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REVIEW

Climate change in scientific literature: a bibliometric analysis of the last decade focusing on environmental crisis, mitigation policies, adaptation, and social vulnerability

Cambio climático en la literatura científica: Un análisis bibliométrico de la última década enfocado en crisis ambiental, políticas de mitigación, adaptación y vulnerabilidad social

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ABSTRACT

Introduction: climate change is one of the most pressing challenges of our time. This study conducts a bibliometric analysis to examine research trends in this crucial field.
Method: data from relevant scientific publications were collected using indexed academic databases in Scopus. Bibliometric techniques were applied to analyze publication frequency by year, keywords, and main themes addressed in the literature. Data were processed using Bibliometrix.
Results: the results show increasing attention to aspects such as emission mitigation, climate change adaptation, environmental sustainability, among others. Emerging research areas were identified, and collaboration networks among researchers were examined. This information is complemented by four main thematic axes: Environmental Impacts, Mitigation, Adaptation, and Socioeconomic Studies.
Conclusions: this study provides an overview of the evolution of climate change research, highlighting the need for interdisciplinary and collaborative approaches to address this global challenge.

Keywords: Climate Change; Sustainability; Bibliometrics; Collaboration.

RESUMEN

Introducción: el cambio climático es uno de los desafíos más apremiantes de nuestro tiempo. Este estudio realiza un análisis bibliométrico para examinar las tendencias de investigación en este campo crucial.
Método: se recopilaron datos de publicaciones científicas relevantes al utilizar bases de datos académicas indexados en Scopus. Se aplicaron técnicas bibliométricas para analizar la frecuencia de publicación por año, las palabras claves y las principales temáticas abordadas en la literatura. Los datos se procesaron con Bibliometrix.
Resultados: los resultados muestran una creciente atención hacia aspectos como la mitigación de emisiones, la adaptación al cambio climático, la sostenibilidad ambiental, entre otros. Se identificaron áreas emergentes de investigación y se examinaron las redes de colaboración entre investigadores. Se complementa esta información con cuatro ejes temáticos principales: Impactos ambientales, Mitigación, Adaptación y Estudios socioeconómicos.
Conclusiones: este estudio proporciona una visión general de la evolución de la investigación sobre el cambio climático, se destaca la necesidad de enfoques interdisciplinarios y colaborativos para abordar este desafío global.

Palabras clave: Cambio Climático; Sostenibilidad; Bibliometría; Colaboración.

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INTRODUCTION

Climate change, driven primarily by human activities, has significant and adverse impacts on natural ecosystems, the global economy, and social welfare and requires urgent collective action to mitigate and adapt to its effects.[1,2] The scientific community has devoted significant efforts to understanding this phenomenon and developing practical solutions.

The increasing frequency of extreme events, sea level rise, and accelerated biodiversity loss have driven unprecedented scientific research to understand their causes, impacts, and possible solutions.[3,4,5] However, the magnitude and diversity of this academic output make it difficult to identify dominant trends, gaps in knowledge, and opportunities for future research.[6,7,8]

According to Bornmann[9] and Lee,[10] climate change research has grown significantly in the last two decades, with an increasing focus on technology, policy, adaptation, and mitigation. However, challenges remain, such as inequality in scientific output between developed and developing countries and lack of interdisciplinary research and climate justice. However, geographical disparities in scientific production persist, with an overrepresentation of developed countries and limited participation of institutions in highly vulnerable regions, such as Africa or Latin America, reflecting inequalities in scientific capital, collaboration, funding, and productivity, as Rungta argues.[11] This asymmetry affects not only the diversity of perspectives but also the effectiveness of the proposed solutions, which often ignore local contexts.[12,13]

Furthermore, the climate change literature is characterized by thematic fragmentation. While areas such as climate modeling or renewable energy have received substantial attention, other critical dimensions, such as climate justice, transboundary governance, or Indigenous knowledge, remain marginal in existing bibliometric analyses.[14,15] In Momade's view,[16] this gap limits the ability of science to respond to the interconnected challenges posed by global warming.

This study seeks to overcome these limitations through a comprehensive bibliometric analysis of scientific production on climate change between 2000 and 2023. The aim is to identify research priorities, assess the balance between disciplinary approaches, and highlight underrepresented areas that require further attention. The findings of this work will provide an empirical basis for guiding future science policy, funding strategies, and research agendas. By integrating quantitative and qualitative perspectives, this article contributes to critical debates on how climate science can become more inclusive, applicable, and effective in a context of accelerating crisis.

METHOD

A rigorous methodology structured in four sequential phases was implemented to conduct this bibliometric analysis. The Scopus database was used due to its wide coverage of scientific literature and its reliability in bibliometric studies.[17,18] In addition, Bibliometric software was used to process the statistical information.[19]

Phase 1. Definition of search criteria and data collection

The process began with the definition of search criteria to collect relevant articles. The keywords selected were "climate change," "global warming," "climate crisis," and "climate action." The publication period was limited from 2015 to 2025 to capture the most recent developments in the field; the following search formula was used (TITLE-ABS-KEY ("climate change" OR "global warming") AND TITLE-ABS-KEY ("environmental crisis" OR "ecological crisis" OR "climate crisis") AND TITLE-ABS- KEY ("mitigation policies" OR "climate policy" OR "decarbonization" OR "emission reduction") AND TITLE-ABS-KEY ("adaptation strategies" OR "climate adaptation" OR "resilience") AND TITLE-ABS-KEY ("social vulnerability" OR "climate justice" OR "environmental inequality" OR "climate and society"). The search was performed on the title, abstract, and keywords of the articles available in Scopus, which ensured that the documents were directly related to the topics of interest of the study.

Phase 2. Data extraction and filtering

Once the data were collected, they were filtered to exclude documents that were not research articles, such as conferences, book chapters, or reviews, by focusing the analysis on published scientific articles. To maintain consistency in the analysis, it was verified that the selected articles were written in English and Spanish.

Phase 3. Bibliometric analysis with Bibliometrix

Bibliometric software was used to perform a bibliometric analysis with the filtered data. This software allowed the creation of keyword co-occurrence maps to identify trends and the most prominent topics in the field of study.

Phase 4. Interpretation and synthesis of results

The last phase consisted of interpreting the data obtained from the bibliometric analysis. The interrelationships between different topics within the field of climate change were examined, and emerging research areas and prominent trends were identified. This process culminated in the synthesis of the results in a broader context, which was complemented by four thematic axes. This allowed us to understand the evolution of the interaction between different approaches and perspectives in climate change research over the last decade.

This methodology provided a detailed and structured overview to explore climate change research's complex dynamics and evolution. By unraveling key aspects of this interdisciplinary field, it was possible to identify critical areas and emerging trends, highlighting crucial points to guide future climate change research.[20,21]

RESULTS

Bibliometric analysis

The information search formula employed identified 143 studies. Research on climate change and its associated effects has increased over the years, from 2015 (with three published studies) to 2025 (with eight studies). The largest peak was observed in 2022, with 53 publications, followed by 2024, with 33 studies, and in 2023, with 29 (figure 1).

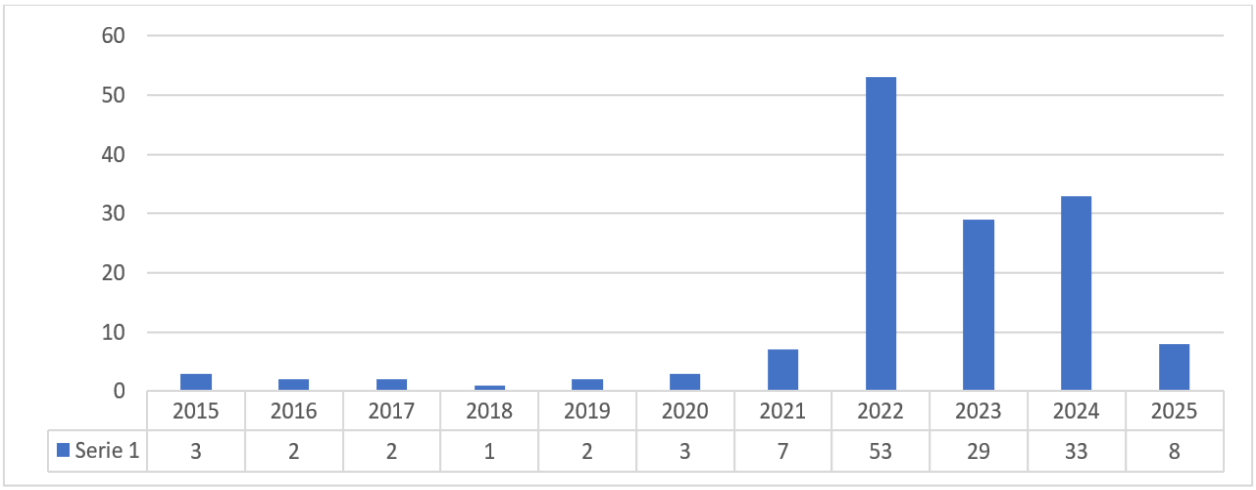


Figure 1. Analysis of publication frequency by year

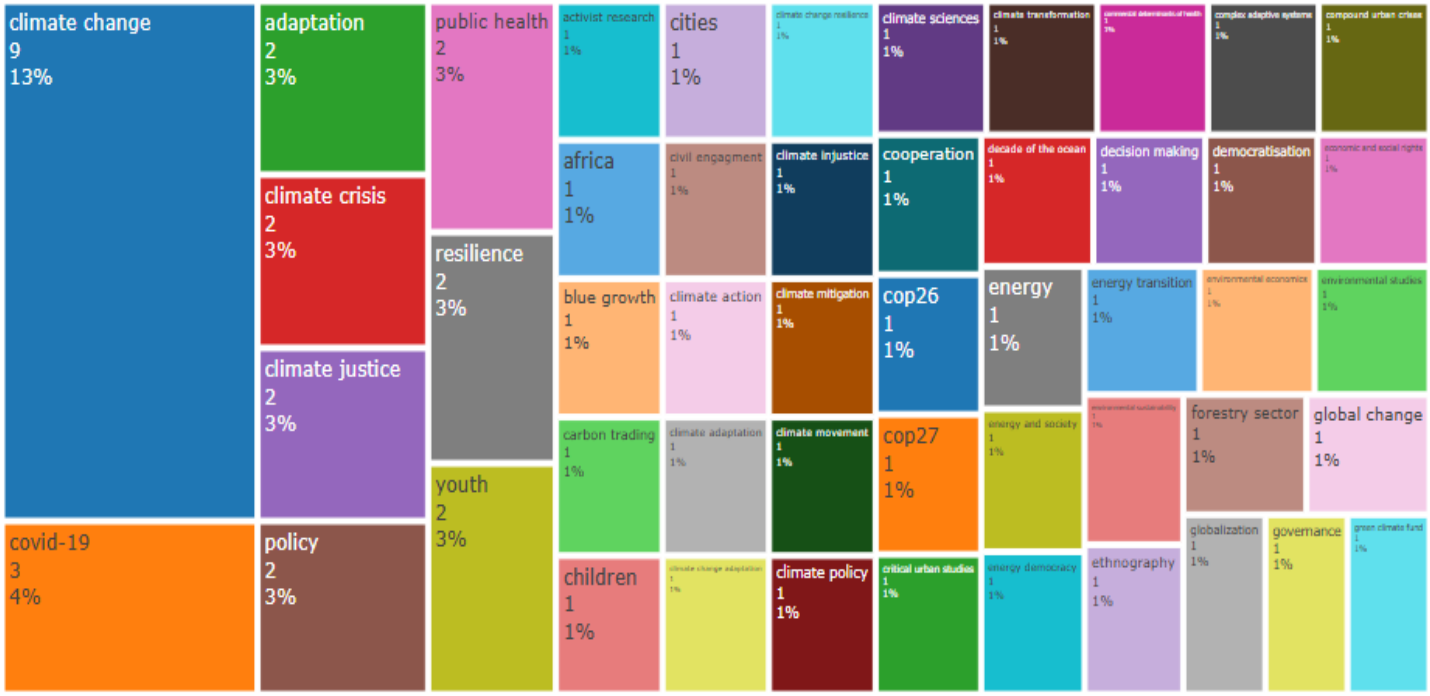


Figure 2. Keyword frequency análisis

Frequency analysis of keywords reveals that climate change is at the core of the research (13 %). In addition, associations are observed between this variable and its effects on society, the environment, public health and energy (figure 2).

Factor analysis of the literature on climate change reveals a close interconnection between the global environmental crisis, mitigation policies, adaptation strategies and social vulnerability, highlighting that climate change acts as a catalyst for irreversible ecological impacts and has ramifications for the increase of extreme events and the collapse of ecosystems, which requires urgent activism and policy responses (figure 3).

As is evident, the bibliometric analysis reveals a dynamic landscape in climate change research. These findings provide valuable insights for future research and collaborations and contribute to a deeper understanding of the challenges and opportunities inherent in this crucial field of study. The bibliometric analysis developed in this study acquires greater depth when articulated with the four key thematic axes that structure climate change research: environmental impacts, mitigation strategies, adaptation processes, and socioeconomic dimensions. This methodological integration makes it possible to quantify scientific production and identify how these lines of research are related and complement each other.[22,23]

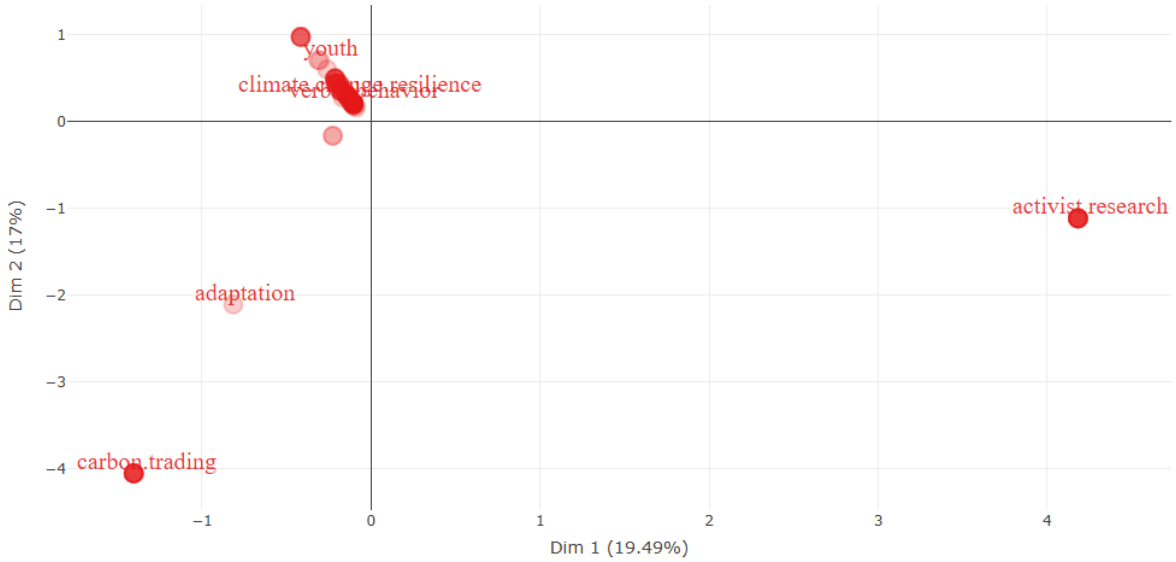


Figure 3. Factor analysis of the main topics addressed in the literature

Environmental impacts

The study of the environmental impacts of climate change has generated a body of knowledge deeply rooted in the natural sciences but whose implications transcend the purely ecological.[24] Gross[25] states that the planet is under stress due to the collapse of ecosystems, alterations in biogeochemical cycles, and a loss of biodiversity at unprecedented rates, driven by climate change, habitat loss, and overexploitation of resources. These works document environmental changes and construct a narrative about the breakdown of natural balance, where concepts such as "points of no return" or "mass extinction" have gone from scientific warnings to empirically verifiable realities.[26,27,28]

Particularly revealing is how this literature has evolved from technical descriptions to discourses incorporating ethical dimensions and existential urgency.[29,30] Recent studies are no longer limited to quantifying arctic ice loss or coral bleaching; they now explore what it means to live in what some authors such as Pascual[31] and Schapheer[32] call "the era of consequences." In the authors' view, science is developing, perhaps unintentionally, a new rhetoric of environmental concern.

A key finding is the growing conceptual interconnectedness between different impacts. Researchers no longer study isolated phenomena but draw lines between, for example, Amazon deforestation, alterations in continental rainfall patterns, and the resulting food crises.[33,34,35] As analyzed by Bahlai and others[36], this systemic approach is reflected in innovative theoretical frameworks that understand environmental impacts as a cascading network of disturbances. Authors such as De Brito & Kuhlicke[37], Detmer[38], and Zennaro[39] especially highlight work that adopts biocultural perspectives, showing how environmental degradation simultaneously erodes ecological diversity and traditional knowledge.

Ultimately, in the authors' view, this evolution towards a deeper and more holistic understanding of the environmental impacts of climate change highlights the pressing need to address these challenges comprehensively and collaboratively. Connecting the dots between diverse phenomena and recognizing the interdependence between ecosystem health and human well-being highlights the importance of adopting interdisciplinary and sustainable approaches to protect our planet and ensure a livable future for generations to come.[40] In this sense, science, by taking on a new rhetoric of environmental concern, not only documents the crisis in which we find ourselves but also urges us to act with determination and responsibility to preserve life on Earth in all its forms and manifestations.

Mitigation

Climate change mitigation is essential for reducing greenhouse gas emissions and limiting global warming.[41,42] According to Arsu[43], one key strategy in this regard is the transition to renewable energy sources, such as solar, wind, and hydroelectric, which generate electricity more cleanly and sustainably. In addition, improving energy efficiency in buildings, transportation, and industry is critical to reducing energy demand and minimizing associated emissions.

According to Zhang and other authors[44], another crucial area of mitigation is the conservation and restoration of natural ecosystems, such as forests, wetlands, and mangroves. These ecosystems act as carbon sinks by absorbing and storing large amounts of CO_2. Protecting these ecosystems not only contributes to mitigating climate change but also helps to preserve biodiversity and ecosystem services vital for life on the planet.

In addition to reducing emissions and conserving natural carbon sinks, climate change mitigation also involves adopting sustainable agricultural practices and implementing clean technologies in emission-intensive industrial sectors.[45] Li reveals that Promoting the circular economy and reducing waste are also essential aspects of mitigation strategies that seek to minimize greenhouse gas generation.[46]

However, while technical advances in renewable energy and energy storage are widely documented, there remains a deficit of critical studies on the limits of technoptimism and the socio-political barriers to implementing these solutions at scale. The

prevailing narrative contrasts with emerging voices questioning green growth models and advocating for degrowth approaches.[47,48]

Climate change mitigation is not only an imperative need to limit the catastrophic impacts of global warming but also presents opportunities to foster innovation, create green jobs, and promote sustainable development. Muljaningsih et al.[49] argue that by adopting concrete mitigation measures and working collaboratively at the local, national, and international levels, we can move towards a more sustainable future for present and future generations. Felix's[50] and Najar's[51] research proposes interdisciplinary frameworks integrating climate science with political, economic, and cultural studies. In the authors' opinion, the current challenge is no longer to develop mitigation technologies but to reimagine their governance in contexts of global inequality, where technical solutions must be negotiated with complex social realities and diverse visions of planetary well-being.

Adaptation

Adaptation to climate change is a crucial process that involves adjusting societies, ecosystems, and infrastructures to cope with the unavoidable impacts of global warming[52] One of the key adaptation strategies is to strengthen the resilience of vulnerable communities to extreme weather events, such as floods, droughts, and more intense storms. Riaz[53] notes that this includes implementing early warning systems, developing evacuation plans, and building a robust infrastructure that can withstand the impacts of climate change, stressing the importance of integrating technology, community participation, and strategic planning for effective response.

Another key aspect of adaptation is the sustainable management of natural resources, such as water and land, to ensure food security and populations' livelihoods in a climate change context.[54,55] Implementing resilient agricultural practices, conserving ecosystems that act as natural climate regulators, and promoting crop diversification are essential strategies for adapting to changing climate conditions and minimizing associated risks.

In addition to measures at the local level, adaptation to climate change also requires integrated approaches at the national and international levels, including long-term planning, collaboration between different sectors, and mobilization of financial and technological resources. Magnan et al.[56] assert that global cooperation is essential to address adaptation challenges effectively and equitably by ensuring that the most vulnerable communities receive the support they need to cope with the impacts of climate change and build a more resilient and sustainable future.

Socio-economic dimensions

Climate change has profound implications for socioeconomic dimensions, affecting communities, economies, and livelihood systems worldwide. Climate change exacerbates economic, health, and gender inequalities, disproportionately affecting vulnerable and marginalized populations, especially in low- and middle-income countries.[57,58] Poor communities and developing countries are often the most affected by extreme weather events, natural resource scarcity, and environmental degradation, which can result in loss of livelihoods, food insecurity, and forced migration.[59]

In addition, Semieniuk[60] posits that climate change poses significant challenges to the global economy by affecting sectors such as agriculture, fisheries, tourism, and infrastructure, which has implications for employment, economic growth, and financial stability. Marmai et al.[61] report that economic losses caused by extreme weather events, ecosystem degradation, and declining agricultural productivity can undermine sustainable development and hinder poverty eradication in many regions of the world.

In the authors' view, integrated approaches that consider both mitigation and adaptation and the promotion of equity and social justice are essential to address the socioeconomic dimensions of climate change. Investing in resilient infrastructure, creating green jobs, technology transfer, and capacity building are some of the key measures that can help build societies that are more prepared, inclusive, and sustainable in the face of the challenges of climate change and its socioeconomic impacts.[62,63]

DISCUSSION

The results of this bibliometric study reveal patterns consistent with previous research but also significant divergences that invite critical reflection. Regarding environmental impacts, our findings agree with works such as that of Parmesan & Singer[64] in documenting the predominance of studies on changes in biodiversity and extreme events. However, while studies such as those by Baldos[65] and Codal[66] reported a balance between global and local approaches, our data show a persistent overrepresentation of temperate versus tropical ecosystems, a gap that has widened in the last decade. This disparity questions the effectiveness of conservation policies based predominantly on knowledge generated in non-representative biogeographic contexts.

On the mitigation axis, our results confirm the exponential growth reported by Tsubouchi[67] but differ in the evaluation of its thematic distribution. While previous literature highlighted a balance between technical and social studies, our analysis identifies a marked predominance of research on clean technologies versus critical analyses of economic models. This trend contrasts with Krumm's warnings[68] on integrating social perspectives into the energy transition by revealing a disconnect between academic recommendations and research priorities.

With respect to adaptation, our data corroborate the shift towards community-based approaches identified by Riaz[53] but extend this observation by demonstrating how this shift has been uneven geographically. This paradox reinforces Mercer and Simpson's[69] criticism of "epistemological colonialism" in climate science, where local knowledge is valued as data but marginalized in decision-making.

In the socioeconomic dimensions, the results confirm previous findings on unequal impacts Méjean[57] and Creti[59] but reveal a critical paradox. Economic losses in developing countries are greater than estimated due to deindustrialization, global economic uncertainty, and a lack of adequate disaster prevention and climate change adaptation funding.[70] In the authors' view, these findings

reinforce the urgency of binding climate justice mechanisms to translate knowledge into concrete interventions.

CONCLUSIONS

The study of the environmental impacts of climate change has evolved significantly, transcending the boundaries of the natural sciences to encompass ethical, social, and economic implications. Emerging narratives of a planet under stress, with endangered ecosystems and threatened biodiversity, underscore the urgency of addressing climate change holistically and collaboratively. The transition to interdisciplinary and sustainable approaches to climate change mitigation and adaptation is imperative to protect the planet and ensure a livable future for future generations. Promoting equity, social justice, and community resilience are key aspects to consider in climate change response strategies. In this context, science and collective action must converge to effectively address climate challenges by generating innovative and equitable solutions to build more prepared, inclusive, and sustainable societies. It is imperative to act now to mitigate the impacts of climate change, adapt to new climate realities, and forge a more resilient and prosperous future for all the planet's inhabitants.

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