Site Suitability Analysis for Solid Waste Disposal using Geospatial Technology: A Case Study of Katsina-Ala Township, Katsina-Ala, Benue State

Tyowuah Michael Ngumom[1], Hundu Williams Terseer[2]

Abstract: ***Solid waste disposal is a serious problem in the urban areas of Nigeria because of indiscriminate dumping. Particularly, Katsina-Ala Town has the problem of identifying suitable sites for solid waste disposal. The main objective of this study was to select potential areas suitable for solid waste disposal for Katsina-Ala Town. The main data used for this study were spot5 satellite image with a spatial resolution of 5m; digital elevation model (DEM) with 0.5 m spatial resolution, and ground control point (GCP) collected through ground point survey (GPS) and topographical map of the study area. The maps were prepared by overlay and suitability analysis using geographic information system (GIS) methods, remote sensing techniques and multi criteria analysis. The final suitability map of the study area was prepared on Arc map and labelled as high, moderate, (low) suitable regions 1.3% less suitable; 21.8% moderately suitable; and 0.37% most suitable. The most suitable areas for solid waste disposal fall on the north-eastern part of the town where there are least environmental and health risks. The GIS and remote sensing techniques are important tools for solid waste site selection. Hence, the capacity to use GIS and remote sensing technology for the effective identification of suitable solid waste dumping site will minimize environmental risk and human health problems.***

Keywords: Site Suitability, Waste Disposal, Geospatial Technology

1. Introduction

Waste is a material discharged and discarded from each stage of daily human life activities, which leads to adverse impacts on human health and the environment (Bringi, 2007); whereas, solid waste refers to the leaves/ twinges, food remnants, paper/cartons, textile materials, bones, ash/dust/stones, dead animals, human and animal excreta, construction and demolishing debris, biomedical debris, household hardware (Sha'Ato et al., 2007; Babatunde et al., 2013). Solid waste is a global environmental problem in today's world both in less developing and developed countries. Increasing population, rapid economic growth and the rise in community living standards accelerate solid waste generation in the world (Elmira et al., 2010).

Solid waste disposal is an important part of waste management system, which requires much attention to avoid environmental pollution and health problems. However, most solid waste disposal sites are found on the outskirts of the urban areas close to water bodies, farmlands, settlement, roads and in most cases blocking drainages and streets. These are suitable sites for the incubation and proliferation of flies, mosquitoes and rodents. They transfer diseases that affect human health (Abul, 2010). Inappropriate disposal of solid waste can be manifested by contamination of surface and ground water, soil contamination through direct waste contact, air pollution by burning of wastes, spreading of diseases by different vectors like birds, insects and rodents, or uncontrolled release of methane by anaerobic decomposition of waste (Visvanathan and Glawe, 2006). Solid wastes indiscriminately thrown can also lead to aesthetic problems, nuisance, and pollution of land and water bodies (Hammer, 2003).Therefore, locating proper sites for solid waste disposal far from residential areas, environmental resources and settlement is the main issue in the management of solid waste.

Management of solid waste at present in Katsina-Ala Township including the collection, transportation and disposal of municipal solid waste is mostly unscientific, considering the scale of the problem, there is a need for immediate attention. Current location of disposal site in the study area is done without regard to environmental and public health hazard arising from disposal of waste in improper location. All social institutions, industries and the public have their way of removal of waste, while some dispose it in the nearby water body others dispose off on streets and drainage channels.

In order to alleviate these problems, we adopt the integration of GIS and remote sensing techniques, a recent essential technology to select the best possible solid wastes dumping site within Katsina-Ala Township District. The selection of solid waste disposal sites using GIS and remote sensing requires many factors that should be integrated into one system for proper analysis.

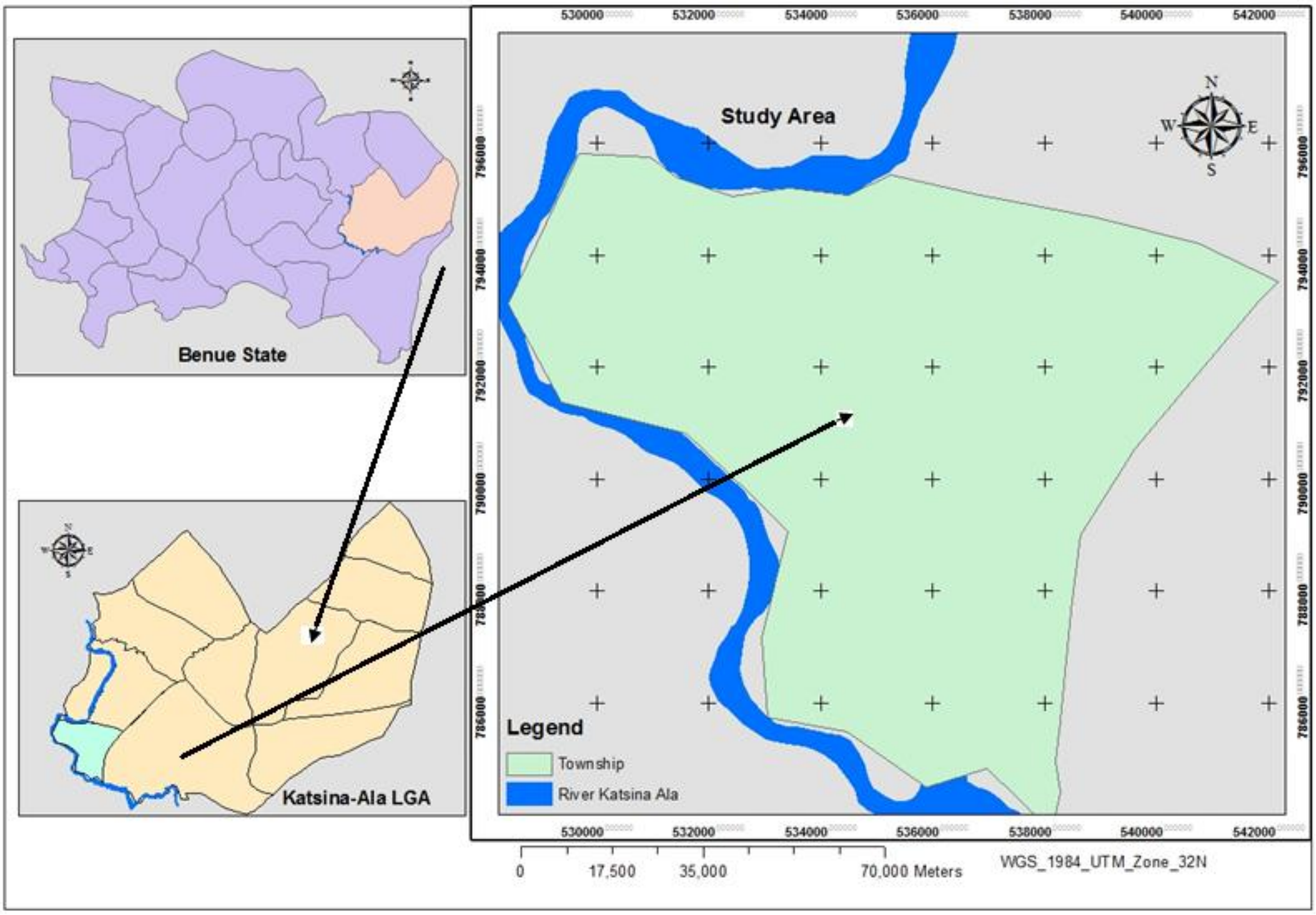

Figure 1: Map of Study Area

2. Study Area

Katsina-Ala Township is one out the 12 council wards in Katsina-Ala Local Government area, with an area of about 84.98 km² and has a geographic extent of Latitude 7° 5′ 30″ N - 7° 12′ 30″ N and Longitude 9° 15′ 0″ E - 9° 23′ 0″ E. It has an elevation of between 105-185 meters above mean sea level. It is located at the bank of River Katsina-Ala and along two major highways, Calabar-Yola road and Katsina-Ala – Takum road.

The wet and dry seasons begin following the northward passage and southward retreat of the inter-tropical convergence zone (ITCZ) over the area in late March and October respectively Temperatures are mostly high throughout the year with average range between 23^0 C – 28^oC with the peak of 38^oC. The mean annual rainfall is about, (1000mm) the area is drained by streams, ponds, and rivers among which River Katsina-Ala is the biggest.(Enokela 2013).

3. Methodology

Methodology is a logical as well as systematic part of the study to guide scientific investigation. In this study, both primary and secondary data were used. The primary data were collected from field surveys and observation. Whereas, internet, reports, books, journals, governmental institutions and other documents form source of secondary data for the study. The main data used for this study were SPOT5 2005 image of the town with spatial resolution of 5 m, topographical map of the town. Pre-processing operations such as radiometric, image restoration and rectification were applied in order to enhance the analysis of the SPOT5 image.

The study used spatial multi-criteria analysis technique to identify the most suitable solid waste site in the study area. Spatial multi-criteria approaches (SMCA) have the potential to reduce the costs and time involved in sitting facilities by narrowing down the potential choices based on predefined criteria and weights and permitting sensitivity analysis of the results from these procedures (Higgs, 2006). The solid waste disposal site selection mapping was done using multi criteria evaluation and creating layers to yield a single output map or index of evaluation (Wiley and Sons, 2009). The weights were developed by providing a series of pair wise comparisons of the relative important factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights were produced follows the logic developed by Saaty (1977) under the analytical hierarchy process (AHP) which is utilized to determine the relative importance of the criteria in a specified decision-making problem. Linear distances were derived for each factor at maximum size for the purpose of classification.
Classifications were done on various layers and the values were assigned ranging from most suitable to unsuitable. Whereas, reclassification of layers were classified into the 1's, 2's, 3's and 4's scoring system, where 1 represented unsuitable, 2 low suitable, 3 moderate suitable and 4 highly

suitable after distance calculation was done, respectively. These criteria were developed by referring to different sources from the literature as indicated above. Then pair-wise comparison of criteria was performed and results were put into a comparison matrix. The matrix was calculated as shown in table 3.

4. Results and Discussion

The suitable site selection for urban waste disposal has been done by Multi-criteria Analysis. An attempt has been made to combine a set of criteria to achieve a single composite basis, a score function, for a decision according to a specific objective. Then reclassified map has been used to locate suitable sites for solid waste disposal in this study area. The environmental, economic, social criteria have been considered for evaluation.

Selected factors for waste disposal site selection in Katsina-Ala Township

Different factors have been selected for the overlay and buffer analysis. This information is basically needed to process the multi-criteria analysis.

River and Streams

Longer distances from river and streams banks were given more preferences for suitable solid waste dumping sites. In Katsina-Ala town, there is River Katsian-Ala running from South-East to North-West of the township, there are also about 17 tributaries that drains the Township council. Hence, to maintain the environmental health of these water sources, a minimum of 500m Euclidean distance is maintained. Accordingly, four different zones were specified considering relative distance from River Katsina-Ala and its tributaries as can be seen in (Tables 1, Figures 2 and 3).

Elevation

Katsina-Ala Township elevation ranges between 105 – 185 meters above mean sea level. An elevation of about 142m or less was given more preferences for suitable solid waste dumping site. In Katsina-Ala town, the elevation rises from western part off the bank of River Katsina-Ala to the Eastern part of the township. Accordingly, four different zones were specified considering relative elevation above mean sea level as can be seen in (Tables2 & Figures 4).

Major Roads

Two major highways, passes through Katsina-Ala Township, the Calabar – Yola Road and the Katsina-Ala – Takum Road. Solid waste dumping site is therefore considered to be located at suitable distance from roads network in order to facilitate transportation and consequently to reduce relative costs. A distance of 2000m and 500m were considered maximum and minimum distance from a dumping site as can be seen in table (Table 2 and Figure 5).

Important places

Important places in this study include Schools, Churches, Hospitals and other private and public institutions. There are about 8 important places in the study area. Waste disposing site is therefore considered not to be located in close proximity to such areas. As distance increases the suitability also increases as can be seen in (Table 1 and figure 6).

Settlement

Katsina-Ala Township and its environs is made up of about 26 settlements including Katsina-Ala Metropolis. High preference was given to settlement areas due to public health and safety as settlements are hub of human population. Like other factors, increasing distance from the settlement also lead to increase in suitable level of site selection as can be seen in (table 1 and figure 7).

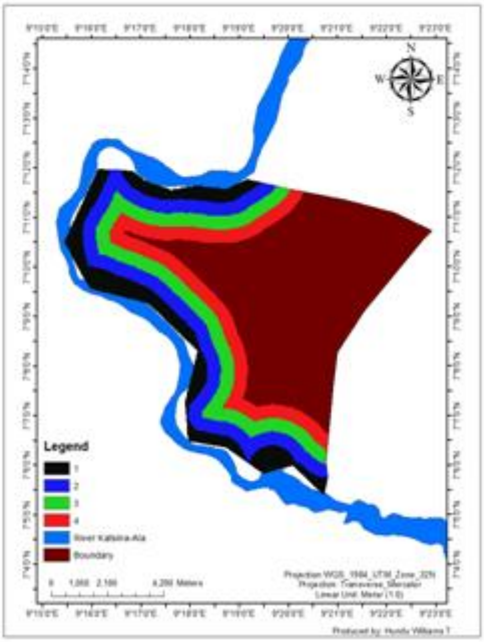

Figure 2: Distance from River

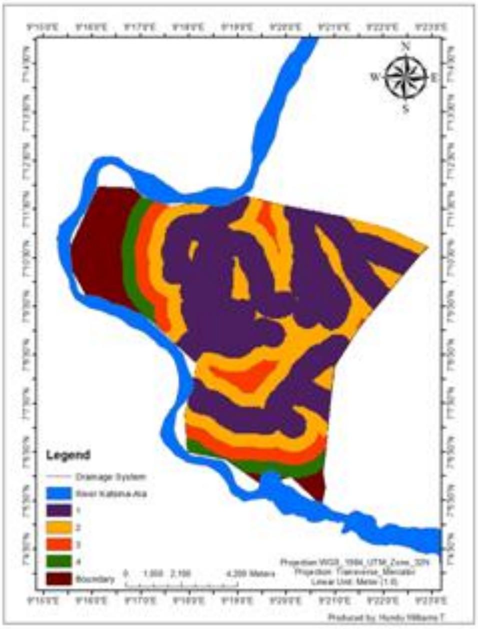

Figure 3 : Distance from drainages

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

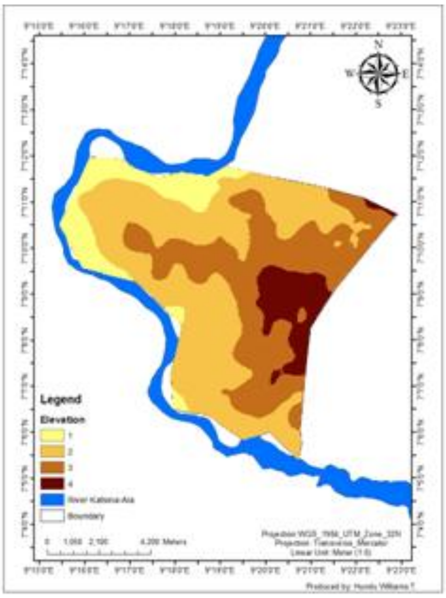

Figure 4: Elevation

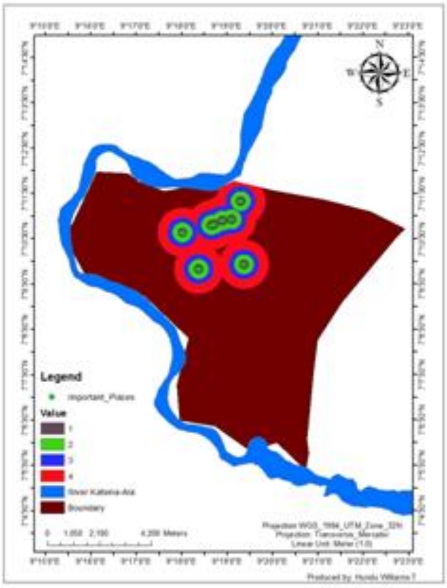

Figure 5: Distance from Important places

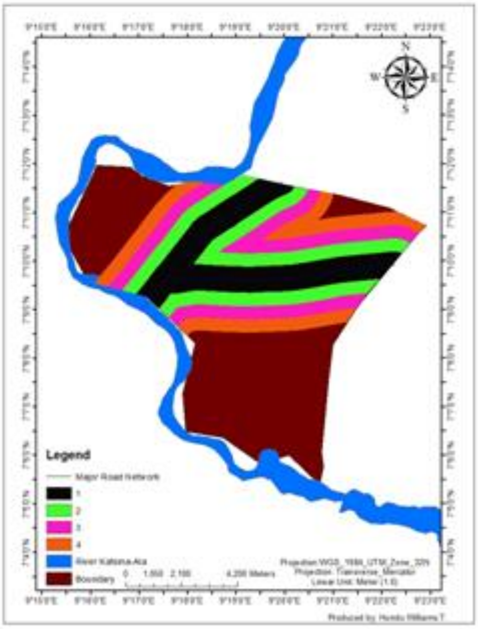

Figure 6: Distance from Major Roads

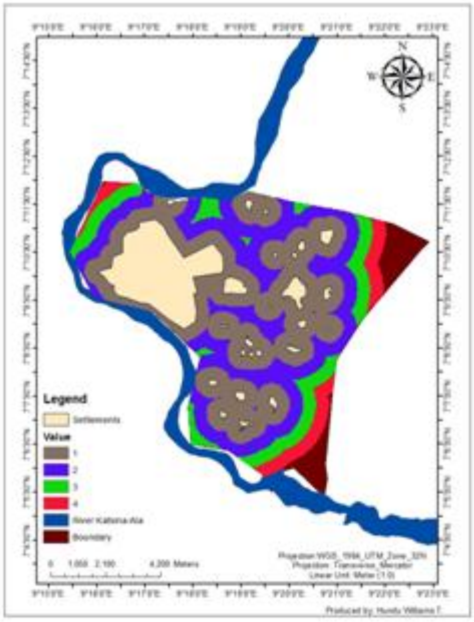

Figure 7: Distance from settlements

Table 1: Showing distance from River, Drainage, Settlement, Important places, and Major road and suitability score

Distance (Meter)	*Scale Value*
0 – 500	1
500 – 1000	2
1000 – 1500	3
1500 – 2000	4

Table 2: **Showing Reclassified elevation and suitability score**

Height above mean sea level (Meter)	*Scale Value*
93.01 - 117.72	3
117.72 - 142.43	4
142.43 - 167.14	2
167.14 - 191.85	1

Overlaying and identifying suitable sites

Suitable site selection for solid waste disposal site involves comparison of different options based on environmental, social and economical impact. Therefore, based on experience and likely impact on surrounding environment, different weights were assigned to all the parameters. The larger the weight, the more significant is the criterion in the overall utility. The weights were developed by providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights were produced follows the logic developed by Saaty (1980) under the Analytical Hierarchy Process (AHP). Weight rates were given based on pair wise comparison of factors as can be seen in (Table 3). These pair wise comparison were then analyzed to produce weights that sum to 1 (Table 4). The factors and their resulting weights were used as input for the Multi Criteria Evaluation (MCE) module for weighted linear combination of overlay analysis.

In order to combine all the layers to process overlay analysis, standardization of each data set to a common scale of 1, 2, 3, 4 (value 1 = unsuitable (restricted), value 2 = less suitable, value 3 = moderately suitable, value 4 = highly suitable) was performed. Finally, all the parameters were weighted with their respective percent of influence and overlay to produce the suitability map. The factors, their values and weights are summarized in Table 5. According to the degree of importance, they have the role of selecting suitable solid waste dumping site. After the overlay analysis of the given factors the following suitable solid waste dumping site map was produced (Figure 7). The final output map (Figure 8) has three colours (classes), red green and yellow. The most suitable area for solid waste dumping site is shaded Red colour as shown in the map legend. Out of the total area of the study site, about 8.74% (743.040 ha) fall under this categories and the highly suitable site for solid waste disposal indicated by red colour with total area of (31.33 ha) making 0.37% of the total land mass of the study area. By using the stated criteria, the suitable areas for solid waste dumping site fall on the north-eastern part of the town along one of the major road (Figure 8). The selected site areas are significantly at the optimum distance from River Katsina-Ala, settlements, drainages, important places and from major roads and it is covered by grass lands on a relatively plain terrain. The area is most suitable for solid waste dumping site in the study area.

Table 3: Pair wise comparison Matrix

	D	R	E	S	I	Rd
D	D	R	D	S	D	D
R	R	R	R	S	I	R
E	E	R	E	S	I	E
S	S	S	S	S	S	S
I	D	R	I	S	I	I
Rd	D	R	E	S	I	Rd

Where
D = Drainages, R = River, E = Elevation, S = Settlement, I = Important Places, Rd = Road

Table 4: Weights derived by calculating the principal eigenvector of pair wise comparison matrix

Factor	frequency	Eigenvector weight	Percentage %
Drainages	6	0.167	16.67
River	8	0.222	22.22
Elevation	4	0.111	11.11
Settlements	11	0.306	30.56
Important Places	6	0.167	16.67
Road	1	0.028	2.78
	36	1	100

Table 5.Weight of suitable solid waste disposal site selection factors

Factor	Class	Value	Level of Suitability	Influence %
Drainages	0 – 500	1	Very low	16.67
	500 – 1000	2	Low	
	1000 – 1500	3	Moderate	
	1500 – 2000	4	Highly	
River	0 – 500	1	Very low	22.22
	500 – 1000	2	Low	
	1000 – 1500	3	Moderate	
	1500 – 2000	4	Highly	
Elevation	93.01 - 117.72	3	Moderate	11.11
	117.72 - 142.43	4	Highly	
	142.43 - 167.14	2	Low	
	167.14 - 191.85	1	Very Low	
Settlements	0 – 500	1	Very low	30.56
	500 – 1000	2	Low	
	1000 – 1500	3	Moderate	
	1500 – 2000	4	Highly	
Important Places	0 – 500	1	Very low	16.67
	500 – 1000	2	Low	
	1000 – 1500	3	Moderate	
	1500 – 2000	4	Highly	
Road	0 – 500	1	Very low	2.78
	500 – 1000	2	Low	
	1000 – 1500	3	Moderate	
	1500 – 2000	4	Highly	

Table 6: Suitability Analysis

Suitability	Area in Hectares	Percentage %
Low Suitable	695.729	93.63
Moderately suitable	15.981	2.15
Highly Suitable	31.330	4.22
	743.040	**100.00**

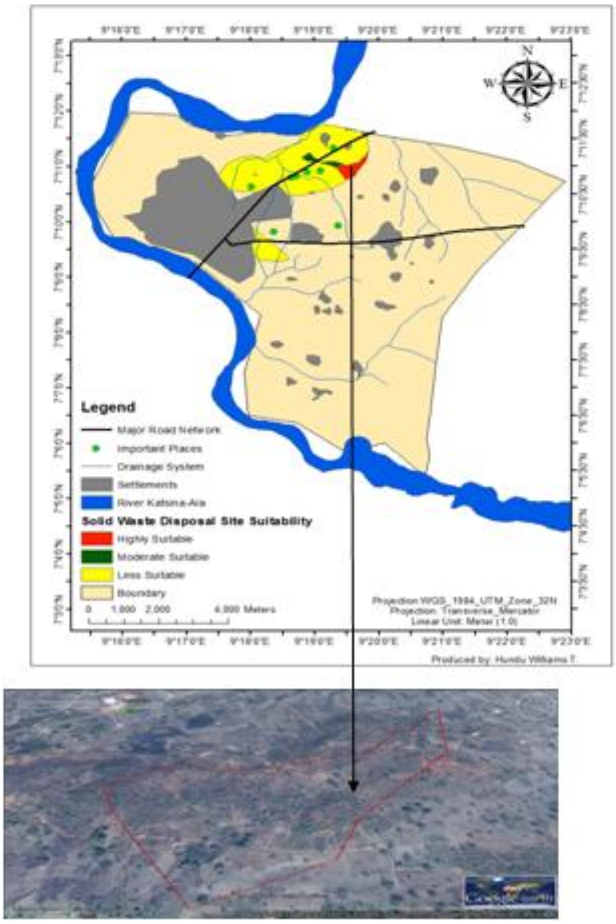

Figure 8: Suitable site for Waste Disposal

5. Conclusion

The findings have demonstrated the ability of GIS and remote sensing as an ideal tool for analyzing the criteria for decision support. The analysis has taken elevation, water sources, settlements, important places and transport facilities as determining factor in order to find appropriate site for solid waste dumping. The results have identified the most suitable site for solid waste disposal. The site is easy to access and manage for disposal of solid wastes. The place is far away from any water sources and other inputs considered in the analysis. It is located in North-Eastern part of the town at a Euclidean distance of 5km aware from the city center, 500m from one of the major highway, 500m from the closet settlement, and 500m from the closet drainage and is a bare land and grass land with an elevation of about 142m above mean sea level. Hence, the capacity to use GIS and remote sensing technology for the effective identification of suitable solid waste dumping site will minimize the environmental risk and human health problems.

References

[1] Abul S (2010). Environmental and health impact of solid waste disposal at mangwaneni dumpsite in Manzini: Swaziland. J. Sustain. Dev. Afr. 12(7):1520-5509.

[2] Akbari D (2011). Appointment of appropriate sites for waste disposal by GIS.Marrakech, Morocco.

[3] Al-Hanbali A, Alsaaideh B, Kondoh A (2011).Using GIS-based weighted linear combination analysis and remote sensing techniques to select optimum solid waste disposal sites within Mafraq City, Jordan. J. Geogr. Inf. Sys. 3(2): 267-278.

[4] Babalola A, Busu I (2010). Selection of landfill sites for solid waste treatment in Damaturu Town-Using GIS Techniques. University Technology Malaysia, Johor state, Malaysia

[5] Baban SMJ, Flannagan J (1998). Developing and implementing GIS assisted constraints criteria for planning landfill sites in the UK. Plan.Pract. Res. 13(2):139-151.

[6] Babatunde BB, Vincent-Akpu IF, Woke GN, Atarhinyo E, Aharanwa UC, Green AF, Isaac-Joe O (2013). Comparative analysis of municipal solid waste (MSW) composition in three local government areas in Rivers State, Nigeria. Afr. J. Environ. Sci. Technol. 7(9):874-881.

[7] Bringi SD (2007). Application of 3D principles to solid waste management on the Asian Institute of Technology (Ait) Campus.Unpublished M.Sc. Thesis.Indonsia.

[8] Dagmawe N (2007). In depth investigation of relationship between index property and swelling characteristic of expansive soil in Bahir Dar. Unpublished MSC Thesis, Eurohazcon. Collaboration Addis Ababa University.

[9] Degnet A (2008). Determinants of solid waste disposal practices in urban areas of Ethiopia: a household-level analysis. East Afr. Soc. Sci. Res. Rev. 24(1):1-14.

[10] Elmira S, Behzad N, Mazlin BM, Ibrahim K, Halima T, Saadiah H (2010). Urban solid waste management based on geoinformatics technology, University Putra Malaysia, Malaysia. Environmental Engineering and Management Program School of Environment, Resources and Development -SERD.

[11] Emun GM (2010). Multi criteria approach for suitable quarry site selection in Addis Ababa using remote sensing a

[12] Gaurav S., Shashi M. & Kamal J(2012) Decision Support System for selecting suitable site for disposing solid waste of township, International journal of Remote Sensing and GIS, Volume 1, Issue 1.

[13] Lawal DU, Matori A-N, Balogun A-L (2011). A Geographic Information System and multi-criteria decision analysis in proposing new recreational park sites in UniversitiTeknologi Malaysia.Mod. Appl. Sci. 5(3):79-86.

[14] Nishanth.T , Prakash M.N , Vijith.H (2010) Suitable site determination for urban solid waste disposal using GIS and Remote sensing techniques in Kottayam Municipality, India. International Journal of Geometrics and Geoscience Volume 1, No 2, 2010

[15] Saaty TL (1977). A scaling method for priorities in hierarchical structures. J. Math. Psycho. 15:231-281.

[16] Saaty TL (1980). The analytic hierarchy process, Mcgraw-hill. New York.

[17] Tirusew A. E. and Amare S. M. (2013) Solid waste dumping site suitability analysis using geographic information system (GIS) and remote sensing for Bahir Dar Town, North Western Ethiopia African Journal of Environmental Science and Technology