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Mapping the Literature on Sustainable Scale-up Strategies: A Bibliometric Review

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ABSTRACT

This study presents a comprehensive bibliometric review of the global scholarly landscape on sustainable scale-up strategies, employing VOSviewer to analyze publication trends, thematic clusters, and collaborative networks. Data were sourced from the Scopus database, covering journal articles, reviews, and conference papers published between 2000 and 2024. The co-authorship, country collaboration, and keyword co-occurrence analyses reveal that scale up, biomass, and wastewater treatment are central research themes, with strong linkages to governance, cost-benefit analysis, environmental impact, and emerging sustainability concepts such as the circular economy. Temporal overlay mapping indicates a thematic shift from early dominance of health-related scaling—focusing on healthcare systems, programs, and quality—towards more integrated approaches encompassing climate action, renewable energy, and resource efficiency. The density visualization further highlights high-intensity research areas while showing the multidisciplinary nature of the field, bridging environmental technology, socio-economic policy, and public health. The findings provide valuable insights for researchers, policymakers, and practitioners, guiding strategic research agendas, fostering cross-sector collaboration, and informing evidence-based policy to achieve scalable and sustainable solutions.

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1. INTRODUCTION

In the face of global socio-economic and environmental challenges, scaling up sustainable initiatives has become a strategic imperative for governments, private enterprises, and non-governmental organizations. While many pilot projects and sustainable innovations emerge with promising outcomes, only a fraction of these succeed in expanding their reach or influencing systemic transformation. As noted by [1], the ability to scale up social and development programs is critical for achieving meaningful and lasting impact. However, scaling up is not merely a matter of replication—it requires navigating complex institutional, financial, and cultural barriers. In the context of sustainable development, scale-up strategies must address not only growth and dissemination, but also long-term viability, equity, and ecological balance.

The academic literature surrounding scale-up strategies has evolved considerably over the past two decades. Early research

primarily focused on health interventions and NGO-led programs, particularly in low- and middle-income countries [2], [3]. Over time, the discussion expanded to include sectors such as agriculture [4], education [5], clean energy [6], and digital technologies [7]. More recently, sustainability has emerged as a central concern in scale-up discourse, reflecting a growing awareness of the need to embed environmental, social, and governance (ESG) principles in any expansion model. This shift aligns with the broader agenda of the United Nations Sustainable Development Goals (SDGs), which emphasize not just innovation but also the ability to scale those innovations responsibly and inclusively [8].

Despite the increased attention to sustainable scale-up, the field remains fragmented across disciplines and lacks a unified conceptual foundation. Studies often vary in their definitions, frameworks, and criteria for success. For instance, [9] identify four pathways for scaling up in development contexts—expansion, replication, spontaneous diffusion, and institutionalization—yet these pathways are not uniformly applied in other domains. Similarly, sustainability itself is operationalized differently depending on whether the study is rooted in environmental sciences, organizational behavior, or public policy. This disciplinary siloing not only complicates cross-sectoral learning but also hinders the accumulation of coherent knowledge about what works, where, and why.

Bibliometric analysis offers a powerful method for addressing these challenges by enabling a systematic mapping of research trends, thematic clusters, and intellectual structures in a given field. In the context of sustainable scale-up strategies, bibliometric techniques can help identify influential authors, dominant themes, under-researched areas, and the evolution of discourse over time. Previous bibliometric reviews have proven effective in synthesizing fragmented bodies of literature in related areas such as sustainability innovation [8], inclusive business models [10], and climate adaptation strategies [11]. However, to date, there is no comprehensive bibliometric review specifically focusing on *sustainable scale-up strategies*—a gap this study aims to fill.

In addition to offering structural insights, a bibliometric review can help inform future research agendas by revealing conceptual blind spots and emerging intersections. For instance, questions about how digital transformation intersects with sustainable scale-up, or how institutional frameworks support or inhibit scaling efforts, remain ripe for exploration. As researchers and practitioners strive to advance sustainability goals across multiple sectors, understanding the landscape of existing knowledge becomes not just valuable but necessary. A clearer picture of the literature can support more coherent theorizing, facilitate interdisciplinary collaboration, and guide funding and policy priorities toward areas of high leverage and need.

While the importance of sustainable scale-up is increasingly acknowledged across disciplines, the scholarly discourse remains scattered, methodologically diverse, and often lacking in cumulative clarity. There is currently no unified map of how this body of knowledge has evolved, who the key contributors are, what methodologies dominate, or which thematic areas remain underexplored. This lack of synthesis hampers both academic progress and the effective translation of research into practice. As sustainable scale-up becomes a critical lever for achieving environmental and social impact at scale, the absence of a bibliometric overview presents a significant barrier to strategic knowledge development and policy relevance. This study aims to systematically map the academic literature on sustainable scale-up strategies using bibliometric analysis.

2. METHOD

This study employed a bibliometric review approach to systematically map the landscape of scholarly research on sustainable scale-up strategies. Bibliometric analysis, as a quantitative method, allows for the identification of publication trends, key

contributors, intellectual structures, and thematic evolutions within a particular research domain [12]. To collect relevant data, we used the Scopus database, recognized for its broad coverage of peer-reviewed journals across disciplines. The search query was carefully constructed using combinations of keywords such as "scale-up," "scaling," "expansion," "replication," and "sustainable," paired with terms like "strategy," "framework," "model," and "approach." The search was limited to articles, reviews, and conference papers published in English from the year 2000 to 2024 to capture contemporary developments while allowing sufficient historical depth.

Following the initial retrieval, all records were screened for relevance based on title and abstract. Duplicates, irrelevant studies (e.g., purely technical engineering scale-ups without sustainability context), and non-scholarly sources were excluded. The final dataset consisted of 587 documents. Each record included bibliographic metadata such as author names, institutional affiliations, journal sources, abstracts, keywords, and cited references. This metadata formed the basis for multiple analyses: performance analysis to determine publication volume and author productivity; science mapping through co-authorship and co-citation networks; and thematic analysis via keyword co-occurrence. The PRISMA flow diagram was adopted to ensure transparency and replicability in the article selection and screening process [13].

The bibliometric analysis was conducted using **VOSviewer** [14] a specialized software for constructing and visualizing bibliometric networks. VOSviewer was used to generate three main types of networks: (1) **co-authorship networks**, to explore patterns of collaboration among authors, institutions, and countries; (2) **co-citation analysis**, to identify the most influential sources and shared intellectual foundations in the field; and (3) **keyword co-occurrence networks**, to uncover the thematic structure and research hotspots.

3. RESULT AND DISCUSSION

3.1. Co-Authorship Networks

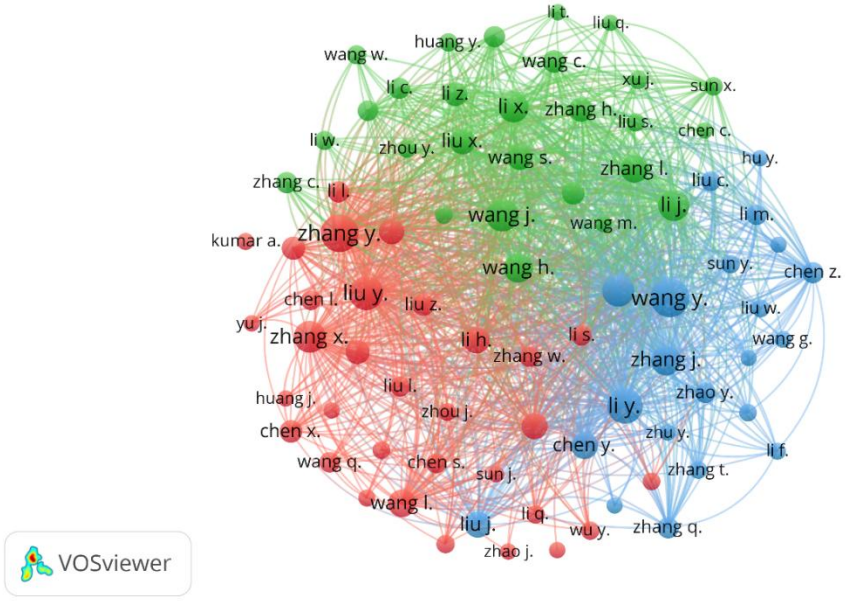

Figure 1. Author Network
Source: Data Analysis

Figure 1 depicts a co-authorship network in the field of sustainable scale-up strategies, where each node represents an author and the size of the node reflects their publication output or citation impact. The colors indicate distinct collaboration clusters,

suggesting groups of researchers who work closely together and share similar thematic or institutional connections. The green cluster appears to be the largest, with central figures such as *wang j.*, *li j.*, and *liu x.* acting as key connectors, indicating a broad and well-linked collaboration network. The red cluster, with prominent authors like *zhang y.*, *liu y.*, and *li h.*, also shows dense interconnections, suggesting strong internal collaboration but comparatively fewer links to other clusters. The blue cluster, led by names such as *wang y.*, *li y.*, and *chen y.*, is more compact but tightly knit, indicating focused research partnerships.

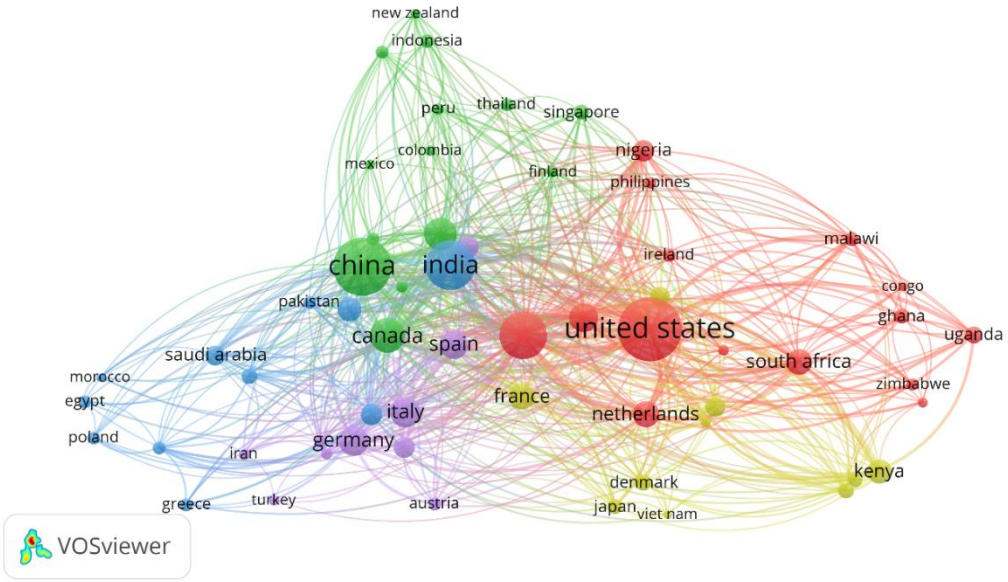

Figure 2. Country Visualization
Source: Data Analysis

Figure 2 represents a **country collaboration network** in the field of sustainable scale-up strategies, where each node corresponds to a country and the size of the node reflects its research output or influence based on co-authorship links. The United States emerges as the most central and dominant node in the red cluster, indicating its strong leadership role and extensive international collaborations, particularly with countries in Europe, Africa, and Asia. The green cluster, anchored by China and India, shows dense interconnections across Asian nations and extending toward emerging collaborations in Latin America and Southeast Asia. The blue cluster, including Canada, Saudi Arabia, and several European countries, reflects a mix of North American–Middle Eastern–European partnerships. The yellow cluster, featuring the Netherlands, Denmark, Kenya, and Japan, highlights a bridging role between European and African research networks.

3.2. Citation Analysis

Table 1. Most Cited Article

Citations	Author and Year	Title
2831	[15]	Global Surgery 2030: Evidence and solutions for achieving health, welfare, and economic development
1943	[16]	Safeguarding human health in the Anthropocene epoch: Report of the Rockefeller Foundation-Lancet Commission on planetary health
731	[17]	Self-supported cobalt phosphide mesoporous nanorod arrays: A flexible and bifunctional electrode for highly active electrocatalytic water reduction and oxidation
607	[18]	Power generation from ambient humidity using protein nanowires
510	[19]	Estimates of global, regional, and national incidence, prevalence, and mortality of HIV, 1980–2015: the Global Burden of Disease Study 2015
501	[20]	Metalla-electrocatalyzed C-H Activation by Earth-Abundant 3d Metals and beyond
484	[21]	Enhanced hydrogen production from biomass with in situ carbon dioxide capture using calcium oxide sorbents
418	[22]	Contribution of the land sector to a 1.5 °C world
411	[23]	Mortality impact of achieving WHO cervical cancer elimination targets: a comparative modelling analysis in 78 low-income and lower-middle-income countries
381	[24]	Carbon nanotube mass production: Principles and processes

Source: Scopus, 2025

3.3. Keyword Co-Occurrence

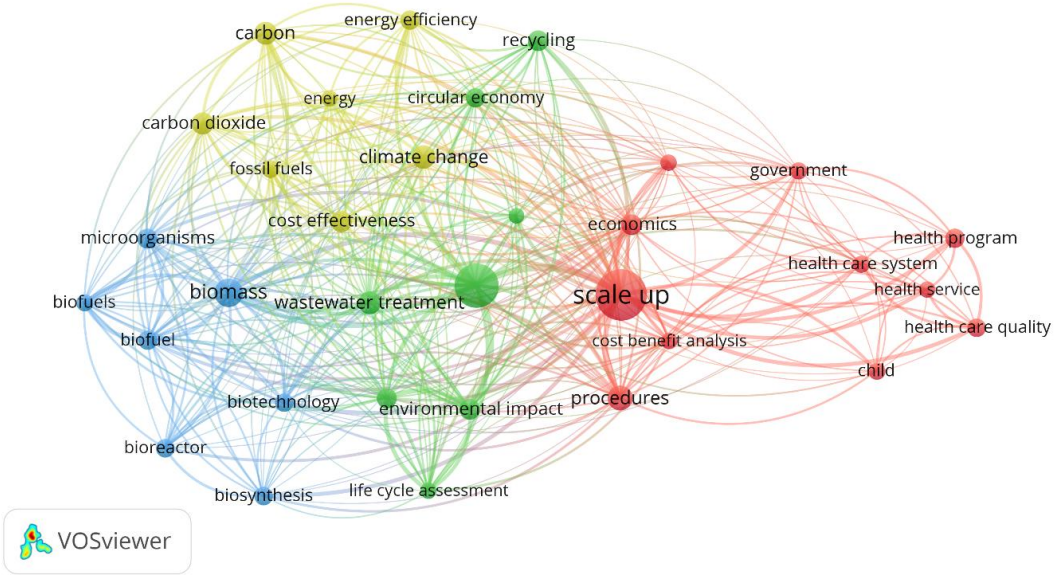

Figure 3. Network Visualization
Source: Data Analysis

Figure 3 illustrates a **keyword co-occurrence network** for literature on sustainable scale-up strategies, showing how frequently and closely certain terms appear together in the same documents. The

network is organized into distinct color-coded clusters, each representing thematic concentrations within the research field. At the center of the map, the term "**scale up**" appears as the largest and most connected node, indicating its role as the core concept that bridges multiple thematic areas, from environmental technologies to health system interventions. The **red cluster** is closely tied to policy, governance, and economic considerations. Keywords such as *economics*, *cost benefit analysis*, *procedures*, *government*, and *health care quality* indicate a strong association between scaling-up strategies and public health interventions. This suggests that part of the literature focuses on scaling health programs, improving healthcare systems, and evaluating their cost-effectiveness. The connections between *scale up* and these governance and health terms highlight an intersection between strategic implementation and societal well-being, particularly in resource-limited settings.

The **green and yellow clusters** focus on sustainability, climate action, and circular economy principles. Keywords such as *carbon*, *carbon dioxide*, *energy efficiency*, *recycling*, *climate change*, and *cost effectiveness* suggest research exploring scale-up strategies within environmental management and low-carbon transitions. These clusters reveal the integration of economic efficiency with ecological responsibility, implying that scaling sustainable technologies often requires balancing environmental impact with financial feasibility. The interlinkages with *circular economy* and *recycling* also point to literature emphasizing resource efficiency in scaling processes. The **blue cluster** is dominated by technological and biotechnological themes, including *biomass*, *biofuels*, *biotechnology*, *bioreactor*, and *biosynthesis*. This grouping reflects a significant body of research on scaling up renewable energ1y production, waste-to-energy processes, and biotechnology innovations. The presence of *wastewater treatment* and *environmental impact* indicates that this technological focus is strongly linked to environmental applications, particularly in water and waste management sectors. These studies often investigate pilot-to-commercial scaling challenges, such as maintaining efficiency, cost control, and ecological benefits.

The network suggests that sustainable scale-up strategies are a multidisciplinary research space that integrates **governance and economics** (red cluster), **environmental sustainability and climate action** (green and yellow clusters), and **technological innovation** (blue cluster). The dense interconnections across clusters indicate that successful scaling efforts often require **cross-domain collaboration**—combining policy design, environmental science, and technological engineering to achieve long-term impact. This thematic diversity reflects the complexity of scaling sustainability solutions, where technological feasibility, policy support, and environmental stewardship must be aligned for effective large-scale implementation.

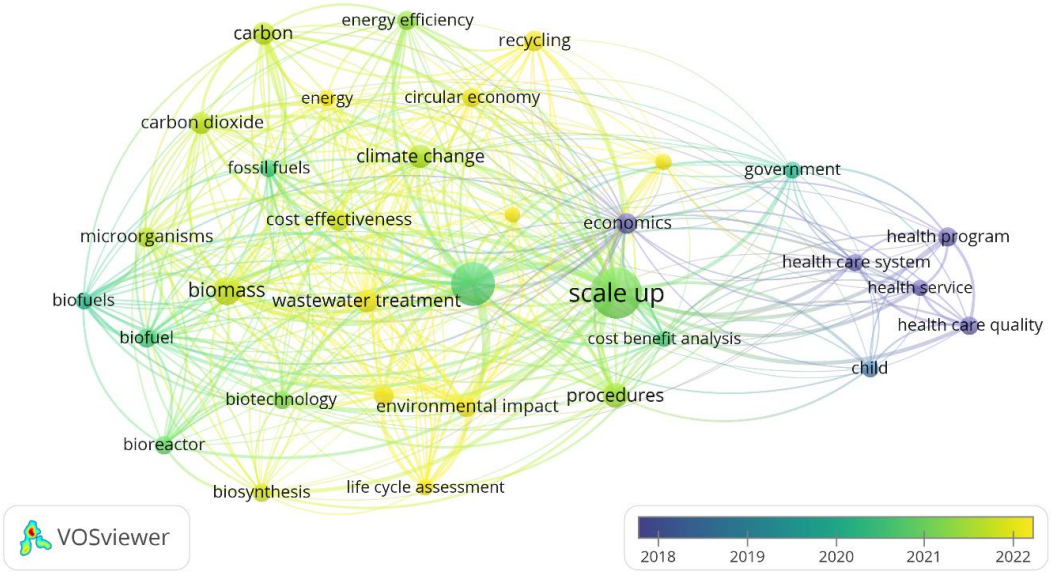

Figure 4. Overlay Visualization
Source: Data Analysis

Figure 4 presents the **temporal evolution** of keywords in sustainable scale-up strategy research, with colors representing the average publication year (ranging from 2018 in dark blue to 2022 in bright yellow). The term *scale up* appears centrally in green, indicating it has been consistently relevant around the mid-period (circa 2020). Surrounding it are thematic clusters spanning environmental technologies, economics, and health systems, each showing different chronological patterns. Earlier studies (2018–2019, in blue and teal) are concentrated around healthcare-related terms like *health program*, *health service*, *health care quality*, and *child*, suggesting that initial scale-up research had strong roots in public health and program implementation.

In contrast, the yellow and light-green terms such as *circular economy*, *energy efficiency*, *climate change*, and *recycling* indicate more recent research fronts emerging between 2021 and 2022. This shift suggests a growing scholarly focus on integrating scale-up strategies into climate action, sustainable resource use, and low-carbon transitions. Terms like *cost effectiveness* and *environmental impact* bridging older and newer areas reveal how economic evaluation has become an enduring linking factor between the health-related origins and newer sustainability-driven directions of the field. The prominence of *carbon*, *carbon dioxide*, and *fossil fuels* also shows an increased engagement with decarbonization agendas.

The blue and teal regions on the right side of the network—covering governance-related keywords such as *government* and *procedures*—reflect topics that gained traction earlier but remain relevant for institutional frameworks and policy alignment in scaling initiatives. Meanwhile, the environmental technology terms in the lower left, including *biomass*, *biofuels*, and *biotechnology*, have maintained a steady presence but also show signs of renewed attention in recent years, likely due to

advances in bio-based solutions and circular economy practices.

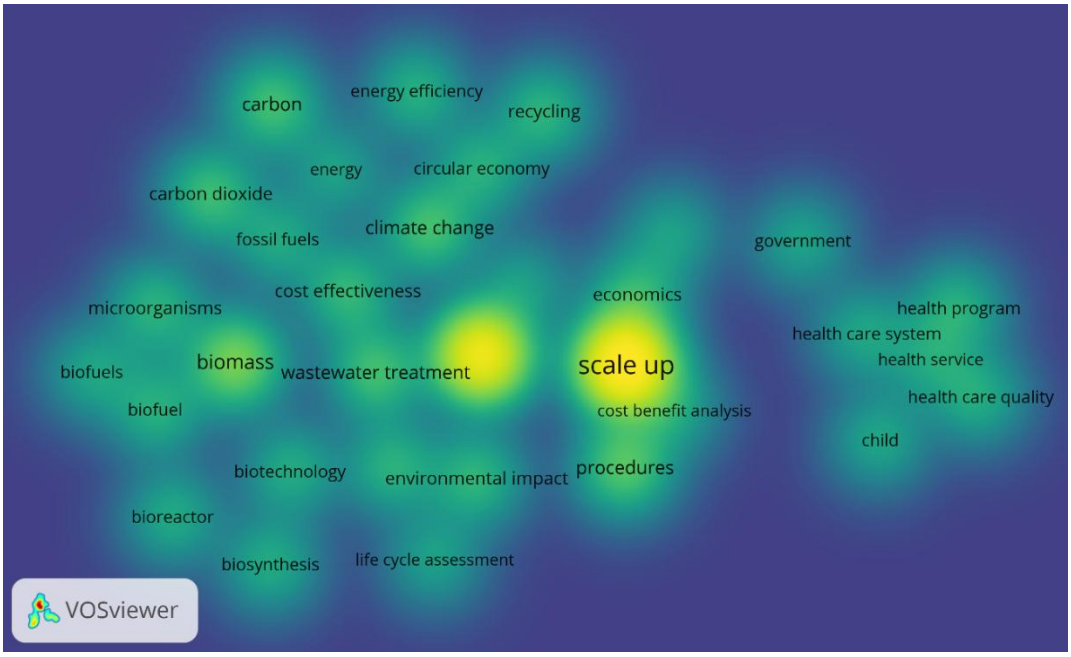

Figure 5. Density Visualization
Source: Data Analysis

Figure 5 highlights the **most frequently occurring and interconnected keywords** in the literature on sustainable scale-up strategies. The bright yellow zones, particularly around *scale up*, *biomass*, and *wastewater treatment*, indicate areas of high research intensity and centrality in the field. These topics act as pivotal nodes linking diverse research themes, reflecting their role as core subjects in sustainability-related scaling discussions. Surrounding these are terms like *economics*, *cost benefit analysis*, and *procedures*, which suggest that economic evaluation and operational frameworks are consistently embedded in scaling studies, ensuring that expansion efforts are both financially viable and systematically managed.

Moving outward, the green and blue areas represent topics with moderate to lower density but still significant connections, such as *climate change*, *carbon*, *biofuels*, *biotechnology*, and *health care quality*. These indicate thematic subfields that, while less frequently occurring than the central nodes, contribute to specialized domains like environmental technology development, renewable energy production, and public health system improvements. The spread of these nodes across different thematic zones shows the **multidisciplinary nature of sustainable scale-up research**, where technical innovation, environmental stewardship, and social service delivery intersect to shape comprehensive, scalable solutions.

3.4. Practical Implications

The findings of this bibliometric review offer actionable insights for policymakers, practitioners, and industry leaders involved in sustainable scale-up strategies. The strong concentration of research around *biomass*, *wastewater treatment*, and *scale up* underscores the need for investment

in green technologies that can be deployed at scale, particularly in energy and environmental management sectors. For policymakers, the results suggest that effective scale-up requires integrating environmental and economic evaluations—highlighting the importance of cost-benefit analyses and procedures as part of policy frameworks. In the health sector, where earlier literature was concentrated, the implications point toward scaling community-based programs that have proven effective in improving health care quality, especially in low- and middle-income contexts. Practitioners in both environmental and public health domains can use these findings to align their scaling strategies with the thematic areas most supported by empirical evidence, thus improving adoption rates and long-term sustainability.

3.5. Theoretical Contribution

This study contributes to theory-building in the sustainable scale-up domain by providing a structured mapping of the intellectual landscape, which has been fragmented across sectors and disciplines. The bibliometric analysis confirms that sustainable scale-up research is inherently multidisciplinary, bridging health systems, environmental engineering, renewable energy, and socio-economic policy. The clustering patterns and thematic evolution revealed in the co-occurrence and overlay visualizations highlight a shift from health-focused scaling models toward integrated frameworks that embed sustainability and climate action. This supports the expansion of theoretical models on scaling from linear growth processes to complex adaptive systems, where environmental impact, resource efficiency, and policy alignment are treated as interdependent variables. By synthesizing these patterns, the study strengthens the conceptual linkage between scaling theory, sustainability science, and innovation diffusion frameworks.

3.6. Limitation

While this study provides a comprehensive bibliometric mapping, several limitations must be acknowledged. First, the analysis relied solely on the Scopus database, which, although extensive, may exclude relevant literature indexed in other sources such as Web of Science or specialized regional databases. Second, the keyword-based search strategy, despite careful design, might have missed studies using alternative terminologies for sustainable scaling, potentially underrepresenting certain niche areas. Third, bibliometric methods focus on quantitative mapping and network visualization; they do not assess the qualitative depth, methodological rigor, or contextual applicability of individual studies. Finally, the use of VOSviewer for network construction, while powerful for visual analysis, is sensitive to threshold settings, meaning that different parameter choices could yield slightly different network structures. Future research could address these limitations by incorporating multi-database searches, qualitative content analysis, and mixed bibliometric approaches to ensure a more nuanced understanding.

4. CONCLUSION

This bibliometric review provides a comprehensive mapping of the scholarly landscape on sustainable scale-up strategies, revealing both the breadth and interconnectedness of research across health, environmental, and economic domains. The

analysis, conducted using VOSviewer, identified *scale up*, *biomass*, and *wastewater treatment* as central themes, surrounded by strong linkages to governance, cost-benefit analysis, environmental impact, and emerging sustainability concepts such as the circular economy. The temporal evolution shows a clear thematic shift—from early emphasis on public health interventions toward more integrated approaches that incorporate climate action, resource efficiency, and renewable energy technologies. This progression underscores the multidisciplinary nature of sustainable scaling, where technical innovation, economic feasibility, and policy frameworks converge to enable large-scale impact. By synthesizing patterns across thematic clusters and timeframes, this study not only fills a gap in the literature but also provides a strategic knowledge base to guide future research, cross-sector collaboration, and informed policy-making in achieving scalable, sustainable solutions.

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