Site Selection and Analysis of Solid Waste Dumpsites in Ile-Ife, Nigeria

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Key words: Management, Remote Sensing, Waste.

Abstract

The solid waste materials in cities are the natural outcome of human activities, in cities and municipalities of most developing countries. In Nigeria, it is a major concern of the government due to the health problems associated with improper disposal of waste. Due to the different parameters involved, deciding upon a suitable location is very complicated, costly and time consuming. Geographic Information System (GIS) allows users to view, understand, query, interpret and visualize spatial and non-spatial data in many ways that reveals relationships, patterns and trends in the form of maps, reports and charts (Lui and Mason, 2009; Bhatta, 2010). This study determined the most suitable site(s) for waste disposal in Ile-Ife, Osun State. Suitable disposal site must follow some safety criteria that will enable the wastes to be isolated so that there is no unacceptable risk to people or the environment. The Criteria for site selection used for this study includes physical characteristics, socioeconomic, and land-use factors (EPA, 2006).

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1.1 Background to the Study

Solid waste is the term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services (Aibor and Olorunda, 2006). History has it that the manipulation of the environment that produced waste may have begun with the domestication of fire (Encyclopaedia of Physical Science and Technology, 2nd ed., 1992). The amount of waste produced by human activities is increasing in most parts of the world, accompanied by problems of disposal (Microsoft Encarta Premium Encyclopedia Suite, 2004). 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 New York state department of environmental conservation defined waste in simple words as any discarded (abandoned or considered waste-like) materials can be solid, liquid, semi-solid or containerized gaseous material. Examples include: waste tires, scrap metal, latex paints, furniture and toys, domestic refuse (garbage), discarded appliances and vehicles, uncontaminated used oil and anti-freeze, empty aerosol cans, paint cans and compressed gas cylinders, construction and demolition debris, asbestos. It can also be seen as consisting of everyday items that are 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). 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 (Global Waste Management Market Report, 2007).

Solid waste; when left unattended to for a long time, constitutes health hazards, causes offensive odour, and pollutes the underground water sources and decreases aesthetics and quality (Federal Ministry of Environment). The inability to manage these wastes effectively in Nigeria becomes an issue of great concern. This is because apart from the destruction of aesthetics of landscape by the waste dumpsites, some of the municipal solid wastes contain both organic and inorganic toxic pollutants (such as heavy metals) that threaten the health of humans and the entire ecosystem. Proper management of solid waste is critical to the health and well-being of urban residents (World Bank, 2003). Nigerians had been concerned with solid waste disposal; but their concern had not gone beyond physical removal of waste from the streets. It has been a common practice to dispose solid wastes using open dump or the use of an open burning.

Dumpsites have been the most organized common methods of waste disposal and remain so in many places in the world (El-Fadel 1995). In developing countries like Nigeria, the prevailing practice of municipal solid waste disposal is to dispose the solid waste in dumpsites (Weiss 1974; Lee and Krieger 1986; El-Fadel et al 1995; Asian Institute of Technology (AIT) 2004). Arimah and Adinu (1995) in their work observed that location of dumpsites in urban areas is beneficial in that they provide the most efficient and safe means of disposal of waste generated; however, the perceived environmental costs, health-related hazards, social and economic impacts associated with waste dumpsite are often confined to the immediate zone of influence of dumpsites and extends up to few kilometres. GIS technology can support assessing the spatial distribution of these solid waste dumpsites as well as identifying the sites suitable for sitting them.

1.2 Statement of Research Problem

Methods of designing spatial models for site planning were first discussed over 30 years ago before the advent of automated geographic information systems (McHarg, 1969). Recently, the process for locating a site has made extensive use of the Geographic Information System (GIS) projects. Pelczar et al. (1993) asserted that, careless and illegal dumping of solid waste has led to the problem of polluting the land as well as the near-by water bodies to serve both irrigation and domestic needs. Pollution of water could aid the transmission of water-borne infections such as typhoid, cholera, gastro enteritis among others. Similarly, polluting the land can aid the spread of food-borne diseases like salmonellas, etc. Moreover, uncontrolled solid waste disposal can also cause environmental problems like traffic congestion on the streets and roads, municipal floods when dumped on waterways etc. There are many drawbacks in the existing Waste Management System. For example, distribution and allocation of waste bins at improper location, no separate bins for recyclable waste, pollution of natural water streams due to waste collection centers proximity and open nature (Nair, 2010).

Hauwa (2003) opined that heaps of solid waste continue to emerge in Nigerian cities on daily basis and the site have become fertile ground for breeding flies and other vectors which have in effect became health hazards, obstructing traffic flow causing environmental degradation and general unsightliness. This problem of refuse disposal is basically a feature of rapid urbanization, which in Nigeria is still in its infancy. Another point is the location problem, most of the dumpsites are not well planned, and this leads to introduction of illegal dumpsites. Ile Ife the study area has been experiencing population growth. As such, there is increase in residential, commercial, industrial, and institutional land-uses leading to settlement expansion. The simultaneous increase in population and settlement expansion of the town has a direct effect on the increase in solid waste generation.

1.3 Aim and Objectives

1.3.1 Aim

The aim of this project is to use Geospatial technique to propose suitable solid waste dumpsites in the study area in aid of proper waste management.

1.3.2 Objectives

In order to be able to achieve the above aim, the following specific objectives were carried out:

1. Determine potential solid waste dumpsites using multi criteria analysis.
2. Assess if the existing dump sites meet stipulated standards.

1.4 Research Questions

1. Where are the existing solid waste dumpsites?
2. Where are the potential sites for sitting dumpsites?
3. Which dumpsites satisfy the stipulated standard?

1.5 Study Area

The study area Ile Ife consists of four Local Government Areas (Ife central, Ife south, Ife east and Ife north). It is located within latitude 7° 25'47.56" N and 7°32'28.85" N and within longitude 4°29'5.17" E and 4°35'23.09" E, covering an area of about 1894Km^2. It is located in the present day Osun State. The study area is as shown in figure 1.1

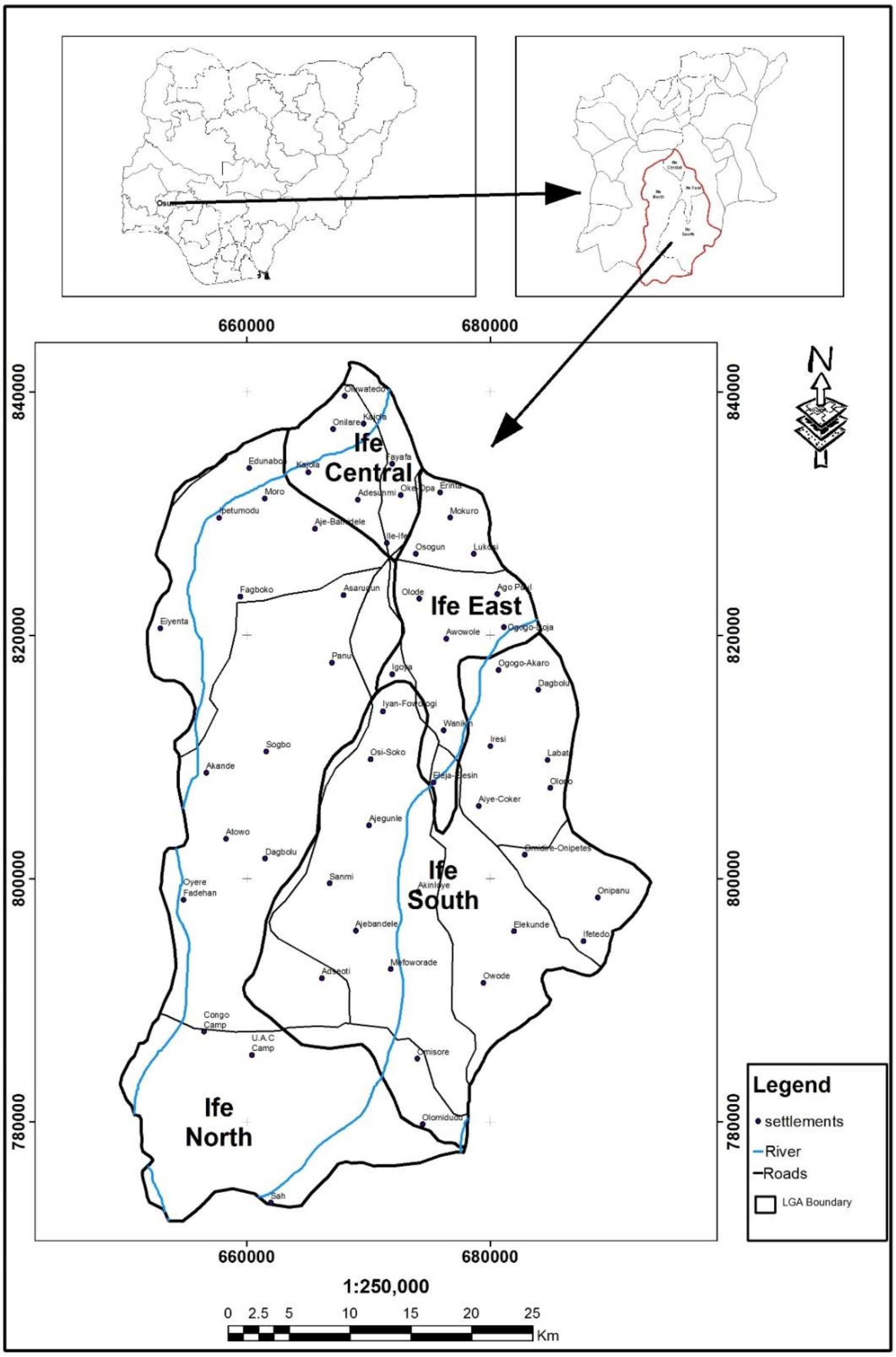

Figure 1.1: The Study Area

Table 1.1: Population of LGA's of the Study Area

LGA	POPULATION	AREA (Km^2)	HEADQUARTERS
Ife central	167,254	111	Ile Ife
Ife East	188,087	172	Okeogbo
Ife North	153,694	889	Ipetumodu
Ife South	135,38	730	Ifetedo

Source: NPC Census (2006.)

2. LITERATURE REVIEW

2.1 Concept of Solid Waste

Solid waste is the term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services. Waste management is a global environmental issue which constitutes a very significant problem in today's world (ERSI, 2001).
Ibrahim (2002) identified solid wastes are categorized into three (3) types based on the composition– Biodegradable, Semi-biodegradable and non- biodegradable. Biodegradable mainly composed of garbage trash, semi-biodegradable consists of rubbish while the non-biodegradable comprises of scraps and other carcasses. Aibor and Olorunda (2006) generalized solid wastes into domestic and estate solid wastes. The domestic solid wastes are those generated directly from households, including garbage, rubbish, ashes, house sweepings, other domestic bulky wastes etc. On the other hand, the estate solid wastes are those generated in larger quantities and are mostly from industrial establishments, hospital wastes, municipal wastes, agricultural wastes, site demolition and construction activities, etc.

2.2 Concept of Dump Sites

Tchobanoglous, et al (1993) observed that dumpsites are places designated for disposal of normally solid or semisolid materials, resulting from human and animal activities that are considered useless, unwanted or hazardous. In other words, they are essential part of any waste management system. According to El-Fadel et al, (1995), dump sites are historically the most used method for waste disposal in the world. It has the longest history, the widest range of capabilities and in most instances, is the least expensive waste disposal method (Weiss, 1974). Most of the existing solid waste disposal sites in developing countries are open dumping because the technology of proper sanitary landfill practice is not totally implemented (Lee and Sivapalasundram, 1979; Lee and Krieger, 1986; Matsufuji and Sinha, 1990). The environmental conditions from these sites are thus expected to be bad especially in terms of the contamination to the environment and lives.

AIT (2004), pointed out that final disposal in most of the developing countries is usually a matter of transporting the collected waste to the nearest available open space and discharging them. This study further pointed out that in Africa; most solid waste is disposed of indiscriminately and in an environmentally unacceptable manner through open or controlled dumping. Jung et al, (2005) establishes that open dumping has potential to reduce environmental quality in neighbourhood and can also pose a threat to public health, the environment and even scavengers that depends on scavenging materials for their livelihood. Consequently, the following associated environmental and health hazards and risks may be experienced continuously (Jung et al, 2005).

a) Unpalatable odour
b) Dust emissions
c) Poor aesthetics
d) Environmental nuisances
e) Attraction of vermin, vector and pest
f) Severe health risks to human beings and animal.
g) Breeding of disease vectors, flies and rats.

The insects and rats are potential disease transmitters (Gray, 1993). These can serve as source of pathogen organisms that can affect the scavengers who depend on recyclable materials for their livelihood and other waste workers (Brash, 1996; Leton and Nweke, 2003 and Cointreau-Levin, 2007; Afon, 2012) observed that there is the need to provide information on this informal activity (scavenging) that is on the increase on daily basis. In terms of occupation, he pointed out that scavenging is becoming an important occupation in waste management disposal system.

2.3 Types of Solid Waste

Solid waste can be classified into different types depending on their source:

1. **Municipal solid waste**

Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue, and waste from streets. This garbage is generated mainly from residential and commercial complexes. With rising urbanization and change in lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly and its composition changing.

2. **Hazardous waste**

Industrial and hospital waste is considered hazardous as they may contain toxic substances. Certain types of household waste are also hazardous. Hazardous wastes could be highly toxic to humans, animals, and plants. Household wastes that can be categorized as hazardous waste include old batteries, shoe polish, paint tins, old medicines, and medicine bottles. Hospital waste contaminated by chemicals used in hospitals is considered hazardous. These chemicals include formaldehyde and phenols, which are used as disinfectants, and mercury, which is used in thermometers or equipment that measure blood pressure. In the industrial sector, the major generators of hazardous waste are the metal, chemical, paper, pesticide, dye, refining, and rubber goods industries. Direct exposure to chemicals in hazardous waste such as mercury and cyanide can be fatal.

3. **Hospital waste**

Hospital waste is generated during the diagnosis, treatment, or immunization of human beings or animals or in research activities in these fields or in the production or testing of biologicals. It may include wastes like sharps, soiled waste, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc. These are in the form of disposable syringes, swabs, bandages, body fluids, human excreta, etc. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner.

2.6 Methods of Solid Waste Disposal

Solid waste disposal method includes the following:

1. **Landfill**

Disposal of waste in a landfill involves burying the waste, and this remains a common practice in most countries including Nigeria. Landfills were often established in abandoned or unused quarries, mining voids or borrow pits. A properly designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. Older, poorly designed or poorly managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin, and generation of liquid leachate. Another common product of landfills is gas (mostly composed of methane and carbon dioxide), which is produced as organic waste breaks down anaerobically. This gas can create odour problems and kill surface vegetation.

2. **Incineration**

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. This method is useful for disposal of residue of both solid waste management and solid residue from waste water management. This process reduces the volumes of solid waste to 20 to 30 percent of the original volume. Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam and ash. Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration is a controversial method of waste disposal, due to issues such as emission of gaseous pollutants. Combustion in an incinerator is not always perfect and there have been concerns about pollutants in gaseous emissions from incinerator stacks. Particular concern has focused on some very persistent organics such as dioxins, furans, etc which may be created which may have serious environmental consequences.

3. **Recycling**

Recycling is a resource recovery practice that refers to the collection and reuse of waste materials such as empty beverage containers. The materials from which the items are made can be reprocessed into new products. Material for recycling may be collected separately from general waste using dedicated bins and collection vehicles are sorted directly from mixed waste streams and are known as kerb-side recycling, it requires the owner of the waste to separate it into various different bins (typically wheelie bins) prior to its collection. The most common consumer products recycled include aluminium such as beverage cans, copper such as wire, steel food and aerosol cans, old steel furnishings or equipment, polyethylene, glass bottles and jars, paperboard cartons, newspapers, magazines and light paper, and corrugated fiber-board boxes. These items are usually composed of a single type of material, making them relatively easy to recycle into new products. The recycling of complex products (such as computers and electronic equipment) is more difficult, due to the additional dismantling and separation required. The type of material accepted for recycling varies by city and country. Each city and country has different recycling programs in place that can handle the various types of recyclable materials. However, certain variation in acceptance is reflected in the resale value of the material once it is reprocessed.

4. **Sustainability**

The management of waste is a key component in a business. Companies are encouraged to improve their environmental efficiencies each year by eliminating waste through resource recovery practices, which are sustainability-related activities. One way to do this is by shifting away from waste management to resource recovery practices like recycling materials such as glass, food scraps, paper and cardboard, plastic bottles and metal.

5. **Biological reprocessing**

Recoverable materials that are organic in nature, such as plant material, food scraps, and paper products, can be recovered through composting and digestion processes to decompose the organic matter. The resulting organic material is then recycled as mulch or compost for agricultural or landscaping purposes. In addition, waste gas from the process (such as methane) can be captured and used for generating electricity and heat. The intention of biological processing in waste management is to control and accelerate the natural process of decomposition of organic matter.

6. **Energy recovery**

The energy content of waste products can be harnessed directly by using them as a direct combustion fuel, or indirectly by processing them into another type of fuel. Thermal treatment ranges from using waste as a fuel source for cooking or heating and the use of the gas fuel (see above), to fuel for boilers to generate steam and electricity in a turbine. Pyrolysis and gasification are two related forms of thermal treatment where waste materials are heated to high temperatures with limited oxygen availability. The process usually occurs in a sealed vessel under high pressure. Pyrolysis of solid waste converts the material into solid, liquid and gas products. The liquid and gas can be burnt to produce energy or refined into other chemical products (chemical refinery). The solid residue (char) can be further refined into products such as activated carbon. Gasification and advanced Plasma arc gasification are used to convert organic materials directly into a synthetic gas (syngas) composed of carbon monoxide and hydrogen. The gas is then burnt to produce electricity and steam. An alternative to pyrolisis is high temperature and pressure supercritical water decomposition (hydrothermal monophasic oxidation).

7. **Resource recovery**

Resource recovery (as opposed to waste management) uses LCA (life cycle analysis) attempts to offer alternatives to waste management. For mixed MSW (Municipal Solid Waste) a number of broad studies have indicated that administration, source separation and collection followed by reuse and recycling of the non-organic fraction and energy and compost/fertilizer production of the organic material via anaerobic digestion to be the favoured path.

8. **Avoidance and reduction methods**

An important method of waste management is the prevention of waste material being created, also known as waste reduction. Methods of avoidance include reuse of second-hand products, repairing broken items instead of buying new, designing products to be refillable or reusable (such as cotton instead of plastic shopping bags), encouraging consumers to avoid using disposable products (such as disposable cutlery), removing any food/liquid remains from cans, packaging and designing products that use less material to achieve the same purpose (for example, lightweighting of beverage cans).

2.7 Factors Influencing the Choice of Refuse Disposal Method

Tajuddeen (2003) reported that, there are some factors which influence the choice of the method to be adopted in refuse disposal, these include:-

1. The physical characteristics of the locality.
2. Availability of land for the disposal method.
3. The character, quality and quantity of waste to be disposed.
4. Refuse quantity and nature varies greatly from region to region.
5. Financial capability of the municipality: Refuse vehicles are very expensive and not easy to manage.

Paradoxically, man is the generator of all other forms of waste but he is incapable of getting rid of the massive waste. The reason is that all the so called methods of refuse disposal are not efficiently sort out because; they will solve one problem to create another. Tajuddeen (2003) described waste as useless, disused or unused materials and that if not properly handled, may be dangerous to the health of man. Therefore cause for eradication in the modern concept, is the tendency to recycle waste materials apart from serving economic purpose. What is regarded as waste by certain group may be a raw material to another group.

2.8 GIS in Solid Waste Management and Analysis

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 datasets with non-spatial data including both quantitative and qualitative data. The role of (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 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 and ArcView as key components for managing its information (Keir, 1997). GIS is a good decision support tool for planning waste management. The trend towards desk top GIS has been increasing significantly in the last few years (Lee, 1997). This is mainly due to the increase in the PC capabilities and reduction in cost. This trend has compelled GIS software vendors to redesign their strategy to suit the situation. For example, ESRI has released ArcInfo NT as a substitute to ArcInfo for workstation and a similar case has been adopted by many other GIS software vendors such as Small World and GenaSys (Lee 1997)

METHODOLOGY

This chapter shows the methodology used for this research work. It describes the spatial and attribute data required to structure the database for effective implementation and management of the project and the resources needed for the effective operation of the software. The method employed for the research involves consideration of important criteria for sitting solid waste dumpsite. Six criteria were identified namely: Slope, Land-use, Geology, Soil, Roads, and Water body.

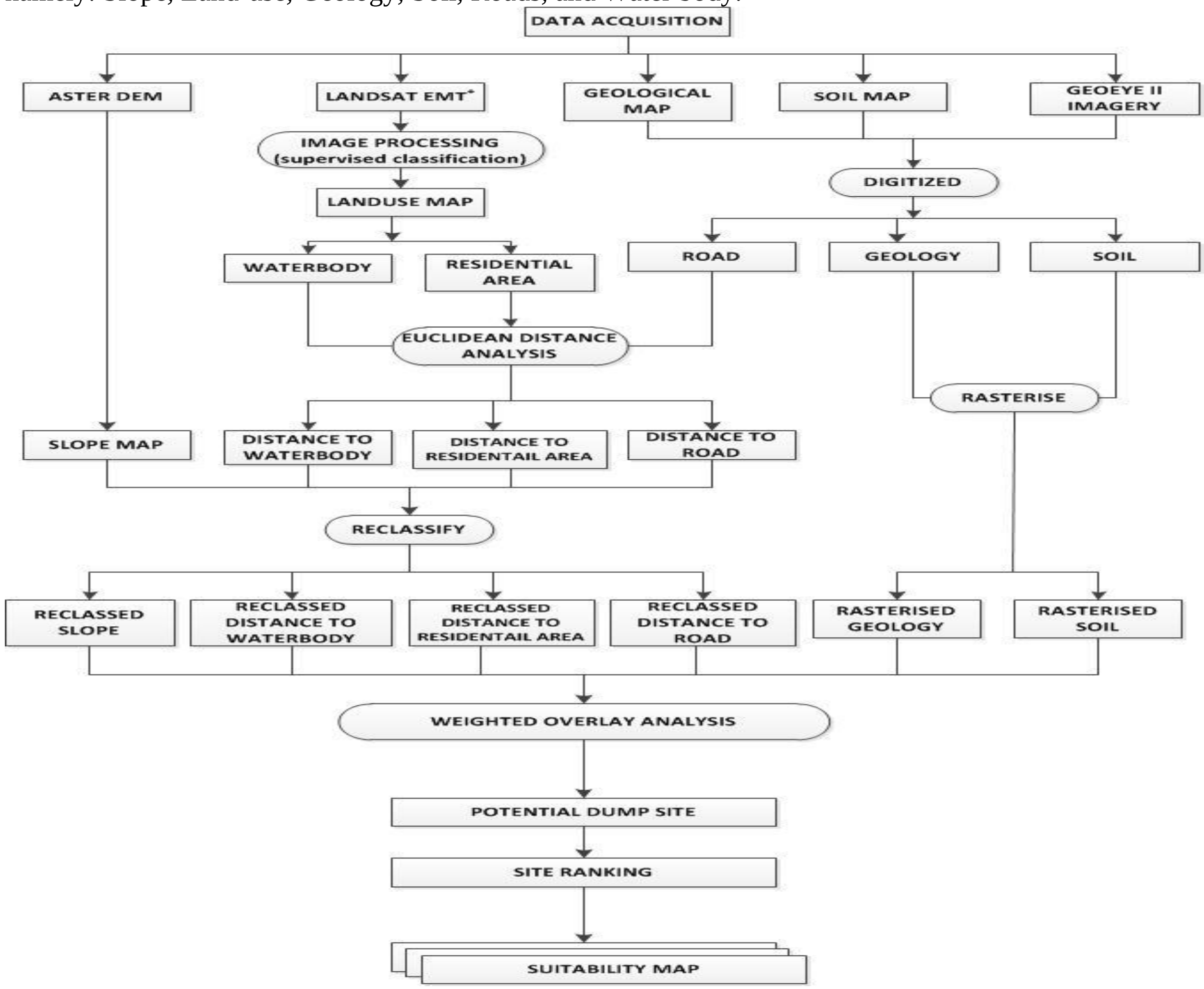

Figure 3.1: The Work flow diagram.

Each of these criteria is generated as a layer in GIS Environment (ArcGis 10.1) using a number of data acquired from different sources. The information compiled from literature (EPA Landfill Manual 2006) about the safe distance to a dump site was used to determine the buffer zones and varying degree of suitability within each layer. See Figure 3.1 for the workflow diagram adopted for the work.

3.1 Data and Materials

The data and materials used for this research are the LANDSAT ETM^{+} (2013, 28.5m resolution, path and row). Also the ASTER imagery of (30m resolution) covering the study area was also used in the research to generate elevation and slope of the study area. The geological map was obtained from Nigeria Geological Surveys from which the geology of the study area was extracted. Soil map was used to extract the soil types in the study area. Topographic map at a scale of 1:50,000 were used to delineate the river systems of the study area. Geo_Eye satellite imagery of the study area was used to extract the road network and also verify water bodies within the study area. The geometric data of the existing dumpsites within the study area was acquired through field survey using a Global Positioning System (GPS). ASTER image was downloaded from the ASTER website and the Geo_Eye II satellite imagery was captured from Google Earth pro 7.0.2 for the purpose of extracting the terrain elevation and roads respectively.

Table 3.1: The Adopted Data and their Attributes

S/n	Data	Source	Year	Resolution	Relevance
1	LANDSAT ETM+	GLCF	2013	28.5m	To extract the Land-use types of the study area.
2	ASTER DEM	ASTER WEBSITE	--	30m	For elevation and to generate slope
3	Geological Map	Nigerian Geological Survey	1965	1:250,000	To extract the geological map of the study area
4	Satellite Imagery	Google Earth Pro 7.0.2	2013		To extract the road network and also verify the water bodies within the study area
5	Administrative map	OSGOF		1:1,300.000	Extract the boundary of the study LGA's that made up the study area
6	GPS coordinates	Field Survey	2013		For the geometric data of the existing solid waste dumpsites within the study area
7	Soil map	Centre for world food Studies.	1997	1:1,300,000	To extract the soil types within the study area.

3.2 Spatial Data Analysis

3.2.1 Identification of Potential Solid Waste Dumpsites Using Multi-criteria Analysis.

To achieve the first objective in this research work the following data were used needed to perform the spatial analysis: Aster image, land-use map, geological map, topographic map, soil map, and GeoEye II satellite imagery. The data were selected based on the criteria that must be satisfied to determine the most suitable location for a dumpsite in the study area according to the Environment Protection Agency Landfill Manual 2006. All the paper maps (Geological, Topographic and soil maps) were scanned, georeferenced, resampled and digitised to convert the analogue map to digital format useable in the GIS software. Soil, geology, water body, residential area, road layers were derived. The various criteria that were created as layer in the GIS environment are:

Table 3.2: Constraint Criteria Table Formulated from EPA landfill manual 2006

Criteria	Unsuitable Areas
Distance to Water Body	Less than 160m
Slope	Areas with a Slope greater than 15^0
Distance to Residential Areas	less than 300m
Distance to Road	Less than 100m
Soil	Areas with Alluvial soils

Table 3.3: Factor Criteria Table Formulated from EPA landfill manual 2006

Criteria	Least Suitable	Moderately Suitable	Highly Suitable
Distance to Water Body	160m - 480m	480m - 960m	> 960
Slope	10^0 - 15^0	5^0 - 10^0	0^0 - 5^0
Distance to Road	> 2000m	1000m - 2000m	100m - 1000m
Distance Residential Area	300m - 500m	500m - 800m	> 8000m
Soil	-	Alisols	Nitisols
Geology	Quartzite	Migmatite-Gness Complex	Charnock /Granite

Spatial Analyst enables desktop GIS users to create, query, and analyse cell-based raster maps; derive new information from existing data; query information across multiple data layers; fully integrate cell-based raster data with traditional vector data sources; and create sophisticated spatial models using Model Builder. Model builder is a tool for creating and managing automated and self-documenting spatial models. Model builder enables users to create process flow diagrams and scenarios to automate the modeling process. In model builder process these themes were converted to grid themes using the vector conversion process. Models are represented as sets of spatial processes, such as buffer, classification, and reclassification and overlay techniques.

Figure 3.2: The Cartographic Model

Each of the input themes is assigned a weight influence based on its importance, then the result successively multiplying the results by each of the constraints. This process is often used in site suitability studies where several factors affect the suitability of a site (Mitchell et al. 2001). Then the GIS overlay process can be used to combine the factors and constraints in the form of a weighting sum process. Designing spatial analysis model is required to create backbone of GIS operations for this research (McCoy, 2001). The process for determining the suitable sites for solid waste dumpsites in this study is performed by a GIS Spatial analysis using ArcGIS Model Builder. It is seen briefly in figure 3.2 and 3.3.

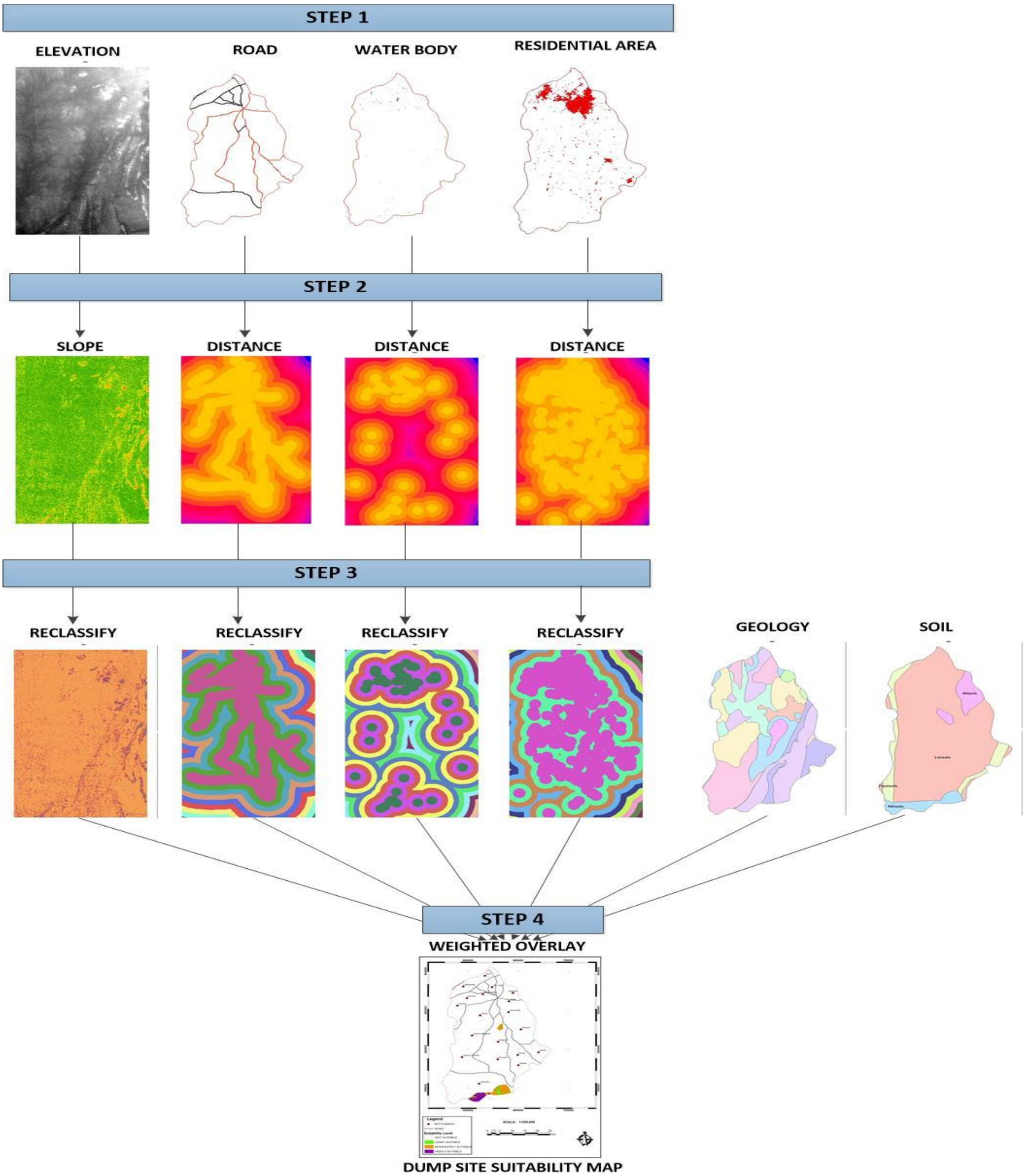

Figure 3.3: Pictorial Steps for Multi-Criteria Analysis

All the criteria were mapped using both remote sensing and GIS techniques. They were created as GIS layers and structured in a geo-database to ensure consistency of the data during spatial analysis. GIS analysis such as: slope analysis, Euclidean distance analysis, reclassification, rasterization and weighted overlay were performed. Supervised image classification was carried out to derive the landuse/ landcover types required for the analysis on the Landsat EMT^{+} 2013 imagery using Erdas Imagine 9.2 application. Slope analysis was carried out on the ASTER DEM to generate the slope of the terrain. Furthermore, Euclidean distance output raster was generated showing the measured distance from the nearest source (road network, residential area and waterbody). The slope map, Euclidean distance raster of road network, residential area and waterbody were reclassified and ranked from 1 (the least suitable) to 10 (the most suitable). Finally, weighted overlay was done using equal level of influence for all the factors in the GIS environment to determine suitable dumpsite areas. All the analysis were accompanied using geoprocessing module of ArcGis 10.1 software.

3.2.2 Assessment of the Existing Solid Waste Dumpsites

To achieve the second objective in this research work the data needed to perform the spatial analysis is the X Y coordinates of the existing solid waste dump sites. The coordinates of the existing solid waste dumpsites were collected through field measurement/ field survey method. Hand-held GARMIN GPS was used to obtain the coordinates. These coordinates are shown in the table below:

Table 3.4: Coordinates of the Existing Dumpsites

Name/ location	X (m)	Y (m)
Awosun along Ibadan Express Road	662135.653	829218.763
Behind Prison, Ifewara road.	677973.075	823819.641

The coordinates of the existing solid waste dumpsites collected during fieldwork were imported into the ArcGIS 10.1 as a text file then converted to shape-file to show the location of the dumpsites. The points were superimposed on the result derived from the identification of potential solid waste dumpsites using multicriteria analysis. This was to determine whether the existing dumpsites within the study area met the stipulated standards.

4.1 Analysis of Potential Solid Waste Dumpsites

Several steps taken for spatial analysis was summarized in figure 3.3. First of all, all data map layers should be converted from vector form to raster form. A raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information. For several data map layers, this first step proceed further with Euclidean distance analysis to apply the safe distance between dumpsites to several criteria that has been set up as indicators mentioned in suitability criteria. The Euclidean distance output raster contains the measured distance from every cell to the nearest source. When all data map layers already set up in certain prerequisite for safety distance through Euclidean distance analysis, the values of classes have to be compared between layers by assigning numeric values to classes within each map layer so they have equal importance in determining the most suitable location. Then finally, all data map layers is ready to be overlaid by using weighted overlay method to create single rank map of suitability analysis.

4.1.1 Euclidean Distance Result

Figure 4.1, 4.2 and 4.3 shows the result of Euclidean distance. The Euclidean distance output raster contains the measured distance from every cell to the nearest source.

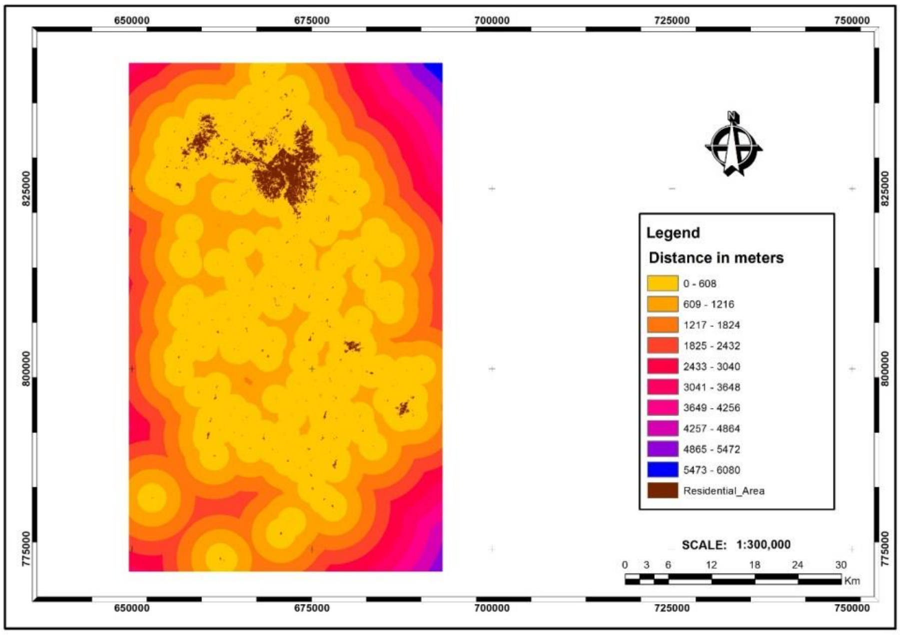

Figure 4.3: Euclidean Distance Analysis for Residential Area Data Map Layer

The distances are measured as the crow flies (Euclidean distance) in the projection units of the raster, in meters and are computed from cell center to cell center. Every layer has different Euclidean distance, for example based on the criteria adopted in this research, residential distance have minimum requirement for safety area of distance 300m from the dumpsites, dumpsites are to be located at a minimum of 100m from the road etc.

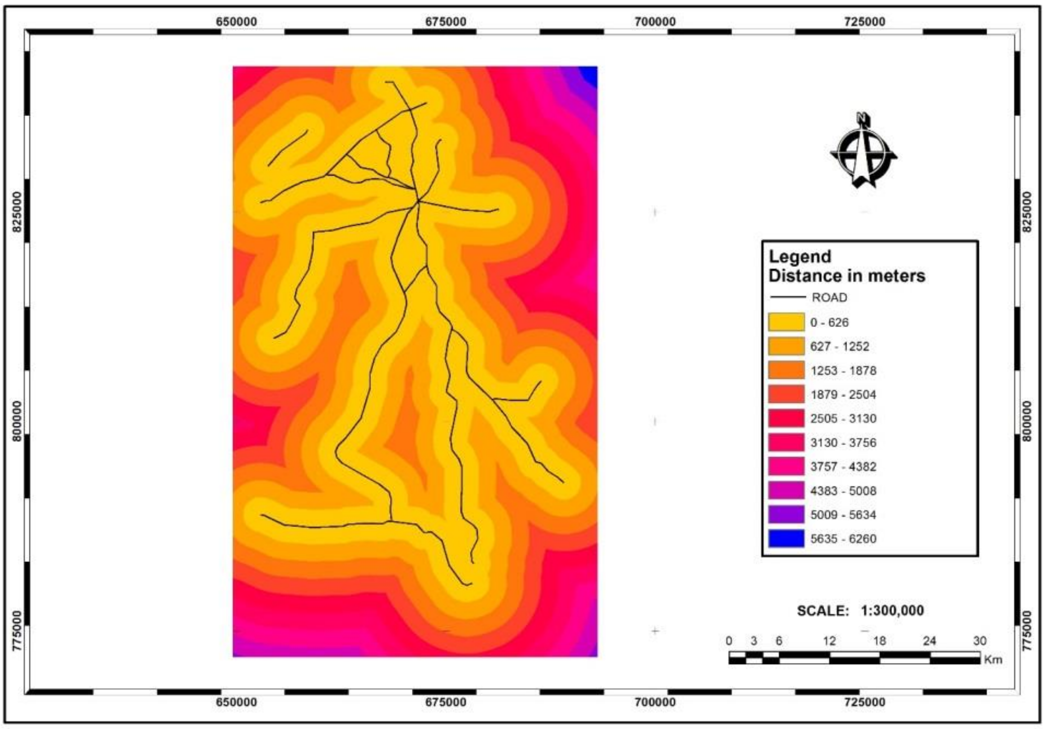

Figure 4.4: Euclidean Distance Analysis for Road Data Map Layer

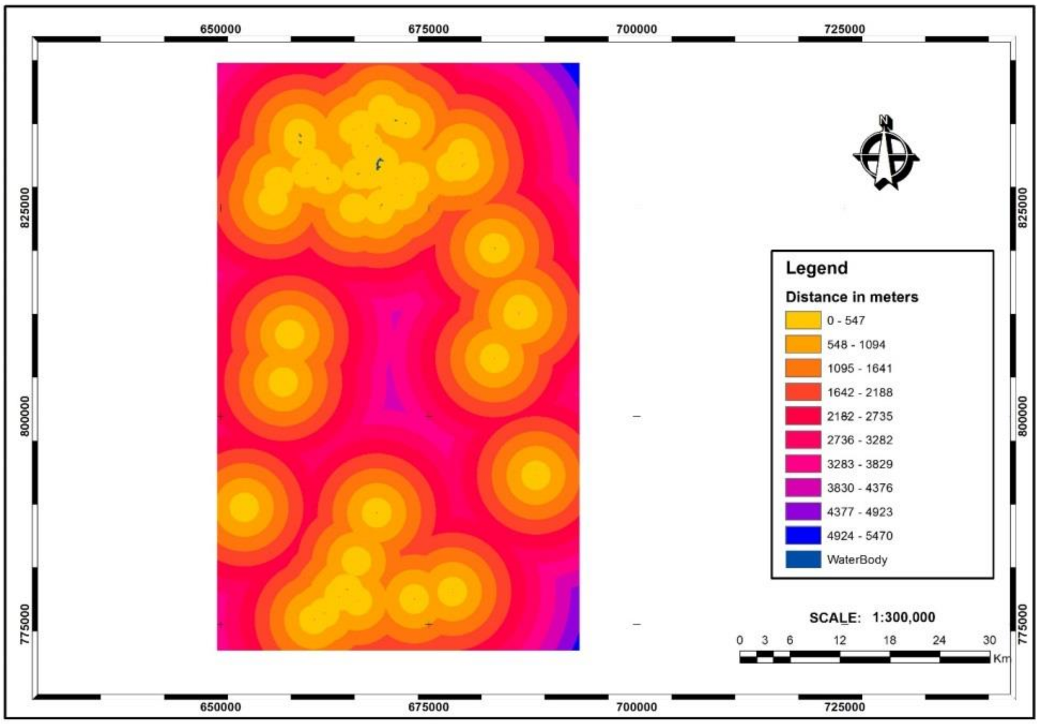

Figure 4.5: Euclidean Distance Analysis for Waterbody Data Map Layer

4.1.2. Reclassification Result

To create a single ranked map of potential areas to site Solid waste dumpsite we have to compare the values of classes between layers by assigning numeric values to classes within each map layer, it is called reclassifying. Having all measures on the same numeric scale gives them equal importance in determining the most suitable locations, hence all data map layers will be reclassified into new numeric value or scoring as '10 to 1' (McCoy et al. 2001). The scores of '10 to 1' are used to identify the differences among areas of suitability. The slope dataset is reclassified at a score of 1 to 10 in order of priority (i.e. the lesser the slope the more suitable the area) so the scaling was reversed, while building, petrol filling station and road dataset are reclassified at a score of 10 to 1 (i.e. the farther the feature the more suitable the area). The figures below show the reclassified datasets.

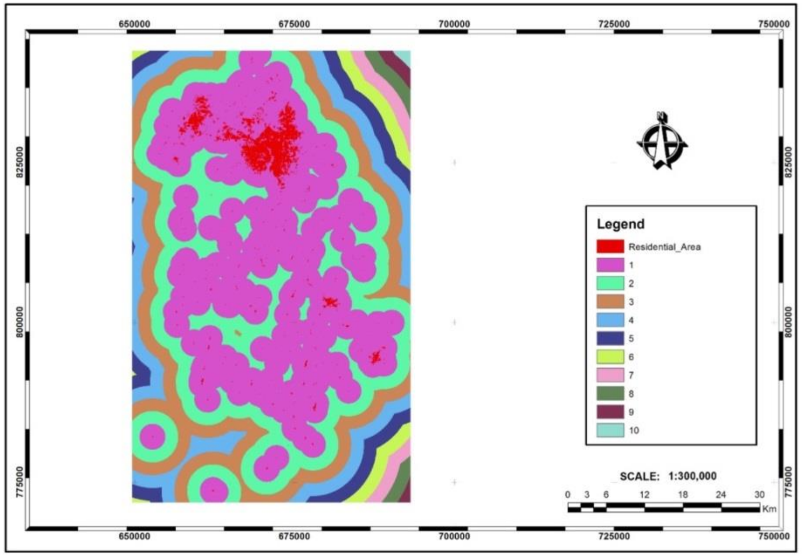

Figure 4.6: Reclassified Residential Area

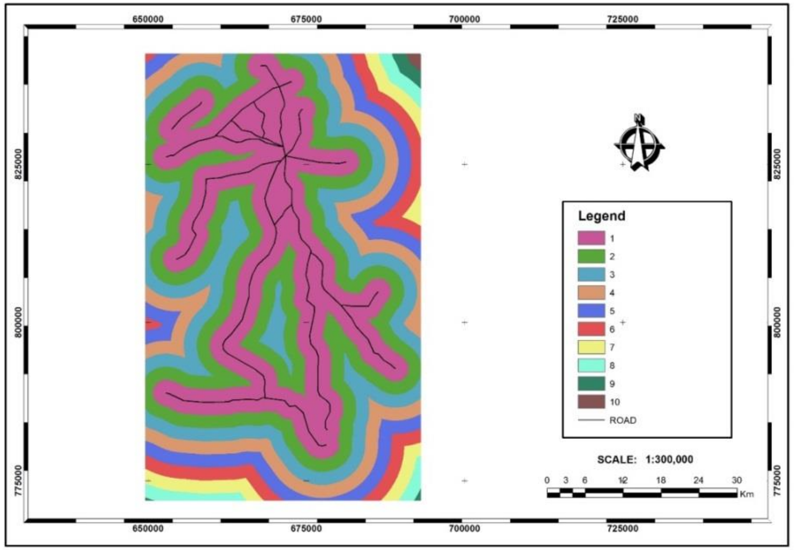

Figure 4.7: Reclassified Road

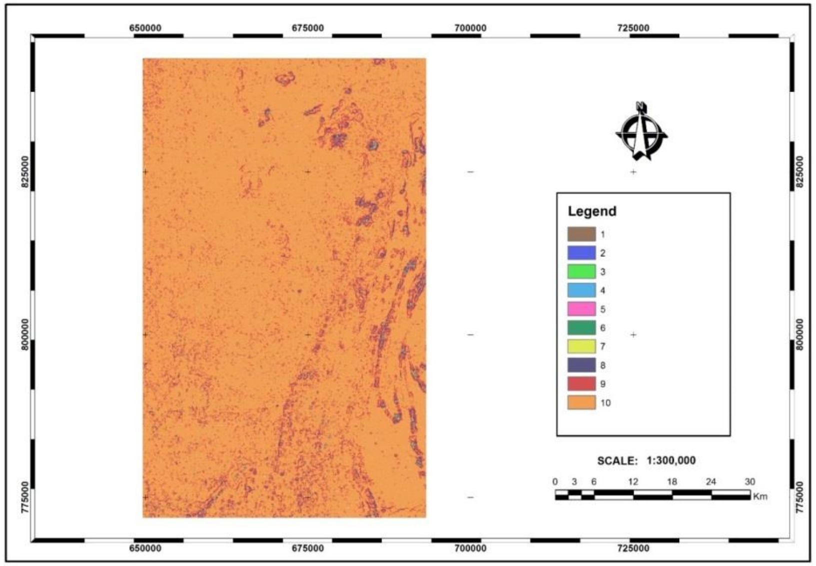	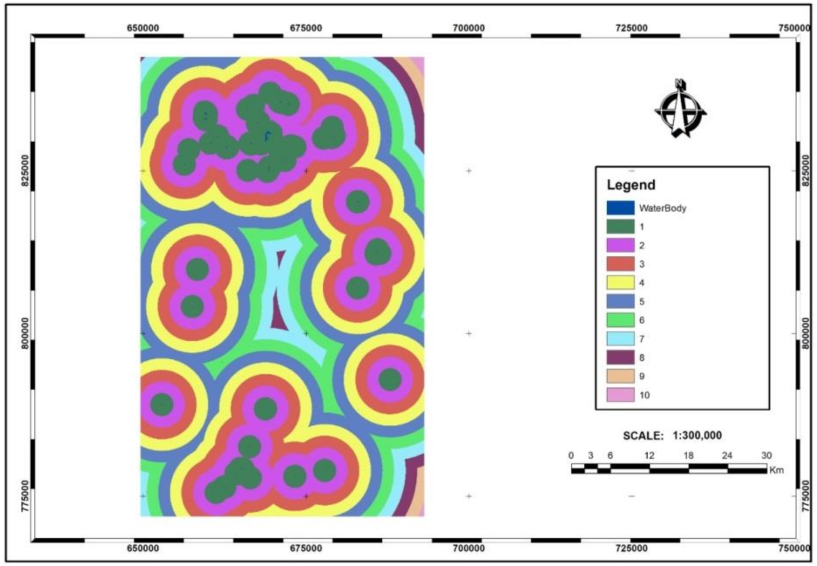
Figure 4.8: Reclassified Slope	Figure 4.9: Reclassified Water Body

a. Reclassification of distance from residential areas at a range of 1 (the least suitable) to 10 (the most suitable). This ranking is based on the criterion which addresses required distance from a residential Area.
b. Reclassification Of distance for road at a range of 1 (the least suitable) to 10 (the most suitable). This ranking is based on the criterion which addresses required distance from road.
c. Reclassification of degree of slope of the terrain at a range of 1 to 10. 1 (the least suitable) to 10 (the most suitable). This ranking is based on the criterion which addresses the degree of slope suitable for the location of a dumpsite. The plainer the better.
d. Reclassification of distance from water body at a range of 1 to 10. 1 (the least suitable) to 10 (the most suitable).This ranking is based on the criterion which addresses required distance from water body. The farther the better.

4.1.3 Weighted Overlay Result

Weighted overlay sum is a method that overlay several raster multiplying each by their given weight and summing them together. One major difference between the weighted overlay tool and the weighted sum tool is the weighted sum tool allows for floating point values whereas the weighted overlay tool only accepts integer raster as inputs (McCoy et al. 2001).
The final suitability map for locating solid waste dumpsites is seen in figure 4.8. Five raster layers are ranked for development suitability on a scale of 1 to 10. And the weighted overlay results are further reclassified to a scale of 1 to 3The result shows that an area of 1838sqkm is not suitable, 4.5sqkm is least suitable, 35.9sqkm is moderately suitable and 17sqkm is highly suitable.

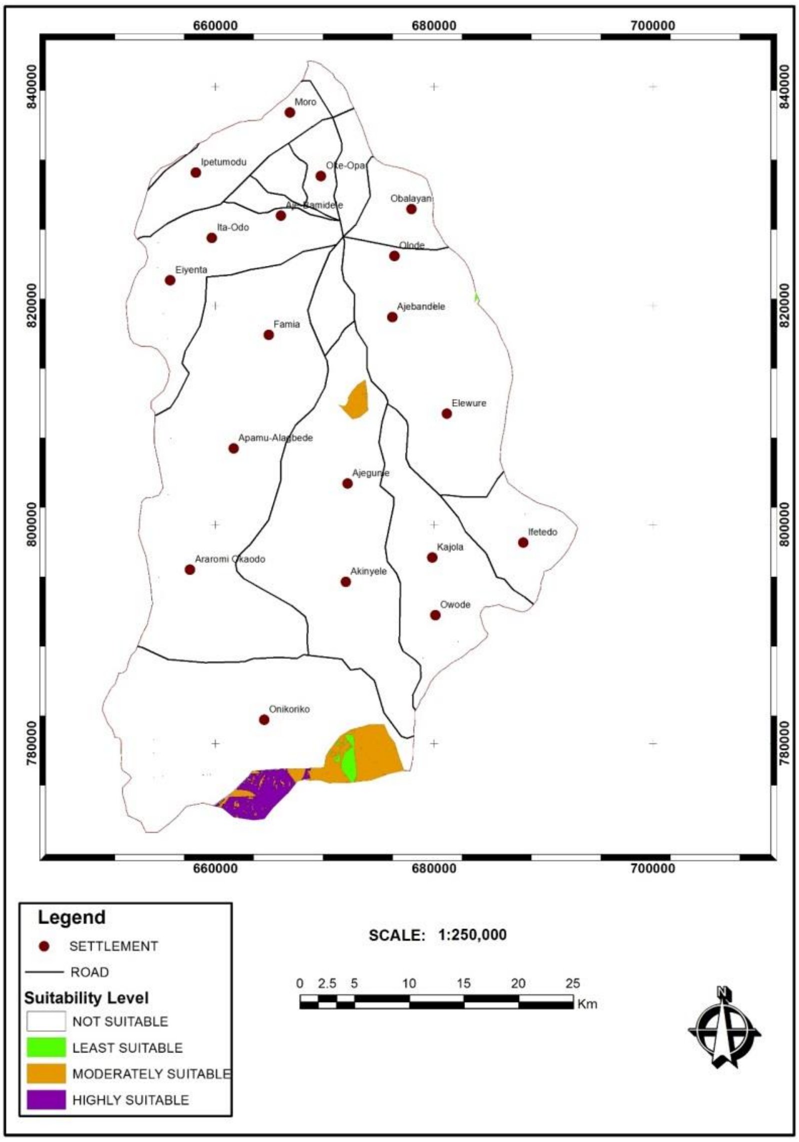

Figure 4.10: Solid Waste Dumpsites Suitability Map

4.2 Assessment of the Existing Solid Waste Dumpsites

To achieve the above stated objective, an overlay operation was carried out. In general, there are two methods for performing overlay analysis—feature overlay (overlaying points, lines, or polygons) and raster overlay. Some types of overlay analysis lend themselves to one or the other of these methods. Overlay analysis to find locations meeting certain criteria is often best done using raster overlay (although you can do it with feature data). Of course, this also depends on whether your data is already stored as features or rasters. It may be worthwhile to convert the data from one format to the other to perform the analysis. The coordinates of the existing solid waste dumpsites collected during fieldwork were imported into the ArcGIS 10.1 as a text file then converted to shapefile to show the location of the dumpsites. The points were overlayed on the result derived from the first objective. This assisted in finding out if the existing dumpsites within the study area are properly sited. From the result derived, it could be concluded that none of the existing dumpsites within the study area is properly located. In order words, none of them met the stipulated standard. The map is shown on Figure 4.9 below.

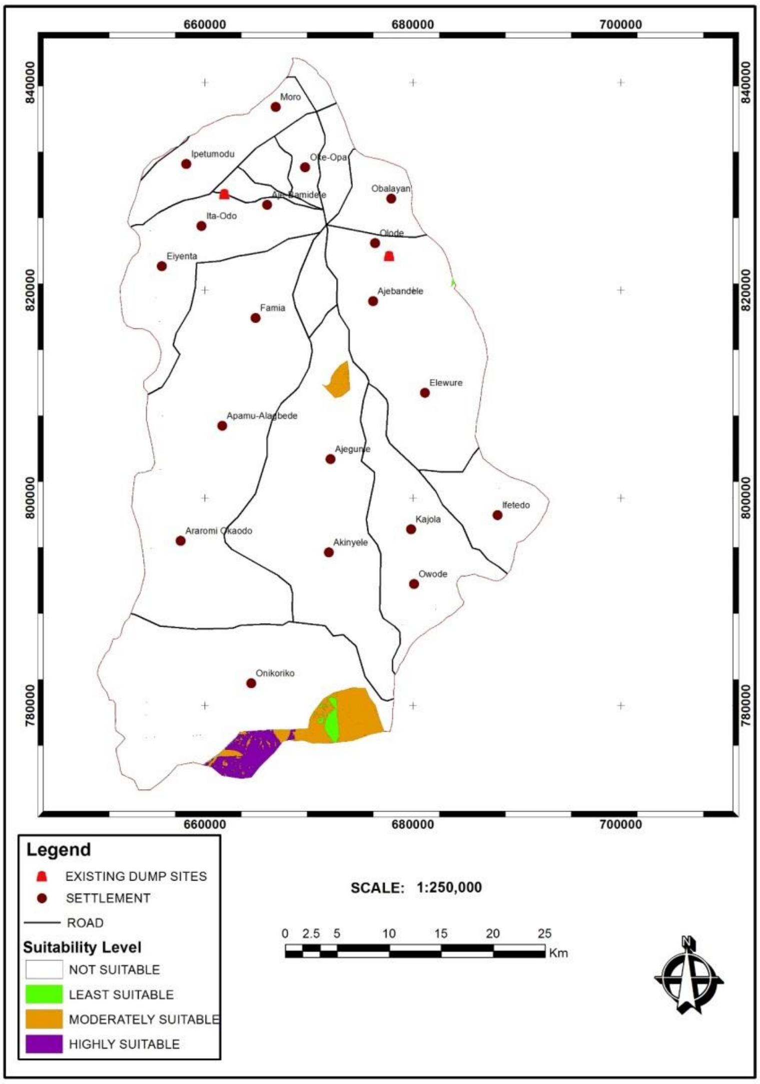

Figure 4.11: Solid Waste Dumpsites Suitability Map Showing the Existing Dumpsites

5.1 Summary of Factors of Potential Dumpsites Selection

1. Geomorphology

Since groundwater contamination issues are a major concern, geologic characteristics of a site are an important consideration. A key factor in decreasing the potential for contamination is the geomorphic characteristics or subsurface geology of the area. Earth material with low hydraulic conductivity, low effective porosity, and high retention (absorption, adsorption) of hazardous solutes are ideal for dumpsite locations (Atkinson *et al.*, 1995; Dorhofer & Siebert, 1998).

2. Proximity to Water Sources

Dumpsites create noxious gases and leakage that make them unsuitable to be in proximity to surface waters (Erkut & Moran, 1991; Dorhofer & Siebert, 1998). If any landfill site were to leak waste-related chemicals into surrounding water, streams, or reservoirs, contamination would occur. The result would be the transfer of hazardous chemicals into drinking water, where reagents such as viruses and toxins could develop

(Bodhankar & Chatterjee, 1994). This would pose a serious health hazard to all organisms dependant on the water, and could also bio-accumulate chemicals within the native species of the area.

3. Land-Use

The importance of minimizing the association of conflicting land-uses in landfill siting can be realized by reviewing Locally Unwanted Land-Use (LULU) areas. Public acceptance of unwanted facility sitings vary with land-use (Baban & Flannagan, 1998). Land-use of lowest value in public opinion reduces conflict over higher valued land-uses.

4. Land Value

Economic factors for siting are based in three areas, explicitly, acquisition costs, and development and operation costs of each site (Erkut & Moran, 1991). Capital costs associated with the acquisition of the dumpsites must be matched by the capital investment put into the project in order for the landfill site to be approved. Acquisition costs connote the consideration or compensation paid for acquisition of land, or on the expropriation of land, or the value thereof other than the value of any service or benefit that accrues to, passes to, or is provided to the persons from whom the land is acquired at the expense of the authority for which the land is required. U.S. Department of Housing and Urban Development (2007) adds that in some cases the land and existing structures will have already been acquired. If the land and existing structures are being refinanced or reimbursed as a part of the development, then enter the relevant acquisition cost. However, if land and existing structures have already been acquired and the project is focused on renovating, demolishing, or otherwise developing the site, then it is not necessary to enter acquisition costs. According to DWAF (2005), there are 10 considerations under economic criteria. These consist of:

i. The possible incorporation of the site into the waste disposal system, either immediately or in the future.
ii. The economies of scale. Large site are economically more attractive.
iii. The distance of the site from the waste generation areas. This is directly proportional to transportation costs.
iv. The size of the operation. A disposal site must cater for the disposal of the waste stream over at least the medium term to justify the capital expenditure. In addition to the size of the landfill proper, the anticipated extent of the ultimate buffer zone should be considered.
v. Access to the landfill site. This has cost convenience and environmental implications, especially if the roads have to be considered.
vi. The availability of on-site soil to provide low cost cover material. Importation of cover increases operating 3costs and cover shortage may reduce site life.
vii. The quality of the on-site soil. Low permeability clayey soil on site will reduce the cost of containment liner and leacheate control systems.
viii. Exposed or highly visible sites. High visibility results in additional costs being incurred for screening.
ix. Land availability and/or acquisition costs. These dependent on present or future competitive land-uses such as agriculture, residential or mining.
x. Other miscellaneous economic or socio-economic issues, e.g., where the displacement of local inhabitants must be addressed.

5. Slope

It is desirable to have a topographic surface that tends to shed water to reduce pounding and incident infiltration. Erkut & Moran (1991) state that if the slope is too steep, it is difficult and costly to construct the dumpsites. Slope is also an important factor when siting a dumpsite since higher slopes would increase runoff of pollutants from the dumpsite, and thereby contaminate areas further away from the dumpsite (Lin & Kao, 1999). As a matter of fact, Lin and Kao's study (1999) suggests that a slope less than 12% would be suitable for the prevention of contaminant runoff.

6. **Soil Properties**

Certain soil characteristics promote a safer and more economically feasible implementation and operation of a dumpsite. Permeability, effective porosity, and workability are important soil considerations (Atkinson *et al*., 1995). Texture analysis, therefore, allows for soils to be characterized based on the above mentioned characteristics. Soils with high silt and clay fractions provide groundwater protection and are an economically cheaper means to construct a dumpsite. Erkut & Moran (1991) and Dorhofer & Siebert (1998) emphasize that if clay is not available at a location, it must be hauled to the site or substituted with a geosynthetic system to maintain water quality levels.

7. **Economic Distance Cost from Population Centres**

Costs associated with economic distance relate to additional costs that come into the picture when development has to be located at a considerable distance from the source of the waste. Having close proximity to the source gives a lower long-term economic cost, since lengths of hauling the waste are decreased and are also more economically suitable (Baban & Flannagan, 1998).

8. **Distance from Populated Centres**

Social and political opposition to selecting dumpsite has been indicated as the single greatest impediment to successfully locating waste disposal facilities (Lober, 1995). The NIMBY phenomenon, described in greater detail by Erkut & Moran (1991), Lober (1995), and Kao & Lin (1996), is both an important consideration and restraint to dumpsite siting. The external cost and undesirable characteristics of dumpsites often cause people to perceive the hazards and risks as outweighing the long-term benefits (Baxter *et al*., 1999). Transportation, noise and congestion, lower property values, and lessening of community or personal self-image are the high costs perceived by the public (Lober, 1995). Costs and benefits are found to be directly proportional to the extent that an increase in the distance at which one lives from an undesired facility reduces the amount of perceived costs. Below are local and international studies/projects conducted with respect to dumpsites selection using the factors mentioned above with an aid of GIS technology.

Solid Waste Site Selection Criteria for Niamey Niger: The aim of this project was to use GIS and remote sensing techniques to identify appropriate areas suitable for waste disposal at Niamey, Niger. It provides a selection of environmentally friendly disposal sites, thus supplying reasonable, convenient and administratively transparent solutions to the waste disposal problem (Twumasi *et al*., 2005).
A number of essential factors were considered in locating dumpsites. Such factors included both physical and social environments. McKechnie *et al*. (1983) documented six factors that constitute these essential factors: topography, climate, hydrology, cover material (land cover), geology, and land uses.
Due to data constraints, Twumasi *et al*. (2005) used topography, hydrology, cover Materials, existing housing and land development (roads etc.) of the area as guides to site selection. Criteria were specified to assume that dumpsite would be outside the 22 buffer zone of the hydrology, forested areas, roads and existing housing. These criteria were:

- 300 meters away from the main road;
- areas less than or equal to 230 square meters based on the contour map;
- minimal noise contamination from truck movement;
- 300 meters away from water bodies;
- located in area not crossed by major roads;
- not located in areas of active agricultural land or near land under development and
- Kilometers away from the nearest population centres.

Different layers relating to these criteria were used to compare maps and located areas which conform to the criteria. It was emphasized that these were the criteria used to solve the siting problem at Niamey. The nearest population centre was the city of Niamey itself. Manu *et al*. (2004) outlined that if these criteria were

to be applied to other siting problems, it would be necessary to modify them in light of the new geographic and demographic constraints. Thus, for some urban areas, it may not be possible to find a site more than 40 kilometers from the nearest population centre; but siting may be possible if the critical separation is reduced to 20 kilometers. Different layers such as water, road networks, wells, market centers' and vegetation were overlaid. Two Boolean operations were performed using the topographic data. One was the area with height less than or equal to 230 meters, and the other with area greater than 230 meters. The final landfill sites also felt within the topography of 230 meters or less. It also showed buffer of 300 meters distances away from the major road network, vegetation (tiger bush) and water (Twumasi *et al*., 2005).
Identification of suitable landfill sites in Western Cape the Centre for Scientific and Industrial Research (CSIR) South Africa was appointed by Spoornet South Africa to conduct the study with the aim to identify suitable areas for a regional landfill site in the Western Cape Province using Geographic Information System (GIS) Technology. The information was required by Spoornet as part of a "pre-prefeasibility" study aimed at assessing possible options and strategies regarding the establishment of a waste-by-rail scheme in the province (Conrad, 1997) In the first place, Frantzis (1993) states, that all areas were excluded where the establishment of a waste disposal site would not be permitted. Examples of exclusionary criteria used are close proximity to residential areas, airfields, mountainous areas, nature reserves, indigenous forests, geological faults, the coast, dams or rivers. Once these areas had been identified, the remaining areas were then rated according to the nature of the geology, depth to groundwater, soil texture and soil depth. From the combination of these criteria favorable areas were identified (DRASTIC, 1987).

There were a number of factors that could not be included in the study, such as the location of water resources used for public water supply, the agricultural potential, land use, location of archaeological/historically important sites and areas with mineral rights. In addition, economic, social and political factors were not taken into account in this project. These factors would have to be considered in any subsequent study aimed at identifying specific sites in potentially suitable areas. In Africa, rapid urban growth since the 1960s has put pressure on the land resources within the area surrounding the cities, and this has led to increased generation of waste. The problem is aggravated by the open dump nature of disposing waste especially in the slum areas of most African cities (Mato, 1999; Hammer, 2003).

The project show the capability of GIS in capturing, storing, processing and analysing spatial data as well as creating spatial database for solid waste dumpsites in Ile Ife. Datasets for the work includes road network, elevation, landuse of study area, existing solid waste dumpsites, Geology, waterbody, and soil within the study area. The coordinates of the existing dumpsites were captured with handheld GPS and entered into excel spreadsheet and exported to ARCGIS 10.1. Spatial analysis were carried out which includes slope, Euclidean distance, reclassification and weighted overlay analysis in order to actualize the aim and objectives of the study. The criteria as relates to the siting of a solid waste dumpsites according to Environmental Protection Agency (EPA Landfill Manual 2006) forms the basis for performing the analysis.

1.5 Justification for Research

Waste disposal is the least preferred option in waste management because it is essentially an end of pipe solution and it has the most impact on the environment (Seuss 1985). Despite this fact, the bulk of solid waste still finds its way into solid waste disposal sites (SWDS) all over the world - 60% in the EU and a little less than that in the US (Bingemer and Crutzen 1987; Smith et al 2001; US EPA 2002).

5.2 Conclusion

The results Shows suitable area for Dumpsites in the study area, by the use of Geoinformation technique realizing that sitting of Solid waste Dumpsites is a big issue in Ile Ife. This project describes the methodology and was a case study for identifying the best area suitable for dumpsites. Specifically, this project shows Spatial Modeling Analysis to build the area suitable for sitting dumpsite using multi-criteria analysis within the GIS environment. The considered criteria include distance from water bodies, distance from major roads and residential areas, geology type, soil type and the slope.

The aim and objectives of this project have been achieved through the acquisition of necessary dataset and implementation of spatial analysis. The strength of this work lies in its simplicity, flexibility, and user-friendliness. The increase in commercial, residential and infrastructural development due to the population growth and urban expansion in Ile Ife is directly affecting the amount of waste generation in the area. This study is therefore considered very imperative because it will serve as a catalyst in the area for further improvement on waste dump siting and management.

The proportion of Municipal Solid Waste (MSW) that goes to disposal sites is likely to be higher in developing countries because they have less recycling and reuse capabilities (Akinwale 2004). This implies that, regardless of the fact that dumpsites are least preferred options for sustainable municipal solid waste (MSW) management, trends show that they will still be around for quite a while. Evidence abound that residential areas of many cities in developing nations cities are plague with diverse environmental challenges (Omotosho 2004; Leitner 2005).
A cursory glance into the landscape of many Nigeria cities does not prove an exception. Indeed cities everywhere face a common dilemma of how best to respond to these challenges. The Nigerian Government included in its National Policy for the Environment (1989) that solid waste must be collected and disposed of in effective and environmentally safe manners.

5.3 Recommendations

Having identified the area best for sitting dumpsites, in their levels of suitability using a Suitability Analysis Model Builder, it is recommended that the Environmental Department of the Local Government Areas within the study area and the Town Planning Authority have the site suitability analysis model in their finger-tips so that it will serve as a guide before a site can be approved for dumpsite, since it has taken care of all the criteria as regards suitable locations for dumpsite in its analysis. A step can still be taken further to incorporating within the model a procedure to enable identification of optimum site for locating a Solid waste dumpsite.

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