https://dx.doi.org/10.4314/dujopas.v9i2a.27
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490

Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 9 No. 2a June 2023*

Geo-spatial Mapping of Plastic Waste Recycling Plants in Kano Metropolis, Kano State, Nigeria

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Abstract
This study adopted a Geographic Information Systems (GIS) approach to map and assessed the geographic distribution of plastic waste recycling facilities in Kano Metropolis. Specifically, the study aimed at creating an inventory for the Kano Metropolis plastic waste recycling facilities and investigating its distribution pattern. Data collected on the plastic waste recycling centers were obtained from Kano State Ministry of Commerce and a field survey. Global Positioning System (GPS) was then utilized to record the coordinates (latitude and longitude) of each plastic recycling facility. The nearest neighbor analysis of the research area's plastic garbage was conducted using the data collected. Results obtained indicate that there were Seventy-eight (78) spatially dispersed plastic recycling plants throughout Kano Metropolis, and the observed mean distance between them was about 750 m, compared to an expected mean distance of about 3030 m. The distribution of recycled plastics showed a weakly clustered pattern with the nearest neighbor distance smaller than 1 (0.22). To illustrate the boundaries separating locations for future detailed spatial studies of the spatial pattern of recycling businesses, it is recommended that a thorough mapping of the plastic recycling plants be done. Since most recycling facilities in Kano Metropolis are not legally recognised, the government should identify and keep an eye on them to ensure that environmental laws and regulations are being followed.

Keywords; Plastic Waste, Recycling, GIS, Distribution, Nearest Neighbor analysis.

INTRODUCTION

During the second half of the nineteenth century, plastic manufacturing as an industrial process has seen a fast increase in plastic variety and volume (Meijer *et al.,* 2021; Heinrich Boll, 2019; Shamsuyeva and Endres, 2021). There have been significant plastic recycling plants in several wealthy and industrialized nations, including Australia, China, Canada, Sweden, Poland, and the United States (Khalil *et al.,* 2017). These countries have made efforts to establish and support recycling infrastructure, promote recycling initiatives, and develop technologies to recycle and repurpose plastic waste (Hopewell *et al*., 2009; Khalil *et al*., 2017). More than 6,300 million metric tons of plastic wastes were generated in 2015; 9% of it was recycled, 12% was burned and 79% ended up in landfills or the environment (Geyer *et al.,* 2017; Ncube *et al.,* 2021). Japan, the United Kingdom, the United States, and other industrialized nations have all implemented waste recycling to a large extent. For instance, recycling rules have been in effect in the United States since 1993 and mandate that a particular amount of household garbage be recycled (Khalil *et al*., 2017). The recycling regulation was successfully implemented, according to a report by the U.S. Environmental Protection Agency (USEPA, 2011; Khalil *et al*., 2017).

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In recent years, rapid population growth, urbanization, and changes in living standards have significantly increased the exploitation of natural resources, especially in less-developed regions, and generated large amounts of waste with different characteristics (Minghua, 2009; Abdel-Shafy and Mansour, 2018; Mahmud *et al.*,2022*)*. For example in Nigeria, the rapidly growing population, which is currently projected to be over 200 million people, the (NPC, 2006; Ali *et al.*, 2017) high consumption of virgin plastics (resins) supports a strong plastic manufacturing sector (Njoku *et al.,* 2015). According to market reports, Nigeria's plastic production is growing rapidly at an annual rate of 13.9%, from 120 kt in 2007 to an expected 513 kt in 2020 (Statista, 2020; WACA, 2021).

Geo-spatial technologies for plastic waste issues, such as GIS and remote sensing have been used to monitor the life cycle of plastic materials (Tran-Thanh *et al*., 2021). Previous geo-spatial-based approaches have used global coverage at country levels (Lebreton *et al.,* 2017; Meijer *et al.,* 2021; Gunasekara *et al.,* 2022) and city levels (Sakti *et al.*, 2021; Gunasekara *et al.*, 2022) to understand the potential of plastic waste discharge. The locations of recycling plants can be determined using GIS and the availability of a geo-referenced database underscores the usefulness of the technology (Asefa *et al.,* 2022). A lot of data may be effectively stored, geo-referenced, retrieved, analyzed, and displayed using GIS in accordance with user-defined criteria (Suresh and Sivasankar, 2014; Shamshiry *et al.,* 2011; Onunkwo *et al*., 2012; Blanco, 2020). It enables the choice of disposal locations while taking into account the location and volume of waste generated, infrastructures, land usage, and social and economic issues. Software for GIS and Global Positioning Systems (GPS) allows for the spatial capture, mapping, and analysis of solid waste management issues (Abdulai, 2015; Fuseini *et al.,* 2021).

Numerous towns in across the globe have been the subjected to research; one that stands out is the study by Zulkifli *et al.,* (2022), which describes the mapping and monitoring of plastic garbage using geo-spatial methods in Sungai Pinang, Malaysia. Another comparable study was conducted by Hidalgo-crepto *et al.,* (2022) in Guayaquil. They quantified and mapped residential plastic waste using a GIS technique. Loulad *et al.,* (2016) investigated the spatial distribution of plastic waste in the South Atlantic Ocean in Morocco. The study found that 80% of Morocco's southern Atlantic litter consisted of plastics, followed by metals, textiles, rubber and glass.

None of the earlier studies accessed in this study used a GIS approach to map and assess the distribution of the plastic waste recycling plants in Kano Metropolis. The reduction of household plastic trash entering landfills has been credited in large part to plastic recycling. Additionally, it gives manufacturers the raw resources they require. Therefore, the primary goal of this study was to use a GIS approach to map out and analyze the spatial distribution of the industries that recycle plastic garbage in Kano Metropolis. Making an inventory for the plastic waste recycling companies and looking at the types and patterns of solid waste collection in the study area were the two main goals that allowed the research to achieve its intended goal.

MATERIALS AND METHODS

Study Area

This study was conducted in Kano metropolis, Nigeria. It is situated in the Sudan Region, located between latitude 11°59′59.57′′N to 12°02′39.57′′N and longitude 8°31′19.69′′E to 8°33′19.69′′E (Ibrahim and Mohammed, 2016). The Kano metropolitan area has undergone dramatic change and growth over the decades, with a projected population of approximately 4.3 million (NPC, 2013; Yunus, 2021) by 2018. It has a considerable range of industrial and commercial activities (Maconachie, 2007; Ali *et al.,* 2017). The population density within the Kano Closed Zone is about 1,000 people/km^2, compared to the national average of 267 people per people km^2. The city also has a large number of migrant workers (UNDP, 2004; Liman *et al.,* 2015). The metropolis is made up of eight local government areas Dala, Fagge, Gwale, Kano Municipality, Nasarawa, and Tarauni and parts of Kumbotso and Ungogo (Maigari, 2016; Yunus, 2021). The total area of metropolitan areas is about 499 km^2 and the urban area is about 137 km^2. The Kano metropolitan area is one of the fastest-growing cities in West Africa, both economically and demographically. It is the most populous region in northern Nigeria (Barau *et al.,* 2015; Yunus, 2021). The Kano metropolitan area is characterized by a semi-arid climate with an average daily temperature of around 30°C. The lowest temperature (i.e., 20 °C) has been recorded between December and February (Liman *et al.,* 2014; Yunus, 2021).

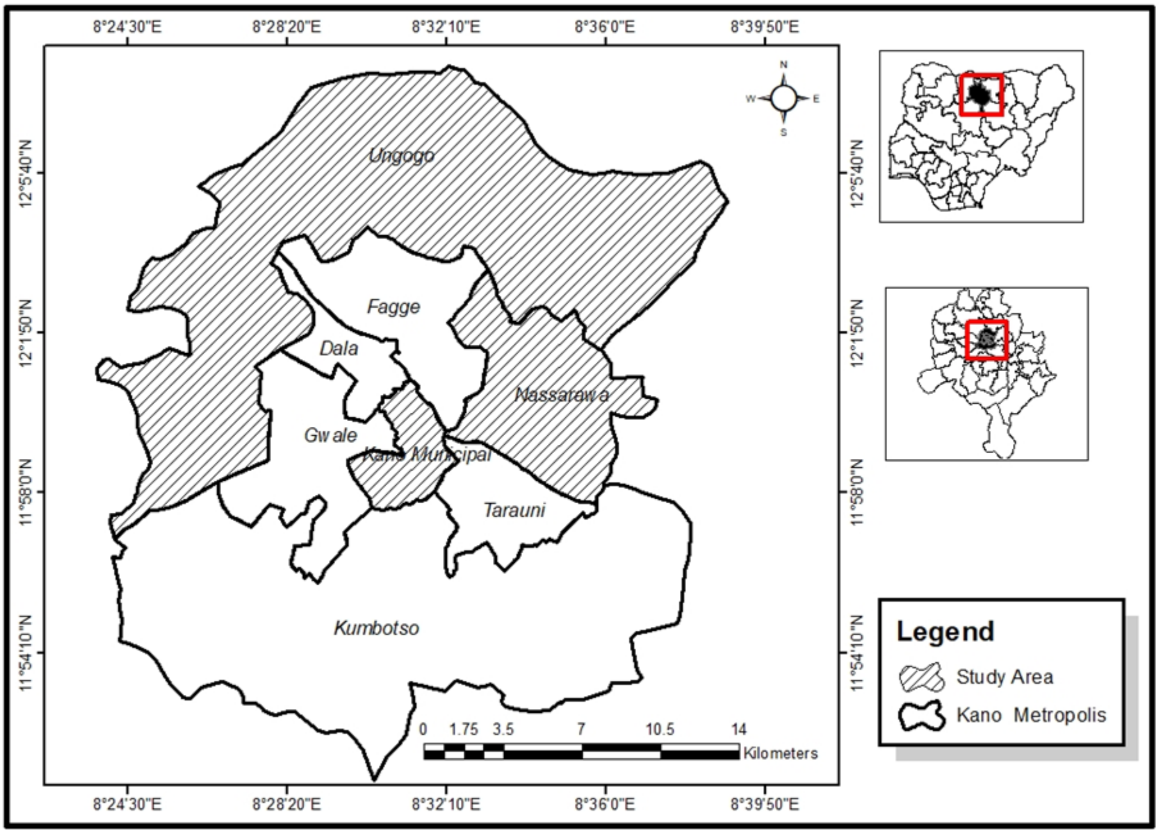


Figure 1: Map Showing the Study Area

Research Design

The study design was a survey study. The survey was conducted in six major plastic recycling plants in the Kano metropolitan area. Established large industrial zones for plastic recycling including Sharada (DDK, Janbulo, Zurefat), Dakata (Kaloma and Fatima Bread), Challawa, Rangaza and Zango.

Research Instrumentation

GPS survey was conducted to obtain the absolute locational attributes (latitude and longitude) of all plastic recycling plants to perform geo-spatial mapping of the recycling plants. A digital camera was used to photograph some of the plastic recycling plants to demonstrate their nature. To map the coordinates of the recycling plant, a digital map was created using ArcGIS software.

Research Methods

In the geo-spatial mapping of plastic recycling and its Nearest Neighbor Index (NNI), the methodology was developed in three main phases. As a first step, the study identified the coordinates of plastic waste recycling plants collected during fieldwork and created a database that was used to record the coordinates, location and addresses of the recycling plants.

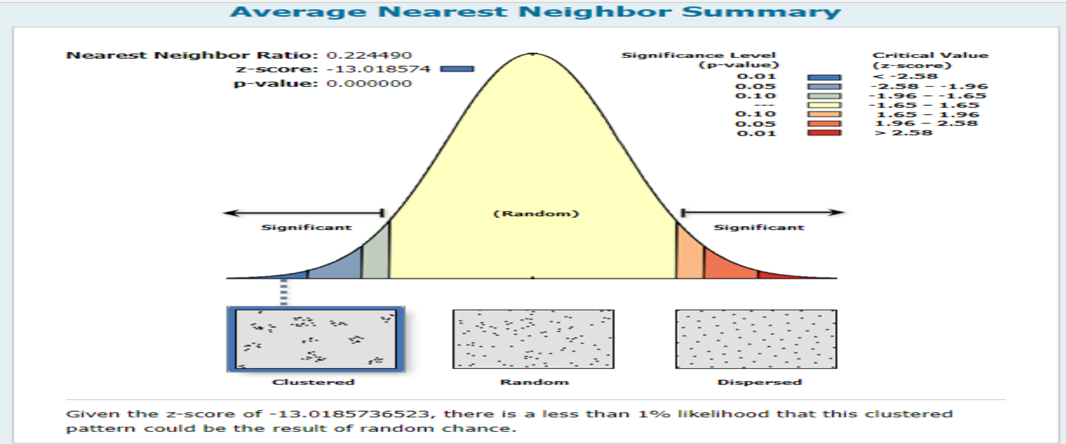
In the second step, ArcGIS was used to display the spatial distribution of plastic recycling on digital maps and satellite imagery using coordinates of plastic recycling plants collected during the fieldwork.

For the spatial pattern of the plastic recycling plants, a Nearest Neighbor Analysis (NNA) was performed in the last step. NNA was performed using Arc GIS software to identify the distribution pattern of the plastic recycling industry in the Kano metropolitan area. An analysis was performed to calculate the NNI based on the average distance from each recycling plant point to its nearest neighbor point. This was done after importing the latitude and longitude attributes of all incidents during the study period into a large city land cover map and using this NNA tools within the Spatial Analyst Toolbox for analysis.

RESULTS AND DISCUSSION

Spatial Analysis of plastic Recycling Plants

The nearest neighbor analysis calculates a NNI based on the average distance from each recycling plant to its nearest neighbor point. In this study, the observed mean distance among 78 spatially distributed plastic recycling plants in the entire Kano metropolis was calculated to be 747.71 m (Figure 2), with an expected mean distance of 3030.70 m. The nearest neighbor's distance was less than 1 (0.22), signifying a weakly clustered pattern of plastic recycling distribution. According to Boateng *at el*., (2019) and Abdulkarim *et al.,* (2021), values of the NNI start from 0 (where there is no travel whatsoever) through to 1.0 (in which spacing of distribution is least, hence distributed uniformly). An index of 0 implies an exclusively clustered distribution; absolute random distributions have a 1.0 index value, and values above 1.0 indicate a propensity to disperse. The findings of this study is in contrast with the finding of Zulkifli *et al.,* (2022) on plastic trash mapping in Malaysia, which claimed to have found the plastic recycling collection and industrial zone dispersedly distributed. This is due to the peculiarities of both countries in terms of economy, urban planning, and population density.



Average Nearest Neighbor Summary

Observed Mean Distance:	747.7098 Meters
Expected Mean Distance:	3330.6977 Meters
Nearest Neighbor Ratio:	0.224490
z-score:	-13.018574
p-value:	0.000000

Dataset Information

Input Feature Class:	Sample Points
Distance Method:	EUCLIDEAN
Study Area:	3416812538.755038
Selection Set:	False

Figure 2: Average Nearest Neighbour Summary Curve for Plastic Recycling plants in Kano Metropolis

Figure 2 shows the overall pattern of distribution for the recycling of plastics, with a Z-score of -13.01, R-value of 0.22 and a significant level of 0.00. The Z-score value of -13.01 is outside the range of -1.96 to 1.96, and the p-value of 0.00 is less than 0.05; thus, the study concluded that the distribution pattern of the plastic waste recycling plants in the study area is weakly clustered. The resulting Z-score (-13.01) and p-value (0.00) are measures of statistical significance indicating whether to reject the null hypothesis. The null hypothesis, which states that the recycling plants are dispersed in Kano city, is rejected in this case.

The weakly clustered nature of the spatial distribution of plastic waste in the study area (Figure 3) is largely because recycling businesses are primarily in the unorganized sector and frequently sited illegally rather than according to strict guidelines established by urban planners, and population distribution and clusters influence the dispersion pattern. The outcome of this study is consistent with the analyses of Loulad *et al.*,(2016) regarding the spatial distribution of plastic waste in the southern Atlantic of Morocco using GIS mapping techniques. The authors reported that the pattern in the sampling area was closely matched to the pattern of distribution of the total quantity of debris because plastic accounts for the largest percentage of solid waste in the area.

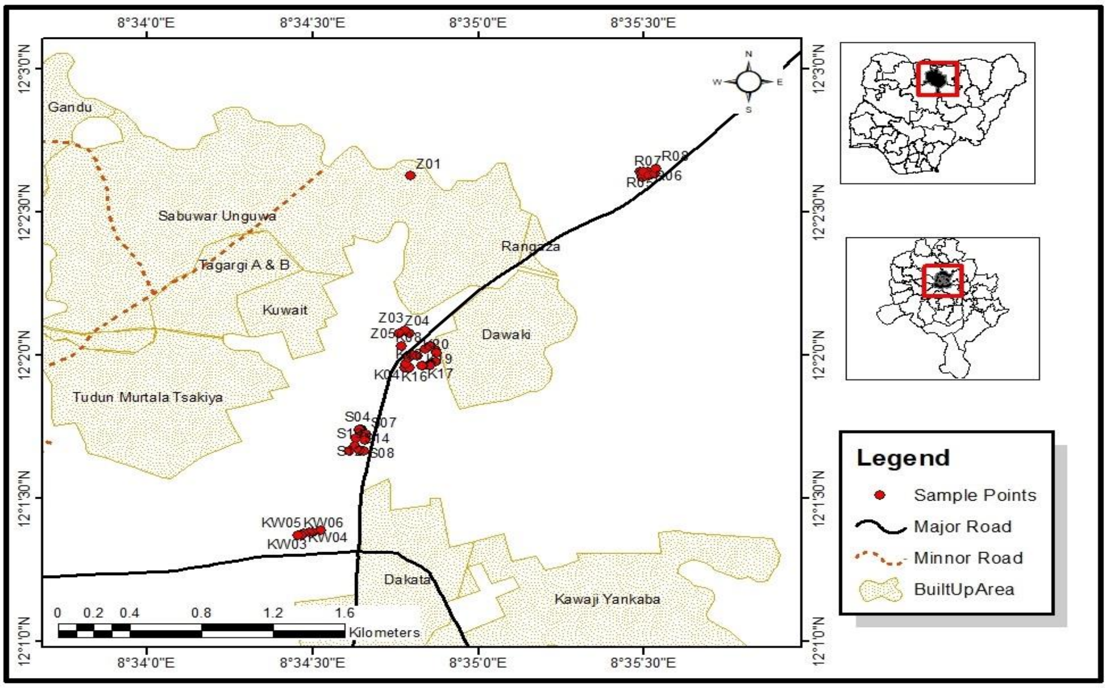


Figure 3: Spatial Distribution of Plastic Recycling Industries in Kano Metropolis

CONCLUSION AND RECOMMENDATIONS

Based on the findings of this study, it can be concluded that there is a weakly clustered pattern in the distribution of recycled plastics, with a nearest neighbor distance of less than 1 (0.22). The study also suggests that detailed mapping of the plastic recycling plants be done in order to show the borders that separate locations for future spatial studies of the spatial pattern of recycling plants. Since most recycling facilities in Kano metropolis are not legally recognised, the government should identify and keep an eye on them to ensure that environmental laws regulating their operations are effective and properly implemented.

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