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GIS Suitability Analysis for Anaerobic Treatment Facility for Slaughter Houses in Anambra State of Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ECC and GOC designed the study. Author ECC wrote the protocol, and the first draft of the manuscript. Author LCO managed the literature searches, while author ECC obtained data and performed the GIS analysis of the study. All authors read and approved the final manuscript.

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ABSTRACT

Investment in anaerobic digestion of bio-energy plants for slaughterhouse wastes is a good venture from environmental, economical and sustainable view point. Several researches have been undertaken in biogas potential of various substrates in Nigeria, there is need therefore to undertake further research on other factors such as site suitability analysis to achieve renewable energy target in the study area. Site selection which is a critical step in actualizing viable bio-energy was carried out in the study area using the power of Geographical Information System (GIS) technology. Several GIS thematic layers were obtained considering important factors in bio-energy plant location analysis. The various map layers were overlaid to obtain the final suitability map index with 4 classes which are the Most Suitable, Highly Suitable, Moderate Suitable and Not Suitable index. The result of the study reveals that the Most Suitable sites constitutes about 2.16% of all the study areas, Highly Suitable comprises of 34.25% of the study area, while Moderately

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Suitable sites forms 45.56% and Not Suitable composes of 18% of the study area respectively. Most of the Most Suitable sites were located in Onitsha North, Oyi and Idemili North Local Government Areas (L.G.A), few patches were seen in Orumba North, Idemili South, Orumba South, and Ekwusigo L.G.A.

Keywords: Site suitability; abattoir; GIS, biogas plant; Nigeria.

1. INTRODUCTION

Due to higher meat demand at present compared to the past, the quantity of organic by-products from slaughterhouses has increased. Approximately 25% of the total animal weight slaughtered is not used for food consumption [1]. A study conducted by [2] on "Analysis of Nsukka metropolitan abattoir solid waste and its bacterial contents in South Eastern Nigeria" shows that a total of 194 kg of solid (rumen/stomach) wastes were generated daily in its municipal abattoir without any clearly defined system of disposal and management. Several researchers has also noted that wastes generated in major abattoirs in the country are mismanaged [3,4].

Anaerobic digestion of slaughterhouse waste offers a safe and sustainable waste management solution. Governmental subsidies for facilitating investments in anaerobic digestion of food industrial waste and slaughterhouse wastes is good investment from a sustainable, environmental and economical point of view [5]. It has been reported that intestinal content comprised a total of approximately 27% of waste utilization in centralized biogas plants in Demark [6]. As the global trend is advocating for a transition from fossil energy to establishment of renewable energy sources based on several socio-economic and environmental justifications, the necessity to embark on a process to capture biogas for energy production is inevitable for Nigeria [7]. Farming sector, in general, is a big producer of manure and thereby a big producer of greenhouse gasses. Methane production from animals on farms should be seen as an opportunity in utilizing green and sustainable energy which would contribute to the reduction of greenhouse effect.

One of the biggest barriers in utilizing biogas potential in Anambra state is the dispersion of slaughterhouses across the states which are relatively small and are not capable of having economical viable biogas production. Anambra State of Nigeria has a small landmass of appropriately 4,416sq.km and ranking among the smallest states in the country. Therefore, the need for effective management of land in the State to meet competing use cannot be over emphasize [4]. GIS is a system for capturing, storing, checking, integrating, analyzing, and displaying data about the earth that is spatially referenced. GIS is applicable in many fields. Their application is cross-disciplinary and may be adopted in a variety of fields, such as resource management, logistics, cartography, archaeology, urban planning, environmental impact assessment and many others [8].

GIS has been used extensively in solving spatial related problems including site selection for bio-energy plant [9,10,11,12]. For instance, [9] assessed site suitability for locating a central waste treatment plant using GIS and multi-criteria evaluation techniques in Nakhonpathom Province Thailand. Hence this study attempts to investigates geographical suitability analysis for Anambra state abattoir wastes community bio-energy plant. The specific objective of this study is to determine suitable sites using GIS techniques for siting abattoir waste treatment facilities in the study area.

2. STUDY AREA

Anambra State is the oldest state in South-Eastern Nigeria. The Capital and the Seat of Government is Awka. Onitsha and Nnewi are the biggest commercial and industrial cities, respectively. Fig. 1 shows the map of Nigeria, and map of the study area.

The study area is located between Latitudes $05°42^{1}56^{11}$N and $06°45^{1}34^{11}$N and Longitude $06°37^{1}30^{11}$E and $07°25^{1}30^{11}$E, its boundaries are formed by Delta State to the West, Imo State and Rivers State to the South, Enugu State to the East and Kogi State to the North. The national population census of 2006 gave the population of Anambra State as 4.06 million with a population density of 1,500 to 2,000 persons living within every square kilometer. The State is divided into 21 local government areas.

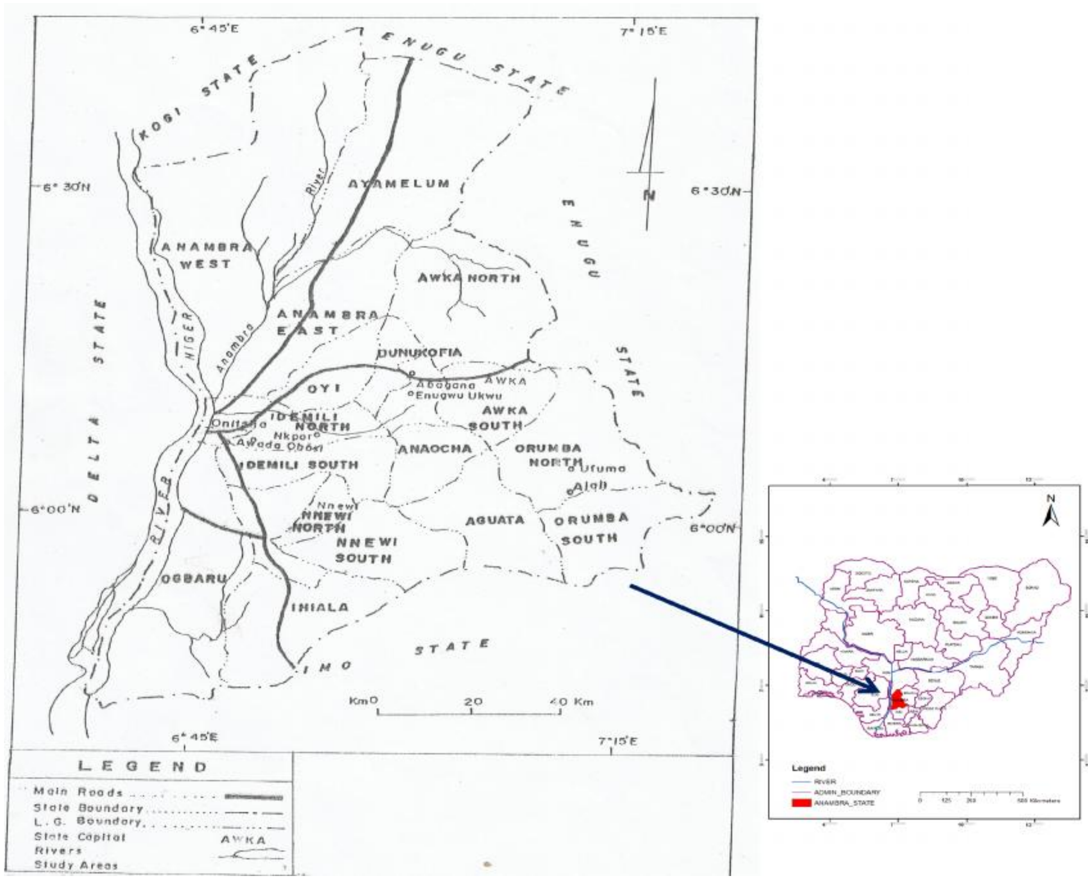

Fig. 1. Map of Nigeria showing the study area

3. MATERIALS AND METHODS

Data used in the study include primary and secondary data collected from various organizations, literatures and individuals. The primary data from the field survey was collected through visit to about 43 slaughter houses in the study area, to determine the biomass potentials of the various abattoirs. Data were also collected using interviews; onsite observations; and use of questionnaires. In addition, a Global Positioning System (GPS) receiver (Handheld GARMIN 76S) was used in the field survey to determine the geographical co-ordinate of the abattoir houses for geo-coding in the data analysis. Data were also collected from Ministry of Land and Survey, Awka, which include administrative map. ArcGIS 10 software was used for all GIS operations and map production. The GIS-based thematic maps used for the production of the suitability map include political boundary map layer, road network layer, Land Use and Land Cover (LULC) map obtained from the Landsat imagery. The residential and reserved areas in the study area were exempted in the suitability map. Biomass potential density layer was obtained from onsite observation and statistical data from the study, while constrain map was made considering several environmental and socio-economical factors (see Table 1). The flowchart of the methodology is shown in Fig. 2.

All the GIS operations mentioned in the flowchart were executed using standard operations in ArcGIS 10 software. 28.5 m resolution Landsat-7 ETM+ obtained from the National Remote Sensing Centre, Jos Nigeria was classified into built-up area, open space, vegetation and water bodies. The slaughterhouse geographical data (geographical coordinate points of the abattoirs) and statistical data (quantity of waste generated in each abattoir centre) were geo-coded. Shuttle Radar Topography Mission (SRTM) was also resampled to produce Digital Elevation Model (DEM). Slope, Hill-view shade layer and elevation layer were all obtain from the DEM.

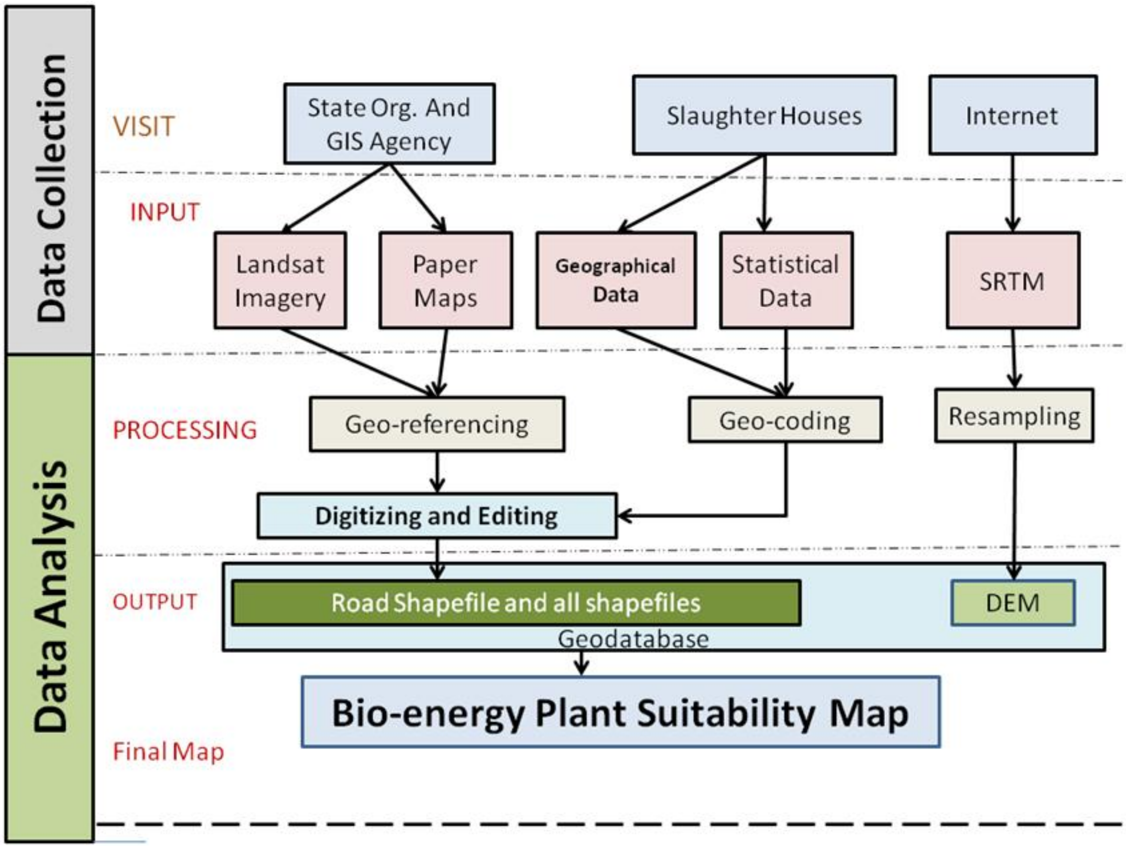

Fig. 2. Flowchart of methodology

Table 1. Criteria for constrain map based on environmental and socio-economic factors

Constraints	Specifications
Rural and urban areas	A distance of 1 km from residential and urban areas
Park and recreational areas	Sites falling within these areas and a buffer of 500 m are avoided
Rivers, lakes and other waterbodies	Sites within buffer zone of 200 m are avoided
Wetlands	Wetland areas and a buffer zone of 200 m are avoided
Environmentally sensitive areas (flood plains, conservation areas, habitat sites)	Sites falling within such areas and a buffer zone of 500 m are avoided
Roads	Sites falling within a buffer of 30 m are avoided
Transmission line	Sites falling within a buffer of 100 m are avoided
Power plant and substation	Sites falling within a buffer of 100 m are avoided
Land surface gradient	Areas with slopes larger than 15% are avoided

3.1 Bio-energy Site Suitability Analysis

Suitability analysis involves the search for the best location of one or more facilities to support some desired function, it is the process to determine whether the land resource is suitable for a particular purpose. Before the spatial analysis was performed to choose a site, siting criteria/factors were evaluated for their applicability for selecting areas based on environmental and socio-economic factors. The site suitability was assessed using equation 1 below:

$$S_i = \sum W_i X_i \quad (1)$$

Where Wi is the weighted score of the factor, Xi is the suitability rank of the factor, S is the suitability value for each factor and i is factor i.

In selecting suitable sites using a weighted score model, the input factors were selected, some constrained (i.e., unsuitable areas blacked out. See Table 1), standardized (i.e., factor attributes classified and ranked), and weighted (i.e., assigned weights to the factor) before combining them. Environmental factors considered in siting energy plant include location of the plant 500m away of residential areas, water bodies (to avoid pollution) etc. Economic factors considered including siting the plant in proximity to previous existing power plant locations, proximity to major road etc, while the social factors include situating the plants far away from parks and recreational areas. These criteria were used to determine exclusive sites. Table 1 shows the environmental and socio-economic criteria.

4. RESULTS AND DISCUSSION

One of the criteria for site suitability analysis for siting abattoir in the study area is biogas potential density. Abattoir wastes are usually produced from slaughtered cattle, goats, pigs

Fig. 3. Abattoir producing areas of Anambra State

and sheep in slaughterhouses which are located mainly in markets and in few cases in isolated areas with cattle ranch. The abattoir centres in the State is shown in Fig. 3 while the detailed production capacity of each abattoir is shown in the Appendix. The Fig. 3 shows the names of the abattoir centres. From the Fig. 3, Anambra West, Ayamelum, and Anambra East L.G.A has no abattoir centre, Ogbaru, Orumba South and Anaocha L.G.A each has one slaughterhouse located in Iyiowa-Odekpe, Umunze and Agulu respectively. Areas with high clustering of abattoir centres are best sites when considering proximity of waste sources as major criteria for bio-energy treatment plant location.

The dots in the Fig. 3 are the location of the abattoirs, the name of each L.G.A is shown in red. To enhance GIS operations, the polygon layer of the spatial density map of abattoir waste was generated and converted to raster, and thereafter reclassify to aid in map overlay in weighted overlay tool. The waste generating capacity of the various regions was classified into 5 classes ranging from the Most Suitable to Not Suitable. This is to ensure that the suitable sites for bio-energy plant location are in proximity to high density waste generating areas. This will eventually reduce transportation cost from the generating points to the suitable treatment sites. The reclassified raster dataset is shown in Fig. 4.

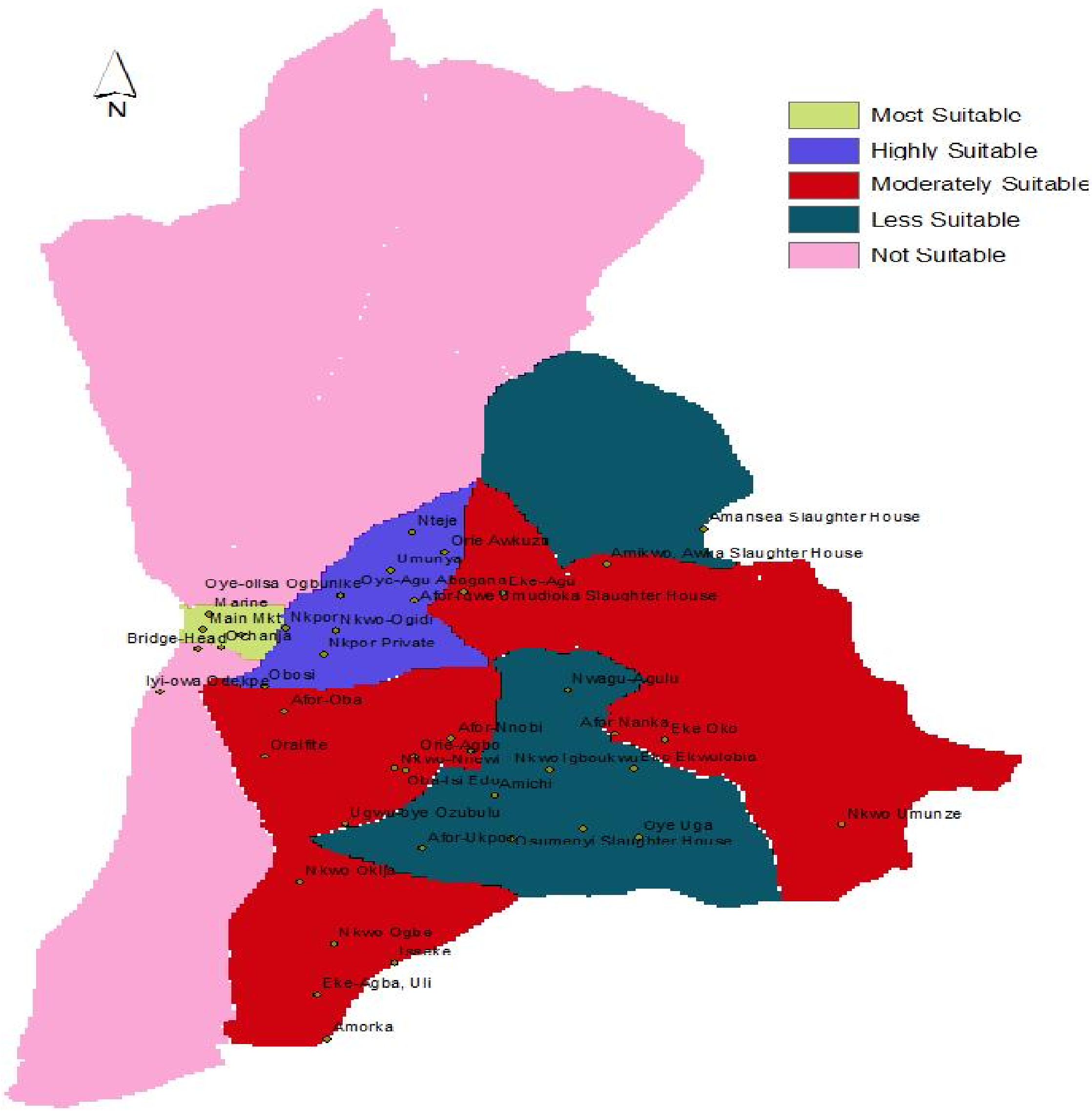

Fig. 4. The spatial waste density index map of abattoir waste generation

4.1 Land Use Suitability Map

The land use suitability map was obtained by excluding unwanted areas identified in the constrain map using Table 1. These are areas prone to flooding, areas that are close to residential areas and water bodies etc. The weighted overlay tool in ArcGIS overlays several rasters using a common measurement scale and weigh each according to its importance. Slope layer obtained from DEM was reclassified, the most suitable sites are the flat areas of the landcover ranked as 1. Since fermentation increases with increasing temperature, Hill-view shade view layer was also classified into 5 classes that ranges from 1 to 5, 1 denotes the most suitable hill-view sites with maximum intensity of sunlight to aid in fermentation process of the wastes. Elevation layer also obtained from DEM was classified into 5 classes. To avoiding flooding; the best sites were sites with higher elevation. Slope layer, Hill-view layer and Elevation layers were overlay at 20%, 40% and 40% weight of importance respectively using Weighted Overlay Tool, the resultant raster was further overlay with the land use layer obtained from Satellite imagery using weighted Overlay tool at equal weights. The resultant dataset is the Land Use suitability map shown in Fig. 5.

The final suitability index map was obtained by overlaying the land use suitability map with the spatial waste density suitability layer. The output is shown in Fig. 6. The blank areas are the exclusive sites based on the criteria listed in Table 1. The site suitability index is shown in 4 classes- the most suitable, highly suitable, moderate suitable and not suitable. The most

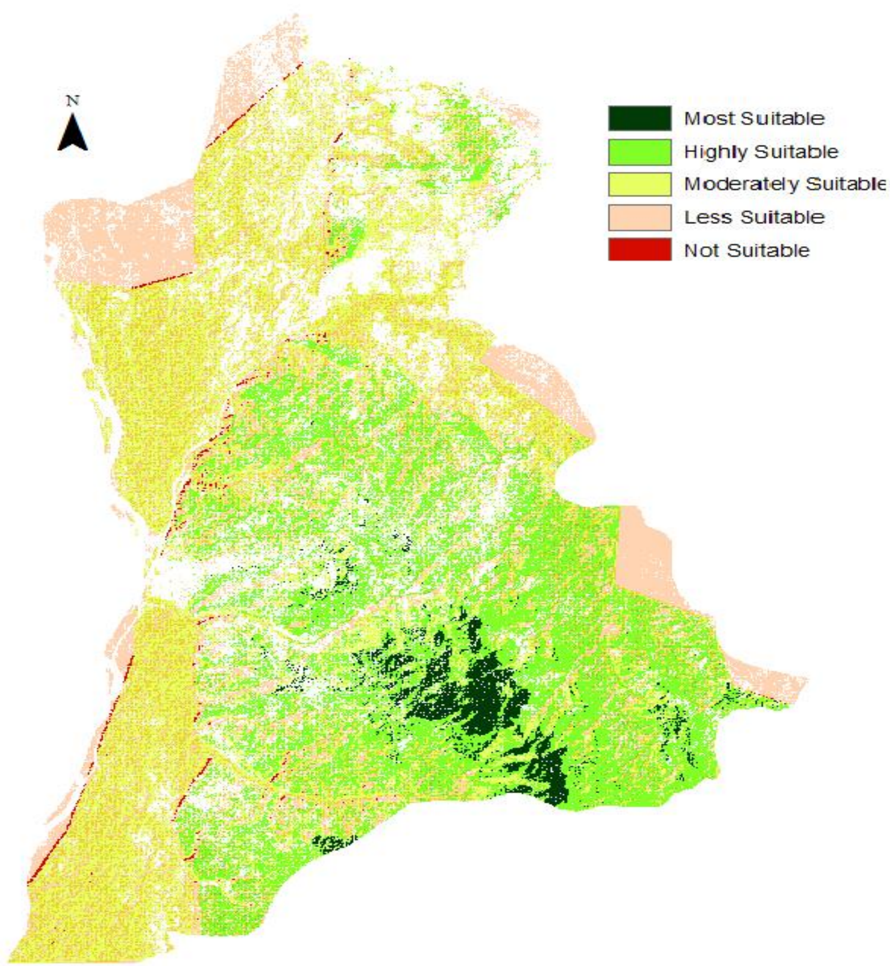

Fig. 5. Land cover and land use suitability map

suitable constitutes 2.16 % of all the study areas, highly suitable comprises of 34.25% of the study area, while moderately suitable sites forms 45.56% and not suitable composes of 18% of the study area respectively. This is similar to a study conducted by [8] on site suitability assessment for central anaerobic treatment facility for biogas production in Nakhonpathom province in Thailand where 66.6% were classified as non-suitable, 18.5% less suitable, 13.5% moderately suitable and 1.6% most suitable. This shows that suitable sites are usually far less than the Less and Not suitable sites, which suggests the power of GIS in extracting useful information for geographical data analysis. Most of the suitable sites were located in Onitsha North, Oyi and Idemili North L.G.As, few patches of suitable sites were also seen in Orumba North, Idemili South, Orumba South, and Ekwusigo L.G.As.

For economic reasons, the best site for siting of biogas plant in the study area should be in Onitsha North L.G.A. This will reduce transportation cost since this is most suitable site with respect to spatial waste density index map. Alternatively, Oyi and and Idemili should be considered since these areas also have high spatial waste density index as shown in Fig. 4.

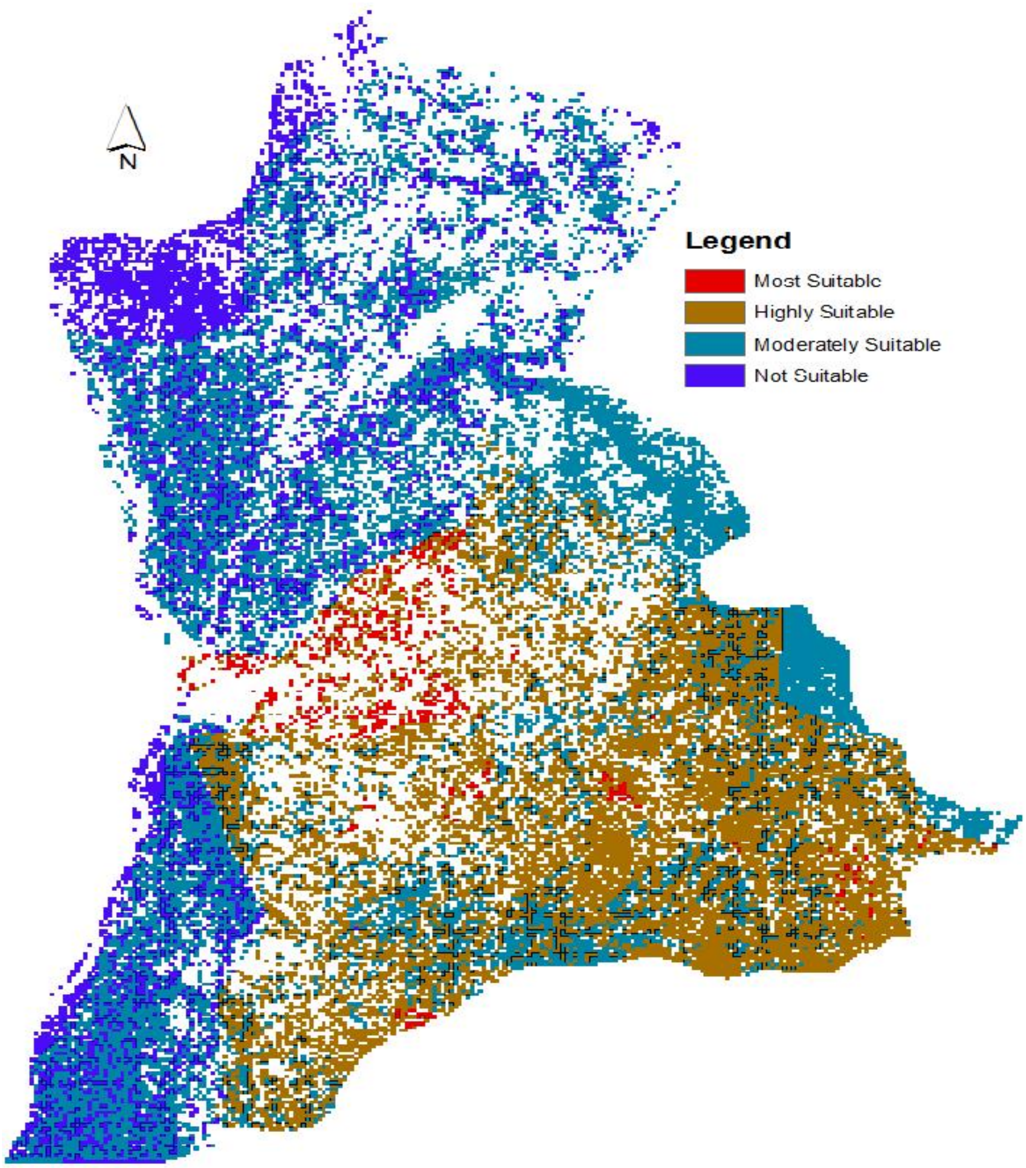

Fig. 6. Final suitable site for bio-energy location

5. CONCLUSION

This paper presents an application of GIS for site selection of bio-energy plant in Anambra State of Nigeria. Several environmental criteria and socio-economic factors were considered and used to obtain the land use suitability index map and spatial density map. The final suitability index map was obtained by overlaying both maps. Final suitability map shows that the Most Suitable sites in the study area constitutes about 2.16%, while the Highly Suitable comprises of 34.25% of the study area, while Moderately Suitable sites forms 45.56% and Not suitable composes of 18% of the study area respectively. Most of the suitable sites were located in Onitsha North, Oyi and Idemili North L.G.A. Site suitability analysis was performed satisfactorily using ArcGIS software. This study therefore will be a veritable tool in selecting suitable sites for siting of abattoir treatment facilities in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Table 1. Waste generation capacity of abattoirs in the study area

	Locations	Aver. no. of daily slaughtered cow	Amount of paunch (kg/day)	Amount paunch (Kg/yr)
1	Nkwo Igboukwu	5	167.5	61137.5
2	Eke Ekwulobia	8.5	284.75	103933.75
3	Oye Uga	10	335	122275
4	Nwagu-Agulu	8	268	97820
5	Amikwo, Awka	18	603	220095
6	Amansea	23	770.5	281232.5
7	Afor-Igwe Umudioka	6.5	217.75	79478.75
8	Ugwu-oye Ozubulu	8	268	97820
9	Oraifite	3	100.5	36682.5
10	Nkwo-Ogidi	14.5	485.75	177298.75
11	Obosi	16	536	195640
12	Nkpor Private	5	167.5	61137.5
13	Nkpor	15	502.5	183412.5
14	Afor-Oba	7	234.5	85592.5
15	Afor-Nnobi	17	569.5	207867.5
16	Eke-Awka Etiti	35	1172.5	427962.5
17	Eke-Agba, Uli	5	167.5	61137.5
18	Amorka	6	201	73365
19	Nkwo Ogbe	10	335	122275
20	Nkwo Okija	5	167.5	61137.5
21	Isseke	4	134	48910
22	Oye-Agu Abagana	6	201	73365
23	Eke-Agu	4	134	48910
24	Nkwo-Nnewi	10.5	351.75	128388.75
25	Orie-Agbo	3	100.5	36682.5
26	Oba-Isi Edo	14.5	485.75	177298.75
27	Amichi	4.5	150.75	55023.75
28	Afor-Ukpor	2	67	24455
29	Osumenyi Slaughter House	3	100.5	36682.5
30	Unubi Slaughter House	0.5	16.75	6113.75
31	Iyi-owa Odekpe	2	67	24455
32	Ochanja	70	2345	855925
33	Bridge-Head	11.5	385.25	140616.25
34	Marine	26	871	317915
35	Ugwunabamkpa	1.5	50.25	18341.25
36	Main Mkt	20	670	244550
37	Afor Nanka	2	67	24455
38	Eke Oko	8	268	97820
39	Nkwo Umunze	4	134	48910
40	Nteje	13	435.5	158957.5
41	Oye-Olisa Ogbunike	52.5	1758.75	641943.75
42	Umunya	65	2177.5	794787.5
43	Orie Awkuzu	12.5	418.75	152843.75
	Total	565.5	18944.25	6914651.25

Amount of paunch (kg/day) = Aver. no. of daily slaughtered cow × 33 kg

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