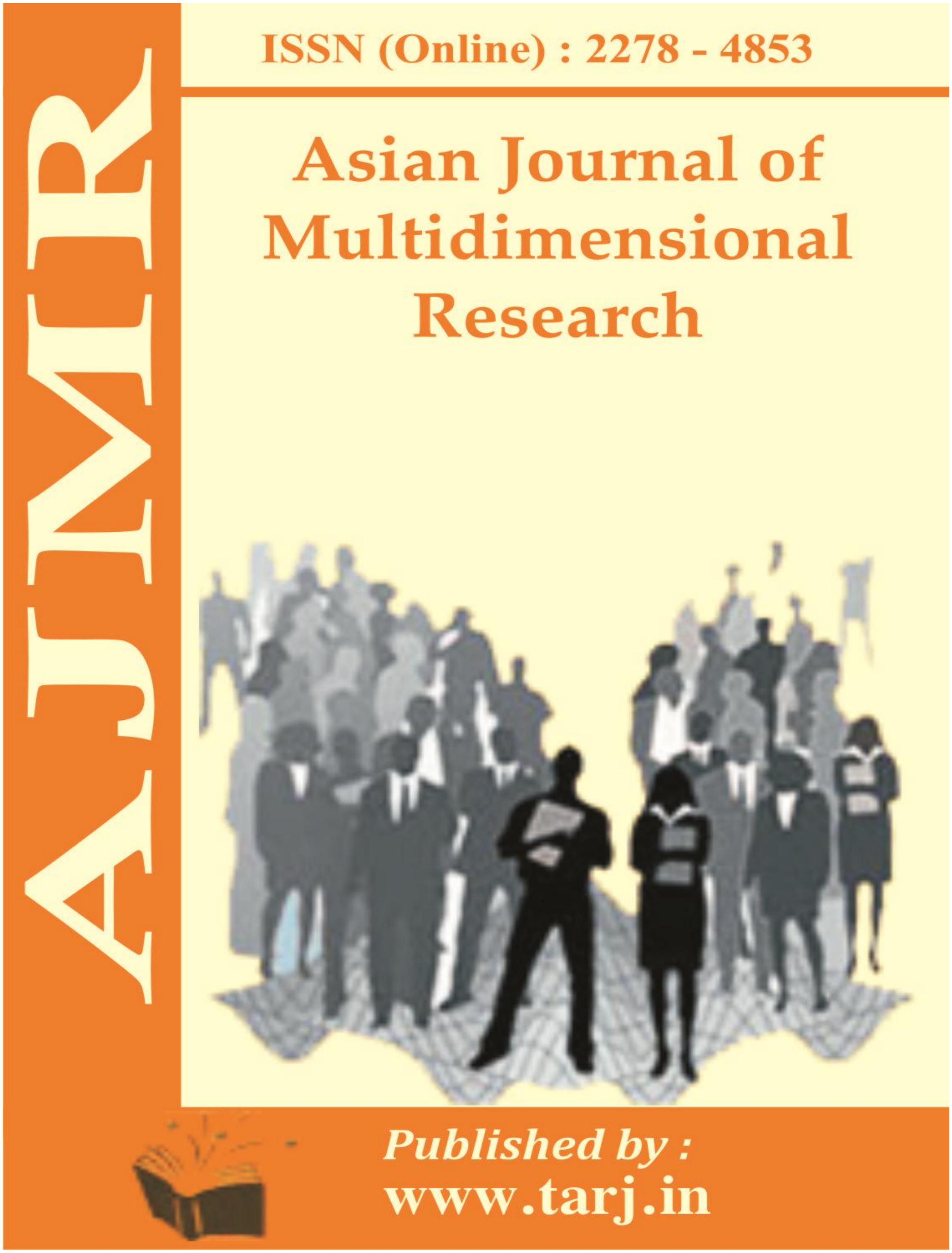
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VISION

The vision of the journals is to provide an academic platform to scholars all over the world to publish their novel, original, empirical and high quality research work. It propose to encourage research relating to latest trends and practices in international business, finance, banking, service marketing, human resource management, corporate governance, social responsibility and emerging paradigms in allied areas of management. It intends to reach the researcher's with plethora of knowledge to generate a pool of research content and propose problem solving models to address the current and emerging issues at the national and international level. Further, it aims to share and disseminate the empirical research findings with academia, industry, policy makers, and consultants with an approach to incorporate the research recommendations for the benefit of one and all.

MAPPING THE GLOBAL RESEARCH LANDSCAPE ON IMPACTS OF HYDROPOWER PROJECTS: A DECADAL BIBLIOMETRIC PERSPECTIVE

Mairembam Rajeev Singh*; Dr. Kh. Tomba Singh**

*Research Scholar,
Department of Commerce
Manipur University, Canchipur, Imphal, INDIA
Email Id: mairembam.rajeev@gmail.com

**Professor,
Department of Commerce,
Manipur University, Canchipur, Imphal, INDIA
Email Id: kctomba@gmail.com

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ABSTRACT

This bibliometric study focuses on analysing 636 Web of Science articles on the impacts of hydropower published between 2016 and 2025. We employed Bibliometrix and VOSviewer to map trends in publications, authorship, journal outlets, thematic clusters and collaborative networks. Annual outputs were maximal in 2021 and have stabilized thereafter, reflecting maturing of the field. Li KF and Peres CA were the most prolific authors and Science of the Total Environment and Journal of Hydrology the most influential journals. Thematically, ten disconnected areas were identified, with climate change emerging as the main "motor theme" alongside biodiversity and sustainability. Four intellectual strands emerged through the co-citation analysis: energy policy and governance, biodiversity conservation, hydrological modeling and ecological flow science. Predominantly international collaborations involving the United States, Brazil, and China among other regions of interest like Southeast Asia. Some key gaps are under-researched transboundary dynamics, and insufficient integration of water–energy–food nexus frameworks. According to the findings, more systematic integration of ecological and social dimensions of hydropower strategies is necessary in order to develop climate-resilient, adaptive hydropower strategies. This review analyses hydropower impact research trends and provides evidence-driven insights to inform future research and sustainable development.

KEYWORDS: *Hydropower, Bibliometric Analysis, Climate Change, Sustainability.*

1. INTRODUCTION

The largest renewable electricity source is hydropower, which accounts for about 14.3% of global supply and is present in over 150 countries (International Hydropower Association, 2025). Its flexible role, fast-ramping, storage and ancillary grid services - enables it to be at the centre of low-carbon energy transition and integration of variable renewables such as solar and wind (International Energy Agency, 2021). Besides electricity, hydropower projects are also associated with co-benefits such as provision of water management for agriculture purposes; flood and drought mitigation; rural development, direct through infrastructure creation and indirect through job creation (Schulz & Skinner, 2022). These functions are in line with global commitments, especially Sustainable Development Goal 7 – affordable and clean energy for all by 2030.

Nevertheless, major hydropower dams lead to substantial externalities from both socio-economic and environmental perspectives. Among the typical ecological impacts are biodiversity depletion, habitat disruption, and sediment disruption (Jiang et al., 2016; Moran et al., 2018), whereas dislocation of local Indigenous peoples and other rural inhabitants continues to be a prevailing socio-economic problem (Schulz & Skinner, 2022; Sharma & Sharma, 2025). However, most compensation and rehabilitation schemes usually do not succeed in regaining their means of sustenance, making them highly susceptible. The impacts of climate change will worsen such threats since climate change brings changes in rainfall patterns, melting of glaciers, and hydrologic extremes (Coelho et al., 2024).

As a result, sustainability frameworks and governance tools have appeared. The Hydropower Sustainability Standard provides international certification based on environmental, social, and governance standards (Hydropower Sustainability Alliance, 2024).As a result, adaptive management methods such as dynamic environmental flow systems and predictive discharge planning are being adopted in more and more countries (World Bank Group, 2018). Current research highlights that viable hydropower development requires holistic approaches that simultaneously address energy security, climate adaptation, environmental protection, and social welfare (Wyrwoll & Grafton, 2022).

There are still important gaps to be filled despite these advances. It has been found out that research has not fully addressed spatial and temporal dynamics of hydropower impacts, particular in transboundary basins and has also not adequately incorporated Indigenous rights, such as Free, Prior, and Informed Consent (FPIC) (Sharma & Sharma, 2025). In addition, although some studies have investigated ecological, technical and governance dimensions separately; research trends over the past decade are not systematically bibliometrically mapped as a whole. To fill this gap, the current study conducted a bibliometric analysis of hydropower impacts research (2016–2025) by identifying publication trends and collaboration networks as well thematic clusters that represent emerging knowledge gaps across multiple diverse fields in an effort to advance future scholarship. The synthesis of these patterns provides a set of empirical paradigms to inform sustainable hydropower development over the coming decades.

2. Research Questions

This study aims to look at the state of Hydropower Projects research through a detailed analysis of existing studies. The research questions that lead this study include:

1. How has the number of publications on hydropower impact research changed from 2016 to 2025? What does this change mean for the growth of the field of Hydropower Projects?
2. Which authors, journals and articles have had an impact on Hydropower Projects research and how do they work together to share knowledge about Hydropower Projects?
3. What are the main topics, such as climate change, biodiversity and governance, that define Hydropower Projects research and how have these topics changed over time as more Hydropower Projects are studied?

4. How do researchers who study Hydropower Projects work together? Cite each others work and does this show that Hydropower Projects research is becoming more interdisciplinary and international?
5. What topics and areas are not well explored in Hydropower Projects research? How can future studies on Hydropower Projects fill these gaps?

3. Materials and Methods

3.1. Data Source and Scope

This bibliometric analysis was based solely on the Web of Science Core Collection (WoS-CC), which indexes more than 21,000 quality-controlled peer-reviewed journals across over 250 disciplines (University of St. Augustine for Health Sciences, n.d.; Web of Science, 2025). We selected WoS due to its long-standing quality control, standardized metadata, along with extensive environmental and energy sciences coverage, which is ideal for bibliometric mapping. WoS was prioritized since alternative databases (e.g., Scopus or Dimensions) would give a more extensive coverage but may pose challenges for data reliability and consistency across the study period.

We could have used databases like Scopus or Dimensions to get more information. We chose the Web of Science Core Collection because it gives us reliable and consistent information. We only looked at publications from 2016 to 2025. We did this to match the United Nations plan for development that started in 2015. We also wanted to see what is new in research about the impact of hydropower. Some researchers like Benavides-Sánchez and others have written about this in 2025.

Search Strategy

On 1 August 2025, a systematic query was executed in the WoS *Topic* field (titles, abstracts, and author keywords) using the following Boolean string: TS = ((“hydropower project” OR “hydroelectric project” OR “hydropower development” OR “hydroelectric dam”) AND (“environmental impact” OR “social impact” OR “economic impact” OR impacts OR effects OR consequences)). This formulation combines synonymous project terms with broad impact descriptors to maximize coverage of environmental, social, and economic outcomes (Web of Science, 2021).

Inclusion Criteria and Filtering

Results were restricted to English-language articles and review articles to ensure quality and to enable international researchers to access them. We chose eight WoS subject categories (Environmental Sciences & Ecology; Water Resources; Biodiversity Conservation; Energy & Fuels; Business & Economics; Social Issues; Social Sciences – Other Topics and Development Studies) to cover the interdisciplinary dimensions of hydropower impacts.

Following automated deduplications, title and abstract screening were performed manually for studies outside the scope of the review. We employed a two-stage review process: (i) a literature search for hydropower projects; (ii) assessments of relevance; and finally, checks whether the papers summarized environmental, social, or economic impacts. This method ensured accuracy and consistency in dataset preparation, despite being blinded and conducted by a single reviewer. The illustrations of our systematic search strategy and selection process for the bibliometric analysis are shown in Fig. 1.

Final Dataset

This process yielded 636 articles for bibliometric analysis. The dataset showed that there was an average annual growth rate of 4.5% in 579 research articles published in journals, 1 data paper article, 6 early access articles, 7 proceedings papers, and 43 review articles. The whole selection process is summarised in Figure 1, which follows a PRISMA-style flow to enhance transparency and reproducibility. Descriptive statistics of the final corpus are summarized in Table 1.

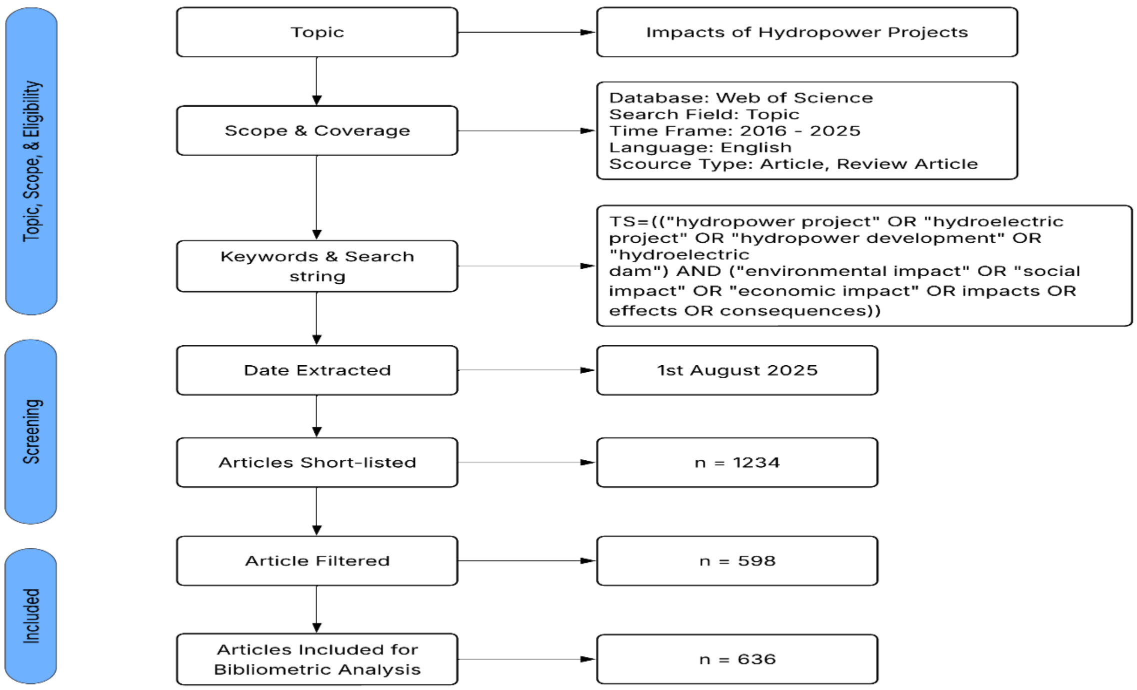


Fig. 1 Flow diagram of the search strategy

Table 1 Overview of Bibliometric Review – Web of Science database from 2016 to 2025

Timespan	**2016:2025**
Sources (Journals, Books, etc.)	200
Documents	636
Annual Growth Rate %	4.5
Document Average Age	4.1
Average citations per doc	18.74
References	33415
DOCUMENT CONTENTS	
Keywords Plus (ID)	1752
Author’s Keywords (DE)	2178
AUTHORS	
Authors	2552
Authors of single-authored docs	33
AUTHORS COLLABORATION	
Single-authored docs	34
Co-Authors per Doc	5.02
International co-authorships %	44.5
DOCUMENT TYPES	
article	579
article; data paper	1
article; early access	6
article; proceedings paper	7
review	43

Source: Biblioshiny (Bibliometrix R package)

3.2 Data Analysis

For the bibliometric analysis, VOSviewer and Biblioshiny (the web interface for the R package Bibliometrix) were utilised to synthesise patterns of knowledge production in Impacts of Hydropower Projects (Büyükkidik, 2022). The data analysis was performed through a combination of descriptive and bibliometric studies. The main contribution of descriptive analysis in bibliometric studies is to allow data to be systematically quantitatively summarised and interpreted, which can provide useful information on research trends, patterns and relationships in a particular field (Arora & Arora, 2022).

This descriptive analysis was performed in Microsoft Excel to examine the publication trends of Impacts of Hydropower Projects on an annual basis. Biblioshiny provides an accessible interface for researchers to visualise and analyse bibliometric data. As a valuable resource for conducting comprehensive bibliometric studies (Moral-Muñoz et al., 2020), VOS viewer allows users to analyse bibliometric data by visualising relationships between countries, journals, and predictors. Users can create maps representing the collaboration between countries, specific journals’ impact, and various predictors’ influencing research trends (Mitrović et al., 2023; van Eck & Waltman, 2010).

VOS viewer and Biblioshiny were selected for this study because their unique functionalities of bibliometric analysis completely aligned with the research objectives. Biblioshiny provided a comprehensive character analysis by the authors as well as the keywords, providing the means to identify leading contributors and key themes in the Impacts of Hydropower Projects literature. VOS viewer was used to analyse this collaboration among countries, prolific journals, and priority indicators while showing general network visualisations of the bibliometric connections. Regarding all such aspects, VOS viewer and Biblioshiny presented themselves as the befitting tools to capture the objectives of this study.

4. Results

4.1 Descriptive Analysis

4.1.1 Publication Trend.

Trends in annual publication output on hydropower impacts show distinct periods of emergence, consolidation and more recent stabilization (Fig. 2). The number of papers increased progressively (from 35 publications in 2016) until the end of 2018 and a strong acceleration occurred after this period, reaching the peak value of articles (89) in 2021. Such a rise is indicative of increasing international awareness of the environmental and social impacts of hydropower. And yet the 41.6% decline by 2025 means that while it is hot right now, there may be an emerging thematic saturation or a shift of scholarly focus to closely related topics like energy transitions and climate adaptation. Collectively, 636 articles were produced during the decade (Table 1), indicating that hydropower impact research had established itself as a sustained academic field with long-run levels of output far in excess of those seen at our initial baseline.

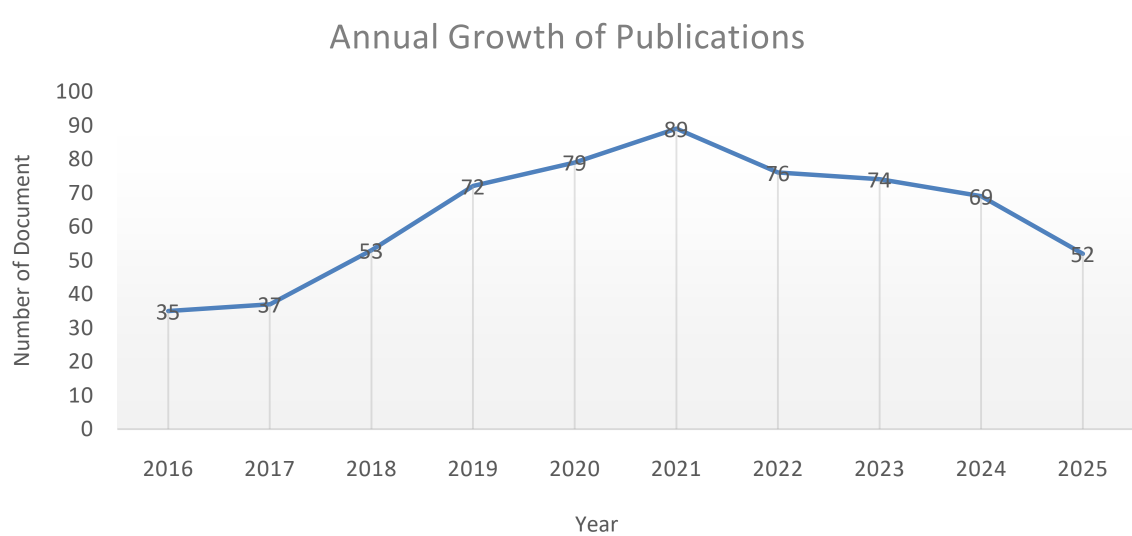


Fig. 2 Annual Growth of Publications (Web of Science database, 2016-2025)

4.1.2 Top Authors.

These prolific individuals comprise collectively the intellectual backbone of hydropower impact research (Table 2). Li KF tops the chart with volume (n = 13), highlighting a sustained level of productivity, at the same time, Peres CA stands out with a highest fractionalized authorship rate (3.23), indicating an involvement in leadership roles on multi-author works. The mid-tier authors like Liang RF and Wang YM have a constant work output with a low independent contribution rate. The rest, such as Habit E and Lopez MC, deliver substantial niche expertise. The agentive pattern depicted through these ten authors is one of spread leadership: productivity exists in equal parts between the clout of individuals and the work of the collective, creating a divergent but integrated scholarly social network.

Table 2: Top Contributed Authors

Rank	Authors	Articles	Articles Fractionalized
1	Li KF	13	2.07
2	Peres CA	11	3.23
3	Liang RF	10	1.56
4	Wang YM	9	1.46
5	Zhang P	8	1.06
6	Habit E	7	1.15
7	Lopez MC	7	1.50
8	Palmeirim AF	7	1.60
9	Pokhrel Y	7	1.28
10	Yao WW	7	1.12

Source: Biblioshiny (Bibliometrix R package)

4.1.3 Top Journals.

Table 3 shows the important role certain journals occupy as the sole vehicle of scholarly work on hydropower impact. Science of the Total Environment and Journal of Hydrology lead in both productivity (~30 articles each) and citation impact (>1,100 citations), establishing their status as outlet leaders linking environmental science with water research. With 43 articles, Water has a higher article count than other journals in our sample but uses citations less intensively (675) suggesting more diffuse coverage generally with less focus on high impact work. Some journals including Renewable & Sustainable Energy Reviews and Sustainability seemed to signify a shift towards integrating hydropower debates within the field of wider sustainability transitions, whereas others like Ecological Engineering were more aligned with applied ecological features. The resulting journal landscape is both interdisciplianry and specialized, assisting diffusion of research across a wide variety of scholarly communities.

Table 3: Top 10 Journals by Productivity and Impact in Hydropower Impact Research

Rank	Journal	Articles	Total Citations	h-Index	m-Index
1	Science of the Total Environment	31	1,167	19	1.90
2	Journal of Hydrology	30	1,200	16	1.78
3	Water	43	675	13	1.30
4	Ecological Engineering	12	201	10	1.00
5	Renewable & Sustainable Energy Reviews	16	406	9	0.90
6	Sustainability	22	288	9	1.00
7	Energies	13	184	8	1.00
8	Environmental Impact Assessment Review	10	187	8	0.80
9	Hydrology and Earth System Sciences	8	362	7	0.70
10	Journal of Cleaner Production	8	241	7	1.17

Source: Bibliometrix R package (Biblioshiny)

4.1.4 Top Articles

Highly cited articles reflect both the themes and the regionally rooted nature of the topic (Table 4). Hecht (2019), the top cited article, is cited 281 times and focuses on the hydrological effects in the Mekong Basin, followed by Lees (2016) on biodiversity in the Amazonia, and Kondolf (2018) on sediment transport dynamics. These articles all point towards the importance of river basins like the Mekong and Amazon in providing examples of hydropower consequences from a global perspective. The contributions made by Pokhrel (2018) and Feng (2020) include climate modeling and forecasting, whereas research by Bene (2018) also covers socio-political conflicts and resistance. The consistency of citation numbers across different issues highlights the lasting legacy of fundamental research on hydropower ecology and governance.

Table 4: Most cited Top 10 Articles in Web of Science from 2016 to 2025

Rank	Article Title	First Author	Year	Journal	TC	TC/ year
1	Hydropower dams of the Mekong River basin: A review of their hydrological impacts	Hecht J. S.	2019	Journal of Hydrology	281	40.14
2	Hydropower and the future of Amazonian biodiversity	Lees A. C.	2016	Biodiversity and Conservation	267	26.70
3	Changing sediment budget of the Mekong: Cumulative threats and management strategies for a large river basin	Kondolf G. M.	2018	Science of The Total Environment	200	25.00
4	A Review of the Integrated Effects of Changing Climate, Land Use, and Dams on Mekong River Hydrology	Pokhrel Y.	2018	Water	192	24.00
5	Monthly runoff time series prediction by variational mode decomposition and support vector machine based on quantum-behaved particle swarm	Feng Z. K.	2020	Journal of Hydrology	191	31.83

	optimization					
6	Observed river discharge changes due to hydropower operations in the Upper Mekong Basin	Räsänen T. A.	2017	Journal of Hydrology	178	19.78
7	More dams, more violence? A global analysis on resistances and repression around conflictive dams through co-produced knowledge	Bene D. D.	2018	Sustainability Science	152	19.00
8	Challenges of river basin management: Current status of, and prospects for, the River Danube from a river engineering perspective	Habersack H.	2016	Science of The Total Environment	143	14.30
9	Global Water Transfer Megaprojects: A Potential Solution for the Water-Food-Energy Nexus?	Shumilova O.	2018	Frontiers in Environmental Science	139	17.38
10	Impacts of climate change, policy and Water-Energy-Food nexus on hydropower development	Zhang X.	2018	Renewable Energy	110	13.37

Source: Biblioshiny (Bibliometrix R package)

The descriptive indicators show that hydropower impact research has matured into a distinct and sustained scholarly field, supported by influential authors, interdisciplinary journals, and highly cited foundational studies.

4.2 Thematic Analysis:

4.2.1 Authors' Keyword Co-occurrence:

The keyword co-occurrence network (Fig. 3) reveals ten thematic clusters. **Cluster 1 (Pink)** is centered around the theme of "hydropower", "hydropower development" and "climate change", genetically connecting energy generation to adaptation research. **Cluster 2 (Red)** was more focused on hydrological impacts, with terms such as cascade reservoirs, flow regime and water quality. **Cluster 3 (Green)**: Governance and equity ("sustainability," "resettlement" and "justice energy"). **Cluster 4 (Dark Blue)**: Regional studies of "China" and "India"; **Cluster 5 (Yellow)** addresses ecological issues in the "Amazon," including "biodiversity" and "habitat fragmentation".

The smaller clusters focus on very specialized topics: **Cluster 6 (Purple)** emphasizes mitigation tools ("environmental flow", "reservoir operation"), **Cluster 7 (Olive)** discusses dams and energy policy. **Cluster 8 (Teal)** methodological tools (e.g., "GIS," "remote sensing") are identified in the cluster as well, out of which one other **Cluster 9 (Grey)** differentiates transboundary governance themes like (e.g. Mekong," "Three Gorges Dam"), or **Cluster 10 (Brown)**(e.g. "renewable energy" "functional diversity") argues sustainability and ecosystem. The combined clusters here validate that this area of research is indeed interdisciplinary, including technical, ecological and social aspects as well as geographical elements.

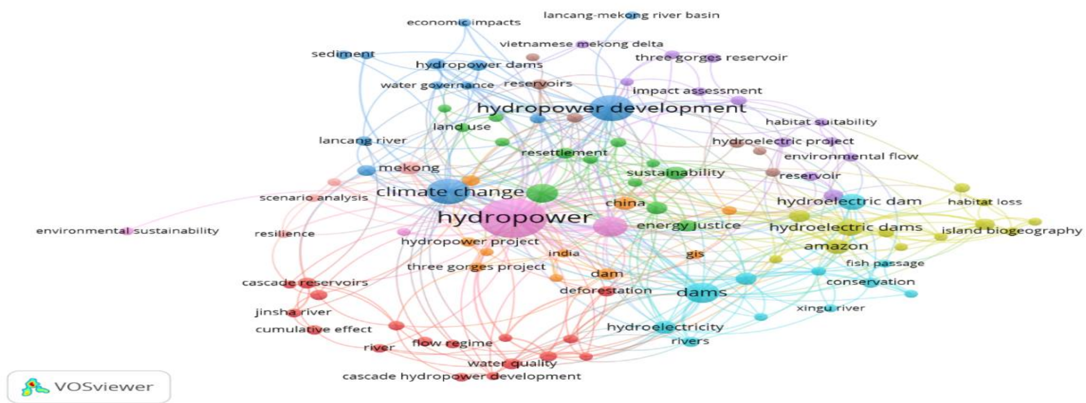


Fig. 3 Authors' Keyword Co-occurrence, *Source:* VOS viewer

4.2.2 Thematic Map:

The thematic map (Fig. 4) indicates the placement of research themes into four quadrants. The first quadrant, the Motor Themes quadrant, shows *climate change* as a mature and well-connected driver of the field, highlighting its importance in predictive modeling and adaptive studies. The second quadrant, Basic Themes, which comprises *biodiversity, hydropower, and impacts*, represents the basic but evolving themes crucial to hydropower research. The Niche Themes quadrant, the third quadrant, *holds habitat fragmentation and challenges*, both of which are in the context of ecological importance. Finally, for the fourth quadrant, Emerging or Declining Themes represented by *migration and assemblages*: niche topics of growing or waning importance.

This thematic arrangement suggests that climate change is the predominant and well-connected theme, whereas biodiversity and sustainability are vital but underdeveloped themes. On the other hand, niche and emerging themes suggest future possibilities of expanding the field to ecological and social perspectives.

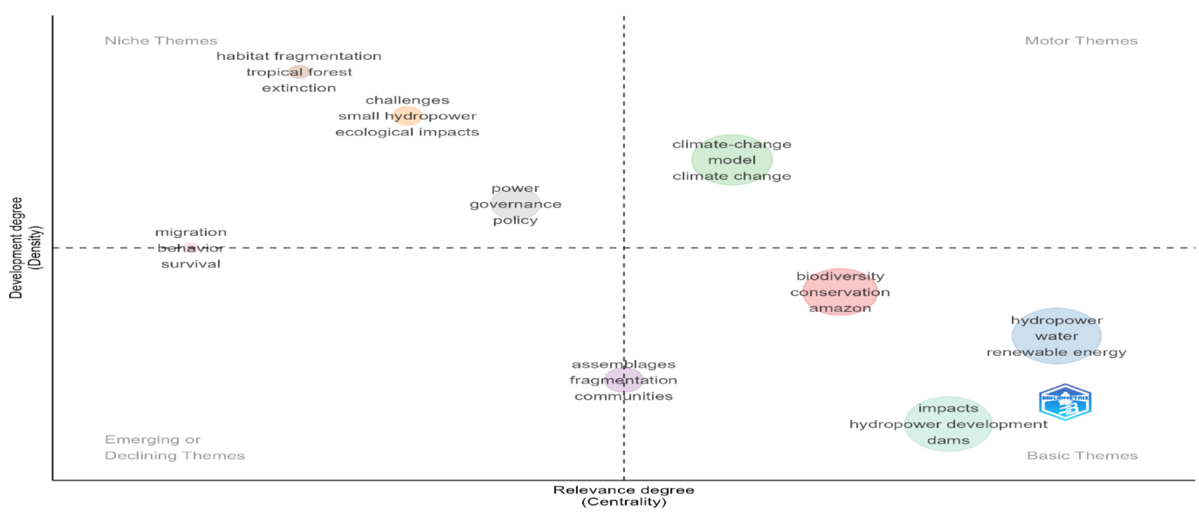


Fig. 4 Thematic Map, Source: Biblioshiny (Bibliometrix R package)

4.2.3 Trend Topic

The historical development of research subjects (Fig. 5) illustrates a very obvious three-phase shift in focus. Studies between 2016 – 2018 were mostly descriptive and case-based, focusing on projects such as the Three Gorges Dam and themes of policy/community. Between 2019 – 2021, research advanced along methodological dimensions increasingly impactful in adapting to climate change and modeling-based approaches to forecasting, as well as considerations of large-scale development of hydropower, whereby predictive tools intermingled with adaptation concerns. Beginning in 2022, the field more prominently integrated aspects related to ecology and society, as evident in keywords like biodiversity, water quality /water resources, small hydropower development/consenting, and energy justice.

Overall, this indicates that hydropower science has progressed from conducting empirical case studies to conducting an integrated analysis combining technical simulation with ecological indicators based on sustainable development and social equality criteria.

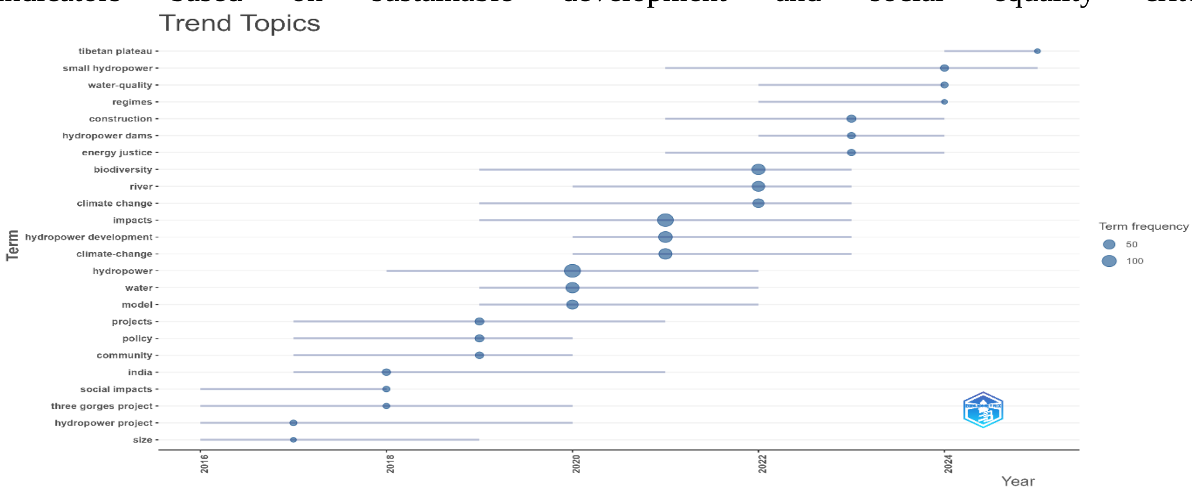


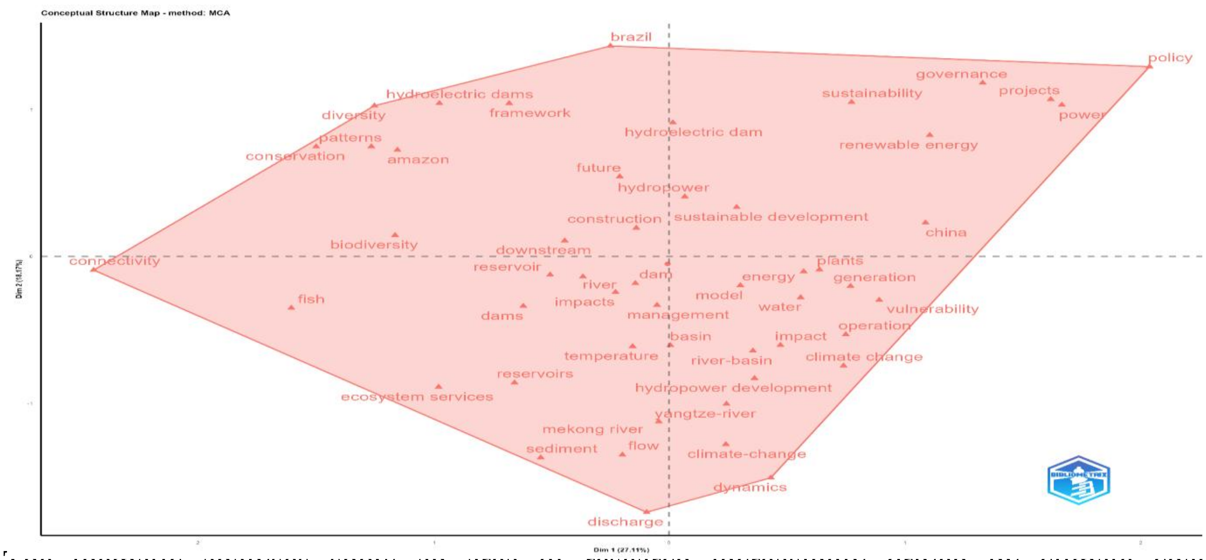
Fig. 5 Trend Topics, *Source*: Biblioshiny (Bibliometrix R package)

4.2.4 Factor Analysis

The factorial map (Fig. 6) - Demarcation of the principal intellectual axes in hydropower research. Studies on connectivity, fish and ecosystem services cluster within one axis around the ecological conservation theme with opposing themes reflecting institutional and policy-oriented research focused upon governance developments. The other axis separates climate change, hydropower development and vulnerability from adaptation and modeling studies on one side, while aligning more basic processes like sediment flow or discharge as well as river basin case studies (i.e., the Mekong River) along this axis.

The analysis identifies a domain that is organised around two key tensions: conservation versus development, and climate vulnerability versus hydrological processes. These dynamics affirm hydropower as a nascent nexus domain at the intersection of ecology, governance and climate resilience.

Fig. 6 Factorial Map, *Source:* Biblioshiny (Bibliometrix R package)



The thematic analyses show an area of research increasingly driven by climate change, broadening methodological sophistication and ecological & social equity concerns signalling hydropower debates are extending beyond technical impacts alone.

4.3 Network Analysis

4.3.1 Co-citation Analysis

The co-citation network (Fig. 7), indicative of four distinct clusters, each constituting a core area in the study on hydropower. **Cluster 1 (Red)** relates to **energy policy and governance**, built on the root of World Commission on Dams (2000), Moran et al. (2018), that frame international discussions on dam decision-making and sustainability criteria. **Cluster 2 (Green)** emphasizes **environmental conservation and biodiversity**, with Zarfl et al. (2015) and Winemiller et al. (2016) leading discussions on global dam expansion and species impacts. **Cluster 3 (Blue)**: **hydrological modeling and water resource management**, clustering with Ziv et al. (2012) by utilizing predictive models to assess how trade-offs between energy generation versus environmental flows can be evaluated. **Cluster 4 (Yellow)** Complements **ecological flow science** — pioneered by Poff et al. (1997), Richter et al. (1996), and Nilsson et al. (2005), which are still foundational for environmental flow assessment.

Collectively these clusters illustrate a shift in the field from ecological and hydrological underpinnings to integrative frameworks combining modeling, biodiversity science, and governance. The close inter-linkages across clusters reveal its interdisciplinary nature of research on the impact from hydropower.

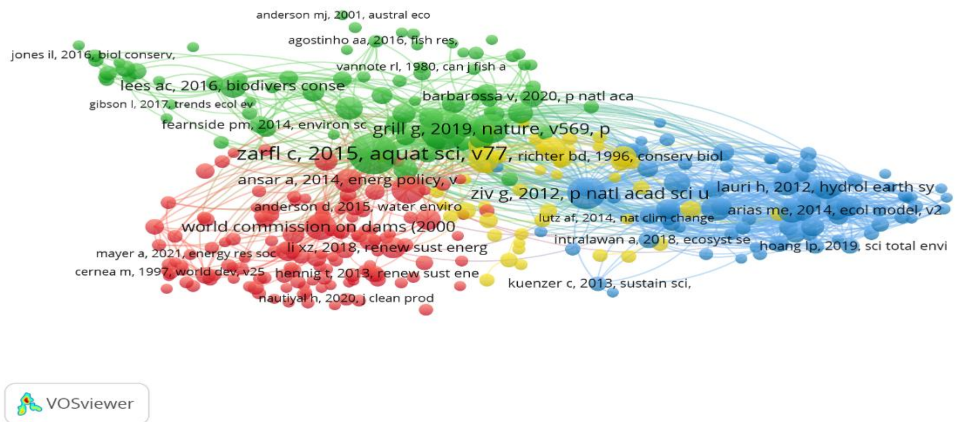


Fig. 7: **Co-citation Network, Source: VOS viewer**

4.3.2 Co-authorship Analysis

The co-authorship network (Fig. 8) provides five thematic clusters that are both strongly inter- and intra-disciplinary, showing the unique quality of each subject. The biggest cluster, headed by Andrea Castelletti, pays attention to energy policy and water systems together with decision-support modeling, underlining the huge connection between technical analysis and governance. Another cluster led by Elizabeth Anderson is focused on conservation and human–ecosystem interactions, particularly biodiversity and freshwater ecosystem management. A third group led by Maria Claudia Lopez focuses on hydrology and water resources, while a fourth, centered around Carlos Peres, brings expertise in river ecology and biodiversity conservation.

Bridging between hydrology, climate change, and governance in smaller yet critical collaborative groups — exemplified through the work of a cluster led by Matti Kummu — illustrates interdisciplinary ties across regions (with independent research also breaking scale limitations) and topics. Combined, these clusters suggest that there is no single intellectual leader in hydropower impact research but rather a patchwork of interlinked communities. The network structure illustrates the need to cooperate and share knowledge across these fields, with different research groups working in parallel but interlinked ways on ecological, social, and governance aspects of hydropower development.

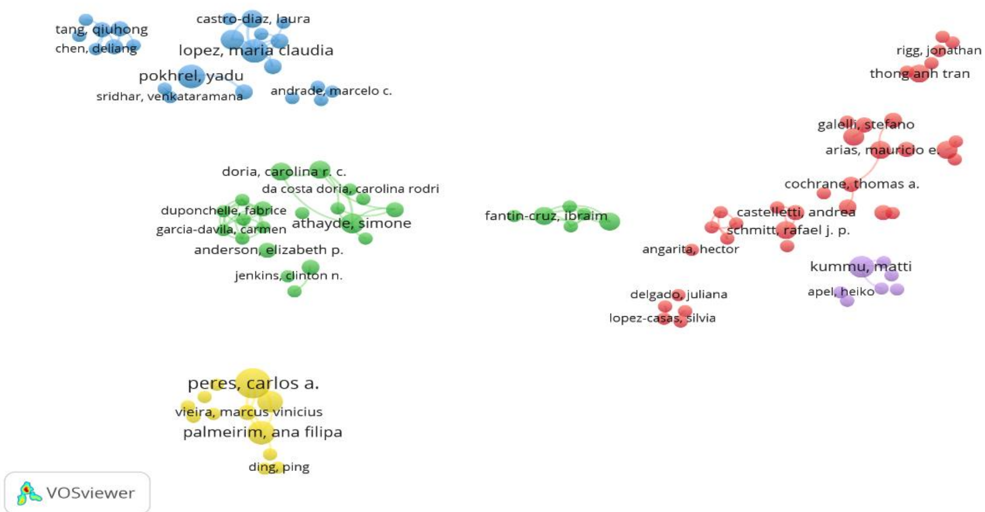


Fig. 8 Co-authorship Network, Source: VOS viewer

4.3.3 Country Collaborations

The country collaboration network (Fig. 9) shows the global landscape of hydropower impact research, with a distribution of hubs that are both strongly international and regionally concentrated partnerships. A principal pivot is between the **United States and Brazil**, as these two nations dominate current policy discussions and biodiversity research on tropical river systems. **China** is another powerhouse, with deep regional collaborations in Asia and international connections that show it as both a leading developer and a global research leader. **India, Sweden, Belgium, Poland,** and **Mexico** are joined by new cross-continental partnerships, adding breadth to the networks between the Global North and South.

Regional collaborations are equally prominent. The Southeast Asian sub-cluster presented high research activity alongside countries like **Vietnam, Cambodia, Laos** and **Nepal** where research on shared river basins such as the **Mekong** is significant, reflecting most pressing ecological and governance challenges. **Pakistan, Australia,** and other new contributors are proving that a broader base of participation is growing. Taken together, the network reflects a field dominated by world powers and emerging partnerships while listening carefully to calls for greater international collaboration to increase hydropower science across complex ecological and social implications.

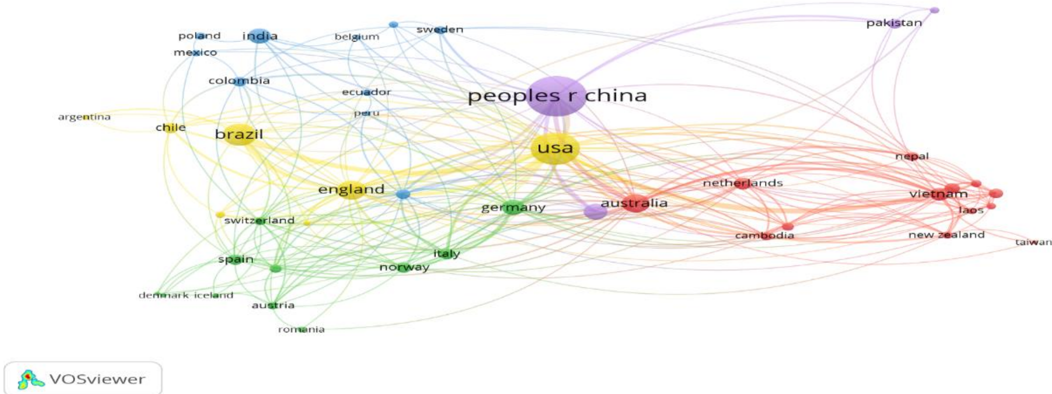


Fig. 9 Country Collaborations Network, Source: VOS viewer

This intertwining of intellectual traditions, collaborative authorship, and global partnerships makes hydropower impact research an interdisciplinary and international field. Accompanied by the descriptive and thematic results, these findings yield a holistic understanding of both in terms of structure and evolution.

5. Discussion

The bibliometric analysis highlights hydropower impact research as one of the fields experiencing substantial evolution between 2016 and 2025, which is characterized by initial growth followed by consolidation and more recently stabilization. This evolution of the publication follows the usual path of academic growth from its humble beginnings to reach a peak of 89 publications in 2021, after which the number falls sharply to 41.6%. This is indicative of field maturation, as described by the literature on bibliometrics, where there is an early burst of growth followed by integration into other research disciplines. Stabilization does not likely mean stagnation but rather shows that hydropower and the broader questions related to energy transitions for climate adaptation are now more systematically integrated into sustainability oriented research frameworks.

The analysis indicate a distributed leadership structure in hydropower impact research, with some authors being consistently productive and by engaging in diverse collaborative work such as Li KF or Peres CA. This is the distributed authorship pattern where productivity and prominence relate, with individual contributions balanced by collaborative networks — ahealthy scholarly ecosystem in which different disciplines exchange knowledge through synthesis. Analysis of the co-authorship network reveals five major interdisciplinary collaborative clusters—energy policy, conservation science, hydrology and biodiversity research—suggesting successful integration across disciplines rather than isolated disciplinary silos.

From the analysis of the journal publications, it is clear that there is a deliberate placement of hydropower literature within a number of academic sources. The *Science of the Total Environment* and *Journal of Hydrology* play an important role in linking the two areas of study i.e., between environmental science and water research, while other publications such as *Water*, which have more publications but lower citations, demonstrate other patterns in citation rates. This spread in both specialized and multidisciplinary journals ensures wide dissemination while still being academically rigorous.

The most represented works provide solid thematic and regional foundations for the discipline, particularly through attention paid to globally important river basins. The works of Hecht et al. (2019) regarding hydrological effects in the Mekong River Basin, Lees et al. (2016) on biodiversity in the Amazon region, and Kondolf et al. (2018) on sediment transport are some of the seminal works. The progress made in this body of work illustrates the evolution within the field from descriptive case study methods towards relatively rich and increasingly sophisticated analytical frameworks that synthesize climate modeling with statistical predictors, as well as socio-political dimensions. Such studies that look at contestations around dams, including ones like Bene et al. (2018), highlights growing concerns with governance and social equity in the field.

The thematic analysis indicates a more complex intellectual landscape structured around ten distinct clusters of technical, ecological, social and regional nature. Climate change stands out as the key “motor theme,” indicating that it has become a central focus in hydropower research lately and permeates several analytical frameworks. By characterizing biodiversity and sustainability as “basic themes”, that suggests the foundation is present but also a potential of room for expansion. Specialized themes on environmental flows, reservoir operations, and methodological tools showcase increasing technical sophistication.

Results from the longitudinal trend of research topics reveal a clear transition from descriptive and case-based studies in the early years (2016-2018) towards methodologically advanced, interdisciplinary investigations in the last period investigated (2022 onwards). This movement toward integrating ecological and social dimensions—indicated by concerns over energy justice, small hydropower, and water quality—is a sign that the field is responsive to broader sustainability demands and policy needs. The field manifests its structure in terms of two dominant tensions identified by factorial analysis, namely conservation vs. developmental objectives and climate vulnerability to hydrological processes, both of which reflect the intrinsic multifactorial complexity of hydropower systems with a multi-message potential that grows along an evolving axis toward more sophisticated approaches for analytical relevance.

The network analyses show an internationally collaborative and intellectually diverse field. This co-citation analysis reveals four distinct intellectual strands, including: (1) energy policy and governance; (2) environmental conservation and biodiversity; (3) hydrological modeling and water resource management; as well as (4) ecological flow science that appear to have been successfully integrated with previously separate research domains. Patterns of the collaboration between countries illustrate that most studies included researchers from the United States, Brazil, and China as research hubs, but also some notable regional patterns, particularly among Southeast Asian countries, which are dominated by transboundary river basin studies. These patterns are also in response to the fact that hydropower resources, like many other environmental challenges facing mankind today, have a global distribution and thus a transboundary nature requiring collaborative solutions.

The results have implications for hydropower policy and practice. The overarching prevalence of climate change themes across the analysis underscores the need for adaptive and forward-looking hydropower development that explicitly incorporates evolving hydrological conditions and extreme weather. The increasing focus on social equity and environmental justice themes suggests that techno-economic assessments, as historically expressed, are hardly sufficient for sustainable contemporary hydropower development. Because the global distribution of hydropower resources is unbalanced, an international collaborative structure provides a basis for knowledge transfer and capacity building, enabling locally appropriate development approaches to emerge.

Based on this analysis, potential research directions arise. The status of climate change as a motor theme means that integrating future projections into spatial referencing for planning and operations will continue to be required. Emerging themes around energy justice and small hydropower highlight growing opportunities for research on more distributed, community-centered forms of hydropower development. However, there are still numerous research gaps, especially in terms of geography as inputs into the global research landscape, as well as through considering water-energy-food nexus factors when designing infrastructure. The underrepresented places within the collaborative networks indicate further possibilities for capacity building and co-production of research.

This bibliometric analysis shows how hydropower impacts research as a mature transdisciplinary field that effectively synthesizes diverse intellectual traditions while remaining relevant to modern sustainability challenges. The collaborative, methodologically sophisticated, and evolving structure of the field makes it well poised to provide critical inputs to address sustainable transitions in energy provision, if geographic and thematic integration gaps are systematically addressed through sustained investments in research and international collaborations.

Conclusion

Hydropower impact research has matured substantially, from descriptive case studies to an international, interdisciplinary field with greater methodological sophistication, between 2016 and 2025. Research publication trends peaked in 2021 and then stabilized, suggesting that both hydropower research concerns are beginning to be embedded among broader energy transition through climate adaptation lenses. Prolific authors and diverse collaboration clusters have established distributed leadership that permitted cross-disciplinary exchange of knowledge, while the identification of key journals such as *Science of the Total Environment* and *Journal of Hydrology* has provided critical dissemination platforms.

Thematic mapping suggests that climate change remains the “motor theme,” while foundational topics like biodiversity and sustainability are still on center stage alongside emerging areas — e.g., energy justice, small hydropower, or the water-energy-food nexus — where there is space for future research directions. Network analyses are performed to demonstrate a total of four central intellectual threads, i.e., policy and governance, biodiversity conservation, hydrological modeling, and ecological flow science that collectively frame the research landscape. The country collaboration patterns highlight advanced nations and important hydropower players behind the development of new regional cooperation efforts in Southeast Asia and elsewhere.

Policy and practice must embrace adaptive, climate-resilient hydropower development that intentionally recognizes changing hydrological regimes as well as social equity and environmental justice. Advanced modeling and integrated assessment frameworks enable detailed simulation of impacts as well as options for adaptive management. Further research directions should address geographic under-representation, nexus perspectives in infrastructure planning and enhanced cross-national collaboration for low-impact community-centered hydropower options. Addressing these gaps ensures a new generation of hydropower researchers are capable to provide the evidence base needed for sustainable energy transitions that can be adapted locally and in changing climates.

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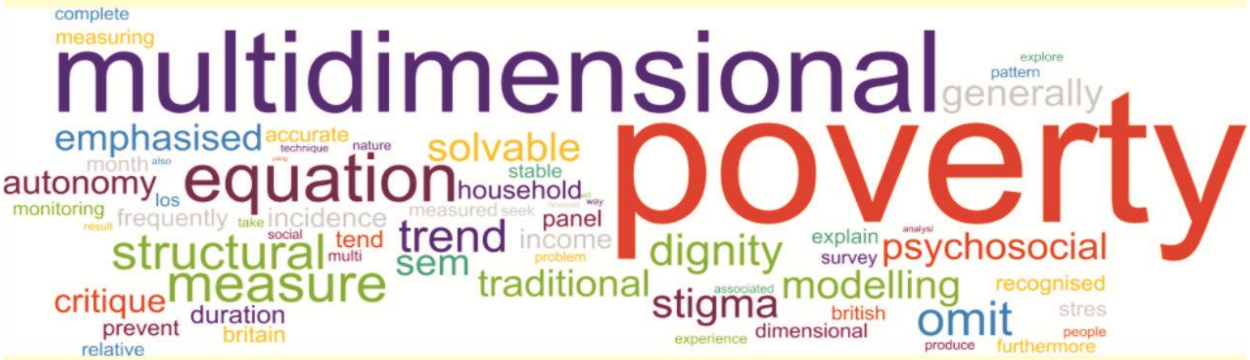

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