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Estimating and Mapping Potential Littering into Canal in Catchment Areas

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ABSTRACT

Waste mismanagement occurs in the canal catchment area due to uneven waste transportation services, allowing waste to leak into the canal. This research aims to identify catchment areas of the canal with the potential for waste mismanagement, estimate the amount of waste that could enter the channels and compare the results with the density of floating waste above the channel. The research method involves spatial analysis using GIS, incorporating various variables such as land use, building data for population and waste generation calculations, road network data for channel access, and service area data for garbage truck transportation. Next, we conduct an overlay analysis to create a zone map of potential littering areas in the channel, accompanied by an estimate of the waste amount. Furthermore, we used aerial mapping with a UAV as comparative data to monitor the density of floating waste. The results indicate that approximately 296 hectares of land, a potential zone for waste disposal into canals, generate 161,750 litres daily, accounting for 33% of the total waste generation in the water catchment area. This research successfully detected the density of floating waste at the top of the canal, particularly in four areas of the potential zone: Sambung Jawa Ward, Bontorannu Ward, Balang Baru Ward, and Pa'baengbaeng Ward, proves that there is mismanagement of waste on land. This situation demonstrates the need to address waste mismanagement by examining regional zones with access to a waste bank as an alternative solution.

Keywords: littering, GIS, kernel-analysis, network-analysis, services-area-analysis.

INTRODUCTION

Waste is still a global challenge that must be resolved (Wilson and Velis, 2015). Municipal waste management is great concern today for authorities and urban planners due to increasing population, urbanization, and limited land (Khan et al., 2018). Waste problems generally occur in urban areas in developing countries (Abdel-Shafy and Mansour, 2018). In many developing countries, the rising of population growth and the expansion in catchment areas as floodplain (Andreadis et al., 2022), increased consumption (especially of single-use goods), inadequate waste collection, and inefficient waste management policies are among the causes of solid waste enters canals, rivers, and banks. The increase in population will impact increasing waste generation (Haerani et al., 2019). Increasing incorrect waste management can reduce environmental quality, especially in the form of pollution and disease transmission (Ferronato and Torretta, 2019), obstruct water flow in drainage channels, and impact the city's aesthetic. Urbanization is increasingly widespread with various human activities in river watersheds, which cause large amounts of waste to be thrown into waterways and end up in the ocean, something that has never happened before (Nunkhaw and Miyamoto, 2024). Pollution must be considered a global problem, especially aquatic waste, which negatively impacts aquatic ecosystems and is recognized as a severe problem in the global aquatic environment (Kataoka and Nihei, 2020). Currently, observations regarding the origins of pollution collected in the sea and along the coast are still limited, so it remains a challenge for scientists to identify or evaluate it (Chenillat et al., 2021). Researchers believe that land activities significantly influence the presence of waste in the waters (Van Emmerik et al., 2022); 80% of marine waste is estimated to enter the sea through land activities. Understanding the main routes through which waste has the potential to enter rivers and canals is fundamental in better managing and reducing seawater pollution (Willis et al., 2022) from an environmental and economic perspective to handle strategies to prevent waste from entering waters continues to increase in number and causes more severe negative impacts.

Furthermore, the suboptimal level of waste service in the water catchment area is thought to be the cause of the waste in the channel, so it is essential to study waste management in the area more deeply. Like other developing countries, most cities in Indonesia still use open drainage facilities to channel wastewater and rainwater. This condition allows rainwater to carry away waste from open water channels during the rainy season, proven by monitoring studies, which conclude that the amount of waste floating in the canals increases during the rainy season (Anggraini et al., 2024). Another factor that causes the appearance of waste floating in the canal is the intentional direct dumping by the community (Sindangan et al., 2024), as evidenced by observations of bags containing large household waste floating in the canal.

This research occurred in Makassar City, the capital of South Sulawesi Province, the largest in Eastern Indonesia and the sixth largest metropolitan city in Indonesia (Muis et al., 2024), with a population of around 1.5 million (Makassar Bureau of Statistics, 2023). Makassar City is also an economic and service centre, with the amount of waste produced every day of 1,000 tons being transported to the landfill and the remaining 450 tons per day are not being transported. Households are the most significant waste producers, reaching 62.99% compared to other sectors such as trade and services, offices, and others (Ministry of Environment and Forestry, 2023). Currently, the waste transportation system in Makassar City uses a "door-to-door" system: household waste is transported directly by garbage trucks. However, not all areas receive this service well, especially areas with roads that do not allow transporting garbage trucks. Most of these areas are in slum areas, especially around canal catchment areas, which allow people littering into local waters.

Therefore, from this gap, it is essential to estimate the potential for waste discharge into channels as a basis for formulating countermeasures to reduce negative impacts. This research aims to calculate the potential generation of waste thrown into the canal by assessing the spatial effectiveness of the waste collection system in the canal catchment area and the canal's accessibility. Then, the results of these findings are compared with the density of litter floating on the canal's surface. The methodology used is spatial analysis in ArcGIS; the result is potential zone map that allows littering into the canal and calculates the amount. The aerial mapping method with a UAV is used to get an image of floating waste and analyse its density. Finally, the conclusion section will summarize the highlights of the findings and recommendations from this paper for the future of the environment and handling solid waste management problems.

METHODOLOGY

This research uses spatial analysis in ArcGIS. Geographic Information System (GIS), a tool consisting of hardware and software, effectively manages, integrates, analyzes, and displays data in geographically based information (Iyengar, 1998). GIS can also integrate large amounts of data and mapping layers into a single output to aid decision-making; its technological advances allow for complex analysis. The research stages are the data collection stage, the data processing analysis, and the conclusion and formulation of recommendations. Data collection uses primary data and secondary data. The variables in this research are land use, building data, and access route to the channel, the dump truck service area, and the waste bank's reach radius. The analysis process is carried out in three stages, namely (1) calculating the total waste generation in the canal catchment area, (2) calculating the potential area zone for littering sources to the canal through a map overlay process and (3) calculating the density of floating litter.

Study location

The research area is in Eastern Indonesia, Makassar City, as waterfront city which has several canals, one of which is the Jongaya Canal. This Research focuses on the Jongaya Canal and its water catchment area (Figure 1) with an area 1,245 Ha. The Jongaya Canal is 8–14 m wide with a length of 9.2 km (Major River Basin Organization Pompengan – Jeneberang, 2018), with embankments along the canal. This urban canal functions as a flood control and primary drainage, a mixture of wastewater and rainwater disposal. The water surface conditions are relatively calm, with prolonged currents. Along the canal, it is jam-packed with buildings. In several parts of the canal, there is floating waste. According to Makassar officials, the waste in the canal generally comes from local drainage channels that serve the water catchment area. Local drainage is a channel that not only drains rainwater but also drains waste into the channel. Extreme flood events that occur almost yearly during heavy rains can cause additional plastic waste to enter canal and river systems.

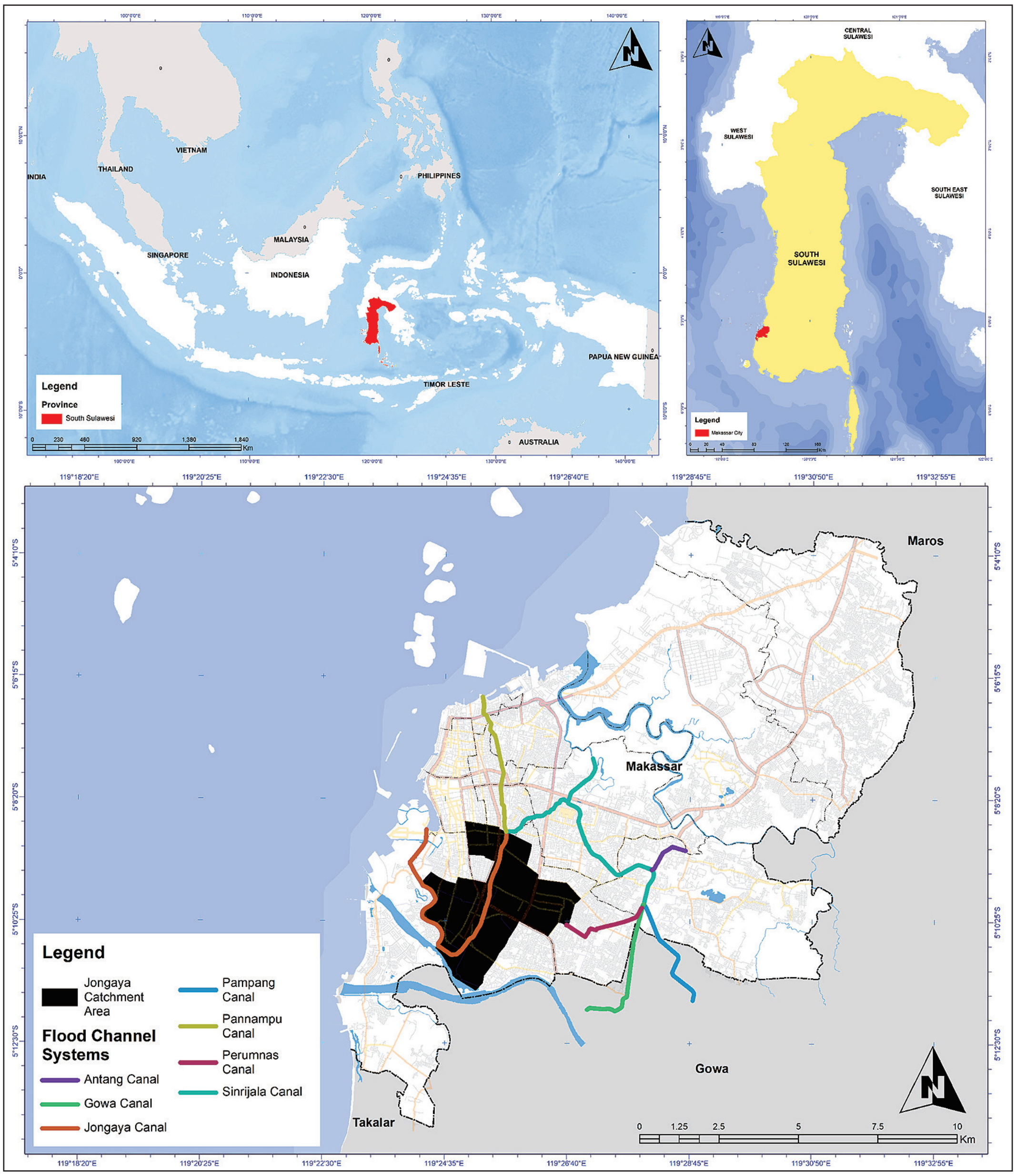

Figure 1. Location of study, Catchment area Jongaya Canal

Waste generation estimation and Kernel Density (spatial analysis)

Urban land use is one factor influencing the amount of urban waste (Gholami et al., 2020). Estimated waste generation calculations were done by assessing land use data in the Jongaya Canal catchment area to obtain building data. As shown in the land use map (Figure 2), the dominant area is residential, followed by building work (commercial) areas, and a small portion of mixed farming and green areas. This research limits the calculation to only residential buildings, which will then become the basis for population data. Figure 2 also shows population density, which illustrates the density of waste generation in the canal catchment area using Kernel Density. The Kernel Density (spatial analysis) is tools in GIS used in this analysis aligns with (Ramadan et al., 2024), who uses Kernel Density to indicate hotspot areas or the largest waste production. Based on the density map, the dominant catchment areas are areas with very high density, especially along canal routes.

Waste generation estimation

1 household × 5 people × 0.4 kg/people/day (1)

or

1 household × 5 people × 2.5 Liter/people/day (2)

Waste generation coefficient for residential 0.4 kg/people/day (Damanhuri et al., 2014).

Coefficient of the number of people per residence, on average each residence consists of 5 people (Anggraini et al., 2023).

Network service area analysis for canal accessibility

Several factors cause the emergence of floating waste in canals, including easy access to the banks of canals and rivers and inefficient waste collection and transportation systems (Franz and Freitas, 2011). This research uses GIS to conduct network analysis to find the most minor impedance path (Maspaitella et al., 2021). Network analysis is a part of GIS modelling that includes the analysis of specific lines involving a series of interconnected paths. Network analysis in this research is used to determine the accessibility of a canal area with roads as the database.

This research divides areas based on the accessibility of access to the canal, with the accessibility limit being 0–500 m considered accessible. In comparison, > 500 m is considered less accessible, concerning the potential for littering into the channel (Figure 3). Based on the results of overlaying channel access distances maps and population density maps, a map of potentially accessible zones is dominated by high-density populations (Figure 3).

Network service area analysis for transportation services area

Garbage transportation in Makassar City uses a garbage truck called "Tangkasaki." Currently, waste transportation in Makassar City eliminates temporary waste disposal sites (TWDS) in residential areas except in markets, terminals, and other public places. Around 37 waste collection trucks are operating in the canal catchment area. The "door-to-door" system is a waste transportation system that transports waste directly from

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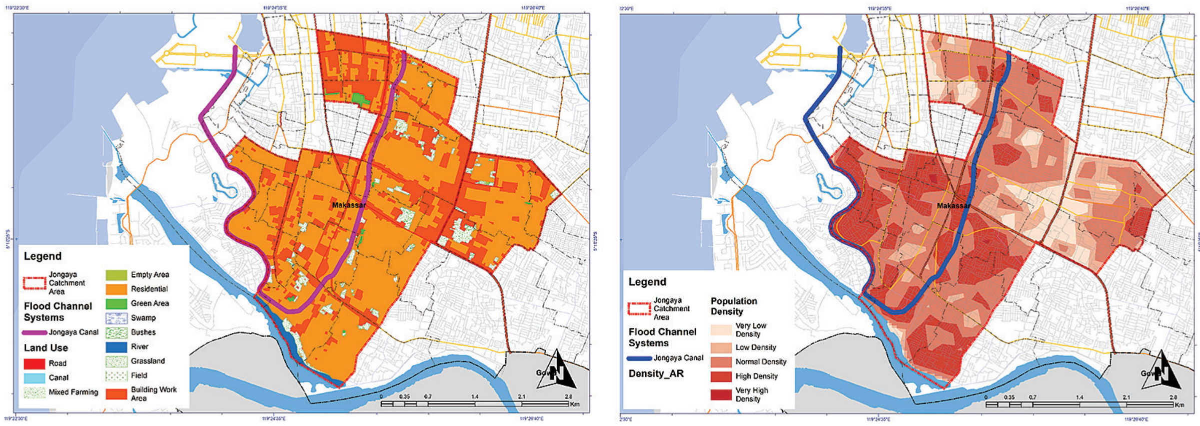

Figure 2. (a) Landuse map, (b) population density

a) b)

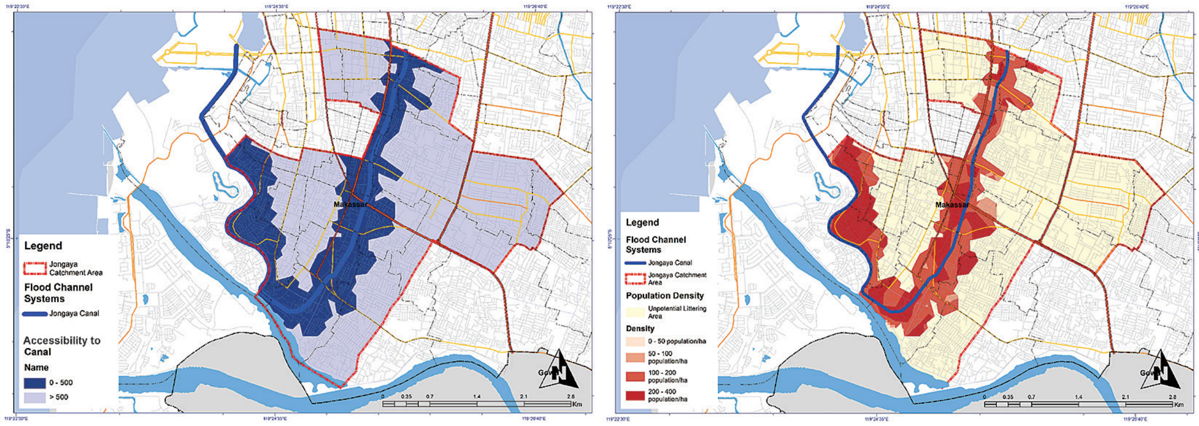

Figure 3. (a) Canal accessibility zone (b) accessibility zone overlaid with population density

garbage trucks to people's homes; the dump truck route is shown on the map (Figure 4). This system is implemented to transport and collect waste in residential areas so that some areas are not served due to the narrowness of the road network, because it impossible for garbage trucks to pass through, especially in slum area (Agamuthu and Babel, 2023). Figure 4 shows the map served and not served zone by garbage truck services.

Network service area analysis for Waste Bank services area

The Indonesian Ministry of Environment has developed the concept of waste banks. Waste Law of 2008 concerning Waste Management in Indonesia states that the Government is obliged to implement reasonable and environmentally friendly waste management. Waste Banks is an alternative solution for handling waste that involves the community, entrepreneurs, and the Government (Fatmawati et al., 2022). At the same time, in 2004, the Mayor of Makassar launched campaign to increase public awareness and create shared responsibility for the city's waste problem, coupled with the Makassar Green and Clean Program, which was launched in 2008 to introduce waste banks (Regulation of Mayor, 2018). The Makassar City Environmental Service has issued a program to improve city cleanliness, which is the responsibility of the Government and the community; one is a program to reduce the use of single-use plastic and the provision of 1,000 waste banks in community areas to help provide waste collection services. In the Jongaya catchment area, there are 34 waste bank points.

Network service area analysis is used to analyze the existence of Waste Banks and their services area. Another research in Putra et al., (2020) uses Network Analysis to Optimize Waste Transport Routes in Malang. From the Waste Bank service area aspect, the waste bank has accessed the dominant

a) b)

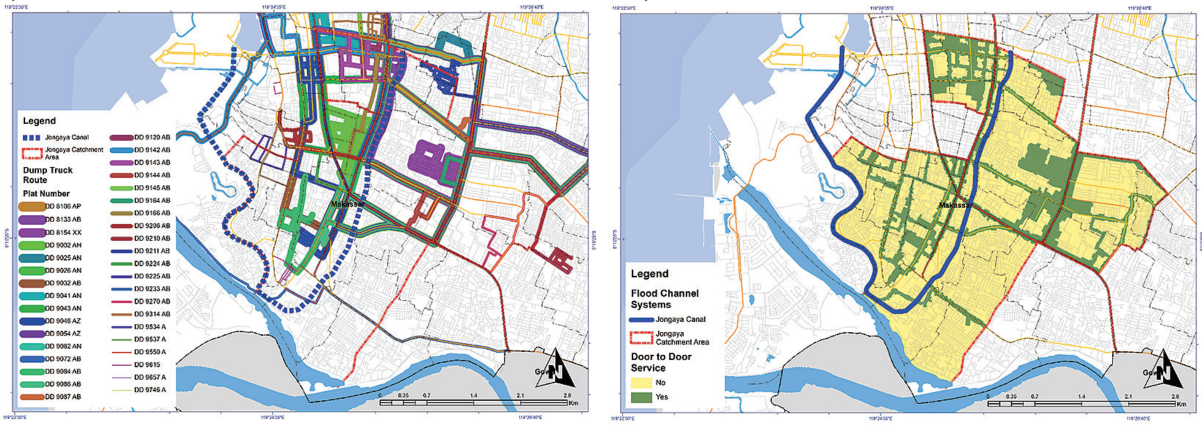

Figure 4. (a) Garbage truck routes, (b) "Door to Door" system services

catchment area in the "good" category. However, a few areas still do not have "good" access to the Waste Bank, as shown on the map (Figure 5).

Aerial mapping survey for density of canal floating waste

Observations using a UAV were carried out on the surface of the channel to observe the floating litter, monitor its condition, and analyse its density. This survey is an area mapping survey using UAVs carried out along a canal with a length of approximately 9 km. The analysis kernel in GIS is used to analyse the density of floating waste, which provides a density percentage. The results show that several spot areas, namely Sambung Jawa Ward and Balang Baru Ward, are densely packed with floating litter, followed by Bontorannu Ward and Pa'baengbaeng Ward (Figure 6).

RESULT AND DISCUSSION

Forecasting littering potential zone

Based on the map overlay of channel access distances and the map of waste transportation service areas, the map (Figure 7) shows areas that can provide waste to the channel. Like cities in other developing countries, in Makassar City, some urban residents live in unsuitable areas, such as areas initially designated for environmental

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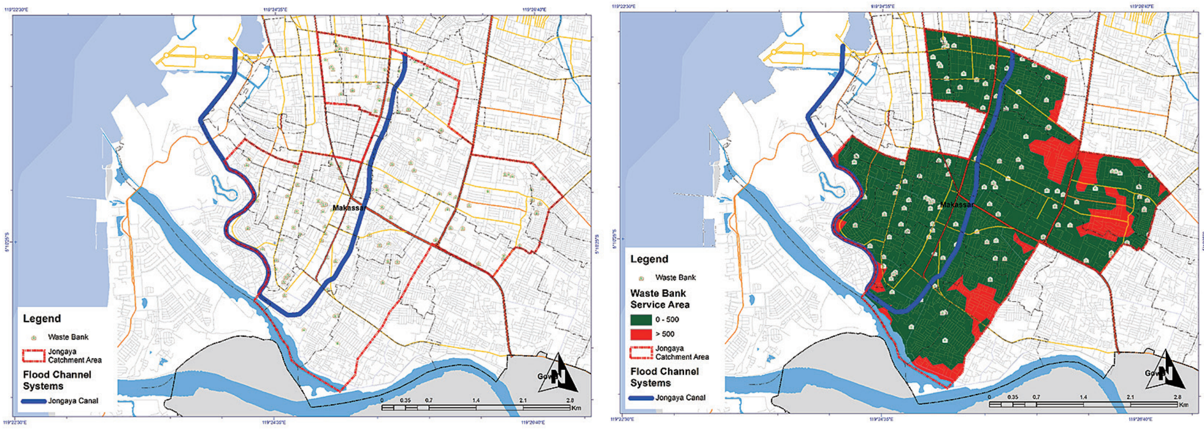

Figure 5. (a) Waste bank distribution point, (b) Waste Bank services

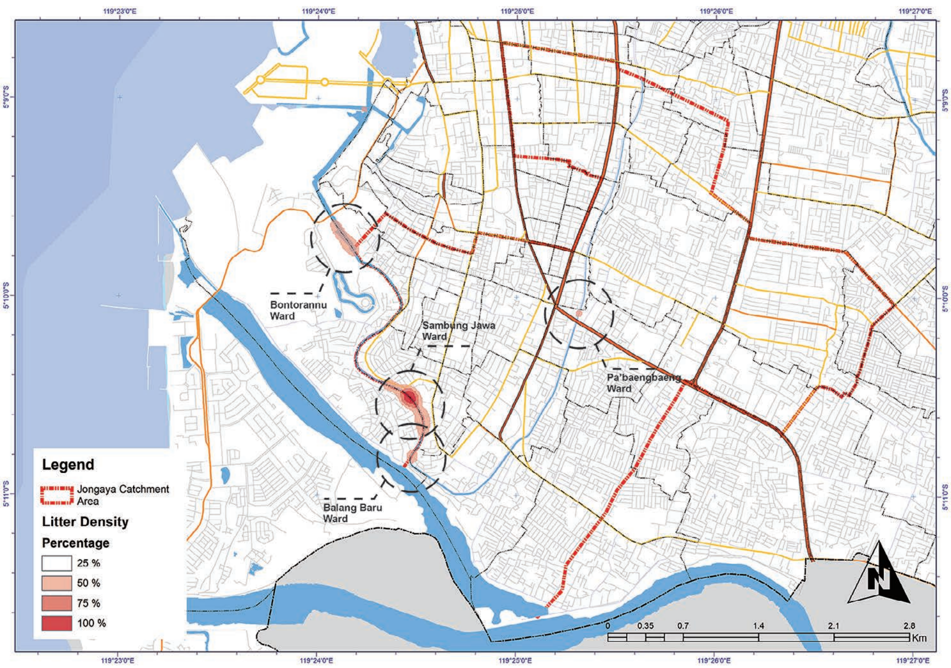

Figure 6. Floating litter density on the surface of canal using UAV monitoring

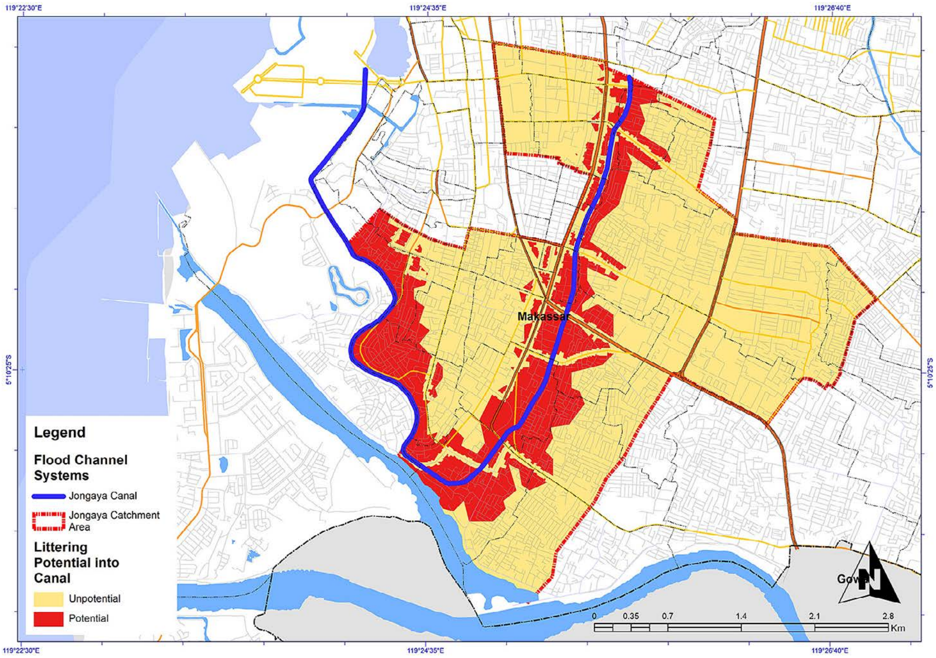

Figure 7. Littering potential zone into canal

conservation or areas prone to flooding, such as water catchment areas (Anggraini et al., 2021). Rapid urban expansion demands adequate solid waste collection and waste disposal. Domestic waste channels are connected to a rainwater channel system so that waste and rainwater mix and settle in water channels and ultimately (in coastal areas) empty into the sea. As stated by other studies in Brazil (Franz and Freitas, 2011), drainage systems are also used for household solid waste disposal, especially in regions that practice inefficient waste collection services policies. When litter enters the drainage system, significant changes occur. It is very likely that this waste will be carried through storm drains, gutters, streams, rivers, and estuaries and ultimately carried out to sea, especially during storms. It is challenging to collect the waste produced in slum areas using a door-to-door system because the width of the road is narrow, it is not possible for trucks carrying waste to transport it in small alleys, thus triggering the practice of throwing waste into waterways and, canals, especially when it rains torrential, becoming floating waste.

The map in Figure 7 illustrates that the area around the Jongaya Canal has the potential for dumping because there is access to the canal, and a waste transportation system does not serve the area. Table 1 shows the size of the potential area and the amount of waste that could be thrown into the canal. The Jongaya canal catchment area is traversed by six sub-districts and 34 wards, with an estimated total population of 193,450 people and a total waste generation of 483,625 liters/day, covering an area of 77,480 Ha. However, the Potential Littering Zone successfully detected in this study was 296 Ha (24% of the catchment area), the most prominent in the Tamalate District. The total population in the Potential Littering Canal zone area is 64,700 people, and the total waste generation in this area is 161,750 liters/day (33% of the waste generation in the catchment area).

Density floating waste result

Urban expansion leads to the dumping of solid waste into canals and rivers and onto their banks (Bangani et al., 2023), corresponding to the ‘floating litter’ especially in many developing countries. Based on the results of the analysis in this research, it is estimated that there are 27,875 litter/day (shown in Table 1) of waste that has the potential to enter the canal from Ballang Baru Ward from 55.99 Ha (56% from catchment area on this ward), this value is the highest compared to another ward – followed by Sambung Jawa Ward as much as 21,938 liters/day or around 98% of the catchment area from 37.9 Ha. These results from aerial mapping with UAV show the high density of waste floating in the canal, in Sambung Jawa Ward and Balang Baru Ward (Figure 8). This area is densely populated and dominated by

Table 1. The amount of waste generation in potential area zone and catchment area

Sub-District	Ward	Potential littering zone				Catchment area			
		Population	Sum of ltr/day	Sum of kg/day	Area (Ha)	Population	Sum of ltr/day	Sum of kg/day	Area (Catchment Area)
Makassar	Bara Baraya Selatan	5	13	2	0	5	13	2	0.48
	Maricaya	145	363	58	1	4740	11850	1896	28.18
	Maricaya Baru	1615	4038	646	4	3945	9863	1578	28.18
Makassar total		1765	4413	706	5	8690	21725	3476	56.84
Mamajang	Baji Mappakasunggu	0	0	0	0	3935	9838	1574	19.63
	Bonto Lebang	2460	6150	984	10	2975	7438	1190	14.26
	Karang Anyar	815	2038	326	3	4200	10500	1680	20.29
	Labuang Baji	85	213	34	1	290	725	116	3.85
	Mamajang Dalam	545	1363	218	2	1235	3088	494	10.19
	Mamajang Luar	0	0	0	0	245	613	98	9.58
	Mandala	670	1675	268	2	930	2325	372	5.20
	Maricaya Selatan	1135	2838	454	6	3085	7713	1234	33.75
	Pa’Batang	0	0	0	0	3435	8588	1374	13.78
	Parang	195	488	78	1	4995	12488	1998	16.44
	Sambung Jawa	8775	21938	3510	38	8925	22313	3570	39.89
	Tamparang Keke	1470	3675	588	5	4065	10163	1626	18.71
Mamajang total		16150	40375	6460	66	38315	95788	15326	205.57
Mariso	Bontorannu	4955	12388	1982	18	4990	12475	1996	18.14
	Mattoangin	1590	3975	636	6	3395	8488	1358	18.84
	Tamarunang	2855	7138	1142	11	5065	12663	2026	21.55
Mariso total		9400	23500	3760	35	13450	33625	5380	58.53
Rappocini	Balla Parang	125	313	50	0	1500	3750	600	8.30
	Banta-Bantaeng	2760	6900	1104	18	16570	41425	6628	146.20
	Bonto Makkio	0	0	0	0	5060	12650	2024	28.04
	Buakana	95	238	38	1	5610	14025	2244	32.16
	Gunung Sari	0	0	0	0	3170	7925	1268	53.30
	Rappocini	3570	8925	1428	19	6370	15925	2548	36.02
	Tidung	0	0	0	0	11830	29575	4732	121.93
Rappocini total		6550	16375	2620	38	50110	125275	20044	425.94
Tamalate	Balang Baru	11150	27875	4460	56	16330	40825	6532	99.69
	Bongaya	405	1013	162	3	7415	18538	2966	39.44
	Bonto Duri	3090	7725	1236	14	12315	30788	4926	62.58
	Jongaya	7940	19850	3176	40	11315	28288	4526	70.07
	Maccini Sombala	170	425	68	2	330	825	132	2.85
	Mannuruki	0	0	0	0	5980	14950	2392	50.68
	Pa’Baeng-Baeng	7920	19800	3168	35	15585	38963	6234	86.05
	Parang Tambung	160	400	64	2	12240	30600	4896	66.35
Tamalate Total		30835	77088	12334	152	81510	203775	32604	477.70
Ujung Pandang	Mangkura	0	0	0	0	1375	3438	550	20.47
Ujung Pandang total		0	0	0	0	1375	3438	550	20.47
Grand total		64700	161750	25880	296	193450	483625	77380	1,245.05

slum areas, according to (Jambeck et al., 2015), who stated that waste originating from land is largely responsible for waste in waterways.

Sources of urban solid waste are generally related to land use, and one of these categories is solid waste that comes from commercial sources, namely markets (Hartono et al., 2015). Several traditional markets in Makassar City are on the canal side. Pa'baengbaeng Ward has dense floating litter spots and is directly adjacent to a traditional market where this market produces much waste (Figure 9).

The estuary area is where waste from the land is trapped and flows through channels and rivers. Apart from that, tidal conditions affect the presence of floating waste. At high tide, waste that

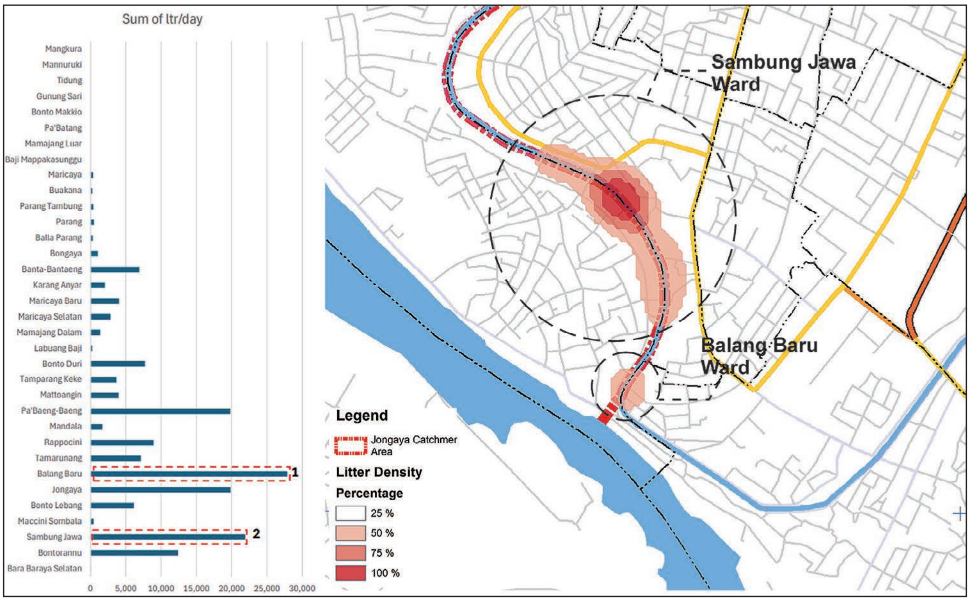

Figure 8. Floating litter density on the surface of canal in Sambung Jawa and Ballang Baru Ward compared to littering potential per day

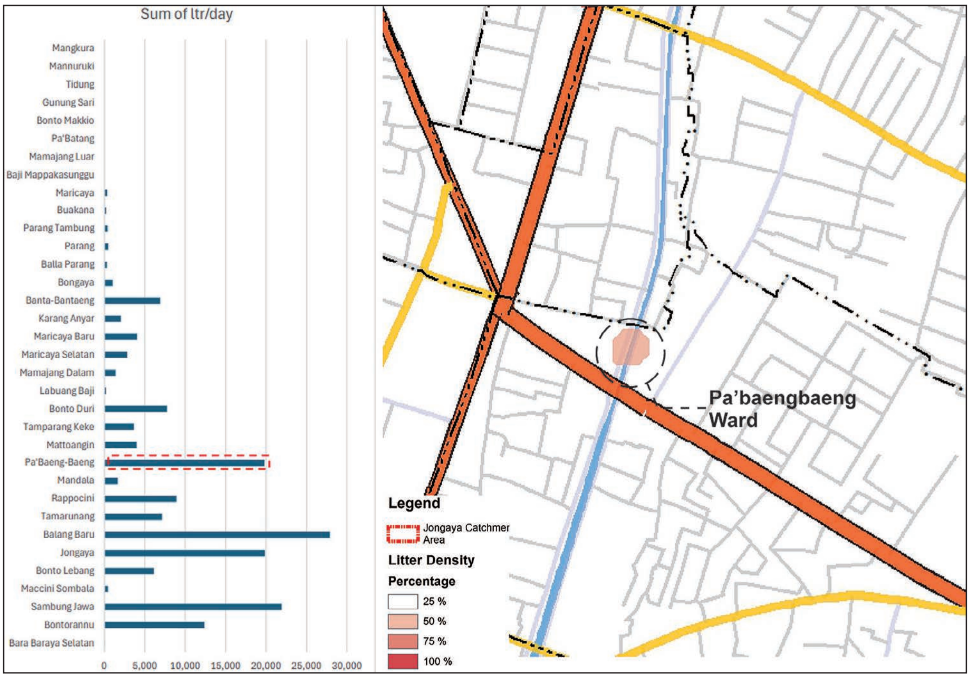

Figure 9. Floating litter density on the surface of canal Pa'baengbaeng ward compared to littering potential per day

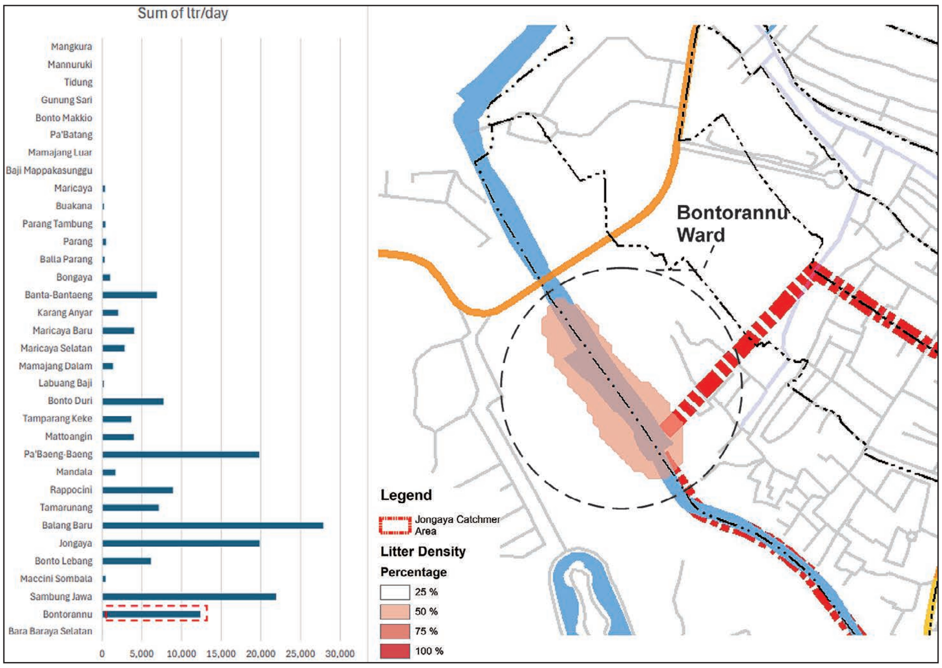

Figure 10. Floating litter density on the surface of canal in Bontorannu ward compared to littering potential per day

should flow into the sea returns to the estuary area so that litter will accumulate (Kurniawan and Imron, 2019). Tidal currents greatly influence the residence time and transport of floating objects in estuaries (Rahim et al., 2020; Sadri and Thompson, 2014). Bontorannu Ward is an estuary area where floating litter collects in this area before entering the sea (Figure 10).

Waste Bank as recommendation

History reveals that human settlements generally developed around water catchment areas. In addition, urbanization is rapid and often unplanned, meaning that water catchments in urban centers are highly threatened by encroachment and pollution (United Nations Human Settlements

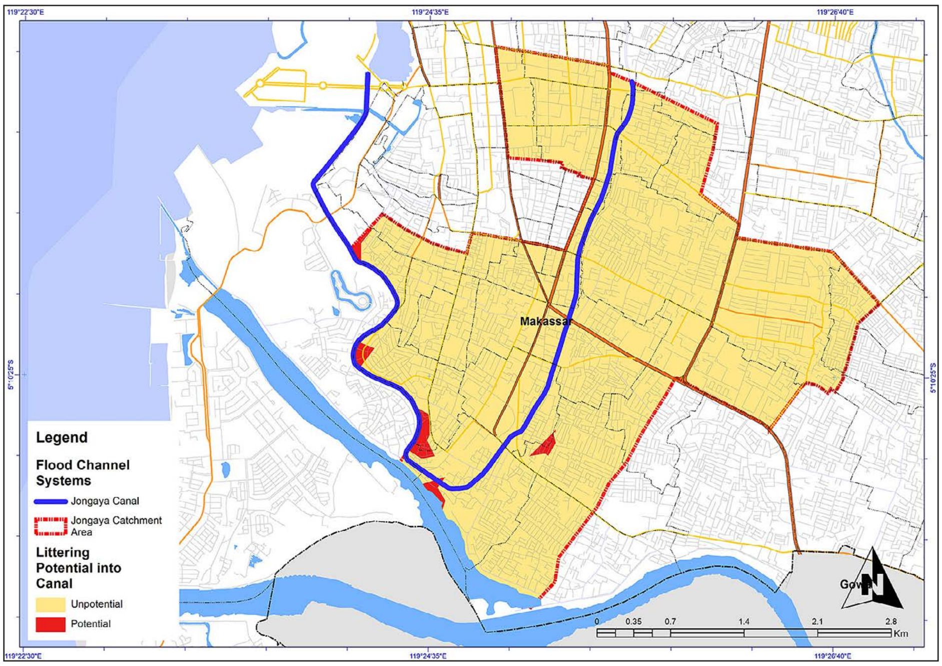

Figure 11. Littering potential into canal overlay with Waste Bank services

Programme, 2005). Implementing mitigation in catchment areas will contribute to reducing pollution originating from waterways and improving ocean health globally. Waste Bank is the Indonesian government's concept of collecting waste like the banking system, but what is saved is not money but waste (Eka et al., 2023). The Waste Bank in Makassar City, especially in catchment areas, could be a recommended alternative solution to serve households that do not have direct access to a "door-to-door" waste transportation system. The waste potential zone map was overlaid with the Waste Bank services area map, and the results showed that the area with the littering potential zone was much smaller, as shown in Figure 11. However, the main obstacle is that currently, the Waste Banks in Makassar City are not yet functioning optimally; even though they are recorded in large numbers, only 40% of the total number of Waste Banks in Makassar City are active (Latanna et al., 2023). The level of waste absorption at waste banks still needs to be deeper, so it needs to be optimized further by increasing public awareness and coaching through education. In addition, efforts are needed to educate the public to change their attitudes towards dumping and waste reduction (Lamond et al., 2012).

CONCLUSSIONS

Research using GIS spatial analysis carried out in densely populated urban areas in the Jongaya Canal area in Indonesia found that a lot of waste could leak into the canal due to uneven service areas of the waste transportation system and high accessibility to the canal from residential areas. It is estimated that 25.8 tons/day (33% of the total waste produced in the catchment area) of waste can enter the Jongaya Canal channel every day from an area of 296 hectares (24% of the total area of the catchment area). The results of the UAV survey as a comparison for calculating the density of floating waste at the top of the canal prove the results of the analysis of potential waste zones entering the canal, where areas that have the potential to produce high waste have a density of floating waste at the top of the canal. The existence of a waste bank could be an alternative solution, especially for canal areas that do not receive waste transportation services. However, an educational campaign is needed to direct the public.

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REFERENCES

1. Abdel-Shafy, H.I., Mansour, M.S.M. 2018. Solid waste issue: Sources, composition, disposal, recycling, and valorization. Egyptian Journal of Petroleum, 27(4), 1275–1290. https://doi.org/10.1016/j.ejpe.2018.07.003
2. Agamuthu, P., Babel, S. 2023. Waste management developments in the last five decades: Asian perspective. Waste Management & Research: The Journal for a Sustainable Circular Economy, 41(12), 1699–1716. https://doi.org/10.1177/0734242X231199938
3. Andreadis, K.M., Wing, O.E.J., Colven, E., Gleason, C.J., Bates, P.D., Brown, C.M. 2022. Urbanizing the floodplain: Global changes of imperviousness in flood-prone areas. Environmental Research Letters, 17(10), 104024. https://doi.org/10.1088/1748-9326/ac9197
4. Anggraini, N., Muis, R., Al Fariz, R.D., Yunus, S., Rachman, I., Matsumoto, T. 2023. Investigation of Solid Waste Management (SWM) in Coastal Settlement: Makassar City, Indonesia. Energy Environment and Storage, 3(3), 81–87. https://doi.org/10.52924/XFBP5264
5. Anggraini, N., Muis, R., Ariani, F., Yunus, S. 2021. Model of Solid Waste Management (SWM) in Coastal Slum Settlement: Evidence for Makassar City. Nature Environment and Pollution Technology, 20(2). https://doi.org/10.46488/NEPT.2021.v20i02.002
6. Anggraini, N., Tawakkal, I., Rachman, I., Matsumoto, T. 2024. Object detection of macroplastic waste using unmanned aerial vehicles in urban canal. Ecological Engineering.
7. Bangani, L., Kabiti, H.M., Amoo, O., Nakin, M.D.V., Magayiyana, Z. 2023. Impacts of illegal solid waste dumping on the water quality of the Mthatha River. Water Practice & Technology, 18(5), 1011–1021. https://doi.org/10.2166/wpt.2023.053
8. Chenillat, F., Huck, T., Maes, C., Grima, N., Blanke, B. 2021. Fate of floating plastic debris released along the coasts in a global ocean model. Marine Pollution Bulletin, 165, 112116. https://doi.org/10.1016/j.

marpolbul.2021.112116

9. Damanhuri, E., Handoko, W., Padmi, T. 2014. Municipal solid waste management in Indonesia. In A. Pariatamby & M. Tanaka (Eds.), Municipal Solid Waste Management in Asia and the Pacific Islands, 139–155. Springer Singapore. https://doi.org/10.1007/978-981-4451-73-4_8
10. Eka, O., Regina, C., Rasha, A., Agnes, S., Nur, S., Nuraisyah, A. 2023. Waste Bank in Indonesia: Problem and opportunities. In S. Jahroh, K. Kamilah, A. Abdullah, R. D. Indrawan, & Sulistyo (Eds.), Proceedings of the Business Innovation and Engineering Conference (BIEC 2022), 236, 284–290. Atlantis Press International BV. https://doi.org/10.2991/978-94-6463-144-9_27
11. Fatmawati, F., Mustari, N., Haerana, H., Niswaty, R., Abdillah, A. 2022. Waste Bank Policy Implementation through Collaborative Approach: Comparative Study—Makassar and Bantaeng, Indonesia. Sustainability, 14(13), 7974. https://doi.org/10.3390/su14137974
12. Ferronato, N., Torretta, V. 2019. Waste mismanagement in developing countries: A review of global issues. International Journal of Environmental Research and Public Health, 16(6), 1060. https://doi.org/10.3390/ijerph16061060
13. Franz, B., Freitas, M.A.V. 2011. Generation and impacts of floating litter on urban canals and rivers: Rio de Janeiro megacity case study. 321–332. https://doi.org/10.2495/ST110291
14. Gholami, M., Torkashvand, J., Rezaei Kalantari, R., Godini, K., Jafari, A.J., Farzadkia, M. 2020. Study of littered wastes in different urban land-uses: An 6 environmental status assessment. Journal of Environmental Health Science and Engineering, 18(2), 915–924. https://doi.org/10.1007/s40201-020-00515-7
15. Haerani, D., Syafrudin, Budi, S.S. 2019. Review modeling of solid waste transportation routes using Geographical Information System (GIS). E3S Web of Conferences, 125, 07006. https://doi.org/10.1051/e3sconf/201912507006
16. Hartono, D.M., Kristanto, G.A., Amin, S. 2015. Potential reduction of solid waste generated from traditional and modern markets. International Journal of Technology, 6(5), 838. https://doi.org/10.14716/ijtech.v6i5.2016
17. Iyengar, J.V. 1998. Application of geographical information systems.
18. Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L. 2015. Plastic waste inputs from land into the ocean. Science, 347(6223), 768–771. https://doi.org/10.1126/science.1260352
19. Kataoka, T., Nihei, Y. 2020. Quantification of floating riverine macro-debris transport using an image processing approach. Scientific Reports, 10(1), 2198. https://doi.org/10.1038/s41598-020-59201-1
20. Khan, Md. M.-U.-H., Vaezi, M., Kumar, A. 2018. Optimal siting of solid waste-to-value-added facilities through a GIS-based assessment. Science of The Total Environment, 610–611, 1065–1075. https://doi.org/10.1016/j.scitotenv.2017.08.169
21. Kurniawan, S.B., Imron, M.F. 2019. The effect of tidal fluctuation on the accumulation of plastic debris in the Wonorejo River Estuary, Surabaya, Indonesia. Environmental Technology & Innovation, 15, 100420. https://doi.org/10.1016/j.eti.2019.100420
22. Lamond, J., Bhattacharya, N., Bloch, R. 2012. The role of solid waste management as a response to urban flood risk in developing countries, a case study analysis. 193–204. https://doi.org/10.2495/FRIAR120161
23. Latanna, M.D., Gunawan, B., Franco-García, M.L., Bressers, H. 2023. Governance assessment of community-based waste reduction program in Makassar. Sustainability, 15(19), 14371. https://doi.org/10.3390/su151914371
24. Major River Basin Organization Pompengan – Jeneberang, I. 2018. Flood Channel Systems. Ministry of Public Works, Indonesia.
25. Makassar Bureau of Statistics. 2023. Makassar in Figures 2023. Makassar Bureau of Statistics. https://makassarkota.bps.go.id/indicator/12/72/1/jumlah-penduduk-menurut-kecamatandan-jenis-kelamin-di-kota-makassar.html
26. Maspaitella, B.J., Susanty, A., Purwaningsih, R. 2021. Waste transportation route garbage using network analysis method, a research method design. IOP Conference Series: Materials Science and Engineering, 1072(1), 012025. https://doi.org/10.1088/1757-899X/1072/1/012025
27. Ministry of Environment and Forestry, I. 2023. Waste Generation. Ministry of Environment and Forestry, Indonesia. https://sipsn.menlhk.go.id/sipsn/public/data/timbulan
28. Muis, R., Al Fariz, R.D., Yunus, S., Tasrief, R., Rachman, I., Matsumoto, T. 2024. Investigating the potential of landfilled plastic waste—a case study of makassar landfill, Eastern Indonesia. Ecological Engineering & Environmental Technology, 25(3), 185–196. https://doi.org/10.12912/27197050/178529
29. Nunkhaw, M., Miyamoto, H. 2024. An image analysis of river-floating waste materials by using deep learning techniques. Water, 16(10), 1373. https://doi.org/10.3390/w16101373
30. Putra, A.H., Amalia, A., Putro, R.K.H., Darmayani, L.F. 2020. Waste transportation route optimization in malang using network analysis. IOP Conference Series: Earth and

Environmental Science, 506(1), 012033. https://doi.org/10.1088/1755-1315/506/1/012033
31. Rahim, S., Widayati, W., Analuddin, K., Saleh, F., Alfirman, Sahar, S. 2020. Spatial distribution of marine debris pollution in mangrove-estuaries ecosystem of Kendari Bay. IOP Conference Series: Earth and Environmental Science, 412(1), 012006. https://doi.org/10.1088/1755-1315/412/1/012006
32. Ramadan, B.S., Ardiansyah, S.Y., Sendari, S., Wibowo, Y.G., Rachman, I., Matsumoto, T. 2024. Optimization of municipal solid waste collection sites by an integrated spatial analysis approach in Semarang City. Journal of Material Cycles and Waste Management, 26(2), 1231–1242. https://doi.org/10.1007/s10163-023-01876-5
33. Regulation of Mayor. 2018. Makassar City Mayor Regulation concerning Policies and Strategies in the Management of Household Waste (36–2018). Makassar City Government, Indonesia. https://peraturan.bpk.go.id/Details/111279/perwali-kota-makassar-no-36-tahun-2018
34. Sadri, S.S., Thompson, R.C. 2014. On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England. Marine Pollution Bulletin, 81(1), 55–60. https://doi.org/10.1016/j.marpolbul.2014.02.020
35. Sindangan, M.F., Ali, M., Sobarsyah, M. 2024. Waste water Management in Pannampu Canal Based on Water Sensitive Urban Design (Wsud) as Supporting Factor for Urban Quality Improvement. 45(1).
36. United Nations Human Settlements Programme (Ed.). 2005. A guidebook for local catchment management in cities. United Nations Human Settlements Programme (UN-Habitat).
37. Van Emmerik, T., Mellink, Y., Hauk, R., Waldschläger, K., Schreyers, L. 2022. Rivers as plastic reservoirs. Frontiers in Water, 3, 786936. https://doi.org/10.3389/frwa.2021.786936
38. Willis, K., Hardesty, B.D., Vince, J., Wilcox, C. 2022. Local waste management successfully reduces coastal plastic pollution. One Earth, 5(6), 666–676. https://doi.org/10.1016/j.oneear.2022.05.008
39. Wilson, D.C., Velis, C.A. 2015. Waste management – still a global challenge in the 21st century: An evidence-based call for action. Waste Management & Research: The Journal for a Sustainable Circular Economy, 33(12), 1049–1051. https://doi.org/10.1177/0734242X15616055