

Optimizing Geographic Information Systems for Evidence-Based Regional Development Planning in Indonesia: A Bibliometric Study

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Abstract: This study aims to analyze the development of research on Geographic Information Systems (GIS) in regional development planning through systematic and bibliometric analysis. Data were obtained from the Scopus database, comprising 116 articles published during 2014–2023 and selected using the PRISMA guidelines. Bibliometric analysis using VOSviewer identified publication trends, keyword co-occurrence, international collaboration, and research theme development. The results show that GIS research in regional development planning increased toward the end of the observation period, reaching approximately 25 publications in 2023. Keyword analysis indicates a shift from conventional themes such as urban planning and land use toward the integration of GIS with remote sensing, machine learning, climate change, and decision-making. International collaboration remains concentrated among China, the United States, and several European countries, while Indonesia has a relatively limited position. These findings indicate that GIS has evolved from a mapping technology into an analytical and decision-support instrument for evidence-based regional planning. The study contributes academically by mapping the intellectual and thematic development of GIS research and identifying emerging directions in the field. In the Indonesian context, the findings highlight the importance of strengthening geospatial infrastructure, human resource capacity, data governance, and inter-institutional collaboration to support more effective and sustainable regional development planning.

Keywords: *Geographic Information Systems, Regional Development Planning, Bibliometric Analysis, Sustainable Development, Indonesia*

INTRODUCTION

Geographic Information Systems (GIS) has developed into one of the technologies that plays an important role in supporting evidence-based regional development planning, especially in developing countries such as Indonesia that face the challenges of urbanization, inequality of development between regions, complexity of natural resource management, and increasingly dynamic environmental changes (Aydinoglu & Bovkir, 2020; Padre et al., 2023). Through GIS, governments can integrate and analyze various spatial information, such as population distribution, land use, infrastructure availability, environmental conditions, and potential

disasters in a more systematic manner to support more effective and accurate decision-making (Kasikoen et al., 2019; Das et al., 2018; Huan & Ngoc, 2023). The development of geospatial technology has also encouraged the change in the function of GIS from just a mapping tool to a decision support system that is able to improve the quality, efficiency, transparency, and accountability of development planning (Chatziioannou & Álvarez-Icaza, 2017). Therefore, the use of GIS is now one of the important components in realizing data-based development governance and supporting the achievement of sustainable development goals.

Indonesia has shown a strong commitment to strengthening geospatial information governance through the implementation of the One Map Policy. Until 2024, the policy has succeeded in integrating 151 thematic maps managed by 23 ministries/institutions and covering all 38 provinces in Indonesia. The implementation of the policy also succeeded in resolving the land use overlap of approximately 19.97 million hectares, which is an important foundation for the provision of an integrated national spatial database. However, the availability of national geospatial data and infrastructure has not been fully followed by the optimal use of GIS in the regional development planning process. Various local governments still face limitations in technological infrastructure, institutional capacity, human resource competence, and the integration of spatial data into planning documents such as Regional Medium-Term Development Plans (RPJMD) and Regional Spatial Plans (RTRW) (Bradley et al., 2015; Rahmawati et al., 2023). This condition is also reflected in the issuance of a Joint Circular Letter of Bappenas, the Ministry of Home Affairs, and the Geospatial Information Agency (BIG) in 2026 which aims to strengthen regional geospatial information governance. In addition, the results of the evaluation of the Electronic-Based Government System Index (SPBE) show that the maturity level of digital transformation of local governments still varies, indicating that the implementation of geospatial information has not been carried out evenly throughout Indonesia (Lalović, 2014).

This condition shows that the main challenge for GIS implementation in Indonesia no longer lies in the availability of geospatial data, but in the gap between the development of national geospatial infrastructure and the capacity of local governments to utilize GIS as the main instrument of evidence-based development planning (Isihak, 2023; Degkwitz et al., 2021). This gap is reflected in the lack of optimal organizational readiness, the limitation of human resources with geospatial competence, weak inter-agency coordination, and the lack of consistent integration of GIS in the process of formulating regional development policies (Milojevic-Dupont et al., 2020; Ihsan et al., 2021). In fact, various studies show that GIS has a very important ability in supporting the analysis of land use change, disaster risk mapping, environmental management, evaluation of infrastructure development, and the identification of socio-economic gaps between regions (Gallardo et al., 2014). Therefore, strengthening GIS implementation requires an approach that is not only oriented towards technology development, but also on increasing institutional capacity, strengthening regulations, developing human resources, and more integrated geospatial data governance (Sobieraj et al., 2023; De Cos et al., 2020).

Although research on GIS continues to develop across regional planning, environmental management, disaster mitigation, remote sensing, and digital governance, the existing literature remains fragmented across disciplinary and application-specific contexts. Most studies emphasize the technical application of GIS for particular planning problems, while relatively limited attention has been given to examining the broader development of the research field itself, including publication trends, international collaboration networks, thematic structures, and the evolution of research topics. Consequently, the intellectual structure of GIS research in relation to regional development planning remains insufficiently mapped. This limitation makes it difficult to identify how the research agenda has evolved from conventional spatial mapping toward data-driven decision support and integrated planning approaches. Therefore, a bibliometric analysis is needed to systematically identify the structure, relationships, and development of research in this field (Ye et al., 2019).

Based on the identified literature gap, this study addresses two related limitations in previous research. First, previous studies have predominantly examined GIS from specific technical or sectoral perspectives, such as land-use analysis, urban planning, environmental management, and disaster mitigation, rather than examining the overall intellectual development of GIS research in regional development planning. Second, limited attention has been given to connecting the global development of GIS research with the institutional and technological conditions required for its application in the Indonesian regional planning context. This study therefore offers novelty by systematically mapping the publication trends, thematic structures, keyword relationships, international collaboration networks, and temporal evolution of GIS research using Scopus-indexed publications and VOSviewer. Beyond identifying dominant research themes, the study interprets these developments in relation to the needs of evidence-based regional development planning in Indonesia. This approach provides a broader perspective that connects the development of GIS scholarship with institutional capacity, geospatial infrastructure, data governance, and inter-organizational collaboration.

METHOD

This study uses the Systematic Literature Review (SLR) approach combined with bibliometric analysis to identify research developments regarding the application of Geographic Information Systems (GIS) in regional development planning. The SLR approach is used to obtain literature in a systematic, transparent, and replicable manner, while bibliometric analysis is used to map the development of publications, collaborative networks, and research themes that develop in the field (Lawelai, 2023). The combination of these two approaches was chosen because it was able to provide a comprehensive overview of the development of GIS research as well as identify future research directions.

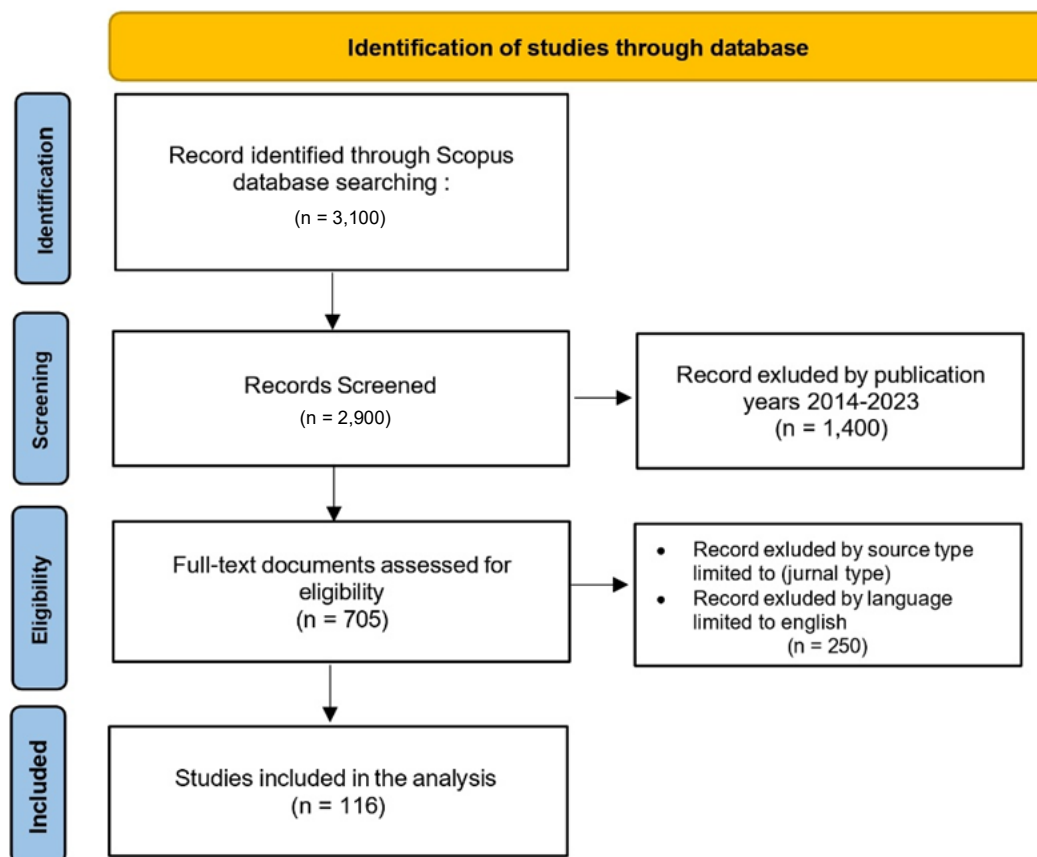


Figure 1. PRISMA

The research data was obtained from the Scopus database, which was chosen because it has a wide coverage of international scientific publications and provides complete metadata for bibliometric analysis (Huo et al., 2022). The literature search was conducted using the keywords "Geographic Information Systems" and "Regional Planning" with a publication period of 2014–2023. The initial search results resulted in 3,100 documents. The article selection process follows the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020). Of these, 200 duplicate documents were deleted, leaving 2,900 documents. Furthermore, 1,400 documents were issued because they did not match the range of publication years that had been set. A total of 1,500 documents were then evaluated based on inclusion criteria, namely journal articles that have gone through a peer review process, written in English, discuss the application of GIS in regional development planning, and have complete metadata. At this stage, 795 documents were excluded for not meeting the criteria based on document type, language, and topic relevance, leaving 705 articles eligible for further assessment. After the final screening of the suitability of the research substance, 116 articles were obtained which were used as data in bibliometric analysis, as presented in figure 1.

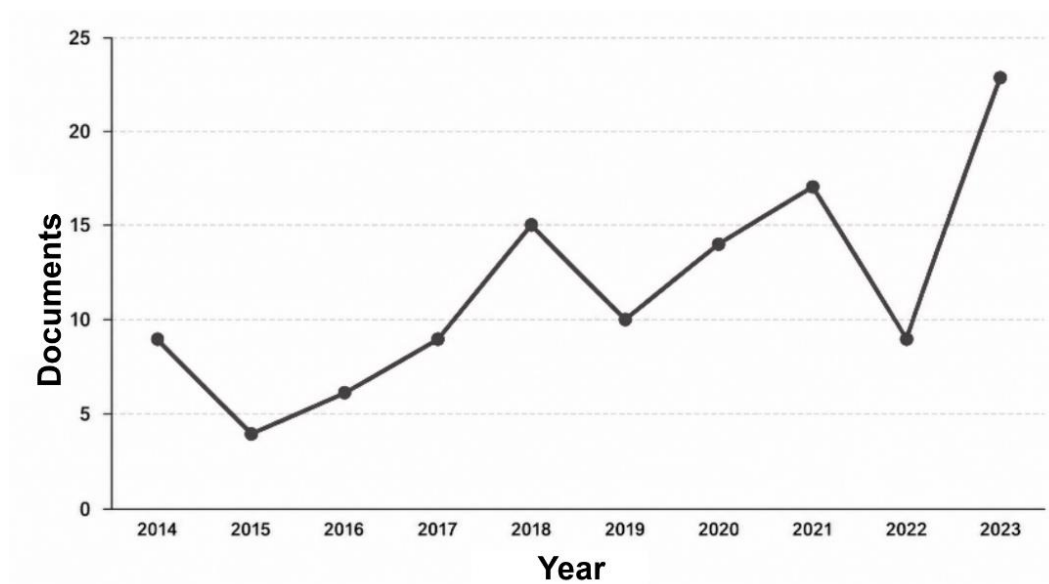
Bibliometric analysis was performed using VOSviewer software version 1.6.20 to visualize the knowledge structure and relationships between scientific publications (Xu, 2021). The analysis carried out includes co-occurrence analysis to identify dominant keywords and research theme clusters, co-authorship analysis to map the patterns of collaboration between authors, institutions, and countries, and citation analysis to identify the most influential publications and authors in GIS studies and regional development planning (Wang et al., 2019). The results of the analysis were visualized in the form of network visualization, overlay visualization, and density visualization to illustrate the development and relationship between research themes. Furthermore, the results of bibliometric analysis are interpreted descriptively by linking the development of global research to the context of regional development planning in Indonesia. The interpretation is focused on identifying research trends, research gaps, research development opportunities, and policy implications that can support strengthening the use of GIS in the preparation of regional planning documents, such as Regional Medium-Term Development Plans (RPJMD) and Regional Spatial Plans (RTRW).

RESULT AND DISCUSSION

Publication Trends in GIS and Regional Development Planning

Figure 2 presents the annual distribution of GIS research in regional development planning during 2014–2023. Publications fluctuated across the observation period, with increases in several years and a notable rise in 2023 to approximately 25 documents. This pattern indicates sustained academic attention to GIS in regional development planning and reflects the growing need for spatially explicit information to address increasingly complex planning problems (Lalović, 2014; Zhu et al., 2022). The fluctuations in publication output also reflect the development of global issues and the increasing need for spatial technology to support planning challenges such as urbanization, climate change, disaster mitigation, and environmental degradation (Ginardi et al., 2017; Kasikoen et al., 2019).

The publication trend indicates that GIS research in regional development planning has gradually become more closely associated with broader transformations in planning practices. The increase in publications toward 2023 suggests that GIS is increasingly positioned within discussions of data-driven planning, digital transformation, environmental management, and decision support rather than being treated solely as a cartographic technology. This development is consistent with previous studies emphasizing the expanding role of geospatial technology in addressing complex regional development problems. The surge in 2023 further indicates that GIS is increasingly viewed as a strategic instrument that supports decision-making and sustainable development planning (Degkwitz et al., 2021).



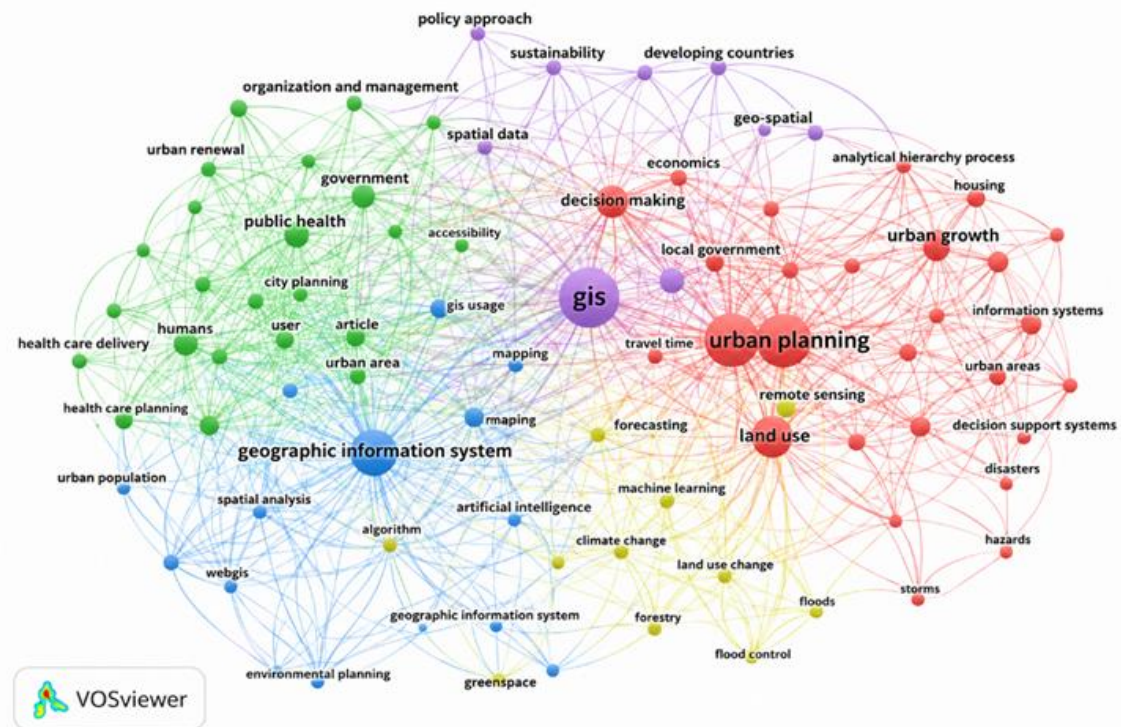
Source: Scopus Database, 2024

Figure 2. Documents by Year (2014-2023)

This, the observed increase in publications reflects not only greater academic interest but also the growing complexity of planning problems that require spatially explicit information. From a regional development perspective, this trend is significant because planning decisions increasingly require the integration of multiple spatial and non-spatial datasets. The development of GIS research therefore indicates a broader transition toward evidence-based planning, in which spatial information can support the analysis of regional disparities, land-use patterns, infrastructure needs, environmental management, and disaster mitigation. This interpretation extends previous studies that examined GIS applications in specific sectors by demonstrating, at the bibliometric level, that these applications are becoming part of a wider and increasingly interconnected research agenda. For Indonesia, this trend provides an opportunity to strengthen the integration of GIS into national and regional development planning, particularly in improving the quality of planning analysis, resource management, disaster mitigation, and data-driven public decision-making (An, 2023; Aydinoglu & Bovkir, 2020; Widjajanti & Damayanti, 2020).

Thematic Structure of GIS Research and Cross-Sectoral Relevance

Figure 3 shows the network visualization based on keyword co-occurrence analysis using VOSviewer. The results indicate that research on Geographic Information Systems (GIS) and sustainable regional planning forms several interconnected themes. The keywords GIS, urban planning, land use, and remote sensing emerge as dominant themes with a high level of connectivity, indicating that the intellectual structure of the field remains strongly rooted in spatial analysis, land-use mapping, and regional planning (Cahya et al., 2018; Martín-Gómez et al., 2015). At the same time, the network shows connections between GIS and themes related to public health, environmental management, climate change, and urban issues. This pattern indicates that the application of GIS has expanded from supporting spatial mapping toward addressing multidimensional regional development problems, including public health, public service equity, and urban area management (Chung et al., 2018).



Source: Data Processing Using VOSviewer, 2024

Figure 3. Network Map Visualization network co-occurrence all keywords

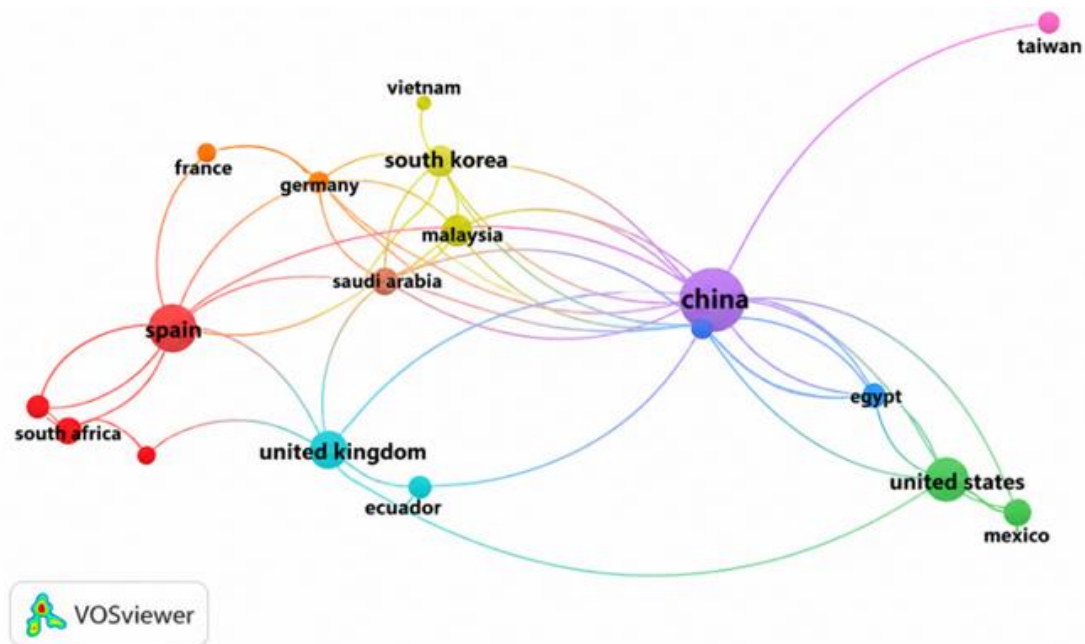
The interconnectedness among spatial, social, economic, and environmental themes further indicates that GIS research is developing toward a more integrated analytical approach. The close relationship between GIS and themes such as green open space, climate change, and environmental management demonstrates increasing research attention to the use of spatial information for sustainable environmental management, climate change mitigation, and adaptive development policy formulation (García-Ayllón & Martínez Marí, 2015). This finding is also consistent with research emphasizing the multidisciplinary use of GIS to integrate different dimensions of regional problems within a spatial framework (Ranabhat & Paudyal, 2019). Therefore, the network structure identified in Figure 3 suggests that GIS is no longer positioned only as a technical mapping technology, but increasingly as an analytical platform that connects different sectors and types of regional information.

From the perspective of regional development planning, these findings have important implications for the role of GIS as a decision-support instrument. The high connectivity among keywords indicates that GIS research is increasingly oriented toward integrating information from different development sectors to support evidence-based planning and policy formulation (Lee & Kim, 2018). In the Indonesian context, this thematic structure indicates potential for strengthening the integration of GIS into regional development planning, particularly in spatial management, environmental quality improvement, public health, disaster mitigation, and sustainable development (Das et al., 2018). Thus, the bibliometric findings extend previous sector-specific studies by showing that the various applications of GIS are not isolated themes, but form an increasingly interconnected research agenda for integrated and sustainable regional development planning.

International Research Collaboration and Indonesia's Position

Figure 4 shows the pattern of international collaboration in Geographic Information Systems (GIS) research based on co-authorship networks between countries. The visualization results show that China occupies a central position in the collaboration network, with connections to countries such as the United States, Taiwan, and Malaysia. This position indicates

that China functions as an important collaboration hub in GIS research, providing broader opportunities for knowledge exchange, methodological development, and joint publications with international institutions. In addition to China, several countries in Europe and Africa also form relatively strong collaborative networks, indicating that GIS research has developed through cross-border cooperation. These findings suggest that international collaboration is an important component of GIS research, particularly because regional development issues such as climate change, disaster mitigation, natural resource management, and sustainable urban planning often require knowledge and approaches that extend across national boundaries (Wanyan et al., 2023).



Source: Data Processing Using VOSviewer, 2024

Figure 4. Network visualization co-authorship by country

The structure of the collaboration network also has implications for the development of research capacity and knowledge transfer. Countries with more extensive collaborative relationships have greater opportunities to access specialized expertise, geospatial data, analytical methods, and technological innovations, which can contribute to the development of research quality and methodological capacity (Liu et al., 2020). In contrast, Indonesia shows a relatively limited position in the global collaboration network. This condition indicates that Indonesian researchers have fewer connections within the international GIS research network compared with the more central countries. Strengthening collaboration with foreign universities, research institutions, and other relevant organizations may therefore provide opportunities for joint research, researcher exchange, and human resource development (Guechi et al., 2023). The finding is relevant to the development of GIS capacity because international collaboration can complement domestic resources through access to knowledge, methodologies, datasets, and technological practices.

From the perspective of regional development planning, the collaboration pattern demonstrates that strengthening GIS capacity involves not only technological infrastructure but also institutional and knowledge networks. For Indonesia, greater engagement with international research networks can facilitate the adaptation of analytical approaches and geospatial technologies to national and local planning contexts. At the local government level, knowledge transfer and institutional partnerships may support improvements in spatial planning, environmental management, disaster mitigation, and the provision of spatial-information-based public services. Such collaboration can contribute to the development of

(Farooq et al., 2022). Thus, the contribution of this finding lies primarily in identifying the direction of the research agenda and areas requiring further empirical investigation.

In the context of this study, the emergence of machine learning, remote sensing, and decision-making keywords in more recent periods indicates that GIS research is increasingly directed toward integrating spatial analysis with digital technologies to support evidence-based regional planning (evidence-based planning) (Cahya et al., 2018). For Indonesia, this development provides opportunities to strengthen the use of GIS in regional development policy formulation through the integration of geospatial data, remote sensing technology, and analytical methods capable of producing more accurate information for decision-making processes (Lestari et al., 2018). However, these bibliometric findings do not by themselves demonstrate successful implementation of such technologies in Indonesia. Rather, they identify emerging research directions that can inform future empirical studies on how these technologies can be adapted and implemented within regional development planning.

Policy Implications for Regional Development Planning in Indonesia

Based on the results of the bibliometric analysis, the development of GIS research shows a shift from its use as a mapping tool toward a decision-support system integrated with climate change, public health, environmental management, and technological analytics. These findings have implications for strengthening regional development planning in Indonesia. The policy implications identified in this study are derived from the convergence of three bibliometric findings: the increasing publication trend, the expansion of GIS research themes toward analytical and decision-support technologies, and the structure of international research collaboration. Together, these findings indicate that strengthening GIS for regional development planning requires technological, institutional, human resource, and collaborative capacities.

First, geospatial infrastructure needs to be strengthened according to regional readiness. The increasing use of GIS to support evidence-based planning indicates that regions with limited spatial data infrastructure, information networks, and integrated systems may face constraints in adopting GIS-based planning approaches (Das et al., 2018). Therefore, the central government needs to assess the level of digital readiness across regions as a basis for determining investment priorities. Infrastructure support can consequently be provided according to regional needs and capacity rather than through a uniform approach (Mulya, 2022).

Second, human resource capacity development needs to be aligned with the emerging direction of GIS research. The overlay analysis shows increasing attention to remote sensing, machine learning, and decision-making, indicating that training should extend beyond the use of basic GIS software (Huan & Ngoc, 2023). Local governments need to develop competencies in geospatial analysis, remote sensing data processing, the use of spatial data for policy evaluation, and the integration of GIS into planning documents such as RPJMD and RTRW. Such capacity development would make human resources more responsive to the analytical requirements identified in the development of GIS research (Acar & Kaya, 2023).

Third, the integration of GIS into the planning process needs to be supported by clear institutional mechanisms. The thematic findings show that GIS research is increasingly connected with public health, climate change, green open spaces, and environmental management (Prado et al., 2021). This development indicates that GIS applications extend across multiple policy sectors and therefore require coordination among regional apparatus organizations (Ginardi et al., 2017; Degkwitz et al., 2021). Local governments can strengthen this integration by establishing geospatial data sharing mechanisms, developing spatial data standards, and incorporating GIS analysis into the formulation, monitoring, and evaluation of regional development policies.

Fourth, research collaboration needs to be strengthened through partnerships among relevant institutions. The co-authorship analysis shows that international GIS research is characterized by collaboration involving countries such as China, the United States, and several European countries, while Indonesia has a relatively limited position in the network (Aydinoglu & Bovkir, 2020). This finding indicates the relevance of strengthening partnerships among local

governments, universities, research institutions, and Geospatial Information Agency (BIG), as well as expanding international cooperation through joint research, data exchange, and geospatial technology development. Such partnerships can facilitate knowledge transfer and the adaptation of relevant practices for regional planning (Ma et al., 2023).

Overall, the bibliometric findings indicate that the development of GIS for regional planning involves more than the provision of technological tools. The convergence of publication trends, emerging research themes, and collaboration networks highlights the importance of developing a broader geospatial ecosystem encompassing infrastructure, human resources, data governance, and inter-institutional collaboration. For regional development planning in Indonesia, this approach provides a basis for strengthening the use of spatial information in planning and decision-making processes and for supporting more adaptive and sustainable development planning.

CONCLUSIONS

This study examined the development of Geographic Information Systems (GIS) research in regional development planning through a bibliometric analysis of 116 Scopus-indexed publications published between 2014 and 2023. The findings demonstrate the dynamic development of GIS research, particularly its integration with remote sensing, machine learning, climate change, environmental management, and decision-making. Co-occurrence analysis identifies GIS, urban planning, land use, and remote sensing as central themes connecting various regional development issues. Meanwhile, co-authorship analysis indicates that international collaboration remains concentrated among several major research-producing countries. This study addresses the research gap by mapping the intellectual, thematic, temporal, and collaborative development of GIS research within a single bibliometric framework. Unlike previous studies that focus primarily on specific technical or sectoral applications, this study integrates publication trends, keyword relationships, thematic evolution, and international collaboration. Its novelty lies in connecting global research patterns with evidence-based regional development planning in Indonesia. Academically, this study demonstrates the evolving intellectual structure of GIS research and the growing connections between spatial planning, environmental issues, technological innovation, and decision-support approaches. These findings position GIS as an evolving analytical and knowledge infrastructure rather than merely a technical mapping instrument.

The practical contribution of this study concerns the institutional conditions needed to translate research developments into regional planning practice in Indonesia. The findings highlight the importance of strengthening geospatial infrastructure, human resource competencies, data governance, and inter-institutional collaboration. These capacities should be developed according to the characteristics and readiness of individual regions rather than through a uniform implementation model. The bibliometric findings also provide a basis for identifying emerging research directions, particularly the integration of GIS with remote sensing, machine learning, climate change, and decision-making. Therefore, GIS development should be understood not only as a technological issue but also as an institutional capacity-building process. This perspective supports the use of GIS for evidence-based planning and informed decision-making. It also extends the role of GIS beyond conventional mapping toward integrated analytical and decision-support functions in regional development planning.

Nevertheless, this study has several limitations. First, the analysis relies exclusively on Scopus-indexed publications. Consequently, it may not fully represent research published in other databases or national journals not indexed by Scopus. Second, bibliometric analysis identifies patterns in the scientific literature but does not directly measure GIS implementation by regional governments. Future research should complement bibliometric analysis with empirical studies at regional and local government levels. Comparative case studies could examine how GIS is integrated into development planning and how institutional capacity

influences geospatial data management. Further research could also investigate the factors affecting the adoption of emerging technologies, including remote sensing and machine learning. These investigations would deepen understanding of the relationship between GIS scholarship and its practical implementation. They could also identify the institutional, technical, and contextual factors that shape the application of GIS in regional development planning.

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CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest related to the research, authorship, or publication of this manuscript.

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