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Research Article

Climate Change Research in Malaysia: A Scientometric Analysis

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ABSTRACT

Climate change, a global challenge and among one of the significant keyword(s) that potentially attract various fields of studies to be performed. Assessing its changes in various types of analysis such as in terms of bibliometrics illustrate the importance of considering its global impacts. Recently, scientometric study has become interactive methods for determining the performance of certain fields of study in which it will show the interactive figures and visualizations of various types of dimensions (i.e., query of information). Scientometric study has also provided tools for summarized literature-based evidence from available or selected scientific databases. The WOS database has been started to collect scientific publications from 1970, and the results of climate change related research in Malaysia have been conducted from 1976, and it shows the increasing trends starting from the year of 1976 until 2021. Thus, the objective of this study is to determine the current status of climate change research in Malaysia through the scientometric analysis. The evolution of scientific research publication in climate change had shown the increasing trends, in which the total overall publication was recorded as low as 2 papers in 1992 up until tenfold in 2020, with a total of 200 papers. The highest total scientific publication in the knowledge domain is 13.01% which is in 2020. The study showed that a total of 1,049 authors with 1,522 organizations have been involved actively in climate change research in Malaysia. The study also showed that a total of 35,550 citations were received from these areas and a total of 38 co-citation clusters of research emerged in the cluster analysis. In conclusion, climate change research in Malaysia is one of the potential top knowledge domains (i.e., field of study) in the future scientific research areas.

Keywords: Climate change, Scientometric analysis, Bibliometric analysis, CiteSpace, Malaysia.

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INTRODUCTION

Climate change is characterized based on the comprehensive long-haul temperature and precipitation trends and other components such as pressure and humidity level in the surrounding environment. Besides, the irregular weather patterns, retreating of global ice sheets, and the corresponding elevated sea level rise are among the most renowned international and domestic effects of climate change.[1-3] Climate change is affecting life in all countries all over the world. Climate change-related activities in Malaysia began between 1993 to 1994, when Malaysia joined as a member of United Nations Framework Convention on Climate Change (UNFCCC or FCCC) on 9 June 1993 and ratified it on 13 July 1994.[4] Since then, the involvement of Malaysia had become active, continued with the Kyoto Protocol in 1997, in which Malaysia

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had signed in March 1999 and was ratified in September 2002. In response to both Convention (i.e., UNFCCC) and the Protocol (i.e., Kyoto), Malaysia along with the rest of the developing countries is grouped under the non-Annex 1 parties followed with Article 4 of the UNFCCC's obligations, in which it stated that no greenhouse gas emission restriction was given to those countries. Malaysia had also established its first National Policy on Climate Change (2009), taken along with the global climate action. Malaysia had first response to the United Nations Framework Convention on Climate Change (UNFCCC) through its first publication in July 2000, in that time was under the Ministry of Science, Technology and Environment in which they submitted their first ever Initial National Communication to the UNFCCC.[5] In 2011, following the obligations, Malaysia responded with the Second National Communication to UNFCCC.

Currently, Malaysian Green Technology and Climate Change Centre which formerly known as Malaysian Green Technology Corporation or GreenTech Malaysia is among one of the active agency involved in climate change research, as one of the agency under the Malaysian Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC) government.[6] Climate change related research in Malaysia[1] When searching using only "climate change" keyword as Topic in Web of Science Core Collection have been first published in early 1995 at Hydrobiologia journal, and being published in Malaysian based journal and publisher in late 2010, by the Journal of Oil Palm Research, publisher of Malaysian Palm Oil Board. In response to the long-term goals set by the Paris Agreement, the Nationally Determined Contributions (NDCs), research on climate change is truly needed.[7] The NDC also known as post-2020 climate actions, and submitted every five years to the UNFCCC's secretariat. Multiple Climatic Impact-Drivers (CIDs) recently published by the IPCC is the projection of climate change's impacts on land, coastal or open ocean regions in the world. It is projected that for another 20 to 30 years from now the climate change will affect the Earth's ecosystem through the increasing of relative sea level rise, coastal flood and erosion, marine heat wave, increasing ocean temperature and ocean acidification. Malaysia has experienced various climate change issues such as extreme rainfall, temperature extreme, sea level rise and extreme weather event.[8,9]Malaysia is located in the central part of south-east Asia and is one of the unique countries which consists of two land masses, Peninsular Malaysia as part of a country with a based-coastal region and East Malaysia as a country with open-ocean region. The East Malaysia consists of two states i.e., Sabah and Sarawak, meanwhile Peninsular Malaysia includes others 11 states, Perak, Selangor, Negeri Sembilan, Melaka, Terengganu, Kelantan and Pahang, Johor, Kedah, Perlis and Pulau Pinang with one Federal Territories which includes Putrajaya, Labuan and Kuala Lumpur. Each Malaysian land base was mostly surrounded by the aquatic environment and ecosystem in which it can be affected mostly from the climate change issues. This fact shows that the aquatic species will be one of the top lists of the most impacted organisms (i.e., creatures) from the climate related changes. Scientometric analysis or also known as evaluation and measurements of scientific research performance and is being introduced to establish the trends and developments of thematic areas or subject issue of new fields of science, technology and innovation.[10,11] It used the collection of various databases, such as from Web of Science, Scopus or Google Scholar. It is also one of the overview methods to analyze the current literature available on selected theme(s) of study. In addition, it is also shows the additional information such as total number of publication (i.e. article) per year, total number of organizations as well as institution involved, sources of publications (i.e. journal), total number of citations and citations per paper, *h*-index, the connection between key paper(s), most keywords founds, etc. This type of information will further affect the academics or researcher's performance, jobs and promotions as well as research grants applications. There are few popular software to analyze the bibliometrics study, especially in terms of scientometric analysis, such as CiteSpace[12] and VOSviewer.[13] These facts suggest that the scientometric based analysis is among one of the types of original research article in which they have their own methodological section, as well as results and discussion. The climate change research agenda and publications in Malaysia have been published by various authors,[14,15] however, there is no current research and publications available in terms of scientometric analysis, especially focused on the Malaysian context. Most of the studies have analyzed climate change related research without analyzing or filtering the available data or publications that are related to climate change issues in Malaysia.

This study, therefore, attempts to highlight the latest trends of climate change research in Malaysia and provides an overview in terms of various research questions as follows:

Research Questions (RQ)

RQ1. What are the evolutions of the publication trends in terms of overall publication output?

RQ2. What are the dominant topics/clusters, and what is their temporal evolution?

RQ3. What are the impactful publications and keywords for these areas?

In order to answer these questions, descriptive results (RQ1) and a scientometric analysis (RQ2 and RQ3) are being used. This type of information can be used by various stakeholders, such as academia, researchers and students to determine the evolution and emerging patterns of climate change research as well as the current gaps and challenges of climate sciences in the future, especially in Malaysia.

METHODOLOGY

The flowchart of the present study is shown in Figure 1.

Data Source

Accurate sources and comprehensive databases is one of the most important criteria for successful quantitative methods, such as scientometrics analysis.[16] Currently, the Thomson Reuters ISI Web

of Science (WOS) is among one of the leading database that covered almost 34,000 journals, 148,000 conference proceedings with more than 1.8 billion cited references.[2] Thus, the WOS, especially their most curated collection, the Core Collection Databases, which contains the peer-reviewed, high-quality scholarly journals published worldwide, was used for retrieval of the scientific literature for the present study. In addition, it's also covered by many areas of discipline of studies and type of knowledge available.[17]

Article search

The search of the related article in the WOS was being checked as "Topics" as it is covered by the title of the article, the abstract of the publication, the author's involved the keywords and keywords plus listed. Identification of the related keywords on Malaysian climate change research was referred from the past studies, the keywords that suggested by the WOS and from the expert's point of view (M.N.A. and M.A.G). There are two tags in WOS that are being used in the searching activities, the Boolean function (OR) and the Asterisk symbols (*). The Boolean of OR was used to include all the synonyms or keywords that are related to climate change and Malaysia. Meanwhile, the Asterisk symbols were applied to identify the various variations of the keywords and further broadening the quest.[18] The search was conducted on 13th January 2022.

Population Keywords

The search term of population keywords is Malaysia. There are 11 states and one (1) federal territory as being mentioned in the introduction section and being inserted in the "Topics" in the WOS searching index services as follows:

TS=((Malaysia) or (Borneo) or ("Peninsula*Malaysia") or ("East Malaysia") or (Sabah) OR (Sarawak) or (Terengganu) or (Kelantan) or (Pahang) or (Perak) or (Selangor) or ("Negeri Sembilan") or (Melaka) or (Johor) or (Kedah) or (Perlis) or ("Pulau Pinang") or (Putrajaya) or (Labuan) or ("Kuala Lumpur")).

Exposure Keywords

The search terms for the present study was based on the multiple Climatic Impact-Drivers (CIDs) recently published by the UNFCCC[7] as well as from the previous studies[19] as follows: TS=(("climate change") or ("global warming") or ("sea level rise") or ("flood") or ("coastal erosion") or ("marine heat wave") or ("ocean acidification") or ("ocean temperature") or ("extreme weather") or ("heavy precipitation") or ("heavy rainfall") or ("drought")).

Eligibility criteria

Several eligibility criteria of inclusion and exclusion indicators were applied when conducting the scientometric based analysis, especially during the scientific literature search.[20]

Inclusion Criteria

The scientific literature used in the present study is restricted to only original research articles, and it was written in English language. In addition, all research designs of qualitative, quantitative and mixed methods were included during the article screening.

Exclusion criteria

Any studies except original research articles such as, short communications, proceedings papers, book, chapter in book, reviews, book reviews, protocol papers, editorial materials, letters, abstracts or news were excluded during the selection of eligibility article for the present study.

Data Analysis

The data analysis for the present study was carried out using the Cite Space, a tool (i.e. computer program) that support the data mining process especially for the major sources of bibliographic databases, such as WOS, through visual analytic observatory, as well as summarization features of the main theme of the selected cluster of scientific publication.[12] Cite Space is software that is written in Java format for measuring, analyzing and visualizing the scientific publications of all fields of study, further mentioned as knowledge domain, which is being referred to as one of the specific topics, such as climate change research in Malaysia or to more undefined field of study. To address the first research question of the overall trends of publication output, the Microsoft Office Professional Plus 2019, the Excel software (i.e., apps) was used to visualize the data trends and the basic analysis of the annual number of publications, the publication sources (i.e., journals) of the knowledge domain where the papers were published, the most productive authors, the countries and university (ies) as well as the institutional where the authors were affiliated. The scientometric analyses were then used to better understand the knowledge domain in question, especially the second, third and the fourth question of dominant knowledge carriers, dominant topic or cluster and the impactful publications and keywords, respectively.

RESULTS

Descriptive Statistics

Evolution of Publications

The WOS database has been started to collect scientific publications from 1970, and the results of climate change related research in Malaysia have been conducted from 1976, and it shows the increasing trends started from the year of 1976 until 2021. Between those years, there were 1545 published articles focusing on the subject matter (i.e., climate change research in Malaysia), also known as the scientific domain or knowledge domain. The results also showed that there was a higher proportion of scientific publication in recent years from 2017 to 2021, with 2020 having the highest number of total publications (Figure 2).

Productive Authors

The descriptive results of the productive author showed that a total of 4993 authors were involved in climate change research in Malaysia. The results also showed that only a total of 1049

authors have been involved actively in this knowledge domain based on the publication number of more than one article (n=2) per author. Authors such as Pradhan Biswajeet (26 publications; 1.68%), Tan Mou Leong (26 publications; 1.68%), Yusop Zulkifli (26 publications; 1.68%), Shahid Shamsuddin (22 publications; 1.42%), Al-Amin Abul Quasem (20 publications; 1.29%), Huang Yuk Feng (18 publications; 1.16%), Juneng Liew (18 publications; 1.16%), Masud Muhammad Mehedi (17 publications; 1.1%), Begum Rawshan Ara (14 publications; 0.90%), Davies Stuart J (14 publications; 0.90%) is the top 10 authors from this domain (Figure 3).

Top Institutions

The paper features a total of 1,522 organizations around Malaysia that conducted research about climate change. Surprisingly, there are a total of ten organizations (i.e., institutions), which contributed 1037 articles equal to more than half (66%) of total publication between 1976-2022 (Figure 4). The National University of Malaysia or popularly known as Universiti Kebangsaan Malaysia contributed the highest number of articles retrieved for this study with proportion of 12.5% of total number of publications, followed by Universiti Teknologi Malaysia (11.65%), Universiti Putra Malaysia (11.2%), Universiti Malaya (11.01%), Universiti Sains Malaysia (6.18%), Kyoto University (3.67%), Universiti Malaysia Sabah (3.22%), Pusat Penyelidikan Hutan or Forest Research Centre (2.57%), National University of Singapore (2.38) and Universiti Malaysia Terengganu (2.38%).

Top journal

A total of 613 journals had published articles which related on the climate change research in Malaysia with a top ten (10) most productive journals is shown in Figure 5. The highest years of publication on Climate change in the journal of Sains Malaysiana is (31 articles: 1.996%). The journal of Sustainability (29 articles; 1.86%), Journal of Tropical Ecology (26 articles; 1.67%), Journal of Cleaner Production (21 articles; 1.35%), Biotropica (20 articles; 1.28%), Environmental Science and Pollution Research (20 articles; 1.28%), PLOS One (20 articles; 1.28%), Journal of Tropical Forest Science (19 articles; 1.22%), Theoretical and Applied Climatology (18 articles; 1.15%), and the lowest years of publication on Climate change is Water (18 articles; 1.15%) within the issue of climate change research in Malaysia with at least a total of 18 article being published.

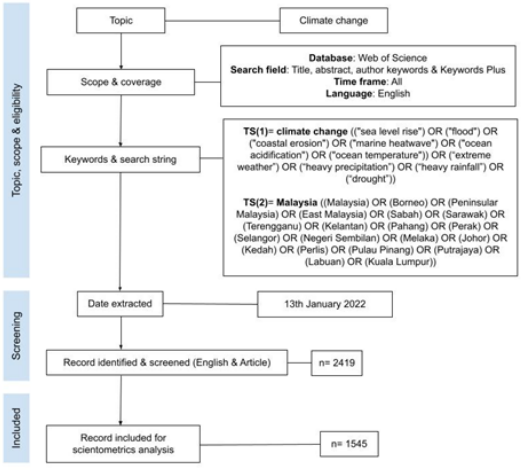

Figure 1: Flowchart for research structure on climate change in Malaysia.

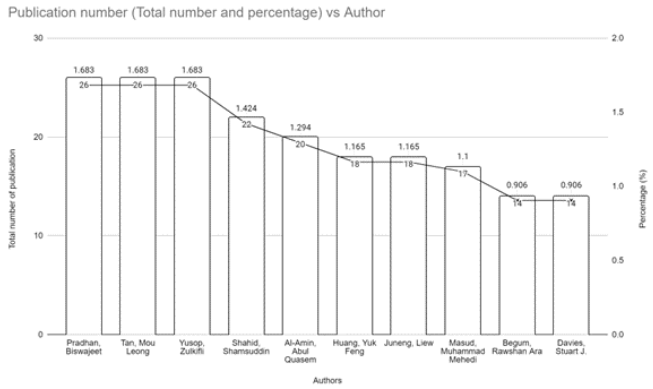

Figure 3: Top ten most productive Malaysian based affiliation scientific authors.

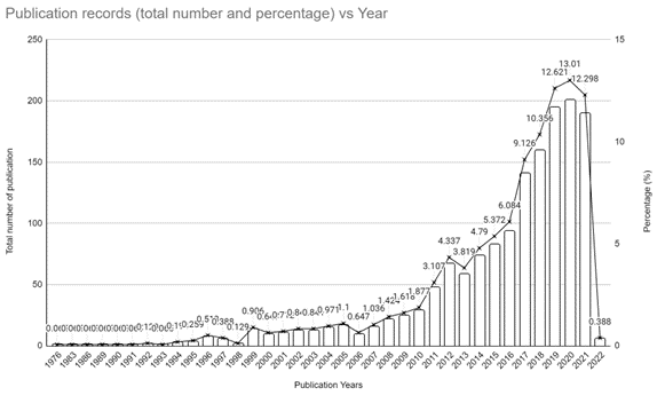

Figure 2: Trend of publication on climate change research in Malaysia between 1976 to 2022.

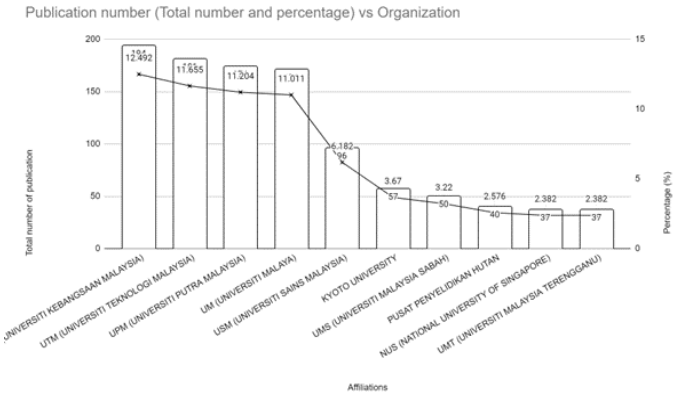

Figure 4: Top ten institutions that had published substantial research articles focusing on climate change research.

Article-citation based analysis

The article citation in terms of total citation received or an average citation received per year is an indicator that indicates the impact of a study in its discipline (i.e., climate change research in Malaysia). The research on climate change in Malaysia shows a total of 35,550 citations received with the *h*-index of the research domains equal to 87, with an average of 22.89 citations per article. The highest citation received by article is from a study by Page *et al.* (2002),[21] published in one of the highest impact factor journals in the world, the Nature. Meanwhile, the highest average number of citations received is from the study by Yaseen *et al.* (2019),[22] published in Elsevier based publisher, Journal of Hydrology. Tables 1 and 2 shows the top ten most influential papers in terms of total citation received and top ten most influential papers in terms of an average citation received per year, respectively.

Document Cluster Analysis

In scientometric analysis, there are two important metrics that indicate overall structural design of the network, the modularity Q and the mean silhouette scores. The mean silhouette score's value ranges between -1 and 1, and the highest value (i.e., 1) represents a perfect solution of the cluster. The value of the silhouette scores is 0.9824, which is in high quality clustering configuration. In addition, the value of the modularity Q is also high, 0.967, which means that the network of the present study is reasonably divided into equally coupled clusters. A total of 38 co-citation clusters have been generated from the raw data of WoS (Figure 6), with a total of 15 largest clusters among the publications. The top 15 clusters that represent a research topic of climate change in Malaysia were shown in Table 3. There are a total of three methods used for determination of each cluster, namely Latent Semantic Indexing (LSI), Mutual Information (MI) and LogLikelihood Ratio (LLR). The LLR was used to extract the cluster among publications since it have been suggested to provide the best results in terms of uniqueness and coverage of the research domains.[35]

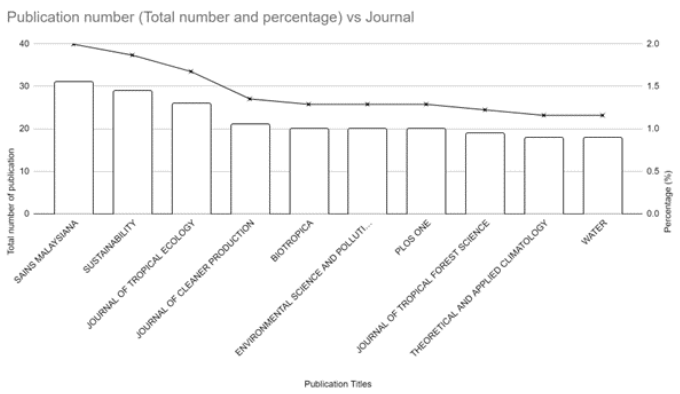

Figure 5: Top 10 Journal.

Co-citation networks

Figure 7 shows a cluster that indicates an underlying theme or a line of research or topic that is related to the climate change research in Malaysia. Figure 7 visualized a merged network characterizing the development of climate change research in Malaysia over 1976 until 2022. Each dot represents a node (i.e., cited references, as shown in different color) in the networks. Lines that connect between nodes are called co-citation links (Figure 7). It also shows some references are indicated with labels, which means that these references are highly cited between articles, suggesting that these are potential landmark papers in the field of climate change research in Malaysia. A total of four landmark publications are being identified, which are Hansen *et al.* (2013),[36] Mayowa *et al.* (2015),[37] Miettinen *et al.* (2016)[38] and Tang (2019)[9] (Figure 7).

DISCUSSION

The aim of this study is to present a scientometric analysis of the impacts of climate changes in Malaysia as one of the potential research domains in the future. The findings and research questions are discussed in this chapter, which was based on the three main subject as follows;

Evolution of the publication trends in terms of overall publication output

There were a total of 1545 published articles in the area of climate change research in Malaysia, when the data was searched back on 13th January 2022. However, there is an increase in the total number of publications when the same keywords and search strings were used on 26th February 2022, in which the total number of publications is 1584. The difference was caused by the fact that the publication number of 2021 was not fully integrated into the WoS database (at 13th January 2022). The previous data shows that there is a difference with the total number of publications in the year of 2021, from 190 to 222 articles. In addition, the year of 2022, there is also an increasing number of publications from 6 to 12 papers published. This data shows that there is a need to generate the publication data based on the year of the publication

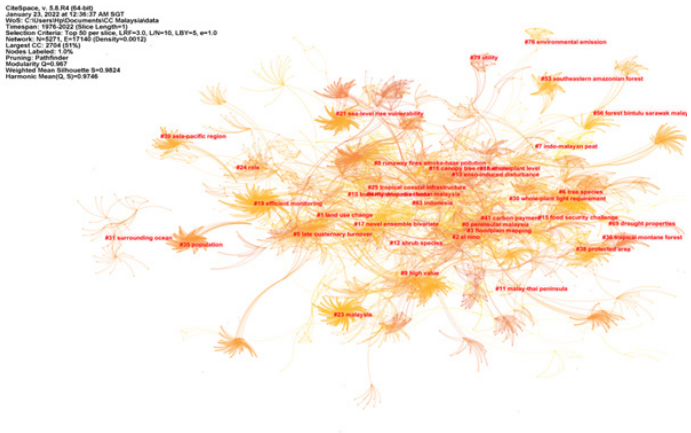

Figure 6: Document co-citation network based on the cluster view available in the knowledge domain of climate change research in Malaysia.

(e.g., 1976-2020), rather than based on the date of publication (e.g., recent database available until the date of searching activity).

Briefly, the highest total scientific publication in the knowledge domain is 13.01% which is in 2020 (until 13th January 2022) and authors such as Pradhan Biswajeet, Tan Mou Leong and Yusop Zulkifli is among the authors with the highest publication number (26 articles). The top five (5) universities listed with the highest total number publications for climate change research are among the "Research-based Universities" in Malaysia. The Malaysian based journal of Sains Malaysiana, publisher of National University of Malaysia itself published the highest article in the research about climate change, a total of 194 publications. The top three (3) articles with the highest citation counts received were Page *et al.* (2002),[21] Condit *et al.* (1995)[23] and Siegert *et al.* (2001),[24] and the highest article with the average citation counts per year were Yaseen *et al.* (2019),[22] Hamilton and Casey (2016)[26] and Page *et al.* (2002).[21]

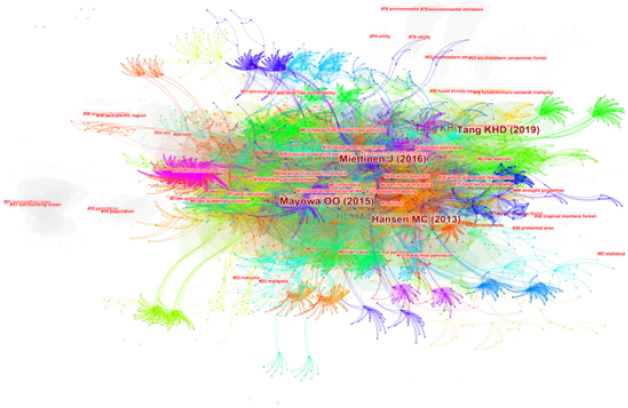

Figure 7: Network of Document Cluster

Page *et al.* (2002)[21] calculated the amount of carbon released from the 1997 fire activities, the burning peat and forest (i.e. vegetation) in Central Kalimantan, Borneo, Indonesia. The study found that the amount of carbon released from the activities significantly contributed to the largest annual increase in atmospheric CO_2 concentration in the world since the records of its concentration began in 1957. This paper was related to the keywords of anthropogenic climate change issue of carbon emissions, however, the study was not related to Malaysia but the use of the keywords of Borneo have captured the article during the analysis. Condit *et al.* (1995)[23] is the second highest citation per year based on the total citation received from the WOS database, which focused on the keywords such as El-Nino, drought and climatic change. Condit *et al.* (1995)[23] study on the effects of drought on the mortality rates of various types of neotropical and shrub tree species in Panama. They found that 70% of the sampling tree had a higher mortality rate during their first census interval (i.e., first five years of development stage) from 1982 to 1990.

Siegert *et al.* (2001)[24] also conducted a research almost the same as the study by Page *et al.* (2002),[21] in which they identified the effects

Table 1: Top ten most influential papers in terms of total citation received.

Title	References	Source Title	Total Citations
The amount of carbon released from peat and forest fires in Indonesia during 1997.	Page *et al.* (2002)[21]	Nature	1070
Mortality-rates of 205 neotropical tree and shrub species and the impact of a severe drought.	Condit *et al.* (1995)[23]	Ecological Monographs	498
Increased damage from fires in logged forests during droughts caused by El Nino.	Siegert *et al.* (2001)[24]	Nature	410
Flood susceptibility mapping using a novel ensemble weights-of-evidence and support vector machine models in GIS.	Tehrany *et al.* (2014)[25]	Journal of Hydrology	388
Creation of a high spatio-temporal resolution global database of Continuous Mangrove Forest Cover for the 21st century (CGMFC-21).	Hamilton and Casey (2016)[26]	Global Ecology and Biogeography	371
Current and future CO_2 emissions from drained peatlands in Southeast Asia.	Hooijer *et al.* (2010)[27]	Biogeosciences	365
Drought-mortality relationships for tropical forests.	Phillips *et al.* (2010)[28]	New Phytologist	355
Spatial prediction of flood susceptible areas using rule-based Decision Tree (DT) and a novel ensemble bivariate and multivariate statistical model in GIS.	Tehrany *et al.* (2013)[29]	Journal of Hydrology	335
Species-area and species-individual relationships for tropical trees: A comparison of three 50-ha plots.	Condit *et al.* (1996)[30]	Journal of Ecology	334
Reliable, verifiable and efficient monitoring of biodiversity via metabarcoding.	Ji *et al.* (2013)[31]	Ecology Letters	323

Table 2: Top ten most influential papers in terms of an average citation received per year.

Title	References	Source Title	Average per Year
An enhanced extreme learning machine model for river flow forecasting: State-of-the-art, practical applications in water resource engineering area and future research direction.	Yaseen *et al.* (2019)[22]	Journal of Hydrology	69
Creation of a high spatio-temporal resolution global database of Continuous Mangrove Forest Cover for the 21st century (CGMFC-21).	Hamilton and Casey (2016)[26]	Global Ecology and Biogeography	53
The amount of carbon released from peat and forest fires in Indonesia during 1997.	Page *et al.* (2002)[21]	Nature	50.95
Flood susceptibility mapping using a novel ensemble weights-of-evidence and support vector machine models in GIS.	Tehrany *et al.* (2014)[25]	Journal of Hydrology	43.11
Flood susceptibility assessment using GIS-based support vector machine model with different kernel types.	Tehrany *et al.* (2015)[32]	Catena	37.38
Spatial prediction of flood susceptible areas using rule based Decision Tree (DT) and a novel ensemble bivariate and multivariate statistical models in GIS.	Tehrany *et al.* (2013)[29]	Journal Oof Hydrology	33.5
World drought frequency, duration, and severity for 1951-2010.	Spinoni *et al.* (2014)[33]	International Journal of Climatology	33
Reliable, verifiable and efficient monitoring of biodiversity via metabarcoding.	Ji *et al.* (2013)[31]	Ecology Letters	32.3
The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental Kuznets curve in four selected ASEAN countries.	Liu *et al.* (2017)[34]	Journal of Cleaner Production	31.5
Current and future CO_2 emissions from drained peat lands in Southeast Asia.	Hooijer *et al.* (2010)[27]	Biogeosciences	28.08

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of drought caused by the El-Nino in tropical rainforests in East Kalimantan, Indonesia. The study concludes that the fires caused by drought in East Kalimantan is the largest ever observed fire disaster in the world, and potentially increased the risk of recurrent fire disaster in that area. The article by Yaseen *et al.* (2019)[22] demonstrated the comprehensive review of the Extreme Learning Machine (ELM) model based on the case study conducted in Kelantan river of Peninsular Malaysia. The study was also captured some keywords related to the climate change research in Malaysia such as flood, climate change, Kelantan and Peninsular Malaysia. The study by Hamilton and Casey (2016)[26] aims to identified the loss of mangrove areas in several countries such as Malaysia related to the various international issue such as climate change, food security fisheries support, conservation and livelihoods. The study was related to the keywords of Malaysia and climate change since their data showed that Malaysia is among countries that recorded the highest amounts of mangrove loss in the Southeast Asia region.

Dominant topics/clusters and their temporal evolution

A short review of each cluster is done based on the highest number of publications of each cluster (>100 articles). Cluster with "land use change" was the largest cluster and had 186 publications and the most relevant article that cited this cluster is the review published by Hergoualc'h and Verchot (2011).[39] They found that the increasing trends of deforestation and degradation of tropical peat swamp forests had greatly contributed towards climate change. The second largest cluster (peninsular malaysia) has 176 articles and the most relevant citer to this cluster is the study by Venter *et al.* (2013).[40] They recognized that the large-scale REDD program (Reducing Emissions from Deforestation and forest Degradation) could potentially be one of the best strategies to mitigate the impacts of climate change impacts in the world. El nino is the third largest cluster with a total of 161 articles associated with, and the study by Harrison (2001)[41] is the most relevant citation in this cluster. The study reveals that during the El Niño Southern Oscillation event in 1997-1998, the figs as one of the keystone plant groups in Lambir Hills National Park, Sarawak was significantly affected by the event (i.e., pollinators of dioecious figs became locally extinct).

The late quaternary turnover and tree species are the 4th and 5th largest clusters in the area of climate change research in Malaysia, with each having of 120 members (i.e articles) and 119 articles, respectively. The study by Cranbrook (2010)[42] is the most relevant article in the 4th cluster and Russo *et al* (2008)[43] is the article that is being associated with the 5th cluster. The study by Cranbrook (2010)[42] indicates that the Quaternary environment is among one

Table 3: A total of fifteen (15) major cluster emerged from document co-citation analysis.

Cluster ID	Size	Silhouette	Label (LSI)	Label (LLR)	Label (MI)	Average Year
0	186	0.99	Peninsular malaysia	Land use change (90.6, 1.0E-4)	Large-scale forest (0.3)	2008
1	176	0.951	Tropical peatland	Peninsular malaysia (185.01, 1.0E-4)	Large-scale forest (0.3)	2014
2	161	0.941	El nino	El niño (79.75, 1.0E-4)	Keystone plant resource (0.09)	1998
3	120	0.997	Late quaternary turnover	Late quaternary turnover (35.45, 1.0E-4)	Peninsular malaysia (0.03)	2004
4	119	0.977	Tree species	Tree species (92.4, 1.0E-4)	Species richness (0.06)	2004
5	114	0.971	Peninsular malaysia	Borneo island (221.86, 1.0E-4)	Future hydro-meteorological drought (1.96)	2015
6	112	0.99	Ecosystem functioning	Indo-malayan peat (42.69, 1.0E-4)	Peninsular malaysia (0.02)	2007
7	103	0.983	Unnatural disaster	Runaway fires smoke-haze pollution (58.79, 1.0E-4)	Tree species composition (0.02)	2000
8	100	0.978	Genetic diversity	Butterfly drupadia theda (55.71, 1.0E-4)	Human-sun bear conflict (0.03)	2000
9	97	0.979	Case study	Floodplain mapping (179.43, 1.0E-4)	Energy resource (0.69)	2018
10	96	0.963	High value	High value (41.4, 1.0E-4)	Environmental correlate (0.02)	2008
11	94	0.961	Drought-mortality relationship	Malay-thai peninsula (61.51, 1.0E-4)	Southeast asian tropical bird (0.04)	2006
12	94	0.988	Severe drought	Shrub species (50.2, 1.0E-4)	Selective drought mortality (0.02)	1994
13	84	0.986	Enso-induced disturbance	Enso-induced disturbance (46.95, 1.0E-4)	Synchronous leaf (0.03)	2003
14	79	0.99	El nino	Canopy tree recruitment (48, 1.0E-4)	Peninsular malaysia (0.03)	1998

of the oscillating patterns of climate change and has a huge impact towards the mammal distribution in Borneo island. Meanwhile, the study by Russo *et al* (2008)[43] is considered as not related to the main research of climate change. The 6th largest cluster in the research of climate change in Malaysia has 114 articles labeled as Borneo island, and the most relevant article in this cluster is the study by Salman *et al.* (2020).[44] They found that General Circulation Models (GCMs) such as Coupled Model Intercomparison Project-Phase 5 (CMIP5) is among one of the major sources for reducing the uncertainty in climate change projections.

The indo-malayan peat has been decided as the 7th largest cluster with a total of 112 publications. The study by Yule (2010)[45] is the most relevant citer to the cluster. The study reviewed some of the factors of climate changes such as logging, fire and agricultural conversion affecting the biodiversity and ecosystem functioning in Indo-Malayan peat swamp forests. The another two cluster with more than 100 articles are runaway fires smoke-haze pollution (8th) and butterfly drupadia theda (9th) and study by Aiken (2004)[46] and Fauvelot *et al.* (2006)[47] has been considered as the most relevant citer to both cluster, respectively. The study by Aiken (2004)[46] focused on the Indonesian deforestation from 1985 to 1997 contributed significantly towards the 1997-1998's out of control fires and smokes towards Southeast Asia. Fauvelot *et al.* (2006)[47] found that the 1997/1998's El Niño Southern Oscillation-induced drought and fire which caused the distribution, abundance and genetic variation in a tropical butterfly.

Impactful publications and keywords for these areas

Based on the document cluster of the co-citation network, we found that there are four articles that have been considered as the most impactful publications and keywords for these areas of climate change research in Malaysia. The study by Hansen *et al.* (2013),[36] Mayowa *et al.* (2015),[37] Miettinen *et al.* (2016)[38] and Tang (2019)[9] was chosen based on the the top ranked item by citation counts and the the top ranked item by burstiness (Appendix 1). Briefly, Hansen *et al.* (2013)[36] stressed the importance of quantification of

global forest change and loss through the high-resolution of earth observation satellite data. They found that the tropical climate forest is in increasing loss of 2101 square kilometers per year, and Malaysia is among one of the countries with well-documented reduction in deforestation. These changes directly affected tropical biodiversity richness, climate regulation and carbon storage as one of the important aspects in the ecosystem services. Mayowa *et al.* (2015)[37] found that coastlines are among one of the most vulnerable regions with respect to the pollution and climate change related activities. In Peninsular Malaysia, most of the coastline has been affected by the climatic changes such as heavy rainfall that led to the annual phenomenon of floods. Surprisingly, they found that there was a substantial increase in the annual rainfall compared to the past four decades (1971-2010).

Meanwhile, Miettinen *et al.* (2016)[38] discovered the importance of Southeast Asian peatlands that faced rapid changes over the past few years, caused by the environmental changes or climate change. They found that the peat land is among one of the global hotspot areas for degradation, deforestation, fires and plantation development. The study evaluated the current status and recent change trends on peat lands in Southeast Asian regions. Tang (2019)[9] reviewed the impacts of climate change on the Malaysian environment, the major contributors of greenhouse gasses in Malaysia as well as the mitigation and adaptations plan in the future. The study also found that climate change had impacted Malaysian agriculture, forestry, biodiversity, water resources, coastal and marine resources, public health and energy.

CONCLUSION

In conclusion, the research of climate change in Malaysia was synthesized, unveiling its trends in terms of publication year, top journals, productive authors, countries, institutions, keywords, and references. Since 2017, there has been an increasing interest in the research landscape on climate change related research, as supported by the increasing number of publications and citations. The most influential article in terms of the highest citation received was published by Page *et al.* (2002)[21] in Nature. Meanwhile, the average number in terms of citation received was published recently in Elsevier based publisher, Journal of Hydrology by the study of Yaseen *et al.* (2019).[22] Based on the scientometric view, the knowledge domain of climate change research in Malaysia has attracted various fields of study with the total number of 38 co-citation clusters having been generated.

RECOMMENDATIONS

Future search terms related to climate change should be chosen based on the multiple Climatic Impact-Drivers (CIDs) recently published by the IPCC (IPCC, 2021).[48] The search terms are suggested to be focused on the fact that CID affected a country based-coastal region (Peninsular Malaysia) and open-ocean region (Borneo) such as Malaysia. The terms referred to the number of coastal regions and open-ocean regions where each CID is projected to increase in the future (20-30-year period centered around 2050 and/or consistent with 2°C global warming) (IPCC, 2021).[48] Enough with climate change impacts, let's talk and do on Climate Actions!

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AUTHORS' CONTRIBUTIONS

All authors conceptualized this study. M.A and M.I. formulated the research objectives, whereas M.A. pointed out the inclusion and exclusion criteria under the supervision of other two authors M.A.G and Y.Y.S. The expert in the subject is M.A and M.A.G. Then, M.I performed the searches. I.Z proof-read the article and reviewed the overall manuscript scientifically. All authors have read and agreed to the published version of the manuscript.

AVAILABILITY OF DATA AND MATERIALS

The datasets generated during and/or analyzed during the current study are available in the Figshare repository, https://doi.org/10.6084/m9.figshare.19294745.v1

CONFLICT OF INTEREST

The authors declare no conflict of interest

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