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LANDFILL SITE SELECTION IN ADO-ODO OTA LGA USING GEOGRAPHIC INFORMATION SYSTEMS

G. A. Adeyemi
Department of Civil Engineering, Covenant University

M. Markus
Department of Civil Engineering, Covenant University

O. G. Gbolahan
Department of Civil Engineering, Covenant University

***S. O. Edeki**
Department of Mathematics, Covenant University, Nigeria
Corresponding Author's Email: soedeki@yahoo.com

ABSTRACT

This study makes an attempt at determining suitable landfill sites in Ado-Odo, Local Government Area, Ota, Ogun State, Nigeria. A multi-criteria evaluation method is applied based on Geographical Information System to identify potentially favourable landfill sites in the study area. The landfill siting process requires the evaluation of several criteria such as land use, vegetation classification, road networks, water bodies and so on based on complex operations on databases containing spatial data of these criteria. The model chosen for site selection involved four (4) stages viz: preliminary analysis, creation of constraint maps, creation of final constraint overlay maps, and creation of final suitability maps depicting suitable areas. The first stage involves the creation of various maps for the study area to input the data layers. The second stage involves the creation of constraint maps using available spatial data which implies the creation of buffered distances according to stipulated criteria. The final constraint map overlay is created by merging all the data layers from the constraint maps. In addition, the final suitability map is created via the use of spatial analysis tools. This final map can be used by the state, local government and its policymakers on their choices of suitable and unsuitable sites that pose no threat to the health of its citizens, as well as minimal damages to the environment.

Key words: Solid Waste Management; Landfill; Decomposition Method; Geographic Information System

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1. INTRODUCTION

As a result of an increase in population growth in line with high rate of goods consumption, the amount of solid wastes being generated globally is on the rise, hence; the urgent need for environmentally safe ways of waste disposition. Landfills are now widely used in developed countries and in some developing nations to manage the solid waste problem. Nonetheless, selection of suitable sites to dispose waste has been problematic. Site selection is quite complicated as a result of the numerous considerations, guidelines and criteria that need to be adhered to. Fifty percent (50%) of the world's next population surge is predicted to take place in the African continent. Nigeria, currently the seventh most populous country in the world and the most rapidly growing nation worldwide has been forecasted to surpass the United State by 2050, with estimates predicting a trend upwards of 300 Million (CNN, 2017). As it is, the majority of the populace are concentrated in urban areas. Although, the expected increase in population has its added advantages, it, however, escalates the numerous issues already associated with solid waste management (Mavropoulos, 2017). The influx of people to urban areas has resulted in a proliferation of plastics with complex compositions, hazardous and toxic chemical seeps occurring due to increased industrial activities which in turn poisons groundwater sources, streams and rivers. Also, the increase in the consumption of processed foods packaged with non-biodegradable materials has increased the volume of food wastes been generated daily. The effects of these activities affect the environment drastically as well as the health and sanitation of the people.

Solid Waste Management (SWM) is a challenge which cuts across continents and is directly or indirectly associated to 12 of the 17 United Nations Sustainable development Goals (SDGs). Proper waste management is crucial to achieving the global Sustainable Development Goals (SDGs). The SDGs have numerous links to chemicals and waste management, particularly Goal 12 – whose goal is ensuring sustainability of consumption and manufacturing processes and Goal 3 – which is to ensure everyone lives a healthy life – has a target to considerably lessen, by 2030, the casualty and diseases from toxic chemicals, air, water and land pollution (United Nations Institute for Training and Research, 2017).

Nigeria's quest to attain the SDGs by 2030 could remain a fantasy if the country continues being hesitant to employ innovative plans, policies, practices, and systems that efficiently manage the rising waste concentrations. Given the fundamental role of effective waste management to achieving the SDGs, the country ought to alter its existing strategies with acute focus to; developing a holistic waste management plan, fostering Public Private Partnerships (PPP) in the sector and restructuring current activities to align with the principles of waste hierarchy, which thrives on the principles of inhibition, reduction, repurposing, recycling, energy generation and finally discarding unusable items (The Guardian, 2017).

Solid waste management as it is, is among the most critical challenges encountered by agencies in charge of environmental protection in Nigeria. The solid waste generation capacity increases immensely with insufficient monetary and technological resources to cater for the exceeding upsurge. In Nigeria, the management of waste is a burdensome issue due to lack of standardized methods of collection, a minimal area of coverage for pickup routes, inappropriate storage, and waste disposal. Urban areas of developed nations have higher rates of waste generation compared to those of emerging nations. Despite this, the waste management situation in developing nations remains cumbersome.

The waste generated by these countries varies from those of advanced nations. Most emerging nations, including Nigeria, have significantly heavier, wetter, hazardous and corrosive wastes which pose more challenges to existing waste management techniques (Joshua, 2013). Due to this difference, problems associated with solid waste management vary in such places. Some of these problems are; awareness and attitude of people to waste, population density, governance and institutional issues, the absence of road networks for efficient waste collection, insufficient quality information to better implement SWM practices and technological deficits in the country.

As a result of the challenges being encountered, the Nigerian Government has made an effort to confront SWM issues through some efforts such as regular evacuation of wastes, placement of more bins close to roads, designated collection points, monthly sanitation days e.t.c The absence of waste management systems and approaches which are sustainable, such as waste reduction and segregation at the source, recycling, composting, thermal treatment and biogas generation from organic wastes, management of waste in municipals has remained ineffectual thus far (Agamuthu, 2010).

Developed and emerging nations alike have resorted to cutting down on waste generation from the source, repurposing and reusing (3R) techniques to handle waste. It has been impossible however to arrive at a zero waste state; leftover waste is always left behind. The need to use the cheapest available technology to dispose of this waste is a looming necessity and landfills have been identified as the most cost-effective methods to employ if properly sited. Although landfills are not the most environmental friendly solid waste management method available due to problems they have triggered in the past, they are the most cost-effective method of dealing with solid waste. Some of the drawbacks have been; pollution of surrounding soil and groundwater sources with toxins and leachates which affect the health of humans and animals, increase to noise pollution levels, traffic congestion and the generation of toxic greenhouse gases (Illinois Department of Public Health, 2017).

The siting of landfills is a problematic one despite the availability of large expanses of land in quite a number of urban areas of the country, the identification and selection process is complex and lengthy as it is required to link environmental and social parameters. Suitable landfill siting is burdened with planning permits, requirements for operation, communal perception of landfill sites, geological, ecological, historical and topographical constraints. Thus, the choice of an appropriate site for a landfill is crucial for sustainable management of waste. Therefore, the sites selected for disposal should not contribute to environmental degradation, raise health risks for humans and animals, cause environmental damages or be economically unviable and unstainable (Sener, S, & Karagüzel, 2010). For these reasons, identifying appropriate sites which ensure ecological conservation and sustainability are achieved economically is essential.

In recent times, an increase in the applications of GIS as an important tool in research for collecting data, analyzing such data, results display and decision making has been observed. Geographical Information System (GIS) is an information system used for acquiring, storage, evaluation, management and presentation of data which consists of a geo-referenced spatial database. GIS had been used successfully in a diverse range of applications, such as health sciences, natural disasters prevention and relief, geology, urban utilities planning and management, natural resources protection, transportation and routing services, various aspects of environmental modelling and engineering etc. (Chalkias & Lasaridi, 2011).

GIS can be applied for effective selection of suitable sites for landfills as it permits precise handling of spatial data with sources that vary, provides a well-organized storing, retrieving, analyzing and visualizing of information and enables tailoring of appropriate solutions to handle landfill siting issues. However, the capabilities of GIS can be hindered by unavailability of appropriate digital data. GIS can be used in siting landfills to support the process of making decisions. Its processing abilities can be applied to large volumes of data and it handles such.

2. STATEMENT OF THE PROBLEM

Present-day estimates in Nigeria reveal an annual solid waste generation of 36 million tons per annum. The increasing rate of globalization has led to an upsurge in the volume of solid wastes being generated in our cities daily which have made the management of solid waste a major environmental and public health concern for governments of developing countries. The rate at which municipal solid wastes are being generated in Ado-Odo/Ota LGA, in Ogun State, Nigeria which is rapidly becoming an urban locale, has been increasing tremendously over the past years (Olukanni & Mnenga, 2015). Babayemi and Dauda (2009) indicated that the shortage of innovative technologies, equipment for segregation at sources of generation and collection centres, flaws and weaknesses in our solid waste management strategies and their implementations, environmental awareness and income of the populace among others, are reasons for the dire waste management situation in the country. The waste streams in Ado-Odo/Ota L.G.A have been observed to exceed the collection capacity. This is evident owing to the heaps of waste springing up in unregulated or illegal dump sites around the budding metropolis. The lack of proper and detailed land use plan has stalled effective waste disposal, ruined the area's aesthetics and has posed serious health challenges to the residents (Olukanni, Akinyinka, Ede, Akinwumi, & Ajanaku, 2014).

3. STUDY AREA

The area is Ado-Odo/Ota Local Government Area, which is located at latitude 6°41′N to 6°68′N and longitude 3°41′E to 3°68′E, it is 52m above mean sea level and covers 878 km², it is one of the second largest of the 20 Local Government Areas of Ogun State 2006 census statistics, the population of the entire state was documented as 3,751,140 with Ado-Odo/Ota Local Government Area contributing to 14% of the total population, 527,242 residents (261,523 Males and 265,719 Females) (City Population, 2017).

4. PURPOSE OF THE STUDY

This main purpose of this study is to use geospatial techniques via the application of Geographic Information System (GIS) to propose an environmentally suitable and economic landfill in the aforementioned study area in order to reduce the health and environmental risks that abound from siting landfills in indiscriminate locations.

5. MUNICIPAL SOLID WASTE

The definition of MUNICIPAL SOLID WASTE (MSW) varies, however it usually comprises waste that arises from households and extends to those gathered by local agencies from different sources. MSW contains a relative amount of household and non-hazardous industrial waste. Subject to location, MSW comprises of:

- domestic waste (recyclable and compostable waste, wastes are taken to dumping sites from households)
- hazardous domestic waste
- litter and waste from sweeping streets
- recreational areas, wastes from parks and gardens

- institutional wastes, workplaces, agencies and bureaus (Hester & Harrison, 2002).

The Resource Conservation and Recovery Act (RCRA) which was passed in 1976 defines solid wastes as any refuse or garbage, sludge from a water supply treatment plant, wastewater treatment plant, or air pollution control facility and other discarded material, that results from industrial, commercial, agricultural, mining operations, and also from community activities (Environmental Protection Agency, 2015). Virtually every human or animal activity leaves behind some type of waste. Although the term is known as "Solid Waste", not all forms of solid wastes are completely in solid states. They could be liquid, semi-solid or contain gases (Criteria for the Definition of Solid Waste, 2017).

In several ways, MSW is the major waste stream because it stems from every member of the society. It reflects the lifestyle choices, consumption trends and resource reclamation decisions of the populace.

6. CLASSIFICATION OF MUNICIPAL SOLID WASTE

Solid wastes can be classified in a number of ways based on different parameters. These could be based on their source of generation, the content of the waste, degree of biodegradability and combustibility. Subject to the integral dangers related to its physical and chemical characteristics, solid waste can be categorized as hazardous or non-hazardous. Solid wastes which can biodegrade are decomposable when acted upon by micro-organisms in the environment, this is mostly categorized by food wastes and animal wastes. The composition process which occurs in the absence of air (anaerobic decomposition) results in the formation of methane and other greenhouse gases which are toxic and highly explosive. Conversely, controlled anaerobic decomposition can be used in biogas production. This gas is valuable for cooking, providing heat, and power production. Wastes that decompose in the presence of air (aerobic decomposition) are useful in the formation of compost which is rich in nutrients that improve quality of soils. Non-biodegradable materials like plastics, glass, and metals etc. are inorganic wastes that cannot be broken down by microbial actions.

Omole, Isiorho, and Ndambuki (2016) Categorized wastes into the type of physical state, threat level, the fate of the waste and the source of its generation. They also posited that to efficiently manage waste, the characteristics of the wastes and the geology of the concentration area must be studied extensively. Also, they suggested that some waste does not clearly fall into a specific category due to the change of state it may undergo. For example, sludge frequently contains solid as well as liquid components. In the process of treating it, gaseous wastes are also

7. WASTE TREATMENT AND DISPOSAL

This is the end of the waste management pool. Treatment techniques are used in reducing the volume and toxicity of solid waste to ensure convenient disposal of the waste. Disposal and treatment techniques are chosen and adopted according to the amount, form and components of the waste material. Some of the key methods include (LeBlanc, 2016):

Thermal Treatment: Refers to processes that use heat in treating waste materials e.g.

- Incineration: One of the most common methods. This approach combusts waste in the presence of oxygen. Wastes are converted into ash, gas, water vapour, and carbon dioxide. This method can also be employed as an energy recovery method to generate energy for heating or as a source of electricity.
- Gasification and Pyrolysis: Both methods break down organic waste by subjecting it to minimal oxygen levels at great temperatures. While pyrolysis does not make use of oxygen,

gasification utilizes minute oxygen levels. Gasification is preferred to pyrolysis because the energy process is carried out without effects to pollution levels.

Open Incineration: This is an environmentally harmful method. Despite being inexpensive it offers no pollution control mechanism. Harmful materials like hexachlorobenzene, heterocyclic hydrocarbons, carbon monoxide, particulates

Dumpsites and Landfills

- Sanitary landfills: This method is quite common in developed countries. It poses minimal health and environmental risks when constructed properly.
- Controlled dumps: Similar to sanitary landfills. They obey some sanitary landfill selection criteria. Some of these dumps might have a properly-planned capacity but lack cell-planning. Partial gas management, basic record keeping, or regular cover may be non-existent.
- Bioreactor landfills: This kind of landfills arose due to innovative research works. They use advanced microbiological methods to hasten decomposition of waste. The continual input of liquids is required for microbial digestion to occur and also to maintain the optimum moisture needed for the method.

Biological Waste Treatment

- Composting: This is the aerobic decomposition of organic wastes in a controlled environment through the action of micro-organisms. Common composting techniques include windrow composting, in-vessel composting, static pile composting and vermin-composting.
- Anaerobic decomposition: Another biological process used to decompose organic materials. However, oxygen and bacteria-free environment are used to decompose the waste material.

Environmental Impact of Disposing Solid Waste on Land

The disposal of waste in open dumps or improperly designed landfills can cause the following impact on the environment (Narendranath & Dr. Vijay, 2010):

- The release of greenhouse gases.
- Contamination of surface water by run-off from waste dump.
- Generation of inflammable gas like methane at the waste dump.
- Contributes to the acidity of the soil.
- Contamination of underground water sources through leachate infiltration.
- Stability and erosion issues due to the slope of the waste dump.
- Epidemics as a result of stray animals feeding on wastes.
- Pests, rodents, bad odour and wind-blown litter around the waste dump.
- Likelihood of fires around the dump.
- Birds flying above the dumpsite affect flying aircraft.

8. METHODOLOGY

The methodology employed used GIS to evaluate the entire Ado-Odo/Ota L.G.A in line with certain evaluation criteria to analyze the suitability of the landfill site. The criteria were selected in accordance with the local characteristics of the study area. The principal criteria taken into consideration were: Land use, surface water, vegetation and major roads, residential areas, economic plantations etc. Each of these was generated as layers in a GIS environment using acquired data and structured in a geo database to ensure data consistency while spatial analysis has been conducted. The GIS analysis carried out included: reclassification and rasterization, clipping, merging, buffering, union, and intersection The World Bank's landfill siting criteria were used as a guide to choosing safe distances at which features and locations should be located away from a landfill site. These distances were used as buffer zones to determine the most suitable sites.

Materials

- Personal Computer
- ArcGIS 10.1 Software
- Geospatial data of Ado-Odo/Ota L.G.A
- GPS
- **Exclusion Criteria and Buffers**

For the creation of binary maps via the Boolean Integration Method, buffer zones were created according to the criteria prescribed by The World Bank. These zones were classified into two classes; Suitable and Unsuitable. Suitable areas were assigned a value of one and unsuitable areas were assigned zero.

Table 1 Criteria and Buffers

S/N	Criteria	Buffer
1	Major Access Roads	3 Kilometres
2	Agricultural Tree Crops	500 Meters
3	Forested Fresh Water Swamp	300 Meters
4	Forest Plantation	500 Meters
5	Major Urban Areas	250 Meters
6	Minor Urban Areas	250 Meters
7	Natural Water Bodies	500 Meters
8	Riparian Forest	500 Meters
9	Teak Gmelina Plantation	500 Meters

9. RESULTS

The final suitable sites were obtained by excluding all the unsuitable areas e.g 500 Meters Buffer for Riparian Forest Vegetation, 500 Meters Buffer for Forested Fresh Water Swamp Vegetation, 500 Meters Buffer for Agricultural Tree Crops Vegetation and so on from the 3 kilometres buffered road layer of the study area through overlay operations. This was achieved using the ERASE feature. It created a new feature class by overlaying the Input Features with the polygons of the Erase Features. Only the portions of the input feature falling outside the erase features boundaries were copied to the output feature class.

The suitable areas on the the map below, represent potential areas where a landfill could be sited in the study area without the fear of surface and underground water contamination, consideration for economic trees, and other very important environmental factors were put into consideration. Areas which will have less resistance from the public and sufficient area requirements to last the full operating life of the landfill are the most convenient after all other factors have been excluded using the multi-criteria decision analysis.

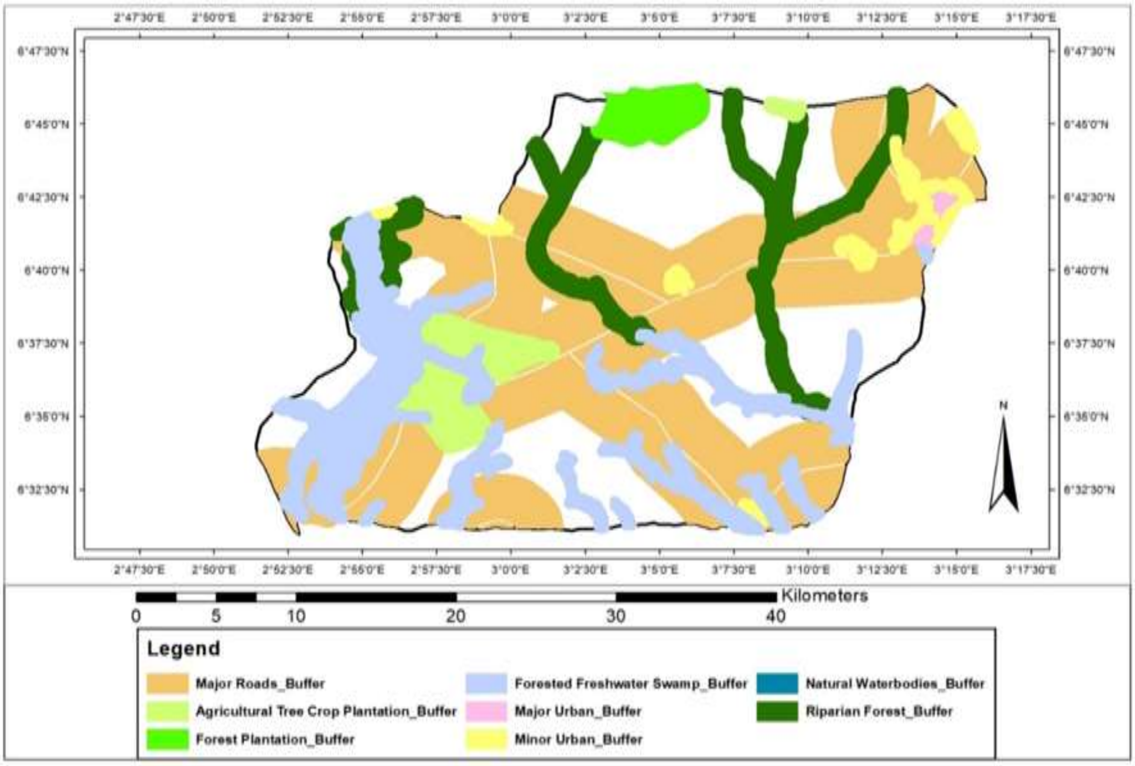

Figure 1 Constrain Map

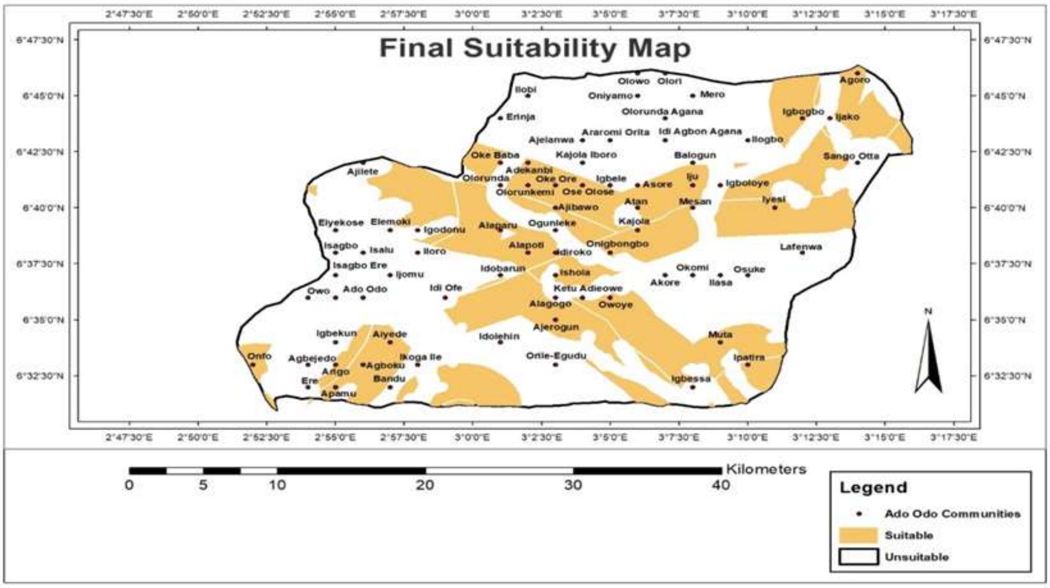

Figure 2 Final suitable map in Ado-Odo Ota LGA in Ogun State

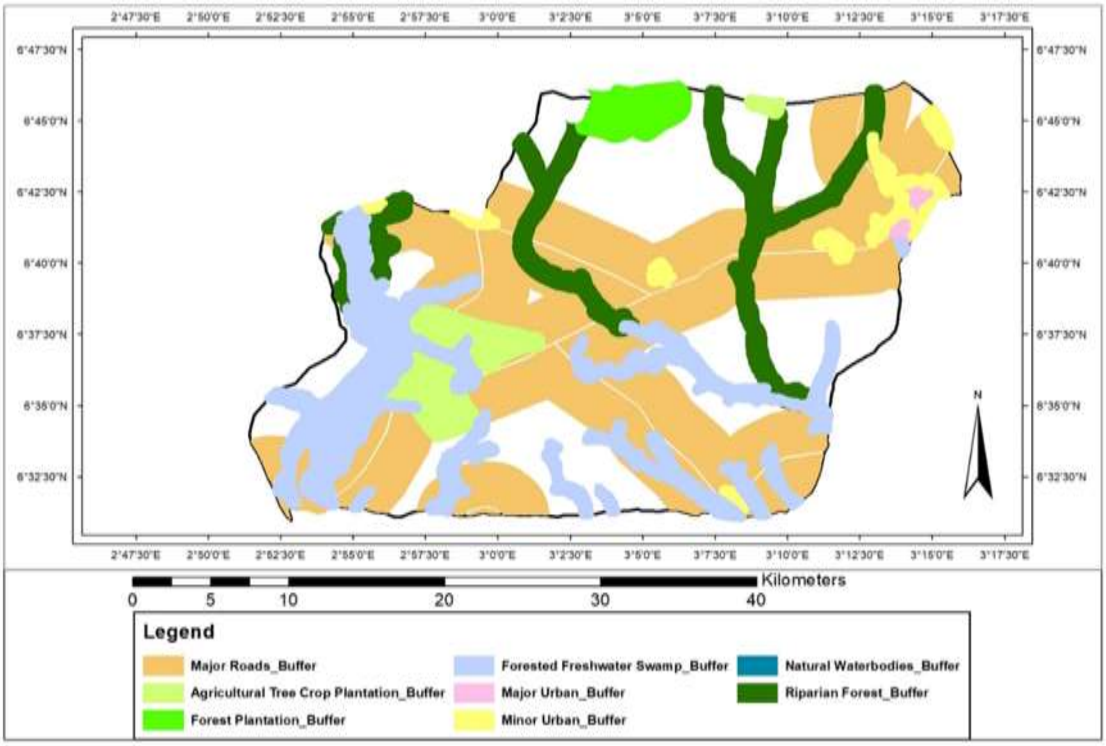

Figure 3 Final Constraint Overlay map of Study Area

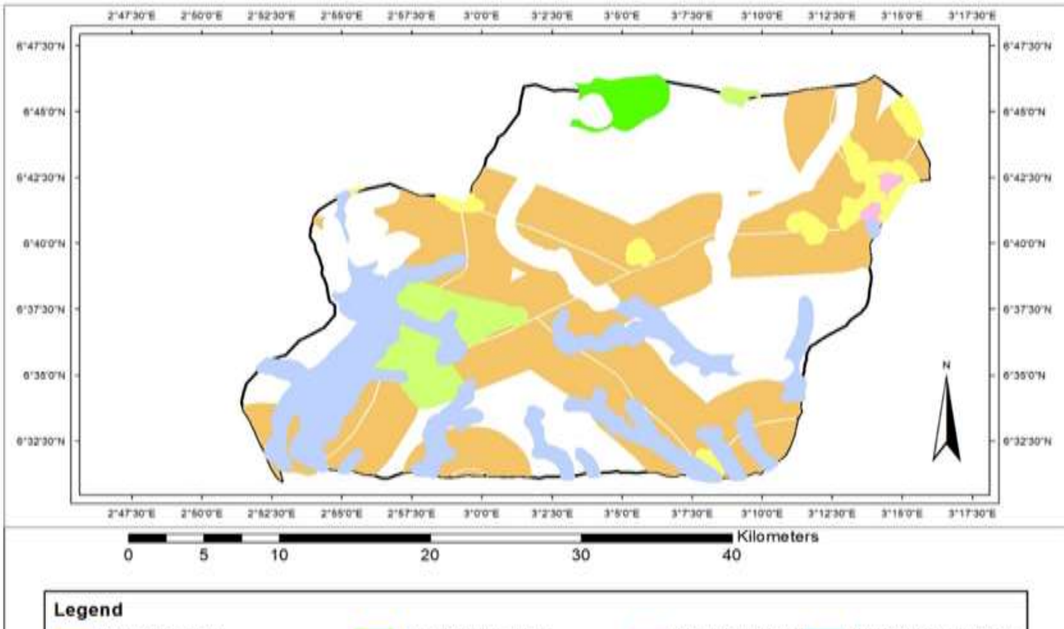

Figure 4 Exclusion of Riparian Forest

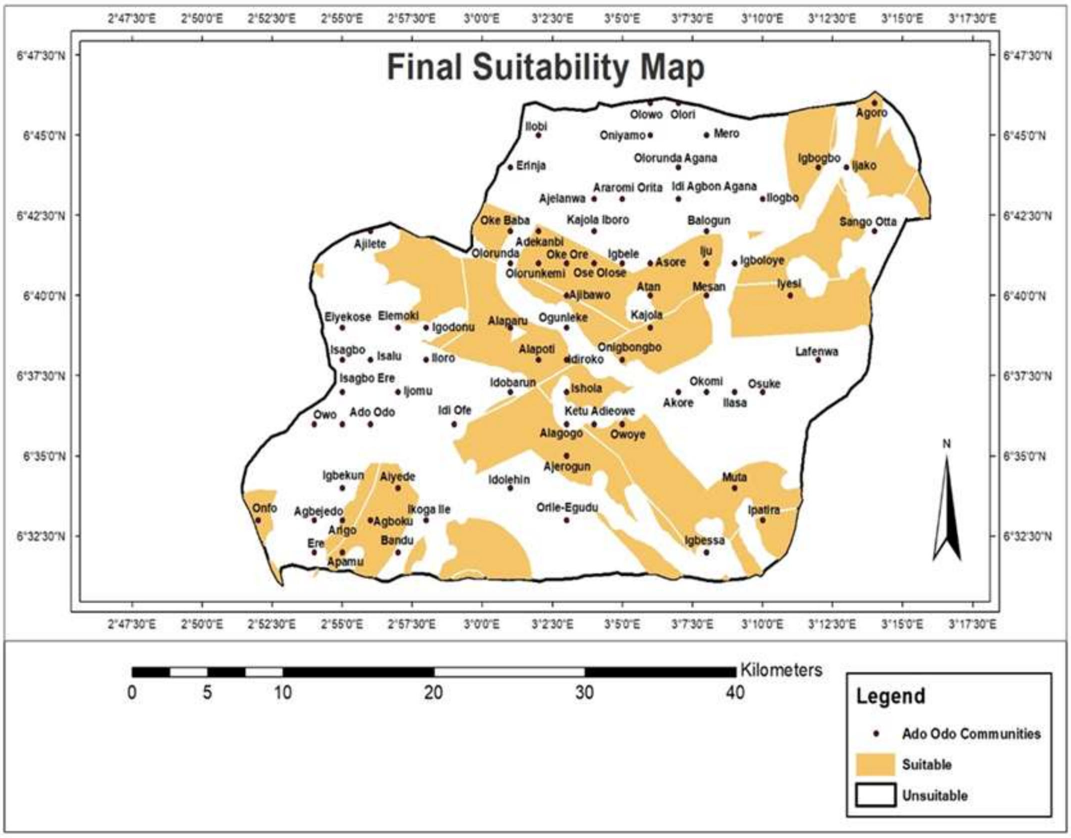

Figure 5 Final Suitable Map

10. CONCLUSIONS

We conclude that applications of Geospatial information in solving wastes management problems would go a long way in enhancing qualitative decision making and proper sanitary in our societies, Safeguarding human health via prevention of diseases and ailments that can emanate from air, soil and water contamination is more needed now than ever. In addition, adequate awareness creation to the public and effective planning by the concerned authorities would provide solutions to illegal dumping of wastes to wrong places.

11. RECOMMENDATIONS

The following courses of action are recommended for future landfill siting projects. Recommendations on providing a circular waste management model and deriving maximum value from waste are also highlighted.

- A further thorough study which should include more data sources, the expected growth of population, the average rate of waste generation, cost of land acquisition and possible cost of compensation settlements should be carried out to increase the accuracy of the GIS model and reinforce the application of GIS as an ultimate decision-making tool.
- Applying GIS models to reach such decisions would provide a transparent, well-defined and technical approach to the selection of sites. This will also reduce the opposition to landfill siting by the public as their safety can be guaranteed as a result of the landfill siting process adhering to well-established criteria.
- Due to the transparency benefits of using GIS in the process of selecting landfills, it would prevent bias in the site selection processes.

- More effort should be made in the collection and storage of data by the states and the federal government. In the collection of data, emphasis should be placed on the accuracy, relevance, and currency of data. This is for the provision of resources which may be required in similar further studies. This data should also be easily accessed at no costs to the individuals or organizations.

GIS should be taken advantage of as a decision support tool in not just landfill siting but all other aspects in highway engineering, environmental assessment, urban planning etc.

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