LANDFILL SUITABILITY

(YEWA SOUTH LOCAL GOVERNMENT AREA, OGUN STATE, NIGERIA)

BY

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ABSTRACT

There exist a large outcry over increasing and indiscriminate dumping of refuse in Yewa South Local Government Area of Ogun State, South West Nigeria. This is as a result of the increasing population which has brought about massive volume of waste being generated every day in the area. Unfortunately the management of these wastes is deteriorating day by day due to the limited resources in handling the increasing rate of generated waste. This work developed a GIS based model with the restriction and factor criteria using Arc toolbox and then employing the GIS based Multi-Criteria Decision Analysis (MCDA) such as Analytical Hierarchical Process (AHP) for selecting a suitable landfill site in Yewa South LGA. Suitability map was created after Restriction and factor maps were produced using ArcGIS analytical tools and possible sites that are suitable for sitting landfills were finally identified. Study showed that the area is characterized mostly by Shrubs, Cultivated lands and Built up areas. The shrub lands are presumed to suitable for siting Landfill but some factors (natural and artificial) needed to be considered in these shrub lands before concluding its suitability for Landfill. Result has shown the effectiveness of GIS's Analytical Hierarchical Process (AHP) for selecting a suitable landfill site in the area even in the next 100years. Despite the availability of highly suitable areas, the application of GIS tools using predefined parameters made the most probable site selection yet a reality. The result of the suitability map could be clearly understood, it can assist in getting full support especially from the public as the selected site is not located on, or near, any environmental interest areas and it is also located at significant distance away from streams, roads and residential areas, which minimizes social conflict and environmental impacts.

Keywords: AHP, Environment, GIS, Landfill, MCDA.

1.1 Introduction

The NIMBY (Not In My Backyard) syndrome has led to the impacts of improperly located landfill sites which are undesirable and can have adverse effects on human, plant and animal health. Landfills are the physical facilities used for the disposal of residual solid wastes in the surface soils of the earth. Landfill site selection is the most sensitive task placed before the participants in the process of planning spatial organization of a waste management system, particularly in countries where there is insufficient awareness and lack of information in the population. Source reduction, recycling and waste transformation are methods widely used to manage solid waste, however, in all these methods there is always a residual matter even after the recovery process for disposal (Alanbari, Al-Ansari, & Jasim, 2014). The necessity of getting rid of these waste yields in an economical way is referred to as landfilling (Tchobanoglous & Kreith, 2002).

The increasing population densities and its resultant less land availability for siting landfills coupled with environmental health concerns, are also the difficulties to over-come (Kao & Lin, 1996). It is on this premise that there exists no international rule that could be applied due to the inconsistencies in the various factors inherent in different countries concerned (Al-Ansari, Pusch, & Knutson, 2013) (Al-Ansari, Al-Hanbali, & Knutsson, Locating Solid Waste Landfills in Mafraq City, Jordan, 2012). It is to this understanding that various international specialized studies were conducted in this present research in order to identify suitable areas for waste landfill location, several using GIS techniques. This method of siting landfill in this part of the world is still at the introductory level.

1.1.1 The study area

The study area is Yewa Local Government Area of Ogun State, South Western Nigeria. It characterized mostly by Shrubs, Cultivated lands and Built up areas. The study area is divided into seven wards; Ajilete, Ilaro wards I-III, Idogo/Ipaja, Iwoye, Ilobi/Erinja, Owode wards I-II and Oke Odan.

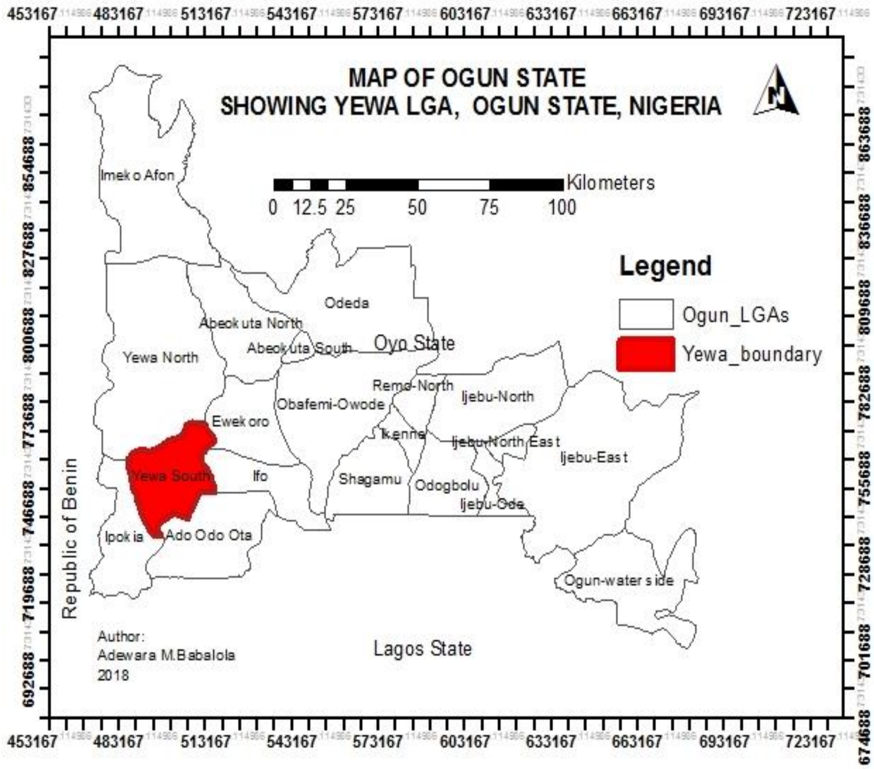

Figure 1: The Study Area

1.1.2 Existing Landfill sites in the study area

Some of the existing landfills in the area have been converted to residential and commercial due to failure on the part of the government to implement strategies that will sustain the landfills. A large number of the landfills cannot accommodate the waste generation by the increasing population of people in the study area.

1.2 Materials and Methods

Environmental factors are mainly considered in locating a land fill to avoid environmental risk. Landfill site should also be located far from residential areas and Agricultural lands. The site should be away from areas that are susceptible to flooding, as this could result in washout of disposal waste into groundwater or stream and would pose risk to human health.

1.2.1 Materials

1. Google earth image (2018)

2. Existing lad use map of the study area
3. SRTM data of the area
4. Geological soil map

1.2.2 Software

Esri's ArcGIS 10.2 Software was used for digitizing and map editing. It is also used for analysis and spatial multi-criteria evaluation. ArcGIS Software was also used for creating and completing a database layer, georeferencing maps, specifying the coordinate and image systems, using the spatial analysis functions for performing the multi-criteria evaluation.

1.2.3 Criteria for Selection of Land fill Site

The most important step in siting a Land fill is to define its selection criteria. Landfill site for solid wastes should be selected on following criteria:

- Land area and volume should be sufficient enough to provide landfill capacity so that the projected need can be fulfilled for several years. In this way the cost coming on all that procedure can be justified.
- The landfill site should not be at locations where suitable buffer zones between land fill site and population are not available.
- The landfill area having steep gradient (where stability of slope could be problematic) should not be selected.
- The water level in ground water table should be sufficient below the base of any excavation to
- Landfill area should not be very close to significant water bodies (water courses or dams). There will be the risk of contamination of water bodies, which can be hazardous for aquatic life.
- No major power transmission or other infrastructure like sewers, water supply lines should be crossing through landfill developmental area.

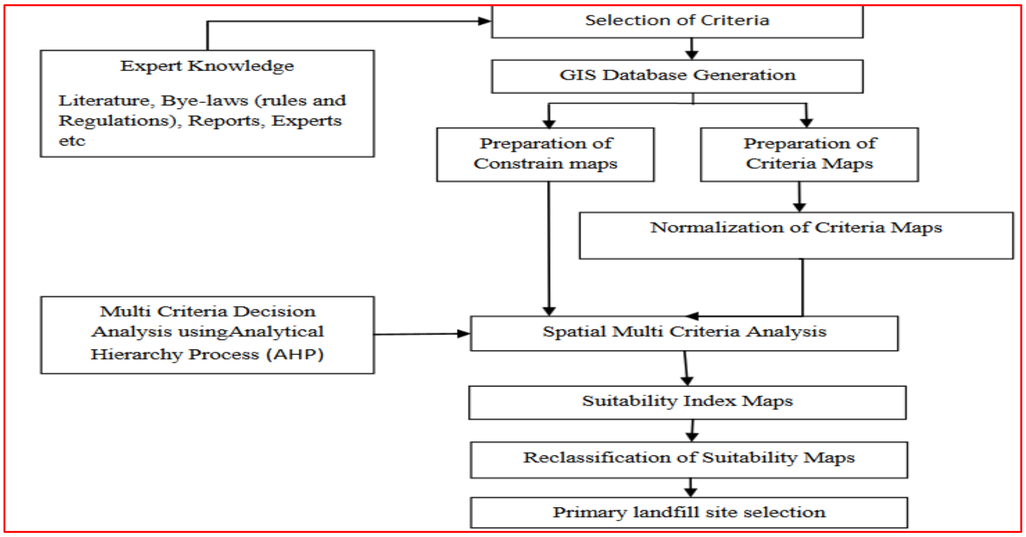

Figure 2: Flowchart of GIS based Landfill selection process (Ohri, Singh, Maurya, & Mishra, 2015)

1.2.4 Specifying-Selection Criteria

One challenge in this study is the availability of data and local or state environmental protection rules and regulations guiding the location of landfill sites. It is against this backdrop that this study considered criteria based on established guidelines from literatures both locally and internationally and modified according to available datasets about the study area for the siting of the landfill.

These criteria were grouped into restriction (distance from built up area, rivers, roads, agricultural lands and educational institution) and factor (soil type, geology, hydrology, land use and land cover, slope, proximity to built-up areas and road) criteria.

1.2.5 Creating Restriction maps

Thematic layers of these criteria were created. Road network, rivers and built up areas were digitized and edited from Landsat 8 (2016) Satellite Imagery. Geology, soil and hydrology maps were also scanned, imported into ArcGIS 10.2 environment and georeferenced.

Soil type, geology, depth to groundwater, slope, land use and restrictions are the factor maps considered for this study. The factor maps were weighted in the analysis and then combined (overlaid) with constraint maps. The restriction criteria were buffered so as to delineate exclusively all unsuitable areas from consideration in the landfill site selection. Table 1 shows the buffer distances for the varying restriction features from literatures.

Table 1: Restriction values extracted from existing Literatures

RESTRICTION FEATURES	**RANGE OF BUFFER DISTANCE**	**ADOPTED BUFFER DISTANCE**
Built up area	500 - 2000	1000
Rivers	100 -1000	500
Major road	100 - 500	250
Minor road	100 - 300	150
Agricultural	100 - 1000	500
transmission line, gas pipeline, crude oil pipeline, drinking water pipeline/Railroads	100 - 500	250
Slope	Relatively flat	
Mining site	500 - 2000	1000
Institutions	100 - 500	250
Parks	300 - 3000	1500

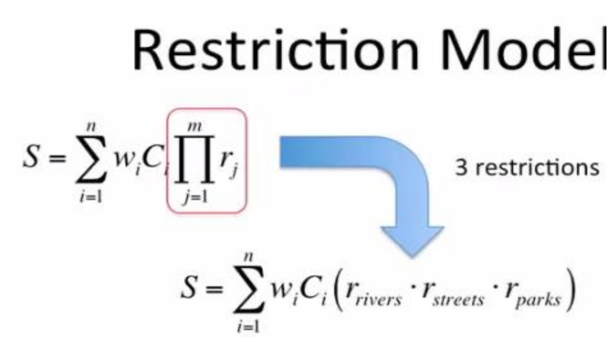

Figure 3: Restriction Model

Where:

r_{rivers} - Restriction related to river
r_{roads} - Restriction related to road
$r_{agricultural}$ - Restriction related to agricultural area
$r_{built\ up\ areas}$ - Restriction related to built-up areas

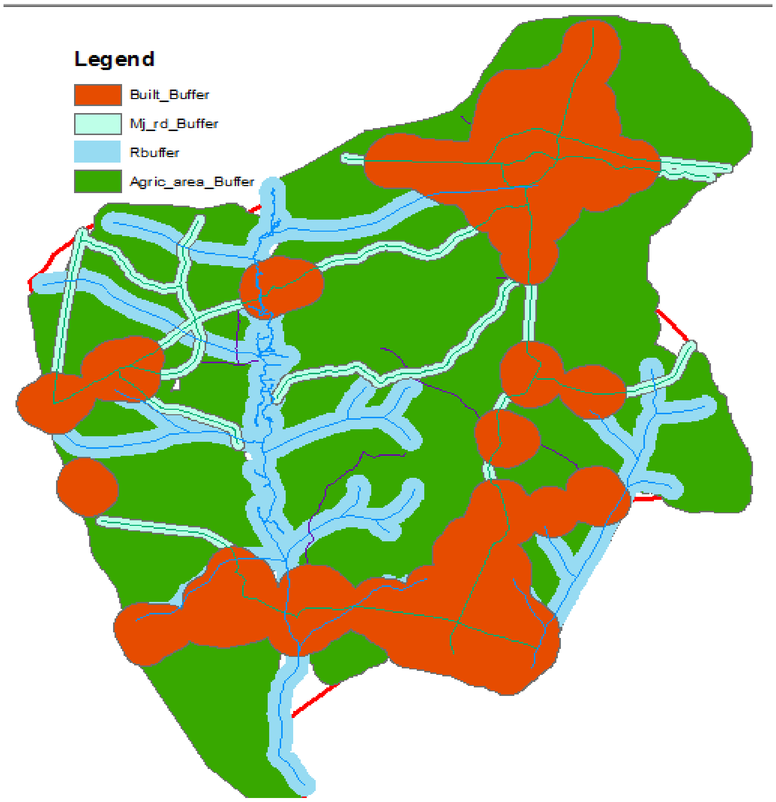

Figure 4: Factor map of the study area

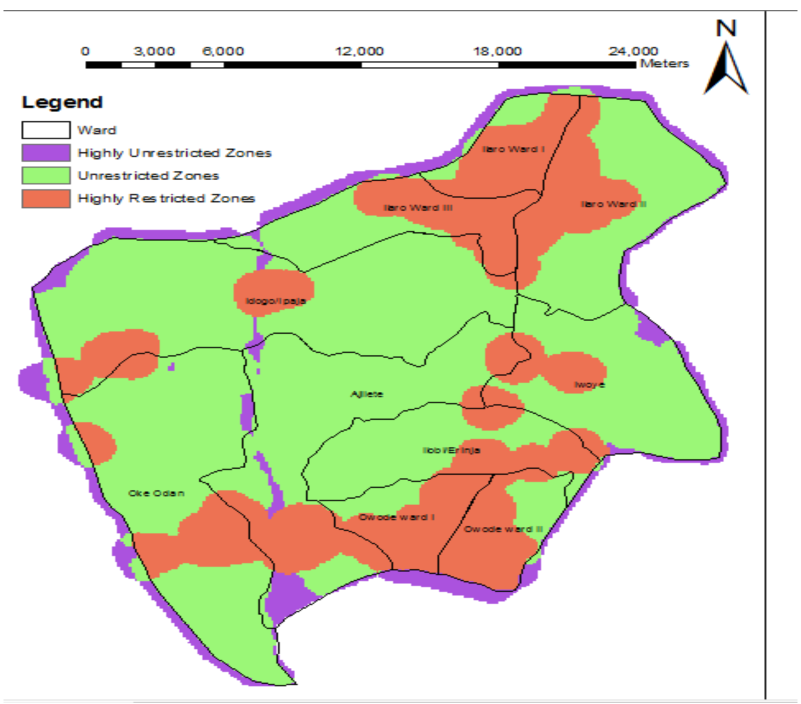

Figure 5: Final restriction map indicating restricted and available areas for landfill sites in the study area

1.2.6 Reclassifications

Slope map of the study area was generated from 30m resolution (2008) SRTM elevation data. The slope map was reclassified in order to use a common scale of measurement, such as 1 to 6, the lower the scale value, the more suitable a location is.

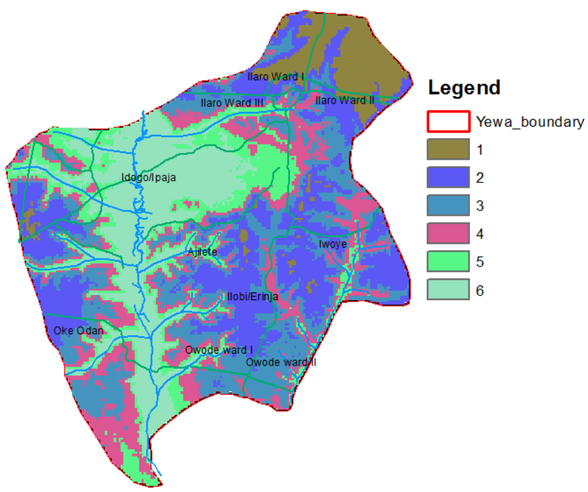

Figure 6: Reclassified slope map

1.2.7 Weighting method

Once the evaluation criteria were converted into the comparable and standard scales, weight and relative importance of each criterion were determined in relation to intended purpose. In this paper scale values of 1 – 5 Analytic Hierarchy Process (AHP) was used to assign a relative weight to each particular criterion. Because the criteria are not of equal importance, AHP's pairwise comparison method was used in calculating criteria weights.

1.2.8 Creating Suitability Index from Weighted Sum Overlay

The spatial multi criteria decision making aimed at combining various criteria and alternatives using Multi Criteria Decision Rules. In order to create a suitability raster for the location of landfill, the Weighted Linear Combination (WLC) technique was used to arrive at single suitability index S from multi attributes.

$$S = \sum_{i=1}^{n} w_i C_i \prod_{j=1}^{m} r_j$$

Where

S = Suitability for landfill site

w_i = Weight for a criteria i (C_i)

C_i = Criteria for suitability

r_j = Restriction

1.2.9 Suitability index overlay

Each factor map were assigned scores (scored maps), as well as the maps themselves receiving different weights. All scored maps were then assigned to a common scale (e.g. ranging between 1 and 5). Weights are generally assigned to these maps to express the relative importance. Determining the weights is, however, quite controversial and is basically accomplished by decision-makers through reviewing the criterion and their relative importance concerning the objective to which they contribute (Siddiqui, Everett, & Vieux, 1996).

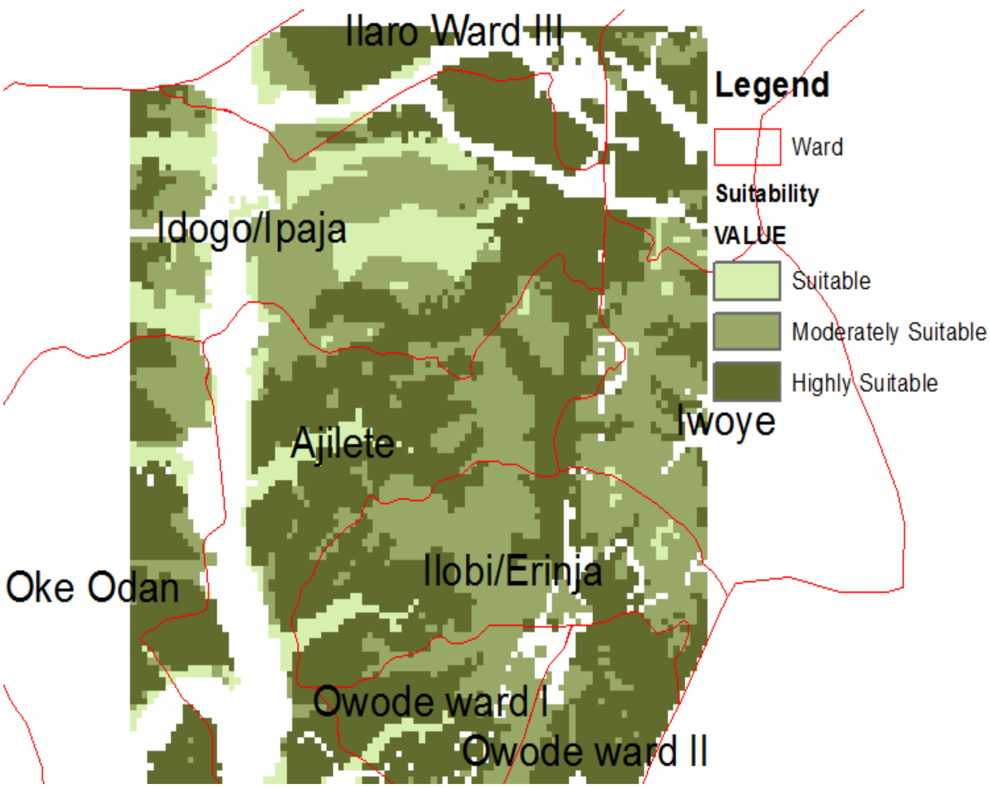

Figure 7: Suitability map

1.2.10 Parcel Coverage Selection

A parcel coverage of 100 hectares was chosen to locate the Landfill site

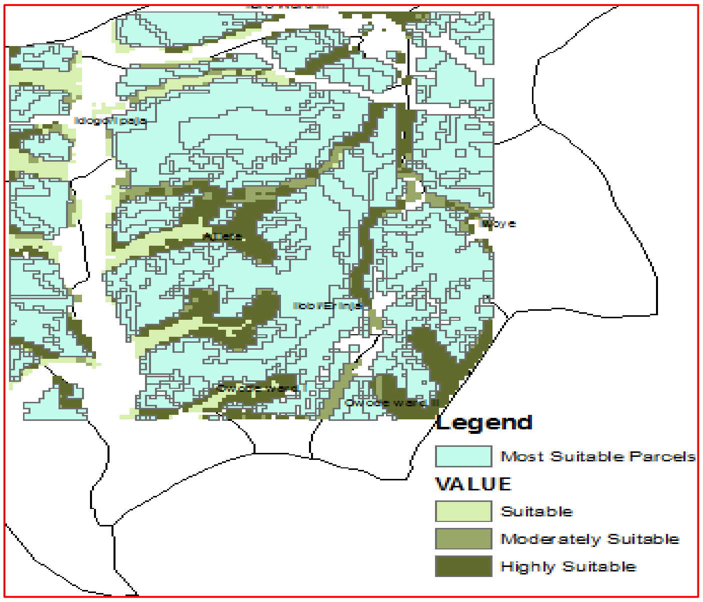

Figure 8: Most Suitable Parcels (Area = 100 Hects) overlaid on Suitability map

1.2.11 GIS Model Development

A user-friendly landfill site selection model (based on the Boolean logic operation) using a GIS framework was developed after identifying important criteria for siting landfills. Restriction model and Suitability model are the models developed for this study. The restriction maps previously created were used as input data in the model development.

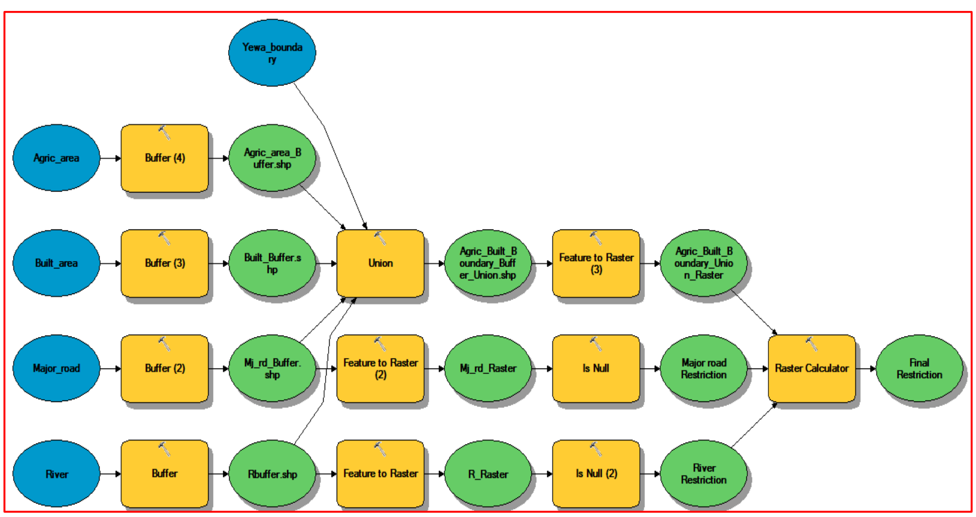

Figure 9: GIS Restriction Model of the study (Author 2019)

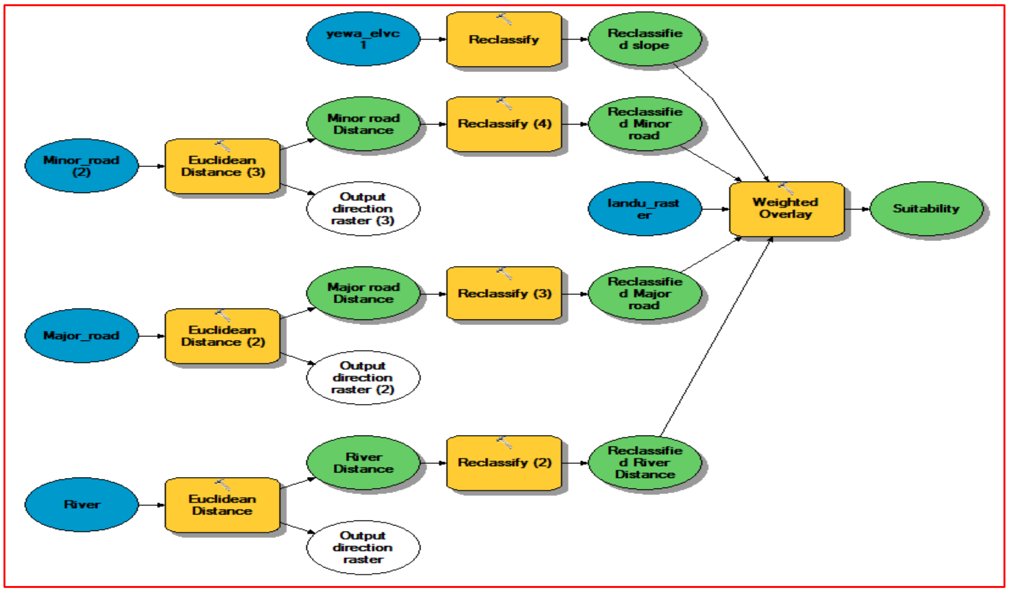

Figure 10: GIS Suitability Model of the study

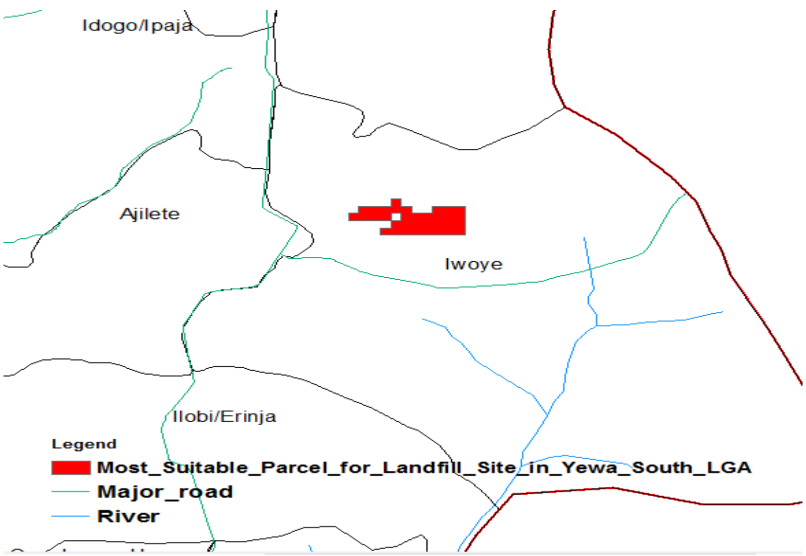

Figure 11: The most Suitable Landfill Site in the study area

1.3 Discussion of Results

In order to evaluate the site selection criterion, ArcGIS MCDA was used to measure the relative importance weights for the parameters used. This is due to the fact that, MCDA divides the decision problems into smaller understandable parts, and analyzes each part separately, and then integrates these parts in a logical manner (Alanbari, Al-Ansari, & Jasim, 2014). The approach used was practical and direct and the outcomes of the approach were easily explained and understandable.

In this study, all input data required for the analyses are generated from three map sources, which are SRTM data, geological maps and land use maps. The SRTM data was used to derive input data layers such as wetlands, slope and elevation. The geological map layer is compiled from available maps and the land use layer is compiled from Google earth image.

Analysis showed that six out of the total of seven wards have locations for landfills except Idogo. This is because majority of Idogo land is relatively low and mostly a flood plain. This is observed in the reclassified slope map of the area (figure 6).

Suitability map (figure 7) also showed that these six wards fall within the moderately and highly suitable regions.

An overlay of environmental factors maps such as road networks, rivers, built up areas and vegetation was used in creation of the restricted map (figure 5) based on the restriction model (figure 3).

Buffer zones and restrictive factors (figure 4) were eliminated using the Euclidean Distance tool in the Spatial Analyst extension of ArcGIS 10.2. The suitable parcels, depicting suitable landfill siting areas, were obtained by summing up the constraint map and the factor map overlays through reclassification and weighting using the GIS models (figures 9 & 10). More than 500 parcels were suitable but the most suitable of these that fall within a 100 hectare of land is in Iwoye ward (figure 8). Different layers relating to these criteria were used to compare maps and located areas which conform to the criteria.

1.4 Conclusion

GIS technology provides the capabilities of data collection, storage and retrieval, manipulation and analysis to develop information that can support environmentally related decisions. The criteria used in this study are not fixed factors since they can vary from area to area and these criteria can be changed accordingly in the analysis process. Field site check was performed to determine the accuracy and suitability of the candidate sites. Conclusively, it was found that the suggested landfill site is suitable and does not affect any existing land use in the study area.

1.5 Recommendation

GIS is a powerful tool that enables organized and systematic analyses of spatial data and presents results in the form of aesthetically pleasing and functional Output maps. The model developed in this study and its operational procedures can be visually simplified and represented as a schematic diagram (flow chart) thereby increasing the comprehension of the tasks performed in site location processes

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