Bibliometric Analysis of Sustainable Natural Resource Management Integration in Urban Development Policies: Insights from Medan City, Indonesia

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Abstract. This study conducts a comprehensive bibliometric analysis of sustainable natural resource management integration in urban development policies for Medan City, Indonesia. Utilizing data from OpenAlex and analyzing it through VOSviewer and Bibliometrix, the research examines publication trends, key themes, and collaborative networks from 2013 to 2023. The findings reveal a significant increase in research output, particularly accelerating from 2020 onwards, indicating growing awareness of urban sustainability issues. The analysis identifies urban design, policy implementation, and economic aspects as dominant themes, while highlighting a relative underrepresentation of explicit environmental and natural resource management topics as a key challenge. Opportunities for improvement include expanding the strong collaborative ecosystem centered around North Sumatran institutions to include more national and international partnerships. The research contributes to several Sustainable Development Goals, notably SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action), but suggests room for greater focus on environmental sustainability goals. The study concludes that while Medan has made significant progress in sustainable urban development research, there remains considerable potential for further integration of natural resource management principles into urban policies to address identified challenges and capitalize on opportunities for sustainable growth.

Keywords: Sustainable development, Urban policy, Natural resources, Medan City, Bibliometric analysis, SDGs, Environmental management, Collaborative research

1 Introduction

Urban development in Indonesia faces complex challenges as cities strive to balance economic growth with sustainable natural resource management. Medan, the capital of North Sumatra province, exemplifies these challenges as it grapples with rapid urbanization, environmental degradation, and the need for sustainable development policies. This study examines the integration of sustainable natural resource management into urban development policies in Medan, with a focus on lessons that can be applied to other Indonesian cities and developing urban areas globally.

Medan has experienced significant growth in recent years, with its Gross Regional Domestic Product (GRDP) per capita increasing from 98,263,688 rupiah in 2018 to 112,310,157.69 rupiah in 2022 [2]. However, this economic growth has been accompanied by environmental challenges, including air pollution, waste management issues, and pressure on natural resources. The city's Human Development Index (HDI) has shown modest improvement, rising from 80.65 in 2018 to 81.76 in 2022, indicating progress in areas such as education, health, and standard of living [2]. Despite these advancements, sustainable urban development remains a critical concern for Medan's policymakers and stakeholders.

The concept of sustainable urban development has gained increasing attention in recent years, particularly in the context of rapidly growing cities in developing countries. Ginting et al. highlight the importance of integrating cultural heritage preservation into urban development strategies, emphasizing the role of local identity in creating sustainable and livable cities [4]. This approach aligns with the broader goals of sustainable development, which seek to balance economic, social, and environmental considerations in urban planning and policy-making.

The United Nations Sustainable Development Goals (SDGs), particularly SDG 6: Clean Water and Sanitation, SDG 7: Affordable and Clean Energy, SDG 9: Industry, Innovation and Infrastructure, SDG 11: Sustainable Cities and Communities, SDG 12: Responsible Consumption and Production, SDG 13: Climate Action, SDG 15: Life on Land, and SDG 17: Partnerships for the Goals, provide a framework for addressing the challenges faced by cities like Medan [11]. These goals emphasize the need for inclusive, safe, resilient, and sustainable urban environments, as well as the protection and sustainable use of terrestrial ecosystems.

Recent research has highlighted the importance of data-driven approaches in urban planning and policy-making. Jiao et al. [5] discuss the growing significance of data journals and papers in understanding how research data is published and reused in the research system. This trend underscores the potential for evidence-based decision-making in urban development, particularly in the context of natural resource management and sustainability initiatives.

The integration of sustainable natural resource management into urban development policies requires a comprehensive understanding of the local context, including environmental, social, and economic factors. In Medan, this involves addressing issues such as air quality, water resources, green spaces, and biodiversity conservation within the urban landscape. The city's efforts to improve its environmental performance are reflected in initiatives such as waste management programs and efforts to increase green open spaces.

Urban development in Indonesia has faced significant challenges related to sustainability and resource management. A study by Siti Nur Aini and Ris Yuwono Yudo Nugroho [9] highlighted the complex relationship between economic growth, education, unemployment, and income inequality in Indonesian cities. Their research emphasized the need for comprehensive policies that address these interconnected issues to achieve sustainable urban development.

The importance of human development in urban planning has been underscored by recent research. [10] investigated the impact of economic growth and human development index on income inequality in West Java. Their findings suggested that improving human capital through education and health initiatives can play a crucial role in reducing urban inequalities and promoting sustainable development.

Environmental concerns have also been at the forefront of urban development discussions. A study by [8] examined the influence of human development index, economic growth, and open

unemployment rate on poverty levels in Indonesia. Their research highlighted the need for policies that balance economic growth with environmental protection and social equity to achieve truly sustainable urban development.

The role of technology in sustainable urban development has gained increasing attention. [5] conducted a comprehensive analysis of data journals indexed in major scholarly databases, providing insights into the growing importance of data-driven approaches in urban planning and resource management. This trend towards data-centric policymaking offers new opportunities for more effective and efficient urban resource management.

Lastly, the application of smart technologies in urban development has been explored as a potential solution to resource management challenges. [13] conducted a bibliometric analysis of home IoT research, revealing the potential of smart home technologies in improving energy efficiency and resource management at the household level. These findings suggest that integrating smart technologies into urban development policies could contribute significantly to sustainable resource management in cities like Medan.

In summary, recent literature highlights the complex interplay between economic, social, and environmental factors in sustainable urban development. The integration of sustainable natural resource management into urban policies requires a holistic approach that considers human development, environmental protection, and technological innovation. Future research and policy development in Medan and other Indonesian cities should focus on creating comprehensive strategies that address these complex challenges.

This study aims to analyze the current state of sustainable natural resource management in Medan's urban development policies, identify key challenges and opportunities, and derive lessons that can be applied to other urban areas facing similar issues. By examining Medan's experience through a bibliometric analysis using VOSviewer and Biblioshiny, this research seeks to contribute to the broader understanding of sustainable urban development in the context of rapidly growing cities in developing countries.

To achieve these objectives, this study employs a comprehensive bibliometric analysis approach. This approach is particularly relevant to the study's aims as it allows for:

1. Systematic mapping of the research landscape related to sustainable urban development in Medan City.

2. Identification of key themes and their evolution over time, revealing both established and emerging areas of focus.

3. Analysis of collaboration networks, highlighting the roles of various institutions and researchers in shaping the field.

4. Quantification of research output and impact, providing an objective measure of the field's growth and significance.

5. Detection of potential research gaps and opportunities for future studies.

By utilizing bibliometric techniques, this study can provide a data-driven, comprehensive overview of the current state of research on sustainable natural resource management and urban development in Medan. This approach enables the identification of challenges and opportunities based on patterns in the literature, and facilitates the extraction of lessons that may be applicable to other urban areas facing similar sustainability challenges.

The findings of this study have implications for policymakers, urban planners, and environmental managers working to create more sustainable and resilient cities. By integrating sustainable natural resource management into urban development policies, cities like Medan can work towards achieving the SDGs while improving the quality of life for their residents and preserving vital ecosystems for future generations.

2 Methods

This study utilizes a comprehensive bibliometric analysis approach to examine the research trends in sustainability from 2013 to 2023. The methodology incorporates the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure a systematic and transparent review process [6].

Data Collection and Preprocessing

The bibliographic data was extracted from OpenAlex, a fully-open index of scholarly works [7]. The search strategy is designed to identify relevant publications addressing the key concepts of sustainability, focusing on its development, implementation, and impact. The following search query is used:

("Sustainable Cities and Communities" OR "Life on Land" OR "Bibliometric" OR "Integrating" OR "Sustainable Natural Resource Management" OR "Urban Development" OR "Policies") AND ("Medan City")

This search query targets to ensure a direct focus on the topic. The abstract and keyword terms broaden the scope to include related concepts and applications of sustainability. The search is limited to English-language peer-reviewed journal articles published from 2013 to 2023, capturing the full range of developments in this research area as specified in the methodology. This timeframe allows for a comprehensive analysis of the field's evolution, from its early conceptualization to the most recent advancements.

The OpenAlex database is used as the primary data source for this bibliometric analysis. OpenAlex provides comprehensive coverage of scholarly literature and offers open access to bibliometric data, making it suitable for large-scale bibliometric studies (Priem et al., 2022). This search strategy aims to capture a broad yet focused set of publications on sustainable energy, enabling a thorough bibliometric analysis of the field's development, key themes, and research trends over the past four decades.

To ensure data quality and relevance, the following inclusion criteria were applied: (1) Articles published in peer-reviewed journals, book chapter and proceeding; (2) OpenAlex exported database with "sustainable tag" that suitable within the SDGs context as mention in the introduction ; (3) Articles published between 2013 and 2023 ; (4) Articles with complete metadata (authors, affiliations, citations, etc.)

Whereas, Exclusion criteria included: (1) Non-English language publications ; (2) Articles with incomplete metadata. The PRISMA flow diagram illustrating the data collection and filtering process is presented in Figure 1.
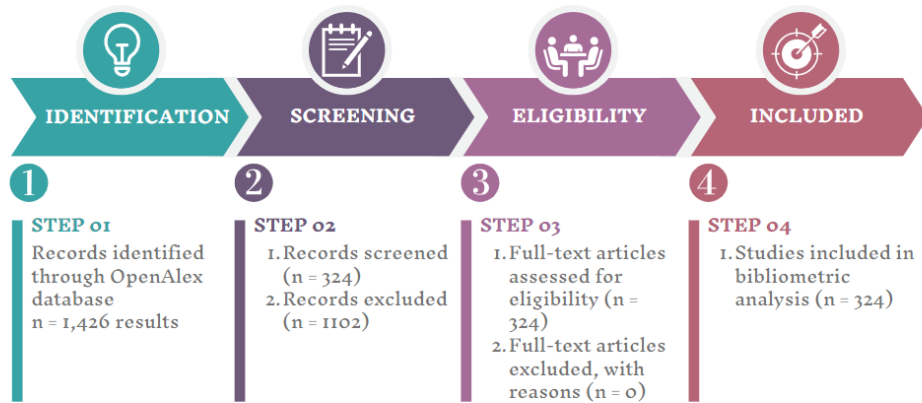
Fig. 1. PRISMA flow diagram

Data Analysis Tools

Two primary software tools were utilized for the bibliometric analysis and visualization: (1) VOSviewer (version 1.6.18): An open-source software tool for constructing and visualizing bibliometric networks [12]; (2) Bibliometrix (R package, version 4.2.2): An R-based tool for comprehensive science mapping analysis [1].

Analytical Methods and Visualization Techniques

The analysis included the following key components:

1. Annual Scientific Production: Tracking the growth of publications over time to identify trends and potential inflection points in the research field.

2. Keyword Analysis:

    ● Keyword co-occurrence network (VOSviewer)

    ● Trend Topics analysis (Bibliometrix - RStudio)

    ● Thematic Map Analysis (Bibliometrix - RStudio)

    ● Word Cloud Analysis (Bibliometrix - RStudio)

3. Authorship and Collaboration Analysis:

    ● Co-authorship Institutional network (VOSviewer)

    ● Author productivity and impact analysis (Bibliometrix - RStudio)

4. Journal Analysis (Bibliometrix - RStudio):

    ● Analysis of connections between authors, journals, and keywords using a three-field plot (Sankey diagram)

Various visualization techniques were utilized to present the results effectively, including network maps, trend graphs, thematic maps, Sankey diagrams, and word clouds. This comprehensive methodology allows for a multi-dimensional analysis of sustainable urban development and natural resource management research in Medan City, providing insights into its historical development, current state, and future directions. The approach enables a robust understanding of the research landscape, aligning with the study's objectives to analyze the current state of sustainable natural resource management in Medan's urban development policies, identify key challenges and opportunities, and derive lessons applicable to other urban areas facing similar issues.

Alignment with Research Objectives

The comprehensive bibliometric approach adopted in this study directly addresses the research objectives in the following ways:

1. Analyzing the current state of sustainable natural resource management in Medan's urban development policies: The annual scientific production analysis and keyword analysis provide insights into the evolution and current focus of research in this area.

2. Identifying key challenges and opportunities: The thematic map analysis and trend topics analysis reveal emerging themes, research gaps, and potential areas for future development, effectively highlighting both challenges and opportunities in Medan's urban sustainability efforts.

3. Extracting insights for other urban areas: The authorship and collaboration analysis, coupled with the journal analysis, provides valuable information on key contributors and institutions in the field. This knowledge can benefit other cities seeking to develop their own sustainable urban development strategies.

4. Integration with SDGs: The keyword analysis and thematic mapping enable the identification of research themes that align with various Sustainable Development Goals, allowing for an assessment of how Medan's urban development policies contribute to broader sustainability objectives.

By combining quantitative bibliometric indicators with qualitative content analysis, this methodology provides a comprehensive view of the research landscape, enabling the identification of trends, gaps, and potential areas for policy intervention in sustainable urban development and natural resource management in Medan City.

3 Result and Discussion

3.1 Result

1. Annual Scientific Publications
Growth trend analysis and Key milestones and inflection points
This analysis of publication trends provides insight into the evolving research focus on sustainable urban development in Medan, helping to identify key periods of growth and potential catalysts for increased scholarly attention.

Figure 2 below, illustrates the annual scientific production related to sustainable natural resource management integration in urban development policies, with a specific focus on Medan City,

Indonesia, from 2014 to 2023. The graph demonstrates a clear upward trend in publication volume over the past decade, with notable acceleration in recent years.
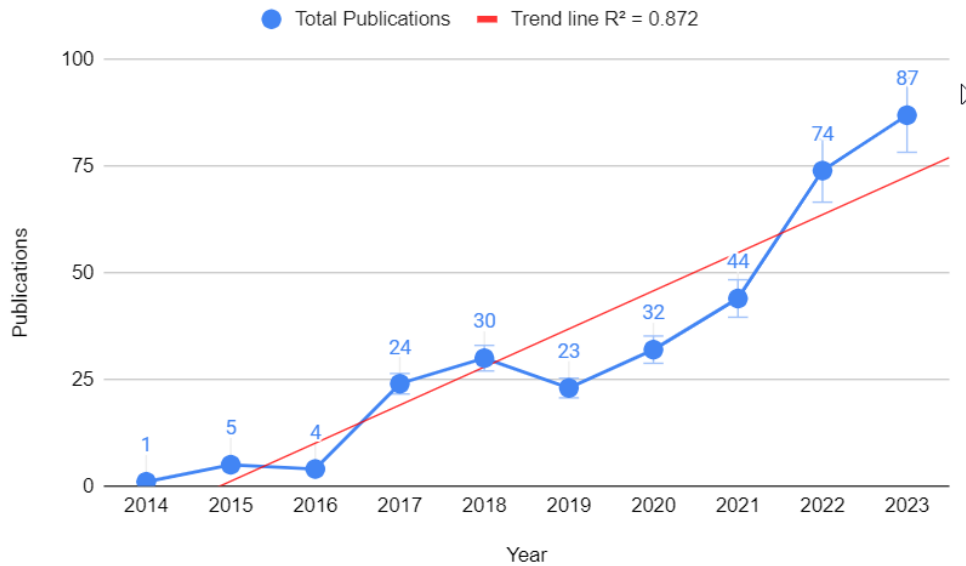

Fig. 2. Annual Scientific Publications - Source: Data Analysis

Key observations from the annual scientific production can be elaborate as follows : (1) Overall growth trend: The number of publications has shown a strong positive trend, as evidenced by the upward slope of the trend line and the high R^2 value of 0.872. This indicates a consistent and significant increase in research interest and output in this field ; (2) Initial low output: In 2014, the field saw minimal research activity, with only 1 publication recorded ; (3) Steady initial growth: From 2014 to 2018, there was a steady but modest increase in publications, rising from 1 to 30 over this five-year period ; (4) Temporary decline: A slight dip in publications occurred in 2019, dropping to 23 from the previous year's 30. This could potentially be attributed to external factors or shifts in research priorities ; (5) Rapid acceleration: From 2020 onwards, there is a marked acceleration in publication output. This period coincides with increased global focus on sustainable urban development and may reflect growing awareness of environmental challenges in rapidly developing cities like Medan ; (6) Peak years: The years 2022 and 2023 show the highest publication outputs, with 74 and 87 publications respectively. This represents a substantial increase from previous years and suggests a surge in research interest and activity ; (7) Year-over-year growth: The most significant year-over-year increase occurred between 2021 and 2022, jumping from 44 to 74 publications, a 68% increase ; (8) Projection: The trend line suggests continued growth in publications for the coming years, indicating sustained or potentially increasing interest in this research area ; (9) Data completeness: The 2023 data point shows a slight upward error bar, which might indicate that the full year's data was not yet available at the time of analysis, suggesting the final count for 2023 could be higher.

This result reveals a robust and accelerating research landscape in sustainable urban development and natural resource management, particularly in the context of Medan City and similar urban environments in Indonesia. The sharp increase in publications over the past few

years underscores the growing importance and recognition of these topics in academic and policy circles.

2. Keyword Analysis

2.1. Keyword co-occurrence network (VOSviewer)

This network visualization reveals the interconnections between key research themes, providing a map of the current research landscape and highlighting potential areas for future policy focus. The following keyword analyses offer a detailed view of the primary themes and focus areas in Medan's sustainable urban development research, crucial for understanding the current state of policy integration and identifying potential gaps or opportunities.

Figure 3 presents a keyword co-occurrence network visualization generated using VOSviewer, offering insights into the key themes and relationships within the research landscape of sustainable natural resource management in urban development policies, with a focus on Medan City.

Fig. 3. Keyword co-occurrence network

Key observations from the keyword co-occurrence network provided by VosViewer can be describe as follows:

1. Central themes: The largest nodes in the network represent the most frequently occurring keywords. "Business", "engineering", and "environmental science" emerge as central themes, indicating their significant role in the research domain.

2. Interdisciplinary nature: The network demonstrates a highly interdisciplinary field, with connections between diverse areas such as engineering, business, environmental science, biology, chemistry, and social sciences.

3. Urban focus: Keywords like "architecture", "urban planning" (inferred from "space (punctuation)"), and "world wide web" suggest a strong emphasis on urban development and digital technologies in urban contexts.

4. Sustainability concepts: Terms such as "green growth", "biodiversity", and "ecology" highlight the integration of sustainability principles in urban development research.

5. Technology integration: The presence of "artificial intelligence", "internet of things", and "cloud computing" indicates the growing role of advanced technologies in urban sustainability efforts.

6. Social dimensions: Keywords like "social psychology", "cultural heritage", and "public health" underscore the importance of social factors in urban development research.

7. Economic aspects: Terms such as "business", "economics", and "prosperity" reflect the economic considerations in sustainable urban development.

8. Environmental concerns: Keywords like "geology", "climatology", and "meteorology" point to the inclusion of environmental factors in urban sustainability research.

9. Resource management: Terms such as "water resources" (inferred from proximity to environmental topics) and "agriculture" suggest a focus on natural resource management in urban contexts.

10. Policy and governance: Keywords like "politics", "decentralization", and "bureaucracy" indicate attention to governance aspects of urban sustainability.

11. Methodological approaches: The presence of "statistics", "data science", and "mathematics" highlights the quantitative and analytical methods used in this research area.

12. Emerging topics: Smaller nodes for terms like "remote sensing" and "photovoltaic system" may represent emerging research areas or technologies in urban sustainability.

13. Interconnectedness: The dense network of connections between keywords illustrates the complex, interrelated nature of issues in sustainable urban development and natural resource management.

This keyword co-occurrence network reveals the diverse nature of research on sustainable natural resource management in urban development, particularly in the context of Medan City. It highlights the integration of environmental, technological, social, and economic considerations in addressing urban sustainability challenges. The network also suggests potential areas for further interdisciplinary research and collaboration in developing comprehensive approaches to sustainable urban development.

2.2 Trend Topics Analysis (Bibliometrix - RStudio)

By identifying the most frequent words and emerging topics, this analysis helps pinpoint the current priorities in Medan's urban sustainability research and policy development. The Trend Topics analysis, conducted using the Bibliometrix package in R, provides valuable insights into the evolution of research themes within the field of sustainable natural resource management and urban development policies in Medan City.

This analysis identifies keywords that have gained significant traction over time, reflecting emerging areas of interest and shifting focus in the research landscape. Figure 4 provides a

comprehensive overview of the most frequent words or keywords in the research literature on sustainable natural resource management and urban development policies in Medan City
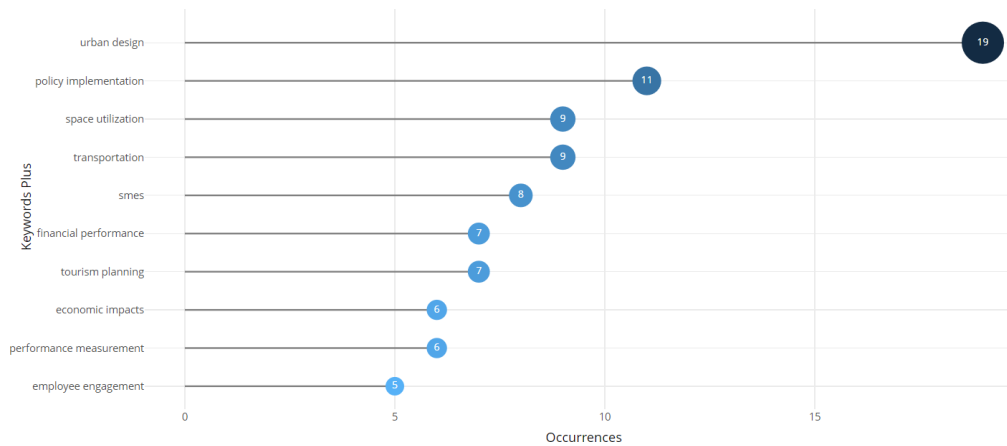

Fig. 4. Most Frequent Words.

This top 10 most frequent words analysis reveals several key insights:
1. Urban Design Dominance: "Urban design" emerges as the most frequently occurring term with 19 occurrences, significantly higher than any other keyword. This underscores the central role of urban planning and design principles in the discourse surrounding sustainable development in Medan City.
2. Policy Focus: "Policy implementation" ranks second with 11 occurrences, highlighting the importance of translating theoretical concepts into practical action through effective governance and policy mechanisms.
3. Spatial and Transportation Concerns: Both "space utilization" and "transportation" appear with equal frequency (9 occurrences each), indicating a strong focus on efficient land use and mobility issues in urban development strategies.
4. Economic Dimensions: The presence of terms like "SMEs" (8 occurrences), "financial performance" (7 occurrences), and "economic impacts" (6 occurrences) reflects the significant attention given to economic aspects of sustainable urban development.
5. Tourism Integration: "Tourism planning" (7 occurrences) suggests that the tourism sector is considered an important component of sustainable urban development in Medan, likely due to its potential economic and cultural impacts.
6. Performance Metrics: The inclusion of "performance measurement" (6 occurrences) indicates a focus on quantifiable outcomes and the importance of assessing the effectiveness of sustainability initiatives.
7. Human Resource Aspect: "Employee engagement" (5 occurrences) appears as the least frequent among the top terms, yet its presence highlights the recognition of human capital in sustainable urban development processes.
8. Balanced Approach: The distribution of frequencies across various domains (urban planning, policy, economics, tourism, and human resources) suggests a comprehensive approach to sustainable urban development in Medan City.
9. Practical Orientation: Many of the frequent terms (e.g., "policy implementation," "space utilization," "performance measurement") indicate a strong emphasis on practical, implementable aspects of sustainable development rather than purely theoretical concepts.

10. Local Context: The frequency of terms specific to urban contexts and local economic factors (like SMEs and tourism) reflects a tailored approach to sustainability that considers Medan's unique characteristics and needs.

This analysis of keyword frequencies provides valuable insights into the primary areas of focus in research on sustainable urban development and natural resource management in Medan City. It reveals a comprehensive approach that encompasses urban design, policy implementation, economic considerations, and specific local factors, all of which are crucial for developing effective and sustainable urban policies.

2.3. Thematic Map Analysis (Bibliometrix - RStudio)

This strategic diagram offers insights into the structure and dynamics of the research field, helping to identify well-developed areas and potential gaps in Medan's approach to sustainable urban development. The thematic map analysis, conducted using the Bibliometrix package in R, provides a strategic diagram that visualizes the research themes in the field of sustainable natural resource management integration in urban development policies, with a particular focus on Medan City. This analysis categorizes themes based on their centrality and density, offering insights into the structure and dynamics of the research field.
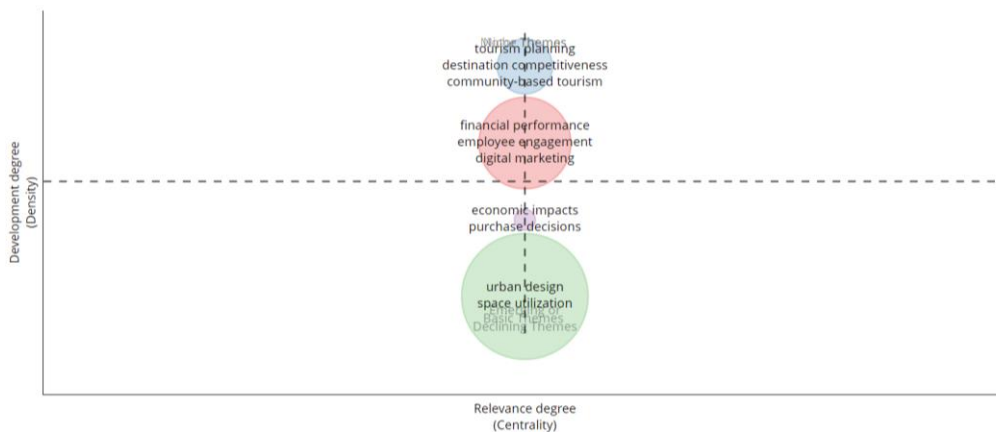

Fig. 5. Thematic Map

Figure 5 provides a strategic overview of research themes in the field of sustainable natural resource management and urban development policies, with a focus on Medan City. This visualization, offering insights into the structure and dynamics of the research field. Key observations from the thematic map analysis:

1. Motor Themes (Upper-right quadrant):

   ● This quadrant is empty, suggesting that there are no themes that are both well-developed and central to the research field at present.

2. Niche Themes (Upper-left quadrant):

   ● The cluster containing "tourism planning", "destination competitiveness", and "community-based tourism" appears in this quadrant.

- These themes are well-developed (high density) but less central to the overall research field.
- This suggests a specialized area of research focusing on sustainable tourism in urban contexts, which may be particularly relevant for Medan City's development strategies.

3. Basic Themes (Lower-right quadrant):

- The largest cluster, containing "financial performance", "employee engagement", and "digital marketing", is positioned here.
- These themes are central to the research field but less developed, indicating their importance as foundational concepts in sustainable urban development and resource management.
- The presence of these business-oriented themes suggests a strong focus on the economic aspects of urban sustainability.

4. Emerging or Declining Themes (Lower-left quadrant):

- The cluster containing "urban design" and "space utilization" is located in this quadrant.
- These themes are neither well-developed nor central to the field, which could indicate either emerging areas of research or topics that are becoming less relevant.
- Given the context of urban development, it's more likely these are emerging themes, suggesting a growing interest in the physical design and spatial aspects of sustainable urban planning.

5. Bridging Themes:

- "Economic impacts" and "purchase decisions" are positioned near the center of the map.
- Their location suggests they may serve as bridging concepts between the more specialized tourism themes and the basic business-oriented themes.

6. Theme Relationships:

- The proximity of tourism-related themes to business and economic concepts indicates a strong interrelation between sustainable tourism development and broader economic considerations in urban planning.

7. Absence of Environmental Themes:

- Significantly, explicit environmental or natural resource management themes do not feature prominently in this visualization, potentially indicating a gap in the current research focus or suggesting a need for greater integration of these aspects with the economic and tourism-oriented themes.

The thematic map analysis reveals that the research landscape in sustainable urban development and natural resource management for Medan City is currently dominated by economic and tourism-related themes. The emerging focus on urban design and space utilization suggests a

growing recognition of the importance of physical planning in sustainability efforts. However, the absence of prominent environmental themes indicates a potential area for future research development, particularly in integrating ecological considerations more fully into urban sustainability strategies for Medan City.

2.4. Word Cloud Analysis (Bibliometrix - RStudio)

The word cloud provides a quick, intuitive overview of dominant themes, offering a snapshot of the current focus in Medan's urban sustainability research and policy landscape. This visualization technique is particularly useful for identifying overarching themes and potential areas of focus that may not be immediately apparent in more complex network visualizations.The word cloud visualization in Figure 6 provides a compelling overview of the key themes and concepts dominating the research landscape of sustainable natural resource management and urban development policies in Medan City.

Fig. 6. WordCloud

The most prominent term, "urban design", stands out as the central focus of the research corpus, indicating its critical role in shaping sustainable urban environments. This is closely followed by "policy implementation", highlighting the importance of translating theoretical frameworks into actionable strategies for urban sustainability. "Transportation" emerges as another significant theme, underscoring the crucial role of mobility and infrastructure in urban development. The prominence of "space utilization" suggests a strong emphasis on efficient land use and urban planning practices.

Economic considerations are evident through terms like "financial performance", "SMEs", and "economic impacts", reflecting the integration of economic sustainability into urban development strategies. The presence of "tourism planning" indicates the sector's importance in Medan's urban economy and development plans. Environmental concerns are represented by "waste management" and "flood risk", pointing to key challenges in sustainable urban

management. The appearance of "cultural sustainability" and "cultural heritage" highlights the importance of preserving local identity in development processes.

Technological aspects are evident through terms like "digital marketing", "e-commerce", and "educational technology", suggesting the growing role of digital solutions in urban development and sustainability efforts. Social dimensions are reflected in terms such as "community participation", "employee engagement", and "patient experience", indicating a focus on inclusive and people-centered urban development approaches.

The word cloud also reveals emerging areas of interest, such as "slum upgrading" and "destination competitiveness", which may represent specific challenges or opportunities in Medan's urban context. Overall, this visualization effectively captures the multidisciplinary nature of sustainable urban development research, encompassing environmental, economic, social, and technological dimensions. It provides valuable insights into the complex interplay of factors shaping urban sustainability policies and practices in Medan City.

3. Authorship and Collaboration Analysis

These analyses of authorship and institutional collaboration patterns help identify key players and networks in Medan's urban sustainability research, crucial for understanding the current research ecosystem and potential for knowledge transfer.

3.1. Co-authorship Institusional network (VOSviewer)

The co-authorship institutional network analysis provides valuable insights into collaborative patterns and key institutional players in the field of sustainable natural resource management and urban development policies, with a particular focus on Medan City. Figure 6 illustrates this network.
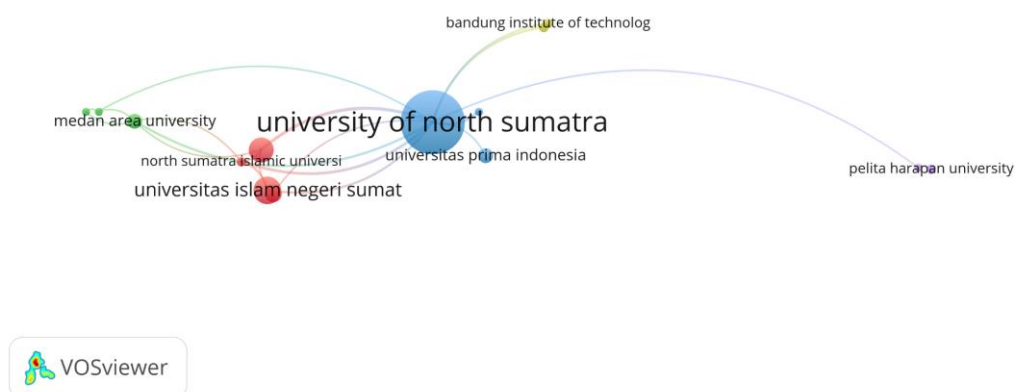

Fig. 7. Co-authorship Institusional network

Figure 7 provides valuable insights into the institutional collaboration landscape surrounding research on sustainable natural resource management and urban development in Medan City. At the center of this network is the University of North Sumatra, which emerges as the primary hub for research activities in this field. The visualization reveals a complex web of connections between various institutions, with the University of North Sumatra serving as the focal point. Several other institutions are shown to have strong ties to this central node, including Medan Area University, Universitas Islam Negeri Sumatera Utara, and North Sumatra Islamic University. These connections, represented by lines of varying thickness, suggest different levels of collaborative intensity between the institutions.

The network also includes institutions that appear to be more peripheral to the main research cluster, such as Bandung Institute of Technology and Pelita Harapan University. Their presence in the network indicates some level of involvement in the research ecosystem, albeit potentially to a lesser extent than the more centrally positioned institutions. The color-coding of the nodes likely represents different clusters or research areas, although without a legend, the specific meanings of these colors are not immediately apparent.

Overall, this visualization paints a picture of a research landscape centered primarily around institutions in North Sumatra, with some connections extending to institutions outside the region. This network structure suggests a collaborative approach to addressing the complex challenges of sustainable urban development and natural resource management in Medan City, with the University of North Sumatra playing a leading role in fostering these research partnerships.

3.2. Author productivity and impact analysis (Bibliometrix - RStudio)

Using the Bibliometrix package in RStudio, this section examines the impact and productivity of researchers in the field. The analysis considers factors such as the number of publications, citation counts, and various bibliometric indices to identify the scholars who have made significant contributions to the body of knowledge. By highlighting these influential authors, we gain a better understanding of the intellectual foundations of the field and the individuals driving innovation and progress in sustainable urban development research. This analysis not only recognizes the work of prominent researchers but also helps in identifying potential collaborators and emerging thought leaders in the domain.

Table 1 provided the data regarding author productivity and impact metrics, a comprehensive analysis reveals significant insights into the contributions of various researchers in the field. The metrics include h-index, g-index, m-index, total citations (TC), number of publications (NP), and the year they began publishing (PY_start).

Table 1. Author productivity

Author	H_Index	G_Index	M_Index	TC	NP	PY_Start
ISNEN FITRI	3	6	0.3	52	6	2015
NURLISA GINTING	3	3	0.3	67	3	2015
ACHMAD DELIANUR NASUTION	2	3	0.25	13	6	2017
AGUSSANI AGUSSANI	2	2	0.4	17	2	2020

B O Y MARPAUNG	2	2	0.25	6	7	2017
BADARUDDIN BADARUDDIN	2	2	0.25	4	6	2017
DEVIN DEFRIZA HARISDANI	2	3	0.25	9	5	2017
DWI LINDARTO HADINUGROHO	2	2	0.25	5	9	2017
DWIRA NIRFALINI AULIA	2	2	0.25	8	9	2017
HAFIZHUL KHAIR	2	2	0.222	4	5	2016

Source: Data Analysis

The data shows that Isnen Fitri and Nurlisa Ginting lead the group with an h-index of 3, indicating that they have published at least three papers that have each been cited at least three times. Notably, Ginting has a higher total citation count (67) compared to Fitri (52), suggesting that Ginting's work has had a broader impact within the academic community despite both authors having the same h-index.

Following closely are Achmad Delianur Nasution, Agussani Agussani, and several others, each with an h-index of 2. This indicates a solid but lesser degree of influence, with Nasution having a total of 13 citations from 6 publications, while Agussani has 17 citations from 2 publications. This disparity suggests that Agussani's work, although fewer in number, has been more impactful in terms of citations per publication.

The m-index, which adjusts the h-index for the number of years an author has been publishing, shows that both Fitri and Ginting have a value of 0.3, reflecting consistent productivity relative to their publication start year (2015). In contrast, authors like Agussani and B O Y Marpaung, who started publishing in more recent years (2020 and 2017, respectively), show lower m-index values, indicating that their impact may still be developing.

Total citations (TC) provide a clear picture of the authors' influence. For instance, while Hafizhul Khair has a lower h-index of 2, his total citations (4) suggest that his work is still gaining traction, indicating potential for future growth in impact as he continues to publish. Overall, the analysis of these metrics highlights the varying levels of productivity and impact among the authors. The data suggests a promising research community with a mix of established and emerging scholars. This diversity in publication history and citation impact can foster collaboration and knowledge exchange, ultimately contributing to the advancement of research in their respective fields.

In essence, the author productivity and impact analysis indicates that while some researchers have established a notable presence in the academic landscape, others are on the cusp of making significant contributions. Understanding these dynamics is crucial for identifying potential collaborators and recognizing influential work within the field. As the research community continues to evolve, tracking these metrics will be essential for gauging future trends and impacts in urban studies and related disciplines.

Journal Analysis (Bibliometrix - RStudio)

This analysis of the connections between authors, journals, and keywords provides a comprehensive view of the research dissemination landscape, offering insights into how knowledge is being shared and potentially influencing policy development in Medan.

The connections between authors, journals, and keywords

The three-field plot (Sankey diagram)   provided offers a visual representation of the relationships between sources (SO) : The leftmost column lists the sources where the research has been published ; authors (AU) : The middle column lists the authors who have contributed to the research and keywords (DE) in the context of urban studies and related fields : The rightmost column lists the keywords associated with the research. This type of plot is useful for understanding how different elements in the research landscape are interconnected. Figure 8 shows detailed information regarding these connections.
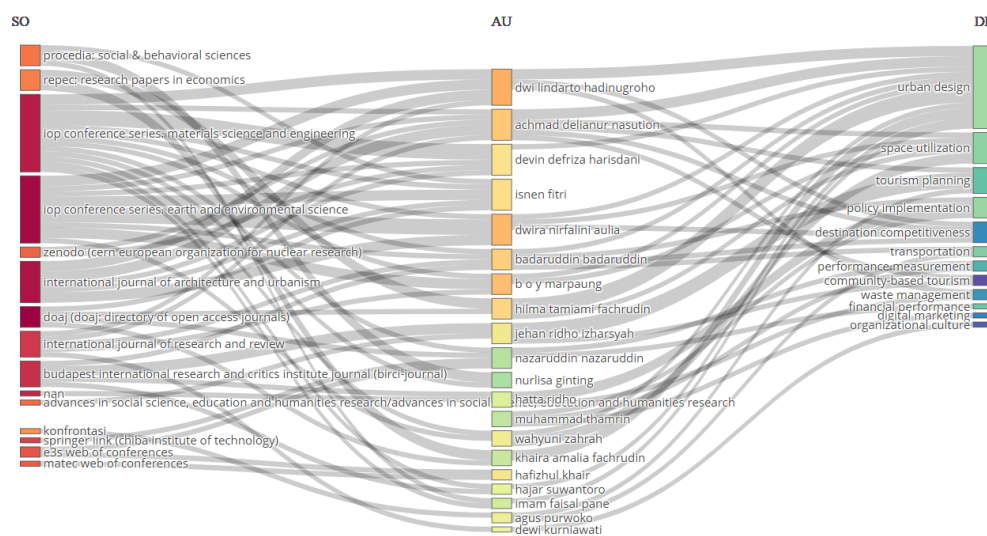

Fig. 8. Sankey Diagram

Figure 8 offers a visual representation of the relationships between sources (SO), authors (AU), and keywords (DE) in the context of urban studies and related fields. This type of plot is useful for understanding how different elements in the research landscape are interconnected. Here is a detailed analysis:

Interdisciplinary Nature: The plot shows a strong interdisciplinary nature of the research, with connections between diverse fields such as urban design, policy implementation, and environmental management. This indicates a holistic approach to addressing urban challenges. The interconnectedness of these fields suggests that research in urban studies often requires a multidisciplinary perspective, integrating insights from various domains to develop comprehensive solutions.

Prominent Authors and Their Contributions: Authors like Dwi Lindarto Hadinugroho and Isnen Fitri appear to be central figures in the research landscape, contributing to multiple themes and publishing in various sources. Their work spans across different aspects of urban studies, indicating their broad expertise and influence. Other notable contributors include Achmad Delianur Nasution, Devin Defriza Harisdani, and Dwira Nirfalini Aulia, who have also made significant contributions to the field.

Central Themes: Keywords such as "urban design," "policy implementation," and "space utilization" are prominently featured, suggesting that these are central themes in the research. These areas are critical for sustainable urban development and are likely to be the focus of ongoing and future studies. The emphasis on these themes highlights the importance of designing urban spaces that are functional, sustainable, and well-integrated with policy frameworks.

Diverse Sources: The wide range of sources indicates that research on urban studies is being published in various journals and conference proceedings, reflecting the multidisciplinary interest and relevance of the topic. Key sources include "Procedia - Social & Behavioral Sciences," "RePEc: Research Papers in Economics," "IOP Conference Series: Materials Science and Engineering," and "Budapest International Research and Critics Institute Journal (BIRCI-Journal)." This diversity in publication venues underscores the broad appeal and applicability of urban studies research.

Emerging Topics: Keywords like "digital marketing" and "organizational culture" suggest emerging areas of interest, possibly indicating new trends and shifts in research focus towards integrating digital technologies and organizational behavior in urban studies. The inclusion of these keywords points to the evolving nature of urban studies, where traditional topics are being complemented by contemporary issues such as digital transformation and organizational dynamics.

The interdisciplinary nature of the research, combined with the diverse range of sources and emerging topics, underscores the complexity and dynamism of the field. This analysis can guide future research directions, identify potential collaborators, and inform policy-making in urban development. By understanding the interconnectedness of various research elements, stakeholders can develop more effective strategies for sustainable urban development.

4 Discussion

This study aimed to analyze the current state of sustainable natural resource management in Medan's urban development policies, identify key challenges and opportunities, and derive lessons that can be applied to other urban areas facing similar issues. The discussion of the results is organized into several subsections, addressing the main findings and their implications, with a focus on how they align with relevant Sustainable Development Goals (SDGs) and provide insights for other urban areas.

Trends in Research Output and Focus
The analysis of annual scientific publications reveals a significant increase in research output related to sustainable urban development and natural resource management in Medan City over the past decade. This trend aligns with global patterns of increasing focus on urban sustainability, as noted by [9], who emphasized the complex relationship between economic growth, education, unemployment, and income inequality in Indonesian cities. The sharp rise in publications from 2020 onwards suggests a growing recognition of the importance of sustainable urban development, possibly influenced by global events and increased awareness of environmental challenges.

This growing body of research contributes to several SDGs, particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). The increasing focus on urban sustainability in Medan aligns with the global effort to make cities inclusive, safe, resilient, and sustainable, while also addressing climate change impacts in urban planning and development. This trend offers valuable lessons for other urban areas, demonstrating the importance of building a robust research foundation to inform sustainable development policies.

Key Themes and Research Focus Areas
1. Urban Design and Spatial Planning
The prominence of "urban design" and "space utilization" in the keyword analysis underscores the central role of physical planning in Medan's sustainability efforts. This focus aligns with SDG 11 (Sustainable Cities and Communities) and SDG 9 (Industry, Innovation and Infrastructure), emphasizing the development of sustainable and resilient urban infrastructure. The emergence of these themes in the research landscape suggests a growing recognition of the need for innovative urban planning solutions to address Medan's sustainability challenges.

Lesson for other urban areas: The emphasis on urban design and spatial planning in Medan's research landscape highlights the importance of integrating sustainability principles into the physical fabric of cities. Other urban areas can learn from this approach by prioritizing sustainable urban design in their development strategies, as demonstrated by Ginting et al. [4] in their study on place identity indicators in cultural heritage tourism areas.

2. Policy Implementation and Governance
The significant attention given to "policy implementation" in the research corpus indicates a strong focus on translating sustainability concepts into actionable strategies. This emphasis on practical implementation is crucial for effective urban management and aligns with recent findings by Saukani and Amaliah [8], who examined the influence of human development index, economic growth, and unemployment rates on poverty levels in Indonesia. Their research highlights the importance of well-implemented policies in addressing urban challenges and promoting sustainable development.

Lesson for other urban areas: Medan's focus on policy implementation offers valuable insights for other cities struggling with the execution of sustainability strategies. Effective governance and policy implementation are critical for achieving sustainable urban development goals, as emphasized by SDG 17 (Partnerships for the Goals).

3. Economic Dimensions of Urban Sustainability
The presence of economic themes such as "financial performance," "SMEs," and "economic impacts" in the research landscape reflects the integration of economic considerations into Medan's urban sustainability strategies. This focus on economic aspects is consistent with the findings of Daniel et.al[3], who studied the effects of economic growth, unemployment rates, and human development index on poverty in North Sumatra. Their research emphasizes the interconnectedness of economic factors and urban development outcomes, underscoring the need for holistic approaches to urban sustainability.

Lesson for other urban areas: Medan's approach to integrating economic considerations into sustainability strategies provides a model for other cities seeking to balance economic growth

with environmental protection. This aligns with SDG 12 (Responsible Consumption and Production) and offers insights into creating sustainable economic practices in urban areas.

4. Environmental Management and Resource Conservation

While environmental themes are present in the research landscape, they appear less prominent compared to urban design and economic considerations. This relative underrepresentation of explicit environmental and natural resource management themes suggests a potential area for future research development. Integrating stronger environmental perspectives into urban sustainability research for Medan could enhance the city's ability to address ecological challenges while pursuing economic development.

Lesson for other urban areas: The identified gap in environmental research presents an opportunity for Medan and other cities to strengthen their focus on natural resource management. Future research should more explicitly address SDG 6 (Clean Water and Sanitation), SDG 15 (Life on Land), and SDG 7 (Affordable and Clean Energy) to ensure comprehensive urban sustainability strategies.

5. Collaborative Research Landscape

The co-authorship institutional network analysis reveals a research ecosystem centered around institutions in North Sumatra, with the University of North Sumatra playing a central role. This collaborative approach to addressing urban sustainability challenges aligns with global trends towards interdisciplinary research in urban studies and contributes to SDG 17 (Partnerships for the Goals). The involvement of institutions from outside the region, albeit to a lesser extent, suggests potential for expanding research collaborations to bring diverse perspectives to Medan's urban sustainability efforts.

Lesson for other urban areas: Medan's collaborative research model demonstrates the value of strong institutional networks in addressing complex urban sustainability challenges. Other cities can benefit from fostering similar collaborative ecosystems, as emphasized by Wang and Kim [13] in their bibliometric analysis of home IoT research, which highlighted the importance of interdisciplinary collaboration in advancing urban technologies.

6. Implications and Future Directions

The findings of this study have several implications for urban policymakers, planners, and researchers:
  a. Integrated Approach: The comprehensive nature of the research landscape underscores the need for integrated approaches to urban sustainability that consider urban design, policy implementation, economic factors, and environmental management. This aligns with the interconnected nature of the SDGs and emphasizes the need for holistic solutions.
  b. Knowledge Transfer: The lessons learned from Medan's experience in integrating sustainable natural resource management into urban policies could be valuable for other rapidly growing cities in Indonesia and beyond, contributing to SDG 17 (Partnerships for the Goals).
  c. Research Gaps: The relative underrepresentation of environmental themes in the current research landscape suggests an opportunity for future studies to more explicitly address natural resource management and ecological sustainability in Medan's urban context.

Future research should focus on addressing gaps related to SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), and SDG 15 (Life on Land).
  d. Collaborative Opportunities: The strong institutional collaboration network centered around local universities provides a foundation for expanding research partnerships, both nationally and internationally, to bring diverse perspectives to Medan's urban sustainability challenges. This aligns with SDG 17 (Partnerships for the Goals) and can enhance the city's capacity to address complex sustainability issues.
  e. Policy Recommendations: Based on the research trends, policymakers should consider strengthening the integration of environmental and natural resource management considerations into urban development strategies, while continuing to address economic and social dimensions of sustainability. This approach would contribute to multiple SDGs, particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action).

This bibliometric analysis provides valuable insights into the current state and future directions of research on sustainable urban development and natural resource management in Medan City. By addressing the identified research gaps and building on existing collaborative networks, Medan can continue to develop innovative, sustainable solutions to its urban challenges, potentially serving as a model for other rapidly growing cities in Indonesia and beyond. Future research and policy efforts should focus on more explicitly addressing the full range of relevant SDGs, particularly those related to environmental sustainability and resource management, to ensure a comprehensive approach to urban sustainability in Medan.

5 Conclusion

This bibliometric analysis of sustainable natural resource management integration in urban development policies for Medan City reveals several key findings and implications for future research and policy development:
  1. Research Growth: There has been a significant increase in research output related to sustainable urban development and natural resource management in Medan over the past decade, particularly accelerating from 2020 onwards. This trend reflects growing awareness and prioritization of urban sustainability issues.
  2. Multidisciplinary Approach: The research landscape demonstrates a comprehensive approach to urban sustainability, encompassing urban design, policy implementation, economic considerations, and environmental management. This aligns well with the complex, interconnected nature of the Sustainable Development Goals (SDGs).
  3. Focus Areas: Urban design, policy implementation, and economic aspects of sustainability emerge as dominant themes in the research corpus. However, there is a relative underrepresentation of explicit environmental and natural resource management themes, suggesting an area for future research development.
  4. Collaborative Networks: The analysis reveals a strong collaborative research ecosystem centered around institutions in North Sumatra, with potential for expanding national and international partnerships to bring diverse perspectives to Medan's urban sustainability challenges.
  5. SDG Alignment: The research trends in Medan contribute to several SDGs, particularly SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals). However, there is room for more explicit focus on SDGs related to environmental sustainability and resource management.

6. Research Gaps: Future studies should address the identified gaps, particularly in relation to SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), and SDG 15 (Life on Land), to ensure a comprehensive approach to urban sustainability in Medan.
7. Policy Implications: The findings suggest a need for policymakers to strengthen the integration of environmental and natural resource management considerations into urban development strategies, while maintaining focus on economic and social dimensions of sustainability.
8. Knowledge Transfer: Medan's experiences and research outputs offer valuable lessons for other rapidly growing cities in Indonesia and beyond, contributing to the broader discourse on sustainable urban development in developing countries.

These findings contribute significantly to identifying both challenges and opportunities in sustainable urban development for Medan City. The challenges include the need for more comprehensive integration of environmental and natural resource management principles into urban policies, addressing research gaps in key areas such as water management and clean energy, and balancing economic development with ecological sustainability. Opportunities lie in leveraging the strong collaborative research ecosystem to foster innovation, expanding partnerships to bring diverse perspectives to urban challenges, and positioning Medan as a model for sustainable urban development in rapidly growing cities.

In conclusion, while Medan has made significant strides in researching and implementing sustainable urban development strategies, there remains considerable potential for further integration of natural resource management principles into urban policies. By addressing the identified research gaps, strengthening collaborative networks, and aligning future efforts more explicitly with all relevant SDGs, Medan can continue to develop as a model of sustainable urban development for other growing cities. This comprehensive approach will be crucial in navigating the complex challenges of urbanization while preserving natural resources and improving quality of life for its residents.

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