

A SPATIO TEMPORAL ANALYSIS OF SOLID WASTE MANAGEMENT IN BIRNIN KEBBI METROPOLIS, KEBBI STATE, NIGERIA

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ABSTRACT

Management of urban solid waste is becoming an endemic problem in Birnin Kebbi, the capital of Kebbi State, Nigeria. There is currently huge amount of solid waste being disposed without proper segregation of the waste stream, defined pickup points and a good waste dump site; this has led to serious environmental problems. The paper determine and identified the volume of solid waste generated and the current location of all waste collection centers, so as to propose appropriate locations of waste collections and dumping sites around the area using GIS. Data for this study was generated with the aid of GPS and overlaid on a DEM to determine the current collection and disposal sites. A multi-criteria Decision Making (MCDM) tool in ArcGIS 10.6 was used to generate a map for the proposed waste collection and waste dump centers and the results of the potential suitable dump site fell within the Western part of the study area. The paper proposed a total of nine pickup locations and additional seven suitable and sustainable sites for waste management in study area. This study serves as GIS-based decision supporting tools for proper and effective waste management system. Therefore, the need arises for a holistic research into systematic data collection using GIS for proper siting of waste collection and effective waste management.

Keywords: Solid Waste Management, GIS, GPS and community collaboration.

Introduction

The issue of solid waste management has become an endemic problem that has characterized major African Urban centers arising from increasing population and associated poor adherence to effective physical planning regulations. Heaps of solid wastes are today a common site even in the main streets of city centres. Indiscriminate waste dumps have resulted in breeding of rodents, flies, pollution

and clogging of major streets especially after every rainfall (Attah, 2008).

Solid Waste management is a global environmental issue because of the significant problem associated with its improper management. Pollution is always prevalent where the solid waste is not properly handled. In order to mitigate the problem, the handling of solid waste becomes a sensitive issue which

concerns every sector in world. The direct dumping method that is practiced leaves a serious impact of environmental pollution causing tremendous health related problems. Managing municipal solid waste has become a serious environmental issue in Birnin Kebbi metropolis. This is perhaps, not unrelated to the growing urban population with emerging poor urban housing system, but also the poor state of managing urban waste from picking points to final destination dumpsite. This has led to the presence of huge heaps of garbage along the major streets of Birnin Kebbi. Management of this current urban phenomenon has continued to be a very critical environmental challenge. Despite government efforts coupled with official pronouncements, there are still no effective and efficient policies and programmes to tackle the menace. Laws governing waste management in our cities are either not respected or enforced. Also underfunding, corruption, power and influence, old machinery, inaccessibility and illiteracy to a large extend have also hindered the process. Therefore, a scientific study of picking and dumping sites will go a long way to put in place a reliable waste pickup and dump sites to effectively respond to the problem of solid waste management in the metropolis. This approach will also provide a data base for future comprehensive and informative management option for effective waste management.

Spatial decision making is a complex task; however, the integration of geographic information system (GIS) and multi-criteria evaluation (MCE) can be used to solve solid waste management problems. These tools can be deployed for decision support in waste management information (Sener et al, 2006).

In the study area, the main issue of greatest environmental concern is the generation and

management of municipal solid waste by the rapidly growing population and their associated anthropogenic activities. Increased in the standard of living has led to the increase in the domestic and commercial waste generation which pose heavy consequences on the environment. The problem has further been complicated by government unimaginative waste management strategies and the usual mismatch between volume of waste generated and resource allocation to manage the problem. It is on this background that the study is set out to proposed appropriate techniques for waste collections and dump site locations in the study area. The associated objectives are to: (i) conduct a spatio-temporal analysis of waste collection points in the study area (ii) Identify the socio-economic implication of solid waste management in the area and (iii) propose spatial information on solid waste management for the purpose of environmental decision-making.

2.0 Materials and Methods

2.1 Study Area

The study area, Birnin Kebbi, is the capital of Kebbi state and also the Headquarter of Birnin Kebbi local government area; it is also the seat of Gwandu Emirate. It is geographical defined within latitudes $12^{\circ} 24' 00''$ and $12^{\circ} 30' 30''$ North and longitude $4^{\circ} 10' 0''$ and $4^{\circ} 15' 30''$ East (Figure. 1). It lies along Sokoto Rima river at the intersection of roads from Jega and Bunza. It boarded at the east by the Gwandu LGA, to the west by Arewa Dandi Local government, and to the south and north are Kalgo and Argungu local government areas respectively (Figure 1). The climate of the area is local steppe which falls within Koppen-Geigers BSh tropical Continental climate. The average annual temperature ranges between 28.4°C to 37°C , with the mean annual rainfall of about 807mm with some local variations (Higgs, 2006). The study area is part of the Sokoto Rima river basin of an elongated

sedimentary basin, which is characterized by gently rolling to undulating relief features, the soils are vertisols, which comprises of heavy, cracking clayed soils with more than (35%) clay have shrinking and swelling properties, the elevation varies from about 225 meters to 238 meters above sea level. (Abubakar, 2015). The landscape of the area is mostly dominated by floodplains of Rima and Shella rivers which are located in the north and south east of the town respectively. The study area falls within the northern Guinea savannah zone which is

mostly described by heterogeneous mixture of vegetation, with few medium height trees.

The population of Birnin Kebbi was estimated to be about 125,594 people according 2006 population census, the area comprises of multiple ethnic groups, major among who are Kabawas, Fulanis, Zabarmawas and Dakarkaris, with Islam as the major religion. The people are predominantly farmers because of the presence of the fadama.

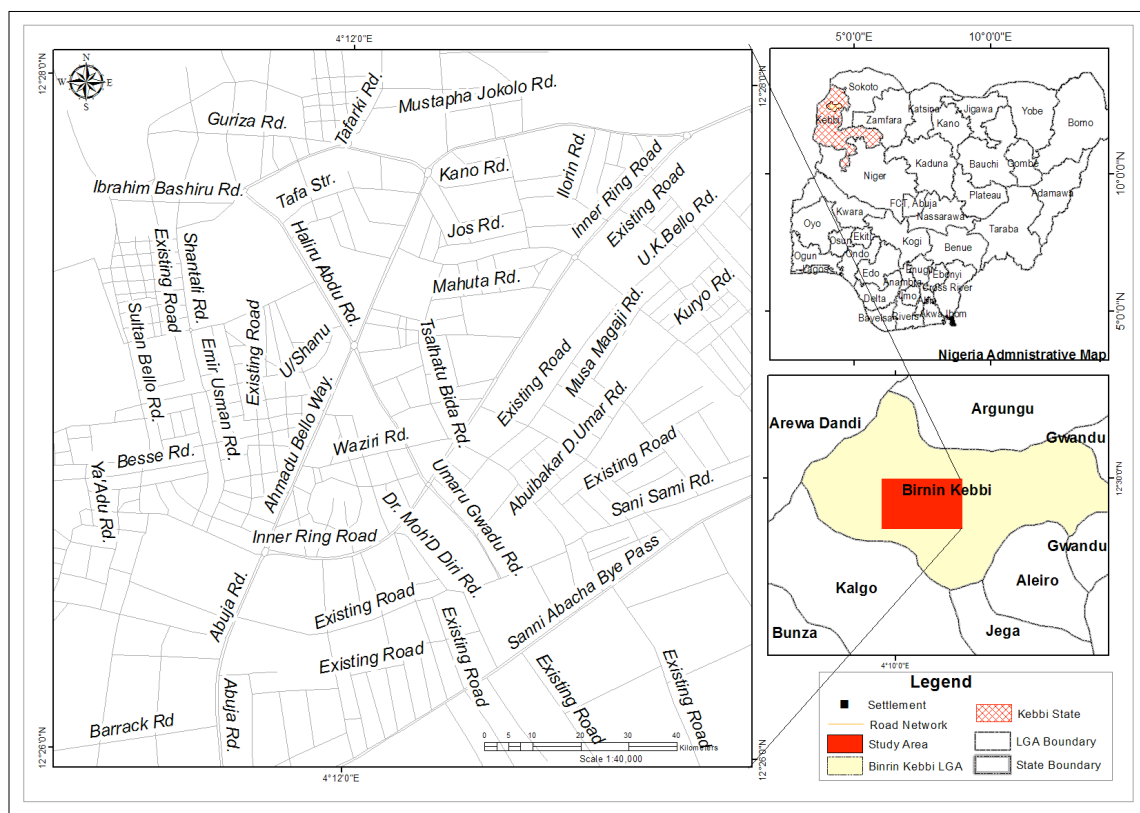


Fig. 1: The study Area in context of Kebbi State and Nigeria

Source: Author's 2018.

2.2 Methods

This study integrates the spatial and non-spatial data with GIS to perform a MCE putting into consideration the aim and objectives of the research, the Primary data for this study was collected through questionnaire and Global

Positioning System (GPS) survey. The exact location of the solid waste bins, the dump sites (both legal and illegal) was collected using GPS (i.e GPS Campaign).The secondary data are obtained from digitized primary maps, Which

was used in preparation of thematic maps for each of the characterizing factor for landfill site selection and the best route analysis for the waste collection.

The other associating data includes: the Google Earth Images, SRTM data, Geological data, soil data, and other relevant information like demographic, waste strategy documents and economic data were all collected from both Government and Non-Government Organizations

which are used to generate the spatial database for the analysis and evaluations.

This information of different kind and forms was converted into the GIS database. The ArcGIS 10.6 software and its network analyst extension was used to recommend waste bins locations and for the preparation of final maps.

The procedure involved was shown in the methodological flow chart below (figure2.0)

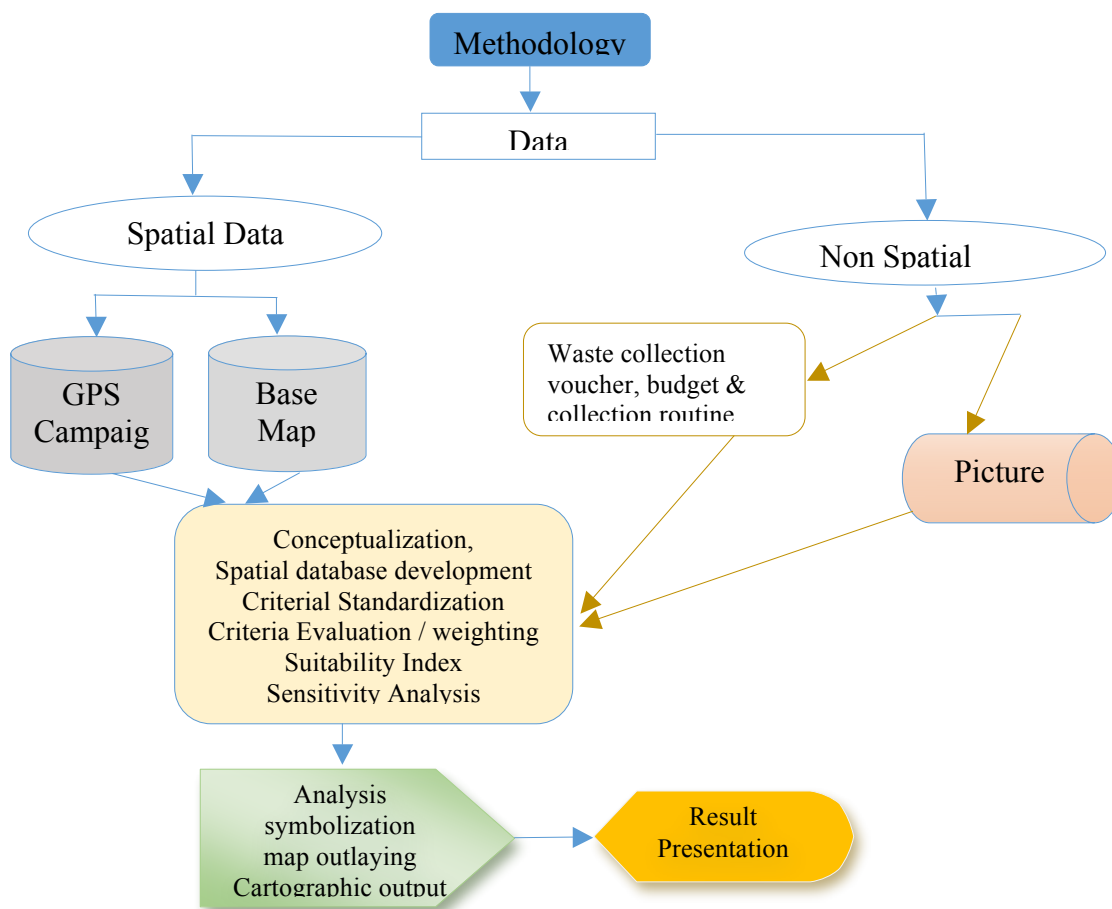


Figure 2. Methodological Flow chart

2.2.1 GIS modelling municipal solid Waste Management

GIS modelling for municipal solid waste management include the spatial distribution of the solid waste collection centre (legal and illegal), rationalization of waste collection bins and route optimisation for waste collection,

with an adequate cartographic representation and the tool like urban utilities planning, network, analysis and transportation, can be used for municipal solid waste modelling and management.

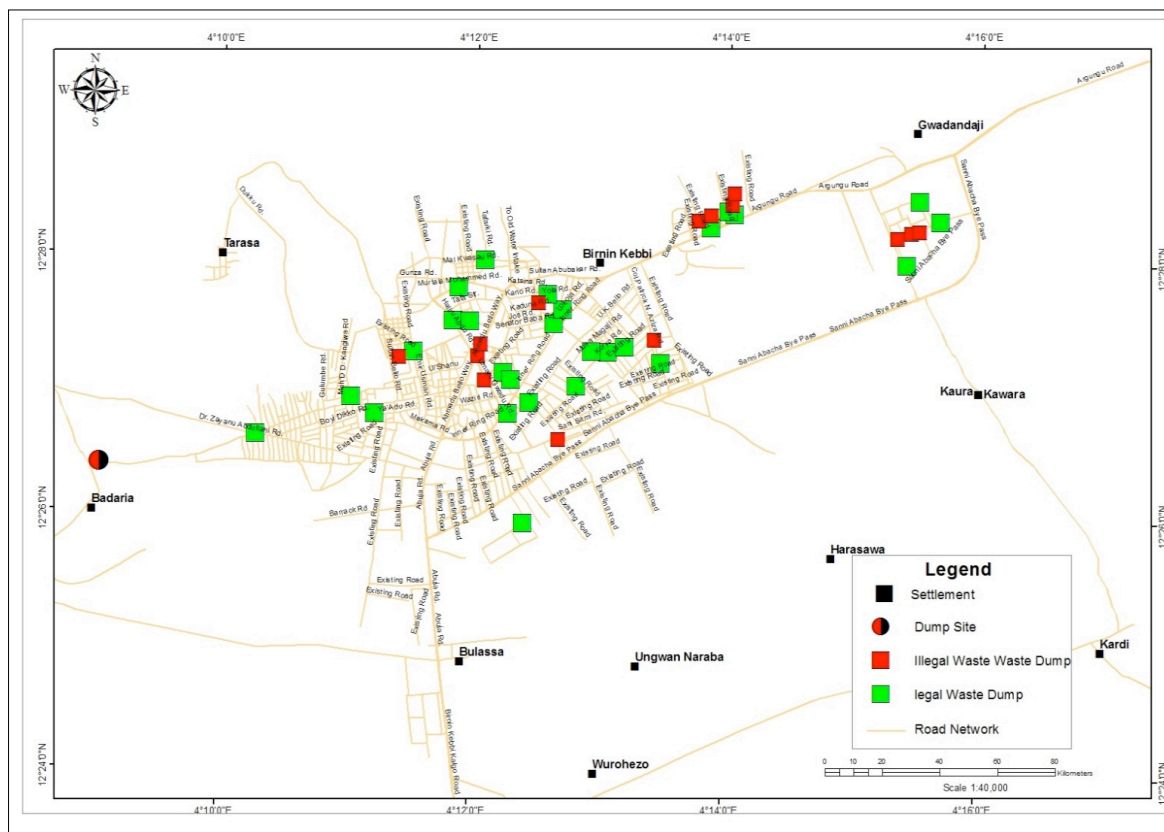


Fig 3. Waste collection point and Dump site
Source: Author's 2018.



Plate 1



Plate 2



Plate 3



Plate 4

3.1.2 Spatio temporal Pattern of the waste collection point

The spatial pattern of waste collection point was analyzed using the nearest neighbor analysis statistic of the ArcGIS. The general distribution from the analysis shows that the pattern is clustered with observed mean distance of 370.734 meters, nearest neighbor

ratio of 0.723, P-value of 0. 000591 And Z-score of -3.436, (Figure 4). The result indicates that there is less than (1%) likelihood that this clustered pattern could be the result of random chance.

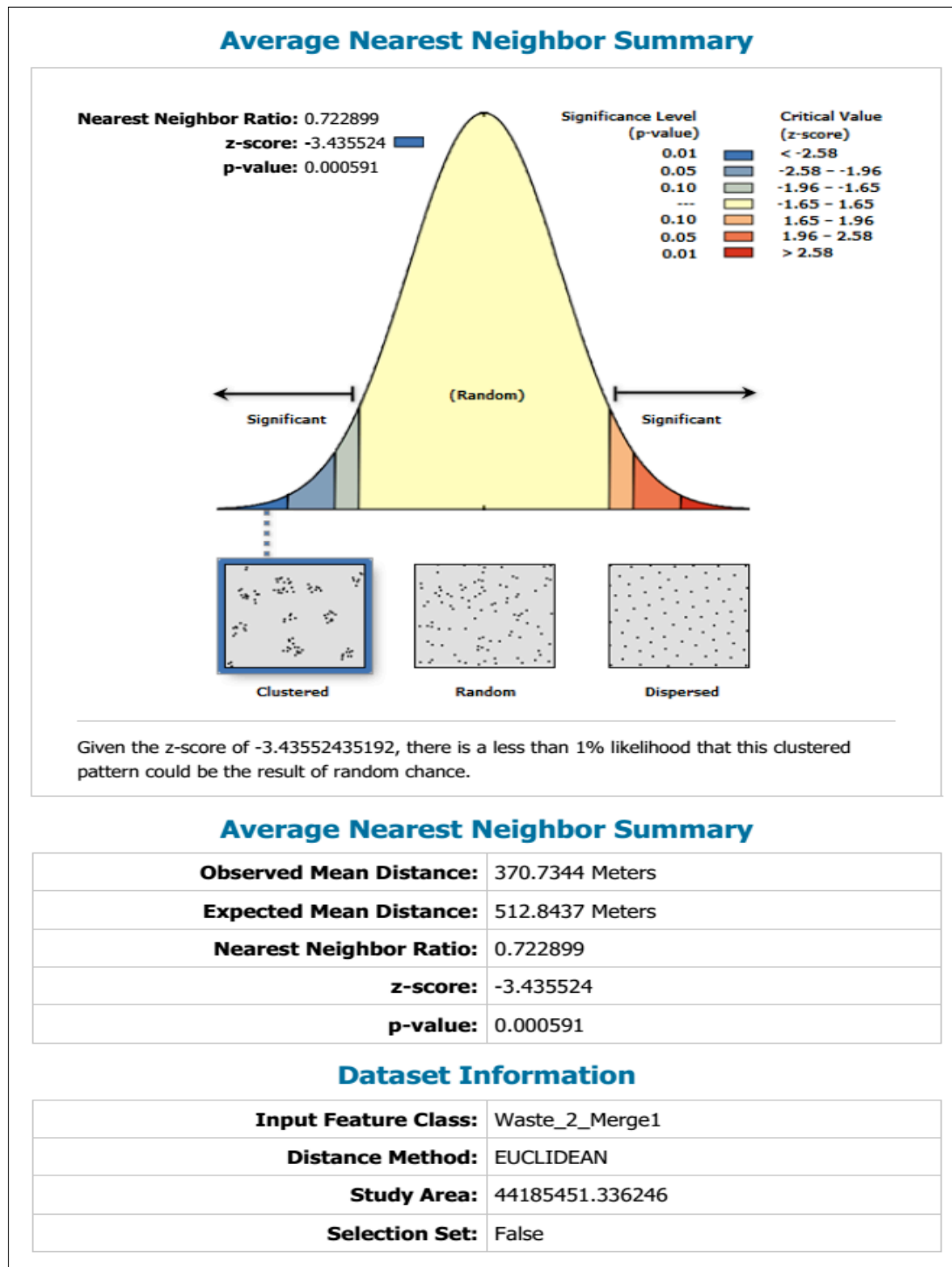


Fig 4 Spatial Pattern of Waste Collection points
Source: Author's 2018.

3.1.3 Route optimization for solid Waste collection in Birnin kebbi

The main aim of route optimization for collection of solid waste is to reduce the cost. In the study the provision for logistic was limited in the study area, so the need for route optimization is essential.

The route optimization involve the consideration of population density, waste generation and its composition, road networks and its accessibility, length and the condition

of the road, the vehicle speed, travel time, traffic situation, and characteristics of vehicles. The optimization of collection route length and time is directly proportional to the operational costs. So the shortest route for waste collection as shown in Figure 5 will serve as waste manager which provide information on the best route.

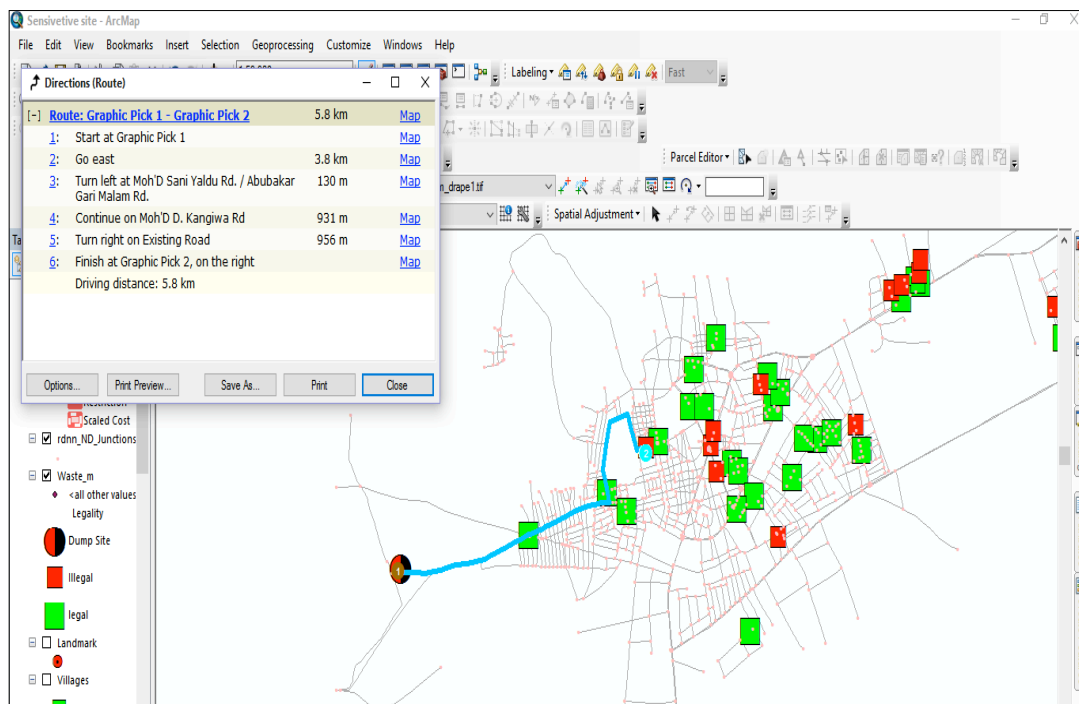


Figure 5. Best route analyses from some of the waste collection points to the main dump site

Source: Author's 2018

3.1.4 Multi criteria evaluation for dumping Site selection

A map was created for each suitability criterion and a final composite map was produced by overlaying the maps. Each of the criteria ranked and then weighted based on the order of severity using analytic hierarchy process (AHP) and pair wise comparison to generate a suitability index as summarized in Table 2. The weights were evaluated by taking

into account the possibility of modifying the natural conditions of the sites with appropriate engineering interventions, so as to increase their suitability (Delgado et al. 2008). Figures 6 to 9 show the composite map for each selection criterion, while figure 11 is the multi-criteria evaluation dump site location suitability index map.

Table 2 Attribute ranking and Layer's weights for the multi criteria evaluation of waste dumpsite selection

S/n	Layers	sub-layers	Ranking	Weights
1	Urban settlements	< 1 km	10	0.2
		1-2 km	9	
		2-3 km	8	
		3-4 km	7	
		4-5 km	6	
		5-6 km	5	
		6-7 km	4	
		7-8 km	3	
		8-9 km	2	
		9-10 km	1	
		>10 km	10	
2	Sensitive Sites	< 500 m	10	0.1
		> 500 m	0	
3	Groundwater	< 500 m	10	0.15
		> 500 m	0	
4	Geology/soils	Geology	10	0.15
		Soil	10	
5	Water body/Drainage Network	< 100 m	10	0.05
		> 100 m	0	
6	Elevation	> 15 %	10	0.1
		5 – 15 %	0	
		< 5 %	5	
7	Road Network	< 1 km	10	0.1
		1-2 km	9	
		2-3 km	8	
		3-4 km	7	
		4-5 km	6	
		5-6 km	5	
		6-7 km	4	
		7-8 km	3	
		8-9 km	2	
		9-10 km	1	
		>10 km	10	

Sources: Delgado et al. 2008

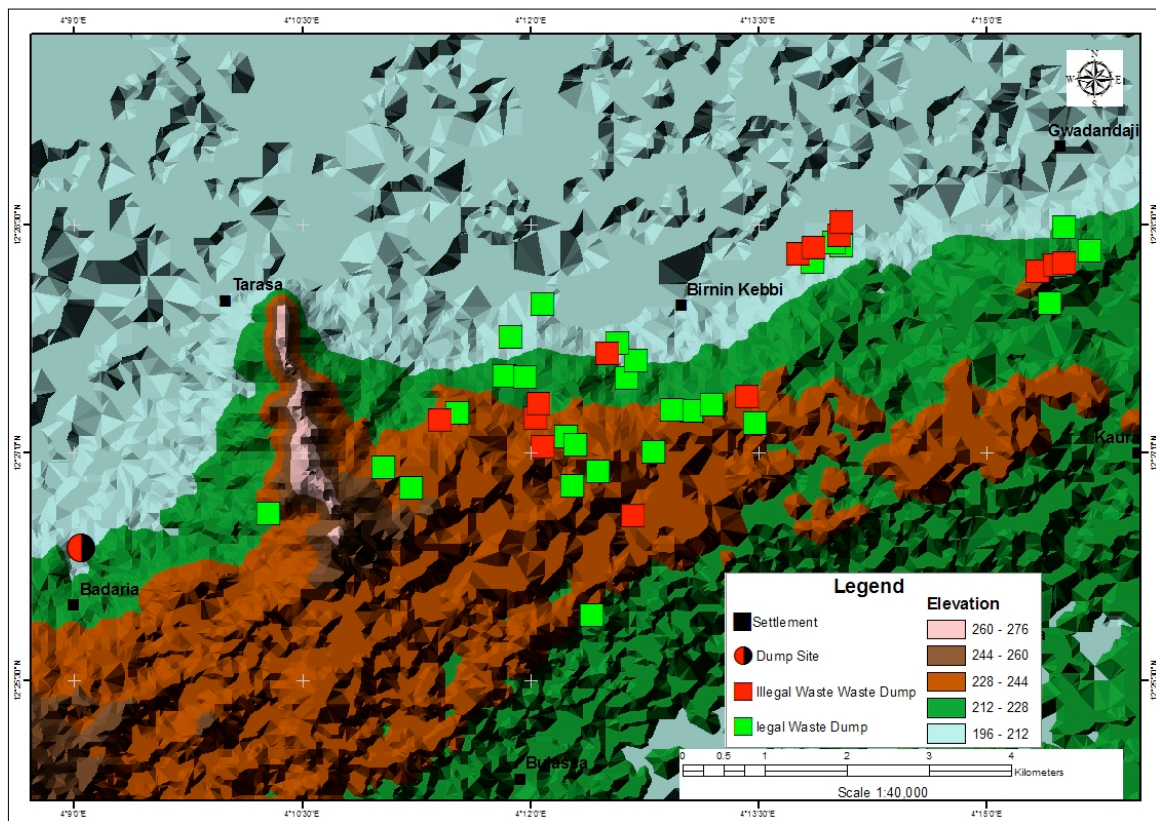


Figure 6. Elevation/ Slope criterion for dumpsite selection

Sources: Author's 2018

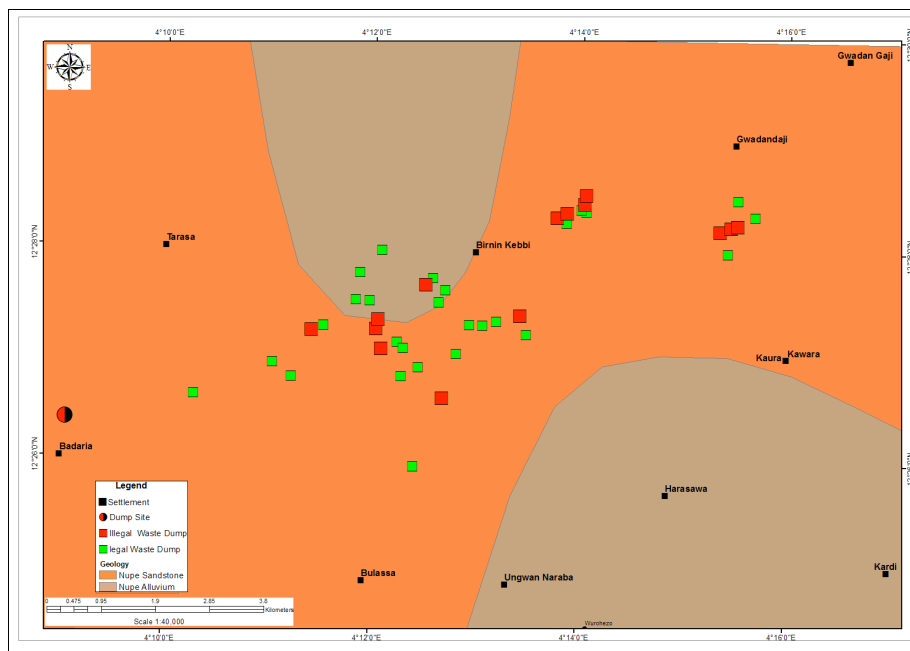


Figure 7. Geological evaluation of the study area

Sources: Author's 2018.

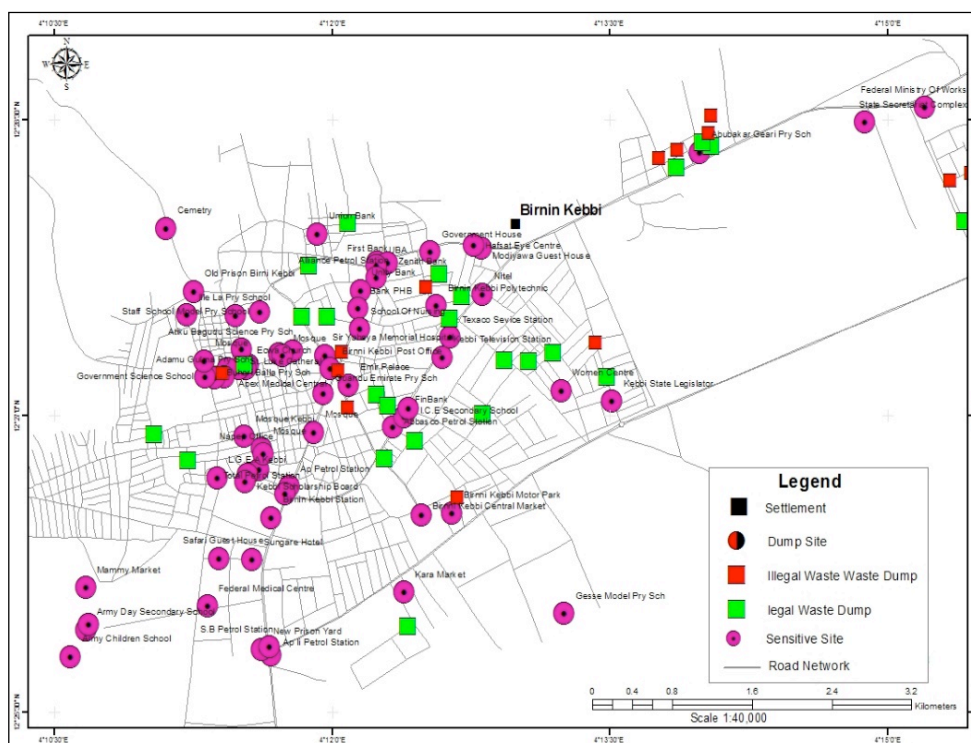


Figure. 8 Sensitive sites

Sources: Author's 2018.

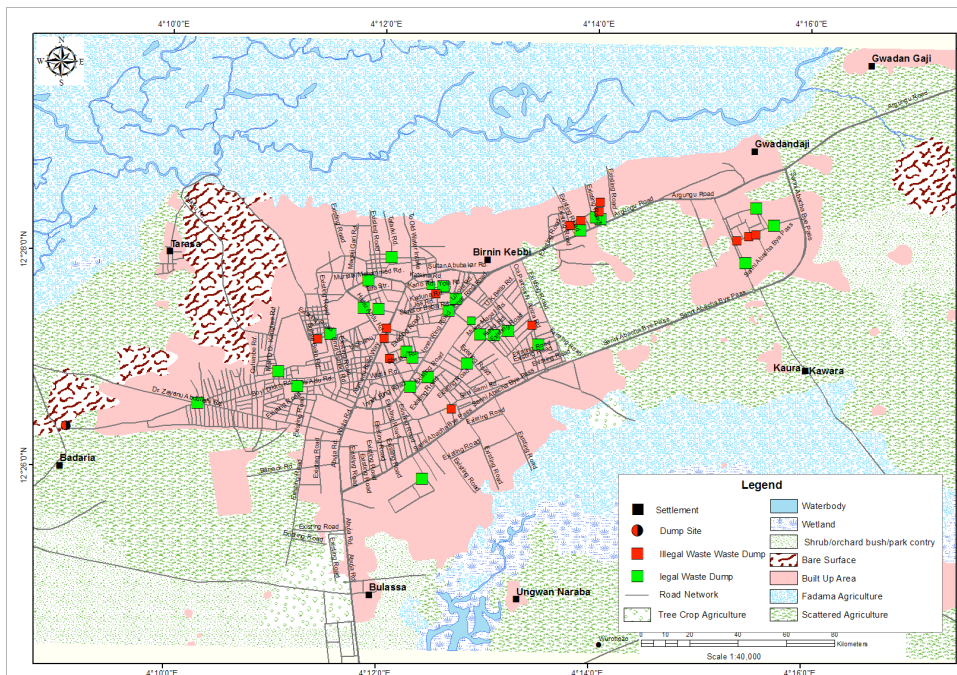


Figure 9. Land use land cover of the study Area

Sources: Author's 2018

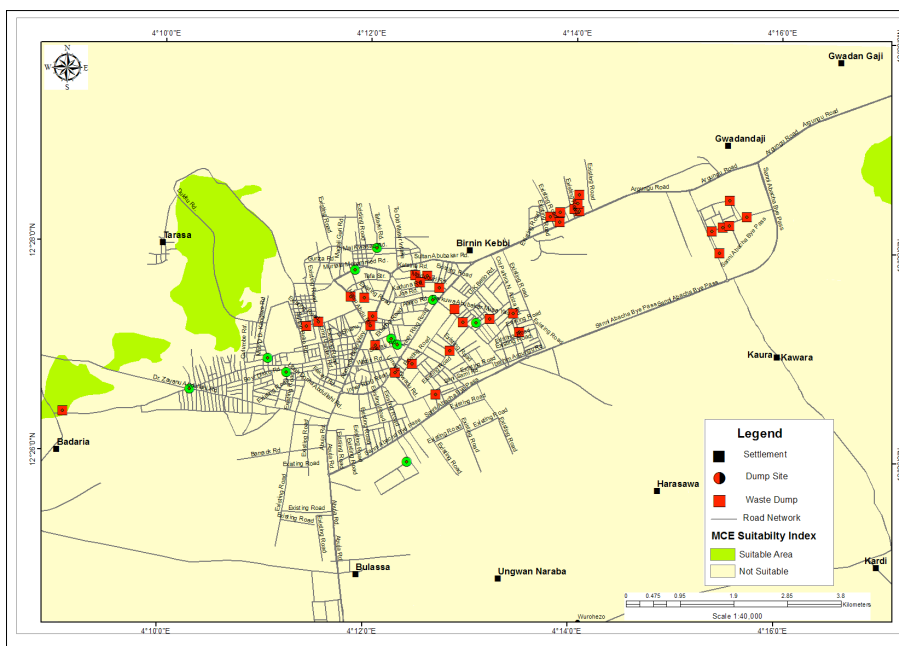


Fig 10. MCE Dump site location suitability index map of the study Area

Sources: Author's 2018

Table 3 underground water parameter of the study area

S/n	Location	Northing	Easting	Temp ^o c	EC	SE	pH	TDS	K ₊	Na ₊	CO ₃	NO ₃ ₋	SO ₄
1	Gesse 1	12.27461	4.13101	32	163	228	6.350	81	35.340	0.910	0.420	5.600	47.500
2	Gesse 2	12.27119	4.12885	32	156	236	6.250	78	38.760	0.100	0.100	5.100	48.900
3	Gra	12.27722	4.12164	33	206	231	8.130	105	22.040	9.810	0.500	6.900	46.300
4	T/Wada	12.27799	4.11962	32	210	240	7.990	102	39.520	10.940	0.400	8.200	52.100
5	Zoramawa	12.27678	4.11489	32	248	248	5.960	123	39.900	1.510	0.020	4.800	56.900
6	M Gandu	12.27674	4.11485	32	256	241	5.930	128	40.280	3.900	0.220	3.400	48.500
7	Nasarawa	12.26846	4.11309	31	231	230	6.270	115	32.680	1.510	0.590	6.300	50.100
8	R/Atiku	12.26866	4.11323	31	205	238	6.290	101	37.240	9.800	0.300	4.900	48.100
9	Badariya	12.26838	4.11111	33	267	248	6.090	134	34.960	0.100	0.060	5.600	39.500
10	B/Kara	12.26253	4.12471	33	271	224	6.100	135	31.920	12.800	0.400	7.400	40.200
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10	B/Kara	12.26253	4.12471	33	271	224	6.100	135	31.920	12.800	0.400	7.400	40.200

Source: Wali et. al, 2018

3.2 socio-economic implication of solid waste management in the study area,

The socio-economic implication is to test the public acceptance of the existing solid waste management in the study area, and to seek the public opinion on the grey area. This was done through conducting a survey on the background of the people. The outcome of the survey is statistically analyzed and the output is shown in Figure 11- 15 below.

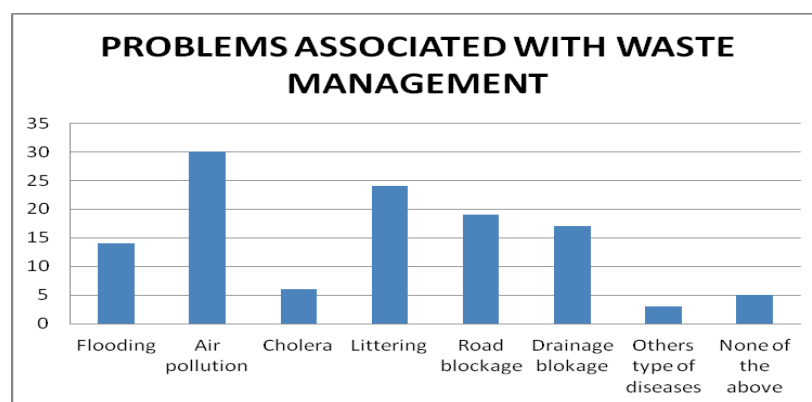


Figure 11. Problem of waste management in the study area

Sources: Author's 2018

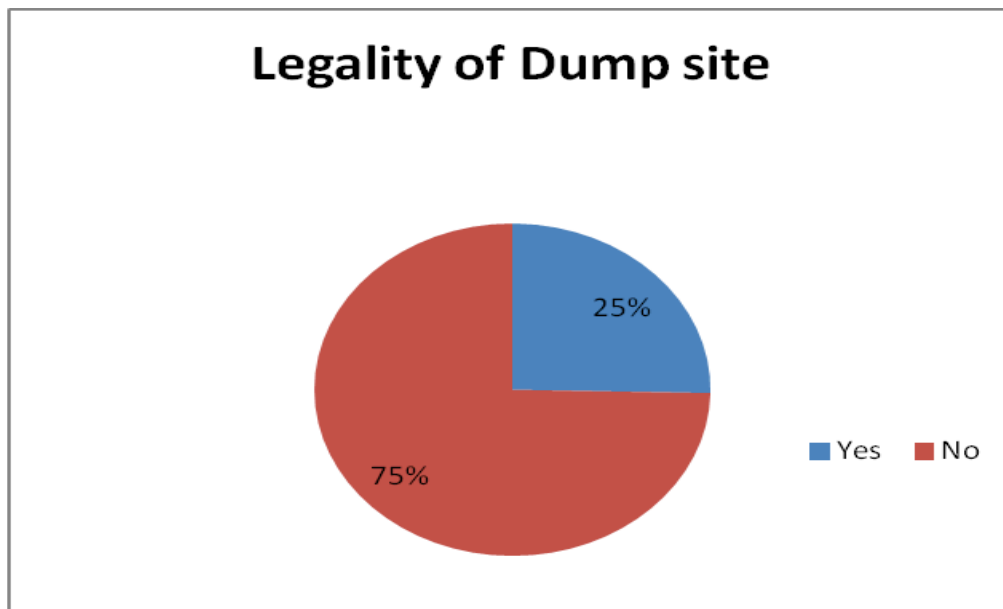


Figure 12. Legality of the dump site usage of the study Area
Sources: Author's 2018

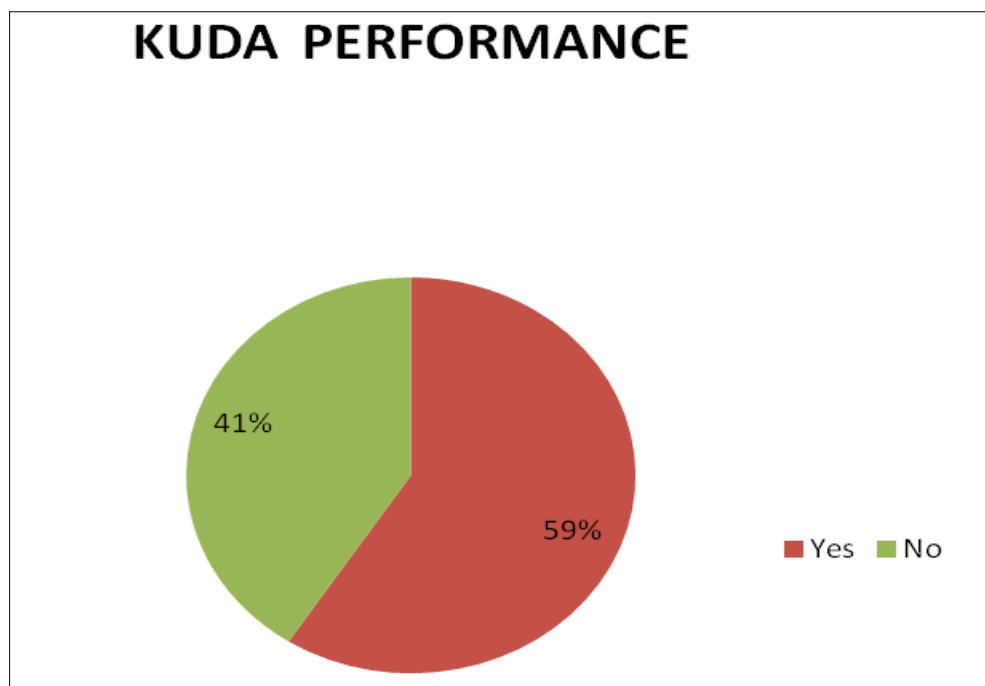


Figure 13. Public perception on performance of state own waste managers in the study Area
Sources: Author's 2018

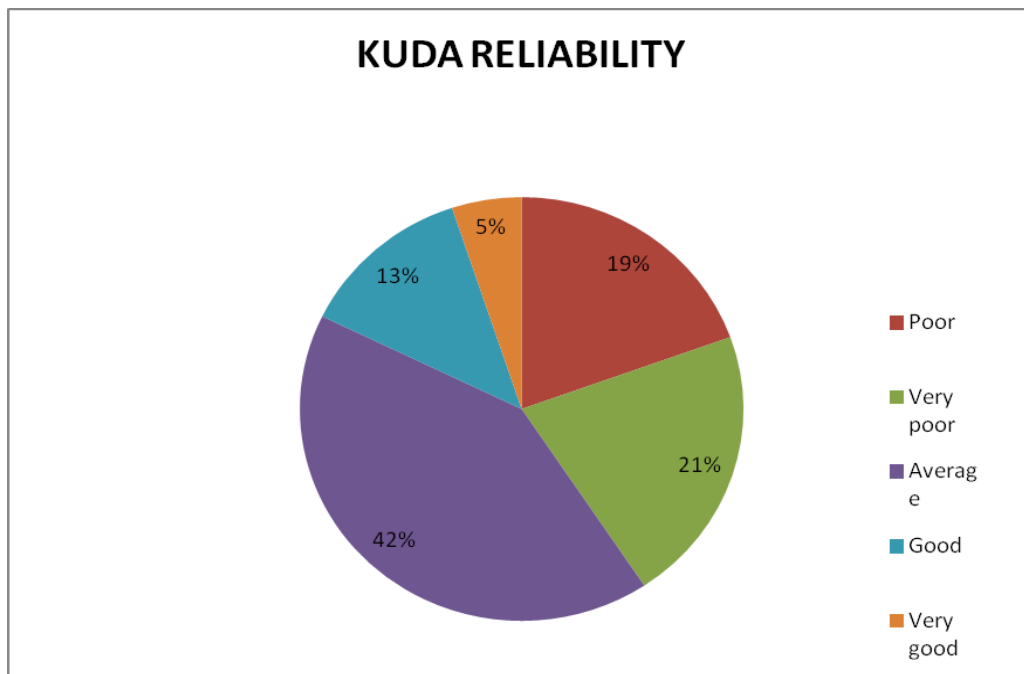


Figure 14. Public perception on reliability of state own waste managers in the study Area

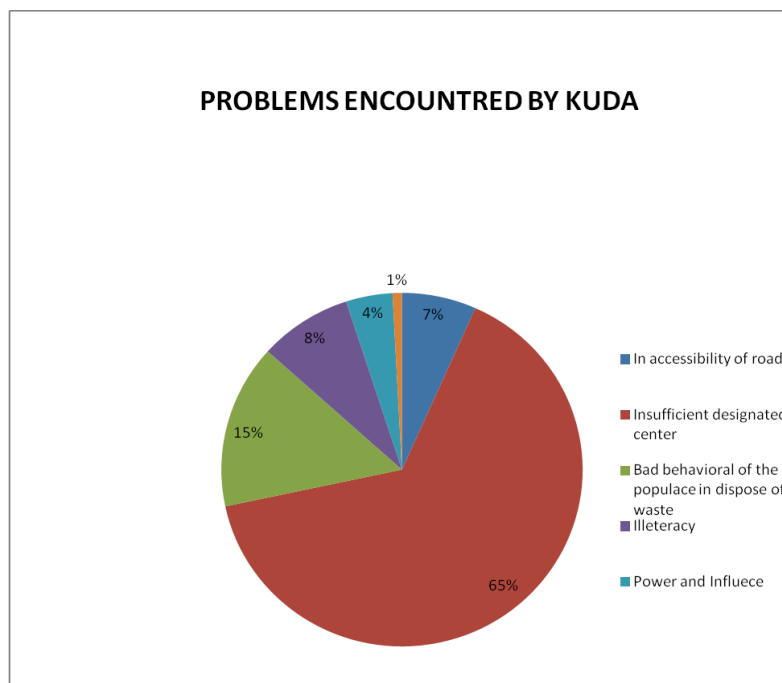


Figure 10. Public perception on the problem of state own waste managers in the study Area
Sources: Author's 2018

4.0 Conclusion and recommendations

The study has examined the solid waste management in Birnin Kebbi metropolis and also the use of GIS modeling and multi criteria evaluation of dump site selection using different criteria for both environmental and economic purposes, to serves as GIS-based mapping for decision making purposes. Review of literature showed that decision making using patterns, tables, charts, lists, graphs and reports, and sometimes it is rather difficult or nearly impossible. The integration of geographic information system (GIS) and Multiple Criteria Evaluation (MCE) has proved to be tools in solving solid waste management problems issues. Geographic information systems however, have the capability to handle several kinds of spatial data information which a useful decision making process could be easily achieve while MCE supplies consistent ranking of the potential locations of dumping sites.

According to the result of the study, there are 41 waste collection dumping sites in the study centres, 27 are legally approved while the 14 are illegal, and with its cluster in a dense popular area within the metropolis with observed mean distance of 370.734 meters. However, the best driving route propose for minimum of 10 waste collections was estimate at average of 45.8 km to the dump site. Multi –criteria evaluation of selection of dumpsite location indicated 642 hectare of land area are suitable for dump site location which is about (4%) of total land area of the study area, the average distance of the suitable area for dump site location is found on the average of 40km

away from the metropolis, which house the existing dumped. However, (59%) of the residence of the study area applaud the performance of the state own waste manager i.e. Kebbi Urban Development Authority (KUDA) while (41%) perceive there is need for improvement in their activities.

Kebbi urban Development Authority (KUDA) should perhaps decentralize the process of managing solid waste with an active working paradigm among the communities in Birnin Kebbi, private sector and non-governmental organizations with appropriate incentives mechanism for effective waste management. Waste management should be seen as a process of change where resources are consistent with present and future needs of Birnin Kebbi. Indeed, as technical knowhow and resources are no longer the main limiting factors in addressing the menace; a strong political will may now hold the key to sustainable solid waste management.

However, understanding the environmental, human and animal health consequences of the menace of solid waste along major streets in our cities has become a necessity. The need therefore arises to educate the people on this new paradigm on solid waste management. This should also be included in the curriculum of primary and secondary schools, and will go a long way to guide the people on environmental understanding for better waste management. Urban solid waste management which has become central to environmental control should not be left to government official alone. All should be involve.

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