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Use of Geographic Information System for Selection of Sustainable Waste Disposal Site in Owerri West, Imo State, Nigeria

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ABSTRACT: One of fundamental problem in waste management is to identify suitable locations for refuse dump. This is because it requires integration of numerous economic and environmental factors. Therefore, the objective of this paper was to use Geographic Information System (GIS) for the selection of sustainable waste disposal site in Owerri West, Imo State, Nigeria. Data used include shuttle radar topographic mission (SRTM DEM) data of 3 arc seconds, LANDSAT satellite data of 30m resolution, geological data, google earth satellite imagery, administrative map of the study area and ground control point (GCP) collected by ground point survey (GPS). These datasets were populated in ArcGIS 10.5 window and harmonized in a common coordinate system. Six factors which include nearness to river and road, settlement, land use, slope and elevation were considered as waste dump siting constrains. These factors were weighted, reclassified and Analytic Hierarchy Process (AHP) and GIS over lay analysis were combined in selecting optimal and sustainable waste dumping locations. The results of the study are categorized into highly suitable, suitable, moderately suitable and unsuitable. Field observations also confirmed suitability of the selected sites. The highly suitable locations are those that possess the optimal quality and characteristics for sustainable waste disposal while the suitable sites can be kept as back up for future use.

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Selection of suitable waste disposal site is one of the problems facing many developing nations including Nigeria. Waste is any material discharged from human activities, which makes adverse impacts on human health and environment (Ahmed 2019). The combine effect of technological development and accelerated urban swell up have resulted to increasing generation of large quantity of waste that proves to be difficult to manage in developing countries. While overwhelming scientific evidences abound, that global warming is taking a significant toll on the Earth and its occupants, communities in Nigeria are striving to join other countries in mitigating the effects. The process of attaining a suitable waste dump site is very tedious, complex and time consuming because it involves various experts from different field of knowledge. This makes the site selection process more challenging as it involves dealing and evaluation of large volume of data which is guided by rules, regulations, factors and constraints (*Gbanie et al* 2013*; Mohammed, et al 2017*). Problems related to solid waste management remain at the forefront of the global environmental policy for sustainable development and is a matter of public health concern. Selection of an appropriate site would minimize environmental impact and forms a sound basis for solid waste management (Yenenesh

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2019; Zain 2009). Most suitable location for siting waste dump depend on many critical factors which include topography, surface water, drainage, hydrogeology (groundwater), geology, access and distance from the community the dump site will service. Waste disposal site should not be placed too close to high-density urban areas. This guard against health problems, noise pollution, odor complaints, decreased property values and un-aesthetic environment. From economic point of view, Slope is considered as an important criterion when siting a waste dump site. Habiba (2019) argued that cost of construction in areas with steep and high slope will be un-economical compared to areas of medium slope. *Yenenesh et al* (2019) and Mcfaden (2003) opined that roads are important constrains in locating waste disposal site. They argued that it should not be located very near to main road where the general public move due to public health problem as waste materials can have harmful effect to health and further emphasized that placing waste disposal site very far from road network is also not advised because it can hamper transportation and access to the site. One way of intensifying the mitigation of the hazard effects of waste is through appropriate and environmentally-friendly waste disposal and management (Anifowose 2011). The application of geographic information system in geodata analysis and management has gained popularity because of its ability to integrate large volume of data from diverse sources in a single platform, perform analysis and display the required result in a user-friendly manner. In Owerri, there is lack of proper waste disposal habit leading to waste being disposed indiscriminately in open and public places like market place, roadside, gutters etc. This waste piles up destroy environmental aesthetics and block drainage systems leading to flooding and degradation of the environment therefore, this calls for attention. In recent times, urban swell up resulting from population explosion has increased the volume of waste generation in Owerri West. Proper disposal of this waste has become increasingly difficult and a thing of concern. The reoccurrence of this problem has popularized monthly sanitation exercises in Owerri west and the state as a whole which has not been able to curb this menace. In Owerri, there are shortage of sites for waste disposal leading to indiscriminate dumping of refuse in open and public places like market place, roadside, gutters etc. this waste piles up and block drainage systems leading to flooding of the environment and other environmental hazards. Therefore, there is need to identify most appropriate sites for waste dump using the most suitable approach so as to maintain a clean and healthy environment in Owerri West and that is the rationale for this study. Hence, the objective of this paper as to use Geographic Information System (GIS) for the selection of sustainable waste disposal site in Owerri West, Imo State, Nigeria.

MATERIALS AND METHODS

Study area: The study area is Owerri west. Owerri West is one of the 27 Local Government Areas in Imo State, Nigeria. Its headquarters are in the town of umaguma. It has an area of approximately 295 km2 and geographically located between latitude 6° 60’ 0"E and 7°3’ 0“E and between longitude 5°21'0"N and 5°27'0"N. and a population of 99,265 at the 2006 census.

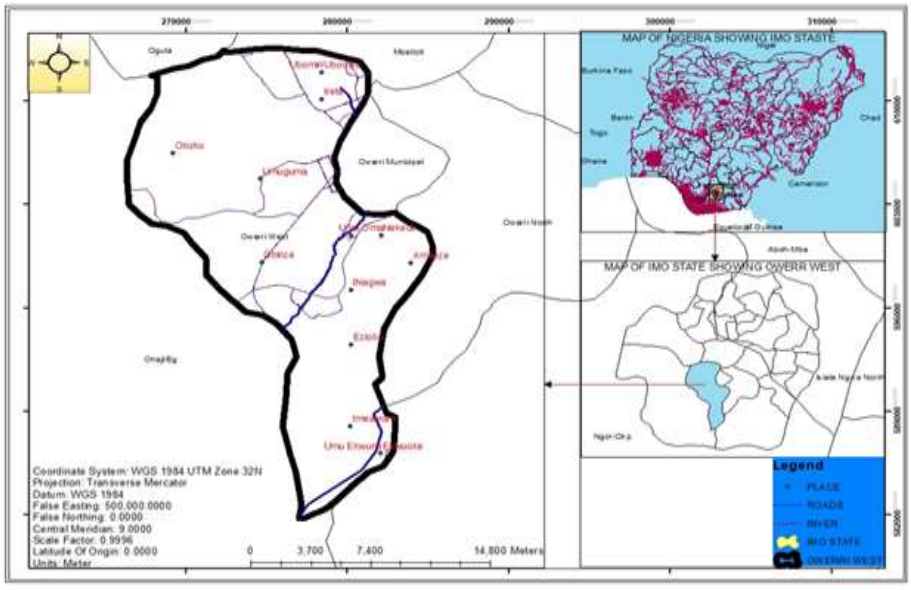

Fig. 1: Location map of the study area

Data Used: Data used for this study include; The Shuttle Radar Topographical Mission/DEM (SRTM) with a spatial resolution of 90m, LANDSAT 8 with a spatial resolution of 30m. Both were down loaded from USGS web site and global land cover facility respectively. Google earth satellite imagery was downloaded from the intermate, Geologic and soil data were collected from the Department of Geology federal university of technology Owerri and administrative map of the study area where the boundary shape file was extracted was obtained from ministry of lands Imo State. These datasets were entered into ERDAS Imagine and Arc-GIS window and harmonized into WGS84-UTM zone 32 projected coordinate system for further processing and manipulation.

Methodology: Siting of refuse dump must conform to some guide line and regulations so as to avoid health hazard and other environmental problems associated with improper dump. Its selection is a complex and expensive process that requires many conflicting criteria (Anifowose, 2011). In this study remote sensing and GIS approach were integrated to determine the most appropriate locations for refuse dump in the study area. Land use/land cover, soil type, slope percentage, proximity from surface water and roads, etc were processed and integrated in GIS window to determine areas most suited for siting refuse dump. Image enhancing was employed to improve the visual quality of the LANDSAT satellite imagery, making it more suitable for this assessment. Progressively, features were clustered into five classes using supervised classification approach. The classes identified are residential areas, water bodies, agricultural areas and thick vegetation areas and vacant lands. The elevation and slope map of the study area were extracted from series of geo-processing tools in surface analysis extension of Arc GIS 10.4 and road networks were extracted from the google earth imagery. Analytical hierarchical process (AHP) technique has been utilized to combine these factors for informed decision. Multi-criteria Evaluation (MCE) methodology was used for assigning criteria weights for each factor maps. When it comes to site selection problems or suitability models, the spatial Multi Criteria Analysis (Weighted Overlay) is the most commonly used method. The most popular and most commonly used MCDA method is Analytic Hierarchy Process (AHP) which was introduced and established by Saat (1988). It is a decision-making tool used in solving multiple criteria problems because of its ability in the determination of relative weight of multiple criteria which are expressed in numerical order of 1 to 9. Different weights were given in preference of each factor relative to other factor and Pair wise comparison method was carried out among the criteria through the scores and weights assigned to each criterion. This study utilized spatial multi-criteria evaluation approach based on Geographic Information System (GIS) analysis, in order to determine the best waste dumping site. Summary of the methodology is shown in figure 2.

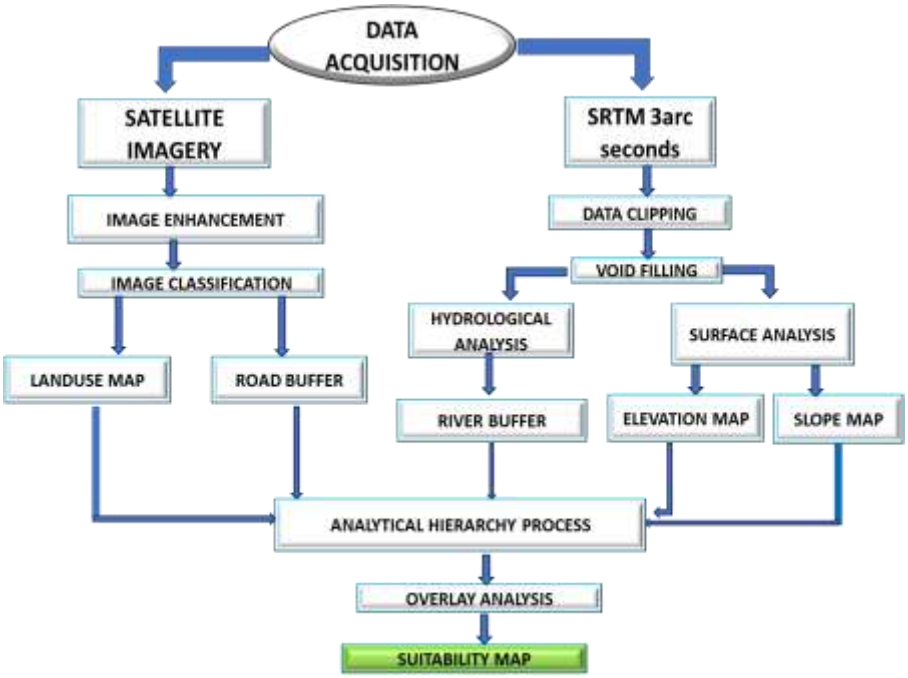

Fig. 2: Methodological flow chart

RESULT AND DISCUSSION

Selection of suitable location for refuse dump is a rigorous process because of the numerous environmental and economic factors that need to be considered. Base on this an optimized approach need to be used to integrate these factors for effective decision making in other to avert its adverse effects to the environment and human health. Figure 3 is the suitability map based on proximity to the river, figure 4 is the suitability map based on proximity to the road networks, figure5 is the suitability map based on land use, figure6 and 7 are the suitability maps based on elevation and slope degrees respectively and figure8 is the overall suitability map for solid waste dumping site in the study area. Proximity of a waste disposal site to streams and rivers is an important environmental criterion in the waste dump site selection. This is due to adverse environmental effects which can occur and contaminates the water body due to leachate originating from the waste. Buffer of 500m around the rivers was categorized as unsuitable zone. Multiple ring buffer distances between 500m to 3000m were use to identify zones of different suitability based on proximity to the river with buffer distance greater than 3000m as the most suitable region (figure1).

Table1. Criteria weight and ranking

Factor	Factor weight	Buffer zones	Ranking	Assigned weight
River	0.3	0 – 500m 500 -1000 1000 -2000 2000 - 3000 > 3000	0 2 6 8 10	0 0.6 1.8 2.4 3.0
Road	0.09	<500m 500 -1000 1000 -2000 2000 - 3000 > 3000	0 2 6 5 0	0 0.18 0.54 0.45 0
Settlements	0.3	<500m 500 -1000 1000 -1500 1500 - 2000	0 2 6 10	0 0.6 1.8 3.0
Land use	0.09	Waterbody Settlement Vegetation Bare Surface	0 2 6 10	0 0.18 0.54 0.9
Slope	0.11	0-2% 2%-8% 8%-15% 15% -30% >30 %	0 10 6 2 0	0 1.1 0.66 0.22 0
Elevation	0.11	30 - 45 46 - 62 63 -77 78 - 94 95 - 111	0 2 6 10 0	0 0.22 0.66 1.1 0

Distance to road: Accessibility of the site must be considered especially for the vehicles used for collection and disposal of waste. Access to the site should be as direct as possible to ensure that people are not tempted to dump their rubbish before getting to the site, and to minimize waste spillage from vehicle and to reduce cost of transportation. However, it should not be located very near to main road where the general public move due to public health and destruction posed to the environmental aesthetics. This study utilized a buffer distance of 500m to 3000m from the roads to categories the levels of suitability. These buffer distances were based on expert knowledge and in consultation with literature. A buffer distance of between 1000m and 2000m from the roads were considered to be most suitable therefore was given high score.

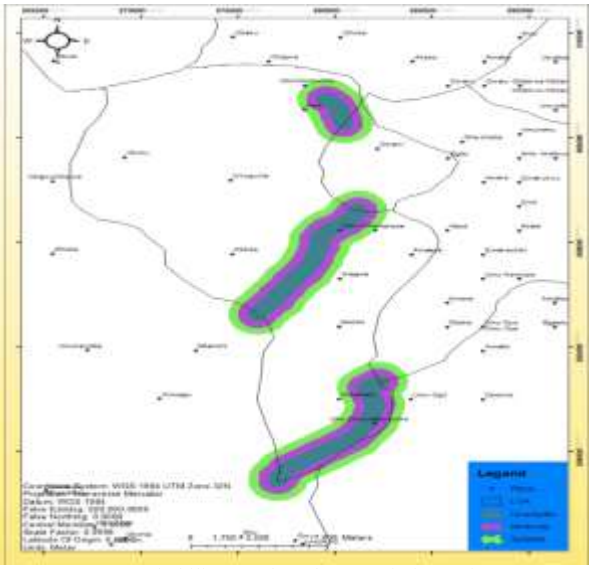

Fig. 3: suitability map based on proximity to river

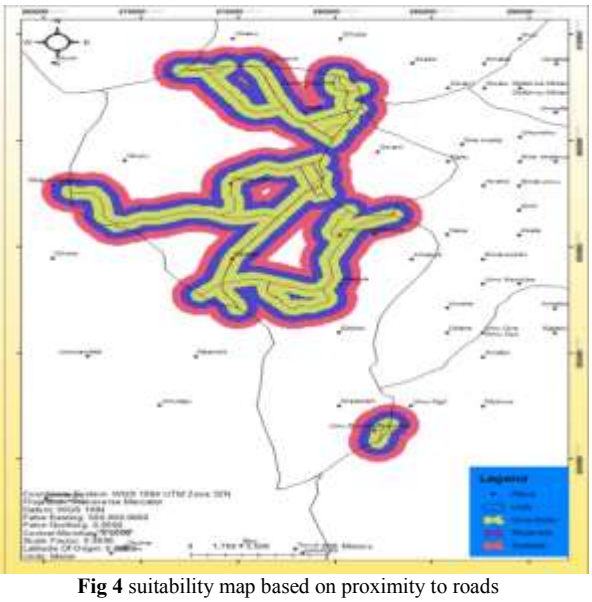

Fig 4 suitability map based on proximity to roads

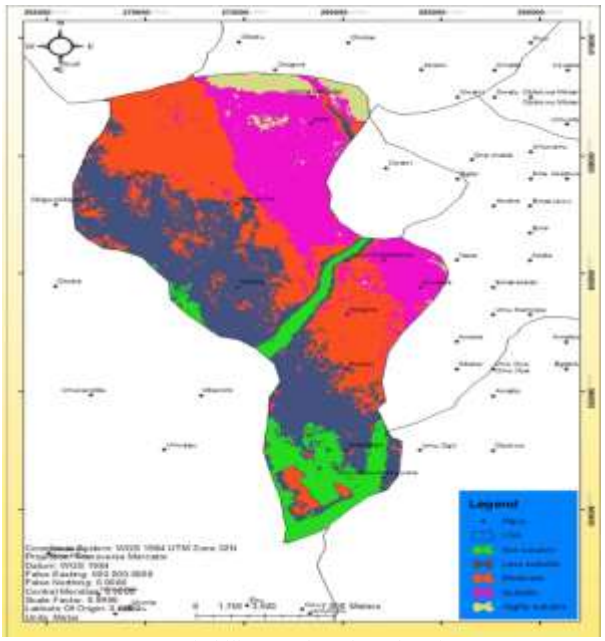

Fig 5: suitability map based on elevation

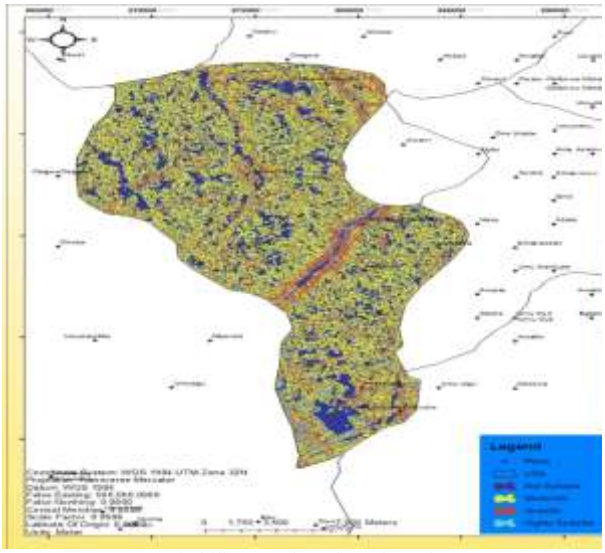

Fig 6: suitability map based on slope degree

Slope: Slope is among the paramount constrains for sitting a waste dump. From economic point of view construction in steep slopes is expensive when compared to medium slopes. Studies have shown that topography of slope greater than 15^0 are considered unsuitable for waste dump. Different researches haves shown that areas with high slopes will have high risk of pollution due to the possibility of fast running water and moving wind transporting refuse into low lying areas. Studies have also shown that flat slopes are not suitable because of the possibility of the settled water leeching into the underground aquifer. The land with a slope less than 10% is highly suitable for solid waste dumping (Tirusew et al 2013; Sener et al. 2011; Leao et al 2001). in This study slope with 0-2% is considered as not suitable, 2%-8% is high suitable, 8%-15% is suitable, 15% -30% moderate suitable and >30 % not suitable. This criterion was adopted from Yenenesh (2019)

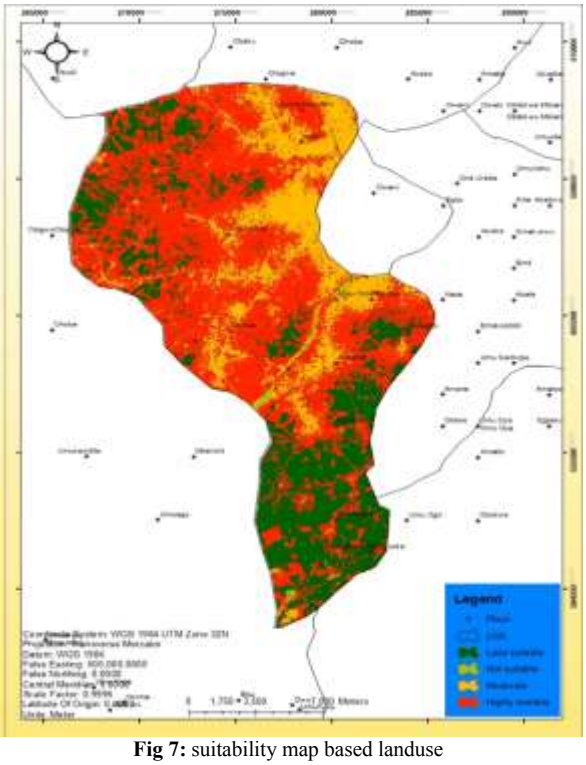

Fig 7: suitability map based landuse

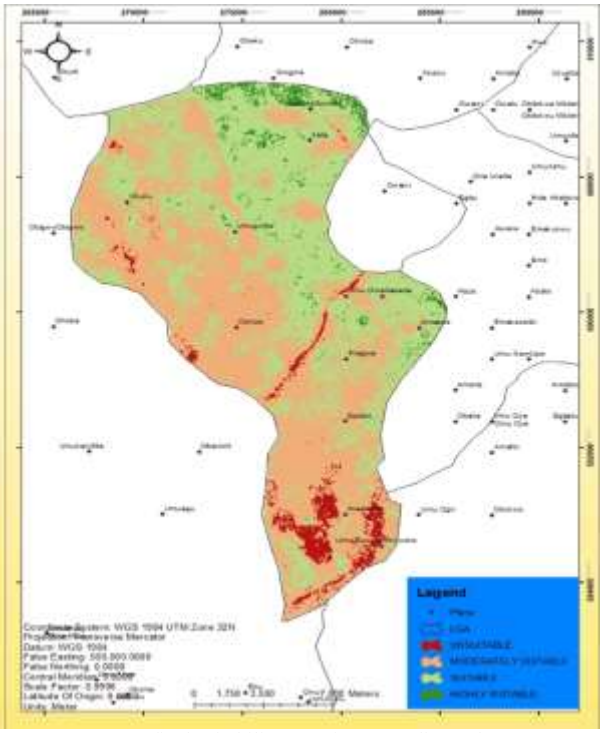

Fig 8: final suitability map for waste disposal

Land Use/Land Cover (LU/LC): different types of land use were identified in the study area. To prevent health issues and environment pollution, a disposal site shouldn't be situated too close to densely populated areas. As per Yenenesh (2019) Landfills should not be placed too close to high-density urban areas in order to mitigate conflicts relating to the Not in My BackYard syndrome (NIMBY). This guard against health problems, odor complaints, decrease in property values and mischief due to scavenging animals. He recommended a buffer distance of 1500m from settlements as ideal for siting waste dump. Habiba (2019) recommended a buffer distance greater than 2000m from settlements as the most appropriate and this was adopted in this study. Consideration of the current and future use of land is also crucial while selecting waste dump site. Based on literature and local, national and international standards, Land with less socio-economic, environmental and political value or cost s such as bare land should be considered the most appropriate.

Elevation: Elevation is among the most critical influential factors to consider while selecting a site for waste dump. In order to avoid waste from being swept away by wind and flowing water resulting to contaminate of water sources, waste disposal sites should be situated in locations with minimal flood risk. Too high elevated zones should also be avoided as it can be inaccessible by waste conveying vehicles. Therefore, moderate high elevation zones are ideal. This study selected location having elevation between 78m to 94m as the most suitable. This range was selected based on the topographical condition of the study area.

Suitability Map: Final suitability map was obtained after assigning weight to each criterion through the AHP method and sub-criteria weighting. Levels of suitability for sighting dump site were determined based on the number of criterions satisfied by different locations. Areas that met the highest number of criterions were selected as the most suitable locations. The results were categorized into four classes which are un-suitable, moderately suitable, suitable, and highly suitable. The final map (Figure 8) has four colors (classes): red, light red, light green and green. The most suitable area for solid waste dumping site is marked by green color and this constitutes 15.30% of the study area. The light green color represents suitable area and covers 39.80% of the study area. The light red and red colored areas represent moderately suitable and unsuitable zones and spatially cover 40.50% and 5.40% of the study area respectively, this study revealed that the highly suitable areas for waste dumping site fall on the north eastern and eastern part of the study area close to Abomiri and Amoze communities.

Conclusion: Due to population swell up resulting to large quantity of waste generation in contemporary times, waste management has become one of the most difficult tasks in many global communities. Base on numerous environmental and economic factors that need to be considered for its effective management, optimized procedures need to be applied for decision making. Studies have shown the ability of GIS and remote sensing as a veritable tool for analyzing criteria for decision support. Based on this GIS and Analytical hierarchical procedure (AHP) was implemented in allocating weight to each parameter based on their relative importance in waste dump site decision. This approach was utilized to categorize the study area into suitability potential zones. The study revealed that the best locations for waste dump site are located at the north eastern and eastern part of the study area close to Abomiri and Amoze communities and spatially occupied 15.30% of the study area.

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