Project Completion Report

CLIMATE CHANGE STUDIES IN THE INDIAN CONTEXT – A SCIENTOMETRIC ANALYSIS

Implemented by

DR. R. SATHYANATHAN

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

KATTANKULATHUR, TAMIL NADU, 603 203

DST PROJECT NO.

F.No. DST/NSTMIS/05/07/2019-20

Study Sponsored by

National Science and Technology Management Information System (NSTMIS)

Department of Science & Technology

Government of India

(February, 2022)

PREFACE

Climate change refers to the long-term changes in the climate that occur over decades, centuries or longer. The increased frequency of rising sea levels, changes in storm patterns, altered ocean currents, changes in rainfall, melting snow and ice, more extreme heat events, fires, and droughts are the repercussions of climate change and these impacts are projected to continue and intensify, affecting human health, infrastructure, forests, agriculture, freshwater supplies, coastlines, and marine systems. The global average temperature has risen by around 1°C since pre-industrial times. India's average temperature has risen by around 0.7°C during 1901–2018 and by the end of the twenty-first century, average temperature over India is projected to rise by approximately 4.4°C relative to the recent past (1976–2005 average). Sea surface temperature (SST) of the tropical Indian Ocean has risen by 1°C on average during 1951–2015 and notable changes in the rainfall pattern is also observed in Indo-Gangetic Plains and the Western Ghats. Overall decrease in the rainfall had led to an increased frequency of droughts especially in areas over central India, southwest coast, southern peninsula and north-eastern India. Apart from this sea level rise, tropical cyclones and changes in the Himalayas are increasing concern. It is therefore important to comprehend the climate change research in India so as to understand the growth pattern of climate change studies in India. This helps to identify the emerging areas in climate change of the country as well as the progress of existing studies occurring in the nation. This project targets to bring forth the history of peer-reviewed climate studies in India and identify the trends in the research field. This will not only throw an idea on the subdisciplines that are important to India in the context of climate change but will also enable an understanding of the presence or absence of impact of climate change on weather events so that the general public and media can be informed judiciously.

ACKNOWLEDGEMENTS

We owe it all to the National Science and Technology Management Information System (NSTMIS), a division of Department of Science and Technology (DST) which provided us with this opportunity and resources to accomplish the project work entitled 'Climate Change Studies in the Indian Context - A Scientometric Analysis'.

We feel deeply honoured in expressing our sincere thanks to Dr. C. Muthamizhchelvan, Vice Chancellor, SRMIST, Dr. S. Ponnusamy, Registrar, Dr. T. V. Gopal, Dean [CET], Dr. B. Neppolian, Dean, Research, of SRMIST and Dr. P. T. Ravichandran, Professor & Head, Department of Civil Engineering, SRMIST for all the facilities provided for the conduction and completion of this work.

We hereby express our genuine gratitude to our former colleague Dr. Deeptha Thattai for her unfailing support, the encouragement and valuable comments without any delay whatsoever.

Our deepest respect to the LPAC committee members Dr. R. Sivakumar, Professor, Department of Civil Engineering, SRMIST and Dr. T. V. Lakshmi Kumar, Research Associate Professor, Department of Physics and Nanotechnology, SRMIST for their valuable time, insights and the fruitful discussions that had steered this work in the right direction.

We thank all the professors who gave us valuable inputs during this study. Thanks are also due to all the teaching and non-teaching staff members of SRMIST for their encouragement.

PRINCIPAL INVESTIGATOR

Dr. R. Sathyanathan ,
Associate Professor / Civil,
SRMIST, KTR.

CO-PRINCIPAL INVESTIGATOR

Dr. P. Rajendran,
Librarian,
SRMIST, KTR.

TABLE OF CONTENTS

	Title	Page No.
	PREFACE	i
	ACKNOWLEDGEMENTS	ii
	TABLE OF CONTENTS	iii
	LIST OF TABLES	viii
	LIST OF FIGURES	x
	EXECUTIVE SUMMARY	xi
CHAPTER 1: INTRODUCTION		**1**
1.1	General Overview	1
1.2	Climate Change Research in India	2
1.3	Bibliometrics and Scientometrics - An Overview	4
CHAPTER 2 : REVIEW OF LITERATURE		8
2.1	Climate Research	8
2.2	Bibliometrics, Scientometrics and Climate Change	10
CHAPTER 3 : METHODOLOGY- SAMPLING DESIGN, DATA SOURCES		25
3.1	Objectives of the Study	25
3.2	Time Period of Analysis	25
3.3	Data Collection and Databases	25
3.4	SCOPUS	26
3.5	Web of Science (WoS)	27
3.6	Search Strategy and Data Retrieval	28

TABLE OF CONTENTS

	Title	Page No.
3.7	Finalization of Keywords	29
3.8	Data Retrieval from SCOPUS Database	30
3.9	Need of Manual Screening of Data Downloaded	31
3.10	Methodology for Screening of RIS Files Downloaded from SCOPUS	31
3.10.1	Method 1: Screening of RIS Files in MS Excel	31
3.10.2	Method 2: Screening of RIS Files in Mendeley	32
3.10.3	Method 3: Screening of RIS Files in Notepad++	32
3.11	Methodology for Screening Records in Web of Science	33
3.12	Selection of Software Tool for Analysis	34
CHAPTER 4: DETAILED ANALYSIS OF THE DATA		37
4.1	Bibliometric Indicators	38
4.1.1	Distribution by Publication Type	42
4.1.2	Relative Growth Rate (RGR) and Doubling Time (DT)	42
4.1.3	Distribution by Number of Authors	43
4.1.4	Distribution by Country	43
4.1.5	Activity Index	43
4.1.6	Analysis of References	44
4.1.7	Number of Citations Received by Each Document	44
4.1.8	Most Cited References	44
4.1.9	Most Productive Keywords and Number (range) of Keywords Used	45
4.1.10	Most Influential Research Areas	45
4.1.11	Distribution by Journal	46

TABLE OF CONTENTS

	Title	Page No.
4.1.12	Most Productive Countries	46
4.1.13	Most Prolific Authors	46
4.1.14	Authorship Pattern	46
4.1.15	Collaborative Coefficient	47
4.1.16	Degree of Collaboration	47
4.1.17	Collaboration Index	48
4.1.18	Co-authorship Index (CAI)	48
4.1.19	Most Productive Countries and Relative Citation Index	48
4.1.20	Most Productive Organisations	49
4.1.21	Cited Reference Analysis	50
4.1.22	Most Cited Publications	50
4.2	Network Analysis	50
CHAPTER 5: RESULT AND DISCUSSIONS		52
5.1	Performance Analysis (Descriptive Analysis)	52
5.1.1	Distribution by Publication Type	52
5.1.2	Relative Growth Rate (RGR) and Doubling Time (DT)	53
5.1.3	Language Analysis	55
5.1.4	Most Productive Publishers	56
5.1.5	Most Productive Journal	58
5.1.6	Number of Citations Received by Each Document	63
5.1.7	Most Prolific Author	64
5.1.8	Authorship Pattern	73

TABLE OF CONTENTS

	Title	Page No.
5.1.9	Collaborative Coefficient	75
5.1.10	Degree of Collaboration	76
5.1.11	Collaboration Index	77
5.1.12	Co-authorship Index (CAI)	78
5.1.13	Most Influential Research Areas	79
5.1.14	Most Productive Keywords	80
5.1.15	Most Productive Countries	83
5.1.16	Most Productive Organizations	86
5.1.17	Most Cited Reference	88
5.1.18	Most Cited Publications	92
5.2	Network Analysis	96
5.2.1	Co-authorship Analysis	97
5.2.2	Co-occurrence of Keywords	104
5.2.3	Bibliographic Coupling	108
5.2.3.1	Bibliographic Coupling of Documents	109
5.2.3.2	Bibliographic Coupling of Authors	113
5.2.3.3	Bibliographic Coupling of Countries	115
5.2.4	Evolution of Climate Change Studies for the Analysis Period (2005-2018)	118
CHAPTER 6: FINDINGS/SUMMARY AND RECOMMENDATIONS		120
6.1	Major Findings of the Study	120
6.2	Suggestions & Recommendations	125
6.3	End Project Deliverables	126

TABLE OF CONTENTS

Title	Page No.
RESEARCH SUMMARY	128
REFERENCES	129

LIST OF TABLES

Table No.	Tables	Page No.
3.1	List of Keywords Used for Retrieving Data	30
5.1	Distribution by Publication Type	52
5.2	Growth of Climate Change Literature from 2005 to 2018	54
5.3	Distribution Based on Languages Published	55
5.4	List of Top 50 Most Productive Publishers	56
5.5	List of Top 25 Most Productive Journals	59
5.6	Year Wise Distribution of Most Productive Journals	61
5.7	Range of Citations	63
5.8	Top 25 Most Prolific Authors in the Research Area across the World	65
5.9	Top 10 Most Prolific Authors in India	69
5.10	Year Wise Distribution of Productivity of Authors	71
5.11	Authorship Pattern	73
5.12	Collaborative Coefficient	75
5.13	Degree of Collaboration	76
5.14	Collaboration Index (CI)	77
5.15	Co-authorship Index (CAI) or Pattern of Co-authorship	78
5.16	List of Top 25 Most Influential Research Areas	79
5.17	List of Top 25 Most Productive Keywords	82
5.18	List of 20 Most Productive Countries that Produces Top Number of Research Papers	83
5.19	List of Countries Based on Relative Citation Index	85
5.20	Top 20 Most Productive Institutes in India	86
5.21	List of Top 25 Most Cited References	89

LIST OF TABLES

Table No.	Tables	Page No.
5.22	List of Top 25 Most Cited Documents	92
5.23	Cluster 1	101
5.24	Cluster 2	101
5.25	Cluster 3	102
5.26	Cluster 4	102
5.27	Distribution of 859 Items in Seven Clusters	105
5.28	Keyword Co-occurrences Cluster 1	105
5.29	Keyword Co-occurrences Cluster 2	105
5.30	Keyword Co-occurrences Cluster 3	106
5.31	Keyword Co-occurrences Cluster 4	106
5.32	Keyword Co-occurrences Cluster 5	106
5.33	Keyword Co-occurrences Cluster 6	106
5.34	Top Five Authors in all the Five Clusters in Bibliographic Coupling of Documents	112
5.35	Top 10 Authors in Cluster 1	114
5.36	Top 10 Authors in Cluster 2	114
5.37	Top 10 Authors in Cluster 3	114
5.38	Top 10 Authors in Cluster 4	114
5.39	Bibliographic Coupling of Countries – List of Top 10 Countries	116
5.40	Top Five Clusters in Bibliographic Coupling of Countries	117
5.41	Evolution of Topics in Climate Change	119

LIST OF FIGURES

Figure No.	Figures	Page No.
3.1	Flowchart of the Methodology Adopted for the Project	36
5.1	Growth of Climate Change Literature from 2005 to 2018.	54
5.2	Relative Growth Rate and Doubling Time for Climate Change Literature from 2005 to 2018	55
5.3	Range of Citations	63
5.4	Point Locations of 20 Most Productive Countries that Produces Top Number of Research Papers	84
5.5	The Layout for Co-authorship Analysis Showing 483 Nodes Distributed in 27 Clusters	99
5.6	The Layout for Co-authorship Analysis Showing 483 Nodes Distributed in 4 Clusters with Nodes in Four Colors	99
5.7	The Network Analysis Layout of Co-authorship data of an Author	100
5.8	An Enlarged View of Co-authorship data of an Author Showing the Nodes and the Links	101
5.9	Overlay Visualization of Database Denoting Documents with respect to Average Publication Year	103
5.10	Item Density Visualization of Database Denoting Co-authorship Network	104
5.11	Density Visualization of Co-occurrence of Keywords	105
5.12	A Screenshot Showing the Cluster 1 and its Links in Keyword Co-occurrences Network Analysis Diagram	107
5.13	Difference between Bibliographic Coupling and Co-citation Coupling	109
5.14	Network Visualization (A), Overlay Visualization (B) and Density Visualization (C) of Bibliographic Coupling of Documents	110
5.15	Network Visualization of Bibliographic Coupling of Authors	115
5.16	Network Visualization of Bibliographic Coupling of Countries	118
5.17	Evolution of Topics in Climate Change	119

EXECUTIVE SUMMARY

Climate change is one of the most persistent topics in the world today as its effects are far-reaching and long lasting. India, because of its geographical position and population, is expected to be affected a lot by climate change. The mix of anthropogenic pollutants in the atmosphere changes the physiochemical properties of the atmosphere leading to numerous negative impacts. The increased aerosol loads over the Indian subcontinent, globally increasing greenhouse gas (GHG) concentrations, and temperature changes, rainfall, and surface-near radiation are some of them. DST funded project "Climate Change Studies in the Indian Context – A Scientometric Analysis", is focused to investigate the progress of climate change studies carried out in India and studies associated with the climate change of India conducted globally.

This work is focused to investigate the progress of climate change studies carried out in India and studies associated with the climate change of India conducted globally. The major intention of the study is to conduct a scientometric analysis of climate change studies in India so as to understand the growth pattern of climate change studies in India in the period of 14 years (2005 to 2018). Approved Objectives of the proposal are as follows:

- To examine the growth pattern of climate change studies in India in the period 2005–2018 (14 years).
- To explore the pattern of authorship and collaborative trend.
- To analyse the citation pattern of climate change papers.
- To study the evolution of co-authorship network.
- To map the research topics and study the growth in terms of sub disciplines in climate change studies.

- To visualize the evolution of climate change studies.

The project work commenced on January 20, 2020. The literatures were collected, reviewed and studied to formulate the methodology of the project work. Data for the analysis is extracted from SCOPUS and Web of Science database using a three-term search string composed of different keywords. The documents downloaded from SCOPUS and Web of Science constituted of 37,682 and 22,211 documents respectively, comprising of journal articles, conference papers and review articles related to climate change in India. The primary analysis pointed to some irrelevant articles in the scientific papers retrieved from the bibliometric sources. A manual screening of datasets was done by going through the abstracts, keywords and title to eliminate the irrelevant data from the datasets and increase the accuracy of the analysis.

After the manual screening and removal of duplicates, SCOPUS had 10,504 documents and WoS yielded 6766 documents. The final dataset is generated after the manual screening and merging of two datasets from SCOPUS and WoS in BibExcel software and is used for further analysis. This comes around 17,270 documents and approximately 3400 documents were identified as duplicates in the merged file. After removing the duplicates the total number of documents that is finalised for the analysis is 13,863 in the master file for the analysis. Bibliometric software BibExcel is used for the descriptive analysis and to determine the major scientiometric indicators, while networking tool VOSviewer is used to monitor the co authorship network and visualize the evolution of climate change studies. BibExcel software, and MS Excel software were used to do the performance analysis which includes the identification of growth pattern of climate change studies in India for a period of 14 years. Growth curve of climate change and doubling time of the literature were studied. The pattern of authorship, collaborative coefficient, degree of collaboration and collaboration index were analysed. Identification of productive publishers, productive journals, most prolific author,

most productive organizations, most cited references and most cited documents in the datasets were done. Citation pattern of climate change papers is deliberated using citation analysis. Network Analysis (science mapping) was done for the creation of networks using bibliometric indicators like authors, articles, keywords etc. to reveal the collaboration trend, bibliographic coupling and so on. Network analysis by VOSviewer version 1.6.16 was used to do the network analysis. The major outcomes of the project are listed below.

- The majority of the database constituted about articles (82.75%) and are published in English language.
- Growth curve of climate change literature from 2005 to 2018 was plotted and the doubling time of the literature was found.
- Springer topped the list of top 50 most productive publishers.
- The journal 'Current Science' topped the list of most productive journals.
- Majority of the documents received less than 10 citations.
- Kumar, A. of Norwegian University of Life Sciences is the most prolific author.
- There is a dominance of multi authored papers compared to single authored ones.
- Collaborative coefficient, degree of collaboration and collaboration index are tabulated.
- The most influential research area was found as 'Meteorology & Atmospheric Sciences'.
- Keyword analysis revealed that majority of the keywords obtained from the analysis are related to India.
- Relative Citation Index is maximum for France while for India it is 18.35 against the maximum value of 30.02.

- The analysis of most productive organizations revealed that the Indian Institute of Science, Bangalore, Karnataka, India and Indian Institute of Tropical Meteorology, Pune, India are the most productive institutes with more than 350 records published.
- 'Increasing Trend of Extreme Rain Events over India in a Warming Environment' by Goswami BN topped the list of most cited references.
- 'Impact of irrigation on the South Asian summer monsoon' by Saeed et al., became the most cited document in the entire datasets.
- Co-authorship analysis, co-occurrence of keywords, bibliographic coupling analysis of documents, authors and countries was done using VOSviewer 1.6.16.
- The clusters were identified and studied and the corresponding overlay visualization and density visualization was also examined.

CHAPTER 1

INTRODUCTION

1.1 General Overview

Climate change, a significant global phenomenon is primarily due to the increased concentrations of greenhouse gases in the atmosphere resulting from the anthropogenic activities such as industrialization, deforestation, and increased use of fossil fuels. This has resulted in global warming, which has increased the temperature at the rate of 0.1 degree per decade over the last 50 years. A global increase in the mean temperature of 1.4-5.8°C is projected by the Intergovernmental Panel on Climate Change (IPCC, 2014). The average annual temperature of India has increased by 0.5°C in the past century (R. Lukwale & S. Sife, 2017). The culmination may lead to unreliable precipitation, unpredictable monsoon, extreme temperatures and storms, and rise in sea level, which have direct and indirect impacts on the environment, water resources, agriculture, forests, biodiversity and livelihoods (Solomon, S., 2007). This severity would be experienced more in tropical areas including India (Sathaye et al. 2006). Though several mitigation and adaptation measures are being formulated in many countries to address climate change and its associated causes, enduring research on climate change and its impacts are imperative in formulating policies and decision making. Globally, research on climate change has grown considerably following climate-related effects (Newton et al. 2005). Generally, climate change research is focused on the causes, impacts and adaptation and mitigation strategies. Many subdisciplines including

atmospheric sciences, geosciences, oceanography and paleoclimatology are included as part of climate change research.

1.2 Climate Change Research in India

Climate change is one of the most pressing topics in the world today as its effects are far-reaching and long lasting. India, because of its geographical position and population, is expected to be affected a lot by climate change. The mix of anthropogenic pollutants in the atmosphere changes the physiochemical properties of the atmosphere leading to numerous negative impacts. The increased aerosol loads over the Indian subcontinent, globally increasing greenhouse gas (GHG) concentrations, and temperature changes, rainfall, and surface-near radiation are some of them (Cramer, 2006).

The climate of India has unique features and is strongly influenced by the Himalayas, the Thar Desert, Western and Eastern Ghats and the Central Plateau. The temperature in India varies from 10°C in winter to about 32 °C in summer. The winter season constitutes in the months of January and February, summer season during March, April and May, southwest monsoon from June to September and northeast monsoon or retreating southwest monsoon season during the months of October to December. 3/4th of the annual rainfall is received during southwest monsoon. This is the most anticipated source of water all over the country as it is the major source of water for agriculture. The southwest monsoon rainfall with an average precipitation of 877.2 mm denotes 74.2% of annual rainfall which accounts around 1182.8 mm. The pre-monsoon rainfall from March-May and post-monsoon rainfall from October-December constitutes around 22% of the total annual rainfall of Indian sub-continent. (Attri & Tyagi, 2010; Gupta et al. 2014).

The climate change has impacted the Indian subcontinent in several ways. The impact is more in the agricultural sector of India. Change in climatic variables has a direct effect in agricultural productivity of India (Sahu & Mishra, 2013). Natural calamities like floods, droughts, cyclones and negative effects in soil fertility, temperature changes, changes in groundwater level, and changes in rainfall level are some of the after effects of the changes in climatic variables (Jha & Tripathi, 2011). The spatial and temporal changes in precipitation, as a result of climate change have made groundwater one of the threatened resources in India. Researches focusing on this area are stressing towards the need of stringent measures to deal with the ground water economy of India which is moving towards devastated consequences (Shah, 2020).

The extreme weather conditions like increase in the ambient temperature, frequency of floods, famines, droughts and cyclones are taking toll over the health of the country's population. The outbreak of water borne and air borne diseases, other vector-borne infectious diseases are increasing each year due to change in Indian climate (Dutta & Chorasiya, 2013; Moors et al. 2013). The socio economic factors like lack of education, poverty, inaccessible health care facilities and restricted assets become barriers for the people living in major area of the country to access the adaptive and mitigative measures formulated by the scientific community of India and the Government in lieu of the climate change events occurring in the country (Barua et al. 2013). It is therefore necessary for us to adapt as quickly as possible to the climate change according to its severity and mitigate the destructive consequences through support from various sectors of the world which may include policy makers, agricultural research institutes, farmers' networks and educational sector (A. Nastis, 2012).

India being the third-largest scientific manpower in the world (Ahuja, 1992). It is no surprise that Indian researchers will want to study the impacts of climate change. There is already a trend of most hydrometeorological events being attributed to climate change in the general media such as decrease in monsoon rainfall and increase in climatological droughts. Numerous research works are being done in the area of climate change and getting published each year in India that deals with the hot topics such 'climate change and its impacts in India', 'climate change research and analysis in India, 'impact of climate change in several agricultural areas and crops in different parts of the country' 'the adaptation and mitigation strategies in response to climate change', 'climate change and global warming in the Indian mass media', 'media attention for climate change' and 'climate change impacts at different geographical areas of India such as Himalayas, the Thar desert, Western and Eastern Ghats, Indian ocean are some of the most researched topics in the scientific world. It is therefore interesting to have a look and identify the trends existing and developing in the area pertaining to climate change research in India. The tool chosen for the above objective is scientiometry which is a sub discipline of bibliometrics and is based on measuring and analysing scholarly literature.

1.3 Bibliometrics and Scientometrics - An Overview

Bibliometrics is the analysis of publication outputs on a quantitative basis by measuring patterns of authorship, publication and the citations. It is important to assess research productivity because it will provide a measure of the research activities, help to identify major and minor research. Bibliometric techniques assess the growth, structure, interrelationship and productivity of scientific disciplines. In bibliometrics distribution patterns of publications are described using statistics.

The method of statistically analysing literature started in the beginning of 1900s and the first analysis was published in 1917 by Cole and Eales (Okubo, 1997). The term 'Bibliometrics' was coined in 1969 by Alan Pritchard and the term "statistical bibliography" was first used by Wyndham Hulme who worked for a patent library (Thanushkodi, 2010).

Another important milestone in the area of bibliography happened in the year 1926 when the contribution of Alfred Lotka, an American demographer led to the founding of Lotka's law which later became a fundamental principle of bibliometric analysis. Lotka's observation was that the number of records published under a specific scientific domain is not consistently distributed among the number of researchers doing research under the specific scientific domain. Instead the prominent research works are focused on a specific group of researchers leading to the formation of research clusters as a result of their research. This observation led to the formation of Lotka's law which states that "the number of authors who have published x papers occupied the proportion of total authors within a certain period; the proportion is denoted as f(x), which varies inversely as the square of x as follows: $f(x) = C/x^2$, where f(x) is the proportion of authors who have published x papers to the total number of authors, x is the number of papers, and C is the characteristic constant in certain subject areas" (Qiu et al. 2017).

Samuel Bradford in the year 1934 investigated the frequency distribution of articles across journals in a specific discipline. His observations resulted in another law of bibliometrics, Bradford's law. Bradford's law mainly dealt with the distribution of articles among the journals that publish the work of a specific scientific domain (Thompson & Walker, 2015). Another mile stone in the area of bibliometrics is the evolution of Science Citation Index (SCI), which is a part of the Web of Science (WoS)

database today. This was developed by Eugene Garfield in the year 1963 and was initially developed as a tool to make the research work easier and efficiently publish their work. This was extended to citation analysis and the availability of online databases along with the growth of SCI helped to evolve bibliometrics as a science as we are familiar today.

Scientometrics is the variation of bibliometrics wherein network mapping techniques are also included. Web of Science, SCOPUS and Google Scholar databases are the major sources for bibliometric analysis. SCOPUS is a comprehensive database from Elsevier and covers wide range of journals from 1996. Books are also covered in the database. The latest feature in SCOPUS is the article metrics module which includes social media analysis. The Field-Weighted Citation Impact (FWCI) is another new metric which measures how the individual article citations compared with that of similar papers.

This study is proposed to take a look at the history of peer-reviewed climate studies in India and identify the trends in the research field. This will not only throw an idea on the subdisciplines that are important to India in the context of climate change but will also enable an understanding of the presence or absence of impact of climate change on weather events so that the general public and media can be informed judiciously.

The major objectives of the study is to conduct a scientometric analysis of climate change studies in India so as to understand the growth pattern of climate change studies in India for the period of 14 years. The span of years chosen is 2005 to 2018. The aim of the study is to analyse the collaborative trend and the pattern of authorship. The citation pattern of the climate change papers is also a focus of the study. Bibliometric software BibExcel is used for the same. In order to monitor the co- authorship network and visualise the evolution of climate change studies networking tool VOSviewer is used.

Limitations:

- The abbreviations for some field tags in SCOPUS and WoS are different for certain parameters. This created difficulties while importing such parameters for analysis. However this hindrance can be rectified by converting the field tags of one database to the other through BibExcel software prior to the analysis.

- The institutional affiliation of documents are indicated differently in different documents. This is counted as separate entities by BibExcel and hence a manual screening is required to find out the most productive organisation in this study.

The contents of the report are elaborated under the following headings.

Chapter 1: Introduction, Objectives, Limitations

Chapter 2: Review of Literature

Chapter 3: Methodology – Sampling Design, Data Sources, etc.

Chapter 4: Detailed analysis of the Data

Chapter 5: Result and Discussions

Chapter 6: Findings/Summary and recommendations

CHAPTER 2

REVIEW OF LITERATURE

2.1 Climate Research

Though the majority of research activities concerning to climate change in India are focused on agricultural sectors, several other areas such as economy, communicable diseases, mass media are also focused. Some papers mentioning climate change are as follows.

Shah (2009**)** in his work dealt about the effect of climate change in ground water levels. The literature gave an insight about the development of Indian irrigation and its dependency in ground water. The difference in the requirement of summer season and monsoon season crops, need of more surface water storage and large reservoirs, changes in rainfall pattern and the need of groundwater recharge are also highlighted.

Billett (2010) conducted a study on the role of Indian mass media in modeling the public understanding as well as the perceptions of Indian government and its viewpoint regarding climate change in global arena, to Indian population. The study focused on 248 articles which were retrieved using selected keywords, published between January 1, 2002 and June 1, 2007 in four major English newspapers in India was done. The study throws light on how the social stratification still existing in India hinders the

outreach of articles talking about climate change to the non-elite community of Indian society and its role in the climate policy making.

Jha & Tripathi (2011) studied the effect of climate change in the yield of wheat. For the analysis, the temperature data during 1901-2003 and rainfall data during 1871–2008 were collected for the areas including Haryana and Bihar. The tool used for the experiment was non parametric MK-test which revealed an increase in the minimum and maximum temperatures recorded during the selected times of the year in the above areas. They concluded that the rise in atmospheric temperature during the winter initially favored the wheat yield, but the further increase of temperature decreased the yield. They put forward the need of development of late- or early-sown varieties of seeds to tackle the changes in the climate.

Sahu & Mishra (2013) focused their studies in farmers of Kendrapara district, Odisha and a survey was conducted to analyze the perception of farmers to climate change and their adaptions to the changes. The twenty year data obtained from the farmers is then compared with the temperature and precipitation data obtained from Indian Meteorological Department (IMD) for Kendrapara district. They reached the conclusion that even though farmers are aware of the climate change, only 59% are taking measures to adapt themselves for the change and the rest of the farmers are incurring huge loss. As a result, the new generation due to the uncertainties and low income yield are losing their interest in agricultural activities and opting other methods for their survival which is termed by the author as “climate change induced vulnerability of people otherwise called stress migration”.

Moors et al. (2013**)** investigated about the effect of climate change in waterborne diarrhoea in Northern India. They found that the number of diarrhoea diseases

reported in Northern India is dependent on temperature, humidity and precipitation rate. The conclusions were made based on a conceptual framework generated and they predicted an increase of 13.1% in diarrhoea cases by 2040. Adaptive strategies as well as recommendations were suggested for the emerging challenges.

2.2 Bibliometrics, Scientometrics and Climate Change

Okubo (1997) explained elaborately about the concept of bibliometrics, its advent and evolution. The document provided information about the major bibliometric databases especially the Science Citation Index (SCI) database. It mentioned about the bibliometric indicators and the precautions to be taken while using it. The main bibliometric indicators and their applications were also well explained in his paper supported with an elaborate array of examples.

Schwechheimer & Winterhager (1999) employed co-citation analysis and identified the latest areas of research in climate change. They found that ENSO (El Nino Southern Oscillation) irregularity, vegetation & ice-age climate, and climate-change & health were the topics of most importance among researchers.

Stanhill (2001) analysed the growth of climate change science and found that the publications doubled every 11 years.

Bornmann & Daniel (2006) in their paper stated the definition, advantages and disadvantages of the h-index. They also discussed about the application, validity of h-index and also about the new indices based on h-index.

Ocholla (2013) used infometric techniques to analyze global warming research indexed in Science Citation Index, Social Sciences Citation Index and Arts and Humanities Citation Index. They also searched the South African Bibliographical

Network (SABINET) databases pertaining to research in South Africa between 1980 and 2007.

Preedip Balaji & Alex (2010) mapped the research output on climate change from India over the years 2005–2009. They wanted to examine some factors including the total works published on climate change science, the journals that published on climate change and their rankings. Papers abstracted in ISI Science Citation Index were extracted. Over the period of study, there were 25,081 publications globally out of which 391 papers were from the Indian subcontinent. The number of journals that published these 391 papers were 101.

Alex and Balaji (2010) limited the scope of their study to the growth and dynamics of Indian research output in climate change research.

Van Eck & Waltman (2010) gave a detailed account about the VOSviewer, a freely available computer program that is used for making and presenting bibliometric maps graphically. Functionality of VOSviewer is clearly and elaborately discussed in the first part of the paper, while the second part deals with the steps included in the construction of a map and the principle behind the operation.

Durieux & Gevenois (2010**)** discussed about the three bibliometric indicators: quantity indicators, quality indicators and structural indicators. The article described in detail about each bibliometric indicators mentioning about the advantages, disadvantages and applications of each.

Li et al. (2011) analysed the scientific output of climate change research since 1992 to assess the characteristics of research patterns, tendencies, and methods in the paper. It was concluded that the items ‘temperature’, ‘environment’, ‘precipitation’,

‘greenhouse gas’, ‘risk’, and ‘biodiversity’ will be the foci of climate change research in the 21st century, while ‘model’, ‘monitoring’, and ‘remote sensing’ will continue to be the leading research methods.

Marx et al., (2017) studied the history of climate change by applying a bibliometric method called Reference Publication Year Spectroscopy (RPYS), and Co-citation analysis based on RPYS (RPYS-CO) to 2,22,060 papers published between 1980 and 2014, retrieved from WoS data derived from Science Citation Index Expanded (SCI-E), Social Sciences Citation Index (SSCI), and Arts and Humanities Citation Index (AHCI). References were extracted from the data set and most cited 35 papers which formed the basis of research in climate change was identified using RPYS and RPYS-CO analyses. This analysis throw light towards the perspectives of the various authors in citing the references and projects the differences between the quantitative and qualitative approach in doing literature analysis.

Cobo (2011) did a review on several science mapping software tools which helps in the network analysis, temporal analysis, geospatial analysis, visualization and interpretation of results obtained from the analysis of different data bases. After analyzing nine software tools such as BibExcel, VOSViewer, Network Workbench Tool, CiteSpace II, CoPalRed, IN-SPIRE, Sci2Tool, Leydesdorff’s Software and VantagePoint, they concluded that for an effective science mapping analysis a combination of the above tools has to be used and that any one cannot be considered as the best in doing any analysis.

Bjurström & Polk, (2011**)** analyzed the journal references from IPCC Third Assessment Report (TAR). They used bibliometric analysis to study the inter-disciplinarily present in the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report. Their objective was to identify the scientific fields which are

incorporated and highlighted in IPCC Third Assessment Report (TAR), the reason for choosing them and the consequences of selecting the above scientific fields as a yardstick in the understanding of responses in climate change research. The sample of analysis is prepared by extracting the references from the 43 chapters of TAR, which was broadly classified into three working groups, that was dealing with physical basis, impact/adaptation and mitigation respectively. Reference analysis and journal content analysis saw the emergence of four major scientific fields; such as, physical, biological, social science and interdisciplinary fields. Earth science was found playing a dominant role in TAR as well as the evolution of IPCC. Their analysis identified the limitations of IPCC Fifth Assessment Report and gave suggestions to overcome the limitations.

Vasileiadou et al. (2011) also performed a bibliometric analysis on the effects of the IPCC reports on scientific research.

Manigandan & Jayaraman (2012) did the bibliometric study to analyze the research developments in global warming for a period of 18 years, from 1992 to 2010. The analysis was done based on the journal articles and book chapters published in online database, the Science direct. Due to the multidisciplinary nature of the term "Global Warming" the publications were distributed in a variety of journals ranging from high impact ones to lower ones. The study observed a dramatic increase in the number of publications after 2007 due to the IPCC meeting followed by the Kyoto Protocol and reported maximum number of publications in 2010. It identified the top ten topics under which global warming was discussed mostly in which CO_2 emission occurring on the top. Additionally, the titles of the articles, average length of articles, authorship pattern were also subjected for analysis.

Elango & Rajendran (2015) studied data collected from 2001 to 2010 published in Indian Journal of Marine Sciences. The areas they did research included authorship pattern, authors' collaboration, applicability of Lotka's law, authors' dominance and level of collaboration in the area of marine sciences.

Venkatesan et al. (2013) studied the worldwide pattern of publications pertaining to climate change for the period of 1999-2012 using web of science database. Microsoft Excel and SPSS were used for the analysis. An increasing trend was observed in the number of publications with 2012 yielding a maximum number. USA topped in research output and the maximum was published in English language throughout the world. Relative Growth Rate and Doubling Time was calculated and top institutions contributed to the field were identified. Various areas of research in which climate change is studied were shortlisted. The role of funding agencies in bringing out the research output in the field of climate research was highlighted.

Belter & Seidel (2013) did a bibliometric analysis in the Science Citation Index Expanded (WoS) database in the period of 1984–2011. Their idea was to, through the study, be able to inform policy discussions surrounding climate engineering experiments, suggest research directions for the future, and provide a baseline for more analyses on a similar topic. They felt that publications are a useful and representative proxy for scientific research because they can give an idea on the nature and evolution of that research, and also bibliometric analysis is good for topics that have a large number of publications over many different disciplines. Database was prepared in two phases; the first one using a search string in WoS and manually removing the irrelevant articles from the search results and the second one based on citation tracking. Bibliographic coupling network and coauthor network was generated using Sci2 Tool and the

visualization of both was done with a network visualization software package, Gephi. The dataset included about 750 articles in the designated period of analysis. The publication trend showed an increase in publication in 2008-2010 and then a fall in 2011. Analysis based on article type showed that about 30% of articles published in climate research are non-research articles. USA was ranked first with 366 publications followed by England by 118 in this area. Further analysis of coupling network and coauthor network revealed the major research topics under which climate engineering research is progressing such as SRM (solar radiation management), air capture, biochar, land based methods and ocean fertilization.

Birender Pal & Merina Ahmed (2014) focused their research on the publications from Universities of North-East India during the period of 20 years. Ten types of documents from the SCOPUS database is used for the analysis and the research revealed Assam University followed by Tezpur University topped in the number of publication list. Maximum publications were occurred in the period of 2009-2013. Annual Growth Rate (AGR) and Average Annual Growth Rate (AAGR) were also examined. Salini, C P et al. (2014) studied the role of India in organic chemistry research through bibliometric analysis. Country wise distribution of papers, activity index, major institutions contributed to research, h-index, leading authors, citation analysis were mainly used to achieve the objective.

Saravanan et al. (2014) analysed the growth and development of climate change literature from Web of Science database for the period 1991–2012. They focused on five developing countries Argentina, Brazil, China, India and Mexico. The comparative study was conducted on year wise, document type, most productive authors,

subject wise, journal wise, institution wise, and language wise distributions. They found that the Chinese Academy of Science, China topped the list with 1843 records.

Navaneethakrishnan (2014) worked on authorship patterns and degree of collaboration of Srilankan journals from data derived from SCOPUS database. 1795 records published during 1960-2012 was analyzed using BibExcel, MS excel and Notepad++. The distribution of publications and authorship patterns were analysed.

Thompson & Walker (2015) in their article defined the history, definition, laws, and elements of bibliometric principles and conducted a descriptive and historical review of bibliometrics. Articles that provided history, application and descriptive analysis were selected from databases such as Medline from the year 1966 to 2014 and Web of Science from 1945 to 2014. Were selected and cross-referenced. The history of bibliometrics and scientiometric, the Bibliometric Laws such as Lotka's Law and Bradford's Law are clearly explained. Different elements of bibliometric analysis such as databases, data fields, search options and use of metrics are also discussed.

Fahimnia et al., (2015) did a bibliometric analysis on Green supply chain management. They used SCOPUS data base for their analysis for a period of 21-years, between1992 and 2013 and retrieved 1586 records for the analysis. This database is refined and 1066 unique papers were shortlisted. Bibliometric analysis was done using BibExcel and Network analysis part uses Gephi to perform a citation analysis.

Li & Zhao (2015) considered a 20-year period to study the literature in terms of trends of growth, subject categories and journals, international collaboration, geographic distribution of publications, and scientific research issues. The research quality was assessed by the h-index.

Haunschild et al. (2016) did a bibliometric study on global research on climate change between 1980 and 2014. They analysed the growth of the overall publication output, subfields, the contributing journals and countries and the citation impact. They also conducted a title word analysis for the time evolution and relative importance of specific research topics. They found that research on climate change is dominated by the USA, followed by the UK, Germany, and Canada.

Garg & Tripathi (2017) through their studies demonstrated that Indian scientists have increased their focus in the area of bibliometrics and scientometrics during 1995-2014 when compared to the data of 1970-1994. Data was extracted for a period of 1994-2014 and Total Number of Publications (TNP), Total Number of Citations (TNC), Citations Per Paper (CPP), Relative Citation Impact (RCI) and Papers Not Cited (PNC) were used as bibliometric indicators. The analysis identified CSIR-NISTADS followed by BARC as the top institutes which contributed most to the field. They found that the author with most number of publications need not have the most number of citations per paper. Another important discovery was that among the total number of publications, one fifth remains uncited.

Lukwale & S. Sife (2017) conducted a bibliometric analysis to assess research trends on climate change in Tanzania. Their study was done for the period 2006–2016. The Publish or Perish programme was used to extract data from Google Scholar. They showed that 319 articles or other items were published in the study period. The search strategy adopted by Lukwale and Sife (2017) included only those publications referring to “climate” and “Tanzania” in their titles. The retrieved metrics were the total number of publications, number of authors for each publication, total citation counts, average citations per paper, average citations per year, h-index, g-index, Hc-index and the HI-

norm. Tian et al. (2018) studied the trends and features of carbon emissions research in the transportation sector which is an important contributor in the climate change area. The database selected was web of science; bibliometric analysis was done using BibExcel, network analysis, visualization analysis, h-index and cluster analysis done using Gephi. They found out that authors from UK, USA and China published most articles and the numbers of publications increased between 1997 and 2016.

Jankó et al. (2017) analyzed the references included in IPCC (Intergovernmental Panel on Climate Change) AR5 and ‘‘Climate Change Reconsidered II’’ (CCR II) and compared it with the reference list of its predecessors which is IPCC AR4 and CCR. The references were imported to a database and analyzed after setting a base year as the benchmark for the analysis. It was found that the reference lists of IPCC AR5 and CCR II like IPCC AR4 and CCR may look similar with respect to the cited journals, but the cited references and lead authors rarely show any similarity. This leads to the conclusion that there is no overlapping between the scientific literature mentioned in IPCC reports and the CCR reports analyzed.

Marx et al. (2017) investigated the reasons behind the slow reception and under-citedness of research papers contributed by Charles David Keeling, known as the discoverer of the risk of global warming. Keeling who always preferred an outdoor job was influenced by the writings of Callender and the discussions he had with Plass. The analysis was done in different stages in which the publication data of Keeling was collected from WoS from 1953 to 2004 and the citation impact was studied. The analysis led to the following conclusions; the late recognition of Keeling’s work, the trend of global cooling discussions prevailed during 1950s which hindered Keeling’s idea of global warming, underestimation of Keeling’s works as regular works or publications and

finally the phenomenon “obliteration by incorporation’’, where innovative scientific works were absorbed and incorporated as part of textbooks which reduces its citation impacts.

Aria & Cuccurullo, (2017) made an attempt to familiarize the readers with a unique open-source tool called bibliometrix. This tool is programmed in R, which is user friendly and can be upgraded and integrated with other statistical R-packages. The entire process is divided into study design, data collection, data analysis, data visualization and interpretation. After a successful study design, data were collected from multiple sources of bibliographic information, such as Web of Science, SCOPUS, Google Scholar and Science Direct. The database generated is then converted to suitable format and cleaned. This is followed by data analysis that included descriptive analysis and network extraction. This was accomplished by the application of R tool called bibliometrix and the final results are obtained.

Clarivate Analytics, (2017) conducted a study commissioned by the Ministry of Earth Sciences (MoES), Government of India, on the research of Earth System Science in India and the world. The study was conducted on research output of India in Earth System Science and also the individual contributions of the research institutions under MoES. Two time-periods, 1996-2005 and 2006-2015 and six research areas under Earth System Science (Antarctic research; Arctic research; Himalayan research; Atmospheric research; Geo research and Ocean research) were studied. Some of the findings were: (1) In 2006-2015, India ranked first in Himalayan research, 9^{th} in Atmospheric research, 12^{th} in Geo Research, 15^{th} in Ocean research, 16^{th} in Antarctic research and 25^{th} in Arctic research (2) India’s research output increased 8,753 to 19,938 between study periods (3) Citation impact increased from 0.62 to 0.72 and percentage of international collaboration

increased from 22.6% to 29.9% (4) Indian contributed 3.5% of the total research in Earth System Science (5) Indian funding organizations funded most of the highly cited papers in Atmospheric research, Geo research, Ocean research and Himalayan research (6) Indian Institute of Tropical Meteorology (IITM), India Meteorological Department (IMD) and National Centre for Antarctic and Ocean Research (NCAOR) published the maximum number of papers.

Liao et al. (2018) did bibliometric analysis in the area of medical big data (MBD). The database used is Science Citation Index Expanded (SCIE) and the Social Science Citation Index (SSCI) databases in Web of Science. The study focused on all the publications in MBD till date and the search yielded 988 documents. VOSviewer was used for co-authorship networks and co-citation network analysis, Citespace to make keywords timeline view, GraphPad Prism 5 was used to make histograms and line charts. The analysis focused on the developing trend of patient-centered model and precision medical information technology. The shortcomings of MBB such as the presence of heterogeneous, large, unstructured data and data sources, perspective of data collection by the concerned people, challenges in both data management and data were also mentioned.

Pan et al., (2018) did a comparative study of use, citation and diffusion of three bibliometric mapping software, CiteSpace, HistCite and VOSviewer. Articles and review papers were retrieved from WoS database mentioning the name of these tools in the title, keyword, and abstract fields. Documents in which these three softwares were used rather than mere mentioning were identified by creating a coding scheme based on Cohen's kappa statistics. The study identified a decrease in citation rates and a gradual increase in diffusion speed of these three software.

Sotelo et al. (2018) developed a bibliometric analysis on climate change using Histcite. 862 articles that were published between 2007 and 2016 were considered for the study. The number of references was used as a measure of the quality of the articles and it indicated that the USA had the highest quality with 26.3% of the citations. The data were extracted from the SCI and SSCI database published by Thomson Reuters Web of Science.

Pilkington (2018) published “BibExcel-Quick Start Guide to Bibliometrics and Citation Analysis”. The manual throws light to the process of installing BibExcel, downloading data from Web of Science or ISI data services and preparing data for analysis in BibExcel. It also addresses the creation of .doc, .out, .cit files, citation analysis, co-citation and networks analysis.

Garg (2019) in a correspondence explained about the evolution and current status of scientiometric research in India. In this document he also tried to address some of the typical problems that can be found in the majority of papers published by the Library and Information Science (LIS) professionals working at different academic or research institutions in India with examples. Elango, B. (2018) in his work explained the methodology of determining authorship pattern, collaborative co-efficient, degree of collaboration, collaboration index, pattern of co-authorship and author productivity.

Alex (2019) in their paper did a scientiometric investigation in climate change research literature in India during a period of 1991-2018.The data of twenty eight years was downloaded from WoS using the search string "Climate Change” and 5360 records were obtained. Relative Growth Rate (RGR), Doubling Time (Dt) , Annual Growth Rate (AGR), year wise and document wise distribution, countries to which the

authors collaborated, most productive authors and institution/organization, prominent research area, journal wise distribution were determined using Microsoft Excel.

Mondal & Raychoudhury (2019) studied the contribution of Indian authors in an international journal. The study was conducted in a total of 221 records published in the international journal 'Scientometrics' during the period 1990-2017, that was retrieved from the Web of Science (WoS) database. The year wise distribution of publications, collaboration trend and scholarly impact, authorship trend and pattern, most prolific foreign authors, most productive institutions and authors in India, most frequently used keywords, citation statistics were analyzed. The authors identified that Indian bibliometric scholars lack technical training and they mostly rely on self-gained knowledge or journals to do their research.

Sangam & Savitha (2019) did a scientometric study on climate change and global warming for a period of 2001-2016. The database chosen was WoS and search keyword "Climate change" yielded 32237 documents. The parameters they studied included Relative Growth Rate, distribution of publications in forms-wise and subject wise and authorship pattern. The studies in collaborative index, collaborative coefficient and degree of collaborations revealed an increase which indicates the increasing collaborations between the authors.

Garg & Kumar (2019) studied the role of women scholars in the field if bibliometrics and scientometrics using pattern of growth of women authors and thus determining the position of women scientists in science world. Other tools adopted for the analysis includes co-authorship, domestic and international collaboration of women scholars, institutes supporting their studies.

Aleixandre-Tudó et al. (2019) did bibliometric analysis to determine the recent research trends in global warming. WoS was selected as database and period of study was 2005-2014. Collaboration patterns were determined using a social network analysis (SNA) and network analysis were done using softwares Pajek and VOSviewer.

Moral-Munoz et al. (2019) did a very useful review mentioning about the various bibliometric tools for doing bibliometric and scientiometric analysis. A comparative analysis of available databases and characteristics of software tools for conducting bibliometric analysis was given in the review. SMA tools (Science Mapping Tools) and their main features were listed and briefly explained for the benefit of the readers.

Munim et al., (2020) conducted a bibliometric review of big data and artificial intelligence (AI) in the maritime industry. 279 studies on the applications published in 214 academic outlets, authored by 842 scholars were extracted from the Web of Science database and analysed it using the Bibliometrix tool in R software. The data collection is followed by bibliometric citation analysis and network analysis which assisted in finding the publication trends, the most influential journals, studies, institutions and authors, as well as collaborations and relationships. Bibliographic coupling was done to identify research clusters and cluster analysis was used to map sub-cluster system. The paper gave a detailed methodology about the bibliometric analysis using R software package.

Wei & Zhang (2020) conducted a document co-citation analysis of 33,045 research articles and reviews from the Web of Science database published in the University of Texas between 1991 and 2018. The aim of the research was to identify the trends in business domain research and to investigate the changes occurred in the given time period. For better understanding of the emerging trends the whole period is divided

into three parts and CiteSpace, a Java-based scientometric software package developed by Chaomei Chen is employed to generate and visualize the bibliographic networks. The document co-citation networks of three periods were studied and clusters were identified.

Hossain et al. (2020) did a review and bibliometric analysis on the topic 'Systems Thinking'. The database used for the analysis was SCOPUS and 6577 articles in RIS format were shortlisted. A total of 5985 articles were retained after removing the duplicates with Endnote software. To narrow down the analysis documents published in peer-reviewed journals were only considered and it came around 3884 records that published in a time span from 1991 to 2018. Data analysis was bibliometric analysis done using the BibExcel software and network analysis using Gephi software.

The inference of the review of literature are summarized as follows

- A brief outline of areas under which the climate change research in India is progressing is found out.
- Studies related to scientometrics and bibliometrics were collected to understand the various parameters that are being used to meet the outcomes.
- Most of the studies related to bibliometrics are done based on databases such as SCOPUS and WoS.
- The methodology required for the successful execution of the project and the thorough understanding about the tools to be used are learnt by a thorough literature survey.

CHAPTER 3

METHODOLOGY – SAMPLING DESIGN, DATA SOURCES

3.1 Objectives of the Study

The general objective of the proposal is to conduct a scientometric analysis of climate change studies in India.

The specific objectives are as follows:

a. To examine the growth pattern of climate change studies in India in the period 2005-2018 (14 years).

b. To explore the pattern of authorship and collaborative trend.

c. To analyse the citation pattern of climate change papers.

d. To study the evolution of co-authorship network.

e. To map the research topics and study the growth in terms of sub disciplines in climate change studies.

f. To visualise the evolution of climate change studies.

3.2 Time Period of Analysis

Literature relating to climate change in India was extracted from the SCOPUS and Web of Science for the time period 2005-2018.

3.3 Data Collection and Databases

Database is considered as the source of bibliometrics. It is the database of bibliographic records maintained by either public or private institutions or businesses

encompassing articles, notes, summaries, letters to the editor, reports, notices, discussions, conference proceedings, patents, books, etc. Google scholar, Web of Science (WoS) and SCOPUS are widely used databases in addition to the bibliometric databases such as Chemical Abstracts (a physics and chemistry database), Compendex (an engineering and technology database), Embase (a specialist medical sciences database) and Inspec (a specialist physical sciences database) (Bar-Ilan, 2008; Kulkarni, 2009; Thompson & Walker, 2015).

3.4 SCOPUS

SCOPUS is a multidisciplinary bibliographic database containing abstracts and citations for academic journal articles. It is one of the largest abstract and citation database of research literature updated daily from Elsevier Publisher and is available online by subscription. Searches in SCOPUS also incorporate searches of patent databases. SCOPUS covers nearly 22,000 titles from over 5,000 publishers of which 20,000 are peer-reviewed journals in the scientific, technical, medical and social science disciplines. Over the year SCOPUS became famous for its quality and standard Indexed Journals. Indexation of a journal is considered a reflection of its quality. SCOPUS' Indexed journals are considered to be of higher scientific quality as compared to other popular indexation services like, PubMed, EMBASE, EBSCO, MedLine, SCIRUS etc (Bar-Ilan, 2008). Search options in SCOPUS includes the following aspects.

- Document Search
- Author Search
- Affiliation Search
- Advanced Search

‘Document search’ includes search by article title, abstract, keyword, author, affiliation, language, ISSN, DOI, references (search in reference lists of documents), ‘Limit to: Date Range’, search for publication year(s) and Document Type (search for a document type). ‘Author Search’ facilitates to locate a particular author easily by typing the name and initials in the corresponding fields and locating the author from the information sheet provided by the database in case of name variants. ‘Affiliation Search’ search for institutes by typing the institute name in the search field and choosing the correct institute from the information sheet. ‘Advanced Search’ facilitates the search using complex queries using operators such as AND, OR, NOT and codes (AlRyalat et al. 2019; Burnham, 2006).

3.5 Web of Science (WoS)

It is a multidisciplinary bibliographic database and is one of the largest and most reputable global citation databases. Its core collection encompasses six citation indexes in the sciences, social sciences, arts and humanities, and collectively contains more than a billion searchable citations spanning over 250 disciplines. Includes full bibliographic information and citation searching and is updated weekly. The depth of coverage of WoS database go back to 1945. It was originally produced by the Institute for Scientific Information (ISI) and is currently maintained by Clarivate Analytics. It comprises of five indexes as listed below (Fahimnia et al. 2015).

- Science Citation Index Expanded
- Social Sciences Citation Index
- Arts & Humanities Citation Index
- Conference Proceedings Citation Index- Science
- Conference Proceedings Citation Index- Social Science & Humanities

Search options in WoS includes the following aspects.

- Basic Search: General search by topic, author, DOI, publication year, address, etc.,
- Cited Reference Search
- Advanced Search

Detailed search fields inside the 'Basic Search' feature includes the following.

Topic (search the following fields within a record: title, abstract, author keywords, keywords plus), title of a publication, author name of a publication, author identifiers such as Researcher ID or ORCID of an author, publication name, DOI, document type, search for a funding agency, grant number and accession number.

The 'Cited Reference Search' includes entering information about the cited work and multiple fields are combined using Boolean AND operator and clicking 'Finish Search'. 'Advanced Search' includes creating complex queries using two character field tags and Boolean operators such as AND, OR, NOT SAME, NEAR (Falagas et al. 2007; Joshi, 2016).

3.6 Search Strategy and Data Retrieval

Data (journal articles, conference papers and review articles related to climate change in India) for the analysis is extracted from SCOPUS and WoS databases using a three-term search string composed of different keywords. Specific keywords are selected from the areas under which the research work in climate change is progressing in India. The list of keywords used are given in Table.1. The terms India* and Climate*, (which yields, for instance, 'climatological', 'climatic' for Climate* and Indian for India*) are

used in common in combination with the other keywords since the analysis is done on 'Climate Change Studies in the Indian Context' (Fahimnia, 2015).

3.7 Finalisation of Keywords

The most important part of the scientiometric study is to limit the scope of study and shortlist the research documents define the core of their study. The keywords shortlisted for retrieving the data from the SCOPUS database was based on the observations from the literatures reviewed as well as the recommendations suggested by IPCC (Intergovernmental Panel on Climate Change). The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) and was later endorsed by the United Nations General Assembly. IPCC reports cover the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. The IPCC does not carry out original research, or monitor climate or related phenomena itself. Rather, it assesses published literature, including peer-reviewed and non-peer-reviewed sources(Birch, 2014). The following IPCC reports were considered for finalizing the keywords.

- Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems, 2019
- Global Warming of 1.5°C, Special Report on the Impacts of Global Warming of 1.5°C, 2018
- The Fifth Assessment Report (AR5) of the United Nations Intergovernmental Panel on Climate Change (IPCC), 2014

- The Climate Change 2007, the Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC).

The list of keywords shortlisted are given in Table 3.1.

Table 3.1 List of Keywords Used for Retrieving Data

Sl. No.	Keywords
1	Acidification
2	Adaptation
3	Climat*
4	Climate model
5	Climate change / India
6	Deforestation
7	GCM (General Circulation Model)
8	Glaci*
9	Global warming
10	Greenhouse
11	India
12	Mitigation
13	RCP (Representative Concentration Pathway)
14	Sequestration
15	Warming

* is provided in the search string to yield more data. For example climat* will yield documents consisting of words such as climate, climatic and climatological.

3.8 Data Retrieval from SCOPUS Database

A total number of 37,682 documents comprising of journal articles, conference papers and review articles related to climate change in India are retrieved from SCOPUS

database. The data is downloaded as separate csv and ris files from SCOPUS database which is compatible for analysing in bibliometric software (Klapka & Slaby, 2018).

3.9 Need of Manual Screening of Data Downloaded

The primary analysis pointed to some irrelevant articles in the scientific papers retrieved from the bibliometric sources. For example, an article might include the phrase climate change and India, even though its subject matter is unrelated to the specific keyword. Since the keyword string included the term 'India*', the climate change studies related to places such as Indiana, Indianapolis were also included in the downloaded dataset which is needless. Also the inclusion of word 'climate' in the search string prompted the downloading of papers related to phrases 'economic climate' 'socio-economic climate' as well as 'job climate'. The elimination of such unwanted records from the dataset will increase the accuracy of the analysis and improves the quality of the results. Thus a manual screening of datasets by going through the abstracts, keywords and title was done to make sure such irrelevant papers are excluded from the analysis (Fahimnia et al. 2015; Hossain et al. 2020).

3.10 Methodology for Screening of RIS Files Downloaded from SCOPUS

3.10.1 Method 1: Screening of RIS Files in MS Excel

The dataset for the analysis consisted of 37,682 documents distributed in 35 RIS documents ranging from 786 KB to 22,863 KB. The screening process involves the monitoring of document title, keywords and abstract. In order to provide an easy access to document title, keywords and abstract of a single document and to enable a quick screening process MS Excel software was chosen. A sample bibliometric analysis conducted with the output files obtained after screening in MS Excel observed a change

of format of RIS file. This will hinder the several process of analysis in bibliometric software such as BibExcel and hence the screening process using method 1 was stopped afterwards.

3.10.2 Method 2: Screening of RIS Files in Mendeley

Due to the short comings in method 1, a second method was adopted using Mendeley desktop software. Mendeley Desktop is a useful software in managing and sharing research papers and generate bibliographies for scholarly articles. The multiple window panes provided by the software provides quick analysis of title, abstract and keywords. The files were imported to the software, screened and the final output was exported and saved in RIS format.

Certain changes in format of RIS file was observed while screening RIS files using Mendeley such as the change in SCOPUS field tags (eg: change of author tag from AU to A1), removal of author affiliations in case of multiple authors, removal of references of the entire documents present in the RIS files when screened using Mendeley and uploaded in BibExcel. Therefore another method using Notepad++ was adopted for the screening process.

3.10.3 Method 3: Screening of RIS Files in Notepad++

Notepad++ is a free source code editor and Notepad replacement that supports several languages. It operates in MS Windows environment and is written in C++ language. It ensures a higher execution speed and smaller program size without losing user friendliness. Notepad++ offers more functions when compared to Notepad.

The RIS files downloaded from the SCOPUS database are opened and unnecessary files are removed in Notepad++. The saved document after editing did not

show any format changes during the sample analysis conducted in BibExcel using the files edited using Notepad++. Therefore the method using Notepad++ software was finalized for editing the RIS documents from SCOPUS database (Subramanian Navaneethakrishnan, 2014).

3.11 Methodology for Screening Records in Web of Science

The Web of Science (WoS) offers three types of document search options. Basic Search, Cited Reference Search and Advanced Search. The search string similar to the one used for SCOPUS is used to retrieve data from the WoS database. A total number of 22,211 documents comprising of journal articles, conference papers and review articles related to climate change in India is appeared in WoS database for all the fifteen combination of search strings generated. The files are then manually screened after analyzing the title and abstract and the unwanted documents are eliminated. The shortlisted data is then downloaded in plain text format for WoS database which are compatible for analyzing in bibliometric software.

After the manual screening and removal of duplicates SCOPUS had 10,504 documents and WoS yielded 6,766 documents. The final dataset is generated after the manual screening and merging of two datasets from SCOPUS and WoS in BibExcel software and is used for further analysis. This comes around 17,270 documents and approximately 3400 documents were identified as duplicates in the merged file. After removing the duplicates the total number of documents that is finalized for the analysis is 13863 in the master file for the analysis

3.12 Selection of Software Tool for Analysis

Bibliometric mapping software tools are programs that have been developed for carrying out bibliometric mapping analysis. Several bibliometric software are available for conducting the bibliometric analysis. Biblioshiny, Bibliomaps, HistCite, VOSviewer, CiteSpace, BibExcel are some of the available software in this area. Each software has distinctive characteristics and are designed with unique purposes (Pan et al. 2018).

Biblioshiny and Bibliomaps uses R and Python as operative system and has a web user interface, while the others runs in Windows and the user interface is desktop. HistCite is easy to operate and offers an extensive citation analysis, but has a limited visualization feature and can be used for WoS database only. CiteSpace allows the analysis of emerging trends in a domain. CiteSpace is able to work with different bibliographic databases, such as WoS, SCOPUS etc. and can be used along Google Earth to generate geographical locations and visualizations (Moral-Munoz et al. 2019).

BibExcel offers many features and can create data files that can be imported to MS Excel for further analysis. It was developed by Olle Persson at University of Umea (Sweden). Though this software is flexible, it can be challenging to use for new users. BibExcel can process data from several bibliographic sources such as WoS, SCOPUS, and PubMed (Persson et al. 2009). Some of the features offered by this software are co-citation, bibliographic coupling, co-author, co-word, keyword analysis or co-occurrence analysis by taking any document's field, or combining them. BibExcel does not support any visualisation options. But it incorporates different export options that allow visualizing the data using external software like Pajek, Ucinet, SPSS or VOSviewer. It was hence decided to use BibExcel for the analysis owing to the wide range of services

provided as well as the compatibility with the database selected (Pan et al. 2018; Pilkington, A., 2018).

The network and visualisation of this project was done using VOSviewer. VoSViewer is a freely available computer programme used for constructing and viewing bibliometric maps with many visualization options. VOSviewer can generate maps of authors or journals based on cocitation data or to construct maps of keywords based on co-occurrence data. It provides the user to examine the bibliometric graphs in full detail which is accomplished using several facilities available in the software such as zooming, scrolling, and searching. VOS stands for 'visualization of similarities' and uses a technique called VOS mapping to generate visualizations which are mainly distance based maps. VOSviewer overcomes the limitations of graphical representations generated by SPSS and Pajek by offering different ways of displaying maps such as the label view, the density view, the cluster density view, and the scatter view. The VOS view generates maps in three steps and the principle behind its operation is a co-occurrence matrix. In the first step, a similarity matrix is calculated using a similarity measure known as the association strength, also mentioned to as the proximity index based on the co-occurrence matrix. A map is generated using a simple open source computer program based on the matrix acquired previously. In order to yield consistent results VOSviewer applies three transformations such as translation, rotation and reflection to the solution obtained earlier and yielding a consistent bibliographic map finally (Al-Shahi et al. 2001; Henderson, 2003; Rahman & Fukui, 2002; van Eck & Waltman, 2010, 2013).

The methodology adopted for the analysis of the project is illustrated with the help of a flow diagram as shown below in Figure 3.1.

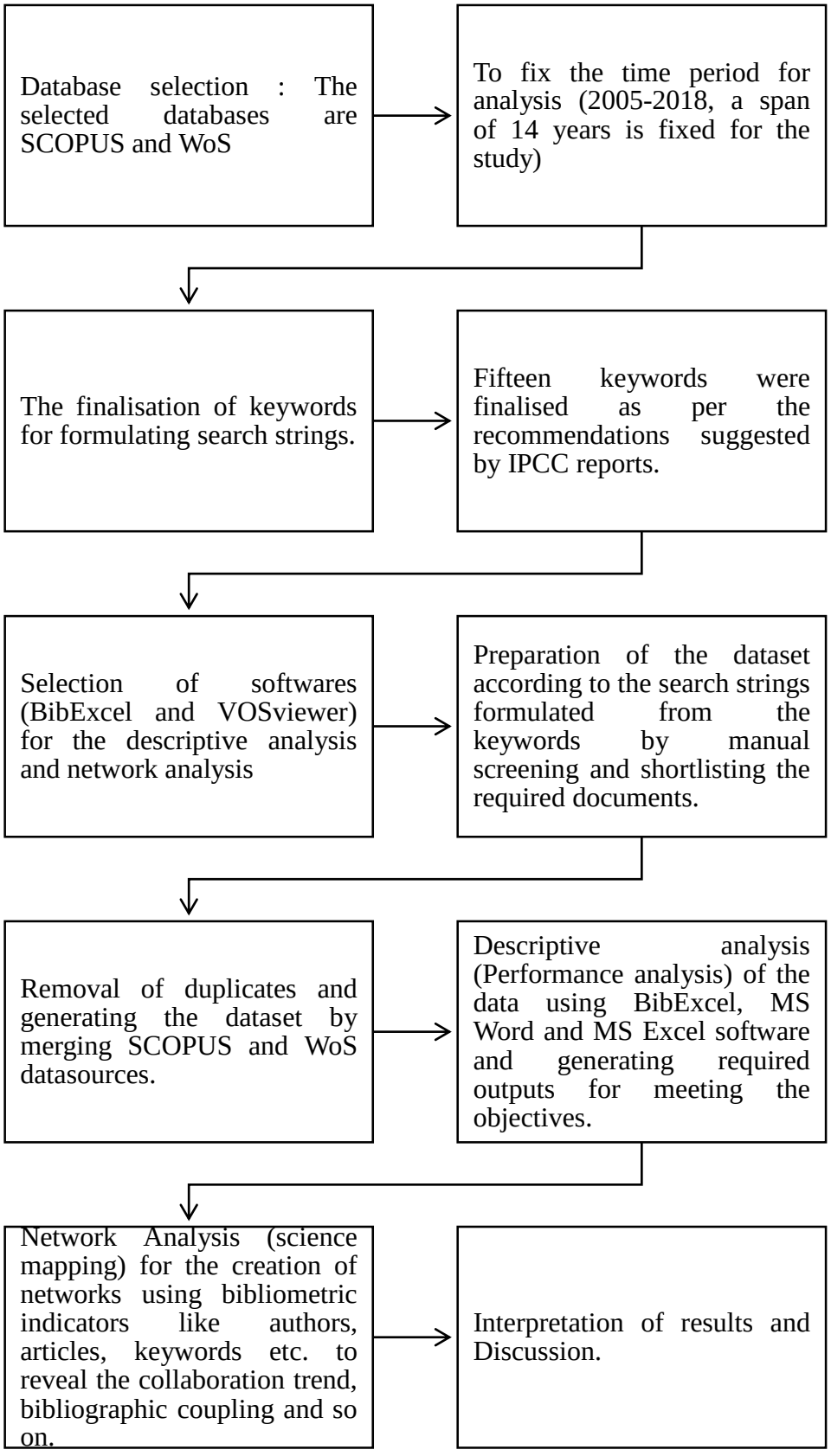


Figure 3.1 Flowchart of the Methodology Adopted for the Project

CHAPTER 4

DETAILED ANALYSIS OF THE DATA

Detailed analysis of the data comprises of the different types of scientiometric analysis required to obtain results that are essential to meet the objectives of the study. Performance analysis and science mapping are the two main applications of bibliometric methods (Munim et al. 2020; Zupic & Čater, 2014).

Performance analysis is also known as descriptive analysis and focuses on determining the objectives by studying parameters such as most important author, most cited paper, most influential organisation and institution, journal, article title etc. Science mapping on the other hand is also known as bibliometric mapping and involves a spatial illustration of how the bibliometric indicators of the documents of different authors are related to each other. It displays the static and dynamic characteristics of a research (Cobo, 2011).

Cobo et al. (2011) described several steps involved in science mapping analysis as data retrieval, pre-processing, network extraction, normalization, mapping, analysis and visualization. The first two steps involves the selection of data sources such as WoS and SCOPUS and the pre-processing step consist of data cleaning such as duplicate removal and deleting misspelled elements and unwanted records. The next steps can be accomplished with the help of bibliometric softwares available or a combination of two or more programmes. Some of the softwares available are listed below.

- BibExcel CiteSpace II
- IN-SPIRE

- Leydesdorff's Software
- VOSViewer

Network extraction is accomplished by selecting different units of analysis such as authors, co-authors, co-citation analysis, bibliographic coupling, document, institution etc. Once a network is finalised, normalisation step is required to identify the similarities in the data using several similarity measures, the most commonly applied being Salton's Cosine, Jaccard's Index, Equivalence Index and Association Strength which is also known as Proximity Index.

This is followed by several analysis methods like Network analysis which is a statistical analysis of the map generated and gathering information, temporal analysis which is meant to identify the trends and patterns and finally geospatial analysis which aims in identifying the impact over the neighbouring areas. Once the above steps are over, visualization and data interpretation can be done depending on one's knowledge in the area.

4.1 Bibliometric Indicators

Bibliometric analysis uses several parameters which serve as an indirect measurement of the impact it has created in the research field. These parameters which gives the quality of scientific publication are called bibliometric indicators. These indicators are important for any researcher since they allow them to select the journals to which they can publish their works. Also they are important for organisations, as they help them in assessing the quality of a research work, individual or group research and also offers help in making decisions regarding the funding and promotions. They are applicable in determining the geographic distribution of research topic and distinguish the impact of countries' research growth in a particular research area. They help in

identifying different research collaborations and research networks that produces successful research outputs. The parameters can be publication year, language of publication, author affiliation, institution affiliation, productive countries, productive organisations, cited references, co-authorship, citations, co-citations keywords and co-words (Al-Shahi et al. 2001; Henderson, 2003; Rahman & Fukui, 2002).

The three types of bibliometric indicators are Quantity indicators, Performance Indicators and Structural indicators.

Quantity indicators measure the productivity of a research group or an individual researcher by monitoring the quantitative aspects of the bibliometric information. For example consider the number of publications by an individual researcher or research group. Higher the number of publications by an author or a research group, higher will be the productivity. This indicator however does not reflect the quality of a research work. Hence to overcome this limitation, it is suggested to monitor the number of publication in the journals with highest quality.

Performance indicators are those indicators which give the quality of a research work or analysis and its author(s). For example consider the number citations received by a document. Higher the citation count of a work, higher will be its impact. Performance indicators are two types: Journal Performance Indicators and Researcher Performance Indicators.

Journal performance indicators are designed to indicate the quality of journals. Journal impact factor, five-year journal IF and cited half-life are some of the journal performance indicators used by bibliometric data sources such as SCI.

Researcher performance indicators are indicators that give the performance of individual researcher or group of researchers. Crown indicator and *h*-index are the examples of researcher performance indicators. (Durieux & Gevenois, 2010)

Some of the most useful bibliometric indicators and their applications are given below. These indicators are explained in detailed by Yoshiko Okubo (1997) in his paper 'Bibliometric Indicators and Analysis of Research Systems: Methods and Examples'.(Okubo, 1997)

Number of papers: This indicator is the most simplest of all the other indicators and gives the direct measure of the quantity of research work generated by a particular researcher, research group, institution, organisation or country in terms of number. This is a rough bibliometric indicator and the major limitation of the indicator is that though the performance of a researcher, research group, organisation, institution or a country can be considered as high when the number of publication increases, it cannot give the quality of research work contributed by them. Also, if the paper has more than one author and each author has contributed differently for the paper, relying on this bibliometric indicator will not do a complete justification for their individual performance.

Number of citations: The citation count of an article gives the direct impact of the article in the research field. It is the direct measurement of the quality of a research work and as the citation count increases, the quality and impact of the research work is also considered high. The citations are done in two ways. The first way is that the authors cite relevant articles of other authors to justify their present work and in the second one the author quotes an earlier work of his/her own to highlight the significance of the present work. This is called self-citation. Though self-citation increases the credit of the

authors, it cannot be considered ethical in certain situations. Thus self-citations is somehow is identified as one of the major draw backs in taking number of citations as a bibliometric indicator.

Number of co-authors: The number of co-authors is the indicator of the collaboration of authors in both national and international level. The increase in number of co-authors indicates increased association of researcher with other researchers in individual, institutional, national and international levels. This can led to the development of two possibilities while doing network analysis such as whole counting and fractional counting. Also another limitation in using the number of co-authors in bibliometric analysis raises while doing affiliation analysis since several famous research and academic organisations are listed under databases under different names which creates confusions while doing the analysis.

Number of co-citations: Co-citations indicates the number of times two different articles or papers are cited concurrently in the same article. It represents that two researchers are doing research under a same theme and hence can be used for generating network maps indicating the evolution of fields and sub fields.

Co-occurrence of words: The analysis indicates two words of the same theme or area are used together in a same document or article. The frequency by which each word is used with another co-word is analysed.

Bibliometric indicators stated above can be further used to find out the following parameters which can be applied to determine the objectives of the study.

4.1.1 Distribution by Publication Type

Publications are done under several categories like reviews, articles, book chapters, conference proceedings, patent publications, books, articles, proceedings papers, notes, letters, editorial materials, erratum, conference reviews, book reviews etc. Analysis is done, documents under analysis are classified according to the type of publication and the distribution is studied.

4.1.2 Relative Growth Rate (RGR) and Doubling Time (DT)

RGR (Relative Growth Rate) is "the increase in the number of articles or publications or pages per unit of time". Hunt (1990) modified an equation that was earlier used for growth analysis studies in plants and is analogous to the rate of compound interest earned on capital. Thus mean RGR over the specific period of an interval can be calculated as

$$Mean\ RGR = 1 - 2^{R} = \frac{log_e W_2 - log\ _e W_1}{T_2 - T_1}$$

where,

$1\text{-}2^{R}$ - Mean relative growth rate over the specific period of interval;

$\log_e W_1$ - Log of initial number of articles;

$\log_e W_2$ - Log of final number of articles after a specific period of interval; and

$T_2\text{-}T_1$ - The unit difference between the initial time and the final time. The unit of time considered here is a year. Therefore, $1 - 2^{R}$ (aa^{-1} $year^{-1}$) represents the mean relative growth rate per unit of articles per year over a specific period of interval.

The time taken by any population or sample that grows exponentially to become double is called doubling time (Dt) (Bornmann & Mutz, 2015). The formula for doubling time is derived from the compound growth equation that is used to project the

population size of any quantity that is growing exponentially. Thus Dt can be approximately calculated as

$$\text{Doubling time (Dt)} = \frac{0.693}{1\text{-}2^{R}} = \frac{0.693}{R}$$

4.1.3 Distribution by Number of Authors

The number of authors contributing to the records to be analysed is studied. The records can be single authored papers or multi authored papers. This parameter can be studied and can be applied along bibliometric tools such as Collaboration Co-efficient, Degree of Collaboration, Collaboration Index and is used to examine the authorship pattern, proportion of single-authored against multi-authored papers, the degree of collaboration and author productivity

4.1.4 Distribution by Country

$$\text{Relative Citation Index (RCI)} = \frac{\text{Citation \%}}{\text{Publication \%}}$$

RCI > 1 indicates that country's citation rate is higher than the world's citation rate,

RCI = 1 indicates that country's citation rate is equal to the world citation rate and

RCI < 1 indicates that country's citation rate is less than the world's citation rate.

4.1.5 Activity Index

Activity Index (AI) is the measure of the productivity of individual countries against the world contribution (Salini, C P et al. 2014). The AI can be used to relate the contribution of mangrove research in India to that of the mangrove research in the whole world. This common and useful bibliometric indicator was first proposed by Frame in the year 1977 and was later explained by Schubert and Braun (1989) in detail. Activity Index (AI) is given by the formula;

$$AI = \frac{\text{Given field's share in the country's publication output}}{\text{Given field's share in the world's publication output}}$$

If AI=1 the country's research output in the given field corresponds exactly to the world's average

AI >1 reflects a higher average than the world's average

AI<1 a lower average than the world's average.

4.1.6 Analysis of References

References allows to acknowledge the contribution of other writers and researchers in any work. Under this process, number of references included by each document adopted for the study is analysed. The number of references present in each document is studied and the range of number of references is tabulated.

4.1.7 Number of Citations Received by Each Document

The total number of citations received by each document directly gives the impact of the work in the scientific world. Documents with zero citations also exist. The number of citations received by each document is identified from the field tag provided by the SCOPUS and WoS database and the results are tabulated which shows the number of most impacted papers produced in the period of analysis.

4.1.8 Most Cited References

This indicates the list of references which are predominantly used in the documents which are considered for the analysis. The field tag CD is used for the analysis and the list of references are obtained as a separate file. This file with the help of BibExcel is analysed and the most commonly used references are identified and tabulated. This indicates the relevance or importance of such references in the scientific

world. The references which topped the list are highly impactful as they are cited more number of times.

4.1.9 Most Productive Keywords and Number (range) of Keywords Used

Keywords are the terminologies which are given by the author that are having close association with the area of study. The number of keywords given by the author for a particular document can range from one to more than thirty. The keywords are given by field tag ‘DE’ in WoS, while in SCOPUS it is given under the field tag ‘KW’. Therefore to get the output we need to change the field tag from DE to KW. The keywords given for each document is extracted using appropriate field tags in BibExcel and the list thus obtained is subjected to frequency distribution analysis to obtain a list of most commonly used keywords and the frequency with which each keyword is used in a document. It is also possible in BibExcel to determine the range of keywords that are used in each record for further analysis.

4.1.10 Most Influential Research Areas

This parameter is offered by only WoS database and is indicated by the field tag ‘SC’. Each paper is assigned under a particular research area. The field tag of the particular data is used to identify the particular research area of each document and the result is tabulated in descending order to identify the most prominent research area. The analysis of most influential research area gives an indication to where the research growth of a country is progressing towards. It gives idea about the existing fields of research as well as the emerging ones. This gives the most prominent research areas under which the concerned topic Climate Change in Indian context is carried out. The name of the prominent research areas are identified and are sorted with the help of BibExcel software.

4.1.11 Distribution by Journal

Each document is published in journals whose data is obtained from the field tag provided by the databases and tabulated separately to identify the most productive journal with maximum number of publications.

4.1.12 Most Productive Countries

The data required for finding the most productive countries is obtained from the affiliations of authors of each document. For this purpose the field tag of both SCOPUS and WoS are made identical ('C1' field tag of WoS is converted to 'AD' field tag of SCOPUS). The name of the countries are then isolated from the affiliation address and the frequency distribution studies is carried out to finalise the list of most productive countries.

4.1.13 Most Prolific Authors

The most prolific author implies the author with highest number of publications. A prolific author is one who publishes in large quantities or with great frequency and are highly productive in nature. The analysis of most prolific author with highest number of publications is done using the author tag 'AU' and article number and sorting it in descending order. The author affiliation is also used to increase the credibility of the sorting.

4.1.14 Authorship Pattern

The analysis is done on the basis of number of authors present in a document. The number of authors per paper is determined through BibExcel and the percentage and cumulative percentage is calculated.

4.1.15 Collaborative Coefficient

Ajiferuke et al. (1988) gave the formula for determining the strength of collaboration among the contributing authors. The formula is given as follows.

$$CC = 1 - \sum_{j=1}^{k} \frac{1}{j} * \frac{Fj}{N}$$

where Fj = the number of articles with 'j' author

J = No of articles (one author, two authors, three authors etc.)

N = the whole number of authors in an article.

(Ajiferuke et al. 1988) through this equation tried to interpret the value got after applying the equation to the data. Collaborative coefficient (CC) is a number between 0 and 1. Depending upon the value of CC the dominance of single authored and multi authored publications can be determined. That is, the value of CC when tends to 0 determines the domination of single authored publication whereas the value near to 1 indicates the domination of multi-authored publications.

4.1.16 Degree of Collaboration

To determine the degree of collaboration the following formula by Subramanyam (1983) is adopted.

$$\text{Degree of Collaboration, } DC = \frac{Nm}{Nm + Ns}$$

where, N_m = number of multiple authored papers and N_s = number of single authored papers

4.1.17 Collaboration Index

Collaboration Index (CI) is the mean number of authors per multi authored paper. This parameter is obtained by dividing the total number of multi authored papers with the total number of authors of multi-authored articles. The count of single author papers are not considered here.

4.1.18 Co-authorship Index (CAI)

Co-authorship Index (CAI) or Pattern of co-authorship can be found by adopting the formula by Garg & Padhi (2010). The formula is given as follows.

$$CAI = \frac{Nij/Nio}{Noj/Noo} \; X \; 100$$

where N_{ij} = Number of papers having j authors in block i

N_{io} = Total output of block i

N_{oj} = Number of papers having j authors for all blocks

N_{oo} = Total number of papers for all authors and all blocks

$j = 1, 2, 3, 4 \geq 5$

4.1.19 Most Productive Countries and Relative Citation Index

The list of 20 most productive countries that produces top number of research papers in the area of climate change in Indian context is studied based on the author affiliation of the first author.

Relative Citation Index (RCI)

Relative Citation Index (RCI) is used to determine the impact of research output. The Institute of Scientific Information developed RCI to calculate the science and engineering indicators. According to Kumari (2010), RCI is a measure of both the influence and

visibility of a nation's research in a global perspective. It is defined as the ratio of a country's share of world citations to the country's share of world publications.

$$\text{Relative Citation Index (RCI)} = \frac{\text{Citation \%}}{\text{Publication \%}}$$

RCI > 1 indicates that country's citation rate is higher than the world's citation rate,

RCI = 1 indicates that country's citation rate is equal to the world citation rate; and

RCI < 1 indicates that country's citation rate is less than the world's citation rate.

4.1.20 Most Productive Organisations

The most productive organisation data is prepared from the affiliation of authors in the database. The affiliation of authors is given under the field tag 'C1' in WoS and 'AD' in SCOPUS. It was therefore necessary to bring two different field tags to one single tag and therefore 'C1' tag was replaced with 'AD' tag and a new file was generated for the analysis. One of the major shortcomings observed in this area is the way each organisation is presented in the affiliation of authors. For example, one of the top institutes identified in bringing out majority number of publications in climate change in India is Indian Institute of Tropical Meteorology, Pune, India. This institution is designated in the following forms;

- Indian Inst Trop Meteorol, Pune 411008, Maharashtra, India
- Indian Institute of Tropical Meteorology, Pune, India
- Indian Inst Trop Meteorol, Pune, Maharashtra, India
- Indian Institute of Tropical Meteorology, Pune, 411008, India
- Indian Inst Trop Meteorol, Ctr Climate Change Res, Pune, Maharashtra, India
- Indian Institute of Tropical Meteorology, Pune 411 008, India

All the above mentioned names are pointing towards the same institute. Since BibExcel software is being used these organisations are considered as separate institutes and their contributions are also identified separately. Hence a manual analysis is done to identify the contributions of the institutes separately and they are added and expressed in the results and discussion part.

4.1.21 Cited Reference Analysis

Cited reference analysis is one of the most important parameter in bibliometrics and is closely related to the Times cited analysis. The former is occurring before the publication of the records while the latter is appearing after publication (Marx & Bornmann, 2016). Cited reference analysis studies the references cited by a specific author in his/her work. This analysis leads to further analysis such as co-citation analysis, collaboration studies with other authors. Times cited analysis investigates the number of publications that are published later have cited the particular paper under question.

4.1.22 Most Cited Publications

Citation counts play a responsible role in determining the eminence of research work. Highly Cited Papers (HCPs), excluding self-citations, throw light on the integrity of research as well as the author's scientific impact.

4.2 Network Analysis

The network analysis is done to visualise the evolution of climate change studies and to map the research topics and study the growth in terms of sub disciplines in climate change studies. VOSviewer 1.6.16 is the software used for the purpose. The analysis done are

- Co-authorship analysis
- Co-occurrence of keywords

- Bibliographic coupling
- Bibliographic coupling of documents
- Bibliographic coupling of authors
- Bibliographic coupling of countries

CHAPTER 5

RESULT AND DISCUSSIONS

5.1 Performance Analysis (Descriptive Analysis)

5.1.1 Distribution by Publication Type

The distribution of type of publication is shown in Table 5.1. The majority of the database constituted about articles (82.75%). There are 11,473 articles followed by 767 book chapters (5.53%), 751 conference papers (5.42%), 493 reviews (3.56%) and 94 books (0.68%) present in the database that mention about the climate change in Indian context.

Table 5.1 Distribution by Publication Type

Sl. No.	Type of Publication	No. of Records	%
1	Article	11473	82.76
2	Book Chapter	767	5.53
3	Conference Paper	751	5.42
4	Review	493	3.56
5	Book	94	0.68
6	Article; Proceedings Paper	80	0.58
7	Note	41	0.30
8	Letter	33	0.24
9	Editorial Material	30	0.22
10	Editorial	20	0.14
11	Erratum	16	0.12
12	Article in Press	13	0.09
13	Short Survey	12	0.09

Sl. No.	Type of Publication	No. of Records	%
14	Review; Book Chapter	10	0.07
15	News Item	8	0.06
16	Correction	8	0.06
17	Conference Review	6	0.04
18	Meeting Abstract	3	0.02
19	Article; Retracted Publication	1	0.01
20	Article; Data Paper	1	0.01
21	Book Review	1	0.01
22	Data Paper	1	0.01
23	Business Article	1	0.01

5.1.2 Relative Growth Rate (RGR) and Doubling Time (DT)

It is essential to obtain the increase in the number of articles or publications or pages per unit of time in order to obtain RGR (Relative Growth Rate) and doubling time (DT). The data required for the analysis is given in Table 5.2. There were only 196 records published in the year 2005. The publication went on increasing in the further years and reached 1878 records in the year 2016. There was a drop in the number of publication in the following year. The number increased further in the year 2018 and reached 1819 records. There were pronounced increase in the number of publications in the years 2007, 2014, 2016 and 2018. The graph was plotted for the growing increase of published records and a polynomial trend line was then fitted to the growth curve as shown in Figure 5.1. The equation for the trend line is generated and a satisfactory R^2 value is obtained. Also graph is plotted for RGR- Doubling time Vs. number of years. This is shown in Figure 5.2. The doubling time of the publications was found to be approximately three years.

Table 5.2 Growth of Climate Change Literature from 2005 to 2018

Sl. No.	Year	Number of Records Published
1	2005	196
2	2006	262
3	2007	371
4	2008	373
5	2009	686
6	2010	722
7	2011	700
8	2012	839
9	2013	1147
10	2014	1567
11	2015	1668
12	2016	1878
13	2017	1635
14	2018	1819

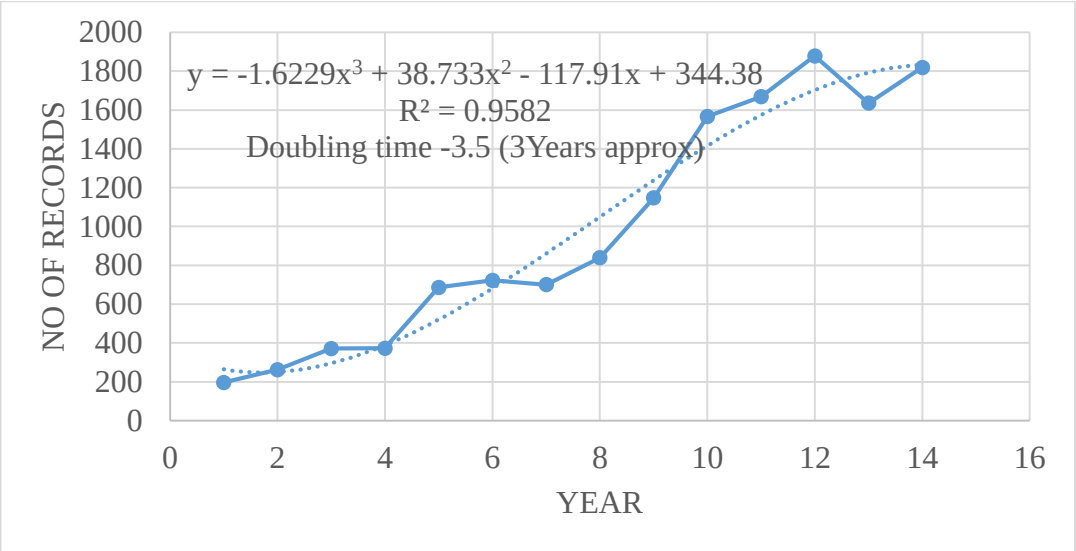


Figure 5.1 Growth of Climate Change Literature from 2005 to 2018. The Dotted Line Shows the Exponentially Fitted Curve

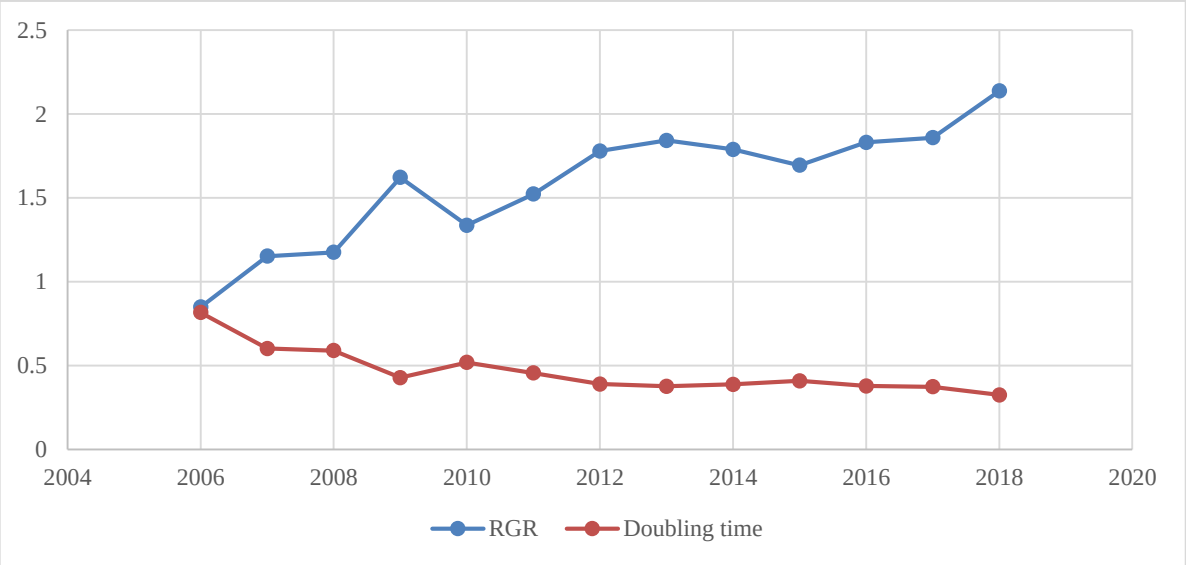


Figure 5.2 Relative Growth Rate and Doubling Time for Climate Change Literature from 2005 to 2018

5.1.3 Language Analysis

The data obtained through language analysis is represented in Table 5.3. The documents are published in English language constituted 93.09 % , 0.07% and 0.06% are published in English/French and Chinese respectively. Data of approximately 6% of the records are not available in the databases for analysis.

Table 5.3 Distribution Based on Languages Published

Sl. No.	Languages	Number
1	English	12906
2	English; French	10
3	Chinese	9
4	French	3
5	Polish	3
6	Russian	2
7	Portuguese	2
8	Norwegian	1

Sl. No.	Languages	Number
9	English; Croatian	1
10	Croatian	1
11	English; French; German	1
12	Finnish	1
13	English; Spanish	1
14	Data Not available	922

5.1.4 Most Productive Publishers

The list of top 50 publishers are given in Table 5.4. Springer topped the list with 825 records. This is followed by Elsevier Ltd with 515 records. Elsevier, Pergamon-Elsevier Science Ltd and Elsevier B.V. occupied third, fourth and fifth position with number of published records 411, 395 and 320. This indicates towards the inclination of Indian authors towards Springer, an American publishing company of academic journals and books for the publications of their research works.

Table 5.4 List of Top 50 Most Productive Publishers

Sl. No.	Name of Publisher	Count
1	Springer	825
2	Elsevier Ltd	515
3	Elsevier	411
4	Pergamon-Elsevier Science Ltd	395
5	Elsevier B.V.	320
6	Springer India	292
7	Indian Acad Sciences	277
8	Springer Verlag	277
9	Blackwell Publishing Ltd	260
10	Wiley	257

Sl. No.	Name of Publisher	Count
11	Amer Geophysical Union	242
12	Elsevier Science BV	233
13	Indian Academy of Sciences	205
14	Springer Netherlands	190
15	Elsevier Sci Ltd	187
16	Taylor and Francis Ltd.	185
17	Copernicus Gesellschaft MBH	170
18	Taylor & Francis Ltd	163
19	Springer International Publishing	162
20	John Wiley and Sons Ltd	161
21	Nature Publishing Group	159
22	Springer Wien	143
23	Springer-Verlag Wien	127
24	Institute of Electrical and Electronics Engineers Inc.	121
25	Amer Meteorological Soc	117
26	Wiley-Blackwell	116
27	Springer Heidelberg	100
28	Sage Publications Ltd	95
29	India Meteorological Department	91
30	Copernicus Gmbh	90
31	American Meteorological Society	89
32	India Meteorological Dept	87
33	Kluwer Academic Publishers	84
34	Springer Berlin Heidelberg	79
35	IOP Publishing Ltd	69
36	Assoc Agrometerologists	69
37	Taylor and Francis	65
38	Elsevier Science Inc	65
39	Indian Council of Agricultural Research	62
40	Springer Singapore	62
41	International Society for Photogrammetry and Remote Sensing	61

Sl. No.	Name of Publisher	Count
42	MDPI AG	54
43	Taylor and Francis Inc.	53
44	ASCE-Amer Soc Civil Engineers	52
45	Science Press	48
46	IWA Publishing	47
47	American Society of Civil Engineers (ASCE)	46
48	Cambridge Univ Press	46
49	MDPI	45
50	Asian Association on Remote Sensing	42

5.1.5 Most Productive Journal

The list of top 25 most productive journal is given in the Table 5.5. Productivity of a journal here relates to the number of records published by a journal rather than the quality of research work published. Therefore it is depending on the count of the records and not on other performance indicators for example, impact factor. Current Science published 424 records pertaining to climate change in Indian context. Current Science is a leading interdisciplinary science journal from India published every fortnight by the Association, in collaboration with the Indian Academy of Sciences. It was started in 1932 and by 2011, the journal completed one hundred volumes. Current Science is indexed by Web of Science, Current Contents, Geobase, Chemical Abstracts, IndMed and SCOPUS. The impact factor of the journal for the year 2019 is 0.725. This was followed by Climate Dynamics in the second position with 305 records. The International Journal Climate Dynamics dealts with high-quality research on all aspects of the dynamics of the global climate system. The impact factor of the journal for the year 2019 is 4.486. The third position is occupied by International Journal of Climatology with 274 records. This journal is a peer-reviewed scientific journal in the field of climatology published 15 times

per year with an impact factor of 3.609. The above two instances of impact factor points towards the publication of high impact research works in the field of climate change in Indian context. Journal of Geophysical Research Atmospheres and Journal of Earth System Science occupied the fourth and fifth position with 242 and 230 publications of climate change. Year wise distribution of most productive journals is shown in Table 5.6.

Table 5.5 List of Top 25 Most Productive Journals

Sl. No.	Name of Journal	No. of Records Published
1	Current Science	424
2	Climate Dynamics	305
3	International Journal of Climatology	274
4	Journal of Geophysical Research Atmospheres	242
5	Journal of Earth System Science	230
6	Theoretical and Applied Climatology	224
7	Journal of Climate	217
8	Mausam	200
9	Quaternary International	198
10	Geophysical Research Letters	183
11	Climatic Change	182
12	Atmospheric Environment	172
13	Natural Hazards	166
14	Journal of Agrometeorology	125
15	Environmental Monitoring and Assessment	121
16	Science of the Total Environment	120
17	Atmospheric Chemistry and Physics	111
18	Journal of the Geological Society of India	110
19	Global and Planetary Change	110
20	Journal of Hydrology	104

Sl. No.	Name of Journal	No. of Records Published
21	Scientific Reports	101
22	Atmospheric Research	100
23	Mitigation and Adaptation Strategies for Global Change	97
24	International Journal of Remote Sensing	95
25	Environmental Research Letters	94

Table 5.6 Year Wise Distribution of Most Productive Journals

Sl. No.	Journal Name	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Grand Total
1	Current Science	13	12	18	20	21	20	49	36	37	37	39	57	32	33	424
2	Climate Dynamics	7	4	5	2	13	12	18	19	33	41	32	57	36	26	305
3	International Journal of Climatology	2	3	8	8	18	12	10	23	26	37	30	18	39	40	274
4	Journal of geophysical research-atmospheres	4	13	17	17	29	29	24	23	23	16	13	12	11	11	242
5	Journal of Earth System Science	1	3	2	5	12	14	14	23	38	24	24	28	23	19	230
6	Theoretical and Applied Climatology	1	1	8	2	-	5	9	17	15	14	31	33	33	55	224
7	Journal of Climate	13	12	24	15	27	12	9	14	11	11	29	13	8	19	217
8	Mausam	-	-	2	6	5	8	12	11	4	16	30	45	39	22	200
9	Quaternary International	-	2	4	2	1	14	5	15	20	56	26	1	44	8	198
10	Geophysical Research Letters	18	35	15	13	17	6	8	7	10	10	13	12	6	13	183
11	Climatic Change	2	2	8	7	7	7	9	16	16	36	17	16	20	19	182
12	Atmospheric Environment	6	1	6	3	8	8	12	10	12	41	20	22	8	15	172

Sl. No.	Journal Name	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Grand Total
13	Natural Hazards	-	4	8	1	1	2	4	10	23	7	23	41	19	23	166
14	Journal of Agrometeorology	-	-	4	5	11	9	6	5	9	15	11	28	15	7	125
15	Environmental Monitoring and Assessment	1	3	4	5	4	3	1	5	5	18	26	18	10	18	121
16	Science of the Total Environment	-	-	-	1	1	2	-	3	31	11	10	10	14	37	120
17	Atmospheric Chemistry and Physics	-	-	-	2	4	11	7	5	4	23	23	5	14	13	111
18	Journal of the Geological Society of India	4	12	5	3	9	5	10	4	8	6	10	5	4	25	110
19	Global and Planetary Change	1	3	1	8	2	4	3	4	14	17	14	7	15	17	110
20	Journal of Hydrology	3	4	1	-	2	7	4	6	8	15	12	13	12	17	104
21	Scientific Reports	-	-	-	-	-	-	-	2	7	5	5	20	30	32	101
22	Atmospheric Research	-	2	1	2	2	4	6	4	10	9	9	19	14	18	100
23	Mitigation and Adaptation Strategies for Global Change	-	1	5	3	5	14	14	5	11	10	10	7	5	7	97
24	International Journal of Remote Sensing	3	-	3	5	4	9	9	8	9	15	7	5	4	14	95
25	Environmental Research Letters	-	-	-	-	3	1	3	8	7	4	21	11	17	19	94

5.1.6 Number of Citations Received by Each Document

Citations count implies the number of times each document is cited by other authors in their respective works. It denotes the impact of each work and the role it plays in the scientific world. Citation count is given as in important parameter in both SCOPUS and WoS databases. The parameter is extracted and the list of citation received is obtained in the BibExcel software. To understand the data in a better manner the range of citations are introduced and is given in Table 5.7. The same is represented in Figure 5.3 in the form of pie chart. Majority of the documents received less than 10 citations. 448 documents received more than 100 citations and the data unavailable comes for 1667 documents.

Table 5.7 Range of Citations

Range of Citations	Count
Zero citations	213
1 to 10	6135
11 to 50	4577
50-100	823
>100	448
Data unavailable	1667

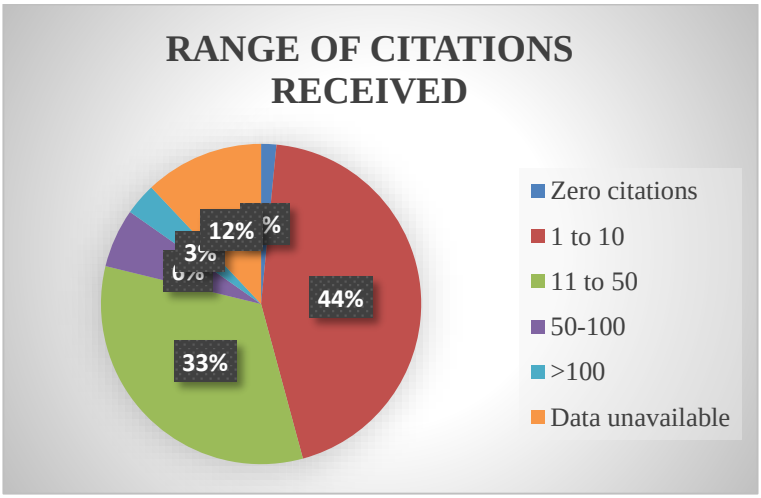


Figure 5.3 Range of Citations

5.1.7 Most Prolific Author

This is analyzed using the author field offered by the databases. List is generated by BibExcel with author name and article number which is then sorted using sort descending command. This finally gives the author name and the number of times the author name is appearing on the list. One of the major challenges while adopting this method is that the authors with identical names are counted as one and therefore this methodology cannot be adopted in the case of large databases where the number of authors is also vast. To overcome this shortcoming another column is added which consist of author affiliation and the sorting command is given to that particular list generated by the BibExcel that consist of author name and affiliation. The result is obtained and the list of top 25 most prolific author is given in Table 5.8.

Kumar, A. of Norwegian University of Life Sciences topped the list with 173 records followed by Kumar, S. of Riverine Ecology and Fisheries Division, ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal with 120 records. Singh, S. of Indian Council of Agricultural Research-Central Research Institute for Dryland Agriculture, Hyderabad, India (96 records) is in the third position.

The most prolific Indian authors are those who does their research inside India and contributed to the research world. The list of top ten authors in India is given in the following Table 5.9. Table 5.10 shows the year wise distribution of productivity of authors.

Table 5.8 Top 25 Most Prolific Authors in the Research Area across the World

Sl. No.	Name of Author	No. of Documents/ Records	Affiliation
1	Kumar, A.	173	Department of International Environment and Development Studies (Noragric), Norwegian University of Life Sciences (NMBU), PO Box 5003, Ã…s, 1432, Norway
2	Kumar, S.	120	Riverine Ecology and Fisheries Division, ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal 700120, India; Aquatic Environment Management College of Fisheries, G. B. Pant University of Agriculture and Technology, U.S. Nagar, Pantnagar, Uttarakhand 263145, India
3	Singh, S.	96	Indian Council of Agricultural Research-Central Research Institute for Dryland Agriculture, Hyderabad, India
4	Singh, A.K.	90	Department of Agricultural Meteorology, Anand Agricultural University, Anand, Gujarat 388 110, India; Punjab Agriculture University, Ludhiana, Punjab, India
5	Kumar, R.	90	Symbiosis International University, India
6	Ghosh, S.	90	Nansen Environmental Research Centre (India), Kochi, Kerala 682016, India
7	Singh, A.	88	Institute of Economic Growth, University of Delhi EnclaveDelhi, India; Morrison School of Agribusiness, Arizona State University, W.P. Carey School of Business, 235M Santan Hall, 7231 E Sonoran Arroyo Mall, Mesa, AZ 85212, United States
8	Kumar, P.	78	IIT Bombay, India; CSRE Department, IIT Bombay, India

Sl. No.	Name of Author	No. of Documents/ Records	Affiliation
9	Singh, R.	69	Germplasm Evaluation Division, ICAR-National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi, 110012, India; Crop Protection Division, ICAR-National Rice Research Institute, Cuttack, India; Division of Vegetable Improvement, ICAR-Indian Institute of Vegetable Research, Varanasi, India; Division of Plant Pathology, ICAR-Indian Agricultural Research Institute, New Delhi, India; Department of Agriculture, Cooperation and Farmersâ€™ Welfare, Ministry of Agriculture and Farmersâ€™ Welfare, New Delhi, India
10	Mohanty, U.C.	68	ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India
11	Kumar, M.	62	Department of Mathematics, School of Advanced Sciences, VIT University, Vellore, 632014, India
12	Das, S.	57	Department of Environmental Studies, University of Delhi, New Delhi, Delhi, India; School of Environmental Sciences, Babasaheb Bhimrao Ambedkar University, Lucknow, UP, India; Department of Zoology and Environmental Sciences, Gurukula Kangri Vishwavidyalaya, Haridwar, Uttrakhand, India; Department of Environmental Science, Babasaheb Bhimrao Ambedkar University, Lucknow, UP, India; Department of Environmental Science, School of Earth Sciences, Central University of Rajasthan, Ajmer, Rajasthan, India; Department of Environmental Science, School of Environmental Sciences, Babasaheb Bhimrao Ambedkar University, Lucknow, UP, India

Sl. No.	Name of Author	No. of Documents/ Records	Affiliation
13	Kumar, V.	54	Indian Institute of Forest Management, Bhopal, 462 003, India; Centre for Climate Change Studies, Indian Institute of Forest Management, Bhopal, 462 003, India; Indian Institute of Remote Sensing, Dehradun, 248 001, India; School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, 110 067, India; Indian Space Research Organisation, Bengaluru, 560 094, India
14	Sharma, S.	50	Political Science, Linnaeus University, Sweden; Criminal Justice, University of Central Missouri, United States
15	Goswami, B.N.	50	Political Science, Linnaeus University, Sweden; Criminal Justice, University of Central Missouri, United States
16	Gupta, A.K.	49	Lecturer of Politics and International Relations, University of the Sunshine Coast, Austria
17	Singh, S.K.	48	College of Business and Economics, Aksum University, Ethiopia
18	Ravindranath, N.H.	48	Centre for Climate Change and Sustainability Studies, School of Habitat Studies, Tata Institute of Social Sciences (TISS), Mumbai, India, India; Asia-Pacific Rural and Agricultural Credit Association (APRACA), Bangkok, Thailand, Thailand; Department of Humanities and Social Sciences, Indian Institute of Technology Tirupati, Tirupati, India, India
19	Dash, S.K.	46	International Maize and Wheat Improvement Center (CIMMYT), El Batan, Mexico; International Maize and Wheat Improvement Center (CIMMYT), New Delhi, India; CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS), Borlaug Institute for South Asia (BISA), New Delhi, India; International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya; Socioeconomics

Sl. No.	Name of Author	No. of Documents/ Records	Affiliation
			Program, International Maize and Wheat Improvement Center (CIMMYT), El Batan, Mexico
20	Singh, R.P.	43	International Maize and Wheat Improvement Center (CIMMYT), El Batan, Mexico; International Maize and Wheat Improvement Center (CIMMYT), New Delhi, India; CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS), Borlaug Institute for South Asia (BISA), New Delhi, India; International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya; Socioeconomics Program, International Maize and Wheat Improvement Center (CIMMYT), El Batan, Mexico
21	Dimri, A.P.	43	Lecturer of Politics and International Relations, University of the Sunshine Coast, Austria
22	Dadhwal, V.K.	43	Carbon Sequestration Center, The Ohio State University, Columbus, OH, United States
23	Saha, S.K.	39	International Water Management Institute (IWMI), New Delhi, India; Indian Council of Agricultural Research (ICAR), New Delhi, India; Central Research Institute for Dryland Agriculture (ICAR), Hyderabad, India
24	Singh, N.	39	International Water Management Institute (IWMI), New Delhi, India; Indian Council of Agricultural Research (ICAR), New Delhi, India; Central Research Institute for Dryland Agriculture (ICAR), Hyderabad, India

Sl. No.	Name of Author	No. of Documents/ Records	Affiliation
25	Mishra, A.	39	International Water Management Institute (IWMI), New Delhi, India; Indian Council of Agricultural Research (ICAR), New Delhi, India; Central Research Institute for Dryland Agriculture (ICAR), Hyderabad, India

Table 5.9 Top 10 Most Prolific Authors in India

Sl. No.	Name of Author	No. of Documents/ Records	Affiliation
1	Kumar, S.	120	Riverine Ecology and Fisheries Division, ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal 700120, India; Aquatic Environment Management College of Fisheries, G. B. Pant University of Agriculture and Technology, U.S. Nagar, Pantnagar, Uttarakhand 263145, India
2	Singh, S.	96	Indian Council of Agricultural Research-Central Research Institute for Dryland Agriculture, Hyderabad, India
3	Singh, A.K.	90	Department of Agricultural Meteorology, Anand Agricultural University, Anand, Gujarat 388 110, India; Punjab Agriculture University, Ludhiana, Punjab, India

Sl. No.	Name of Author	No. of Documents/ Records	Affiliation
4	Kumar, R.	90	Symbiosis International University, India
5	Ghosh, S.	90	Nansen Environmental Research Centre (India), Kochi, Kerala 682016, India
6	Kumar, P.	78	IIT Bombay, India; CSRE Department, IIT Bombay, India
7	Singh, R.	69	Germplasm Evaluation Division, ICAR-National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi, 110012, India; Crop Protection Division, ICAR-National Rice Research Institute, Cuttack, India; Division of Vegetable Improvement, ICAR-Indian Institute of Vegetable Research, Varanasi, India; Division of Plant Pathology, ICAR-Indian Agricultural Research Institute, New Delhi, India; Department of Agriculture, Cooperation and Farmersâ€™ Welfare, Ministry of Agriculture and Farmersâ€™ Welfare, New Delhi, India
8	Mohanty, U.C.	68	ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India
9	Kumar, M.	62	Department of Mathematics, School of Advanced Sciences, VIT University, Vellore, 632014, India

Sl. No.	Name of Author	No. of Documents/ Records	Affiliation
10	Das, S.	57	Department of Environmental Studies, University of Delhi, New Delhi, Delhi, India; School of Environmental Sciences, Babasaheb Bhimrao Ambedkar University, Lucknow, UP, India; Department of Zoology and Environmental Sciences, Gurukula Kangri Vishwavidyalaya, Haridwar, Uttrakhand, India; Department of Environmental Science, Babasaheb Bhimrao Ambedkar University, Lucknow, UP, India; Department of Environmental Science, School of Earth Sciences, Central University of Rajasthan, Ajmer, Rajasthan, India; Department of Environmental Science, School of Environmental Sciences, Babasaheb Bhimrao Ambedkar University, Lucknow, UP, India

Table 5.10 Year Wise Distribution of Productivity of Authors

Sl. No.	Author Name	Years														
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Grand Total
1	Kumar, A.	-	1	2	1	4	5	7	13	8	30	28	30	19	25	173
2	Kumar, S.	-	-	1	1	4	7	2	7	6	12	16	32	18	14	120
3	Singh, S.	-	2	3	3	6	1	1	4	7	11	10	16	16	16	96
4	Singh, A.K.	2	3	-	-	1	1	3	5	2	9	25	17	12	10	90

Sl. No.	Author Name	Years														Grand Total
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
5	Kumar, R.	1	3	5	-	3	2	5	4	7	11	6	21	5	17	90
6	Ghosh, S.	-	1	1	4	5	7	5	5	7	11	10	13	5	16	90
7	Singh, A.	4	-	-	-	1	6	6	10	8	7	7	16	10	13	88
8	Kumar, P.	-	-	1	-	-	2	2	1	10	11	11	10	14	16	78
9	Singh, R.	-	1	2	1	-	2	1	4	5	9	8	11	10	15	69
10	Mohanty, U.C.	2	-	5	1	2	3	-	5	11	10	6	12	4	7	68
11	Kumar, M.	-	1	-	-	4	-	4	3	2	6	8	11	12	11	62
12	Das, S.	2	-	3	-	4	1	3	4	2	8	9	7	5	9	57
13	Kumar, V.	-	1	1	3	-	1	2	6	5	7	2	10	4	12	54
14	Sharma, S.	-	3	-	-	-	3	-	1	9	3	6	8	8	9	50
15	Goswami, B.N.	-	3	-	2	2	6	4	5	4	5	8	4	6	1	50

5.1.8 Authorship Pattern

The authorship pattern is demonstrated in Table 5.11. It is evident from the table that about 89.91% of the papers are multi authored. Only 10.09 % of the papers are single authored. Highest number of papers are two authored papers (3195 papers, 23.07%) followed by three authored (21.62%), four authored (16.13%) and five authored (10.57%) papers. Remaining 18.52% of papers are contributed by six or more authors. Six papers had more than 400 authors and the document with highest number of author consisted of 469 authors.

Table 5.11 Authorship Pattern

No. of Authors	No. of Records (Article Frequency)	Percentage	Cumulative Percentage
1	1397	10.09	10.09
2	3195	23.07	33.16
3	2994	21.62	54.78
4	2234	16.13	70.91
5	1464	10.57	81.48
6	898	6.48	87.96
7	527	3.81	91.77
8	372	2.69	94.45
9	223	1.61	96.06
10	143	1.03	97.10
11	118	0.85	97.95
12	77	0.56	98.51
13	56	0.40	98.91
14	30	0.22	99.13
15	17	0.12	99.25
16	20	0.14	99.39

No. of Authors	No. of Records (Article Frequency)	Percentage	Cumulative Percentage
17	14	0.10	99.49
18	11	0.08	99.57
19	6	0.04	99.62
20	14	0.10	99.72
21	4	0.03	99.75
22	2	0.01	99.76
23	3	0.02	99.78
26	1	0.01	99.79
27	1	0.01	99.80
28	1	0.01	99.81
31	2	0.01	99.82
32	1	0.01	99.83
34	1	0.01	99.83
39	1	0.01	99.84
40	3	0.02	99.86
48	3	0.02	99.88
52	1	0.01	99.89
62	1	0.01	99.90
76	1	0.01	99.91
84	3	0.02	99.93
87	2	0.01	99.94
118	1	0.01	99.95
370	1	0.01	99.96
423	2	0.01	99.97
447	2	0.01	99.99
468	1	0.01	99.99
469	1	0.01	100.00
Total	13849	100	100.00

5.1.9 Collaborative Coefficient

The Table 5.12 gives the collaborative coefficient of the publications which indicates single authored, two, three, four, five and more than five authored publications. The corresponding collaborative coefficient is provided in the last column. The values showed a fluctuating pattern in the initial years which increased gradually and reached the highest point in the year 2017. The mean value of the collaborative coefficient is 0.600 which indicates the domination of multi authored publications.

Table 5.12 Collaborative Coefficient

Sl. No.	Year	No. of Authors						
		1	2	3	4	5	>5	CC
1	2005	26	60	56	25	12	16	0.559
2	2006	46	62	54	42	22	36	0.558
3	2007	48	109	71	64	26	53	0.579
4	2008	69	96	91	47	23	47	0.540
5	2009	98	153	176	104	54	101	0.582
6	2010	98	190	168	121	65	74	0.575
7	2011	86	166	136	112	59	141	0.603
8	2012	102	200	147	154	103	133	0.604
9	2013	97	247	275	198	144	180	0.631
10	2014	158	340	298	285	160	326	0.627
11	2015	166	401	340	231	188	330	0.619
12	2016	146	453	395	289	223	372	0.636
13	2017	123	318	387	261	178	350	0.647
14	2018	134	400	400	300	207	378	0.644
				Mean				0.600

5.1.10 Degree of Collaboration

The degree of collaboration is given in Table 5.13. The table consist of details of single authored, two, three, four, five and more than five authored publications. The degree of collaboration is calculated in the last column. The lowest value was found in the year 2006 and 2008. 2018 saw the maximum value in degree of collaboration. The mean value is found to be 0.88, which indicates the governance of collaborative research in the field of climate change studies in Indian context.

Table 5.13 Degree of Collaboration

Sl. No.	Year	No. of Authors						
		1	2	3	4	5	>5	DC=N_m/(N_m+N_s)
1	2005	26	60	56	25	12	16	0.87
2	2006	46	62	54	42	22	36	0.82
3	2007	48	109	71	64	26	53	0.87
4	2008	69	96	91	47	23	47	0.82
5	2009	98	153	176	104	54	101	0.86
6	2010	98	190	168	121	65	74	0.86
7	2011	86	166	136	112	59	141	0.88
8	2012	102	200	147	154	103	133	0.88
9	2013	97	247	275	198	144	180	0.91
10	2014	158	340	298	285	160	326	0.90
11	2015	166	401	340	231	188	330	0.90
12	2016	146	453	395	289	223	372	0.92
13	2017	123	318	387	261	178	350	0.92
14	2018	134	400	400	300	207	378	0.93
Mean								0.88

5.1.11 Collaboration Index

The collaboration index calculated is presented in Table 5.14. This parameter gives the direct measurement of the collaboration between the researchers on scientific projects and are often measured by both the quantity and the quality of the resultant peer-reviewed publications. The calculation of collaboration index gave an average value of CI between three and four which indicates that the number of members in the research team falls between three to four in the area of climate change studies in Indian context.

Table 5.14 Collaboration Index (CI)

Year	No. of Multi Authored Papers	Total No. of Authors	CI
2005	169	579	3.43
2006	216	811	3.75
2007	323	1154	3.57
2008	304	1018	3.35
2009	588	2176	3.70
2010	618	2185	3.54
2011	614	2334	3.80
2012	737	2835	3.85
2013	1044	4066	3.89
2014	1409	5611	3.98
2015	1490	5893	3.96
2016	1732	6715	3.88
2017	1494	6165	4.13
2018	1685	6874	4.08
	Mean		3.78

5.1.12 Co-authorship Index (CAI)

The following formula is used for the computation of co-authorship index.

$$CAI = \frac{Nij/Nio}{Noj/Noo} X\ 100$$

The Co-authorship Index (CAI) calculated is summarized in Table 5.15. Co-authorship index of single author, two author, three author, four author, five author and more than five author is computed for the period from 2005 to 2018. For the single author, two author and three author it was showing a decreasing trend while for the next three the analysis showed an increasing trend.

Table 5.15 Co-authorship Index (CAI) or Pattern of Co-authorship

Sl. No.	Year	CAI (Single author)	CAI (Two author)	CAI (Three author)	CAI (Four author)	CAI (Five author)	CAI (More than five author)
1	2005	131.90	133.09	132.56	79.35	58.09	44.70
2	2006	173.69	102.36	95.14	99.21	79.27	74.85
3	2007	127.99	127.08	88.34	106.76	66.16	77.82
4	2008	183.00	111.33	112.61	77.98	58.21	68.64
5	2009	141.32	96.47	118.43	93.83	74.31	80.20
6	2010	135.40	114.78	108.31	104.59	85.70	56.30
7	2011	121.54	102.58	89.68	99.02	79.57	109.73
8	2012	120.27	103.11	80.87	113.60	115.89	86.35
9	2013	84.10	93.64	111.25	107.40	119.14	85.94
10	2014	99.75	93.85	87.78	112.56	96.39	113.33
11	2015	99.17	104.74	94.77	86.33	107.17	108.55
12	2016	76.91	104.34	97.09	95.24	112.09	107.90
13	2017	75.25	85.07	110.47	99.90	103.92	117.91
14	2018	72.88	95.12	101.50	102.07	107.43	113.20

5.1.13 Most Influential Research Areas

The field of climate change is a very broad field comprised of many smaller specialty areas. Each of these specialty areas has been strengthened over the years by research studies deliberated to ascertain or contradict different theories and hypotheses that interest scientists throughout the world. Therefore the analysis of the most influential research area will throw light to the development of prevailing areas of the studies as well as evolution of new emerging fields. The data thus obtained is summarized and given in Table 5.16. 'Meteorology & Atmospheric Sciences' is the area that dominated with 1723 records followed by 'Environmental Sciences & Ecology', 'Geology', 'Water Resources' and 'Science & Technology - Other Topics' in the fifth position. The nature of the topic chosen 'Climate Change in Indian context- a Scientiometric Analysis' is an interdisciplinary topic and covers a wide array of research disciplines such as Agriculture, Engineering, Remote Sensing, Marine & Freshwater Biology, Astronomy & Astrophysics, Development Studies and so on.

Table 5.16 List of Top 25 Most Influential Research Areas

Sl. No.	Name of Research Areas	No. of Records Published
1	Meteorology & Atmospheric Sciences	1723
2	Environmental Sciences & Ecology	1489
3	Geology	1058
4	Water Resources	563
5	Science & Technology - Other Topics	522
6	Agriculture	384
7	Engineering	362
8	Physical Geography	360

Sl. No.	Name of Research Areas	No. of Records Published
9	Energy & Fuels	149
10	Geochemistry & Geophysics	149
11	Remote Sensing	117
12	Business & Economics	109
13	Paleontology	80
14	Imaging Science & Photographic Technology	73
15	Plant Sciences	70
16	Biodiversity & Conservation	68
17	Forestry	66
18	Marine & Freshwater Biology	63
19	Construction & Building Technology	50
20	Development Studies	49
21	Geography	48
22	Oceanography	48
23	Astronomy & Astrophysics	43
24	Public, Environmental & Occupational Health	38
25	Chemistry	32

5.1.14 Most Productive Keywords

The list of 25 most productive keywords used and the frequency of usage is presented in Table 5.17. Further analysis of the number of keyword in each document, it is revealed that 6148 documents have 1 to 10 keywords, 2276 have 11 to 20 keywords, 1879 documents have 21 to 30 keywords and the rest have more than that.

Since the topic is dealing with ‘Climate Change Studies in the Indian Context’, the keyword ‘India’ topped the list. This is followed by ‘Climate Change’. The word ‘Monsoon’ is in the third position followed by the word ‘Rainfall’ since the climate changing is driving India’s climate more disordered and unpredictable. Extreme precipitation events are on the

rise in India, driven by warming temperatures and changes in the monsoon. The term "Indian Ocean' is in the fifth position and gives indication that researchers are focusing on the ocean events such as sea surface temperatures, frequency of occurrence of severe cyclones, and Indian Ocean Dipole (IOD) changes and their aftereffects in the Indian subcontinent. The word 'Rain' is in the sixth position which implies the main source of water and associated with major four climatological seasons. 'Remote sensing' in the seventh position indicates the vast research work that is done towards the climate changes focused on remote sensing and its allied areas. The 'Himalayas' have a profound effect on the climate of the Indian subcontinent as they prevent cold, dry winds from blowing south into the subcontinent, which keeps South Asia much warmer than corresponding temperate regions in the other continents. The impacts of climate change in the Himalayas include melting glaciers, erratic and unpredictable weather conditions, changing rainfall patterns, and increasing temperatures which are of great interest of Indian researchers which contributes to the research world in huge. Thus the keyword 'Himalayas' occupying in the eighth position can be justified. The ninth position is occupied by the keyword 'Asia' since India is the part of Asian continent and the studies focused on Asia's climate needs the mentioning about India's climate and climate change. 'Atmospheric Thermodynamics' needs to be mentioned as this is an emerging research area where many researchers are focusing due to the climate change and its possible impacts. Thus it is in the tenth position of the list. 'Global warming', 'Seasonal variation', 'Precipitation', 'Temperature', 'Climate modelling', Climate models' 'Drought' are the other important keywords in the list which are linked to the topic of interest 'Climate Change Studies in the Indian Context'.

Table 5.17 List of Top 25 Most Productive Keywords

Sl. No.	Keywords used	Frequency
1	India	6012
2	Climate Change	5950
3	Monsoon	1548
4	Rainfall	1067
5	Indian Ocean	1041
6	Rain	1002
7	Remote Sensing	790
8	Himalayas	780
9	Asia	689
10	Atmospheric Thermodynamics	667
11	Global Warming	658
12	Seasonal Variation	653
13	Article	649
14	South Asia	648
15	Climatology	630
16	Precipitation	606
17	Temperature	576
18	Climate Modelling	571
19	Eurasia	566
20	Climate	559
21	Summer	552
22	Agriculture	537
23	Climate Models	537
24	Sea Surface Temperature	490
25	Drought	488

5.1.15 Most Productive Countries

The list of 20 most productive countries that produces top number of research papers in the area of climate change in Indian context is given in the Table 5.18. Since the study is done with respect to Indian context, most number of documents, 79 % are published from India.

Table 5.18 List of 20 Most Productive Countries that Produces Top Number of Research Papers

Sl. No.	Countries	No. of Records Published	Percentage
1	India	10655	76.86
2	United States	1260	9.09
3	Germany	619	4.47
4	UK	468	3.38
5	Australia	376	2.71
6	Japan	370	2.67
7	France	370	2.67
8	China	331	2.39
9	Canada	240	1.73
10	Netherlands	235	1.70
11	Switzerland	193	1.39
12	Italy	177	1.28
13	Sweden	166	1.20
14	South Korea	132	0.95
15	Norway	110	0.79
16	Nepal	107	0.77
17	Austria	106	0.76
18	South Africa	76	0.55
19	Spain	74	0.53
20	Singapore	69	0.50

The Unites States of America occupied the second position in the list with 9.09%. This is followed by Germany with 4.47% of documents. United Kingdom and Australia occupied fourth and fifth positions with 3.38 and 2.71% of publications. This gives indication that apart from Indian researchers, researchers from USA, Germany, UK and Australia are also doing research in Indian context of climate change. The research done by the foreign countries can be direct or indirect, which means that the studies is directly done on the climate change in India or it is done as the part of their studies in global climate change or issues associated with climate change occurring globally. The point locations of most productive countries is shown in Figure 5.4.

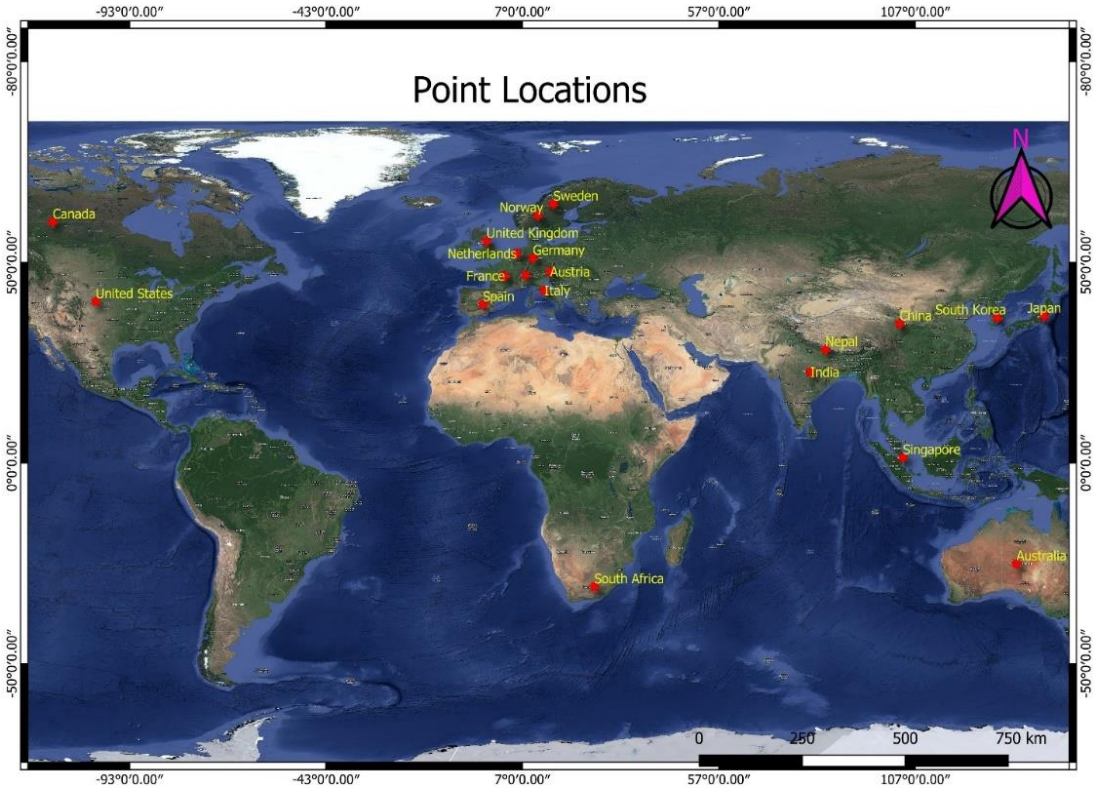


Figure 5.4 Point Locations of 20 Most Productive Countries that Produces Top Number of Research Papers

Relative Citation Index:

$$\text{Relative Citation Index (RCI)} = \frac{\text{Citation \%}}{\text{Publication \%}}$$

The country-wise number of citations in the same time period and the Relative Citation Index (RCI) are also shown in Table 5.19.

Table 5.19 List of Countries Based on Relative Citation Index

Sl. No.	Countries	No. of Records Published	No. of Citations	Relative Citation Index
1	India	10655	195474	18.35
2	United States	1260	31453	24.96
3	USA	1258	33936	26.98
4	Germany	619	16075	25.97
5	United Kingdom	468	9457	20.21
6	UK	396	11401	28.79
7	Australia	376	8389	22.31
8	Japan	370	10097	27.29
9	France	370	11106	30.02
10	China	331	7281	22.00
11	Peoples R China	310	7274	23.46
12	Canada	240	5498	22.91
13	Netherlands	235	6422	27.33
14	Switzerland	193	4254	22.04
15	Italy	177	4494	25.39
16	Sweden	166	3025	18.22
17	South Korea	132	3279	24.84
18	Norway	110	2780	25.27
19	Nepal	107	1978	18.49
20	Austria	106	2620	24.72

The Relative Citation Index is maximum for France. The RCI value of 30.02 for France is obtained from 11,106 citations got from 370 documents. This is followed by UK with an RCI value of 11,401 citations from 396 documents. This values are closely followed by Netherlands, Japan and USA. Though India has published 10655 documents and obtained 1,95,474 citations altogether for this much documents, the average number of citations each document obtained is comparatively less when equalled to these countries. Thus the RCI value of India dropped to 18.35 against the maximum value of 30.02. This suggest that India need to publish research papers which are high impacted valuable content papers rather than concentrating on the number of papers published in each year.

5.1.16 Most Productive Organisations

In order to identify the most productive institutes in India the original list of first 100 institutes obtained from BibExcel is manually analysed to identify the top organisations that yield maximum contributions in the subject area and the following Table 5.20 is obtained.

Table 5.20 Top 20 Most Productive Institutes in India

Sl. No.	Name of Institutes	No. of Records
1	Indian Institute of Science, Bangalore 560012, Karnataka, India	418
2	Indian Institute of Tropical Meteorology, Pune, 411008, India	397
3	Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India	159
4	Jawaharlal Nehru University, New Delhi 110067, India	129
5	Indian Inst Technol, Bombay 400076, Maharashtra, India	85
6	Phys Res Lab, Ahmadabad 380009, Gujarat, India	79
7	Indian Meteorol Dept, New Delhi 110003, India	76

Sl. No.	Name of Institutes	No. of Records
8	India Meteorological Department, Pune, India	64
9	Indian Inst Technol Delhi, New Delhi 110016, India	63
10	Banaras Hindu Univ, Varanasi 221005, Uttar Pradesh, India	52
11	Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur, 721302, India	39
12	Wadia Inst Himalayan Geol, Dehra Dun 248001, Uttar Pradesh, India	38
13	Natl Ctr Medium Range Weather Forecasting, Noida, India	32
14	Indian Agr Res Inst, Div Environm Sci, New Delhi 110012, India	29
15	Int Crops Res Inst Semi Arid Trop, Patancheru 502324, Andhra Pradesh, India	24
16	Cent Res Inst Dryland Agr, Hyderabad 500059, Andhra Pradesh, India	23
17	Indian Inst Technol, Dept Civil Engn, Kanpur 208016, Uttar Pradesh, India	21
18	Vikram Sarabhai Space Ctr, Space Phys Lab, Trivandrum 695022, Kerala, India	17
19	Natl Inst Hydrol, Roorkee 247667, Uttar Pradesh, India	16
20	Department of Meteorology and Oceanography, Andhra University, Visakhapatnam, India	16

From the above table it can be understood that Indian Institute of Science, Bangalore, is the most productive organisation in India. But IISC, Banglore is publishing papers pertaining to climate change from different subdivisions of IISc such as Department of Civil Engineering, Ctr Ecol Sci, Divecha Centre for Climate Change, Ctr Atmospher & Ocean Sci, Ctr Sustainable Technol, Ctr Earth Sci atc. This on the other hand is counted as separate entities by BibExcel. Hence there is a need to do a manual analysis so that all subdivisions are considered under one main organisation which is Indian Institute of Science, Bangalore, Karnataka. The total number of records thus contributed by IISc, Bangalore thus became 418 and IISC topped the list.

The second most productive institute is Indian Institute of Tropical Meteorology, Pune, 411008, India with 397 documents and the third position is occupied by Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow. Jawaharlal Nehru University, New Delhi, India and Indian Inst Technol, Bombay, Maharashtra, India are in fourth and fifth positions with 129 and 85 published records.

5.1.17 Most Cited Reference

This analysis is done by analysing the field tag 'CD' given by WoS and SCOPUS databases. The list of references of each paper is prepared in BibExcel software by considering the field tag 'CD' and then the references are identified and sorted according to the number of times they are appearing in the reference list. Table 5.21 gives the list of twenty five most cited reference, the name of the paper and the number of times that reference is cited by several authors.

'Increasing Trend of Extreme Rain Events over India in a Warming Environment' by Goswami BN published in the year 2006 was cited 285 times and topped the list. 'The NCEP/NCAR 40-Year Reanalysis Project' by Kalnay E ranked second place was cited 279 times. The title of the record and author of the document is respectively. 'High resolution daily gridded rainfall data for the Indian region: Analysis of break and active monsoon spells' by Rajeevan M and 'High-resolution climate change scenarios for India for the 21st century' by Kumar K R, both records published in the year 2006 occupied the third and fourth position with more than 200 times citations in the reference tag. These documents are referred more times and are cited due to their impact of their work and the importance in the concerned research areas. It is therefore concluded that the most cited reference analysis gives the list of documents which are most impactful under a certain research area in which the bibliometric analysis is done.

Table 5.21 List of Top 25 Most Cited References

Sl. No.	Name of the Document	Name of Reference (Analysis of CD tag)	No. of Times Reference Used
1	Increasing Trend of Extreme Rain Events Over India in a Warming Environment	Goswami BN, 2006, V314, P1442, Science, Doi 10.1126/Science.1132027	285
2	The NCEP/NCAR 40-Year Reanalysis Project	Kalnay E, 1996, V77, P437, B Am Meteorol Soc, Doi 10.1175/1520-0477(1996)077<0437:Tnyrp>2.0.Co;2	279
3	High resolution daily gridded rainfall data for the Indian region: Analysis of break and active monsoon spells	Rajeevan M, 2006, V91, P296, Curr Sci India	208
4	High-resolution climate change scenarios for India for the 21st century	Kumar KR, 2006, V90, P334, Curr Sci India	204
5	Atmospheric brown clouds: Impacts on South Asian climate and hydrological cycle	Ramanathan V, 2005, V102, P5326, P Natl Acad Sci Usa, Doi 10.1073/Pnas.0500656102	187
6	Monsoons: Processes, predictability, and the prospects for prediction	Webster PJ, 1998, V103, P14451, J Geophys Res-Oceans, Doi 10.1029/97Jc02719	179
7	An Overview of CMIP5 and the Experiment Design	Taylor KE, 2012, V93, P485, B Am Meteorol Soc, Doi 10.1175/Bams-D-11-00094.1	170
8	A Dipole Mode In The Tropical Indian Ocean	Saji, N.H., Goswami, B.N., Vinayachandran, P.N., Yamagata, T., A Dipole Mode In The Tropical Indian Ocean (1999) Nature, 401, Pp. 360-363	168
9	On the Weakening Relationship Between the Indian Monsoon and ENSO	Kumar KK, 1999, V284, P2156, Science, Doi 10.1126/Science.284.5423.2156	149

Sl. No.	Name of the Document	Name of Reference (Analysis of CD tag)	No. of Times Reference Used
10	An improved method of constructing a database of monthly climate observations and associated high-resolution grids	Mitchell TD, 2005, V25, P693, Int J Climatol, Doi 10.1002/Joc.1181	121
11	Climate change and the South Asian summer monsoon	Turner AG, 2012, V2, P587, Nat Clim Change, Doi 10.1038/Nclimate1495	117
12	Anthropogenic aerosols and the weakening of the South Asian summer monsoon	Bollasina MA, 2011, V334, P502, Science, Doi 10.1126/Science.1204994	114
13	Increasing Trend Of Extreme Rain Events Over India In A Warming Environment	Goswami, B.N., Venugopal, V., Sengupta, D., Madhusoodanan, M.S., Xavier, P.K., Increasing Trend Of Extreme Rain Events Over India In A Warming Environment (2006) Science, 314, Pp. 1442-1445	112
14	Some evidence of climate change in twentieth-century India	Dash SK, 2007, V85, P299, Climatic Change, Doi 10.1007/S10584-007-9305-9	112
15	Aerosols, Climate, and the Hydrological Cycle	Ramanathan V, 2001, V294, P2119, Science, Doi 10.1126/Science.1064034	109
16	Climate Change Will Affect the Asian Water Towers	Immerzeel WW, 2010, V328, P1382, Science, Doi 10.1126/Science.1183188	107
17	Climate Effects of Black Carbon Aerosols in China and India	Menon S, 2002, V297, P2250, Science, Doi 10.1126/Science.1075159	107

Sl. No.	Name of the Document	Name of Reference (Analysis of CD tag)	No. of Times Reference Used
18	South Asian summer monsoon precipitation variability: Coupled climate model simulations and projections under IPCC AR4	Kripalani RH, 2007, V90, P133, Theor Appl Climatol, Doi 10.1007/S00704-006-0282-0	105
19	Analysis of variability and trends of extreme rainfall events over India using 104 years of gridded daily rainfall data	Rajeevan M, 2008, V35, Geophys Res Lett, Doi 10.1029/2008Gl035143	103
20	The State and Fate of Himalayan Glaciers	Bolch T, 2012, V336, P310, Science, Doi 10.1126/Science.1215828	102
21	Global observed changes in daily climate extremes of temperature and precipitation	Alexander LV, 2006, V111, J Geophys Res-Atmos, Doi 10.1029/2005Jd006290	99
22	The Indian Monsoon and Its Variability	Gadgil S, 2003, V31, P429, Annu Rev Earth Pl Sc, Doi 10.1146/Annurev.Earth.31.100901.141251	97
23	Abrupt changes in the Asian southwest monsoon during the Holocene and their links to the North Atlantic Ocean	Gupta AK, 2003, V421, P354, Nature, Doi 10.1038/Nature01340	96
24	Trends in the rainfall pattern over India	Guhathakurta P, 2008, V28, P1453, Int J Climatol, Doi 10.1002/Joc.1640	91
25	The version-2 global precipitation climatology project (GPCP) monthly precipitation analysis (1979–present)	Adler RF, 2003, V4, P1147, J Hydrometeorol, Doi 10.1175/1525-7541(2003)004<1147:Tvgpcp>2.0.Co	89

5.1.18 Most Cited Publications

Table 5.22 shows the list of top 25 most cited documents. The paper 'Impact of irrigation on the South Asian Summer Monsoon' which was published in 2009 by Saeed et al, topped the list with 1230 citations. 'Extreme weather: World-record rainfalls during tropical cyclone gamede' by Ouetelard, H. et. al., occupied the scond position with 1157 citations.

Table 5.22 List of Top 25 Most Cited Documents

Sl. No.	Title of the Document	Number of times Cited	Authors	Year	Journal Name
1	Impact of irrigation on the South Asian summer monsoon	1230	Saeed, Fahad, Stefan Hagemann, and Daniela Jacob	2009	Geophysical Research Letters
2	Extreme weather: World-record rainfalls during tropical cyclone gamede	1157	Quetelard, H., Bessemoulin, P., Cerveny, R. S., Peterson, T. C., Burton, A., & Boodhoo, Y.	2009	Bulletin of the American Meteorological Society
3	Energetics of lower tropospheric ultra-long waves: A key to intra-seasonal variability of Indian monsoon	1081	Bawiskar, S. M., Chipade, M. D., & Puranik, P. V.	2009	Journal of earth system science
4	Aerosol black carbon radiative forcing at an industrial city in northern India	994	Tripathi, S. N., Sagnik Dey, V. Tare, and S. K. Satheesh	2005	Geophysical Research Letters
5	Persistent volcanic signature observed around Barren Island, Andaman Sea, India	888	Laluraj, C. M., Balachandran, K. K., Sabu, P., & Panampunnayil, S. U.	2006	Marine Geophysical Researches
6	Remote sensing-based inventory of glacial lakes in Sikkim Himalaya: semi-automated approach using satellite data	855	Raj, K. G., Kumar, K. V., & Remya, S. N.	2013	Geomatics, Natural Hazards and Risk

Sl. No.	Title of the Document	Number of times Cited	Authors	Year	Journal Name
7	Optimal Ecological Management Practices (EMPs) for Minimizing the Impact of Climate Change and Watershed Degradation Due to Urbanization	848	Sarma, B., Sarma, A. K., & Singh, V. P.	2013	Water resources management
8	Use of digital elevation models and drainage patterns for locating active faults in the Upper Gangetic Plain, India	845	Bhosle, B., Parkash, B., Awasthi, A. K., & Pati, P.	2009	International Journal of Remote Sensing
9	Do the large carbon isotopic excursions in terrestrial organic matter across Paleocene-Eocene boundary in India indicate intensification of tropical precipitation?	838	Samanta, A., M. K. Bera, Ruby Ghosh, Subir Bera, Timothy Filley, Kanchan Pande, S. S. Rathore, Jyotsana Rai, and A. Sarkar	2013	Palaeogeography, Palaeoclimatology, Palaeoecology
10	Horizontal and vertical structures of the northward-propagating intraseasonal oscillation in the south Asian monsoon region simulated by an intermediate model	767	Drbohlav, Hae-Kyung Lee, and Bin Wang.	2007	Journal of climate
11	The clean energy dilemma in Asia: Is there a way out?	738	Wilbanks, Thomas J.	2008	Eurasian Geography and Economics
12	India and the United States: Grand strategic partnership for a better world	647	Bajpai, K.	2008	South Asian Survey
13	The vulnerability of global cities to climate hazards	646	De Sherbinin, Alex, Andrew Schiller, and Alex Pulsipher	2007	Environment and urbanization
14	Erratum: Impact of climate change on Indian agriculture: A review (Climatic Change (2006) 78, (445-478) DOI: 10.1007/s10584-005-9042-x)	580	Mall, R. K., Singh, R., Gupta, A., Srinivasan, G., & Rathore, L	2006	Climatic change

Sl. No.	Title of the Document	Number of times Cited	Authors	Year	Journal Name
15	Seasonal variation in the major ion chemistry of Pandoh Lake, Mandi District, Himachal Pradesh, India	575	Ramanathan, A. L	2007	Applied Geochemistry
16	The influence of DOC trends on light climate and periphyton biomass in the Ganga River, Varanasi, India	572	Pandey, U	2013	Bulletin of environmental contamination and toxicology
17	A generalized 3-D geological and hydrogeological conceptual model of granite aquifers controlled by single or multiphase weathering	553	Dewandel, B., Lachassagne, P., Wyns, R., Maréchal, J. C., & Krishnamurthy, N. S.	2006	Journal of hydrology
18	Projected impact of climate change on waves at Mumbai High	539	Pentapati, S., Deo, M. C., Kerkar, J., & Vethamony, P.	2015	Proceedings of the Institution of Civil Engineers-Maritime Engineering
19	Land use and land cover analysis in Indian context	527	Roy, P. S., & Giriraj, A.	2008	Journal of Applied sciences
20	Managing extreme natural disasters in coastal areas	527	Kesavan, P. C., & Swaminathan, M. S.	2006	Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences
21	Oceanic and atmospheric influences on the variability of phytoplankton bloom in the Southwestern Indian Ocean	516	Raj, Roshin P., Benny N. Peter, and Dhanya Pushpadas	2010	Journal of Marine Systems
22	Role of air-sea interaction in the long persistence of El NiÃ±o-induced north Indian Ocean warming	500	Du, Yan, Shang-Ping Xie, Gang Huang, and Kaiming Hu.	2009	Journal of Climate

Sl. No.	Title of the Document	Number of times Cited	Authors	Year	Journal Name
23	Development, Malaria and Adaptation to Climate Change: A Case Study from India	498	Garg, A., Dhiman, R. C., Bhattacharya, S., & Shukla, P. R	2009	Environmental management
24	Palaeo-moisture evolution in monsoonal Central Asia during the last 50,000 years	479	Herzschuh, Ulrike	2006	Quaternary Science Reviews
25	Predicting the Distribution Pattern of Small Carnivores in Response to Environmental Factors in the Western Ghats	478	Kalle, Riddhika, Tharmalingam Ramesh, Qamar Qureshi, and Kalyanasundaram Sankar	2013	PLoS One

5.2 Network Analysis

VOSviewer 1.6.16 is the software used for network mapping and cluster analysis. The principle behind the operation of this software is the study based on generating a distance-based visual representation of networks, where each cluster is represented by a specific colour. The cluster consist of nodes which represents the authors (number of articles published by the author), keywords and countries depending upon the area of analysis and the distance between two nodes symbolises the degree of their closeness. Keywords, countries and name of authors were labelled with coloured circles. Each node is a circle and the size of the label and diameter of the circle determines the relevance or 'weight' of the item, may it be a keyword, number of articles published by the author, institution or country. Each node representing the item of question interrelates or connected with other nodes of varied sizes by curved lines of different lengths and thickness (Xie et al., 2020; Yu et al., 2020). Placing the cursor on the top of each node will specifically show the collaboration of item representing that node to other nodes as well as the name of the item, be it an author, country or a keyword, the cluster which it belong to, number of links, total link strength and the number of documents related to the node under consideration. This denote the relevant information of cooperation between the two items under question. Thus with this approach it is useful to illustrate the collaboration between authors, countries, institutes and keywords in addition to study the co-citation network, co-authorship network, bibliographic coupling network, co-occurrence studies etc which can permit us an improved understanding of topic under study(Rajeswari et al., 2021; Xiyang, 2020.).

Creating maps based on network data:

VOSviewer can be used to construct networks of scientific publications, scientific journals, researchers, research organizations, countries, keywords, or terms. Items in these networks can be connected by co-authorship, co-occurrence, citation, bibliographic coupling,

or co-citation links. There are three different methods to generate network maps and express the results. They are network visualization, overlay visualization, density visualization.

Network Visualization

- Used to visualise complex relationships between a huge amount of elements.
- Illuminates relationships between entities

Overlay Visualization

- Allows to classify the items using timescale
- The default colours range from blue (lowest score) to green to yellow (highest score).

Density Visualization

- In item density visualization each point is represented by a colour that specifies the density of items at that point.
- If a point has larger number of items nearby higher will be the density and the colour will be close to yellow

5.2.1 Co-authorship Analysis

Network Visualization

After launching VOSviewer 1.6.16 software the option ‘create’ is selected from the action panel. The option for selecting a map based on bibliographic data is selected from the ‘create map’ window that appears afterwards and ‘next’ command is given. The data source is chosen depending upon the type of database or file format available and the files are uploaded after selecting the required database. The next option comes is to choose the type of analysis and counting method.

Here, co-authorship needs to be analysed first and full counting methodology is adopted. The unit of analysis chosen is ‘authors’. The maximum number of authors per document is kept as 25 owing to the huge database under consideration. The next step is to fix the minimum number of documents and minimum number of citations of an author. The minimum number of documents is kept as five and minimum number of citations of an author is kept as zero. The number of authors who met the selected criteria is 580 and the list of the authors are displayed in the window from which we can exclude the unwanted entries. After clicking ‘finish’ a window appears asking what we wanted to do with the items that are not connected to each other. The option is chosen accordingly and the network mapping file is displayed in the main panel of the VOSviewer.

The total number of authors were 580 and among them 483 authors were connected to each other and the result is shown in Figure 5.5. This 483 items are distributed in 27 clusters and the resultant figure is difficult to interpret. To simplify the resultant co-authorship diagram, it is necessary to reduce the number of clusters. This can be done by updating the cluster size in the analysis bar provided in the action panel. Here the minimum cluster size is given as 50 and the number of clusters is reduced from 27 to 4 as shown in Figure 5.6. All the nodes are distributed in four clusters and are indicated using four colours as shown in the figure. The total number of links formed is 1621 and the total link strength is 3457. Thus it will be easier to interpret the co-authorship analysis results by exporting the cluster list into an MS excel sheet and studying the nature of papers in each cluster.

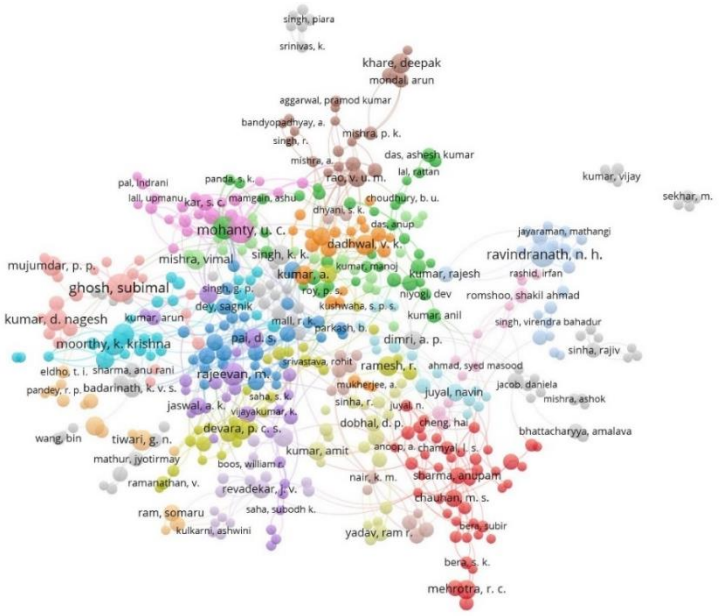


Figure 5.5 The Layout for Co-authorship Analysis Showing 483 Nodes Distributed in 27 Clusters

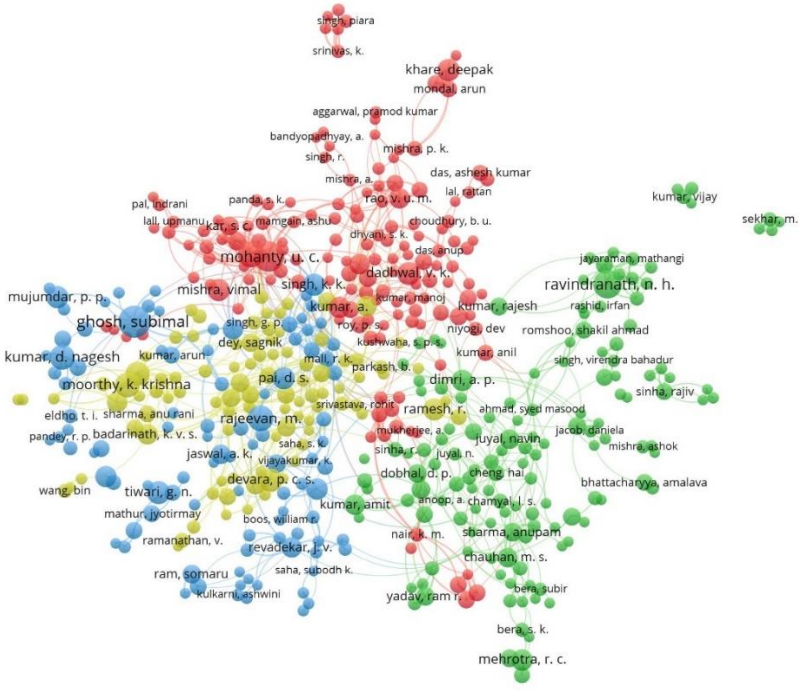


Figure 5.6 The Layout for Co-authorship Analysis Showing 483 Nodes Distributed in 4 Clusters with Nodes in Four Colors

The minimum cluster size is reduced to 50 as shown in the figure 5.6. In order to observe the co-authorship details of each author, an option is available in the action panel. To accomplish this the cursor is pointed in the particular author's name and on right clicking it a

command ‘show item in visualization’ appears. On clicking it the node representing the particular author is enlarged and the co-authorship details of the author under study can be identified easily. This is shown in the Figures 5.7 and 5.8. The co-authorship particulars of author Aggarwal P. K in cluster 1 is identified by the software and is shown in an enlarged mode. The central node denotes the author name and the corresponding curved lines represents the details of researchers who has co-authored with Aggarwal P. K. The cluster 1 of co-authorship analysis contains 149 items, cluster 2 has 140 items, cluster 3 has 99 items while the last one cluster 4 has 95 items. The list of authors with the number of citations in all the four clusters are shown in the Tables 5.23 to 5.26. The detailed study of the records of each cluster will give us the information of what the cluster is all about.

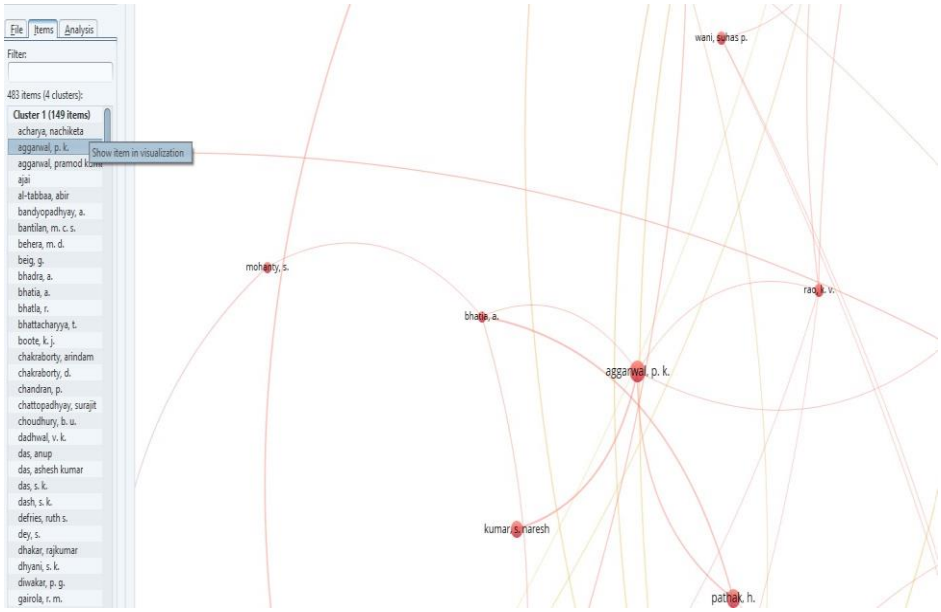


Figure 5.7 The Network Analysis Layout of Co-authorship data of an Author (Aggarwal P. K)

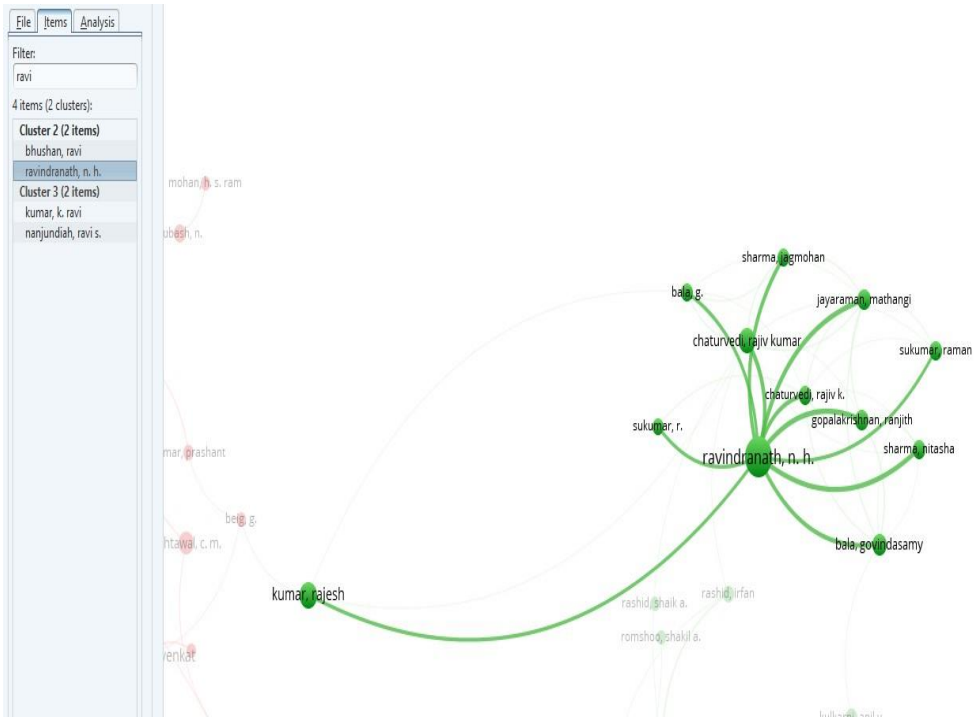


Figure 5.8 An Enlarged View of Co-authorship data of an Author (Ravindranath N H) Showing the Nodes and the Links

Table 5.23 Cluster 1

Sl. No.	Author Name	Number of Citations
1	Dash, S. K.	1177
2	Mohanty, U. C.	922
3	Mishra, Vimal	896
4	Aggarwal, P. K.	576
5	Pathak, H.	571
6	Khare, Deepak	506
7	Niyogi, Dev	484
8	Wada, Yoshihide	479
9	Singh, Vijay p.	450
10	Kumar, A.	407

Table 5.24 Cluster 2

Sl. No.	Author Name	Number of Citations
1	Kumar, Vijay	858
2	Cheng, Hai	710
3	Edwards, R. Lawrence	699
4	Jain, Sharad K.	639
5	Ravindranath, N. H.	620
6	Dimri, A. P.	594
7	Kumar, Rajesh	552
8	Kumar, Pankaj	527
9	Jacob, Daniela	448
10	Sinha, Ashish	428

Table 5.25 Cluster 3

Sl. No.	Author Name	Number of Citations
1	Rajeevan, M.	2363
2	Ghosh, Subimal	1799
3	Goswami, B. N.	1693
4	Pai, D. S.	1039
5	Mujumdar, P. P.	1034
6	Tiwari, G. N.	849
7	Sreejith, O. P.	670
8	Boos, William R.	665
9	Krishnan, R.	630
10	Kumar, D. Nagesh	616

Table 5.26 Cluster 4

Sl. No.	Author Name	Number of Citations
1	Ramanathan, V.	1320
2	Sarin, M. M.	940
3	Ramaswamy, V.	904
4	Moorthy, K. Krishna	898
5	Tripathi, S. N.	840
6	Ming, Yi	748
7	Babu, S. Suresh	735
8	Singh, R. P.	729
9	Holben, B. N.	694
10	Praveen, P. S.	660

Overlay Visualization

The overlay visualization is similar to network visualization except for the fact that a colour gradient is used to denote the nodes (Figure 5.9). The visualization pattern can be changed according to the weights and scores displayed in the options panel.

To denote the colour gradient, a colour bar is shown in the bottom right corner of the visualization. The user has to set the scores or set user defined colours in order to generate the colour bar. The colour bar is shown only if colours are determined by scores of items. The colour bar indicates how scores are mapped to colours.

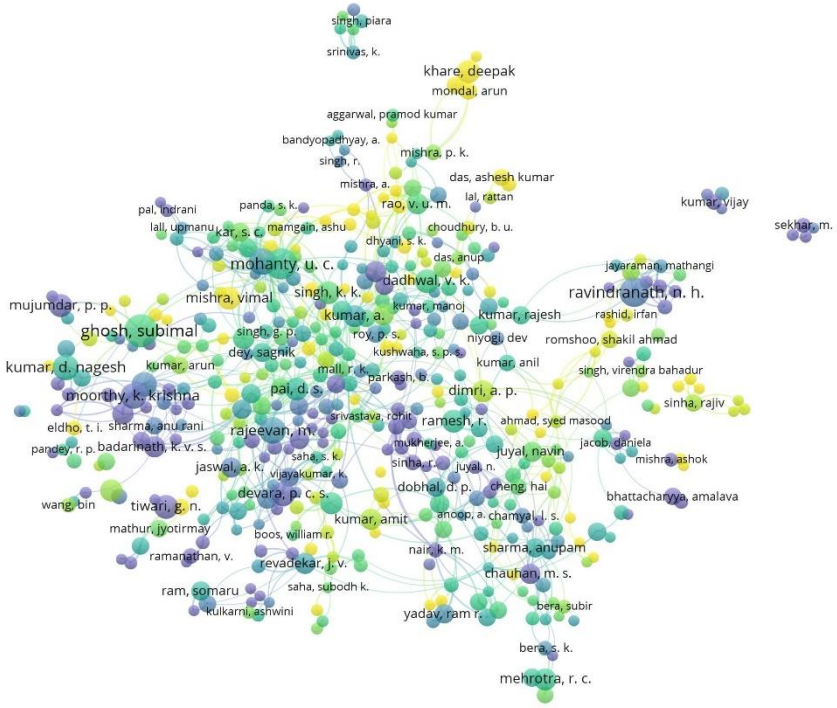


Figure 5.9 Overlay Visualization of Database Denoting Documents with respect to Average Publication Year

The Figure 5.9 shows the co-authorship distribution of database records according to the average publication year. The default colours range from blue (lowest score) to green to yellow (highest score). The blue colour denotes relatively older papers (here 2012) and the yellow colour indicates relatively new papers (here 2016).

The user can place the cursor on top of the required node and see the range of publication years chosen by a specific author, be it old classical papers or the new ones of the research area under study.

Density Visualization

There are two types of density visualization. They are item density visualization and cluster density visualization. The desired type of density visualization can be selected from the options panel according to the requirement. In item density visualization each point is represented by a colour that specifies the density of items at that point. The colour ranges from blue to green and then to yellow. If a point has larger number of items nearby higher will be

the density and the colour will be close to yellow. Similarly if a point has smaller number of items nearby smaller will be the density and the colour will be close to blue. The item density visualization of the co-authorship network is shown in Figure 5.10.

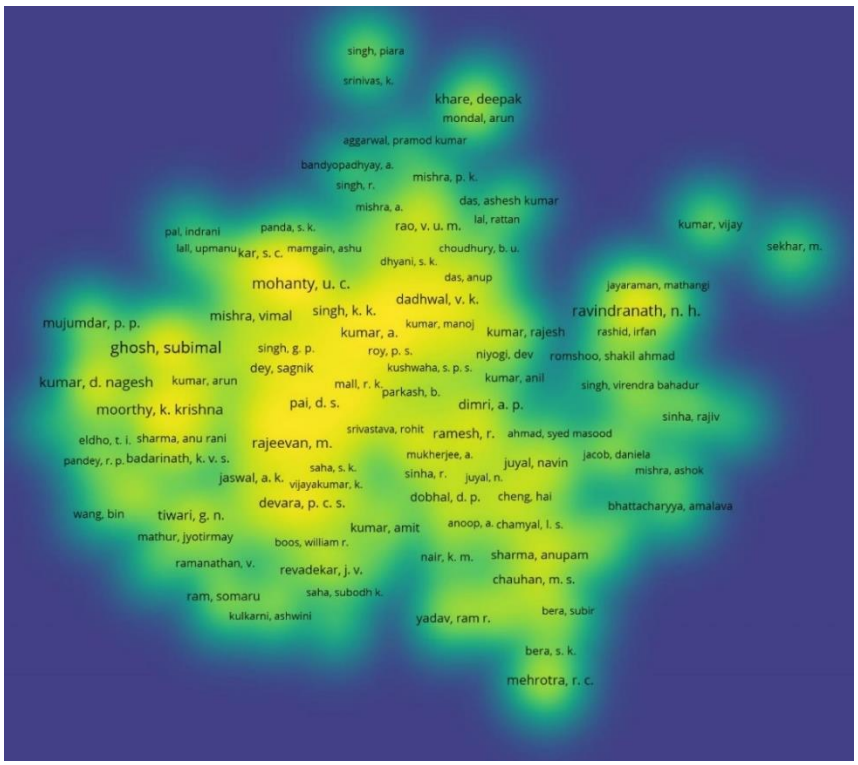


Figure 5.10 Item Density Visualization of Database Denoting Co-authorship Network

5.2.2 Co-occurrence of Keywords

Co-occurrence is a concept which refers to the common presence, frequency of occurrence, and close proximity of similar keywords in several papers. Co-occurrence of keywords analysis include keywords that are similar to each other and based on the same topic, but are not exactly the same.

The Figure 5.11 shows the density visualisation of co-occurrence of keywords. The minimum number of occurrences of a keyword is set as 10. Among 18485 keywords, only 859 met the threshold. The number of clusters formed is 6.

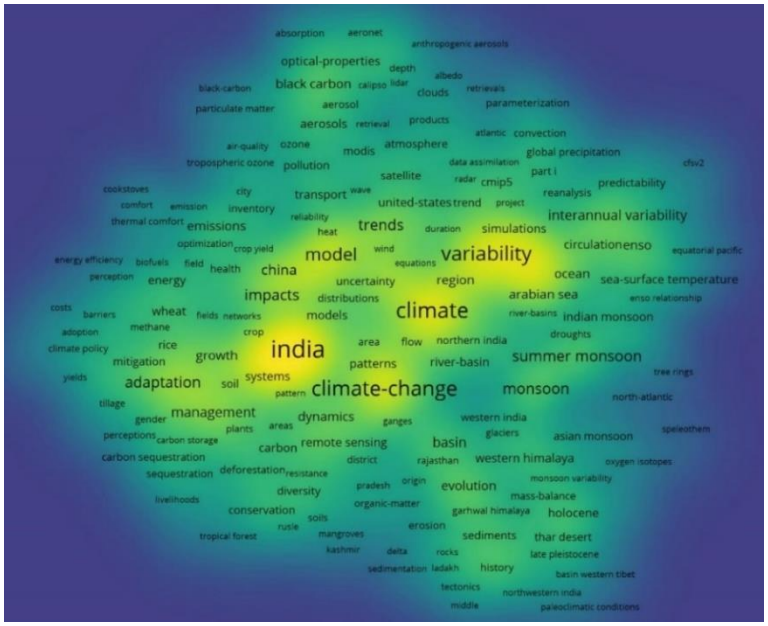


Figure 5.11 Density Visualization of Co-occurrence of Keywords

The details of the cluster is as shown in the below Table 5.27. The details of the cluster are shown from Table 5.28 to 5.33.

Table 5.27 Distribution of 859 Items in Seven Clusters

Sl. No.	Cluster Number	No. of Items
1	Cluster 1	173
2	Cluster 2	168
3	Cluster 3	146
4	Cluster 4	139
5	Cluster 5	129
6	Cluster 6	104

Table 5.28 Keyword Co-occurrences Cluster 1

Sl. No.	Keywords	No. of Occurrences
1	Climate-change	656
2	Impact	314

Table 5.29 Keyword Co-occurrences Cluster 2

Sl. No	Keywords	No. of Occurrences
1	Monsoon	230
2	Basin	153

3	Management	166	3	Evolution	133
4	Agriculture	130	4	Himalaya	121
5	Vegetation	126	5	Tibetan plateau	109
6	Dynamics	116	6	Holocene	102
7	Growth	115	7	Record	86
8	Models	104	8	Western Himalaya	82
9	Patterns	102	9	Sediments	75
10	Systems	100	10	River	73

Table 5.30 Keyword Co-occurrences Cluster 3

Sl. No.	Keywords	No. of Occurrences
1	India	1049
2	Climate change	768
3	Impacts	240
4	Adaptation	228
5	China	201
6	Vulnerability	134
7	Performance	103
8	Energy	101
9	Mitigation	80
10	Risk	80

Table 5.31 Keyword Co-occurrences Cluster 4

Sl. No.	Keywords	No. of Occurrences
1	Variability	613
2	Precipitation	524
3	Rainfall	451
4	Summer monsoon	240
5	Simulation	173
6	Interannual variability	169
7	Prediction	165
8	ENSO	144
9	Sensitivity	144
10	System	140

Table 5.32 Keyword Co-occurrences Cluster 5

Sl. No	Keywords	No. of Occurrences
1	Climate	749
2	Emissions	136
3	Black carbon	121
4	Arabian sea	119
5	Asia	97
6	Aerosols	91

Table 5.33 Keyword Co-occurrences Cluster 6

Sl. No.	Keywords	No. of Occurrences
1	Model	396
2	Temperature	382
3	Trends	269
4	Water	148
5	United-states	101
6	River-basin	93

7	Transport	88	7	Validation	76
8	Optical-properties	87	8	Runoff	72
9	Satellite	77	9	Uncertainty	71
10	Modis	68	10	Trend	69

From the above analysis the six clusters formed as a result of keyword co-occurrence analysis and tables contain top 10 keywords coming under each cluster.

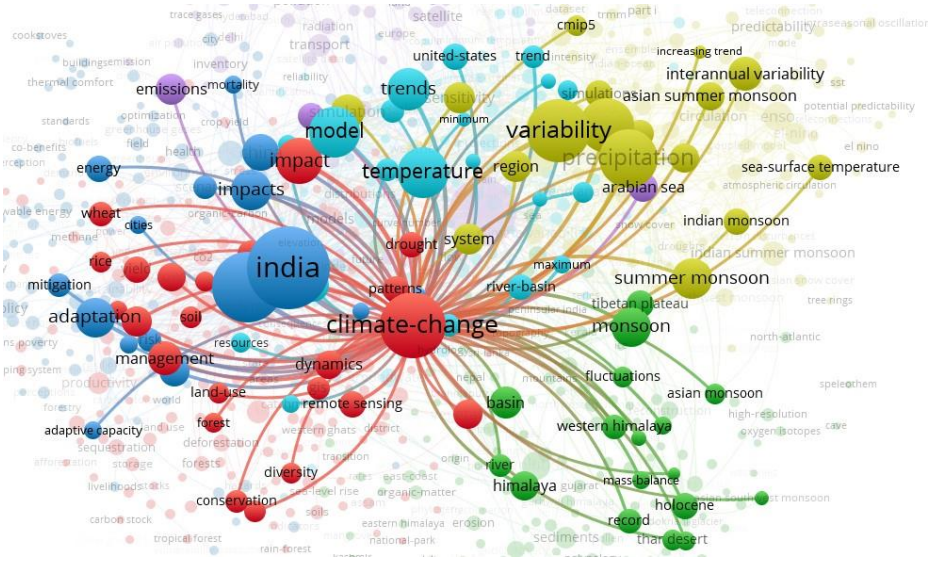


Figure 5.12 A Screenshot Showing the Cluster 1 and its Links in Keyword Co-occurrences Network Analysis Diagram

It can be seen that the cluster 1 of keyword co-occurrences in Table 28 is about the dynamics and impact of climate change in agriculture as well as vegetation and the respective measures taken for its management. Figure 5.12 is a screenshot showing the cluster 1 and its links in keyword co-occurrences network analysis diagram. The cluster 2 deals with geographical attributes such as Himalaya, Tibetan plateau, Western Himalaya and the effect of such in climatic conditions such as monsoon. Also it deals with the river and its basin and deposition of sediments through it. The climate change in India and its adaptation and mitigation strategies and the associated risks are expressed in cluster 3. The interannual variability as well as variability of precipitation, summer monsoon and rainfall data is formed

as a separate cluster which is cluster 4. It also includes the prediction and simulation of the same. Cluster 5 is associated with the transport and optical properties of aerosols and black carbon emissions around Asia and Arabian Sea and the influence of the process in climate. It also studies the intervention of satellites in studying the process. Cluster 6 is basically dealing with the run off, trends and models of water in the river basin and also with the temperature trends affecting the same.

5.2.3 Bibliographic Coupling

The concept of bibliographic coupling was introduced by Dr. M. M. Kessler of Massachusetts Institute of Technology in a paper published in 1963. He postulated that a "number of scientific papers bear a meaningful relation to each other (they are coupled) when they have one or more references in common." (Kessler, 1962). According to the Encyclopaedia of Linguistics, Information, and Control bibliographic coupling is given in the definition as "An association between two documents, established when they are found to have in common a high proportion of keywords, descriptors, citations, or other simple indications of what they are concerned with". Bibliographic coupling occurs when two works reference a common third work in their bibliographies. This indicates that the two works are dealing with a subject matter related to each other (Weinberg, 1974).

The coupling strength is said to be higher when more citations, the two referring works have in common. This coupling shows the similarity of subject matter of the two works. Bibliographic coupling is respectively valuable in all fields of research since it helps the researcher to find related research done in the past. The application of bibliographic coupling involves several such as to find the relationship between two subjects or articles, to understand the evolution and development of new subject areas, to understand if there is any patterns evolving in a research area and so on.

Bibliographic coupling is closely related to another term called co-citation coupling. Co-citation coupling is the mirror image of bibliographic coupling. Co-citation coupling is a method to establish a subject similarity between two documents. This can be illustrated with an example. If papers A and B have both cited by paper C, then they can be said as related to one another. But if papers A and B are cited together by many more authors other than paper C, then there exist to have a stronger correlation or relationship. The difference in Bibliographic coupling and Co-citation coupling is illustrated in Figure 5.13.

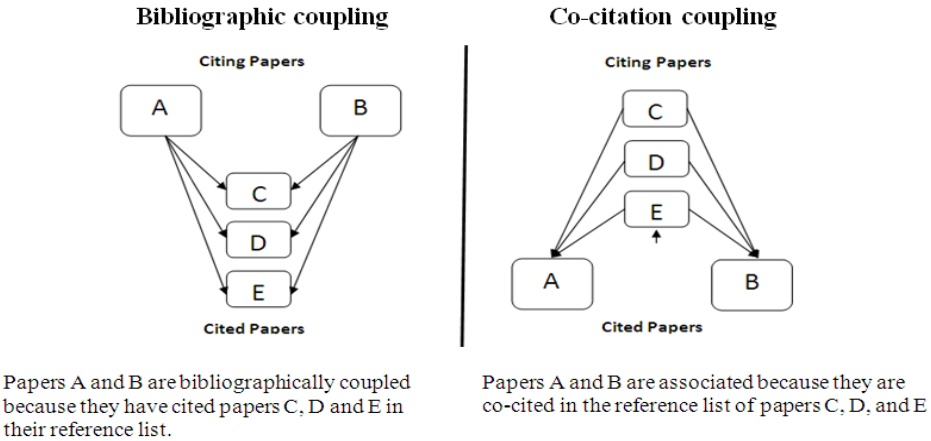
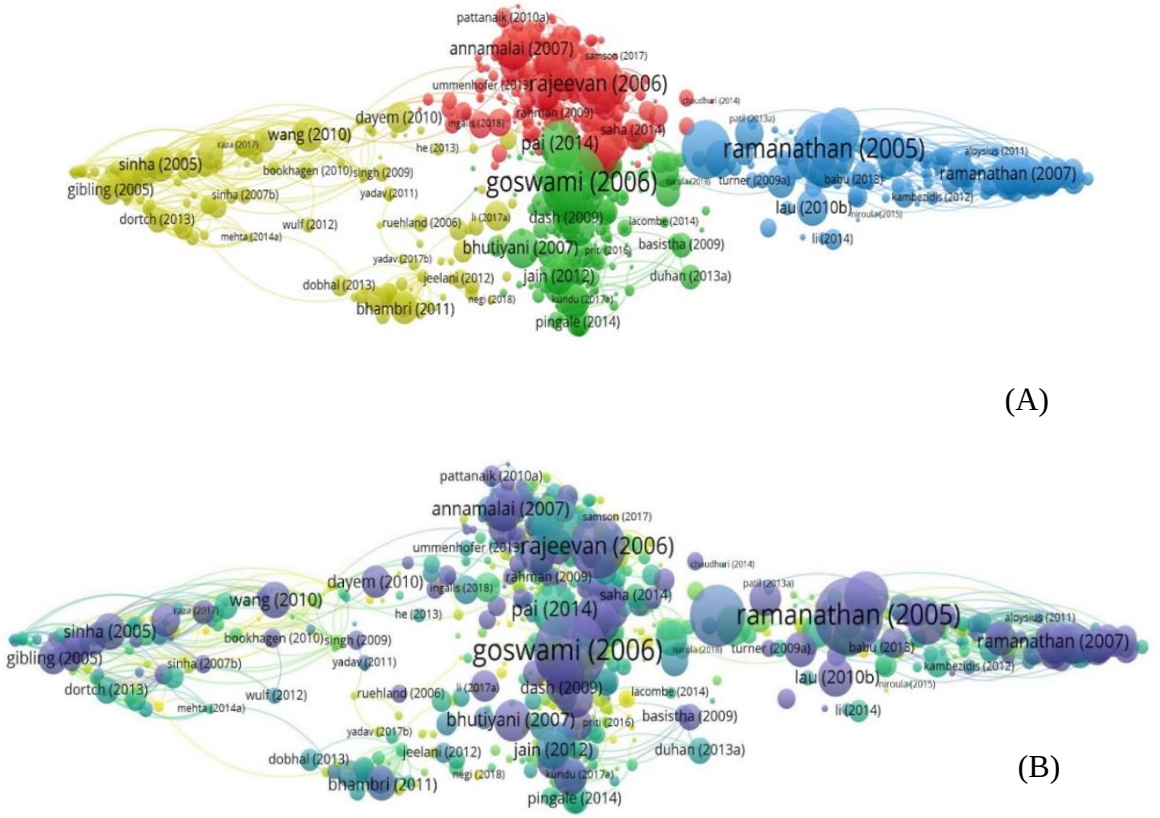


Figure 5.13 Difference between Bibliographic Coupling and Co-citation Coupling Diagram taken from (Surwase et al. 2011)

5.2.3.1 Bibliographic Coupling of Documents

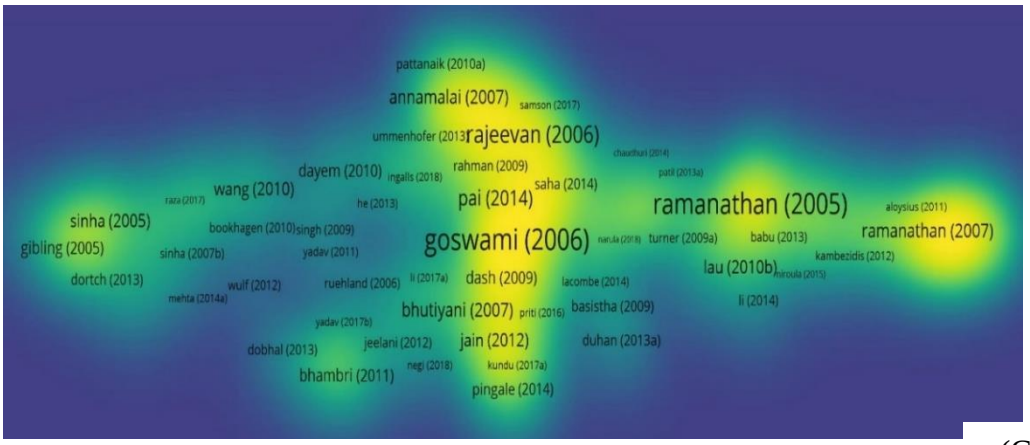
The initial step to do the bibliographic coupling of documents is to launch the VOSviewer and follow the initial steps until the selection of desired file. In the dialog box the type of analysis and counting method is chosen in which 'Bibliographic coupling' and 'Documents' is selected. The minimum number of citations of a document is kept as zero here and 5541 documents met the threshold. The total strength of bibliometric coupling links with other documents is calculated and the documents with greatest total link strength is selected. Here number of documents selected is 1000. On clicking 'finish' the network visualization of bibliographic coupling of documents is displayed. The diagram of network visualization,

overlay visualization and density visualization of bibliographic coupling of documents are displayed in the Figure 5.14.



(A)

(B)



(C)

Figure 5.14 Network Visualization (A), Overlay Visualization (B) and Density Visualization (C) of Bibliographic Coupling of Documents

Four clusters are formed while doing bibliographic analysis when the minimum cluster size is set as 100. Cluster1 has 326 items, cluster 2 has 253 items, 243 items in cluster 3 and 178 items in cluster 4. In the above Figure 5.14 (A) denotes the distribution of top 1000

linked documents distributed in four clusters. They are indicated in four colors such as red, blue, light green and dark green. In cluster 1, author Rajeevan (2006) dominated with 600 citations (indicated in red color).

The cluster 1 mainly deals with the climate change and precipitation data in and around Asia. Goswami (2006) dominated cluster 2 (indicated in dark green color). The second cluster links between the rainfall events, temperature and agriculture in India. Ramanathan (2005) topped cluster 3 indicated in blue color. This cluster has records about the anthropogenic aerosols and atmospheric brown clouds and their effect on the Indian monsoon. Cluster 4 has Wang (2010) on top with research topics such as evolution of the Indian and Asian summer monsoon and variability of southwest Indian summer monsoon, glacier changes etc.

The dominating authors like Rajeevan (2006), Goswami (2006), Ramanathan (2005), Wang (2010) has been citing old classical papers and it is indicated in blue color in the Figure 5.14 (B). The yellow color denotes the new emerging fields which is shown very less in the figure. This means that in bibliographic coupling of documents, old established papers are cited by most of the prominent authors. Also recent papers, which can be considered as the contribution of new authors is very less comparatively.

The density visualization is shown in Figure 5.14 (C). The yellow colored portion shows the ones with high intensity of collaboration while the rest forms the links where the weightage and collaboration is very less. Table 5.34 gives top five authors in all the five clusters in bibliographic coupling of documents.

Table 5.34 Top Five Authors in all the Five Clusters in Bibliographic Coupling of Documents

Sl. No.	Author Name	Cluster No.	No. of Citations	Title of the Paper
1	Rajeevan (2006)	1	600	High resolution daily gridded rainfall data for the Indian region: analysis of break and active monsoon spells
2	Sperber (2013)	1	478	The Asian summer monsoon: an intercomparison of cmip5 vs. cmip3 simulations of the late 20th century
3	Tripathi (2006)	1	287	Downscaling of precipitation for climate change scenarios: a support vector machine approach
4	Annamalai (2007)	1	277	The South Asian summer monsoon and its relationship with ENSO in the IPCC ar4 simulations
5	Kripalani (2007)	1	238	South Asian summer monsoon precipitation variability: coupled climate model simulations and projections under IPCC
6	Goswami (2006)	2	994	Increasing trend of extreme rain events over India in a warming environment
7	Pai (2014)	2	390	Development of a new high spatial resolution (0.25 degrees x 0.25 degrees) long period (1901-2010) daily gridded rainfall data set over India and its comparison with existing data sets over the region
8	Rajeevan (2008)	2	296	Analysis of variability and trends of extreme rainfall events over India using 104 years of gridded daily rainfall data
9	Bhutiyani (2007)	2	269	Long-term trends in maximum, minimum and mean annual air temperatures across the northwestern Himalaya during the twentieth century
10	Wassmann (2009)	2	251	Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation
11	Ramanathan (2005)	3	889	Atmospheric brown clouds: impacts on south Asian climate and hydrological cycle

Sl. No.	Author Name	Cluster No.	No. of Citations	Title of the Paper
12	Bollasina (2011)	3	570	Anthropogenic aerosols and the weakening of the south Asian summer monsoon
13	Lau (2006)	3	377	Observational relationships between aerosol and Asian monsoon rainfall, and circulation
14	Meehl (2008)	3	291	Effects of black carbon aerosols on the Indian monsoon
15	Ramanathan (2007)	3	280	Atmospheric brown clouds: hemispherical and regional variations in long-range transport, absorption, and radiative forcing
16	Wang (2010)	4	204	Asynchronous evolution of the Indian and east Asian summer monsoon indicated by Holocene moisture patterns in monsoonal central Asia
17	Sinha (2005)	4	199	Variability of southwest Indian summer monsoon precipitation during the boiling-allerod
18	Gibling (2005)	4	173	Discontinuity-bounded alluvial sequences of the Southern Gangetic plains, India: aggradation and degradation in response to monsoonal strength
19	Bhambri (2011)	4	171	Glacier changes in the Garhwal Himalaya, India, from 1968 to 2006 based on remote sensing
20	Dayem (2010)	4	161	Lessons learned from oxygen isotopes in modern precipitation applied to interpretation of speleothem records of paleoclimate from eastern Asia

5.2.3.2 Bibliographic Coupling of Authors

The initial step to do the bibliographic coupling of documents is to launch the VOSviewer and follow the initial steps until the selection of desired file. In the dialog box the type of analysis and counting method is chosen in which ‘Bibliographic coupling’ and ‘Authors’ are selected. The maximum number of authors is kept as 25 and full counting method

is adopted. Minimum number of documents of an author is set as 5 and 580 authors meet the threshold. Minimum cluster size is kept as 50. Four clusters formed with 223 items in cluster 1, 133 items in cluster 2, 125 items in cluster 3 and 99 items in cluster 4 are shown in Figure 5.15. The data obtained in the VOS visualization tab is downloaded in MS excel format and the top 10 authors in each cluster is tabulated in four tabular columns from Tables 5.35 to 5.38. The authors coming under each clusters are bibliographically coupled which means that at least one reference is common in their publications.

Table 5.35 Top 10 Authors in Cluster 1

Sl. No.	Authors	No. of Citations
1	Kumar, Vijay	858
2	Tiwari, G. N.	849
3	Jain, Sharad K.	639
4	Ravindranath, N. H.	620
5	Aggarwal, P. K.	576
6	Pathak, H.	571
7	Kumar, Rajesh	552
8	Khare, Deepak	506
9	Wada, Yoshihide	479
10	Singh, Manoj Kumar	474

Table 5.36 Top 10 Authors in Cluster 2

Sl. No.	Authors	No. of Citations
1	Rajeevan, M.	2363
2	Ghosh, Subimal	1799
3	Goswami, B. N.	1693
4	Dash, S. K.	1177
5	Pai, D. S.	1039
6	Mujumdar, P. P.	1034
7	Mohanty, U. C.	922
8	Annamalai, H.	910
9	Mishra, Vimal	896
10	Ming, Yi	748

Table 5.37 Top 10 Authors in Cluster 3

Sl. No.	Authors	No. of Citations
1	Cheng, Hai	710
2	Edwards, R. Lawrence	699

Table 5.38 Top 10 Authors in Cluster 4

Sl. No.	Authors	No. of Citations
1	Ramanathan, V.	1320
2	Sarin, M. M.	940

Sl. No.	Authors	No. of Citations
3	Owen, Lewis A.	453
4	Sinha, Ashish	428
5	Ramesh, R.	424
6	Bhambri, Rakesh	414
7	Dobhal, D. P.	409
8	Bookhagen, Bodo	402
9	Breitenbach, Sebastian F. M.	390
10	Prasad, Sushma	373

Sl. No.	Authors	No. of Citations
3	Ramaswamy, V.	904
4	Moorthy, k. Krishna	898
5	Tripathi, S. N.	840
6	Babu, S. Suresh	735
7	Singh, R. P.	729
8	Holben, B. N.	694
9	Praveen, P. S.	660
10	Gautam, R.	633

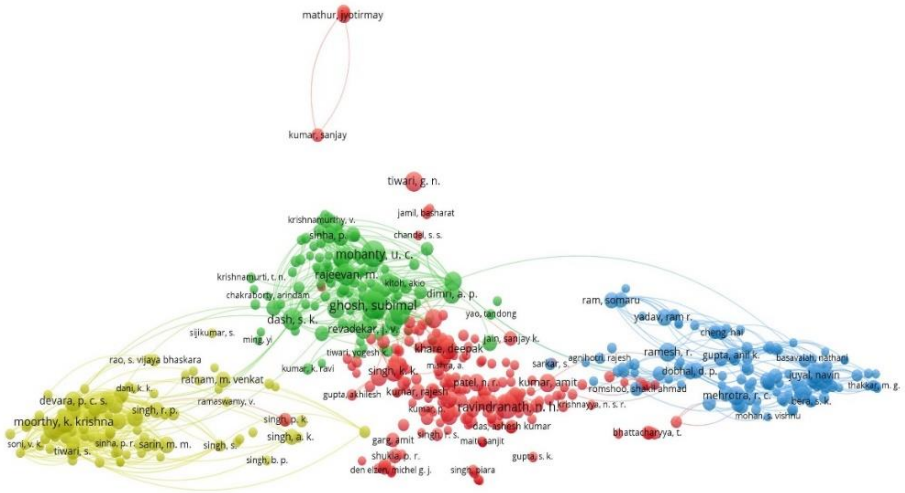


Figure 5.15 Network Visualization of Bibliographic Coupling of Authors

5.2.3.3 Bibliographic Coupling of Countries

The desired file is selected for the analysis in VOSviewer after launching the software and the type of analysis and counting method is chosen in which 'Bibliographic coupling' and 'Countries' are selected. Documents co-authored by large number of countries are ignored and the maximum number of countries per document is fixed as 50. Minimum documents of a country is fixed as 5 and out of 104 countries 62 countries met these

requirements. Minimum number of citations of a country is set as 0 and the analysis is carried out. 62 items were distributed in 9 clusters and with maximum number of clusters in cluster 1(22 items), cluster 2 (15 items) and cluster 3 (7 items).

India comes in the first cluster with maximum number of documents and citations (82,686 citations from 3,990 documents). This is followed by USA (Cluster 5) with 48,558 citations from 1026 documents. England, China and Germany comes in Cluster numbers 1, 5 and 9 respectively occupies third, fourth and fifth position in the list. The list of top 10 countries are displayed in the following Table 5.39.

Table 5.39 Bibliographic Coupling of Countries – List of Top 10 Countries

Sl. No.	Name of the Country	Cluster Number	Number of Documents	Total Number of Citations
1	India	1	3990	82686
2	USA	5	1026	48558
3	England	1	385	16632
4	Peoples R China	5	341	11904
5	Germany	9	308	13262
6	France	7	193	10173
7	Japan	5	183	7218
8	Australia	2	179	6906
9	Netherlands	2	113	7362
10	Canada	2	107	5836

The distribution of the countries in the clusters is shown in, Tables 5.40 and Figure 5.16. Different colors represent distinct non-overlapping clusters. Items (keyword) in different

colors represents different clusters. Size of items (document represented by dots) corresponds to the impact made by the countries and the thickness of interconnected links (lines) corresponds to the strength of relationship between countries.

Table 5.40 Top Five Clusters in Bibliographic Coupling of Countries

Sl. No.	Country	No. of Citation	Sl. No.	Country	No. of Citation
	CLUSTER 1			CLUSTER 2 (contd.)	
1	India	82686	6	Austria	4043
2	England	16632	7	Norway	3368
3	Scotland	2631	8	Spain	1773
4	Mexico	1285	9	New Zealand	1583
5	South Africa	1259	10	Belgium	1322
6	Denmark	1226	11	Finland	959
7	Brazil	1045	12	Colombia	448
8	Bangladesh	869	13	Ireland	411
9	Philippines	832	14	Qatar	166
10	Malaysia	817	15	Argentina	147
11	Iran	792		CLUSTER 3	
12	Kenya	655	1	Sweden	2346
13	Vietnam	327	2	Pakistan	1201
14	Indonesia	265	3	Saudi Arabia	559
15	Russia	260	4	Wales	322
16	Jordan	198	5	Portugal	234
17	Bhutan	131	6	Cyprus	200
18	Nigeria	103	7	Egypt	66
19	Poland	99		CLUSTER 4	
20	Ghana	90	1	Nepal	1681
21	Zambia	52	2	Israel	878
22	Ethiopia	30	3	Sri Lanka	813
	CLUSTER 2		4	Czech Republic	275
1	Netherlands	7362		CLUSTER 5	
2	Australia	6906	1	USA	48558

Sl. No.	Country	No. of Citation	Sl. No.	Country	No. of Citation
3	Italy	6459	2	Peoples R China	11904
4	Switzerland	6442	3	Japan	7218
5	Canada	5836	4	South Korea	2596

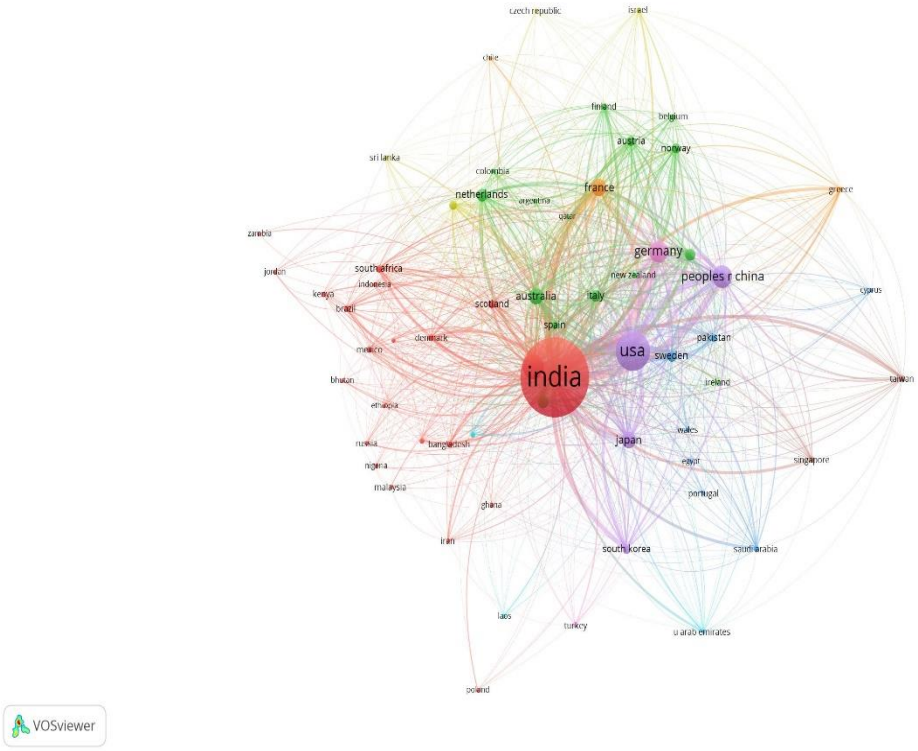


Figure 5.16: Network Visualization of Bibliographic Coupling of Countries

5.2.4 Evolution of Climate Change Studies for the Analysis Period (2005-2018)

For analysing the evolution of climate change studies for the period of study, overlay visualisation is done for the keywords and the output is analysed. The period can be divided into three. The period 2005-2009, 2010-2014 and 2015-2018. The keywords dominated is given in the Table 5.42 and Figure 5.17 shows an example of how evolution of topics in climate change from the keyword ‘temperature’ is shown in overlay visualisation.

Table 5.41 Evolution of Topics in Climate Change

Sl. No.	Year Span	Evolution of Keywords in Climate Change by Overlay Visualization
1	2005-2009	Agriculture, climate, atmosphere, holocene, paleoclimatic conditions, record, sulphur di oxide emission
2	2010-2014	Climate change, precipitation, Indian monsoons, trends, variability, aerosols, model, impact, adaptation
3	2015-2018	Temperature, drought, extreme rainfall, adaptation, management, mitigation, river basin, climate change, thermal comfort, buildings, carbon stock

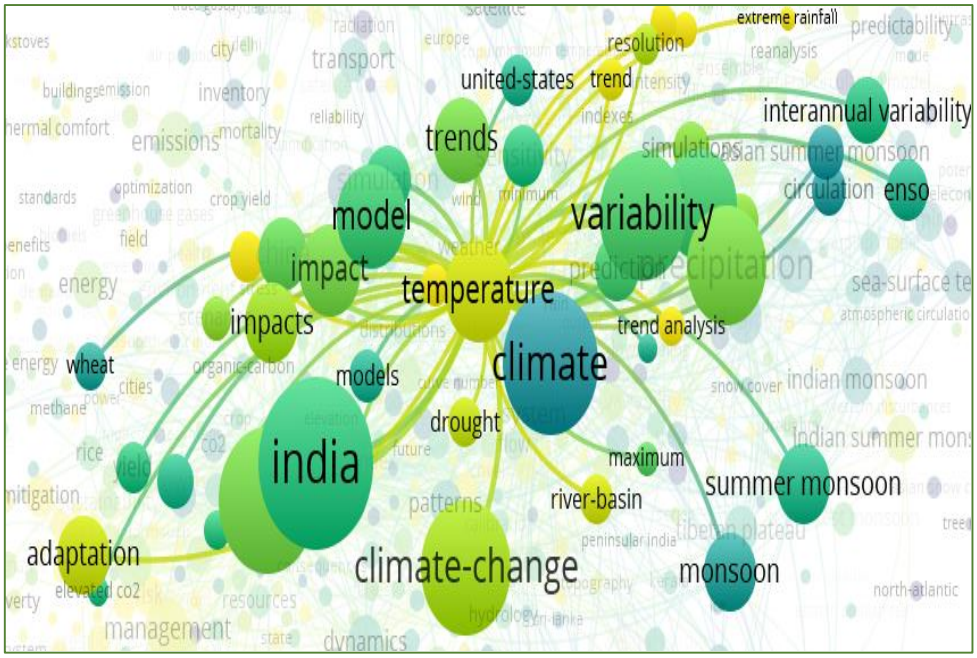


Figure 5.17: Evolution of Topics in Climate Change

CHAPTER 6

FINDINGS/SUMMARY AND RECOMMENDATIONS

The major objectives of the study is to conduct a scientometric analysis of climate change studies in India so as to understand the growth pattern of climate change studies in India in the period of 14 years, from 2005 to 2018. The aim of the study is to analyse the collaborative trend and the pattern of authorship. The citation pattern of the climate change papers is also included in the study. Bibliometric software BibExcel is used for the descriptive analysis and to determine the major scientiometric indicators while networking tool VOSviewer is used to monitor the co-authorship network and visualise the evolution of climate change studies.

6.1 Major Findings of the Study

Data (journal articles, conference papers and review articles related to climate change in India) for the analysis is extracted from SCOPUS and Web of Science databases using a three-term search string composed of different keywords. Specific keywords are selected from the areas under which the research work in climate change is progressing in India. The keywords shortlisted for retrieving the data from the databases were based on the observations from the literatures reviewed as well as the recommendations suggested by IPCC (Intergovernmental Panel on Climate Change) reports. A total number of 37,682 documents comprising of journal articles, conference papers and review articles related to climate change in India is retrieved from SCOPUS database. A total number of 22,211 documents comprising of journal articles, conference papers and review articles related to climate change in India appeared in WoS database for all the fifteen combination of search strings generated were retrieved. The primary analysis pointed to some irrelevant articles in the scientific papers retrieved from the bibliometric sources. A manual screening of datasets by going through the abstracts, keywords and title was done to eliminate the irrelevant data from the datasets and

increase the accuracy of the analysis. Descriptive analysis (Performance analysis) of the data was done using BibExcel software and MS Excel softwares for generating required outputs in meeting the objectives. Network Analysis (science mapping) is done for the creation of networks using bibliometric indicators like authors, articles, keywords etc. to reveal the collaboration trend, bibliographic coupling and so on.

Outcomes of the project are summarized below.

- The growth pattern of climate change studies in India for a period of 14 years is analysed. Along with that the growth curve of climate change was plotted and the doubling time of the literature was found.
- The pattern of authorship whether there is the dominance of single authored or multi authored papers can be understood.
- Identification of productive publishers, productive journals, most prolific author, most productive organizations, most cited references and most cited documents in the dataset.
- Collaborative coefficient, degree of collaboration and collaboration index are tabulated.
- Citation pattern of climate change papers is deliberated using citation analysis.
- Evolution of co-authorship network is studied using VOSviewer

Each outcomes deliberated the study to certain key findings pertaining to the Climate Change Studies in Indian Context and some of the observations of analysis is as discussed below.

The majority of the database constituted about articles (82.75%). There were only 196 records published in the year 2005 and went on increasing in the year reaching the number 1819 in the year 2018. Growth curve of climate change literature from 2005 to 2018 was plotted and the doubling time of the literature was found to be 3.5 years. 93.09 % of the documents are

published in English language followed by a nominal number of documents in French and Chinese.

The analysis of most productive publishers found out that Springer is the most productive most productive publisher with 825 records followed by Elsevier Ltd.

Among the journals, the journal 'Current Science' published 424 records pertaining to climate change in Indian context and topped the list of most productive journals. This was followed by Climate Dynamics and International Journal of Climatology with 305 and 274 publications.

Number of citations received by each document was the next parameter analysed and it revealed that majority of the documents received less than 10 citations. 448 documents received more than 100 citations.

The most prolific author which implies the author with highest number of publications. This is analysed using the author field offered by the databases. Kumar, A. of Norwegian University of Life Sciences topped the list with 173 records. The analysis of authorship pattern indicated the dominance of multi authored papers. Kumar, S. of Riverine Ecology and Fisheries Division, ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal secured the second position with 120 records. Singh, S. of Indian Council of Agricultural Research-Central Research Institute for Dryland Agriculture, Hyderabad, India came in the third position with 96 documents.

The analysis of authorship pattern revealed that highest number of papers are two authored papers (3195 papers, 23.07%) followed by three authored (21.62%) and four authored papers (16.13%). Single authored papers constituted around 10.09% with 1397 documents in number. This domination of multi authored papers is very well visible in the analysis of collaborative coefficient as the mean value of the collaborative coefficient is 0.600 which

indicates the domination of multi authored publications. The computation of degree of collaboration gave the value as 0.88 which directs the governance of collaborative research in this area. The mean value of collaboration index is 3.78 which indicates that the number of members in the research team falls between three to four members in the area of climate change studies in Indian context.

The most influential research area was found to be 'Meteorology & Atmospheric Sciences' followed by 'Environmental Sciences & Ecology' and 'Geology' in the third position. Keyword analysis is widely used as a bibliometric tool to identify the most impacted fields of research and since the topic is dealing with 'Climate Change Studies in the Indian Context', majority of the keywords obtained from the analysis are related to India. The most frequently used keyword used here is 'India' (6012 times) followed by 'climate change'(5950 times).The keyword 'monsoon' is in the third position with the frequency of usage 1548 times and this indicates the notable amount of work accomplished in India in the subject area 'monsoon' and also its prominence in the Indian climate.

The analysis was done to find out the most productive countries who conducts more number of studies in this subject area. 79 % of the documents are published from India and USA and Germany follows second and third with 9.09 and 4.47 % respectively. Relative Citation Index is maximum for France while for India it is 18.35 against the maximum value of 30.02.

The analysis of most productive organizations revealed Indian Institute of Tropical Meteorology, Pune, India on the top of the list obtained from BibExcel software. Since the organizations are abbreviated differently in different journals total publications was manually found for each organization and tabulated separately. Indian Institute of Science, Bangalore came on the top with 418 records followed by Indian Institute of Tropical Meteorology, Pune, with 397 records and Birbal Sahni Institute of Palaeobotany, Lucknow with 159 records.

Foreign institutes like Met Office Hadley Centre, United Kingdom, Max Planck Institute for Meteorology, Germany, National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies, USA also are placed in the list of top 50 most productive organisations which studies Climate change studies in Indian Context.

'Increasing Trend of Extreme Rain Events over India in a Warming Environment' by Goswami BN was cited 285 times and topped the list of most cited references. This means that this document was cited or used by the authors of the master data set of Climate change in Indian context 285 times in at least 285 different documents. 'The NCEP/NCAR 40-Year Reanalysis Project' by Kalnay E and 'High resolution daily gridded rainfall data for the Indian region: Analysis of break and active monsoon spells' by Rajeevan M was cited 279 and 208 times respectively.

'Impact of irrigation on the South Asian summer monsoon' by Saeed et al., earned 1230 citations and became the most cited document in the entire dataset. This was followed by 'Extreme weather: World-record rainfalls during tropical cyclone gamede' by Quetelard, H et al., with 1157 citations and 'Energetics of lower tropospheric ultra-long waves: A key to intra-seasonal variability of Indian monsoon' by Bawiskar et al., with 1081 citations.

Network analysis by VOSviewer 1.6.16 is used to find for network mapping and cluster analysis. The first analysis done is co-authorship analysis. Four clusters with a minimum cluster size of 50 is formed. The top ten authors of all the four clusters are identified according to the number of citations. Co-occurrence of Keywords is the subsequent analysis accomplished in the VOSviewer. Six clusters, with number of items ranging from 104 to 173, were formed. 'Climate-change', 'Monsoon', 'India', 'Variability', 'Climate' and 'Model' are the keywords dominated in each cluster. Bibliographic coupling was the following network analysis done in VOSviewer. Four clusters were formed while doing bibliographic coupling

analysis of documents when the minimum cluster size is set as 100 and the top five documents in each cluster were identified and listed. Bibliographic coupling of authors were done and four clusters were formed with minimum cluster size of 50. Top ten authors with maximum number of citations are identified and listed. While doing the bibliographic coupling of countries India secures the first position and comes in the first cluster with 82,686 citations from 3,990 documents. This is followed by USA, England, China and Germany.

6.2 Suggestions & Recommendations

DST funded project "Climate Change Studies in the Indian Context – A Scientometric Analysis", presents the climate scientists with data to understand the growth of research in this area.

The progress of climate change studies carried out in India and studies associated with the climate change of India conducted globally is studied which helps in the identification of unexplored areas in the area of climate change.

Majority of climate change research within India is focused in the agricultural sector while least attention is given on research areas such as impact of climate change in media, responses of Indian population towards climate change and implementation of climate change courses in curriculum.

The citations received by the Indian papers is less compared to the foreign papers (w.r.t RCI) and hence it is recommended that the Indian researchers should focus on publishing data with a high impact.

Resources development and management policy of neighbouring countries towards India depends on the research publication on climate change and other allied areas of research.

6.3 End Project Deliverables

A scientiometric paper entitled: “Climate Change Studies in Indian Context – A Bibliometric Analysis for the Period 2005-2018” is prepared and communicated for publication in “Scientometrics”. The paper highlights the main outcomes of the project such as the analysis of growth pattern of climate change studies in India from 2005-2018, the pattern of authorship, identification of productive publishers, productive journals, most prolific author, most productive organizations, most cited references and most cited documents in the dataset. Citation pattern of climate change papers is deliberated using citation analysis.

Another important deliverable is the project report initiated to produce specific, unique outcomes based on the scientometric analysis of climate change studies in India so as to understand the growth pattern of climate change studies in India in the period of 14 years (2005 to 2018).

A bibliometric master data set of publications pertaining to the climate change studies in India in the period 2005 to 2018 published in SCOPUS in RIS format will be communicated to the funding agency to facilitate in continuing the research in same arena by other researchers.

A bibliometric master data set of publications pertaining to the climate change studies in India in the period 2005 to 2018 published in Web of Science in plain text format will be communicated to the funding agency to facilitate in continuing the research in same arena by other researchers.

How the Outcome of this Project will be Beneficial to Various Stakeholders

The outcome of this project will be beneficial for various stakeholders and the benefits are enlisted below.

- Federal, state and local governments and associated groups can identify the trend of climate change research progressing in India and this report can be helpful in designing future research in climate change and fund allocation.
- Scientific community can be benefitted since this project is identifying most prolific authors, productive publishers, productive journals, most prolific author, and most productive organizations thus focusing more on this data for publishing their work in future.
- Associations and non-government organizations, including those responsible for the built environment, the natural environment, and those involved with indigenous issues will be able to identify the emerging research trends in climate change research and their outcomes and design their future work plan accordingly.

RESEARCH SUMMARY

CLIMATE CHANGE STUDIES IN THE INDIAN CONTEXT – A SCIENTOMETRIC ANALYSIS, by Dr. R Sathyanathan, Associate Professor, Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, 603 203

Climate change is one of the most pressing topics in the world today as its effects are far-reaching and long lasting. India, because of its geographical position and population, is expected to be affected a lot by climate change. Indian researchers will hence want to study the impacts of climate change and innumerable works are being published each year with regard to the recent developments in the field of climate change. This study is proposed to take a look at the history of peer-reviewed climate studies in India and identify the trends in the research field. The span of 14 years is chosen is from 2005 to 2018. The databases chosen for the analysis were SCOPUS and Web of Sciences using a three term search string. Descriptive analysis (Performance analysis) of the data was done using BibExcel software and MS Excel softwares in generating required outputs for meeting the objectives. Network Analysis (science mapping) is done using networking tool VOSviewer for the creation of networks using bibliometric indicators like authors, articles, keywords etc. to reveal the collaboration trend, bibliographic coupling. The outcomes of the project includes the analysis of growth pattern of climate change studies in India for the period of analysis, the pattern of authorship, identification of productive publishers, productive journals, most prolific author, most productive organizations, most cited references and most cited documents in the dataset. Citation pattern of climate change papers is deliberated using citation analysis. Evolution of co-authorship network is studied using VOSviewer.

REFERENCES

- Ahuja, D. (1992). Estimating national contributions of greenhouse gas emissions The CSE-WRI controversy. *Global Environmental Change*, *2*(2), 83–87. https://doi.org/10.1016/0959-3780(92)90010-5

- Ajiferuke, I., Burell, Q., & Tague, J. (1988). Collaborative coefficient: A single measure of the degree of collaboration in research. *Scientometrics*, *14(5-6)*, 421–433.

- Aleixandre-Tudó, J. L., Bolaños-Pizarro, M., Aleixandre, J. L., & Aleixandre-Benavent, R. (2019). Current trends in scientific research on global warming: A bibliometric analysis. *International Journal of Global Warming*, *17*(2), 142–169.

- Alex, P. (2019). *Climate Change Research literature in India: A Scientometric Analysis during 1991–2018.*

- Airyalat, S. A. S., Malkawi, L. W., & Momani, S. M. (2019). Comparing Bibliometric Analysis Using PubMed, Scopus, and Web of Science Databases. *Journal of Visualized Experiments*, *152*. https://doi.org/10.3791/58494

- Al-Shahi, R., Will, R. G., & Warlow, C. P. (2001). Amount of research interest in rare and common neurological conditions: Bibliometric study. *BMJ (Clinical Research Ed.)*, *323*(7327), 1461–1462. PubMed. https://doi.org/10.1136/bmj.323.7327.1461

- Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

- Attri, S. D., & Tyagi, A. (2010). Climate profile of India. Environment Monitoring and Research Center, India. *Meteorology Department: New Delhi, India.*

- Bar-Ilan, J. (2008). Informetrics at the beginning of the 21st century—A review. *Journal of Informetrics*, *2*(1), 1–52. https://doi.org/10.1016/j.joi.2007.11.001

- Barua, A., Katyaini, S., Mili, B., & Gooch, P. (2013). Climate change and poverty: Building resilience of rural mountain communities in South Sikkim, Eastern Himalaya, India. *Regional Environmental Change*, *14*(1), 267–280. https://doi.org/10.1007/s10113-013-0471-1

- Belter, C. W., & Seidel, D. J. (2013). A bibliometric analysis of climate engineering research. *Wiley Interdisciplinary Reviews: Climate Change*, *4*(5), 417–427. https://doi.org/10.1002/wcc.229

- Billett, S. (2010). Dividing climate change: Global warming in the Indian mass media. *Climatic Change*, *99*(1), 1–16. https://doi.org/10.1007/s10584-009-9605-3

- Birch, E. L. (2014). A Review of "Climate Change 2014: Impacts, Adaptation, and Vulnerability" and "Climate Change 2014: Mitigation of Climate Change." *Intergovernmental Panel on Climate Change.*

- Birender Pal & Merina Ahmed. (2014). *Measuring the Publication Productivity of N.E-Indian Universities Using Scopus:A BibliometricAnalysis*.

- Bjurström, A., & Polk, M. (2011). Climate change and interdisciplinarity: A co-citation analysis of IPCC Third Assessment Report. *Scientometrics*, *87*(3), 525–550. https://doi.org/10.1007/s11192-011-0356-3

- Bornmann, L., & Daniel, H.-D. (2006). Selecting scientific excellence through committee peer review—A citation analysis of publications previously published to approval or rejection of post-doctoral research fellowship applicants. *Scientometrics*, *68*(3), 427–440. https://doi.org/10.1007/s11192-006-0121-1

- Bornmann, L., & Daniel, H.-D. (2007). What do we know about the h index? *Journal of the American Society for Information Science and Technology*, *58*(9), 1381–1385. https://doi.org/10.1002/asi.20609

- Bornmann, L., & Mutz, R. (2015). Growth rates of modern science: A bibliometric analysis based on the number of publications and cited references. *Journal of the Association for Information Science and Technology*, *66(11)*, 2215–2222.

- Burnham, J. F. (2006). Scopus database: A review. *Biomedical Digital Libraries*, *3*, 1–1. PubMed. https://doi.org/10.1186/1742-5581-3-1

- Cobo, M J. (2011). Science mapping software tools: Review, analysis, and cooperative study among tools—Cobo—2011—Journal of the American Society for Information Science and Technology—Wiley Online Library. Journal of the American Society for Information Science and Technology, 62(7), 1382–1402. https://doi.org/10.1002/asi.21525

- Clarivate Analytics. (2017). *Bibliometric analysis of research in the field of earth system science. Report submitted to MoES, Government of India, 2017.*

- Cramer, W. (2006). Air pollution and climate change both reduce Indian rice harvests. *Proceedings of the National Academy of Sciences*, *103*(52), 19609–19610. https://doi.org/10.1073/pnas.0610075103

- Durieux, V., & Gevenois, P. A. (2010). Bibliometric indicators: Quality measurements of scientific publication. *Radiology*, *255*(2), 342–351.

- Dutta, P., & Chorasiya, V. (2013). Scenario of climate change and human health in India. *International Journal of Innovative Research and Development*, *2(8).*

- Elango, B. (2018). A Bibliometric analysis of authorship and collaboration trend in nature nanotechnology. *Journal of Applied Informatics and Technology, 1*(1), 56–63.
- Elango, B., & Rajendran, P. (2015). Global Tribology Research Output (1998—2012): A Macro Level Scientometric Study. *Journal of Information Science Theory and Practice*, *3*(4), 35–48. https://doi.org/10.1633/jistap.2015.3.4.3
- Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. *International Journal of Production Economics*, *162*, 101–114. https://doi.org/10.1016/j.ijpe.2015.01.003
- Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2007). Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. *The FASEB Journal*, *22*(2), 338–342. https://doi.org/10.1096/fj.07-9492lsf
- Garg, K. C. (2019). Whither Scientometrics in India. *Journal of Scientometric Research*, *7*(3), 215–218. https://doi.org/10.5530/jscires.7.3.34
- Garg, K. C., & Kumar, S. (2019). Contribution of Indian women scholars to Indian output in bibliometrics/scientometrics and the pattern of co-authorship and collaboration. *COLLNET Journal of Scientometrics and Information Management*, *13*(1), 127–138. https://doi.org/10.1080/09737766.2018.1564590
- Garg, K. C., & Padhi, P. (2010). A study of collaboration in laser science and technology. *Scientometrics*, *51(2)*, 415–427.
- Gupta, S., Sen, P., & Srinivasan, S. (2014). Impact of Climate Change on the Indian Economy: Evidence from Food Grain Yields. *Climate Change Economics*, *05*(02), 1450001. https://doi.org/10.1142/s2010007814500018

- Haunschild, R., Bornmann, L., & Marx, W. (2016). Climate Change Research in View of Bibliometrics. *PLOS ONE*, *11*(7), e0160393. https://doi.org/10.1371/journal.pone.0160393

- Henderson, S. O. (2003). Predictors of Academic Productivity in Emergency Medicine. *Academic Emergency Medicine*, *10*(9), 1009–1011. https://doi.org/10.1197/s1069-6563(03)00323-3

- Hirsch, J. E. (2005). Climate profile of India. Environment Monitoring and Research Center, India. *Proceedings of the National Academy of Sciences*, *102(46)*, 16569–16572.

- Hossain, N. U. I., Dayarathna, V. L., Nagahi, M., & Jaradat, R. (2020). Systems Thinking: A Review and Bibliometric Analysis. *Systems*, *8*(3), 23. https://doi.org/10.3390/systems8030023

- Jankó, F., Papp Vancsó, J., & Móricz, N. (2017). Is climate change controversy good for science? IPCC and contrarian reports in the light of bibliometrics. *Scientometrics*, *112*(3), 1745–1759. https://doi.org/10.1007/s11192-017-2440-9

- Jha, B., & Tripathi, A. (2011). Isn't Climate Change Affecting Wheat Productivity in India? *Indian Journal of Agricultural Economics*, *66*, 353–364. https://doi.org/10.1007/s10584-009-9605-3

- Joshi, A. (2016). Comparison between Scopus and ISI Web of Science. *Journal Global Values*, *7(1)*, 1–11.

- Kailash chandra Garg & Harish Tripathi. (2017). (PDF) Bibliometrics and scientometrics in india: An overview of studies during 1995-2014 Part I: Indian

publication output and its citation impact. *Annals of Library and Information Studies*, *65*, 8–36.

- Kessler, M. M. (1962). *An Experimental Study of Bibliographic Coupling Between Technical Papers*. Massachusetts Inst of Tech Lexington Lincoln Lab. https://apps.dtic.mil/sti/citations/AD0278226

- Klapka, O., & Slaby, A. (2018). Visual Analysis of Search Results in Scopus Database. *Digital Libraries for Open Knowledge*, 340–343. https://doi.org/10.1007/978-3-030-00066-0_36

- Kulkarni, A. V. (2009). Comparisons of Citations in Web of Science, Scopus, and Google Scholar for Articles Published in General Medical Journals. *JAMA*, *302*(10), 1092. https://doi.org/10.1001/jama.2009.1307

- Kumari, G. (2010). Synthetic organic chemistry research: Analysis by scientometric indicators. *Scientometrics*, *80(3)*, 559–570.

- Li, J., Wang, M.-H., & Ho, Y.-S. (2011). Trends in research on global climate change: A Science Citation Index Expanded-based analysis. *Global and Planetary Change*, *77*(1), 13–20. https://doi.org/10.1016/j.gloplacha.2011.02.005

- Li, W., & Zhao, Y. (2015). Bibliometric analysis of global environmental assessment research in a 20-year period. *Environmental Impact Assessment Review*, *50*, 158–166. https://doi.org/10.1016/j.eiar.2014.09.012

- Liao, H., Tang, M., Luo, L., Li, C., Chiclana, F., & Zeng, X.-J. (2018). A Bibliometric Analysis and Visualization of Medical Big Data Research. *Sustainability*, *10*(2), 166. https://doi.org/10.3390/su10010166

- Lukwale, R., & Sife, S., (2017). Climate change research trends in Tanzania: A bibliometric analysis. International Journal of Biodiversity and Conservation, 9(6), 224–231. https://doi.org/10.5897/ijbc2017.1099

- Manigandan, I., & Jayaraman, S. (2012). Global Warming: A Bibliometric Study. *Global Warming*, 6.

- Marx, W., & Bornmann, L. (2016). Change of perspective: Bibliometrics from the point of view of cited references—A literature overview on approaches to the evaluation of cited references in bibliometrics. *Scientometrics*, *109(2)*, 1397–1415.

- Marx, W., Haunschild, R., Thor, A., & Bornmann, L. (2017). Which early works are cited most frequently in climate change research literature? A bibliometric approach based on Reference Publication Year Spectroscopy. *Scientometrics*, *110*(1), 335–353. https://doi.org/10.1007/s11192-016-2177-x

- Mondal, D., & Raychoudhury, N. (2019). Contribution of Indian authors inScientometrics– An international journal during 1990-2017. *COLLNET Journal of Scientometrics and Information Management*, *13*(2), 231–245. https://doi.org/10.1080/09737766.2020.1716642

- Moors, E., Singh, T., Siderius, C., Balakrishnan, S., & Mishra, A. (2013). Climate change and waterborne diarrhoea in northern India: Impacts and adaptation strategies. *Science of The Total Environment*, *468–469*, S139–S151. https://doi.org/10.1016/j.scitotenv.2013.07.021

- Moral-Munoz, J. A., López-Herrera, A. G., Herrera-Viedma, E., & Cobo, M. J. (2019). Science Mapping Analysis Software Tools: A Review. *Springer Handbook of Science and Technology Indicators*, 159–185. https://doi.org/10.1007/978-3-030-02511-3_7

- Munim, Z. H., Dushenko, M., Jimenez, V. J., Shakil, M. H., & Imset, M. (2020). Big data and artificial intelligence in the maritime industry: A bibliometric review and future research directions. *Maritime Policy & Management*, *47*(5), 577–597. https://doi.org/10.1080/03088839.2020.1788731

- Nastis, A S. (2012). Climate change and agricultural productivity. African Journal of Agricultural Research, 7(35). https://doi.org/10.5897/ajar11.2395

- Newton, J., Paci, C. J., & Ogden, A. (2005). Climate change and natural hazards in northern Canada: Integrating indigenous perspectives with government policy. *Mitigation of Natural Hazards and Disasters: International Perspectives,* 209–239.

- Ocholla, D. (2013). *Information ethics education in Africa. Where do we stand?: International Information & Library Review: Vol 41, No 2*. https://www.tandfonline.com/doi/abs/10.1080/10572317.2009.10762802

- Okubo, Y. (1997). *OECD iLibrary | Bibliometric Indicators and Analysis of Research Systems: Methods and Examples*. https://doi.org/doi:https://doi.org/10.1787/208277770603

- Okubo Y. (1997). *Bibliometric Indicators and Analysis of Research Systems* (No. 1815–1965; OECD Science, Technology and Industry Working Papers). Organisation for Economic Co-Operation and Development (OECD). https://doi.org/10.1787/208277770603

- Pan, X., Yan, E., Cui, M., & Hua, W. (2018). Examining the usage, citation, and diffusion patterns of bibliometric mapping software: A comparative study of three tools. *Journal of Informetrics*, *12*(2), 481–493. https://doi.org/10.1016/j.joi.2018.03.005

- Persson, O., Danell, R., & Schneider, J. W. (2009). *How to use BibExcel for various types of bibliometric analysis. Celebrating scholarly communication studies: A Festschrift for Olle Persson at his 60th Birthday*. *5*(9–24).
- Pilkington, A. (2018). BibExcel-quick start guide to bibliometrics and citation analysis. *World Scientific Publishing.*
- Preedip Balaji, & Alex, P. (2010). *Mapping climate change research in India: A bibliometric approach*. *110*(1), 335–353.
- Qiu, J., Zhao, R., Yang, S., & Dong, K. (2017). Author Distribution of Literature Information: Lotka's Law. *Informetrics*, 145–183. https://doi.org/10.1007/978-981-10-4032-0_6
- Rahman, M., & Fukui, T. (2002). A Decline in the U.S. Share of Research Articles. *New England Journal of Medicine*, *347*(15), 1211–1212. https://doi.org/10.1056/nejm200210103471523
- Rajeswari, S., Saravanan, P., Kumaraguru, K., Jaya, N., Rajeshkannan, R., & Rajasimman, M. (2021). The scientometric evaluation on the research of biodiesel based on HistCite and VOSviewer (1993–2019). *Biomass Conversion and Biorefinery*. https://doi.org/10.1007/s13399-021-01461-6
- Sahu, N. C., & Mishra, D. (2013). Analysis of Perception and Adaptability Strategies of the Farmers to Climate Change in Odisha, India. *APCBEE Procedia*, *5*, 123–127. https://doi.org/10.1016/j.apcbee.2013.05.022
- Salini, C P, P, N., Vishnumaya, R S, & Mini, S. (2014). *A bibliometric evaluation of organic chemistry research in India.*

- Sangam, S. L., & Savitha, K. S. (2019). Climate change and global warming: A scientometric study. *COLLNET Journal of Scientometrics and Information Management*, *13*(1), 199–212. https://doi.org/10.1080/09737766.2019.1598001

- Saravanan, G., Rajan, V R;, Prasad, S., & Muthusankar, G. (2014). Climate change research (1991-2012): Comparative scientometric study of Argentina, Brazil, China, India and Mexico. *Library Philosophy and Practice*.

- Sathaye, J., P R, S., & N. H, R. (2006). Climate change, sustainable development and India: Global and national concerns. *Current Science*, 314–325. https://doi.org/10.1177/1094428114562629

- Schwechheimer, H., & Winterhager, M. (1999). *Highly dynamic specialities in climate research | SpringerLink*. https://link.springer.com/article/10.1007/BF02458495

- Shah, T. (2009). Climate change and groundwater: India's opportunities for mitigation and adaptation. *Environmental Research Letters*, *4*(3), 035005. https://doi.org/10.1088/1748-9326/4/3/035005

- Shah, T. (2020). Climate Change and Groundwater. *Water Resources Policies in South Asia*, 213–243. https://doi.org/10.4324/9780367818487-14

- Sidiropoulos, A., Katsaros, D., & Manolopoulos, Y. (2006). Generalized h-index for revealing latent facts in social networks of citations. In Proceedings of the 4th ACM. *International Workshop on Link Analysis: Dynamics and Static of Large Networks (LinkKDD),(in Conjunction with ACM KDD)*, 45–52.

- Solomon, S. (2007). *IPCC (2007): Climate change the physical science basis. In Agu fall meeting abstracts*. *2007*(U43D-01).

- Sotelo, L. F., Obregon, L. G., & Valencia, G. E. (2018). Global trends research in mitigation of climate change during 2006-2016: A bibliometric analysis. *Contemporary Engineering Sciences*, *11*(5), 229–236. https://doi.org/10.12988/ces.2018.818

- Stanhill, G. (2001). The Growth of Climate Change Science: A Scientometric Study. *Climatic Change*, *48*(2), 515–524. https://doi.org/10.1023/A:1010721600896

- Subramanian Navaneethakrishnan. (2014). Authorship patterns and degree of collaboration of Sri Lankan scientific publications in Social sciences and Humanities – a picture from SCOPUS. *Library Philosophy and Practice*.

- Surwase, G., Sagar, A., Kademani, B., & Bhanumurthy, K. (2011). *Co-citation Analysis: An Overview*.

- Thanushkodi, S. (2010). Bibliometric analysis of the journal Library Philosophy and Practice from 2005-2009. *Library Philosophy and Practice, 1(7).*

- Thompson, D. F., & Walker, C. K. (2015). A Descriptive and Historical Review of Bibliometrics with Applications to Medical Sciences. *Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy*, *35*(6), 551–559. https://doi.org/10.1002/phar.1586

- Tian, X., Geng, Y., Zhong, S., Wilson, J., Gao, C., Chen, W., Yu, Z., & Hao, H. (2018). A bibliometric analysis on trends and characters of carbon emissions from transport sector. *Transportation Research Part D: Transport and Environment*, *59*, 1–10. https://doi.org/10.1016/j.trd.2017.12.009

- van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

- van Eck, N. J., & Waltman, L. (2013). VOSviewer manual. Leiden: Univeristeit Leiden. *Meteorology Department: New Delhi, India.*, *1(1)*, 1–53.

- Vasileiadou, E., Heimeriks, G., & Petersen, A. C. (2011). Exploring the impact of the IPCC Assessment Reports on science. *Environmental Science & Policy*, *14*(8), 1052–1061. https://doi.org/10.1016/j.envsci.2011.07.002

- Venkatesan, M., Gopalakrishnan, S., & Gnanasekaran. D. (2013). Growth of Literature on Climate Change Research: A Scientometric Study. International Journal of Information Dissemination and Technology, 2(4), 236–242.

- Wang, M., & Chai, L. (2018). Three new bibliometric indicators/approaches derived from keyword analysis. *Scientometrics*, *116(2)*, 721–750.

- Wei, F, & Zhang, G. (2020). *A document co-citation analysis method for investigating emerging trends and new developments: A case of twenty-four leading business journals.*

- Weinberg, B. H. (1974). Bibliographic coupling: A review. *Information Storage and Retrieval*, *10*(5), 189–196. https://doi.org/10.1016/0020-0271(74)90058-8

- Xie, L., Chen, Z., Wang, H., Zheng, C., & Jiang, J. (2020). Bibliometric and Visualized Analysis of Scientific Publications on Atlantoaxial Spine Surgery Based on Web of Science and VOSviewer. *World Neurosurgery*, *137*, 435-442.e4. https://doi.org/10.1016/j.wneu.2020.01.171

- Xiyang, H. (2020). *Bibliometric Analysis and Visualization of College Students' Entrepreneurial Psychology Research Based on VOSviewer Software*. International Journal of Research in Engineering and Science, 8(12), 36-43

- Yu, Y., (et al.) (2020). A bibliometric analysis using VOSviewer of publications on COVID-19. *Annals of Translational Medicine*, *8*(13), 816. https://doi.org/10.21037/atm-20-4235

- Zupic, I., & Čater, T. (2014). Bibliometric Methods in Management and Organization. *SAGE*, *18*(3), 429–472. https://doi.org/10.1177/1094428114562629

NSTMIS Division
Department of Science & Technology
Ministry of Science & Technology
Technology Bhawan, New Mehrauli Road,
NewDelhi-110016
Phone: 91-011-26567373

Website: www.nstmis-dst.org/

About NSTMIS:

The National Science and Technology Management Information System (NSTMIS), a division of Department of Science and Technology (DST) has been entrusted with the task of building the information base on a continuous basis on resources devoted to scientific and technological activities for policy planning in the country.

Citation:

The report may be cited as DST (2022): Report on CLIMATE CHANGE STUDIES IN THE INDIAN CONTEXT – A SCIENTOMETRIC ANALYSIS; Dr. R Sathyanathan, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu. New Delhi, Govt. of India

Disclaimer:

Every care has been taken to provide the authenticated information. However, the onus of authenticity of data rests with the PI of the project.