SELECTION OF SUITABLE LANDFILL FOR REFUSE DUMP SITES IN ILARO TOWN USING GIS TECHNOLOGY

BY

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ABSTRACT

Landfill is becoming recognized as the cheapest form for the final disposal of solid waste and as such it has been the most used method in the world. However, sitting landfill is an extremely complex task mainly due to the fact that the location and selection process involves many factors and strict regulations. The study identifies the important criteria for sitting landfills and develop a user-friendly landfill site selection model using a Geographic Information Systems (GIS) tools. The objectives of the study were to develop GIS criteria for locating the landfill, identify possible sites that were suitable for this type of development and evaluate the effectiveness of these GIS methods used in the study. Constraint and factor maps were produced after which a final suitability map was created using ArcGIS analysis tools. The results revealed that although highly suitable areas were limited, a site was still able to be chosen under the predefined parameters. 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: Constraint map, Environment, Factor map, GIS, Landfill, Solid waste, Suitability map

1.1 Introduction

Landfill siting is an extremely difficult task to accomplish because the site selection process depends on different factors and regulations. The ever increasing global concern on environmental health demands that wastes be properly managed and disposed of in the most friendly and acceptable way (Kolawole & Adewara, 2017). The dumping of a major toxic waste in Koko town of Warri in Delta State of Nigeria in 1987 by a foreign company led to the establishment of Federal Environmental Protection Agency (FEPA) by decree No. 58 of 1988. However, in June 1999 the Federal Government of Nigeria created the Ministry of Environment and, as a result, FEPA's function was absorbed by the new Ministry.

The goal of siting a sanitary landfill is to provide long-term environmental protection that is economically efficient and complies with applicable regulations. Very few potential landfill sites are ideal. But the landfill's design phase allows managers to overcome site deficiencies using proven engineering techniques. A good location of a well-developed landfill will make construction, operation and closure less technically difficult and more cost-effective by using GIS techniques.

GIS has matured into a powerful tool that can integrate driven types of spatial data and perform a variety of spatial analysis (Mohammad, Nadhir , & Hadeel, 2014). This technological evolution, driven by significant advances in computer technology and the availability and quantity of data informed the use of GIS in this study. For proper identification and selection of appropriate sites for landfills careful and systematic procedures need to be adopted and followed. Wrong siting of landfill many result in environmental degradation and often time public opposition (Babalola & Busu, 2011).

Because of the high degree of risk from improper waste disposal, landfill design and operation are heavily regulated. FEPA requirements placed restrictions on locating landfills near airports and in flood plains, wetlands, utilities, structures, soil, bedrock and climatological information, seismic impact zones, and unstable areas.

Every design package for a landfill will require site maps which usually shows the landfill location in relation to surrounding communities, roads and other features. A site map shows:

- Slope, Aspect or Contour maps;
- Clearly delineated property lines;
- Easements and rights-of-ways;
- Utility corridors, buildings, wells, roads and other features;
- Drainage ways; and
- Neighboring property ownership and land uses.

Contour maps show drainage patterns adjacent to and through possible disposal sites. Areas with excessive slope or direct overland flow from a site to surface waters must be carefully evaluated.

Subsurface formations and groundwater conditions will influence the landfill's design features in the leachate collection system and liner requirements. A formation's geotechnical characteristics will determine its suitability as a construction material.

1.2 Statement of the Problem

Finding a site to locate undesirable facilities such as landfill sites is becoming a significant problem in today's economy. The study area is characterized by indiscriminate dumping of wastes along the major roads, gullies, forests, and any open space which in the nearest future will begin to be confronted with a chronic health hazards if not properly tackled at the present. The general public idea of "Not in my backyard" and "not in anybody's backyard" has made siting of landfill site a serious issue that cannot be over emphasized. This is due to the fact that there is increasing rate of consumption of resources and as such generate increased amounts of waste.

1.3 Aim

The aim of this work was to use GIS techniques to identify the appropriate area that is most suitable for waste disposal in Ilaro town.

1.4 Objectives

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

- To identify existing land use in the study area
- To determine important criteria for locating a landfill site
- To develop a model as a siting tool in landfill site selection
- To identify a possible suitable location for the landfill site

1.5 Methodology

Identification of evaluation Criteria required for landfill siting selection in the study area were identified and evaluated by first determining the existing land uses in the area, scrutinizing important criteria for siting the landfill. A GIS model was developed as a tool for efficiently sitting the landfill location. All these criteria had been identified based on the local guidelines of Federal Environmental Protection Agency (FEPA), waste disposal siting. In addition to the above, related information about landfill siting was also reviewed from both academic and international perspectives, such as the Environmental Protection Agency (EPA).

1.5.1 Existing land use

The existing land use in the study area are farmland, forest and human settlements. The total residential area is 132.km^2. The total farmland area is 173.6km^2 while forest is 28.2km^2.

1.5.2 Selection Criteria

Literary evidences show that different researchers have used varying criteria for site selection purposes. This is because different criteria applies to different region and all facilities. The adopted method in this work provides a selection of environmentally friendly disposal sites, thus supplying reasonable, convenient and administratively transparent solutions to the waste landfill problems.

Due to data constraints; river system, land use, human settlements, road networks and slope of the area were modeled (Figure 1.1a & 1.1b) and used as guides to select suitable landfill. Areas of cultural and historical importance such as church yards, Muslim prayer grounds, and graveyards etc. are exempted from landfill siting. . Criteria were specified in accordance to the legislation in force to assume that landfill sites would be located on flat areas using elevation map (Figure 1.3 aspect map) and outside the buffer zones of the rivers, roads, farmlands and residential areas. These criteria are:

- 2km away from residential areas
- 1km away from the main road;
- 500m away from the minor road;
- 500m away from the water course;
- 500m away from active farm land
- Elevation on relatively flat terrain

1.5.3 Landfill Selection modeling

In this study; river system, land use, reserved areas, human settlements, road networks and elevation factors are considered and their corresponding constraint map are created. A model of approach for these study is created. These factors are transferred into information system separately by using ArcGIS software. GIS-based analyses were conducted using ArcGIS Spatial Analyst. Spatial Analyst provides a platform for working with gridded data sets. It was used to produce suitability maps highlighting "suitable" geographic areas derived from weighted and combined map layers based on established criteria.

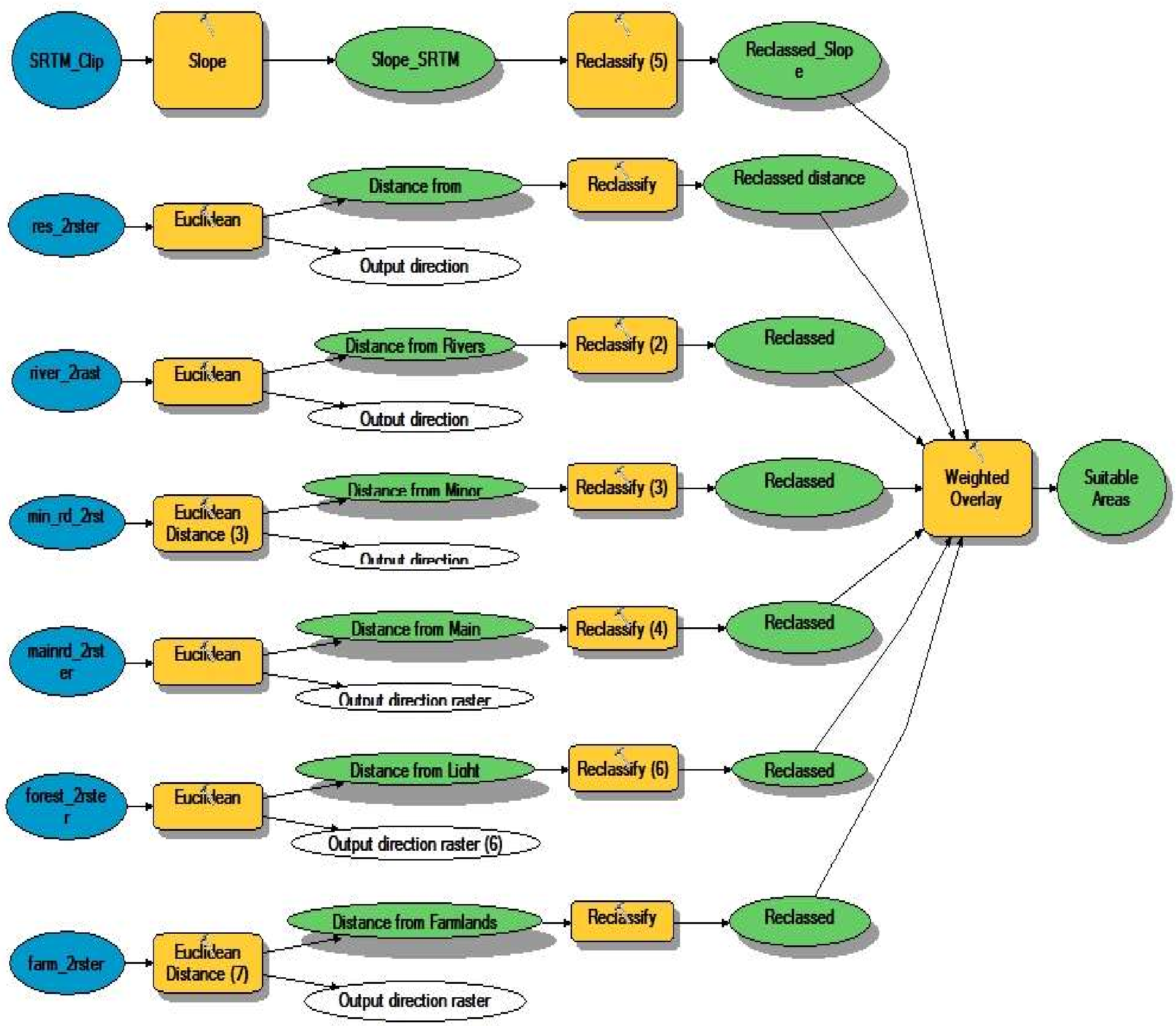

Figure 1.1a: Designed model for the study
Source: Author 2017

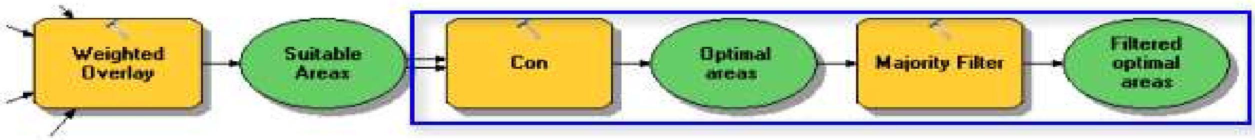

Figure 1.1b: Work Model followed in GIS to achieve results
Source: Author 2017

1.5.4 Determining possible suitable landfill locations

All the alternative locations from the outcome of the overlays are suitable. The last step in this exercise was to locate the best site out of these alternatives.

1.5.4.1 Analyzing maps

The land use map was obtained through interpretation of Landsat satellite image from 2015 of the study area. Four different land use types (Figure 1.2) were identified and categorized using visual interpretation and then digitized to create land use layers. These were sensitive areas, water body, residential areas and farm lands areas. Analyzing maps essentially involves setting the study area boundary, making aspect map, buffer zone maps. The output maps were reclassified to produce a suitability map.

1.5.4.2 Buffer analysis

A buffer distance is determined (500m, 1km, 2km etc.) for each layer by considering related legal legislations or properties of the buffer area analysis. Map layers are created for each layer with buffer area analysis. Map layers are created by buffer area analyses (Figure 1.4) which are done for each numerical factor. Buffer area distance is chosen by considering legislative regulations in the country, applications abroad and characteristics of the area. Buffer zones are the non-suitable areas in the study area. These zones were also used as factor maps representing areas that range from low suitability to high suitability. Then overlay analysis was applied and alternative areas are chosen for landfill area of solid wastes (Figure 1.5). Since all analyses over layers have to be limited to the extent of the study area, a boundary map (base map) is generated and has to be used for future calculations.

1.5.4.3 Obtaining Topography

According to the criteria, an elevation map is needed due to the fact that slope is a relevant factor in siting the landfill, given that an area is an important consideration for excavation. The elevation of the study area generally ranges between 35 and 134 meters. Areas around 35m are close to waters while areas around 134m are high lands. The sites identified to be steep are not considered as they are not suitable for landfill siting. To limit the potential spread of contaminated runoff, a landfill should not be located on the divides of major drainage basins or steep slope areas, rather, flat areas are better and more suitable for landfill siting.

1.5.4.4 Reclassification and weighting

Each map layer is to be ranked by how suitable it is as a location for a new landfill. However, in order to be able to combine them, a common scale for example,0s and 1s (Table 1.1) giving higher values (scores) to more suitable attributes, is usually assigned to each class, using “Reclassify” option.

Table 1.1: Factor ranking

Sn	Rank	Buffer distances (m)
		Distance to Residences
1	0	<2km
	1	≥2km
		Distance to Main road
2	0	<1km
	1	≥1km
		Distance to Minor road
3	0	<500m
	1	≥500m
		Distance to River
4	0	<500m
	1	≥500m
		Distance to Farm
5	0	<500m
	1	≥500m
		Elevation
6	0	>0
	1	flat

Source: Author 2017

1.5.4.5 Optimal Site location

The conditional expression tool was used to extract only the optimal sites. Sites that are considered optimal must have a suitability value of 9. There are five sites that have suitability value of 9. The original values of all areas with 9 were retained while areas with value of less than 9 were changed to No Data.

1.5.4.6 Selecting best site

All the locations in the Filtered optimal areas layer are suitable. The last step in this exercise is to locate the best site out of the alternatives. The roads within the study area is displayed in the roads layer. By examining the Filtered optimal areas layer with the roads layer, it was observed that there are some suitable areas for the landfill site that are not close to roads within the town. These areas were first excluded by locating suitable sites that are intersected by roads and then best site is located based on area.

1.6 Discussion of Result

The principal aims 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).

Thus, in order to eliminate buffer zones and restrictive factors, the Euclidean Distance tool in the Spatial Analyst extension of ArcGIS 10.2 was used. The final map, depicting suitable landfill siting areas, was obtained by summing up the constraint map and the factor map overlays through reclassification and weighting. 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 in Ilaro.

Different layers such as water course, road networks, residences, and farmlands were overlaid. Two Boolean operations were performed using the topographic data. One was the area with heights relatively flat or near flat, and the others which are sloppy. The final landfill sites also felt within the topography of a flat terrain.

Runoff from rains must be planned for by developing drainage channels within the site careful study of the slope map. Sloping areas within the landfill will cause larger volumes and higher peak runoff flows from the site than would occur naturally. The runoff would be directed into channels that are capable of carrying most storms without overflowing or flooding adjacent areas.

From analysis, there are five suitable location areas in the study area which are found in the East, North east and south eastern regions of the area. These regions are located plains in the outskirts of the town covering in totality about 4.758km^2 which is 1.4% of the total study area. Probably the two landfills in the South eastern region would have been the most suitable but they are intercepted by the buffer zone of the river passing the South eastern area.

Of the remaining three landfill locations, two of which are eastern have small coverage areas which is not sufficient for landfill because it will require expansion in the nearest future as the population of the study area increases. All the five selected landfill locations in the study area do not have nearness to road network but then the most suitable out of these five is found in Oke-Ela in the North eastern region because of its size and closeness to road. It covers an area of about 1.2km^2 which is 0.3% of the total area coverage of the study area.

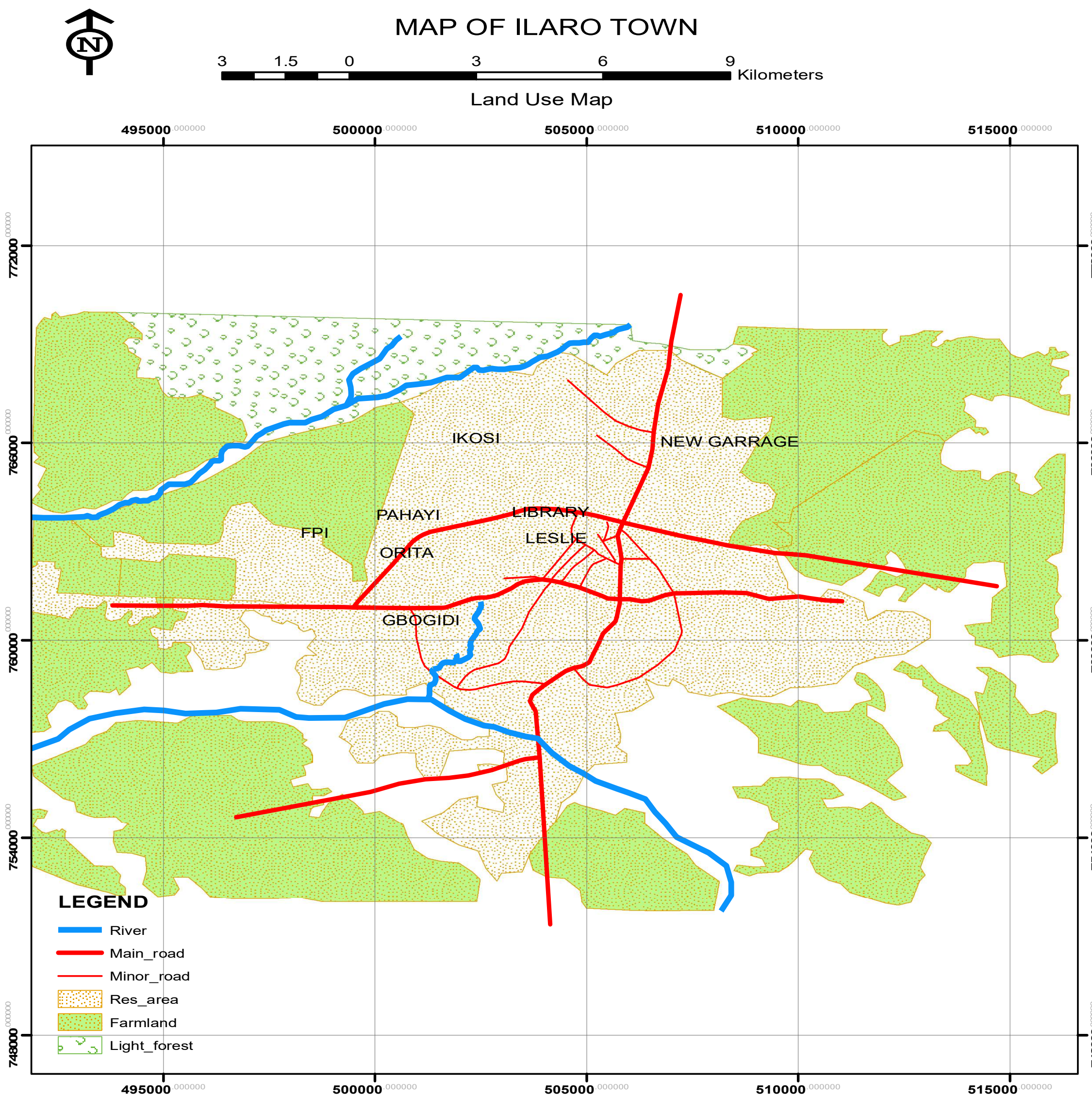

Figure 1.2: Land use map of the study area
Source: Author 2017

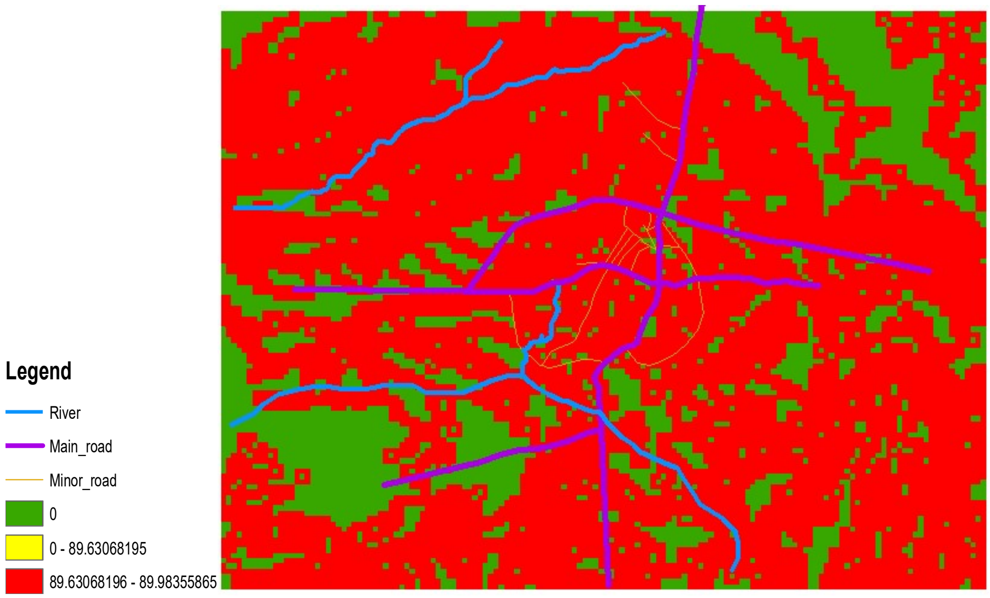

Figure 1.3: Slope Map of the study area
Source: Author 2017

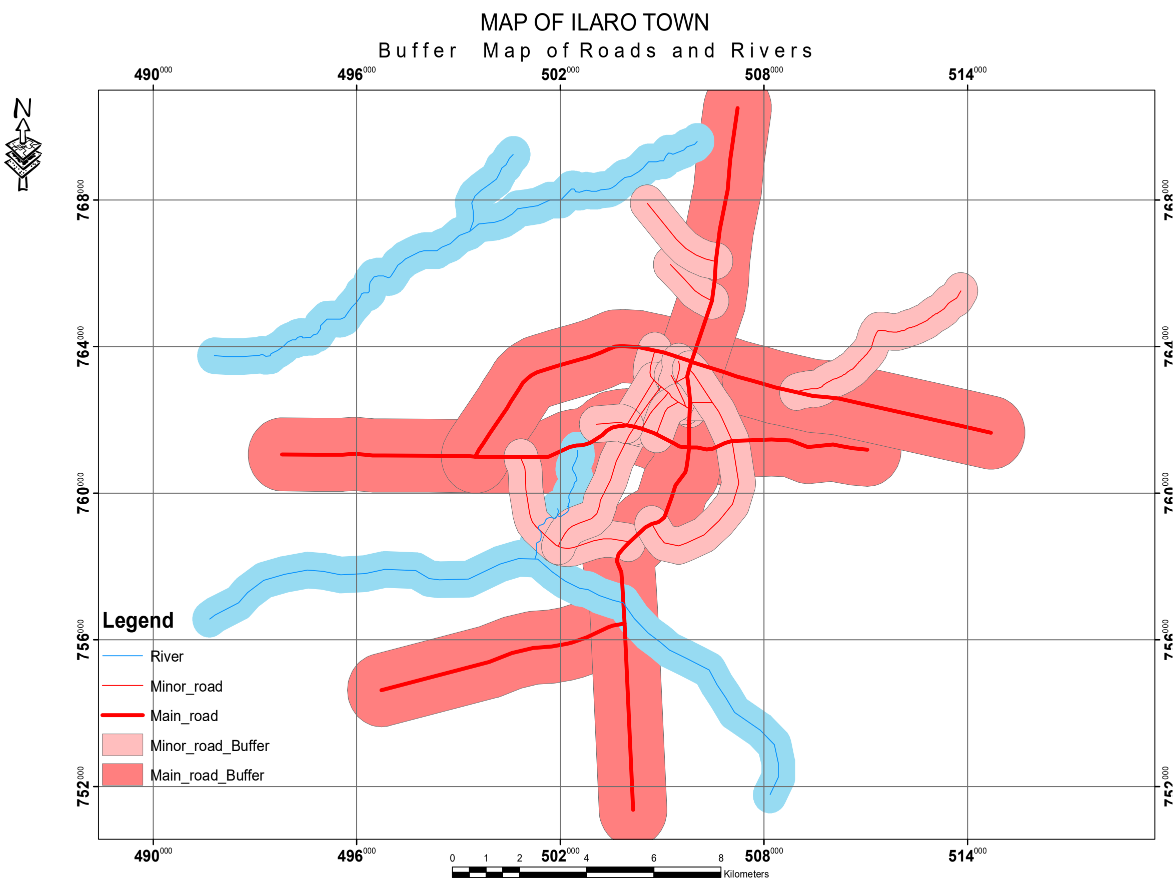

Figure 1.4: Buffer Map of Roads and Rivers in the study area
Source: Author 2017

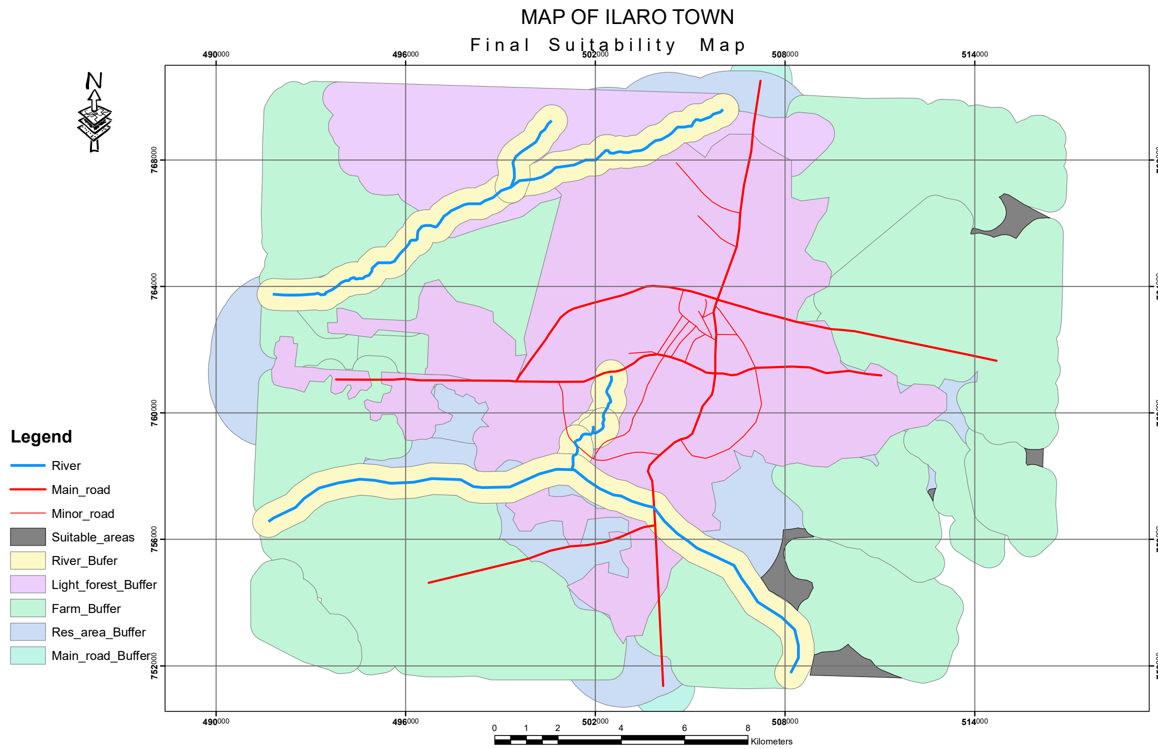

Figure 1.5: Landfill Buffer suitability Map of the study area
Source: Author 2017

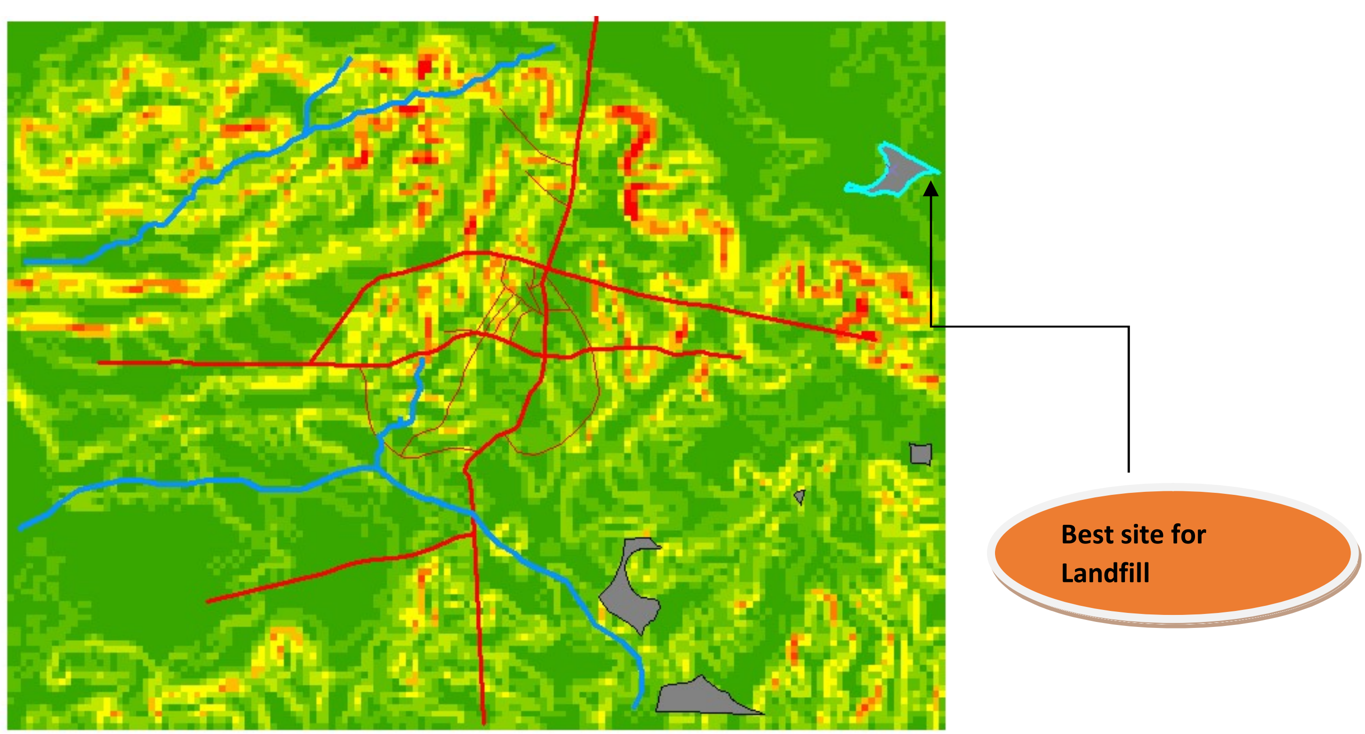

Figure 1.6: Best site for Landfill in the study area
Source: Author 2017

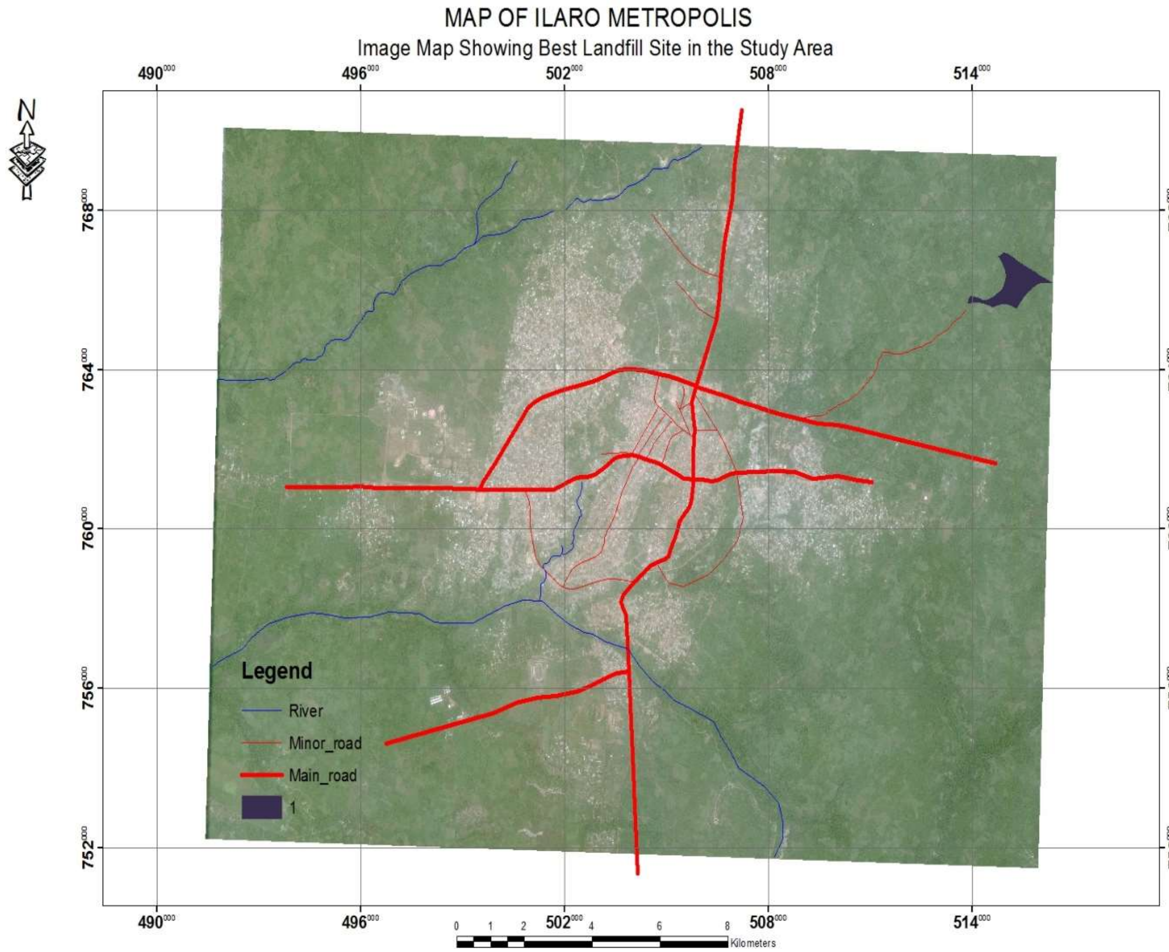

Image map showing Best Landfill location
Source: Author 2017

1.7 Recommendation and Conclusion

The presented approach is easy to understand and it can illustrate which areas are better or less suitable for landfill site selection. Analysis showed that there are 5 suitable location areas in the study area which are found in the East, North east and south eastern regions of the area. 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. Conclusively, it was found that the suggested landfill site is suitable and does not affect any existing land use in the study area.

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