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Geospatial Technology Approach to Suitable Landfill Determination Based on Spatial Multi-Criteria Evaluation for Bauchi Metropolis in Bauchi State of Nigeria

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Abstract

Landfill refers to suitable end destination for refuse residues to be finally dumped. The major challenge has been the identification of method for the determination of suitable landfill. Also is the multi-objective nature of the site identification spatial processes. Recently, researchers have indicated that the use of geospatial technology in Multi-Criteria Evaluation (MCE) technique for site selection analysis looks more appropriate for the location of landfill. This study used the satellite image 2014 and Geographic Information System (GIS) technique of Maximum Likelihood Classification (MLC) to classify land cover/use that serve as basic land cover data of the study area. Global Positioning System (GPS) and Integrated Land and Water Information System (ILWIS) 3.3 Academics were respectively used as hardware and software for data capture and analysis while the data manipulation was carried out using the Spatial Multi-Criteria Evaluation (SMCE) technique. All inputs criteria for the analysis were treated as constrains that participated based on Boolean Logic (BL). While working within the criteria tree of SMCE, constrains were normalized after the imputations of all the map layers. Aggregation to obtain the composite index map was then carried. The outcome revealed that three suitable landfills were successfully located to be utilized as standard landfills in Bauchi Metropolis. Therefore, the study recommends the use of geospatial technology in SMCE to suitably locate the spatial positions of landfills in developing cities.

Keywords: *Geospatial Technology, Spatial Multi-Criteria Evaluation, Landfill and Refuse*

1. Introduction

Refuse (solid wastes), which are jumbled on the environment of urban areas in Nigeria, has attracted the attention of researchers (Dauda and Osita, 2003; Walling et al., 2004; Rabia, 2011). The situation has not only signaled ugly aesthetic scenes of refuse heaps glaring at all manner of places but associated with high potential risks to man and the environment in the country. Also, the unguided nature of the refuse disposal often seen in most urban areas of Nigeria has continued to raise alarm on the refuse disposal approach (if any) adapted for the country (Ayotamuno and Gobo, 2004; Rabia, 2011; Bogoro, 2013).This has led investigators to find out the root cause of the problem and offered some solutions such as the used of tool for situation analysis, the landfill and optimization of route for refuse disposal respectively (Rabia, 2011; Ayo and Ibrahim, 2011; Musa, 2012). One of the means to refuse disposal seen to have been used everywhere in Nigeria was the utilization of landfill. Landfill refers to end destination where refuse residues are finally dumped and its usage has found global acceptance as the commonest. However, the selection of suitable locations for landfill has always been the greatest challenge due to its multi-objective nature that is very tasking. Hence, this has resulted to disposal of refuse on unsuitable areas such as borrow pits and vacant plots of land both inside and outskirts of cities in the country as evidenced in Bauchi metropolis. Many methods exist for site selection but acceptable and suitable landfill site identification is very much challenging and are completely lacking in the study area thereby leading to a number of problems (Shuaibu, 2014). To address this situation, three important issues must be taken into consideration. These are (a) Not In My Back Yard (NIMBY), (b) Not In Anyone's Back Yard (NIABY) and (c) Locally Unwanted Land Use (LULU) phenomena (Bilgehan, Tayfun and Fatih, 2010). The reason is from the fact that planning has now incorporated public opinions and their views as regards to site selection greatly count. This is done to avoid misunderstanding and outright rejection of landfills locations in a particular area. Therefore, as a panacea to refuse disposal problems in Nigeria, it is the objective of this research to attempt the use of geospatial technology to find suitable landfills for refuse disposal in Bauchi metropolis.

2. Study Area

The red colored shaded part of the inset map of Nigeria, as shown in figure 1, is Bauchi State while the study area is Bauchi metropolis shown in pink color. Bauchi metropolis is geographically bounded by latitudes 10° 19′ 55′′ and 10° 20′ 58′′ and longitudes 9° 50′ 50′′ and 9° 51′ 29′′. It is the capital of both Bauchi Local Government Area (LGA) and Bauchi State and covers an area of about 3,687km^2. Its population figure, according to Nigeria 2006 population census result, stands at four hundred and ninety-three thousand eight hundred and ten (493,810). It is a mountainous terrain that lies in the crystalline uplands of Northern Nigeria covering between 600m and 650m heights above sea level (OnlineNigeria.Com**,** 2013). The prominent mountains are the Wambai and Warinje hills located at the northeast of the metropolis, the Jahun and Gudum hills in the south and the Kobi hill that dominates the center of the old walled town of the metropolis. It has rivers and watersheds with many streams from its uplands which is characterized by latrite soil and flood plains. The rivers have numerous

headwaters and tributaries within the metropolis. This pattern of drainage has produced productive clay and loam soil from Fadama land that surrounding the metropolis. The Gubi dam lies to the northeast of the metropolis and provides a good source of water for urban uses. Agricultural practices for production of both food and cash crops have captured the life of the inhabitants of the city while its climatic condition ranges from hottest in the month of April to coldest in the month of December. Mean daily temperature ranges from maximum of about 36.6°C in April to minimum of about 13.3°C in December (Climate-data.org, 2013). There are two major seasons in Bauchi. These are rainy and dry seasons. The rainy season months are May to October while the dry season starts from November to April (Weather-bug, 2013).

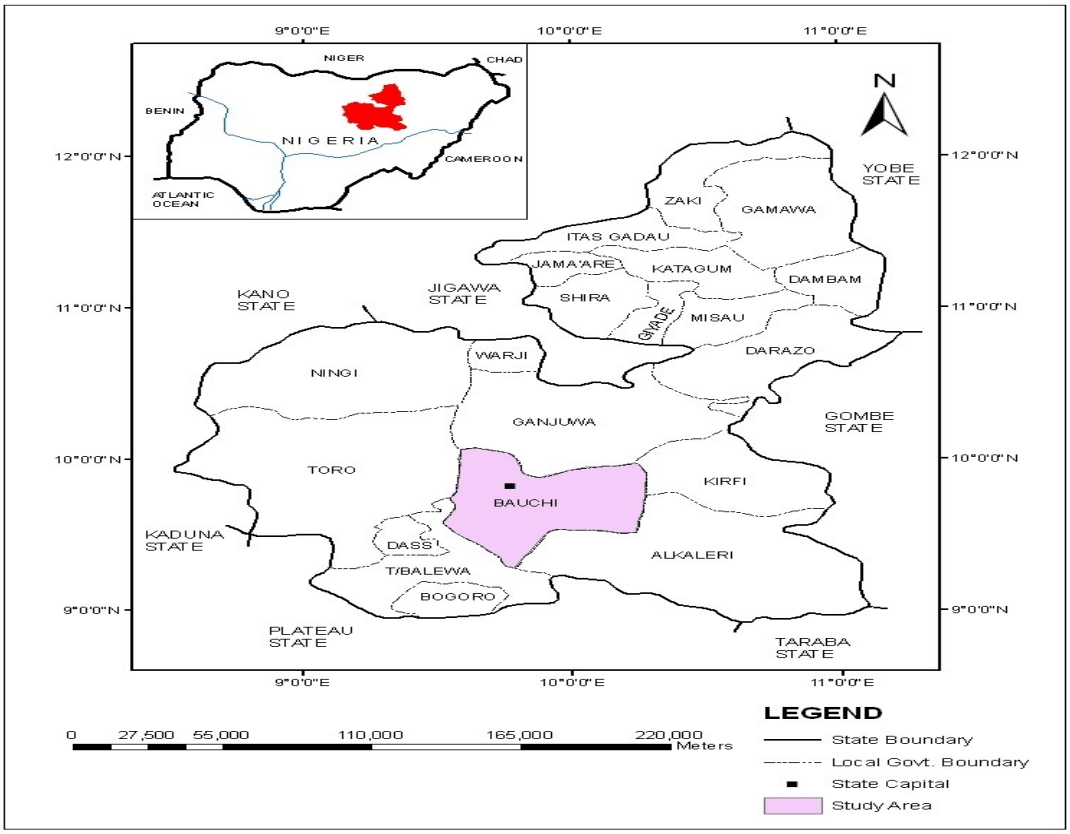


Figure 1: Location map of the study area.

Source: Bauchi State Ministry of Lands and Housing (2013).

3. Methodology

The methodology adopted, for this study, required the acquisition of various data from many sources. The steps followed to achieve the study objective were based on different techniques of data acquisition and processing as discussed below.

Data Acquisition

The data used for this research can be categorized into primary and secondary data. Primary data includes the coordinates of some sites obtained from the use of Global Positioning System (GPS) and attribute information obtained from other field surveys. Secondary data are the Landsat satellite image and streets guide map of Bauchi metropolis obtained from the National Center for Remote Sensing (NCRS), Jos and Bauchi State Ministry of Lands and Housing respectively.

Development of multi-criteria rules

Multi-Criteria Evaluation (MCE), as a reliable method of decision making, was used to achieve the above objective. This comprises a set of rules for selecting between prioritized requirements and alternatives. While developing the criteria, adequate care was taken to ensure that balance existed between the multi-objectives and to allow SMCE operates in GIS platform (Allen *et al.,* 2001). To ensure the acceptability of the sites at the end of the process, the criteria were developed in collaboration with BASEPA, Ministry of Land and Survey, Bauchi State Development Board (BASDB) and related private organizations including results of different researchers on best practices (Sumathi, Usha and Chinmoy, 2007). These are shown in table 1.

Table 1: Bauchi Landfill Multi-criteria Evaluations Rules

Landfill criteria	Constraints Factors	Consideration
The site must:		
(1) be located outside populated area	Population	Planning
(2) be located within 4km of the urban area	Access	
(3) be located outside 0.4km zone of major road		
(4) not be located within 0.5km of surface water	Hydrologic	Environmental
(5) not be located on rocks	Geological	Resource
(6) not be located in forest	Ecological	
(7) be located on bare surface or farmland	Land use	Planning
(8) not be less than 5Ha in size of land area	Land use	
(9) be accepted by the public	Population	Political/ Environmental

Source: Field survey, 2014

Spatial Multi-Criteria Evaluation (SMCE) Technique

The methods identified for landfill site selection abound in literature and include; the landfill model, the use of Boolean, Fuzzy Logic and the SMCE among others. The SMCE of ILWIS 3.3 approach was chosen based on its effectiveness in tackling multi-objectives problem and to identify different possibilities and select the most preferred site between numbers of alternatives. The method works on two basic principles of factors and constrains to achieve the decision making goal. In this technique, constrains are developed directly under the main goal in the criteria tree of SMCE while factors are usually weighted based on their importance, grouped and added to the main goal. Since SMCE requires different map layers that covered the multi-objectives as spatial inputs, different layers were created and these include the land use, the hydrological, geological and ecological layers. Each layer created represents a spatial criterion for landfill selection. All the layers obtained were in the form of reclassified maps. The first layer made emphasis that landfill location must be located outside densely populated areas. Therefore, settlements in the area were identified and reclassified as built-up. Thereafter, it was added to the main goal as constrain. The map was further standardized with values ranging from 0 to 1. The value '0' (false) represents areas that are considered not suitable while '1' (true) indicates suitable areas for landfill location. The suitability increases as the site is located away from 0 to 1 and vice versa. The layer that follows was on the location of landfill within the areas known as urban land but not on built-up. Urban land refers to areas designated for statutory right control covering 20km radius in Nigeria from the city center. Areas within the built-up are reclassified as not suitable while outsides this limit are considered suitable as indicated in figure 2. The creation of layers continued with the hydrological criterion. Surface water such as rivers, ponds and dams are buffered at 400m as shown in figure 3. However, it can be observed, from figure 4 that the farther the locations of landfill away from the surface water the better since constrained distance has increased. This was done to ensure free or minimize contamination of the water sources. The buffered map was further normalized. Areas within the buffer got "false" meaning not suitable while other areas got value of "true" for their suitability. Access to landfill location was one of the requirements. Thus all major roads in the area were buffered at 0.4km as shown in figure 5. The land use layer was incorporated as part of the requirements for the analysis as shown in figure 6. All the above were achieved by launching the SMCE from the ILWIS 3.3 environment. The criteria tree was used and the goal of the site determination was defined. Constrains used for the sites criteria were stated under the criteria tree. Also, spatial data for each constrain were inputted respectively as in the above. The data were edited during normalization process so that set criteria are not violated. Thereafter, an evaluation (aggregation) was carried out which generated an outcome. The aggregation method masked out unsuitable areas for the landfills. Also, the suitability map (a composite index map) has same range value which sum to one. Furthermore, slicing operation was carried out on the composite index map to determine the range of the suitability analysis and a result was obtained which was used in the discussion of results.

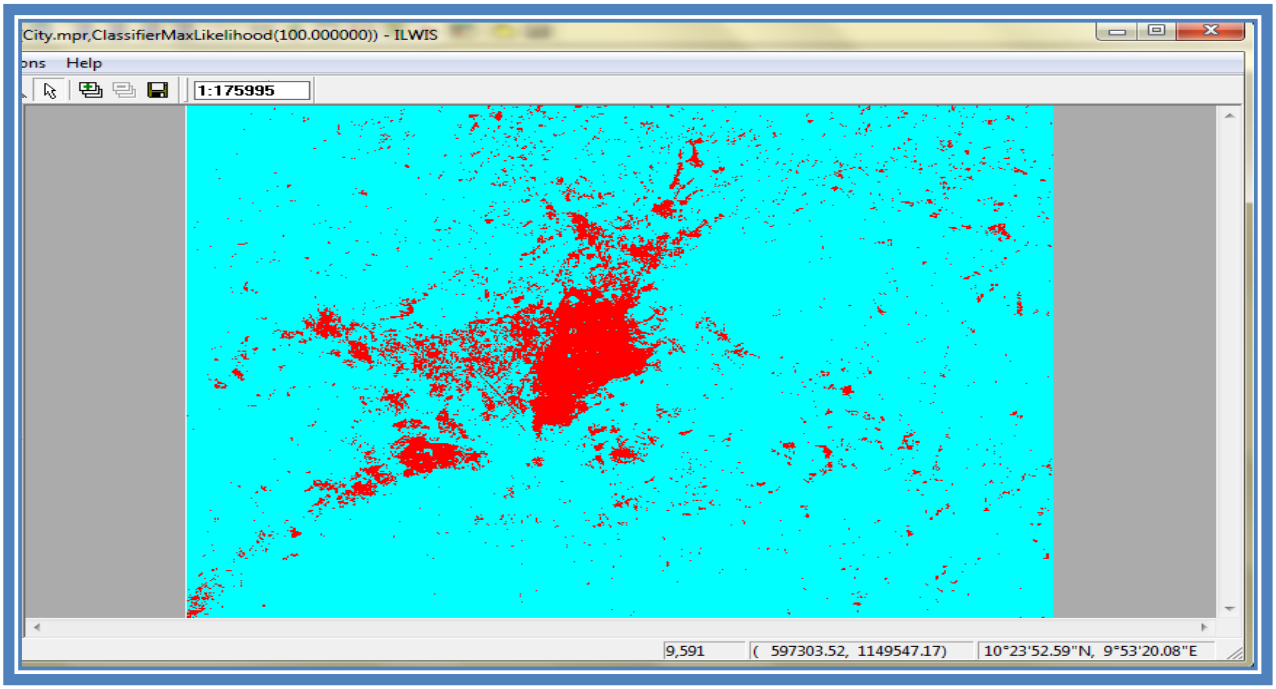


Figure 2. Built-up areas reclassified

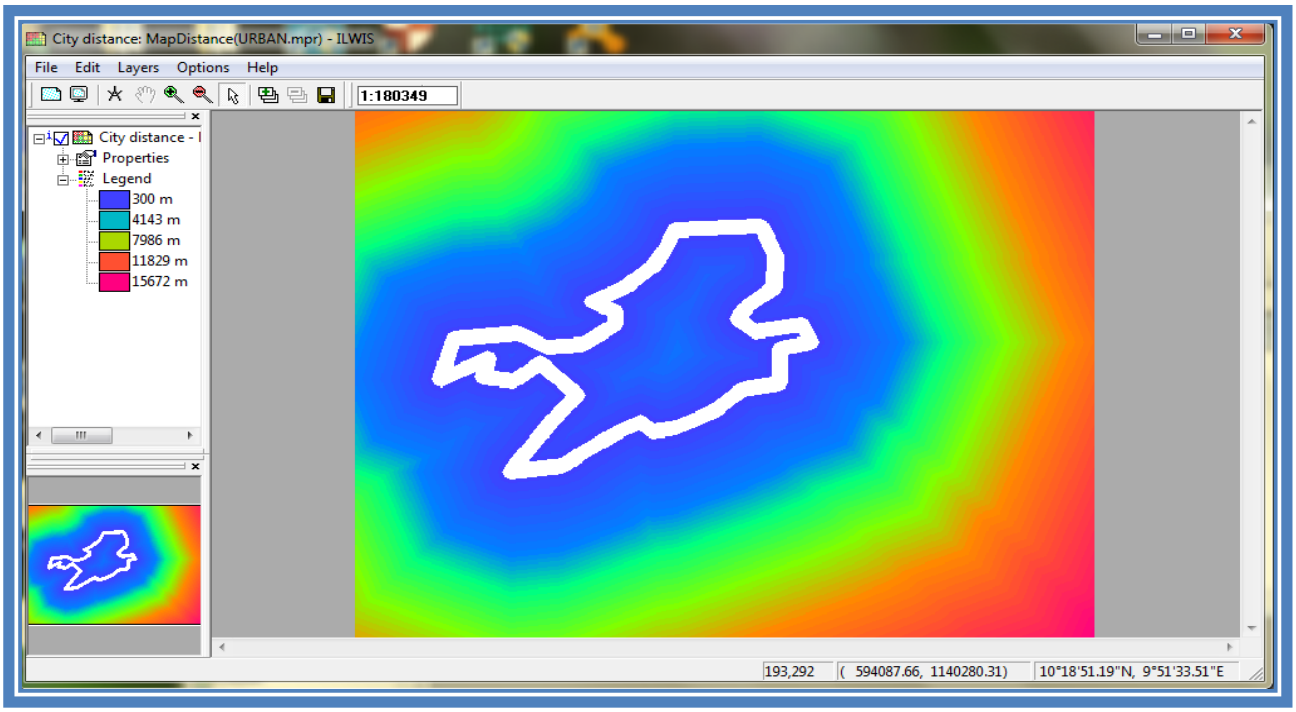


Figure 3. 300m city distance

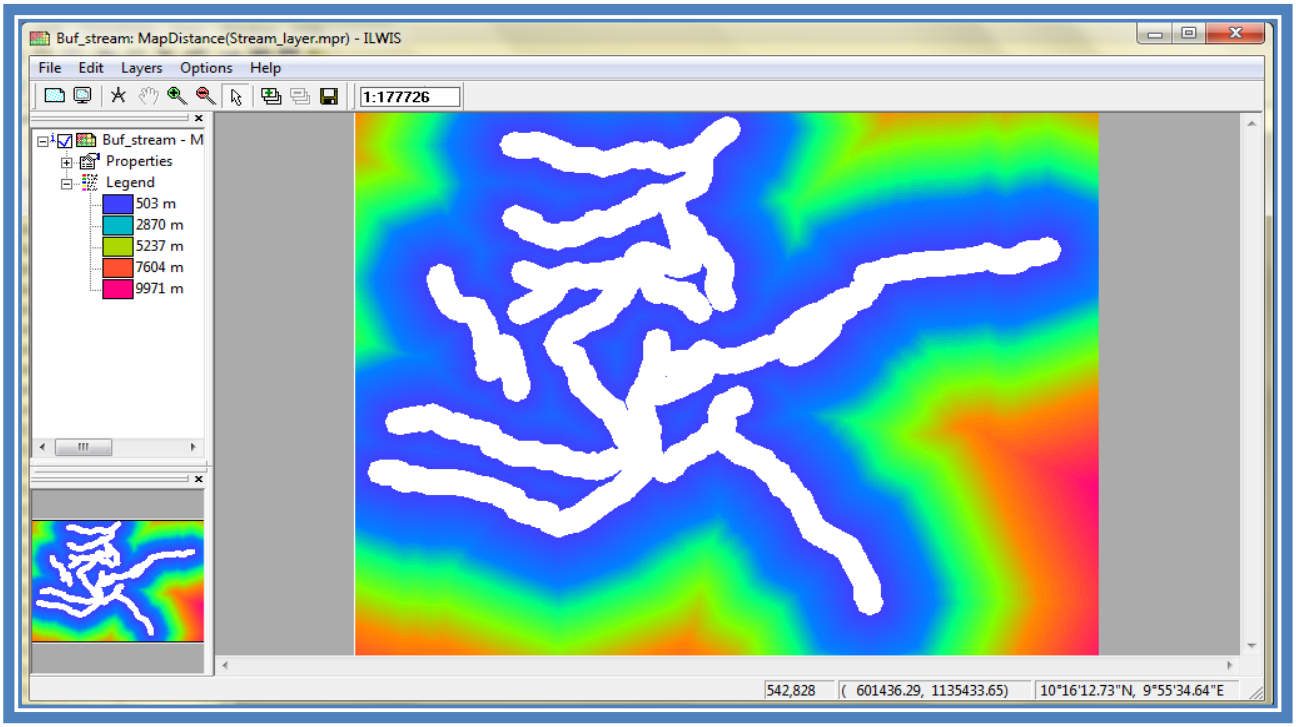


Figure 4. 400m buffered streams

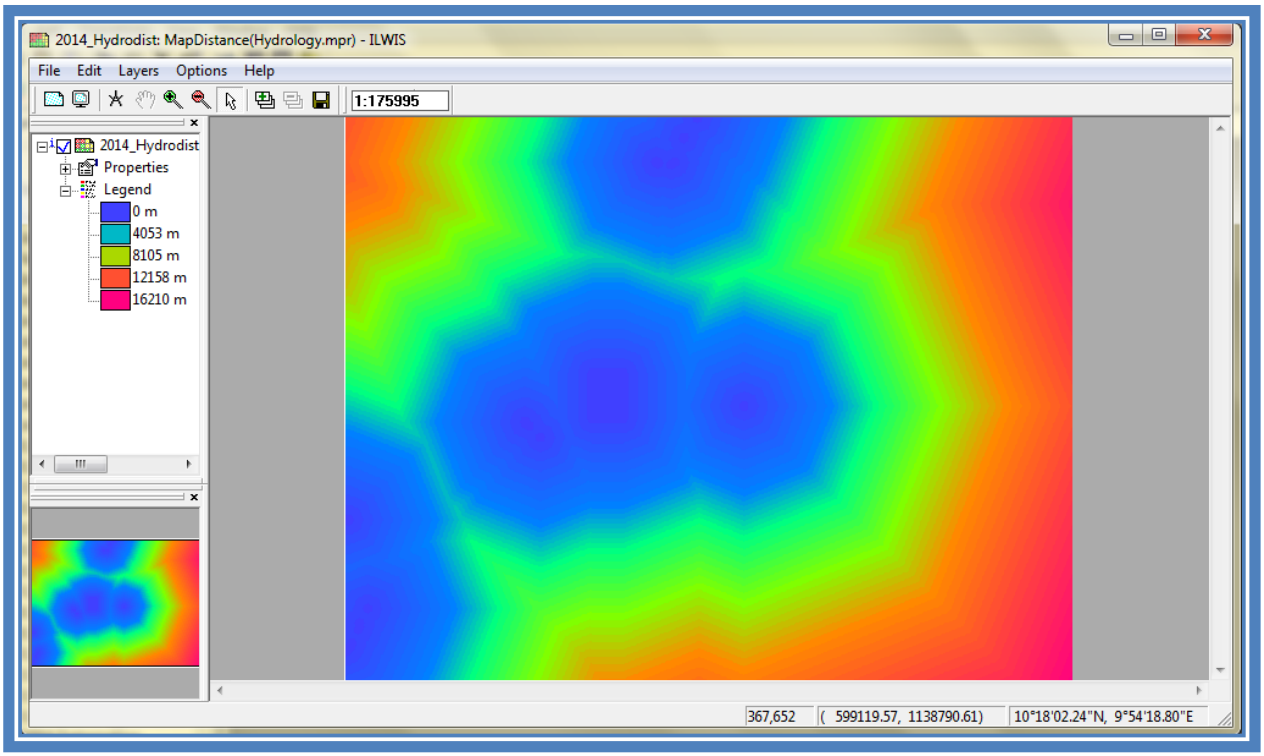


Figure 5. Hydrology distance

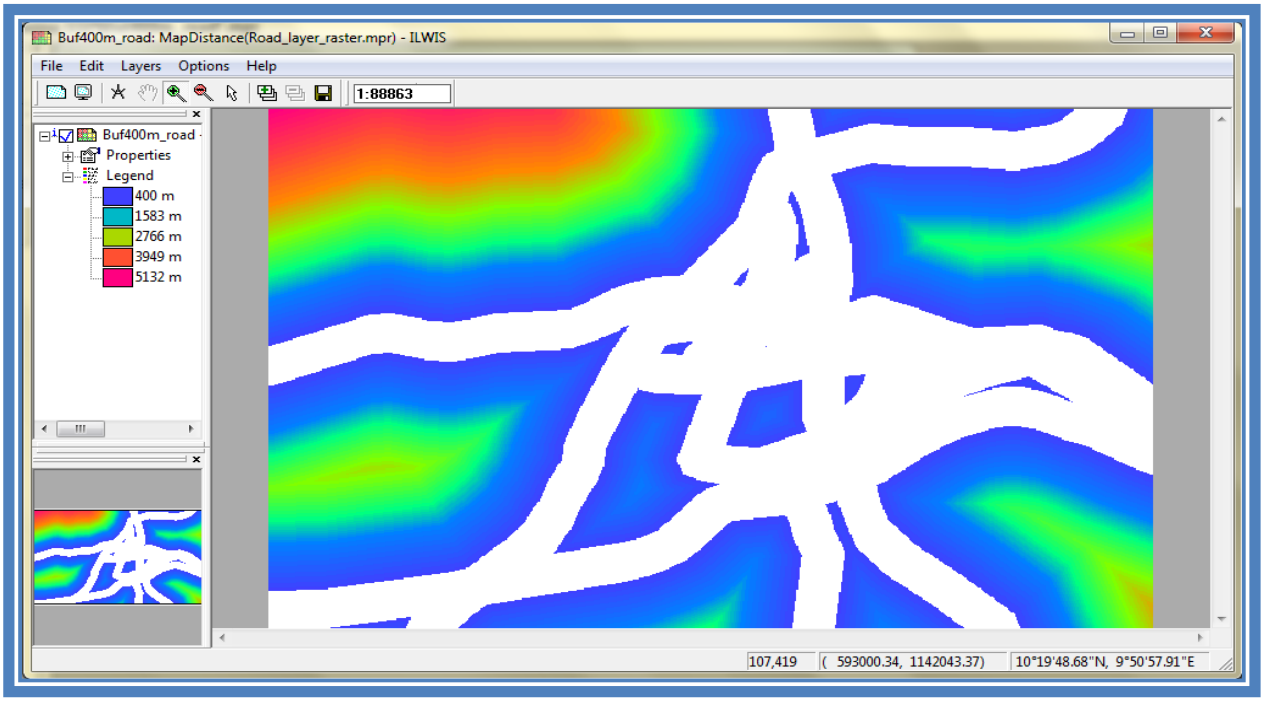


Figure 6. 400m buffered access road

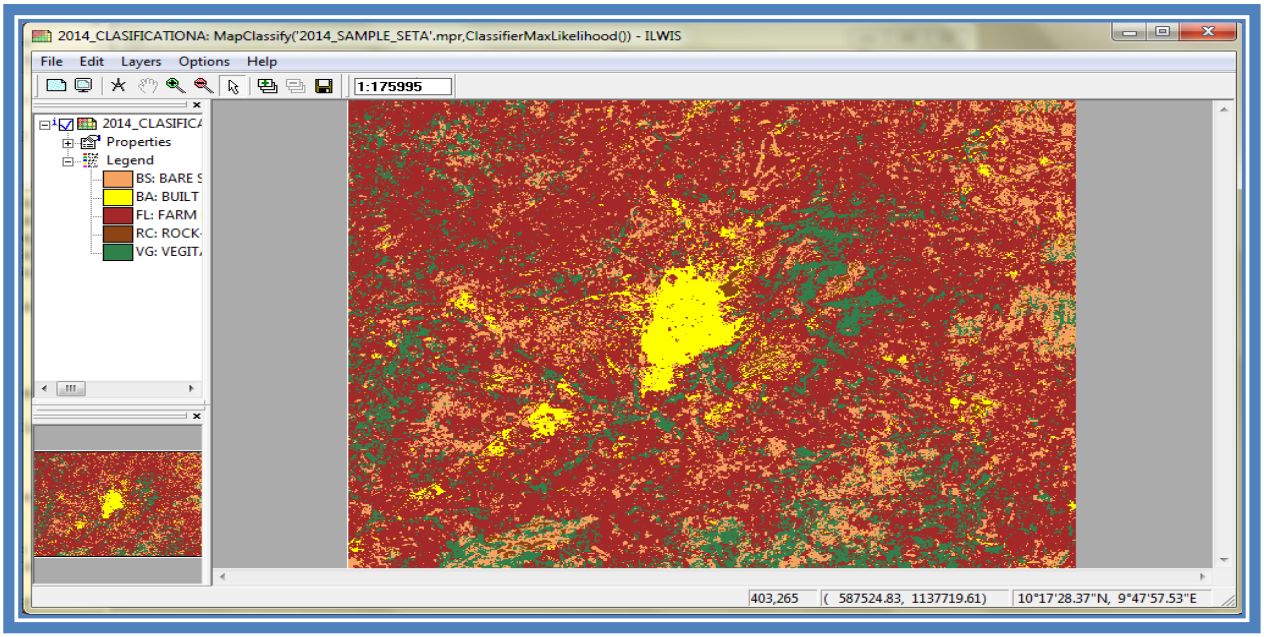


Figure 7. 2014 Bauchi land use reclassified

4. Results and Discussion

Figure 8 shows that three most suitable landfills sites were determined in the study area. Two of the landfills are small while one is big, in fact far more than the two in terms of area extent. All the three sites can be utilized as standard landfill for refuse end destination in the area as they covered a total area of 577413900m^2 as shown in table 2. The biggest landfill was found to be located along Bauchi-Gombe road after Inkil settlement. It also has some patches within representing areas not suitable for landfill but less dominant to be masked out. The second landfill was discovered to be south-westerly located along Bauchi-Dass road after Bayara settlement with all the areas suitable while the third was located south-west along Bauchi-Jos road after Miri settlement. The suitability range analysis from 0.00 to 1.00 of the slicing operation indicates that only 0.80 and 1.00 were considered most suitable as shown in figure 9 but the areas covered by landfills after the slicing remained the same as indicated in table 3.

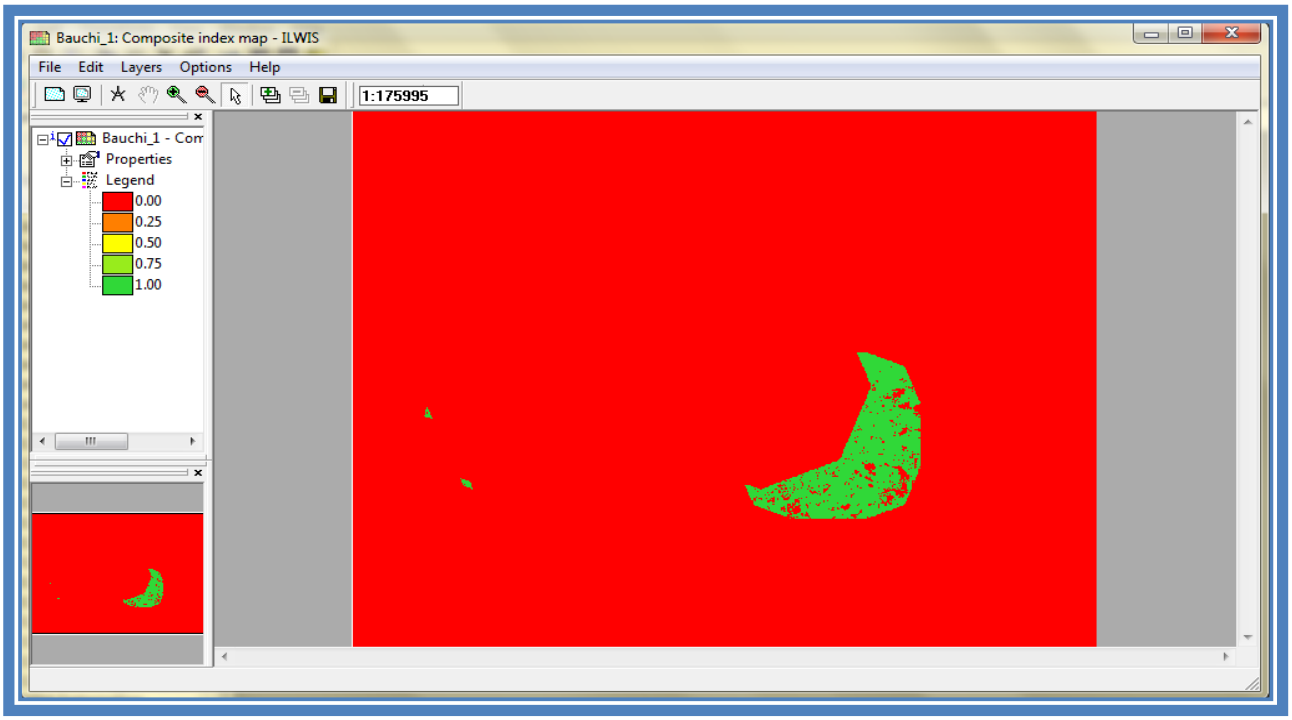
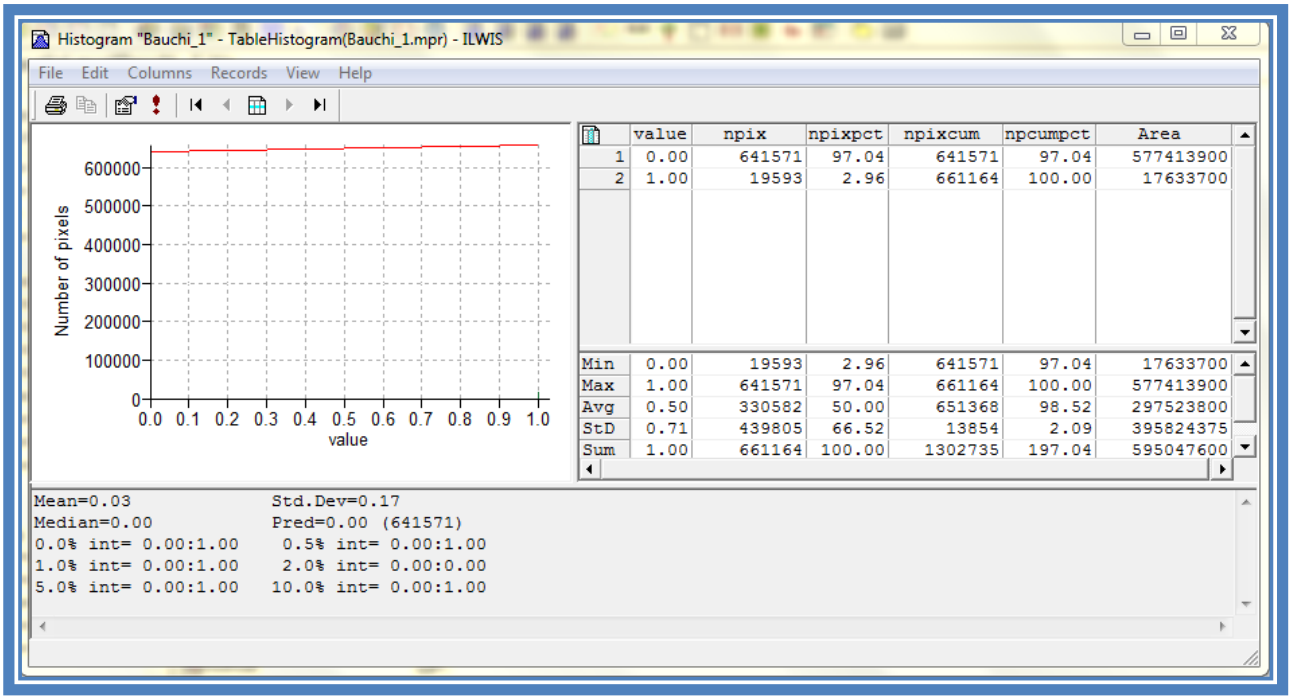


Figure 8. Suitable Landfills map of Bauchi metropolis

Table 2: Histogram of the landfills map of Bauchi metropolis



	value	npix	npixpct	npixcum	npcumpct	Area
1	0.00	641571	97.04	641571	97.04	577413900
2	1.00	19593	2.96	661164	100.00	17633700
Min	0.00	19593	2.96	641571	97.04	17633700
Max	1.00	641571	97.04	661164	100.00	577413900
Avg	0.50	330582	50.00	651368	98.52	297523800
StD	0.71	439805	66.52	13854	2.09	395824375
Sum	1.00	661164	100.00	1302735	197.04	595047600

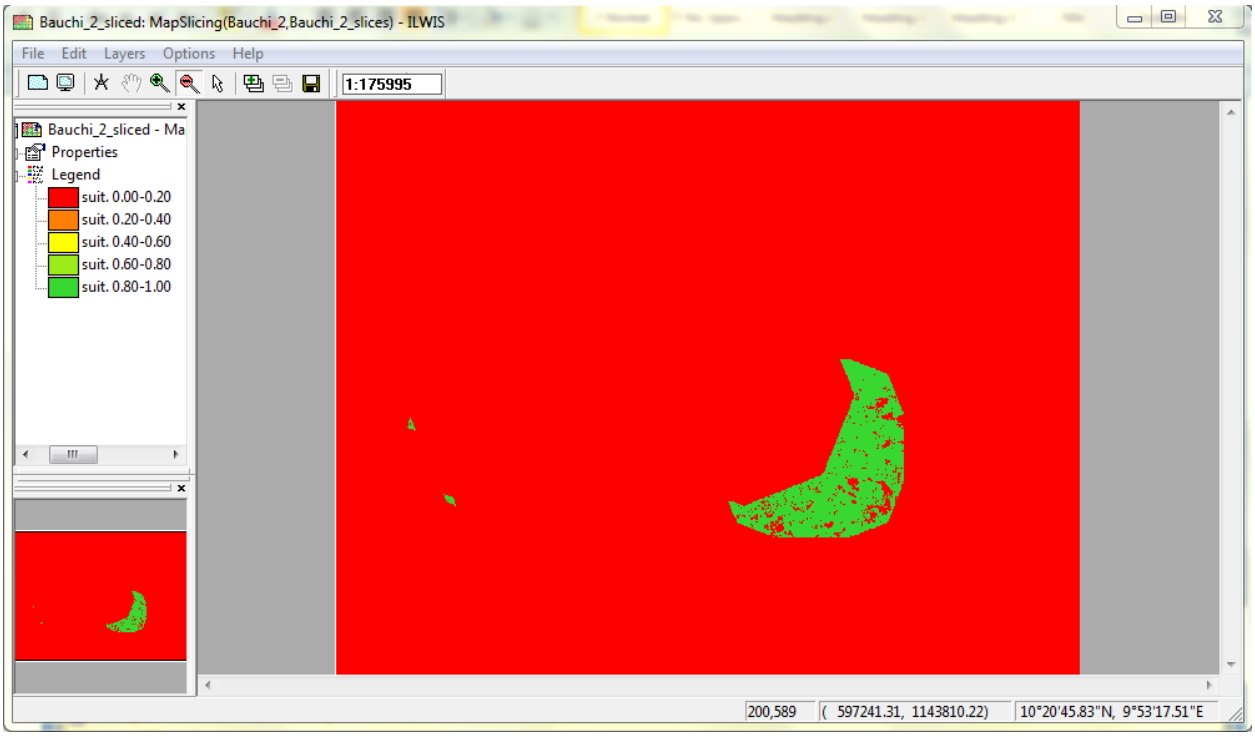
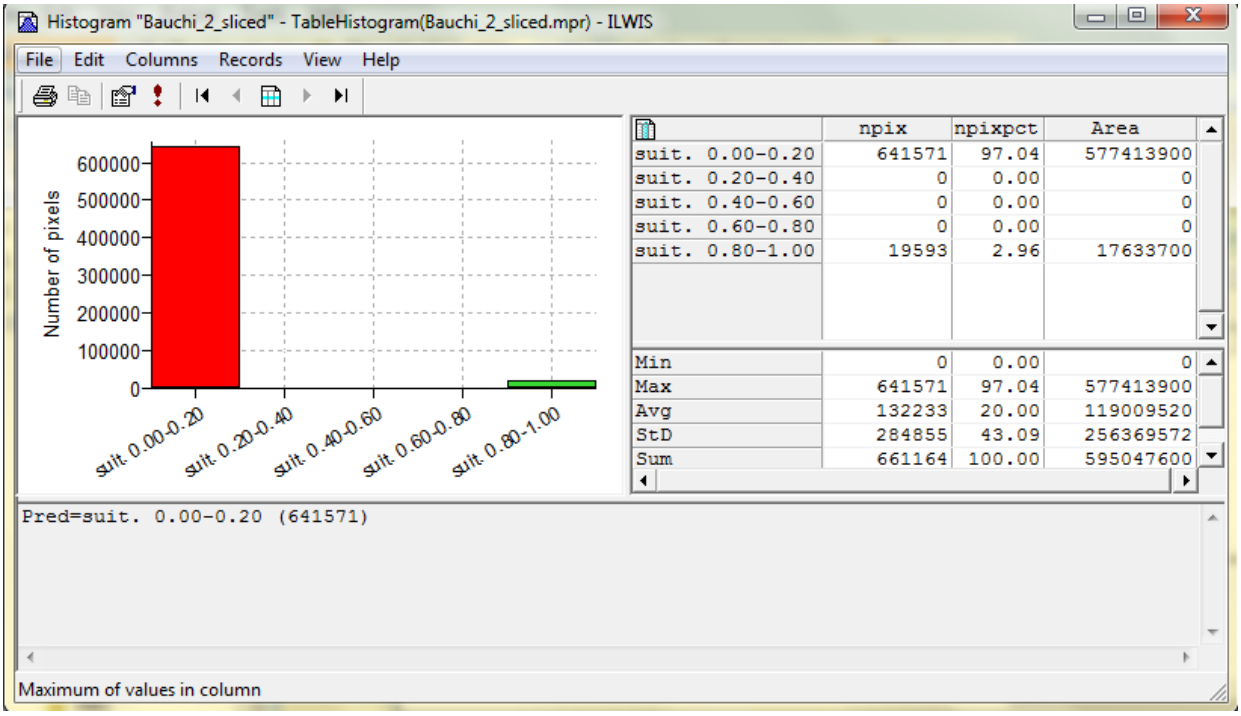


Figure 9: Landfills after slice operation

Table 3: Histogram after landfills after slice operation



	npix	npixpct	Area
suit. 0.00-0.20	641571	97.04	577413900
suit. 0.20-0.40	0	0.00	0
suit. 0.40-0.60	0	0.00	0
suit. 0.60-0.80	0	0.00	0
suit. 0.80-1.00	19593	2.96	17633700
Min	0	0.00	0
Max	641571	97.04	577413900
Avg	132233	20.00	119009520
StD	284855	43.09	256369572
Sum	661164	100.00	595047600

5. Conclusion and Recommendation

There are only three most suitable landfill sites found in the Bauchi Metropolis at present. The most suitable sites are within the rages of suitability classes of 0.8 to 1 while less suitable sites are in the ranges of 0.0 to 0.6. This was obtained as a result of slicing technique. All the sites discovered are accessible and covered an area of 577413900m^2. Therefore, the landfills sites are considered standard to be used as final locations for refuse disposal in the study area. If the located suitable sites are utilized, problems of indiscriminate dumping at borrow pits, vacant plots, near or on the streets will be eliminated. Therefore, the study has shown that geospatial technology with MCE technique looks more appropriate for landfill sites suitability analysis and selection and this has been demonstrated, in this study, for Bauchi metropolis. Therefore, it is hereby recommended that Bauchi State Environmental Protection Agency (BASEPA) should maximize the use of the suitable sites determined, in this study, for sanitary landfill development in Bauchi metropolis. This will be attainable by stepping up an effort to acquire the landfill sites through compulsory acquisition due to overriding public interest. Also, the government and private organisations should utilize the advantage the geospatial technology approach has offered to carry out suitability sitting of landfill locations for their areas. This will not only provide areas for sanitary landfills but also encourage privatization of landfills for economic growth and development within the Bauchi metropolis.

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