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SITE SUITABILTY ANALYSIS FOR SOLID WASTE LANDFILL SITE LOCATION USING GEOGRAPHIC INFORMATION SYSTEM IN YOLA NORTH L.G.A, ADAMAWA STATE

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ABSTRACT

Exponential increase in population in Jimeta and the resulting urbanization has brought the need to develop environmentally sustainable and efficient solid waste Landfill site. Landfill constitutes one of the primary methods of municipal solid waste disposal. Appropriate selection of landfill site is important in order to minimize environmental damage as well

Introduction

The aim of this study was to analyze the effectiveness of Geographic Information Systems (GIS) and remote sensing in the selection of suitable sites for a municipal landfill in Jimeta town. Specific objectives included to establishing the strategies used in the selection of the current landfill sites in Jimeta, assessing the suitability of the current landfill site, identifying suitable sites for landfill or dumping sites in Jimeta using GIS and remote sensing so as to produce a map showing environmentally suitable areas for locating dumping sites. Although a blueprint to adopting GIS technology in Yola municipalities have been evoked for by several researchers the practical application of GIS in landfill site selection is still very limited. In the waste management sector just like other industries people are largely uninformed of the tremendous potential of GIS and RS application in waste management. In environmental planning waste management had become a serious menace plaguing the cities, this

as to prevent negative impact to the public health, thereby improving the overall sustainability associated with the life cycle of the landfill. Current there is no proper landfill site in Jimeta and does not meet the appropriate landfill siting criteria which is not to be sited around artery road, resident area, airport water surface and high slope areas. Environmental implications of indiscriminate dumping of solid wastes on the society are enormous. In order to ensure a sustainable and clean environment, establishment of sanitary landfill for effective disposal of solid waste is very essential. A GIS-based multi-criteria decision analysis approach was a good tool to help in finding suitable sites for the disposal of urban solid wastes. This is expected to provide the decision makers with landfill suitability index in terms of unsuitable, low suitability, moderately suitable and high suitability in order to understanding probable areas for siting environmentally good landfill sites. To achieve this, Google earth imagery and Digital elevation model were subjected to image processing algorithms to generate following GIS layers: Slope, Airport layer, CBD, Settlement and road network. The multi criteria decision analysis technique was employed as a decision tool to decipher the Five factors that would enhance the siting of landfill in Jimeta Metropolis. From the analysis, a suitability map was created of which three locations were identified as suitable site for land fill (A,B and C). these locations were further analyze using synthesis of the models which identify location C as the most suitable and accept site out of the three locations for siting Landfill site in the study area.

Keywords: *Solid waste, Landfill, GIS, Analytical Network Process, weighted, suitability and hazards.*

is mainly due to lack of knowledge to newly developed technologies for efficient and proficient environmental performance GIS being the apt robust technology due to its ability to select the optimal sites for landfill location and collection routes optimization.

A method used in dumpsite location in Jimeta has been based on crude methods that do not take into account several environmental, social, economic and even political (administrative) factors. This is because of the ignorance of the power of Geographic Information System and remote sensing technologies that take into consideration all possible factors. Dumpsites are reliant on the environment. It is phenomena which in the lack of proper planning can tend to erode its resource base thereby threatening survival of the environment on which it is situated together with all life in their close proximity. GIS use has been very narrow in Jimeta in the waste management sector due to lack of know-how of the use of GIS and RS technologies in sustainable solid waste management and environmental planning. However, the situation at hand demands the adoption and application of GIS in locating a new landfill site. This research thus aims to formulate a technical GIS and remote sensing formula technique that can be used for locating optimal and sustainable sanitary landfills especially in Yola North context. The GIS and remote sensing technique for establishing suitable sanitary landfill sites is vital in bringing up sustainability in all environmental spheres ranging from the biophysical to the socio-economic aspects. The municipality will benefit from this research through achieving sustainable landfill standards that are acceptable to the surrounding community and environmentally responsive. The Environmental Management Agency can also tap from this research an ideology that can help them formulate a legally binding legislative framework that can be used in sanitary landfill sites location across the nation. In the Environmental Impact Assessment framework this research's methodology can be used as a tool for achieving a sustainable landfill for municipalities, mines or industries. The Environmental Impact Assessment framework will benefit the nation at large, Environmental Management Agency, and Environmental Consultancy Companies as a standard for EIA process. Furthermore, this research will shed light to all environmental participators that practice waste management that there is a more sustainable way for siting a landfill that can be adopted.

Generally, this research will add to the pool of knowledge concerning solid waste management. This research also will pave a way for others who may also want to carry out some further studies associated with sanitary landfill location using GIS and remote sensing. Above all this research will help in conserving the environment ranging from reduced water contamination, diseases spread, air pollution from the landfill etc.

Study Area

Jimeta, town, Adamawa state, eastern Nigeria. Jimeta as it's called today derived its name from one of the early (BATA) inhabitants or the place in Rugange area. The BATA people being fishermen lined on the Southern Bank of the river Benue from where the present Jimeta emerged. It lies on the south bank of the Benue River, and on the highway between Zing and Girei with its geographical coordinates are 9° 17' 0" North, 12° 28' 0" East and its original. Merged with Yola in 1935 by the Fulani administration, Jimeta regained independent town status with its own council in 1955. The town's population was 73,080 in 1991. The elevation of Jimeta is 135 m, with the construction of a spur road to Yola (5.5 miles [9 km] south-southeast), the town became a river port for Yola, gradually taking over most of the river-borne traffic along the Benue River. From mid-July to mid-October, when the Benue has deep water, boats carry peanuts (groundnuts) and cotton from Cameroon and hides and skins from the hinterland of Yola-Jimeta downstream to the Niger River delta ports for export. Local trade handles sorghum, millet, yams, shea nuts, onions, peppers, indigo, cattle, sheep, goats, and poultry.

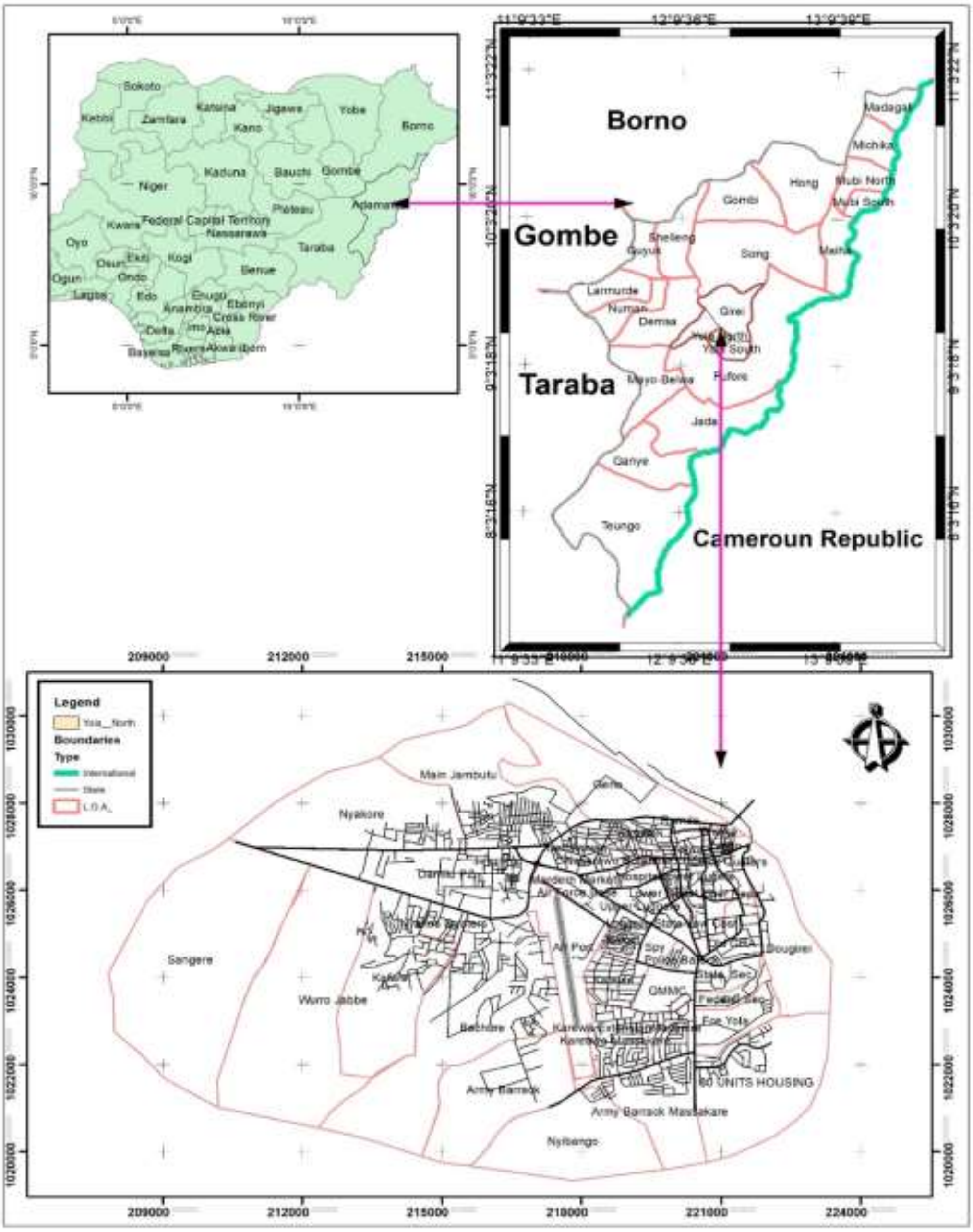


Figure 2.1. location Map of Jimeta/Yola North Local Government Area (Study area map)
Source: ArcGIS 10.8 (G N TSUNDASS NIG LTD)

3.0 Method and Data Analysis

3.1 Data Required

The data required to successfully carry out this research are as follows;
Physical condition of the study area

i. Base map of the study area

ii. Digital Elevation Model
iii. Existing Waste disposal conditions

Data Types And Sources

Table 3.1; Sources and Types of Data Used in achieving Objectives

S/N	Dataset Name	Description	Source	Type of Data	Year
1	Road Network	Line feature	Digitized Google Maps	Static	2000, '09, '19
2	Built up areas	Polygon feature	Open street maps	Static	2021
3	Water Body	Polygon feature	Open street maps	Static	2021
4	Airport	Polygon feature	Open street map	Static	2021
	CBD	Point feature	Open street map	Static	2021
5	Digital Elevation Model (DEM)	.tiff raster	USGS Earth Explorer	Dynamic	2021

Source; Research, 2021

Methods of Data Analysis

Digitizing

Digitizing is a digital process of converting image data to vector digital format. The researcher generated data using digitization. The data created included points lines and polygons. Using the mouse cursor by tracing on scanned images and Google Maps Lines the researcher managed to generate data in form of points lines and polygons. The data representing the geographical features were saved as shape files manipulative by the GIS software. The data were saved as distinct layers separately for the sake of separate buffering determinant on the specific parameters used for analyzing the data. For example, a layer for road network was saved separate from other geographic phenomenon like rivers and residential area layers.

Buffering/Euclidean Distance

Buffering is a well pronounced way of producing areas or regions of numerically calculated distances from a feature which can be a point, line or polygon (Lunkapis 2006). This process is achieved through reclassification of regions from a feature. With regard to Jimeta land uses the researcher used buffering as a technique of distinguishing unsuitable areas for locating dumpsites. Using ARCMAP 10.2.2, the considered environmental parameters using respective buffer distances were buffered. The buffered parameters included hydrological network, roads, water bodies and the central business district. The buffer distances were drawn from literature and were backed by Yola North Urban development board. Finally, a framework similar to the one provided by (Pawandiwa, 2013).

Euclidean Distance Analysis

Euclidean Distance is a tool that gives the distance from each cell in the raster to the closest source. This process was used to determine the distance of road, urban settlement, rural settlement and stream. The table below shows the classes and their corresponding distances; Environmental parameters and their respective buffer distances Landfill selection criteria according to Environmental Protection Agency (EPA).

Table 3.2; Classes and their corresponding distances

S/No	Item Description
1	The site should be 7000m away from an urban area
2	The site should be 3000m away from forest area
3	The site should be 3000m away from forest area
4	The site should be 2000m away from water source i.e. running stream in order to prevent leachate passage
5	The site must be 2000m away from road for easy access
6	Leachate collection point should be built within the landfill site

7	Construction of bole hole for time to time monitoring to detect contamination of water
8	The landfill must be fenced and an office attached to security purpose
9	The site must be in stable environment i.e. soil should not be porous but loamy clay
10	A good drainage system
11	The slope should be less than ≤ 12°
12	The geology of the site should have a good hydraulic conductivity and the permeability level should be moderate.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty (1977 and 1994). The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub criteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency. AHP allow some small inconsistency in judgment because human is not always consistent.
AHP involves the following step-wise processes:

Selection of criterion

Use of paired comparison matrix for setting priority or weighting of criterion Pair wise comparison of options on each criterion For each option to get an overall score AHP is quite helpful in solving the complex sustainability issues and the difficulties regarding the decisions which are decomposed into small components and are organized hierarchically. Paired comparison approach is considered as most reliable technique because each individual trade-off is included by the decision makers which increase the accuracy of the process and results.

Weighted overlay

Is a tool in spatial analyst tools that Overlays several raster datasets using a common measurement scale and weights each according to its importance? The reclassified raster was overlaid together in order to produce a suitability map identifying areas suitable. For the weighted overlay operation to be successful, the raster dataset must be in integer.

Criteria to be Considered

1. Built up area 2. Road 3. Slope 4. Water body 5. Airport

All of the criteria were incorporated in the super decision software and each criterion was compare to another with accordance of relative importance using ANP. In an ANP network model, the interactions among the elements are illustrated by arcs and the directions show the dependency of one criterion to another. The goal is connected to criteria by an arrow which indicates that there is relationship between them. Also, criteria are connected to each other. The internal dependencies among the criteria of a criterion cluster are represented by loop of arcs. (Saaty, 2003)

Roads:

Landfill location must be close to roads network for accessibility and ease of transportation, consequently reducing relative costs. Minimum and maximum distance from road network for this study was set after summarizing different literatures. Most studies suggest that landfills should be located within a 1 km buffer from the roads and other transportation facilities. For this study a distance of greater than 1000 m from road network is considered as the best distance for siting process.

Water Bodies:

In order to reduce vulnerability to ground and surface water pollution from contamination, landfills should not be located near streams and river. multiple ring buffers were used to prepare multiple polygons around each streams and rivers within the following distances: 0-500,500-1000,1000-1500, >1500m.

Airport:
Site for landfill should be safe distance from the airport to prevent interference of the birds and dust arising from the waste with pilot. Therefore, a distance of 3000m and above was considered suitable location of landfill from the airport (National Indonesia Standards., 2008).

Built up Area:
Distance of 500m and above from the urban area to the landfill was considered as the suitable location of landfill sites (Mohd Din, 2008). The aim is to protect sensitive areas from being affected by landfill siting. This is to avoid health problems and decrease in land value and any future development.

Central Business District (CBD):
Land fill most be sited within the minimum distance of 3,000m away from the CBD. This was considered as the suitable location of landfill sites (Mohd Din, 2008). The aim is to protect sensitive areas from being affected by landfill locations.

Planning Criteria for Selection of Land Fill Site
Landfill site for solid wastes should be selected on following criteria:
Land area and volume should be sufficient enough to provide landfill capacity so that the projected need can be fulfilled for several years. In this way the cost coming on all that procedure can be justified.
The landfill site should not be at locations where suitable buffer zones between land fill site and population are not available.
The landfill area having steep gradient (where stability of slope could be problematic) should not be selected.
The water level in ground water table should be sufficient below the base of any excavation to enable landfill development.

The land which is significant environmentally (lands of biodiversity); the sensitive ecological area of such a land should be present within potential area of landfill site.
Public & private irrigation water supply wells should be well away from the boundaries of landfill site because these supply wells will be at risk of contamination.
Landfill area should not be very close to significant water bodies (water courses or dams). There will be the risk of contamination of water bodies, which can be hazardous for aquatic life.
No major power transmission or other infrastructure like sewers, water supply lines should be crossing through landfill developmental area.
No residential development should be near the boundaries of landfill site. The waste disposal site must be very away from residential or commercial areas and water resources.
Landscaping and protective shelf should be included in the design so that to minimize the visibility of operations.
Unstable areas that have significant seismic risk which could cause destruction of berms are not recommended for landfill site.
There should not be fault lines and significantly fractured geological structure. These fault lines can allow the unpredictable movement of gas within 500 meters of perimeter of proposed landfill development.
Groundwater quality should not be disturbed during the site developmental phase. There should be monitoring facilities at site in order to ensure that ground water quality is maintained.
In areas under the laws of concerned municipality it should be responsibility of municipality to identify landfill site and handover to operators for operations.
Selection of landfill site should be based upon the examination of environmental issues.
The landfill site should be near the wastes recycling facility otherwise, the waste recycling facility should be planned as integral part of landfill site.

Constraints

Built up areas/settlement and water bodies will be the major constraints in siting land fill site in Jimeta. This is because waste if not properly manages and disposed leads to spread of various communicable diseases causing death of people through cholera, typhoid, measles, Diarrhea, polluting the water causing death of aquatic animals like fishes, toads etc. and general air pollution.

ANALYSIS

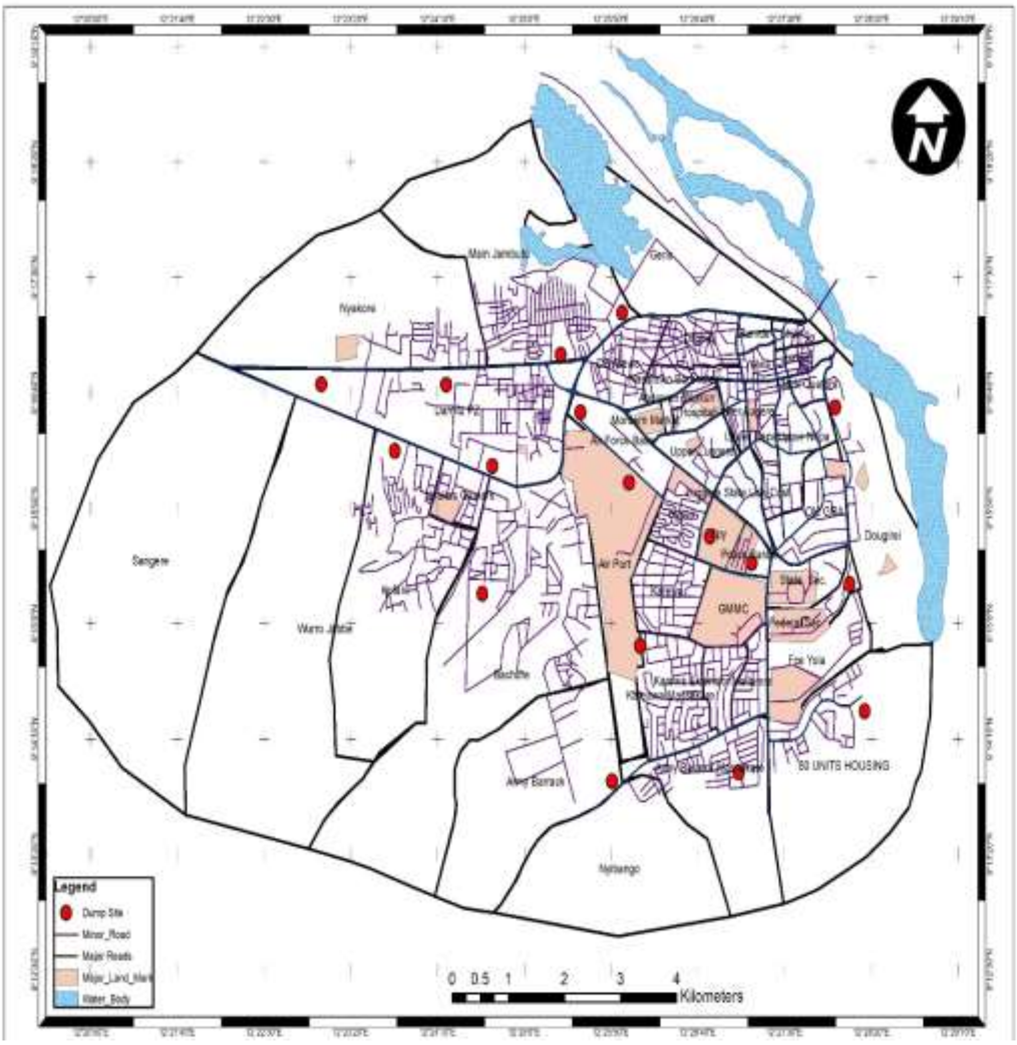
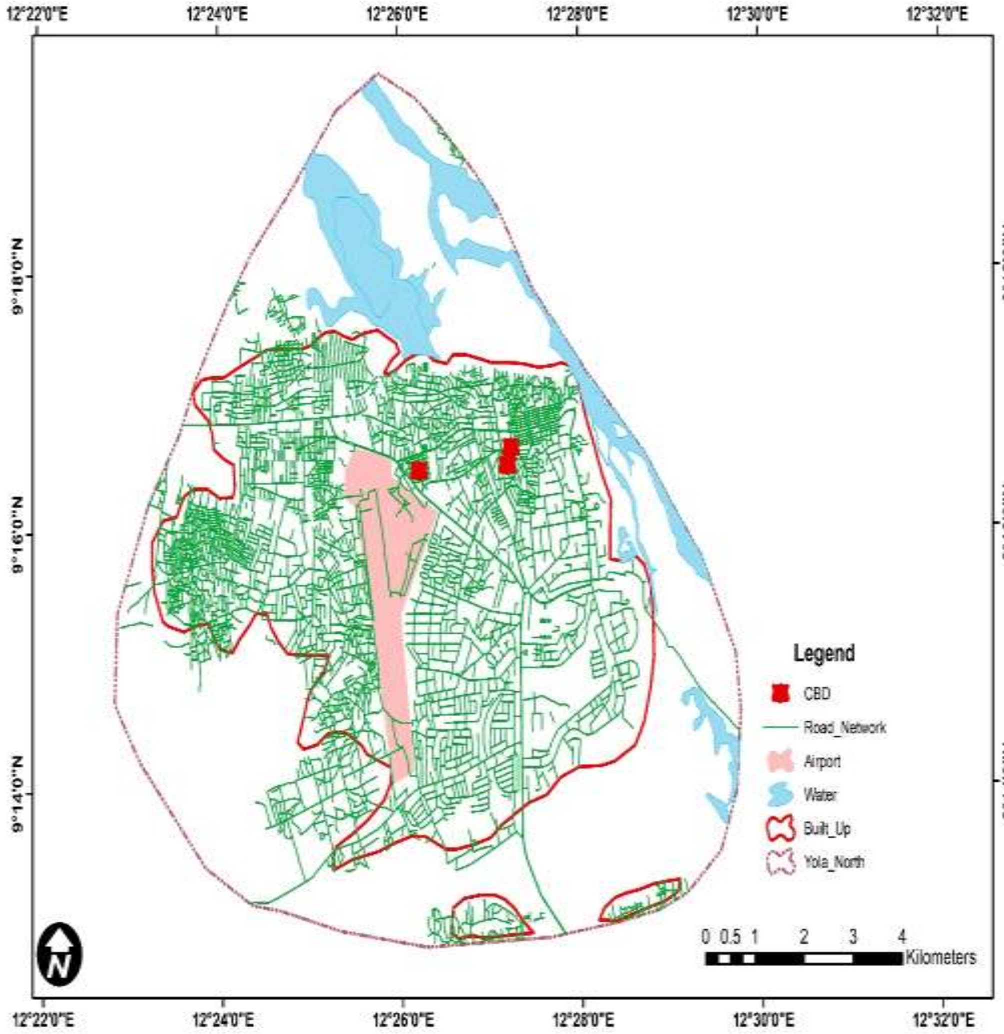


Figure 3.1 Map of the study Jimeta Showing the Existing Dump Site
Source: ArcGIS 10.8 (G N TSUNDASS NIG LTD)

Location suitability against considered Factors.

The study used a number of environmental parameters or factors to establish the potentially suitable sites for locating dumpsites in Jimeta. Parameters used range from road the network, Water bodies, Central Business District to build up areas. Using the map layers for these parameters buffer/Euclidean Distance had been established for each parameter.



: Unprocessed Factors incorporated together to be considered for Identifying Land fill site in the study area.

Slope Suitability

Slope is needed to get a good drainage system to prevent leaching of waste water and other soluble from landfill into underground and surface water. It is also important because it affects the ease of construction and susceptibility to land sliding (Dai et al. 2001; Kolas et al. 2006; Sumanthi et al. 2008). The study area slope map was generated from SRTM data using Universal Traverse Mercator WGS 1984 Zone 33 and reclassified into four classes of 1 to 4, highly suitable, moderately suitable, less suitable and unsuitable.

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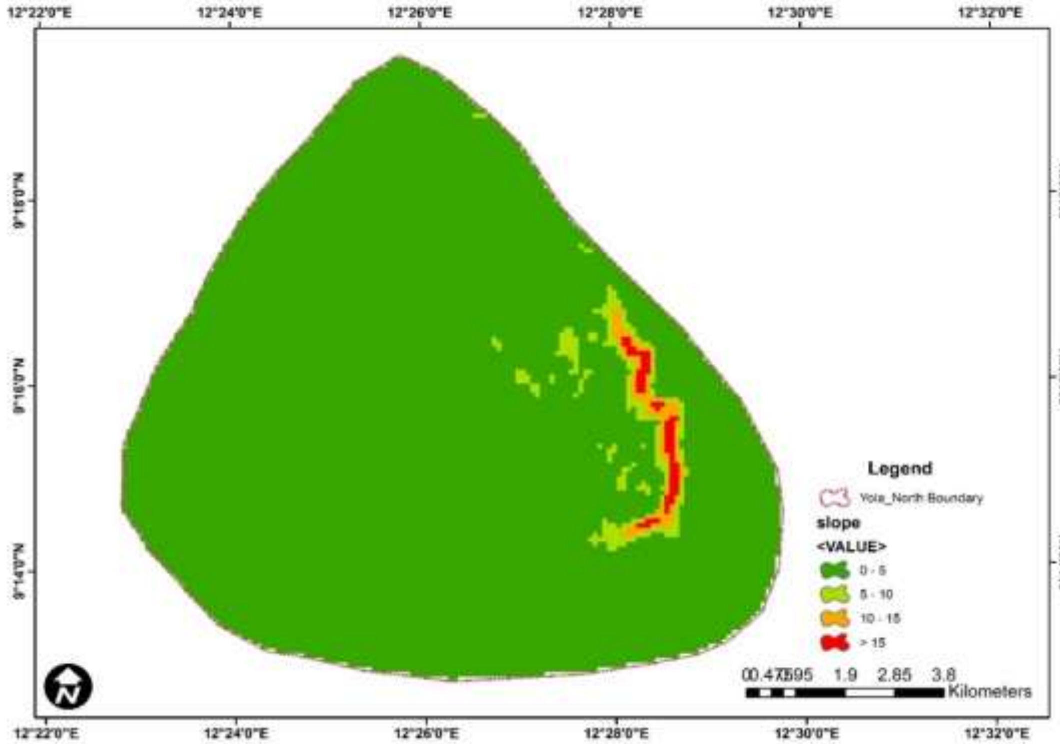


Analysis of Slope class with their respective suitability levels

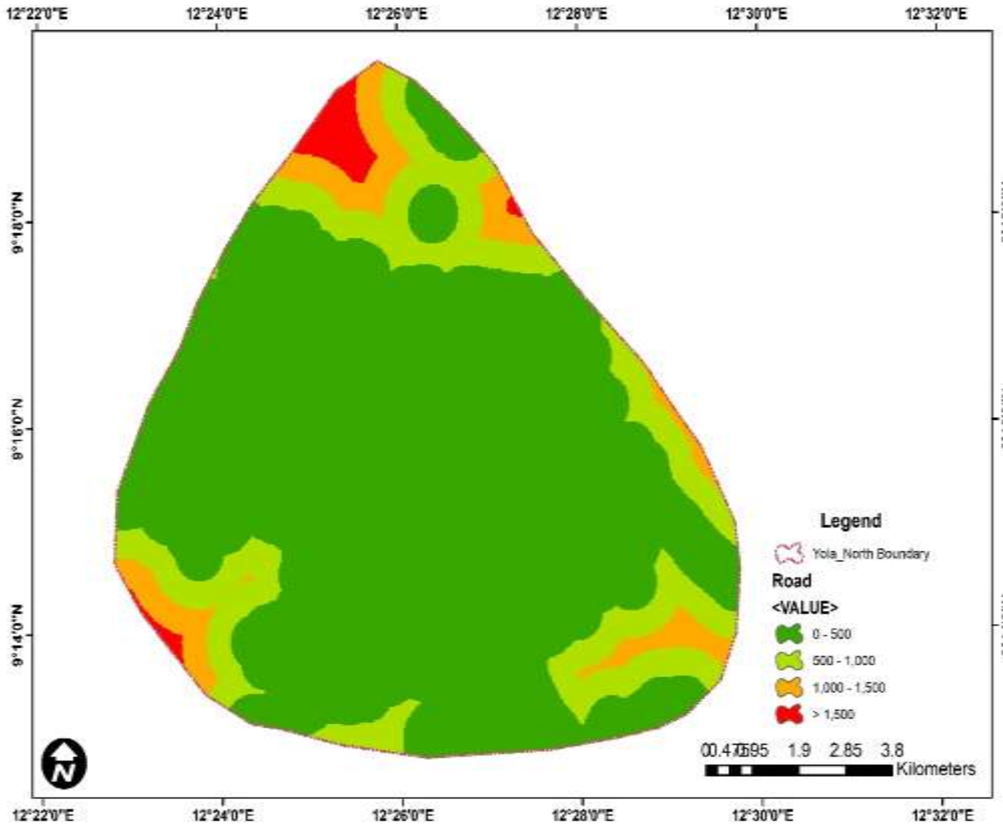
Table 4.1. Slope Suitability Classification

	Scale	Score	Classification	
Slope	Greater than 15	4	Most Suitable	Factor 1
	10-15	3	Suitable	
	5-10	2	Less Suitable	
	0-5	1	Unsuitable	

The above analysis shows that Scale 0-5 scoring 1 is considered as the unsuitable site due to the height of the area. 10-15 is considered as the most suitable site for locating Landfill site.

Suitability against major roads.

The general trend has most of the roads converging in the Central Business District. Using the 700-meter buffer for major roads and 500 meters for other roads are suitable for Land fill. This shows that the whole region that lies within the 1000 meter and 500-meter buffer of the road are suitable for establishing a landfill. The map serves to distinguish suitable areas and unsuitable areas for landfill location. Economically, the dumpsite should not be very far from the point of generation and should also be easily accessible. The road network in turn should not lie very far from the landfill site and as well it should not also be situated in the immediate zone of the road network more importantly the major roads.



Analysis of Road network class with their respective suitability levels

Table 4.2 . Road Network Suitability Classification

	Scale	Score	Classification	
Road Network	0-500	4	Most Suitable	Factor 2
	500-1000	3	Suitable	
	1000-1500	2	Less Suitable	
	Greater than 1500	1	Unsuitable	

The Figure and table Classification above show that the red colored zone scaled above 1500 is considered as unsuitable for siting landfill due to the distance and the Green zone is considered as Most suitable.

Suitability against Water bodies

Jimeta is a poorly drained area probably as a result of its clay soils that do not permit effective infiltration but rather surface runoff. Coupled with its undulating terrain it also has numerous runoff water. A landfill should not lie any closer to a hydrological feature because of it higher potential to pollute water sources through leachates and surface runoff as they are sources of higher concentrations of pollutants. Therefore, Water body is considered as a constraint in the analysis.

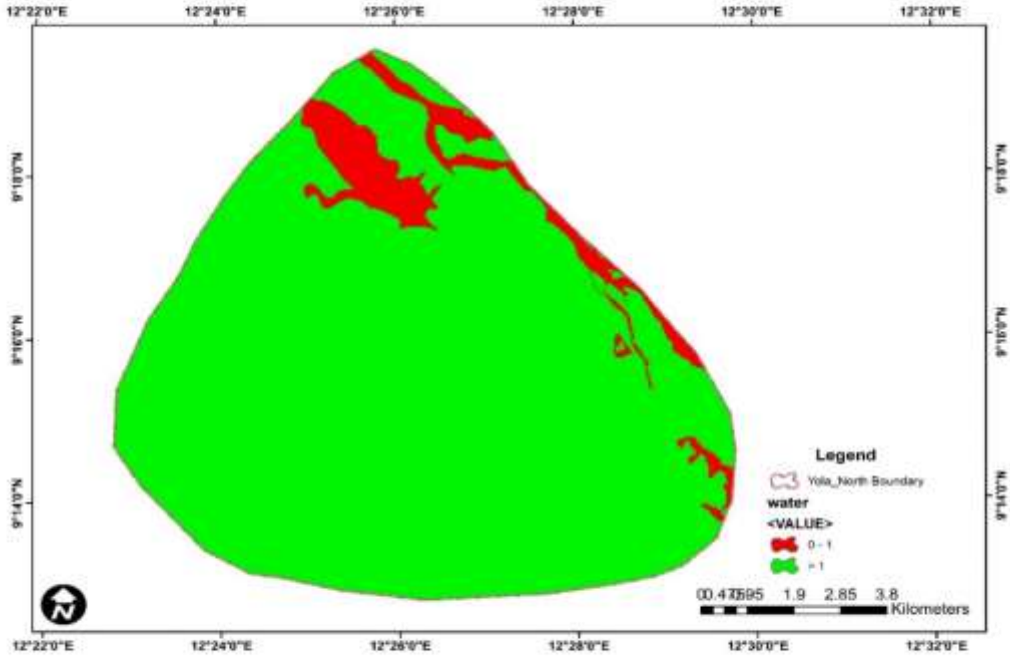


Figure Analysis of Water bodies class with their respective suitability levels

The above shows that the areas in Red polygon is considered as unsuitable while the area in blue are considered as suitable locations from water bodies and should be sited not less than 700m away from the water bodies to avoid having contacts with the stream, or rivers or any water bodies.

Table 4.3 . Water Bodies Suitability Classification

Water Bodies	Scale	Score	Classification	Constraints
	Inside polygon	4	Most Suitable	1

	Outside polygon	1	Unsuitable	

Suitability against built-up features

The Built-up areas or developed areas are illustrated in the figure below. The developed areas cover a wide spectrum of varied structured for different purposes usually around the vicinity of the Central Business District. The Built up area is also considered as the second constraints in the analysis because Human built areas are factors to be considered as highly important in siting Landfill site in the study area. There for all areas in blue are suitable for landfill locations.

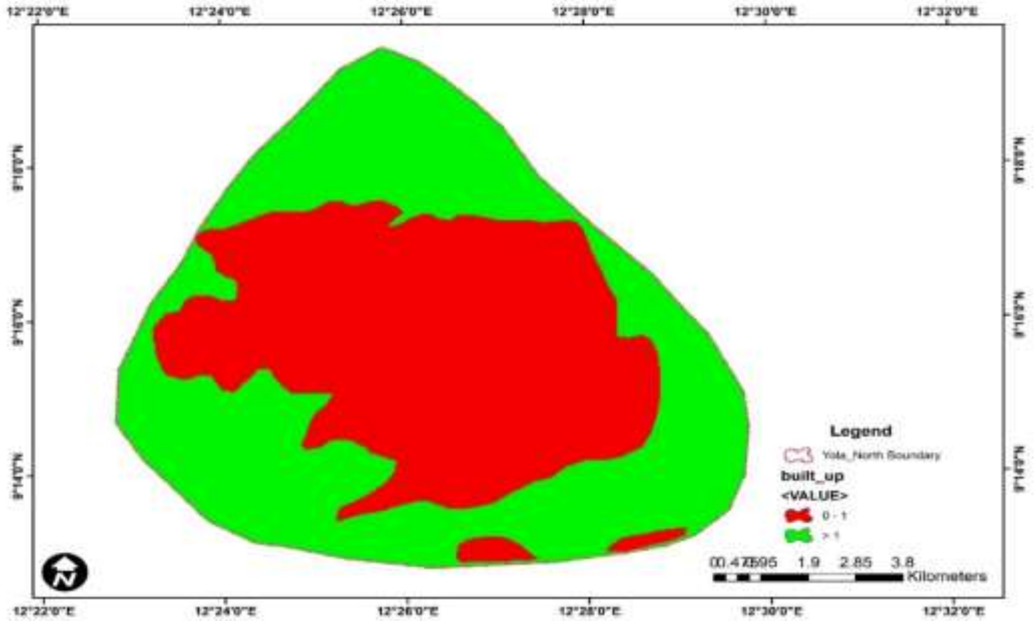


Figure Analysis of built up features class with their respective suitability levels

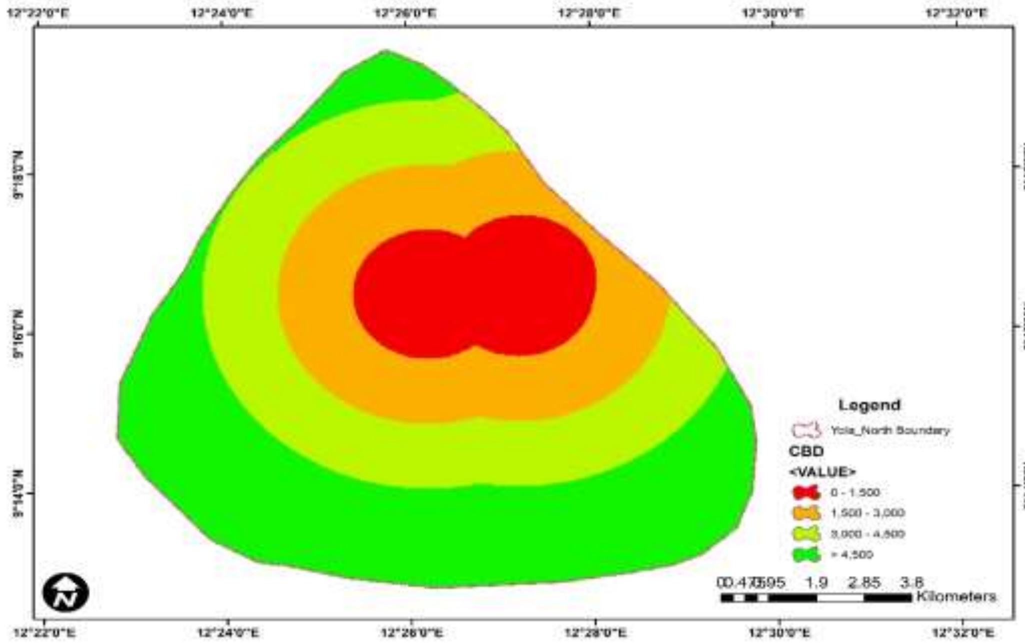
Table 4.4 Built-up Areas Suitability Classification

	Scale	Score	Classification	
Built-up areas	Inside polygon	1	Unsuitable	Constraints 2
	Outside polygon	4	Most Suitable	

The residents of the area where the current dumpsite is located complained that they were affected by odors, noise and visual intrusion effects from the dumpsite. Like other criteria, settlement areas were classified according to their suitability. The study considered the reclassified distances as unsuitable from 0 to 2500 m, less suitable between 2500 and 4500 m, suitable from 4500 to 5500 m and most suitable from 5500 to 7000 m for the urban area, urban settlement was reclassified into four (4) classes. This was done so as to further simplified their level of suitability.

Suitability against the CBD

A buffer distance of 3000 Meters from the CBD was used based on the size of Jimeta town to test for suitability. According to the map the Dumpsite threatens the relative position of the CBD since it lies within its 3000 buffer. The effect of the dumpsite reaches the CBD making its position not suitable this serves as a function for town expansion that if the town continues to grow the dump will be found even within the urban built up area.



FAnalysis of CBD class with their respective suitability levels

The map also provides for a suitability map which shows potentially suitable and the unsuitable region from which in terms of planning a dumpsite should be situated. The map has factored out the 3000 regions from the CBD as it is not suitable for landfill location. For suitability mapping, the CBD buffer is used as an overlay layer because it is used as a critical parameter in siting landfill sites.

Table 4.5. Central Business District (CBD) Suitability Classification

	Scale	Score	Classification	
CBD	0-1500	1	Unsuitable	Factor 3
	1500-3000	2	Less Suitable	
	3000-4500	3	Suitable	
	4500 and above	1	Unsuitable	

Analytical Hierarchical Process

AHP is a structured and hierarchical decision-making process used in solving complex decisions. It reduces complex decisions to a series of pairwise comparisons. This process captures both subjective and objective aspects of decision. Furthermore, the process includes an added step that checks the inconsistency of the decision maker's evaluations to reduce bias in the decision-making process.

The AHP process commences with a creation of a pairwise matrix where each criteria (factor) is compared to each other and assigned a numeric scale (Judgement Value from 1 to 9). See **Table Below.**

Table 4.6; Saaty's pairwise comparison scale

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two factors contribute equally
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favor one factor over another
4	Moderate Plus	

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5	Strong Importance	Experience and Judgement strongly favor one factor over another
6	Strong Plus	
7	Very strong or Demonstrated Importance	One factor is favored very strongly over another, its dominance demonstrated in practice
8	Very, very strong	
9	Extreme Importance	

Note: For instance, if factor A is compared to factor B, and factor A is assigned one of the numbers above (1-9), then factor B will be assigned the reciprocal value of A (i.e. 1 / (value for A)

Table 4.7 : AHP Pairwise Comparison Matrix

Weightage of Factors					
1	Airport	Road	Built up Area	Slope	CBD
Airport	1.000	0.500	0.333	3.000	0.333
Road	2.000	1.000	0.500	3.000	0.333
Built up Area	3.000	2.000	1.000	6.000	2.000
Slope	0.333	0.333	0.167	1.000	0.500
CBD	3.000	3.000	0.500	2.000	1.000
Total =	**9.333**	**6.833**	**2.500**	**15.000**	**4.167**

Each factor is compared to another and assigned a judgement value. To construct **Table 4.5**, each factor is compared to another on a pair by pair basis. See (row 2, column 2) - *Airport* is compared to *airport* and assigned a 1 (since comparing a factor with itself). In row 4, column 5 – a judgement value of 6 is assigned between the comparison of the *Built-up area* factor with *Slope* factor and in column 2, row 5 a judgement value of 3 is assigned to the comparison of *CBD* with *Airport*.

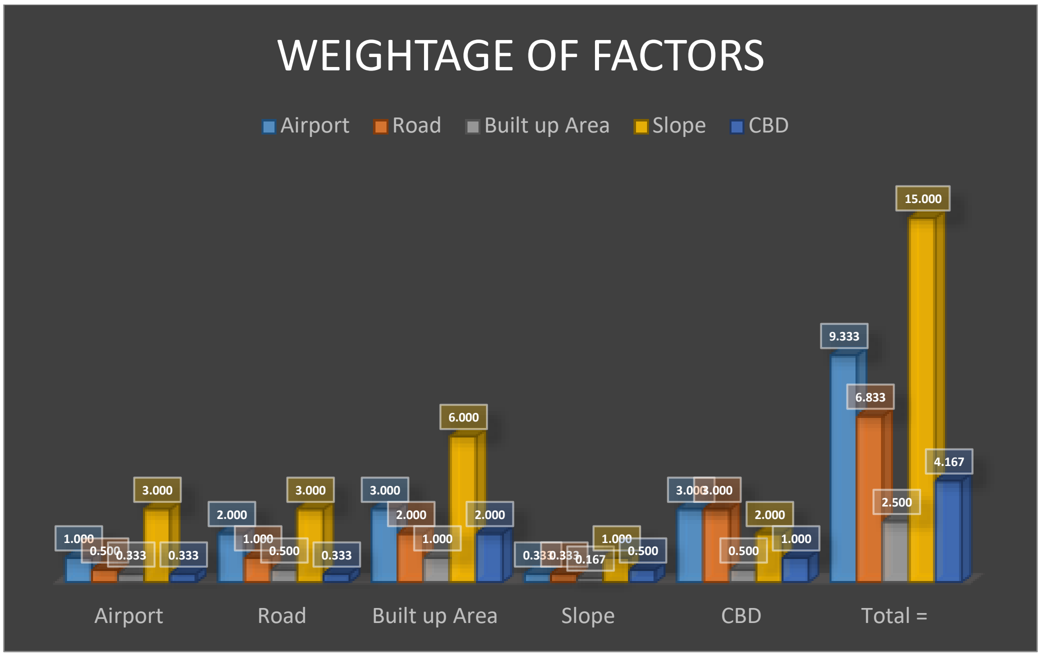

Figure4.1; Weightage of Factors

In the preparation of this weightage procedure, I did not have the opportunity to arrange such a meeting and therefore the numbers assigned above are based on researched interviews and my personal feeling on the relative importance of one factor over another.

The normalization process involved dividing each of the record in **Table 4.5** by its corresponding column total. The result was a normalized relative weighting. See **Table 4.6** for normalization and weighting calculations.

Table 4.8; AHP Pairwise Comparison Normalized Matrix

Normalization of Factors and Calculation of Priorities						
2	Airport	Road	Built up Area	Slope	CBD	**Priority**
Airport	0.107	0.293	0.133	0.200	0.080	**0.163**
Road	0.054	0.146	0.200	0.200	0.080	**0.136**
Built up Area	0.321	0.293	0.400	0.400	0.480	**0.379**
Slope	0.036	0.049	0.067	0.067	0.120	**0.068**
CBD	0.321	0.439	0.200	0.133	0.240	**0.267**
Priority = Average Sum of Normalized Weights						

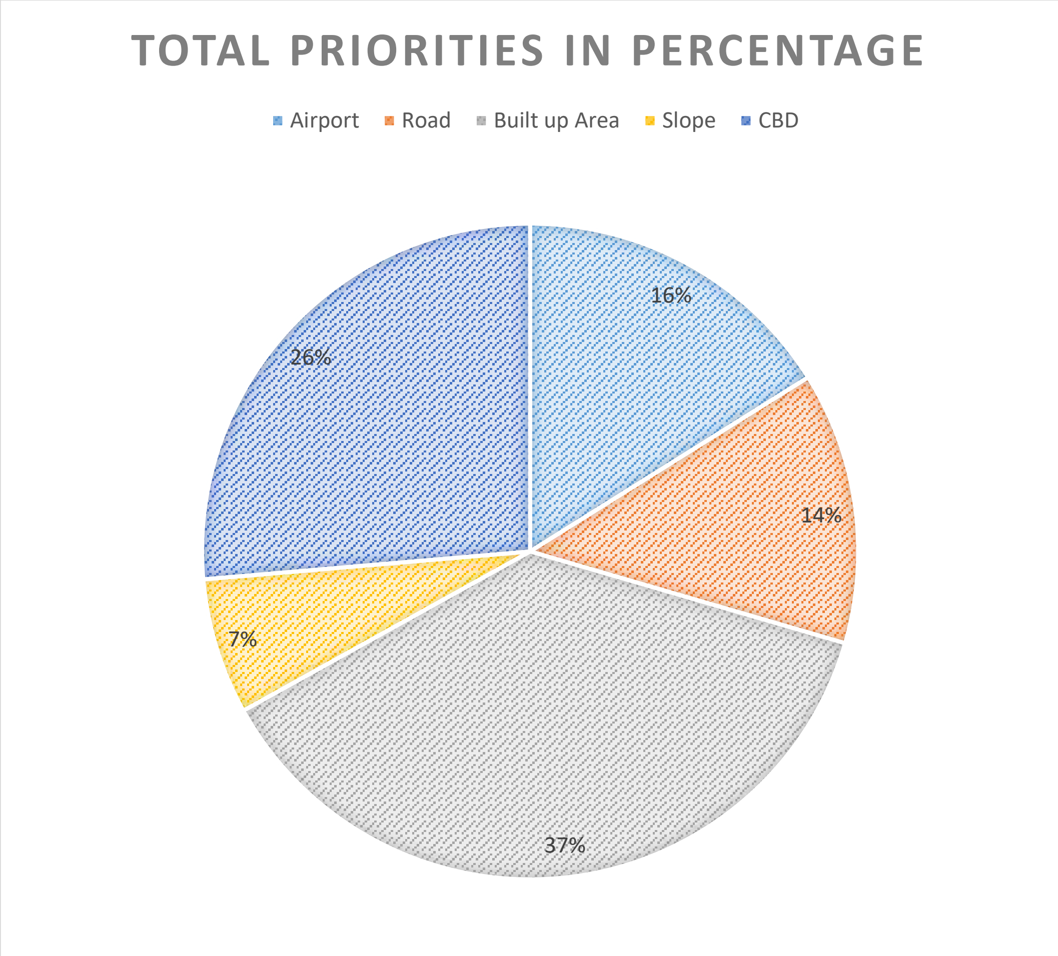

Figure4.2 Total Priorities in Percentage

According to the normalized Eigen vector (also known as priority vector), Built-up areas was the most important factor weighted at (37%), followed by CBD (26%), Airport (16%), Road (14%), and Slope (7%). For this purpose, AHP calculates a consistency ratio (CR) comparing the consistency index (CI) of the matrix in question (the one with our judgments) versus the consistency index of a random-like matrix (RI). A random matrix is one where the judgments have been entered randomly and therefore it is expected to be highly inconsistent. More specifically, RI is the average CI of 500 randomly filled in matrices. Saaty (2012) provides the calculated RI value for matrices of different sizes as shown below;

CR = Consistency Index (CI) / Random Consistency Index (RI)

$CI = \lambda_{max} / n$

Note: λ_{max} is the Principal Eigen value and n = number of factors

Table 4.9; Calculation of Weighted Sum

CALCULATION OF WEIGHTED SUM						
4	Airport	Road	Built up Area	Slope	CBD	
Criteria Weights =	0.163	0.136	0.379	0.068	0.267	**Weighted Sum**
Airport	0.163	0.272	0.126	0.203	0.089	**0.852**
Road	0.081	0.136	0.189	0.203	0.089	**0.698**
Built up Area	0.488	0.272	0.379	0.405	0.534	**2.078**
Slope	0.054	0.045	0.063	0.068	0.133	**0.364**
CBD	0.488	0.408	0.189	0.135	0.133	**1.354**

The Principal Eigen value (λ_{max}) is obtained by multiplying the summation of products between each element of the Eigen vector above by the sum of columns of the reciprocal matrix and summing each row to derive a weighted sum as shown in above. Hence, the Principal Eigen value (λ_{max}) is the sum of divisions between the weighted sums and priority vector. Mathematically expressed as;

CR = Consistency Index (CI) / Random Consistency Index (RI)

CI = λ_{max} /n

Note: λ_{max} is the Principal Eigen value and n = number of factors, i.e. λ_{max} = WS/CW

λ_{max} = (0.852/0.163) + (0.698/0.136) + (2.078/0.379) + (0.364/0.068) + (1.354/0.267) = 5.264

The CI = 5.264 – 5 / 5 – 1 = ***0.065***

Table 4.10; Random Consistency Index Table

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.25	1.32	1.41	1.45	1.49

Source; Saaty (2012)

Based on the Relative Consistency Index Table by Saaty (See **Table 4.8** above) the Consistency Ratio was calculated as:

CR = 0.065 / 1.12 = 0.0589

Possible suitable sites determination by overlay analysis

All the crucial parameters were overlaid in GIS to produce a map that shows the possible suitable sites for locating a dumpsite against the unsuitable regions according to the considered parameters. The result of the overlay analysis is shown below. According to the overlay, three sites where determined to be suitable foe siting landfill site in the study area namely; Location A, B and C.

The overlay map shows numerous potentially suitable sites for situating a landfill. All areas represented by green color code are potential sites for landfill location. A total number of almost 3 potential sites were established as clearly represented below.

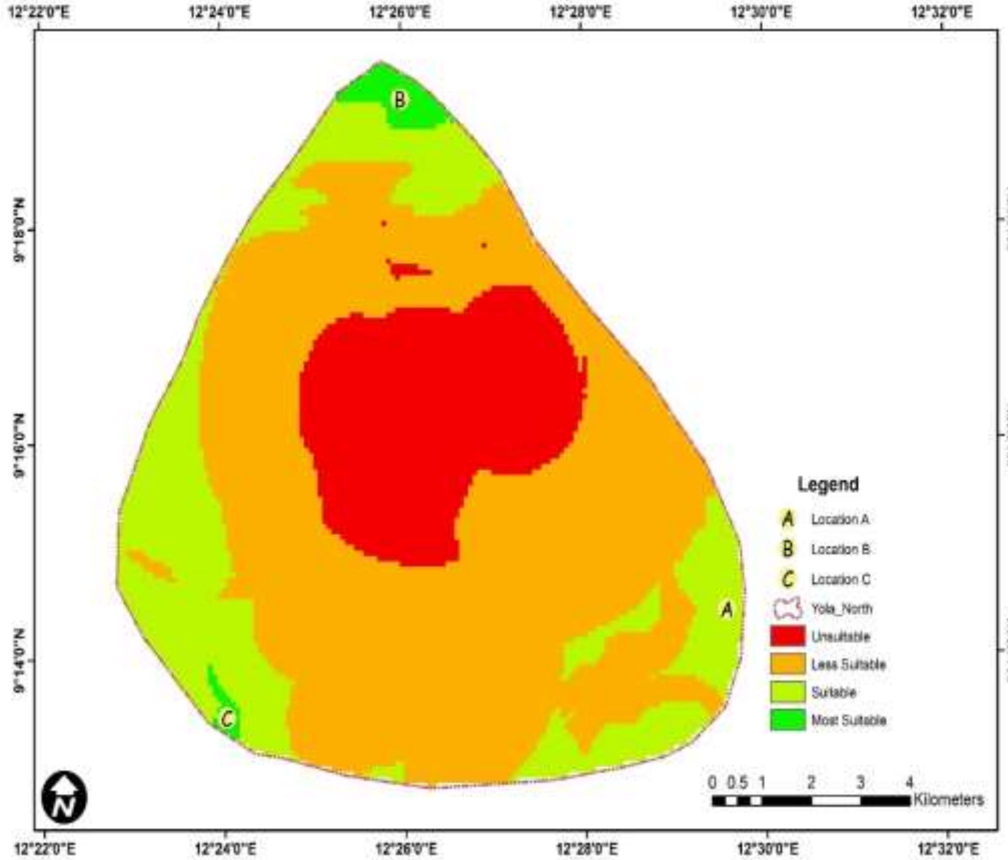

Figure 4.8; Suitability Map identifying suitable Locations

Deriving Local Priorities (Preferences) for the Alternatives (A, B and C)

This consists of deriving the relative priorities (preferences) of the alternatives with respect to each criterion. Since these priorities are valid only with respect to each specific criterion, they are called local priorities to differentiate them from the overall priorities to be calculated later. As indicated, we need to determine the priorities of the alternatives with respect to each of the criteria. For this purpose, we do a pairwise comparison (using the numeric scale from) of all the alternatives, with respect to each criterion, included in the decision making model. In a model with two alternatives it is required to make only one comparison (Alternative 1 with Alternative 2) for each criterion; a model with three alternatives would require to make three comparisons (Alternative A with Alternative B, Alternative B with Alternative C, and Alternative. Consistency 15 with alternative C) for each criterion; and so on. There will be as many alternatives comparison matrices as there are criteria. In our example, we only have three alternatives: A and B and we have three criteria. This means that there will be three comparison matrices corresponding to the following three comparisons:

Table 4.11 Comparison of importance in Locations with respect to each factor.

comparison with respect to Road				comparison with respect to CBD			
1a	Location A	Location B	Location C	1b	Location A	Location B	Location C
Location A	1.000	7.000	3.000	Location A	1.000	3.000	0.333
Location B	0.143	1.000	0.500	Location B	0.333	1.000	0.167
Location C	0.333	2.000	1.000	Location C	3.000	6.000	1.000
Total =	**1.476**	**10.000**	**4.500**	**Total =**	**4.333**	**10.000**	**1.500**

Comparison with respect to Built-up				comparison with respect to Slope			
1c	Location A	Location B	Location C	1d	Location A	Location B	Location C
Location A	1.000	3.000	0.500	Location A	1.000	0.143	0.333
Location B	0.333	1.000	0.167	Location B	7.000	1.000	3.000
Location C	2.000	6.000	1.000	Location C	3.000	0.333	1.000
Total =	**3.333**	**10.000**	**1.667**	**Total =**	**11.000**	**1.476**	**4.333**

comparison with respect to Airport			
1e	Location A	Location B	Location C
Location A	1.000	4.000	7.000
Location B	0.250	1.000	3.000
Location C	0.143	0.333	1.000
Total =	**1.393**	**5.333**	**11.000**

The above table shows comparison of factors that were used in the analysis in the case of importance. This is to ascertain the overall priorities by considering each suitability factor in comparing the locations using pairwise comparison (Weight values for locations with respect to each factor).

Preferences Normalizing

By normalizing the matrix and averaging the rows we obtain the local priorities (or preferences) for each one of the alternatives for each one of the alternatives. The results are summarized in the table below.

Notice that having only three alternatives to compare with respect to each criterion, simplifies the calculations with respect to consistency. When there are only two elements to compare the respective comparison matrices will always be consistent (CR = 0).

Table Preferences with Respect to Each Location

Preference with respect to Road				**Preference with respect to CBD**			
2a	Location A	Location B	Location C	2b	Location A	Location B	Location C
Location A	0.677	0.700	0.667	Location A	0.231	0.300	0.222
Location B	0.097	0.100	0.111	Location B	0.077	0.100	0.111
Location C	0.226	0.200	0.222	Location C	0.692	0.600	0.667
Priority =	**0.681**	**0.103**	**0.216**	**Priority =**	**0.251**	**0.096**	**0.653**

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Preference with respect to Built-up				Preference with respect to Slope			
2c	Location A	Location B	Location C	2d	Location A	Location B	Location C
Location A	0.300	0.300	0.300	Location A	0.091	0.097	0.077
Location B	0.100	0.100	0.100	Location B	0.636	0.677	0.692
Location C	0.600	0.600	0.600	Location C	0.273	0.226	0.231
Priority =	**0.300**	**0.100**	**0.600**	**Priority =**	**0.088**	**0.669**	**0.243**

Preference with respect to Airport			
2e	Location A	Location B	Location C
Location A	0.7179	0.7500	0.6364
Location B	0.1795	0.1875	0.2727
Location C	0.1026	0.0625	0.0909
Priority =	**0.7014**	**0.2132**	**0.0853**

However, consistency must be checked if the number of elements pairwise compared is 0.1 or more.
To summarize these results of this step by indicating that if the only criterion were built up area, Location B would be best option; if only criterion were slope, best would be the Location B and finally, if only criteria were airport, best option be Location C. As previously indicated, the priorities (preferences) of the alternatives, with respect to each criterion, are called local priorities (or preferences). The summary of the local priorities for each alternative is shown below.

Derive Overall Priorities (Model Synthesis)

Up to this point we have obtained local priorities which indicate the preferred alternative with respect to each criterion. In this fourth step, there is need to calculate the overall priority (also called final priority) for each alternative; that is, priorities that take into account not only our preference of alternatives for each criterion but also the fact that each criterion has a different weight. Given that we are using all the values provided in the model, this step is called model synthesis.

Table:4.13 Summary of local Priorities

Local Priorities					
3	Road	CBD	Built-up	Slope	Airport
Criteria W	***0.136***	***0.267***	***0.379***	***0.068***	***0.163***
Location A	0.681	0.251	0.300	0.088	0.701
Location B	0.103	0.096	0.100	0.669	0.213
Location C	0.216	0.653	0.600	0.243	0.085

Source: Research, 2021

Synthesis of the Model

This shows the summary of priorities derived from local priorities in the above table. Location A having (0.393), location B (0.157) and location B (0.461). From theses overall priorities, Location C is considered as the best site for siting the Landfill.

Table 4.14: Final Overall Priority Among Location A, B and C

Synthesis of the Model						
2	Road	CBD	Built-up	Slope	Airport	
Criteria weight	***0.136***	***0.267***	***0.379***	***0.068***	***0.163***	**Overall Priority**
Location A	0.093	0.067	0.114	0.006	0.114	**0.393**
Location B	0.014	0.026	0.038	0.045	0.035	**0.157**
Location C	0.029	0.174	0.227	0.016	0.014	**0.461**

Source: Research, 2021

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Figure4.9 ; Overall Priority for Suitable Locations for Locating Land fill Site

Conclusion

This study aimed to select suitable sites for landfill in Jimeta using the best methodology and also by taking into account the scientific and environmental criteria which are followed in advanced countries. In order to determine the most suitable site for solid waste landfill site in Jimeta, layers were incorporated in the process of analysis using GIS, which is considered a powerful tool for assisting in the selection of a site for landfill due to its ability to deal with a large volume of data from different sources. Here, these layers were water bodies, airport, central business district, slope, built areas/settlement and roads. An Analytical Hierarchical Process was used to derive the weightings for multi-criteria using a pair-wise comparison to construct a comparison matrix. Then, a synthesis of the model method was used to produce a suitability index for the final output map for the study area. Finally, in the category of "most suitable" on the final map, three locational sites were identified for landfill. These sites were checked on the satellite images (2021) to make sure that these sites were suitable for landfill. Generally, these sites satisfy the minimum requirements of the landfill sites. The area of Sites

A, B and C respectively. The required area in the present study that can well accommodate such waste is site C.

Recommendations

Having identified the area best for sitting Landfill site, in their levels of suitability using a Suitability analytical hierarchical process model, it is recommended that the Environmental Department of the Local Government Areas within the study area and the Town Planning Authority have the site suitability analysis model in their finger-tips so that it will serve as a guide before a site can be approved for dumpsite, since it has taken care of all the criteria as regards suitable locations for dumpsite in its analysis. A step can still be taken further to incorporating within the model a procedure to enable identification of optimum site for locating a Solid waste landfill site

Further recommendations for future urban planning and further research are the following:

1. Establish a solid waste management structure that improves MSW collection; transportation, treatment and disposal.
2. Conduct further studies, including a comprehensive Environmental Impact Assessment, to establish the suitability of potential landfill sites in the study area.
3. Launch public education and awareness campaign on safe waste handling and disposal methods.
4. Government should improve and implement the existing policy for the management of solid waste in the study area.
5. Government should sensitize the people on the importance of a cleaner environment.
6. Government should endeavor to construct an additional landfill to support the existing one so as to prevent waste being dumped near residential area and along the roads.
7. The people should be made to be responsible for the indiscriminate disposal of the solid waste they generated.
8. The local waste disposal agent in the community should be ordered not to dumped waste anywhere they deem fit else they pay a certain amount of fine.

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