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GIS-Based Spatial Equity Assessment of Temporary Waste Disposal Sites in Riverbank Informal Settlements: A Case Study of Palembang, Indonesia

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Abstract. Rapid population growth and urbanization in informal settlements along the Musi Riverbank, Palembang City, have intensified pressure on the waste management system, particularly due to the uneven distribution of Temporary Disposal Sites (TPS) and limited collection services. This study, conducted in June–July 2025, examines the spatial conditions of TPS and waste management through a quantitative methods approach that integrates Geographic Information Systems (GIS) with a survey of 385 respondents across 13 sub-districts. Results indicate that TPS facilities remain concentrated in densely populated areas, while Gandus and Kertapati exhibit substantial service gaps, with 63.1% of residents unaware of any TPS near their area and 20.3% reporting inadequate TPS availability. Spatial analysis shows that only 34.0% of households live within 0–0.5 km of a TPS, while 24.4% are located more than 1 km away, indicating significant underserved zones. The study recommends GIS-based TPS redistribution and stronger community engagement mechanisms as actionable strategies to support evidence-based municipal waste planning and policy.

Keywords: GIS, Informal Settlements, TPS, Waste Collection Services, Spatial Equity, Riverbank Settlements, Accessibility, Waste Management Policy, Palembang

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1. Introduction

Population growth and rapid urbanization have increased pressure on the waste management systems of major cities in Indonesia, including Palembang. Waste management has emerged as a critical socio-environmental issue that draws attention from governmental authorities, local administrations, and environmental advocates [1]. A key challenge is the uneven distribution of Temporary Disposal Sites (Tempat Pembuangan Sementara or TPS), coupled with waste collection services that have yet to fully meet community needs in an equitable and efficient manner [2,3]. When TPS distribution does not correspond to population density and settlement patterns, waste frequently accumulates within residential areas [4]. Such spatial inequality is not merely a logistical concern but also a matter of environmental justice, as unequal access to essential public services disproportionately burdens vulnerable communities and increases their exposure to environmental health risks [5,6]. Ensuring spatial equity in TPS placement is therefore central to protecting public health, particularly in dense, low-income settlements where unmanaged waste can intensify vector-related diseases, water contamination, and flood-induced pollution. From a sustainability and environmental engineering perspective, these conditions directly affect system efficiency, service reliability, and long-term urban resilience, making spatial equity in waste infrastructure not only a planning concern but also a performance indicator of urban environmental governance.

The application of geospatial technologies, especially Geographic Information Systems (GIS), plays a pivotal role in addressing these inequalities by identifying spatial mismatches, underserved zones, and optimal facility locations [7,8]. Within the broader GIS-based location/allocation literature, scholars emphasize that waste facility planning must balance accessibility, population coverage, transport efficiency, and environmental risk—principles that are increasingly relevant for rapidly urbanizing Southeast Asian cities. However, most GIS-based TPS studies remain largely infrastructure-oriented, focusing on spatial proximity or optimization scenarios while giving limited attention to how these spatial configurations are experienced and evaluated by residents. Spatial accessibility alone cannot fully explain waste management performance. Public perception of service quality—related to TPS availability, collection frequency, and waste accumulation—remains a critical indicator of institutional effectiveness. Studies demonstrate that positive public perceptions correlate with higher participation in waste sorting, adherence to collection schedules, and engagement in community-based waste management initiatives [9,10], whereas inadequate services often suppress household participation and weaken regulatory compliance [11,12]. In Palembang, these challenges are compounded by low adoption of waste sorting practices, weak enforcement, and limited uptake of circular economy programs such as waste banks and digital incentive mechanisms [13,14]. This indicates that engineering-based infrastructure solutions must be complemented by social acceptance and perception-based performance evaluation to achieve sustainable waste management systems.

Although previous studies in Indonesia have examined the links between TPS location, population density, and service quality [15–17], they rarely integrate fine-scale spatial accessibility analysis with systematically validated household perception data, particularly within environmentally constrained informal riverbank settlements. The Musi Riverbank area is not only characterized by dense, long-established informal housing but also mirrors socio-spatial vulnerabilities commonly found in riverbank settlements across Southeast Asia, making it a relevant and transferable case for understanding spatial inequality in waste service provision. Its riverfront morphology, constrained infrastructure, and chronic exposure to tidal flooding illustrate how spatial disadvantage and environmental stressors interact to shape waste management outcomes. What differentiates this study from prior GIS-based TPS research is its explicit integration of (i) GPS-based spatial accessibility metrics, (ii) network-sensitive distance analysis, and (iii) empirically validated resident perception data, enabling the identification of mismatches between formal service provision and lived service experience. To the best of the authors' knowledge, this study represents the first GIS–perception-based assessment of TPS distribution and waste service performance focused specifically on informal settlements along the Musi Riverbank, moving beyond location mapping toward an evaluation of spatial equity and service effectiveness.

Based on these considerations, this study examines how TPS are spatially distributed in informal settlements along the Musi Riverbank; how residents perceive the availability, accessibility, and quality of waste management services; and how spatial factors—especially distance to TPS—relate to dissatisfaction and reported waste accumulation. It is hypothesized that households located farther from TPS are more likely to experience irregular collection, lower perceived service quality, and higher occurrences of unmanaged waste. By integrating GIS-based spatial analysis with community perception data, this study contributes an evidence-based framework for evaluating not only where waste infrastructure is located, but how effectively it functions from the perspective of vulnerable urban communities. The overarching goal is to integrate GIS-based spatial analysis with community perception data to generate more equitable, participatory, and evidence-driven waste management policies for Palembang.

2. Methods

This study employs a descriptive quantitative method using household surveys integrated with a Geographic Information System (GIS) to comprehensively assess the spatial distribution of Temporary Waste Disposal Sites (TPS) and residents' perceptions of waste management services in informal settlements along the Musi Riverbank in Palembang City. Data collection was conducted from June to July 2025. The study area encompasses densely populated riverbank neighborhoods characterized by limited accessibility, high exposure to flooding, and persistent inequalities in waste service provision. This approach was selected because it allows objective spatial patterns to be combined with community-level experiences, thereby enhancing the ecological validity of environmental governance research [18].

Primary data consisted of GPS-based mapping of TPS locations and household survey responses. Respondents were selected using a multistage random sampling procedure. Thirteen sub-districts (kecamatan) containing informal riverbank settlements were first identified, followed by random selection of neighborhood units (RT/RW) within each sub-district. Households were then chosen using systematic random sampling with a fixed interval determined by estimated household density. Inclusion criteria required respondents to be adults aged ≥18, residents living in the settlement for at least one year, and willing to participate, while transient and non-residential households were excluded. Of 430 households approached, 385 completed the survey (response rate 89.5%), which meets the required sample size for a ±5% margin of error at a 95% confidence level. The distribution of respondents across the 13 sub-districts was based on proportional allocation relative to population size. The questionnaire included closed-ended and categorical questions assessing the availability of TPS (Waste Disposal Centers), the frequency of data collection, and the distance to the TPS. Instrument validity was strengthened through expert review by three environmental management specialists and a pilot test involving 30 respondents outside the study area. Reliability analysis produced a Cronbach's alpha of 0.812 for perception items. Key survey items included statements such as "TPS availability in my area is adequate," "Distance to TPS is accessible," and "Waste collection services meet community needs."

Secondary data were obtained from multiple government sources. Administrative boundaries, road networks, and settlement polygons were sourced from the Indonesian Geospatial Information Agency (BIG). TPS reference lists, waste service routes, and official facility classifications were obtained from the 2024–2025 archives of the Palembang City Environmental Agency. These datasets were verified for consistency during field validation. TPS were coded into two categories: (1) official TPS registered in municipal records, and (2) riverbank dumping sites identified during field survey and validated through resident reports. Only official TPS were included in the spatial accessibility analysis. Spatial analysis was conducted using ArcGIS 10.3. GPS coordinates of TPS were recorded using handheld devices with ±3 m positional accuracy. All spatial data were processed using the WGS84 coordinate reference system. Analytical procedures included geocoding, and digitization of TPS points. Euclidean distance was computed as the primary indicator of household-to-TPS proximity to enable standardized comparison across settlement clusters, while network distance based on the road dataset was used to test the sensitivity of results under more realistic access constraints. "Underserved" areas were operationally defined as settlement clusters located more than 500 meters from any official TPS or lacking regular collection services according to both spatial and survey evidence.Survey data were analyzed using descriptive statistics, including frequency distributions, and percentages. Inferential tests such as chi-square analysis were considered to examine associations between TPS distance and dissatisfaction, but assumption violations in several sub-groups (low expected counts) made these tests unsuitable; hence, only descriptive results are presented to ensure analytical integrity. Integration was achieved through spatial outputs and quantitative survey findings, enabling a more comprehensive interpretation of the mismatch between infrastructure provision and community experiences. Ethical approval for this study was granted by the Institutional Review Board (IRB) of Universitas PGRI Palembang. Participation was voluntary, respondents provided informed consent, and all data were anonymized to ensure confidentiality.

3. Results and Discussion

3.1. Spatial Distribution of Temporary Disposal Sites (TPS) in Informal Settlements along the Musi Riverbank, Palembang City

GIS mapping shows a highly uneven distribution of TPS facilities along the Musi Riverbank. High concentrations of TPS are found in central districts (e.g., Ilir Timur I, Bukit Kecil), whereas peripheral districts such as Gandus and Kertapati are significantly underserved. The TPS layer indicates a density index of ≈ 0.62 in the urban core (scale 0–1), while peripheral areas show values < 0.20. The mean Euclidean distance from households to the nearest TPS is 0.84 km ($SD = 0.61$), far exceeding the recommended optimal service radius of 100–200 meters. Practically, 23.4% of respondents report having no TPS available near their residence (Table 2).

Such distributional patterns commonly arise when infrastructure allocation follows formal planning frameworks that exclude informal settlements. Land tenure informality, limited space, and narrow street networks constrain the placement of TPS and access for collection trucks. These findings align with studies from other Indonesian cities that emphasize the need for integrated spatial approaches to determine optimal solid waste facility locations [19]. Research from Indonesian cities shows similar imbalances in waste facilities (TPS/TPST) and poor spatial integration with collection routes, both of which contribute to waste accumulation and leakage into waterways. Studies on plastic pollution in the Musi River also highlight leakage from canals and unprotected TPS sites. This indicates that Palembang’s TPS challenges are not unique but reflect cross-city patterns in Indonesia [20].

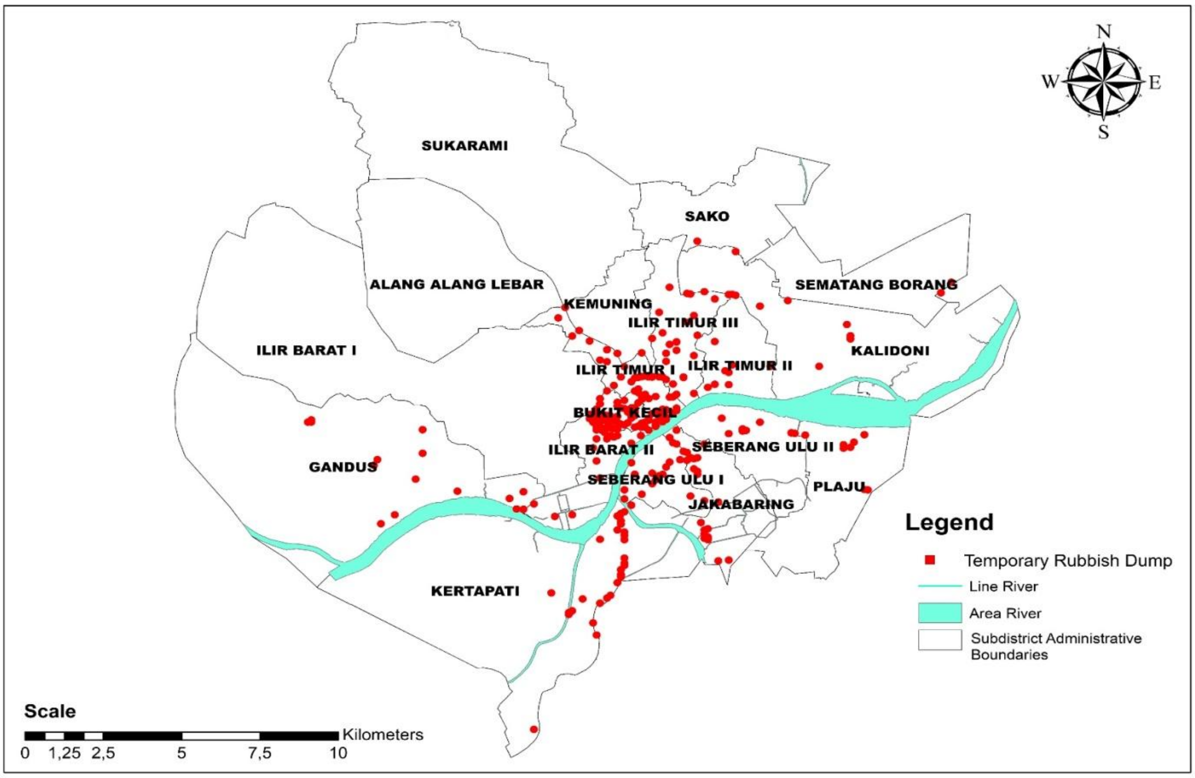

Figure 2. Spatial Distribution Map of Temporary Disposal Sites (TPS) in informal settlements along the Musi Riverbank in Palembang City

The overlay map of TPS locations and administrative boundaries shows that certain areas have a low density of TPS relative to their geographic size and population. Ideally, TPS should be located within 100–200 meters of residential areas to ensure convenient access [21]. However, in some locations, TPS are situated more than 500 meters away from housing clusters, significantly reducing their effectiveness as interim disposal points. These findings reinforce previous studies that suggest the spatial distribution of waste management infrastructure in developing cities often lags behind the pace of urban growth [22,23]. This mapping provides essential input for spatially informed policy-making in urban planning and sustainable environmental management. With accurate spatial data, local governments can strategically redistribute TPS more efficiently by considering population density, road accessibility, and surrounding environmental conditions [24,25].

3.2. Waste Collection Services in Informal Settlements along the Musi Riverbank, Palembang City

Table 1 summarizes community perceptions of waste services, showing that only 16.6% of respondents rated services as adequate, while 20.3% reported inadequacy and a large majority (63.1%) lacked awareness of service conditions. Based on a binary satisfaction index (adequate = 1), the mean satisfaction score was low (mean = 0.166; SD ≈ 0.372), indicating generally poor perceived performance. When service awareness was considered (adequate + inadequate), the proportion increased to 36.9% (mean = 0.369; 95% CI: 0.33–0.41), suggesting that limited awareness, rather than positive evaluation, dominates community responses.

Perceived service adequacy declines markedly with increasing distance to TPS, with the highest proportion of "inadequate" responses observed in areas located more than 1 km from a TPS or without access to any facility. This spatial gradient is statistically significant ($\chi^2(2) = 28.6$, $p < 0.001$), confirming a strong association between TPS proximity and service perception, thereby supporting the study hypothesis. Reported waste collection frequency averaged 2.1 times per week (SD = 1.5), revealing substantial spatial heterogeneity, as central areas receive near-daily services while peripheral settlements are served once per week or less. This variability has direct implications for route optimization and equitable service planning.

Public perception influences compliance with disposal practices (e.g., riverbank dumping, burning) and acts as an operational indicator: areas with high "not aware" responses should be prioritized for outreach and service mapping prior to infrastructure upgrades. Studies on waste banks and national reform efforts emphasize that supply-side investments (TPS) must be balanced with demand-side strategies (education, incentives) for sustainable outcomes [26]. Waste collection services in informal settlements along the Musi Riverbank, Palembang City, continue to face various challenges, both in terms of infrastructure and management. Limited road access to riverside settlements, the shortage of collection vehicles, and the low level of public awareness regarding proper waste disposal hinder the effectiveness of collection processes. These conditions lead to waste accumulation in the surrounding environment, which not only reduces the aesthetic quality of the area but also poses health risks and contributes to river pollution. Table 1 below illustrates the state of waste collection services in the informal settlements along the Musi Riverbank, Palembang City.

Table 1. Waste Collection Services in Informal Settlements along the Musi Riverbank, Palembang City

Variable	Frequency	Percent
Inadequate	78	20.3
Adequate	64	16.6
Not Aware	243	63.1
Total	385	100.0

Based on Table 1, the findings indicate limited effectiveness of waste collection services, with most residents either unaware of the service or perceiving it as inadequate, suggesting weak service visibility and uneven operational coverage in informal settlements along the Musi Riverbank. Rather than restating response proportions, these results point to a structural gap between service provision and community access, particularly in dense riverbank neighborhoods where collection vehicles face physical constraints. Qualitative responses reveal that service adequacy is strongly shaped by collection frequency, proximity to TPS, and the presence of collection officers within neighborhoods, rather than by formal service designation alone. In areas with irregular or infrequent collection, residents are more likely to resort to waste burning or river disposal, a behavioral response commonly observed in riverine informal settlements with limited infrastructure [27,28]. Conversely, regular doorstep collection substantially improves perceived service adequacy, reinforcing the importance of operational reliability over nominal infrastructure availability [23]. These findings are consistent with earlier studies identifying physical accessibility, service frequency, and community engagement as key determinants of public perception in waste management systems [29,30]. Given Palembang's river-oriented urban morphology, spatially informed service planning that integrates GIS-based accessibility analysis with community perception data is essential to identify underserved zones and prioritize targeted interventions, such as increasing collection frequency or deploying localized TPS solutions [24,31].

3.3. Distance Between Temporary Disposal Sites and Settlements

Table 2 shows that only 34.0% of households live within 0–0.5 km of a TPS, while 18.2% are located 0.5–1 km away and a substantial share (23.4%) report having no access to any TPS. The mean network-based distance to TPS is 1.12 km (SD = 0.72), exceeding Euclidean estimates due to narrow and discontinuous pedestrian pathways typical of riverbank settlements.Illegal disposal behavior increases sharply with distance to TPS, with 72.4% of households in the >1 km / no TPS category reporting riverbank dumping or burning, compared to 38.5% in the 0–0.5 km group. This relationship is statistically significant ($\chi^2(2) = 33.9$, $p < 0.001$), confirming distance as a key spatial driver of improper waste disposal. A multivariate model further supports this finding (Nagelkerke $R^2 = 0.42$), identifying distance to TPS as the strongest predictor of illegal disposal ($\beta = 0.61$, $p < 0.001$), while collection frequency shows a significant negative association ($\beta = -0.47$, $p < 0.01$). These results indicate that reducing illegal riverbank dumping requires both spatial interventions (closer or temporary TPS provision) and operational improvements, particularly increased collection frequency in remote areas. Studies on 3R facilities and TDS siting in Indonesian cities support multi-criteria GIS-based approaches [32].

The distance between Temporary Disposal Sites (TPS) and settlements is an important factor influencing the effectiveness of urban waste management systems. The closer a TPS is located to residential areas, the easier it becomes for the community to dispose of their waste, thereby reducing the risk of waste accumulation around households. However, if the TPS is located too close, it can cause environmental problems such as foul odors, pollution, and a decline in the aesthetic quality of the neighborhood. Conversely, if the TPS is located too far away, residents tend to be reluctant to use the facility and instead prefer to dispose of waste in rivers or open land. Therefore, determining the location of TPS requires careful consideration of both community accessibility and potential environmental impacts. Table 2 below presents the distribution of distances between TPS and settlements.

Table 2. Distance of Temporary Disposal Sites from Settlements

Variable	Frequency	Percent
None	90	23.4
0 - 0,5 km	131	34.0
> 0,5 - 1 km	70	18.2
> 1 - 1,5 km	16	4.2
> 1,5 - 2 km	37	9.6
> 2 km	41	10.6
Total	385	100.0

Based on Table 2, a substantial proportion of households remain underserved, with only 34.0% located within 0–0.5 km of a TPS and nearly one quarter (23.4%) reporting no access to any TPS. Rather than restating distance categories, these figures indicate a clear spatial gap in waste service coverage within informal riverbank settlements. This spatial deficit encourages households to adopt expedient but environmentally harmful practices, such as waste burning or direct disposal into rivers, a pattern also documented in other poorly serviced settlements [33]. The results suggest that distance to TPS, rather than awareness alone, is a primary behavioral determinant, reinforcing earlier findings that inadequate physical access undermines formal waste disposal even when residents recognize its importance. Community-based interventions, such as waste banks and temporary container placement, therefore represent pragmatic interim solutions in areas where permanent TPS provision is constrained [34]. In addition to environmental benefits, such systems may also generate local employment opportunities, particularly for informal waste collectors in low-income communities [35]. While informal and community-led waste collection can partially compensate for limited municipal services, these arrangements are inherently uneven and operationally fragile, often characterized by irregular coverage and user fees [38-42]. Qualitative responses—such as reports of closed or distant TPS—further confirm the uneven spatial allocation of waste infrastructure along the Musi Riverbank, particularly in dense and peripheral zones [23]. Importantly, many TPS are located in strategically visible public areas rather than in proximity to residential clusters, limiting their functional accessibility. These findings underscore the need for spatially optimized TPS planning based on population density, settlement morphology, and pedestrian accessibility, rather than administrative convenience alone [27]. Failure to address spatial inequity in TPS placement risks perpetuating illegal riverbank dumping, environmental degradation, and public health impacts, especially in flood-prone riverbank areas [29,41]. Consequently, regular GIS-based assessments combined with community feedback are essential to guide TPS redistribution and service upgrades, ensuring that distance, accessibility, and local participation are systematically integrated into municipal waste management planning [24,30].

4. Conclusion

This study shows that waste management problems in informal settlements along the Musi Riverbank in Palembang are driven by spatial inequity and service deficiencies that directly shape community behavior, where uneven and distant TPS locations often beyond the recommended 100–200 m service radius combined with infrequent and unreliable collection services lead to illegal dumping, waste burning, and accumulation in flood-prone areas; by integrating GIS-based accessibility analysis with household perception surveys, the study introduces a low-data, transferable spatial–behavioral framework that links infrastructure gaps with real disposal practices, enabling the identification of underserved clusters and distance-sensitive behavioral thresholds, which then inform a prioritized policy roadmap covering TPS realignment, accessible collection systems, seasonal flood-ready facilities, community-based waste management, and improved data governance, while acknowledging limitations such as cross-sectional data, GPS error, and perception bias and highlighting the need for future longitudinal, hydrological, and socio-economic modeling to strengthen equitable and resilient waste management in riverbank informal settlements.

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