Site Screening for Landfill Development at the District Level: Case Study in the Prestea Huni-Valley Municipality of Ghana*

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Abstract

The acquisition of sites for landfill development as suitable alternatives to solving the environmental and health problems associated with open dumping has been a difficult challenge for many urban areas in Ghana and other developing countries. This paper presents the steps and results of a simple but practical GIS-based methodology for meeting existing regulatory requirements, policy guidelines and local conditions in the selection of landfill sites. A case study approach was adopted with the Prestea Huni-Valley Municipal Area (PHMA) as the study area. Using the waste management needs of the study area and the regulatory requirement as bases, the necessary data sets were gathered and organized into a spatial database suitable for site selection analysis. The factors considered include proximity to water bodies, roads, railways and settlements, and considerations for land cover/use types, slope classes, hydrogeological conditions and soil characteristics. The analytical processes used include supervised classification, constraint mapping, buffering, overlays, raster-vector conversion, boolean algebra and simple additive weighting for the multi-criteria decisions involved. The initial results gave over 100 sites that met the regulatory requirements but these were prune to about 50 suitable ones in a second stage screening, where sites that were not economical for landfill development in terms of their morphology, accessibility and lifespan capacity were dropped and classified as unsuitable. Accuracy assessment was done to ensure the reliability of data used and results obtained by using ground-truthing and input data comparison with model results. The paper recommends the method for waste management departments in PHMA and other similar areas, and that the few suitable sites constituting about 0.67% of the entire area should be protected to serve the growing needs for improved waste disposal in the study area.

Keywords: Waste Disposal, Landfill, Site Selection, Regulatory Requirements, Prestea Huni-Valley

1 Introduction

Many communities in Ghana and other developing countries are plagued with several municipal waste management challenges such as increasing volumes of waste generation, low levels of waste collection, crude waste disposal practices, high environmental sanitation problems and inadequate acceptable final disposal sites and facilities (Kwesi *et al.*, 2018; Miezah *et al.*, 2015; Anon., 2014; Hamer, 2003). There has therefore been increasing concerns and demands for sustainable solutions to the rising municipal waste management problems (Shekdar, 2009). Based on an estimated population of 31 million in 2021 and an average daily waste production per capita of 0.45 kg, Ghana is generating about 5.1 million tons of solid waste annually (Anon., 2021; Miezah *et al.*, 2015; Anon., 2014; Anon., 2010). These quantities may double by the next decade. A high percentage of these volumes of waste are being disposed without adequate protection from the nuisance and harm caused to the environment and public health. One area that has been identified as having potential for improving waste disposal in developing countries, is the use of engineered landfilling. This was a major reason that necessitated the development of the Landfill Guidelines (LG) by the Environmental Protection Agency (EPA) of Ghana and other countries (Anon., 2010; Anon., 2002). Amongst other functions, the guideline was to provide the basis upon which Environmental Permits and Certificates for land operations would be issued and renewed by the EPA and other related Local Authorities like the Metropolitan, Municipal and District Assemblies (MMDAs) in the country. Meeting these permit requirements start with the identification of sites that meet regulatory requirements for locating landfills and other waste disposal facilities. The guidelines entreat all MMDAs to identify, acquire and secure such sites for current and future use so as to eliminate or reduce the perennial lack of appropriate final disposal sites for effective waste management.

Unfortunately, this has not been embarked upon in a number of MMDAs (Kwesi *et al.*, 2018; Anon., 2002). One way to help address this need is the provision of a simple practical step by step scientific method for carrying out the complex site screening and selection exercise to meet the requirements described in the guidelines and regulations (Arkoc, 2014; Khan and Samadder, 2014; Onuigbo and Bello, 2014; Nishanth *et al.*, 2010; Kwesi and Asabere, 2010; Wang *et al.*, 2009; Khoshnam, 2006). Thus, the objective of this paper is to present and demonstrate the application of survey and mapping, and GIS in a simple and practical approach for addressing the site screening need, using the

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Prestea Huni-Valley Municipality of Ghana as a case study area.

1.1 Physiological and Socio-economic Background of Study Area

The study area is the Prestea Huni-Valley Municipal Area (PHMA) with Bogoso as the administrative capital. Fig. 1 shows the study area which is located in the Western Region of Ghana within latitudes 5° 15′ N and 5° 40′ N and longitudes 1° 40′ W and 2° 15′ W. PHMA has an area of about 1200 km^2 and a population of about 159, 304 with Prestea, Aboso, Huni-Valley, Bogoso, and Damang as the major urban centres. (Kwesi *et al*., 2020; Anon, 2014). The area is one

of the major mining centres in Ghana that attracts many people from other parts of the country, other African countries and the world at large. Many of the major mining operations in the country are located in PHMA (Kwesi *et al*., 2020; Kusi-Ampofo and Boachie-Yiadom, 2012; Kuma and Ewusi, 2009). Thus, the economy of the area centers on mining and agriculture and related commerce and services. The administrative capital, Bogoso, also serves as an important commercial and transit centre connecting the western and coastal towns to the northern parts of Ghana, and travellers from southern Cote d'Ivoire to Burkina Faso (Kwesi *et al*, 2018). These factors attract migrants to the area for jobs and business which in turn contribute to the rapid urbanisation and increasing waste disposal and sanitation problems observed in the area (Kwesi *et al*, 2020; Anon., 2014).

The study area has a topography that is generally undulating with some scarps ranging from 150 - 300 meters above sea level (Kwesi *et al.*, 2018; Mantey, 2014). Small scale mining operations frequently take place along these ridges and valleys (Kwesi *et al*, 2018; Kusi-Ampofo and Boachie-Yiadom, 2012; Asante, 2011). In terms of Geology, the area forms part of the Birimian and Tarkwain formations (Fig. 2). Aquifers in the area are considered possessing dual and variable porosity and limited storage capabilities (Kuma and Ewusi, 2009; Kortatsi, 2004; Kesse, 1985). Surface and ground water, and the general environment are prone to pollution due to the prevalence of inappropriate mining and waste disposal practices in the area (Kwesi *et al*., 2020; Kyerematen *et al.*, 2018; Sackey, 2016; Wilson *et al.*, 2015; Yankey *et al.*, 2011; Asante, 2011).

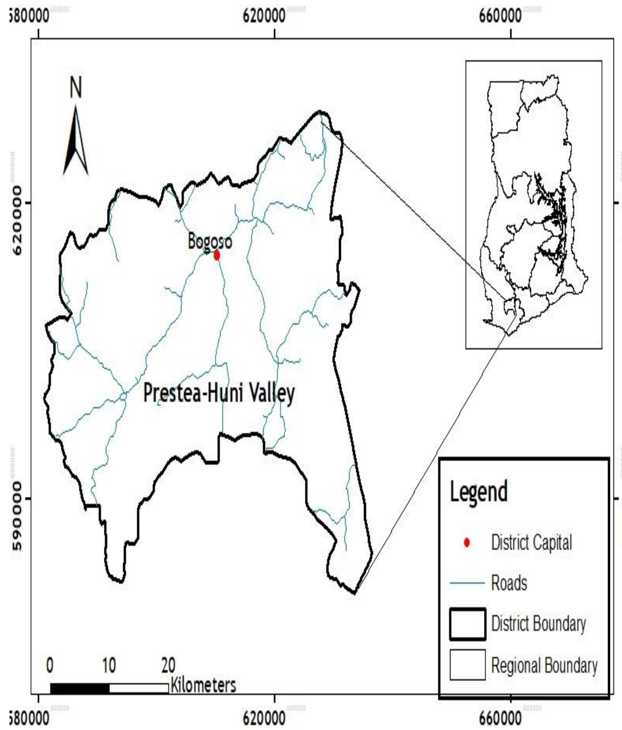

Fig. 1 Map Showing Location of Study Area within Ghana

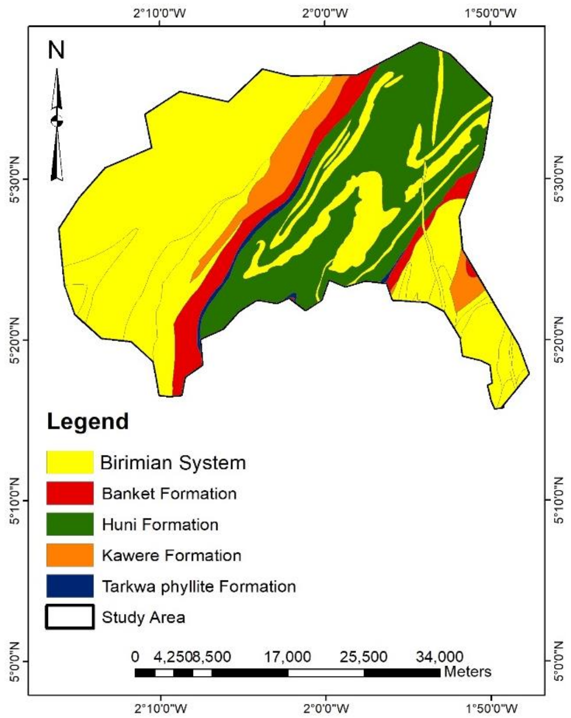

Fig. 2 Simplified Geological Map of the Study Area

2 Resources and Methods Used

2.1 Materials Used

The materials used for the study include secondary data comprising criteria information, maps and related information on topography, geology, hydrogeology, soil, land-use/cover, utility and communication lines, climate and administrative and property boundaries. The primary data comprise of field coordinates, photographs, and interviews; and data capturing, processing and analyses equipment like GPS receivers, cameras, scanners, computers and their associated software and accessories. The data sources include Landsat ETM+ images of 2015, the US Geological Surveys (USGS.com), Google Earth, data vendors and government and private organisations (such as EPA, MMDAs, TCPD, Lands Commission, High Ways Authority, Forestry Commission, Geological Survey Department, Minerals Commission and Meteorological Service) dealing with or related to waste management issues. The Digital Elevation Model (DEM) for the slope analysis was obtained from ASTER Global DEM (GDEM) whereas the soil data was obtained from maps published by FAO ISRIC. The software used include ArcGIS (10.4 and 10.5) and Microsoft Office Suite (2013 and 2016).

2.2 Methods Used

The general methodological steps employed include review of relevant literature on waste disposal and site selection for municipal waste management; data collection and processing, formation of geodatabase, criteria selection for the analysis, data analysis and accuracy assessment, and results presentation and discussions. Details of these steps are presented in the proceeding sub-sections.

2.2.1 Data Collection

The main data used were secondary in nature, and consisted of remote sensing images and land cover/use maps, geology and topographic maps, legal requirements and site selection criteria from government and private agencies and experts dealing with waste management; as well as shapefiles of Ghana from data vendors (see section 2.1 for sources). Some of the remote sensing data were downloaded in the form of Landsat imagery from the United States Geological Survey website (www.usgs.com). The raw satellite imagery covered large portions of the western parts of Ghana from which information on the study area were extracted in raster forms. The shapefiles on the other hand provided vector data on regional boundaries, the districts, rivers, climate, railways, elevation, slope, major roads, capital cities and majors towns of the study area. Primary data were captured in points, photo images and interview forms using a handheld GPS and cameras for ground truthing, accuracy assessment and augmenting of the secondary data and the model results of the analysis.

2.2.2 Development of the Geodatabase

The geodatabase for this work was developed as a digital repository of all the necessary information for carrying out the analyses required to address the study objectives. It facilitated easy and fast retrieval of information and the execution of queries to obtain needed results. The ArcCatalog module of ArcGIS 10.4 was applied prominently in the creation of the geodatabase. It was spatially referenced to the Ghana Meter Grid Projection to enable all work done in the database to remain in one projection.

2.2.3 Image Classification

The supervised classification technique was employed in this work for the image classification which involved the assigning of land cover classes to pixels. Representative samples known as training samples for each land cover class were selected to help the algorithm (programme) determine and compile all the land cover classes in the work based on their resembles with the classes in the training samples set. Five land cover/use classes were identified in this work, namely forest, grass, built-up, mining and bare-land areas.

2.2.4 Criteria Selection and Application

The criteria for site screening and selection were compiled from the established guidelines from Ghana Environmental Protection Agency (GEPA) and other relevant literature into a general pool of criteria. Table 1 shows a sample of these criteria. These were grouped into two, the permissible criteria which indicated conditions for sites to be either permitted or not permitted for use, and the suitability criteria which indicated conditions for a site to be selected as desirable or not desirable after meeting the permissible criteria. Table 2 shows a sample of this sub-classification.

These criteria took into consideration the welfare of the inhabitants, the environmental impact of any decision taken and then finally, the financial capacity of decision makers. The criteria that influenced decision making for permissible site include buffers to major social utilities and amenities in the study area such as roads and rivers. Slope component of the study area was also key in the decision-making process of landfill siting.

Table 1 Examples of the Site Selection Criteria and Buffer Zones Used

Criterion Factors/Elements	Restrictions Related to Criterion Element Based on Regulatory Requirements	Criteria Applied
Land Use (Residential Areas, Active Mining Sites, Cemeteries, etc)	Areas within 500 m of residential and other sensitive land-uses	500 m buffer for residential, 200 m buffer for cemeteries and 300 m for active mining areas.
Land-cover (cash crops/farms, forests/game reserves, etc.)	Areas within 300-500 m of reserves and other properties	300 m buffer
Surface Water Bodies	Areas within 90-360 m of rivers, lakes, ponds, dams, wells, and springs	400 m buffer was used for important wells and 500 m buffer around other important water bodies
Roads, Railways and Utility Lines (water, gas, power and telecom lines)	Areas within 100-200 m of public transport and import utility lines	200 m buffer
Airport Runways and landing strips	Areas within 3 000 m from the end of airport runways and landing strips in direct flight paths and areas within 500 m of airport or airfield boundaries	3 000 m buffer and 500 m buffer
Slope	Areas with slopes ≤ 2% and ≥ 10%	slopes ≤ 2% and ≥ 10%
Soil	Areas with shallow bedrock and little soil cover	Based on the geology and soil information of the study area, locations characterized by the Fluvisols soil groups were rated as unsafe and thus restricted for use.
Geology	Subsidence, fault, seismic, mining and other unstable areas	Based on the geological information of the study area, locations having the Banket Series (Phyllite, Quartzite and Conglomerate hosting gold mineralisation), as well as the Huni Sandstone Formations within the Tarkwaian system were rated as unsuitable and thus restricted for use.

Table 2 Examples of Sample the Site Selection Criteria for Desirable Conditions

Criterion Factors/Elements	Conditions Related to Criterion Element Based on Desirable Requirements	Criteria Applied
Site size and morphology	Big enough to allow smooth development and operation of landfilling for long lifespan	areas ≥ 4 km^2 and dimensions ≥ 100 m
Accessibility to site	Site proximity to access routes	within 5 km from main roads (outside restriction buffers)
Ground water Pollution	Areas with low ground water contamination risk	Ground water vulnerability map of area

2.2.5 Buffering for Restricted Linear Features

In ArcMap, buffer zones were created for the restricted linear features such as roads and rivers within which landfill sites would be unacceptable. Conditions were then set for areas within the buffer zones to be classified as unsuitable (or not permissible) but the regions outside as suitable (or permissible). The restriction maps for both major roads and rivers were then produced as individual criterion map layers.

2.2.6 Land Cover/Use Restriction Application

The classes in the land cover/use map were applied in the creation of the restricted areal maps showing features like residential, mining and forest reserve areas that were to be set as prohibited for landfill siting. The allowable areas on the land cover/use maps include the bare and grasslands. The Con tool in the ArcToolbox of the ArcMap was employed to set these criteria.

2.2.7 Slope Generation

Using the Con Tool in the Spatial Analyst tool of ArcGIS 10.4, various slope classes for the study area were generated from the shapefiles and other datasets acquired for the study. Based on the criteria, areas with slopes below 2ºor above 10º were considered unsuitable for the work while those within this range were considered suitable or permissible.

2.2.8 Vector-Raster Conversion

The resultant maps from the road, river and slope restriction were feature classes which were all in vector formats. There was the need to convert these vector map layers into raster formats for the weighted overlays to be carried out. This was done using the Feature to Raster tool in the Conversion toolbox. Conversion into raster made the identification of permissible sites easier in the ArcGIS environment since it identifies and works with pixels more readily.

2.2.9 Reclassification of Raster Data

As part of converting all vector data formats into raster formats, reclassification became necessary. It was used to streamline or change the reading of the newly formed raster data formats, by changing a single value to a new value or grouping ranges of values into single values. The process involved criteria weighting by the ranking method and the application of colours for symbolizing the segregation and classification of the input or output data. All suitable criteria assigned in this work took a rank of 1 while the unsuitable classes took a rank of 0. For example, using the raster calculator tool, the resultant slope map was segregated into two regions; areas with slopes =< 10º and >= 2º reclassified as suitable (1), and areas with slopes > 10º and < 2º reclassified as unsuitable (0).

2.2.10 Weighted Overlay

The Simple Additive Weighting (SAW) method which is one of the simplest and most often used multi-attribute decision technique was employed in this work. The first step of GIS based Simple Additive Weighting method was to define the set of evaluation criteria involving the set of map layers and feasible areas on them. The set of feasible alternatives which are the pixels of the map suitable for landfill siting were obtained by excluding the areas restricted by rules and physical constraints. Since the score (% influence) of the criteria were given on different scales, they were standardized to a common dimensionless unit. Table 3 shows a sample of the gravity of influence each criterion had on the total overlay of data layers.

The SAW method evaluates each alternative, Ai, by the following formula as in Equation (1):

$$A_i = (\sum_i W_j * X_{ij}) \quad (1)$$

where x_{ij} is the score of the i^{th} alternative with respect to the j^{th} attribute, w_j is the normalized weight. Fig. 3 shows a simplified flowchart of the simple additive weighting method employed for this study.

Table 3 Influence (%) of each Criteria

Permissible Data Layer	**% Influence**
Roads	30
River	30
Slope	10
Land cover	30
Resultant Map of Permissible Sites	**100**
Suitability Data Layers	**% Influence**
Size and morphology	*30*
Proximity to Access Route	*30*
Ground water Pollution	*40*
Resultant Map of Suitable Sites	***100***

2.2.11 Accuracy Assessment

The accuracy of the classified image points from the image data used for the work was assessed relative to reference points obtained from ground truthing survey. The accuracy of this project was examined by picking sample points from the Landsat image and relating them to points obtained by reference ground truthing. The confusion matrix which involves the relationship between two classes of land cover image at a time, was the foundation for this accuracy assessment as shown in Equation (1).

$$\text{The Overall classification accuracy} = \frac{\text{Number of correct points}}{\text{Total number of points}} \times 100\% \quad (2)$$

The Kappa coefficient may be used as a measure of agreement between the model predictions and reality. Using Kappa Statistic for accuracy assessment reflects the difference between actual agreement and the agreement by chance.

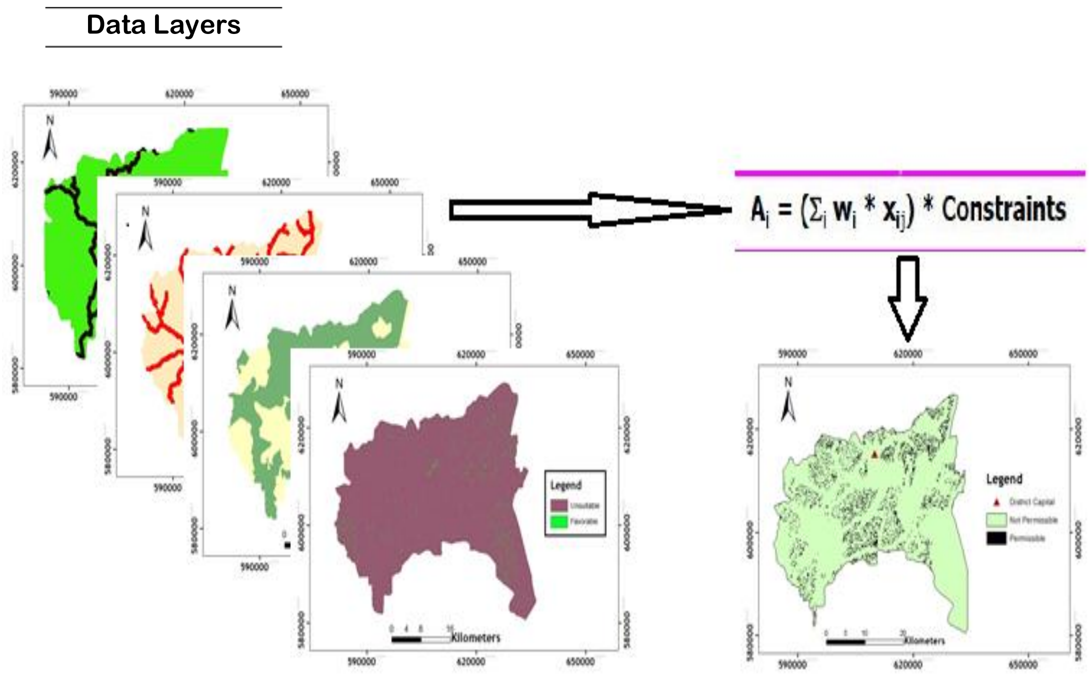

Fig. 3 Flowchart of the Simple Additive Weighting Method Used

The formula is expressed as in Equation (3):

A Kappa coefficient equal to 1 means perfect agreement where as a value close to zero means that the agreement is no better than would be expected by chance. Table 4 shows the categorization of Kappa the statistics.

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_i \times X\ x_{+1})}{N^2 - \sum_{i=1}^{r}(x_i \times X\ x_{+1})} \qquad (3)$$

Table 4 Rating Criteria of Kappa Statistics

S/No	Kappa Statistics	Strength of Agreement
1	<0.00	Poor
2	0.00 - 0.20	Slight
3	0.21 - 0.40	Fair
4	0.41 - 0.60	Moderate
5	0.61- 0.80	Substantial
6	0.81 - 1.00	Almost perfect

(Source: Rwanga and Ndambuki, 2017)

3 Results and Discussion

The results of the data processing and analysis based on the criteria applied for identifying suitable sites for municipal solid waste disposal in the study area are presented in Figs. 4 to 12. The subsequent sections discuss these in details.

3.1 Derived Land Cover/Use Maps

Five (5) land cover classes namely built-ups, mining, forest, grassland and bare lands were derived from the supervised classification process of the satellite images based on the land cover/use restriction requirements. Fig. 4 and Tables 5 and 6 provide more information on these. The results show that grassland which encompassed all other forms of vegetative cover aside forest areas, was predominant over the study area.

Table 5 Land Cover Description

SN	Land Cover/ Use Type	Description of Features in Land Cover/use Type
1	Built-up Areas	Areas where much of the land has been covered by structures such as towns, buildings, recreational areas, and ponds
2	Mining Areas	Areas of active mining activities such as pits, sand tails and slime discharge areas, mining ponds and spillways
3	Forest	Rain forest, secondary re-growth, trees with no overhead canopy
4	Grass lands	Farm lands, crops, grass cover, bushes and freshly cleared /planted areas
5	Bare lands	Uncovered land patches and fallow vegetation which dry up in the dry season exposing partly the soil cover

Table 6 Land Cover/Use Areas

Cover Type	Area(km^2)	% of Area
Built-ups	79.0245	5.1362
Mining Areas	75.5325	4.9092
Forest	213.2163	13.8579
Grassland	1139.0166	74.0302
Bare land	31.7943	2.0665
Total	**1538.5842**	**100**

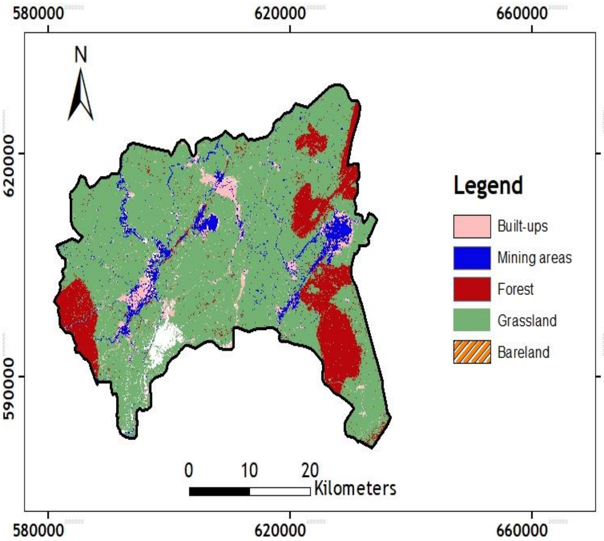

Fig. 4 Map Showing Land cover/use Categories

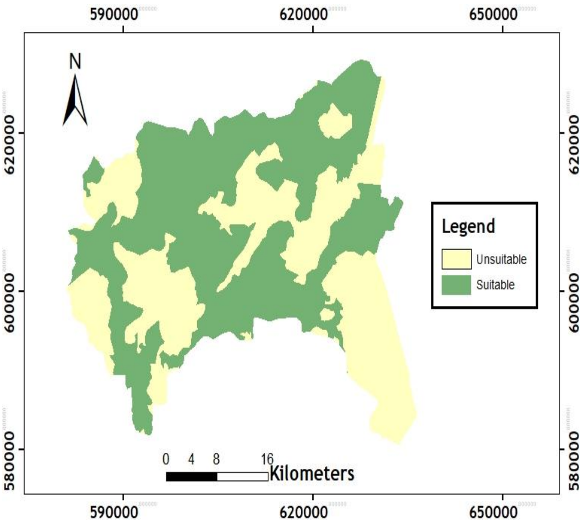

Fig. 5 Map Showing Permissible Areas based on Land cover/use Criteria

3.2 Permissible Areas Based on Land Cover /Use Restrictions

Due to the presence of mineral reserves within the study area, population influx and growth was high and the rate of expansion and development in the urban centres were also high. Thus, reasonable buffer limits had to be set for landfill siting so as to avoid unnecessary land use conflicts with the current and future economic and social developments of the area. Using information from Tables 1 and 2, buffers ranging from 300-500 m were applied to rule landfill siting in close proximity to the forest reserves, residential areas and mining sites. Fig. 5 and Table 7 show the results of the application of the land cover/use restriction criteria.

Table 7 Area Analysis on Land Cover/Use Constraints

Constraint	Ranking	Area (km^2)	% of Area
Mining, Forest and Built-up Areas	0	657.2790	42.7135
Grassland, Bare land	1	881.5302	57.2865

3.3 Permissible Areas based on Slope Restrictions

Based on the slope criteria for this study (Tables 1 and 2), areas with slopes between 2% and 10% were considered permissible (suitable) for landfill use and ranked 1; whiles areas with slopes less than 2% and greater than 15% were considered unsuitable (restricted) and thus ranked 0. Fig. 6 and Table 8 show the site classification of the area based on the slope criteria and analysis. The slope of an area is one of the basic parameters considered when deciding on potential landfill sites. Areas having gradients greater than 10%, would not be suitable for landfilling since the stability of the slopes might be difficult to guarantee and runoff rate could be high and carry contaminants into the wider environment.

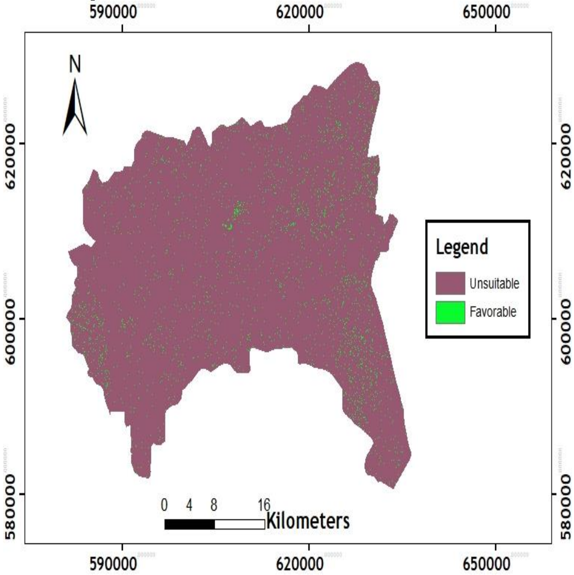

Fig. 6 Permissible Areas based on Slope Criteria

Table 8 Area Analysis based on Slope Constraints

Slope Constraint	Ranking	Area (km²)	% of Area
> 10° and < 2°	0	1503.297	97.6805
=< 10° and => 2°	1	35.6967	2.3195

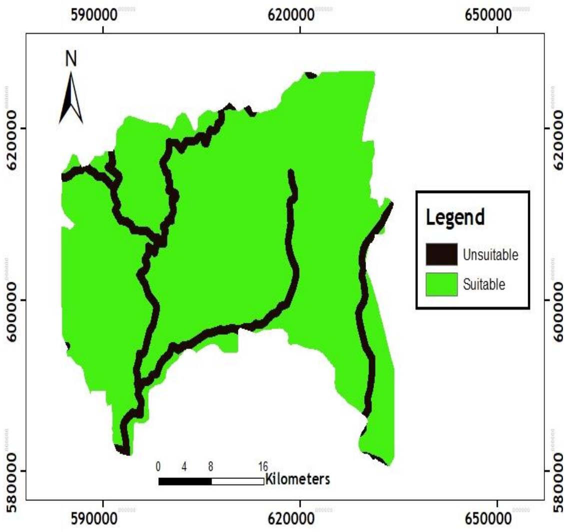

Fig. 7 Permissible Areas based on Criteria for Water

3.4 Permissible Areas based on Surface Water Restrictions

The study location is a mining area where the effects of both legal and illegal surface mining activities on water bodies are already of a great concern to the general public with increasing threats of deteriorating water quality and health implications in the future. Fears of such threats will be heightened when landfill are sited in close proximities water bodies. Accordingly, 500 m buffer was used for the restriction. The entire study area was segregated into two broad regions, those within the buffer zones classified as not permissible or unsuitable for waste disposal, and those outside the buffer zones classified as permissible for locating waste disposal sites. Fig. 7 and Table 9 show the site classification of the area based on the criteria and analysis for surface water restrictions.

Table 9 Area Analysis based on Surface Water Constraints

Constraint	Ranking	Area (km²)	% of Area
=< 500 m buffer	0	1637.271	10.9493
>500 m	1	13315.968	89.0507

3.5 Permissible Areas based on Roads, Railways and Utility Lines Restrictions

According to the constraint requirements (Table 1 and 2), landfills should not be located within 300 m of any roads so as to avoid the nuisance caused by birds and other scavenging animals crossing the roads. To reduce the nuisance effects on humans plying the roads, 300-500 m buffers were applied to set off landfill siting from railways, roads and other utility lines based on their relative importance. Fig. 8 and Table 10 are samples of the analysis results showing the site classification of the area based on these restrictions.

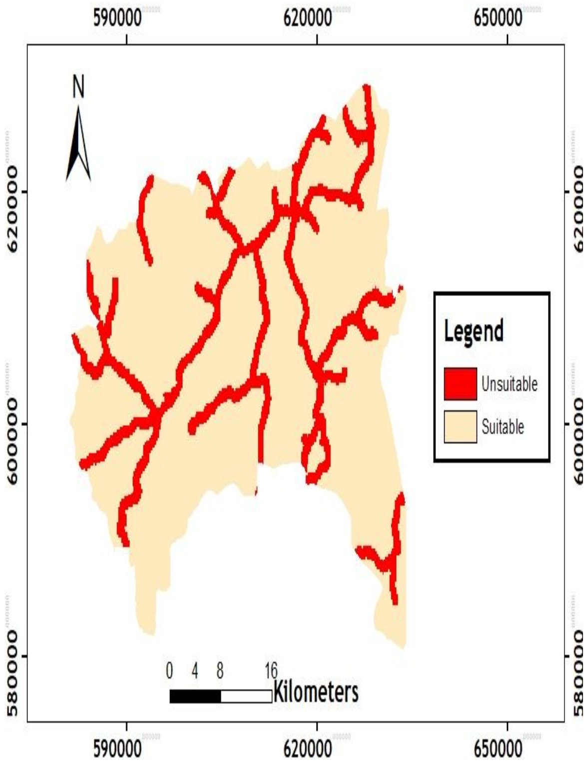

Fig. 8 Permissible Areas based on Constraints Criteria

Table 10 Area Analysis based Road Constraints

Constraint	Ranking	Area (km²)	% of Area
=< 500 m buffer	0	269.4141	17.6735
>500 m	1	1254.978	82.32645

3.6 Permissible Areas based on Geology and Soil

Geologically (Fig. 2), only a small part of the study area has locations considered to be unsafe and thus rated as restricted zones. These consist of Phyllite, Quartzite and Conglomerates hosting gold mineralization in the area. Fig. 9 shows the results of the application of the restriction criteria on soil based on information from available literature and Table 1. The soil information of the study area is generally okay requiring no restrictions for most parts of the area except the western, north-western and south-western parts of the area. These are made up of Fluvisols, comprising mainly of sandy and silt materials which together with the underlining geology make them unfavourable and thus rated as unsuitable zone. The remaining areas are dominated by acrisols and ferralsols consisting mainly of laterite and silt materials respectively rated as suitable and very suitable for use.

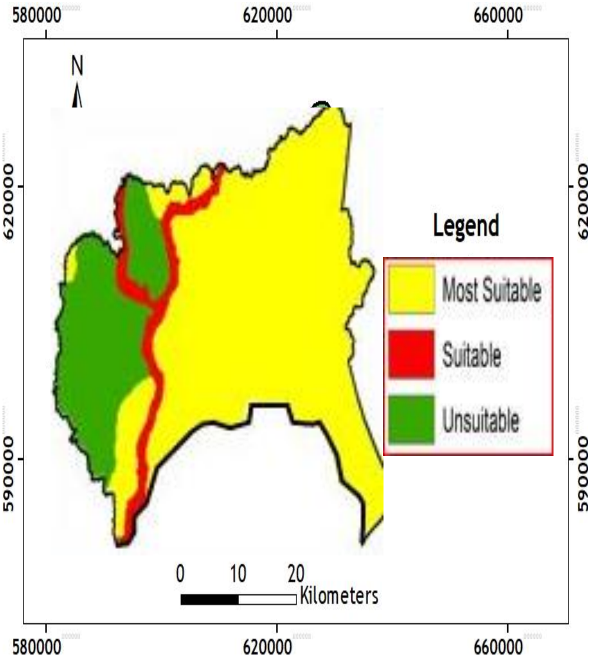

Fig. 9 Permissible Area Categories Based on Soil Types

3.7 Permissible Areas from All Restrictions

Fig.10 and Table 11 show the results of the overly of all the constraint maps prepared from the set of constraint criteria employed (Table 1). Equation 1 and the model at Fig. 3 were employed in this weighted overlay analysis. The results of this composite mapping analysis indicate the permissible areas from all the restriction criteria imposed on the search analysis according to the regulatory requirements and the related data used for the work. The total size of the permissible sites for landfilling was estimated to be 8.7651 km^2, constituting about 0.67% of the study area. This shows that the available land for landfilling is small and must be protected to serve the growing needs for improved waste disposal in the study area

Table 11 Area Analysis based Road Constraints

Constraint	Ranking	Area (km^2)	% of Area
Areas Not Permissible	0	1299.7728	99.33016
Permissible Areas	1	8.7651	0.669839

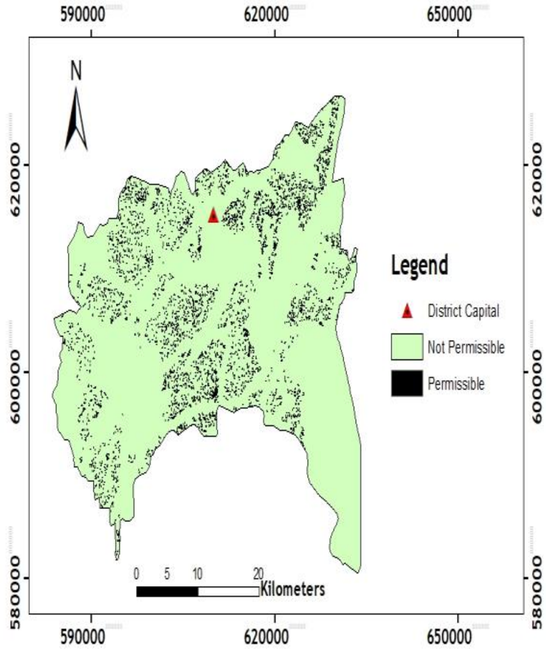

Fig. 10 Final Map of Permissible Sites based on all Restrictions Imposed

3.8 Overlay of Permissible Areas with Desirability Criterion Maps

Some of the permissible areas or sites shown at Fig. 10 may not be suitable for landfill development that can meet the basic needs or objectives of waste disposal in the study area. The criteria for meeting these types of requirement may be termed desirability criteria and Table 2 shows examples of these. These set of criteria may be used as a second stage screening analysis to prune down the permissible sites to few desirable ones or to rank them in terms of their relative suitability for the project objectives. In this work, site size and morphology, accessibility and soil type were applied as desirability criteria to prune the permissible areas to few suitable ones for the final presentation. Using the criteria in Table 2, all sites with sizes less than 4 km^2 and dimensions less than 100 m were rated as unsuitable and thus dropped from the list of permissible sites for the next suitability analysis. This led to about 47 sites with sizes ranging between 4 km^2 and 56.57 km^2 that met size criteria. The site accessibility criteria were then applied to prune down the 47 sites to those that were within 2 km proximity to existing roads and about 24 sites met this desirability requirement Fig. 11 and Fig. 12 show the results of the size and accessibility suitability analysis.

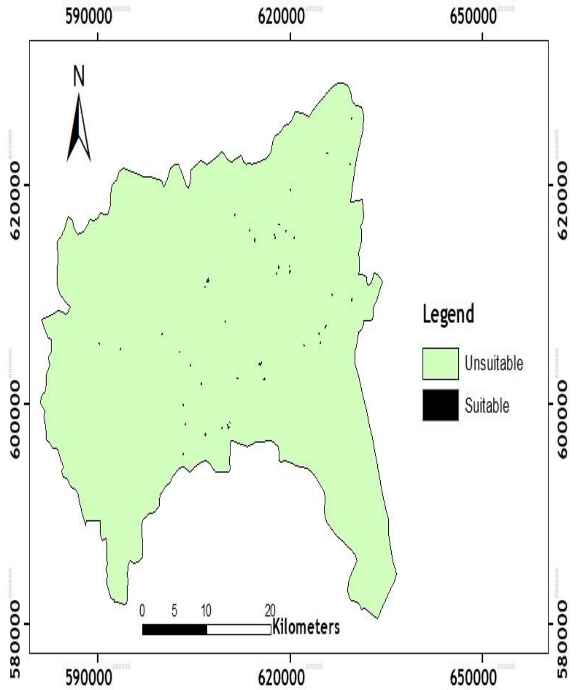

Fig. 11 Suitable Areas based on all Criteria

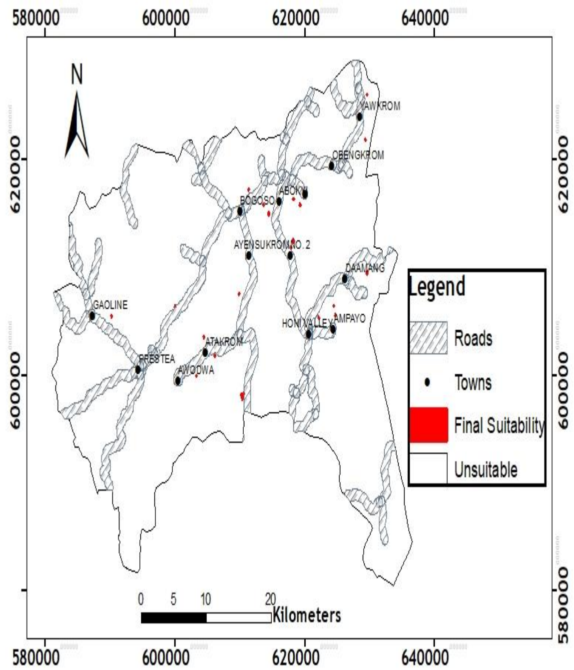

Fig. 12 Suitable Sites Relative to Settlements and Road Network

3.9 Accuracy Assessment

The final results shown in Figs. 10, 11 and 12, were superimposed on some of the input and constraint maps to assess the positional accuracy of the model results. This was necessary to ensure that the permissible and suitable sites actually fall outside the restricted and unsuitable zones in the study area. Fig.12 is one example of such checks showing that the suitable sites were located outside the restricted road lanes and settlements and also meet the proximity criteria to access routes. Accuracy assessment were also done on the input data and land cover/use classification using ground-truth data comparison and basic statistics. Table 9 shows the error matrix for the land cover/use classification applied in this work. The diagonal values show the pixels that were classified correctly. Pixels that were not assigned to the proper class do not occur along the diagonal and these give indication of the confusion between the different land cover/use classes in the classification done. The study had a kappa coefficient of 0.7151 which is rated as substantial and hence the classified image found to be fit for the work. The overall accuracy obtained from the random sampling process for the image classification was 77.281%.

Table 12 Land Cover/Use Classification Accuracy Assessment by Error Matrix

	Points from Ground Truth Data						
Points from Classified Map	Counts	Built-up Areas	Mining Areas	Forest	Grassland	Bare land	Total
	Built-up Areas	34	7	0	0	1	42
	Mining Areas	12	44	0	0	5	61
	Forest	0	2	35	10	0	47
	Grass land	0	0	14	49	0	63
	Bare land	0	6	0	0	33	39
	Total	46	59	49	59	39	252
Overall Accuracy = 77.281 %							
Kappa Coefficient = 0.7151							

4 Conclusions and Recommendations

4.1 Conclusions

Meeting regulatory requirements in site selection for landfilling and other waste disposal facilities is an important and elaborate process that requires systematic analysis and evaluation of numerous factors, criteria and data from engineering, economic, environmental, socio-cultural and regulatory considerations. This study used Geographic Information System and spatial-based decision-making models to identify permissible sites for landfill developments in the Prestea-Huni Valley Municipality that meet regulatory requirements and other suitability needs. The criteria used for the work was based on the regulatory requirements and guidelines from the EPA, MMDAs, and other Public and private bodies. The final composite maps show areas that are permissible and suitable and those that are not for landfill development. The suitable areas constitute 0.67% of the area indicating that available suitable land for landfilling may be scarce and thus need to be protected. This is especially necessary for mining areas like PHMA where the rates of urbanization, waste generation and land development are growing very fast due to mining and its related activities.

4.2 Recommendations

The methods and approach used in this paper are recommended for waste management departments in PHMA and other similar areas in their efforts to identify and provide safe sites for landfill development to improve the existing waste disposal practice. Due to some constraints with data availability, not all the legal requirements were used in this study. The results do not therefore reflect all the necessary criteria. Further work incorporating all the other legal requirements is recommended before accepting or using the results as sites that meet all legal requirements in the study area for actual work. It is further recommended for ground water vulnerability maps to be included in the site selection analysis to ensure protection of ground water.

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