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Identification of Potential Zones for Solid Waste Disposal in Jos South Local Government Area of Plateau State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author KS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BBO managed the analyses of the study. Author FM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Disposal is a critical phase in the management of municipal solid waste, due to unavailability of suitable facilities to treat and dispose of the large amount of municipal solid waste generated daily in metropolitan cities. Improper municipal solid waste disposal locally, cause environmental impacts such as contamination of soil, water pollution, and increase methane emissions. In this study, an attempt has been made to use GIS and remote sensing to identify high potential zones for solid waste disposal in Jos South Local Government Area of Plateau State between 2019 and 2020. Primary data and secondary data were used for this study. The position data of the existing dumpsites in the study area were acquired in-situ with a handheld Global Positioning System (GPS) receiver. The secondary data consists of NigeriaSAT-X, geological, administrative maps, Google map, hydro-geophysical data and Shuttle Radar Topographic Mission (SRTM) images. Thematic

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layers considered in this study include drainage, road and land use/land cover, lithology and geology. The dumpsite point (X, Y) was imported as shapefile and superimposed on the study area boundary to show the existing location. Digital image segmentation of NigeriaSAT-X and geology dataset was carried out to derive the land use/ land cover and geology classifications of the study area. Lithological analysis was carried out using Kriging Method to interpolate the hydro-geophysical data. The slope, land/use, geology, drainage, road, waterbody, built-up and lithology were reclassified and overlaid using Weighted Sum Overlay Method a Spatial Analyst tool in ArcGIS 10.4 to generate the potential zones for solid waste disposal. The result shows the potential zones for solid waste disposal and characterized into unsuitable, less suitable, moderately suitable, suitable and highly suitable.

Keywords: Municipal solid waste; geographic information system; global positioning system; shuttle radar topographic mission; green house gases; land use; land cover.

1. INTRODUCTION

Human activities in urban areas are always associated with municipal solid waste generation [1]. According to the United Nations Environmental Program (UNEP), wastes are substances or objects, which are or intended to be disposed or are required to be disposed of by the provision of national law. Municipal solid waste disposal started when cities were created and expanded after industrialization, as large parts of the population migrated from rural to urban areas [2]. The municipal solid waste generation in the world is increasing and reflects consumer habits and lifestyles [3]. The large amount of municipal solid waste being generated exceeds the capacity of the environment to assimilate through natural processes [4]. The increasing volume of solid waste being generated, coupled with lack of infrastructure for adequate waste treatment and indiscriminate disposal of waste, particularly in low-income countries is expected to contribute 70.9% of overall solid waste around the world [5]. In developed countries, the issue of solid waste is properly handled through the effective management process of waste reduction, reuse, recycle and disposal, while in developing countries, municipal solid waste management system is either not efficient or still at the rudimentary stage and as such, solid waste generated has become a threat to the environment [6]. The lack of proper municipal solid waste management is a major environmental problem, since disposal sites are facilities that pose risks to the environment and population which as a result need to be monitored for extended periods of time [7].

Improper municipal solid waste disposal locally, cause environmental impacts such as contamination of soil, water pollution, and increase methane emissions [8]. Poor management practices are responsible for the accumulation of municipal solid waste at every nook and corner of low-income countries [9]. The management of municipal solid waste is going through a critical phase, due to unavailability of suitable facilities to treat and dispose of the large amount of municipal solid waste generated daily in metropolitan cities. Improper management of solid waste has been reported by several researchers in different cities of developing countries [10]. The situation is not different in Jos South metropolis and its environs, a rapid growing urban centre with growth rate of +2.74 % / year as projected by NPC [11].

2. MATERIALS AND METHODS

2.1 Study Area

Jos South Local Government Area is located between Latitude 9°30′N and 10°0′N and Longitude 8°30'E and 8°50′E (see Fig. 1). It is situated in the north western part of the State with its headquarters at Bukuru. The Local Government Area has four Districts; Du, Gyel, Kuru and Vwang with a total land area of 1,037 km^2 with a population of 407,900 [11]. Jos South falls within the Jos Plateau climatic condition of the middle belt of Nigeria. Jos South has an average temperature of 180°C to 220°C. The warmest temperatures usually occur in the dry season months of March and April. The mean annual rainfall varies between 1347.5 and 1460 mm per annum [12]. The landscape is characterized by flat, or broadly undulating with flat-topped hills, above which raise the picturesque alkali younger granite bodies [13]. The average elevation of the study area is 1265 m and the approximate highest elevation is about 1325 m [14]. The geology of the study area falls within the Jos-Bukuru Complex which is predominantly of biotite-granite type as exhaustively studied by [14, 15 and 16]. At the eastern part of the area, the streams tend to move into a branching network system resembling a tree dendrite drainage pattern. The two drainage patterns flow from their point sources to major rivers and ponds present within the area [17]. At present the vegetation of the area is mostly covered with grasses, shrubs, and little woodland which is heavily used for fuel, building construction and other purposes [13]. [18] revealed that the land use and land cover in the study area changed over time whereby some increased while others reduced in terms of spatial extent.

2.2 Materials

Primary data and secondary data were used for this study. The position data of the existing dumpsites in the study area was acquired *in-situ* with a handheld Global Positioning System (GPS) receiver. The secondary data consists of NigeriaSAT-X with spatial resolution of 22 m sourced from [19]; Administrative maps obtained from Nigeria Geological Surveys; Google map sourced from Google Earth pro 7.0.2; and text materials, which included technical reports, journals, governmental and non-governmental institutions manuals. The position data (X, Y) of the dumpsite was composed, saved as an excel file and exported to ArcGIS 10.4 as a table. Google Earth Pro image of the study area was used as a reference to update the drainage and road networks in ArcGIS 10.4. The NigeriaSAT-X (2012), Google map, Shuttle Radar Topographic Mission SRTM and geology data were imported into ERDAS Imagine 9.2 and subset the area of interest from the images using boundary shapefile of the study area. The shapefile of bio-physical objects such as built-up, waterbody, vegetation, grassland, bareland, and rock-outcrop and geological units such as biotite granite, hornblende biotite granite, migmatite, laterite and basalt were created in personal geodatabase as polygon feature while drainage and road networks as line feature. The polygon and line features were extracted from NigeriaSAT-X, Google Earth Pro images and geology dataset for land use and geology classification.

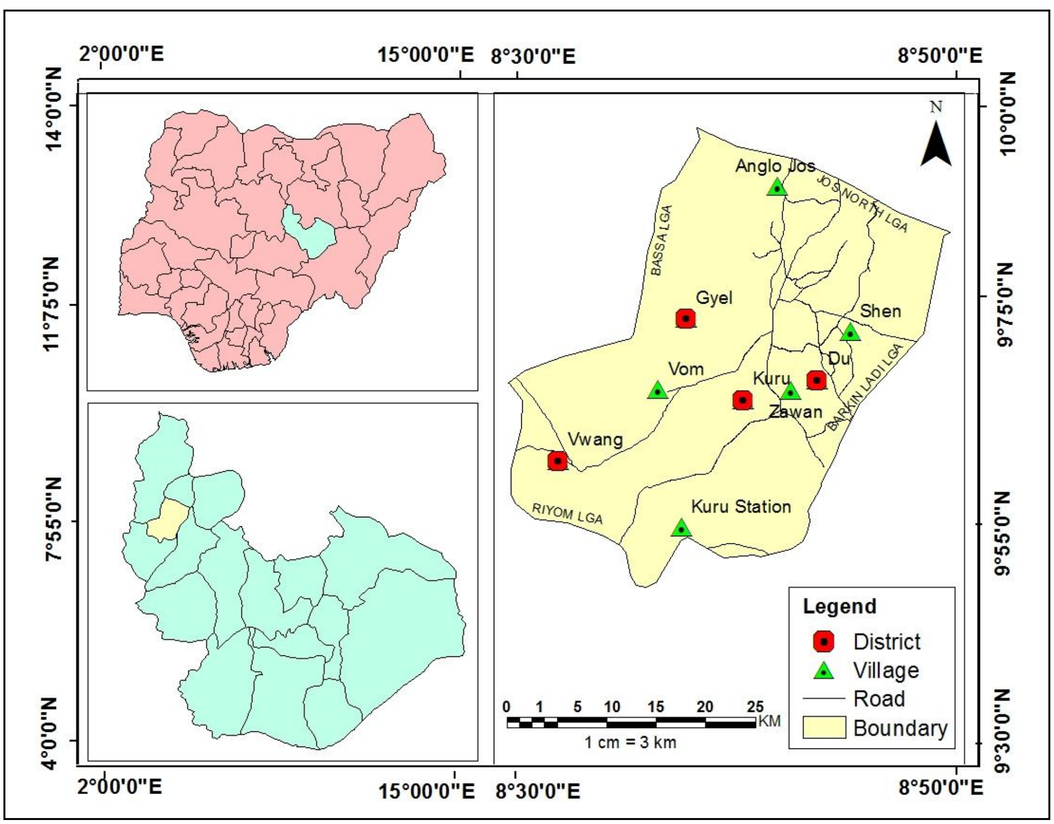

Fig. 1. The study area

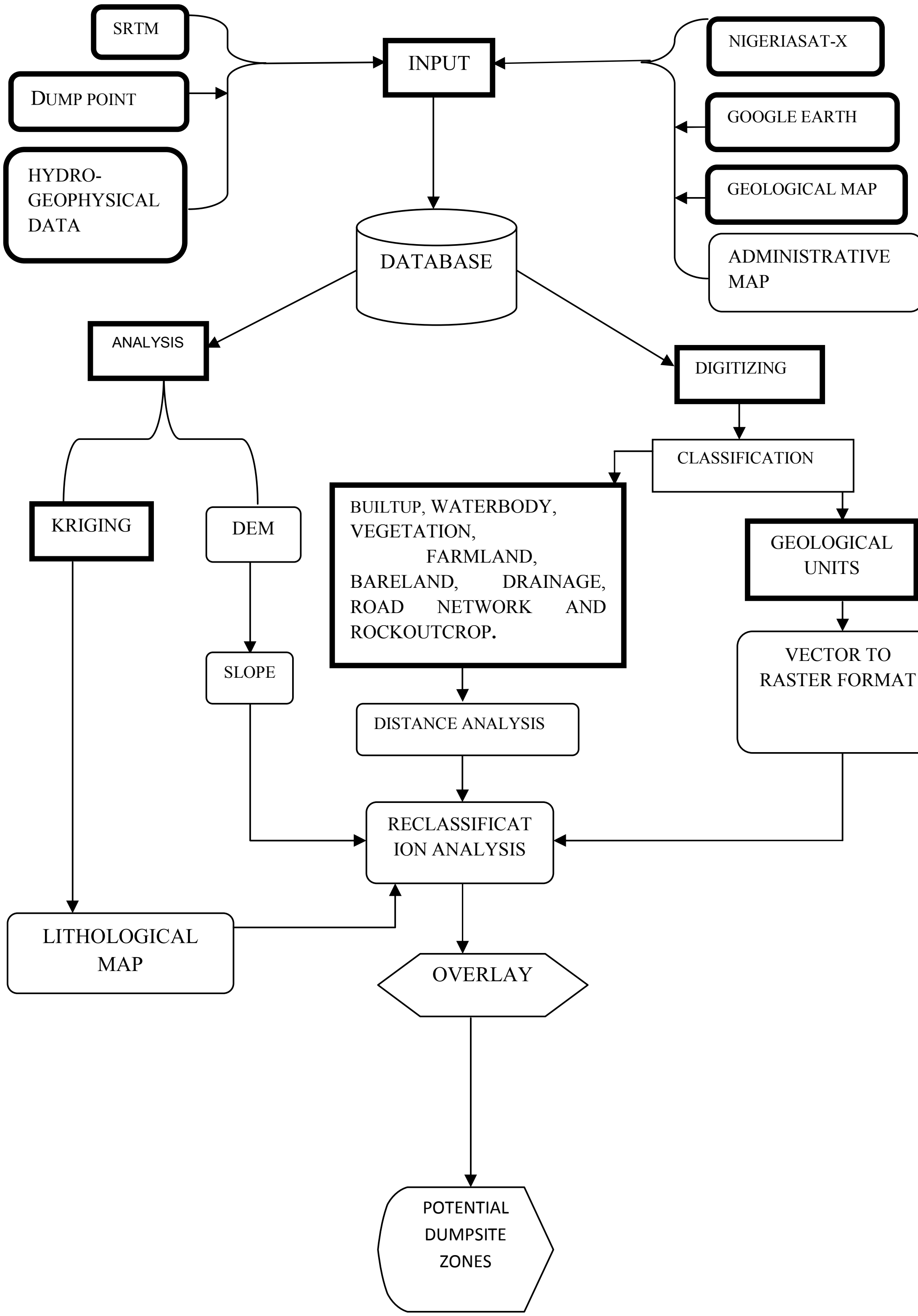

Fig. 2. Work flow

2.3 Methods

The dumpsite point was imported as shapefile and superimposed on the study area boundary to show the existing location of the dumpsites in the study area. Digital image segmentation was carried out on NigeriaSAT-X and Google Earth Pro images to derive the land use and land cover of the study area in ArcGIS 10.4. Shapefile of the dump point was superimposed on environmental sensitive bio-physical objects such as drainage, roads, waterbody, built-up and farmland. The elevation and slope analyses were carried out on the SRTM image using Surface Analyst tool in ArcGIS 10.4 to generate the altitude and steepness of slope. Digital image segmentation was carried out on geology map to derive the geology classification in ArcGIS 10.4. Rasterization Method a Spatial Analyst tool in ArcGIS 10.4 was used to convert the classified geology map from vector to raster format. Lithological analysis was carried out using Kriging Method to interpolate the hydro-geophysical data. The slope, land/use, geology, drainage, road, waterbody, built-up and lithology were reclassified and overlaid using Weighted Sum Overlay Method a Spatial Analyst tool in ArcGIS 10.4 to generate the potential zones for solid waste disposal see Fig. 2 for details.

3. RESULTS AND DISCUSSION

Fig. 3 shows the spatial location of the dumpsite in the neighborhood of drainage, road, waterbody, built-up and farmland contained in the study area.

Fig. 4 shows the result of Land Use and Land Cover and consists seven classes. The classification result shows that grassland occupies total land mass of about (40%), followed by farmland (23%), built-up (19%), rock-outcrop (7%), vegetation (5%), bare-land (4%), and waterbody (2%). However, the assessment and final determination of the most suitable locations will be dependent on other factors, which are also being considered in this study.

Fig. 5 shows the Slope and locations of dumpsites within the study area, Slope which is one of the factors that influence the identification of dumpsite in the study was generated from the DEM. The analysis shows that dumpsite located near Bukuru Market is on a very low slope and the remaining three located at Giro Road are on moderate Slope. In view of Slope, the gentle Slope in the study area can be suitable for sitting dumpsites to control contaminated runoff. However, the assessment and final determination of the most suitable locations will be dependent on other factors, which are also being considered in this study.

Fig. 6 shows the digitized geological composition of the study area and was carried out by digitizing an existing geological map. Five (5) major rock exposures were identified in the study area and they are biotite granite, hornblende biotite, migmatite, laterite and basalt. However, the assessment and final determination of the most suitable locations will be dependent on other factors, which are also being considered in this study.

Fig. 7 shows the physical makeup, including the mineral composition, grain size and grain packing of the sediments or rocks that make up the geological system. Clay is an important factor that impedes the permeability of any liquid form of matter from one area to another. The rock type is characterized by clay, sand, clayey sandy and their content. The analysis shows that all the dumpsites are located on clayey sandy. However, the assessment and final determination of the most suitable locations will be dependent on other factors, which are also being considered in this study.

Fig. 8 shows the weighted overlay map with scale value ranked from 1 – 5. The weighted overlay result shows that; where 1 represents unsuitable (restricted), 2 represents less suitable, 3 represents moderately suitable, 4 represents suitable and 5 represents highly suitable for solid waste disposal within the study area.

Table 1. Shows statistics of the land use coverage (Area and Percentage)

Land use class	Area (Km^2)	Percentage (%)
Bareland	4208.2086	4.145578691
Built-up	19620.7486	19.33816933
Farmland	22828.723	22.48896777
Grassland	40805.6804	40.20257182
Rock-outcrop	7000.9288	6.896735561
Vegetation	4791.6676	4.720354209
Waterbody	2240.5066	2.20762262
TOTAL	**101496.4636**	**100**

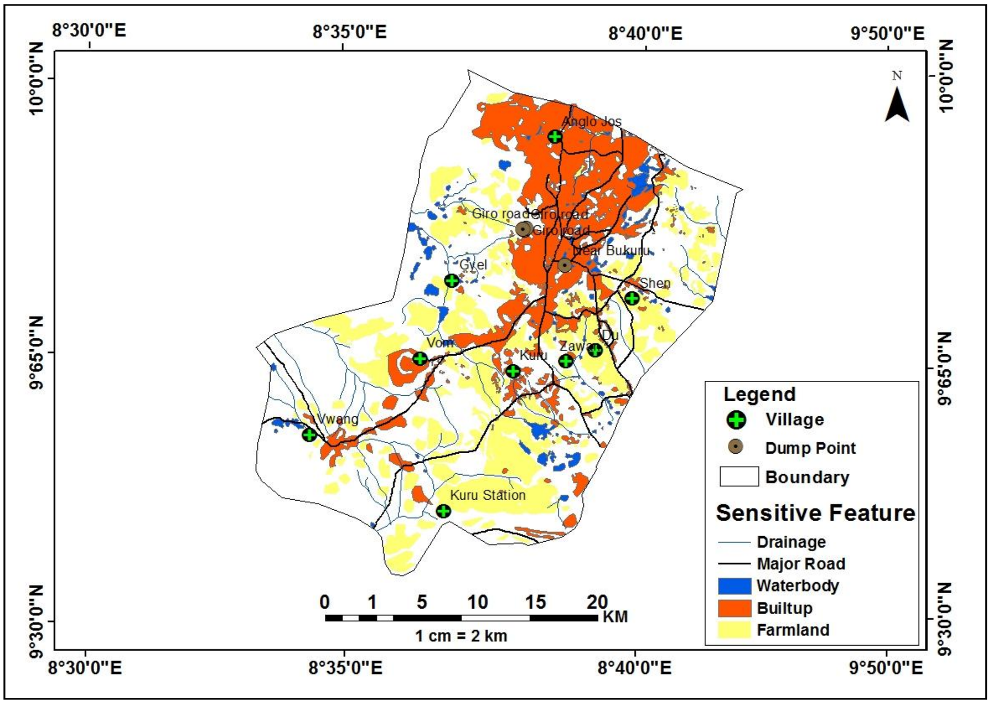

Fig. 3. Spatial location of dumpsite on environmental sensitve features

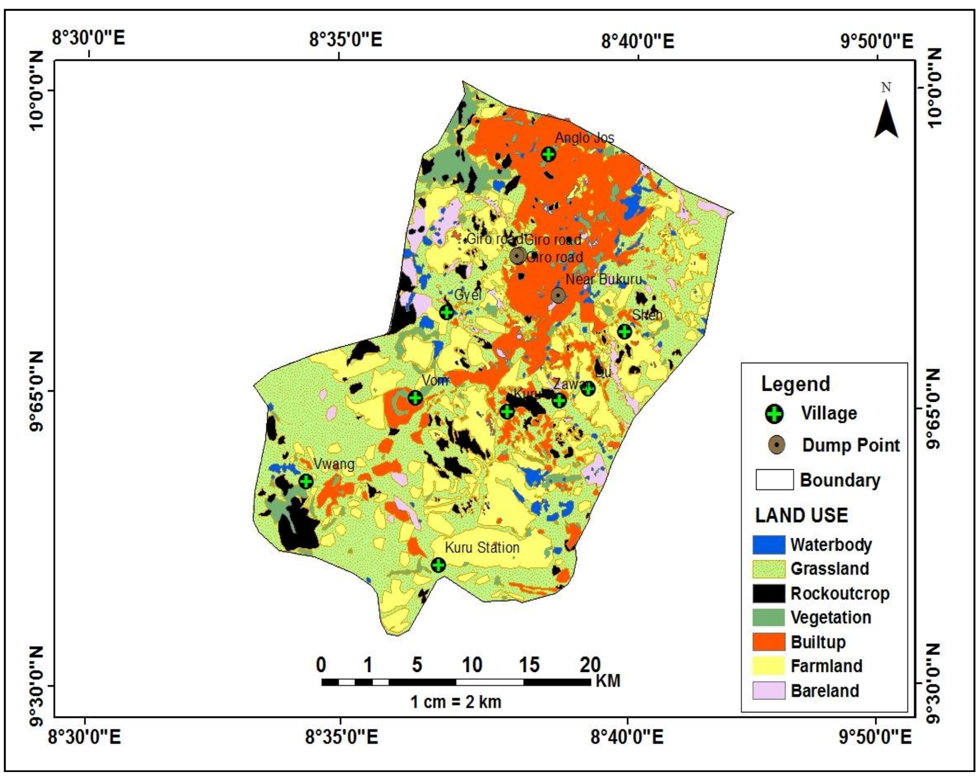

Fig. 4. The Land Use and Land Cover Map

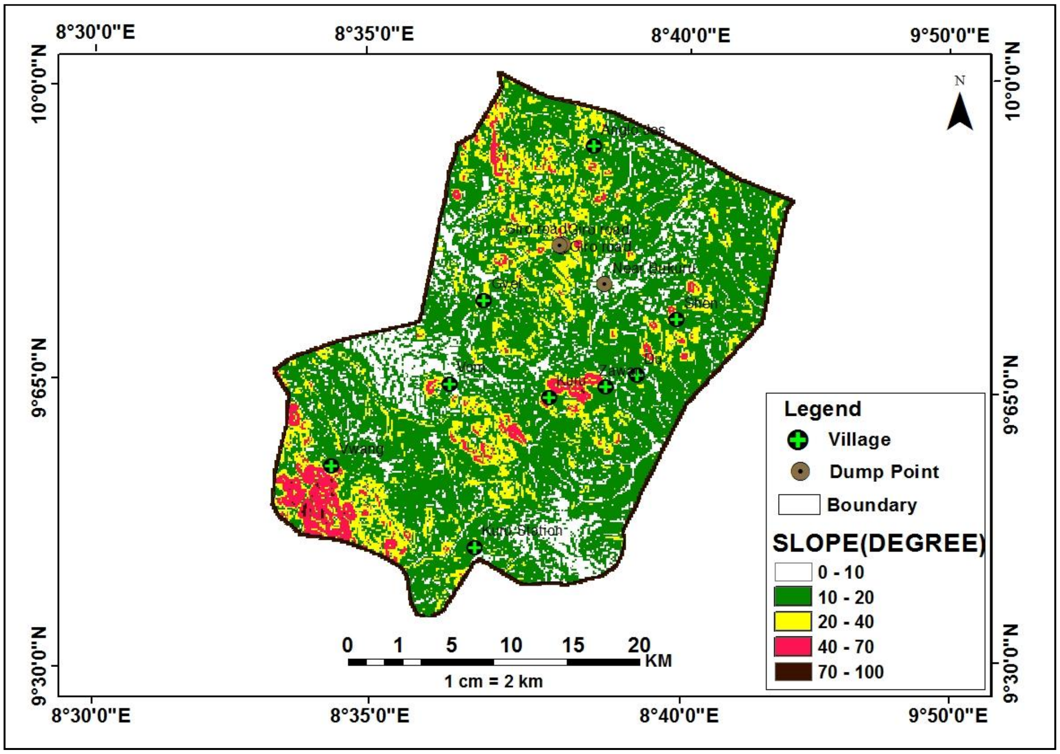

Fig. 5. Slope Map

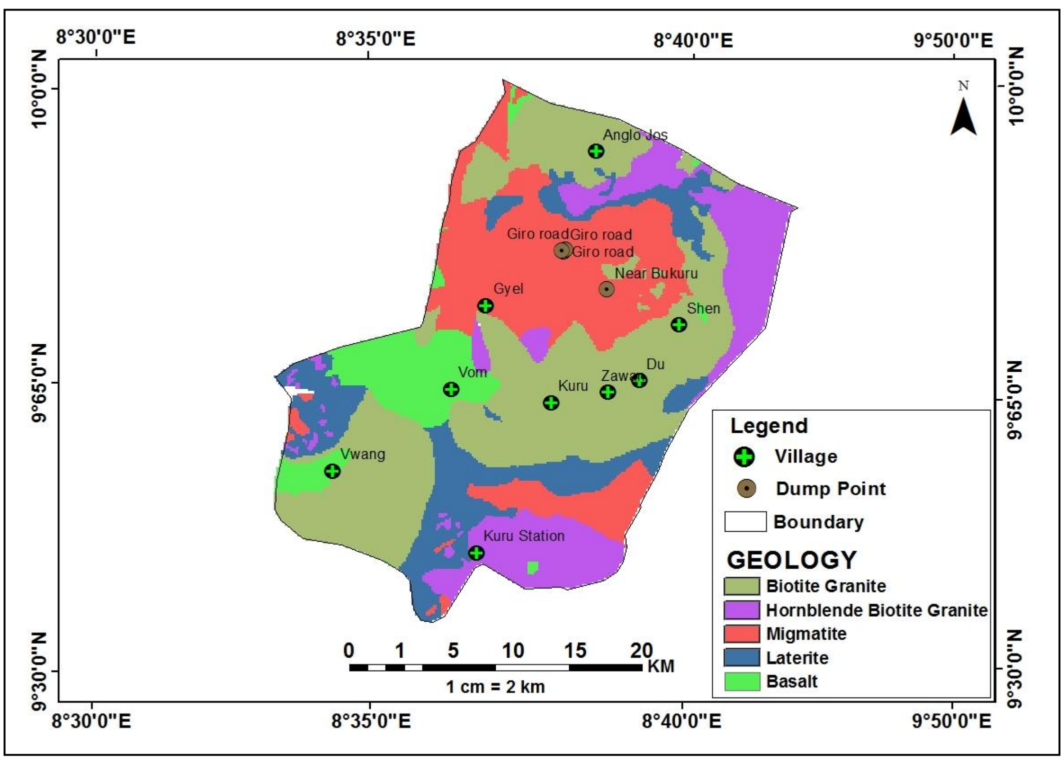

Fig. 6. Geology Map

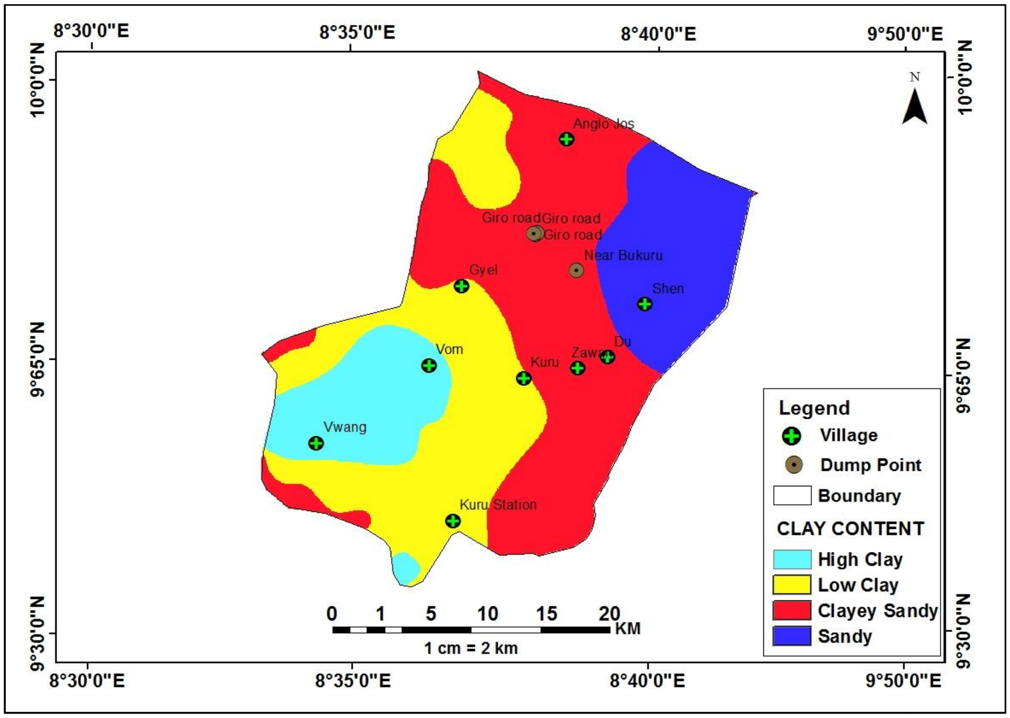

Fig. 7. Lithology Map

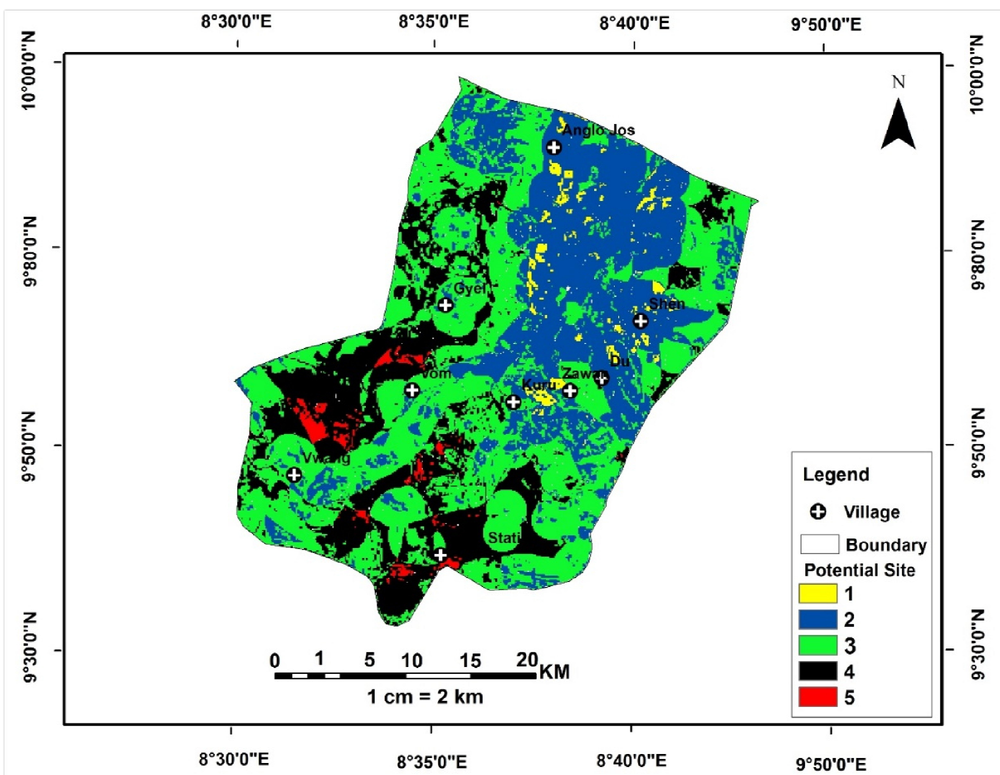

Fig. 8. Overlay map

3.1 Spatial Location of Dumpsite

The result in (Fig. 3) shows that the dumpsite are located in four major different places, three of the dumpsite are located along Giro Road and one is located near Bukuru market in Northern Central part of the study area where daily market activities take place. The dumpsite exists and surrounded by Gyel, Kuru, Zawan, Du, Shen and Anglo Jos villages. The dumpsite exists in a built-up area where social-economic and human activities take place. Waste generation kept increasing around these villages as a result of population increase with different kinds of lifestyles. The municipal solid waste generation in the world is increasing and reflects consumer habits and lifestyles [3].

The dumpsites are spatially located in the neighborhood of drainage, road, waterbody, built-up and farmland as contained in (see Fig. 4.1). The blockage of drainage channels by solid waste at Giro road may cause flooding, piles of wastes found by roads near Bukuru market may obstruct traffic flow, cause ground and surface water contamination. Therefore, accumulation of municipal solid waste at Giro road and near Bukuru market are mostly located in residential and commercial areas which may pose risks to the environment and teeming population. Solid waste disposal site should not be placed near a residential or an urban area, to avoid adversely affecting land value, future development and to protect the general public from possible environmental hazards released from dumpsite. Inappropriate location of solid waste disposal sites has resulted in the contamination of surface and ground water, soil contamination, air pollution, spreading of diseases by various vectors, aesthetic problems and societal nuisance [20]. Indiscriminate disposal of waste have significant economic impacts, in reducing property values and rendering open spaces unusable as well as causing blight for tourist and this may reduce tourism revenue of the country [21].

3.2 Land Use

Land use is one of the most important sub-criteria in environmental assessment. The agriculture lands, pastures control and preservation are the goal of these sub-criteria. Land use types such as grassland, forests, agricultural land, wet land, bush lands would be considered and assigned an appropriate index of land use suitability. Therefore, the southern, western and eastern part of the study area is considered good for solid waste disposal because it consists mostly grassland that occupied total land area of about 40805.68km² and bareland 4208.21km² represents 40% and 4% respectively and if dumpsites is sited there it may not pose challenge on health and environmental concerns as it is shown in (Figs. 4 and 2). The importance of minimizing the association of conflicting land use (LU) in solid waste disposal sitting can be realized by reviewing locally unwanted land use areas. According to sustainable development, it should be tried to use arid and less potential agriculture lands for solid waste disposal. When improperly managed, waste lying in the streets, sewage and dumpsites attract flies, rats, and other vectors, which in turn, spread infectious diseases [22].

3.3 Slope

(Fig. 5) shows the result of Slope and locations of the dumpsites within the study area. It is desirable to have a topographic surface that tends to shed water to reduce pounding and incident infiltration. A study conducted by Erkut and Moran, (1991) states that if the slope is too steep. It is observed from the result that slope ranges from (0° - 10°) represents low slope, (10° – 40°) occupies larger area represents moderate slope and (70° - 100°) represents high slope. It is clear that areas that have the value of slope ranging from (0° - 10°) is a very good ground in retaining the movement of dangerous liquid waste materials and those areas with high slope ranging from (70° - 100°) is very poor in retaining the movement of dangerous liquid materials. In relation to solid waste disposal, flat areas where the slope amount is low are capable of preventing surface and groundwater pollution, steep slope may permits high run-off of dangerous liquid chemicals from waste materials. The dumpsite located near Bukuru Market is on a very low slope and the remaining three located at Giro Road are on moderate Slope.

3.4 Geology

Geology of an area plays a vital role in identifying a suitable site for dumpsite. The geological units comprises of biotite granite, migmatite, laterite and basalt as shown in (see Fig. 6). The biotite granite covers large portion and basalt covers a small portion at south western part of the study area. It is observed that dumpsites are located on migmatite that is characterized by clayey sandy soil and covers large portion of Anglo Jos, Shen, Du, Zawan and Kuru villages. The basalt is characterized by clay with little or no sand and the soils are derived from heavy clay within the study area and covers large portion of Vom and Vwang villages. The result shows that the dumpsites are clearly located on clayey sandy soil in the study area which is coarse, porous in nature and can enhance the underground movement of dangerous liquid substances from the dumpsites to underground water. In view of rock exposure, the sitting of dumpsite may be suitable on basalt because it contains high clay portion of the study area that may prevent groundwater and environmental pollution. There are many factors which should be considered in locating a solid waste disposal area such as topography, hydrology and geology of the area.

3.5 Lithology

Lithology of the study area consists of clay content. The result shows that the dumpsites are located on a clayey sandy area surrounded by Anglo Jos, Du and Zawan villages as represented in (Fig. 7). Clay is an important factor that hinders the permeability of any liquid substances from one area to another. It is observed that Vwang and Vom villages are covered with high clay content and has a clay. Kuru, Kuru Station and Gyel villages are covered with low clay content and has clay. Anglo Jos, Du and Zawan villages are covered with clayey sandy content and has clay. Shen village is covered with sandy and content low clay. The sitting of dumpsite may be suitable on a thick clay portion of the study area that could hinders the movement of dangerous liquid substances from the dumpsite to groundwater.

3.6 Potential Zone

The final result in Fig. 8 shows the classification of the identified area where 1 represents the following bio-physical datasets such as built-up, waterbody and rock-outcrop are considered restricted, 2 represents vegetation considered to avoid degrading natural environmentally sensitive areas, 3 represents farmland considered of economic value and does not disturb food security, 4 represents grassland considered with less economic value and 5 represents bare-land considered with less economic value for solid waste disposal. The result shows the potential zones for solid waste disposal and characterized into unsuitable, less suitable, moderately suitable, suitable and highly suitable.

4. CONCLUSION

The findings have shown the ability of GIS and remote sensing as a veritable tool for analyzing and supporting a multi-criteria decision making process. The analysis relied on various land use, environment and topographic information as input factors in order to find appropriate site for solid waste dumping site. These places are far away from any water sources and other variables input into the analysis. Information on different aspects for this study like land use, road, slope, drainage, lithology etc., has been derived using this technique. Further integrating these data using GIS has helped in the analysis of the study, which would have otherwise been difficult to do manually using the conventional method. The suitable sites are located in southern and south western part of the study area and the site is predominantly occupied by farmland areas, bare-land and grass land with (0% - 10%) slope. This study has demonstrated the capacity of GIS and remote sensing technology for the effective identification of suitable solid waste dumping site, which is necessary to minimize the environmental risk and human health problems arising from dumpsite pollution and contamination.

5. RECOMMENDATIONS

The use of GIS for site selection process can make the identification of a potential site for solid waste disposal more transparent, helping local authorities to adhere to environmental protection regulations and reduce public opposition. Dumpsites should be properly located and managed to minimize its effects on the environment and human health. The local government authority and municipalities should revise laws regarding the locations of dumpsites. These laws should include properly managed sites, which are well fenced in and away from human settlements. The government should annex laws which see to it that dumpsite are located properly and if it is not then action should be taken according to the law. There should be a follow up in the functioning of the dumpsites to avoid pollution on the environment and health hazards. Municipalities should open dumpsites on remote areas with no residents closer to them to avoid the effect of the dumpsite on the nearby residents and monitor the dumpsite properly. They also have to control the indiscriminate litter of solid waste and monitor their volume. People need to be educated by health motivators about the effects of dumpsites on their health. There should also be a follow-up to make sure that what they teach the residents is applied.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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