A Comprehensive Mapping and Assessment of the Evolution of River Rehabilitation Research

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https://doi.org/10.5109/7395530

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.282-287, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences
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A Comprehensive Mapping and Assessment of the Evolution of River Rehabilitation Research

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Abstract*: Research on river rehabilitation is in high demand for mitigating the ecological and social issues using infrastructure and urban development. This study produces a bibliometric analysis to examine the scope and development of scientific literature from 2005 to 2025. It identifies key themes, influential researchers, and networks that contribute to the development of the research landscape. Major research focuses include river restoration strategies, urban development, and sustainable planning. network maps and heatmaps reveal how these topics have developed and connected over time. The findings highlight the importance of integrating river rehabilitation into urban planning and sustainable infrastructure projects to enhance environmental resilience. This analysis lays a research-oriented foundation for the benefit of future research and investigation.*

Keywords: River rehabilitation; sustainability; bibliometric analysis

1. INTRODUCTION

It is important to assess and monitor current research trends and thematic in a multidisciplinary field of sustainable urban development and engineering. Assessing this sort develops our understanding of the topic at hand and serves as a future roadmap and reference for further study and investigation, and even policymaking. [1] Assessing the range and variety of the topics can also indicate which topics may need further exploration and research and which topics have a surplus of publications. This method provides us with a comprehensive way of analyzing and monitoring key themes, collaborations, and influential publications, through a structured in-depth analysis of research publications.

Producing research centered on river rehabilitation strategies proves essential for understanding, mitigating, and finding appropriate solutions for issues ranging on waste and pollution management as well as implementation of structures to aid in river rehabilitation. The objectives of this analysis are to identify important publication themes, influential authors and collaborations, and assess the trends of publication topics. This study serves to fill the void in current literature and can be a useful basis for future investigators, researchers, students, who are interested in the same themes and focus of this research and those who aim to develop a stronger and more meticulous development of sustainable infrastructure and urban planning aimed towards the rehabilitation of rivers.

The outcome of a comprehensive and thorough bibliometric analysis offers a solid fact-based foundation for well-informed decisions. Examples would be network maps and Sankey diagrams used in bibliometric analysis that show the connections between research topics and how they reflect the needs and demands of the society at that specific time by reflecting changes in research focus. These visualization maps provide a clear picture of the topics with most scholarly research. It can also highlight gaps in scientific literature pertaining to certain topics which can motivate other researchers and authors to contribute more literature in that field.

Insights on topics such as Urban development, sustainable infrastructure, and natural or aquatic rehabilitation research are valuable and are currently in-demand due to an increasing awareness of the situation of the earth pertaining to inadequate waste management, lackluster urban planning, and depletion of natural resources causing an absurd amount of aerial and aquatic pollution leading to the degradation of natural habitats and ecosystems, among others [2]. This research will aid stakeholders in deciding to assist in collaborations and initiatives that attempt to mitigate urban development issues that cause marine pollution and contribute to the development of sustainable marine rehabilitation infrastructures in a more critical and informed manner by understanding which topics the authors and publishers are currently focusing on. Publications like this also provide Data-driven and evidence-based policy making in allocating materials and resources.

Bibliometric analysis is useful in providing a perspective that can prove to be useful in examining the field of river rehabilitation and development. This method identifies a plethora of trends from collaboration patterns to the development of research in time. This is needed for developing the field of research and enhancing our capacity to find solutions to mitigate pollution and aid in river restoration. The results drawn from this analysis are reflected in the incoming sections which provide important information about past and present trends in river rehabilitation.

2. METHODOLOGY

The methodology of a standard bibliometric analysis is given in Figure 1. It starts with the START phase and moves through a series of organized stages. Data Acquisition comes first; here pertinent research data is gathered. Data organization is prioritized in the processing of the data. Network Visualization then produces visual representations to aid the viewer in examining specific trends. Then, Cluster Analysis finds and organizes related themes into clusters or groups. Then thematic Analysis is then performed to investigate the temporal evolution of the research topics. Finally, Results and Discussions where the analysis of results and conclusion summary are made.

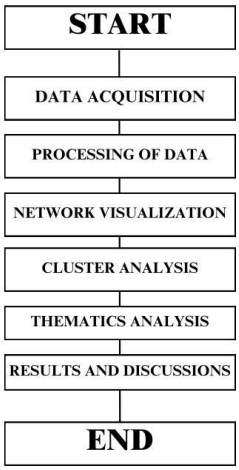

Fig. 1. The methodology of the bibliometric analysis

2.1 Data Acquisition

This step requires the collection of relevant scientific literature available via Scopus database. The search was made customizable to include research topics relevant to river rehabilitation, strategies and sustainable river development. The information accumulated includes the publication titles, authors, keywords, and important details that will prove useful for the bibliometric analysis.

2.2 Data Processing

This step requires the organization and processing of the data after its initial accumulation. Erasing duplicates and depicting consistencies in the information. The data was customized to fit the research topic which includes the extraction of data and information provided in the literature including authors, year of authorship, and keywords.

2.3 Network Visualization

To depict the links and connections between plenty of research topics, the network visualization tool VOS viewer was utilized. This allowed the authors to make co-occurrence maps. This is represented by keywords, and edges showed their degree of co-occurrence in the previously accumulated literature. This visualization tool helped to identify themes, both peripheral and central, in the field.

2.4 Cluster Analysis

Categorization of research groups occurred using cluster analysis depending on the similarities of each topic. keyword co-occurrence aided in clustering related subjects. This provides analysis of the main emphasis areas under river rehabilitation. This step was required for understanding the organization of the research field.

2.5 Thematic Analysis

To be able to monitor temporal trends within a research landscape, a Trend analysis was utilized. Heat maps were also used to highlight areas with significant scholarly research and a Sankey Diagram was produced to depict the change of topic interests over a span of time. To further categorize research themes according to relevance (centrality) and development (density). A Thematic map was also utilized where the themes are grouped into the quadrants: niche, motor, emerging or declining, and basic, resulting in an adequate overview of the research landscape.

2.6 Results and Discussions

Finally, the analysis of the maps is collated to draw conclusions about the trends and relationships within research topics relating to river rehabilitation. The major themes present within the visualizations were highlighted as well as its connections to other topics. The significance of the results was also reviewed to aid in further research.

3. RESULTS AND DISCUSSIONS

3.1. Network Analysis

The network analysis depicts the connections and relatedness of the research themes from 2014-2017. The network analysis is illustrated in Figure 2. By depicting relationships and co-occurrences of keywords in the scientific literature over the span of three years, the central, peripheral, and emerging topics in the field are highlighted. The color gradient of blue to yellow represents the progression of time with earlier literature appearing in a dark blue color and literature written in more recent literature appearing in bright yellow.

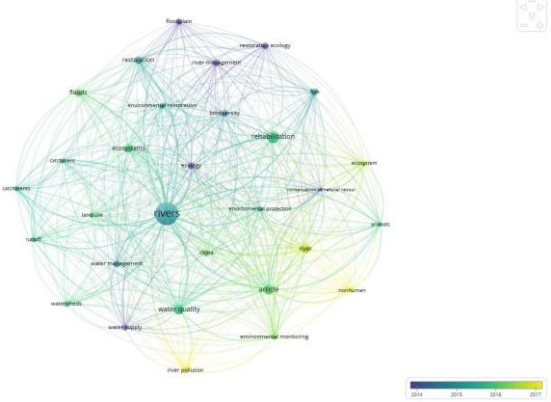

Fig. 2. The Network Analysis

The central nodes depicted in the analysis include “rivers”, “ecology”, “land use”, “China”, “water management”, and “environmental protection”. These play important roles in the development of river restoration research. River rehabilitation has proven to be a multidisciplinary feat due to the high degree of connections between the nodes. Examples of this is how words like “fish”, “biodiversity”, and “river management”, connect with “restoration” indicating an emphasis on marine biological factors and its usefulness in assessing the cleanliness and state of a river. The centrality of the word “China” can indicate how a plethora of literature has been centered around Chinese rivers, encompassing methods and technology geared towards its rehabilitation. [3]

The connections between the words “environmental monitoring”, “non-human”, and “water quality”, to “river” proves to be interesting because it emphasizes the need for consistent monitoring systems for rivers in sustainable river rehabilitation which can be aided through non-human means like Artificial Intelligence (AI) [4] and robotic mechanisms through the Internet of Things (IoT) [5]. These topics are also in the periphery and are recent which could denote a new interest in developing technology that could further propel the field into modernization of river rehabilitation infrastructure, and urban development.

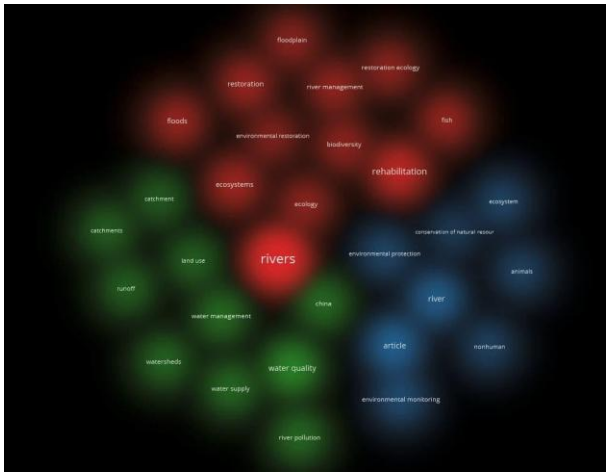

Fig. 3. The Density Visualization

The density visualization provided in Figure 3 connotes an extensive overview of intensity and theme distribution of scientific research focused on river rehabilitation. This map uses color to categorize research clusters. The larger and more vibrant clusters suggest a greater research activity and connectivity between specific keywords. The visualization also highlights major focal points and the relative significance of each topic within the field.

The most prominent among all the terms is “rivers” showing its importance in the literature centered around river rehabilitation. It would be expected that a substantial amount of scientific literature about river rehabilitation would be concerned and focused on “rivers” including various strategies attempting to restore the rivers which also explains why the second brightest word in the central plain “rehabilitation” is. Surrounding the central theme are the terms “ecosystem”, “land use”, “water management”, “water quality”, “China”, “environmental protection”, “ecology”, and “ecosystems” with “water quality” and “ecosystems” having more research outputs. On the other hand, the terms, “land use”, “ecology”, and “environmental protection” have lesser research focus. This underscores that more of the researchers focus on topics pertaining to ecosystems of rivers, water quality, and land use, showcasing the importance of these concepts in contributing to long term river rehabilitation such as the conducting of water quality tests to assess appropriate river treatments [6] and evaluating the ecosystems living in the river [7].

The map also highlights distinct thematic categories. The green category includes terms such as “land use”, “catchments”, “watersheds” and “water management”. All these topics are related to components of a river and how it can be assessed and utilized to rehabilitate a river through strategies like appropriate land use and watershed monitoring. The blue category includes terms like “environmental protection”, “river”, “conservation of natural resources”, and “environmental monitoring”. This refers to ongoing environmental protection and conservation research efforts aimed at mitigating damages caused by factors such as pollution and improper acquisition of natural resources made to rivers. The red category features terms such as “rehabilitation”, “biodiversity”, “fish”. This category mainly focuses on the biological aspect that researchers have contributed to their study of river rehabilitation. These studies include biodiversity studies, fish population studies, and biological rehabilitation.

The map also highlighted emerging research topics like the aforementioned “non-human” and “river pollution” which signifies the increasing trend of studying and developing technologies that use a combination of AI, IoT, and robotics, to aid in river rehabilitation and develop more robust monitoring systems [8].

3.2. Identification of Influential Authors and Trends

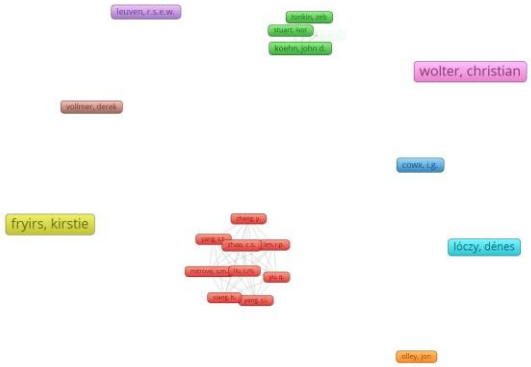

Fig. 4. Network Visualization of Authors

The visualization of the identification of influential authors and collaborative networks are given in Figure 4. The connections between the nodes are visuals of co-authorship and collaborations on scientific research in the field. Each node represents a single author. The size of the nodes and the varying colors denote the intensity and frequency of the collaborations presented. The nodes in the central plain of the network depicted in prominent red include the names: Zhang, Yang, Zhao, Lim, Mitrovic, Liu, Yu, Xiang, and Yang. This suggests an ample degree of collaboration among the authors. Though the small

size of the nodes indicates the lesser degree of publications and co-authorships achieved together. Nonetheless, their centrality in the plain give's emphasis on their research influence in the progression of the field of river rehabilitation, particularly that of water quality and fish habitat rehabilitation [9].

A smaller cluster that appears in the upper portion of the network with the names of Tonkin, Stuart, and Koehn, also prove to be noteworthy. This cluster, colored in prominent green, illustrates a strong collaborative network between the three researchers suggesting a substantial number of publications co-authored together. The node of Koehn, J.D. is slightly larger indicating a larger amount of research published. The subgroup is also colored differently, underscoring the specific cooperatives within the group. The visual difference caused by the color of the nodes proves to be essential so that the sub-groups can be easily differentiated from each other.

The network then illustrates independent nodes with names including: Wolter (pink), Fryirs (yellow green), Lóczy (bright blue), Leuven (purple), Cowx (dark blue), Vollmer (brown), and Olley (orange). Within the network, the nodes corresponding to Wolter and Fryirs are the most prominent, followed by Lóczy, suggesting that these authors have contributed the greatest volume of scholarly publications. The presence of smaller nodes of Vollmer, Cowx, and Olley, indicate a lesser volume of research publications aimed towards river rehabilitation or these authors are just commencing in the establishment of their research partnerships in the field.

3.3. Thematic Analysis

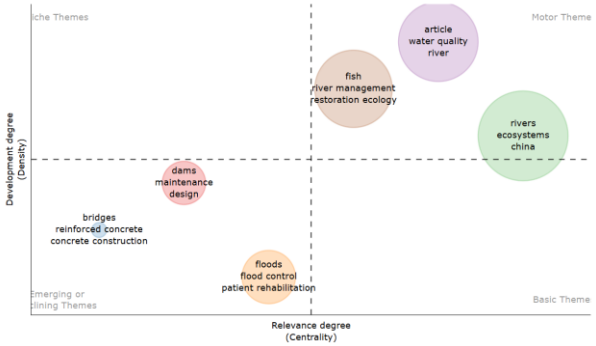

Fig. 5. Visual of the Thematic and Trends Analysis

Figure 5 offers a visual representation of key research themes in river rehabilitation. These themes are mapped based on two dimensions: their level of development (density) and level of significance to the field (centrality). The map is divided into four quadrants: Motor Themes, Niche Themes, Emerging or Declining Themes, and Basic Themes. Indicating different roles and stages of development in the research landscape.

In the upper right quadrant, themes such as "water quality" and "river", are present and are classified as Motor Themes. These themes are well developed and are central, meaning that these are highly connected and influential in the field of river rehabilitation.

The upper-left quadrant, representing Niche Themes, includes topics like "fish", "river management", "restoration ecology", These themes are developing and are less central, implying that these topics have the potential to be more relevant or central as further research is produced.

Basic Themes, found in the lower-right quadrant, cover subjects such as "rivers", "ecosystems" and "China" These topics are central indicating its high relevance in the field; and a sizable volume of scientific literature has been contributed to it. This positioning suggests that although plenty of publications have been made on these topics, this area can still be further developed.

In the lower-left quadrant are the Emerging or Declining Themes. These include "bridges," "reinforced concrete," "concrete construction," "dams," "maintenance design," "floods," "flood control," and "patient rehabilitation." These themes have low centrality and low development with "bridges," "reinforced concrete," and "concrete construction," having the lowest volume of scientific literature in the field. The positioning of these topics indicate that these are either in the early stages of development, are gradually losing relevance and focus from the academe, or have matured enough to the point that the topics have branched out into more sophisticated themes.

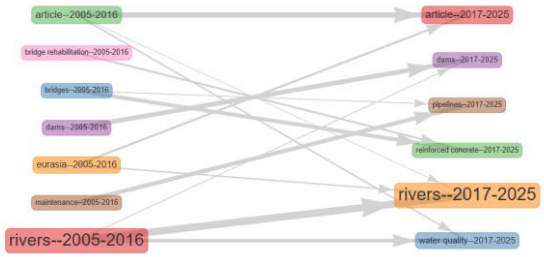

Fig. 6. Visual of Thematic Evolution [10]

The visual of the Thematic Evolution is shown in Figure 6. This chart shows the thematic progression of topics involving river rehabilitation from 2005 - 2016 and 2017 - 2025. The width of the arrows symbolizes the relative amount of scientific literature written on the topic. The nodes represent the dominant topics at that span of time. The visualization aids in understanding how certain topics pertaining to river rehabilitation have somewhat diversified in the span of two decades. From 2005 - 2017, a plethora of research publications were dedicated to the broad topic of "rivers". This may include topics such as river pollution (both causes and effects), river water quality, watersheds, river basins, runoffs, and the like. Other dominant topics include "article", "bridge rehabilitation," "bridges," "dams," "Eurasia," and "maintenance."

Bridge rehabilitation, bridge and maintenance studies both had substantial amounts of literary focus from 2005-2017. The role bridge rehabilitation has on river rehabilitation could be supportive and could even be crucial at times. The restoration of outdated bridges and usage of more robust materials and durable designs can help in disaster prevention caused by factors like water

erosion, contributing to sustainable practices in the field [11].

The inclusion of “dams” and” maintenance” within the dominant topics of 2005-2017 is notable. These topics may include ideas such as the causes and effects of poorly planned dams in river quality or ecosystems within rivers, which are useful in a handful of communities or countries who may require dams.

The term “Eurasia” pertains to studies conducted or are centered around rivers within the European Asian countries. These rivers include Yangtze and Mekong (China), Ganges (India), Tigris and Euphrates (Iraq, Turkey, Syria), Volga (Russia), Danube (Central and Eastern Europe), and Rhine (Germany, Netherlands). Plenty of the rivers enumerated have studies and publications that can prove to be useful or influential in river restoration work.

The diagram shows the diversification of topics from 2017 - 2025. “rivers” still has the most amount of literature produced proving the centrality of the topic within the field. Though it has diversified and encompassed “water quality” and “dams” indicating a rising interest in the contribution of water quality tests and the effects of dam studies and infrastructure management in the overall rehabilitation of rivers. Notably, “bridge rehabilitation” and “bridge” branched out to encompass topics including “reinforced concrete “and “pipelines”. The inclusion of these terms denotes the increasing awareness of the academe to produce more research outputs on robust and durable bridges and pipeline systems that can sustain itself against environmental stresses while adapting to an eco-friendly design and can aid in sewage and pollution management.

The diagram illustrates the diverse and multidisciplinary nature of river rehabilitation and sustainable development research over the span of two decades. The diagram emphasized the necessity of multiple factors and comprehensive studies which can aid in structuring innovative and improved approaches to achieve pivotal milestones in the field of river rehabilitation and sustainable development.

3.4 Applications

Due to the multidisciplinary nature of river rehabilitation, plenty of its research outputs can be applied. Firstly, research focusing on infrastructure retrofitting and development near rivers such as bridges, pipelines, roads, and other structures are essential for minimizing waste caused by lackluster infrastructure and inadequate sewage treatment. Research centered around Infrastructure management can also expand to accommodate innovative eco-friendly designs which can empower and protect wildlife within the region and can even serve as public spaces or tourist attractions to boost the local economy. Due to the rapid development of AI and IoT usage in recent years, the application of these technologies to river water quality and flood control monitoring systems could drastically improve pre and post disaster response in flood prone areas and could improve pollution response and assessment in river restoration. Proper urban development, land use, and adequate housing can also benefit river rehabilitation and the surrounding communities and cities that live near or in the river area.

3.5 Comprehensive Narrative of Field Progress

The trends of the dataset indicate a rising interest in integrating technology and robotics in river rehabilitation monitoring systems in addressing pollution and developing disaster response. Integrating proper and sustainable infrastructure, such as the utilization of reinforced concrete and durable materials and complex sewage treatment systems to mitigate aquatic pollution caused by household and manufacturing waste especially in urban settings are also gaining more attention from authors and researchers. A further developing interest in the biological aspect of river rehabilitation can also be noted, namely, ecosystem studies that have contributed to the research landscape playing a supportive role in aquatic and marine life rehabilitation in biologically dead rivers.

3.6. Future Research

It can be predicted that river rehabilitation and sustainable development studies pertaining to river restoration are expected to focus firstly on the further development and application of automated mechanisms aided by updated technology in sustainable monitoring systems for rivers to improve disaster responses in, for example, flood prone areas. This development is due to the growing trend of robotics and AI use in multiple fields within the recent years. Literature Involving innovative, environmentally friendly materials and sustainable designs for infrastructures [12] surrounding the river area could also be focused by multiple authors in response to the need for durable infrastructure and more transportation networks connecting multiple cities and communities caused by rapid urbanization. In continuation with the topic of rapid urbanization, particularly in developing countries, it can expect that a substantial amount of research pertaining to appropriate land use and proper urban or land development near river communities will be further explored to assess appropriate road layouts, city centers, appropriate transport routes, and other related ideas, which could benefit the river and the community long term.

4. CONCLUSION

The results of the thorough bibliometric analysis focused on river rehabilitation and sustainable development research were able to produce insights and further comprehend the progression and current state of the research landscape through an evaluation of literature from 2005 to 2025, identifying key themes, authors, and collaborations that proved to be influential for the field's development. The results highlight the importance of river rehabilitation and sustainable infrastructure development in overall community development. A plethora of trends were discovered, providing authors and publishers with adequate knowledge of the focus of the scientific community at present and their future endeavors, particularly with its interconnectedness with topics such as engineering, urban development, biology, ecology, chemistry, and even policymaking. The

utilization of heatmaps, network visualizations, and Sankey Diagrams were able to aid in analyzing valuable insights pertaining to topic evolutions, relatedness, co-occurrences within studies, and apparent diversification of topics throughout time, highlighting the multidisciplinary nature of river rehabilitation and the necessary expertise required in its application. It is imperative that the research community continue to develop research in the field focused on the trends of AI and IoT-based monitoring, sustainable and environmentally friendly infrastructure layouts, responsible and appropriate land use, and urban development, among others, due in part to rapid urbanization and growth particularly in developing countries. To focus on these topics is crucial for the further development of speedy disaster preparedness and response, long-term structure sustainability, and intelligently designed urban communities within river areas. A focus on effective policymaking and enforcement pertaining to urban development and land use near rivers could also be useful since it can alleviate situations such as inadequate or lackluster housing near rivers, or over congestion of cities and river communities causing an increasing amount of household, transport, and factory waste. A focus on policy making can also produce a heightened social awareness on river rehabilitation efforts and can cause responsible community practices such as appropriate waste management strategies. The essentiality of constant development of ideas, formulating innovations, best practices, and effective strategies for river rehabilitation must be highlighted to enhance urban quality of life and safeguard natural resources through local and international participation.

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