University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

Library Philosophy and Practice (e-journal)

Libraries at University of Nebraska-Lincoln

6-2021

Global Research Trends and Network Visualization on Climate Action : A Bibliometric Study

Binod K. Das

GLS Law College, Ahmedabad, binod.bkumar1@gmail.com

Mayuri Pandya

GLS Law College, Ahmedabad, mayurihimanshu@gmail.com

Shanti P. Chaudhari

Pandit Deendayal Energy University, shanti.chaudhari@gmail.com

Atul Bhatt

Gujarat University Ahmedabad, dratulbhatt@gmail.com

Dharmendra Trivedi

L&T Institute of Project Management, Vadodara, 1974dtrivedi@gmail.com

Follow this and additional works at: <https://digitalcommons.unl.edu/libphilprac>

Part of the [Library and Information Science Commons](#)

Das, Binod K.; Pandya, Mayuri; Chaudhari, Shanti P.; Bhatt, Atul; and Trivedi, Dharmendra, "Global Research Trends and Network Visualization on Climate Action : A Bibliometric Study" (2021). *Library Philosophy and Practice (e-journal)*. 5818.

<https://digitalcommons.unl.edu/libphilprac/5818>

Global Research Trends and Network Visualization on Climate Action : A Bibliometric Study

Binod K. Das

Assistant Professor
GLS Law College, Ahmedabad, India
Email: binod.bkumar1@gmail.com

Mayuri Pandya

Director
GLS Law College, Ahmedabad, India
Email: mayurihimanshu@gmail.com

Shanti P. Chaudhari

Pandit Deendayal Energy University
Gandhinagar, India
Email: shanti.chaudhari@gmail.com

Atul Bhatt

Associate Professor
Dept. of LIS, Gujarat University,
Ahmedabad, India
Email: dratulbhatt@gmail.com

Dharmendra Trivedi*

Librarian, L&T Institute of Project Management
L&T Knowledge City, Vadodara, India
Email: 1974dtrivedi@gmail.com

Abstract

The purpose of the study is to explore the bibliometric features of scientific publications in the area of climate action for the period during 1995–2020, thus, enabling the scientific community to understand the research progress on the topic. The data of the scientific publications were retrieved from the Scopus database. The key word “Climate Action” were applied as topic terms to search articles published during the study period. Total 1638 scientific publications retrieved for statistical analysis for bibliometric analysis and for visualization network analysis study has VOSviewer© tools along with RStudio and MS Excel. Result shows steady progress on the annual production of publications. In the year 2016 received maximum 3321 citations followed by year 2018 and 2015 with total citation of 2078 and 2038 respectively. in the year 2017 maximum cite rate reported in the study. USA, Netherland and UK received highest citation in the domain of climate action. Uni. Of Oxford contributed with maximum publications and climate policy and sustainability were the most productive source title reported in the study. Present study also calculate the most prolific authors and production life of author. The network visualization was presented in terms of co-authorship, co-occurrence of keywords, citation and co-citation of references and bibliographic coupling analysis with clusters, links and total link strength. The study provides significant information on the trends of academic publication in the domain. It is one of the most comprehensive study on climate action which will aid the potential researchers to identify the most prominent contributions, county-wise research distribution, author and journal productivity and other related indicators.

Key Words: Climate Action; Bibliometric; Citation Analysis; Scientometrics; Climate Change; VOSviewer©; RStudio

*corresponding author

1. Introduction

Climate action means reduction of greenhouse gas emissions and capacity to minimize climate induced impacts and integrating climate change actions into national policies. Owing to global warming, countries are compelled to undertake climate related actions to minimize the impact of global warming. As a collective effort of the countries, Paris agreement agreed to undertake climate related actions and mobilize 100 billion US dollar annually by 2020. This would help to adapt to climate change and invest in low-carbon emission by developing countries (UNDP 2020). The United Nations Framework Convention on Climate Change (UNFCCC) advocates adaptation and mitigations are part of climate actions. Therefore, international action to address climate change is primarily aimed at reducing carbon dioxide emissions. Climate Change Vulnerability Assessments (CCVAs) are a central component of the climate action (Joakim et al. 2015). Indeed, adapting to climate change effectively is to assess the vulnerabilities that shape the potential impacts (Fussel 2007). In order to implement climate actions, National Adaptation Plans (NAPs) helped countries to enhance adaptive capacity and strengthen resilience to climate change. In 2019, at least 120 of the 153 developing countries had undertaken activities to formulate and implement NAPs. Further in study, authors argued that climate actions constitute the basis of climate governance. The article emphasized the role of non-state and sub-national actors in implementing climate actions. It argued that the intergovernmental and transnational spheres of global climate governance could mutually reinforce each other by engaging regional and non-State actors. UNFCCC should work in this regard (Sander et al. 2016).

United Nation organized Climate Action Summit in 2019. Sixty countries were expected to announce steps to reduce emissions and support populations vulnerable to the climate crisis (Rosane, 2019a). In the summit, China did not increase its Paris agreement commitments, India did not pledge to reduce use of coal, and the U.S. was absent in the conference (Rosane, 2019b). The Climate Action Summit 2019 enlisted series of actions. First, undertake mitigation commitments, net zero-emission plans by major emitters. Second, countries must focus on health, gender, climate and security, Three, countries must ensure youth and civil society participation across all tracks of work. Four, countries must adapt energy transition, renewable energy, energy storage, access and innovation and mobilizing investments for energy transition. Five, countries must adapt industry transition creating commitments from hard-to-abate sectors (steel, cement). Six, countries must scale-up commitments on low-emission infrastructures and focus on smart agriculture and food systems. Seven, countries must enhance regeneration of life in water bodies. Eight, in order to undertake adaptation, countries must integrate public and private sector to assure food, water and jobs for vulnerable groups. Lastly, countries, must adapt climate finance and carbon pricing (United Nation 2019). Above all, experts have argued conservation of biodiversity is a solution to mitigate climate change impacts on the functioning of forest ecosystems (Hisano et al. 2018)

2. Rationale of Climate Action

According to goal 13 of United Nations' Sustainable Development Goals, climate action is essential due to four factors. First, Climate change could increase the risk of hunger and malnutrition by up to 20 per cent by 2050. Second, Climate change could force more than 100 million people into extreme poverty. Third, nearly 211 million people were affected every year by natural disasters between 2000 and 2013. Fourth, Climate change could cause 250,000 additional deaths per year between 2030 and 2050 (UNDP 2021). The magnitude of this problem grossly justifies the intense research on climate action.

In recent years, climate actions have been studied by the academic community and relevant research results have emerged. In the present study, a bibliometric analysis of academic works published between 1995 and 2020 related to climate change actions. The publication on climate action has increased and the topic has become interdisciplinary involving natural sciences, social sciences and management. Most of the research works emanated from USA, China, Canada, Australia, and European countries. The problem of mitigation and adaption has drawn maximum attention in research work. Despite many studies, authors have paid limited attention to the trends of research in the climate action. The publications as of now are limited to climate action in urban areas, sustainable development goal and governance.

In order to provide an objective overview of research on climate actions, this study identifies bibliometric characteristics and visualizes relationships between articles published in the Scopus indexed journals between 1995 and 2020 by means of a scientometrics analysis based on Rstudio and VOSviewer©

3. Review of Literature:

Climate action is relatively a new concept and research is very limited. Even in the limited research, due attention was not paid to define the trends of research in this field. Some empirical and qualitative studies have offered an overview of climate action research; however, they are limited in some specific aspects, such as mitigation and adaption in general (González-Sánchez et al. 2012). Interestingly, the studies show that the number of publications has increased rapidly and climate action research has become interdisciplinary (Huang et.al 2020). Few general studies on the domain of climate change and climate action undertaken which give more focus on economic case, climate action, sustainable development goal and social mandate. (Brian et.al 2012; Gouldson et al. 2015, Francesco et al.2019, Candice et.al 2020)

Saravanan et al explore the bibliometric analysis on climate change of the scientific works published in major five developing countries. Study considered WoS (Web of Science) bibliographic database and retrieved total 7065 records during the study period from 1991 to 2012 and compare the results. Results revealed that Argentina secured top position in degree of collaboration followed by Brazil and China and more research work undertaken on environment science subject whereas less work reported for the subject meteorology atmospheric science (Saravanan et al., 2014).

The systematic study conducted by Bing et al., on bibliometric analysis of climate change vulnerability has retrieved total 3004 scientific publications from total 658 professional journals available under WoS bibliometric database on the core topic climate change vulnerability during the period 1991 to 2012. Findings revealed that University of East Anglia and Potsdam Institute for Climate Impact Research are most productive institutions in this domain and study found that ecological diversity and water resource management are the major research areas in this domain. (Bing et al., 2014)

The study undertaken by Prakash and Jayprakash focus on scientometrics analysis on the journal entitled “Journal of Climate”. Study considered total 2787 records from WoS database from five years of publications between 2014 to 2018. Results of the analysis shows that USA lead in number of publications followed by China and UK and maximum of 97% of published articles were written by joint author. Study also discovered relative growth rates and it was reported in decreasing order. (Prakash and Jayprakash, 2019)

Bibliometric study on Climate Change Vulnerability Assessment (CCVA) identified frequently occurring research terms and their citation impact on CCVA. A set of scientific papers related to CCVA retrieved through Scopus database were analysed for the 20 years of period. Result revealed that co-occurrences of keywords fallen in four clusters and highly co-citation terms were related adaptation, exposure factors and global change. (Di Matteo et.al. 2018).

Einecker and Kirby discovered bibliometric trends on climate change of last 30 years from 1991 to 2019. Study used WoS database. Study reported that there was maximum research integration in the domain of climate change. It was observed that co-occurrences of highly cited 513 papers on topic mitigation and climate and more researcher were published on resilience in recent time. (Einecker and Kirby, 2020)

Sweileh evaluated bibliometric analysis of scientific production of publications on climate change and human health with special emphasis on infectious diseases. The data retrieved from period 1980 to 2019 from Scopus and total 4247 documents considered for the analysis. Findings reported that malaria and dengue were most frequently encountered from the published work. Food security and public health top cited areas. Australian National University were secured top in production of health related literature. The journal entitled environment health perspective reported under highly cited journal. Study concluded with remarks that institute must receive monitory funds and support for international research collaboration. (Sweileh, 2020)

In the study taken by Sharifi et al., on bibliometric analysis on climate change and peace emphasis on trend of the publications in this domain in last three decades. Study contended analysis of total 1337 documents retrieved from WoS database and mapped the network visualisation with help of VOSviewer© tool. Results revealed that after 2007 the publication trends increased rapidly in this domain and it was reported in the study that war and violent conflict, water resource, human displacement were the major thematic work reported in the

study. It was also mentioned that environment security was gained more attention in terms of research trends. (Sharifi et al., 2020)

In the research work of Asmi et al. (2019) explored the knowledge area of climate change communication. Study explored total 454 journals, 1408 articles and 51786 references and discovered the scholarly development and research facades in this domain. (Asmi et al., 2019)

Huang et al. conducted the scientometrics study on climate change and carbon sink. Total 747 published works were evaluated during 1991 to 2018 on this domain. Study reported significant publication growth in interdisciplinary domain and USA, China, Canada and Australia were leading most productive country of publications. Drought issues were attracted more attention in the domain of climate change and carbon sink. (Huang, et al., 2020)

The summary of literature review focuses to basic bibliometric data analysis and method. It is observed that all the past published works are based on the sub areas of climate action. The approach of bibliometric visualization has not been fully explored in the domain of climate action, hence the present study attempt to bridge some of the existing gaps in this area.

4. Objectives of the Study:

Viewing the above context, the present study attempts to undertake assessment of research work considering the following objectives.

- 1 To study the year-wise growth of global research publications in terms of total publications (TP), total citation (TC), average citation per publications(ACPP) and cited rate (CR) and average citation per year(ACPY) of the research trends in domain of climate action
- 2 To study country-wise research trends with most cited counties with total and average citation per publications in the area of climate action.
- 3 To identify most prolific authors and authors productive life in the realm of climate action.
- 4 To understand the distribution of top productive institutions, source titles and highly cited research papers in the field of climate action.
- 5 To understand network visualization of co-authorship, co-occurrence of keywords, citation and co-citation of references and bibliographic coupling analysis in the sphere of climate action.

5. Data Collection and Methodology

The Scopus collection contains high quality academic journals, the reputations of which have been acknowledged by the global academic community. The current study takes “Scopus collection” as the object database with a time span of 26 years (1995-2020). The present study used, R Studio, and visualisations were analysed with VOSviewer©. This is a software tool for constructing and visualizing bibliometric networks. These networks included journals, and individual publications. Third, Microsoft Bing was used for search services, Fourth, Microsoft excel applied for spreadsheet purposes. All these tools were collectively used on presenting the distribution of scientific knowledge in the context of data analysis and information visualization. Visual maps created by VOSviewer© composed of two elements, nodes and

links. Nodes represented authors, institutions, countries, keywords, subject categories, cited references, while the link represented the relationship between nodes (Chen et al. 2014). Three types of nodes (Chen and Wu 2017) large nodes (firmed by country publication), purple rings (firmed by centrality) and red inner rings (firmed by surge) were used.

Similarly, two types of scientometrics techniques were used in this study: collaboration analysis and keyword co-occurrence analysis. Collaboration analysis included author names, countries of publication and institutional affiliation as the unit of analysis (Song et al. 2016). Keyword analysis followed the research hotspots and trends over time by establishing network of co-occurring keywords. All the parameters (node, type) were selected matching with the research objectives. Besides, H-index was used to evaluate the influence of journals, institutions, countries, and authors. The H-index combines an assessment of quantity (number of articles) and impact (amount of citations) of the study (Hirsch 2005). In this study, H-index was used to measure the academic achievements of different journals, institutions and countries. Additionally, the number of citations a paper received reflects the paper's influence. While the academic influence of a journal may vary between research fields, the average number of citations is a suitable measure to count relative importance of the journal (Ji et al. 2014). Therefore, these two indices were calculated in this study. Total 1638 publications were retrieved form Scopus database for the period 1995 to 2020 and study has considered for the further analysis

6. Results and Analysis

6.1 Distribution of Annual Growth of Publications

The quantum of publications on yearly basis reflects the quantity of publications in particular field. Further, it judges both quantity and quality of publications. This is an important aspect to assess the importance of the topic in academics. The following table analyses the quantum of publication on yearly basis.

Table I
Distribution of Annual Growth of Scientific Publications

Year	Total Publications (TP)	Total Citations (TC)	Average Citation Per Pub. (ACPP)	Cited Rate (CR)	Average Citation Per Year (ACPY)	Citable Year (CY)
1995-2010	164	3991	24.34	45.12	0.97	26
2011	49	792	16.16	67.35	1.62	10
2012	63	1049	16.65	74.60	1.85	9
2013	67	1208	18.03	77.61	2.25	8
2014	77	1351	17.55	72.73	2.51	7
2015	111	2038	18.36	74.77	3.06	6
2016	124	3321	26.78	77.42	5.36	5
2017	123	1026	8.34	85.37	2.09	4
2018	203	2078	10.24	79.80	3.41	3
2019	254	1901	7.48	79.13	3.74	2
2020	403	1027	2.55	58.31	2.55	1

As noted in Table I, consistent rise in publication was noticed since 2011. Maximum publications (403 articles) were marked in 2020 while stagnancy was noticed in 2017. In the fifteen years period ranging from 1995 to 2010, only 164 articles could be published (11 articles per year). This clearly proves climate action gained importance in academic discourse since 2011. Seeing the significance of environmental concerns, climate action topics will continuously draw attention of the researchers in forthcoming years.

While on citations, the total citation was relatively low in the fifteen years period form 1995-2010. Hover the citation increased from 2012 onwards. In the year, 2015 and 2018, the annual citation logged at 2038 and 2078 respectively. While on average citation per year, maximum citation was noticed in 2016 (26.78) followed by 2015 (18.36). An abysmally lowest (2.55) citation was reported in 2020. The citation rate was highest in 2017 (85.37) followed by 2018 (79.80) and 2019 (79.1). The lowest citation rate was reported during the period 1995-2010. The average citation was highest in 2016 (5.36 per cent) followed by 2019 (3.74 per cent).

6.2 Distribution of Country wise research publications, citations and average citations

Figure I shows the total scientific research publications with regards to counties. It is reflected from the figure that USA published maximum research in this domain followed by UK and Germany. Country like Norway and Switzerland has observed less publications.

Figure I
Distribution of Country-wise Scientific Research Production

Figure I depicts the most productive countries. The USA had the most publications (1001 articles). UK had the second highest number of publications (399 articles) followed by Germany (263 articles). Other productive countries include Australia (195 articles), Canada (167 articles), Netherland (128 articles) in turn. India had nearly 77 publications. Among the

Latin American countries, Brazil recorded 37 publications. In nutshell European Countries recorded highest publications and China logged modest publications (127).

Analysis of country wise citations has high relevance for the research work. It signifies the importance of country in a particular field of research and the country is according importance to research. The below table II shows the analyses of total and average citation in the field of climate action research.

Table II
Distribution of Country wise Citations and average citations

Country	Total Citations (TC)	Average Citation Per Pub. (ACPP)	Country	Total Citations (TC)	Average Citation Per Pub. (ACPP)
USA	6513	23.178	Norway	416	23.111
Netherlands	1647	56.793	Sweden	394	9.61
UK	1252	10.433	Italy	344	10.75
Canada	944	17.811	Portugal	337	21.062
Germany	902	11.136	Spain	265	9.815
Australia	586	8.371	Austria	236	13.882
China	506	14.882	India	216	8
France	198	9			

As noted in the table II, the USA reported maximum (6513) citations followed by Netherlands (1647) and United Kingdom (1252). These three countries reported citations of 23.178 per cent, 56.793 per cent and 10.433 percent respectively. France (198) and India (216) reported lowest citations. China logged a modest citation figure (506). Interestingly, the figures of total citations and average citations do not report in a uniform way. Though Netherland reported only 1647 total citations, the country's average citations went up to 56.793. Though total citation is abysmally low in case of India (8) and Australia (8.371), the total citation is reasonably good in case of both the countries.

This study used VOSviewer© software to analyse the countries and regions where climate action research is published. The analysis shows at figure II focus on present study featured in the sample come from around the world, mainly distributed in Europe, North America, East Asia, and Oceania.

Figure II
Distribution of Citations Received by Countries

6.3 Distribution of most Productive Institutions, Source titles and research papers

6.3.1 Most productive Institutions

In the context of research organisation, bibliometric researchers have defined research productivity of academic institutions, which is measured by citations. The following table III describes the research productivity of the institutions.

Table III
Distribution of Top Productive Institutions

Name of Institutions	Total Pub	Total Citations	Cited Rate	Average Citation Per Pub	Country
University of Oxford	28	389	89.29	13.89	UK
Utrecht University	22	609	90.91	27.68	Netherlands
Stockholm Environment Institute	22	542	95.45	24.64	Sweden
London School of Economics and Political Science	21	450	85.71	21.43	UK
University of Leeds	21	200	95.24	9.524	UK
University of Toronto	20	315	80.00	15.75	Canada
Arizona State University	18	259	77.78	14.39	United States
The University of Queensland	18	568	88.89	31.56	Australia
European Commission Joint Research Centre	18	421	94.44	23.39	Belgium
Wageningen University & Research	17	1440	100	84.71	Netherlands
International Institute for Applied Systems Analysis, Luxemburg	17	2006	100	118	Austria
The Australian National University	16	129	87.5	8.063	Australia
University College London	16	221	81.25	13.81	UK
Potsdam Institute for Klimafolgenforschung	16	1674	93.75	104.6	Germany
Lunds University	15	160	86.67	10.67	Sweden

Note: The SCImago Journal Rank indicator is a measure of the scientific influence of scholarly journals that accounts for both the number of citations received by a journal and the importance or prestige of the journals where the citations come from.

As noted in table III, Oxford University reported highest number (28) of research contribution on climate action followed by Utrecht University (22), London School of Economics and Political Science (21) and University of Leeds (21). The European universities have more publications compared to others. None of the Indian University listed in the top fifteen institutions of the world contributing on research. Similarly, the International Institute for Applied Systems Analysis, Luxemburg reported highest (2006) citations followed by Potsdam Institute (1674) and Utrecht University (609).

6.3.2 Most productive source titles

Study analysed most productive source titles. Analysis revealed with total 339 selected articles on climate action referenced in this study appeared in top fifteen journals and other resources. Table IV shows the analysis of most productive source titles on climate action. As can be seen from Table IV, Climate Policy, and Sustainability (Switzerland), Climatic Change, Journal of Cleaner Production and Global Environmental Change are journals that publish more than 174 articles. Further, it can be found that the journals with more than high impact factors that have more than ten articles featured are Climate Policy, Sustainability (Switzerland), Nature of Climate Change, Journal of Cleaner Production and Global Environmental Change.

Table IV
Distribution of most productive source title, scimago rank and country

Name of the source title	Total Pub	Total Citations	SG Rank	Average Citation Per Pub.	h-Index	Country
Climate Policy	47	451	1.89	9.6	12	UK
Sustainability (Switzerland)	47	360	0.58	7.66	12	Switzerland
Climatic Change	29	293	1.91	10.1	9	Netherlands
Journal Of Cleaner Production	28	379	1.89	13.54	12	Netherlands
Global Environmental Change	23	760	4.3	33.04	13	Netherlands
Nature Climate Change	22	1133	7.74	51.5	13	UK
Energy Policy	19	287	2.17	15.11	11	UK
IOP Conference Series: Earth And Environmental Science	19	5	0.18	0.26	2	UK
Proceedings Of The Air And Waste Management Association's Annual Conference And Exhibition, Awma	17	NA	NA	NA	NA	United States
Wiley Interdisciplinary Reviews: Climate Change	17	210	5.53	12.35	7	United States

Environmental Science And Policy	16	271	1.82	16.94	8	Netherlands
CHEM	15	561	6.14	37.4	9	United States
Environmental Research Letters	15	75	2.68	5	5	UK
Environmental Politics	14	230	2.07	16.43	9	UK
Bulletin of The Atomic Scientists	11	52	0.43	4.73	3	UK

As indicated by journal performance, there was a greater concentration of articles within the two top fifteen journals Climate Change and Sustainability (published 84 articles out of 339 total). The top fifteen journals received 5067 citations. Nature Climate Change and Global Environmental Change received 1133 and 760 citations respectively. In addition, Global Environmental Change journal holds the highest H-index of 13, a value greater than that of any other journal. The analysis of citation in top fifteen journals in Table IV revealed that the journal of Climate Policy has published highest number of articles (47) with highest citations (451). Again, the SG rank (1989) and H. Index (12) is highest in Climate Policy journal. This is followed by Sustainability journal (47 articles). The lowest number of articles (11 only) was published in Bulletin of the Atomic Scientists. Most of the journals were published in U.K, USA, Netherlands and Switzerland.

6.3.3 Most productive research papers and its source journals

As noted in table V, maximum citations recorded in Journal of the American Planning Association (1909) followed by Nature (1201) and Science (385). The Journal of Global Environmental Change has reported lowest citations (115). While on authors, R. Ewing and R. Cervero have been cited in maximum publications. Most of the articles are based on climate change, Climate Governance and adaptation. Similarly, article Travel and the Built Environment logged maximum citations followed by the article Paris agreement climate proposal. A review of the article reveals that the research on climate action laid a solid foundation for future research.

Table V
Highly cited research papers and its source journals

Research Paper Title	Authors	Total Citation	Name of Journals	Pub. Year
Travel and the built environment	Ewing R., Cervero R.	1909	Journal of the American Planning Association	2010
Paris Agreement climate proposals need a boost to keep warming well below 2 °c	Rogelj J., Den Elzen M., Höhne N., Fransen T., Fekete H., Winkler H., Schaeffer R., Sha F., Riahi K., Meinshausen M.	1201	Nature	2016
The broad footprint of climate change from genes to biomes to people	Scheffers B.R., De Meester L., et al	385	Science	2016

Predictors of public climate change awareness and risk perception around the world	Lee T.M., Markowitz E.M., Howe P.D., Ko C.-Y., Leiserowitz A.A.	361	Nature Climate Change	2015
International climate policy architectures: Overview of the EMF 22 International Scenarios	Clarke L., Edmonds J., Krey V., Richels R., Rose S., Tavoni M.	347	Energy Economics	2009
Personally Relevant Climate Change: The Role of Place Attachment and Local Versus Global Message Framing in Engagement	Scannell L., Gifford R.	291	Environment and Behavior	2013
Something borrowed, everything new: Innovation and institutionalization in urban climate governance	Anguelovski I., Carmin J.	215	Current Opinion in Environmental Sustainability	2011
Emergence of polycentric climate governance and its future prospects	Jordan A.J., Huitema D., Hildén M., Van Asselt H., Rayner T.J., Schoenefeld J.J., Tosun J., Forster J., Boasson E.L.	197	Nature Climate Change	2015
Personal experience and the 'psychological distance' of climate change: An integrative review	McDonald R.I., Chai H.Y., Newell B.R.	158	Journal of Environmental Psychology	2015
Innovation and climate action planning: Perspectives from municipal plans	Bassett E., Shandas V.	143	Journal of the American Planning Association	2010
Roadmap towards justice in urban climate adaptation research	Shi L., Chu E., Anguelovski I., Aylett A., Debats J., Goh K., Schenk T., Seto K.C., Dodman D., Roberts D., Roberts J.T., Van Deveer S.D.	139	Nature Climate Change	2016
The case for consumption-based accounting of greenhouse gas emissions to promote local climate action	Larsen H.N., Hertwich E.G.	139	Environmental Science and Policy	2009
Eco-efficient construction and building materials research under the EU Framework Programme Horizon 2020	Pacheco-Torgal F.	129	Construction and Building Materials	2014
Vulnerability before adaptation: Toward transformative climate action	Ribot J.	129	Global Environmental Change	2011
Hurricane Sandy and adaptation pathways in New York: Lessons from a first-responder city	Rosenzweig C., Solecki W.	115	Global Environmental Change	2014

6.4 Distribution of most prolific authors and authors productive life

6.4.1 Most prolific authors and their relationship

Authors are the core element of a research field. Table VII indicates the top fifteen most productive authors on Climate Action Research. According to the table 5, Gouldson, A. dominated the list of publications (8 papers). Other authors include Chan, S. Dale, A.Hewage,

K. Höhne, N. Sadiq, R. have contributed seven articles each. As for institutional affiliation, (Table 5), most of the authors are affiliated with an institution of UK, Canada, Germany and Netherlands. Interestingly, although N. Hohne has contributed maximum papers with author's average citation per paper is highest (206 per cent). Similarity, the said author has received highest citations (1442).

Table VII
Most prolific Author and their relationship with Country and Institution

Author Name	Total Pub. (TP)	Total Citations	Average Citation Per Pub	h-Index	Institution	Country
Gouldson, A.	8	120	15	5	University of Leeds	UK
Chan, S.	7	222	31.71	7	Deutsches Institut fur Entwicklungs politik	Germany
Dale, A.	7	72	10.29	4	Royal Roads University	Canada
Hewage, K.	7	129	18.43	6	University of British Columbia Okanagan	Canada
Höhne, N.	7	1442	206	5	Wageningen University & Research	Netherlands
Sadiq, R.	7	129	18.43	6	University of British Columbia Okanagan	Canada
Boswell, M.R.	6	79	13.17	2	Mayo Medical School	United States
Brown, S.	6	92	15.33	3	Winrock International	United States
CastánBroto, V.	6	25	4.17	3	Faculty of Social Sciences	UK
Kona, A.	6	104	17.33	6	European Commission Joint Research Centre	Belgium
Robinson, J.	6	64	10.67	3	University of Toronto	Canada
Rose, A.	6	38	6.33	4	University of Southern California	United States
Ruparathna, R.	6	128	21.33	6	University of Windsor	Canada
Setzer, J.	6	67	11.17	4	London School of Economics and Political Science	UK
Sudmant, A.	6	85	14.17	4	University of Leeds	UK

6.4.2 Author production overtime:

As noted in the figure III, most of the authors have contributed papers during last six years. (2014-2020). However author entitled Q.A Rose, contribution period extended from 2006 to 2017. Similarly, author S. Brown contribution period extended from 2000 to 2016.

Figure III
Authors' Research Production over Time

6.5 Analysis of Network Visualization:

6.5.1 Network visualization of publications and authorship

Co-authorship analysis when the unit of analysis is authors

Figure IV explains the collaboration network of authors. Nodes represent authors. The size of a node is proportional to the number of papers written by the author. The colour of rings and links correspond to the year. VOSviewer© analysis shows in figure IV observed total 16 clusters and 682 network link with total link strength of 881. Further analysis of co-authorship collaboration revealed that “Hohne, N.” received maximum of 84 total link with maximum collaboration followed by “Kuramochi, T.” and “Riahi K” with similar of 55 total link strength.

Figure IV
Co-authorship analysis – when unit of analysis is author

Co-authorship analysis when the unit of analysis is countries

With regards to co-authorship analysis with country collaboration, study reported total 13 clusters and 541 links. Total 1468 link strength found during analysis. Figure V indicates the collaboration network of countries on co-authorship. Nodes represent the countries. The size of a node is proportional to the amount of papers produced by the country. The colour of rings and links corresponds to the year. The countries such as United States, Australia, China, Germany, Spain and Netherland reported highest collaboration on authorship. Contrarily, Argentina, Fiji and Lithuania reported lowest collaborations.

Figure V
Co-authorship analysis – when unit of analysis is countries

Co-authorship analysis when the unit of analysis is organisations

Figure VI depicts collaboration network with institutions or organisations. The collaboration network of institutions; nodes represent institutions. The size of a node is proportional to the amount of research published by the institutions. The colour of rings and links correspond to the year. The purple rings indicate high centrality. Total 6 clusters with 63 network link found during the analysis and total 80 link strength was counted while analysis. The institutes such as Copernicus institute of sustainable development of Utrecht university and Newclimate institute, cologne, Germany reported highest collaboration with 16 total link strength of both the institutions.

Figure VI
Co-authorship analysis – when unit of analysis is Institutions

The keyword co-occurring map for climate action research was drawn to scientifically to measure the main research hotspots in this field. In the figure VII shows the each node in the figure represents a keyword. Larger node indicates; more the lines, higher the frequency of keyword co-occurrence. VOSviewer© analysis revealed with total 10 clusters and 42293 links. Total link strength of co-occurrence of keywords observed 60362. Keyword climate change with 5778 link strength has the highest frequency of occurrence followed by greenhouse gas and sustainable development with 3498 and 1674 link strength respectively.

Figure VII
Network visualization of Co-occurrence of all keywords

6.5.3 Network visualization of citation and references

Citation analysis when the unit of analysis is authors

Figure VIII indicates the citation network of authors. Nodes represent authors and the size of a node is proportional to the citation frequency of the author. Purple rings indicate high centrality. Total 19 clusters with 2183 links was observed in the study. Total 3450 link strength was reported for citation analysis of authors. The authors Ewing R, Riahi K. and Hohne N. have reported high citations relationship.

Citation analysis when the unit of analysis is countries

With regards to citation analysis with countries illustrated in figure IX. Total 11 clusters with 587 links and 3323 link strength emphasis more inter-county citation analysis. USA (10657), UK,(3611) Australia (3082), Germany(3076) and Netherland(2814) has secured top five position in this group and showing close relationship.

Figure IX

Citation analysis – when unit of analysis is Countries

Citation analysis when the unit of analysis is organizations

Figure X illustrated the collaboration network of institutions. Nodes represent institutions and the size of a node is proportional to the amount of research published by the institution. VOSviewer© analysis shows total 22 clusters, 8154 links and 8621 link strength. The institutes such as Copernicus Institute of Sustainability and World Resource Institute has observed maximum link strength.

Figure X

Citation analysis – when unit of analysis is Institutions

Co-citation analysis when the unit of analysis is authors

VOSviewer© analysis for co-citation shows stronger relationship as depict from the figure XI reflects total 9 clusters, 163692 links and 1092490 link strength. The major link strength was received by Bulkeley H., Riahi K. and Paearson P. on top three positions.

Figure XI
Co-citation analysis – when unit of analysis is Authors

Co-citation analysis when the unit of analysis is sources

Figure XII shows the co-citation visualization of source title. It is observed from the analysis that total 13 clusters has 77308 links and 735824 link strength emphasis the source citation is an important aspect in the visualization network analysis. Study reported that Energy policy and has highest link strength and with other sources.

Figure XII
Co-citation analysis – when unit of analysis is Source title

6.5.4 Network visualization of Bibliographic coupling

Bibliographic coupling analysis when the unit of analysis is countries

Form the network visualization image presented in figure XIII shows that total 73 countries are related with connected with each other in 9 clusters and 1519 links. Study reported total 206431 link strength. Again it is observed that USA, UK and Germany lead in the bibliographic coupling in the domain of climate action.

Figure XIII
Bibliographic coupling – when unit of analysis is countries

7. Research Hotspots

Analysis of research hotspots and study of pattern of research provide potential information for futures scope. As shown in figure 10 the research hotspots during the previous decades (1992-2010) mainly focused on renewable energy, UNFCCC, climate change mitigation, adaption and sustainability. However, in the last decades (2011-2020), research domain shifted to climate change in urban areas, climate governance, climate justice and sustainability.

In the early 1990s, with the ratification of United Nations Framework Convention on Climate Change, the issue of climate change became a matter of great concern to all countries. During this period, scholars focused on keywords such as climate change and other greenhouse gases. Keywords for this period mainly included climate change mitigation and adaption, renewable energy and carbon emission. The Paris Agreement 2015 sensitised the countries for undertaking climate action and reduce carbon emissions. The declaration of Sustainable Development Goals in 2015 placed targeted goals to achieve climate action. The five targeted goals were (a) strengthen resilience and adaptive capacity to climate related disasters, (b) integrate climate change measures into policies and planning, (c) build knowledge and capacity to meet climate change, (d) implement the UN framework convention on climate change, (e) promote mechanisms to raise capacity for planning and management. All the member nations are working in this direction. Figure XIV shows the three filed relationship of authors, publications and keywords using RStudio in the publications trends of discipline of climate action. As visualised in figure XIV, the keywords Climate Change and Climate Actions were frequently used in academic publications. Subsequently, climate action, mitigation and adaptation keywords were used 2018 onwards.

Figure XIV
Three field relationships - Authors, Publication Year and Keywords (Using RStudio)

8. Conclusion

The present study is based on bibliometric analysis and Rstudio and VOSviewer© provide a comprehensive visualization of the climate action research. Although climate actions are evolving into research fields, a bibliometric analysis stressing the rational base, research topic evolution and research hotspots are yet to be developed. This has identified the intellectual base and provided the guidelines of evolution of research topics and hotspots. This is acknowledging the current research developments in climate action and opening possibilities for future research as well.

As most of the analysis of climate action is based on existing methods and the results are reliable. However, big data technology in climate action research can be applied. Future studies can focus on applying big data technology to climate action research.. Though this study has made some contributions to the field of climate action research, it also has some limitations. As the Scopus database covered majority of journals, it might have ignored some relevant research on the topic which has not covered under the said database. Future study can be conducted along with use of WoS (Web of Science) and Google Scholar (GS) which may give a more clear picture in the domain of climate action.

References

- Asmi Fahad, Muhammad Azfar Anwar, Rongting Zhou, Dong Wang & Aqsa Sajjad (2019): Social aspects of 'climate change communication' in the 21st century: a bibliometric view, *Journal of Environmental Planning and Management*, DOI: 10.1080/09640568.2018.1541171
- Brian Stone! Jason Vargo, Dana Habeeb (2012), Managing climate change in cities: Will climate action plans work? *Landscape and Urban Planning* 107, 263– 271,
- Candice Howarth, Peter Bryant, Adam Corner , Sam Fankhauser, Andy Gouldson, Lorraine Whitmarsh, Rebecca Willis, (2020) Building a Social Mandate for Climate Action: Lessons from COVID-19, *Environmental and Resource Economics*, 76:1107–1115, <https://doi.org/10.1007/s10640-020-00446-96>
- Chen CM, Dubin R, Kim MC (2014) Orphan drugs and rare diseases: a scientometric review (2000–2014). *Expert Opin Orphan Drugs* 2:709–724
- Chen Y, Wu C (2017) The hot spot transformation in the research evolution of maker. *Scientometrics* 113:1307–1324
- Di Matteo, G., Nardi, P., Grego, S. *et al.* (2018). Bibliometric analysis of Climate Change Vulnerability Assessment research. *Environ Syst Decis* **38**, 508–516. <https://doi.org/10.1007/s10669-018-9687-4>
- Einecker, Rachel; Kirby, Andrew (2020). "Climate Change: A Bibliometric Study of Adaptation, Mitigation and Resilience" *Sustainability* 12, no. 17: 6935. <https://doi.org/10.3390/su12176935>
- Francesco Fuso Nerini, Benjamin Sovacool, Nick Hughes, Laura Cozzi, Ellie Cosgrave, Mark Howells, Massimo Tavoni, Julia Tomei, Hisham Zerriffi, and Ben Milligan (2019), Connecting Climate Action with Other Sustainable Development Goals, *Nature Sustainability*, Perspective, <https://doi.org/10.1038/s41893-019-0334-y>
- Füssel HM (2007) Vulnerability: A Generally Applicable Conceptual Framework for Climate Change research. *Global Environ Change* 17:155–167. <https://doi.org/10.1016/j.gloenvcha.2006.05.002>
- Giovanni Di Matteo, Pierfrancesco Nardi, Stefano Grego, Caterina Guidi, (2018) Bibliometric analysis of Climate Change Vulnerability Assessment research, *Springer Science+Business Media, LLC, Environment Systems and Decisions* 38:508–516, <https://doi.org/10.1007/s10669-018-9687-4>
- Gouldson Andy, Colenbrander Sarah, Sudmant Andrew, Anulla Faye Mc, Kerr Niall, Paola Sakai, Stephen Hall, Effie Papargyropoulou, Johan Kuylensstierna, (2015), Exploring the economic case for climate action in cities, *Global Environmental Change* 35, 93–105, www.elsevier.com/locate/gloenvcha
- González-Sánchez EJ, Ordóñez-Fernández R, Carbonell-Bojollo R, Veroz-González O, Gil-Ribes JA (2012) Meta-analysis on atmospheric carbon capture in Spain through the use of conservation of agriculture. *Soil Tillage Res* 122:52–60
- Hirsch JE (2005), An index to quantify an individual's scientific research output. *Proc Natl Acad Sci U S A* 102:16596–16572
- Hisano M, Searle EB, Chen HYH (2018) Biodiversity as a solution to mitigate climate change impacts on the functioning of forest ecosystems. *Biol Rev* 93:439–456

Huang, L., Chen, K. & Zhou, M. (2020) Climate change and carbon sink: a bibliometric analysis. *Environ Sci Pollut Res* **27**, 8740–8758. <https://doi.org/10.1007/s11356-019-07489-6>

Ji Q, Pang X, Zhao X (2014) A bibliometric analysis of research on Antarctica during 1993–2012. *Scientometric* 101:1925–1939

Joakim EP, Mortsch L, Oilahen G (2015) Using vulnerability and resilience concepts to advance climate change adaptation. *Environ Hazards* 14:137–155. <https://doi.org/10.1080/17477891.2014.1003777>

Huang, Li, Chen Ke, and Zhou Mi, (2020) Climate Change and Carbon Sink: A Bibliometric Analysis, Springer-Verlag GmbH Germany, part of Springer Nature, Environmental Science and Pollution Research, 27:8740–8758, <https://doi.org/10.1007/s11356-019-07489-6>

Mark Howells, Massimo Tavoni, Julia Tomei, Hisham Zerriffi and Ben Milligan, (2019) Nature Sustainability, Perspective, <https://doi.org/10.1038/s41893-019-0334-y>

Prakash, M. and Jayaprakash M. (2019) "A Scientometrics study on journal of climate based on web of science database." *Library Philosophy and Practice (e-journal)*. 2557. <https://digitalcommons.unl.edu/libphilprac/2557>

Rosane, Olivia (2019a), "UN Climate Action Summit Falls 'Woefully Short' of Expectations". Ecowatch. 2019.

Rosane, Olivia (2019b), "What to Expect From Today's UN Climate Action Summit". Ecowatch. 2019

Sander Chan, Clara Brandi and Steffen Bauer (2016), Aligning Transnational Climate Action with International Climate Governance: The Road from Paris, Review of European Community and International Environmental Law (RECIEL), John Wiley & Sons Ltd. 25 (2) 2016. ISSN 2050-0386 DOI: 10.1111/reel.12168

Saravanan G.; V.R., Rajan Dr.; S., Prasad Mr.; and G., Muthusankar Dr., (2014) "Climate change research (1991–2012): comparative scientometric study of Argentina, Brazil, China, India and Mexico". *Library Philosophy and Practice (e-journal)*. Paper 1134. <http://digitalcommons.unl.edu/libphilprac/1134>

Sharifi, A., Simangan, D. & Kaneko, S. (2020) Three decades of research on climate change and peace: a bibliometrics analysis. *Sustain Science*. <https://doi.org/10.1007/s11625-020-00853-3>

Song JB, Zhang HL, Dong WL (2016) A review of emerging trends in global PPP research: analysis and visualization. *Scientometric* 107:1111–1147

Sweileh, W.M. (2020). Bibliometric analysis of peer-reviewed literature on climate change and human health with an emphasis on infectious diseases. *Global Health* **16**, 44. <https://doi.org/10.1186/s12992-020-00576-1>

United Nations (2020), Goal 13, Climate Action, Take urgent action to combat climate change and its impacts, available at <https://unstats.un.org/sdgs/report/2020/goal-13/>

UNDP (2021), Sustainable Development Goals, Goal 13: Climate action, available at <https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-13-climate-action.html>

United Nations (2019), Climate Action Summit, available at <https://www.un.org/en/climatechange/2019-climate-action-summit>.

Wang B, Pan S-Y, Ke R-Y, Wang K, Wei Y-M.(2014). An overview of climate change vulnerability: a bibliometric analysis based on Web of Science database. *CEEP-BIT Working Paper*.

Authors Profile:

Dr. Binod K. Das

Dr Das (1969b) teaches Political Science and International Relations at GLS Law College, Ahmedabad (India). In a nearly three decades of experience, he has taught at Gujarat University, GLS University, Nirma University, Amity University and Entrepreneurship Development Institute of India. Previously, he was a consultant to UNICEF Bihar and West Bengal and worked in public health programmes. In 2020, Dr Das coordinated an international conference on Green Justice which had attracted participants from 14 countries. His research areas include international relations, climate change, environmental governance and climate action. He has numerous publication in national and international journals. Further, he has authored several consultancy reports on social sectors. Dr. Das has obtained a doctorate degree from JNU in political studies.

Dr. Mayuri Pandya: She is the Director, GLS Law College, Ahmedabad having more than 20 years of teaching experience. Her area of interest is Environmental Law; Intellectual Property Rights; Constitutional Law; Human Rights; Gender Issues and International Law. She is actively involved in the research and publications and has published over 55 research papers in reputed national and international journals, while providing research guidance to law students. She is strongly associated with many reputed university as chairperson of board of studies, member of academic council, members of various cells of university and member of editorial boards of reputed law journals. She is also serving as active member in various statutory body under state and central government.

Mr. Shanti P. Chaudhari: He is working with Pandit Deendayal Energy University, Gandhinagar. He has more than 10 years of work experience and is currently pursuing doctoral studies at Gujarat University. His area of interest is academic library system, information technology, web analysis and development of web-based tools for academic institutions.

Dr. Atul Bhatt: He is working as Associate Professor with Dept. of LIS at Gujarat University, Ahmedabad. He has rich 20+ years of professional experiences. His area of interest is library networking, Service quality, Bibliometrics and Scientometrics and information seeking behaviour. He has published many research papers in Scopus indexed journals and providing research guidance in LIS discipline. He serve in variety of professional capacities including member of board of studies and academic advisor of many institutions & universities.

Dr. Dharmendra Trivedi: He has total 24+ years of rich experience in academic, special and corporate librarianship. His area of interest are cloud computing, customer satisfaction and service quality. He has published and present many papers in national and international level. He is corresponding author and can be contacted: 1974dtrivedi@gmail.com