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INTEGRATION OF GEOSPATIAL DATA IN EDUCATION MANAGEMENT SYSTEMS: A MULTIPLE STUDY IN EASTERN JAVA REGIONS, INDONESIA

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Abstract: This study aims to analyze the integration of geospatial data into the education management system through a multi-case study in three regions of East Java in Indonesia, namely Surabaya City, Malang City, and Jember Regency. In line with SDGs 4, this study strategically applies GIS to advance equitable access to education by reducing spatial disparities across East Java's metropolitan and non-metropolitan regions. This study adopted a quantitative approach, calculating student–teacher–school ratios at a sub-district level and referencing national education standards using official statistical datasets. The research employs a spatial analysis approach using Geographic Information Systems (GIS) through the map of Education Spatial Index (ESI) to assess the alignment between the distribution of educational facilities and the spatial distribution of students at the kindergarten, elementary, junior high, and senior high school levels. The results show that the study also evaluates the distribution of higher education institutions within a 100-kilometers radius to measure accessibility to tertiary education. The findings indicate that urban areas such as Surabaya and Malang generally exhibit an ideal ESI across most education levels, whereas Jember continues to display significant disparities, particularly at the primary and secondary levels. Several areas across the three regions remain categorized as either overloaded or critically underserved, suggesting pressure on educational service systems as well as deficiencies in infrastructure. Regarding higher education, institutions are predominantly concentrated in metropolitan areas, while certain regencies lack access to public universities within the coverage radius. These results highlight pronounced spatial disparities in educational access and equity across the study regions.

Keywords: Geospatial data integration, Geographic Information Systems (GIS), Educational accessibility, Spatial analysis, Spatial disparity

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INTRODUCTION

Education plays a strategic role in improving the quality of human resources; therefore, the existence and equitable distribution of educational facilities must be ensured (Prasetyo et al., 2022; Putri & Abdullah, 2021; Widiharti et al., 2019). This agenda aligns with the 2030 Sustainable Development Goals (SDGs) point 4, which emphasize reducing disparities in access to education (Holst et al., 2024). To achieve this objective, education planning can leverage geospatial data and evidence-based Geographic Information Systems (GIS) to formulate more effective policies tailored to local contexts (Aggarwal et al., 2024; Kumar et al., 2014). GIS not only provides spatial visualization but also offers in-depth analyses to identify priority areas, such as regions vulnerable to school dropouts or lacking infrastructure (Barber et al., 2024; Merchant et al., 2013), including non-metropolitan zones that often lag despite substantial investment (von Hanxleden & Wedemeier, 2019). Furthermore, GIS facilitates spatial data integration for zoning planning, facility mapping, and education access evaluation, while improving transparency and accuracy in determining new school locations (Murad et al., 2020; Ruhimat et al., 2024). The analytical capacity of GIS has grown significantly over time, encompassing predictive modeling and real-time monitoring that enable governments to respond swiftly and accurately to social, economic, and environmental changes (Salim & Sandy, 2023). In this context, GIS has become an essential tool for supporting knowledge-intensive decision-making processes (Prastiyono &

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Trisliatanto, 2018). By harnessing these capabilities, education planning can be executed with greater precision, including school siting decisions based on student travel distance, population density, and land-use patterns, thereby enhancing the equity of educational service provision (Purwadhi, 2019; Sumarah & Tiara Wulandari, 2023). GIS-based education management planning is particularly relevant for East Java Province, which faces complex geographical and demographic challenges, particularly disparities between urban and rural access. To address these issues, this study employs a multi-case approach focusing on Surabaya City, Malang City, and Jember Regency. This approach allows for cross-context comparisons to strengthen the validity of policy recommendations (Takyi et al., 2025). Surabaya represents a metropolitan area characterized by rapid urbanization and expansion of the ”Gerbangkertosusila” (abbreviation for the regencies and cities near) region (Purnama, 2025; von Hanxleden & Wedemeier, 2019); Malang is recognized as an educational hub with its Tri Bina Cita development framework (Aliman et al., 2019; Sopiah et al., 2025); while Jember exemplifies a non-metropolitan region with diverse geographical conditions affecting access to educational services (Afidah, 2020; Tjahjandari et al., 2019). The combination of these three cases provides a comprehensive picture of spatially informed education policy implementation in East Java.

Although the central government, through the Geospatial Information Agency (BIG) and the Ministry of Education, Culture, Research, and Technology Republic of Indonesia, has initiated geospatial data integration, its implementation at the local level remains suboptimal and underexplored in empirical research. Spatial data, however, holds significant potential to support teacher distribution management, zoning for student admissions, and the development of educational facilities (Musadad & Purwanta, 2023). Therefore, this study seeks to fill the existing literature gap while providing practical recommendations for local policymakers to design adaptive, responsive, and equitable education management systems.

According to Indonesia’s Law Number 4 of 2011, geospatial data refers to information concerning the location, dimensions, and/or characteristics of natural or artificial objects on the Earth's surface. Such data can be derived from various sources, including satellite imagery, weather sensors, mobile devices, digital maps, and social media platforms (Mihály et al., 2021). As geospatial data is processed, it transforms into geospatial information. This information can then be used to formulate policies, make decisions, or implement activities related to spatial planning. The management of geospatial data and information relies on a Geographic Information System (GIS) that focuses on processing and analyzing spatial data, distinguishing it from general information systems (Hansen, 2025). A Geographic Information System (GIS) use a computer-based information system designed to manage and analyze data with spatial references. GIS functions to record objects, activities, and locations while providing analytical tools to understand spatial relationships and dynamics on the Earth's surface (Ummah, 2019a). GIS not only facilitates the visualization of spatial data but also enables the analysis of distributions, hot spots, and clustering, which are essential for ensuring equitable service provision (Azzahra et al., 2023).

GIS comprises two main components: spatial and attribute data for phenomenon analyze (Ramaano, 2025). The implementation of GIS in public policy is crucial, as it provides a platform for in-depth spatial analysis. This enables decision-makers to understand inter-object relationships and design effective development strategies.

A major challenge often encountered in the education sector is the lack of accurate and real-time information regarding school locations, available facilities, and the physical conditions of school buildings (Ul Jannah et al., 2025). Therefore, one key application of GIS is school mapping, which plays a vital role in more targeted and efficient planning and management of educational resources (Ana et al., 2020). The development and planning of equitable education services must be rooted in the principle of spatial-based educational access. GIS is employed to identify underserved areas, analyze student travel distances, and objectively establish school zoning (Ahmad Ansar, 2024; Hansen, 2025).

MATERIALS AND METHODS

To analyze the capacity and disparities in educational services within the study areas, a quantitative approach was employed by calculating the ratios of students, teachers, and schools at the sub-district level.

All ratios were spatially analyzed using QGIS software (Maymuna et al., 2025). This study employed multiple datasets obtained from from Statistics Indonesia Bureau in 2021, specifically educational data for the 2020/2021 academic year (kindergarten, elementary, junior high, and senior high schools) at the sub-district level.

The analytical technique for calculating these ratios refers to the National Education Standards (SNP) (Helda & Syahrani, 2022) as outlined in the Regulation of the Minister of Education, Culture, Research, and Technology of Republic of Indonesia Number 25 of 2024 on the Fulfillment of Workload Requirements for Teachers, Principals, and School Supervisors (Rohmah, 2024). The ratio formula and the ideal category for each indicator are presented in Table 1.

Tabel 1. Ratio Formula and Ideal Categories (Source: Indonesian National Education Standards)

Ratio Formula	Ideal Categories
a. Student-to-Teacher Ratio (STR) to measure the teaching workload per teacher	
$STR = \frac{Number\ of\ Students}{Number\ of\ Teachers}$	Kindergarten : 15 students/teacher Elementary School : 20-28 students/teacher Junior High School : 20-30 students/teacher Senior High School : 25-32 students/teacher
b. Student-to-School Ratio (SSR) to indicate the level of capacity utilization of an educational institution	
$SSR = \frac{Number\ of\ Students}{Number\ of\ Schools}$	Kindergarten : 50 students/school Elementary School : 200-300 students/school Junior High School : 250-300 students/school Senior High School : 300-500 students/school

Scoring dan Weighting

After the ratios were calculated, as shown in Table 2, the Student–Teacher Ratio (STR) falls into different categories based on the established criteria. As presented in Table 3, the Student–School Ratio (SSR) is divided into several categories. These categories are according to the applied standards.

Table 2. The Category of Student–Teacher Ratio (STR) (Source: Modification Indonesian National Education Standards by Author, 2025)

Score	Category	KG	ES	JHS	SHS	Color
1	Very Low	<10	<15			
2	Low	10-12	15-20			
3	Ideal	12-15	20-28			
4	*Overload*	>15	>28			

Table 3. The Category of Student–School Ratio (SSR) (Source: Modification Indonesian National Education Standards by Author, 2025)

Score	Category	KG	ES	JHS	SHS	Color
1	Very Low	<30	<150			
2	Low	30-35	150-250			
3	Ideal	35-50	250-400		250-500	
4	*Overload*	>50	>400		>500	

Subsequently, a composite weighting of the Education Spatial Index (Lange & Alves, 2011) was applied to generate a single final value for each sub-district or region using the following formula:

$Education\ Spatial\ Index = \{(w1 \times STR\ Score) + (w2 \times SSR\ Score)\}$ Description: w1 = 0.6; w2 = 0.4

As shown in Table 4, the Educational Spatial Index (ESI) is categorized into several levels that reflect spatial disparities.

Table 4. The Classification of Educational Spatial Index

Weight	Category	Description
< 3	Very Low	Indicates inefficiency or potential resource waste.
3 - 5	Low	Still tolerable but requires monitoring.
5 - 8	Ideal	Indicates distribution aligned with national standards.
> 8	*Overload*	Indicates lack of facilities/teachers and risk of declining service quality.

RESULTS AND DISCUSSION

The main findings of this study are presented through the interpretation of spatial data using the map of Education Spatial Index (ESI) as a metric for assessing the equity of educational service provision at the district/city level. The integration of geospatial data in the form of the ESI's map identifies disparities in the distribution of educational facilities based on weighted ratios of student enrollment and the availability of educational institutions (SSR) as well as teaching staff (STR). This approach enables an evaluation of the existing educational conditions at various levels, providing a strategic foundation for formulating targeted policy interventions to improve both accessibility and quality of education across regions (Zhao & Lam, 2026). The map of the Education Spatial Index (ESI) employs four color categories are used: green indicates ideal conditions, red indicates overload, orange represents low conditions, and yellow signifies very low conditions. Based on the Education Spatial Index (ESI) map, the overall distribution of educational services in Surabaya City is relatively equitable, particularly at the elementary school level. However, there remain significant spatial disparities, especially at the kindergarten and senior high school levels (Figure 1).

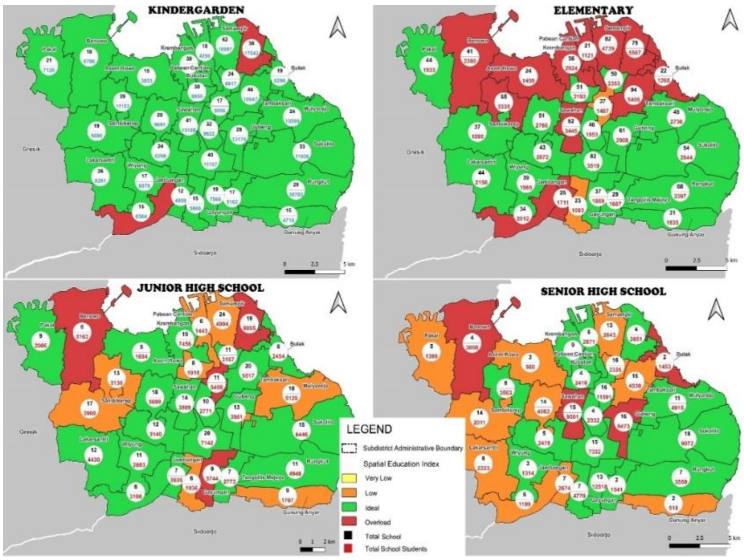

Figure 1. The Map of Spatial Education Index in Surabaya City, Academic Year 2020/2021 (Source: Original data from researchers)

These findings highlight the need for more strategic, spatially informed policy interventions. At the kindergarten level, 17 sub-districts in Surabaya fall into the ideal ESI category, whereas 12 sub-districts are categorized as overloaded, particularly in the northern and western areas (a). In addition, two sub-districts are categorized as low, indicating an insufficient number of adequate educational institutions. This condition reflects that access to early childhood education services is not yet fully equitable. At the elementary school level, the ESI demonstrates the most balanced distribution, as the majority of sub-districts fall into the ideal category (b). Nevertheless, two sub-districts, Karangpilang and Kenjeran, experience overload due to population growth. Such overload conditions continue to serve as indicators of local imbalances that warrant policy attention. At the junior high school level, spatial complexity increases. Nineteen sub-districts fall into the ideal ESI category; however, four sub-districts (Benowo, Kenjeran, Genteng, and Wonocolo) are categorized as overloaded (c), and eight sub-districts fall into the low category. This situation indicates a dual challenge: on one hand, there are sub-districts experiencing overcapacity, while on the other hand, there are areas lacking sufficient infrastructure and educational services. The issue of spatial disparities at the senior high school level is even more pronounced. Sixteen sub-districts fall into the ideal ESI category, four are categorized as overloaded, and eleven are categorized as low (d).

The overload category indicates areas experiencing capacity pressures due to high student concentrations or the presence of elite schools that attract students from outside the local area. Meanwhile, the low category reflects sub-districts with insufficient numbers of schools and teachers. These disparities risk creating spatial exclusion, particularly for students from low-income families. Proportion are categorized as low and overload, indicating an number of in balance educational institutions (Vidi & Azizu, 2020). Based on the ESI analysis, Surabaya City has successfully established a relatively strong foundation for educational equity at the elementary school level and, to some extent, at the junior high school level.

Nevertheless, disparities remain a significant challenge, particularly at the kindergarten and senior high school levels. Therefore, the integration of spatial data–driven approaches is crucial to enable local governments to design policies that are more adaptive and responsive to local needs, ensuring that every child has access to equitable, inclusive, and high-quality education. The analysis of the Education Spatial Index (ESI) map in Malang City reveals varying dynamics of educational service equity across different school levels (Figure 2).

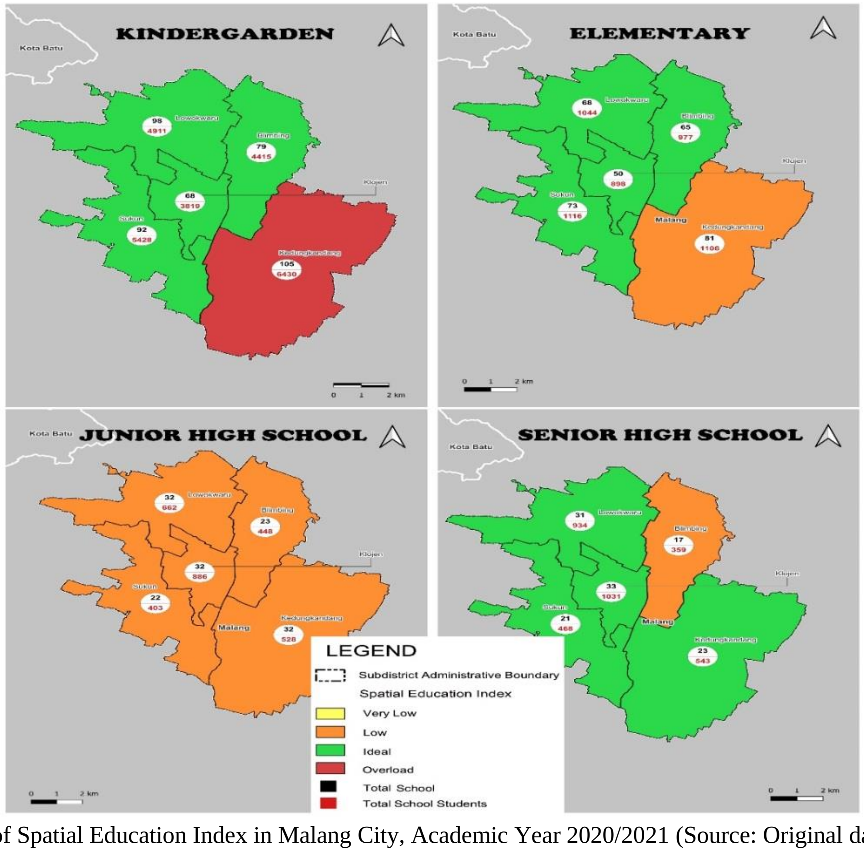

Figure 2. The Map of Spatial Education Index in Malang City, Academic Year 2020/2021 (Source: Original data from researchers)

The findings indicate that there has been partial success in the spatial management of educational infrastructure. However, they also highlight structural challenges that must be addressed through data-driven policies. The spatial distribution of kindergarten education services in Malang City demonstrates relatively strong performance. Four out of five sub-districts—Lowokwaru, Blimbing, Klojen, and Sukun—fall into the ideal ESI category (a). Kedungkandang Sub-district, however, falls into the overloaded category, indicating that student numbers exceed the capacity of institutions or available teaching staff. This condition underscores the need for spatial interventions in educational service development plans, capacity strengthening of existing institutions, or rezoning to prevent regional disparities. The ESI pattern at the elementary school level is similar: four sub-districts fall into the ideal category, while Kedungkandang is categorized as low (b). This phenomenon may be attributed to various factors, including limited spatial access to educational institutions due to their concentration in certain areas, uneven regional development, or deficiencies in supporting infrastructure. At the junior high school level, most sub-districts in Malang City fall into the low ESI category (c).

This situation may reflect limited spatial access to educational institutions due to school concentration in certain areas, uneven regional development, or suboptimal supporting infrastructure. Such spatial disparities have the potential to undermine the effectiveness of zoning policies and increase student mobility burdens. At the senior high school level, the ESI distribution shows that four sub-districts—Kedungkandang, Klojen, Lowokwaru, and Sukun—fall into the ideal category (d), while Blimbing is categorized as low. This situation may be attributed to disparities in access to senior high schools, such as inadequate school distribution or population growth among high school–age students that has not been sufficiently addressed by the construction of new schools. Overall, the ESI findings for Malang City indicate that most areas have achieved spatial balance at the kindergarten, elementary, and senior high school levels.

However, persistent the persistence of overload in Kedungkandang Sub-district, in conjunction with the consistent low ESI values across all junior high schools in the sub-district, underscores the urgent necessity for local government intervention to prevent the emergence of social disparities. Consequently, this spatially informed approach is crucial to ensuring that every student, regardless of geographic location, enjoys equal rights to inclusive, equitable, and high-quality education (Lajçi & Kuqi, 2025; Muhaimin et al., 2022). The Education Spatial Index (ESI) in Jember Regency reveals highly uneven distribution of educational facilities across different school levels and geographic areas (Figure 3).

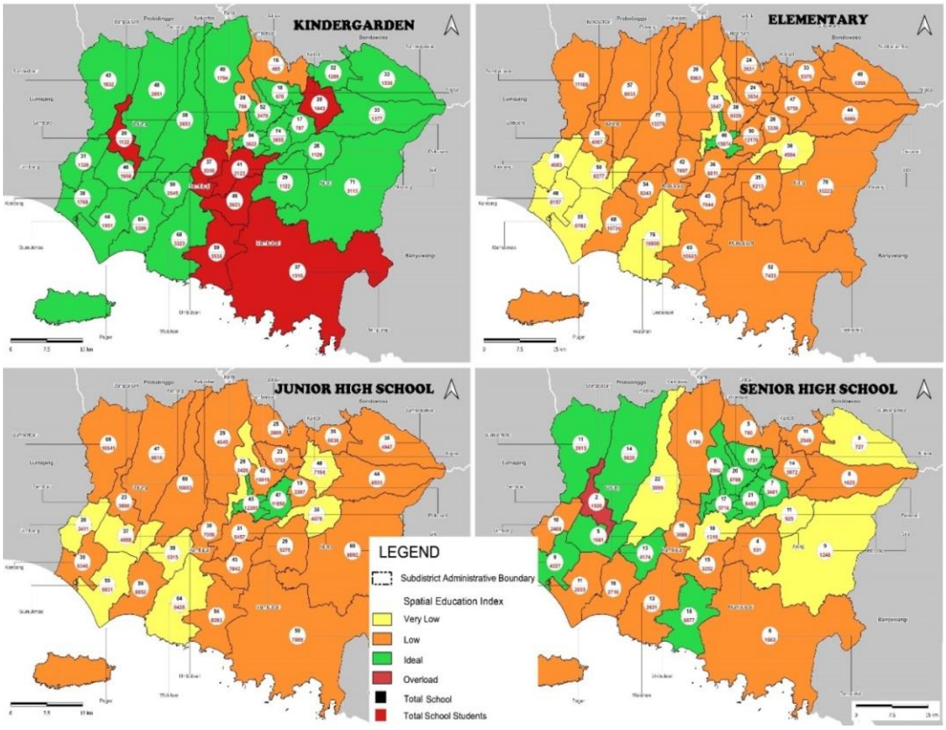

Figure 3. The Map of Spatial Education Index in Jember Regency, Academic Year 2020/2021 (Source: Original data from researchers)

At the kindergarten level, most sub-districts in Jember have reached the ideal ESI category (a). However, several sub-districts, particularly in the southern and central regions, fall into the overload category, likely due to high student density. Additionally, Jelbuk and Kaliwates Sub-districts are categorized as low because of insufficient educational services. These conditions underscore the need for more adaptive spatial planning to balance kindergarten services between densely populated areas and underserved regions. At the elementary school level, spatial disparities are pronounced, as most sub-districts in Jember are classified as low, with several others categorized as very low (b). Only Kaliwates Sub-district falls into the ideal category. This condition indicates that the issue lies not only in the overall number of schools but also in the uneven distribution of teachers and educational institutions throughout the region. At the junior high school level, most schools fall into the low and very low ESI categories (c), with only Kaliwates and Sumbersari classified as ideal due to their location in the urban core. The key challenge in Jember Regency is not about overcapacity, but rather limited access to educational services across many areas, requiring strategic efforts to equalize junior high school availability between regions.

At the senior high school level, clear differences exist in both availability and distribution of schools (d). Several sub-districts, such as Kaliwates, Patrang, and Sumbersari, fall into the ideal ESI category. However, most sub-districts remain in the low category, indicating that upper-secondary education services are still unevenly distributed across Jember Regency. A few sub-districts are even classified as very low, reflecting significant infrastructure and service gaps, while Semboro is recorded as the only sub-district in the overload category. This spatial disparity pattern demonstrates that SMA-level education access remains concentrated in the central and western parts of Jember, whereas the southern, eastern, and northeastern regions are lagging in terms of infrastructure and service coverage.Overall, the ESI in Jember Regency highlights the spatial distribution of educational institutions as a central issue in achieving equitable education services. Each education level presents distinct challenges. Therefore, local government authorities can use these ESI data as a basis for formulating more responsive policies to address spatial inequalities. Through strategies such as establishing new schools in deficit areas, redistributing teachers, enhancing regional connectivity, and reformulating zoning systems that are adaptive to local geographic and demographic characteristics (Iranmanesh & Mousavi, 2022; Shrestha et al., 2023).

Map of Higher Education Distribution

The analysis of higher education distribution in East Java demonstrates the impact of constrained public access to quality tertiary education, emphasizing the necessity for more targeted and spatial data-driven policies to advance equitable development of educational infrastructure. This map (see figure 4) serves as a strategic tool for identifying priority areas for higher education development while also supporting education planning initiatives across East Java.

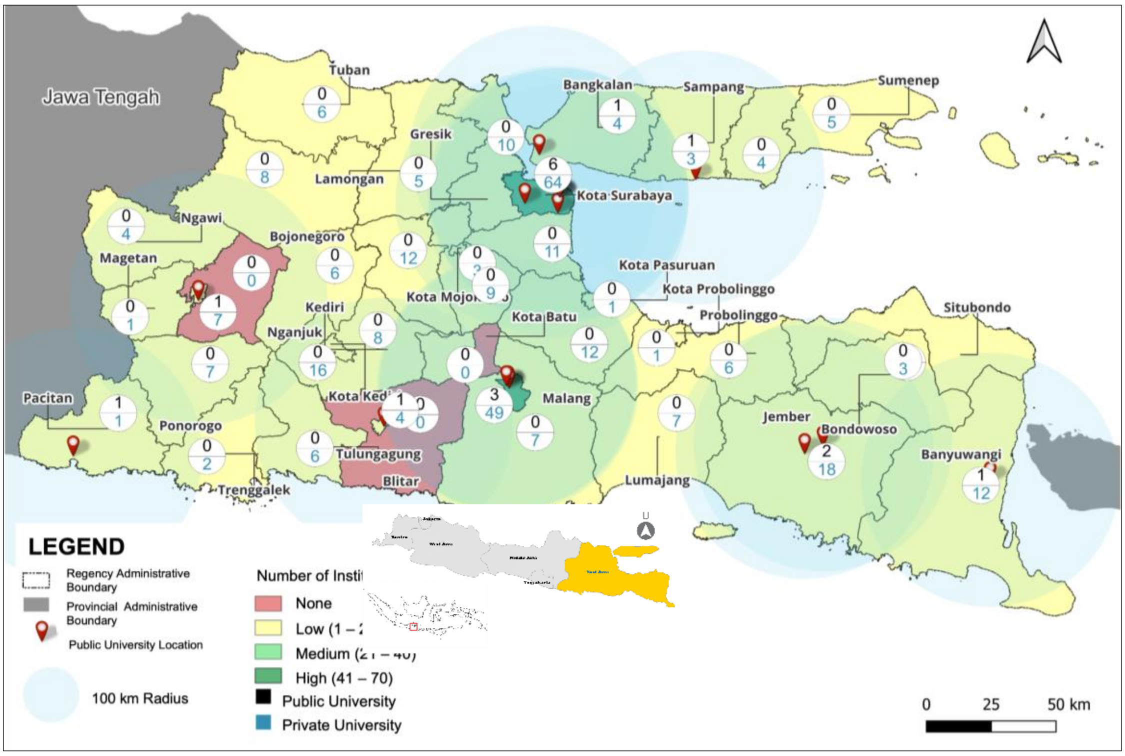

Figure 4. The Map of Higher Education Institutions Distribution in East Java Province, Indonesia (2022)

The distribution map of higher education institutions in East Java Province in 2022 reveals a marked disparity in the spatial distribution of tertiary education facilities. The highest concentration is observed in major urban centers such as Surabaya and Malang, which host 70 and 52 higher education institutions, respectively, within a 100-kilometer radius. This pattern indicates that access to tertiary education remains largely dominated by central urban regions, while peripheral areas outside these growth centers face more limited opportunities. The Jember Regency is classified as a medium-sized category, with a total of 20 higher education institutions, including the University of Jember as the primary institution. However, rural and inland areas within the regency continue to encounter substantial geographic barriers to accessing higher education. Similarly, Banyuwangi Regency also ranks in the medium category, with 13 institutions concentrated primarily in urban areas. In contrast, Sumenep Regency falls into the low category, lacking any public higher education institution within a 100-kilometer radius, reflecting accessibility constraints shaped by its archipelagic geography.

Although the 100-kilometer radius is used as a spatial reach indicator, factors such as topography, transportation quality, and economic disparities substantially affect actual accessibility to education. Strategies to achieve equitable distribution cannot rely solely on the number of institutions; rather, they must adopt geospatial data–driven approaches. Such methods enable the identification of low-access regions, support the planning of new campus developments, and promote distance learning initiatives adapted to local conditions (Jakavonytė-Staškuvienė & Ignatavičiūtė, 2022; Ruhimat et al., 2024; Shrestha et al., 2023). Overall, the distribution of higher education institutions in East Java underscores the need for more equitable and context-sensitive planning, particularly in regions such as Jember, Banyuwangi, and Sumenep.

The integration of geospatial analysis into school management draws heavily on **spatial justice theory**, which emphasizes that equitable distribution of public services, including education, is a prerequisite for social sustainability (Purwadhi, 2019; Wang et al., 2023). By employing geospatial indices such as the **Education Spatial Index (ESI)**, policymakers can systematically identify service gaps, disparities in accessibility, and mismatches between demand and supply of educational resources. This approach resonates with the principle of **location theory**, which posits that service provision should be strategically distributed to minimize spatial inequalities and optimize access (Muhaimin et al., 2022;

Ummah, 2019b). In the context of school management, these theories underscore that the placement of schools, teacher allocations, and supporting infrastructure cannot be divorced from spatial considerations.

Geospatial analysis provides actionable insights into **school quality management** by linking spatial data with performance indicators such as **student–teacher ratio (STR)** and **student–school ratio (SSR)**. Previous studies demonstrate that spatial mapping enhances evidence-based policy by enabling real-time monitoring of facility utilization and workforce deployment (Bondarenko, 2025; Szabó-Szentgróti et al., 2025). For example, identifying "overload zones" through geospatial tools allows managers to redistribute teachers or expand facilities, thereby addressing bottlenecks that directly affect educational quality. In this sense, GIS-based approaches function as both **diagnostic tools** and **decision-support systems**, ensuring that management strategies are not only reactive but also predictive. Higher education institutions into school management does not only enhance educational equity but also opens new avenues for **educational-based tourism**, particularly through structured campus visits and student engagement programs. In regions where universities serve as central educational hubs, spatial mapping provides strategic insight into accessibility, transport routes, and facility distribution, which are essential for organizing academic tourism activities (Szabó-Szentgróti et al., 2025; Widodo et al., 2024). Educational-based tourism aligns with the broader framework of **experiential learning**, which underscores the importance of active, hands-on engagement in knowledge acquisition. Campus tours that allow students to explore laboratories, interact with equipment, and observe real academic practices provide valuable opportunities for pre-tertiary learners to connect theoretical school lessons with applied higher education contexts (Rezapouraghdam & Hidalgo-García, 2024; Žalėnienė & Pereira, 2021). Empirical evidence demonstrates that such field-based learning environments foster deeper interest in STEM disciplines, improve motivation, and stimulate career aspirations (Prastiyono et al., 2021; Weng et al., 2022).

The implications of adopting geospatial frameworks in educational planning are substantial. First, they promote **data-driven equity**, ensuring that disadvantaged areas are prioritized in school expansion, teacher training, and resource allocation (Ruhimat et al., 2024; Ummah, 2019b). Second, they strengthen **adaptive management**, allowing local governments and school administrators to adjust zoning regulations, transportation support, or digital learning initiatives based on spatial disparities (Kuswardani & Paramita, 2023). Third, geospatial analysis enhances **community accountability**, as stakeholders can visualize disparities transparently, fostering participatory governance in education (Ngobeni, 2024). Such implications align with global development agendas, particularly **SDG 4 on quality education and SDG 10 on reducing inequalities**, by embedding spatial justice into the management of educational services (Campagnolo & Davide, 2019; Holst et al., 2024). Ultimately, the integration of geospatial analysis into school management highlights a paradigm shift: from traditional, enrollment-based planning toward **holistic spatial governance** of education. By recognizing geography as a determinant of educational opportunity, policymakers can design more inclusive interventions, ranging from new school construction in underserved districts to digital platforms mitigating geographic barriers (Drescher et al., 2022; Lange & Alves, 2011). Thus, geospatially informed school management is not merely a technical exercise but a strategic pathway to ensuring equitable, inclusive, and high-quality education across diverse territories.

CONCLUSION

This study demonstrates that integrating geospatial data into education management systems provides a novel perspective for understanding spatial disparities in access to and distribution of educational services at the local level. By utilizing the Education Spatial Index (ESI), significant variations in the equity of educational facility distribution were identified: urban areas such as Surabaya tend to exhibit ideal ESI scores in terms of service availability, whereas non-metropolitan regions such as Jember continue to experience infrastructure shortages and capacity pressures.

Malang City also displays more varied imbalances, particularly at the kindergarten, elementary, and junior high school levels, indicating the need for spatially informed governance evaluations across diverse regional contexts. These findings are consistent with previous research demonstrating the effectiveness of Geographic Information Systems (GIS) in analyzing spatial inequalities and educational service accessibility. GIS-based Nearest Neighbor Analysis to map the distribution of secondary education facilities in Tangerang Regency, while integrated remote sensing and GIS to examine the spatial distribution of senior high schools and vocational schools in Klaten. At a global level, GIS has been applied to evaluate geographic access to upper secondary education in Italy, underscoring the cross-contextual relevance of spatial methodologies. The integration of geospatial data into education planning and management is therefore essential for improving resource allocation efficiency and strengthening accountability in local education governance.

Moreover, this study has certain limitations. The spatial data employed remains contingent upon the availability and accuracy of official government datasets. The analysis was conducted at the subdistrict level, which may obscure variations in educational disparities at the village or neighborhood scale. Moreover, non-spatial variables—such as socioeconomic conditions, teacher quality, and transportation accessibility—were not incorporated into the model. Moving forward, regular updates to spatial datasets, the inclusion of non-spatial indicators, and finer-scale analyses are required to enhance the mapping of educational inequalities. These steps would provide a stronger foundation for evidence-based, location-specific policymaking and support the creation of a more equitable and inclusive education system.

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