Analysis of Spatial Distribution of Informal Waste Collection Sites in Kupang, East Nusa Tenggara

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Abstract. Population growth in Kupang has consequently led to an increase in solid waste generation. On the other hand, the provision of waste management infrastructures, such as temporary waste collection sites and waste transportation services, are not distributed equally in several areas. This condition and the community's low awareness of proper waste management have resulted in the emergence of informal waste collection sites. This study aims to examine the distribution of formal and informal waste collection sites in regards to their distribution patterns, characteristics of the sites using a descriptive survey method supported by a Geographical Information System. The study was conducted in Alak and Kelapa Lima Sub-Districts, Kupang, East Nusa Tenggara. The study identified a total of 57 informal waste collection sites, 14 sites in Alak Sub-District and 43 in Kelapa Lima. The distribution of informal waste collection sites was influenced by geophysical factors, where 79% of collection sites were located on vacant land and 53% are on local roads. However, the distribution of informal waste collection sites was not affected by population density nor the type of settlement.

Keywords: spatial distribution, GIS, solid waste, informal collection site.

1. Introduction
The waste problem has become a global issue in recent years, including in Indonesia. Nationally, the average waste managed in Indonesia only reaches 67% (KLHK, 2018). Based on the National Basic Health Survey, 2018, only 36.8% of households in Indonesia manage their waste properly (Kemenkes RI, 2018). The general perception of communities is that waste management is the responsibility of the government. Within this perception, the main method in waste management is the old 'collect-transport-throw' paradigm. Moreover, the limited facilities and infrastructure for waste collection further triggers the emergence of informal waste collection sites (Mulasari & Sulistyawati, 2014). This is an issue of many settlements and municipalities in Indonesia, as well as in Kupang, the capital city of East Nusa Tenggara Province. It is an indication of problems related to the distribution of waste collection service in the city (Fandoe, 2010; Naatonis, 2010), where the provision of formal waste collection sites (formal WCS) was found to be limited in sub-districts of Alak District, Kota Raja, and Kelapa Lima. (Pratama et al, 2019).

The waste generation in Kupang was 684 m$^3$ per day in 2017 and increased to 793 m$^3$ per day in 2018, with predicted volume that was not managed by the collection system reach 229 m$^3$ per day in
2018 (Widya, Andianti dan Pragesari, 2019). This issue is also an indication of the limiting capacity and location of formal WCS as well as limited coverage of waste collection service.

Furthermore, the spatial distribution of formal and informal waste collection sites in Kupang has not been examined in regards to characteristics of the sites, distribution patterns and the association between the formal and informal WCS. Therefore, this research aims to examine the distribution of informal and formal WCS in regards to its distribution patterns, characteristics of the sites using spatial analysis.

Spatial analysis using Geographical Information Systems (GIS) can be used to determine patterns and characteristics of a site and provide specific information regarding events that are happening in an area along with trends occurring at certain intervals (Setyawan, 2014). GIS has been used in several studies related to solid waste issues. Research by Mizwar (2012) and Maulidah et al. (2013) have used GIS to recommend the location for municipal landfill by analyzing the site criteria. GIS can be used to evaluate the waste transportation system to improve service coverage (Hidayat, 2013). GIS can also be used to optimize waste transportation routes based on geographic spatial data (Ridha et al, 2016).

This research will demonstrate the spatial analysis using GIS to examine the distribution of informal WCS in two sub-district in Kupang. The research will not only provide current practice and situation of waste management but also deepens our understanding of particular needs for improving the waste management system in the city.

2. Research Methods
This study used a descriptive survey design to plot the waste collection sites. The research was conducted in 2 sub-districts in Kupang City, namely Kelapa Lima and Alak Districts from April - July 2020. Primary data collected was the coordinates and physical site characteristics of formal and informal WCS; while secondary data includes population density data, road types from the landscape plan document of Kupang 2011-2031, and addresses of formal WCS from Kupang Environmental Office. Data were processed using QGIS 3.12 Bucuresti. The analytical method used is descriptive analysis and network analysis for service areas and shortest paths.

3. Results and Discussion

3.1. Overview of the Research Area
Kupang is the capital city of the Province of East Nusa Tenggara (NTT), which is located in the southeast of the province with an area of 180.27 km2 and consists of 6 sub-districts (BPS Kota Kupang, 2020). In this study, 2 sub-districts were chosen, namely Alak and Kelapa Lima Sub-Districts, because these two sub-districts had limited site for formal WCS in the year 2016 to 2021 (Pratama et al. 2019).

Alak sub-district has a population of 76,291 people with waste generated was 64,542 m$^3$ in 2016 and was predicted to increase to 73,514 m$^3$ in 2021 (Pratama et al., 2019). Meanwhile, Kelapa Lima District has a population of 76,573 with waste generated was 81,965 m$^3$ in 2016 and was predicted to increase to 97,743 m$^3$ in 2021 (Pratama et al., 2019). The level of economic growth in Kupang from the 2015 - 2019 period shows a slowing trend and fluctuations while the percentage of the workforce has increased to 58.75% in 2019 (BPS Kota Kupang, 2020).

3.2. Distribution of Waste Collection Sites
In the Alak sub-district, there were 13 formal WCS in only 5 out of 12 urban villages, namely Nunnhila (3 sites), Penkase Oeleta (3 sites), Namosain (3 sites), Nunbaun Sabu (2 sites), and Nunbaun Delha (2 sites). The conditions of formal WCS were good in general, only one formal WCS was damaged. On the other hand, the informal WCS was distributed in 8 out of 12 urban villages, namely Namosain (5 sites), Batuplat (2 sites), Oleta Penkase (2 sites), and Manulai II, Nainoni, Alak, Fatufeto, and Nunbaun Sabu each found 1 site. The category of informal WCS based on size can be seen in Table 1.
Table 1. Size of informal waste collection sites in Alak

| No | Name of urban village | Area of Informal WCS | Total |
|----|-----------------------|----------------------|-------|
|    |                       | 0-53 m² (small)      | 54-107 m² (medium) | 108-160 m² (large) |       |
| 1  | Nainoni               | 1                    | -                  | -                  | 1     |
| 2  | Batuplat              | 2                    | -                  | -                  | 2     |
| 3  | Manulai II            | 1                    | -                  | -                  | 1     |
| 4  | Penkase Oeleta        | 1                    | 1                  | -                  | 2     |
| 5  | Alak                  | 1                    | -                  | -                  | 1     |
| 6  | Fatufeto              | 1                    | -                  | -                  | 1     |
| 7  | Nunbaun Sabu          | 1                    | -                  | -                  | 1     |
| 8  | Namosain              | 4                    | -                  | 1                  | 5     |
|    | Total                 | 12                   | 1                  | 1                  | 14    |

The mapping of the distribution of formal and informal WCS in Alak can be seen in the following figure.

Figure 1. Map of the Distribution of formal and informal WCS in Alak sub-district.

In Kelapa Lima sub-district, the 23 formal WSCs were distributed in 4 out of 5 urban villages, namely Kelapa Lima (15 sites), Oesapa (3 sites), West Oesapa (3 sites), and South Oesapa (2 sites). Most legal WCSs were found to be in good condition (21 sites). Meanwhile, there were total 43 informal WCSs which were distributed in South Oesapa (16 sites), West Oesapa (13 sites), Kelapa Lima (8 sites), Oesapa (5 sites), and Lasiana (1 site). The size of these informal WCSs can be seen in Table 2.
### Table 2. Size of informal waste collection sites in Kelapa Lima.

| No | Name of urban village | Area of Informal WCS |
|----|-----------------------|----------------------|
|    |                       | 0-53 m² (Small)  | 54-107 m² (Medium) | 108-160 m² (Large) | Total |
| 1. | Kelapa Lima           | 7                   | -                   | 1                   | 8     |
| 2. | Oesapa                | 4                   | 1                   | -                   | 5     |
| 3. | West Oesapa          | 10                  | 2                   | 1                   | 13    |
| 4. | South Oesapa         | 15                  | 1                   | -                   | 16    |
| 5. | Lasiana               | 1                   | -                   | -                   | 1     |
|    | Total                 | 37                  | 4                   | 2                   | 43    |

The mapping of the distribution of formal and informal WCS in Kelapa Lima Sub District can be seen in the following figure.

![Map of the Distribution of formal and informal WCS in Kelapa Lima.](image)

**Figure 2.** Map of the Distribution of formal and informal WCS in Kelapa Lima.

#### 3.3. The Distance of Formal to Informal WCS

We conduct a network analysis to identify informal WCSs that were located within a distance of less than 1 km by the shortest path to the nearby formal WCS. It was assumed that the waste pick up service was able to cover the area within 1 km distance from the formal WCSs and able to transport the waste to the designated collection site. In Alak, there were 8 informal WCSs located within 1 km distance, while there were 6 informal WCSs that were located about 2 – 6.2 km from the nearby formal WCS (Table 3 and Figure 3).
Table 3. Informal WCSs with distance 1 km or more from nearby formal WCSs in Alak.

| No. | Informal WCS                  | Formal WCS                  | Distance |
|-----|--------------------------------|-----------------------------|----------|
| 1   | A1 point Yos Sudarso street, Alak village | TL11 point Penkase street, Penkase Oeleta village | 4 km     |
| 2   | P2 point Penkase street, Penkase Oeleta village | TL10 point Penkase street, Penkase Oeleta village | 2 km     |
| 3   | B1 point Behind of Batuplat village office | Penkase street, Penkase Oeleta village | 6.2 km   |
| 4   | B2 point Batuplat village |                                 | 2 km     |
| 5   | M1 point Viquam Tabun street, Manulai II village | 6 km | 7 km     |
| 6   | N1 point 40 Route, Nainoni village | 7 km | 7 km     |

Figure 3. Informal WCSs with distance 1 km or more from nearby formal WCSs in Alak.

In Kelapa Lima, there were 40 informal WCSs that were located within a distance of less than 1 km from the nearby formal WCSs and only 3 informal WCS that were located 1 km or further from the nearby formal WCSs, with a range from 1 – 3 km (see Table 4 and Figure 4).
Table 4. Informal WCSs with distance 1 km or more from nearby formal WCSs in Kelapa Lima.

| No. | Informal WCS                      | Formal WCS                      | Distance |
|-----|-----------------------------------|---------------------------------|----------|
| 1.  | O4 point Tidar III street, Oesapa village | TL20 point Timor Raya street (Dutalia), West Oesapa village | 2 km     |
| 2.  | O5 point Bunda Hati Kudus street, Oesapa village |                      | 1 km     |
| 3.  | L1 point Yohanes Fanggi street, Lasiana village | TL24 point Timor Raya street, Oesapa village | 3 km     |

Figure 4. Informal WCSs with a distance of 1 km or more from nearby formal WCSs in Kelapa Lima.

This analysis shows that many of the informal WCSs were located within a very short distance from the formal WCSs. That condition could be explained that the coverage of waste pick up service in that area was not evenly distributed or not reaching all houses within the distance. Meanwhile, the informal WCSs that were located 1 km or further from formal WCSs indicate that the number of legal TPS is uneven (Mizwar & Kartini, 2016). This finding was in line with a previous study by Pratama et al. (2019) that Alak and Kelapa Lima Districts need to increase the number of formal WCS and also with a study by Faradilla et al. (2018) that waste management facilities in the area have not met the needs of the community and thus causing informal WCSs were formed in several locations.

3.4. Geophysical Characteristic of the Informal WCSs

There are two main characteristics that were analyzed: the land use and road type of the site. In regards to land use, there are three different categories which are empty land, land of the former building, and located on the border of the road. Many of the informal WCSs in both sub-districts were empty land (57% in Alak and 86% in Kelapa Lima), followed by location on the border of the road (43% in Alak, and 12% in Kelapa Lima) and located on the land of a former building (2% in Kelapa Lima).
This characteristic distribution shows that the existence of empty land within a settlement can trigger informal WCS to be formed. Even though the nearby formal WCS was within a short distance, empty land with shorter distance was preferred more by some residents. The informal WCSs located on the border of the road usually used by residents who can easily pass the road (Mulasari & Sulistyawati, 2014). The existence of easily accessible sidewalks has the potential to form informal WCSs as an alternative for residents (Siswandi & Wahyudin, 2019). Both conditions show that the convenience of accessing the WCS triggers the continuous use of the sites as waste dumping by residents. The existence of empty land or space on the side of the road as an important trigger for the forming of informal WCS has also been identified by Faradilla et al (2018); Widiatmoko et al (2018), and Siswandi & Wahyudin (2019).

In terms of road types, the WCS was categorized into 4 groups, which are arterial roads, collector streets, local streets, and neighborhood streets. In Alak, informal WCSs were distributed evenly in every type of road, while many formal WCSs were located in arterial roads (7 sites) and followed by location at collector street and local street (3 sites each). In Kelapa Lima, there were no informal WCSs located on the arterial road, and many of them were located on the collector (20 sites) and neighborhood streets (16 sites), fewer were on local streets (7 sites). Meanwhile, many formal WCSs were located in arterial roads and collector streets (9 and 11 respectively).

Based on the distribution above, the formal WCSs were located more on the main road such as arterial road and collector streets which can be easily accessed by the waste transportation truck to pick up the waste and easily transport it to the landfill. The ease of road access can shorten the time required to transport the waste to the landfill (Nadiasa et al., 2009; Widiatmoko et al., 2018). Therefore, residents' houses that were far from the main road, will have limited access to formal WCSs and thus lead to the formation of informal WCSs. Similarly, Akbar et al. (2018), Faradilla et al. (2018), Widiatmoko et al.(2018) also found that road types can influence the formation of informal WCSs due to limited access to the formal WCSs by residents and also the size of waste transport vehicle that is used.

3.5. Population and Settlement Characteristics of the WCSs

Population density can influence the amount of waste generated, while also limit the availability of land to be used as formal WCS. Based on Figure 6, the population density in Alak is varied from 1 to 142 residents/ hectare, and informal WCSs were found more (5 sites) in the area with medium population density (56 residents/hectare) compare to areas with lower and higher density.
Meanwhile, in Kelapa Lima, more informal WCSs were found in an area with a population density of 26-30 residents/hectare and followed by the area with a population density of 240 residents/hectare (Figure 7). Although this figure does not show a clear pattern of association between population density and the number of informal WCSs, the informal WCS tends to be easily formed in medium population density (20-60 residents/hectare), where more available empty spaces tend to exist.

The previous study also found that there was no clear pattern of association between population density and the formation of informal WCSs (Faradilla et al, 2018), however, other studies show that areas with lower population density have a higher probability of the presence of illegal polling stations (Mizwar & Kartini, 2016), this could be explained because in a very high populated areas, an empty space potentially used as waste dumping will be more difficult to be found.

In regards to the type of settlement where the informal WCSs were located, in Alak 44% of informal WCSs were found in irregular settlements, 44% were found in regular dense settlements and 12% were in commercial areas. While in Kelapa Lima, it was found that 81% of informal WCSs were in dense regular settlements (35 sites) and there was no informal WCSs found in the irregular settlement in Kelapa Lima, because this area has been densely packed with houses, and leaves no space for waste dumping. However, when the irregular settlement is with lower population density, then more spaces are available for waste dumping. Thus the residents are more likely to manage waste...
individually such as burning or burying it in the yard of the house, thereby reducing the potential for communal illegal TPS (Mulasari & Sulistyawati, 2014). The existence of informal WCSs might also be influenced by the existence of economic activities such as markets and other services, which is indicated by the fact that 19% of informal WCSs are located in commercial areas. Therefore, the formation of informal WCSs was not highly influenced by the type of settlements, but more on the available empty spaces for waste dumping.

4. Conclusion
In conclusion, there were 14 informal WCSs in Alak and 43 in Kelapa Lima which the distribution is influenced by the land use pattern and road types. The more empty land or space available in an area will trigger the use of that space as waste dumping, and smaller streets where formal WCSs rarely available also trigger the formation of informal WCSs. However, this study does not found a clear relationship between population density and type of settlement with the formation of informal WSC. Future studies can use wider areas to obtain more samples of informal WCSs, thus it allows more rigorous spatial statistical analysis to be carried out to demonstrate the association of these geophysical factors and demographic characteristics with the formation of informal WCS.

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