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Research Paper

Bibliometric analysis on machine learning in climate change article during ten years

Dr. Minh Thu Nguyen*
*Vietnam Institute of Meteorology, Hydrology and Climate change, Vietnam.

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ABSTRACT

This research used bibliometric method to calculate scientific productivity of corresponding author, first author, affiliation, and correspondence country for machine learning in climate change articles on SCOPUS database from 2015 to 2024. Moreover, spatial simulation of country output is displayed by geographic information system, showing distribution of scientific productivity in each country on the world. Total 4,406 articles are analyzed and simulated, they indicated that research productivity has increasing trend and increases sharply from 2021 to 2024 year with 528 to 1239 articles. Y. Wang correspondence author is 1st ranking and the most research output with 19 articles, including 12 articles in China, 1 article in Finland, and 6 articles in United States. Almost authors publish strongly from 2022 to 2024 with high output as Y. Wang, J. Li, Y. Li, J. Yin, and J. Chen correspondence authors. Y. Zhang first author has the most scientific output with 16 articles and 1st ranking, concluding 13 articles publish in China, 2 articles in Canada, and 1 article in Singapore. Publication of affiliation increases strongly from 2021 to 2024 year and Department of Civil Engineering has the most publication with 97 articles in 20 countries, 1st ranking. China has the most publication in 2015-2024 with 1148 articles, 1st ranking in correspondence author. Publication in countries is increased strongly from 2020 to 2024 year and from 2021-2024, the whole countries have publication at all.

Corresponding Author:
Dr. Minh Thu Nguyen
Vietnam Institute of Meteorology, Hydrology and Climate change, Vietnam.
Email: ruanthuminh@gmail.com

1. INTRODUCTION

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer [1]. It is attributed directly or indirectly to human activity that alters the composition of the global atmosphere such as burning of fossil fuels [2], land use change and agriculture that are increasing the atmospheric concentrations of greenhouse gases, and aerosols [3]. Climate change and its impacts are major concerns for humanity and pose significant challenges and obstacles to achieving sustainable development worldwide [4]. The consequences of climate change, such as famine, droughts, extreme weather events, and regional conflicts, are factors that increase the incidence and severity of diseases and other adverse health effects [5], [6], [7]. Climate change has become a major scientific, political, economic, and environmental issue during the last decade [8] and scientific articles on climate change have demonstrated a rapid increase in quantity over the past several decades, a number of papers presenting the latest research achievements have been published in authoritative scientific journals such as Nature and Science [8].

Machine learning is a branch of artificial intelligence (AI) that has seen an exponential increase in recent years [9]. It plays an increasingly important role in our daily life as part of a wide variety of applications [10] because it is focused on systems learning from data [11]. In 1947, the British mathematician Alan Turing envisioned a machine that could, based on an initial set of instructions, modify its own operating instructions over time [12]. Machine learning describes a set of techniques that are commonly used to solve a variety of real-world problems with the help of computer systems which can learn to solve a problem instead of being explicitly programmed [13]. Machine learning influences our daily lives in several aspects [14], especially in tasks related to high-dimensional data such as classification, regression, and clustering, with good applicability [15], and learning from previous computations and extracting regularities from massive databases, it can help to produce reliable and repeatable decisions [16].

Bibliometric is used to describe the study of science as growth, structure, interrelationships, and productivity [17]. Nowadays bibliometric is regarded as a research tool cannot be absent in investigation of information science field, because of its strength in qualitative analysis [17] and quantitative to improve efficiency rates of information handling process [18]. Many scientists have tried to evaluate the research trend in the publication outputs of paper title [19], author keywords [19], [20], words in abstracts [21], languages [20], document type [22], words in abstracts [23], [24] or to be predictable in a relationship [25]. However, they were merely publication counts, but they have not been revealed yet research productivity of each title in annually or countries as well as its spatial distribution. Therefore, goal of research is 1) describing and analyzing research productivity of author and affiliation annually in countries, 2) understanding about corresponding country output in ten years and its spatial distribution on the world.

2. RELATED WORK

Bibliometric is a set of tools for analyzing publication data [26] and it is regarded as a research tool cannot be absent in investigation of information science field, because of its strength in qualitative analysis [17] and quantitative to improve efficiency rates of information handling process [18] and increase understanding of the information science research [17]. The bibliometric information associated with a publication includes author, affiliation, country, author subject category and it describes the quantity research as well as focuses on research output by a particular organization that scientific output depends on the amount or type of information, which is selected for different purposes. Bibliometric statistic has high reliability because database form is drawn exactly, therefore it is described publication system and has high validity, is used extensively to analyze research fields, review looking back in time and searching of research directions in the future.

Moreover, climate change nowadays impacts to all aspects of global, politics, economy, and society. Climate change and its impacts are major concerns for humanity and pose significant challenges and

obstacles to achieving sustainable development worldwide [4]. The consequences of climate change, such as famine, droughts, extreme weather events, and regional conflicts, are factors that increase the incidence and severity of diseases and other adverse health effects [5], [6], [7]. Climate change has become a major scientific, political, economic, and environmental issue during the last decade [8] and scientific articles on climate change have demonstrated a rapid increase in quantity over the past several decades, a number of papers presenting the latest research achievements have been published in authoritative scientific journals such as Nature and Science [8]. Furthermore, Machine learning describes a set of techniques that are commonly used to solve a variety of real-world problems with the help of computer systems which can learn to deal a problem instead of being explicitly programmed [13]. Machine learning influences our daily lives in several aspects [14]. From the above, this research conducts to describe and analyze research productivity of author and affiliation annually in countries as well as understanding about corresponding country output in ten years and its spatial distribution on the world.

3. METHODOLOGY

Data source is downloaded from SCOPUS in 2015-2024 year with term of "machine learning in climate change" including machine learning and climate change keywords of 4406 articles. It focuses on estimating total research productivity, author, country, and affiliation as well as simulation of spatial distribution on the world. Before using bibliometric method, 4406 articles need to be implemented some steps as group all the documents from Hong Kong, China, Ma Cao, and Taiwan is China heading; the documents are from United State is called as USA; United Kingdom is UK; Russian Federation is reclassified as Russia; and United Arab Emirates is UAE to unify in country name.

Calculation is estimated for total research output, scientific publication of author, affiliation, and country. It is detailed for each year, country, and affiliation, in which first author document is identified after removing cooperative authors. First author is head of author in each article and it is presented FA-first author productivity. Correspondence author is contacted by journal during submitting process and corresponding country includes articles, which have corresponding author and author's country. Affiliation is calculated when separating authors and countries in each affiliation, then it is estimated scientific productivity for each affiliation in annually. Moreover, spatial distribution of research productivity for country is displayed via Geographic Information System. It is a computer tool for mapping and analyzing real world to display total scientific output in countries on the world.

4. RESULTS AND DISCUSSION

Basing on 4406 articles is extracted from SCOPUS database. This research conducts calculation and analysis research productivity. The results are presented as following:

Trend of scientific output in 2015-2024

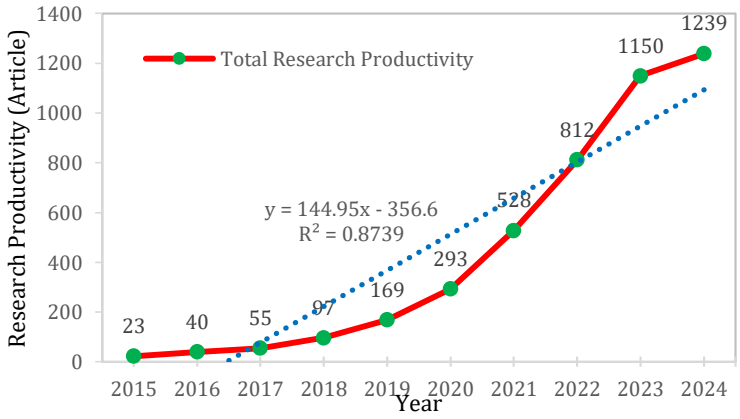

Figure 1. Annual Research Publication of Machine Learning in Climate Change Article

With 4406 articles, the research is calculated total scientific productivity in 2015-2024, in which 2015 year published 23 articles, 2016 year is 40 articles, 55 articles in 2017 year, 97 articles in 2018 year, 169 articles (2019), 293 articles (2020), 528 articles (2021), 812 articles (2022), 1150 articles (2023) and 1239 articles (2024). In the Figure 1 indicates annual scientific productivity increases from 2015 to 2024 that it increases sharply from 2021 to 2024 year, from 528 articles to 1239 articles. It also reveals scientific output of machine learning in climate change field is increasing trend. It demonstrates that scientists are being paid attention in machine learning with climate change field in recent ten years Figure 1

Publication of Authors

Corresponding author is often contacted by journal while reviewing. Corresponding author has important role in an article and its value is the same first author. With 4406 articles of machine learning in climate change field, correspondence author is calculated by bibliometric and Table 1 is 25 corresponding authors, who have the most research productivity. 1st ranking is Y. Wang with 19 articles. Following by Z. Zhang (14 articles), Y. Liu, X. Wang, and J. Li with 13 articles, Y. Yang and Y. Li have 12 articles, X. Li and J. Yin with 11 articles, L. Zhang, J. Zhang, and J. Im with 10 articles, Y. Chen (9 articles), Y. Huang, X. Zhao, X. Zhang, F. Chen, and C. Zhang with 8 articles, J. Chen, H. Wang, H. Saijad, G. Wang, and H. Zhang with 7 articles, X. Yang and W. Li are 6 articles with 10th ranking. Almost authors publish strongly from 2022 to 2024 with high output, including Y. Wang, J. Li, Y. Li, J. Yin, and J. Chen. Especially, J. Chen author started publication in 2020 with one article and to 2024 had 6 articles or J. Li author started with 1 article in 2017 and it increases strongly in 2024 with 9 articles. Thus, Y. Wang is 1st ranking and the most research output in 2015-2024 Table 1.

Table 1. Scientific Productivity of Corresponding Author in Ten Years

CRA name	TP (R)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Y. Wang	19(1)					1		2	4	5	7
Z. Zhang	14(2)					2		2	4	2	4
Y. Liu	13(3)	1			1		2		4	3	2
X. Wang	13(3)				1			3	4	2	3
J. Li	13(3)			1			1		1	1	9
Y. Yang	12(4)			1	4			1	1	1	4
Y. Li	12(4)								1	3	8
X. Li	11(5)								4	4	3
J. Yin	11(5)							1		3	7
L. Zhang	10(6)					1	1		3	2	3
J. Zhang	10(6)						1	1	2	1	5
J. Im	10(6)		1	1	2		1	2	2		1
Y. Chen	9(7)					2	1	1	1	3	1
Y. Huang	8(8)						1	1	1	3	2
X. Zhao	8(8)								1	3	4
X. Zhang	8(8)					1		2	1	2	2
F. Chen	8(8)			1			1	1	1	1	3
C. Zhang	8(8)						1	2		3	2
J. Chen	7(9)						1				6
H. Wang	7(9)						1	1	1	2	2
H. Sajjad	7(9)									3	4
G. Wang	7(9)							1		4	2
H. Zhang	7(9)							2		2	3

X. Yang	6(10)									3	3
W. Li	6(10)								1	3	2
CRA Correspondence Author, TP Total research productivity, R Ranking											

Corresponding author publishes not only annual year, but they also present each country. Table 2 concludes 12 countries of 25 corresponding authors and indicates that China has the most publication, next is United States, in which Y. Wang has 19 articles including 12 articles in China, 1 article in Finland, and 6 articles in United States. Following by Z. Zhang with 14 articles (12 articles in China and 2 articles in USA), Y. Liu is 13 articles (10 articles in China and 3 articles in USA), X. Wang with 13 articles (10 articles in China, 1 article in France, and 2 articles in USA), Y. Li is 12 articles (10 articles in China, 1 article in Singapore, and 1 article in USA), X. Li with 11 articles (8 articles in China, 2 articles in Canada, and 1 articles in USA), L. Zhang is 10 articles (9 articles in China and 1 article in USA), Y. Chen with 9 articles (7 articles in China, 1 article in Germany, and 1 articles in USA), Y. Huang is 8 articles (3 articles in China and 5 articles in USA), X. Zhao with 8 articles (7 articles in China and 1 article in USA), C. Zhang with 8 articles (4 articles in China and 4 articles in USA), J. Chen and H. Wang have 7 articles (6 articles in China and 1 article in Canada), H. Zhang is 7 articles (6 articles in China and 1 article in Belgium), and W. Li has 6 articles (2 articles in China, 2 articles in Germany, and 2 articles in USA). Especially, J. Li, Y. Yang, J. Yin, J. Zhang, X. Zhang, F. Chen, G. Wang, and X. Yang authors only publish in China in 2015-2024. Moreover, most corresponding authors belongs to be China and one or two countries as Canada, France, Singapore, etc. Besides, some corresponding authors come from other countries, such as J. Im is from Korea with 10 articles and H. Saijad is from India with 7 articles Table 2.

Table 2. Scientific Productivity of Corresponding Author in Country

CRA name	TP (R)	Bel	Can	Chile	Chi	Fin	Fra	Ger	Ind	Jap	Sin	Kor	USA
Y. Wang	19(1)				12	1							6
Z. Zhang	14(2)				12								2
Y. Liu	13(3)				10								3
X. Wang	13(3)		2		10		1						
J. Li	13(3)				13								
Y. Yang	12(4)				12								
Y. Li	12(4)				10						1		1
X. Li	11(5)		2		8								1
J. Yin	11(5)				11								
L. Zhang	10(6)				9								1
J. Zhang	10(6)				10								
J. Im	10(6)											10	
Y. Chen	9(7)				7			1					1
Y. Huang	8(8)				3								5
X. Zhao	8(8)				7								1
X. Zhang	8(8)				8								
F. Chen	8(8)				8								
C. Zhang	8(8)				4								4
J. Chen	7(9)		1		6								
H. Wang	7(9)		1		6								
H. Sajjad	7(9)								7				
G. Wang	7(9)				7								

H. Zhang	7(9)	1			6								
X. Yang	6(10)				6								
W. Li	6(10)				2			2					2
CRA Correspondence Author, TP Total research productivity, R Ranking, Bel Belgium, Can Canada, Chi China, Fin Finland, Fra France, Ger Germany, Ire Ireland, Ind India, Sin Singapore, USA United states, Jap Japan, Kor Korea.													

Corresponding author is different from first author. In an article, first author is main author and the highest value. Similarly, first author is also presented country of first author and Table 3 includes 20 first authors. It indicates that Y. Zhang has the most scientific output with 16 articles and 1st ranking, concluding 13 articles publish in China, 2 articles in Canada, and 1 article in Singapore. Next is X. Wang with 14 articles (10 articles in China, 1 article in Australia, 1 article in Canada, 1 article in France, and 1 article in Netherland). X. Li, J. Wang, and Z. Wang authors publish in 3 countries as China (8-10 articles), Canada (1 article), and USA (1-2 articles). Z. Zhang and W. Li publish in China (4-9 articles), Germany (2 articles), and USA (1-2 articles). H. Zhang with 10 articles in China (8 articles), Belgium (1 article), and USA (1 article). S. Wang is in China (8 articles), Japan (1 article), and USA (1 article). A. Jamali with 9 articles including in Iran (4 articles), Canada (1 article), and Turkey (4 articles). C. Zhang, X. Liu, Y. Chen, and Y. Liu authors publish in two countries including China and USA or Germany. L. Zhang publishes in 4 countries as China (9 articles), Ireland (1 article), Netherland (1 article), and USA (1 article). However, Y. Li, S. Liu, J. Zhang, and J. Liu publish only in China with 10-13 articles Table 3.

Table 3. Research Output of First Author in Country

FA name	TP (R)	Aus	Ban	Bel	Can	Chi	Fra	Ger	Ira	Ire	Jap	Net	Sin	Tur	USA
Y. Zhang	16(1)				2	13							1		
X. Wang	14(2)	1			1	10	1					1			
X. Li	14(2)				1	12									1
J. Wang	13(3)				2	9									2
Y. Li	13(3)					13									
Z. Zhang	12(4)					9		2							1
L. Zhang	12(4)					9				1		1			1
S. Zhang	12(4)	1				9									2
S. Liu	11(5)					11									
H. Zhang	10(6)			1		8									1
S. Wang	10(6)					8					1				1
J. Zhang	10(6)					10									
Z. Wang	10(6)				1	8									1
J. Liu	10(6)					10									
C. Zhang	9(7)					5									4

X. Liu	9(7)					8									1
A.Jamali	9(7)				1				4					4	
Y. Chen	9(7)					8		1							
Y. Liu	8(8)					6									2
W. Li	8(8)					4		2							2
FA First Author, TP Total research productivity, R Ranking, Aus Australia, Ban Bangladesh, Bel Belgium, Can Canada, Chi China, Fra France, Ger Germany, Ire Ireland, Net Netherlands, Sin Singapore, Tur Turkey, USA United states, Chi China, Ira Iran, Jap Japan.															

Output of Affiliation

Affiliation is working place of authors. Table 4 presents output of 25 affiliations in 2015-2024 and it indicates that Department of Civil Engineering has 97 articles, 1st ranking. Following by Department of Geography with 68 articles, 2nd ranking, Department of Civil and Environmental Engineering (53 articles, 3rd ranking), Department of Computer Science (34 articles, 4th ranking), Department of Computer Science and Engineering (30 articles, 5th ranking), State Key Laboratory of Remote Sensing Science (21 articles, 6th ranking), Department of Biology (19 articles, 7th ranking), Department of Civil (17 articles, 8th ranking), School of Civil Engineering (16 articles, 9th ranking), Key Laboratory of Land Surface Pattern and Simulation (15 articles, 10th ranking), Faculty of Engineering (13 articles, 11th ranking), two affiliations are Department of Earth and Environmental Sciences and Department of Earth System Science has 12 articles, 12th ranking, 13th ranking is State Key Laboratory of Water Resources Engineering and Management, Department of Environmental Sciences, and Department of Electrical and Computer Engineering with 11 articles.

14th ranking is State Key Laboratory of Hydro-science and Engineering, State Key Laboratory of Earth Surface Processes and Resource Ecology, School of Economics and Management, Key Laboratory of Watershed Geographic Sciences, Department of Mechanical Engineering, College of Hydrology and Water Resources, and Civil Engineering Department with 10 articles. Last ranking (15th ranking) is School of Geography and School of Engineering with 9 articles. Except for Department of Civil Engineering, Department of Civil, and Department of Environmental Sciences have the first publication in 2015, most of other affiliations publish late about 2018-2019 year. However, publication of affiliation increases strongly from 2021 to 2024 year. Especially, in 2023-2024, all the affiliations reveal strong output, which is Department of Civil Engineering, Department of Geography, Department of Civil and Environmental Engineering, and State Key Laboratory of Water Resources Engineering and Management Table 4.

Table 4. Research Productivity of Affiliation in 2015-2024

No	Affiliation name	TP (R)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1	Department of Civil Engineering	97(1)	1			1	2	3	14	15	32	29
2	Department of Geography	68(2)				2	5	2	7	14	15	23
3	Department of Civil and Environmental Engineering	53(3)		3	2	1	6	3	3	5	16	14
4	Department of Computer Science	34(4)					3		3	11	8	9
5	Department of Computer Science and Engineering	30(5)				2		4	4	3	8	9
6	State Key Laboratory of Remote Sensing Science	21(6)					3	1	3		10	4
7	Department of Biology	19(7)			1	1	1	1	2	4	5	4

8	Department of Civil	17(8)	1					1	2	3	7	3
9	School of Civil Engineering	16(9)						2	2	4	3	5
10	Key Laboratory of Land Surface Pattern and Simulation	15(10)						1		7	2	5
11	Faculty of Engineering	13(11)				1		1	1	3	2	5
12	Department of Earth and Environmental Sciences	12(12)				1			2	1	4	4
13	Department of Earth System Science	12(12)							3	3	2	4
14	State Key Laboratory of Water Resources Engineering and Management	11(13)									1	10
15	Department of Environmental Sciences	11(13)	1						1	4	3	2
16	Department of Electrical and Computer Engineering	11(13)						1	4	3	1	2
17	State Key Laboratory of Hydro-science and Engineering	10(14)					2	1	1	2	2	2
18	State Key Laboratory of Earth Surface Processes and Resource Ecology	10(14)							3	1	4	2
19	School of Economics and Management	10(14)							1		7	2
20	Key Laboratory of Watershed Geographic Sciences	10(14)						1	1	2	3	3
21	Department of Mechanical Engineering	10(14)						1	1	1	5	2
22	College of Hydrology and Water Resources	10(14)								4	5	1
23	Civil Engineering Department	10(14)							4	2	1	3
24	School of Geography	9(15)							1	1	1	6
25	School of Engineering	9(15)				1		1		2	3	2
TP Total research productivity, R Ranking												

Research output of affiliation normally includes many authors and countries. Table 5 is 15 affiliations, which have the most scientific productivity. Firstly, Department of Civil Engineering has 97 articles with 1st ranking and publishes in 20 countries as Australia (1 article), Bangladesh (1 article), Canada (7 articles), Chile (1 article), China (9 articles), India (28 articles), Iran (19 articles), Iraq (3 articles), Malaysia (5 articles), Nepal (1 article), Nigeria (2 articles), Romania (1 article), Saudi Arabia (4 articles), South Africa (2 articles), South Korea (3 articles), Spain (1 article), Sri Lanka (2 articles), Turkey (3 articles), United Kingdom (1 article), and United States (2 articles). 2nd ranking is Department of Geography with 68

articles in 18 countries, including Belgium (2 articles), Canada (4 articles), Chile (1 article), China (4 articles), France (1 article), Germany (4 articles), Greece (2 articles), India (21 articles), Indonesia (1 article), Norway (1 article), Viet Nam (1 article), Pakistan (3 articles), South Africa (2 articles), Spain (2 articles), Thailand (2 articles), Togo (1 article),), United Kingdom (1 article), and United States (15 articles). Similar, output of other affiliations is published in different countries and it is presented in Table 5, in which more publication distributes in China, Canada, India, and United States countries Table 5.

Table 5. Research Output of Affiliation in Country

Country name	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Australia	1								1		1				
Austria				1											
Bangladesh	1														
Belgium		2										2			
Brazil				1											
Canada	7	4	5	2			2	2							
Chad				1											
Chile	1	1													
China	9	4	4		1	20			5	14	1		5	11	
Colombia											1				
Finland				1	1					1					
France		1													
Germany		4													
Ghana				1											
Greece		2													
India	28	21	1	3	26				2			1			
Indonesia		1													
Iran	19		2						4		2				
Iraq	3						1								
Italy								5			1	2			5
Japan			2												
Kazakhstan			1												
Lebanon															1
Malaysia	5								3						
Mexico				1											
Morocco				1											
Nepal	1														
New Zealand			1												
Nigeria	2		1	1							1				
Norway		1	1	1											
Viet Nam		1													
Pakistan		3		3					1		1				1
Peru											1				
Portugal											1				
Puerto Rico															1
Romania	1			1											
Saudi Arabia	4		1	7											

Singapore			1			1									
Slovakia				1											
South Africa	2	2		1							1				
South Korea	3		4		1		2	1							
Spain	1	2					1								1
Sri Lanka	2														
Switzerland															1
Thailand		2		1											
Togo		1													
Turkey	3										2				
UAE					1										
UK	1	1													
USA	2	15	29	6			13	9				7	7		1
Total	97	68	53	34	30	21	19	17	16	15	13	12	12	11	11
A Department of Civil Engineering, B Department of Geography, C Department of Civil and Environmental Engineering, D Department of Computer Science, E Department of Computer Science and Engineering, F State Key Laboratory of Remote Sensing Science, G Department of Biology, H Department of Civil, I School of Civil Engineering, J Key Laboratory of Land Surface Pattern and Simulation, K Faculty of Engineering, L Department of Earth and Environmental Science, M Department of Earth System Science, N State Key Laboratory of Water Resources Engineering and Management, O Department of Environmental Science															

Productivity of Corresponding Country

Corresponding information concludes author name, affiliation, country, and private information as email, etc. calculation with country of correspondence author is displayed in Table 6 including 25 countries, where have the most scientific publication. It indicates that China has 1148 articles with 1st ranking. Following by United States (651 articles, 2nd ranking), India (241 articles, 3rd ranking), Canada (158 articles, 4th ranking), Germany (149 articles, 5th ranking), Australia (132 articles, 6th ranking), South Korea (124 articles, 7th ranking), Italy (118 articles, 8th ranking), United Kingdom (115 articles, 9th ranking), Spain (99 articles, 10th ranking), Iran (96 articles, 11th ranking), Brazil (80 articles, 12th ranking), France (68 articles, 13th ranking), Turkey (63 articles, 14th ranking), Japan (52 articles, 15th ranking), Netherlands (42 articles, 16th ranking), Malaysia (41 articles, 17th ranking), Viet Nam (38 articles, 18th ranking), Sweden (36 articles, 19th ranking), Switzerland (35 articles, 20th ranking), Norway (33 articles, 21th ranking), Portugal (30 articles, 22th ranking), Thailand (29 articles, 23th ranking), Saudi Arabia (28 articles, 24th ranking), and South Africa (27 articles, 25th ranking). Except for United States, United Kingdom, and Turkey have published early in 2015, left countries are normally from 2016 to 2019. Especially, publication is increased strongly from 2020 to 2024 year and from 2021-2024, the whole countries have publication at all. Thus, China is still a country, where has the most publication in corresponding author of machine learning in climate change field Table 6.

Table 6. Scientific Publication of Corresponding Country in Ten Years

CRC name	TP (R)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
China	1148(1)		6	8	18	34	57	110	199	338	378
USA	651(2)	3	9	11	17	45	52	89	118	157	150
India	241(3)				5	4	9	27	37	71	88
Canada	158(4)		3	2	6	8	15	27	31	32	34

Germany	149(5)			3	10	6	15	24	32	25	34
Australia	132(6)				7	5	17	17	22	38	26
South Korea	124(7)		2	4	3	5	9	15	27	31	28
Italy	118(8)		1	2	3	2	8	14	24	30	34
UK	115(9)	1	1	4	2	6	8	17	25	23	28
Spain	99(10)		2		5	6	9	16	17	16	28
Iran	96(11)		1	1	2	4	6	7	24	27	24
Brazil	80(12)		2	3	1	2	5	8	18	21	20
France	68(13)				2	2	7	10	12	20	15
Turkey	63(14)	1					1	9	11	22	19
Japan	52(15)		1	2	2		3	6	11	12	15
Netherlands	42(16)				1	5	5	4	4	14	9
Malaysia	41(17)						2	7	7	11	14
Viet Nam	38(18)			1		1	4	4	10	8	10
Sweden	36(19)				1	2		2	6	15	10
Switzerland	35(20)				1	2	2	6	5	10	9
Norway	33(21)						2	9	7	9	6
Portugal	30(22)				1	2	1	10	4	3	9
Thailand	29(23)						2	3	4	10	10
Saudi Arabia	28(24)							3	7	10	8
South Africa	27(25)				1		1	4	8	6	7
CRC Correspondence Country, TP Total research productivity, R Ranking.											

Scientific productivity distribution in Figure 2 is displayed by geographic information system method and presents total research output of each country on the world. Basing on this method, it is easy

to reveal the highest research output belonging to China country and it is exhibited by purple color, around 3112-6717 articles. Next is United States with red color about 883-3111 articles in total research publication. Blue color countries have 381-882 articles of machine learning in climate change. Yellow color countries are about 62-380 articles, and 0-6 articles are left countries on the world. Total research productivity is distributed in countries on the map with its color making a picture of scientific output on machine learning in climate change field. It helps us to understand about publication and scientific productivity on the world via countries Figure 2.

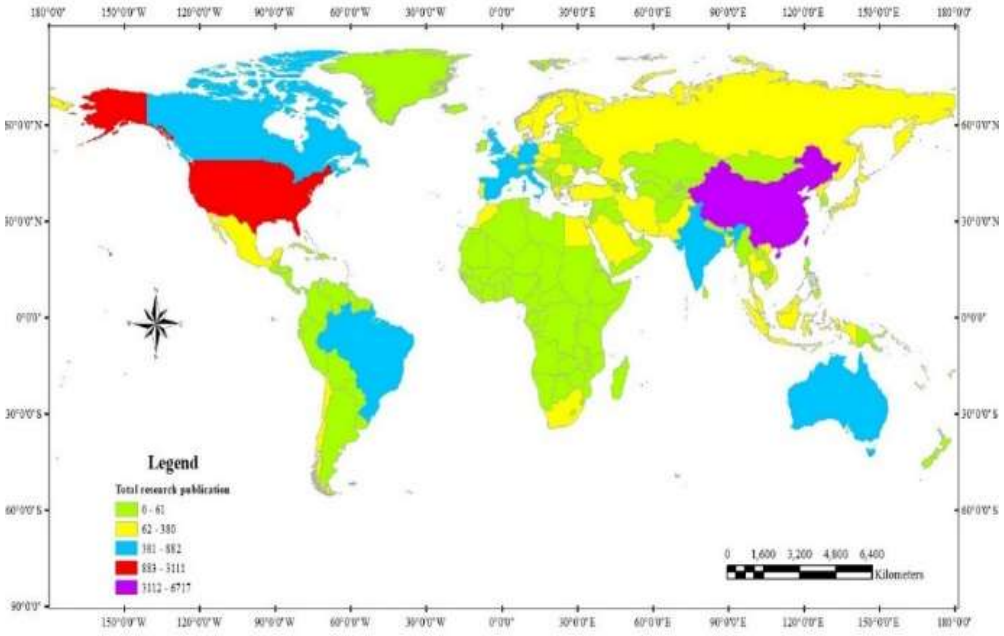

Figure 2. Distribution of Scientific Productivity on the World

5. CONCLUSION

Therefore, from 4406 articles and applying bibliometric methodology, spatial analysis provided to be more understanding about machine learning in climate change field on SCOPUS. It reveals that total research productivity has increasing trend and increases sharply from 2021 to 2024 year with 528 to 1239 articles. Y. Wang correspondence author is 1st ranking and the most research output with 19 articles, including 12 articles in China, 1 article in Finland, and 6 articles in United States. Almost authors publish strongly from 2022 to 2024 with high output as Y. Wang, J. Li, Y. Li, J. Yin, and J. Chen correspondence authors. Y. Zhang first author has the most scientific output with 16 articles and 1st ranking, concluding 13 articles publish in China, 2 articles in Canada, and 1 article in Singapore. Publication of affiliation increases strongly from 2021 to 2024 year and Department of Civil Engineering has the most publication with 97 articles in 20 countries, 1st ranking. China has the most publication in 2015-2024 with 1148 articles, 1st ranking in correspondence author. Publication in countries is increased strongly from 2020 to 2024 year and from 2021-2024, the whole countries have publication at all.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Dr. Minh Thu Nguyen	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	

C: **C**onceptualization
M: **M**ethodology
So: **So**ftware
Va: **Va**lidation
Fo: **Fo**rmal analysis
I: **I**nvestigation
R: Resources
D: Data Curation
O: Writing- **O**riginal Draft
E: Writing- Review& **E**diting
Vi: **Vi**sualization
Su: **Su**pervision
P: **P**roject administration
Fu: Funding acquisition

Conflict of Interest Statement

Author state no conflict of interest.

Informed Consent

Corresponding author has obtained informed consent from author in this research.

Ethical Approval

This research is implemented by author and she state that no infringement in ethical issue as well as plagiarism.

Data Availability

The whole data is extracted from SCOPUS database and it is reliable data source to research and take out good results.

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BIOGRAPHIES OF AUTHOR

Dr. Minh Thu Nguyen is a specialist in environmental science, she is interested in research fields as Environmental pollution, Climate change, non-point source, Multiple objective optimizations, social network analysis, Bibliometric, loss and damage, greenhouse gases inventory, spatial analysis, vulnerable and risk, air pollution, water pollution, wastewater pollution treatment, green energy, circular economy, deep learning, machine learning, geographic information system, environmental management with many publications on SCOP/ISI. With Bibliometric, she started to study in 2010. After 15 years, she found many interesting things via bibliometric method, such as trend of scientific productivity in different fields, publication of Journal title, Keywords, Language, author, country, affiliation, etc. Moreover, from bibliometric analysis, she discovered out distribution of research productivity on the world and it is displayed on the map. Therefore, this study on machine learning in climate change field brings to her interesting research in bibliometric. Email: ruanthuminh@gmail.com