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Spatial Analyses of Suitable Solid Waste Dumping Sites in Damaturu, Yobe State Nigeria

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Abstract

The generation and disposal of solid waste is a serious problem in urban areas especially in developing countries. This is because of high generation rates, insufficient budget and machinery for solid waste management, inappropriate techniques and few or non-existent suitable dumping sites. The main objective of this study is to propose suitable areas for solid waste dumping in Damaturu Town, which are environmentally suitable and economically viable. The main data used for this study were Landsat 8 OLI TIRS image with a spatial resolution of 30m; digital elevation model (DEM) with 30m spatial resolution, and ground control point (GCP) collected with a handheld global positioning system (GPS). The maps were prepared by overlay and suitability analysis was carried out using geographic information system (GIS), remote sensing techniques and multi criteria analysis methods. The final suitability map was produced by overlay analyses in ArcMap and levelled as high, moderate, less suitable, and unsuitable regions. The results indicate that 65% of the study area is unsuitable for solid waste dumping; 1.3% less suitable; 21.8% moderately suitable; and 11.9% most suitable. The potential most suitable areas for solid waste dumping sites fall on southern, south eastern and south western parts of the town where there are least environmental and health risks. The GIS and remote sensing techniques are important tools for solid waste site selection. Hence, the capacity to use GIS and remote sensing technology for the effective identification of suitable solid waste dumping site will minimize the environmental risk and human health problems.

Keywords: Urbanization, Solid waste, Dumping sites, Geographic information system, Remote sensing, Global positioning system, Spatial, Digital elevation model.

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Contents

1. Introduction

Increasing population levels, booming economy, rapid urbanization and the rise in community living standards have greatly accelerated the municipal solid waste generation rate in developing countries [1]. However, they often face problems beyond the ability of the municipal authority to tackle mainly due to lack of organization, financial resources, complexity and system multi dimensionality [1].

In Nigeria, majority of inhabitants in most towns and cities often use unsafe solid waste disposal practices, such as open dumping, burning and burying [2]. As a result, many households practice uncontrolled open dumping and others employ various household solid waste disposal practices, such as burning, burying and composting. However, all self-managed waste disposal practices do not guarantee cleanliness and safety. Similarly, in Damaturu town, the study area, there are inadequate or inappropriate solid waste disposal sites. There are no scientifically approved sites and no standard transfer stations in the city. All health institutions and industries follow their way of removal of waste, while some others dispose it to the nearby water body, bushes and farmlands. The dumping sites are not well planned and are usually open field close to settlements or at the heart of the city center.

In order to alleviate these problems, integrating GIS and remote sensing techniques to select the best possible solid wastes dumping sites is a recent essential technology [3]. The selection of solid waste disposal sites using GIS and remote sensing requires many factors that should be integrated into one system for proper analysis.

The selection criteria should consider and combine surface water, soil type, slopes, settlements, groundwater, protected areas, land use and road networks. However, because of absence of data geology, groundwater data were not included in the study. Remote sensing can provide information about the various spatial criteria such as land use/land cover, drainage density, slope, etc [2] whereas GIS aided utilizing and creating the digital geodatabase as a spatial clustering process and easily understood way for solid waste dumping site selection process.

In multi-criteria evaluation many data layers are to be handled by GIS and remote sensing in order to arrive at the suitable site, this can be achieved conventionally using GIS. Therefore, the study was aimed at proposing suitable solid waste disposal sites by using GIS and remote sensing techniques in order to minimize risk of ecological and human health problem in Damaturu town. It is also helpful to set appropriate selection criteria for the identification of new solid waste dumping sites through scientific methods [3].

Therefore, locating proper sites for solid waste disposal and selecting appropriate landfill site far from residential areas, environmental resources and settlement is the main issue for the management of solid waste. One way to dispose solid waste is to place it in properly designed, constructed, and managed landfills, where it is safely contained. Many studies suggested that the solid waste dumping site should be located within a 1 km buffer from the roads and other transportation facilities Chang, et al. [4]. Sener, et al. [5] had shown that the distance between disposal sites and settlement areas must be more than 1000 m and the haul distance between the solid disposal site and the main city center should not exceed 30 km. Land use types such as grassland, forests, agricultural land, wet land, bush lands should be considered in designing appropriate land use suitability for solid waste dump.

In Nigeria however, the proximity analysis based on the National Environmental Standards and Regulations Enforcement Agency (NESREA) used at distances 1000m, 500m and 250m showed that built-up areas, major roads, and watercourses fall within buffer range to dumpsites [6]. The present study employed GIS techniques to arrive at the most suitable solid waste disposal site by integrating some factors such as: proximity to road networks, distances from residences and important built up areas as well as watercourse. Application of GIS and multi criteria decision analysis is desired in site selection problems. GIS is flexible in considering criteria and it is possible to develop this method by taking into account other effective criteria that helps in the finding suitable sites for waste dump. Multi criteria decision analysis provides necessary conditions to consider in site selection evaluation and therefore helps decision makers towards correct option selection. GIS combination with decision analysis as decision supporting system can assist decision makers in making the right choice for waste dumpsite site [7].

1.1. Summary

In summary, the use of Geographical Information System as an effective tool to assess and manage dump sites in Damaturu town for a sustainable development will help to identify suitable location for municipal waste dump which would have minimum impact on the environment. It will also help in monitoring possible environmental problems for effective and proper management of solid waste in dump sites. This study therefore, is aimed at providing a frame work for effectively selecting suitable solid waste dumping site for sustainable waste management in Damaturu, Yobe state using geo-spatial analyses.

2. Literature Review

2.1. The Concept of Solid Waste Management

Strategies and measures commonly adopted for municipal solid waste management in most of the cities in Nigeria create the wrong impression that solid waste management problems are daunting and intractable task. This came from the simple fact that the rate at which solid waste collection and subsequent disposal is done is in no way closer to the rate of waste generation. This makes solid waste accumulation one of the major Municipal solid waste is defined as that type of waste collected and treated by, or for municipalities [8]. This includes waste from households, bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, yard and garden, street sweepings, contents of litter containers, and market cleansing. Waste from municipal sewage networks and treatment, as well as municipal construction and demolition is excluded.

Solid waste management is a daily routine that is continuous and never finished. As each day passes, it brings new task of streets to sweep, waste to collect, waste loads to haul and safely to dispose. Urbanization and solid waste generation are closely interrelated.

In many fast-growing cities of developing countries, dealing with household waste has become a vital policy problem. Policies and regulations aimed at good management of wastes, ranging from specifically controlling wastes at the household level to integrated municipal and economy-wide waste reduction efforts have been implemented with mixed outcomes [9].

Scarcity of land for waste disposal in most large urban areas is one of the serious and growing potential problems nowadays. Even though there are some efforts to reduce and recover the waste, land filling is still the most common method for waste destination. Landfill and dumpsite selection in urban areas is a critical issue due to its huge impact on the economy, ecology, and the environmental health [10].

In Africa, it is currently estimated that, the rate at which solid waste is growing in urban areas is much faster than the urbanization itself [11]. This may not be unconnected with rapid urban growth in the continent since the 1960s which has put pressure on land resources within the areas surrounding cities and led to increased generation of waste. The problem is aggravated by the open dump nature of disposing waste especially in the slum areas of most African cities [12].

The imperfect environmental nuisances in most cities in Nigeria [13]. The huge volume of solid wastes that are commonly visible in most of the roads and streets of our major cities in Nigeria is an indication that the current adopted strategies to cope with the unavoidable bye products of development appeared to be ineffective.

What is common practice in developing world is dumping in open areas, along the roadsides and valleys and rivers and also within the cluster of houses. Many studies have investigated the determinants of various behaviors and attributes on the dumping practices for household waste [9]. However, little is done on the application of scientific tool such as the GIS and multi criteria decision technique for suitability analyses of solid waste disposal site, particularly in cities and towns of developing countries like Nigeria.

Identification of the suitability of potential landfill sites, and modifications to existing facilities, requires a comprehensive assessment of site conditions and potential impacts on the environment. This includes consideration of topography, surface water, drainage, hydrogeology (groundwater), geology, climate (including air quality and odor modeling) and flora and fauna, access and distance from the community the landfill will service [12].

2.2. GIS in Waste Management

Technological development in computer science has introduced Geographic Information System (GIS) as an innovative tool in solid waste management including landfill process [14]. GIS combines spatial data (maps, aerial photographs, Satellite images, etc.) with non-spatial data including both the quantitative and qualitative. The role of GIS in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data [5].

In general, GIS plays a key role in maintaining account data to facilitate collection operations; customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial customers to transfer stations and from transfer stations to landfills; locating new landfills and monitoring the landfill [14]. GIS is a tool that not only reduces time and cost of the site selection, but also provide a digital data bank for future monitoring program of the site.

One of the most important applications of GIS is the display and analysis of data to support the process of environmental decision-making. A decision can be defined as a choice between alternatives, where the alternatives may be different actions, locations, objects, and the likes. The role of GIS in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data [7].

For instance, Uwadiegwu and Chukwu [13] developed an engineered design of solid waste collection using GIS with a vehicle tracking system and final disposal by composting with investment costs. The GIS was used to analyze existing maps and data, to digitize the existing ward boundaries and to enter data about the wards and disposal sites. The GIS model for solid waste disposal would give information on the planning of bins, vehicles and the optimal route. In the case of disposal and composting, it would be a successful strategy to accelerate the decomposition and stabilization of the biodegradable components of waste in municipal solid waste management [14].

Nowadays GIS has been used as a tool in a dumpsite and landfill site selection analysis, it provides the decision makers with a powerful set of tools for the manipulation and analysis of spatial information. Using GIS, it is possible to process a huge amount of spatial data in short time and so the screening process is much easier. GIS can help to reduce remarkably the areas that have to be examined on the site, although the final decision has to be taken after field studies [10].

Site selection analysis can be improved by using GIS, since it has the capability to manage large amount of spatial data that comes from various sources. Danbuzu, et al. [14] pointed out that large amount of spatial data can be processed using GIS and thus, it potentially saves time that would normally be spent in selecting an appropriate site. While Akbari, et al. [15] claimed that GIS is an ultimate method for preliminary site selection as it efficiently stores, retrieves, analyzes and displays information according to user-defined specification. However, GIS can be limited by the existing sources of data needed in siting analysis [10].

2.3. Criteria for Site Selection

The factors to be considered as criteria for selection of suitable sites mainly consist of: public health, extend and topography of the area, hydrology, geology drainage system and weather of the area, proximity to the residential and industrial areas, the distance to and from the city, the weather of the area, the drainage system of the area, cost and the future land use of the area [4].

A waste dump site must be situated and designed to meet the necessary conditions for preventing pollution of the soil, groundwater or surface water and should be kept as far as possible away from population density, for reducing pollution impact to public health. Also, Aziz and Khodakarami [7] emphasis that waste dumpsite should not be placed as close as possible to existing roads and also not too far from the roads in order to minimized cost of road development, transportation, and collection costs. Some suitability criteria, commonly used as criteria for analysis for dumpsite suitability selection is described as follows;

Residential areas: Dumpsite or landfill site should be located away and far from populated centers of the city, as it causes aesthetic, bad odors and depreciation of land value of the surrounding area [7]. In a study by Bera, et al. [16] in India, they opined that dumpsites should not be placed too close to high-density urban areas in order to mitigate conflicts relating to the Not in My Back-Yard syndrome (NIMBY). This helps to protect against health

problems, noise complaints, odor complaints, decreased property values and mischief due to scavenging animals. Sener, et al. [5] stated that in Turkey, dumpsites are to be located within 1000 m of settlement areas. However, In Nigeria, Olaide, et al. [6] reported that for built-up areas, National dumpsite was placed at least 1000m away from all settlements for hygienic reasons.

Road network: Aesthetic considerations would be of good practice for good planning and based on this principle, waste dumpsites should not be located Within 1000 meters of any major highways, city streets or other transportation routes [16]. However, in Nigeria, 2000 meters away from existing roads was chosen under NESREA guideline so as to reduce transportation expenses [6]. In another view, waste dumpsite is suggested not be placed too far away from existed road networks. It should be sited in such a location that can be reached by alternative roads under all weather conditions. Hence, it is required that a distance of <1000 m away and >250 m away is desired as suitable dumpsite [5].

Proximity to water bodies: Water bodies such as; surface streams, lakes, rivers, wells, or wetlands are one of the major factors to be considered when siting waste dumpsite. Also, proximity to wells and other underground water reservoir is an important criterion to be considered when locating suitable waste dumpsite [7].

According to Bera, et al. [16] solid waste dumping sites must not be located near any surface water body such as streams, lakes, rivers or wetlands. Thus, significant distance is required to prevent problems of erosion and leaching of hazardous substances and buffer around all surface waters is required when siting suitable dumpsite. However, for watercourse in Nigeria, dumpsite should be placed at least 1000m away from surface water bodies to avoid hazardous emission as well as leaching from waste under National Environmental Standards and Regulations Enforcement Agency (NESREA) [6].

3. Methodology

3.1. Study Area

Yobe state is one of the 36 states in Nigeria, with Damaturu as the state capital. The state has 17 local government areas. It is located within latitude 11 north and longitude 12.5 East with a total land area of 47, 153 square kilometres. The state shares boundaries with Borno state to the east and south-east, Jigawa state to the north while Bauchi and Gombe states to the south-west. It also shares an international border with the Republic of Niger. This boundary stretches over 323km to the north of the state. According to NPC [17] Yobe had the population of 2.5 million. The vegetation of Yobe state is generally Savannah Grassland. Grasses, sparse dwarf trees and shrubs are the most common features of the state.

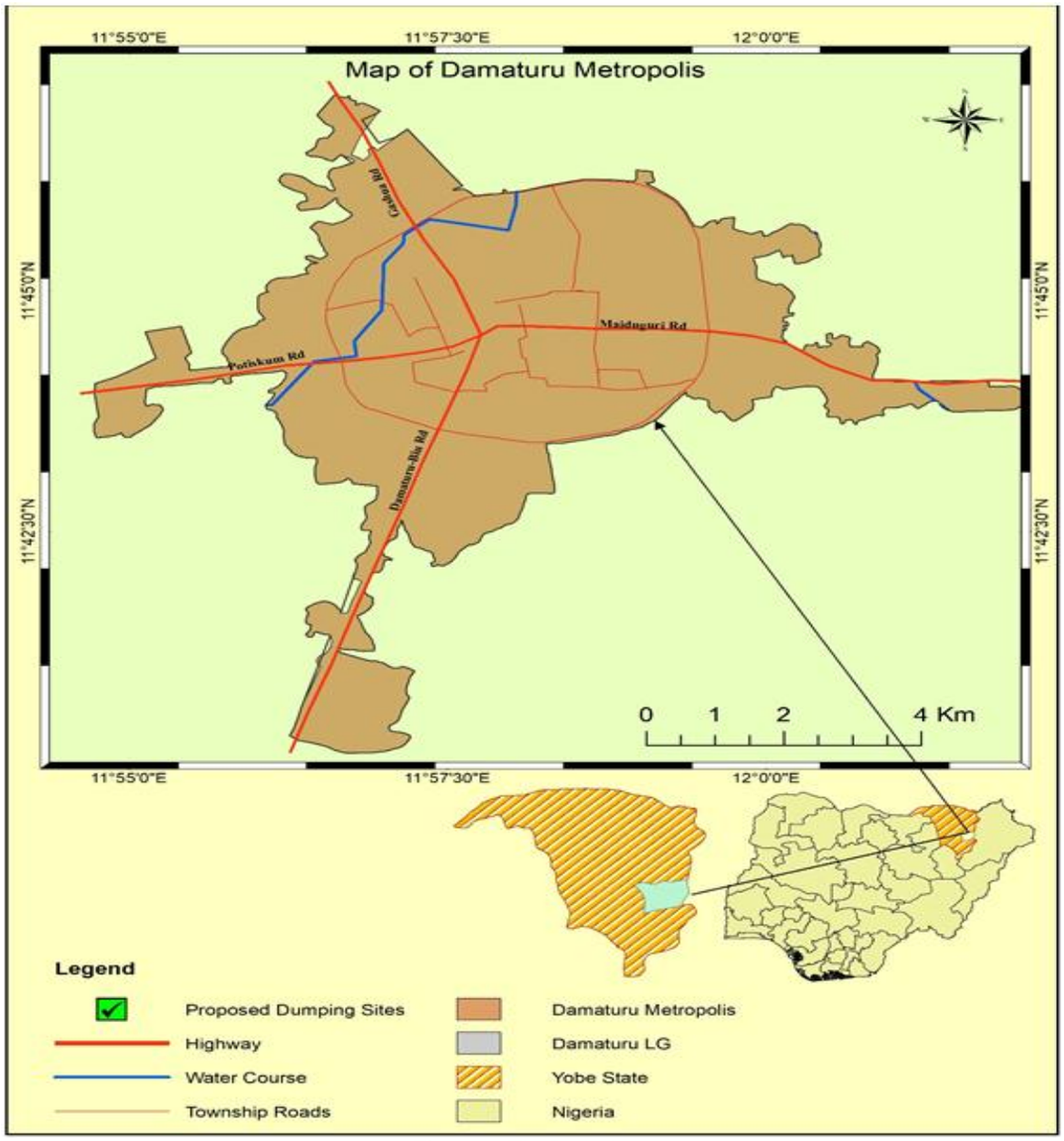

Figure-1. The Study Area.

Source: Google Earth Map.

Human activities such as farming and grazing of animals are the major sources of household wealth and income in the state and are worsen desert encroachment. Yobe state government encourages tree planting campaigns in other to control desert enrichment especially at the northern part of the state. The state is multi-ethnic with Kanuri, Bade, Fulani, Ngizim, Bolewa, Kare-kare, Ngamo, Babur/Maga, Hausa and other Nigerian groups constituting the main groups in the state. The Hausa language is widely spoken in the state.

With regard to the economy the state Yobe is relatively small compared to her counterparts such as Lagos, Kano and Borno in Nigeria. The gross state product (GSP), which evaluate the output of annual economic activities of the state, was estimated to be about US$222.99 compared to the national average for the same year put at US$887.63. The state economy makes contributes about 0.42% to the National Gross Domestic Product (GDP).

3.2. Sampling Frame

As this study relied on secondary data, the nature of sampling differs from those of primary data, hence, the study considers the population of Damaturu town as the population of the study in order to determine the required number of dumping site around the town. The estimated population of the town based on NPC [17] it was about 110,000 people (about 18,000 households). Also, based on available literatures on solid waste management in Nigeria [6, 13, 18] quantity of waste generated in urban centers in Nigeria is to the tune of 500 to 850 metric ton daily, with each dumpsite serving average of 1,000 households. Thus, this study based on the number of the households in the study area, and the average number of households per dumping site, it therefore estimated to have about 6 suitable dumping sites at the outskirts of Damaturu town.

4. Data Analyses

4.1. Geo-Referencing and Digitization

Images for 2018 of the city, Landsat 8 Operational Land Imager Thermal Infrared Sensor for the month of March was downloaded free of charge from the United States Geological Survey (www.earthexplorer.usgs.gov). These images were already geometrically corrected but little radiometric and atmospheric corrections were applied since the time of image acquisition coincided with the dry season when no clouds were present in the sky. However, the corrections removed some of the few impurities associated with the image and generally improved its visual quality.

The city was then digitized and clipped from the image using the shape file already obtained. The clipped image was then imported to ArcMap from which, digital maps were produced. Population density map was produced base on field experience and satellite imagery observation. Land uses and housing pattern were used as guide. Shape files were also created for the following features; roads, rivers, (waterbody), and settlement. On-screen digitizing was done for all the created shape files from the imagery.

4.2. Geospatial Analysis

The basic spatial analysis employed during this work was buffering operation and proximity analysis was also demonstrated in the ArcGIS environment. Buffers of specific distance were created around the city and the dumpsites so as to determine the proximity level of the dumpsites to the roads, rivers and the built-up areas.

4.3. Site Selection Criteria

For the selection of the most suitable site for dumpsites and sorting centers, the following criteria were considered for the available datasets. The proximity analysis based on the National Environmental Standards and Regulations Enforcement Agency (NESREA):

For built-up areas, dumpsite was placed at least 1000m away from all settlements for hygienic reasons.

i. For Watercourse, dumpsite was placed at least 1000m away from watercourses to avoid hazardous emission from waste.
ii. For roads, dumpsite was placed at least <1000m away from an existing road so as to reduce transportation expenses.
iii. For elevation, dumpsite was placed on slopes with less than 9% inclination.

5. Result and Discussion

Geospatial analysis using ArcGIS was conducted to identify the most suitable sites for waste dump in Damaturu town, Yobe state. 6 suitable candidate sites were determined on the basis of accessibility and significant distances from residents, roads and water bodies. All sites within 1000m away from residences and the major roads were determined as the most suitable sites for the municipal solid waste disposal. These sites as shown in the map Figure 1 are located in different part of the town.

The major goal of the municipal solid waste dumping site selection process is to ensure that the disposal facility is located at the best possible location with little negative impact to the environment. Using Arc GIS 10.1 software creating different thematic layer and overlay analysis were done and identify six points as suitable for solid waste dumping zone in Damaturu Figure 2. The selected zones are on an open free space and grass land area.

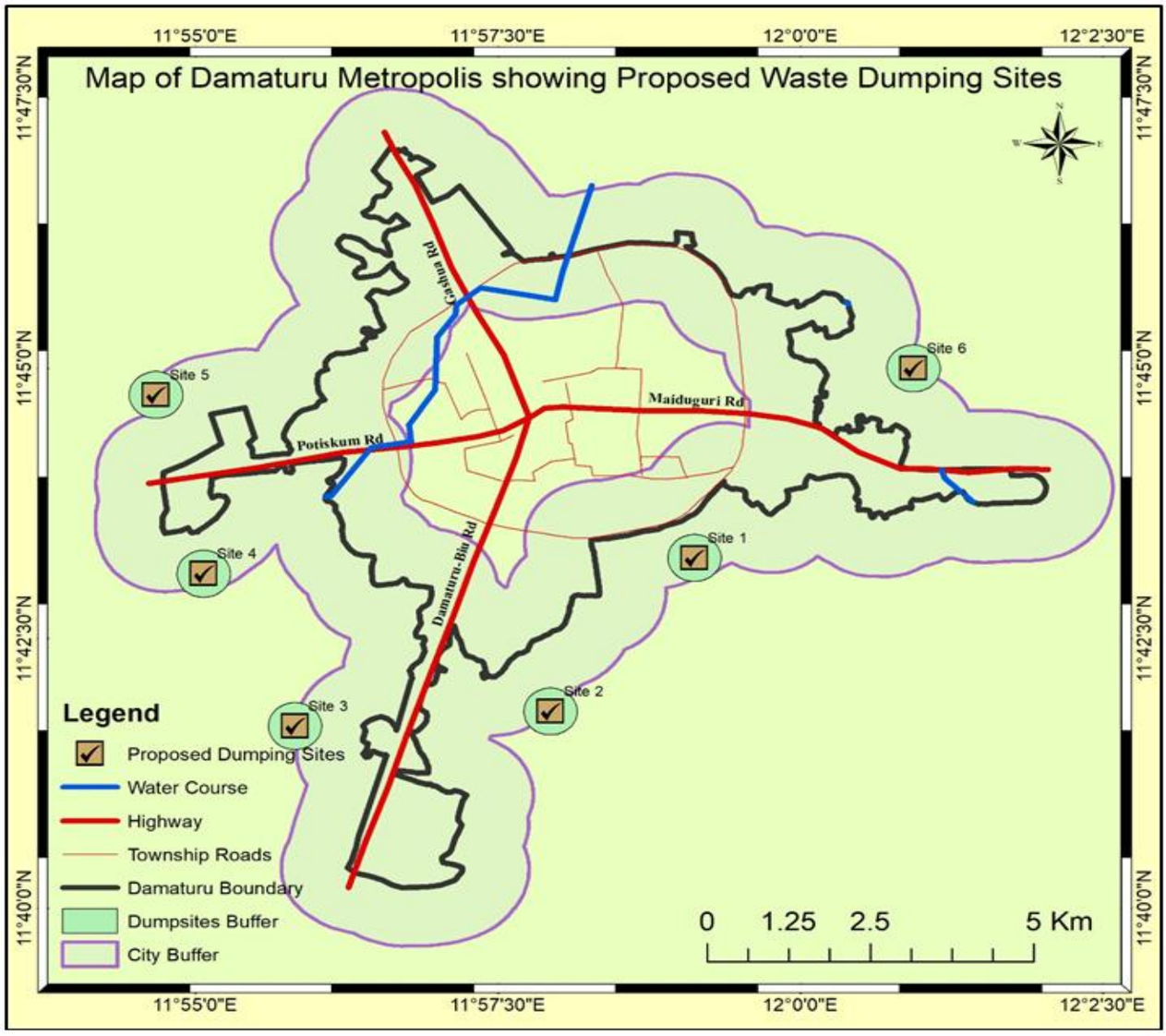

Figure-2. Waste Disposal Sites in the Buffer Zone.

Source: Google Earth Map.

6. Conclusion and Recommendations

The use of Geographic Information System in spatial analysis especially when representing the real-world phenomenon, helps in the integrating and simplifying the interpretation of a distribution of a facility especially the visual analysis and interpretations. GIS play a significant role in Solid Waste Management System as it helps the managers in database creation and the stakeholders to know the exact areas where there is need for more attention rather than concentrating on a particular area.

This study used the integration of GIS and Remote Sensing in identifying the best sites for the dumping the solid waste material in a typically urbanizing city. A multi-criteria approach was employed in conjunction with GIS-based overlay analysis to identify the most suitable site for solid waste dumping in the Damaturu. The study was based upon a set of key criteria, which were selected in relation to already available knowledge from research literature as well as the pre-existing local level factors of the area. A set of six (6) potential sites were identified as the most suitable sites for solid waste dumping in Damaturu town. The integration of GIS and Remote Sensing techniques contributed to the achievement of the results obtained. Remote Sensing techniques made it possible to study the various land cover types within the study area whereas GIS aided in the modeling and preparation of needed maps. Indeed, it has been an effective and efficient tool in carrying out this study.

The sites selected as the suitable locations for waste dump are expected to serve the purpose for of protecting downstream surface water pollution, runoff and nuisance to the public. The present study considered a few of environmental, social and economic factors for solid waste dumping site selection. However, other factors such as geology, elevation, slope, ground water table depth etc. and community preferences were not considered as part of the suitability criteria, partly because of expensiveness of remotely sensed data. Hence, further study should fill this research gap by including these layers as part of the suitability criteria.

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