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APPLICATION OF GIS AND REMOTE SENSING TECHNOLOGY IN WASTE DISPOSAL AND ENVIRONMENTAL IMPACT ASSESSMENT

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Abstract: Selecting a site for a waste dump in cities is a complex process that involves proper geographical consideration because the volume of waste generated has increased over time and it is on a steady rise due to population increase and Urban living. In most cases, indiscriminate dumping of refuge has been recorded in growing cities, especially in developing countries where the volume of waste being generated has attained an alarmingly high rate and there are no proper waste collecting and disposing systems. Several factors must be duly considered in selecting waste disposal sites as the location will involve the interplay of geological, hydrological, environmental, and geotechnical parameters, with regulations incorporated in government policies. As such, it will require the processing of a considerable amount of geospatial data. This article reveals an extensive analysis of the role of Geographic Information Systems (GIS) and Remote Sensing (RS) in solid waste disposal. Several kinds of literature have indicated the proficiency of utilizing Remote sensing and GIS techniques to identify inherent sites and assess the effects on the surrounding environment. It is well established that utilizing techniques such as GIS and RS can incorporate spatial data and secondary experiments to produce consistent monitoring of landfills. This practical method is a suitable application for cities.

Keywords: Geographic Information Systems (GIS) *remote sensing (RS), waste, landfill, urban living, underdeveloped, EIA*

1. INTRODUCTION

Waste can be seen as any material or product that is no longer useful which is usually discarded at the end of its use or the end of a process. It is also considered to be any material that needs to be disposed of during the waste management process in an environmentally acceptable manner (Kimwatu & Gitonga Ndiritu, 2013). Waste could occur in gaseous, liquid, or solid forms, but the emphasis is mostly made on the solid waste form as it stands to be the most generated and the most carelessly disposed of. Solid waste is identified as non-liquid and non-gaseous products of human activities (Kimwatu & Gitonga Ndiritu, 2013). The current state of population in the municipal areas as well as the rate of urbanization globally determines the heterogeneous collection of solid waste produced in which the nature of occurrence varies from one region to another, this determines the level of municipal solid waste (MSW) generation and collection (Karsauliya, 2013). The rapid growth of population in a city requires a larger area for disposal of effluent and toxic waste otherwise it becomes a major environmental issue posing threats to the existence of human beings (Basavarajappa & Manjunatha, 2013). For this singular reason the enormous waste generated and its management has been crucial to the environment and human health both in developed and developing nations. It stands to reason that collection, transportation, landfill selection, and treatment are the major challenges that are encountered in the context of municipal solid waste management (Biotto et al., 2009). The advent of computer technology and the continuous rate of its advancement has resulted in the introduction of innovative tools like Geographic Information Systems and Remote Sensing that can be applied directly to site selection and spatial analysis of the effect of waste on the environment. GIS is a digital database management system that is ideal for advanced site selection studies because it can effectively store, retrieve, analyze and display information according to user-defined specifications (Sivasankar & Rathinam, 2017). Simply put, the primary application and function of these innovative tools are to seek and monitor landfills and associated environmental hazards. This has simplified

accessibility to important waste management data and environmental impact assessment in comparison to the manual conventional techniques which undergo a tedious process of data collection and consequent flawed results. Embedded in the GIS are other advanced methods/techniques that enhance the process of decision making like the multi-criteria decision technique which helps the decision-maker to prioritize and make the best decision by reducing complex evaluations to a series of pairwise comparisons to arrive at optimal solutions in waste disposal area siting process.

1.1 Aim

This paper aims at providing critical information about the need for proper waste disposal management by unearthing the application of GIS and Remote Sensing in environmental conservation for site monitoring and landfill selection.

1.2 Methodology

To achieve the aim of this paper and to ensure the quality of information laced within, the authors consulted journals with research topics; articles related to the topic, and based their findings explicitly on the use of open-source materials.

2. LITERATURE REVIEW

The application of Geographic Information Systems and Remote Sensing ensures a well-coordinated waste disposal planning routine with every stake parameter in play (Glanville & Chang, 2015). The technology enhances suitability in environmental Risk Assessment Management as revised by several academicians, researchers, and authors in the field of environmental monitoring and management and as seen in a similar study by (Kimwatu & Gitonga Ndiritu, 2013). Consequently, it is gradually gaining acceptability in Africa for its susceptible function, especially in Nigeria. The ability to map the land surface to determine the status in terms of its cover and uses has been remarkable and additionally, the visualization of these land surface features depicts intuition for inexperienced or first-time users with basic interest. Certain functionality such as the buffer function could determine the proximity and distance between dump sites and settlement areas and the surrounding environments which will ultimately inform decision making. One very important characteristic in the application of GIS and RS is that it can readily analyze a larger area of interest as compared to the regular and conventional mays in waste site surveying, selection, and monitoring. Furthermore, manual conventional techniques are difficult because of the inaccessible location of the landfills and associated health hazards (Biotto et al., 2009). For this reason, the Role of GIS and Remote Sensing in remote identification and monitoring prevents and alleviates field hazards.

2.1 Definition of GIS and Remote Sensing (RS)

The concept of Geographic Information systems and Remote Sensing are relatable in general terms as they function as a unified tool. In a book by Koroleva & Nikitin (2014), a geographic information system is defined as a computer-based system that supports the study of natural and man-made phenomena with an explicit location in space. In other words, it is a support system that uses a computer to understand the interactions between species and their surrounding in a given space and time. Remote sensing, on the other hand, requires obtaining specific information about the earth's surface without physical contact or presence, this is made possible by measuring its reflected and emitted radiation at a distance typically from satellite or aircraft (Kairu, 1982) and (Jong, 2007). Relatedly, RS obtains data that is processed and analyzed in a GIS environment that ultimately provides new insight that informs decision making.

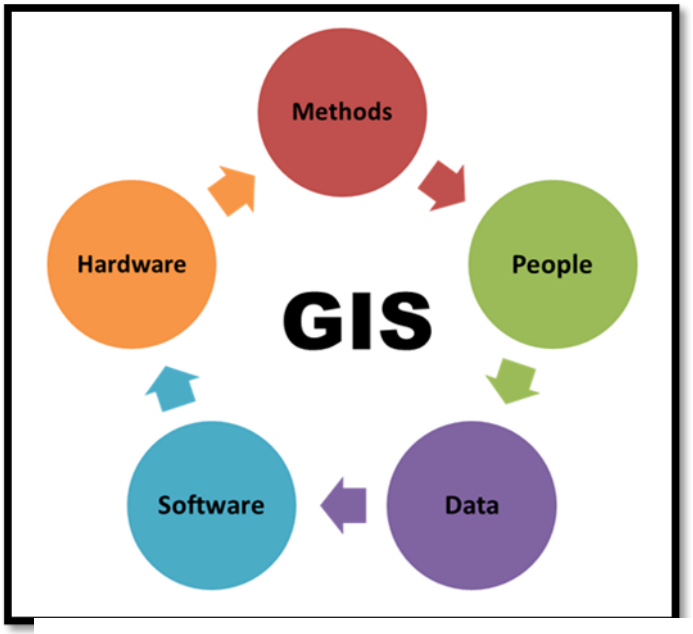

Figure 1: Geographic Information Systems Component

2.2 How it works

The emergence of Geographic information systems in the last decades has been essential in urban planning and environmental resource management due to its capacity to store, retrieve, analyze, model, and map large areas with huge volumes of spatial data (Hunter & Bishop, 2013). This technology also facilitates the process by which we can visualize, analyze and understand spatial data acquired by the means of Remote Sensing which is one of the methods commonly used for collecting physical data as recorded by Glanville & Chang (2015). Data acquired by remote sensing are then integrated into a GIS. The method of Remote sensing works by sensors that collect data from objects on the earth without any direct contact, these sensors read back reflective properties of the earth's surface at a given wavelength to make sense of the phenomenon as shown in figure 1 below.

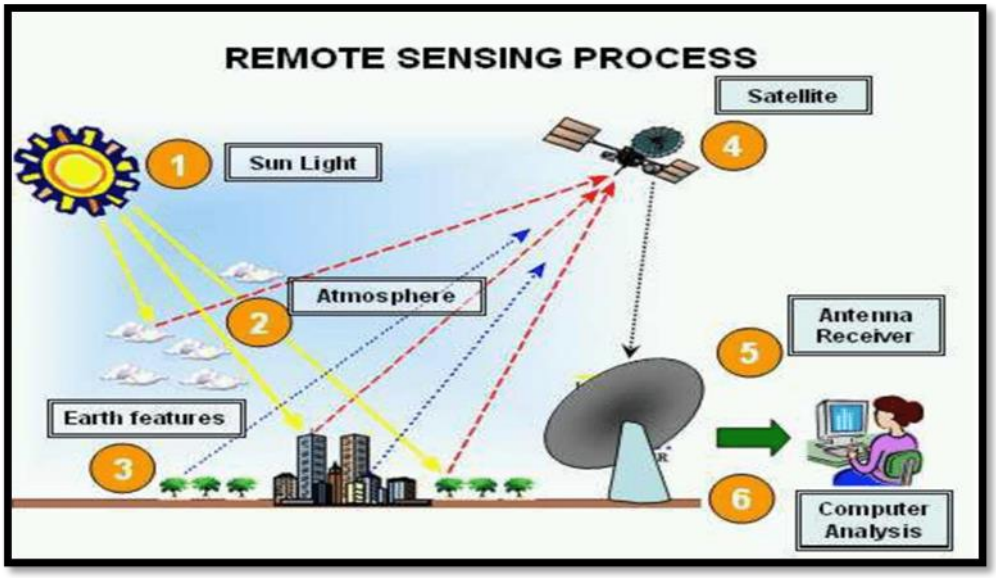

Figure 2: Remote Sensing component and Process (jaihindiasacademy.com)

As presented in the image above, the components are required to enhance remote sensing as the satellite platform holds the sensors that detect the target object or earth feature, and the sunlight and atmosphere contribute immensely to the electromagnetic spectrum of which the needed wavelength for sensing occurs. When data on the target object is detected, it is then received and compiled by the computer analyst after which the data received is then projected to the GIS environment where further modeling and analysis are carried out to achieve the desired results.

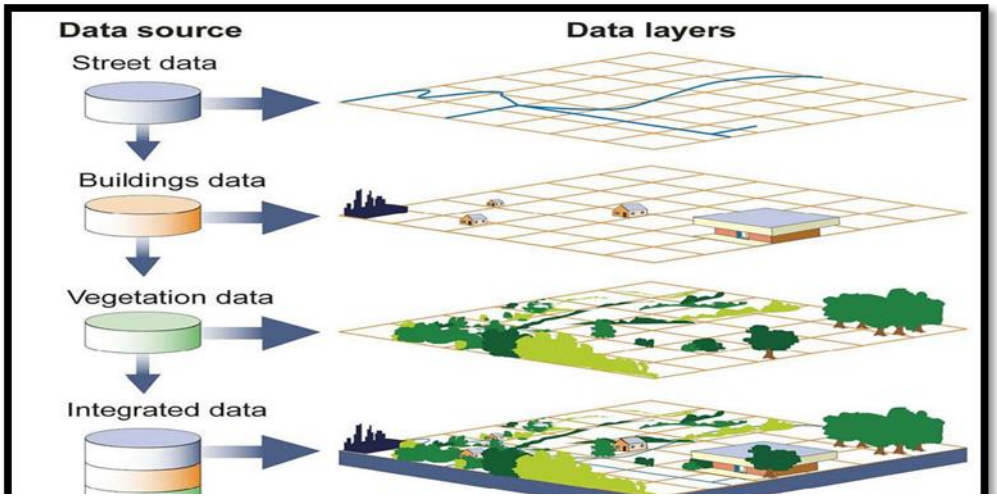

Figure 3: GIS model showing sample variables and integrated data (nationalgeographic.org)

2.3 Areas of applications

Geographic information systems and Remote Sensing are now used broadly in different areas of study and professions ranging from land use planning, utility management, ecosystems modeling, landscape assessment and planning, transportation and infrastructure planning, market analysis, visual impact analysis, facilities management, tax assessment, real estate analysis and many other applications. The most prominent areas of GIS and RS application are outlined below as follows;

2.3.2 Agriculture

Geographic information systems (GIS) have been widely applied and have been recognized as an effective and powerful tool in detecting land cover and land-use change (Gebeyehu, 2019). Its application in agriculture is important to understand the health of the crop, extent of the infestation, potential yield, and soil conditions (Gebeyehu, 2019), it is also applied to explore agricultural applications such as crop identification, area estimation, crop condition assessment, soil moisture estimation, yield estimation, agriculture water management, etc.

2.3.3 Weather and Climate

The applications of GIS and RS in meteorology is a much-needed method in the study and analysis of weather and climate phenomenon as recorded by Wilhelmi & Brunskill (2003), this is primarily because it uses sophisticated techniques and tools to predict the weather, study satellite data, maps and radar information (Wilhelmi & Brunskill, 2003). For the most part, experts in the field of meteorology cannot overemphasize the use of GIS and RS as they focus primarily on the prediction of weather trends and forecasts using visual presentation in the forms of 2 D, 3D, and even 4 dimensions representation of atmospheric phenomena (Wilhelmi & Brunskill, 2003).

2.3.4 Biodiversity

The method of Geographic Information Systems and Remote sensing stands today as an important aspect when it comes to getting concrete information on conservation management and biodiversity because it helps, in taking measurements that broaden our understanding of phenomena occurring around us (Upreti et al., 2015). Remote sensing is a world-accepted method of taking and analyzing data about the earth in which decisions are made concerning the ongoing and future state of our beloved planet. This data is analyzed through sensors (remote sensors) that record transmitted and emitted energy. Biodiversity talks about the number and variety of species of plant and animal life within a region. Without biodiversity, there is no life, it determines our breath, the food we eat, and our day-to-day living. In recent years, researchers have been looking for ways to sustain biodiversity on planet earth because of its services.

2.3.5 Urban planning

Urban planning entails the design and regulation of the uses of space that focus on the physical form, economic functions, and social impacts of the urban environment and the location of different activities within it (britannica.com). Urban planning is usually concerned with both the development of open land and the revitalization of existing parts of the city, thereby involving goal setting, data collection and analysis, forecasting, design, strategic thinking, and public consultation (Kumar, 2021). Increasingly, the technology of geographic information systems (GIS) has been used to map the existing urban system and to project the consequences of changes. In the late 20th century, the term sustainable development came to represent an ideal outcome in the sum of all planning goals. GIS in urban planning enables spatial analysis and modeling, which can contribute to a variety of important urban planning tasks. These tasks include site selection, land suitability analysis, land use and transport modeling, the identification of planning action areas, and impact assessments. GIS functionality such as interpolation, buffering, map overlay, and connectivity measurement help urban planners achieve these tasks (unearthlabs.com).

2.4 Waste Management in Nigeria

Municipal solid waste management (MSWM) is the practice of collection of solid waste and all the process that leads to adequate and harmless disposal which includes storage, treatment and even recycling as the need arises (Kimwatu & Gitonga Ndiritu, 2013). Solid waste disposal and management have been of critical concern in most metropolitan cities in Nigeria, with an enormous amount of solid waste being generated on an annual basis mostly in the state capitals and other fast-growing towns (Ezechi et al., 2017). In Abuja for example, Municipal solid waste management poses severe challenges to the safety of the public as well as the environs with severe public health consequences that affect the welfare of citizens. Several factors contribute to the problem of waste but the most recognized is the indiscriminate dumping of waste along the roadsides, drainages, streets, green areas and even open empty fields. Consequently, the impact of these inappropriate waste disposal practices

could result in deteriorating health on a wider scale and even though they have been attempts to improve waste management, they are notable deficiencies and no significant progress.

2.5 Challenges of waste disposal in the Municipal Areas

Selecting a proficient waste management plan relies heavily on several indicators ranging from the waste type, available land-fill areas, and the obtainable technology in a specific location. When narrowed down to Africa at large and in Nigeria particularly, the challenges can be seen to be diverse as outlined according to their significance below;

2.5.1 Lack of awareness of public health and the environment

Lack of awareness about waste disposal is primarily attributed to the deficiency in educational awareness of the trending issues surrounding the subject matter, absence of acceptable technology to tackle the existing and emerging issues, lack of incentive for recycling initiatives, and poor funding or sponsorship for environmental organizations. Above all, it is recorded that poor educational programs on environmental handling have been the primary limitation to waste management in Nigeria (Ezechi et al., 2017). It is widely accepted that environmental education and awareness programs that produce enduring knowledge and commitment can transform the residents into environmentally conscious people.

2.5.2 Lack of Suitable Technologies

Constraint in technological advancement has been a tremendous obstacle to proper waste management, especially in developing countries. This includes insufficient equipment for collection, transportation, and disposal of waste, and poor knowledge and skill of existing technologies. Due to these impediments, the most common waste management strategy in Nigeria is landfilling in open dumpsites which requires the disposal of solid waste in selected land areas.

2.5.3 Lack of Incentives for Recycling Initiatives

In some developed countries, incentives were used to motivate residents to recycle their waste products. This is significantly effective as it encourages the resident to sort and store their waste it will also significantly influence the waste generation and disposal.

2.5.4 Poor Funding of Environmental Agencies

In developing countries, a lack of adequate resources and technical expertise hinders municipal corporations from proper execution of waste management. Additionally, if the obvious challenges that hinder proper waste management can be checked it will significantly improve the quality of life and create a better environment and atmosphere for living. In a study at Aba, Nigeria, Ezechi et al., (2017) proposed a management method as he recorded the urgent need for a restructuring of waste management as illustrated in the figure below;

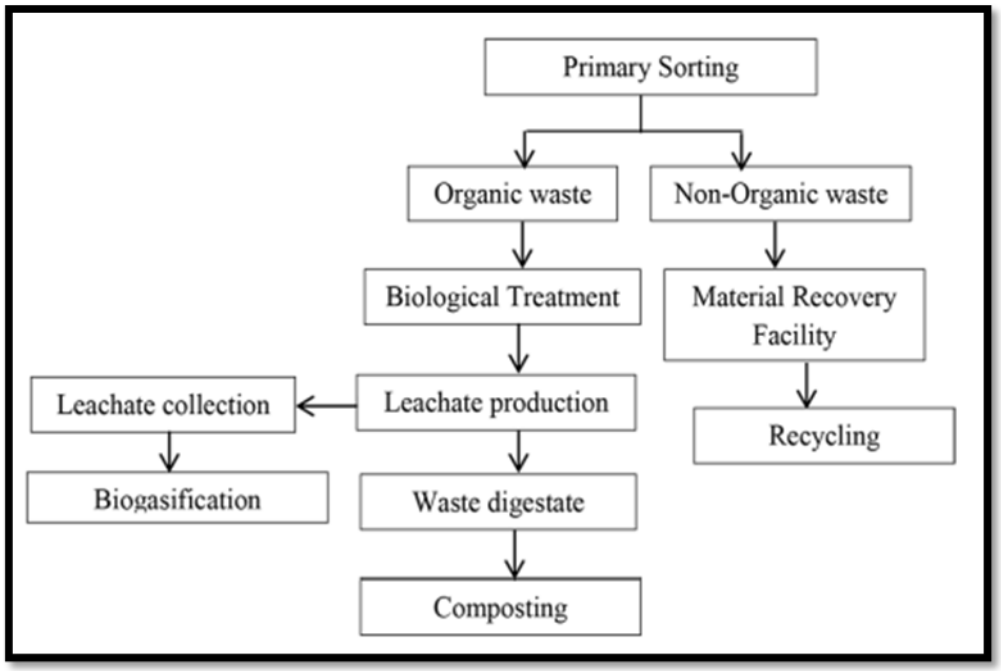

Figure 4: Municipal Waste management method

APPLICATION OF GIS AND RS IN SOLID WASTE MANAGEMENT

GIS and Remote sensing are required for sufficient structuring and planning in waste management. Numerous methods can be selected when applying these functions as tested in several research studies. Glanville & Chang, (2015) tested the use of high-resolution satellite images to identify illegal waste dumping sites in Australia while examining the applicability for future detection. Similarly, Sivasankar & Rathinam, (2017) applied Remote Sensing techniques to determine land use land cover at Mellor municipal India and further applied the method of weighted overlay analysis which considers factors like proximity to existing services, slope, and flood frequency among others. Other techniques such as Analytical Hierarchy Process (AHP) were found to be appropriate in establishing general indices to quantify overall environmental impact as well as individual indices for specific environmental components such as surface water, groundwater, atmosphere, soil, and human health (T, Basavaraj Appa, et al., 2013). Most commonly, land use land cover mapping from satellite imagery gives a clear definition of the land status, further analysis using the buffer tool could inform the proximity of potential sites to settlement, waterbody, vegetation reserved areas, etc.

4. CONCLUSION

The use of modern technology to solve modern-day problems has proven to mitigate the surrounding issues of waste management and its environmental impact. GIS and RS have now become the leading technology to that effect as it is capable of depicting crucial information about the environmental phenomenon on a spatiotemporal scale. This has in turn improved situational awareness and overall decision making. The application cuts across various utility areas and is seen to be interchangeably dependent on one another. However, developing countries with specifics to Nigeria still face numerous challenges related to inadequate waste disposal which is attributed to some factors highlighted in item 2.5 above. It is imperative that government institutions, private environmental practitioners, and the general public at large work together to curb waste management challenges through proper orientation, education, and awareness of waste generation and the consequences of improper waste disposal.

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