Review Article

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## A Review of Participatory Management's Role in Reducing Vulnerability and Enhancing Resilience to Climate Change and Drought (2006-2024)

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**Abstract**

Given the escalating challenges posed by climate change and the increasing frequency of droughts, participatory management has emerged as a critical strategy for enhancing resilience and mitigating vulnerability within the governance frameworks of water resources. This includes influencing decision-making processes, policies, and institutional arrangements related to water management. This study critically examines the role of participatory management in mitigating vulnerability and enhancing resilience to climate change and drought, utilizing bibliometric analysis of articles published between 2007 and 2024, sourced from the Web of Science. Analysis of the data using advanced tools such as VOSviewer and Biblioshiny revealed a marked increase in participatory management research within the context of climate and drought resilience, particularly since 2015. Key themes emerging from the literature include resilience, vulnerability, and the integration of public participation in water resource management decision-making processes. The transition from conceptual to applied research has been accompanied by the growing incorporation of cutting-edge technologies, including remote sensing, Geographic Information Systems (GIS), and machine learning models. These technologies have been proven instrumental in facilitating data sharing,

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modeling climate change impacts, and enhancing participatory decision-making frameworks. Geographically, there is a global trend toward strengthening local community engagement in water resource governance, with such participatory efforts playing a pivotal role in building resilience and developing sustainable water crisis management strategies. This study identifies key research gaps including the development of predictive resilience models, enhancement of local participation, and effective use of real-time data and advanced technologies to improve water resource management under changing climate conditions.

**Introduction**

Climate change and the crises arising from droughts represent some of the most significant challenges faced by human societies in the contemporary era (Ewane et al., 2023). These crises, particularly in arid and semi-arid regions, are increasingly impacting the quality of life and well-being of communities through heightened drought frequency and severity, reduced water resources, and significant environmental and economic threats (Kapica et al., 2024). In this context, climate change is a primary driver of many water-related challenges, as shifts in precipitation patterns, rising temperatures, and altered evaporation rates exacerbate water crises and drought events (Yassebi Naeini et al., 2016). Specifically, in water-scarce and semi-arid regions, these changes lead to a reduction in both surface and groundwater resources, extended drought periods, and threats to food security (Johnson et al., 2020). Therefore, effective water resource management in the face of these challenges is crucial for ensuring the sustainability and resilience of communities and ecosystems.

In response to these crises, various management approaches have been employed to address the impacts of droughts and climate change, particularly in the domain of water resources management and climate change adaptation (Tosan & Beyranvand, 2023). Traditionally, top-down, centralized approaches to water management have been prevalent, often focusing on technical solutions such as large-scale infrastructure projects.

However, these traditional approaches have often proven inadequate in addressing the complex and multifaceted challenges of climate change and drought. They often fail to consider the specific needs and knowledge of local communities, leading to ineffective or unsustainable outcomes. Furthermore, they can exacerbate social inequalities and undermine local resilience.

Among the more effective solutions are the adoption of "participatory management" models and "multi-stakeholder governance" frameworks, which have increasingly gained prominence in the management

of natural resources, especially water resources, in the face of drought and climate change challenges (Salvador et al., 2020; Tosan et al., 2024). These approaches emphasize enhancing synergies and fostering collaboration between local communities, various stakeholders, and governmental and non-governmental entities in decision-making and planning processes for water resource management and climate change adaptation (Rezvani Moghaddam et al., 2016). This form of governance, which is bottom-up and inclusive of all stakeholders in making key decisions, is increasingly recognized as a sustainable and effective strategy for addressing crises and droughts (Feizi & Tosan, 2016). Participatory management, as a governance model, holds significant potential for strengthening the resilience of communities in the face of crises. This approach is particularly crucial in the management of water resources under climate change, as active community participation in decision-making processes can significantly contribute to reducing vulnerabilities and enhancing resilience to climate change impacts (Markowska et al., 2020).

Therefore, understanding the role and impact of participatory management in addressing drought and climate change, especially in the areas of "drought risk management", "drought adaptation", "governance and participatory governance" and "water resource management under climate change," is of paramount importance (Savari et al., 2022; Yuan et al., 2023). These approaches are especially critical given the need for collective decision-making and participatory strategies that incorporate both indigenous knowledge and scientific expertise, thereby contributing to addressing drought and climate change crises (Hedayat & Kaboli, 2024).

This paper presents a bibliometric analysis of the literature concerning the role of participatory management in tackling drought and climate change challenges. The aim of this study is to explore research trends, recent advancements, and evaluate the impact of participatory approaches in addressing water crises and climate change. Additionally, this study analyzes various models of participatory governance at both the local and national levels and examines how these approaches can serve as effective tools for enhancing resilience to drought and climate change crises. Our bibliometric analysis reveals key trends in this research area, including a significant increase in publications since 2015 and a growing emphasis on specific themes such as resilience, co-management, and the use of advanced technologies. Ultimately, the paper emphasizes the importance of "participatory decision-making processes", "water resource management," and "climate change adaptation" at various levels

of governance and local communities, illustrating the positive changes that can result from employing these approaches in water resource management and mitigating the effects of droughts.

**Materials and Methods**

To investigate the role of participatory management in reducing vulnerability and enhancing resilience to climate change and drought, research data were collected from the reputable Web of Science (Pranckutė, 2021) database. This database is one of the leading global sources that provides access to scholarly articles, books, conference papers, and other academic resources across various disciplines, offering comprehensive data extraction capabilities (Akbarpour et al., 2024; Tosan et al., 2024). Given its vast coverage and accuracy in sourcing relevant information, the Web of Science was selected as the primary data source for this study. The data collection process was completed on December 8, 2024, and all extracted data pertained to publications spanning the years 2007 to 2024.

In selecting keywords for this study, an initial review of literature on participatory management and climate change was conducted. The primary aim was to analyze and assess the role of participatory management in reducing community vulnerability and enhancing resilience against the challenges of drought and climate change. Keywords were specifically chosen to emphasize concepts related to water resource management and community resilience in the context of environmental crises. These keywords were categorized into two main groups. The first category pertains to participatory management and local governance, including terms such as "Participatory management", "Community-based management", "Collaborative management", "Stakeholder involvement", "Participatory decision-making" and "Local governance." These terms focus on the significance of social collaboration and shared decision-making processes across various levels of governance. This category underscores the importance of cooperation among diverse stakeholders and local governance for the effective management of resources and enhancing community resilience in the face of crises. The second category includes keywords related to drought management and resilience to climate change, encompassing terms such as "Drought management," "Drought resilience," "Drought adaptation," "Drought mitigation," "Water scarcity and drought," and "Climate change adaptation." These keywords address the challenges and strategies associated with managing droughts and mitigating the impacts of climate change. The focus of this category is on the development of strategies for adaptation and reducing the adverse

effects of climate change and drought on water resources and community resilience. To analyze the research content and identify emerging patterns in the literature, two advanced software tools, VOSviewer 1.6.20 (Arruda et al., 2022) and Biblioshiny 2.0 (Rógora Kawano, 2024), were employed. These tools are powerful instruments for bibliometric analysis and the examination of co-authorship, citation networks, and keyword clustering (Tosan et al., 2024). VOSviewer is widely used for visualizing data and analyzing scientific networks, allowing for the graphical representation of relationships between articles, authors, keywords, and other scientific indicators (Van Eck & Waltman, 2010; Van Eck & Waltman, 2011). This methodology facilitates the identification of research trends, international collaborations, and the impact of various publications. Additionally, Biblioshiny, operating within the R software environment, was used for the precise bibliometric analysis (Derviş, 2019), enabling the evaluation of citation trends and the clustering of relevant keywords in this field (Aria & Cuccurullo, 2017).

## Results and Discussion

### Analysis of Scientific Publication Trends on Participatory Management in Addressing Climate Change and Drought

The initial data extracted from the Web of Science (WoS) regarding the role of participatory management in addressing the challenges of drought and climate change include 247 publications from 2007 to 2024, spread across 158 different journals (Figure 1). The collected articles exhibit an average publication rate of 12.73 per year, with an average of 22.76 citations per article. The extracted data comprised 219 journal articles, two book chapters, 17 review papers, 10 conference proceedings, and 8 other types of publications. Furthermore, the research field is characterized by 585 indexed keywords (Keyword Plus), 782 author keywords, and 896 individual authors contributing to the body of work.

The publication trend in the Web of Science from 2007 to 2024 in the field of participatory management's role in mitigating drought and climate change challenges reflects a scientific growth and evolution in this domain. Analysis of this trend shows that participatory management has gradually became a central theme in water resource management research.

In the early years of the research period, the number of publications was relatively limited, indicating the novelty of the field and global awareness being in its nascent stages regarding the effects of climate change and drought. However, the early papers laid the theoretical foundations for

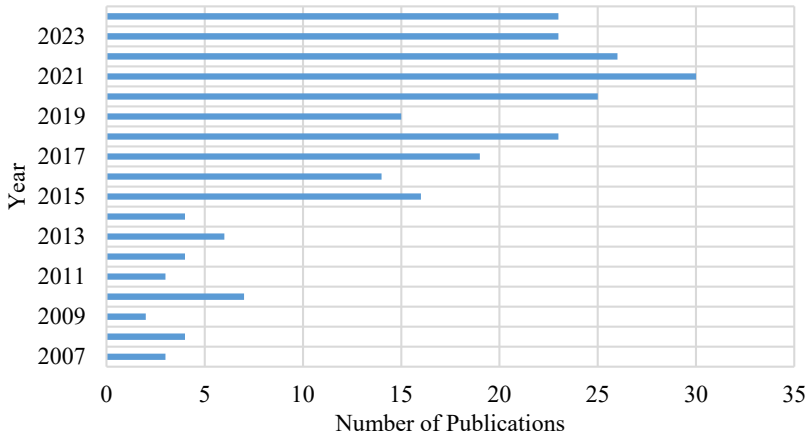


**Fig 1. Distribution of articles on the role of participatory management in reducing vulnerability and increasing resilience to climate change and drought.**

participatory management and highlighted the relationship between this approach and resilience against climate crises. From the mid-2010s, a significant increase in publications marked the growing convergence between global needs for sustainable resource management and the influence of participatory climate policies. The increase, from 6 publications in 2013 to 30 publications in 2021, reflects global efforts to develop management frameworks that integrate local communities and stakeholders directly into decision-making processes. This shift in perspective is largely due to the exacerbation of climate and drought crises across many regions, necessitating participatory, localized approaches to water management.

Published research in this area has gradually shifted from theoretical studies to more applied, data-driven research. Emerging technologies, such as Geographic Information Systems (GIS), remote sensing, and machine learning models, have increasingly been integrated into these studies to facilitate participatory management. The role of these technologies in enabling data sharing platforms, modeling climate change impacts, and fostering effective community engagement has been particularly significant. These technological innovations have provided robust tools for collaborative decision-making, allowing for more precise assessments of climate vulnerability and drought resilience. Furthermore, they have enhanced the ability to monitor and manage resources effectively, supporting the development of participatory strategies that are increasingly aligned with scientific advancements and practical, real-world applications.

This progression demonstrates the growing interdisciplinary nature of participatory management in the context of environmental crises, positioning

it as a key approach in contemporary water resource management and climate resilience research.

**Analysis of Key Publications and Scholarly Sources**

Figure 2 presents the top 20 publications with the highest number of articles published on the role of participatory management in mitigating vulnerabilities and enhancing resilience against climate change and droughts, as reflected in the Web of Science database. This indicates the breadth and diversity of research within this domain. These sources represent leading journals that focus specifically on natural resource management, climate change, and drought-related challenges. Among these, the journal *Sustainability* stands out with 12 articles published on this topic, making it a primary source for participatory management and climate change studies. *Sustainability* regularly addresses issues of sustainable development, natural resource management, and various strategies for dealing with environmental crises. The articles published here often propose innovative models and approaches aimed at advancing participatory management to tackle droughts and climate change. Given that *Sustainability* focuses on analyzing various aspects of sustainability, especially in water and natural resource management, it plays a crucial role in shaping policy recommendations for adapting local communities to climate change impacts.

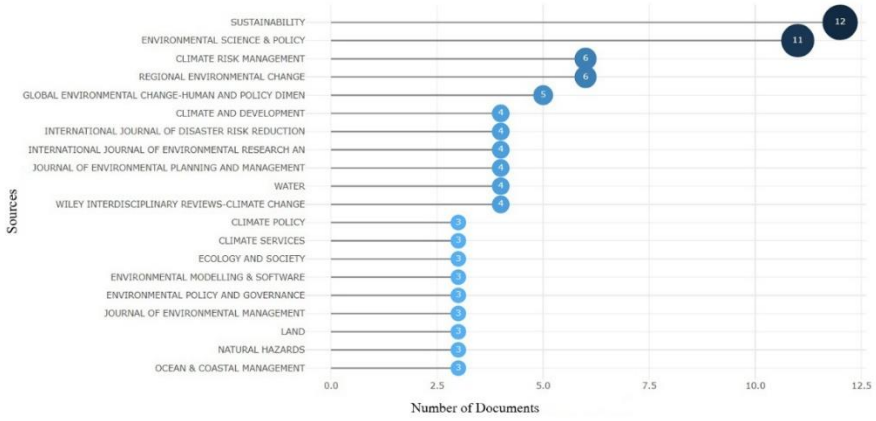


**Fig 2. Number of published articles on the role of participatory management in reducing vulnerability and increasing resilience to climate change and drought in the top 20 journals.**

Another prominent source is *Environmental Science & Policy*, which has published 11 articles within this field. This journal focuses on the policies and management strategies designed to confront the challenges posed by droughts and climate change. It primarily discusses the legal, policy-making, and governance aspects of natural resource management, with a significant emphasis on participatory

management's role in addressing environmental crises. It remains an essential reference for scholars and policymakers globally, providing practical solutions for enhancing collaboration between local and government stakeholders in managing natural resources. Articles in this journal often adopt an analytical approach, examining the effects of different policies on climate change and drought outcomes. Other noteworthy journals such as *Climate Risk Management*, *Regional Environmental Change*, and *Global Environmental Change-Human and Policy Dimensions* have also contributed significantly to advancing research in participatory management for climate change and drought. *Climate Risk Management* (6 articles) focuses on risk analysis and management strategies for reducing vulnerabilities and enhancing community resilience against climate-related risks. *Regional Environmental Change* (6 articles) takes a regional perspective on environmental changes, playing a critical role in understanding the localized impacts of climate change and droughts across various geographic areas. *Global Environmental Change-Human and Policy Dimensions* (5 articles) addresses the intersection of human dimensions and global policy responses to climate change and drought, examining how interdisciplinary approaches can inform climate action.

Although other journals have published fewer articles, they still contribute valuable analyses on policymaking, strategies, and management frameworks at different levels, especially in the context of crisis management and environmental governance.

**Journal Impact and Citation Influence**

The local impact of journals, as indicated by their H-index, reflects their varied scholarly influence (Loan et al., 2022). The H-index measures both the quantity of publications and the frequency of citations received for each article, highlighting the journal's overall academic impact. *Global Environmental Change* leads with an impressive 407 citations, underscoring its significant influence on climate change and environmental policy studies. *Ecology and Society* follows with 323 citations, recognized for its role in exploring the interplay between social and environmental dynamics in natural resource management. *Environmental Science & Policy* also holds substantial influence with 260 citations, reflecting its focus on environmental policy and participatory management in crisis situations.

Additional highly cited journals include *Climatic Change* (149 citations) and *Sustainability* (149 citations), both of which emphasize the importance of sustainable development and climate change within global policy frameworks. The *Journal of Environmental Management* (131

citations) and *International Journal of Disaster Risk Reduction* (114 citations) are also considered vital sources in the field of natural disaster management and climate change mitigation strategies.

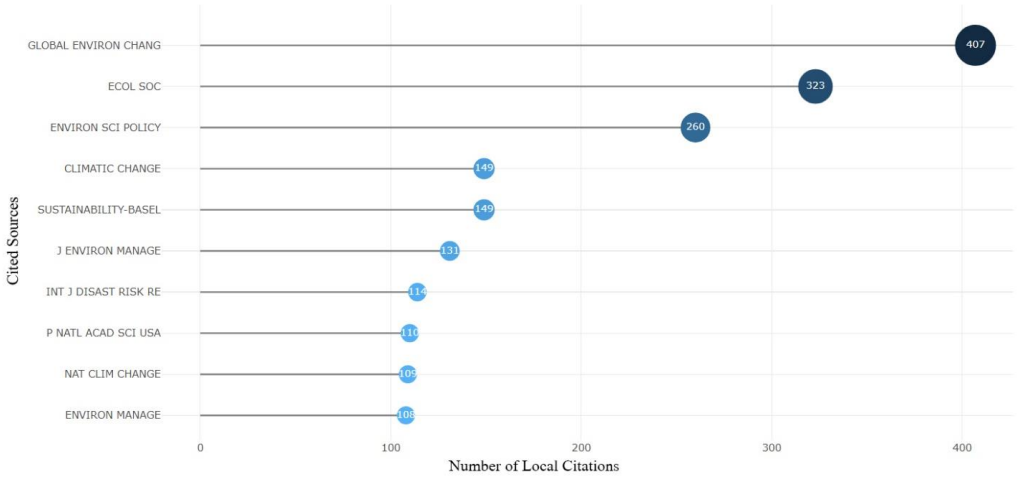


**Fig 3. Journals' impact based on H-index**

Figure 3 presents a visual representation of journal impact, where the size and color of the nodes correspond to their H-index, with larger and darker nodes indicating higher impact. This type of analysis offers a comprehensive view of the relative influence of each journal, accounting not only for publication volume but also citation frequency. An increased H-index is indicative of greater scholarly influence within the scientific community.

**Temporal Trends in Publication Growth**

As shown in Figure 4, the growth in journal publications over time reflects the increasing academic attention to participatory management in addressing climate change and drought challenges. *Sustainability* has consistently published the highest number of articles, with a marked increase in publications since 2019, signaling the growing recognition of participatory approaches in climate adaptation strategies. Similarly, *Environmental Science & Policy* has emerged as a central reference in this field, with a steady increase in published articles in recent years.

Notably, *Climate Risk Management* has also experienced significant growth since 2020, contributing to the broader dialogue on climate risk reduction and resilience. Journals such as *Regional Environmental Change* and *Global Environmental Change-Human and Policy Dimensions*, while having fewer articles, have consistently contributed valuable research to the field. The overall growth in publications from 2017 onward illustrates the heightened global interest in participatory management strategies for

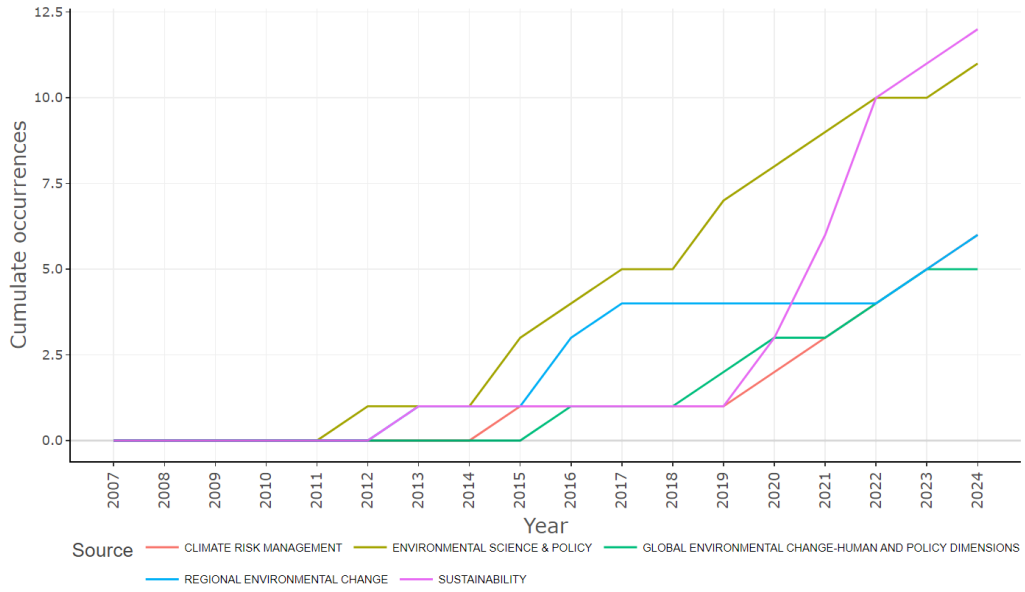


**Fig 4. Journals' growth (cumulative) based on the number of papers**

climate change and drought resilience. This analysis highlights the increasing scholarly engagement with participatory management as a critical approach for addressing the complex challenges of climate change and drought, both at the global and local levels.

**Author Contributions to Participatory Management in Climate Change and Drought Resilience**

In the author analysis, we focus on those authors most intricately linked to the subject of participatory management in the context of drought and climate change. The top 10 affiliations, authorship productivity over time, and the leading countries responsible for the highest number of publications are also examined. As depicted in Figure 5, three collaborative clusters emerge. Prominent scholars in the realm of participatory management in the face of climate change and drought challenges include Baird J., Plummer R., Komendantova N., Cilliers L., Williams D.S., and Armitage D. Notably, Armitage D. emerges as the author with the highest degree of collaboration, positioned centrally in the network visualization presented below.

Regarding the timeline of scientific publications, this analysis focuses on the publication trends of the top 10 authors with the highest number of papers. A leading figure in this field is David Armitage, recognized for his substantial contributions in 2017 and 2023, particularly in the areas of collaborative knowledge production and adaptation strategies for climate change in water resources management. His work, especially concerning governance structures and power dynamics in

these processes, has gained significant recognition. For instance, his 2023 article in *Water Resources Management* titled *Collaborative Knowledge Production and Strategies for Supporting Climate-Resilient Water Resources* has been influential, with 17 citations and an annual citation rate of 5.8, underlining the impact and acceptance of his approach (Figure 6).

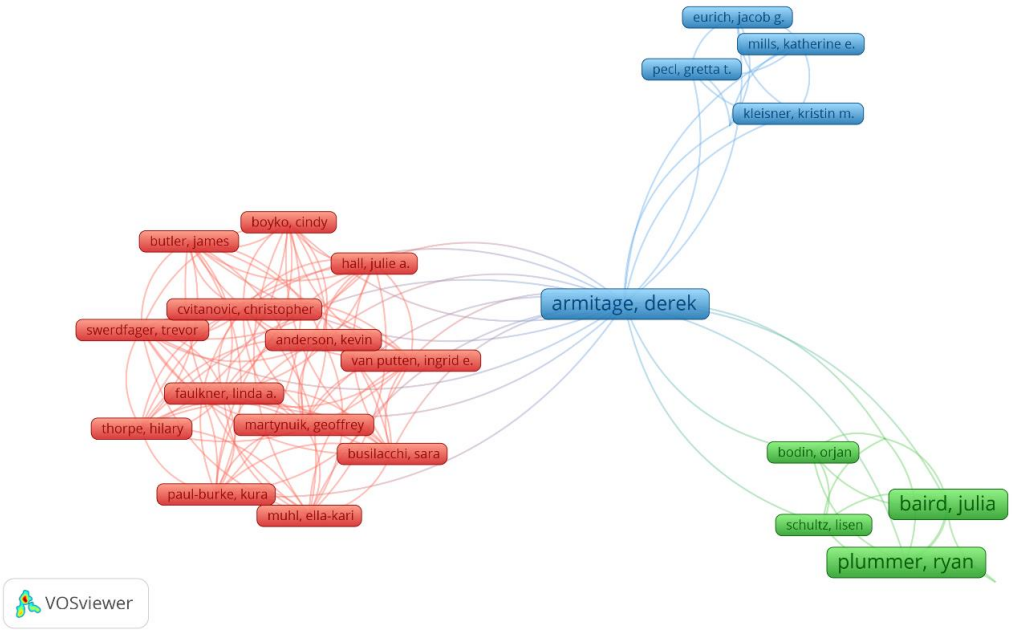


**Fig 5. Author Collaboration Network Visualization (Source: Web of Science, 2007-2024)**

In addition, the works of Williams and Cilliers, particularly their 2020 articles in *Climate Policy* and *Earth's Future*, have significantly contributed to discussions surrounding local governance capacities required for effective climate change adaptation. These studies emphasize the critical role of strengthening local capacities to confront climate and drought challenges, becoming foundational for subsequent research in governance and social participation.

Similarly, Komendantova and Plummer's papers, published in 2016 and 2017, underscore the growing attention to local participation and its effects on water management under climate change conditions. These works are particularly focused on fostering international cooperation and empowering local communities in the face of climate and drought challenges in Asia and Africa. The works published by Brown and Chapin on societal resilience in the face of climate change and natural hazards, with an emphasis on socio-ecological analyses, highlight their role in shaping decision-making processes and policy development in the context of climate adaptation. Brown's article in *Ecology and*

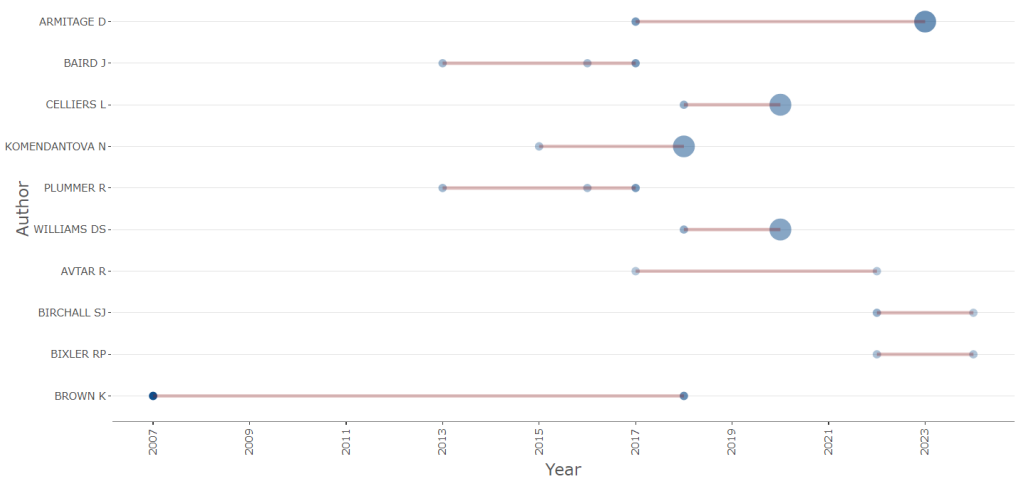


**Fig 6. Top 20 Authors' Production over Time**

*Society*, titled *Resilience as an Emerging Characteristic of Socio-Ecological Systems*, emphasizes the importance of community resilience in adapting to climatic crises, such as droughts and storms. Despite these advancements, challenges remain in participatory management, particularly regarding imbalances in power distribution, the lack of accurate information, and governance instability. These structural and institutional challenges continue to slow the decision-making and policy implementation processes.

Figure 7 presents the countries with the highest number of corresponding authors engaged in this research. These authors primarily focus on the application of artificial intelligence in local and regional studies. To identify the countries with the most significant number of corresponding authors, two criteria were considered: Single-Country Publication (SCP) and Multi-Country Publication (MCP). These metrics provided essential insights into the nature and frequency of collaboration between articles. The United States leads this field with 50 articles related to water resources management and addressing drought and climate change challenges, 45 of which are single-country publications (SCP), and 5 are multi-country collaborations (MCP). The high proportion of SCP (90%) indicates a focused, localized approach to addressing drought and climate change issues. The presence of five multi-country publications (MCP) demonstrates the U.S.'s involvement in international projects. This success can be attributed to substantial government and academic support for climate change and drought research, as well as extensive research infrastructure and funding availability in the country.

The United Kingdom follows closely with 26 articles, 14 of which are single-country publications (SCP), while 12 are multi-country collaborations (MCP). The MCP ratio of 0.462 highlights the

UK's significant role in international collaborative research, especially in climate policy and global climate forecasting models. Australia ranks third with 20 articles, with 9 SCP and 11 MCP publications. The higher MCP ratio (0.55) emphasizes Australia's active participation in international collaborations, particularly given the country's frequent droughts and climate variability. The Netherlands, with 19 publications (7 SCP, 12 MCP), has a high MCP ratio (0.632), indicating its active engagement in international water management and drought research, particularly in global water resource modeling. Canada, with 15 articles (8 SCP, 7 MCP), also shows a high level of international collaboration, with an MCP ratio of 0.467, positioning it as a leader in research related to water resources management in cold climates.

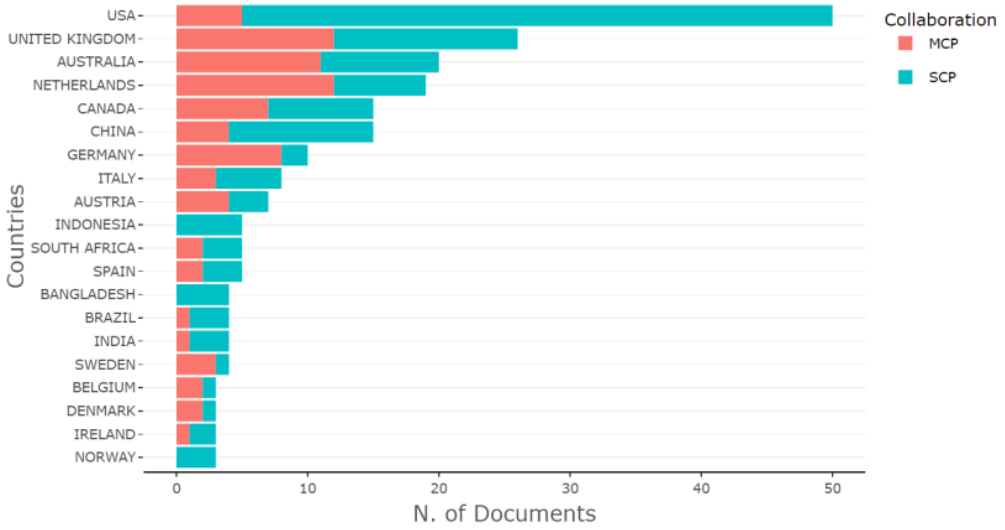


**Fig 7. Top 20 Most Relevant Corresponding Authors' Countries**

The map in Figure 8 illustrates scientific production based on the country of origin. The gray color represents countries with no scientific output, while varying shades of blue indicate the volume of scientific output from each country. A darker blue shade signifies higher volumes of published articles, whereas lighter shades correspond to fewer articles. The map clearly indicates that some countries lead the global research landscape, while others have a more limited contribution.

The United States, with 156 articles on water resources management and climate change, is undeniably a global leader in this field. This extensive publication output reflects the country's significant emphasis on addressing global climate challenges, particularly in climate modeling and drought management. U.S. research is notably centered on the application of advanced technologies in water resource modeling, such as complex climate models and satellite data integration (Rode et al.,

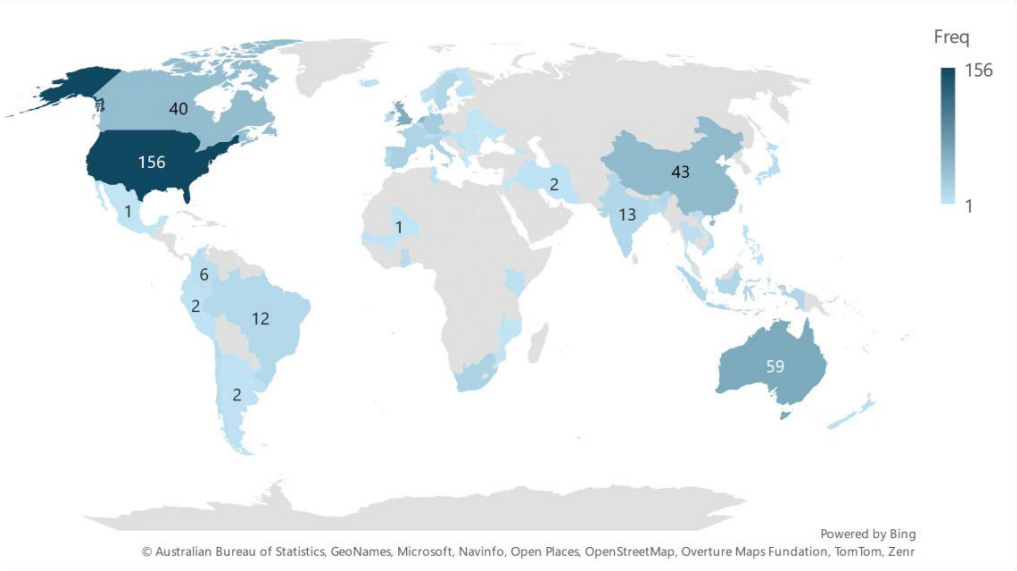


**Fig 8. Scientific Production Based on Country**

2021). Moreover, the U.S. plays a pivotal role in developing predictive models for climate change impacts and scenario analysis in water resources management, thereby influencing global policy-making on climate change (Barari & Simko, 2023). The United Kingdom, with 57 publications, has made a notable contribution to international climate change research, owing to its geographical location and proactive climate policies. UK research mainly focuses on water resources management under crisis conditions and the prediction of climate change impacts on aquatic ecosystems (Kay et al., 2020). As a leading player in global climate change studies, the UK's research extends to analyzing challenges faced by different climatic regions and participating in international climate policy frameworks such as the IPCC (Bevan, 2020).

Australia, with 59 articles, is particularly prominent in water resources management and climate change research, driven by its unique climatic conditions, which include persistent droughts and significant temperature variations (Walker et al., 2021). Australian research often centers on techniques to bolster water resilience against climate changes and model the impacts of climate change on water resources in arid and semi-arid regions (Marshall & Lobry de Bruyn, 2021). Additionally, Australia actively participates in international projects designed to develop resilience models and perform comparative analyses to address water challenges in similar regions across Asia and the Pacific.

China, with 43 articles, has a particular focus on water resource modeling and predicting water crises. The country has emerged as a leader in utilizing cutting-edge technologies for sustainable water

management and addressing climate change-induced water challenges. China's research priorities include climate change adaptation, integrated water resource management, and the use of satellite data for real-time monitoring of water resources, making it a key player in global climate change research (Qin et al., 2020; Shi et al., 2022).

India (13 papers) has made significant advances in climate change and drought-related research, focusing on agricultural water resource management and the economic and social analysis of drought impacts. India, with its vast and diverse climatic conditions, faces specific challenges in water resource management and the effects of climate change on agriculture (Mahato et al., 2022). Consequently, much of its research has concentrated on improving water resource management predictions in drought-prone areas and assessing the vulnerability of local communities.

In South Africa (18 papers), research is focused on water resource management during drought crises and innovative techniques to address water challenges in arid and semi-arid regions. The country has made notable contributions, particularly in using predictive models to assess the impacts of climate change and drought on aquatic ecosystems and agriculture (Rankoana, 2020). Similarly, Kenya (4 papers) has concentrated its research on agricultural water resource management and strategies for combating water crises in dry areas.

**Semantic Trend Analysis of Keywords in Water Resource Management Research**

To provide an effective method for reviewing the existing literature or content within scientific documents, an analysis of keywords was conducted. This analysis not only offers valuable insights into the research areas but also uncovers trends or features prevalent in specific domains (Patil et al., 2023). The study of keywords serves as a critical step in understanding the core concepts and terminology within a research field, and it proves highly useful in clarifying certain terms or when there is a need for further elaboration (North & Lombardi, 2020). Moreover, by examining groups of words that frequently appear together within documents, clusters or groupings of related terms can be identified, where each term is connected to others. Furthermore, topics that hold strong relationships within the research domain can be revealed, particularly through the number of citations these specific keywords attract. Consequently, this analysis not only provides a summary of key themes or subfields but also uncovers influential topics within the field of study, as seen in the Word Cloud in Figure 9. A comprehensive analysis of frequently used keywords in the field of study is presented below.


**Fig 9. 50 Most Common Words Based on Keywords Plus**

**1. Core Concepts of Water Resource Management in the Context of Climate Change and Drought**

This section examines keywords related to the foundational and general aspects of water resource management in the face of climate change and drought. Terms such as “Management” (46 occurrences) highlight the critical importance of water management in addressing the crises induced by climate change and drought. This term refers to management processes and the need for sustainable strategies in managing water resources. Keywords like “Governance” (24) and “Policy” (25) reflect the governmental and policy-related aspects of water resource management, emphasizing their role in improving resilience and reducing vulnerability to climate change impacts. Additionally, the term “Framework” (24) indicates the significance of establishing scientific management frameworks in this context.

**2. Resilience and Vulnerability to Climate Change and Drought**

This section focuses on concepts related to assessing and enhancing resilience against the challenges posed by climate change and drought. The term “Vulnerability” (30 occurrences) predominantly addresses the susceptibility of communities and ecosystems to these crises, aiming to identify and evaluate the threats posed by these challenges. The concept of “Resilience” (18) refers to the ability to recover to normal conditions after crises, which is a central concept in climate change studies and water resource management.

Alongside these, terms like "Adaptation" (26) and "Climate-change adaptation" (27) highlight efforts to cope with climate changes and adaptive strategies within the sector.

**3. Public Participation and Collaborative Management in Water Resource Decision-Making**

Public participation in water resource decision-making and planning is a cornerstone of effective water management. Keywords such as "Participation" (20) and "Public-participation" (9) underline the importance of engaging local communities and the public in water-related decisions and climate crisis management. The term "Co-management" (11) refers to collaborative approaches where responsibility for resource management is shared between governments and local communities, stressing the significance of joint management in ensuring sustainability.

**4. Risk Assessment and Challenges in the Face of Climate Change and Drought**

This section discusses keywords related to the evaluation and management of risks and challenges arising from climate change and drought. Terms like "Risk" (16) and "Challenges" (15) focus on analyzing the threats and crises related to water resources due to climate change. The term "Impact" (11) highlights the effects of these crises on natural resources and human communities, indicating the importance of understanding the consequences of these changes within water resource studies.

**5. The Role of Knowledge and Science in Water Resource Management and Crisis Response**

This section emphasizes the importance of scientific knowledge and evidence-based decision-making in addressing water crises. The term "Knowledge" (22) highlights the crucial role of scientific and documented information in water resource management, suggesting that effective decisions require the use of reliable and up-to-date data. Similarly, the term "Science" (29) underscores the foundational role of scientific research in informed decision-making processes concerning climate change and drought management.

**6. Modeling and Analytical Tools in Water Resource Management**

This section focuses on models and analytical tools that are applied to data analysis and simulation of various scenarios in water resource management and climate change studies. The keyword "Model" (10) specifically refers to the use of simulations and modeling to assess crises and changing conditions. Additionally, the term "Uncertainty" (9) points to the uncertainties inherent in predictions and modeling efforts regarding water resources and climate change, highlighting the ongoing efforts by researchers to mitigate these uncertainties.

By examining these keyword clusters, it is evident that water resource management in the face of climate change and drought is a multifaceted field, involving governance, resilience, vulnerability, public participation, risk assessment, scientific knowledge, and advanced modeling. Each of these aspects plays a vital role in developing effective strategies for addressing current and future water challenges.

**Analysis of Past Research Topics and Future Trends in Collaborative Water Resource Management**

The analysis of past research trends and the identification of emerging future research directions regarding the role of participatory management in reducing vulnerability and enhancing resilience to climate change and drought was conducted using the R-Studio software, as depicted in Figure 10. This keyword trend analysis from the Web of Science database highlights a shift in the focus of research themes over time. While some concepts have gained prominence, others have gradually diminished in research priority.

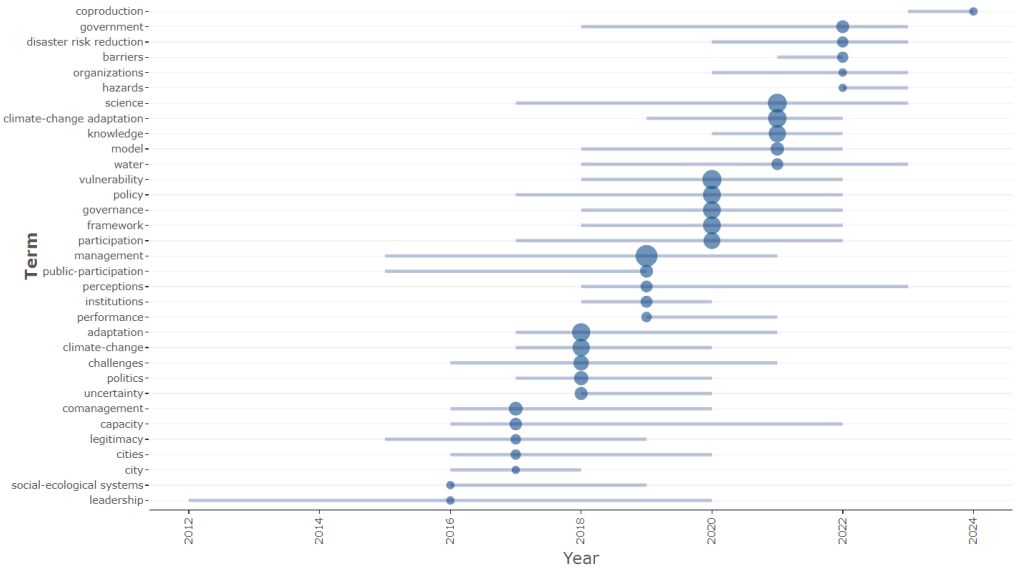


**Fig 10. Topic Trends Based on Keywords (Utilizing the Biblioshiny R Package)**

**Retrospective Trend Analysis**

**1. Management**: The keyword "Management" has seen the highest frequency of use compared to other keywords, exhibiting a notable increase from 2015 to 2021. This trend suggests that the role of management frameworks, including natural, social, and economic resource management in the context of climate change and drought, has garnered significant attention. Moving forward, participatory and co-management approaches are expected to remain central in the field.

**Public Participation**: The concept of "Public Participation" has steadily appeared in articles from 2015 to 2019, reflecting the growing importance of participatory approaches in addressing climate and drought crises. Given its foundational role in fostering collaborative responses to environmental challenges, this concept is likely to maintain its prominence in future research.

2. **Social-Ecological Systems**: The "Social-Ecological Systems" keyword has emerged in research from 2016 to 2019, focusing on the interactions between human and environmental systems under critical conditions, particularly the impacts of climate change and drought. This approach is expected to continue gaining importance, especially concerning adaptation strategies to mitigate climate impacts.

3. **Policy**: The frequency of the term "Policy" has steadily increased from 2017 to 2022, indicating the growing emphasis on governance, regulatory frameworks, and climate strategies. As participatory management and climate-resilience strategies continue to evolve, policy-related discussions will likely remain critical in future studies.

**Prospective Trend Analysis**

1. **Co-management**: The keyword "Co-management" gained prominence in research between 2016 and 2020, with an accelerating trend in recent years. Given the pivotal role of local communities in responding climate and drought-related challenges, co-management models—emphasizing shared responsibilities and decision-making between governments and local populations—are expected to become more prominent in future literature.

2. **Resilience**: Keywords related to resilience, such as "Resilience," "Social Resilience," and "Drought Resilience," have increasingly appeared in articles since 2017. Future research will likely focus on strengthening community resilience to the impacts of climate change and water crises, with a particular emphasis on adaptive strategies for vulnerable regions.

3. **Hydrological Systems and Water Scarcity**: This area has gained significant attention, especially from 2018 to 2023, and is expected to remain a key focus in future research. Studies will likely center around modeling hydrological systems and simulating the effects of climate change on water resources and water scarcity. The growing severity of droughts and climate-related water issues suggests this will remain a critical research area, particularly in arid and semi-arid regions.

4. **Decision-making Participation**: The importance of public involvement in decision-making is increasingly recognized, with keywords such as "Participatory Decision-making," "Governance Participation," and "Collective Decision-making" likely to

feature more prominently in the future. This is especially pertinent in the context of natural resource management and water governance, where collaborative decision-making is essential for effective climate adaptation.

**5. Co-production and Collaboration**: Keywords like "Co-production" and "Collaborative Business" have recently emerged and are expected to gain traction in future research, particularly in the development and implementation of climate policies. These models of collaboration, which emphasize partnerships between stakeholders, could play a critical role in enhancing community resilience to climate and drought impacts.

**6. Modeling Approaches**: The use of models to predict, evaluate, and manage climate-related crises will continue to be a vital research tool. Keywords associated with modeling have seen an increase since 2018, and are expected to be increasingly utilized in climate data analysis, impact forecasting, and predictive climate modeling. As the complexity of climate scenarios grows, the need for advanced modeling techniques will likely intensify, offering insights into sustainable resource management and climate resilience strategies.

## Conclusion

In recent decades, participatory management has emerged as a pivotal research domain in the context of climate change and drought resilience within water resource management sciences. The analysis of scholarly documents extracted from the Web of Science database reflects a notable growth in this field from 2007 to 2024, highlighting the increased attention to this approach in response to global climate crises. The analysis reveals that key terms such as resilience, vulnerability, local governance, social participation, and water resource management have established a scientific framework for assessing and evaluating the role of participatory management in addressing environmental challenges.

From a trend analysis of publication output, there is a marked increase in scientific production in this domain post-2015, directly correlating with the intensification of global climate and drought crises. Research has transitioned from theoretical and conceptual approaches to more practical and data-driven investigations. Notably, the integration of advanced technologies, such as remote sensing, Geographic Information Systems (GIS), and machine learning models, has expanded significantly in participatory management analyses. These tools are critical in facilitating data sharing, modeling the effects of climate change, and enhancing community involvement in decision-making processes.

Geographically, international research,

particularly in North America and Europe, emphasizes the use of predictive models and cutting-edge technologies to manage crises and water resources. In contrast, Asian and African countries, influenced by their unique climatic and hydrological conditions, focus more on predicting water crises and ensuring sustainable water resource management. These geographical and climatic disparities introduce diversity and complexity into the research trajectories and management solutions.

In terms of reputable journals, *Sustainability* and *Environmental Science & Policy* stand out as key references in this field. These journals, through publishing influential and innovative research, significantly contribute to managerial and analytical advancements. They provide a platform for developing scientific and practical solutions to global crises such as climate change and drought, with notable contributions to governance, social-ecological resilience, and local participatory models in water resource management.

Future research is expected to concentrate on critical themes such as co-management, resilience, decision-making participation, and collaborative efforts. The adoption of advanced models, particularly involving real-time data and artificial intelligence, will play a central role in more accurate crisis predictions and water resource management facilitation. These advancements are expected to substantially reduce community vulnerability to climate change and enhance their resilience.

Ultimately, to advance scientific objectives in water resource management and address climate and drought crises, it is essential to more effectively integrate international collaboration and local capacity-building in decision-making and crisis management processes. Key areas for future research include predictive resilience modeling, strengthening local participation, analyzing the effects of international and national policies, and leveraging real-time data. Additionally, interdisciplinary research will be crucial in expanding comprehensive and innovative solutions to address climate change and drought challenges, paving the way for more robust and sustainable water management frameworks.

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