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SEARCHING FOR A SUITABLE LANDFILL SITE

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ABSTRACT

Landfill is becoming acknowledged as the cheapest form for the final disposal of solid waste and as such it has been the most used method in the world (Babalola, & Busu, 2011). However, siting landfill is an extremely complex task mainly due to the fact that the location and selection process involves many factors and strict regulations. There is a large outcry over the increasing and indiscriminate dumping of refuse in Yewa South Local Government Area of Ogun State, South West Nigeria 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. In this study important criteria for siting landfills were identified and a user-friendly landfill site selection model was developed using a Geographic Information Systems (GIS). 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. The shrub lands are presumed to be suitable for siting Landfill. 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. Results from this study has also shown the effectiveness of GIS's Analytical Hierarchical Process (AHP) and Multi-Criteria Decision Analysis (MCDA) rule for selecting a suitable landfill site in the area even in the next 100years.

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

1.0 INTRODUCTION

The loss of vegetation, degradation of soil and pollution of water, soil and air are seen as signs of land degradation and reduced soil quality, and solutions to these problems need to be found. Land and soil degradation processes can be seen in landfills. In developing countries it is necessary to develop efficient waste management systems due to increased waste production as a consequence of population growth. Despite developments that have improved waste management systems, the disposal of solid waste in landfills is still the most commonly used method in developing countries (Yazdani, Monavari, & Omrani, 2015).

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.

The Not In My Backyard (NIMBY) syndrome has also led to the impacts of improperly located landfill sites which are undesirable and can have adverse effects on human, plant and animal health. One of the most challenging environmental issues for Yewa South local government area is the management of solid waste. With an increasingly dense population and a current shortage of places to dispose solid waste properly, the local government faces a huge environmental problem.

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, 2012). It is to this understanding that various international specialized studies are conducted in this present research in order to identify suitable areas for waste landfill location, using GIS techniques. This method of siting landfill in this part of the world is still at the introductory level.

For environmental sustainability where numerous criteria factors are crucial in decision making, many multi-criteria techniques have been used, one of which is the Analytic Hierarchy Process (AHP).

The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty in the 1970s as a method for organizing and analyzing complex decisions, using math and subjective judgment such as experience (Mohammed & Rami, 2015). Many studies have applied the Analytical hierarchy process, including Prioritizing Alternative Strategies for Malaria Control (Joel, Ali, Ahmed, & Akpensuen, 2019); Overview of analytical hierarchy process decision making method for construction risk management (Putri & Noram, 2019); Prioritization of Evacuation of Solid Waste at Municipal Solid Waste Disposal Center ; (Modu, Wajiga, Okolo, & Muazu, 2014); Analysis of Poverty and Inequality Among Farmers in Yola North Local Government Area of Adamawa State Nigeria (Abubakar & Girie, 2014);

This present study used AHP model to develop the pairwise comparison matrices from the Experts opinions to analyze the various factors such as soil type, slope, land use and restrictions that are used as inputs.

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1.1 STUDY AREA

The study is aimed at siting of landfill in suitable locations using Yewa South Local Government Area as the study area.

Yewa South was formerly known as Egbado South. It is a Local Government Area in the west of Ogun State, Nigeria bordering the Republic of Benin. Its headquarters are in the town of Ilaro at 6°53’00”N, 3°01’00”E/6.88333°N 3.01667°E in the North of the Area. It has a population of 168,850 according to the 2006 census and cover a total land area of 629km². The people speak the Yewa and Egun dialects of the Yoruba Language. There are ten areas or villages headed by Obas or Royal Fathers: Ilaro, Idogo, Iwoye, Oke-Odan, Ijanna, Itoro, Owode, Erinja, Ajilete and Ilobi. Site visitations during this study have shown that many of the existing landfills in the area have been converted to residential and commercial areas 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.

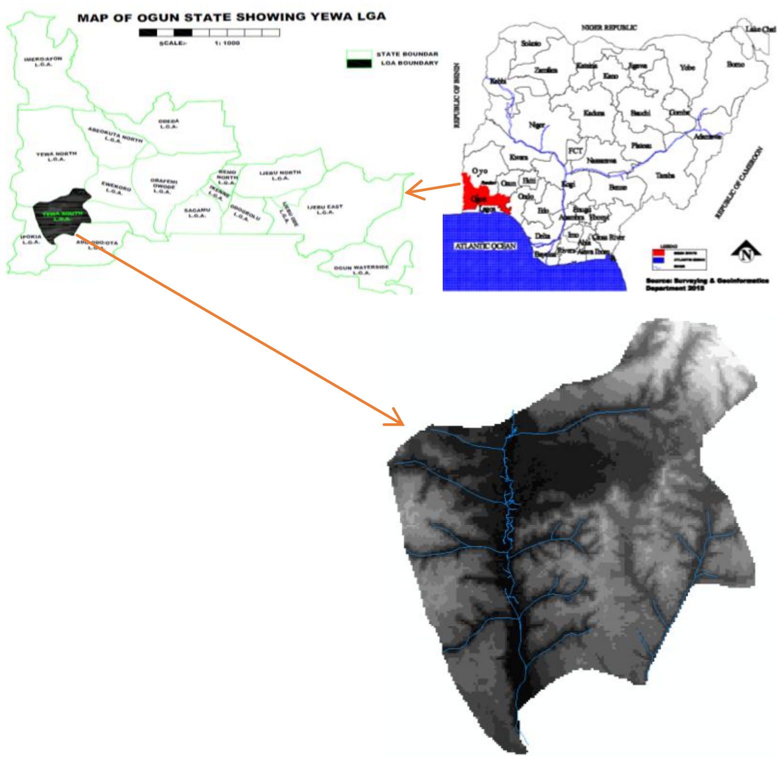

Figure 1: Description of Study Area

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2.0 MATERIALS AND METHOD

A number of environmental factors were considered in locating the land fill to avoid environmental risk. Landfill sites are located far from residential areas and Agricultural lands. The most important step in siting a Land fill is to define its selection criteria (Table 1). The landfill should be sited away from low lying 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.

The criteria considered are 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.

Esri's ArcGIS 10.2 Software was used for digitizing and map editing as well as 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.

Thematic layers of these criteria were created such as the road network, rivers and built up areas were digitized and edited from Landsat image. Geological soil and hydrology maps were also scanned, imported into ArcGIS 10.2 environment and georeferenced.

Soil type, depth to groundwater, slope from shuttle radar topographic mission (SRTM), 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 (m)**	**Adopted Buffer Distance (m)**
Built up areas	500-2000	1000
River	100-1000	500
Major road	100-500	250
Minor road	100-300	150
Agricultural lands	100-1000	500
Transmission line, gas pipe line, crude oil pipeline, drinking water pipep line, rail roads	100-500	250
Slope	Relatively flat	Relatively flat
Mining site	500-2000	1000
Institution	100-500	250
Parks	300-3000	1500

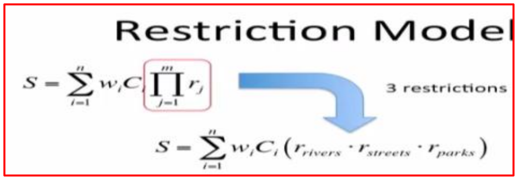

Figure 2: Restriction Model

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

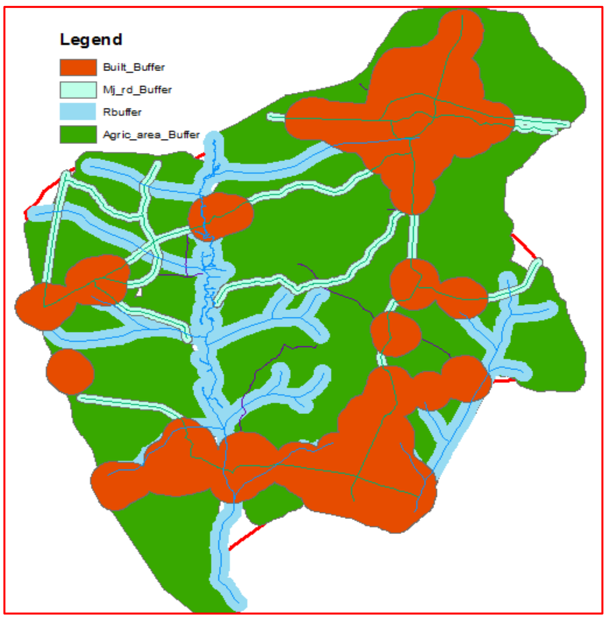

Figure 3: Factor map of the study area

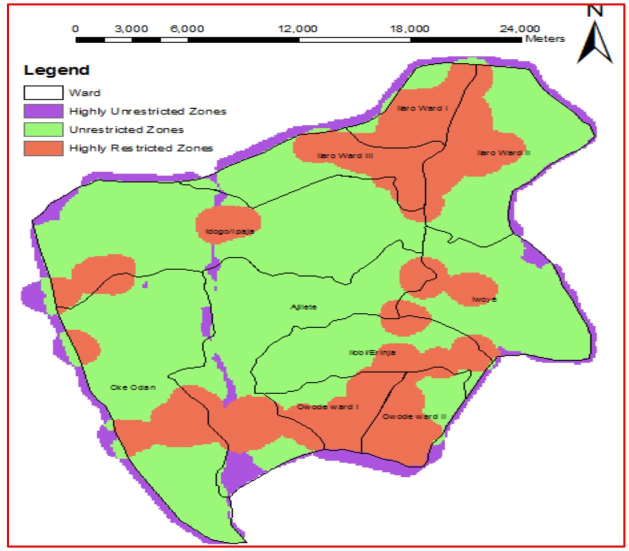

Figure 4: Final restriction map indicating restricted and available areas for landfill sites in the study area

2.1 RECLASSIFICATIONS

Slope map of the study area was generated from 30m resolution 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.

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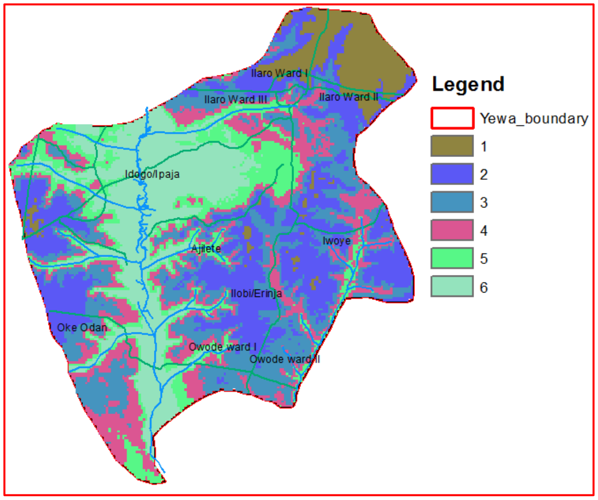

Figure 5: Reclassified slope map

2.2 WEIGHTING USING THE ANALYTIC HIERARCHY PROCESS (AHP)

Criteria weight can be defined as a value assigned to an evaluation criterion which indicates its importance relative to other criterion under consideration (Alanbari, Al-Ansari, & Jasim, 2014). Assigning weights of importance for the evaluation criteria accounts for 1) the changes in the range of variation for each evaluation criterion, and 2) the different degrees of importance being attached to these ranges of variation (Kirkwood, 1997).

In this study the evaluation criteria were converted into the comparable and standard scales (table 2) after which weight and relative importance of each criterion were determined in relation to intended purpose. Scale values of 1 – 5 AHP were 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. These pair wise comparison were then analyzed to produce weights that sum to 1. The factors and their resulting weights were used as input for the multi criteria evaluation (MCE) module for weighted linear combination of overlay analysis.

Table 2: Scale for pairwise comparison

Intensity of importance	Definition
1	Equal importance
2	Weak or slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong
8	Very very strong
9	Extreme importance

2.3 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

2.4 SUITABILITY INDEX OVERLAY

A suitability model was developed (Figure 6) to determine areas that are suitable (Figure 7) to locate the landfill. Each factor map (Figure 3) was 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).

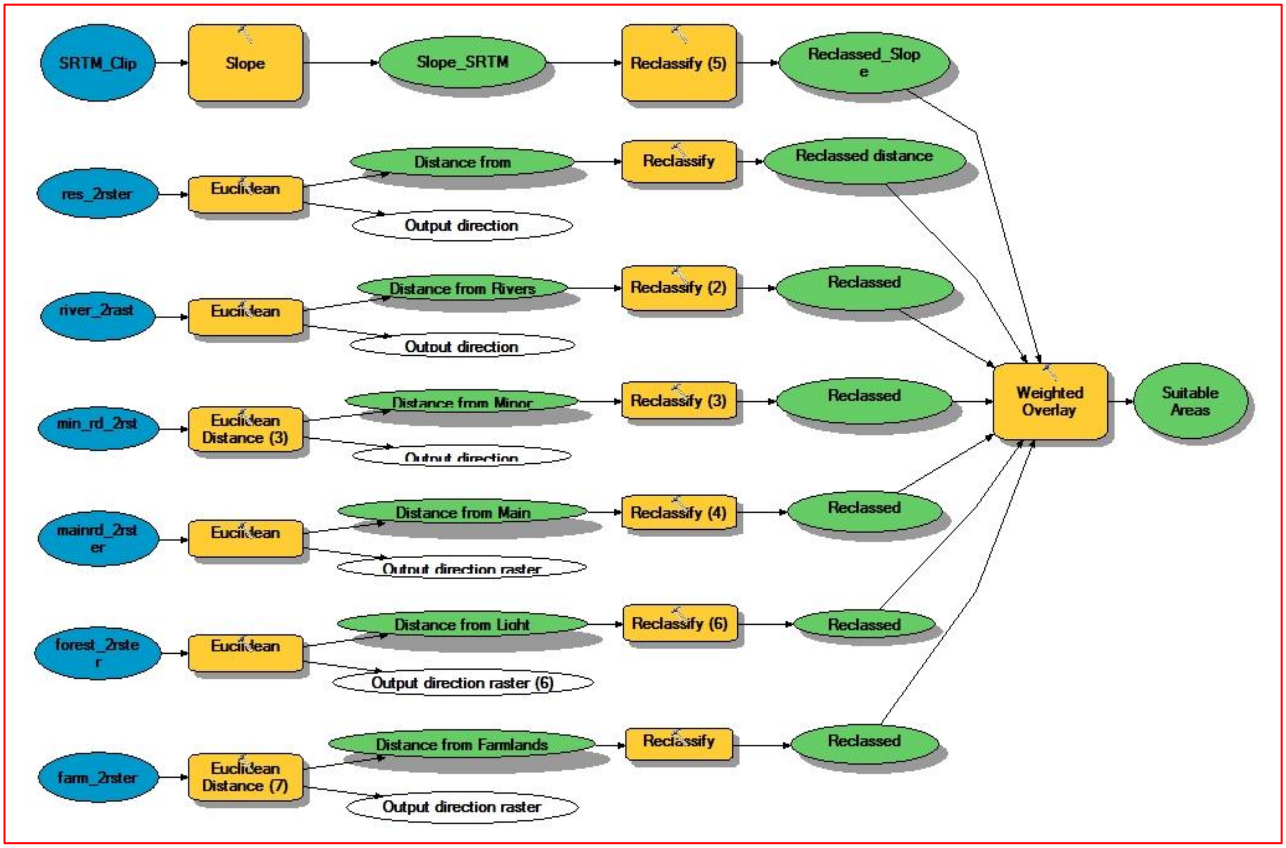

Figure 6: Designed model for the suitable areas (Author 2019)

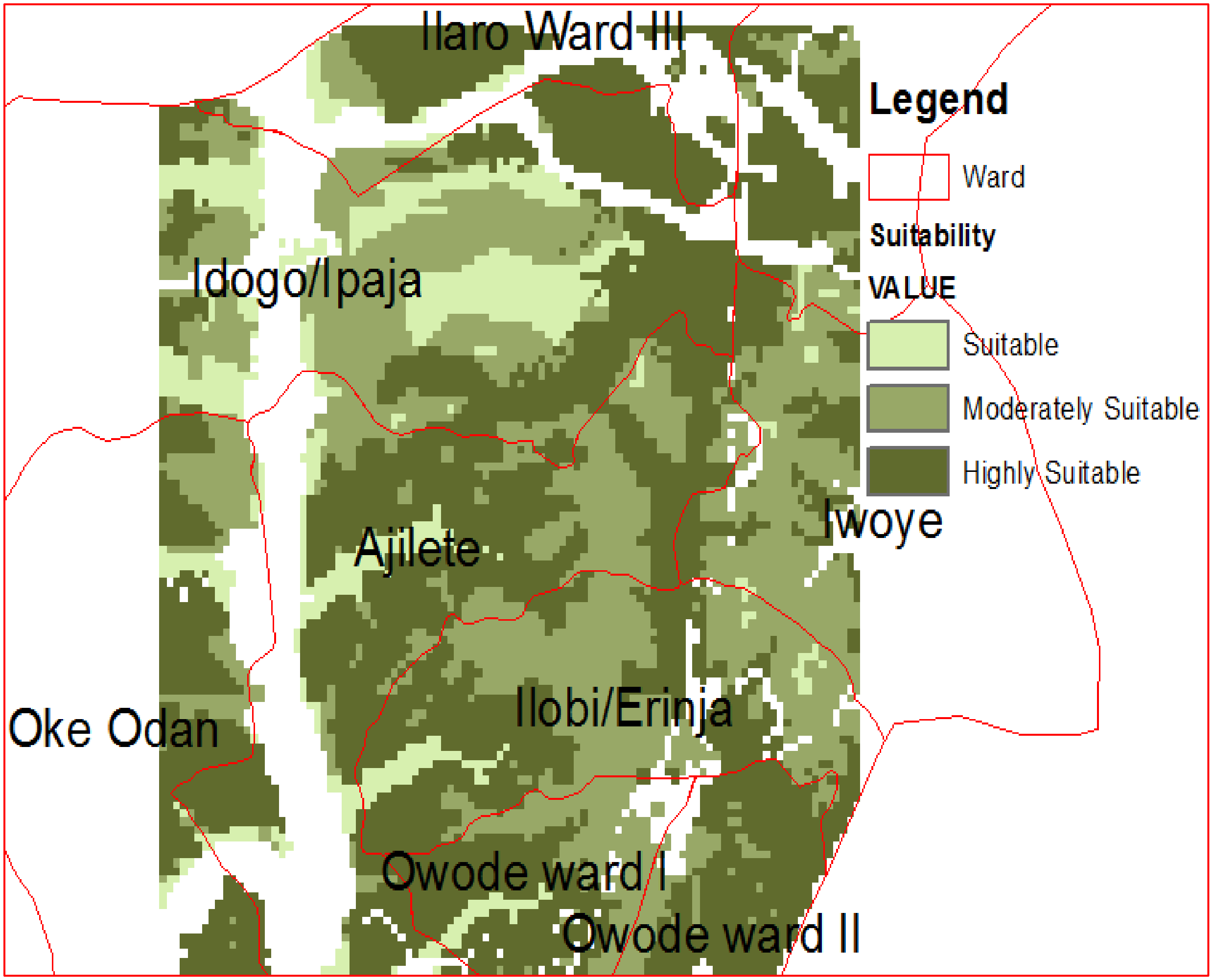

Figure 7: Suitability map

2.5 COVERAGE SELECTION

As a selected criteria in this study, a coverage of 100 hectares was chosen to locate the Landfill site. This criteria considered the total land size of the study area and the availability of spaces.

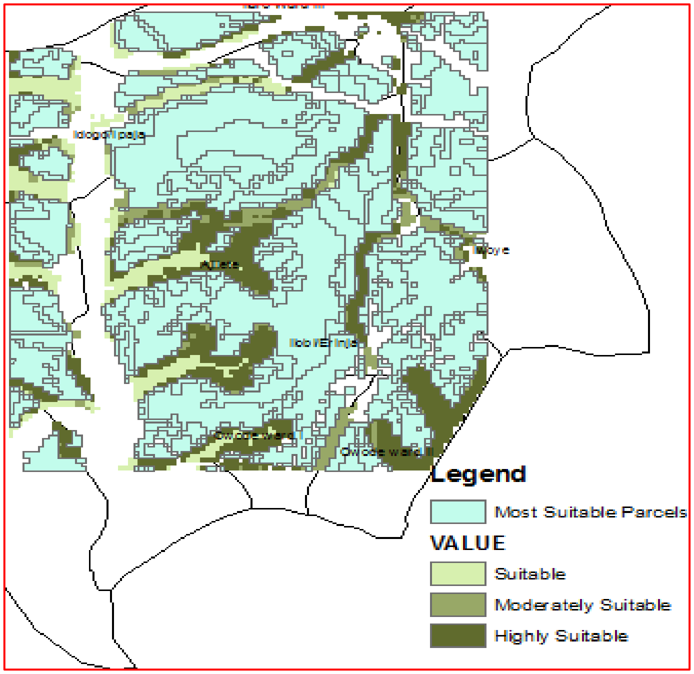

Figure 8: Suitable Parcels (Area = 100 Hects) overlaid on Suitability map

2.6 RESTRICTION AND SUITABILITY 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 (Figure 9) and Suitability model (Figure 10) are also developed for this study. The restriction maps created were used as input data in the model development.

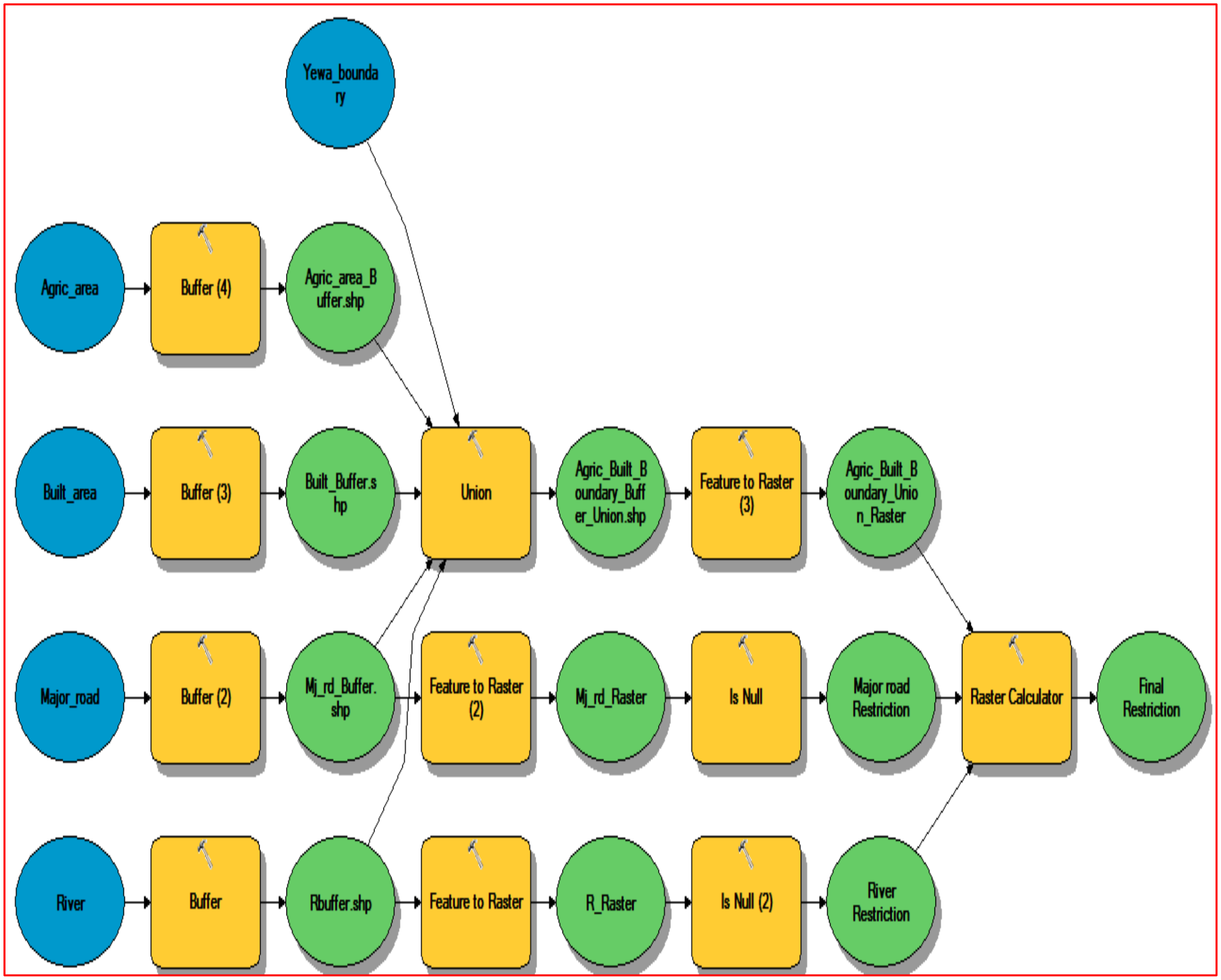

Figure 2: Designed GIS Restriction Model of the study (Author 2019)

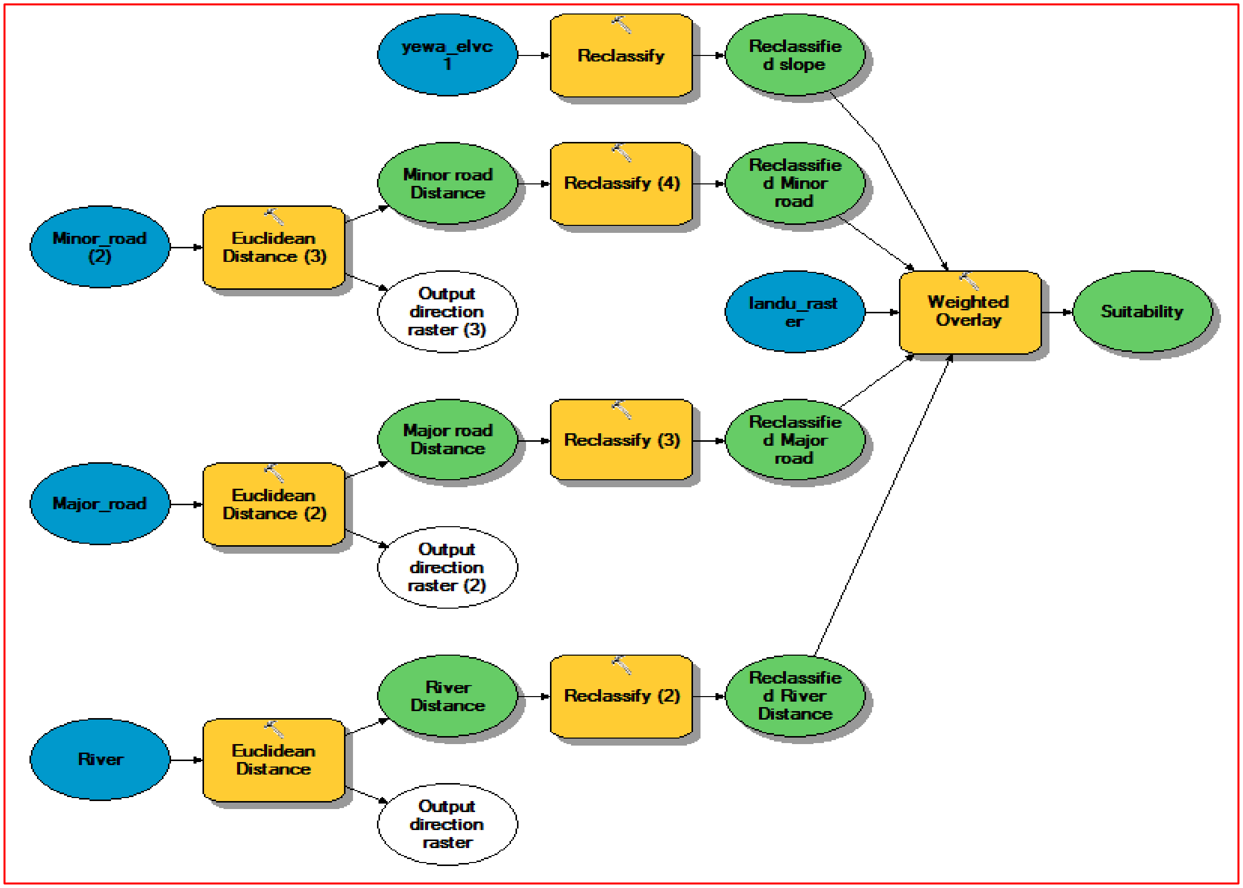

Figure 3: Designed GIS Suitability Model of the study (Author 2019)

3.0 RESULTS AND DISCUSSION

The principal aim of the overall site selection process from an environmental perspective are to find a landfill site, which will safeguard public health, have minimal impact on the environment, and provide for safe disposal of waste (Manoiu, Fontanine, Costache, Pravalie, & Mitof, 2013).

The ArcGIS MCDA has been used to measure the relative importance weights for the parameters used to be able to evaluate the selection criteria. 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.

Elevation data from SRTM, geological maps and land use maps are input data used in this study for analysis. 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 Landsat image.

The results showed that six out of the total of seven wards have locations for landfills except Idogo. This is because majority of Idogo lands are relatively low and are mostly flood plain. This is observed in the reclassified slope map of the area (Figure 5).

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

An overlay of environmental factor maps such as road networks, rivers, built up areas and vegetation was used in creation of the restriction map (Figure 4) based on the restriction model (Figure 2).

Buffer zones and restrictive factors (Figure 3) were eliminated using the Euclidean Distance tool in the Spatial Analyst extension of ArcGIS 10.2. The suitable parcels (Figure 7), 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). This procedure is applicable when considering any particular coverage area. Different layers relating to these criteria were used to compare maps and located areas which conform to the criteria.

4.0 CONCLUSION

The presented approach is easy to understand and it can illustrate which areas are better or less suitable for landfill site selection. 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. The accuracy and suitability of candidate sites were determined in order to check the suitability of the area derived from the analysis and the actual case requirement. The most suitable landfill sites were checked on the Landsat image and physical site visitation was performed to ensure that there are no ongoing projects in the selected area.

Conclusively, it was found that the suggested landfill site is suitable and does not affect any existing land use in the study area.

5.0 RECOMMENDATION

The search for a suitable Landfill site is complex as it involves evaluation of numerous factors such as government regulations, environmental, socio-cultural, engineering and economic factors. It is recommended that the Town Planning Authority have the site suitability analysis model in their domains so that it will serve as a guide before a site can be approved for landfill and also use this study as a tool for locating landfill sites in each local government areas in the state since it has taken care of all the criteria as regards suitable locations for landfill in its analysis.

6.0 REFERENCES

Abubakar, A., & Girie, B. D. (2014). Analysis of poverty and Inequality among Farmersin Yola North Local Government Area of Adamawa State, Nigeria. *International Review of Social Science and Humanities*, 126-132.

Alanbari, M. A., Al-Ansari, N., & Jasim, H. K. (2014). GIS and Multicriteria Decision Analysis for Landfill Site Selection in Al-Hashimyah Qadaa. *Natural Science*, 283.

Al-Ansari, N. A., Al-Hanbali, A., & Knutsson, S. (2012). Locating Solid Waste Landfills in Mafraq City, Jordan. *Journal of Advance Science and Engineering Research*, 40-51.

Al-Ansari, N. A., Pusch, R., & Knutson, S. (2013). Suggested Landfill Sites for Hazardous Waste in Iraq. *Journal of Natural Science*, 463 - 477.

Babalola, A., & Busu, I. (2011). Selection of Landfill Sites for Solid Waste Treatment in Damaturu Town-Using GIS Techniques. *Journal of Environmental Protection*, 1.

Joel, S., Ali, A., Ahmed, A., & Akpensuen, S. H. (2019). Analytical Hierarchy Process (AHP) Model for Prioritizing. *Asian Journal of Probability and Statistics*, 1-8.

Kao, J. J., & Lin, H. (1996). Multifactor Spatial Analysis for Landfill Siting. *Journal of Environmental Engineering*,, 902-908.

Kirkwood, C. W. (1997). *Strategic Decision Making: Multiobjective Decision Analysis with Spreadsheets.* Belmon: Duxbury Press.

Manoiu, V., Fontanine, L., Costache, R., Pravalie, R., & Mitof, L. (2013). Using GIS Techniques for assessing waste landfill placement suitability in Prahova county, Romania. *Geographia Technica*, 47-56.

Modu, B., Wajiga, G., Okolo, A., & Muazu, H. G. (2014). Prioritization of Evacuation of Solid Wwaste at Municipal Solid Waste Disposal Centre. *International Journal of Science and Technology*., 298-305.

Mohammed, B., & Rami, A. (2015). Application of the Analytical Hierarchy Process (AHP) to Multi-Criteria Analysis for Contractor Selection. *American Journal of Industrial and Business Management*, 581-589.

Putri, Z., & Noram, I. R. (2019). Overview of analytical hierarchy process decision making method for construction risk management. *National Colloquium on Wind & Earthquake Engineering*, 1-110.

Siddiqui, M. Z., Everett, J. W., & Vieux, B. E. (1996). Landfill siting using geographic information systems: a demonstration. *Journal of Environmental Engineering*, 515-523.

Tchobanoglous, G., & Kreith, F. (2002). *Handbook of Solid Waste Management.* New York: McGraw-Hill.

Yazdani, M. O., Monavari, S. M., & Omrani, G. A. (2015). *Landfill Site Suitability Assessment by means of Geographic Information System Analysis.* Tehran: Solid Earth.