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SUITABILITY ANALYSIS AND SITE SELECTION FOR MUNICIPAL SOLID WASTE DISPOSAL IN NASARAWA TOWN, NASARAWA LOCAL GOVERNMENT AREA, NASARAWA STATE.

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ABSTRACT

Selecting a suitable location for municipal solid waste disposal is a complex process due to the technicalities involve. However, with advance in geospatial technology, this process has been made less strenuous. Thus, using GIS and remote sensing method, this complex process was successfully achieved for Nasarawa town. Using ArcGIS 10.5 and Envi 4.2, and remotely sensed data, five locations along Nasarawa – Abaji and Nasarawa – Loko roads axis's totaling about 84.907848 Ha were found to be most suitable for municipal solid wastes disposal in Nasarawa town, based on their land use land cover and elevation characteristics, proximity to the streets and distances away from water bodies.

Keywords: *Suitability, Analysis, Selection, Municipal, Solid Waste.*

INTRODUCTION

Waste is any material, object or substance its possessor discard or wishes to discard as it's no longer considered valuable to retain; or simply any unwanted by-product of human activities (Institute for Prospective Technological Studies, 1997; Gilpin, 1976). Waste can be in gaseous, liquid or solid form (Sada, 1977). Gaseous wastes are unwanted gaseous materials generated as by-product of human activities. Waste that can pass through 0.45 micro filter at a pressure differential of 75 psi is classified as liquid waste (wastewaters) (Environmental Protection Authority, 2003). And waste that are neither in gaseous form nor having sufficient liquid content to flow freely are categorized as solid wastes (American Public Works Association1975).

Solid waste includes all agricultural, commercial, domestic, industrial and mineral wastes. Because of its nature, solid waste if not properly managed, have the tendency to accumulate and consequently degrade the environment. Critical to effective solid waste management is selecting suitable site for its disposal. Indiscriminate dumping or unscientific site selection for disposal of solid waste can encourages all kinds of pollution (air, land and water), proliferation of vectors (birds, insects and rodents) and vector-borne diseases (dengue, cholera, lymphatic filariasis, malaria and typhoid) (Hammer, 2003; Visvanathan & Glawe, 2006). Thus, the importance of selecting suitable site for solid waste disposal can never be over emphasized.

There are different kinds of solid waste distinguishable mainly based on their sources. However, solid wastes have generally been classified into three. These include hazardous, industrial and municipal solid waste. Hazardous solid wastes refer to solid wastes from industries and other related sources considered harmful and needing special handling due to their special characteristics of ignitability, corrosivity, reactivity and, or toxicity. Industrial solid wastes are solid wastes generated as by-product of industrial processes and manufacturing not considered toxic or containing listed materials such as radio-active (Bhide & Sundaresan, 1983). Municipal solid waste refers to combine wastes generated from municipalities, incorporating wastes streams from administrative, agricultural, domestic and institutional settings. It also includes non-hazardous solid wastes from especially light industries. Municipal solid waste usually consist of glasses, matter, metals, papers, plastics, rubbers, textiles and vegetables among other things (Cointreau, 1982; United State Environmental Protection Agency , 2002; Daniel & Perinaz, 2012).

Across the world today, due to increasing population, urbanization, industrialization, economic prosperity and rise in the standard of living of especially urban dwellers; municipal solid waste generation is enormously increasing in volume and varieties (Ogwueleka, 2004; Adeniyi, 2014).

According to (Daniel & Perinaz, 2012), the estimated 3billion urban dweller as at 2012 were annually generating about 1.3billion tonnes of municipal solid waste per year at 1.2kg per person per day; and by 2025 about 4.3billion urban dwellers will be generating about 2.2billion tonnes of municipal solid waste annually, at about 1.42kg per capita per day. Managing this enormous amount of waste in especially the developing countries where in some municipalities government agencies responsible for waste management are ineffective or even nonexistent, is a serious challenge. Hence, indiscriminate dumping of solid waste on sites within or outside some municipalities is a common practice (Adeniyi, 2014). This unhealthy and unscientific practice poses health risk and environmental challenge.

Because of the biological, chemical and physical properties of waste materials, indiscriminate dumping or dumping at improper sites can inter alia cause air pollution, contamination of surface or underground water sources, degradation of sensitive areas, nuisance or even have high cost implication. Thus, certain economic, environmental and social factors are often considered when selecting suitable sites for solid waste disposal. Among these factors are slope and altitude, landuse, distance from road, distance from water bodies, soil and geology. Slope and altitude are considered because they influence soil water content, soil erodability, surface water runoff and groundwater pollution. Thus, areas with low to medium altitudes and slopes are often considered most suitable (Akbari, 2008). Distance from road is important for both economic and social implications. Whereas siting waste disposal site very close to the road can have health and safety (traffic congestion) implications, siting it far away from the road can also result in high cost of transportation. Thus, areas neither too close nor too far from the road are most preferred (Rafiee, Syed, Afshin, & Nematolah, 2011). Distance from water bodies are important to avoid contamination of surface water by pollutants from dumpsites through runoff, leaching and seepage. Thus, areas too close to surface water are less desirable (Akbari, 2008). Land use is also considered to protect productive lands and preserve sensitive areas.

Selecting a suitable site for municipal solid waste disposal is a complex process. This is because of the many and diverse data sets and conditions involve (Süleyman & Burhan, 2017). However, with advances in computer and geospatial technologies, integration of geographic information system

(GIS) and remote sensing is continually being considered as an effective method of carrying out this challenging task (Nishanth, Prakash, & Vijith, 2010; Iyappan & Gopi, 2014; Asha & Vinod, 2016). while GIS is basically a computer based system for capturing, story, retrieving at will, analyzing, integrating, maintaining and presenting information about geographic facts, with a view to revealing what is otherwise invisible in geographic information (Aronoff, 1989; Burrough, 1986; Longley, Goodchild, Manquire, & Rhind, 2005). Remote sensing is the art and science of acquiring information about the physical, chemical and biological properties of the earth surface at a distance through measurements of emitted, reflected or scattered electromagnetic radiation from the surface of the earth (Longley, Goodchild, Manquire, & Rhind, 2005; Anji, 2008; CampBell & Wynne, 2011).

However, like in many Nigerian cities once described as some of the dirtiest, unsanitary and aesthetically displeasing in the world (Mabogunje, 1996), indiscriminate disposal of solid waste on drainage channels, streets, uncompleted buildings and vacant plots are commonplace in Nasarawa town as depicted in figure 1. This unhygienic open dumping practices can lead to contamination of drinking water sources (underground and surface), air and land pollution, and be harmful to health (Bogoro & Babanyara, 2011). These among other concerns rises important questions as to where is/are the most suitable location(s) for solid waste disposal in Nasarawa town and how can these sites be determined. Thus, the need for this study to determine suitable sites that are at least 10 hectare (Ha).

a. Dump site along a stream at down Oversea b. Dumpsite along river Hadari behind downbest

C. Dumpsite behind Agwan Sarkin Pada

d. Dumping on an undeveloped plot

Figure 1: Some dumpsites around Nasarawa Town

STUDY AREA SETTING

Nasarawa town, covering an approximate land area of 252 km^2, is situated within latitudes 8^0 27' and 8^0 37', and longitudes 7^0 38' and 7^0 46' as depicted in Figure 2. The town is the administrative headquarters of Nasarawa local government area of Nasarawa state, in north-central Nigeria. The town is the center of activities for the surrounding settlements within the local government area. According to Nigeria's 2006 national population and housing census, the population of the entire Nasarawa local government area was 189,835 (National Bureau of Statistics, 2009). The town has a cosmopolitan population outlook owing to the presence of the Federal Polytechnic Nasarawa and some few other federal and states institutions.

The town has an undulating terrain, varying between 167 and 417 meters above sea level. Two major rivers: river Hadari and river Kurafe that meet at a point called Magami, traverse through and drain the entire area into the famous river Benue. Climatically, the area has two distinct seasons; wet (rainy) and dry seasons. The rainy season prevails for about seven months (April - October), while the dry season prevail for five months (November-March). During these periods, the temperature, rainfall and humidity pattern follow closely, the pattern of the two dominant air masses, leading to the emergence of distinct climatic regimes as; hot and humid period (April - June), cool and humid period (July - October), cool and dry period (November - January), and hot and dry period (February - March).

Economically, the people in and around Nasarawa are into all kinds of agricultural and commercial activities. Goats, cows, and all kinds of domestic birds are among the animals reared for protein. Food crops such as maize, sorghum and yam are the important food crops produce for sustenance (Ibrahim, Zaubairu, Mohammed, & Abdullahi, 2008). Melon, beniseed and cassava are some of the cash crops that influence commercial and industrial activities in Nasarawa. The two market days (Friday and Monday) usually attract buyers and sellers who trade in especially melon and beniseed. The Mailauni cassava processing plant at Gunki and several light industries for preparing and standardizing beniseed for export around the Nasarawa main market are some of the industrial activities in Nasarawa. Thus, all kinds of solid waste are generated in Nasarawa, which form the municipal solid waste stream.

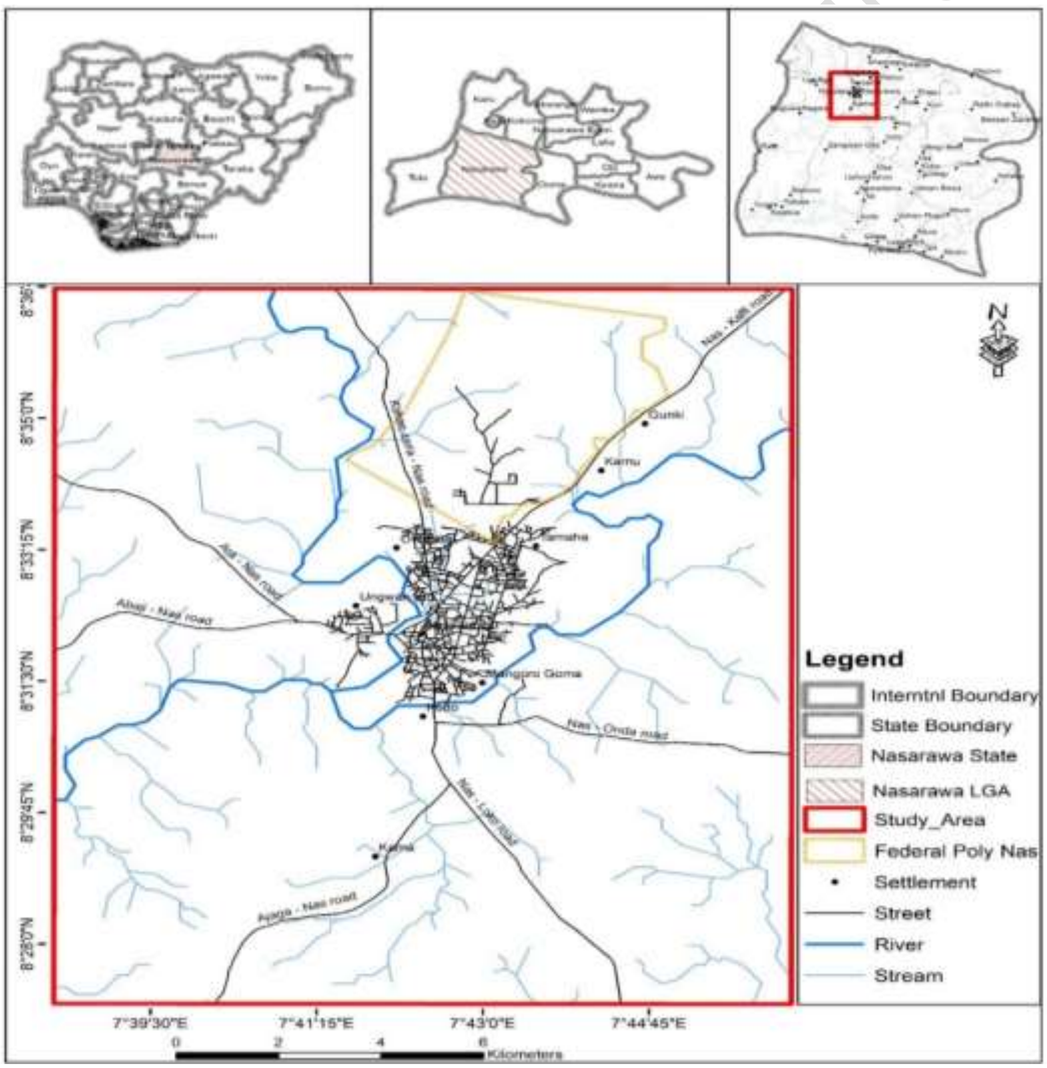


Figure 2: Study area

MATERIAL AND METHOD

GIS and remote sensing methods were used to carry out the study. While remotely sensed data were partly used as data sources, GIS was mainly used as an analytical tool. ArcGIS 10.5 and Envi 4.2 were the GIS softwares used throughout the study. Envi 4.2, which is basically a raster based GIS software was mainly used for image classification; while ArcGIS 10.5 was used for all other analysis.

Data used for this study includes data on street, river and stream networks, land-use, and altitude. The street network was sourced from Google Open Street Map (OSM). The river and stream networks, and altitudes were extracted by analyzing Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) of the study area. The land use of the study area was acquired from supervised classification of Landsat Enhanced Thematic Mapper (ETM+) satellite image of row 054, path 188 acquired on 12th of January, 2019; downloaded from United State Geologic Survey (USGS) website.

To achieve the aim of this study, which was to determine the most suitable parcels for solid waste disposal in Nasarawa town, the ArcGIS modelBuilder was used to design geo-processing models as presented in figure 3. Consequently, two different models (restriction and suitability models) were designed and used to summarize all the data acquired for this study. The output of the two models were later integrated in a third model (most suitable site model).

The restriction model was used to define restricted areas waste disposal sites must not be found within. Factors considered in the restriction model includes street, streams and rivers. These features were respectively buffered, the buffer extents converted to raster and later were all integrated using raster calculator to finally produce a restricted area raster. Restricted areas in this study included areas within 500m from rivers, 200m from streams and 300m from streets.

The suitability model was used to rank suitability of areas for solid waste disposal within Nasarawa. Factors considered in the suitability model includes elevation, street and land use. Here, the Euclidean distance for the street was first determine and reclassified together with the elevation, and finally integrated and ranked together with land use using weighted overlay to determine suitability of areas ranked on a scale of 1 to 5.

Finally, most suitable site model was used to integrate the result of the restriction model (restricted raster) and the result of the suitability model (suitability raster) using weighted overlay, to determine the most suitable parcels (parcels equal or greater than ten hectares).

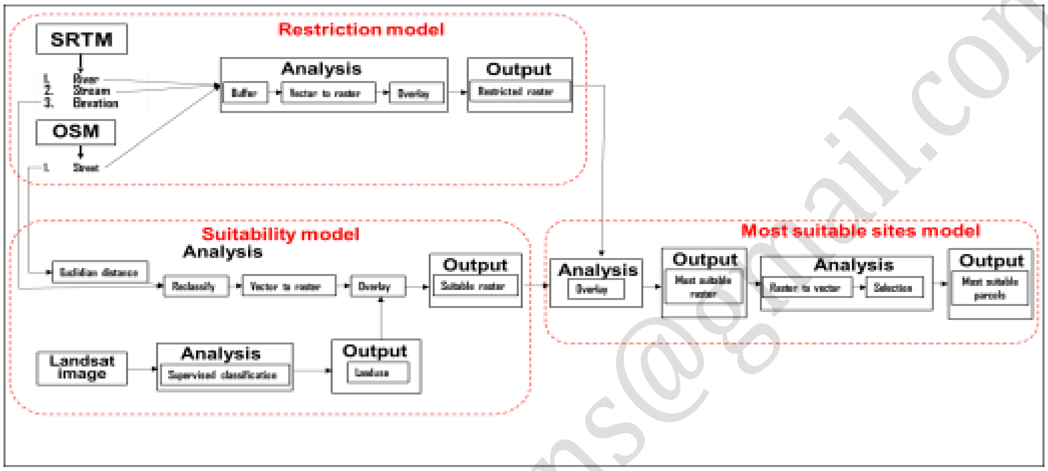
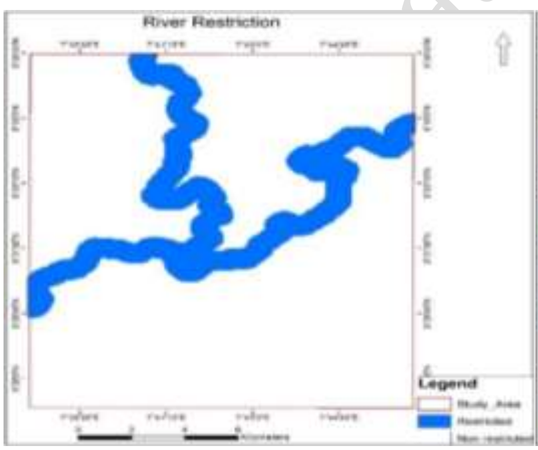


Figure 3: Models flow diagram

RESULT



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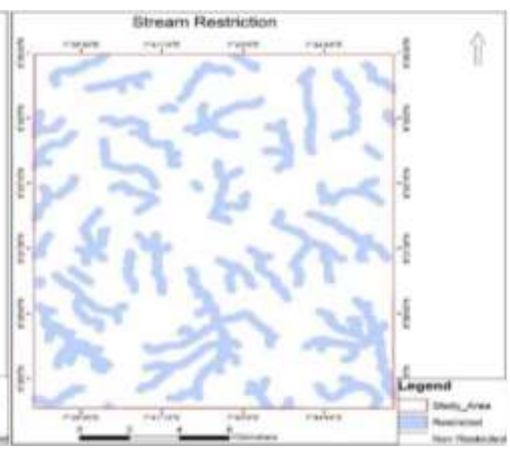

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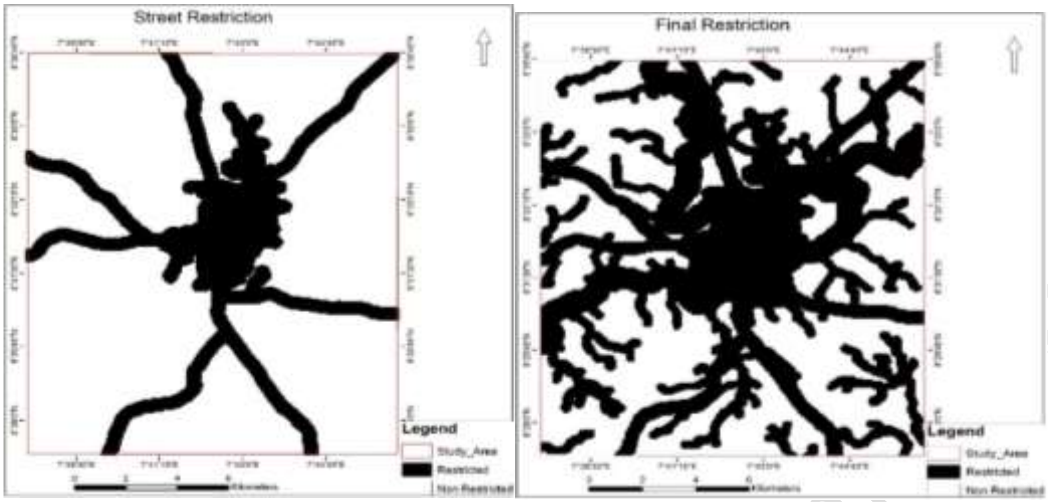

Figure 4: Restricted areas

Figures 4a, 4b and 4c present restricted areas based on distances from rivers, streams and streets respectively; while figure 4d presents the final restriction which integrate all the restrictions imposed. Restricted areas are areas within which waste disposal site must not be found.

Table 1: Restricted areas determination criteria.

Feature	**Distance from (meters)**
River	500
Stream	200
Street	300

Table 1 presents the criteria used in defining restricted areas.

Table 2: Suitability rank criteria

Rank	**Suitability**	**Distance from Street (Meters)**	**Elevation (Meters)**	**Land use Land cover**
5	Very High	301-800	167-196	Grass land Barren land
4	High	801-1200	197-207	Wood land
3	Medium	1201-2000	208-217	Rock outcrop
2	Low	>2000	218-229	Farm land
1	Very Low	1-300	230-417	Water body
0	Restricted			Built-up land

Table 2 present the criteria for ranking suitability of areas in relation to land use land cover, streets and elevation respectively.

a b

c d

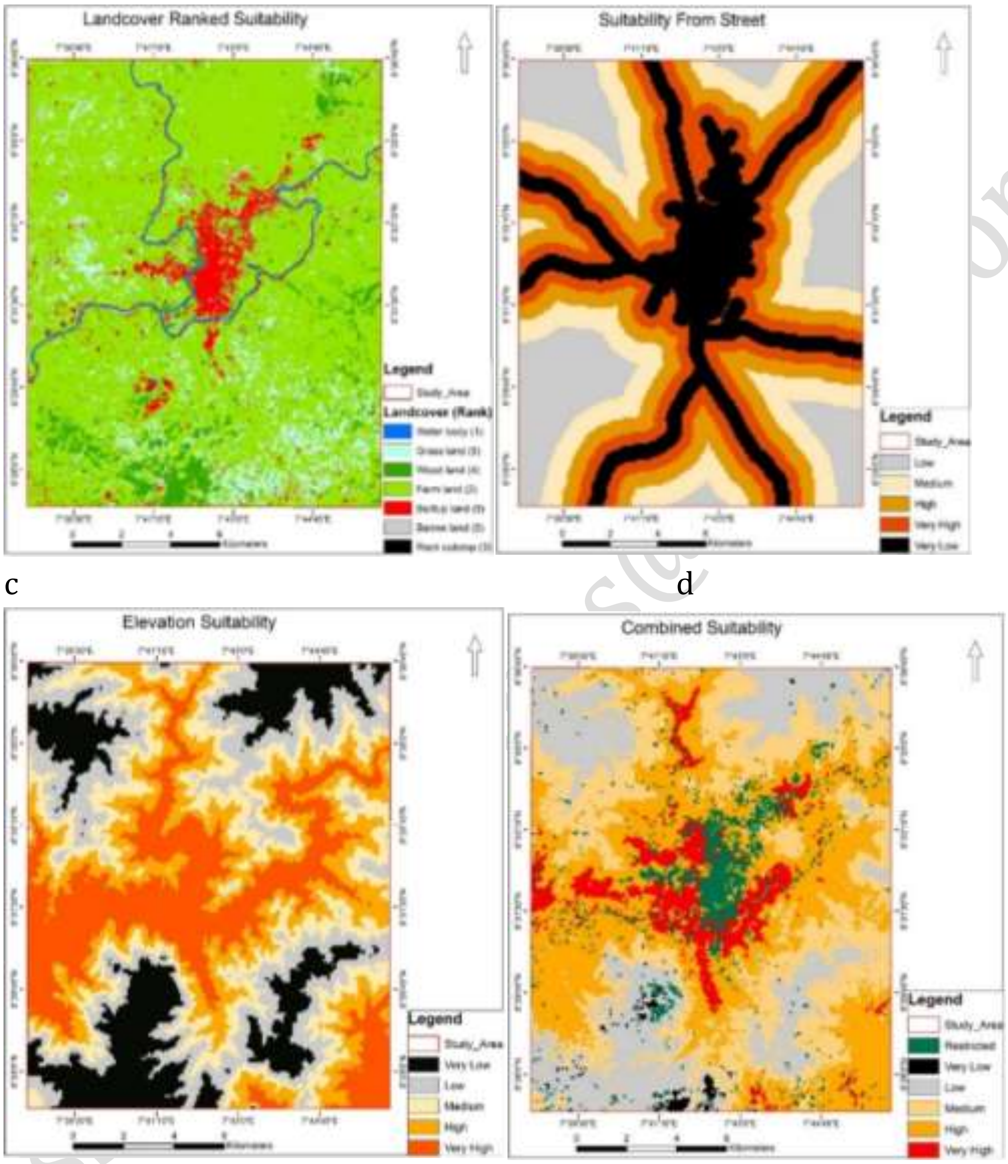

Figure 5: Areas suitability

Figure 5a, 5b and 5c presents suitability of areas in the study area for waste disposal in relation to land use land cover, streets and elevation respectively. Figure 5d present combined suitability, integrating suitability with respect to all the aforementioned criteria.

a b

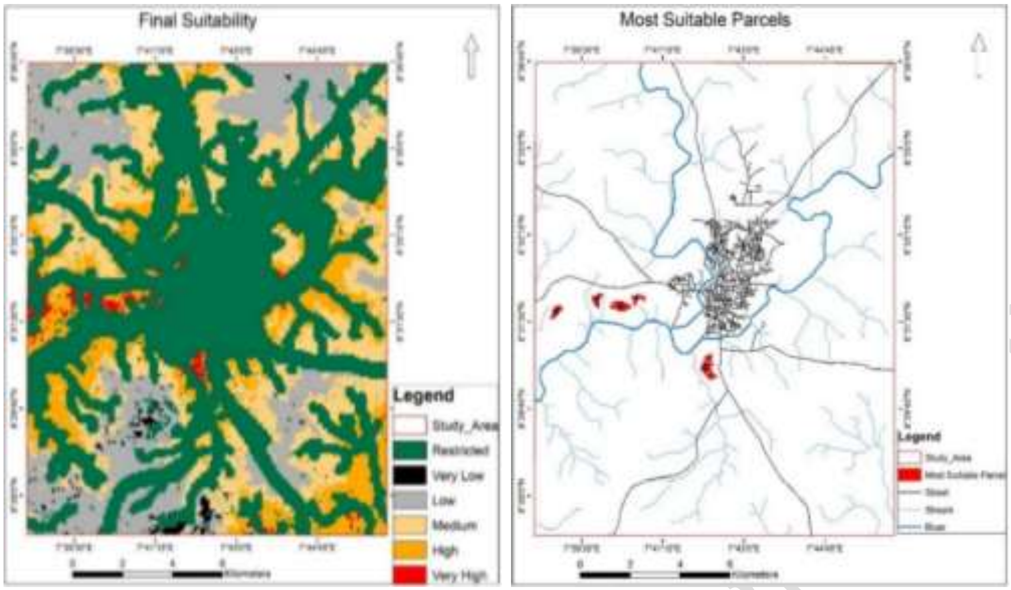

Figure 6: Final suitability

Figure 6a present final suitability of areas for solid waste disposal, integrating combine suitability and final restriction; while figure 6b present most suitable parcels for municipal solid waste disposal.

Table 3: Final suitability

Suitability	Rank	Total Area (Ha)	Total Area (sqkm)
Restricted	0	13178.45	131.7845
Very Low	1	169.28	1.6928
Low	2	4275.166	42.75166
Medium	3	4736.454	47.36454
High	4	2650.078	26.50078
Very High	5	190.44	1.9044

Table 3 present the final suitability of areas and their total respective sizes.

Table 4: Most suitable parcel

ID	Area (Hectares)
1	10.087832
2	12.60995
3	21.01655
4	11.769541
5	29.423975
Total Area	84.907848

Table 4 presents sizes of the parcels analyzed to be the most suitable parcels.

DISCUSSION

To analyze areas suitability for and determine most suitable parcels for municipal solid waste disposal in Nasarawa town, GIS and remote sensing method was adopted. Factors such as land use land cover, elevation, proximities or distance away from features such as streets, rivers, and streams with the study area were considered and ranked. Based on the factors considered in the analysis, some areas were defined restricted. These restricted areas are areas deemed totally unsuitable for municipal solid waste disposal. These restricted areas are built-up areas and areas within 500m, 200m and 300m away from rivers, streams and streets respectively. Other areas outside the restricted areas were analytically ranked and found to have either very high, high, medium, low or very low suitability for municipal solid waste disposal. And finally parcels found to be above 10 Ha from areas with very high suitability were selected as the most suitable sites for municipal solid waste disposal in Nasarawa.

The result indicates that of the total 25199.87 Ha or 251.9987 km^2 considered as the areas coverage of Nasarawa town, 13178.45 Ha or 131.7845 km^2 is not suitable for municipal solid waste disposal; of the remaining areas, 169.28 Ha have very low suitability; 4275.166 Ha have low suitability; 4736.454 Ha have medium suitability; 2650.078 Ha have high suitability; and 190.44 Ha have very high suitability (figure 3). And out of the areas of 190.44 Ha found to have very high suitability, only five locations mostly along Nasarawa – Abaji and Nasarawa – Loko roads axis's assessed to be up to 10 Ha or above, totaling about 84.907848 Ha are found to be most suitable (table 4) for municipal solid waste disposal in Nasarawa.

CONCLUSION

This study demonstrates the effectiveness of GIS and Remote sensing in location based suitability analysis studies in general and location suitability assessment for municipal solid waste in particular. The study can be helpful to Nasarawa local government authority in addressing the challenge of solid waste management considered as one of the problems confronting municipal and local authorities in especially developing countries the world over. The study also readily provides useful insight into the land use land cover situation in Nasarawa town. Thus, the study can be useful to both policy makers, researchers and professionals such as town planners, ecologist, agriculturist among others.

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