ISSN XXXX-XXXX

SUSTAINABLE FINANCING MODELS FOR RURAL WATER SUPPLY SYSTEMS: A BIBLIOMETRIC REVIEW USING VOSVIEWER

Trimo Pamudji Al Djono[1], M. Benny Alexandri[2], Anang Muftiadi[3], Daniel[4]

[1]Mahasiswa S3 Department of Business Administration, FISIP, University of Padjadjaran
[2]Dean at Faculty of Social and Politic Sciences (FISIP), University Padjadjaran
[3]Department of Business Administration, FISIP, University of Padjadjaran
[4]Daniel, Faculty of Medicine, Public Health and Nursing, University of Gadjah Mada
[*]trimo24001@mail.unpad.ac.id

ABSTRACT

Access to safe drinking water is a fundamental component of sustainable development, particularly in rural areas. In Indonesia, the PAMSIMAS program has played a crucial role in expanding such access. However, the program's sustainability heavily depends on the effectiveness and longevity of its financing models. This study adopts a bibliometric approach using VOSviewer software to map global and national research trends related to sustainable financing in rural water supply services from 2014 to 2025. An analysis of 93 publications from the Scopus database reveals that topics such as sustainability, water supply, and community participation dominate, while more specific themes like financial models, subsidies, and public-private partnerships remain underexplored. Identifying these knowledge gaps highlights the need for integration of technical, social, and financial aspects in water financing. The study recommends developing innovative, community-based financing models, engaging stakeholders, and securing policy support from the government. By applying business administration and risk management approaches, this research offers both a conceptual framework and practical recommendations to enhance the sustainability of rural drinking water systems in Indonesia and in a broader global context.

Keywords: PAMSIMAS, Rural water supply, Sustainability, Financial, Bibliometric, VOSviewer

INTRODUCTION

Access to safe drinking water and sanitation is a human right and a core pillar of sustainable development, both in urban and rural areas. In Indonesia, the Community-Based Drinking Water and Sanitation Program (PAMSIMAS), launched in 2006, has been a key initiative for achieving Sustainable Development Goal (SDG) 6—ensuring availability and sustainable management of water for all, especially in rural areas. According to recent reports,

ISSN XXXX-XXXX

the program has improved access to safe drinking water for over 24 million people and to adequate sanitation for 16 million people across more than 80% of the country's districts and municipalities (World Bank, 2023). As of August 2022, PAMSIMAS has been implemented in nearly 36,000 villages (pamsimas.pu.go.id), demonstrating the government's commitment to sustainability. The program continued with national budget (APBN) funding to around 2,600 villages during 2022–2023, following the conclusion of World Bank support.

However, PAMSIMAS's success depends not only on infrastructure development but also on sustainable financing models and effective risk management strategies. Persistent challenges include reliance on external funding, variations in household income, geographical accessibility, and social risks such as community resistance (Daniel et al., 2022).

This study aims to analyze how extensively community-based rural water financing models have been developed. To understand the current research landscape and identify underexplored areas, a bibliometric analysis using VOSviewer was conducted on literature related to water supply management (excluding sanitation) from 2014 to 2025. The analysis includes not only PAMSIMAS (Indonesia-specific context) but also global rural water supply projects, such as community-based rural water supply systems.

In this study, the application of VOSviewer-based bibliometric analysis aligns with theoretical frameworks by offering a structured approach to mapping the research landscape on sustainable financing models for rural water supply services—particularly PAMSIMAS at the local level and rural water supply at the global level. The co-occurrence analysis identifies key themes such as financial models, cost-benefit analysis, and sustainability, while also highlighting gaps in fields like business administration and risk management. Grounded in bibliometric theory and VOSviewer's visualization capabilities, this study adopts a systematic, evidence-based approach to understanding the intellectual structure of the field.

METHODOLOGY

Bibliometric analysis using VOSviewer involves quantitative methods to map and visualize relationships between keywords in the scientific literature, as reflected in the tables and maps provided. Below is an explanation of the method used, related to the data collected as of 10:27 AM (WIB), June 7, 2025:

- This research employed a bibliometric analysis approach using VOSviewer software to map the research landscape and identify knowledge gaps related to economic feasibility, sustainable financing, and risk management in PAMSIMAS

ISSN XXXX-XXXX

projects. Literature data was sourced from the Scopus database using a combination of keywords or search strings reflecting the research problem.

- The search string used—refined through repeated trials and Boolean operator techniques—was:

  "sustainabilit*" AND "financ*" AND ("water-supply" OR "Pamsimas" OR "community-based water supply" OR "rural water") AND "rural"

The main method in VOSviewer is co-occurrence analysis, which measures how frequently two keywords appear together in the same document, indicating thematic correlation. In the table, the "Occurrences" column shows keyword frequency (e.g., "water supply" appears 108 times), while "Total Link Strength" measures the strength of relationships between keywords (e.g., 853 for "water supply"). This process begins with importing metadata from databases like Scopus (93 documents were found using the above string) into VOSviewer, where keywords are extracted and filtered to select relevant terms—as seen in the 18 selected keywords list.

VOSviewer uses the VOS (Visualization of Similarities) algorithm to build maps that group keywords into clusters based on co-occurrence similarity. The map displays clusters such as "water supply," "sustainability," and "community participation," with lines reflecting relationship strength (e.g., 240 for "community participation"). Map colors (from dark blue to yellow, spanning 2012–2020) indicate time evolution, calculated through time overlay visualization, which helps track emerging trends—such as the appearance of "water economics" in recent years.

This method also includes normalization of association strength to reduce frequency bias and ensure balanced representation. Parameter settings, such as the minimum occurrence threshold (e.g., 10 for "environmental sustainability"), filter the data to focus on significant terms. The resulting maps highlight research foci (technical and social) and gaps (financial and environmental), which can be further explored through in-depth analysis of the 93 documents.

RESULTS AND DISCUSSION

Research Landscape Map from Bibliometric Analysis and VOSviewer Figures

The results of the bibliometric analysis using VOSviewer (Figure 1) on Scopus literature reveal that the keywords with the highest "Occurrences" are "water supply" (108 times) and "rural" (86 times), indicating that water provision and rural contexts are the main

ISSN XXXX-XXXX

focus areas. Keywords like "sustainability" (86) and "sustainable development" (59) highlight the strong attention on sustainability, while "rural water" (49) and "water management" (42) further reinforce the specific theme of rural water issues.

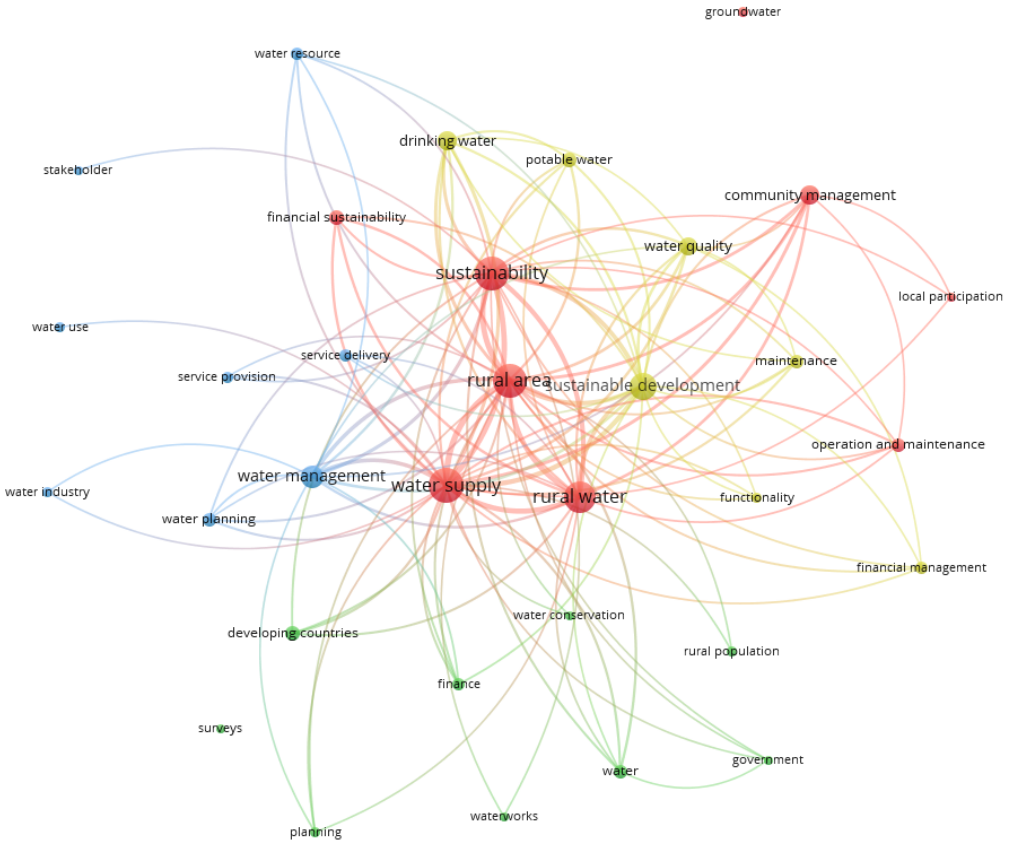

Figure 1: Co-occurrence of Keyword Network Visualization (Min Strength 5)

"Total Link Strength" measures the strength of connections between keywords, with "water supply" (853) and "rural" (711) showing the strongest relationships—demonstrating their extensive integration with other topics such as "sustainability" (688) and "community participation" (240). Terms like "financial management" (16 occurrences, 153 total links) and "water resource" (14, 159) appear less frequently but remain relevant, suggesting growing attention to finance and resource management. Keywords with lower occurrences, such as "environmental sustainability" (10, 125), point to areas that are still underexplored. This analysis indicates that the research landscape primarily focuses on technical and social aspects, while financial and environmental integration presents a potential gap—one that could serve as a focal point for future studies.

ISSN XXXX-XXXX

Based on the VOSviewer network visualization in Figure 1 (with a minimum link strength threshold of 5), the relationship between "rural water supply" and sustainable financing models can be analyzed, though a significant knowledge gap is evident. The keyword "rural water supply" shows strong connections with terms such as "rural population", "rural community", "service provision", and "functionality", reflecting a reliance on service infrastructure and community involvement.

Sustainable financing aspects are represented by keywords like "financial management", "financial sustainability", "finance", "costs", and "willingness to pay", supported by related terms such as "cost-benefit analysis" and "economic". However, the direct relationship between "rural water supply" and sustainable financing models appears limited, connected mainly through the broader concepts of "sustainability" and "sustainable development", which in turn relate to "financial sustainability".

The knowledge gap becomes particularly evident due to the absence of specific keywords such as "funding models", "subsidies", or "public-private partnerships", which are typically associated with sustainable financing mechanisms. While "willingness to pay" is identified as a key term, it is not sufficiently supported by data on the implementation or effectiveness of practical financing schemes. Similarly, terms like "costs" and "maintenance" suggest a need for cost management that has yet to be fully integrated into long-term financing strategies.

Therefore, sustainable financing models for rural water supply could be further developed by addressing these gaps through research on innovative funding schemes, government support, and community participation—while also ensuring the long-term maintenance of water infrastructure.

Bibliometric Map Analysis and Identification of Knowledge Gaps

The bibliometric map in Figure 2, presented as an overlay visualization using VOSviewer, illustrates the interconnections between keywords in the scientific literature on rural clean water provision, with an additional layer indicating the average time of keyword emergence. The color gradient on the map signifies the dominance period of each topic:

- **Blue** represents keywords that appeared more frequently before 2016,
- **Green** for the period from 2016 to 2018, and
- **Yellow** indicates newer keywords that became more prominent after 2019.

ISSN XXXX-XXXX

From the visualization, terms such as "sustainability", "rural area", "rural water", "sustainable development", and "water supply" appear at the center of the network and are widely connected, reflecting their central role in the research and their foundational place in the literature. The predominance of bluish-green hues around these terms suggests that they have been key focus areas over an extended period and remain highly relevant today.

On the other hand, several keywords displayed in yellow—such as "financial sustainability", "stakeholder", "finance", and "government"—indicate a shift in research focus toward strategic issues like sustainable financing, institutional roles, and governance. This reflects a new trend in the literature responding to the implementation and long-term sustainability challenges of rural water supply systems.

However, several notable knowledge gaps remain. First, although financing topics are starting to gain attention, there is a lack of integration of keywords specifically referring to practical financing models, such as subsidies, income-based water tariffs, result-based financing, or public-private partnerships (PPP). Second, keywords like "government" and "stakeholder" appear insufficiently connected to core terms like "water supply" and "rural water", indicating that institutional and policy dimensions are still not integral to sustainability model design.

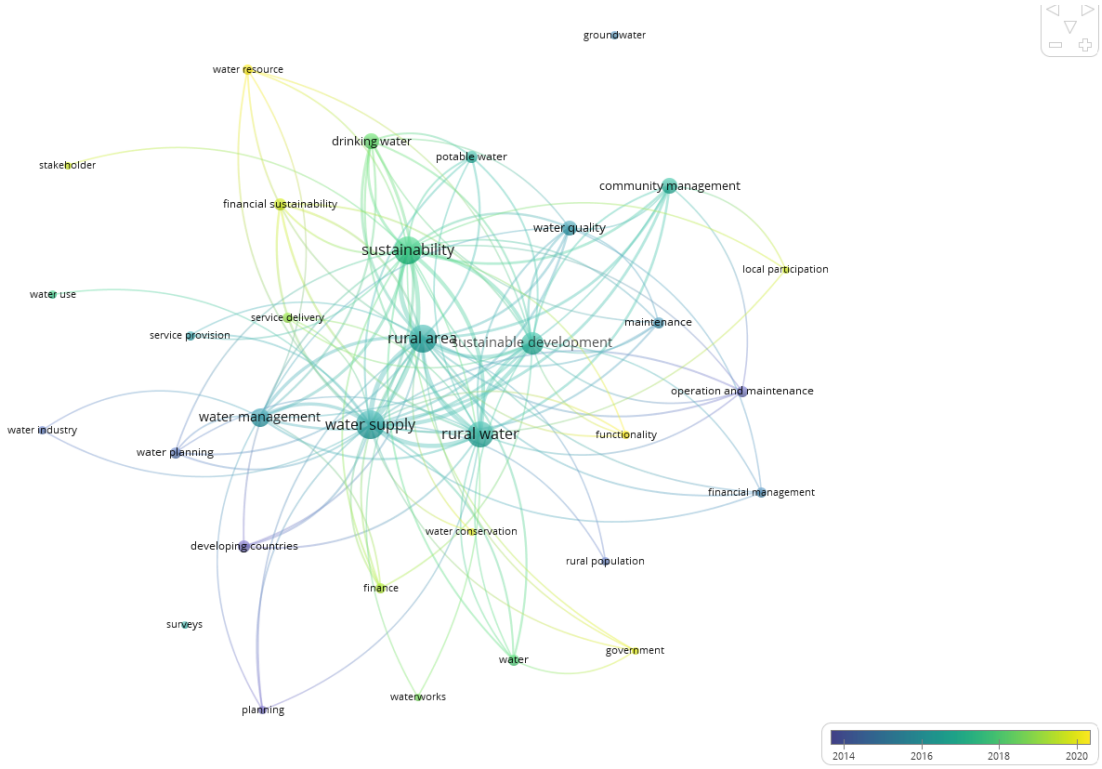

Figure 2: Co-occurrence of Overlay Visualization

ISSN XXXX-XXXX

Furthermore, technological and innovation aspects remain largely unexplored. Terms such as IoT, digital monitoring, or smart water systems are notably absent from the network, suggesting that the application of modern technologies in water financing and management remains an underdeveloped area.

While "water quality" does appear and connects with several other keywords, it lacks direct association with cost or financial sustainability, indicating that the link between water quality and its financing implications still needs further exploration. Similarly, local socio-economic dimensions like "rural population" and "local participation" are not prominent in terms of node size or connectivity—despite the fact that community involvement and willingness and ability to pay are essential factors in ensuring system sustainability.

Recommendations Based on Findings:

- Future research should support the development of innovative, inclusive, and context-specific financing schemes, such as result-based financing, microfinance, or public–private sector collaboration.
- Integrating digital technologies in rural water system management represents a major opportunity that has not yet been fully explored in the literature.
- There is also a need for interdisciplinary approaches that combine social, technical, financial, and institutional dimensions into a unified sustainability framework.

By strengthening these dimensions, future research can significantly contribute to designing rural clean water solutions that are not only technically effective but also financially sustainable and socially inclusive.

Co-occurrence of Keyword Density Visualization Analysis

Figure 3 displays a keyword density map from the literature on rural clean water supply. The color scale on the map represents the frequency or intensity of term occurrences in scientific publications—bright yellow indicates the highest frequency, green indicates medium frequency, and blue indicates low frequency.

At the center of the map, the most prominent keywords are "water supply," "rural water," "rural area," "sustainability," and "sustainable development." The dominance of these terms suggests that the literature's primary focus is on clean water provision in rural areas, with strong emphasis on the sustainability dimension of development.

ISSN XXXX-XXXX

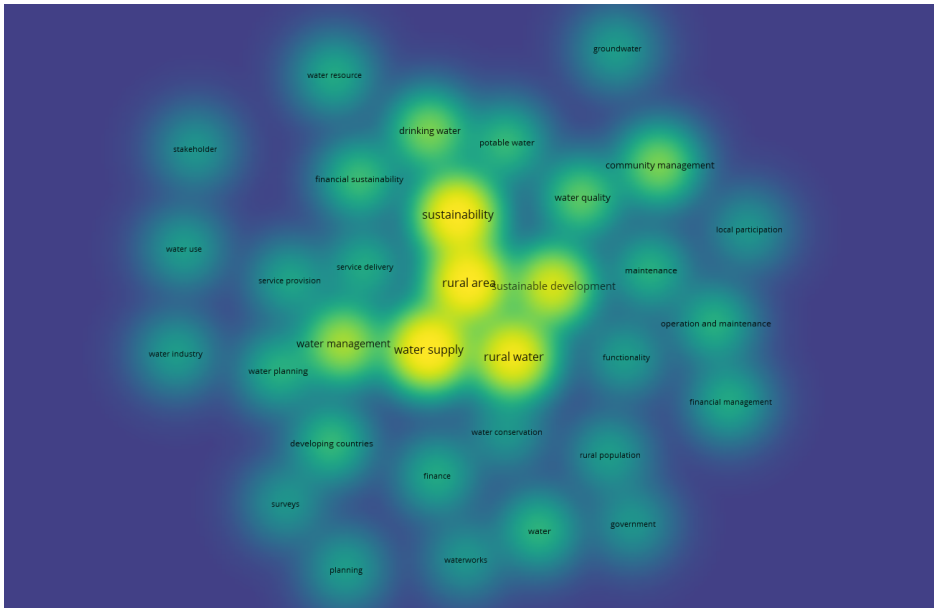

Figure 3: Co-occurrence of Keyword Density Visualization

Surrounding the map's core are medium-density keywords such as "water management," "financial sustainability," "community management," "water quality," "operation and maintenance," and "local participation." These terms reflect growing attention to managerial and technical aspects, such as the importance of community management, financial viability, and the reliable operation and maintenance of water systems. The presence of keywords like "local participation" and "functionality" also indicates increasing interest in local community involvement and infrastructure performance for long-term sustainability.

Meanwhile, low-frequency keywords appear on the map's periphery—these include "government," "planning," "finance," "stakeholder," "groundwater," and "developing countries." Although less frequent, these topics are highly relevant and signal important research gaps. For example, the weak presence of keywords such as "government" and "finance" suggests a lack of exploration into policy support, public financing, and strategic planning within rural water management contexts. The same applies to themes like groundwater management and stakeholder involvement, which also remain underexplored in current academic discourse.

Overall, the map reveals that while sustainability and rural water management are well-established academic themes, there remains substantial room to deepen research on supporting issues—particularly those related to technical systems, institutional frameworks, and policy integration. Thus, future studies should focus on integrating innovative financing

models, participatory governance approaches, and synergies between government policy and community-based development strategies. Research that holistically combines technical, social, and financial dimensions will strengthen the sustainability framework of rural clean water provision.

CONCLUSION AND RECOMMENDATIONS

Based on the VOSviewer overlay visualization analysis, it can be concluded that although the literature on clean water provision in rural areas has extensively highlighted aspects of sustainability and geographic coverage, there remains a significant gap in the integration of financing dimensions, governance, technological innovation, and community participation. Terms such as financial sustainability, stakeholder, and government have begun to appear in new trends, but they are not yet strongly connected to core concepts like water supply or rural water, indicating that a cross-sectoral approach has not fully developed in the literature. The lack of exploration of concrete financing models, the application of digital technology, and community involvement present major challenges that need to be addressed in future research. Therefore, the development of interdisciplinary research combining social, technical, and economic perspectives is important to create a more inclusive, adaptive, and sustainable rural drinking water supply system. In conclusion, this analysis reveals that although "rural water supply" and sustainable financing are conceptually linked through sustainability and community engagement, the lack of a detailed financing framework indicates a critical knowledge gap as of Saturday, June 7, 2025.

References:

Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L. (2018). *Cost-benefit analysis: Concepts and practice*. Cambridge University Press.

Carter, C. R., & Rogers, D. S. (2019). A framework of sustainable supply chain management: Moving toward new theory. *International Journal of Physical Distribution & Logistics Management, 38*(5), 360–387. https://doi.org/10.1108/09600030810882816

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE Publications.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research, 133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Drucker, P. F. (2011). *Management: Tasks, responsibilities, practices*. Harper Business.

Flyvbjerg, B. (2014). What you should know about megaprojects and why: An overview. *Project Management Journal, 45*(2), 6–19.

Freeman, R. E. (2010). *Strategic management: A stakeholder approach*. Cambridge University Press.

Harvey, P. A., & Reed, R. A. (2007). Community-managed water supplies in Africa: Sustainable or dispensable? *Community Development Journal, 42*(3), 365–378. https://doi.org/10.1093/cdj/bsl001

Hutton, G., & Varughese, M. (2016). *The costs of meeting the 2030 Sustainable Development Goal targets on drinking water, sanitation, and hygiene*. World Bank Water and Sanitation Program. https://www.worldbank.org/en/topic/water/publication/the-costs-of-meeting-the-2030-sustainable-development-goal-targets-on-drinking-water-sanitation-and-hygiene

Kerzner, H. (2017). *Project management: A systems approach to planning, scheduling, and controlling* (12th ed.). Wiley.

Project Management Institute (PMI). (2021). *A guide to the project management body of knowledge (PMBOK guide)* (7th ed.). Project Management Institute.

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics, 84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Waltman, L., Van Eck, N. J., & Noyons, E. C. M. (2010). A unified approach to mapping and clustering of bibliometric networks. *Journal of Informetrics, 4*(4), 629–635. https://doi.org/10.1016/j.joi.2010.07.002

Whaley, L., Cleaver, F., & Mwathunga, E. (2019). Community-based water supply: Lessons from the global south. *Water International, 44*(3), 256–272. https://doi.org/10.1080/02508060.2019.1594572

Whittington, D., Jeuland, M., Barker, K., & Yuen, Y. (2015). Setting priorities, targeting subsidies among water, sanitation, and preventive health interventions in developing countries. *World Development, 40*(8), 1546–1568.

World Bank. (2023). *Indonesia: Expanding access to clean water for the rural poor*. World Bank.

World Bank. (2023). *PAMSIMAS: Improving access to water and sanitation in rural Indonesia*. World Bank Group. https://www.worldbank.org/en/results/2023/04/15/pamsimas-improving-access-to-water-and-sanitation-in-rural-indonesia