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Spatial Distribution of Solid Waste Collection Points Using GIS Approach In Urban Katsina, Katsina State, Nigeria

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Abstract: - The advancement of technology today, helps in the depiction of reality for a particular phenomenon. The use of Geographical Information Systems (GIS) as part of the organization helps in development, especially when it comes to analysis and the distribution of facilities within a given area. This paper attempted to map out and analyze the spatial distribution of Solid Waste Collection Points in Urban Katsina using GIS approach. The objectives used in achieving the aim are: To make an inventory for the solid waste collection points in Urban Katsina and to examine the type and patterns of the distribution. Data related to the list of the collection points were sourced from Katsina State Environmental Protection Agency (SEPA) and field survey; and GPS was then used for taking the coordinates (latitude and longitude) of the each solid waste collection point in the study area. Arc GIS 9.3 (version) was used to analyze the result showing that there are 741 collection points in Urban Katsina, from which only 96 (12.96%) are Legal (authorized) while all the other 645 (87.04%) are Illegal (Unauthorized). The paper also revealed that the amount of illegal disposal increases as you move from low to high density settlement areas, while the reverse is the case for refuse hips size. Meanwhile, areas with high population density have more legal collection points than areas with medium population density, with high clusters of illegal collection points around the medium density populated areas. The nearest neighbor analysis shows that both the legal and the illegal collection points, are R- values of 0.67, 0.64 and 0.89 respectively. The study concludes that there is clustering and randomness of the collection points' distribution. Therefore, the study recommends for more authorized collection points in the medium population density areas. And population should also be use as a criterion for facility allocation. Moreover, there is need for institutionalization of the use of GIS in waste management.

Keywords: *- Solid Waste, Collection Points, GIS, Distribution, Nearest Neighbor analysis.*

I. INTRODUCTION

Solid Waste consists of everyday items that is used and then thrown away such as, product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. Wastes come from homes, schools, hospitals, and businesses (EPA, 2011). Man, in an attempt to satisfy his daily needs, engages in the production of goods and services. In the process waste is generated (Beede and Bloom, 1995). Virtually all aspects of man's productive activities involve the generation of waste (Muhammad, 2007). The way these wastes are handled, stored, collected and disposed of that can pose risk to the environment and to public health.

Solid waste generation is experiencing a rapid increase all over the world as a result of continuous economic growth, urbanization and industrialization. It is estimated that in 2006 the total amount of *municipal solid waste* (MSW) generated globally reached 2.02 billion tones, representing a 7% annual increase since 2003. It is further estimated that between 2007 and 2011, global generation of municipal waste will rise by 37.3%, equivalent to roughly 8% increase per year (Global Waste Management Market Report 2007).

Waste management is a global environmental issue; solid waste management in urban areas is one of major problems facing city planners all over the world. The problem is especially severe in most developing countries where poor planning and lack of adequate resources contribute to the poor state of municipal solid waste management (Obirih-Operah, and Post, 2002; Mato, 1999; Doan, 1998; Mwanthi *et al*, 1997). Solid waste management according to Ibrahim (2002) is the scientific way or established procedure and sanctioned legislation for the collection, transportation and disposal of waste products which is economically feasible and

environmentally viable. Warnless (2009) noted that waste management differs for developed and developing nations, urban and rural areas, for residential and industrial producers.

Urban Katsina, the capital of Katsina State, has been experiencing a population growth, since the creation of the state in 1987. As such there is increase in residential, commercial, industrial and institutional land uses leading to urban expansion. The simultaneous increase in population and settlement expansion of Urban Katsina has a direct effect on the increase in solid waste generation. According to Katsina Waste Management and Pollution Control (2004), 80% of waste generation in Katsina Metropolis is from household, commercial, institutional, construction and demolition wastes account for only 15%. The Katsina State Environmental Protection Agency (SEPA) has created designated refuse collection centers for community storage and evacuation. Despite of this, refuse litters the entire landscape. This made the Katsina State Department of Waste Management and Pollution Control (2004) to confess that there is improper allocation and distribution of solid waste collection points in urban Katsina, leading to negative setbacks which should be addressed. These are:

a. A lot of undesignated refuse dumps have been created especially on our main roads, making the area clumsy and create an eyesore. And improper waste disposal is another issue of concern and should be addressed.
b. Our drainages, gutters and other water passages were turn to be refuse collection centers thus causing flood during the rainy season and a vectors breading places sometimes lead to unpleasant odor due to stagnant of the water.

Zakariya'u (2010) also confirmed that the proliferation of illegal waste collection sites and indiscriminate dumping of refuse at any available space has now become a common scene. Moreover, the Katsina Waste Management and Pollution Control (2004) admitted that there is no available map showing the distribution of the refuse collection points in Urban Katsina. Thus, the map produced at the end of this study will be of vital importance to both planners and managers.

II GIS AND SOLID WASTE MANAGEMENT

Technological development in computer science has introduced Geographic Information System (GIS) as an innovative tool in solid waste management including landfill process (Kontos *et al*., 2003). GIS combines spatial data (maps, aerial photographs, Satellite images, etc) with non spatial data including both the quantitative and qualitative. The role of Geographic Information Systems (GIS) in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data. In general, GIS plays a key role in maintaining account data to facilitate collection operations; customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial customers to transfer stations and from transfer stations to landfills; locating new landfills and monitoring the landfill. GIS is a tool that not only reduces time and cost of the site selection, but also provide a digital data bank for future monitoring program of the site. It has taken an initiative to setup a GIS like ArcInfo, ArcView 3.2a and ArcGIS etc as key components for managing its information (Keir, 1997). Technological development in computer science has introduced geographic information (GIS) as an innovative tool in landfill.

According to Burrough, (1998), Geographic Information System (GIS) is a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. Smith *et al* (1987) argued that GIS is a database system in which most of the data are spatially indexed and upon which a set of procedures operated in order to answer queries about spatial entities in the database. It is a decision support system that involves the integration of s ati 1 referenced data in a problem solving environment. While Environmental Systems Research Institute (ESRI) California (1990), defined GIS as an organized collection of computer hardware, software and personnel to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information. GIS software allows law enforcement agencies to produce more versatile electronic maps by combining their crime databases of reported crime locations with digitized maps of the target areas (Sahu and Peeyush, 2011).

Thirumalai *et al.* (2010) developed an engineered design of solid waste collection using GIS with a vehicle tracking system and final disposal by composting with investment costs. The GIS was used to analyze existing maps and data, to digitize the existing ward boundaries and to enter data about the wards and disposal sites. The proposed GIS model for solid waste disposal would give information on the planning of bins, vehicles and the optimal route. In the case of disposal, composting would be a successful strategy to accelerate the decomposition and stabilization of the biodegradable components of waste in MSW.

GIS technology has also been documented in the United States. Montgomery County, Maryland has been using GIS since 1996 to enable users from different disciplines to access, share, and manage various data types for many purposes including solid waste management (Chen, 2004). The Geographical Information System (GIS) can provide an opportunity to integrate field parameters with population and other relevant data or

other associated features, which will help in selection of suitable disposal site. The technology can also provide ways for decision making during planning especially when it comes to solid waste collection and disposing.

III. AIM AND OBJECTIVES

The main aim of this study is to map out and analyse the spatial distribution of solid waste collection points in Urban Katsina using GIS approach.

The objectives through which the aim of the research was achieved are as follows:

i. To make an inventory for the solid waste collection points in the study area
ii. To examine the type and patterns of the solid waste collection points

IV. STUDY AREA

Urban Katsina is the capital of Katsina state; it is located between latitude 12^0 45^1N and13^0 15^1N, and Longitude 7^0 30^1 and 8^0 00E (fig 2). The location is at the extreme part of Northern Nigeria, some 30Km from the Nigeria-Niger border. The town and its immediate environs form the present study area. Urban Katsina comprises of two Local Government Areas, i.e. Katsina and (some parts of) Batagarawa Local Government Areas (Zayyana, 2010).

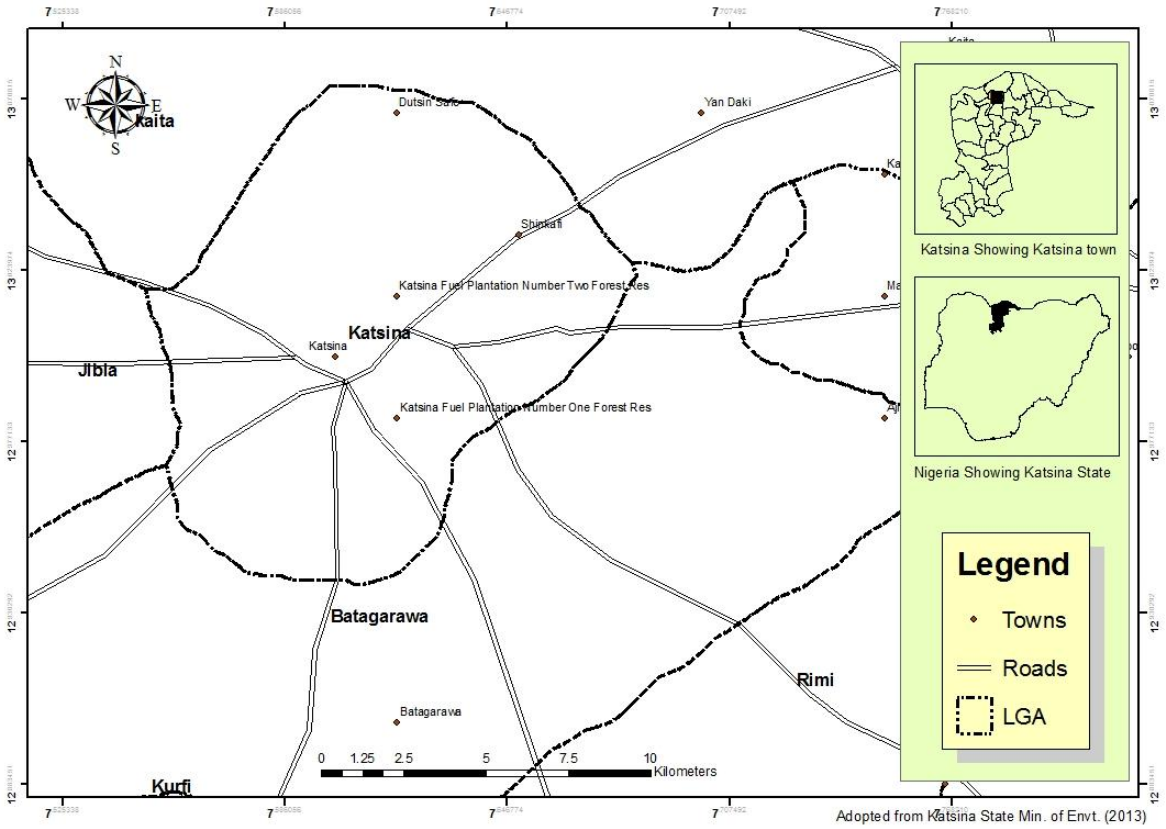

Figure 1: Showing Urban Katsina

Land use in the study area is dominated by urban activities, such as residential, institutional, commercial and industrial land uses, with few areas (mostly undeveloped) devoted farming activities. In addition to the major urban land uses mentioned above, other land uses such as livestock production and gathering are also carried out in the area. Residential area cover most part of the study area, different land uses such as commercial, institutional and educational can also be seen within the residential areas. *Sabuwar Unguwa* extension is the major area functioning as industrial layout. Industries such as steel rolling, packaging, beverages processing etc, are found in this area. Commercial activities happened to be growing very fast in the area.

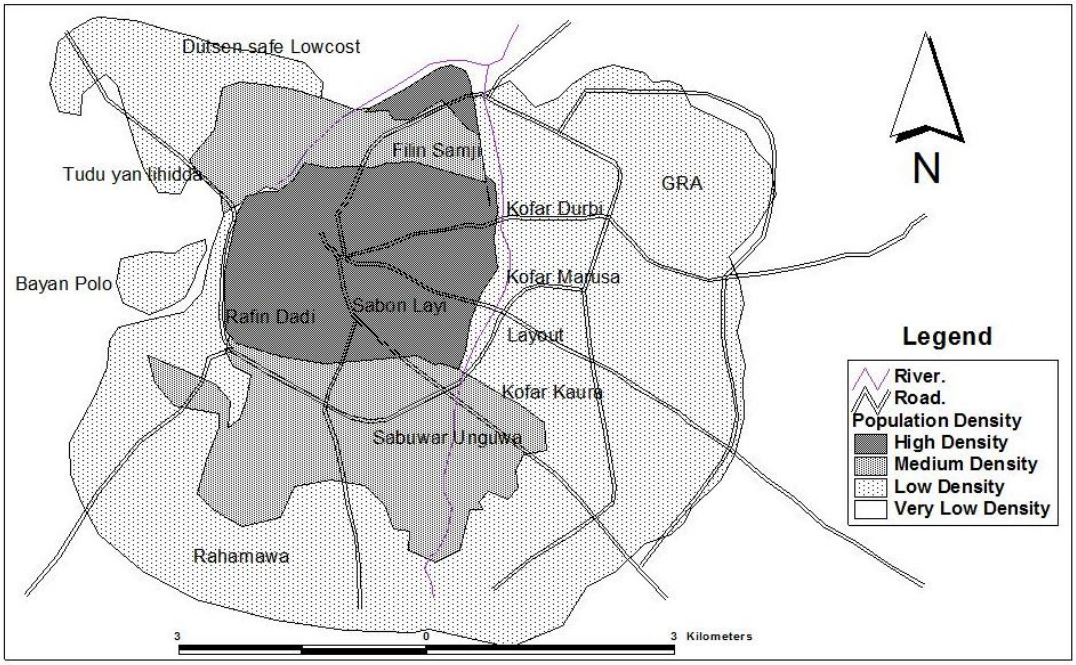

Figure 2: Urban Katsina Showing the Population Density

V. MATERIALS AND METHODS

Research tools

Global Positioning System (Garmin 76csx GPS model), Digital Camera, Google Earth Imagery, and GIS software (ArcGIS 9.3 version).

Method of data collection and Analysis

Ground Positioning System (GPS) was used to take the co-ordinates of the solid waste collection points, through which a database was created and used to record the coordinates, legality, locations and addresses of the collection points. A digital camera was also used to take pictures of some selected solid wastes collection points so as to show their type/nature.

Geo-Referencing and Digitization

Urban Katsina was zoomed and extracted from satellite imagery, Google Earth imagery specifically. The extracted image was then imported to Geographic Information System (GIS) software, specifically ArcGIS 9.3, and then geo-referenced and digitized to produce a digital maps. Population density map was produced base on field experience and satellite imagery observation. Land uses and housing pattern were used as guide.

Distribution of the Solid Waste Collection Points

The coordinates of the solid waste collection points taken during the fieldwork were imported into the ArcGIS 9.3 as text file, then converted to shape file to show the spatial distribution on the digital maps as well as the satellite imageries too. Points (dots) were used to show the solid waste collection points; the types of collection points as well as the legality were shown using different symbols (points) in terms of shape and color variations.

VI. RESULT AND DISCUSSIONS

Solid Waste Distribution

The Solid Waste Collection points in Urban Katsina irrespective of whether legal (authorized) or illegal (unauthorized) have been located and numbered to come up with their total number as 741 distributed across 78 areas (locations) in the area.

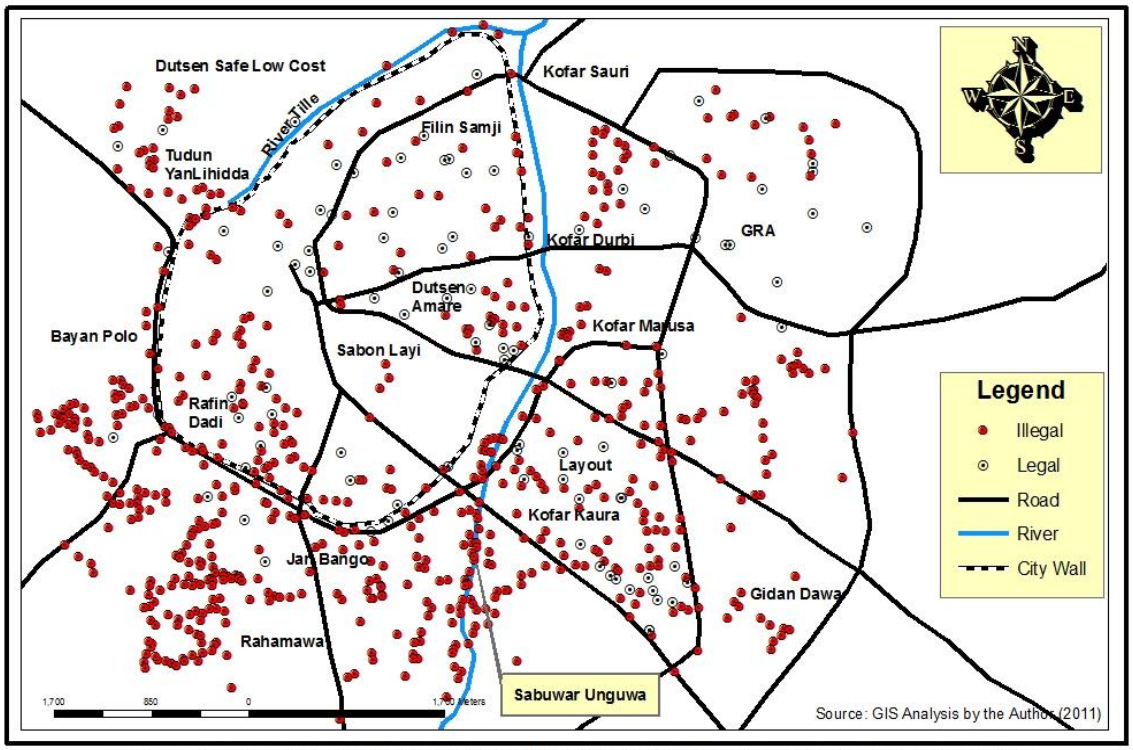

Figure 3: Showing the Distribution of Legal and illegal Solid Waste Collection Centers in Urban Katsina

The Spatial Distribution of the legal and the illegal collection points is shown below on figure 4, the illegal collection points are more concentrated in the low-medium density populated part of the Urban Katsina. The high population density areas have fewer collection points but larger hips of refuse as no space is provided for indiscriminate waste disposal all over the landscape as in the case of the low and medium density settlement areas (observed during the field work). The illegal (unauthorized) solid waste collection points can also be found along the old city wall as well as along water channels most especially the two major rivers – River Ginzo and River Tille.

From the analysis in the city wall there are reasonable distributions of legal than the illegal dumpsites even though, to some extend at the South-western part of the old-city there are few number of illegal dumpsites especially at the *Rafin Dadi* area while at the Eastern part of the city wall particularly along the *Dutsen Amare* area. While outside the old-city, at the South western part where there are clustering of illegal dumpsite in the area, these includes; part of *Rahamawa* and *JanBango*. Furthermore, at the South eastern part, areas like *Kofar Kaura*, *Gidan Dawa* and part of layout which are situated at the eastern part of the area, *Kofar Durbi* and part of GRA at the North eastern part of the area are having fewer illegal collection points.

The settlement pattern of Urban Katsina has been characterized into two categories base on population density. The first category is the high to medium density settlements which include the *Cikin Birni* (Old City) and their peripheral areas respectively. While the second category is the low density settlements of Government Reservation Areas (GRA), *Kofar Marusa* Low Cost and the New Layout among others outside the city wall. The *Cikin Birni* which is the old city and the most densely populated area in the metropolis consists of buildings closely packed together thus providing no space for indiscriminate waste disposal all over the landscape unlike in the case of the low and medium density settlement areas.

Moreover, the characteristics of solid waste collection points between high density and medium to low density areas is different in the sense that most of the collection points within former are over used, as large volumes of refuse hips were observed during fieldwork (2011) at both the authorized and the unauthorized

disposal sites, most especially around the core *Cikin Birni* (Old City). *Sabuwar Unguwa* being a medium density urban extension and the major area functioning as industrial layout with industries such as steel rolling, packaging, beverages processing etc accommodates 73 solid waste collection points of the study area of which all are unauthorized as not even a single one is provided by the respective agency -- The State Environmental Protection Agency (SEPA), and this is the highest number across the whole locations making up to 9.85% of the entire 741 collection points.

Out of the 741 Solid Waste Collection Points only 96 (12.96%) are legal (authorized), while all the other 645 (87.04%) are illegal (unauthorized). The State Environmental Protection Agency (SEPA) classified them into that (legal and illegal) base on the nature of their provision. The collection points provided jointly or completely by the agency are termed as legal ones, while the collection points (sites) where people are just disposing their household refuse without authority from SEPA are illegal. The former are of two categories – A three sided walled site built on a squarely shaped piece of land called Refuse Collection Center (RCC) and a moveable metal container called Roll-on Roll-up (*Roro*). While the later are unauthorized sites like open space, water channels, roadside, uncompleted buildings among others (see plate 1, 2 and 3).

The 95 legal (authorized) solid waste collection points in the study area are made up of two types of collection facilities: Roll-on Roll-up (*Roro*) and Refuse Collection Centers (RCC) as stated earlier, the former are 28 (29.47%), while the later are 67 (70.53%) as shown on table 4 above. The Refuse Collection Centers (RCC) is more evenly distributed within the city wall than Roll-on Roll-up (*Roro*). The later is made available adequately at areas like Government Reservation Area (GRA), Layout, Kofar Kaura, Dutsen Safe Low Cost and the likes (see figure 4).

The State Environmental Protection Agency (SEPA) stated that the Roll-on Roll-up (*Roro*) are normally fixed at places that are not appropriate for the Refuse Collection Centers (RCC) such as roadside, near shops or other form of public activity area. However, it can also be found very close to the Refuse Collection Centers (RCC) serving as its extension when necessary.

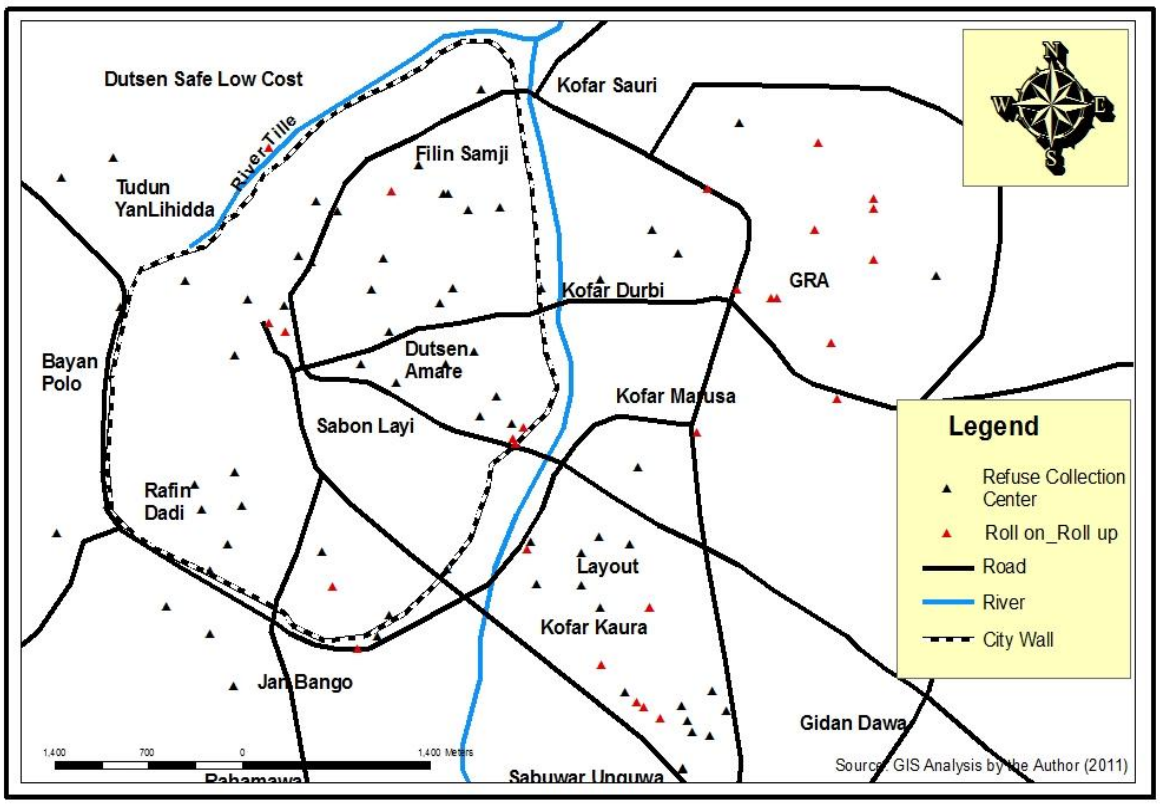

Figure 4: Showing the Distribution of Legal Solid Waste Collection Points by Type

In addition to the State Environmental Protection Agency (SEPA) that is responsible for managing entire waste of not only urban Katsina, but Katsina State, there are also 4 private waste management agencies that alongside with SEPA manages the solid waste in Urban Katsina. These are:

1. Immaculate Company; responsible for provision of household refuse storing facility as well as transporting the refuse to dispose at collection its clients. This company is responsible for managing the entire household refuse generated at Barhim Housing Estate, behind Katsina State Secretariat, and some part of Umaru Musa Yar'Adua University.
2. Express Environmental Services; operates similar services as Immaculate Company above, but for the Federal College of Education and Diamond Bank branches in urban Katsina.
3. Tri-Dynamic Waste Management Company; operates similar services as Express Environmental Services above for its respective clients. These include: Federal Medical Center and the Administrative Blocks of Umaru Musa Yar'Adua University. The company also operates special services such as general when invited among others.
4. Annur Cleaners; operation is mainly special services such as general cleaning, soak-away evacuation, spraying, fumigation, etc.

The State Environmental Protection Agency (SEPA) had set up some criteria for selecting site to fix a legal (authorized) collection points, these are:

- The population of the area must be taken into consideration before fixing a solid waste collection point in an area so as to avoid underuse by fixing a multiple collection points in a very low population density area. Because it is but a waste of resource as there are likely other shareable collection points in the neighboring areas;
- The community leaders of the area which comprises the elders and traditional leaders must be contacted by the State Environmental Protection Agency (SEPA) and then ask them to make a formal request for solid waste collection point in their area from the agency, or in some cases require that the community should make the request from their local government; and
- The site must also be owned by the government.

Plate 1: Roll-On Roll-Up (Roro) at Unguwar Yari, CPS Junction

Plate 2: A Refuse Collection Center (RCC) at Kofar Yandaka, near Kofar Yandaka Gate

Plate 3: Roll-On Roll-Up (Roro) at Kofar Soro, near Magajin Gari's Office

Spatial patterns using Nearest Neighbor Analysis of the Solid Waste Collection Points

The spatial patterns were performed using the nearest neighbor analysis in the ArcGIS. The analysis were done using 3 different stages, these are the general collection points (both legal and illegal). The general distribution from the analysis shows that (figure 5) there is clustering with the R-value of 0.67 and showing the Z-score of -17.24, while the scale were ranges within the critical value of -2.58 and the significant level of 0.01. The result indicates that there is less than 1% likelihood that this clustered pattern could be the result of random chance.

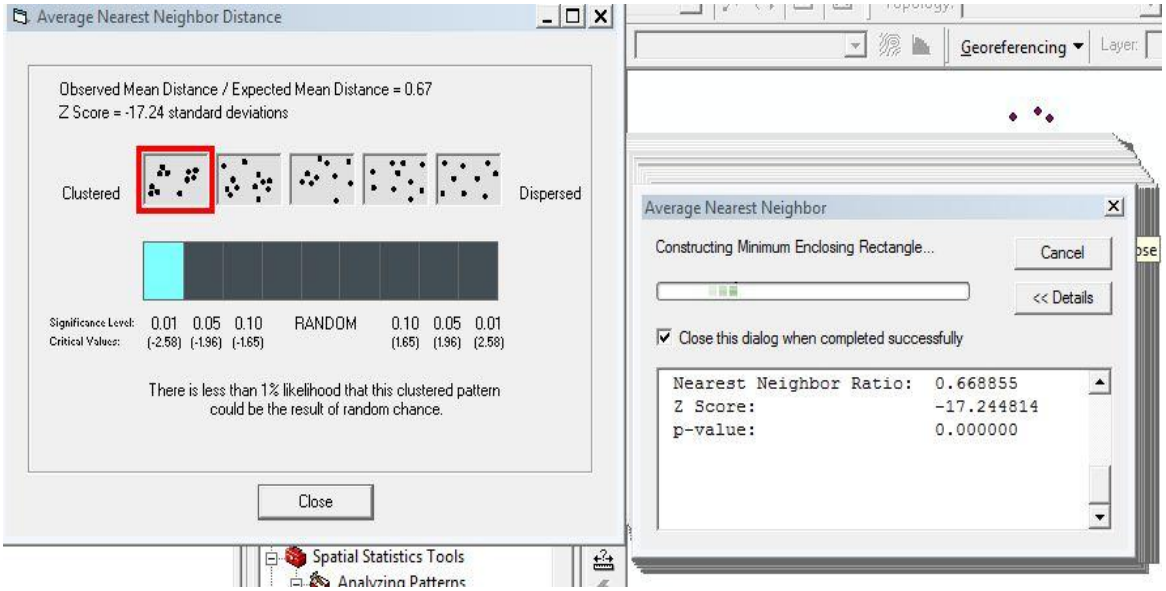

Figure 5: Showing the nearest neighbor analysis of the Collection Points

The distribution of the illegal solid waste collection centers (Figure 6) shows that there is clustering with the R-value of 0.64 from the nearest neighbor analysis with the Z score of -17.62 while the critical values of -2.58. The significant level of 0.01 and there is less than 1% likelihood that this clustered pattern is as the result of random chance.

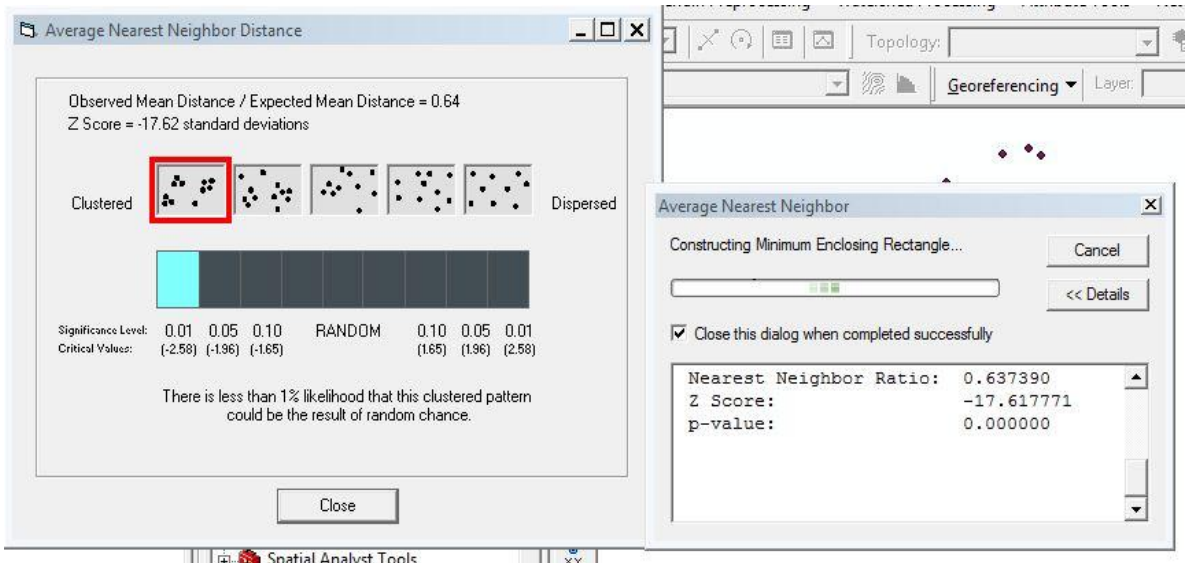

Figure 6: Showing the nearest neighbor analysis of the Illegal Collection Points

The distribution of legal Collection Points in the area (Figure 7) shows that the R-value of the nearest neighbor analysis of 0.89 with the Z scores of -2.03 which is an indication of weak random, that is it's not properly clustered, however the critical values of -1.65 from the scale and with the significant level of 0.05. There is less than 5% likelihood that this clustered pattern is as a result of random chance.

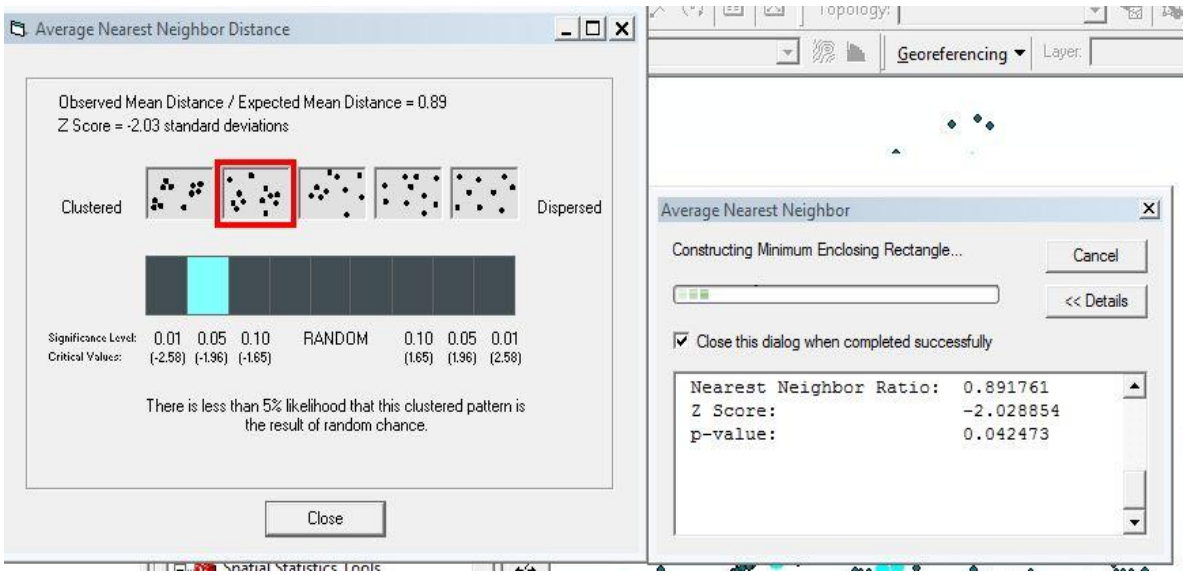

Figure 7: Showing the nearest neighbor analysis of the Legal Collection Points

Conclusion and Recommendations

The use of Geographic Information System in analyzing a spatial analysis especially when representing the real world phenomenon, helps in the integrating and simplifying the interpretation of a distribution of a facilities especially the visual analysis and interpretations. GIS play a significant role in Solid Waste Management System; it helps the Managers in database creation and the stakeholders to know the exact areas where there is need more attention rather than concentrating on a particular area.

This paper attempted to analyze the distributions of the Solid Waste Collection Points in the Urban Katsina. The result shows that areas with the highly density population are more served with the Solid Waste facilities, while there are concentration of illegal dumpsites in the Medium density populated areas and volumes and hips of solid waste are more in the old-city.

Solid waste for both legal and illegal are more clustered, and the illegal alone is showing a clustering in the distribution when analyzing it using Nearest neighborhood analysis while the distribution of the Legal dumpsite in the area shows a closely to randomness in the area, this to say population is not considered during the distribution of Solid waste collection facilities. Therefore, the study recommend for;

- Considering population as a criterion for the allocation of the Collection centers.
- GIS for solid waste collection needs to be institutionalized. It needs to be introduced to the Contractors, municipal and city councils officials in order to ease information management for both spatial and non-spatial data.
- GIS can be used as a planning tool for solid waste management. On the other hand, the spatial and non-spatial data should be updated from time to time in order to support decision making.

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