GIS AND SOLID WASTE MANAGEMENT IN MULTI-CAMPUS UNIVERSITIES: EVIDENCE FROM UNIVERSITY OF NIGERIA NSUKKA, NIGERIA.

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A b s t r a c t
Solid waste management (SWM) has posed serious environmental threat and challenges over the years especially in developing countries such as Nigeria. Commensurate evidence suggests that this anomaly is yet to be satisfactorily addressed in University of Nigeria Nsukka (UNN). As a result, the study examined the import of Geographical Information System (GIS)in engendering automated and sustainable solid waste management (SWM) system in the Enugu Campus of the university. Methods adopted for data collection were field survey using handheld GPS and GARMIN 78sC to obtain geographic coordinate of dumpsites located within the Campus. High resolution Image (IKONOS) covering the study area was used to extract and produce the Composite Map. Data was analyzed in ArcGIS 10.5 in Windows OS environment. A geo-data base was created and several spatial analyses were performed using ArcGIS 10.5. The spatial analysis performed were the location of dumpsters located in the study area, and its proximity to each other; proximity of dumpsters to buildings; location of dumpsters along the roads, and the location of two major dumpsites in the study area.

Keywords: Geographical Information System, Solid Waste, Solid Waste Management, University of Nigeria Enugu Campus

1.0 introduction

Solid wastes (SW) are useless, unwanted or ill-discarded materials that inevitably arise from man's activities. Its rise is symmetric to increases in population, urbanization and industrialization (Adipah & Kwame, 2019; Alam & Ahmade, 2013; Butu et al, 2013). Hence, the dynamics in demographics certainly demand more proactive approaches in solid waste management (SWM). No doubt, challenges in the management of solid wasteis a global phenomenon (Kahn et al., 2022; Song et al., 2015), with research evidence citing its accentuation in the Global South (Adipah & Kwame, 2019; Ganguly & Chakraborty, 2021). Nigeria, a developing country in West Africa, is no exception to this (Duru et al., 2019; Ezechi, 2017).

Such assertion stems from inadequate public sensitization and collaboration in solid waste management, insufficient provision of close-proximity solid waste collection points, subnormal enactment of waste management laws, deficit of solid waste recycling plants,

lack of effective monitoring of waste contractors, insufficient provision of waste evacuation equipment and dump sites (Amuda et al., 2014; Agwu, 2012; Duru et al., 2019; Ezechi, 2017; Ugwuanyi & Isife, 2012).The case of University of Nigeria is further visible with the multi-campus operated by the Institution. The University has the following campuses: Nsukka Campus; Enugu Campus; Ituku- Ozalla Campus; and Aba Campus.

In the University of Nigeria Nsukka (UNN) alone, mean daily solid waste generation was an estimated 2,218.66kg, with polythene (32.35%) and organic (34.29%) waste constituting the largest portions (Ugwu et al., 2020). The study further made vivid statistical presentations of other sources of solid waste generated daily within the university, comprising textiles (2.69%), medical (2.16%), metal (1.67%), food containers (1.04%), electronic waste (0.98%), glass (0.97%), rubber (0.28%), amongst several others (Ugwu et al., 2020). Lending credence, Ugwu et al. (2021) argue that the university has a per capita waste generation rate of about 0.06kg. In spite of these statistics, solid waste management in UNN has not performed well, and is yet to amass adequate empirical attention (Nzeadibe & Ejike-Alieji, 2020; Ugwu et al., 2020). This anomaly may be attributed to inefficient waste reduction, composting, recycling and re-usage (Nnaji et al., 2021; Nzeadibe et al., 2020; Ugwu et al., 2020; 2021).

Following these submissions, the study presents a micro-analytic investigation of solid waste management from the perspectives of the Enugu campus of the university. Our approach is angled on the sustainability viewpoint as a result of statistics which suggest that 96.58% of total waste generated in the university is recyclable with about 51.85% biomass potential (Ugwu et dumpsters necessitated an automated approach to the solid waste management (SWM) in the campus. Also, the use of sensors will also ensure timely evacuation of the waste once an alert is received (Cerchecci et al., 2018; Vasagade et al., 2017).

Our approach is premised on the logic that a lot can be achieved through automation of the solid waste management (SWM) in tertiary institutions, such as the University of Nigeria Enugu Campus. Worryingly, enquiries made at the university, a foremost Federal-owned tertiary institution in Nigeria, regrettably indicates a lack of an official geo-data base for its solid waste management (SWM). In light of these arguments, this paper makes a case for improved solid waste management (SWM) in University of Nigeria, Enugu Campus (UNEC) by automation of the

system through the development of a geo-data base for solid waste management (SWM), and spatial analysis thereafter.

Therefore, the aim of this paper is to examine the application of GIS in determining the spatial location and distribution of the solid waste dumpsters in University of Nigeria, Enugu Campus with a view to achieving a more efficient and effective solid waste management system.

The specific objectives of this study are:
i. Identify the various locations of the dumpsters/waste bins in University of Nigeria, Enugu Campus.
ii. Execute spatial analysis for route optimization, suitability of the dumpsters/waste bins location among others.
iii. Develop a geo-data base for the waste dumpsters in University of Nigeria, Enugu Campus.

2.0 Literature review

2.1 Conceptual Review

2.1.1 Concept of Solid Waste

Solid waste (SW) consists of everyday items that is used and then thrown away such as, product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries (Danbuzu et al, 2014). Solid wastes are non-liquid and non-gaseous products of human activities, regarded as being useless (Hailu, 2017). Solid waste refers to the leaves/twinges, food remnants, paper/cartons, textile materials, bones, ash/dust/stones, dead animals, human and animal excreta, construction and demolishing debris, biomedical debris, household hardware (Babatunde et al., 2013;Bringi, 2007). Solid waste is an inevitable consequence of production, and consumption activities in an economy (Sasikumar & Krishna, 2009).Increasing population, rapid economic growth and the rise in community living standards accelerate SW generation in the world (Elmira et al., 2010).Solid waste is a global environmental problem in today's world both in less developing and developed countries.

2.1.2 Concept of Geographical Information System

Geographic Information Systems (GIS) are a powerful set of computer-based tools used to collect, store, manipulate, analyze and display spatially referenced information (Burrough et al, 2015;Rusko et al. 2010;Yogesh, 2018).GIS is a computerized system that combines spatial and descriptive data for mapping and analysis. GIS are a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 2015).GIS is any system that captures, stores, analyzes, manages, and presents data that is linked to location

(Akankpo, & Igboekwe, 2012). Technically, GIS is a system that includes mapping software and i ts application to remote sensing, land surveying, aerial photography, mathematics, photo g ra m me t r y, a nd g e o g raphy. (Akankpo, & Igboekwe, 2012).

One of the main strengths of a GIS is its ability to integrate different types of spatial data. GIS provides facilities for data capture, data management, data manipulation, analysis, and the presentation of geographical data (Rusko et al, 2010). GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps (Environmental Systems Research Institute, 1999). From the foregoing, we define GIS as a computerized tool that is used to collect, store, manage, manipulate, transform, analyze, update, display and retrieve geographical data in a quick and efficient manner in order to aid analysis and decision making.

This s tudy will examine the application of GIS in engendering automated and sustainable solid waste management in UNEC. GIS will be used to obtain geographic coordinate of dumpsites; extract and produce relevant maps; map out the location of dumpsters; proximity of dumpsters to each other; proximity of dumpsters to buildings; location of dumpsters along the roads, location of major dumpsites in the study area; and develop a geo-data base for the waste dumpsters in the study area.

2.1.3 Solid Waste Management (SWM)

SWM is the control of generation, storage, collection, transfer, transportation, processing and disposal of SW in a manner that is in accordance with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations (Yadav, 2015). SWM is a multidisciplinary field requiring information about the physical, environmental, social, and economic implications of a SWM system. SWM includes the generation, storage, collection, t ransfer, t ransportation, disposal, processing and treatment of SW which includes recycling of organic waste, thermal treatment techniques, recovery of recyclable products and landfilling (Ramakrishnaiah et al, 2011; Sharholy et al, 2008).

In its scope, SWM includes all administrative, organizing, financial, legal, planning and engineering functions involved in the whole spectrum of solutions to problems of SW thrust upon the community by its inhabitants (Tchobanaglous et al., 1997).SWM is made up of many drivers that can be used to reduce the volumes of SW and this are reusing and recycling materials,

composting, and source reduction (Jibril et al, 2012). The main objectives of SWM are the maintenance of clean and hygienic conditions and reduction in the quantity of SW which is disposed of in the sanitary landfill facility (SLF) of the area after recovery of material and energy from it (Ammar et al, 2019).

2.2 Empirical Review

2.2.1 Solid Waste Management (SWM) in Tertiary Institutions

Ugwu et al. (2020) examined the waste generated in the University of Nigeria, Nsukka Campus using ASTM D5231-92 method. The study revealed that 96.58% of the total waste is recyclable, and has about 51.85% biomass potential. Parvez et al (2019) evaluated SWM at Indian Institute of Technology Roorkee (IITR). Data was retrieved through observations, and interviews with staff and students. The study revealed that SWM at IITR was disorganized and incompetent due to lack of awareness and improper collection, imprecise segregation, exposed transportation, amongst others. Coker et al (2015) examined SWM in Covenant University, Nigeria. Data was gotten using key-informant interview and field observations. The study revealed that SW was collected using appropriate waste collection bags and mobile bins positioned at strategic corners of the university premises. Taghizadeh et al (2012) analysed SWM in University of Tabriz, Iran. The study showed that more than 80% of waste generated could be diverted through waste reduction, recycling and composting activities.

2.2.2 Application of GIS in Solid Waste Management

Mali & Ingole (2021) evaluated SW collection in Juhu Mumbai, India. The study revealed that with GIS based SWM, there was efficiency in routing transportation vehicles. Resources like labor and vehicles were properly scheduled and effectively managed. Gudeta et al. (2020) optimized the transportation route of municipal solid waste (MSW) using the Network Analyst tool for Jimma, Ethiopia. Data used were coordinates of individual MSW collection container location, disposal site location, master plan, and road shapefile. The result obtained includedthe proposed number and location of MSW containers and the best possible route for the evacuation of MSW from individual container location to the disposal site.

Makinde et al. (2020) created a GIS geo-database for waste management in University of Lagos, Nigeria. Data was retrieved via field observations using GPS, questionnaires and, Google Earth satellite image data of the University of Lagos. The study revealed that the model created could serve as a useful alternative method in managing waste in the

University. Randazzo et al. (2018) used multi-criteria analysis and GIS to identify suitable sites for SW landfill in Sicily, Italy. The study revealed several suitable areas to host sites for SW landfill in Sicily, Italy.

Ehisienmhen et al. (2016) carried out a geospatial analysis of SWM in Obafemi Awolowo University (OAU), Nigeria. This research showed the usefulness of integrating remote sensing techniques and GIS to identify appropriate areas suitable for waste disposal and provide a selection of environmentally friendly disposal sites. Abdulai et al. (2015) developed a GIS model and used it to analyze proximity of municipal solid waste collection system (MSWCS) to boreholes drinking water sources in Wa town, Ghana. The results revealed poor management (about 67%) of MSWCS sites; and 15% of mechanized boreholes failed the minimum proximity requirement (≥100 m) of the model.

2.2.3 Application of GIS in Facility Management (FM)

This review is important as Abigo et al (2015) revealed that waste management is a vital component of facility management, as waste not well managed in facilities would cause environmental pollution with negative impact to the life of the occupants, and with damaging effect in accomplishing the goal of the facility. Similarly Esara & Okon (2016); and Khalil et al (2011) showed that solid waste management is one of the key functions of facility management. Mirarchi et al. (2018) examined FM processes through end-users' integration and coordinated BIM-GIS technologies. A workflow was designed, in which a FM supporting platform was proposed and characterized, featuring indoor positioning systems to allow end users to send geo- referenced reports to central virtual models. The proposed framework allows the identification of wide physical building elements; and the entire cycle of maintenance activities is managed through a unique integrated system. Makinde et al. (2017) created a 2D and 3D visual facility map of University of Lagos, Nigeria. Google earth software was used as source of data to produce 2-dimensional facilities. SRTM Digital elevation model image data was used for the 3-dimensional representation. The 2D and 3D model identified numerous cultural and natural ground features, such as roads, buildings, power transmission lines, lakes, streams, etc.

Kang et al. (2016) created a software architecture for the integration of BIM into a GIS-based FM system at the Korea Institute of Construction Technology (KICT). The databases were Excel based structures constructed for the BIM-based FM of the

main building at KICT, and the BIM objects were modeled using the Revit software. The results showed that BG-DI and BIM/GIS integration has benefits such as reusability and extensibility. Mwaniki & Odera (2014) examined the application of GIS in space management in International Livestock Research Institute (ILRI), Ethiopia. A GIS database which integrated spatial and non-spatial data of facilities in ILRI was built. Data obtained from AutoCAD, Arch-CAD and PDF files was geo-referenced, and used to create spatial entities. A web map of the underground and surface facilities was built using features stored in the geo-database.

An important fact that has emerged from the review of extant related literature is that most previous studies on the application of GIS to SWM was centered on cities and towns with paucity of studies that examined the application of GIS to SWM within tertiary institutions. Only few studies such as Makinde et al. (2020); and Ehisienmhen et al (2016) examined the use of GIS in SWM in the University of Lagos, and Obafemi Awolowo University respectively. Therefore, from literatures available to the researchers no study has examined the application of GIS in SWM in the University of Nigeria, Enugu Campus; hence the need for this study to fill this extant literature lacuna.

3.0 Study Area

University of Nigeria, Enugu Campus (UNEC) is located in the heart of Enugu the administrative capital of Enugu State in South-Eastern Nigeria. The Campus is an offspring of the former Nigerian College of Arts, Science and Technology, and was integrated into the University of Nigeria in 1961. It is situated in Enugu North Local Government Area of Enugu State between longitude of 7^{o} 27' 49.35" and 7^{o} 31' 0.94" and Latitudes of 6^{o} 19' 52.76" and 6^{o} 25' 18.14"

(Ndukwe et al. 2011). UNEC covers an estimated land area of about 123.885 hectares. The study area is bordered by Maryland Layout to the East, Kenyatta Market to the South, Osadebe Street to the West and the Women Training Centre (WTC) to the North. The study area is an institutional environment and is composed of lecture rooms/halls, laboratories, administrative buildings, student hostels, staff quarters, churches, banks and other ancillary facilities. The faculties in UNEC are: Business Administration , Environmental Studies, Law, Health Sciences and Medical Sciences.

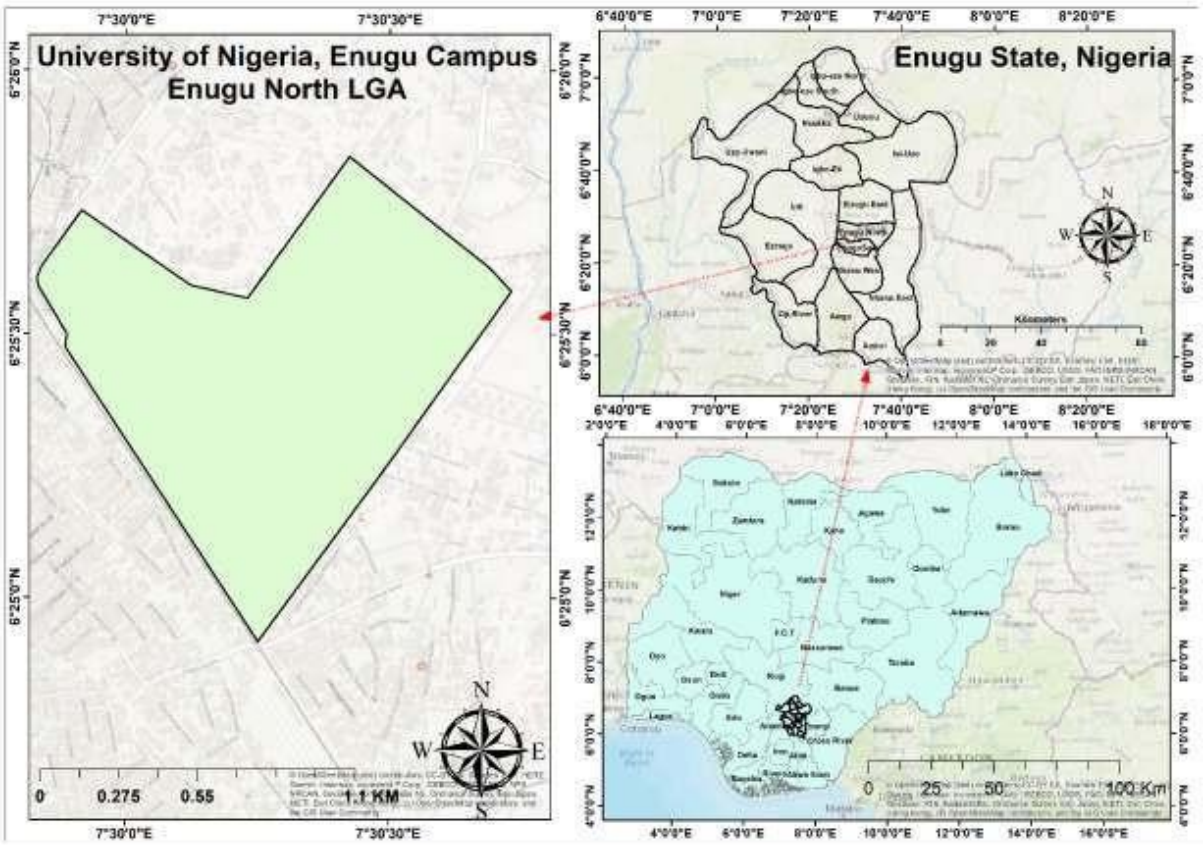


Figure 1: Map of the Study Area

Source: Created by Kingsley Chika Chukwu, Department of Geoinformatics and Surveying, University of Nigeria, Enugu Campus [ArcGIS 10.8, 12/01/2022]

4.0 Methodology

The study adopted descriptive research design. Primary data include the geographical coordinates of all the dumpsites in University of Nigeria, Enugu Campus (UNEC), and obtained using hand held Geographical Positioning System (GPS) while the secondary data used include; administrative boundary maps (Ancillary data). Other secondary data used in this study were sourced from journal articles, conference papers and dissertations/thesis. The methods adopted for data collection were field survey using handheld GPS, GARMIN 78sC to obtain geographic coordinates of dumpsites located within UNEC. High resolution Image (IKONOS) covering UNEC was used to extract and produce the Composite Map. Data was analyzed in ArcGIS 10.5 in Windows OS environment. The methodology adopted in carrying out this study in order to achieve its aim and objective is represented in Figure 2: Flow Chart of Methodology, below.

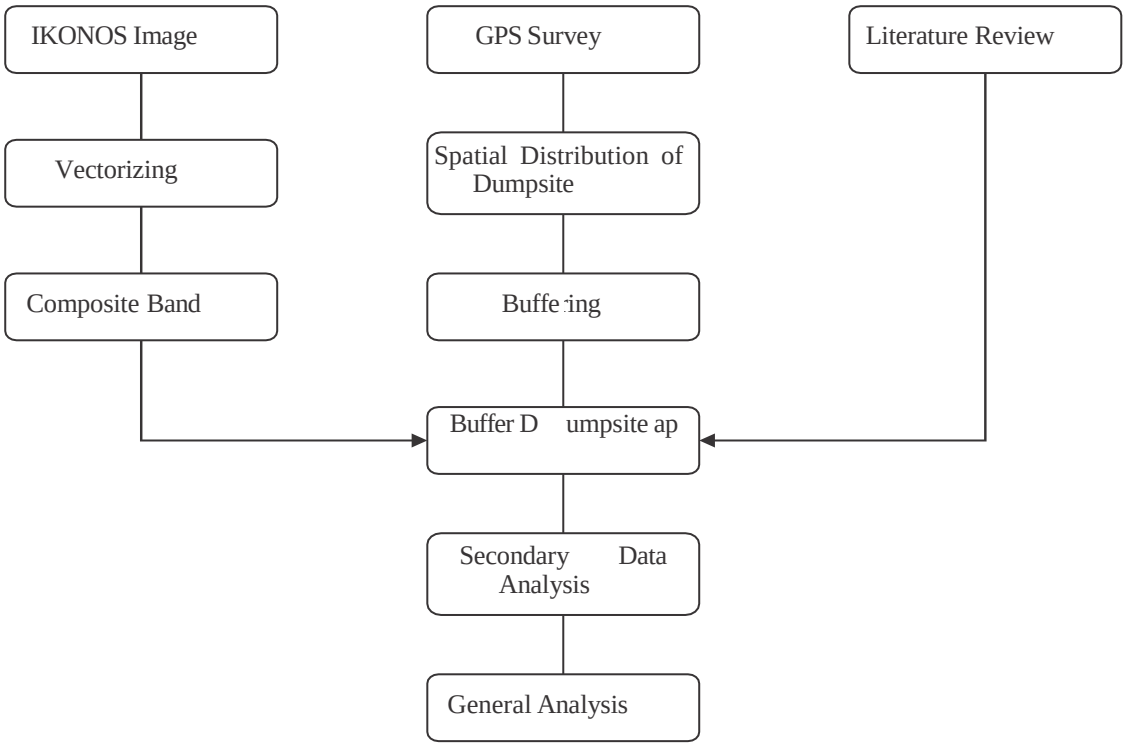


Figure 2: Flow Chart of Methodology

The flow chart of methodology adopted in this study is discussed below:

i. IKONOS Imagery: Acquiring IKONOS imagery involved the process of obtaining high-resolution satellite images captured by the IKNOS satellite which has 0.30266666m Spatial Resolution with total of 5927, 6106 columns and rows in IMAGINE Image format.

ii. Vectorization: This is the process of converting raster data, which consists of pixels or grid cells, into vector data, which represents geographic features as points, lines, and polygons.

iii. Composite Band: This is a single image created by combining multiple spectral bands from a satellite or remote sensing sensor into a single image.

iv. GPS Survey: GPS survey of picking waste bin points involved using GPS technology to accurately collect the geographic coordinates (latitude and longitude) of the locations of waste bins in the study area.

v. Spatial Distribution of Dumpsites: This refers to the arrangement or pattern of waste disposal sites across the study area

which was done using the point of waste bin picked using GPS

vi. Buffering/Buffering the Dumpsite: This refers to the process of creating a region around the study area, such as a point, line, or polygon, based on a specified distance or radius. The resulting buffer are as represented a zone within the defined distance from the feature, and were used for various spatial analyses and operations. Buffers are commonly used to assess proximity, analyze spatial relationships, and determine areas of influence around specific features.

vii. Secondary Data Analysis: This involves the examination and interpretation of existing data like integrating the known data of 4m offset from building road and NUC standard.

viii. General Analysis: The general analysis of points, l ines, and polygons is a fundamental concept in GIS and spatial analysis. These geometric features represent different types of geographic information, and analyzing their spatial relationships, attributes, and characteristics is crucial for understanding geographic phenomena and making informed decisions.

ix. Literature Review: This involved the review of extant related literatures on SWM in tertiary institution, and the application of GIS in SWM.

4.0 Results and Discussion

The aim of this paper is to examine the application of GIS in determining the spatial location and distribution of the SW dumpsters in University of Nigeria, Enugu Campus (UNEC) with a view to achieving a more efficient and effective SWM system. Geospatial analysis (Fig. 3) of the SW management facilities, revealed a total of 41 dumpsters and 2 major waste collection points (located behind Lady Ibiam Hostel and Ojukwu Hostel) were identified in the study area and mapped. The resulting feature layer was used to develop a waste collection system. It was observed (Fig. 3) that there were more dumpsters located in the Northern part of the Campus when compared to the other parts. This could be because of the high population of people occupying that axis of the university. The administrative buildings/offices, and classrooms/halls are in this section of the university, while the Southern side are where the staff quarter is located.

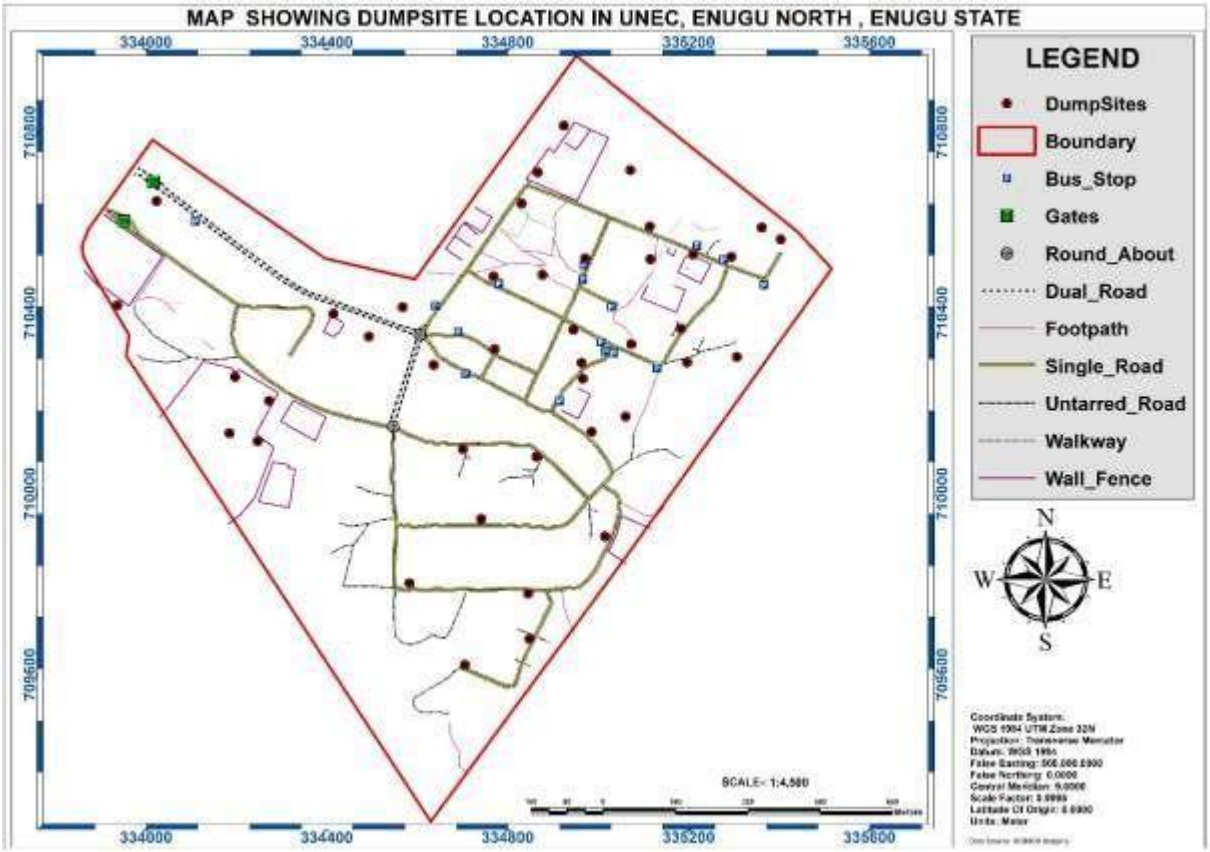


Figure 3: Map Showing the Location of Dumpsters in the Study Area
Source: Created by Kingsley Chika Chukwu, Department of Geoinformatics and Surveying, University of Nigeria, Enugu Campus [ArcGIS 10.8, 12/01/2022]

The proximity of the dumpster was assessed. It was observed that within 50m radius, certain areas on campus had their dumpster filled up and littered around the dumpster.



Overfilled Dumpsters at Jereton Marriere Hostel



Overfilled Dumpsters at Kwame Nkrumah Hostel



Overfilled Dumpsters at Presidential Hostel



Overfilled Dumpsters at Lady Ibiam Hostel

A proximity analysis was performed of dumpsters to buildings on campus. It was observed (Fig. 3) that most of the buildings do not have any dumpster located within 4m. Places such as Lady Ibiam Hostel, Presidential Hostel, Jereton Marriere Hostel, and Kwame Nkrumah Hostel, had its closest dumpster within about 10m and it was filled up. Others were CEMAC building, Faculty of Law areas of the campus. Thus, it is suggested that dumpster should be placed at least 4m of every building on campus for proper waste management.

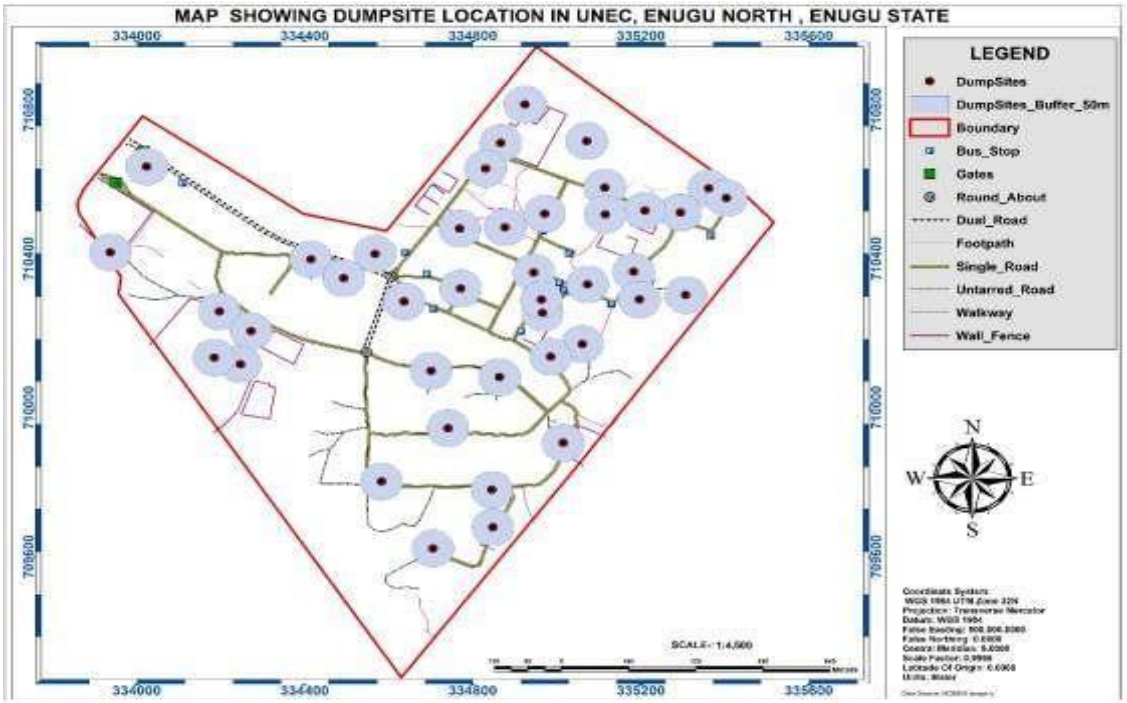


Figure 4: Map Showing the Proximity of Dumpsters
Source: Created by Kingsley Chika Chukwu, Department of Geoinformatics and Surveying, University of Nigeria, Enugu Campus [ArcGIS 10.8, 12/01/2022]

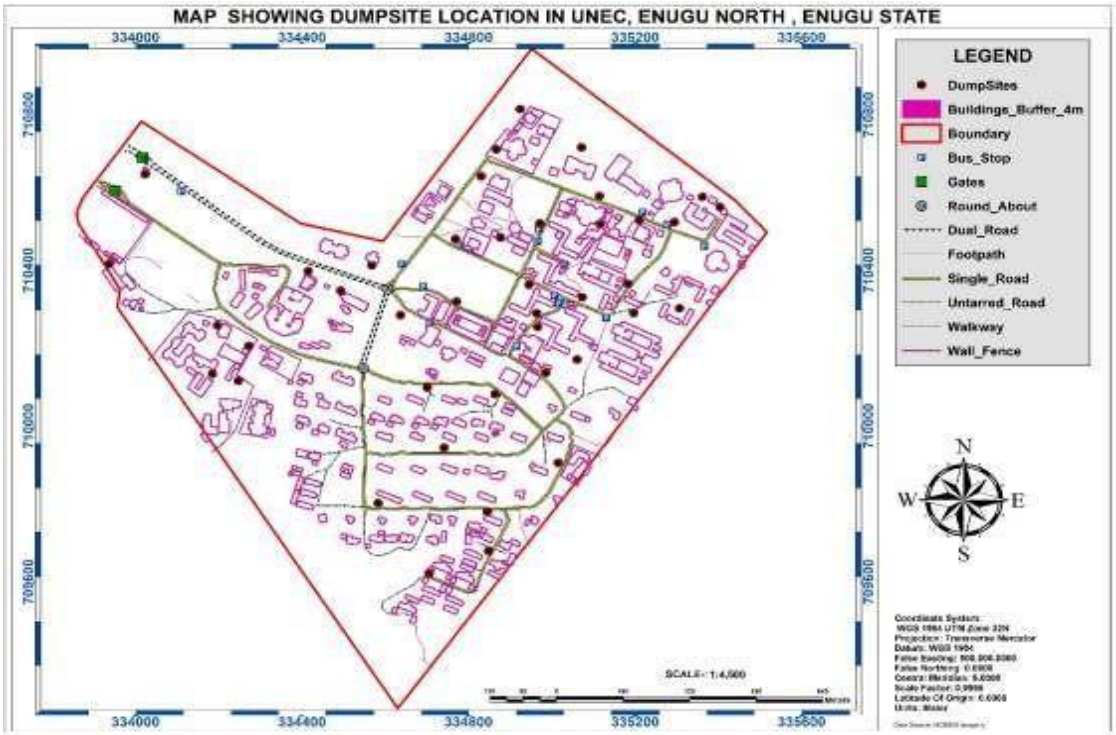


Figure 5: Map Showing a Buffer of Placing Dumpsters within 4m Radius Source: Created by Kingsley Chika Chukwu, Department of Geoinformatics and Surveying, University of Nigeria, Enugu Campus [ArcGIS 10.8, 12/01/2022]

An analysis was performed to identify the location of dumpsters along the roads, to assess the ease of pedestrians disposing their waste on campus. The study observed (Fig. 6) that the most of the major roads in UNEC did not have sufficient roadside dumpsters.

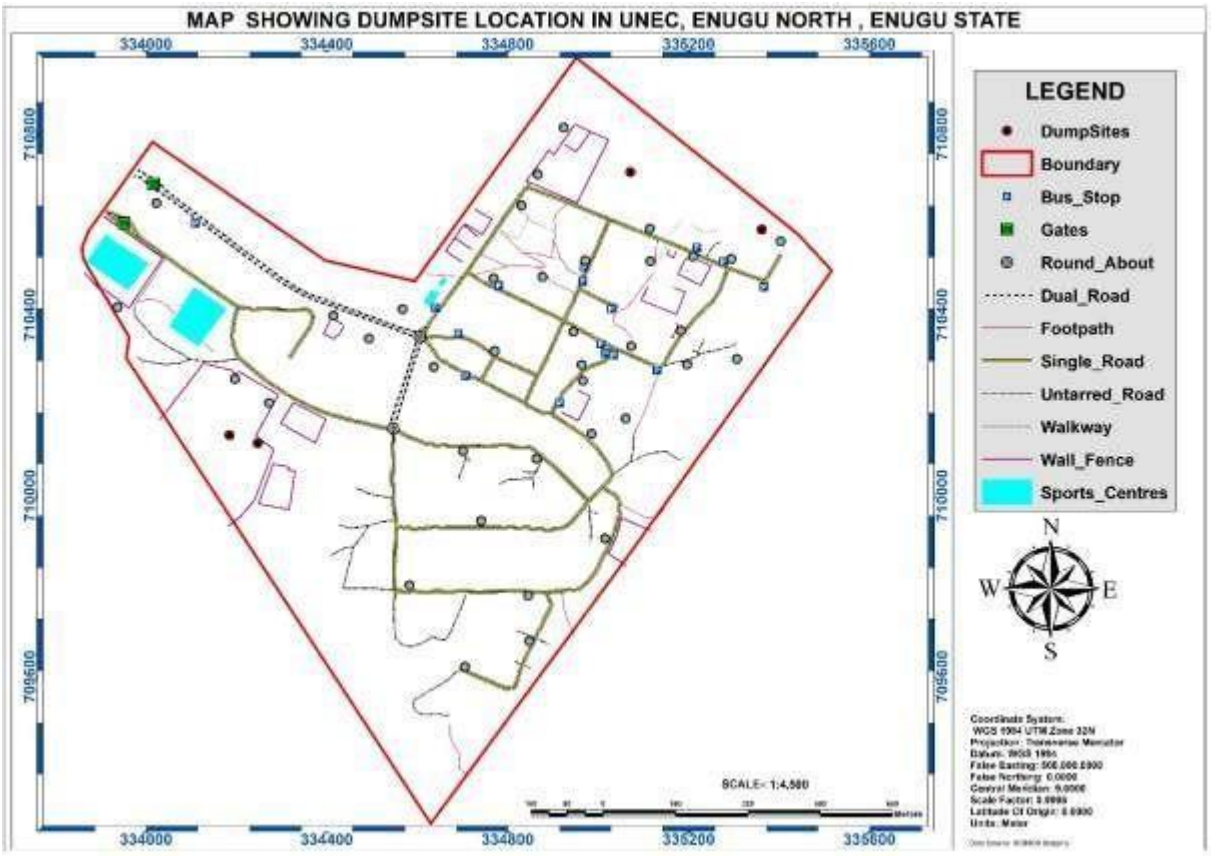


Figure 6: Proximity of Dumpsters to Road Side
Source: Created by Kingsley Chika Chukwu, Department of Geoinformatics and Surveying, University of Nigeria, Enugu Campus [ArcGIS 10.8, 12/01/2022]

The study observed that there are currently two major dumpsites in the study area.The first one (which is the main one) is located behind Lady Ibiam Hostel while the second is located behind Ojukwu Hostel and Manuwa Hostel. Waste is moved from first dumpsite to the second for sorting and some form of recycling. Suitability analysis (Fig.7) was applied to assess the location of one of these two dumpsites and it was observed that the dumpsite behind Lady Ibiam Hostel fell within the 500m buffer even the one behind Ojukwu Hostel and Manuwa Hostel Intercepted with the Lady Ibiam at Buffer of 500m. It is recommended that this dumpsite should be relocated far away from buildings for health and environmental reasons, or the University should provide an alternative to daily disposal of SW generated.

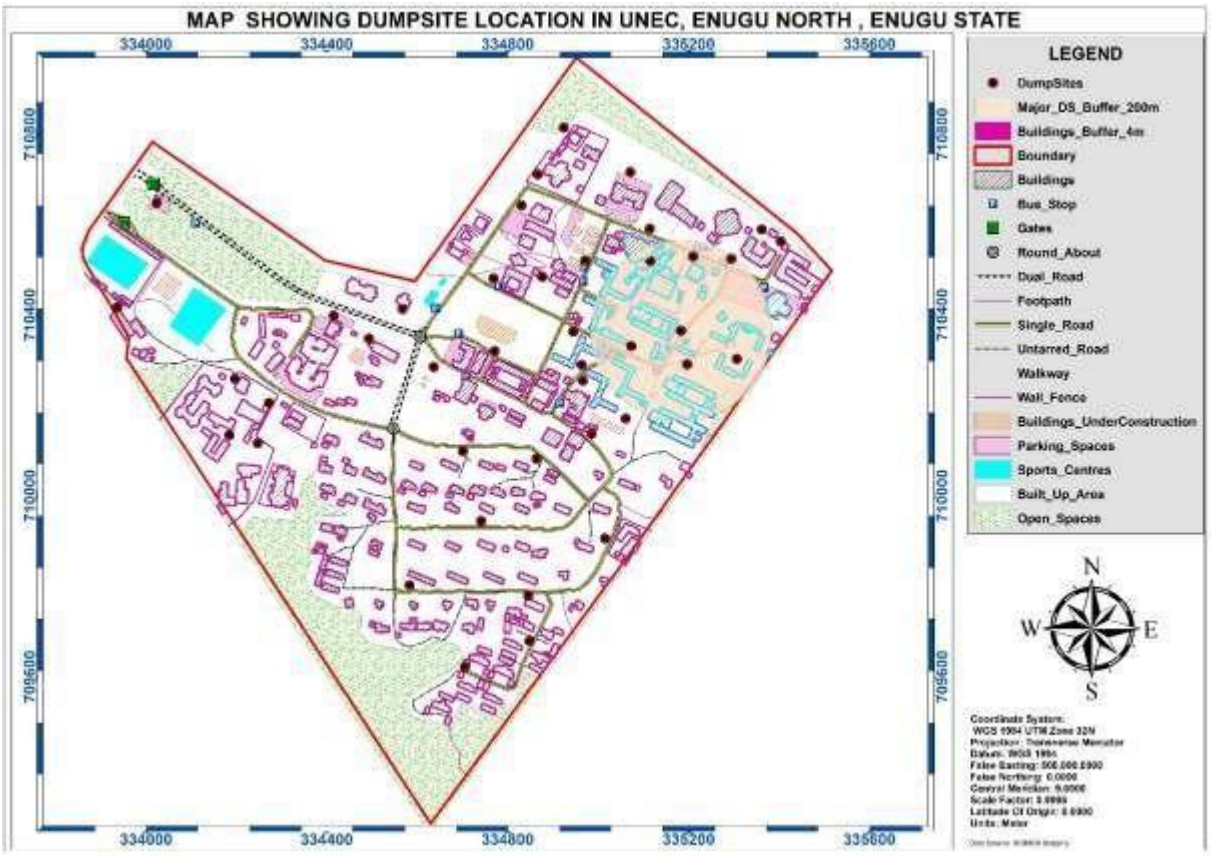


Figure 7: Map Showing the Suitability Analysis for Siting a Dumpsite
Source: Created by Kingsley Chika Chukwu, Department of Geoinformatics and Surveying, University of Nigeria, Enugu Campus [ArcGIS 10.8, 12/01/2022]

5.0 Conclusion

This study created a GIS database model for solid waste management in the University of Nigeria, Enugu Campus. It incorporated the use of GIS and GPS methods of survey to solving the management of solid waste. Spatial analysis was performed, and maps created. The maps created can be used by appropriate authority within the campus as a decision support tool to enhance the current SWM system. The research ends up providing spatial location of waste bins located in the study area and its proximity to each other buildings (offices, library, classroom, hostels and guest houses) roads and so on. Their spatial locations will help in further research, decision making and was well as having analysis on its effects to proximity to either buildings or road.

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