Fronteiras: Journal of Social, Technological and Environmental Science
http://periodicos.unievangelica.edu.br/fronteiras/
ISSN 2238-8869

Article

A Bibliometric Mapping of Artificial Intelligence Applications in Climate Change Research

Khairul Hafezad Abdullah[1], Zulkiffly Baharom[2]

[1] PhD Senior Lecturer. School of Business Management, College of Business, Universiti Utara Malaysia, Malaysia. ORCID: 0000-0003-3759-6541. E-mail: hafezad@uum.edu.my

[2] PhD Student. Tunku Puteri Intan Safinaz School of Accountancy. College of Business, University Utara Malaysia, Malaysia ORCID: 0009-0002-0310-7893. E-mail: zulkifflybaharom100@gmail.com

ABSTRACT

Artificial intelligence (AI) in climate change study is a huge step forward in understanding, predicting, and dealing with environmental problems in the modern research world. This bibliometric study examines the evolution and landscape of artificial intelligence (AI) applications in climate change research from 1996 to 2024. The current analysis covers 399 publications based on two leading databases, Web of Science (WoS) and Scopus. ScientoPy is used to evaluate and analyse publication patterns, whereas VOSviewer generates network visualisation. Results in this study depicted substantial research growth of previous publications, with WoS demonstrating a high annual growth rate of 20.5 and Scopus showing significant recent activity with 61.7% publications in the last years. The key findings also indicated that Sustainability was the leading publisher, the Chinese Academy of Sciences was the top contributing institution, and Environmental Sciences & Ecology was the dominant subject area. This analysis also granted three main keyword clusters: AI methodologies, climate science concepts, and application domains. This study presents an exhaustive bibliometric examination of artificial intelligence implementations in climate change benefits for various stakeholders. Notwithstanding the constraints of concentrating on Anglophone publications (English-language journals), the results furnish significant perspectives regarding the domain's evolution, principal contributors, and prospective trajectories. The results are relevant for researchers, practitioners, and policymakers to harness AI technologies to climate change research and environmental analysis.
Keywords: artificial intelligence, climate change, bibliometric analysis, environmental science, machine learning.

RESUMO

A inteligência artificial (IA) no estudo das mudanças climáticas representa um grande avanço na compreensão, previsão e enfrentamento de problemas ambientais no mundo da pesquisa moderna. Este estudo bibliométrico examina a evolução e o panorama das aplicações da inteligência artificial (IA) na pesquisa sobre mudanças climáticas no período de 1996 a 2024. A análise atual abrange 399 publicações baseadas em duas bases de dados líderes, Web of Science (WoS) e Scopus. O ScientoPy é utilizado para avaliar e analisar os padrões de publicação, enquanto o VOSviewer gera visualizações de rede. Os resultados deste estudo demonstraram um crescimento substancial das pesquisas anteriores, com a WoS apresentando uma alta taxa de crescimento anual de 20,5% e a Scopus exibindo uma atividade recente significativa, com 61,7% das publicações nos últimos anos. As principais descobertas também indicaram que Sustainability foi o principal periódico publicador, a Academia Chinesa de Ciências foi a principal instituição contribuidora, e Ciências Ambientais & Ecologia foi a área temática predominante. Esta análise também identificou três principais clusters de palavras-chave: metodologias de IA, conceitos da ciência do clima e domínios de aplicação. Este estudo apresenta um exame bibliométrico abrangente sobre as implementações da inteligência artificial nas pesquisas sobre mudanças climáticas, beneficiando diversos stakeholders. Apesar das limitações de focar em publicações anglófonas (periódicos em inglês), os resultados oferecem perspectivas significativas sobre a evolução do campo, seus principais contribuintes e trajetórias futuras. Os resultados são relevantes para pesquisadores, profissionais e formuladores de políticas interessados em aproveitar as tecnologias de IA para pesquisas sobre mudanças climáticas e análises ambientais.
Palavras-chave: inteligência artificial, mudanças climáticas, análise bibliométrica, ciência ambiental, aprendizado de máquina.

Submissão: 07/03/2025 Aceite: 07/07/2025 Publicação: 04/09/2025

v.14, n.3, 2025 • p. 161-178. • DOI http://dx.doi.org/10.21664/2238-8869.2025v14i3.7927

Introduction

In this epoch, using Artificial Intelligence (AI) in climate change research marks a significant evolution in understanding, predicting, and responding to ecological challenges (Pimenow et al., 2024). Thus, AI has surfaced as an essential instrument in climatology, transforming conventional environmental data examination and modelling methodologies. Hamdan et al. (2024) asserted that AI and machine learning frameworks are proficient in anticipating climate dynamics, including critical weather occurrences and variations in oceanic levels. In this sense, the research highlighted these tools' particular strength in uncovering intricate relationships and nonlinear connections in climate datasets. In addition, Kumar et al. (2024) noted that incorporating AI frameworks in climate assessment enhances forecast dependability, amplifies the capacity to identify patterns in climate datasets, and facilitates the development of more intricate ecological models. Accordingly, AI has significantly influenced research on climate change mitigation by improving analytical capabilities and supporting the development of effective environmental strategies.

The nexus between AI capabilities and the efficacy of climate change research is multifarious, shaped by data integrity, computational assets, and methodological sophistication. Recent empirical investigations underscore the need to thoroughly comprehend how AI augments climate prediction precision and environmental surveillance systems (Balakrishnan et al., 2024; Kim et al., 2023; Materia et al., 2024). While numerous research institutions recognise the strategic significance of AI in climate science, a limited number have successfully assimilated these technologies into their research frameworks (Rolnick et al., 2023), highlighting a considerable implementation deficit. These observations resonate with the findings of Cowls et al. (2023), which disclosed that discrepancies in AI adoption can be ascribed to constraints in technological infrastructure, challenges in data accessibility, and heterogeneous levels of expertise among research institutions.

AI applications are pivotal in shaping climate research methodologies, presenting unparalleled opportunities and substantial challenges. Qiu (2024) accentuates that recent advancements in climate modelling have escalated expectations for more precise long-term environmental forecasts and comprehensive impact evaluations. This expectation is congruent with machine learning principles, which advocate for robust data-driven methodologies as critical elements of effective climate research. By integrating AI capabilities into climate analysis strategies, researchers can more adeptly discern environmental patterns, implement preemptive measures, and formulate adaptive solutions to climate adversities (Srivastava & Maity, 2023).

The obstacles to AI's incorporation in climate change studies are represented by a lack of a well-rounded bibliometric exploration of its theoretical constructs and practical functions. Although extensive inquiries have been executed on AI technologies and climate science independently, a systematic examination of their intersection remains limited. Machine learning advances have transformed climate science, as shown in research by Mansfield et al. (2020), revealing how these computational methods strengthen climate modelling through three key mechanisms: streamlined data analysis, enhanced identification of patterns, and more precise forecasting capabilities. They also emphasised the importance of rigorous model validation in their work. These observations correspond with Chaiechi (2020), who contends that traditional climate research frameworks inadequately represent the transformative impact of AI on environmental analysis, thereby necessitating innovative methodological approaches.

Integrating artificial intelligence (AI) into climate change research has significantly advanced environmental analytical capabilities. Chin and Lloyd (2024) posit that machine learning algorithms, including deep learning and neural networks, are pivotal in processing extensive climate datasets and identifying complex environmental patterns. Furthermore, Chen et al. (2023) highlight that the application of state-of-the-art AI technologies in climate research has enhanced the precision of extreme weather predictions and facilitated more comprehensive climate assessments, underscoring the indispensable contribution of AI to this domain.

Despite the growing research on AI and climate change, there remains a limited understanding of how AI technologies influence climate research processes. While research exists on individual uses of AI in environmental studies, there has not yet been a thorough bibliometric study mapping out how this field of knowledge has developed over time. This disparity is particularly evident in understanding the progression of research themes, the geographical distribution of academic contributions, and integrating AI methodologies into climate change research frameworks.

This study employs comprehensive bibliometric methods to analyse academic literature on AI's role in climate change research and environmental analysis. It addresses six key research questions (RQ):

- RQ1. What are the publication growth trends and patterns in AI applications in climate change research across WoS and Scopus databases from 1996 to 2024?
- RQ2. Which journals have demonstrated the highest productivity and impact in publishing research on AI applications in climate change research, as measured by publication metrics and citation impact?
- RQ3. Who are the most influential authors, and what are their significant contributions to AI applications in climate change research based on citation analysis?
- RQ4. Which research institutions have made substantial contributions to AI applications in climate change research, and how are these contributions geographically distributed?
- RQ5. What are the dominant subject areas in AI applications in climate change research, and how do they reflect the field's disciplinary composition?
- RQ6. What are the key research themes and emerging trends in AI applications in climate change research, as revealed through keyword network analysis?

This study charts how AI has been applied to climate change research and environmental modelling. It offers a valuable perspective for researchers and professionals incorporating AI into climate science. The analysis reveals promising applications of AI in climate research, pinpoints gaps in current environmental studies, and charts a course for future research combining climate science and AI technologies

Methodology

Materials and Method

This study employs a bibliometric methodology to examine the integration of AI in climate change research. The research leverages two advanced analytical tools: VOSviewer for mapping analysis and ScientoPy for trend evaluation . ScientoPy is ideal for evaluating research trends over time, offering clear insights into publication growth, prolific authors, and keyword evolution. VOSviewer excels in mapping intellectual structures such as co-authorship networks and thematic keyword clusters. Compared to tools like CiteSpace and Bibliometrix, this combination offers a more accessible, efficient, and visually intuitive approach for researchers without requiring advanced programming skills.

A comprehensive dataset was extracted from WoS and Scopus databases using carefully defined article title search criteria focusing on AI applications in climate change contexts. The dataset formation relies on specific keyword combinations outlined in Table 1, which are essential for identifying relevant literature on AI applications and climate change research. The datasets were retrieved in February 2025. Nevertheless, the data collection spans from 1996 to 2024 to ensure comprehensive coverage of research developments over nearly three decades. WoS and Scopus databases were selected in this study due to their established positions as premier sources for bibliometric research in interdisciplinary studies involving artificial intelligence and environmental science (Hafiar et al., 2024).

Table 1. Search Strategy for Extracting Data from the Scopus Database

Database	Search Strategy	Records
WoS	TITLE ((“artificial intelligence” OR “AI” OR “machine learning” OR “deep learning” OR “neural network*”) AND (“climate change” OR “global warming” OR “climate crisis” OR “climate action” OR “climate mitigation”))	324
Scopus	TITLE ((“artificial intelligence” OR “AI” OR “machine learning” OR “deep learning” OR “neural network*”) AND (“climate change” OR “global warming” OR “climate crisis” OR “climate action” OR “climate mitigation”))	364

Source: Authors

The analytical framework employs two complementary software tools: ScientoPy and VOSviewer, each serving distinct analytical purposes. ScientoPy functions as the primary bibliometric analysis tool, systematically evaluating key research elements, including dominant themes in AI applications, author contributions to climate change research, geographic distributions of AI studies, and significant publications in the field (Abdullah, 2022). It is an open-source, Python-based tool that ensures transparent and reproducible analysis protocols. Its sophisticated pre-processing capabilities are valuable for reducing individual publication biases (Ruiz-Rosero et al., 2019). VOSviewer generates detailed co-occurrence maps of authors’ terms related to AI applications and climate change research for visualisation and network analysis. This approach enables systematic identification and analysis of research themes that have shaped the global scholarly discourse (Abdullah & Sofyan, 2023), including AI’s impact on climate change research and environmental analysis.

Pre-processing of Retrieved Datasets

The dataset underwent rigorous pre-processing to ensure data integrity, eliminating duplicates and consolidating key data points using ScientoPy software. Table 2 shows that the initial data collection yielded 688 unrefined data items from both databases, with WoS contributing 324 papers (47.10%) and Scopus providing 364 papers (52.90%). The analysis confirmed that no articles were excluded based on document-type filtering criteria. From the original dataset, the preliminary screening process found 289 duplicated papers (42.00%). Among these, six papers (1.90%) were removed from WoS and 283 (77.70%) from Scopus. Notably, 211 duplicated documents (73.00%) showed different citation counts. Following thorough screening and removal of duplicates, 399 papers were retained for subsequent analysis, with 318 papers (79.70%) from WoS and 81 papers (20.30%) from Scopus. The final dataset of 399 documents is considered sufficient for conducting a reliable bibliometric analysis. This number allows for valid trend analysis, keyword co-occurrence mapping, and collaboration network visualisation while maintaining analytical clarity. Moreover, the documents were carefully selected from two major databases (WoS and Scopus), ensuring the dataset reflects both the breadth and quality of scholarly output in the research domain. This refined dataset comprises articles examining the intersection of AI and climate change research, providing a robust foundation for comprehensive bibliometric analysis.

Table 2. Information on initial data analysis.

Information	Number	Percentage
Original data:		
Loaded papers	688	
Omitted papers by document type	0	0.00%
Total papers after omitted papers removed	688	
Loaded papers from WoS	324	47.10%
Loaded papers from Scopus	364	52.90%
Duplicated removal results:		
Duplicated papers found	289	42.00%
Removed duplicated papers from WoS	6	1.90%
Removed duplicated papers from Scopus	283	77.70%
Duplicated documents with different cited by	211	73.00%
Total papers after removing duplicate	399	
Papers from WoS	318	79.70%
Papers from Scopus	81	20.30%

Source: Author's figure generated via ScientoPy v2.1.3

Results

The investigation's findings thoroughly respond to the research questions established in the methodology. The results are illustrated using graphical tools, ScientoPy and VOSviewer

Publication Growth Trends

Figure 1 and Table 3 present the bibliometric analysis of research publications on AI applications in climate change research from 1996 to 2024. The analysis shows the distribution across two significant databases, with WoS contributing 312 publications and Scopus providing 81 publications. The WoS database shows an annual growth rate (AGR) of 20.5, with an average of 82 documents annually (ADY), and 52.6% of publications produced in recent years (PDLY). These publications achieved an h-index of 39, reflecting their citation impact. The Scopus database records an AGR of 12.5, ADY of 25, and PDLY of 61.7%, with an h-index of 8. Figure 1 illustrates these publication trends over the studied period, depicting the temporal distribution of research output across both databases. The WoS publications demonstrate a higher overall volume and growth rate than Scopus, while Scopus shows a more significant percentage of recent publications.

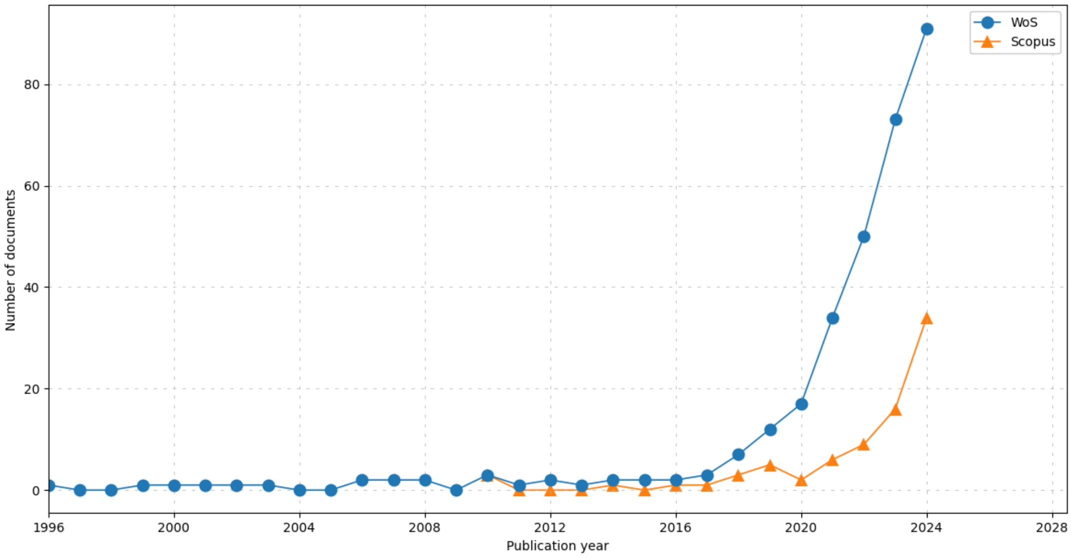

Figure 1. The Publication Growth Trends. Source: Author, using ScientoPy v2.1.3

Table 3. Total Publication in WoS and Scopus Databases by AGR, ADY, PDLY, and h-index

Rank	Database	Total	AGR	ADY	PDLY	h-Index
1	WoS	312	20.5	82	52.6	39
2	Scopus	81	12.5	25	61.7	8

Note: AGR=Average growth rate, ADY=Average documents per year, PDLY=Percentage of documents in last years, h-index=standard scholarly metric in which the number of published papers, and the number of times their author is cited, is put into relation.

Source: Author's figure generated via ScientoPy v2.1.3

Publications by Source Title

Figure 2 and Table 4 show the bibliometric analysis of source titles in AI and climate change research, identifying the top 10 contributing journals based on publication metrics. Sustainability leads with 12 publications and an h-index of 8, demonstrating an annual growth rate (AGR) of -2 and average documents per year (ADY) of 2, with a percentage of documents in the last year (PDLY) of 33.3%. Environmental Research Letters, Journal of Hydrology, and Remote Sensing in Earth Systems Sciences share the second position with seven publications each, showing varying impact metrics (h-index: 6, 5, and 1, respectively). Environmental Research Letters maintain steady output (AGR: 0, ADY: 1, PDLY: 28.6%), while the Journal of Hydrology shows positive growth (AGR: 1, ADY: 2.5, PDLY: 71.4%). Journal of Water and Climate Change and Water each contribute 6 publications, with Journal of Water and Climate Change showing higher recent activity (PDLY: 66.7% versus 16.7%). Water Resources Management, Climate Dynamics, Journal of Environmental Management, and Applied Sciences-Basel complete the top 10, with publication counts ranging from 4 to 6 and h-indices between 2 and 5. Remote Sensing in Earth Systems Sciences demonstrates the highest recent growth (AGR: 3.5, PDLY: 100%), while the Journal of Environmental Management shows vigorous recent activity (PDLY: 80%).

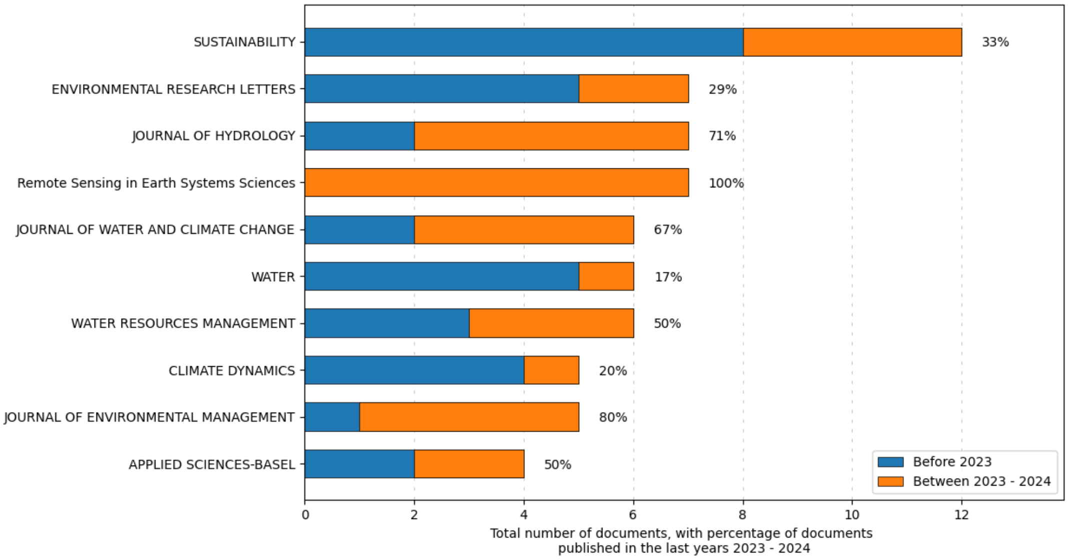

Figure 2. Publications by Source Title. Source: Author, using ScientoPy 2.1.3

Table 4. Total publication by source title: AGR, ADY, PDLY, and h-index ()

Rank	Source Title	Total	AGR	ADY	PDLY	h-Index
1	Sustainability	12	-2	2	33.3	8
2	Environmental Research Letters	7	0	1	28.6	6
3	Journal of Hydrology	7	1	2.5	71.4	5
4	Remote Sensing in Earth Systems Sciences	7	3.5	3.5	100	1
5	Journal of Water and Climate Change	6	0	2	66.7	5
6	Water	6	-0.5	0.5	16.7	5
7	Water Resources Management	6	0	1.5	50	5
8	Climate Dynamics	5	0.5	0.5	20	4
9	Journal of Environmental Management	5	1.5	2	80	2
10	Applied Sciences-Basel	4	0	1	50	3

Note: AGR=Average growth rate, ADY=Average documents per year, PDLY=Percentage of documents in last years, h-index=standard scholarly metric in which the number of published papers, and the number of times their author is cited, is put into relation

Source: Author's figure generated via ScientoPy v2.1.3

Publications by Authors

Table 5 presents the bibliometric analysis of influential authors in AI and climate change research, identifying the field's top 10 most cited publications and their impact. Rolnick et al. (2023) lead with 275 citations for their work on tackling climate change with machine learning. Crane-Droesch (2018) follows with 267 citations for research on machine learning methods for crop yield prediction and climate change impact assessment in agriculture. O'Gorman and Dwyer (2018) rank third with 245 citations for their study using machine learning to parameterise moist convection. Huntingford et al. (2019) have 197 citations for their work on machine learning and artificial intelligence in climate change research. Kaack et al. (2022) and Knutti et al. (2003) contribute 137 citations each for research on aligning artificial intelligence with climate change mitigation and probabilistic climate change projections using neural networks, respectively. The rest of the top 10 includes Makkeasorn et al. (2008), Poff et al. (1996), Chang et al. (2015), and Cowls et al. (2023), with citations ranging from 109 to 112, showing sustained interest in AI applications across different aspects of climate change research.

Table 5. Publication by authors

Rank	Authors	Title	Source Title	Cited by	Document Type	Source
1	Rolnick et al. (2023)	Tackling Climate Change with Machine Learning	ACM Computing Surveys	275	Article	WoS
2	Crane-Droesch (2018)	Machine learning methods for crop yield prediction and climate change impact assessment in agriculture	Environmental Research Letters	267	Article	WoS
3	O'Gorman and Dwyer (2018)	Using Machine Learning to Parameterise Moist Convection: Potential for Modeling of Climate, Climate Change, and Extreme Events	Journal of Advances in Modelling Earth Systems	245	Article	WoS
4	Huntingford et al. (2019)	Machine learning and artificial intelligence to aid climate change research and preparedness	Environmental Research Letters	197	Article	WoS
5	Kaack et al. (2022)	Aligning artificial intelligence with climate change mitigation	Nature Climate Change	137	Article	WoS
6	Knutti et al. (2003)	Probabilistic climate change projections using neural networks	Climate Dynamics	137	Article	WoS
7	Makkeasorn et al. (2008)	Short-term streamflow forecasting with global climate change implications - A comparative study between genetic programming and neural network models	Journal of Hydrology	112	Article	WoS
8	Poff et al. (1996)	Stream hydrological and ecological responses to climate change assessed with an artificial neural network	Limnology and Oceanography	112	Article; Proceedings Paper	WoS
9	Chang et al. (2015)	Simulation and prediction of suprapermafrost groundwater level variation in response to climate change using a neural network model	Journal of Hydrology	110	Article	WoS
10	Cowls et al. (2023)	The AI gambit: Leveraging artificial intelligence to combat climate change-opportunities, challenges, and recommendations	AI & Society	109	Article	WoS

Source: Author's figure generated via ScientoPy v2.1.3

Publications by Institutions and Country

Table 6 displays the bibliometric analysis of institutional contributions to AI and climate change research, identifying the top 10 contributing institutions worldwide. The Chinese Academy of Sciences leads with 14 publications, showing consistent performance with an annual growth rate (AGR) of 0, average documents per year (ADY) of 3, and percentage of documents in the last year (PDLY) of 42.9%, achieving an h-index of 8. Beijing Normal University follows with 8 publications (h-index: 6), while Islamic Azad University and University of Florida share the third position with 5 publications each (PDLY: 100% and 40%, h-index: 3 and 4 respectively). The University of Illinois Urbana-Champaign and Wuhan University each contribute 5 publications, with varying impact metrics and growth patterns. King Saud University, University of Regina, University of Tabriz, and Zagazig University complete the top 10, each with 4 publications and h-indices ranging from 2 to 3. Islamic Azad University and King Saud University demonstrate the highest recent activity (PDLY: 100%), while the Chinese institutions show sustained research output across the study period.

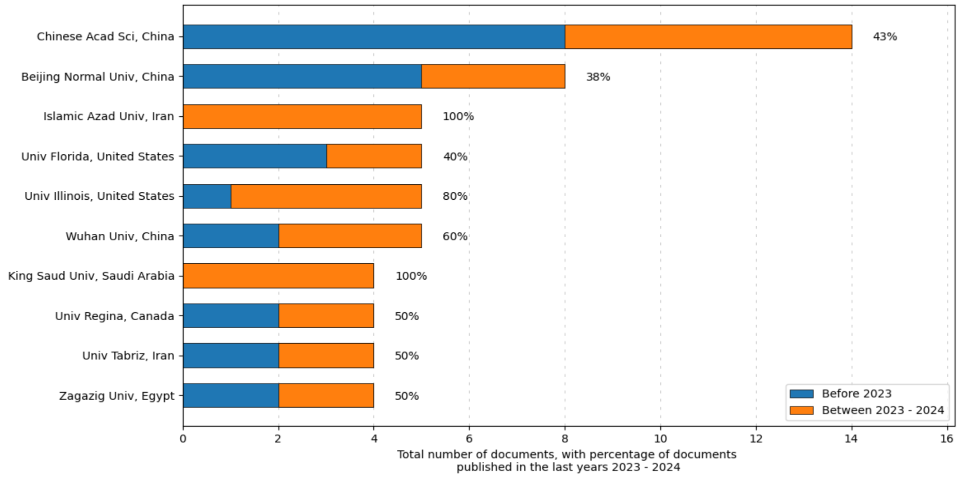

Figure 3. Publication by Institution and Countries.Source: Author, using ScientoPy 2.1.3

Table 6. Publication by Institution and Country

Rank	Institution With Country	Total	AGR	ADY	PDLY	h-Index
1	Chinese Academy of Sciences, China	14	0	3	42.9	8
2	Beijing Normal University, China	8	0	1.5	37.5	6
3	Islamic Azad University, Iran	5	1.5	2.5	100	3
4	University of Florida, United States	5	0	1	40	4
5	University of Illinois Urbana-Champaign, United States	5	1	2	80	3
6	Wuhan University, China	5	0.5	1.5	60	4
7	King Saud University, Saudi Arabia	4	1	2	100	3
8	University of Regina, Canada	4	0.5	1	50	3
9	University of Tabriz, Iran	4	0.5	1	50	3
10	Zagazig University, Egypt	4	0.5	1	50	2

Note: AGR=Average growth rate, ADY=Average documents per year, PDLY=Percentage of documents in last years, h-index=standard scholarly metric in which the number of published papers, and the number of times their author is cited, is put into relation

Source: Author's figure generated via ScientoPy v2.1.3

Publications by Subject Areas

Table 7 presents the bibliometric analysis of AI and climate change research subject areas, identifying the top 10 contributing fields. Environmental Sciences & Ecology dominates with 104 publications, demonstrating an annual growth rate (AGR) of 1, average documents per year (ADY) of 24.5, and 47.1% of publications in recent years (PDLY), achieving an h-index of 21. Engineering ranks second with 67 publications (ADY: 15.5, PDLY: 46.3%, h-index: 16), while Water Resources follows with 62 publications (AGR: 4, ADY: 16.5, PDLY: 53.2%). Science & Technology - Other Topics and Meteorology & Atmospheric Sciences contribute 43 and 41 publications, respectively, maintaining significant impact (h-index: 16 and 21). Geology and Computer Science show intense recent activity (PDLY: 64.3% and 61.5%), while Agriculture demonstrates the highest growth rate (AGR: 4.5) and recent publication percentage (PDLY: 77.8%). Energy & Fuels and Remote Sensing complete the top 10, with publication counts of 17 and 11, respectively, showing varying patterns of growth and impact across the study period.

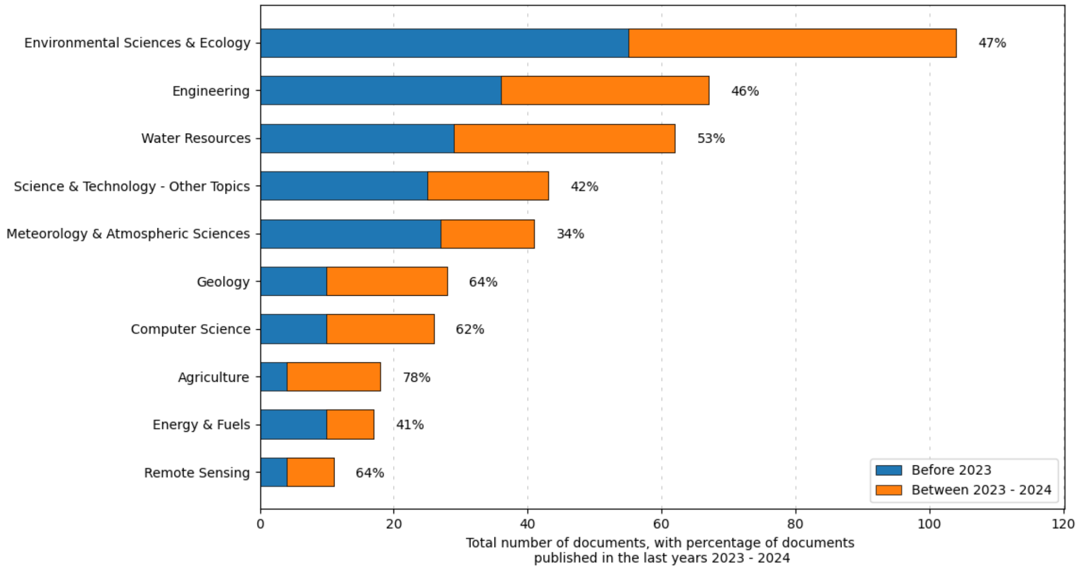

Figure 4. Publication by Subject Areas. Source: Author, using ScientoPy 2.1.3

Table 7. Publication by Subject Areas

Rank	Subject Areas	Total	AGR	ADY	PDLY	h-Index
1	Environmental Sciences & Ecology	104	1	24.5	47.1	21
2	Engineering	67	4	15.5	46.3	16
3	Water Resources	62	4	16.5	53.2	16
4	Science & Technology - Other Topics	43	-1	9	41.9	16
5	Meteorology & Atmospheric Sciences	41	1	7	34.1	21
6	Geology	28	2.5	9	64.3	12
7	Computer Science	26	2.5	8	61.5	9
8	Agriculture	18	4.5	7	77.8	7
9	Energy & Fuels	17	1.5	3.5	41.2	10
10	Remote Sensing	11	1	3.5	63.6	6

Source: Author's figure generated via ScientoPy v2.1.3

Publications by Authors' Keywords and Emerging Trends

Figure 5 visualises the bibliometric mapping of authors' keywords in AI and climate change research through network analysis. The network visualisation reveals three distinct clusters: AI methodology terms (shown in red), including "artificial intelligence," "machine learning," and "deep learning"; climate science concepts (displayed in blue), encompassing "climate change," "global warming," and "climate modelling"; and application domains (depicted in green), featuring "environmental monitoring," "prediction models," and "forecasting." The strongest connections appear between "artificial intelligence" and "climate change" as central nodes, with multiple bridging terms like "neural networks," "data analysis," and "climate prediction" linking the clusters. Emerging themes include "deep learning applications," "climate pattern recognition," and "environmental monitoring systems" in the peripheral nodes. The spatial distribution and node sizes indicate keywords' relative frequency and co-occurrence patterns, revealing the field's conceptual structure and evolving focus areas.

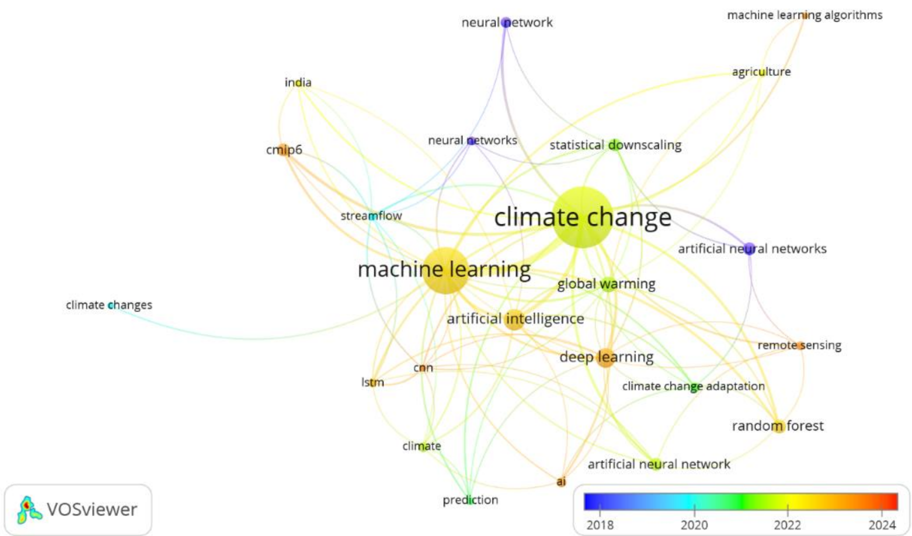

Figure 5. The Overlay Visualisation of the Co-occurrence of Authors' Keywords. Source: Author, using ScientoPy v2.1.3

Discussion

In addressing RQ1, the analysis reveals robust growth patterns in research output, particularly in the Web of Science database with an AGR of 20.5 and ADY of 82 publications. Such substantial growth aligns with the broader trend of increasing scholarly interest in artificial intelligence (AI) applications within climate science, as observed in bibliometric studies on emerging technological domains (Barre et al., 2024; Bracarense et al., 2022). The consistent rise in AI-related climate research suggests a rapidly evolving field driven by advancements in computational modelling, climate data analytics, and policy-driven research agendas (Hamdan et al., 2024). The notable difference in database coverage, with WoS contributing 312 publications compared to Scopus's 81, indicates potential indexing policies and scope variations. WoS's indexing of high-impact journals may contribute to the strong growth observed, reflecting a concentration of influential research in this domain (Aria & Cuccurullo, 2017). The significant h-index disparity (WoS: 39, Scopus: 8) suggests different citation patterns and impact measurements between databases. The high PDLY values (WoS: 52.6%, Scopus: 61.7%) demonstrate growing contemporary interest, reflecting the increasing adoption of AI technologies in climate research. Compared to related fields, these growth patterns indicate that AI applications in climate science are gaining momentum faster than traditional climate research methodologies.

Regarding RQ2, the publication source analysis reveals diverse dissemination patterns. The dominance of Sustainability (12 publications, h-index: 8) underscores the field's strong orientation towards environmental science. It is indicated that sustainability-focused journals often act as primary knowledge hubs for interdisciplinary environmental research. Furthermore, highly specialised journals such as Environmental Research Letters and Journal of Hydrology reinforce the multidisciplinary nature of AI applications in climate studies, reflecting the integration of computational techniques into traditional environmental science domains. The emergence of Remote Sensing in Earth Systems Sciences (AGR: 3.5, PDLY: 100%) indicates growing methodological sophistication in data-driven approaches. The varying impact metrics across journals suggest different levels of influence and readership within the research community. The concentration of publications in environmental journals suggests limited cross-pollination with core computer science and AI-focused venues. This publication pattern indicates potential opportunities for expanding the field's reach into more technically oriented journals.

The author impact analysis (RQ3) reveals trending research influence and citations. Table 5 shows how leading authors have used AI in climate change research, making methodological advances. With 275 and 267 citations, respectively, Rolnick et al. (2023) and Crane-Droesch (2018) laid the groundwork for climate science's rapid adoption of machine learning techniques. O'Gorman and Dwyer (2018) and Huntingford et al. (2019) research using machine learning to parameterise moist convection and aid climate change preparedness have highlighted new application areas. The citation distribution suggests a growing focus on advanced AI methods and complex climate challenges. AI research in climate science is global and requires international collaboration, as institutional diversity among highly cited authors shows. Established and emerging scholars are well-represented in the field, indicating active knowledge transfer and innovation. The citation analysis may underrepresent theoretical contributions by focusing on novel AI applications. Future research could examine the intellectual structure more comprehensively to better understand the field's development.

The institutional analysis (RQ4) reveals complex research dynamics and geographical patterns. The Chinese Academy of Sciences (14 publications) reflects China's substantial investment in AI and climate research infrastructure. China is investing massively in artificial intelligence, from chips to algorithms, and other nations are seeking to harness AI advances for enhanced surveillance and censorship, as well as for military purposes (Larson, 2018). This indicates that China is focused on developing AI embedded in research for military applications and environmental purposes, specifically in addressing climate change. The diverse geographical distribution of contributing institutions suggests global recognition of AI's potential in climate science. The varying performance metrics across institutions indicate different research priorities and resource allocations. The presence of both established research centres and emerging institutions suggests ongoing democratisation of AI applications in climate research. The collaboration patterns between institutions reveal emerging research networks and knowledge-sharing frameworks (Al-Balushi et al., 2025).

The subject area analysis (RQ5) reveals evident disciplinary emphases and research priorities. Environmental Sciences & Ecology's dominance (104 publications) demonstrates the field's primary orientation toward environmental applications. This is likely driven by the growing global urgency to address climate change, sustainability, and ecological conservation through technological advancements, including AI. Integrating AI in environmental sciences enables more precise climate modelling, improved resource management, and enhanced monitoring of ecological systems (Miller et al., 2025). The emphasis on this discipline underscores its critical role in leveraging AI-driven solutions to address complex environmental challenges. The significant contributions from Engineering (67 publications) and Water Resources (62 publications) reflect the practical implementation focus of AI in climate research. Engineering plays a crucial role in developing AI-driven technologies for climate resilience, including smart infrastructure (Tang et al., 2024), renewable energy systems (Parameshwari & Gnanaguru, 2024), and adaptive environmental solutions (Ashok et al., 2025). The representation across multiple disciplines suggests growing recognition of AI's versatility in climate applications. The relative positions of different subject areas indicate potential areas for increased cross-disciplinary collaboration. The distribution of publications across subject areas reveals both the field's maturity in certain domains and emerging opportunities in others.

The keyword network analysis (RQ6) uncovers sophisticated interconnections between research domains and methodological approaches. The three distinct clusters: 1) "AI methodology" (including "artificial intelligence," "machine learning," and "deep learning"), 2) "climate science concepts" (encompassing "climate change," "global warming," and "climate modelling"), and 3) "application domains" (featuring "environmental monitoring," "prediction models," and "forecasting"). These facets demonstrated the field's maturity in integrating technical and environmental perspectives. The "AI methodology" cluster highlights algorithm advancements, machine learning models, and computational techniques tailored for climate-related applications. A novel machine learning approach is important to predict and mitigate climate change impacts on global ecosystems, combining ecological models with adaptive resource allocation, real-time monitoring, and hybrid modelling for accurate and ecologically relevant forecasts (Rani et al., 2024). The "climate science concepts" cluster reflects the foundational scientific principles and processes that guide AI-driven climate research, ensuring accuracy and reliability in environmental predictions. AI-driven models, such as deep learning and neural networks, enhance the accuracy and efficiency of climate forecasts by analysing large, complex datasets like satellite imagery and atmospheric variables (Maideen et al., 2024). The application domains cluster underscores the practical deployment of AI across various sectors, such as climate adaptation, disaster risk management, and sustainable resource planning. This study found that the strong connections between central nodes suggest effective knowledge integration across different aspects of the field. The emergence of peripheral themes indicates new research directions and methodological innovations. The keyword co-occurrence patterns reveal both established research pathways and emerging trends. The network structure suggests opportunities for strengthening connections between theoretical AI development and practical climate applications.

Implications for Practice

The bibliometric findings reveal critical implications for integrating AI in climate change research. The strong growth patterns suggest accelerating adoption of AI technologies, requiring researchers and practitioners to continuously update their technical skills and domain knowledge. The dominance of environmental science journals indicates the need to bridge the gap between AI methodological sophistication and practical environmental applications. This evolution requires practitioners to develop multifaceted competencies, particularly in emerging areas of AI applications and climate science. The journal analysis highlights the importance of evidence-based practice, with high-impact publications demonstrating successful integration of AI technologies in climate research. Practitioners should note the significant influence of interdisciplinary approaches, as evidenced by the diverse subject area distribution spanning environmental sciences, engineering, and computer science. The geographical distribution of research suggests the need for internationally adapted approaches, particularly in regions with unique climate challenges.

Organisations and research institutions should focus on three key areas: (1) developing integrated AI frameworks that specifically address climate challenges while ensuring methodological rigor, (2) enhancing cross-disciplinary collaboration between AI specialists, climate scientists, and domain experts, and (3) establishing standardised methodologies for AI applications in climate research while maintaining flexibility for local adaptations. The keyword network analysis suggests practitioners should balance technical AI competencies with deep understanding of climate science fundamentals. The strong institutional presence from multiple geographical regions indicates the importance of international collaboration and knowledge sharing. Practitioners should actively participate in global research networks while maintaining sensitivity to regional climate priorities. The emerging trends in subject areas and keywords suggest the need for continuous professional development and adaptation to new methodological approaches. Special attention should be given to emerging application areas such as real-time climate monitoring, predictive modeling, and integrated environmental assessment systems.

Limitations and Future Research Recommendations

This bibliometric analysis identifies several significant limitations requiring careful consideration. While comprehensive, the differential coverage between WoS (312 papers) and Scopus (81 papers) may affect result interpretation and suggest potential indexing biases. The focus on English-language publications potentially overlooks valuable contributions from non-English research traditions, particularly from regions with significant AI and climate research activities. The temporal scope (1996-2024) may not fully capture the most recent developments in AI applications, given the rapid evolution of artificial intelligence technologies. The keyword analysis, while revealing meaningful patterns, may not adequately reflect the technical depth of AI implementations in climate research. Additionally, the bibliometric approach, though systematic, may not capture the qualitative aspects of AI-climate research integration.

Future research should address these limitations through several key directions. Scholars should incorporate more diverse methodological approaches beyond traditional bibliometric analysis, examining the technical effectiveness of AI applications and their practical impact on climate research outcomes. The field would benefit from systematic studies examining AI's transformation from an analytical tool to an integral component of climate science methodology. Researchers should explore innovative approaches to evaluating AI effectiveness in climate applications, considering both quantitative performance metrics and qualitative environmental impacts.

Particular attention should be given to emerging areas such as:

- Deep learning applications in climate pattern recognition and prediction
- Real-time environmental monitoring systems using AI
- Integration of multiple AI technologies in comprehensive climate modeling
- Cross-validation methodologies for AI-driven climate predictions
- Standardisation of AI implementation frameworks in climate research

These recommendations aim to enhance both theoretical understanding and practical applications while addressing current limitations in the field. Longitudinal studies tracking the evolution of AI applications in climate science would provide valuable insights into methodological trends and effectiveness. Future research should also focus on developing standa rdised evaluation metrics for AI applications in climate science, enabling more systematic assessment of different approaches.

The critical review suggests that while AI applications in climate research show significant progress, substantial opportunities exist for deeper integration and methodological advancement. Future work should prioritise strengthening the connection between AI capabilities and climate science needs while maintaining scientific rigor and practical relevance.

Conclusion

This bibliometric analysis investigates the development of AI applications in climate change research from 1996-2024, examining 399 publications from Web of Science and Scopus. The study reveals a rapidly expanding field with substantial growth in Web of Science (AGR: 20.5, h-index: 39) and increasing recent activity in Scopus (PDLY: 61.7%). The field has evolved from basic AI implementations to advanced methodological approaches. Sustainability emerges as the leading publication venue (12 publications, h-index: 8), reflecting an environmental science focus. Institutional contributions highlight established centers like the Chinese Academy of Sciences (14 publications) and emerging hubs across continents.

Subject area analysis shows a multidisciplinary composition, with Environmental Sciences & Ecology (104 publications) as the primary focus, alongside Engineering (67 publications) and Water Resources (62 publications). Keyword network analysis illustrates progression from basic AI applications to integrated environmental analysis frameworks, with emerging themes like deep learning and climate pattern recognition. Despite increasing sophistication, opportunities for advancement remain. Future research should enhance AI-climate science integration, explore innovative methods, and evaluate AI effectiveness in diverse contexts, with attention to emerging economies and developing regions.

This study contributes to understanding the AI-climate change research interplay and establishes a foundation for future investigations in this rapidly evolving field. The insights are valuable for researchers, practitioners, and policymakers navigating the challenges and opportunities of AI integration in climate science.

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