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## Bibliometric Review of Monsoon Rainfall Prediction Models: With Special Reference to Use of Artificial Intelligence in Rainfall Prediction

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# **Bibliometric Review of Monsoon Rainfall Prediction Models: With Special Reference to Use of Artificial Intelligence in Rainfall Prediction**

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## **ABSTRACT**

Rainfall is a result of several complex atmospheric processes making it challenging to predict. For countries whose economy is dominated by agricultural sector, accurate rainfall prediction is highly essential. A huge network of weather stations is spread across the globe for the observation of meteorological parameters. These generate vast amounts of data which can be used to accurately predict the weather. This necessitates the use better tools such as various artificially intelligent algorithms. This study aims to explore global research trends in monsoon rainfall prediction techniques using Artificial Intelligence (AI) and Artificial Neural Networks (ANN). Scopus database has been used for carrying out bibliometric analysis for the period 1979 to 2021. The Scopus database has been analyzed for a number of publications, sources, languages, countries, affiliations etc. The analysis revealed that monsoon rainfall is sensitive to various factors such as sea surface temperature, El Nino, Southern Oscillation and many more. Statistical and dynamic models were used for monsoon rainfall forecasting and AI tools have been used for monsoon rainfall forecasting since 2000. Publications are mainly in the form of research articles and 99.7% of the literature is in the English language. Of the total publications, contributions from India are 55% while the United States and China contributed 18.67% and 14.3%, respectively.

**Keywords:** Monsoon, rainfall prediction, regression, Global Climate Model (GCM), Artificial Intelligence (AI), Artificial Neural Network (ANN), Support Vector Machine, Genetic Algorithm

## 1. INTRODUCTION

Weather forecasting has always been a challenging task for meteorologists and forecasters. Rainfall is a vital parameter for water resource management, agriculture planning and for the livelihood of humans and other living beings. Tropical countries experience the monsoon phenomenon. For developing countries as well as for other countries where agriculture is the pillar of their economies, prediction of monsoon is essential. Over the past two decades, technological advances in the field of monsoon rainfall prediction are happening at a rapid rate. A vast network of radars for weather observations and automated weather stations have been set up around the globe. This network is generating a massive set of observations of various weather parameters. With an aim to make optimum use of all this generated data scientists and researchers have begun incorporating the use of tools such Artificial Intelligence (AI) for better and more accurate weather forecasting.

Monsoon rainfall shows both interannual and intra-seasonal variability, making it difficult to predict it with high accuracy over small geographical regions. Several parameters play a role in predicting rainfall accurately. Monsoon rainfall and its prediction is vital for many countries such as India, Thailand, Africa, China (Camberlin, 1997; Singhrattna et al., 2005; Zhou et al., 2008). There are statistical and dynamic models for monsoon rainfall forecasting (Acharya et al., 2011). For sufficient lead time forecasting, various prediction models have been explored including regression models (Bhalme et al., 1986; S. V. Singh et al., 1979)., Multi Model Ensemble (MME) (Kar et al., 2012; Wang et al., 2009), Global Climate Model (GCM) (Alapaty et al., 1995; A. Singh et al., 2018), Climate Forecast System (CFS) (Dong et al., 2020), GCM with Artificial Neural Network (ANN) and Genetic Algorithm with ANN (Ding et al., 2013; Nair et al., 2018). The first publication on the prediction of monsoon rainfall was in 1979, whereas publications that used AI tools for monsoon rainfall forecasting were first seen in 2000. AI covers tools such as ANN, Support Vector Machine (SVM), Genetic Algorithms (GA), Bagging etc. From these tools, ANN has been explored by most of the researchers, in the publications under analysis for prediction of monsoon rainfall (Sahai et al., 2000; Khosla, E., Dharavath, R. & Priya, 2020). Precipitation estimation generated using ANN (PERSIANN) has been utilized with Tropical Rainfall Measuring Mission (TRMM) dataset for hourly frequency and daily rainfall forecasting by ( Zhou et al., 2008; Miao et al., 2015).

For data retrieval, the most popular database used was the Scopus database. The Scopus database was searched based on keywords “Artificial Intelligence”, “Artificial Neural Network”, “rainfall forecasting”, “rainfall prediction” and “monsoon”. The details of data collection and keywords are given in Section 2. Results of the bibliometric analysis are discussed in the subsections of Section 3. Section 4 throws light on some limitations of the analysis carried out in this study and Section 5 concludes the paper.

## 2. DATA COLLECTION

The Scopus database covers a wide range of topics and is a major repository of peer reviewed publications. The Scopus database was accessed on 20<sup>th</sup> February 2021 from the access provided by the University. The use of AI for rainfall prediction started a few decades ago. While there are many tools of AI, Artificial Neural Network (ANN) is found to be used for rainfall forecasting more than other tools such as Fuzzy Systems, Genetic Algorithms (GA), and Support Vector Machine (SVM). Hence, keyword search for Artificial Neural Network was added with the keyword “Artificial Intelligence”. The important keywords required to carry out the search were “Artificial Intelligence or

Artificial Neural Network for rainfall forecasting or rainfall prediction” with the years from 2010 to 2021. These keywords were searched by adding Advanced Search by including “AND” and “OR” conditions in the Scopus database. There were 974 results for the said duration and keyword search. The search was further refined by adding the word “monsoon” and the number of publications then found were 305. These were used for carrying out bibliometric analysis.

### 3. BIBLIOMETRIC ANALYSIS AND RESULTS

Bibliometric analysis was undertaken to explore the research trends in monsoon rainfall forecasting techniques with the use of AI tools in a systematic manner. This analysis helped to understand the contributions made by authors from various countries, institutions, journals, books etc. Initially, important keywords related to the search, publication type, and publication trends were analyzed. Statistical analysis of authors, subject areas, affiliations, and citations were carried out next. Following this Geographical region and network analysis were also carried out.

#### 3.1 Details of keywords for advance search

The important keywords required to carry out the search were “Artificial Intelligence”, “rainfall forecasting”, “Artificial Neural Network”, “rainfall prediction” AND “monsoon”. These keywords were searched by adding advanced search including “AND” and “OR” conditions in the Scopus database. As stated earlier with the addition of the keyword “monsoon”, results obtained were 305. For the refined search, years were not limited, and results received were from the year 1979 to 2021. As there are many keywords related to rainfall, few important keywords required for the analysis are listed in Table 1.

*Table 1: List of important keywords*

Keywords	Number of Publications
Rain	108
Rainfall	96
Monsoon	93
Weather Forecasting	85
Forecasting	66
India	66
Neural Networks	66
Atmospheric Thermodynamics	63
Artificial Neural Network	62
Prediction	41
Climate Prediction	39
Artificial Intelligence	36
Sea Surface Temperature	31
Summer	28
Rainfall Prediction	27
Rainfall Forecasting	25
Remote Sensing	25
Climatology	23
Artificial Neural Networks	21
Asia	21

Source: <http://www.scopus.com> (accessed on 20<sup>th</sup> February 2021)

### 3.2 Publication Type

The search was further restricted to English publications as 99.7% publications are in English. Other publications in the area are in French and Croatian languages. Researchers have published 77% papers in journals, 18% papers in conferences, 3.67% in book series and 1.33% are available as books. The search was refined by excluding two publication types of Erratum and Letter. With the exclusion of publication type and limiting the search to publications in English language, number of results was 300. As can be seen, major publications appear in the form of articles in Journals. The percentage division of the publications based on its source type is given in Table 2.

Table 2: Publication type

Publication Type	Number of Publications	Percentage from 300
Journal	231	77%
Conference Proceeding	54	18%
Book Series	11	3.67%
Book	4	1.33%

Source: <http://www.scopus.com> (accessed on 20<sup>th</sup> February 2021)

### 3.3 Highlights of Preliminary Data

The refined keyword search in the Scopus database extracted 300 publications from the year 1979 to 2021. The results are further analyzed for trend in publication count. All publications from journals, conferences, book series and books were considered. Publication count from 1979 to 2021 is shown in Table 3.

Table 3: Publication count per year

Year	Publication Count	Year	Publication Count
1979	1	2006	4
1985	1	2007	16
1986	1	2008	13
1990	1	2009	18
1991	1	2010	12
1993	1	2011	13
1994	1	2012	13
1995	2	2013	13
1996	3	2014	15
1997	2	2015	25
1999	1	2016	15
2000	3	2017	12
2001	2	2018	39
2002	4	2019	15
2004	2	2020	41
2005	6	2021	4

Source: <http://www.scopus.com> (accessed on 20<sup>th</sup> February 2021)

The graph depicting trend in the publication count is shown in Figure 1. From the graph increasing trend of publication count for the study of monsoon rainfall forecasting can be observed.

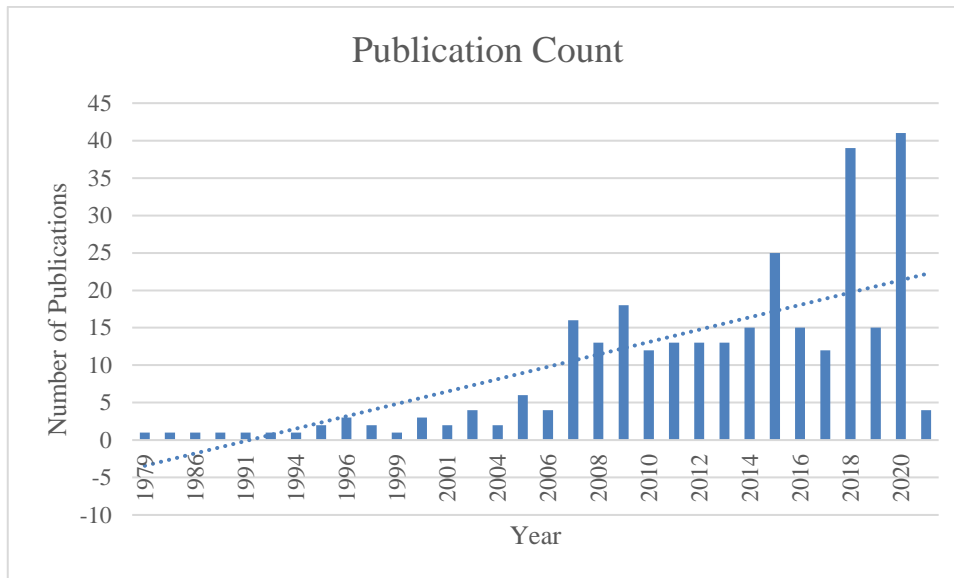


Figure 1: Yearly publishing trend

### 3.4 Geographical Region Based Analysis

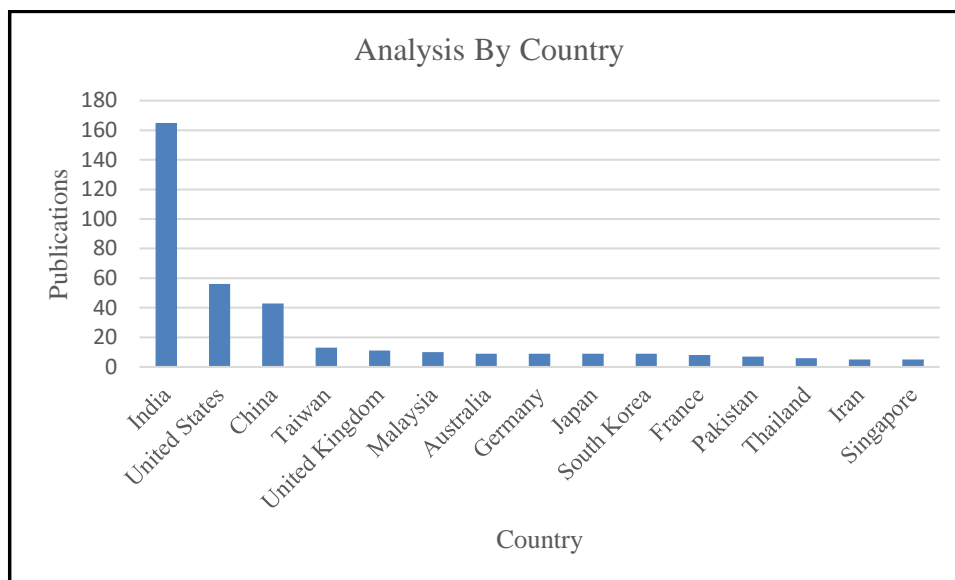
To analyze the county-wise contribution to the study of monsoon rainfall forecasting, GPS Visualizer tool is used. This is online tool available at [gpsvisualizer.com](http://gpsvisualizer.com). Figure 2 shows the contribution from the various countries for this study.



Figure 2: Geographic locations of the study of monsoon rainfall forecasting

Although, 48 countries have contributed to this study, 165 publications are from India, followed by 56 from United

States and 43 from China. The monsoons are a phenomena typically observed in tropical countries , which explains why, 55% contributions are from India, 33% contribution is from the United States and China whereas other 45 countries have contributed approximately 20% leaving the undefined contribution which is 1.6%. Figure 3 shows the contribution in publications by 15 countries.



*Figure 3: Analysis by Country /Region*

Source: <http://www.scopus.com> (accessed on 20<sup>th</sup> February 2021)

### **3.5 Analysis Pertaining to Subject Area**

This study has been done in 19 subject areas such as Earth and Planetary Sciences, Environmental Science, Computer Science, Engineering. Major research contribution in descending order is noticed in Earth and Planetary Sciences, Environmental Science, Computer Science, and Engineering. Figure 4 represents the subject wise research contribution through pie chart. Subject “Others” in the figure includes 11 subject areas such as Energy, Multidisciplinary, Decision Sciences etc. For the details of publication numbers per subject area, refer figure 5.

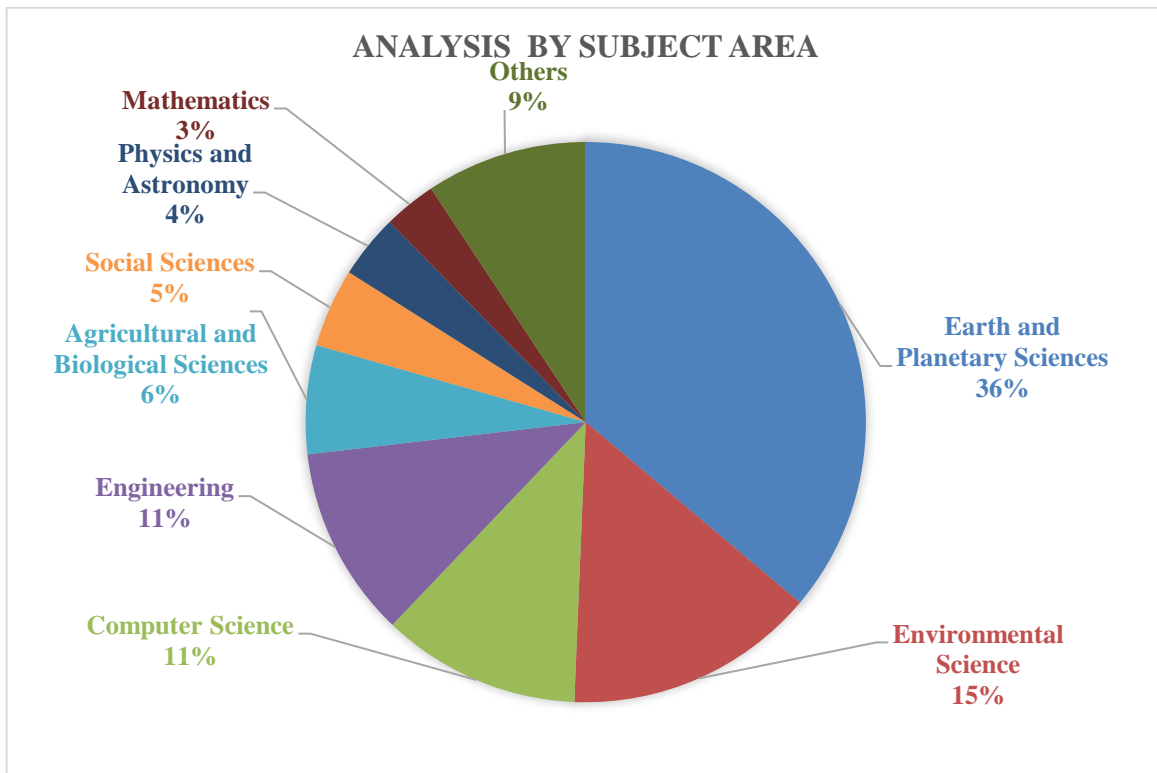


Figure 4: Analysis by Subject Area

Source: <http://www.scopus.com> (accessed on 20<sup>th</sup> February 2021)

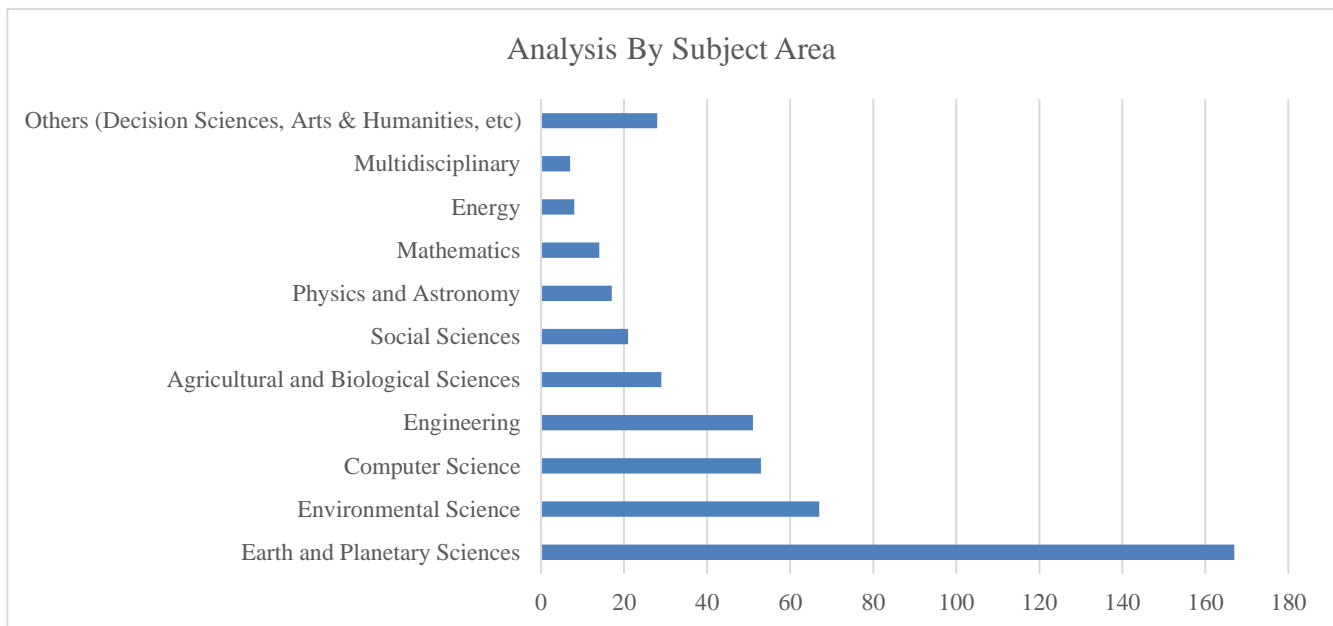


Figure 5: Analysis of papers published on monsoon rainfall forecasting based on subject area

Source: <http://www.scopus.com> ((accessed on 20<sup>th</sup> February 2021)



### 3.6 Analysis Based on Affiliation

Worldwide, universities, institutes, and meteorology departments have contributed to the study of monsoon rainfall forecasting techniques with and without using AI tools. Figure 6 shows dominating contribution by Indian meteorology organizations as well as Technology Institutes. Top affiliations publishing in this field have been shown in Figure 6.

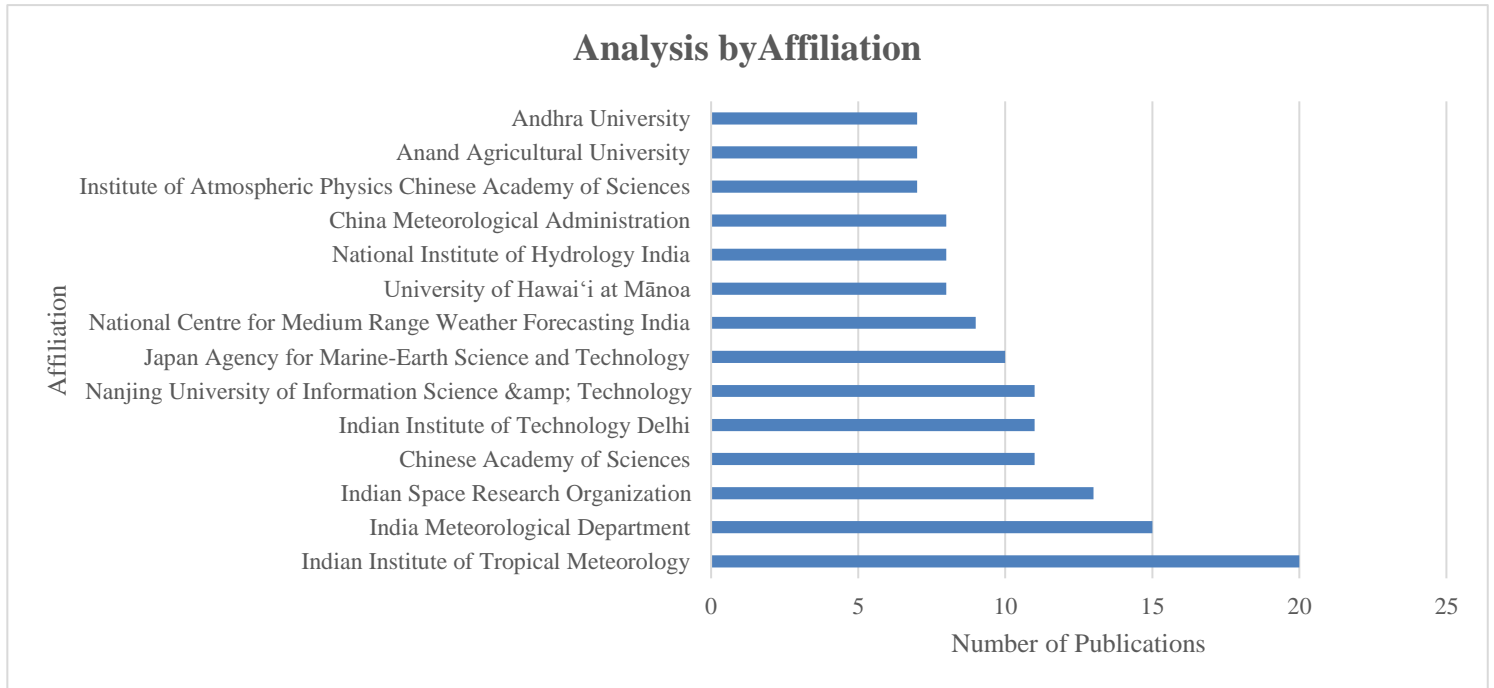


Figure 6: Analysis of publications based on affiliations contributing to monsoon rainfall forecasting

Source: <http://www.scopus.com> (accessed on 20<sup>th</sup> February 2021)

### 3.7 Analysis by Number of Publications per Author

Key authors contributing to the field of study of monsoon rainfall forecasting techniques are depicted in Figure 7. First ten authors were considered from the available accessed data from the Scopus database.

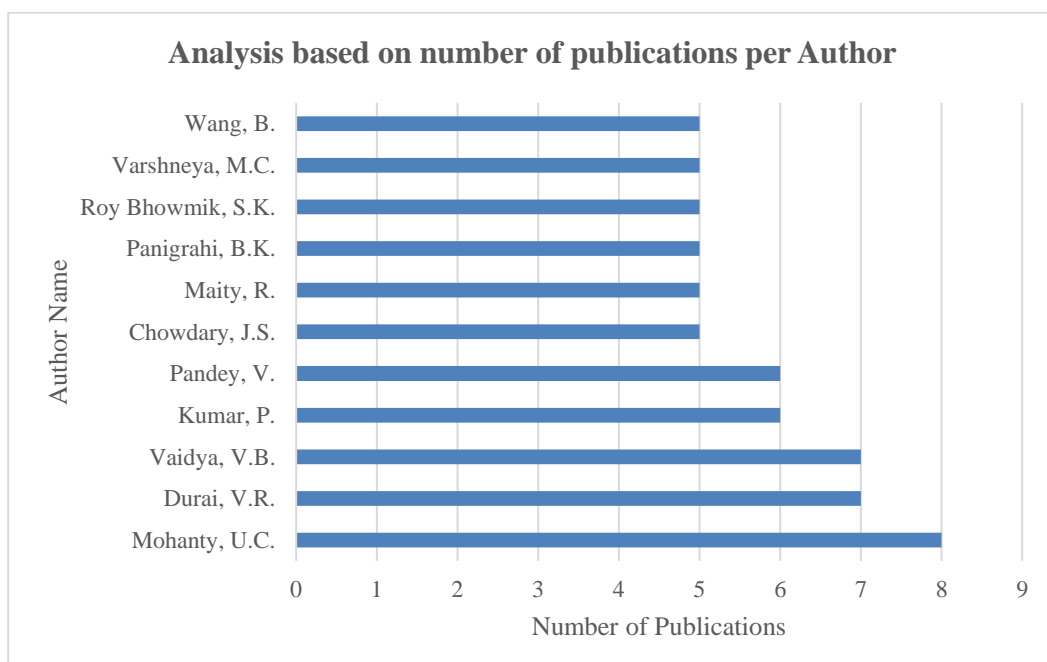


Figure:7 Major contributors in publishing

Source: <http://www.scopus.com> (accessed on 20<sup>th</sup> February 2021)

### 3.8 Leading Research Journals

For the area of monsoon rainfall forecasting techniques, the database was further analyzed for source titles and number of publications under those titles. The Table4. below indicates the journal name and number of publications in each of these journals. This table lists source titles having 5 or more publications in the area of study.

Table 4. Leading source titles where research work in monsoon rainfall forecasting has been published.

Journal Name	Number of Publications
Climate Dynamics	14
International Journal of Climatology	10
Remote Sensing	8
Atmospheric Research	7
International Journal of Remote Sensing	7
Journal of Earth System Science	7
Meteorology and Atmospheric Physics	7
Journal of Hydrology	6
Pure and Applied Geophysics	6
Theoretical and Applied Climatology	6
Journal of Climate	5
Journal of Hydrometeorology	5

Source: <http://www.scopus.com> (accessed on 20<sup>th</sup> February 2021)

### 3.9 Network Analysis

For analyzing interrelations between keywords, source type, citations, source titles, open-source software Gephi version 0.9.2 was used. Cluster of keywords and affiliations was first formed using the first 15 records. Various layouts available in Gephi were explored and for the first cluster Noverlap layout was used. To identify the relation of keywords with source titles, Yifan Hu layout was used. Keyword “rain” was selected as a node for this cluster that revealed network of keywords with source titles. These clusters are shown in Figure 8 and 9, respectively.

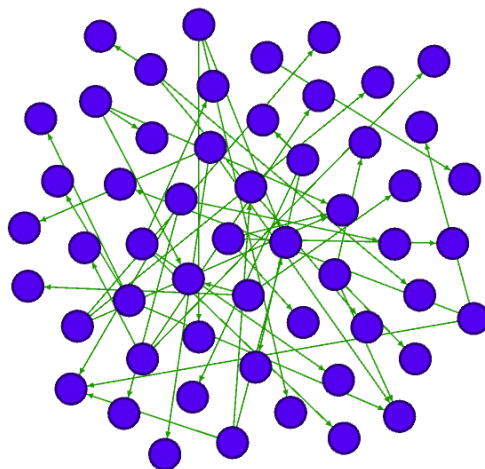


Figure: 8 Network of keywords and affiliations

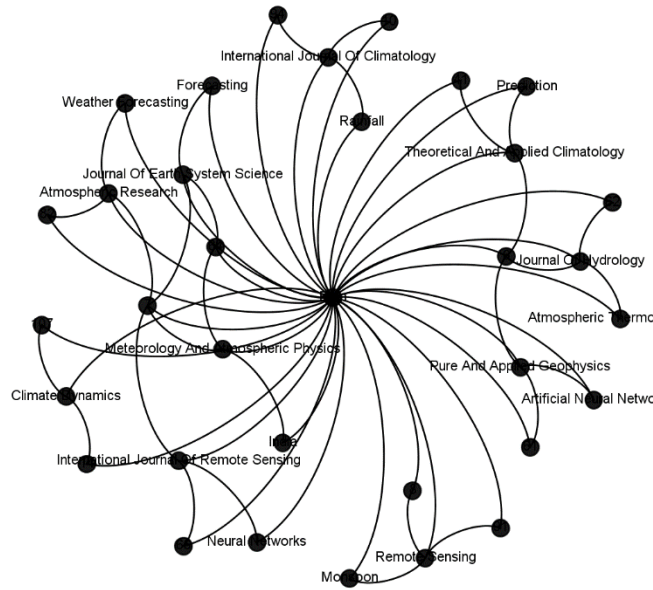


Figure:9 Cluster of keywords and source title with central node set to keyword “rain”

### 3.10 Citation Analysis

In the area of monsoon rainfall forecasting techniques, the most cited publications till date are as given in Table 5. The table shows the author name and citations obtained from the year 2017 onwards. Citations before 2017 are given in the second column. This analysis is based on the Top 10 authors who received maximum citations along with the name of the journal that published the research paper. Database shows that publications in Climate and hydrometeorology journals have received maximum citations.

Table 5: Number of citations per author with maximum citations in the area of monsoon rainfall forecasting

Authors	Journal Title	Year						Total
		<2017	2017	2018	2019	2020	2021	
Wang B., Lee J.-Y., Kang I.-S., Shukla J., Park C.-K., Kumar A., Schemm J., Cocke S., Kug J.-S., Luo J.-J., Zhou T., Wang B., Fu X., Yun W.-T., Alves O., Jin E.K., Kinter J., Kirtman B., Krishnamurti T., Lau N.C., Lau W., Liu P., Pegion P., Rosati T., Schubert S., Stern W., Suarez M., Yamagata T.	Climate Dynamics	171	23	32	31	23	5	285
Zhou T., Yu R., Chen H., Dai A., Pan Y.	Journal of Climate	122	21	33	31	33	3	243
Miao C., Ashouri H., Hsu K.-L., Sorooshian S., Duan Q.	Journal of Hydrometeorology	25	27	24	33	33	4	146
Hong Y., Gochis D., Cheng J.-T., Hsu K.-L., Sorooshian S.	Journal of Hydrometeorology	69	5	18	15	24	2	133
Camberlin P.	Journal of Climate	97	10	7	11	4	1	130
Rajurkar M.P., Kothiyari U.C., Chaube U.C.	Hydrological Sciences Journal	76	6	12	7	7	2	110

Lau K.-M., Kim J.H., Sud Y.	Bulletin of the American Meteorological Society	96	1	2	2	1	0	102
Wang B., Xiang B., Li J., Webster P.J., Rajeevan M.N., Liu J., Ha K.-J.	Nature Communications	4	15	24	25	22	10	100
Sahai A.K., Soman M.K., Satyan V.	Climate Dynamics	60	5	13	13	8	1	100
Singhrattna N., Rajagopalan B., Krishna Kumar K., Clark M.	Journal of Climate	65	4	9	8	10	0	96

Source: <http://www.scopus.com> (accessed on 20<sup>th</sup> February 2021)

#### 4. LIMITATIONS OF THIS STUDY

As the Scopus database was used for the bibliometric analysis, few journals and articles not under Scopus database could not be covered. English was the main language used for articles (99.7%), hence, publications in other languages were not considered in this analysis. The term “monsoon rainfall prediction” is closely related to other keywords such as flood, groundwater, rainfall-runoff, satellite data, etc. Hence the documents used for analysis includes publications related to such keywords (Adamowski & Chan, 2011).

#### 5. CONCLUSIONS

The bibliometric analysis of monsoon rainfall forecasting techniques with AI tools was carried out using the Scopus database. The analysis highlighted the complexity of monsoon rainfall prediction due to various interrelated weather parameters and importance of its prediction for tropical countries like India. The analysis of the data extracted from the Scopus database revealed that Artificial Neural Network is the most used AI tool than Support Vector Machine, Genetic algorithms, Fuzzy systems etc. The major publications are from India, United states, and China in the subject area of Earth and Planetary Sciences and Environmental Science. The results extracted from Scopus database included publications encompassing CFS, GCM, coupled models, ensemble models and many others. Results also showed publications related to flood, rainfall-runoff, groundwater forecasting. Monsoon rainfall prediction is essential for most of the tropical countries. Increasing use of AI for the same has been observed in the literature for making more accurate predictions related to the monsoons.

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