaner production	3	1.1	11.1
9th	Revue medicale suisse	3	1.1	NA

IF is the impact factor extracted from 2022 Journal Citation Reports®, Clarivate 2023

*Book series by Springer

list is the Lancet Planetary Health journal, which has contributed 15 documents (5.7%), followed by Frontiers in Public Health with 11 documents (4.2%), and the International Journal of Environmental Research and Public Health with 10 documents (3.8%). Notably, the majority of the top ten sources are prestigious journals. The Lancet Planetary Health journal, in particular, is renowned for its significant impact, boasting an impressive impact factor of 25.7. It is followed by Current Opinion in Environmental Sustainability with an impact factor of 7.2, and Proceedings of the Nutrition Society with an impact factor of 7.

3.6 The most cited publications on planetary health-climate change

During the data extraction period, research papers on planetary health-climate change accumulated a total of 4158 citations. The h-index, indicating the number of papers with at least the same number of citations as the index value, stood at 27. This suggests that 27 papers out of the entire corpus of publications on planetary health-climate change received at least 27 citations each. On average, each document garnered approximately 16 citations. Table 4 displays the top 20 publications in the relevant field, which have garnered the highest number of citations. These publications consist of 13 articles and 7 reviews, with citation counts ranging from 44 to 1283 [5, 53–71]. The most cited review article published in The Lancet summarized the key issues addressed by The Rockefeller Foundation–Lancet Commission on planetary health [5]. It advocates for sustainable consumption, population control, and leveraging technology as potential solutions to redefine prosperity, prioritize quality of life, and improve overall health while preserving the integrity of natural systems [5].

3.7 Co-citation analysis of journals and sources

Figure 7, the visualization map of the co-citation network, displays the 20 major sources that are highly co-cited, with a minimum citation threshold of 30. These sources play a crucial role in disseminating knowledge and providing information on the intersection of planetary health and climate change. The map categorizes these sources into three distinct clusters, each represented by a different color, based on shared characteristics relevant to the research topic. The Lancet journal holds a central position in the map, with the highest strength of total links and the largest collection of citations. Notably, the strongest link observed on the map is between the journals The Lancet and Science, followed by the link between The Lancet and Nature, and finally, the link between The Lancet and the International Journal of Environmental Research and Public Health. The map highlights the limited representation of significant social sciences journals as central outlets for research on planetary health-climate change, with a predominance of health and environmental sources.

3.8 Top funding sponsors for planetary health-climate change research

Approximately 17.0% of the total published works on planetary health-climate change were funded by 12 funding sponsors mentioned in Table 5, which highlights the top 10 sponsors for this research field. The Wellcome Trust, based in the United Kingdom, emerged as the primary funding organization, contributing to 7 documents (2.7%). Following closely is the National Institutes of Health, located in the United States, with 5 documents (1.9%). All funding sponsors are renowned organizations primarily based in developed countries, with one international organization, the World Health Organization, included. These sponsors are widely recognized for their significant contributions to supporting scientific research activities on a global scale.

3.9 Planetary health-climate change primary topics

A co-occurrence analysis was performed to reveal the most mentioned and interconnected topics and concepts. The research domains were categorized into three major clusters: (cluster 1 represented by red color, cluster 2 by green color, and cluster 3 by blue color) based on an examination of term cooccurrence in the titles and abstracts of publications related to planetary health-climate change, Figure 8. The following are the frequently recurring terms and their corresponding clusters, excluding general terms like example, paper, article, review, study, and research: climate change (244 occurrences; cluster 1), planetary health (228 occurrences; cluster 1), health (149 occurrences; cluster 1), impact (114 occurrences; cluster 1), human health (81 occurrences; cluster 2), change (76 occurrences; cluster 2), action (72 occurrences; cluster 1), challenge (71 occurrences; cluster 3), environment (67 occurrences; cluster 3), practice (56 occurrences; cluster 1), effect (51 occurrences; cluster 1), population (50 occurrences; cluster 3), role (50 occurrences;

Table 4 Top 20 cited works on planetary health-climate change

Rank	Authors	Year	Title	Source	Times cited	Type of document
1st	Whitmee S. et al	2015	Safeguarding human health in the Anthropocene epoch: Report of the Rockefeller Foundation-Lancet Commission on planetary health	The Lancet	1283	Review
2nd	Fuller R. et al	2022	Pollution and health: a progress update	The Lancet Planetary Health	194	Review
3rd	Downs S.M. et al	2020	Food environment typology: Advancing an expanded definition, framework, and methodological approach for improved characterization of wild, cultivated, and built food environments toward sustainable diets	Foods	145	Article
4th	Mason-D'Croz D. et al	2019	Gaps between fruit and vegetable production, demand, and recommended consumption at global and national levels: an integrated modelling study	The Lancet Planetary Health	133	Article
5th	Ellwanger J.H. et al	2020	Beyond diversity loss and climate change: Impacts of Amazon deforestation on infectious diseases and public health	Anais da Academia Brasileira de Ciencias	130	Article
6th	Stanley S.K. et al	2021	From anger to action: Differential impacts of eco-anxiety, eco-depression, and eco-anger on climate action and wellbeing	The Journal of Climate Change and Health	107	Article
7th	Fresán U. and Sabaté J	2019	Vegetarian Diets: Planetary Health and Its Alignment with Human Health	Advances in Nutrition	106	Review
8th	Jackson R.B. et al	2019	Persistent fossil fuel growth threatens the Paris Agreement and planetary health	Environmental Research Letters	103	Review
9th	Shaw E. et al	2021	AMEE Consensus Statement: Planetary health and education for sustainable healthcare	Medical Teacher	93	Article
10th	Houlton B.Z. et al	2019	A World of Cobenefits: Solving the Global Nitrogen Challenge	Earth's Future	90	Review
11th	Friel S. et al	2011	Climate change, noncommunicable diseases, and development: The relationships and common policy opportunities	Annual Review of Public Health	86	Article
12th	Krystosik A. et al	2020	Solid Wastes Provide Breeding Sites, Burrows, and Food for Biological Disease Vectors, and Urban Zoonotic Reservoirs: A Call to Action for Solutions-Based Research	Frontiers in Public Health	77	Review
13th	Leffers J. et al	2017	Mandate for the Nursing Profession to Address Climate Change Through Nursing Education	Journal of Nursing Scholarship	74	Article
14th	Omrani O.E. et al	2020	Envisioning planetary health in every medical curriculum: An international medical student organization's perspective	Medical Teacher	69	Article
15th	Mardones F.O. et al	2020	The COVID-19 Pandemic and Global Food Security	Frontiers in Veterinary Science	59	Article
16th	Lang T	2009	Reshaping the food system for ecological public health	Journal of Hunger and Environmental Nutrition	55	Article
17th	Culebras M	2020	Lignin Doped Carbon Nanotube Yarns for Improved Thermoelectric Efficiency	Advanced Sustainable Systems	54	Article
18th	Kuguyo O. et al	2020	Singapore COVID-19 Pandemic Response as a Successful Model Framework for Low-Resource Health Care Settings in Africa?	OMICS A Journal of Integrative Biology	51	Review
19th	Kurth A.E	2017	Planetary Health and the Role of Nursing: A Call to Action	Journal of Nursing Scholarship	48	Article
20th	Shea B. et al	2020	Assessment of Climate-Health Curricula at International Health Professions Schools	JAMA Network Open	44	Article

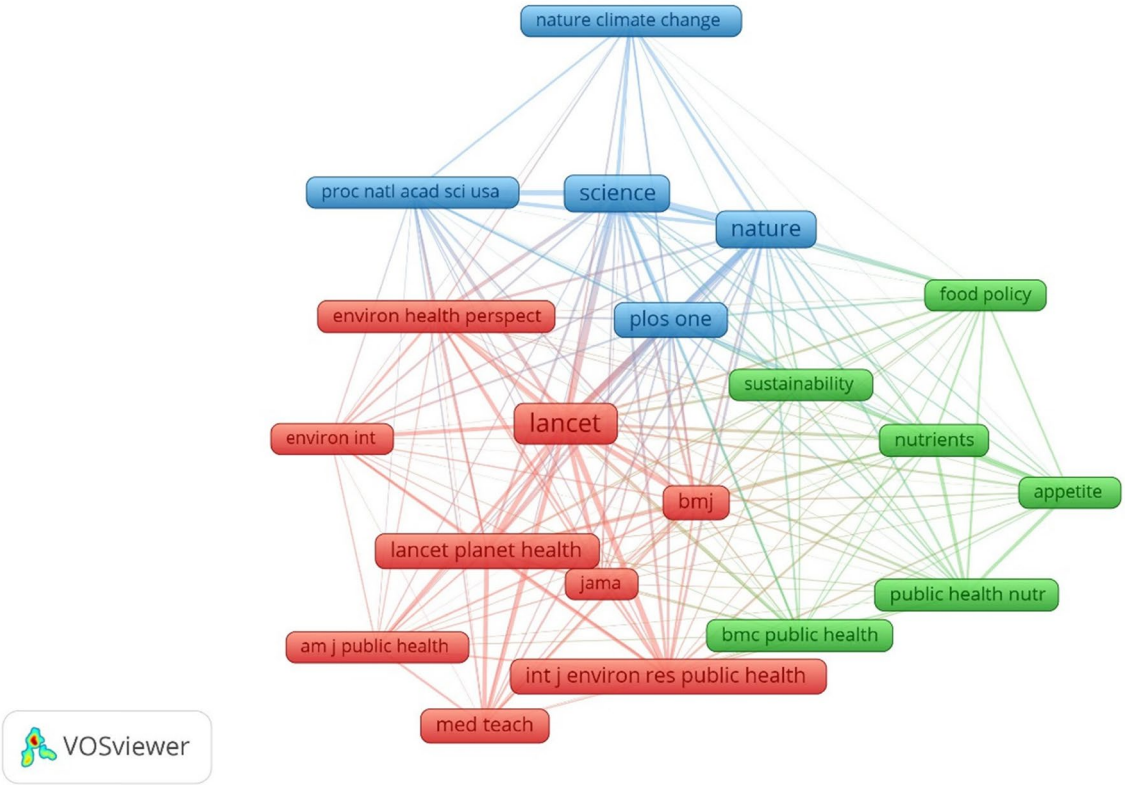

Fig. 7 Network visualization map. The minimum number of citations of a source was set as 30. Full counting is employed, where each co-citation link is assigned equal weight. Of the 6787 sources, 20 met the threshold. For each of the 20 sources, the total strength of the co-citation links with other sources was calculated. The sources with the greatest total links strength were selected

Table 5 Top 10 funding sponsors on planetary health-climate change

Rank	Funding sponsor	Country	Number of publications	%
1st	Wellcome trust	United Kingdom	7	2.7
2nd	National institutes of health	United States	5	1.9
3rd	Bill and melinda gates foundation	United States	4	1.5
3rd	Horizon 2020 framework programme	European Union	4	1.5
3rd	National science foundation	United States	4	1.5
4th	Australian research council	Australia	3	1.1
4th	European commission	European Union	3	1.1
4th	Johns Hopkins university	United States	3	1.1
4th	Natural environment research council	United Kingdom	3	1.1
4th	Natural sciences and engineering research council of Canada	Canada	3	1.1
4th	Rockefeller foundation	United States	3	1.1
4th	World health organization	International organization; Switzerland	3	1.1

cluster 3), policy (50 occurrences; cluster 3), food (49 occurrences; cluster 3), community (49 occurrences; cluster 1), and education (47 occurrences; cluster 1). The main topics of highest relevance revolved around knowledge and practice of planetary health principles within the context of climate change, particularly among health professionals, communities, and students. These studies emphasized the importance of incorporating planetary health and climate change issues into the curricula, particularly in the fields of health, nursing, and medicine. The impacts of climate change on biodiversity loss and ecosystem services, and how they are linked to the transmission of infectious diseases like COVID-19 viruses

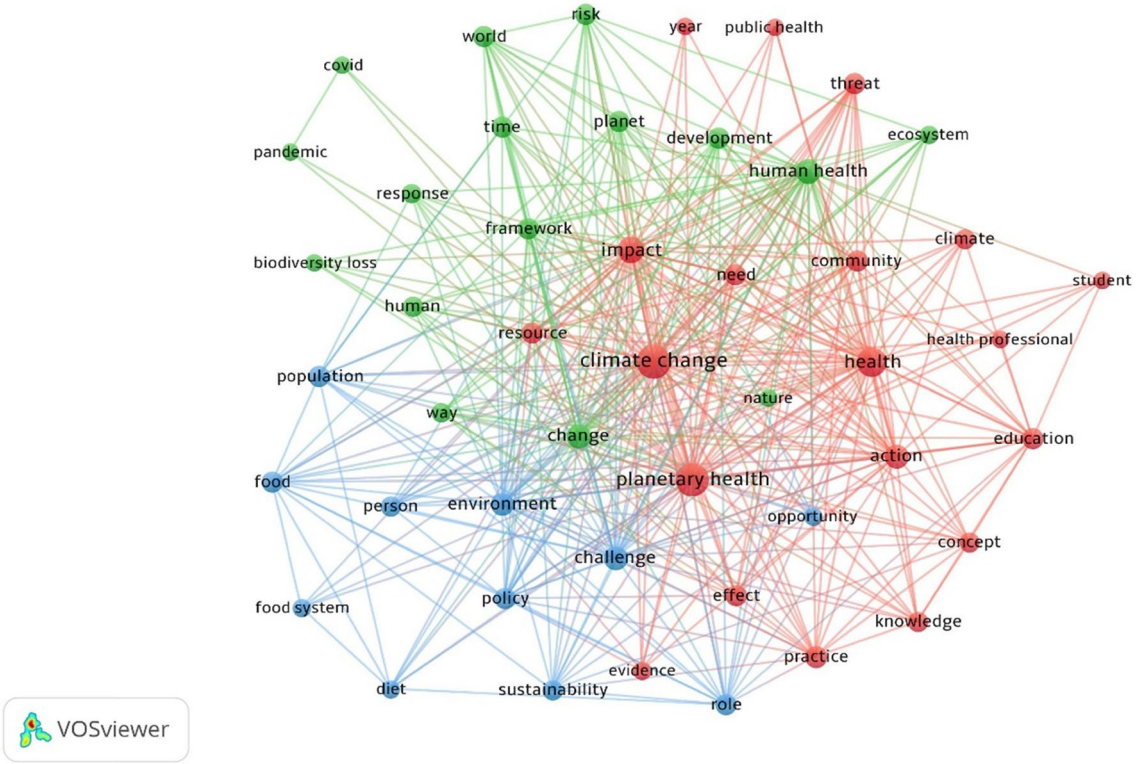

Fig. 8 The network visualization map of terms co-occurrence in titles and abstracts of planetary health-climate change publications. 20 occurrences of a term were set as the minimum number (Binary counting: involves assessing the presence or absence of a term in the titles and abstracts of documents, with the frequency of occurrences within a document being disregarded). A total of 53 terms out of 7009 terms met the set threshold. The most relevant terms were 47 terms (after excluding the general terms) categorized into 3 major clusters; cluster 1: red color (20 terms) concerned primarily with knowledge regarding Planetary health in the context of climate change among health professionals, community and students (curriculum), cluster 2: green color (16 terms) concerned mainly with the impacts of climate change on biodiversity loss and ecosystem services and their links to transmission of infectious diseases such as COVID-19 viruses, and cluster 3: blue color (11 terms), concerned mainly with diet practices, food systems and their impacts towards sustainable development

were highlighted. Additionally, significant research emphasized the importance of diet practices, food systems, and food security in promoting sustainable development. Finally, the need for well-defined climate change policies aimed at reducing non-communicable diseases and preventing pollution was strongly emphasized in major works. Regarding the significance of planetary health education for health professionals, the studies of Eustachio, Filho [72] and Leal Filho, Eustachio [26] highlighted this issue. The conclusions on the significance of themes like food systems and non-communicable diseases and how they pertain to climate change and planetary health correspond with the findings revealed by Rossa-Roccor, Acheson [28], who researched planetary health in a general context.

3.10 Strategic diagram and thematic evolution

Figure 9 presents the strategic diagram illustrating the major themes of planetary health-climate change research activities at a global level, with each circle's size representing the number of documents incorporating the respective term. The primary driving and motor themes encompass various aspects. Firstly, demographic change is linked to an increased risk of contracting and transmitting vector-borne diseases, associated with alterations in human demographics. Secondly, informal settlement and the intense interactions between people, animals, and environmental systems in urban informal settlements pose threats to both human and environmental health. Thirdly, air pollution emerges as a critical global public health concern. Fourthly, the significance lies in identifying contexts that foster pro-environmental attitudes and behaviors, while also addressing the issue of alienation from nature, starting from childhood, to enhance awareness regarding urgent environmental matters, including climate change, and their impacts on individual and environmental health. Lastly, the carbon footprint of animal-based foods and the need to reduce food system impacts on climate change are recognized as major contributors to greenhouse gas emissions. These topics will continue to play a primary role in

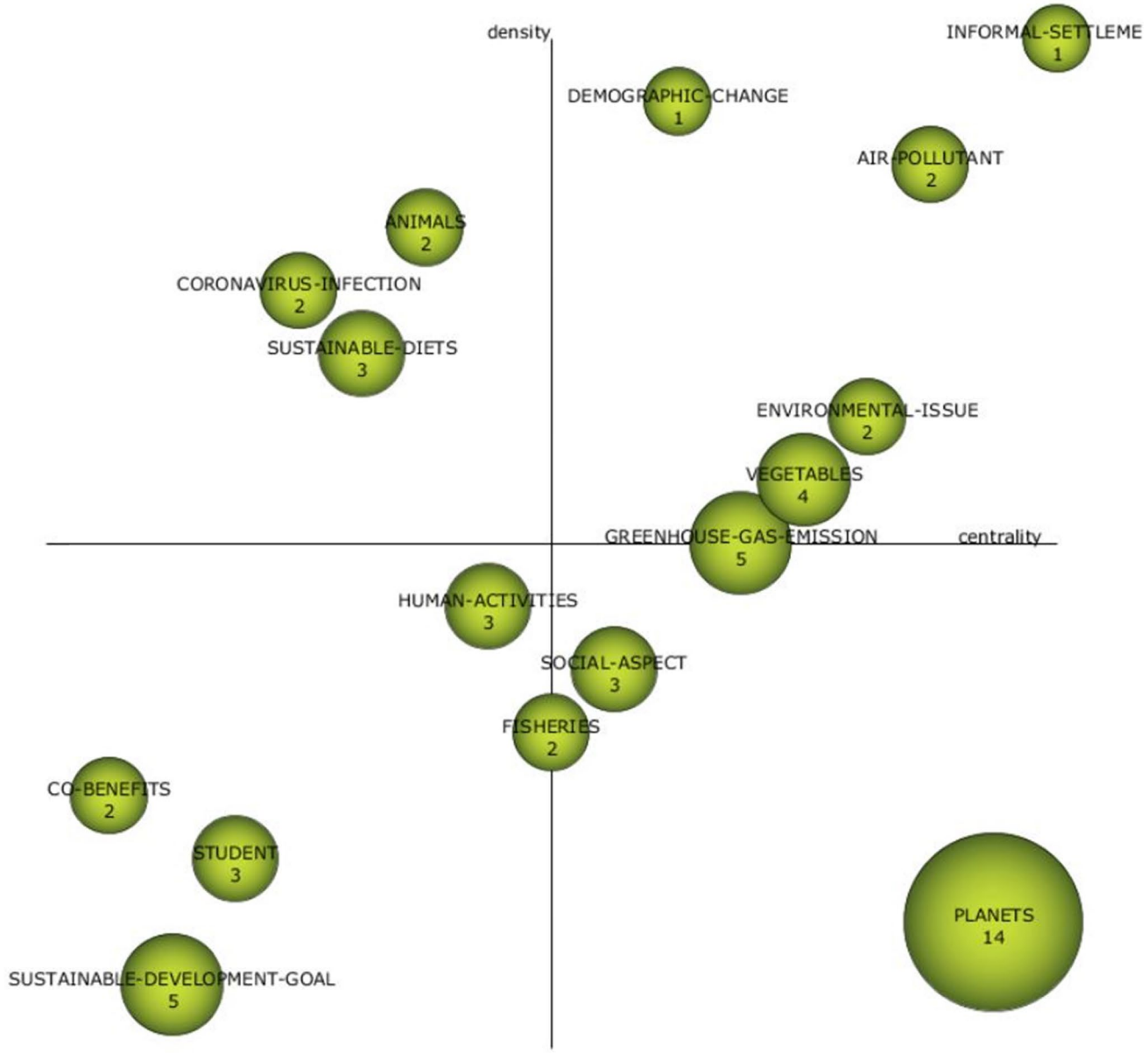

Fig. 9 The strategic diagram depicts the number of published works and combines the different themes of planetary health-climate change research at the global level

structuring and shaping planetary health-climate change research works in the foreseeable future. The fundamental matters, in the lower right zone, comprise social aspects, fisheries, and planet. Declining or emerging topics, such as human activities, co-benefits, student, and sustainable development goals, are shown in the lower left zone. Issues that are characterized by their high specialty (i.e., animals, coronavirus infection and sustainable diet) are shown in the upper left zone. According to citation counts, Figure 10 of the strategic diagram identifies the overexploitation of fisheries as a significant global environmental threat to health, along with other impacts such as the loss of tropical forests, land degradation, biodiversity loss, declining freshwater resources, and ocean acidification. Furthermore, the scientific community working on planetary health and climate change has shown considerable interest in recognizing and defining air pollution as the world's largest single environmental health risk factor. This is evident from the high citation rates of research discussing air pollution, air quality, and related standards and guidelines.

An analysis of thematic evolution is presented, examining the themes identified in each period, their keywords, and their development over time, as depicted in Figure 11. The research in the field of planetary health-climate change exhibits a certain degree of cohesion, as most detected themes are grouped under specific thematic areas, often stemming

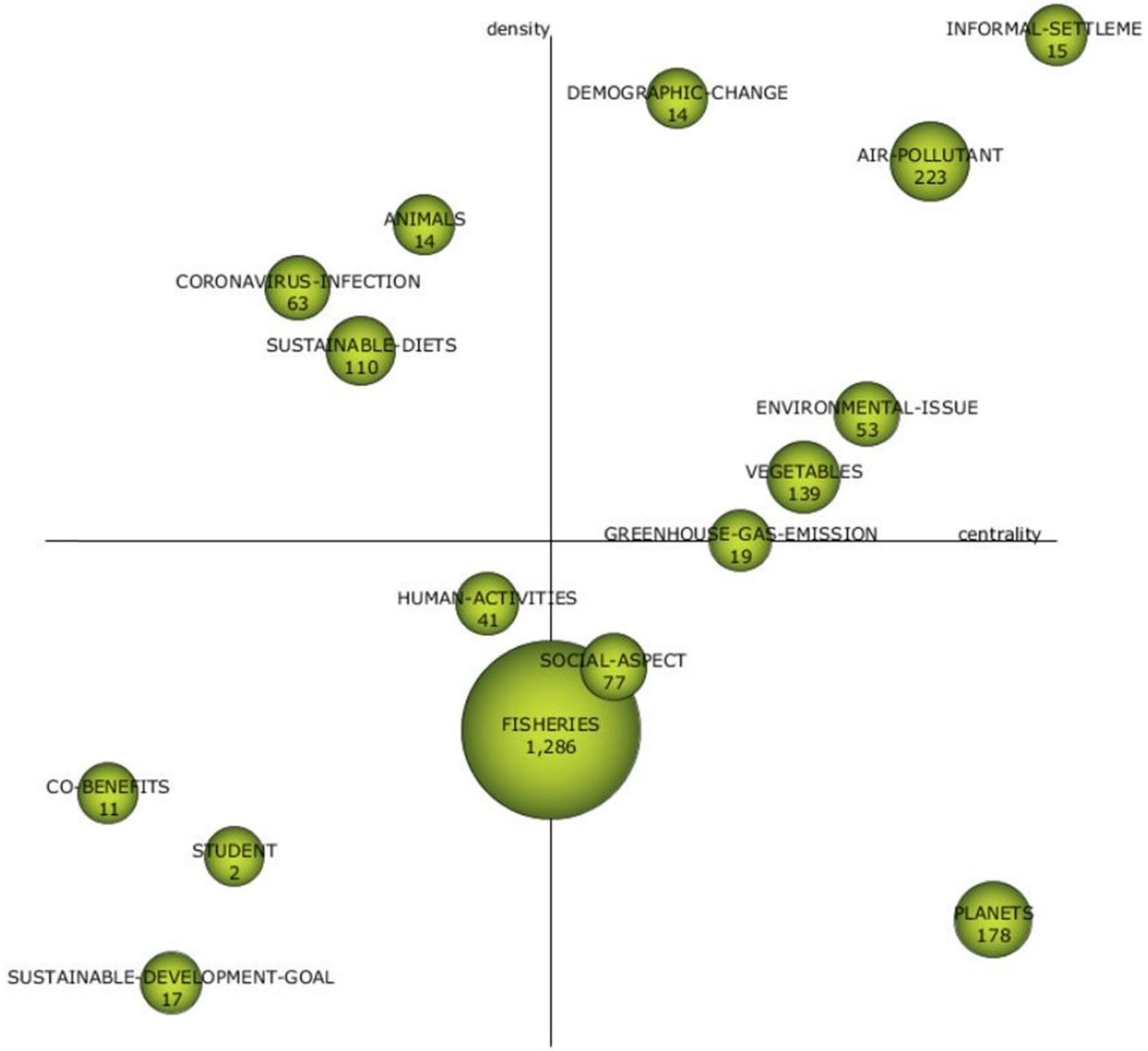

Fig. 10 The strategic diagram depicts the citation count associated with different themes of planetary health-climate change research at the global level

from themes established in previous periods. Several factors influence this cohesion, including the relatively new emergence of the field as a prominent area of research, significant breakthroughs occurring after 2019, and the ongoing potential for new publications in 2023. Certain thematic areas persist across multiple periods of study. For instance, cardiovascular disease is identified as a major noncommunicable disease linked to human-induced climate change. Additionally, the importance of dietary patterns is emphasized in optimizing cardiovascular disease prevention and mitigating climate change by reducing greenhouse gas emissions associated with food consumption. Additionally, coronavirus infection emerged as a major theme in later periods, discussing its links to air pollution in two ways: high-risk premature deaths for infected individuals in highly polluted areas and positive impacts on the natural environment due to reduced human activities during lockdowns. The implications of COVID-19 on achieving the sustainable development goals were also extensively discussed in planetary health-climate change research. Addressing soil pollution and maintaining healthy soil were among the core priorities of planetary health-climate change research. This is because, the issue of soil pollution poses a growing threat to human health, emphasizing the crucial role of healthy soil in providing crops, sustaining populations, preventing floods, capturing carbon, and mitigating the effects of global climate change.

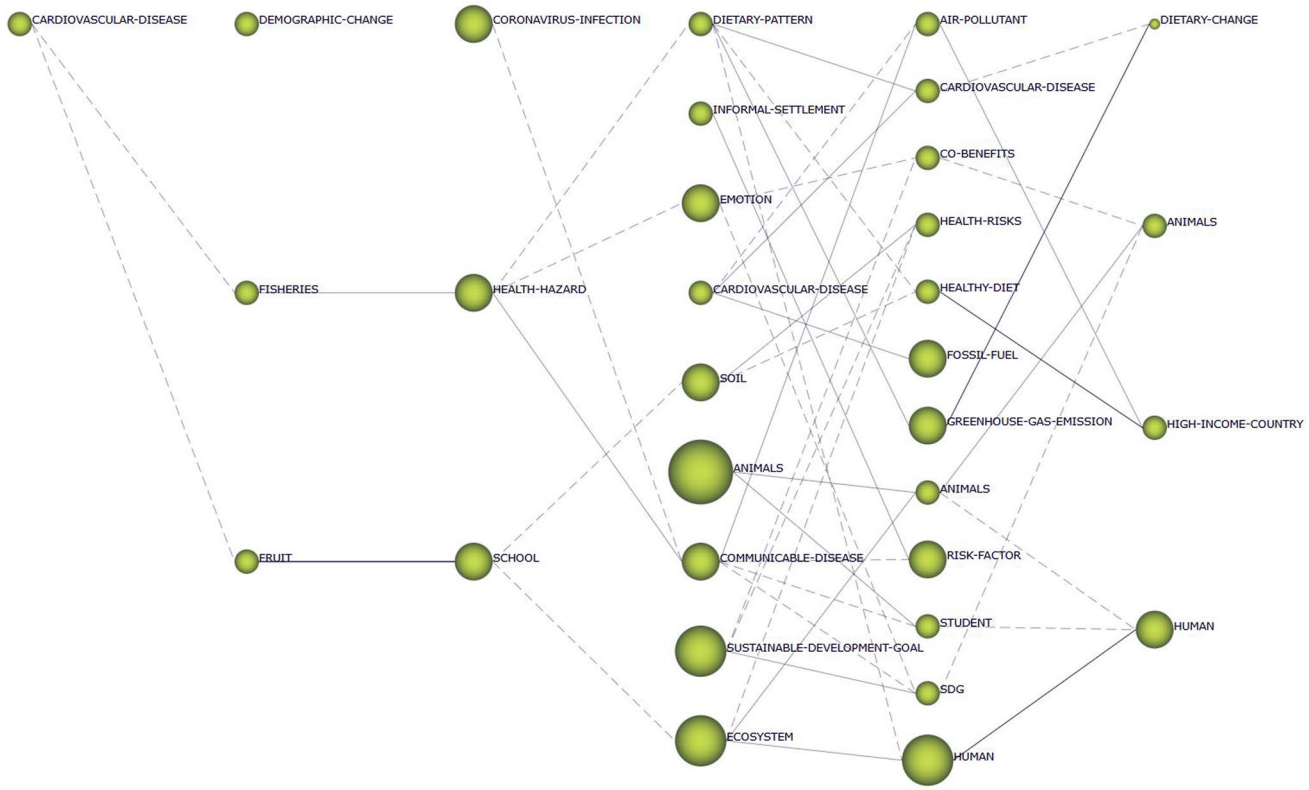

Fig. 11 The thematic evolution of planetary health-climate change research at the global level can be categorized into six major periods (from left to right): 2009–2014, 2015–2019, 2020, 2021, 2022, and 2023. This categorization considers publications prior to 2015, which coincide with the establishment of The Rockefeller Foundation–Lancet Commission on planetary health. The period from 2015 to 2019 is regarded as part of the pre-COVID-19 era, whereas the subsequent years are marked by significant advancements in publications on planetary health

4 Discussion

This analysis conducted a thorough examination of the development of planetary health-climate change, encompassing global trends and research horizons. The growing number of research works in this subject indicates that researchers are keenly interested in it, a trend that has been exacerbated by the COVID-19 pandemic. The discrepancies in research productivity amongst countries could be explained by an array of factors, including the country's economic conditions, the populations' size, the extent of development, scientific resources and capabilities, and national technological and scientific infrastructure. As developed countries adopted well established scientific research systems more swiftly than other countries across the globe, they have an advantage and an edge in planetary health-climate change research. The United States, which is recognized globally as a key player in research productivity and collaboration, plays a crucial role in planetary health and climate change. The country is home to a plethora of institutions and organizations that have a mandate and are motivated toward establishing planetary health policies, programs, projects and initiatives, and implementations in practice. Particularly, the US Environmental Protection Agency (EPA) is an important body that's active in this field and maintains public health from air, water, and soil pollution [73]. Based in the United States likewise, the Planetary Health Alliance is an organization that includes about 360 institutions, non-governmental organizations, academic institutions, and government departments from many different countries. The Planetary Health Alliance was formed because of joint efforts including Harvard University, the Wildlife Conservation Society, and other partner organizations. The primary objective of this alliance is to substantially advance the understanding of the globally links between environmental change and human health [74].

In the following subsections, there will be a comprehensive discussion of the main topics related to planetary health within the context of climate change. This discussion will consider the significant findings from the present analysis and highlight key issues.

4.1 Climate change impacts on human health

4.1.1 Direct health impacts

The expanding health concerns throughout the world are mostly due to numerous important variables, including climate change, which has significant and direct impacts on human health. Due to climate change, extreme weather phenomena including heatwaves, storms, and floods are occurring more frequently and with greater intensity [75]. The lives and wellbeing of people are immediately threatened by these occurrences. For example, heat waves can cause heat-related diseases, heat strokes, and even fatalities, especially in populations who are already at risk, such the elderly and people with underlying medical issues [76, 77]. Another worrying effect of climate change is changing disease patterns [78, 79]. The habitats of vectors of disease like ticks and mosquitoes are expanding as temperatures increase [79]. This spread affects greater populations and formerly untouched areas, increasing the transmission of infectious diseases including Lyme disease, malaria, and dengue fever [80, 81]. Furthermore, unpredictably shifting climate conditions can destabilize ecosystems, altering the location and number of pathogen-carrying species [81].

Climate change also makes it harder to have enough food and clean water [77, 82]. Rising temperatures and unpredictable precipitation patterns can impair agricultural productivity, leading to lower crop yields and food shortages [83]. This scarcity of food supply, especially in developing nations, can result in malnutrition and increase the risk of long-term health problems [84]. Variations in precipitation can also affect the quality and quantity of water, leading to shortages and contamination, which can worsen pre-existing public health problems and cause waterborne illnesses [85]. Human health may be directly impacted by wildfires, especially in light of climate change. For example, Liu, Mickley [86] predicted that, in the context of future climate change, over 82 million Americans will experience a 57% rise in the frequency and a 31% increase in the severity of smoke waves. It is urgent to address the direct effects of climate change on human health. To reduce these risks and safeguard human welfare amidst climate change, it is imperative to adopt adaptable strategies, allocate substantial resources to resilient infrastructure, and prioritize public health initiatives. Collaboration between national and local government agencies, as well as international organizations, is necessary to create a more sustainable and healthier future for everybody.

4.1.2 Indirect health impacts

A number of areas of mental health and wellbeing are impacted by the indirect effects of climate change on human health [77]. Prolonged exposure to catastrophic weather events and ongoing environmental changes can make people and communities feel more stressed, anxious, and powerless [87]. Losing familiar surroundings and facing unclear futures can have a negative influence on mental health, increasing the risk of psychological illnesses including depression [88]. Displacement and migration are significant effects of climate change because they compel many people to leave their homes owing to rising sea levels, more frequent natural catastrophes, and the loss of habitable land [88]. The social unrest commonly amplifies the risks of infectious diseases thus rendering residing in refugee camps or settlements risky [89]. Moreover, the migration journey itself can be challenging and exhausting, which resulting in adverse impacts on the mental state of the individuals at stake [90].

The repercussions of climatic changes are intricately associated with social and economic changes. People who are vulnerable endure the greatest when severe weather, droughts, and changing environmental shifts undermine livelihoods and economies [91]. Insecurity food supplies, loss of income, and constrained access to healthcare facilities are all determinants that may aggravate already-existing inequalities in health while having unfavorable impacts on the quality of life [82, 91]. When a disproportionate share of the burden lies on disadvantaged populations, imbalances in wellness and health worsen. Comprehensive and integrated strategies must be implemented for handling the more subtle impacts of climatic changes on human health. It is crucial to build up systems that provide support for mental disorders, deliver psychosocial services to those negatively impacted, and endorse adaptability to reduce the negative impacts on mental health. Additionally, securing climate-resilient strategies into effect as well as making advancements and investments in sustainable development could be beneficial to curb migration and social instability [92]. Setting priorities for wellbeing and health within initiatives to lessen and cope with climate change could assist communities advance toward a more inclusive and well-conscious future.

4.2 Understanding the feedback loops between human activities and the climate system

The climate of the planet and its complex web of dependent ecological systems are greatly impacted via feedback loops involving human activities and the planetary climate. Amongst the major feedback loops requiring consideration include ones pertaining to land use changes and declining biodiversity, emissions of greenhouse gases and climatic forcing, air quality and wellness, health behavior and climate changes, acidification of the oceans, and the health of marine ecosystems. To cope with all the complicated associations that are present involving the actions of humans and the climate systems, it is vital that these loops of feedback be fully comprehended. Realizing the way the wellbeing of humans and the natural environment are interconnected offers the emergence of holistic strategies that alleviate the detrimental impacts of climate changes and move forward world wellbeing.

4.2.1 Air pollution and human health

Volatile organic compounds, sulfur dioxide, nitrogen oxides, and particulate matter constitute just some impurities that human beings discharge into the atmosphere. The air pollution brought about by these compounds is being associated with an array of health concerns. Particulate particles and ozone at ground level, for example, may contribute to lung disorders, problems with the heart and respiratory system [93]. People who are most vulnerable are further impacted from poor air quality, among them children, the elderly, and those with chronic medical disorders [94].

4.2.2 Greenhouse gas emissions and climate forcing

Greenhous gases are emitted into the earth's atmosphere because of human-induced activities comprising the combustion of fossil fuels, manufacturing processes, and deforestation. The climate forcing term explains the way pollutants like methane, carbon dioxide, and nitrous oxide retain heat resulting in the greenhouse impact, which elevates global average temperature [95]. Ecological feedback responses could get active as temperatures rise, consequently magnifying the warming impacts. As an example, as a greater heat is captured by the surface of the earth as an ice and snow melt, the process of warming intensifies [96].

4.2.3 Land use change and biodiversity loss

The climate systems are profoundly impacted by shifts in land uses triggered by growing urbanization, developments of agriculture, and deforestation [97]. Deforestation diminishes the capacity of the planet for absorbing carbon dioxide, therefore boosts the levels of greenhouse gases in the environment [97]. Diminished adaptation to climate changes, distortion in ecological cycles, and a correspondence reduction in ecological diversity represent consequences of ecosystems loss. The capacities of ecosystems to manage temperatures are susceptible to compromise and degradation of the environment intensified by declining biodiversity.

4.2.4 Ocean acidification and marine ecosystems

As atmospheric carbon dioxide rises, correspondingly increases the proportion of carbon dioxide captured by the oceans. The ocean gets increasingly acidic as well as alters its chemistry as an outcome of this phenomenon, which is commonly referred to ocean acidification [98]. Ocean acidification could pose damage to aquatic life, notable to calcified organisms like plankton, shellfish, and corals that require calcium carbonate for the creation of their structures [98]. Coastal communities that utilize marine resources are seriously impacted by the ocean acidification as it disturbs fisheries, diminishes biodiversity, and disrupts the marine environment [99].

4.2.5 Climate change and health behaviors

Climate change has both direct and indirect impacts on health behaviors. Direct effects are observed when phenomena like heat waves directly influence sleep physiology [100]. Indirect effects occur when extreme weather events lead to stress and anxiety, thereby affecting sleep patterns. Climate change also induces short-term behavioral shocks, like

immediate responses to extreme weather events, and long-term secular trends, such as temperature increases, which shape health behaviors [100]. Moreover, health behaviors themselves can exert both positive and negative effects on climate change. These behaviors play dual roles in terms of mitigation and adaptation [100]. Some health behaviors can positively contribute to mitigating climate change, while others may have negative consequences on the environment [100].

4.3 Co-benefits of climate action for planetary and human health

Climate action offers several co-benefits for both planetary and human health in addition to addressing the urgent need to halt global warming. The opportunity to advance human wellbeing can be achieved by the application of efficient mitigation measures. For instance, lowering greenhouse gas emissions via the use of renewable energy, energy-saving techniques, shifting to the planetary health diet and forest preservation not only slows down climate change but also improves air quality, which has important health advantages as an added benefit [101]. Making the transition to renewable energy sources, such solar and wind power, lowers harmful pollutants in the air as well as carbon emissions, alleviating respiratory and cardiovascular diseases and ultimately improving human health [102].

Urban planning and sustainable transportation are essential for reducing climate change and promoting healthy communities. In addition to lowering carbon emissions, increasing bicycle usage, encouraging public transportation, as well as developing pedestrian-friendly cities help ease traffic congestion and boost air quality [103]. Urban green space development may also enhance mental health and provide a respite from the stresses of city life [104]. Optimizing the agriculture and food chains' sustainability and resilience diminishes the likelihood of dietary-related diseases, stimulates heathy and nutritious food habits, while helping in the effort to combating climate changes [101]. Two prime examples of climate-smart framing strategies that boost security of food while simultaneously assisting with carbon capture and storage, and maintain the environment are diversification of crops and agroforestry [105].

Additionally, strategies of adaptation must be developed to build up substantial resistance over the negative impacts of climate changes. The risks to health triggered by catastrophic weather conditions, including floods, storms, and heatwaves, can be reduced by making investments in early-warning technologies and systems and climate-resilient systems [106]. Communities are able to reduce the damages that has been caused to the public health and more effectively handle the natural calamities driven by climate changes by restoring the communities' resilience and response capacities [106]. In a similar vein, improving the adaptability of health systems to climate changes is fundamental [107]. By fortifying healthcare infrastructure and expanding capacity, health systems may better prepare to address climate-related health issues such vector-borne illnesses, heat-related disorders, and waterborne infections [107].

4.4 COVID-19 as a matter of planetary health in the context of climate change

Inextricably linked to the urgent problem of climate change, the COVID-19 pandemic has come to pose a threat to both human and world health. Even while the pandemic's immediate focus has been on human health, its wide-ranging consequences have demonstrated the connections between planetary stability and climate change and ecological, social, and economic systems [33]. Biodiversity loss is closely linked to climate change and has a substantial impact on the rising occurrence of zoonotic illnesses such as COVID-19 [108, 109]. Deforestation, wildlife trade, and habitat degradation disrupt ecosystems, increasing human-animal interaction and the risk of zoonotic spillover events [109]. Therefore, addressing biodiversity loss is essential to controlling pandemics in the future and maintaining the health of the planet and people.

A short-term drop in the release of greenhouse gases amid the COVID-19 pandemic prompted the overall quality of the ambient air to slightly improve in particular environments, revealing a first glimpse of the prospective environmental impacts of diminished human activities [33]. However, due to the absence of permanent structural alterations, these improvements remained simply temporary. The COVID-19 pandemic's impacts on ecological systems have raised spotlight to exactly how fragile ecosystems are to both climate changes and human activities. A couple of examples that demonstrate how activity by humans shapes the planet's resilience include alterations to urban ecosystems triggered by shifting human mobility habits and a decreasing trend in fishing in the marine environment [110].

It became increasingly apparent during the COVID-19 pandemic how closely the provision of water, sanitation, and hygiene facilities, in particular for communities that are vulnerable, is connected to the implications of climate changes [111]. Floods and droughts are prominent examples of catastrophic weather events that are capable of harming water supplies and sanitation systems, posing concerns over health [112]. Along with eliminating infectious diseases,

maintaining equal accessibility to hygienic water is critical to establishing communities resilience to climate changes [111]. The pandemic further has exposed deficiencies in global food supply infrastructures, and this had impacts on the security of food and nutrition [112]. It is projected that climate changes will worsen theses vulnerabilities, causing food deficits, interruptions to crop production, and even massive migrations [113]. A key component of planetary health is the establishment of reliable, ecologically sound, and climatic-adaptable food chains to confront both the risks to food supplies brought out by climate changes and the challenges triggered by the COVID-19 pandemic.

At last, the COVID-19 pandemic's impacts on mental disorders have served to demonstrate how crucial it is to recognize the association between humans wellbeing and the planet's ecosystem and health [114]. The risks associated with climate change and the lack of certainty regarding the future that contributes to anxiety and distress represent an immense psychological burden [115]. Building resilience and stimulating collaboration are crucial for successfully managing climate change, and both demand incorporating mental health within the concepts of planetary health.

5 Policy implications and future directions

There is an association between climate change and planetary health that will likely have significant implications on future planning, policies, and initiatives. The successful incorporation of planetary health principles into climate change policies and strategies is key for advancing the goals towards planetary health and the combat against climate changes. Policies demand to consider taking the associations between the health of humans, ecosystems, and climate changes to accomplish that. Policymakers should set a significant emphasis on strategies that curb greenhouse gas emissions while simultaneously considering both ecological sustainability and public health. Optimizing collaboration across disciplines is a must to confronting the complicated challenges driven by climate changes including how they impact public health [116]. In order to deliver decisive responses, policymakers would do well to encourage partnerships amongst multiple sectors like agriculture, the environment, urban development, and public health [116]. In partnership, counterparts can formulate more efficient policies and strategies which consider different perspectives and expertise, facilitating a more holistic approach towards planetary health.

Managing the socioeconomic drivers of equality and health ought to remain the primary focus of climate change programs. The adverse impacts of climate changes are particularly detrimental to vulnerable groups, including disadvantaged humans, people of indigenous origin, and communities with limited resources. These communities typically experience hurdles to healthcare and availability of resources [117]. The planning and implementation of policies should be equitable and inclusive, featuring a priority on actions that benefit those who are most vulnerable and diminish disparities in health [117]. To keep track of the implications of climate changes on human beings and assess the usefulness of initiatives, substantial investments in research and monitoring platforms must be made [118]. It is crucial to provide funding for research on climate changes and health to continue supporting continual evaluations and policy advancements [118]. Setting up robust monitoring infrastructures boosts preparedness and facilitates swift responses, ensuring a prompt recognition of risks to health associated with climate changes.

6 Conclusion

The present analysis affords an exhaustive assessment of planetary health in the context of climate change. This analysis has stipulated potential pathways for future studies and enriched the comprehension of the fundamental advances accomplished following an extensive investigation of scholarly literature. The outcomes suggest that integrating planetary health concepts to comprehend the associations between climate change, human health, and the environment is of tremendous significance. Such suggestions propose tangible strategies for sustaining the wellbeing and health of humanity while securing a sustainable and resilient future for subsequent generations. It is essential to take advantage of the momentum that results from the increasing incidence of infectious diseases like COVID-19 and associated major impacts on every aspect of life to further develop and advance the principles of planetary health. Additionally, the universal consensus on planetary health principles and the pressing significance of confronting the catastrophic repercussions of climate changes should act as catalysts towards advancements in this field. While the outcomes of the present analysis reveal the success of planetary health in the climate change context, it is of utmost significance for researchers to sight that this subject is still relatively fresh. In this regard, recognizing and tackling the persistent challenges associated with the merging of social scientific fields and scholars from different disciplines is fundamental. Likewise, incorporating

political science into planetary health research is an opportunity to eliminate the gap between academia and public officials. This is going to contribute to more effective engagement and commitment, collaborative efforts, as well as knowledge sharing. A key initial step in realizing sustainable development, preserving the environment, and advancing human wellbeing involves recognizing the mutual benefits. In climate initiatives, disparities in health and socioeconomic considerations must be given priority, with a particular emphasis on those who are most vulnerable comprising communities with low income, indigenous communities, and disadvantaged individuals who experience substantially from the repercussions of climate changes. Policies that ensure justice and inclusion must lessen health disparities and assist the most vulnerable. To monitor the impact of climate change on human wellbeing and measure the efficacy of treatments, research and monitoring systems investment are essential for continuous assessment and enhanced preparedness. Planetary health should develop its own uniqueness. While this is significant, it ought to establish robust links with other fields like One Health to manage plenty of challenges more effectively.

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Declarations

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