Rapid Urbanization and its Impact on Municipal Solid Waste Management in the Greater Accra Region of Ghana.

by

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Abstract

Most cities in developing countries are currently experiencing a rapid increase in urbanization which has stressed out the ecosystem and environment. Human activities have resulted in a myriad of problems of which management of solid waste is one of the top on the list, though not always highlighted. However, effective solid waste management strategies are crucial in addressing this issue and promoting sustainable urban development. This study, therefore examined the recent pattern of growth of the Greater Accra region between 1991 and 2021. Therefore, understanding the interaction between the region's inhabitants and the changes in the region's landland cover time depended greatly on land use and land cover change analysis. A remote sensing tool was implemented to run an unsupervised classification analysis and to reveal the growth of the region over the years specifically from 2000 to 2021 using unsupervised classification analysis. The results showed that the urban vegetation in the region decreased from 63.4% in 1991 to 12.9% in 2021, while the built-up features increased from 6.4% in 1991 to 52.2% in 2021. Additionally, the study evaluated how this growth has affected the region's solid waste management. This was crucial for identifying current practices and strategies and enabled the researcher to determine its effectiveness. Recommendations were made on the identifiable areas of solid waste management that needed improvement to ensure a healthy and sustainable environment for future generations.

Dedication

Dedicated to my beloved sister **Veronica Ainooson**, who was not only my sibling but also my mentor, friend, and biggest supporter. She believed in me and my dreams, and her unwavering encouragement and guidance helped shape me into the person I am today. Without her belief in my abilities, I would not have been able to accomplish all that I have. This work is a tribute to her memory and the love and inspiration she brought into my life. Big sis "the fruits of your laborious and persistent investment are now apparent". I hope to continually see your halo shine!

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"Behold, I am with you and will keep [careful watch over you and guard] you wherever you may go, and I will bring you back to this [promised] land; for I will not leave you until I have done what I have promised you" Genesis 28: 15.

I am inexpressibly thankful to God for giving me such an opportunity and for sailing with me throughout this academic journey. Indeed, I do acknowledge that all knowledge and understanding come from Him, and it is by His grace that I was able to accomplish this work.

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Abbreviation	Definition
SW	Solid Waste
SWM	Solid Waste Management
MSW	Municipal Solid Waste
MSW	Municipal Solid Waste Management
MSWD	Municipal Solid Waste Disposal
ISWM	Integrated Solid Waste Management
EPA	Environmental Protection Agency
MSWLF	Municipal Solid Waste Landfill
LULC	Land Use Land Cover
GIS	Geographic Information System
TM	Thematic Mapper
ETM	Enhanced Thematic Mapper
HH	Household
MLGDRD	Ministry of Local Government and Rural Development
TCPD	Town and Country Planning Department
IHDP	International Human Dimension Program
UNDP	United Nations Development Program
SDG	Sustainable Development Goal

Chapter 1: Introduction and Study Area

1.1 Introduction

The global population is increasingly migrating from rural to urban areas making urbanization one of the most significant factors in the transformation of cities. The 2022 report from the World Population Prospects reveals that more than 55% (4.3 billion) is urban population, even though only 3% was reported in the year 1800 (World Urbanization Prospects, 2018). By 2030, for the first time in history, 43 megacities with more than 10 million people are expected to exist throughout the world, with the majority of them anticipated to be located in developing countries (World Population Prospects Revised, 2018); therefore, making issues of urbanization crucial, particularly with the need for spatial management and society's adaptions to this change. The consequence of rapid population growth accompanied by a high rate of urbanization has caused an increase in human engagement in economic activities resulting in a deteriorating environment visible in all cities around the globe (Levis et al., 2013).

Africa and Asia are anticipated to experience unprecedented urban population growth by 2050 due to natural growth, and rural-urban migration reclassifying the towns and villages (World Population Prospects 2022). Predominantly, there has been a significant evacuation of labor from traditional industries and rural areas for employment prospects in urban areas. This exodus has not necessarily affected the improvement, living standards, or overall economic growth of persons in cities (Ebeke & Ntsama Etoundi, 2017), instead, it has impacted people's consumption rate mostly in developing countries (Aleluia & Ferrão, 2016). However, with rapid population growth and unplanned urbanization, many developing countries are struggling to manage all sorts of anthropogenic wastage, especially municipal solid waste (Ara et al., 2021).

One of the significant consequences of urban life is municipal solid waste, which is generated faster than urbanization itself (Tawfik et al., 2022). Many cities in developing countries are providing unhealthy environments due to overcrowding and poor sanitation conditions accompanied by high frequencies of contagious diseases yet, challenging healthy habitable urban conditions (Elmqvist et al., 2013). This is usually due to their underdeveloped economies, inability to uphold environmental regulations, financial mismanagement, and inadequate administrative capabilities resulting in problems with solid waste management (Muniafu & Otiato, 2010).

Municipal Solid Waste (MSW) management has become a major concern globally as a result of increased industrialization and urbanization, particularly for emerging nations (World Bank, 2022). This is a major influence on the achievement of sustainable development especially in less-developed countries (Zhou et al., 2015). Due to this, it is anticipated that 4.3 billion people would live in urban areas throughout the world by 2025, producing 2.2 billion tons of MSW annually at a rate of 1.42 kg per person each day (Addo-Fordwuor & Seah, 2022; Priti & Mandal, 2019) (Priti & Mandal, 2019) resulting in an adverse effect on human health and their surrounding environment.

As cities grow, their management becomes more complex. Therefore, it is important to recognize and appreciate the overall range of benefits derived from cities while ensuring they function ceaselessly. Cities can create economic and social advantages, yet they can also cause inherent challenges to the well-being of urban inhabitants and their environment. For this reason, the efficient management of rapid urban expansion to produce sustainable cities could be significantly dependent on sustainable planning and development. For instance, with the development of the Sustainable Development Goals (SDG) as a means of providing a shared blueprint for people and the planet's peace and prosperity now and in the future, several countries

have put in diverse efforts to instill sustainable measures into their national and developmental agenda (Bayulken & Huisingh, 2015; United Nations, 2015). Therefore, a way of making cities habitable without compromising the environment and social systems, while ensuring maximum satisfaction of developmental demands of both the present and future generations (Rufus & Olugbemiga, 2018).

Urbanization is often essential for the development of every country, but Ghana's rapid rate of urbanization has severely strained the nation's resources and the environment. More than half of Ghana's population currently lives in urban areas as a result of the country's rapid rate urbanization since 2010, which has resulted in a striking shift in the country's demographics from rural to urban. (Ghana Statistical Service, 2021). According to the Ghana Statistical Service's most recent population and housing census report, the country's urban population has been steadily growing from 12,545,229 (50.9%) in 2010 to 17,472,530 (56.7%) in 2021, and it is expected to reach 72.3% by 2050, despite a serious infrastructure and service backlog. Ghana's increasing rate of urbanization is a common situation in many African countries as a result of the combination of two main factors, a high rate of natural increase of the country's population and net in-migration to urban centers (Ardayfio-Schandorf et al., 2012). Undoubtedly, Ghana's population is continuing to grow without keeping up with the need for infrastructure services, leading to adverse challenges, especially in the nation's largest towns and cities.

The Greater Accra region of Ghana, which includes the nation's capital Accra, was identified as the region with the highest level of urbanization in the most recent census report. (Ghana Statistical Service, 2021). Accra has been the focal point for economic growth, innovation, and employment in the country, therefore, resulting in a substantial alteration of its urban landscape (Anarfi et al., 2020). With significant government and corporate buildings, Accra serves

as Ghana's Central Business District (CBD), making it the busiest location for commercial and political activity in the region (E. Agyemang, 2017) as shown in Figure 1.1. The city of Accra is struggling with indiscipline, haphazardness, and a lack of an appropriate and well-maintained infrastructure due to a lack of comprehensive planning and the absence of developmental regulations amidst its growing population.

Figure 1. 1 Accra's Sprawl and Congestion. Source: (Ofori, 2021)

However, the most urgent issues resulting from the rapid rate of urbanization in the country must be addressed (UN-Habitat, 2022) while capitalizing on the growing rate of urbanization. During the past few decades, a large portion of Ghana's Greater Accra region's natural environment has been transformed into a built-up area with an increasing spatial extent due to rapid urban expansion (Wemegah et al., 2020a). Deforestation, loss of habitat, creation of slums

and squatters, poor air, and water quality, flooding, extreme climate changes, and waste management issues are all challenges faced by the region, and this is mainly attributed to its nature of population expansion (Deku, 2020). There is no doubt that the absence of effective solid waste management in Ghana's developmental plans has resulted in several negative repercussions for urban residents and their surrounding urban environment, especially in major towns and cities across the country. Municipal Solid Waste Management is one of Ghana's most pressing environmental issues, and the unlawful disposal of uncollected municipal solid waste in open spaces, water bodies, or along the sides of roadways poses a severe environmental concern for the country. The present waste management facilities, especially in Accra and Kumasi, are inadequate for meeting the expanding requirements of the urban inhabitants.

The current situation of solid waste management in the Greater Accra region of Ghana presents an opportunity for a thought-provoking conversation about potential implications and solutions among stakeholders within the country. However, the growing solid waste management issue identified in Ghanaian urban areas due to the significant rise in the volume of solid waste produced occurs concurrently with the concentration of people and commercial activity. In Ghanaian cities, this MSW issue is becoming worse and majorly unsolvable. Institutional, technological, and budgetary limitations at the different levels of government, including the private sector and those at the national and municipal levels often make it challenging to provide the right quality of service in response to the growing demand for acceptable sanitation services (Adorsu-Djentuh, 2018; Amoah & Kosoe, 2014). For instance, trash collection vehicles sometimes find it difficult to access certain areas within the Greater Accra region of Ghana due to the lack of well-laid-out streets and too tiny untarred roadways, usually in slum areas (Oteng-Ababio et al., 2013). Again, the rapid rate of urbanization has increased the average distance that collection vehicles must travel because

of urban expansion while adding to the expense of trash management. All these have resulted in the accumulation of heaps of solid waste of all kinds which have been untidily spread across almost everywhere within the cities in the region (Adorsu-Djentuh, 2018) resulting in a threat to public health while endangering the quality of the urban environment. In each of these instances, the ability of the local governments to provide even the most fundamental services under their authority in the face of the nation's expanding solid waste generation in the various sectors of municipal solid waste management comprising of generation and composition, collection and transportation, and disposal and treatment (Sharholy et al., 2008) has been severely hampered mainly by the unanticipated rapid population expansion.

Yet, before recent times, there was a dearth of reliable data quantitative data regarding waste management practices in urban areas of developing countries (Wilson et al., 2009). Locally, potential advantages and future directions are being constrained by a lack of knowledge of the proactive strategy required to reduce urbanization difficulties including solid waste management, especially in the cities of Ghana. Notwithstanding, solid waste management in Ghana's Greater Accra region is becoming more serious and is predicted to worsen if not addressed, making further urban development and solid waste management essential. Given this, to achieve the worldwide objective of achieving inclusivity in urban areas and settlements, while making them safe, resilient, and sustainable for all, it is essential to promote resilient and sustainable cities globally, especially as part of the Sustainable Development Goal 11's key objectives (United Nations, 2015).

Currently, several research studies have examined the benefits and drawbacks of solid waste management within the Greater Accra region in great detail (Amoah & Kosoe, 2014; Deku, 2020; Miezah et al., 2015; Oduro-Appiah et al., 2017; Oteng-Ababio et al., 2013). But no

study was found that links solid waste disposal to the increasing rate of urbanization within the region. Keeping this in mind, the focus of this study will address three research questions on this topic:

Q1. How much has the Greater Accra region grown over time?

Q2. How is Greater Accra's rate of urbanization impacting Municipal Solid Waste Disposal (MSWD) in the region?

Q3. How could MSWD in the Greater Accra Region be improved and incorporated into urban planning and development?

The study aims at analyzing how much the Greater Accra region has grown over the years, analyze the impacts of urbanization on SWM and establishing the foundation for yet more effective and efficient responses to forthcoming urban expansion. The study employs techniques based on geographic information systems (GIS) and remote sensing for spatial analysis to determine how the rapid population growth of Greater Accra has affected the region's land use land cover features with the analysis of limited built-up areas, bare lands, vegetation, and water bodies within the region. Consequently, analyzing urban growth will help people comprehend the significance of how urban areas change shape and form and they influence the creation of programs and policies necessary for development and planning (Mundhe & Jaybhaye, 2014). Also, this study aims to clarify the scope, nature, and links between fast urban population change, urban growth, and MSWD and its management within the region. However, to achieve a sustainable urban future and a comprehensive balanced national development, the study further highlights a few parameters that must be met as a nation with emphasis on how important it is for local government officials to create suitable techniques for effective solid waste management. This will be essential for a better understanding of decision-making while ensuring the incorporation of sustainability

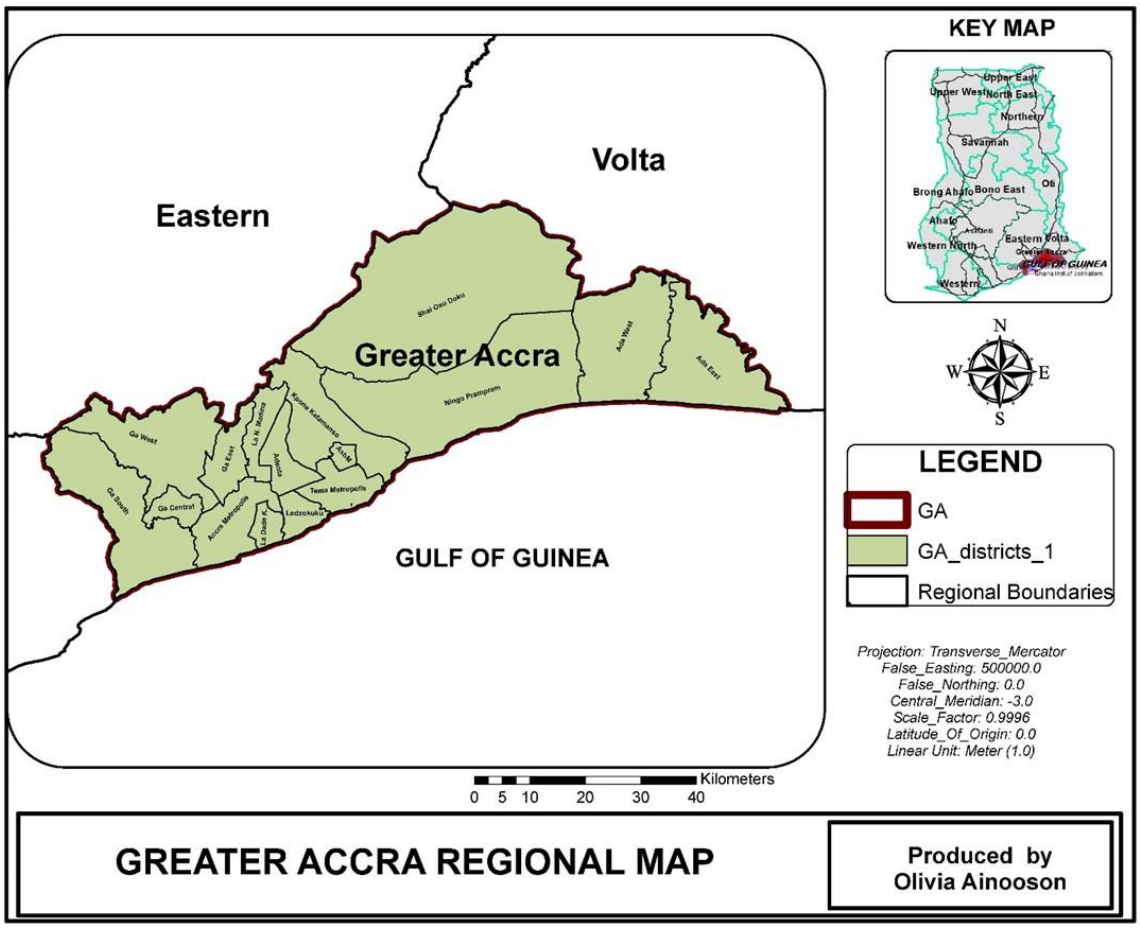
assessment regularly into the development and planning goals of the country at large in the future since the country's urban population keeps increasing year after year. The studies will also serve as precedents for the development of similar research in the future.

1.2 Study Area

Ghana's Greater Accra region as shown in Figure 1.2 has been selected as the research location for this study. This is because, Greater Accra is the nation's fastest-growing urbanizing, populating, industrializing, and commercializing area (Ghana Statistical Service, 2021) and its capital, Accra is one of the fastest-growing cities in Africa (UN-Habitat, 2022). The region encompasses 16 administrative districts as well as neighboring linked built-up areas in the Central and Eastern regions (F. S. K. Agyemang et al., 2017). Accra is the country's largest urban agglomeration, accounting for about a quarter of the national GDP (Gaisie et al., 2019).

The region is situated in Ghana's coastal region, with geographic coordinates lying between 6°6'34.07'' N and 0°30'28.76'' W to the North-East and 5°28'25.76'' N and 0°37'28.21'' W to the South-West (Osman et al., 2022). Its southern border is formed by the Gulf of Guinea and the Atlantic Ocean, while its northern boundary is formed by undulating hills that rise 20 meters above sea level. Since the land slopes down to the Atlantic Ocean, the drainage system drains into the sea in a southerly direction (Nyarko, 2002; Wemegah et al., 2020b). Greater Accra experiences bi-modal seasonal rainfall patterns with the minor rainy season extending from September to November, and the major wet season spanning from March to July (Baidu et al., 2017). The coastal zone's average annual rainfall ranges from 740 mm to 890 mm (Manzanas et al., 2014). The warmest months are February and March, with average temperatures ranging from 24 to 33 degrees Celsius, while the coldest months are June to September, with average temperatures ranging from 22 to 29 degrees Celsius (Wemegah et al., 2020b).

Figure 1. **2** Greater Accra regional map showing all the districts in the region.



The Greater Accra region has the highest concentration of employment and economic prospects in the nation, according to a government labor force report, thus luring young people to move from rural areas or other towns to this area (International Labor Organization, 2015). Urban sprawl is prevalent outside of Accra's congested core area. Greater Accra now has a population of 5,455,692 people, up from 4,000,000 in 2010; its total land area is 3,245 km2, and a population density of 1,681.3 people per km². Greater Accra is made up of 1,702,160 households comprising a total household population of 5,384,268 people, 71,424 non-household populations, and an average household size of 3.2 people (Ghana Statistical Service, 2021). Greater Accra recorded the

highest increase in population density from 445 persons per square kilometer in 2010 to 1,681 in 2021 while that of the entire country increased from 26 persons per square kilometer from 2010 to 129 in 2021 (Ghana Statistical Service, 2021).

The region is the home to the most significant seaport in the nation (Tema), it also houses the only international airport in Ghana (Kotoka International Airport), hospitals, schools, stadia, administrative offices, industries, market centers, and many more making it Ghana's primary center for politics and economics. The population of Greater Accra has grown quickly as a result of natural increase, in-migration from other areas and the rural hinterland, and an outward urban built-up expansion, which has frequently resulted in conversions from diverse land-cover types (Akubia et al., 2020). The region's population is expected to double to 10.5 million people by 2040, according to a growth projection by the Ghana Statistical Service (Ghana Statistical Service, 2021). This directly implies that the region will face tremendous pressure to urbanize further in the years to come due to the region's accelerated rate of urbanization leading to a reduction in environmental quality and its associated impact on the urban inhabitants making it crucial to take appropriate measures timely.

1.3 References

Addo-Fordwuor, D., & Seah, S. (2022). Factors influencing households' willingness to comply with municipal solid waste management regulations in the Kumasi Metropolis, Ghana. *African Geographical Review*, *0*(0), 1–19. https://doi.org/10.1080/19376812.2022.2162092

Adorsu-Djentuh, F. Y. (2018). *Implementation of Environmental Sanitation Policies: Assessing the Role of Local Actors in Ghana* [Ph.D., The University of Manchester (United Kingdom)]. https://www.proquest.com/docview/2408819550/abstract/68A48CD7A3514208PQ/1

Agyemang, E. (2017). Mode choice for long distance trips: Evidence from the Greater Accra Metropolitan Area of Ghana. *Journal of Transport Geography*, *64*(C), 150–157. https://ideas.repec.org//a/eee/jotrge/v64y2017icp150-157.html

Agyemang, F. S. K., Amedzro, K. K., & Silva, E. (2017). The emergence of city-regions and their implications for contemporary spatial governance: Evidence from Ghana. *Cities*, *71*, 70–79. https://doi.org/10.1016/j.cities.2017.07.009

Akubia, J. E. K., Ahmed, A., & Bruns, A. (2020). Assessing How Land-Cover Change Associated with Urbanisation Affects Ecological Sustainability in the Greater Accra Metropolitan Area, Ghana. *Land*, *9*(6), Article 6. https://doi.org/10.3390/land9060182

Aleluia, J., & Ferrão, P. (2016). Characterization of urban waste management practices in developing Asian countries: A new analytical framework based on waste characteristics and urban dimension. *Waste Management*, *58*, 415–429. https://doi.org/10.1016/j.wasman.2016.05.008

Amoah, S. T., & Kosoe, E. A. (2014). *Solid Waste Management in Urban Areas of Ghana: Issues and Experiences From Wa*. http://udsspace.uds.edu.gh:80/handle/123456789/204

Anarfi, K., Hill, R. A., & Shiel, C. (2020). Highlighting the Sustainability Implications of Urbanisation: A Comparative Analysis of Two Urban Areas in Ghana. *Land*, *9*(9), Article 9. https://doi.org/10.3390/land9090300

Ara, S., Khatun, R., & Salah Uddin, M. (2021). Urbanization Challenge: Solid Waste Management in Sylhet City, Bangladesh. *International Journal of Engineering Applied Sciences and Technology*, *5*(10). https://doi.org/10.33564/IJEAST.2021.v05i10.004

Ardayfio-Schandorf, E., Yankson, P. W. K., & Bertrand, M. (2012). *The Mobile City of Accra*. African Books Collective.

Baidu, M., Amekudzi, L. K., Aryee, J. N. A., & Annor, T. (2017). Assessment of Long-Term Spatio-Temporal Rainfall Variability over Ghana using Wavelet Analysis. *Climate*, *5*(2), Article 2. https://doi.org/10.3390/cli5020030

Bayulken, B., & Huisingh, D. (2015). A literature review of historical trends and emerging theoretical approaches for developing sustainable cities (part 1). *Journal of Cleaner Production*, *109*, 11–24. https://doi.org/10.1016/j.jclepro.2014.12.100

Deku, P. S. (2020). *An assessment of sustainable solid waste management in Accra- Ghana.* [MASTERS THESES]. Southern Illinois University.

Ebeke, C. H., & Ntsama Etoundi, S. M. (2017). The Effects of Natural Resources on Urbanization, Concentration, and Living Standards in Africa. *World Development*, *96*, 408–417. https://doi.org/10.1016/j.worlddev.2017.03.026

Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P. J., McDonald, R. I., Parnell, S., Schewenius, M., Sendstad, M., Seto, K. C., & Wilkinson, C. (Eds.). (2013).

Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. Springer Netherlands. https://doi.org/10.1007/978-94-007-7088-1

Gaisie, E., Kim, H. M., & Han, S. S. (2019). Accra towards a city-region: Devolution, spatial development and urban challenges. *Cities*, *95*, 102398. https://doi.org/10.1016/j.cities.2019.102398

Ghana Statistical Service. (2021). *2021 Population and Housing Census*. https://census2021.statsghana.gov.gh/

International Labour Organization. (2015). *Ghana—Labour Force Survey 2015*. https://www.ilo.org/surveyLib/index.php/catalog/7134/related-materials

Levis, J. W., Barlaz, M. A., DeCarolis, J. F., & Ranjithan, S. R. (2013). A generalized multistage optimization modeling framework for life cycle assessment-based integrated solid waste management. *Environmental Modelling & Software*, *50*, 51–65. https://doi.org/10.1016/j.envsoft.2013.08.007

Manzanas, R., Amekudzi, L. K., Preko, K., Herrera, S., & Gutiérrez, J. M. (2014). Precipitation variability and trends in Ghana: An intercomparison of observational and reanalysis products. *Climatic Change*, *124*(4), 805–819. https://doi.org/10.1007/s10584-014-1100-9

Miezah, K., Obiri-Danso, K., Kádár, Z., Fei-Baffoe, B., & Mensah, M. Y. (2015). Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana. *Waste Management*, *46*, 15–27. https://doi.org/10.1016/j.wasman.2015.09.009

Mundhe, N., & Jaybhaye, R. (2014). Impact of urbanization on land use/land covers change using Geo-spatial techniques. *International Journal of Geomatics and Geosciences*, *5*, 50–60.

Muniafu, M., & Otiato, E. (2010). Solid Waste Management in Nairobi, Kenya. A case for emerging economies. *Journal of Language, Technology & Entrepreneurship in Africa*, *2*(1), 342–350. https://doi.org/10.4314/jolte.v2i1.52009

Nyarko, B. K. (2002). *Application of a Rational Model in GIS for Flood Risk Assessment in Accra, Ghana*.

Oduro-Appiah, K., Scheinberg, A., Mensah, A., Afful, A., Boadu, H. K., & de Vries, N. (2017). Assessment of the municipal solid waste management system in Accra, Ghana: A 'Wasteaware' benchmark indicator approach. *Waste Management & Research*, *35*(11), 1149–1158. https://doi.org/10.1177/0734242X17727066

Ofori, F. N. K. (2021). Sprawl and Congestion in Accra—Challenges and Opportunities of Sustainable Development in Ghana's Capital City. *Regions*. https://doi.org/10.1080/13673882.2021.00001092

Osman, A., Yawson, D. O., Mariwah, S., & Dadson, I. Y. (2022). Towards a concrete landscape: Assessing the efficiency of land consumption in the Greater Accra Region, Ghana. *PLOS ONE*, *17*(6), e0269120. https://doi.org/10.1371/journal.pone.0269120

Oteng-Ababio, M., Melara Arguello, J. E., & Gabbay, O. (2013). Solid waste management in African cities: Sorting the facts from the fads in Accra, Ghana. *Habitat International*, *39*, 96–104. https://doi.org/10.1016/j.habitatint.2012.10.010

Priti, & Mandal, K. (2019). Review on evolution of municipal solid waste management in India: Practices, challenges and policy implications. *Journal of Material Cycles and Waste Management*, *21*(6), 1263–1279. https://doi.org/10.1007/s10163-019-00880-y

Rufus, A., & Olugbemiga, T. (2018). Impacts of Building Collapse on Sustainable Development in Nigeria. *Civil and Environmental Research*.

Sharholy, M., Ahmad, K., Mahmood, G., & Trivedi, R. C. (2008). Municipal solid waste management in Indian cities – A review. *Waste Management*, *28*(2), 459–467. https://doi.org/10.1016/j.wasman.2007.02.008

Tawfik, A., Mohsen, M., Ismail, S., Alhajeri, N. S., Osman, A. I., & Rooney, D. W. (2022). Methods to alleviate the inhibition of sludge anaerobic digestion by emerging contaminants: A review. *Environmental Chemistry Letters*, *20*(6), 3811–3836. https://doi.org/10.1007/s10311-022-01465-2

UN-Habitat. (2022). *Ghana: Accra Urban Profile | UN-Habitat*. https://unhabitat.org/ghana-accra-urban-profile

United Nations. (2015). *Global Sustainable Development Report 2015 (Advance Unedited Version) (GSDR 2015) | Department of Economic and Social Affairs*. https://sdgs.un.org/publications/global-sustainable-development-report-2015-advance-unedited-version-gsdr-2015-17874

Wemegah, C. S., Yamba, E. I., Aryee, J. N. A., Sam, F., & Amekudzi, L. K. (2020a). Assessment of urban heat island warming in the greater accra region. *Scientific African*, *8*, e00426. https://doi.org/10.1016/j.sciaf.2020.e00426

Wemegah, C. S., Yamba, E. I., Aryee, J. N. A., Sam, F., & Amekudzi, L. K. (2020b). Assessment of urban heat island warming in the greater accra region. *Scientific African*, *8*, e00426. https://doi.org/10.1016/j.sciaf.2020.e00426

Wilson, D. C., Araba, A. O., Chinwah, K., & Cheeseman, C. R. (2009). Building recycling rates through the informal sector. *Waste Management*, *29*(2), 629–635. https://doi.org/10.1016/j.wasman.2008.06.016

World Bank. (2022). *Solid Waste Management*. World Bank. https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management

World Population Prospects Revised. (2018). *2018 Revision of World Urbanization Prospects | Multimedia Library—United Nations Department of Economic and Social Affairs*. https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html#:~:text=2018%20Revision%20of%20World%20Urbanization%20Prospects%2016%20May,is%20expected%20to%20increase%20to%2068%25%20by%202050.

World Urbanization Prospects. (2018). *World Urbanization Prospects—Population Division—United Nations*. https://population.un.org/wup/

Zhou, J., Shen, L., Song, X., & Zhang, X. (2015). Selection and modeling sustainable urbanization indicators: A responsibility-based method. *Ecological Indicators*, *56*, 87–95. https://doi.org/10.1016/j.ecolind.2015.03.024

Chapter 2

The Growth of the Greater Accra Region of Ghana Overtime

2.1 Urbanization Background

History reveals that the human population first clustered together in small numbers primarily depending on agriculture and hunting (Ugwuanyi & Isife, 2012), but gradually they started to settle down and congregate forming urban centers over the centuries (Roser et al., 2013). In 2007, more people were living in cities than in rural areas worldwide (Griffiths et al.2010) resulting in a shift in rural to urban population in the developing world too (*The World Population Prospects*, 2015). Consequentially, the concept of globalization has harmed urbanization leading to changes in the quality of life and utilization of resources, policies, and laws about immigration and emigration, importation and exportation of goods and services, and management of solid waste, especially in African cities (Achankeng, 2003). This is mostly caused by the high rate of population increase, shrinking prospects in rural areas, and migration from the stagnating and low-paying agricultural industry to more lucrative urban jobs (Vlahov, 2002).

Usually, urban pull factors and interconnected globalization serve as the reasons for the origination of megacities, which are sometimes plagued with mismanaged resources as so many people are moving to urban areas at a rapid rate (Griffiths et al. 2010). Generally, cities serve as centers for contemporary society where women make up the majority of the labor force (Cohen, 2006). Also, cities normally operate as the major hubs for the provision of important economic, political, social, and cultural centers that houses industries, better education health care facilities, museums, art galleries, film industries, cinemas, fashion houses, recreational facilities, transportation, telecommunication, and broadcasting service to the urban inhabitants which turn

to attract more people to live and settle there. On the other hand, cities are usually known to have terrible roads, obstructed drainage, traffic congestion, unkempt trash dumps, poor hygienic practices, unpleasant odor, and a high crime rate (Okeke, 2010). Despite these, cities continue to attract new immigrants, who often contribute to the development of slum communities and shanty towns (Cohen, 2006).

Generally speaking, the capacity of most cities particularly in developing nations to provide their residents with basic necessities has been greatly outpaced by the massive influx of people from rural areas into urban areas, which normally lead to the threats of the immediate environment, local natural resources, health impacts, sociocultural cohesiveness, and personal rights in these urban centers (Cohen, 2006). Urbanization refers to the situation where cities grow in size, density, and heterogeneity (Vlahov, 2002). Urbanization is caused by two main factors; rural-urban migration and natural increase (birth rate-death rate) (Jedwab et al., 2017). The movement of people from rural areas to urban areas is usually propelled by four main reasons comprising of economic, sociocultural, political, and environmental factors (Semenza & Ebi, 2019). These reasons can be broadly grouped into push and pull factors (Elgin & Oyvat, 2013). Pull factors are the factors that attract migrants, often the rural populace into the urban areas. It consists of educational and employment opportunities and religious or political freedom (Phuttharak & Dhiravisit, 2014). The urban pull factors are usually marked by subsistence resulting in an increase in human population swiftly in the urban areas. The driving forces behind people's migration from their home regions to urban areas are known as "push factors" (Fan & Zhang, 2019; Gizelis et al., 2021). Notable among these factors are rural poverty, unemployment, poor education, medical care, and religious or political prosecution. The history of human settlement has completely changed as a result of the recent huge migration of people from rural to

urban regions (Liu et al., 2012; Roser et al., 2013). This can be attributed to the epidemiological change of the 20th century resulting in lower urban mortality far earlier in the development process, even while fertility in the developing world has remained high, therefore, causing urban areas to grow at a rapid rate naturally, which in turn seems to have exacerbated the impacts of migration (Jedwab et al., 2017).

In most African countries, the increasing population in major cities leads to everyday problems but forging the right conditions for a habitable urban environment in these cities is very challenging (Elmqvist 2013). Several recent literature reveal urbanization and its related impact on urban environmental quality, biodiversity, and land use planning as major primary elements driving Africa's urban growth (Asongu et al., 2020; Darkwah & Cobbinah, 2014; Kassouri & Okunlola, 2022; Obi-Ani & Isiani, 2020). For this reason, it is crucial to ensure efficient, inclusive, and sustainable African cities in the presence of urbanization, the implementation of sustainable technology, and population growth awareness programs are to be made possible by smart urban planning measures complemented by fundamental infrastructure expenditures and avoidance of check-in investments that could prove impossible to change in the future (Effiong, 2016; Freire et al., 2015).

Urban sprawl is the most visible marker of change recounted as any widening of the residential fringe, expansion of growth onto delicate green spaces and agricultural soils, escalating traffic on the roads, and a surge in the number of homogenous, limited, single-family dwelling complexes (Jelena et al., 2012). Even though urban areas are the plight of change to the environment over a great scale (Grimm et al.2008), considering the general neglect for cities in the current national and international discussions on development (Ivan Turok & Gordon McGranahan, 2013), it is crucial to acknowledge the role that urbanization plays in economic

and social growth (Beall & Fox, 2009). The revised edition of the 2018 World Urbanization Prospects reveals that, well-managed urbanization informed by long-term population patterns can assist to maximize benefits of agglomeration while limiting environmental degradation and other possible negative effects of the growing population in cities (World Urbanization Prospects, 2018).

2.1.2 Ghana's Urbanization Process

The development of urbanization in Ghana can be categorized into three different periods namely, a) The pre-colonial period b) The colonial period, and c) The post-independence period.

2.1.2.1 The Pre-Colonial Period (16th Century AD to 1850)

Urbanization in Ghana started during the medieval period in Sub-Saharan Africa. Here, nations in Sub-Saharan Africa including Ghana featured a diverse range of civilizations with religion (predominantly Islamic) playing an important role and forming the foundation for the ultimate transition and growth of urban centers like Kumasi, Begho, Salaga, and along major routes in the Northern part of the country. The great majority of the ethnic groups that comprise the contemporary Ghanaian population had settled in their present areas by the end of the 16th century (Ghana's Urbanization, 2010). Once more, the coming of the traders from Europe in the middle of the 15th Century led to the emergence of towns and cities along the shore which had raw material sources (Songsore, 1979). As a result, clusters of towns sprung up around these trading centers of the country and its interior, some of which still exist.

2.1.2.2 The Colonial Period (1945 to 1957)

The colonial era was the second stage of Ghana's urbanization and development. The 20th Century's British rule over the Gold Coast saw considerable advancement in the country's social, economic, and educational growth (Gocking, 2005). This growth was unbalanced and favored resource-rich areas which caused growth division between the country's southern and northern areas (Fuseini & Kemp, 2015).

2.1.2.3 The Post-Independence Period (after 1957)

In Ghana, changes brought about by independence in 1957 made cities more attractive (Ghana's Urbanization, 2010). Rural-urban movement increased as a result of initiatives to industrialize, the expansion of public service, and the elimination of the last remaining inflow control measures (Songsore, 2009). Several new towns appeared on the outskirts due to the concentration of the main urban hubs, politics, and administration, which served as an additional draw for investors who needed access to the governmental machinery. Because of this, the country's rural-urban migration has intensified, and urban centers have continued to grow (Ghana's Urbanization, 2010).

2.1.3 *Urbanization in the Greater Accra Region: Historical and Spatial Development*

The Ga people established Accra (Yankson & Bertrand, 2012) as a little fishing community in the sixteenth century, but it quickly expanded after the British had chosen it as the location of their administrative headquarters in the late nineteenth century. After the Europeans arrived in Ghana, they aided urban expansion by establishing trade forts and castles along the coast (Yankson & Bertrand, 2012). With this, the Danish built the Christiansburg Castle in 1651, the Dutch constructed Ussher Fort in 1650, and the British constructed James Fort in 1673

(Amesimeku, 2019). All these were situated in Accra leading to the commencement of Accra's development mainly after the Christiansburg Castle was chosen as the seat of the British administration on the Gold Coast in 1877. This decision strengthened and secured Accra's future growth following its selection as the Eastern Railway's maritime terminus (Yankson & Gough, 1999). Again, the improvement in accessibility of the railway increased Accra's geographical impact and triggered the region's expansion (Yankson & Bertrand, 2012).

Ghana neither has a long history of physical planning nor a solid framework for managing urban environmental issues. Physical planning efforts only took place during the colonial era when colonial officials and expatriate workers resided. Beyond such places, the city's expansion was chaotic, leading to a fragmented urban structure and an entirely unregulated pattern of urban development (Larbi, 1996). According to the Ghana Statistical Service's 2021 Population and Housing Census Data Report, the country's overall population is 30,832,019, which is five times the population in 1960 as shown in Figure 2.1 and Table 2.1 respectively. With this, the Greater Accra region alone constitutes 17.7% of the entire population. Figure 2.1 shows how Ghana's urban population as well as the Greater Accra region has continuously increased from 12,545,229 (50.9%) in 2010 to 17,472,530 (56.7%) in 2021 with a higher female population than the male population as shown in Table 2.1.

Almost half of Ghana's population increase (47.8%) has transpired in the Greater Accra and Kumasi regions out of the 16 regions in the country. The Greater Accra region is the most highly urbanized in Ghana with 91.7% of its populace living in urbanized areas while the remaining 8.3% live in rural areas (Ghana Statistical Service, 2021). The region has been experiencing a rapid rate of urbanization since 2010 and all this has led to significant alterations in the country's landscape and demography (Anarfi et al., 2020). The region has a population

growth rate of 2.9 percent from 2010 to 2021 with more than 70% of the populace as migrants (Ghana Statistical Service, 2021). Much of the population of the region is concentrated primarily within the Greater Accra Metropolitan Area (GAMA) which serves as a place where migrants settle and emigrants commute (Addae & Oppelt, 2019b) as well as the greatest urban agglomeration to neighboring West African countries, particularly Nigeria between 1973 and 1983 (Songsore, 2020).

Accra is referred to as "No man's land" or the "Home for everybody." With time, this flood of people prompted the sale of properties, stores, and open spaces that made room for new economic operations (Obi-Ani & Isiani, 2020) which also prompted the construction of unauthorized homes. The preceding directly implies that the region will face tremendous pressure to urbanize more in the next years if the current issue remains unattended (Akubia et al., 2020). In Accra, the prevalent land tenure system is the family land tenure, where families own the great majority in terms of the total land area. Even with that, the government has purchased substantial amounts of land for urban development over the years for commercial, residential, and industrial purposes (Songsore et al., 2004).

Ghana’s largest urban agglomeration, Accra, contributes over a quarter of Ghana’s total Gross Domestic Product (GDP) and attract an enormous 83% of all direct foreign investments (DFI) in the country (Musah et al., 2020). Previous studies have shown that the ongoing economic growth in the country accompanied by an increase in the standard of living has resulted in the rising demand for goods and services and a corresponding rise in per capita waste generation (Oteng-Ababio et al., 2013). Rapid urbanization and population growth, insufficient trash cans, and lack of waste transportation infrastructure are the primary barriers to effective waste management in Ghana. Greater Accra's urbanization trend has reached saturation, with almost the entire

population expected to be urbanized in the coming years. (Addae & Oppelt, 2019b). All these constitute to make Accra the research hub for researching urban growth, the security of natural resources, and related socio-environmental and demographic challenges in recent years (Addo-Fordwuor & Seah, 2022; Bixby et al., 2022; Chapman-Wardy et al., 2021; Gaisie et al., 2019; Møller-Jensen, 2021; F. N. K. Ofori, 2021; Wemegah et al., 2020).

Figure 2. 1 *Population growth in Ghana and the Greater Accra region from 1960 to 2021 (Ghana Statistical Service, 2021).*

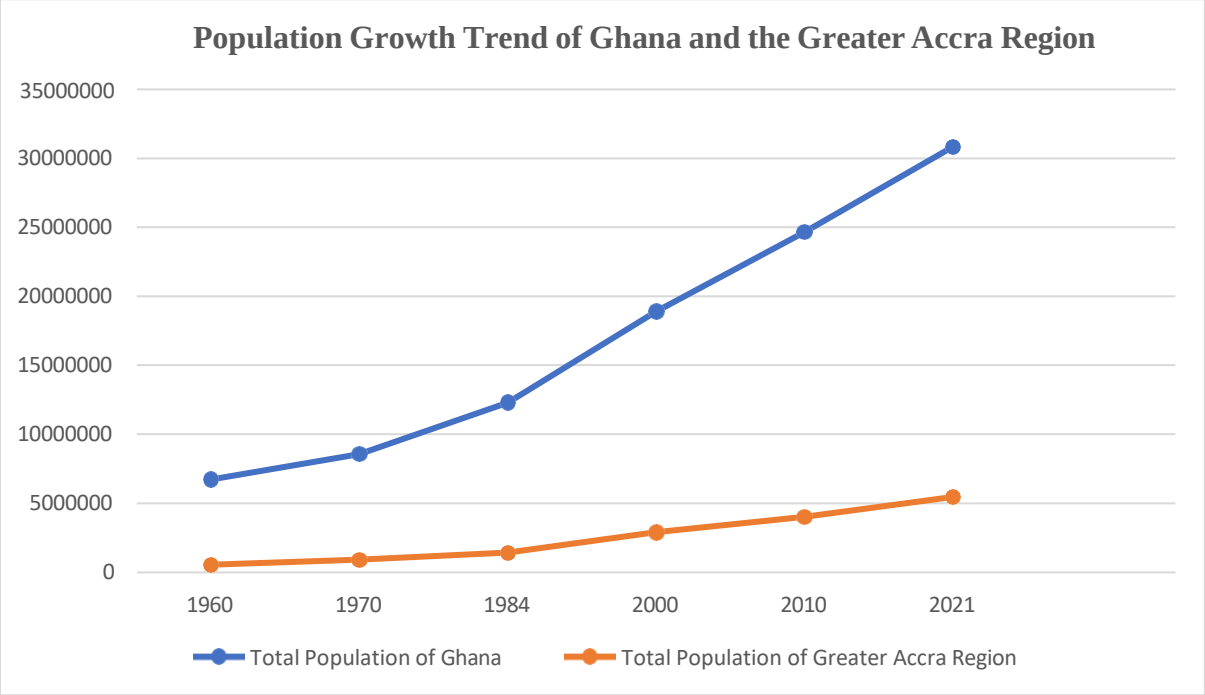
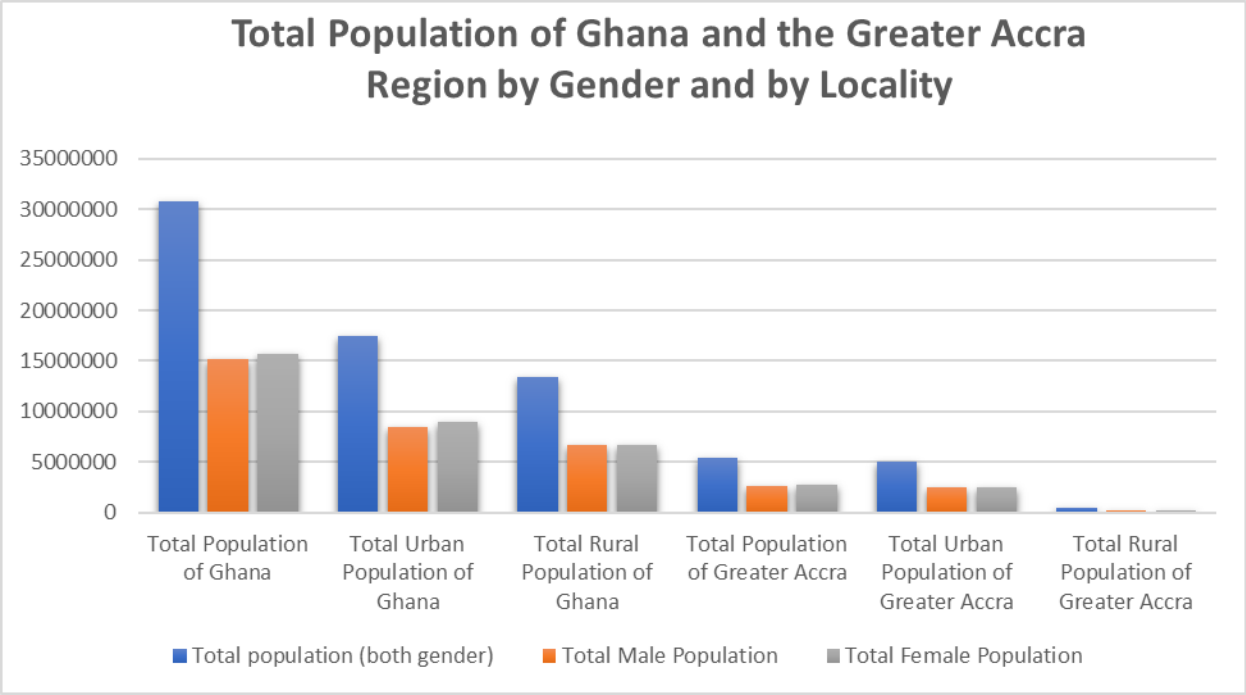


Table 2. 1 *Population growth in Ghana and the Greater Accra region from 1960 to 2021 (Ghana Statistical Service, 2021)*

Year	*Total Population of Ghana*	*Total Population of Greater Accra Region*
1960	6726815	*541933*
1970	8559313	903447
1984	12296081	*1431099*
2000	18912079	1431099
2010	24658823	*4010054*
2021	30832019	*5455692*

Figure 2. 2 Population sex structure of both urban and rural Ghana and the Greater Accra Region. Source: Ghana Statistical Service, 2021 Population and Housing Census Report.



2.1.2.4 Causes of Urbanization in Ghana

The growing pattern of urbanization in Ghana has been attributed to the following demographic trends (Ghana's Urbanization, 2010).

- Natural increase: The spatial variation between the birth rate and the death rate is responsible for determining population growth which aids in deciding the rate of urbanization in localities in Ghana. As a result, areas that see significant population growth with a high number of fertility than mortality each year are a greater likelihood of moving from a rural to an urban (Ghana's Urbanization, 2010).

- Rural-urban migration*:* The rate at which a region gets urbanized is influenced by the number of migrants entering the region since migration increases population at a rate that is necessary for a region to meet Ghana's criteria for urban localities (Ghana Statistical Service, 2021). In Ghana, internal migration has always played a significant role in population redistribution. As there is often a north-south development gap, people tend to migrate from less developed regions in the northern part of the country to those that are seen as more developed (the southern part of the country) and have more socioeconomic prospects for improving living standards (Ghana's Urbanization, 2010).
- Decentralization and Reclassification: In Ghana, the implementation of the decentralization system of government has led to the creation of many more districts. This is accompanied by the provision of some basic infrastructure, which frequently occurs in conjunction with the promotion of a community to serve as the district capital. For instance, currently, there are 216 districts in Ghana as compared to 110 districts in 1988 (Ghana Statistical Service, 2021). This is done purposely to ensure effective planning and development but ends up intriguing enormous growth in their population, which results in the reclassification of these areas as urban. In Ghana, an area is reclassified as urban once they reach the 5,000 criteria for population (Ghana's Urbanization, 2010).

2.2 The Growth of Greater Accra and its Impact on the Region's Land Use Land Cover Change

2.2.1 Land Use Land Cover

Land is a critical component of the ecosystem which serves as the foundation for various ecological processes and also provides natural resources that are essential for human survival(Abebe et al., 2021). The alteration of the earth's surface happens as a result of the

interaction between anthropogenic and biophysical factors comprising environmental and biological processes that could be measured by landscape patterns (Chen et al., 2021). Recently, changes in land use land cover (LULC) are one of the most significant themes for discussion when it comes to issues of urbanization, migration, and industrialization (Arsiso et al., 2018; Nath et al., 2021; Zhou & Chen, 2018). Land cover change refers to a shift in some constant features of the land, such as plant type, soil conditions, and water, among others, whereas land-use change refers to a shift in how a specific piece of land is utilized or controlled (Kevin J. Gaston, 2010; Patel et al., 2019). Urbanization can result in the modification of the natural ecosystem. For instance, natural habitats are permanently altered by the processes of urbanization and urban growth (Jiménez-Peñuela et al., 2019). It is noteworthy that this change is causing several problems across the globe, including species extinction and the degradation of ecological systems, as well as resource depletion and the resulting consequences on human health (Patel et al., 2019a). Urban expansion is the main factor influencing changes in land use and cover globally, and it is crucial currently for developing and underdeveloped nations (Chen et al., 2021; Hyandye & Martz, 2017; Rindfuss et al., 2007).

Analyzing global patterns of land-use change requires a thorough understanding of the impact of humans on the modification of land cover and land use (Biney & Boakye, 2021; Kullo et al., 2021). LULC changes are so inevitable that, when they add up globally, they fundamentally affect important components of the global framework such as the environment and regional climate (Al-Bakri et al., 2013; Lambin & Geist, 2008). Yet everyone with concerns about the preservation of natural resources, including researchers, conservationists, urban planners, entrepreneurs, and legislators, should be interested in understanding LULC change (Gennaretti et al., 2011; Kullo et al., 2021). With this, the International Human Dimension Program (IHDP)

emphasizes the significance of effectively modeling techniques, projecting, and comprehending land patterns from a global to local scale, concentrating particularly on the spatial formalization of the procedures and effects as a result of the tremendous effects and ramifications that the LULC has introduced (Islam & Ahmed, 2011).

Urbanization, excessive reliance on land-based resources, agricultural practices, and deforestation are examples of human-induced variables that contribute to LULC change in Africa (Kullo et al., 2021). For instance, Ghana's economy relies extensively on natural resources, therefore, leading to the over-exploitation of LULC (Frimpong, 2015). Changes in land use are impacted by several variables, including economic, political, demographic, and environmental factors, however, political and economic factors are also known to be important variables due to their threshold of the effect they can cause (Addae & Oppelt, 2019a; Ampim et al., 2021). For instance, the government of Ghana's micro-economic initiatives and industrialization measures have facilitated the expansion of Accra and Tema, resulting in the clustering of industrial parks and corporate offices in the Greater Accra region. This has therefore served as a pull factor to attract people into the region while contributing to the already existing urbanization issue and its associated influence on the region's land use and land cover, resulting in degradation, habitat destruction, and loss of farmland (Ampim et al., 2021). All of these make it significant to monitor LULC changes to detect difficulties and take steps to ensure sustainability.

2.2.2. Land Cover Change of the Greater Accra Region

The Greater Accra region, which began as a collection of coastal fishing settlements has grown to be Ghana's economic center, with Accra being the basis of Ghana's urbanization process. The region draws visitors from all around Ghana and other countries to its diverse population mostly as a result of the abundance of job possibilities (Ghana Metropolitan Cities,

2016; Ghana Statistical Service, 2021). Accra and Tema serve as the Greater Accra region's economic hubs whereas the Greater Accra Metropolitan Area operates as the most economically active district in the region. Due to the high cost of land and the scarcity of housing options in Accra, migrants and low-income citizens have been forced to live in slums and squatter settlements many of which lack basic amenities like water and sanitation (Yankson & Bertrand, 2012). Problems about urban sprawl have given rise to new approaches for achieving an appropriate urban shape as well as monitoring and analyzing its impacts, and this includes LULC analysis.

Land use/land cover (LULC) changes through is best quantified with the use of remote sensing and Geographic Information Systems (GIS) techniques (Mukesh Singh Boori & Vít Voženílek, 2014) In several places of the world, GIS and remote sensing have emerged as crucial tools for performing change analysis. While traditional inventories and surveys may be used to track changes in land use and land cover, satellite remote sensing offers advantages in terms of cost and time savings for regions with a regional scale as well as more comprehensive details on how these modifications are distributed geographically (Yuan et al., 2005). It is important to know that, remotely sensed images offer an effective way to gather data on temporal patterns and the geographical distribution of urban centers for studying, predicting, and projecting land change (Weng, 2012).

The objective of this research aims at analyzing how the Greater Accra region of Ghana has grown over time. By so doing, this study used GIS and remote sensing technology to examine the urban land use and land cover changes of the Greater Accra region from 1991 to 2021 using satellite imagery. The effect of the growth of the region on the urban land use land cover in the area is anticipated to result in an increase in human activities, therefore placing more

demands on the earth’s finite supply of arable, pastoral, urban, and industrial land, considering it appropriate for this study. The assumption is that urban areas are more urbanized, and this is generally based on the idea that urban areas are usually characterized by a high level of development accompanied by a concentration of people and infrastructure. However, the study hypothesized that the rapid urbanization and population growth in Greater Accra region will lead to an increase in urban built-up areas in the region. Therefore, causing a significant decline in vegetative cover and an abundance of built-up features in the region. The overloaded infrastructure in the Greater Accra region can result in various problems including environmental degradation, periodic floods, destruction of natural vegetation, and loss of biodiversity, habitat, and soil fertility. The study's findings will aid in understanding how such expansion affects the local ecology, therefore serving to decipher the causes and possible solutions to the issues of sustainable development. Again, the findings of this study will aid in urban land use planning and development by demonstrating the influence of increasing urbanization on the urban land cover of Ghana's Greater Accra region.

2.3. Methodology

2.3.1. Data

2.3.2 Satellite Imagery

Using the geocoding technique, data from the Landsat 4-5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM), and Landsat 8-9 Operational Land Imager and Thermal Infrared (OLII/TIRS) satellites images were obtained from the United States Geological Survey (USGS) online data repository. The geocoding technique in remote sensing entails creating a pleasant image size to a universal pixel size and map projection. The geocoding is important because incorrect registration results in artificial colors or characteristics in multisensory data

sets, which subsequently distort the interpretation (Pohl & Van Genderen, 1998). These satellite images were gathered for the years 1991, 2001, and 2021 in an attempt to be used in the land use land cover analysis. For additional processing and analysis, the images were gathered in Tiff format which is widely recognized in the scientific community. Table 2.3 below provides a summary of the specific image attributes. To generate quality images with cloud free and minimize differences in land cover reflectance from influencing of seasonal variation, the images were obtained for the months of December and January, which are part of Ghana's dry season. All these were done mainly to improve the generation of analyzable Landsat images to facilitate easier distinction between land cover types. Characteristics of multitemporal Landsat 7 and 8 data utilized in the study can be seen in Table 2.4. Because this study employed single-date images in all the years for the LULC classification, atmospheric correction had little impact. As a result, no extra atmospheric correction was implemented. In addition, the associated classified images served as the source of the classification training data , therefore atmospheric adjustment in these circumstances cannot improve classification accuracy in this instance (Song et al., 2000).

Table 2. 2 Utilized Landsat Satellite Data Characteristics

Date of Acquisition	Landsat	Sensor	Path/Row	Spatial Resolution	Number of Bands
1991/01/10	Landsat 4	TM	193/056	30m	7
2001/12/07	Landsat 7	ETM	193/056	30m	8
2021/12/22	Landsat 8	OLI/TIRS	193/056	30m	11

Table 2. 3 Characteristics of multitemporal Landsat 7 and 8 data utilized in the study (Oliphant et al., 2019).

Band Name	Landsat 7 ETM Spectral Range	Landsat 8 OLI Spectral Range
Blue	0.45-0.52	0.452-0.512
Green	0.52-0.60	0.533-0.590
Red	0.63-0.69	0.636-0.673
NIR	0.77-0.90	0.85-0.879
SWIR 1	1.55-1.75	1.566-1.651
SWIR 2	2.09-2.35	2.107-2.294
Thermal	10.40-12.50	10.60-11.19

2. 3.3. Software Used

The software listed below were utilized for the overall processing and data analysis for the purpose of the study (Tilahun, 2015).

a) ERDAS Imagine 13: Utilized for categorizing images.

b) Arc GIS 10.1: Preparation of the study area's location and creation of a data base

c) Google Earth Pro: For the verification of points that were generated randomly.

2. 3.4 Image Pre-Processing

The GeoTIFF Data product was downloaded. The downloaded files were processed to obtain the individual band TIFF files. Several individual single band images were obtained but preferably, single multispectral images for performing three different layer stacks for the three years were used for the study while ERDAS imagine was further used to create the layer stacks for the three images using TIFF extension with the addition of the individual bands.

2.4. Method of Data Analysis and Classification

To obtain the land use land cover of the Greater Accra region over the past years, the study focused on three different years, 1990, 2001 and 2021, to run an unsupervised classification analysis using an ISODATA algorithm. Unsupervised classification is a form of classification that yields an output image in which a few classes are identified, and each pixel is assigned to a class (M.S. Boori et al., 2018). For the purpose of using the unsupervised classification, the ERDAS ribbon in the ERDAS imagine, a raster graphics editor and remote sensing application was used. The input file, the output file and the signature editor were all set on the unsupervised classification dialogue box image and ISODATA was also set as the method for each year's classification. The maximum number of iterations was set to 10. The minimum and maximum number of classes assigned to each year were 20 while the color was set-to gray scale which ERDAS further examined the data and assigned each pixel to a spectral class. The classified images were loaded to other viewer to display the spectral clusters identified by IMAGINE. The land cover classes represented by each cluster were further determined. The Attribute table for the second viewer was displayed purposely to load the table containing the attribute information for each of the 20 classes. To determine the land cover type for the classes, both viewers were viewed by matching up specific pixels in each viewer by linking the two viewers. After the viewers were linked up, the inquire cursor was used to match up specific locations for each viewer. On the map, longitude, and latitude (WGS84) were selected for the values of the geographic coordinates to be displayed. Google Earth Explorer was used to display the landcover type or feature of the selected classes comprising of water bodies, built up, vegetation, and bare land for all the years under study. The color of the classes was changed to

represent the color of the classification scheme, blue represents water bodies, dark green represents vegetation, red represents built-up, and sienna represents bare- land.

Information labels were assigned to all the 20 spectral clusters while using a table documented in word to record the class designations. This is because the documented table needed to reclassify (recode) the images to the designated class schemes. The file was then saved after assigning all the 20 classes to a specific land cover type among the four land cover features considered for the purpose of the study in the raster attribute editor and recorded in the table. Using the information recorded in the table in the document, a reclassified image was produced using the recode function. A recode was then set up for the input file. Each of the classes were assigned the new values based on the analysis and information recorded in the table to be able to run the recode. The reclass1.img was opened in a new viewer in pseudo color, the raster attribute editor was also opened, and the colors were changed to the color scheme in the raster attribute editor where the class names were also added. The images from 2001 and 2021 underwent the same procedure. Figure *2.5* shows the final output maps that were created for the three different years.

Table 2. 4 *Land use and Land Cover Types Classification (Anderson, 1976)*

Land-Use/Land-Cover Type	**Description**
Built-up	Residential areas, Mixed urban areas Industrial and Commercial units, Transportation facilities
Vegetation	Evergreen Forest land, Mixed Forest land, Forest reserves, Deciduous Forest land, bush areas, Grassland Herbaceous vegetation,
Bare-land	Mixed grassland with few scattered trees. Beaches, Sandy areas, Exposed rocks, Riverbanks, Quarries and gravel pits, transitional areas

Water bodies	Lakes, Rivers, Streams, Canals, Reservoirs, Estuaries, Bays, Forested wetlands, Aquaculture facilities

2.5 Results and Discussion

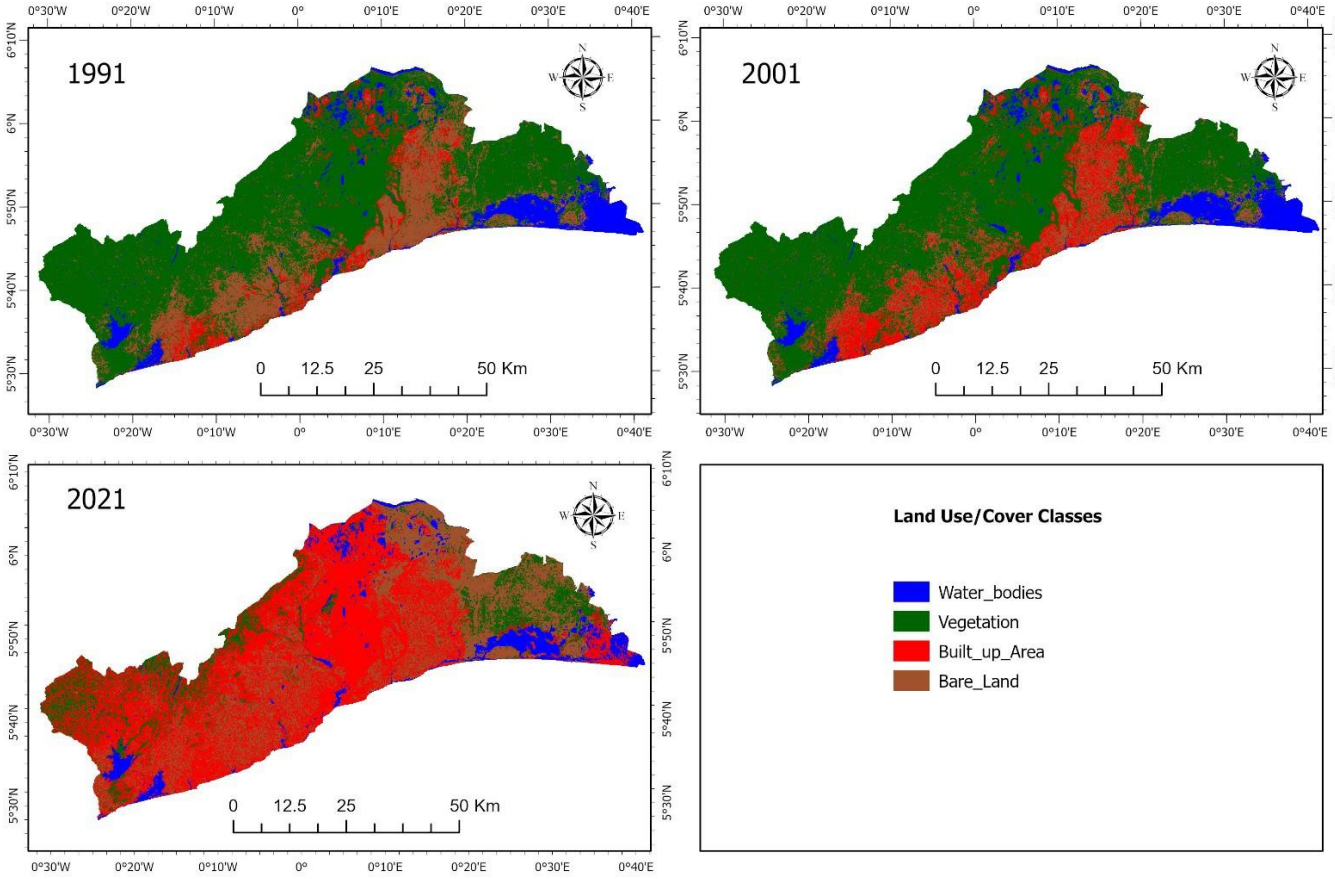
2.5.1. Geographical Change of the Greater Accra Region from 1991 to 2021.

The land use land cover maps of 1991, 2001 and 2021 of the Greater Accra Region are shown in *Figure 2.1 Vegetation*, bare land, water and built up were the major land cover taken into consideration in this study. The figure shows a great transformation of the region's vegetative cover from 1991 to 2021. It could be seen that, there were few built up features around the Northeastern and the Southwestern part of the region specifically in the Shai Osudoku, Greater Accra Metropolitan Area, and Tema area while almost everywhere in the Northwestern area was covered with vegetation while most part of the Southernmost area of the region was covered with bare land and water body in 1991. However, in 2001, the built-up area increased in the southern part of the region while spreading through the entire region in 2021 except the Northeastern part which had majority of the land covered with vegetation and some portion of the areas left bare after the vegetative cover had been cleared.

Primarily, there was an increase in bare land from 1991 to 2021 in the region mainly by activities of urban planners and real estate developers for creating a potential use of the land for building and construction purposes in the areas mentioned above including the Old Ningo. There was also bare land that was present in the region in 1991 which has been turned into built-up features in 2021. Again, the water bodies present in the region have been narrowed from 1991 to 2021 and replaced with built up features especially for recreational purposes mainly due to the concentration of such features in the region comprising of Beach Holiday Resort, Maranatha

Beach Camp, Bojo Beach Resort and Tsaley Kopey Beach Resort which are mainly concentrated in the Accra metropolitan area. Overall, the change detection maps of the region can help justify how the region has changed significantly between 1991 and 2021. All these are as a result of human encroachment for settlement associated with increase in human population, urban growth, and urbanization in the region (B. Y. Ofori et al., 2022). Figure 2.1 is a land use land cover maps of the Greater Accra region of Ghana showing the growth of the region from 1991 to 2021.

Figure 2. 3 *Land Use Land Cover Change of the Greater Accra Region from 1991 to 2021*



2.5.2 Statistical Change of the Greater Accra Region from 1991 to 2021

As evident from figure 2.1, built-up features have seen a significant increase in the Greater Accra region and bare land from 1991 to 2021 as shown in table 2.6 with a corresponding decrease in the region's volume of vegetation. While an estimated area of 23,457km² of land was built-up during 1991, its scope has extended 193163km² during 2021. In a similar manner, the proportion of bare land expanded from 79,623km² to 103,521km² from 1991 to 2021. In contrast, the area of vegetation shrunk from 235,558 km² during 1991 to 48006 km² in 2021. The overall land cover of the region in 1991, 2001, and 2021 have been represented in figure 2.2, figure 2.3, and figure 2.4 respectively. The observed modifications in the region's land usage and land cover can be associated to increase in human settlement in the area resulting in the conversion of the urban vegetation cover to built-up features. The study adequately demonstrated the application of multi-temporal Landsat TM data to analyze land-use/land-cover dynamics in an area subject to human intervention (Dwivedi et al., 2005).

Table 2. 5 Landcover types and their percentage change from 1991 to 2021

Land Cover Type	Area of Land Cover in Percentage (%)				
	Land Cover in 1991	Land Cover in 2001	Land Cover in 2021	Land Cover Changes from 1991 to 2001	Land Cover Changes from 2001 to 2021
Water Bodies	8.74	8.46	7.1	-3.08	-16
Built-up	6.4	14.03	52.2	121.922	271.065
Vegetation	63.4	58.09	12.9	-8.4904	-77.7

Bare land	21.46	19.42	27.8	-9.54	43.7314

Figure 2. 4 Graphical Representation of Land Cover Type of Greater Accra in 1991

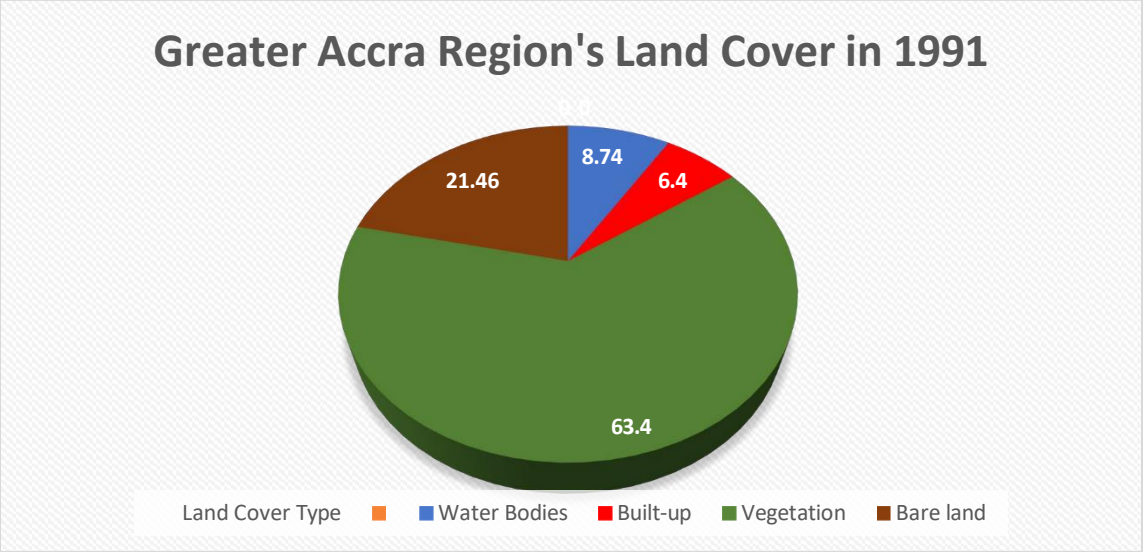


Figure 2. 5 Graphical Representation of Land Cover Type of Greater Accra in 2001.

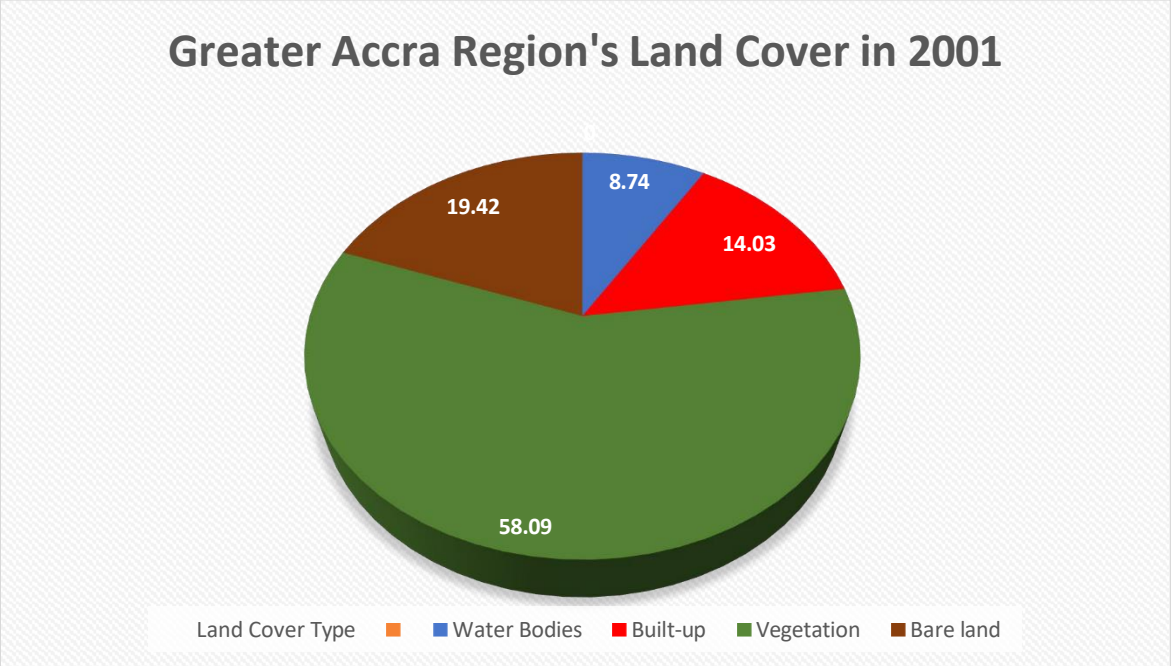
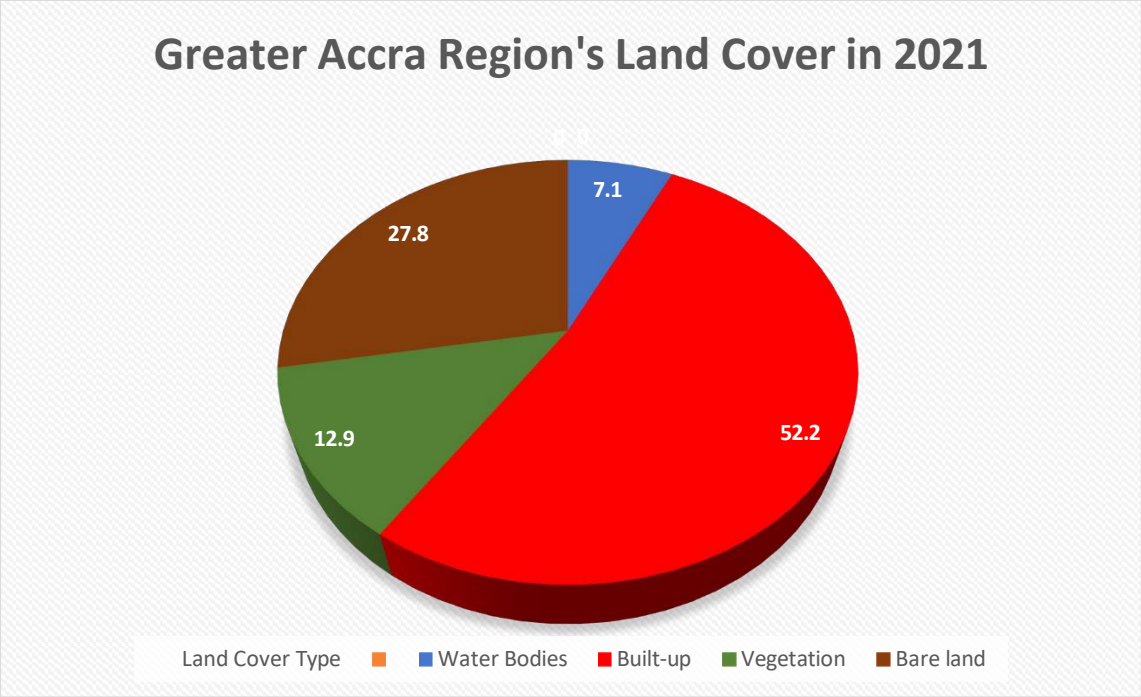


Figure 2. 6 Graphical Representation of Land Cover Type of Greater Accra in 2021



2.5.3. Accuracy Assessment of the Greater Accra Region

Accuracy assessment is one of the significant steps in image classification because it helps in the determining the precision of a thematic map created from a satellite image (Frimpong, 2015b). Figure 2.1 shows the multi-temporal Landsat TM data-based land-use and land-cover maps of the Greater Accra Region for the years 1991, 2001 and 2021. The categorization technique used previous Google Earth images from the "Google Earth Pro" application as a reference. A comparison of the classification results with the actual reference point for a particular land cover was made using an error matrix approach. In addition, the study quantified the kappa coefficient, a measurement used to determine how much more accurate the categorization is randomly. The user's accuracy was also quantified to be 75% in 1991, 100% in 2001 and 83% in 2021 as shown in Table 2.7. The user's accuracy is the percentage of pixels in a given class that have been

correctly classified out of the total number of pixels in that class (Enderle & Weih, 2005). The user accuracy is significant to the user because it reflects how closely the classified image matches the actual conditions on the ground. Lastly, the producer's accuracy was quantified to be 100% in 1991, 75% in 2001 and 83% in 2021. Producers' accuracy is the total number of correctly classified reference pixels (Gómez-Sapiens et al., 2021). The producer's accuracy also helps in understanding how well the algorithm performs in detecting the land cover features under the study. Additionally, the overall accuracy of the of the categorized images were 90% for 1991, 95% for 2001 and 90% for 2021 showing how good and reliable the overall precision is. This is so because , if the overall accuracy of a categorized image/map is said to be 73 percent, the figure indicates the correctness of the entire product (Story, 1986).

Table 2. 6 Accuracy Assessment Result for the classified output

Category	Years		
	1991	2001	2021
Overall accuracy	90%	95%	90%
Kappa value	0.80	0.91%	0.84%
Producers Accuracy	100%	75%	100%
User Accuracy	75%	100%	83%

2.5.4 Other Problems Associated with Urbanization in the Greater Accra Region of Ghana

a) **Traffic Congestion**

Economic development and urbanization can have consequences such as traffic congestion as well as environmental health issues (Armah et al., 2010). In Accra, increasing traffic and associated congestion are two main factors that slow down movement (Møller-Jensen,

2021). Traveling within the city remains challenging amidst recent and ongoing advancements of the major highways within the city due to the functional connectivity between both the city center and burgeoning periphery as well as the inadequate operations of urban buses "trotro", (Agyapong & Ojo, 2018) which aggravate peak hour tension and restrict roadway for picking up passengers. This can cause tension, dissatisfaction, and future problems resulting in strained relationships and financial distress (Agyapong & Ojo, 2018; Quarshie, 2007).

b) **Seasonal Flood Hazard**

Research conducted on the study area reveals that frequent flooding which occurs annually in Accra is attributed to climate change, excess river overflow, and influences of human actions mainly by unmanageable solid waste disposal methods propelled by the rapid rate of urbanization (Abeka et al., 2020; Afeku, 2005; Damte et al., 2023). A study conducted by (Damte et al., 2023) reveals that the primary causes of flooding disasters in Accra were evaluated to be a lack of vegetation cover, inadequate drainage systems, storm surges, and heavy rainfall. Accra's susceptibility and exposure to flood risks is as a result of the unchecked expansion of unplanned housing development mainly squatter settlements in flood-prone low-lying areas in the region (Abeka et al., 2020). Another study by (Afeku, 2005) reveals that buildings in Accra become susceptible to floods and subsequently flood after severe downpours as a consequence of urbanization and a lack of effective spatial planning, drainage, and waste services. Further study suggested that, the use of drainage systems for the collection of rainwater to deal with Accra's ongoing water supply constraints as part of Accra's urbanization's concerns in context of seasonal rainfall and impervious surfaces could help address the issue of flooding in Accra (Amoako & Frimpong Boamah, 2015)**.**

c) Pollution of water bodies

An in-depth literature review on the study area reveals that rapid rate of urbanization in the region is a key cause of pollution of two major water bodies in the jurisdiction. For instance,

research conducted by (Boadi & Kuitunen, 2002) titled " Urban waste pollution in the Korle Lagoon, Accra, Ghana" reveals that the discharge of untreated industrial and municipal waste into storm drains has increased due to heightened levels of industrial activity as well as the consumption patterns by the growing urban populace. Also, (Aglanu & Appiah, 2014) in their paper titled "The Korle Lagoon in Distress: The Stress of Urban Solid Waste on Water Bodies in Accra, Ghana" also reveals that the high amounts of trash dumped into the Korle lagoon has made it impossible to sustain lives of aquatic animals and plants over the years as a result of lack of dissolved oxygen, and other hazardous compounds due to the high degree of pollution. Therefore making the Korle Lagoon in Accra one of the world's most contaminated water bodies (Boadi & Kuitunen, 2002). Based on this literature-based research, this study establishes that prioritizing issues of solid waste amid growing rapid urbanization is a critical step toward protecting our water resources and fostering environmental sustainability.

d) Creation of Slums

The research findings by (Addi & Ayambire, 2022) reveals that neoliberalism has actively and passively influenced Ghana's housing market through the commercialization of land and the commodification of homes which has led to the growth of slums in the Greater Accra region and this is one of the major consequences of uncontrolled urbanization, therefore resulting to an impact on human settlement. Many residents in Accra are confronted with pervasive nature of slum settlements which adversely have a negative social, economic, and health impact on urban dwellers (Ghana Demographic and Health Survey, 2008). A recent study that reveals that slum residents in Accra are identified as the most prevalent to encounter infectious, respiratory, and skin disorders during the past two years, as substantiated by information on illness prevalence that the Municipal Health Directorate of the La-Nkwantanang Madina Municipality (Damte et al., 2023). Many of these issues are the result of clogged gutters, inadequate drainage,

and hygiene issues that are aggravated by climatic conditions all as a result of the increasing rate of urbanization in the region.

2.6. Discussion

The major objective of this study was to examine the growth of the Greater Accra region over the years using classified Landsat imagery. It was hypothesized that, due to the region's expanding population and accelerating rate of urbanization, there would be an expansion of the urbanized area on the city's landcover which will cause a significant decline in the urban vegetation. As evaluated by human settlement expansion, the result showed that the dominant land use and land cover of the Greater Accra Region was built-up features. It was found that urban vegetation decreased by 63.4% in 1991 to 12.9 in 2021, while the urban built-up features increased from 6.4% to 52.2% from 1991 to 2021 respectively. The vegetative degradation intensified significantly between 2001 and 2021 as vegetation was decreased by extra 45.19% from 215558.26km² in 2001 to 48005.55km² in 2021. All of these confirms the findings from (United States Geological Survey, 2017) that, the rate at which Ghana's forest resources are being lost is detrimental to ecology. As anticipated, the results showed an increase in the urban built-up area on the city's landcover causing a significant decline in the urban vegetation (12.9%). Again, the study's observation of increased urban built-up (52.2%) is consistent with the findings of other research that contend that urbanization is a key factor in the loss of urban greenery or vegetation (Carlson & Traci Arthur, 2000; de la Barrera & Henríquez, 2017; Luo et al., 2021; Scherner et al., 2013; Yin, 2022; Zhao et al., 2016). In figure 2.9.1.2 above, the built-up area comprises of low, medium, and high-density, residential neighborhoods, mixed-use developments, industrial and commercial units, and transportation infrastructure (Assiam, 2020) as well as other man-made features that has witnessed a great increase comparing the difference between the land use landcover change map of 1991, 2001 and 2021 of the Greater Accra

Region. The difference is due to the rapid population growth coupled with it rate of urbanization in the region which has caused a great demand for built-up affecting the land use land cover available in the area. Tropical forests once dominated Greater Accra, but agricultural clearing and urban expansion have altered the region's ecology, with herbaceous and shrub vegetation predominating in less populated regions and fast regrowth in places with little residential development (Stow et al., 2013). The main water bodies present in Accra are lagoons, rivers, and a lake. Also present in the region is the Weija lake which is the only lake situated in the Greater Accra region of Ghana. Most of the water bodies have been obstructed by activities of man mainly with influences from construction activities and solid waste disposal with the Odaw river being at the forefront of this improper waste disposal in the region.

These hindrances to the flow of the river cause a seasonal flooding in the respective areas whenever it rains heavily, hence making flooding an annual problem in some parts of the region. Figure 2.9.2.6 clearly shows that the built environment has certainly had the most direct impact on the geomorphology of the land use of the Greater Accra Region. Urbanization in the region has greatly modified the regions landscapes making population growth (Adeyemi Michael & Addo Kwasi Appeaning, 2013) and deforestation key factors for the conversion of natural cover like vegetation to artificial cover like built up in the Greater Accra Region. All of this is consistent with the findings by (Agyarko, 2001) which claims that land use land cover issues are a concern in Ghana and many other nations whose economies rely heavily on the usage of natural resources. Rapid urbanization of the Greater Accra region is due to natural and human factors such as high birth rate and migration of people from all walks of the country and foreigners for various purposes, including employment, education, tourism, health care, transportation, commercial and political infrastructure (Ghana Statistical Service, 2021). This has

therefore led to major problems like overpopulation, environmental deterioration, pollution, congestion, diseases, and other socio-economic problems. Even though (Van der Geest et al., 2010) argues that the Greater Accra Region's population growth is due to in-migration rather than natural growth. Urbanization could also have an impact on the global climate. Rapid urbanization and elevated dangers from climate change are converging on the African continent (Finn & Cobbinah, 2022).

This necessitates universal acknowledgement of the importance of urban sustainability in achieving sustainable development globally. Population increase, migration, urbanization, and mining pressures all cause changes in land use and land cover (Kullo et al., 2021). Human actions and environmental sources are the primary drivers of LULC, with political and economic issues being the most influential (Ampim et al., 2021). These demographic fluctuations, together with growth has outpaced and technological developments, and as well altered the planet's surface in both disadvantageous and advantageous ways (Addae & Oppelt, 2019a). Ghana's population increased by 26 million throughout the course of its 64 years as a sovereign state, from 5 million in 1957 to 31 million in 2020.This rise has been accompanied by significant changes in land use and cover (LULC), particularly the growth of cities (Ampim et al., 2021). Again, migration-driven urbanization and population growth have also forced migrants into peri-urban regions with insufficient access to pipe-borne water services, such as Abokobi, Amasaman, and Kpone, as well as Nima, Maamobi, and Sabon Zongo as slums or unofficial communities (Tetteh et al., 2022).

Formerly porous and humid surfaces become impenetrable and dry. Urban areas grow warmer than their rural surrounds as a consequence of these modifications, creating an "island" of hotter temperatures in the environment. The danger of several additional ailments rises when

exposed to high temperatures comprising of poor reproductive results - Respiratory disease - Kidney disease - Cardiovascular disease, behavioral and mental health disadvantage (Mitra, 2014). Moreover, poorly executed land use and spatial planning regulations have made the housing crisis worse and caused the region to develop unevenly. It is important to note that , unplanned informal dynamics have a significant impact on urban development resulting to haphazard development which is encouraged by the uncertainty brought on by inadequate spatial planning (Korah et al., 2017). To appropriately address the urban development challenges confronting the Greater Accra region of Ghana, this study promotes awareness and incorporation of conscious efforts and multivariate mechanisms in spatial planning initiatives in subsequent two chapters. African cities' spatial planning must go beyond producing several formal plans, giving cities the chance to take a variety of factors into account in a way that allows them to formulate and incorporate formal plans while allowing for self-organization as a crucial step in the decision - making process, especially in terms of planning (Roo, 2010).

2.7 Conclusion and Recommendation

This study demonstrates how the combination of GIS and remote sensing offers a potent tool for tracking changes in land use and cover over time and space. Without considering geographical information like population density, income, and employment distribution, the LULC change analysis identified the major shift trajectories in the Greater Accra area. The study found that there was an increase in the urban built-up area in the region’s landcover from 6.4% to 52.2% from 1991 to 2021 respectively and a significant decline in urban vegetation from 63.4% in 1991 to 12.9 in 2021. The ability of the land use land cover change study to forecast the future may be enhanced by integrating socioeconomic data, land-use policy, and human variables. Being geographically and functionally connected, Kasoa and the Greater Accra region of Ghana are

anticipated to combine in the upcoming years. To further comprehend how interrelated and interdependent the Greater Accra Region and its satellite towns are, future studies should take into account the neighboring regions (Musa et al., 2017). Also, local developers may need to use multidimensional modeling approaches to solve the problem of dependency on individual outcomes when measuring urban or rural as a community-level attribute "if the study is not already ecologic in nature"(Hall et al., 2006).

2.8 References

Abebe, G., Getachew, D., & Ewunetu, A. (2021). Analysing land use/land cover changes and its dynamics using remote sensing and GIS in Gubalafito district, Northeastern Ethiopia. *SN Applied Sciences*, *4*(1), 30. https://doi.org/10.1007/s42452-021-04915-8

Abeka, E., Asante, F. A., Laube, W., & Codjoe, S. N. A. (2020). Contested causes of flooding in poor urban areas in Accra, Ghana: An actor-oriented perspective. *Environment, Development and Sustainability*, *22*(4), 3033–3049. https://doi.org/10.1007/s10668-019-00333-4

Achankeng, E. (2003). Globalization, Urbanization and Municipal Solid Waste Management in Africa. *Conference Proceedings*, 22.

Addae, B., & Oppelt, N. (2019a). Land-Use/Land-Cover Change Analysis and Urban Growth Modelling in the Greater Accra Metropolitan Area (GAMA), Ghana. *Urban Science*, *3*, 26. https://doi.org/10.3390/urbansci3010026

Addae, B., & Oppelt, N. (2019b). Land-Use/Land-Cover Change Analysis and Urban Growth Modelling in the Greater Accra Metropolitan Area (GAMA), Ghana. *Urban Science*, *3*(1), Article 1. https://doi.org/10.3390/urbansci3010026

Addi, B., & Ayambire, R. A. (2022). Neoliberalism and the growth of slums in Accra, Ghana. *SN Social Sciences*, *2*(11), 243. https://doi.org/10.1007/s43545-022-00558-7

Addo-Fordwuor, D., & Seah, S. (2022). Factors influencing households' willingness to comply with municipal solid waste management regulations in the Kumasi Metropolis, Ghana. *African Geographical Review*, *0*(0), 1–19. https://doi.org/10.1080/19376812.2022.2162092

Adeyemi Michael & Addo Kwasi Appeaning. (2013). Assessing the impact of sea-level rise on a vulnerable coastal community in Accra, Ghana: Original research. *Jamba: Journal of Disaster Risk Studies*, *5*(1), 1–8. https://doi.org/10.4102/jamba.v5i1.60

Afeku, K. (2005). *Urbanization And Flooding in Accra, Ghana*.

Aglanu, L. M., & Appiah, D. O. (2014). *The Korle Lagoon in Distress: The Stress of Urban Solid Waste on Water Bodies in Accra, Ghana*. *7*(2).

Agyapong, F., & Ojo, T. K. (2018). Managing traffic congestion in the Accra Central Market, Ghana. *Journal of Urban Management*, *7*(2), 85–96. https://doi.org/10.1016/j.jum.2018.04.002

Agyarko, T. (2001). *Ministry of Lands and Forestry, Ghana. Forest Outlook Study for Africa.*

Akubia, J. E. K., Ahmed, A., & Bruns, A. (2020). Assessing How Land-Cover Change Associated with Urbanisation Affects Ecological Sustainability in the Greater Accra Metropolitan Area, Ghana. *Land*, *9*(6), Article 6. https://doi.org/10.3390/land9060182

Al-Bakri, J., Duqqah, M., & Brewer, T. (2013). Application of Remote Sensing and GIS for Modeling and Assessment of Land Use/Cover Change in Amman/Jordan. *Journal of Geographic Information System*, *5*, 509–519. https://doi.org/10.4236/jgis.2013.55048

Amesimeku, N. O. (2019). *The urban political ecology of flood occurrences in Accra, Ghana* [Master thesis, Norwegian University of Life Sciences, Ås]. https://nmbu.brage.unit.no/nmbu-xmlui/handle/11250/2623066

Amoako, C., & Frimpong Boamah, E. (2015). The three-dimensional causes of flooding in Accra, Ghana. *International Journal of Urban Sustainable Development*, *7*(1), 109–129. https://doi.org/10.1080/19463138.2014.984720

Ampim, P. A. Y., Ogbe, M., Obeng, E., Akley, E. K., & MacCarthy, D. S. (2021). Land Cover Changes in Ghana over the Past 24 Years. *Sustainability*, *13*(9), Article 9. https://doi.org/10.3390/su13094951

Anarfi, K., Hill, R. A., & Shiel, C. (2020). Highlighting the Sustainability Implications of Urbanisation: A Comparative Analysis of Two Urban Areas in Ghana. *Land*, *9*(9), Article 9. https://doi.org/10.3390/land9090300

Anderson, J. R. (1976). *A Land Use and Land Cover Classification System for Use with Remote Sensor Data*. U.S. Government Printing Office.

Armah, F. A., Yawson, D. O., & Pappoe, A. A. N. M. (2010). A Systems Dynamics Approach to Explore Traffic Congestion and Air Pollution Link in the City of Accra, Ghana. *Sustainability*, *2*(1), Article 1. https://doi.org/10.3390/su2010252

Arsiso, B. K., Mengistu Tsidu, G., Stoffberg, G. H., & Tadesse, T. (2018). Influence of urbanization-driven land use/cover change on climate: The case of Addis Ababa, Ethiopia. *Physics and Chemistry of the Earth, Parts A/B/C*, *105*, 212–223. https://doi.org/10.1016/j.pce.2018.02.009

Asongu, S. A., Agboola, M. O., Alola, A. A., & Bekun, F. V. (2020). The criticality of growth, urbanization, electricity and fossil fuel consumption to environment sustainability in Africa. *Science of The Total Environment*, *712*, 136376. https://doi.org/10.1016/j.scitotenv.2019.136376

Assiam, B. Y. (2020). *A STUDY OF THE FOSU LAGOON WATERSHED IN GHANA: A REMOTE SENSING APPROACH*.

Beall, J., & Fox, S. (2009). *Cities and development*. Routledge.

Biney, E., & Boakye, E. (2021). Urban sprawl and its impact on land use land cover dynamics of Sekondi-Takoradi metropolitan assembly, Ghana. *Environmental Challenges*, *4*, 100168. https://doi.org/10.1016/j.envc.2021.100168

Bixby, H., Bennett, J. E., Bawah, A. A., Arku, R. E., Annim, S. K., Anum, J. D., Mintah, S. E., Schmidt, A. M., Agyei-Asabere, C., Robinson, B. E., Cavanaugh, A., Agyei-Mensah, S., Owusu, G., Ezzati, M., & Baumgartner, J. (2022). Quantifying within-city inequalities in child mortality across neighbourhoods in Accra, Ghana: A Bayesian spatial analysis. *BMJ Open*, *12*(1), e054030. https://doi.org/10.1136/bmjopen-2021-054030

Boadi, K. O., & Kuitunen, M. (2002). *Urban Waste Pollution in the Korle Lagoon, Accra, Ghana*.

Carlson, T. N., & Traci Arthur, S. (2000). The impact of land use — land cover changes due to urbanization on surface microclimate and hydrology: A satellite perspective. *Global and Planetary Change*, *25*(1), 49–65. https://doi.org/10.1016/S0921-8181(00)00021-7

Chapman-Wardy, C., Asiedu, L., Doku-Amponsah, K., & Mettle, F. O. (2021). Modeling the Amount of Waste Generated by Households in the Greater Accra Region Using Artificial Neural Networks. *Journal of Environmental and Public Health*, *2021*, 1–12. https://doi.org/10.1155/2021/8622105

Chen, H., Chen, C., Zhang, Z., Lu, C., Wang, L., He, X., Chu, Y., & Chen, J. (2021). Changes of the spatial and temporal characteristics of land-use landscape patterns using multi-temporal Landsat satellite data: A case study of Zhoushan Island, China. *Ocean & Coastal Management*, *213*, 105842. https://doi.org/10.1016/j.ocecoaman.2021.105842

Cohen, B. (2006). Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. *Technology in Society*, *28*(1), 63–80. https://doi.org/10.1016/j.techsoc.2005.10.005

Damte, E., Manteaw, B. O., & Wrigley-Asante, C. (2023). Urbanization, climate change and health vulnerabilities in slum communities in Ghana. *The Journal of Climate Change and Health*, *10*, 100189. https://doi.org/10.1016/j.joclim.2022.100189

Darkwah, R. M., & Cobbinah, P. B. (2014). *Stewardship of Urban Greenery in an Era of Global Urbanisation*. *8*(10).

de la Barrera, F., & Henríquez, C. (2017). Vegetation cover change in growing urban agglomerations in Chile. *Ecological Indicators*, *81*, 265–273. https://doi.org/10.1016/j.ecolind.2017.05.067

Dwivedi, R. S., Sreenivas, K., & Ramana, K. V. (2005). Cover: Land-use/land-cover change analysis in part of Ethiopia using Landsat Thematic Mapper data. *International Journal of Remote Sensing*, *26*(7), 1285–1287. https://doi.org/10.1080/01431160512331337763

Effiong, E. (2016, July 31). *Urbanization and Environmental Quality in Africa* [MPRA Paper]. https://mpra.ub.uni-muenchen.de/73224/

Elgin, C., & Oyvat, C. (2013). Lurking in the cities: Urbanization and the informal economy. *Structural Change and Economic Dynamics*, *27*, 36–47. https://doi.org/10.1016/j.strueco.2013.06.003

Enderle, D., & Weih, R. (2005). Integrating Supervised and Unsupervised Classification Methods to Develop a More Accurate Land Cover Classification. *Journal of the Arkansas Academy of Science*, *59*(1), 65–73. https://scholarworks.uark.edu/jaas/vol59/iss1/10

Fan, W., & Zhang, L. (2019). Does cognition matter? Applying the push-pull-mooring model to Chinese farmers' willingness to withdraw from rural homesteads. *Papers in Regional Science*, *98*(6), 2355–2369. https://doi.org/10.1111/pirs.12462

Finn, B. M., & Cobbinah, P. B. (2022). African urbanisation at the confluence of informality and climate change. *Urban Studies*, 00420980221098946. https://doi.org/10.1177/00420980221098946

Freire, M., Lall, S., & Leipziger, D. (2015). Africa's Urbanization: Challenges and Opportunities. In C. Monga & J. Y. Lin (Eds.), *The Oxford Handbook of Africa and Economics: Volume 1: Context and Concepts* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199687114.013.9

Frimpong, B. F. (2015a). *Land Use and Cover Changes in The Mampong Municipality of The Ashanti Region*. 85.

Frimpong, B. F. (2015b). *Land Use and Cover Changes in The Mampong Municipality Of The Ashanti Region*.

Fuseini, I., & Kemp, J. (2015). A review of spatial planning in Ghana's socio-economic development trajectory: A sustainable development perspective. *Land Use Policy*, *47*, 309–320. https://doi.org/10.1016/j.landusepol.2015.04.020

Gaisie, E., Kim, H. M., & Han, S. S. (2019). Accra towards a city-region: Devolution, spatial development and urban challenges. *Cities*, *95*, 102398. https://doi.org/10.1016/j.cities.2019.102398

Gennaretti, F., Ripa, M. N., Gobattoni, F., Boccia, L., & Pelorosso, R. (2011). *A methodology proposal for land cover change analysis using historical aerial photos*. 15.

Ghana Demographic and Health Survey. (2008). *Ghana Demographic and Health Survey 2008 | GHDx*. https://ghdx.healthdata.org/record/ghana-demographic-and-health-survey-2008

Ghana Metropolitan Cities. (2016). *Future Cities Africa*. https://www.arup.com/en/perspectives/publications/research/section/future-cities-africa

Ghana Statistical Service. (2021). *2021 Population and Housing Census*. https://census2021.statsghana.gov.gh/

Ghana's Urbanization. (2010). *Ghana—Urbanization 2011-2021*. Statista. https://www.statista.com/statistics/455827/urbanization-in-ghana/

Gizelis, T.-I., Pickering, S., & Urdal, H. (2021). Conflict on the urban fringe: Urbanization, environmental stress, and urban unrest in Africa. *Political Geography*, *86*, 102357. https://doi.org/10.1016/j.polgeo.2021.102357

Gocking, R. (2005). *The History of Ghana*. Greenwood Publishing Group.

Gómez-Sapiens, M., Schlatter, K. J., Meléndez, Á., Hernández-López, D., Salazar, H., Kendy, E., & Flessa, K. W. (2021). Improving the efficiency and accuracy of evaluating aridland riparian habitat restoration using unmanned aerial vehicles. *Remote Sensing in Ecology and Conservation*, *7*(3), 488–503. https://doi.org/10.1002/rse2.204

Hall, S. A., Kaufman, J. S., & Ricketts, T. C. (2006). Defining Urban and Rural Areas in U.S. Epidemiologic Studies. *Journal of Urban Health*, *83*(2), 162–175. https://doi.org/10.1007/s11524-005-9016-3

Hyandye, C., & Martz, L. W. (2017). A Markovian and cellular automata land-use change predictive model of the Usangu Catchment. *International Journal of Remote Sensing*, *38*(1), 64–81. https://doi.org/10.1080/01431161.2016.1259675

Islam, M. S., & Ahmed, R. (2011). Land Use Change Prediction In Dhaka City Using Gis Aided Markov Chain Modeling. *Journal of Life and Earth Science*, *6*, 81–89. https://doi.org/10.3329/jles.v6i0.9726

Ivan Turok & Gordon McGranahan. (2013). *Urbanization and economic growth: The arguments and evidence for Africa and Asia* -. https://journals.sagepub.com/doi/10.1177/0956247813490908

Jedwab, R., Christiaensen, L., & Gindelsky, M. (2017). Demography, urbanization and development: Rural push, urban pull and…urban push? *Journal of Urban Economics*, *98*, 6–16. https://doi.org/10.1016/j.jue.2015.09.002

Jelena, Ž.-M., Tijana, C., & Igor, M. (2012). Land use planning for sustainable development of peri-urban zones. *Spatium*, *2012*(28), 15–22. https://doi.org/10.2298/SPAT1228015Z

Jiménez-Peñuela, J., Ferraguti, M., Martínez-de la Puente, J., Soriguer, R., & Figuerola, J. (2019). Urbanization and blood parasite infections affect the body condition of wild birds. *Science of The Total Environment*, *651*, 3015–3022. https://doi.org/10.1016/j.scitotenv.2018.10.203

Kassouri, Y., & Okunlola, O. A. (2022). Analysis of spatio-temporal drivers and convergence characteristics of urban development in Africa. *Land Use Policy*, *112*, 105868. https://doi.org/10.1016/j.landusepol.2021.105868

Kevin J. Gaston. (2010). *Urban Ecology: Emerging Patterns and Social-Ecological Systems [1 ed.] 0128207302, 9780128207307*. Dokumen.Pub. https://dokumen.pub/urban-ecology-emerging-patterns-and-social-ecological-systems-1nbsped-0128207302-9780128207307.html

Korah, P. I., Cobbinah, P. B., & Nunbogu, A. M. (2017). Spatial Planning in Ghana: Exploring the Contradictions. *Planning Practice & Research*, *32*(4), 361–384. https://doi.org/10.1080/02697459.2017.1378977

Kullo, E. D., Forkuo, E. K., Biney, E., Harris, E., & Quaye-Ballard, J. A. (2021). The impact of land use and land cover changes on socioeconomic factors and livelihood in the Atwima Nwabiagya district of the Ashanti region, Ghana. *Environmental Challenges*, *5*, 100226. https://doi.org/10.1016/j.envc.2021.100226

Lambin, E. F., & Geist, H. J. (2008). *Land-Use and Land-Cover Change: Local Processes and Global Impacts*. Springer Science & Business Media.

Larbi, W. O. (1996). Spatial planning and urban fragmentation in Accra. *Third World Planning Review*, *18*(2), 193. https://doi.org/10.3828/twpr.18.2.512j2355x17032m1

Liu, J., Zhang, Q., & Hu, Y. (2012). Regional differences of China's urban expansion from late 20th to early 21st century based on remote sensing information. *Chinese Geographical Science*, *22*(1), 1–14. https://doi.org/10.1007/s11769-012-0510-8

Luo, Y., Sun, W., Yang, K., & Zhao, L. (2021). China urbanization process induced vegetation degradation and improvement in recent 20 years. *Cities*, *114*, 103207. https://doi.org/10.1016/j.cities.2021.103207

Mitra, C. (2014). *Urban Heat Island*.

Møller-Jensen, M. (2021). Frictions of everyday mobility: Traffic, transport and gendered confrontations on the roads of Accra. *Mobilities*, *16*(4), 461–475. https://doi.org/10.1080/17450101.2021.1917969

M.S. Boori, Boori, M., American Sentinel University, Paringer, R., The Hong Kong Polytechnic University, IPSI RAS – Branch of the FSRC "Crystallography and Photonics" RAS, Choudhary, K., Samara National Research University, The Hong Kong Polytechnic University, Kupriyanov, A., The Hong

Kong Polytechnic University, & IPSI RAS – Branch of the FSRC "Crystallography and Photonics" RAS. (2018). Comparison of hyperspectral and multi-spectral imagery to building a spectral library and land cover classification performance. *Computer Optics*, *42*(6), 1035–1045. https://doi.org/10.18287/2412-6179-2018-42-6-1035-1045

Mukesh Singh Boori & Vít Voženílek. (2014). Remote Sensing and Land Use/Land Cover Trajectories. *Journal of Geophysics & Remote Sensing*, *03*(03). https://doi.org/10.4172/2169-0049.1000123

Musa, S. I., Hashim, M., & Reba, M. N. M. (2017). A review of geospatial-based urban growth models and modelling initiatives. *Geocarto International*, *32*(8), 813–833. https://doi.org/10.1080/10106049.2016.1213891

Musah, B. I., Peng, L., & Xu, Y. (2020). Urban Congestion and Pollution: A Quest for Cogent Solutions for Accra City. *IOP Conference Series: Earth and Environmental Science*, *435*(1), 012026. https://doi.org/10.1088/1755-1315/435/1/012026

Nath, B., Ni-Meister, W., & Choudhury, R. (2021). Impact of urbanization on land use and land cover change in Guwahati city, India and its implication on declining groundwater level. *Groundwater for Sustainable Development*, *12*, 100500. https://doi.org/10.1016/j.gsd.2020.100500

Obi-Ani, N. A., & Isiani, M. C. (2020). Urbanization in Nigeria: The Onitsha experience. *Cities*, *104*, 102744. https://doi.org/10.1016/j.cities.2020.102744

Ofori, B. Y., Obeng, E. A., & Attuquayefio, D. K. (2022). Urbanization influences small mammal composition, but not species richness in forest fragments in Accra, Ghana. *Environmental Monitoring and Assessment*, *194*(2), 60. https://doi.org/10.1007/s10661-021-09729-0

Ofori, F. N. K. (2021). Sprawl and Congestion in Accra—Challenges and Opportunities of Sustainable Development in Ghana's Capital City. *Regions*. https://doi.org/10.1080/13673882.2021.00001092

Okeke, O. (2010). *A political and administrative history of Onitsha, 1917-1970*. https://www.africabib.org/rec.php?RID=326613676

Oliphant, A. J., Thenkabail, P. S., Teluguntla, P., Xiong, J., Gumma, M. K., Congalton, R. G., & Yadav, K. (2019). Mapping cropland extent of Southeast and Northeast Asia using multi-year time-series Landsat 30-m data using a random forest classifier on the Google Earth Engine Cloud. *International Journal of Applied Earth Observation and Geoinformation*, *81*, 110–124. https://doi.org/10.1016/j.jag.2018.11.014

Oteng-Ababio, M., Melara Arguello, J. E., & Gabbay, O. (2013). Solid waste management in African cities: Sorting the facts from the fads in Accra, Ghana. *Habitat International*, *39*, 96–104. https://doi.org/10.1016/j.habitatint.2012.10.010

Patel, S. K., Verma, P., & Shankar Singh, G. (2019a). Agricultural growth and land use land cover change in peri-urban India. *Environmental Monitoring and Assessment*, *191*(9), 600. https://doi.org/10.1007/s10661-019-7736-1

Patel, S. K., Verma, P., & Shankar Singh, G. (2019b). Agricultural growth and land use land cover change in peri-urban India. *Environmental Monitoring and Assessment*, *191*(9), 600. https://doi.org/10.1007/s10661-019-7736-1

Phuttharak, T., & Dhiravisit, A. (2014). Rapid Urbanization-Its Impact on Sustainable Development: A Case Study of Udon Thani, Thailand. *Asian Social Science*, *10*(22), p70. https://doi.org/10.5539/ass.v10n22p70

Pohl, C., & Van Genderen, J. L. (1998). Review article Multisensor image fusion in remote sensing: Concepts, methods and applications. *International Journal of Remote Sensing*, *19*(5), 823–854. https://doi.org/10.1080/014311698215748

Quarshie, M. (2007). Integrating cycling in Bus Rapid Transit system in Accra. In G. M. Morrison & S. Rauch (Eds.), *Highway and Urban Environment* (pp. 103–116). Springer Netherlands. https://doi.org/10.1007/978-1-4020-6010-6_11

Rindfuss, R. R., Entwisle, B., Walsh, S. J., Mena, C. F., Erlien, C. M., & Gray, C. L. (2007). Frontier Land Use Change: Synthesis, Challenges, and Next Steps. *Annals of the Association of American Geographers*, *97*(4), 739–754. https://doi.org/10.1111/j.1467-8306.2007.00580.x

Roo, G. de. (2010). Planning and Complexity: An Introduction. In *A Planner's Encounter with Complexity*. Routledge.

Roser, M., Ritchie, H., Ortiz-Ospina, E., & Rodés-Guirao, L. (2013). World Population Growth. *Our World in Data*. https://ourworldindata.org/world-population-growth

Sahalu, A. G. (2014). *Analysis of urban land use and land cover changes: A case of study in Bahir Dar, Ethiopia* [PhD Thesis].

Scherner, F., Horta, P. A., de Oliveira, E. C., Simonassi, J. C., Hall-Spencer, J. M., Chow, F., Nunes, J. M. C., & Pereira, S. M. B. (2013). Coastal urbanization leads to remarkable seaweed species loss and community shifts along the SW Atlantic. *Marine Pollution Bulletin*, *76*(1), 106–115. https://doi.org/10.1016/j.marpolbul.2013.09.019

Semenza, J. C., & Ebi, K. L. (2019). Climate change impact on migration, travel, travel destinations and the tourism industry. *Journal of Travel Medicine*, *26*(5), taz026. https://doi.org/10.1093/jtm/taz026

Song, C., Woodcock, C. E., Seto, K. C., Lenney, M. P., & Macomber, S. A. (2000). *Classification and Change Detection Using Landsat TM Data: When and How to Correct Atmospheric Effects?*

Songsore, J. (1979). *Structural Crisis, Dependent Capitalist Development and Regional Inequality in Ghana* (No. 71). Article 71. https://repub.eur.nl/pub/38009/

Songsore, J. (2009). *THE URBAN TRANSITION IN GHANA: URBANIZATION, NATIONAL DEVELOPMENT AND POVERTY REDUCTION*.

Songsore, J. (2020). *The Urban Transition in Ghana: Urbanization, National development and Poverty Reduction*.

Songsore, J., McGranahan, G., & Kjellen, M. (2004). Tenure, housing and environmental management among families in the Greater Accra Metropolitan Area (GAMA) of Ghana. *Institute of African Studies Research Review*, *2004*(sup-5), 69–83. https://doi.org/10.10520/EJC45850

Story, M. (1986). *Accuracy Assessment: A User's Perspective*.

Stow, D. A., Weeks, J. R., Toure, S., Coulter, L. L., Lippitt, C. D., & Ashcroft, E. (2013). Urban Vegetation Cover and Vegetation Change in Accra, Ghana: Connection to Housing Quality. *The Professional Geographer*, *65*(3), 451–465. https://doi.org/10.1080/00330124.2012.697856

Tetteh, J. D., Templeton, M. R., Cavanaugh, A., Bixby, H., Owusu, G., Yidana, S. M., Moulds, S., Robinson, B., Baumgartner, J., Annim, S. K., Quartey, R., Mintah, S. E., Bawah, A. A., Arku, R. E., Ezzati, M., & Agyei-Mensah, S. (2022). Spatial heterogeneity in drinking water sources in the Greater Accra Metropolitan Area (GAMA), Ghana. *Population and Environment*, *44*(1), 46–76. https://doi.org/10.1007/s11111-022-00407-y

The World Population Prospects: 2015 Revision. (2015). [Report]. https://www.un.org/en/development/desa/publications/world-population-prospects-2015-revision.html

Tilahun, A. (2015). Accuracy Assessment of Land Use Land Cover Classification using Google Earth. *American Journal of Environmental Protection*, *4*(4), 193. https://doi.org/10.11648/j.ajep.20150404.14

Ugwuanyi, R., & Isife, T. C. (2012). *URBANIZATION AND SOLID WASTE MANAGEMENT CHALLENGES IN NIGERIA*. https://www.researchgate.net/publication/319448696

United States Geological Survey. (2017). *Land Use, Land Cover, and Trends in Ghana | West Africa*. https://eros.usgs.gov/westafrica/land-cover/land-use-land-cover-and-trends-ghana

Van der Geest, K., Vrieling, A., & Dietz, T. (2010). Migration and environment in Ghana: A cross-district analysis of human mobility and vegetation dynamics. *Environment and Urbanization*, *22*(1), 107–123. https://doi.org/10.1177/0956247809362842

Vlahov, D. (2002). Urbanization, Urbanicity, and Health. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, *79*(90001), 1S – 12. https://doi.org/10.1093/jurban/79.suppl_1.S1

Wemegah, C. S., Yamba, E. I., Aryee, J. N. A., Sam, F., & Amekudzi, L. K. (2020). Assessment of urban heat island warming in the greater accra region. *Scientific African*, *8*, e00426. https://doi.org/10.1016/j.sciaf.2020.e00426

Weng, Q. (2012). Remote sensing of impervious surfaces in the urban areas: Requirements, methods, and trends. *Remote Sensing of Environment*, *117*, 34–49. https://doi.org/10.1016/j.rse.2011.02.030

World Urbanization Prospects. (2018). *World Urbanization Prospects—Population Division—United Nations*. https://population.un.org/wup/

Yankson, P. W. K., & Bertrand, M. (2012). *Challenges of Urbanization in Ghana*.

Yankson, P. W. K., & Gough, K. V. (1999). The environmental impact of rapid urbanization in the peri-urban area of Accra, Ghana. *Geografisk Tidsskrift-Danish Journal of Geography*, *99*(1), 89–100. https://doi.org/10.1080/00167223.1999.10649426

Yin, X. (2022). The influence of urbanization on vegetation carbon pools under a tele-coupling framework in China. *Environment, Development and Sustainability*, *24*(3), 4046–4063. https://doi.org/10.1007/s10668-021-01603-w

Yuan, F., Sawaya, K. E., Loeffelholz, B. C., & Bauer, M. E. (2005). Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan Area by multitemporal Landsat remote

sensing. *Remote Sensing of Environment*, *98*(2), 317–328. https://doi.org/10.1016/j.rse.2005.08.006

Zhao, S., Liu, S., & Zhou, D. (2016). Prevalent vegetation growth enhancement in urban environment. *Proceedings of the National Academy of Sciences*, *113*(22), 6313–6318. https://doi.org/10.1073/pnas.1602312113

Zhou, X., & Chen, H. (2018). Impact of urbanization-related land use land cover changes and urban morphology changes on the urban heat island phenomenon. *Science of The Total Environment*, *635*, 1467–1476. https://doi.org/10.1016/j.scitotenv.2018.04.091

Chapter 3

Assessment of Solid Waste Management in the Greater Accra Region of Ghana

3.1. Introduction

Solid waste management (SWM) has been known to be a global concern as the urban population keeps increasing, and consumption patterns change (Marshall & Farahbakhsh, 2013). A report from United Nations Habitat in 2016 revealed that global municipal solid waste generation is anticipated to reach more than 4 billion tons by 2050 from 2 billion tons in 2016 (Hoang et al., 2022; United Nations Habitat, 2016). This is an outcome of the increasing rate of urbanization, population growth, and industrial advancement which affects various aspects of livelihood including health, productivity, and cleanliness (Ahmed et al., 2023). Solid waste constitutes the non-liquid or nongaseous everyday items that people no longer have value for because it has already fulfilled their mission (Leton & Omotosho, 2004). The Ghana Statistical Service (GSS) defines solid waste as a variety of waste products that are abandoned as undesirable and pointless and that result from both human and animal actions (Ghana Statistical Service, 2021). Solid waste is sometimes referred to as “rubbish”, “crap”, “garbage”, “filth”, “trash”, “refuse”, or “junk” (Zurbrugg, 2003). Wood, plastic, paper, glass, food scraps, and yard debris, among others, are all examples of solid waste. Even though excreta from animals or humans frequently finds its way into the stream of solid waste materials, such items are not typically considered to be part of solid waste (Zurbrugg, 2003).

Improper solid waste management is of significant concern to the world, especially in cities of developing countries owing to the imbalances between solid waste generation and collection (Hussien & Meaza, 2019; Muheirwe et al., 2022). Solid waste management is the process of attempting to minimize the detrimental consequences that solid waste has on the environment,

human health, and obtrusive aesthetics (Ogbonna et al., 2007; Zurbrugg, 2003). Typically, all waste produced in a community is known to be municipal solid waste (MSW), except waste produced by municipal services, treatment facilities, and industrial and agricultural operations (Tchobanoglous & Kreith, 2002). The United Nations Environment Protection Agency (EPA) defined municipal solid waste as waste made up of everyday items that are discarded because they are no longer useful (Staley & Barlaz, 2009). The definition of MSW, however, differs across nations, representing the various waste management techniques (Kawai & Tasaki, 2016). MSW usually ends up in municipal solid waste landfill (MSWLF) (Tan et al., 2015). The United Nations EPA defined MSWLF as a specific location on earth or pit where refuse from households is dumped (US EPA, 2016). Recently, the threat posed by hazardous, non-biodegradable single-use plastics has spread globally and as a result, excessive plastic waste production in cities might cause drainage to block during the rainy season, resulting in urban floods (. Kumar & Agrawal, 2020). Also, improper management of solid waste can lead to a reduction in environmental quality, pollutes the oceans, clog sewers, spreads infections, worsens respiratory issues, harm animals, impedes economic progress, and bring about social concerns (World Bank, 2022).

The management and disposal of MSW is an integral part of urban expansion and human economic activity, and this has become a global problem for municipal administration due to expanding waste generation and growing environmental and health issues (Khan et al., 2022). Management of solid waste is highly problematic, especially for low- and middle-income countries owing to the lack of resources and knowledge for planning, contract administration, and operational monitoring, lack of competent labor, inconsistent waste collection services and inadequate equipment, and insufficient legislative requirements (Kamaruddin et al., 2021; Khanal et al., 2023; Song et al., 2022; World Bank, 2022). Usually, the quantity and quality of

waste, dietary habits, cultural norms, geographical conditions, and collecting points significantly affect the composition of MSW (Joseph et al., 2018; S. Kumar, 2016). In the industrialized world, MSW is appropriately processed using a systematic procedure to generate energy and lessen environmental effects, but the treatment of urban MSW is still carried out in underdeveloped nations using outdated, inefficient technologies that impact the environment negatively (Shah et al., 2023). Consequentially, several households are more vulnerable to environmental health risks including respiratory conditions, typhoid, diarrhea, hepatitis, and other waterborne infections because of these unsatisfactory waste management practices (Cruvinel et al., 2019). Unfortunately, waste management infrastructure which is essential for healthy living has not been given the same attention as electricity and water, particularly in developing nation's leading to adverse effects on the residents in these places (Vergara & Tchobanoglous, 2012).

Waste management systems involve a wide range of factors comprising social, political, environmental, and technological factors. These factors are all linked together and evolve throughout time (Ahmed et al., 2023). The six organizational functions of waste management include waste generation, collection, transportation, disposal, treatment, and reform (Tchobanoglous & Kreith, 2002). Also, data on MSWM provides valuable information for improving waste management, especially in cities (Zohoori & Ghani, 2017). It is however important to note that, efforts to manage solid waste effectively must go along with waste reduction which involves actions like source reduction, recycling, and reusing materials (Dawda Badgie et al., 2012). Similarly, efforts to preserve the environment and human health must include Integrated Solid Waste Management (ISWM). ISWM is a comprehensive solid waste management approach that concentrates on solid waste prevention, and recycling (US EPA,

2014). These actions can lessen the quantity of waste that has to be processed and disposed of in various places, therefore, lessening its impact on the environment and human health.

Solid waste management issues have become very challenging in Ghana, one of the African countries that are urbanizing at a rapid pace (World Urbanization Prospects, 2018). In Ghana, large amounts of solid waste have been produced in main urban centers as a result of the country's fast urbanization and population increase, outpacing the capacity of the local government to handle and dispose of waste in a hygienic way (Lissah et al., 2021a). The uncontrolled dumping of waste in public spaces demonstrates the country's officials' weak waste management capabilities. In the five main cities of Ghana, Accra, Tema, Kumasi, Takoradi, and Tamale, the percentage of solid waste that is collected and dumped in sanitary landfills was 79% in 2015, 70% in 2017 and 85% in 2021 (Ministry of Sanitation and Water Resources, 2021). Currently, the Greater Accra region which houses Ghana's capital Accra is facing several challenges including solid waste management (Tutu, 2014). The quantity of solid waste generated in the region is increasing as the region's population grows and the population density rises.

With the substantial volume of waste produced from many sources within the Greater Accra region, the urban leadership is still under tremendous struggle to manage waste in an environmentally friendly manner. The unlawful formation of informal settlements and congestion in cities has led to careless waste disposal practices in such areas (Omona & Maderu, 2022). SWM demands of high-density low-income settlements are frequently unmet owing to a lack of space and the inability to provide alternative measures for waste disposal, although these communities have the greatest need for such services (Marshall & Farahbakhsh, 2013). For instance, as Greater Accra's population keeps growing, more people, especially the urban poor,

are forced to live in slums, where the living conditions are poor and there are no facilities for disposing of trash. Consequentially, wastes generated by people who live in such areas are been deposited in open areas, resulting in mosquito breeding grounds and leaching into soil and rivers, leading to contamination of food, water, and soil, which may result in major health and environmental impacts (S. Kumar, 2016; Marshall & Farahbakhsh, 2013). In the long run, these challenges have an impact on the wellness of all urban residents as well as the standard of living of urban impoverished people (Oduro-Kwarteng, 2011). Sadly, the poor suffer disproportionately from the effects of inadequate waste management because they are frequently uninvolved in or have little control over the official or informal waste disposal site which is often known to be sited in the surroundings of such individuals (Serge Kubanza & Simatele, 2020).

Management of urban solid waste could be very expensive due to its complex operation ranging from generation and composition to disposal and treatment (Kaza et al., 2018). Policy barriers add to 75% of solid waste mismanagement in developing countries (Aparcana, 2017). Most developing countries have recognized the dangers of pollution from poor management of solid waste and have begun to consider improved technology and low-cost efficient solutions (S. Kumar, 2016) but MSWM has received less attention in underdeveloped nations due to limited resources and technological availability. Typically, the sector responsible for the management of waste is solely unable to adequately get rid of this trash, resulting in a pollution concern for the inhabitants especially surrounding neighborhoods of landfill sites. For instance, the stinking, rotten waste around the community and residences near the trash dump may pose health risks that affect the quality of life ((Phuttharak & Dhiravisit, 2014).

Ghana's planning for SWM has been unsuccessful due to inadequate reliable data on solid waste generation and thus substantially contributes to the improper disposal of solid waste in the

country (K. O. Boadi & Kuitunen, 2003). Also, inadequate regulation, widespread opposition, a lack of appropriate and well-maintained infrastructure, lack of systematic land use planning, hinders proper waste and sanitary management strategies in Accra, Ghana (K. O. Boadi & Kuitunen, 2003). Nonetheless, the growing volume of MSW constitutes a significant environmental risk as a substantial volume of MSW takes up precious land area (Cheng et al., 2020). Unattended solid waste could lead to serious health impacts if the appropriate facilities needed for its management are not provided (Douti et al., 2017). Although environmental issues affect all urban dwellers, the urban poor are exposed to higher risk than the ordinary urban resident because, usually they cannot afford the amenities and services that provide a healthy living environment (K. O. Boadi & Kuitunen, 2005). Waste from decades of economic expansion that has gone unmanaged and badly handled, needing immediate attention at all levels of society to ensure sustainable living while contributing to goals 6 of the sustainable development goals (clean water and sanitation) and 11 (sustainable cities and communities) (UNDP, 2015). Therefore, it is significant to put in place efficient management systems and policies, especially in urbanizing cities to accomplish MSW reduction. Thus, the motivation behind this study.

This study focuses on the impact of the rapid rate of urbanization on municipal solid waste management in the Greater Accra region of Ghana. It is therefore hypothesized that the rapid rate of urbanization in the region places an excessive strain on solid waste management challenges because of inadequate sanitary facilities and governance to accommodate the expanding needs of the urban dwellers. Primarily, this effort is necessary for a holistic and integrated approach collaboratively between government officials, cooperating entities, and inhabitants, especially in the Greater Accra region to address the challenges the region is facing in

managing its solid waste. This could be done through further incorporation of matters of MSWM in their decisions while ensuring effective urban planning and development.

3.2. Background of the study

3.2.1 Generation and Composition of Municipal Solid Waste

The generation of waste is a fundamental aspect of human activity that is affected by social processes and economic growth (Ayuba et al., 2013). The intense drive of human civilization toward modern urban living creates vast volumes of municipal solid waste since the rate of its generation outpaces the rate of urbanization across the world, particularly in emerging countries (Sujauddin et al., 2008). Generally, there is more waste generated than a disposal system can handle, and the amount of waste generated keeps growing as cities grow and the population density rises (Jenna R. Jambeck et al., 2015). Municipal solid waste (MSW) is a natural consequence of human activity that originates because of inefficient use of resources and energy. Due to the possibility that certain MSW may be harmful to human health, they cannot be directly reused for societal benefit (K. D. Sharma & Jain, 2020). Table 3.1 shows various sources of generation of MSW.

Table 3. 1 Sources of Generation of Municipal Solid Waste

Domestic Waste	Kitchen waste, old documents, wrapping, bottles, earthenware: plates, dishes waste, furniture materials, and lawn clippings are examples of household waste.
Commercial Waste	Naturally produced, inorganic substances, chemically reactive, and toxic waste produced

	in commercial buildings, retail stores, offices, marketplaces, and department stores (paper, wrapping materials, spoilt rejected items.
Institutional Waste	Waste from institutions such as schools, hospitals, hotels, restaurants, markets, community centers, and houses of worship.
Street sweeping	Unperturbed throwing, littering from pedestrians, vehicles, stray animals, tree leaves on the side of the road, trash from cleaning the drains, and debris.
Industrial waste	Waste is generated by the manufacturing and material processing industries.
Construction rejects	Frequent road construction activities involve the use of different utilities using brick, stones, logs, etc.
Waste offal and dead animals	Offal waste is generated by cold storage facilities, food-packing plants, and slaughterhouses.

Source: Dr. Adrain Coad (2001), Swiss Center for Development Corporation in Technology and Management (SKAT), Switzerland, cited in (Tchobanoglous & Kreith, 2002).

The issue of urbanization has a direct impact on waste generation. Poor management of this could hurt both the urban environment and human well-being. In 2018, the World Bank Projected that by 2050, the generation of solid waste will double globally, especially across two

key continents, Africa and Asia (Wilson & Velis, 2015). The amount of waste produced annually in emerging nations would rise to 480,000,000 tons, compared to 86,000,000 tons in industrialized nations by 2025 (Deku, 2020). For example, India alone generated 52.9 million tons of solid waste in 2018 and 53.2 million tons in 2019 (Ministry ofHousing and Urban Affairs India, 2019). In 2025, waste management will require a total investment of $375 billion with the amount of waste produced by urban dwellers predicted to nearly double to 6.1 million metric tons/day in 2025 compared to 3.5 million metric tons/day in 2002 (Khandelwal et al., 2019). Several kinds of literature reveal that a large proportion of the solid waste generated in developing nations has its sources between (55 and 80 percent), markets (10 to 30 percent), organizations, and a few other sources from homes (Nabegu, 2010; Nagabooshnam, 2011; Okot-Okumu, 2021). The amount of solid waste produced is mostly proportional to a society's economic status (Shekdar, 2009). Also, the rise in living conditions brought about by the industrial revolution and subsequent economic growth has fundamentally altered peoples' consumption patterns (Gour & Singh, 2023) which likewise has an impact on solid waste generation.

The composition of the MSW of a country changes according to the country's developmental status and gross national revenue (Sondh et al., 2022). *Table 3.2* shows various types of waste and their characteristics. In addition, economic growth, societal standards, geographical location, energy sources, and climate all have an impact on the composition of the waste (Cheremisinoff, 2003).

Table 3. 2 Composition and Characteristics of Types of Waste

Types of waste	**Waste components**
Old newspapers	Magazines, comics, and newspapers

Paper and cardboard	Paper goods including wrapping paper, bags made of paper, paper towels, writing paper, cigarette packaging, books, and corrugated paper boxes are also common.
Food waste	Eggshells, spoilt food, leftover vegetables and fruit, bones from meat and fish, etc.
Plastic	Toys, Styrofoam, plastic containers, bags, etc.
Textiles	headgear, carpets, rags, clothes, and other materials
Rubber and leather	Leather purses, shoes, and tires.
Petroleum products	Glycerin, oil, etc.
Yard wastes	Clippings from plants, flowers, and grass
Wood	Branches from trees, furniture, plywood boxes, toys, and other materials.
Aluminum cans	Cans and other containers made of aluminum
Metals	Iron, steel, wire, automobile components, etc.
Glass	Jars, bottles, shattered glass, etc.
Inert material	Sand, dirt, ashes, cinder, tiles, bricks, tiles, pottery, etc.
Hazardous wastes	Pesticides chemicals, batteries, etc.

Source: Soncuya and Viloria, 1992 cited by (Tchobanoglous & Kreith, 2002).

The generation and composition of waste vary from one region to another owing to the various sources of waste production. MSW is generated in substantially greater quantities in

developing and underdeveloped countries with low and moderate incomes (Kumar & Agrawal, 2020)While countries with sophisticated infrastructure and high levels of affluence produce more plastic, glass, metallic trash, and paper (Hasan et al., 2021). Organic waste accounts for 158,000,000 tons of waste produced in developing countries each year (Deku 2017).Various activities that involve the management of municipal solid waste are usually sources of short-lived climate pollutants (Kanhai et al., 2021), and prioritizing this will lead to the reduction of the content of greenhouse gases and average global temperatures will be moderate (Pörtner & Roberts, 2021).

Therefore, it is very important for generated solid waste to be managed properly. For instance, in Ghana, the rate of waste generation varies from a geographic region. The waste generated in the northern savannah areas is higher as compared to the coastal and forest areas (Miezah et al., 2015). The lack of studies on the composition of local solid waste makes effective management problematic in developing countries (Buenrostro et al., 2001). Therefore, effective solid waste management requires appropriate policies and regulations right from the global level through to the local level (Muheirwe et al., 2022).

3.2.2 Collection and Transportation

The collection and transportation of solid waste vary from one region to the other and are usually due to differences in geographical location (Deku 2017). Collection and transportation of waste can be defined as the process of gathering unwanted materials and conveying them from their source of generation to the point of destination for disposal or treatment (Momodu et al., 2011). Waste collection is an important step before its treatment and utilization. One of the most expensive procedures in solid waste management is the process of collecting and transporting waste and this is the reason why it is significant to have an optimized system to operate these

activities smoothly and efficiently as possible while ensuring cost reduction (Afzal et.al.2022). In developing countries, there is a high percentage of records for uncollected waste mainly due to challenges associated with urban planning (Faten Loukil & Lamia Rouachad, 2020) including poor institutional, legislative, and participative strategies (Hettiarachchi et al., 2018). Waste collection systems can be grouped into formal, informal, and formalized techniques (Gutiérrez et al., 2019). The informal or traditional techniques are when citizens separate their waste for it to be collected by city officials or quality private services. The informal technique is when the waste is separated by recyclers without any formal process (Tong et al., 2021). The formalized technique is a combination of both the formal technique and the informal technique with an authorized system (Kashyap & Visvanathan, 2014).

Most developed countries have made huge sums of investment towards efficient management of solid waste, which constitutes collection and disposal of solid waste while developing countries are still struggling to attain effective management of their solid waste (Deku 2017). Comparably, most developing countries lack appropriate technological skills and infrastructure or tools and equipment for waste management (Singh et al., 2022). Solid waste can be collected and transported by trucks, tricycles, central containers, push carts, wheelbarrows, and others. Usually, waste collection vehicles collect waste and transfer it to haulage vehicles for transportation to a disposal facility (Chaerul et al., 2007). For instance, in Ghana, 13.2% of solid waste is collected using tricycles, and Greater Accra is the region where this practice is most common. Ghana only has a 33.4% household solid waste collection rate, with a significantly higher urban 51 percentage than a rural 33.4% percentage. 57.3% of rural households in Ghana use an open area or public landfill for the dumping of their solid waste whereas urban households constitute 24.6% (Ghana Statistical Service 2021).

3.2.3 Disposal and Treatment

An unorganized municipal solid waste (MSW) disposal system stresses ecosystems and disrupts multiple natural cycles as well as human health (Abir et al., 2023). The places available for the disposal of solid waste are decreasing as regions grow more urbanized at the same time as the amount of waste produced by residents is generally rising (Leao et al., 2001). Therefore, maintaining a healthy urban environment requires a system that is effective at disposing of solid waste (Yankson & Gough, 1999). The rising amount of waste needs to be disposed into landfills despite all attempts to minimize, recycle, and reuse waste. Unfortunately, sanitary landfilling procedures have not been successfully implemented, most likely as a result of ineffective operational management and bad design (Shekdar, 2009) even though several countries are increasingly acknowledging its importance.

Solid waste can be disposed of in a variety of ways and when selecting the best one, it is important to take local factors into account (Schindler & Demaria, 2020). Usually developing countries dispose of their solid waste in either engineered landfill sites (Shaker & Yan, 2010) or nonengineered landfill sites (Rana et al., 2017; A. Sharma et al., 2019). Engineered landfill sites are often known to include an impermeable liner and drainage system at the ground level of the dump purposely to prevent leachate from seeping into the subsurface (Mor et al., 2006). On the other hand, non-engineered landfill sites are known for the movement of leachate under and around the dump site in these which usually results in the degradation of the adjacent surface and sub-surface water resources (Ghosh & Kartha, 2022).

Means of solid waste disposal and treatment include:

- ***Landfilling***: Landfilling is a method of waste disposal where solid waste is dumped directly on the ground (Ojha et al., 2007). This is very common in urban centers where

solid waste is dumped directly on the ground which is geographically a low-lying area located outside the city without following any sanitary landfilling principles. As a result, methane, a potent greenhouse gas that influences global warming, may be produced (Pazoki et al., 2015).

- ***Recycling****:* Recycling is another form of waste treatment. It can be defined as the process by which unwanted materials can be converted or recovered into new forms of material ,products, or substances either for the original or other purposes (Humaid et al., 2023). It contributes to the conservation of natural resources and minimizes the quantity of waste that must be disposed of in different ways. Again, recycling offers an additional advantage by decreasing pollutants, improving mineral recovery, and lowering energy costs for solid waste treatment. Yet, recycling has made solid waste management extremely complicated (H. Wang et al., 2020).
- ***Composting***: This is a means of disposing of solid waste where organic waste can be transformed naturally into a nutrient-rich soil additive by composting. It is a sustainable and efficient method of disposing of organic waste (Gajalakshmi & Abbasi, 2008).
- **Incineration**: Incineration is the process of burning waste at high temperatures to minimize the volume of waste and create renewable energy in the form of heat or power (Udomsri et al., 2011). Nevertheless, incineration can emit dangerous chemicals into the atmosphere. Notwithstanding, efforts to minimize (GHG) emissions from the waste sector demand more efficient trash collection and waste treatment systems and these are required, particularly in most developing countries (Oteng-Ababio et al., 2013).

Every method of disposal has benefits and drawbacks, and the best option will be determined by several elements, including the kind and volume of waste produced, local laws, and the accessibility of infrastructure and resources. To minimize the amount of waste that must be dumped in landfills or incinerators, a mix of techniques such as waste reduction, recycling, and composting can be used. Landfills sites are the traditional means of municipal solid waste disposal in Ghana (Amano et al., 2021). Many urban places in Ghana are currently battling solid waste disposal due to the failure of allocation of lands for landfills during urban planning. As a result, landfill sites are chosen inconsistently specially to meet the increasing waste generation associated with population growth without appropriately specified criteria. However, this puts other SWM systems under pressure and as well contributes to making solid waste management a key environmental issue.

3.3 Current Solid Waste Management in the Greater Accra Region

Management of solid waste comprises all the systematic approaches ranging from generation, separation, collection, transportation, disposal, and treatment (Abila & Kantola, 2017). Ghana neither has a long history of physical planning nor a solid framework for managing urban environmental issues. In Ghana, the Ministry of Local Government, Decentralization and Rural Development (MLGDRD), the Ministry of Sanitation and Natural Resource together with the Town and Country Planning Department (TCPD) oversee establishing policies and guidelines for the use and development of properties, as well as creating comprehensive development plans and recommendations to guide development. Even though there have been several attempts to address the problems associated with SWM in the country, it is still not being approached holistically. Accra's per capita waste generation of 0.70kg per day from households, markets, and institutions (Accra Metropolitan Assembly, 2020). It is saddening to know that only 10% of the country's

daily solid waste generation, which is estimated to be 12,710 tons, is collected, and dumped in approved landfills (Lissah et al., 2021b). Most of the waste is biodegradable (organics and papers), while the least typical is non-biodegradable (metals, glass, fabrics, leather, and rubbers). In 2020, the Ministry of Sanitation and Water Resources of Ghana estimated that the Greater Accra Region alone produced 4,260 tons of solid waste daily 2020 (Ministry of Sanitation and Water Resources, 2021). This is equivalent to over 1.55 million tons of waste yearly. However, 80% of the total solid waste generated in the region was collected in the same year (Ministry of Sanitation and Water Resources, 2021). Nevertheless, most communities in the region still lack waste collection services.

Figure 3. 1 Accumulation of solid waste in unhygienic way in the Greater Accra Region

Image A was obtained from (Acquah, 2021), *Image B* from (Prime News Ghana, 2018), *Image C* (Hagan, 2015), and *Image D* from (Segbefia, 2021).

Management of solid waste has become a significant concern for the Greater Accra region over time due to high volumes of human engagement in diverse productive activities. The region's expanding solid waste production has outpaced its current waste management infrastructure,

resulting in uncollected waste, indiscriminate dumping, and pollution of streets, drains, and aquatic bodies. *Image A* is the Odawna River located in the Greater Accra region. The river is specifically known for its vulnerability to annual flooding due to the constant accumulation of solid waste in the river and its tributaries. Plastics, food waste, and other debris are often disposed of improperly, especially by the urban inhabitants, which end up in the river. This waste accumulates over time and causes blockages that prevent the free flow of rainwater causing the river to overflow its banks whenever it rains heavily. Meanwhile, the river serves as a major drainage channel for the city's central business district and its surrounding areas. *Image B* shows an overflowing neighborhood trash container. This could be a result of irregular times associated with the waste collection trucks. This can lead to unpleasant odors, unsanitary conditions, and health hazards, especially for the residents who live near the trash container. *Image C* shows a gutter filled with piles of solid waste which is a common situation in the region. *Image D* is a picture of the Oblogo landfill site (the oldest landfill site) also located in the Greater Accra region of Ghana.

Oblogo was a primary waste disposal facility in the Greater Accra area which is 12.8 kilometers from Accra. It ran for almost six years and was run by the Accra Metropolitan Assembly. The facility was not adequately decommissioned when operations ended, which allows additional leachate to be produced each time it rained (Sackey et al., 2020). The leachate is discharged into the Densu wetland (Osei et al., 2011).

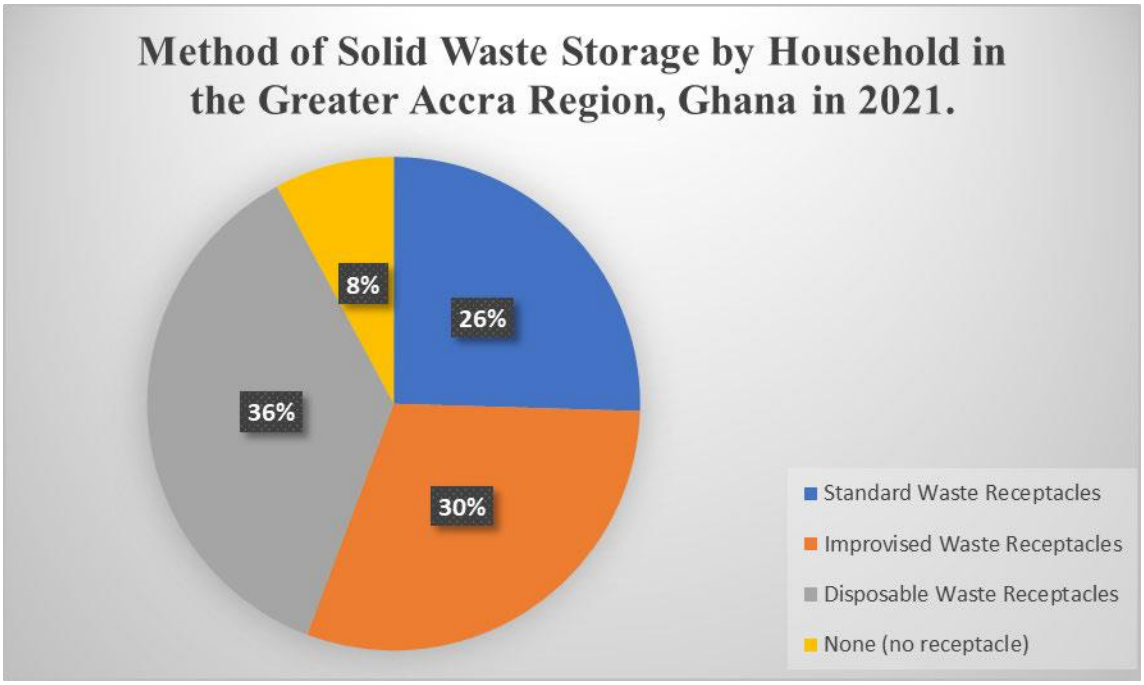
Unfortunately, the Oblogo landfill is poorly situated next to a wetland of ecological significance, and in an area with competing land uses, resulting in nuisances including noise, odor, vermin infestation, and rubbish dispersal (Osei et al., 2011). All these hurt human health and ground- and surface water pollution. Therefore, this calls for the need for stakeholders and urban

inhabitants to put necessary measures in place to ensure waste reduction and recyclable activities towards the management of solid waste in the region.

Ghanaian city governments spend roughly GHc 6.7 million on waste collection and transportation each year, and GHc 550,000.00 monthly to waste contractors to keep landfills operating (Ministry of Sanitation and Water Resources, Ghana, 2019). Poor sanitary conditions alone cost the country $290 million a year, or 1.6% of the country's Gross Domestic Product (GDP) (Lissah et al., 2021a). The most prevalent method of Ghana's solid waste disposal is still through landfills (Ghana Statistical Service, 2021). Also, in the Greater Accra region, landfills are the most predominant method of solid waste disposal and the most common of these landfill sites in the region include "Mallam SCC" landfill, "Abokobi" landfill site, and "Tema-Kpone" landfill site (Rockson et al., 2013). In 2019, the Ministry of Sanitation and Water Resources (MSWR) estimated that by the year 2020, the region's landfills will have a total capacity of about 10 million cubic meters (Ministry of Sanitation and Water Resources, 2021). In addition to this, in December 2021, MSWR disclosed that it has secured a 65.5-acre land for the development of a new engineered landfill site in Ayidan in the Greater Accra Region's Ga South Municipality (Segbefia, 2021). Despite these efforts, much more needs to be done to address the root causes of the problem and ensure sustainable management of waste.

Figure 3. 2 Methods of storing household solid waste in the Greater Accra Region.

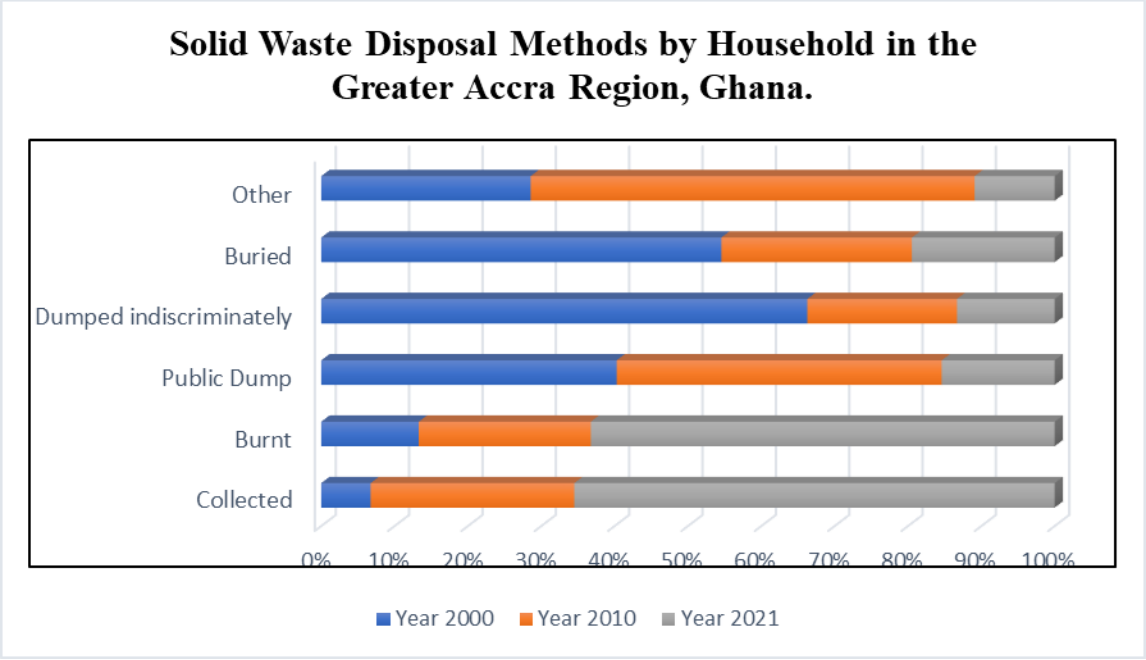
Source of data*: (Ghana Statistical Service, 2021).*



The current situation of solid waste in the Greater Accra region of Ghana is concerning due to inadequate waste management infrastructure and poor waste disposal practices. Usually, storage of solid waste in Ghana is done using various means comprising of standard waste receptacles (covered standard waste bin and uncovered standard waste bin), improvised waste receptacles (covered container, uncovered container, and covered/uncovered basket), disposal waste receptacles (sack, polythene bag alone, among others) and none (no receptacle). Receptacle refers to a container (trash bin) or anything that temporarily stores created waste (Ghana Statistical Service, 2021). Out of the total solid waste generated in the Greater Accra region, standard waste receptacles are used to store 26%, improvised waste receptacles 30%, disposal waste receptacles 36%, and no receptacle is used to store 8% as seen in Figure 3.2. This shows how prevalent the storage of waste in disposable waste receptacles is in Greater Accra. Unfortunately, it happens to be the most unsustainable way of storing

waste. Solid waste storage in suitable containers is not generally performed in cities in developing countries (Batool & Ch, 2009) and this includes the Greater Accra region of Ghana. This could be due to the lack of knowledge about solid waste, storage, inappropriate container placement at storage facilities, and access to solid waste storage infrastructure, as well as cultural attitudes towards waste disposal. All these could lead to environmental pollution, public health hazards, and ecosystem damage.

Figure 3. 3 Methods of disposing of household solid waste in the Greater Accra Region *Source of data:* **(Ghana Statistical Service, 2021).**



Reports from the 2021 population and housing census by the Ghana Statistical Service reveal that 11.1% of households in Ghana do not have any form of receptacle for solid waste generated. Also, 33.4% of households have their solid waste collected and 13.2 % out of the total households who have their solid waste collected have them done using tricycles and this is prevalent in Greater Accra where 42.4% of households have their solid waste collected through

the use of tricycles. Comparably, 29.1% of households in Ghana do not have their solid waste collected (Ghana Statistical Service, 2021). Similarly, uncollected solid waste is disposed of through burning, indiscriminately dumping, and burying in the ground, among others and this constitutes 77.5%, 11.4%, and 0.5% respectively. In the Greater Accra Region, open burning of waste is a frequent practice and the most common technique for getting rid of uncollected solid waste, especially in low-income areas (Cogut, 2016). Figure 3.3 shows the various methods of solid waste disposal in the Greater Accra region in the years 2000, 2010, and 2021. In the year 2000, only about 10% of solid waste generated in the region was collected and this increased to 35% in 2010 and 55% in 2021. This shows how much effort has been put in place to encourage sustainable means of waste disposal in the region.

Yet, more work needs to be done to get the remaining percentage associated with the uncollected method addressed. Also, the burning method of disposing of solid waste by households increased exponentially from 15% in 2000 to 30% in 2010 and 55% in 2021. Comparably, solid waste dumped indiscriminately and buried by households has dropped from 70% and 55% in 2000 to 10% and 15% in 2000 to 10% and 15% in 2021 respectively. Additionally, public dump and other means of solid waste disposal which does not fall under any of the waste disposal categories have received a significant improvement dropping from 40% in 2000, 45% in 2010, and 15% in 2021 for the public dump and 30% in 2000 to 60% in 2010 and 10% in 2021 for the others. Overall, the improvement in the sustainable methods of solid waste disposal in the region could be associated with technological advancements, public demand and awareness, legal restrictions, and economic advantages. Therefore, serving as a means of fostering environmental sustainability.

3. 4. Method

3.4.1 Data

As part of the research question on the management of solid waste, the study analyzed how rapid urbanization affects solid waste disposal in the Greater Accra Region of Ghana. Secondary data for the population and housing census report of Ghana from 1990 to 2021 was derived from the Ghana Statistical Service (GSS) online database for analysis. The reports provide information on various socio-economic characteristics such as educational status, employment status, and solid waste disposal methods, among others of the regions in the country including the Greater Accra region. This will help to identify areas that may require special attention in terms of waste collection and disposal.

3. 4.2 Statistical Analysis

As part of the study, urbanization was assessed using data on Household Population (Hhpop), Number of Households (No_of_HH), Population 15 years and above who are not literate (illiterate) (Pop15y_Nli), Population 15 years and above who are literate (Pop15yr_L), Population 15 years and above who are employed (Pop15y_Emp), Population 15 years and above who are unemployed (Pop15y_Uem) and Average Household Size (Av_HH_Size) using Statistical Package for the Social Sciences (SPSS version 25). Similarly, waste disposal methods were assessed using collected, burnt, dumped indiscriminately, and buried waste disposal methods. Multiple regression analysis was conducted to find the effect of household population on each of the waste disposal methods in the Greater Accra Region of Ghana. Regression analysis is a technique for describing conditional connections in data (Berk, 2010). The regression analysis is important for this study because it can be an effective tool for the analysis of solid waste disposal in the study area especially because it can help identify and examine the impact of multiple factors that influence the various methods of solid waste disposal by

households in the study area. By examining the relationship between the dependent variable (the various methods of solid waste disposal) and the independent variables (household population size, and socio-economic variables comprising of, educational status (literate or illiterate), employment status (employed or unemployed), and average household size would help provide insights into which factors are most important in determining waste disposal patterns in the Greater Accra region. Also, Analysis of Variance (ANOVA) is a statistical technique used to determine if the means of two or more groups differ significantly from one another (Schad et al., 2020). This was used to determine whether changes in a variable under the study would have a significant effect on another variable.

3. 5 Results and Discussion

Table 3. 3 ANOVA (effect of rapid urbanization on the collection method of waste disposal)

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**R**	**R Square**
1	Regression	1559679297597.153	7	+222811328228.165	28.857	.000*	.950	.902
	Residual	169866987163.647	22	7721226689.257				
	Total	1729546284760.800	29					

a. Dependent Variable: collection method of waste disposal. p<0.05*

b. Predictors: (Constant), Av_HH_Size, Pop15y_Nli, Pop15y_Uem, Pop15y_Emp, Hhpop, No_of_HH, Pop15yr_L

Table 3.3 showed the ANOVA test used to determine whether the model for measuring the effect of rapid urbanization on the collection method of waste disposal is fit for the study.

The model is said to be fit for the sample if the p-value of the F-statistic is less than the significance value of 0.05. Similarly, the model is considered unfit for the sample if the F-statistic p-value exceeds the significance level of 0.05. From Table 3.7.1, the F-statistic ($F = 28.857$, $df = 7$, $p<0.05$) leads to the inference that the study's linear regression model is adequate for explaining the effect of rapid urbanization on collected as a selected method of waste disposal. The r square value of .902 revealed that 90.2% of the variance in the dependent variable (collected) is influenced by the independent variables. Table 3.4 showed the coefficients of the regression analysis.

Table 3. 4 Coefficients (effect of rapid urbanization on the collection method of waste disposal)

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	-665577.740	150889.405		-4.411	.000
	Hhpop	-.008	.027	-.053	-.300	.767
	No_of_HH	.768	.188	1.188	4.088	.000
	Pop15y_Nli	-.344	.133	-.290	-2.577	.017
	Pop15yr_L	.174	.174	.582	1.000	.328
	Pop15y_Emp	-.231	.152	-.475	-1.518	.143
	Pop15y_Uem	.143	.528	.041	.270	.790
	Av_HH_Size	117577.298	31100.726	.587	3.781	.001

a. Dependent Variable: Collected

The coefficients shown in Table 3.4 for the regression analysis showed that there is no significant relationship between the household population (Hhpop), Population of persons with ages 15 years and above who are literate (Pop15y_L), Population 15 years and above who are employed (Pop15y_Emp), population 15 years and above who are unemployed (Pop15y_Uem) and collected as a method of solid waste disposal. This is because each of these variables is not statistically significant. Even when simulating solid waste disposal, it is critical to take economic issues like the unemployment rate into account, particularly during economic downturns when economic reasons might outweigh the impact of population change on waste creation and, consequently, disposal (Khajevand & Tehrani, 2019).

However, the study showed that there is a significant relationship between the number of households, the Population of 15 years and above who are not literate, the Average household size, and the collection method of solid waste disposal. Specifically, several households have a significantly positive ($\beta = 0.768$, $p < 0.05$) effect on the collection method of waste disposal. Also, the Population of 15 years and above who are not literate has a significantly negative ($\beta = -0.344$, $p < 0.05$) effect on the collection method of waste disposal while average household size had a significantly positive ($\beta = 117577.298$, $p < 0.05$) effect on waste disposal. Thus, a unit increase in the number of households and average household size will increase the collected method of waste disposal by 0.768 and 117577.298 units respectively, and vice versa. Again, a unit increase in the population of 15 years and above who are not literate will reduce the collected method of waste disposal by -.344 units and vice versa.

This result showed that the sustainable way of collecting waste (collected method) increased as the number of households and average household sizes increases. Thus, the populace has increased their awareness of sustainable ways to dispose of waste. The

understanding is that when people move to urban areas in search of job opportunities or better education, there will be an increase in solid waste generation in several forms (K. Boadi et al., 2005), which has various negative effects on the environment, public health, and quality of life. However, the study showed that while there's an increase in people and solid waste materials, there is an improvement in the sustainable way of collecting this waste from the region.

Zoomlion, a government-owned company was established to collect waste substances from all communities in the region. Zoomlion provided bins at vantage positions and homes in an attempt to reduce indiscriminate waste disposal and its effect on the environment. However, the population 15 years and above who are illiterate reduces the sustainable way of handling waste as awareness and willingness to cooperate was minimal. Therefore, causing illiterate pollution 15 years and above to dispose of their solid waste in other methods than in solid waste collection bins. This confirms (Debrah et al., 2021) research findings that, when it comes to environmental sustainability challenges, age, and education are directly proportionate to environmental attitudes, knowledge, and practice. Correspondingly, the sustainability of waste management is affected by people's lack of practical environmental knowledge, which inevitably affects their understanding of sustainable waste management (SWM) and its related environmental challenges (Debrah et al., 2021). Therefore it is important to note that illiteracy contributes to SWM mismanagement (Rahman, 2013). Therefore, Greater Accra's unsustainable solid waste disposal can be associated with illiteracy among the existing and in-migrating population. Thus, as the population increases and illiterate people also increase, there will be more indiscriminate disposal of waste as these people do not help in a sustainable way collecting waste.

Table 3. 5 ANOVA (effect of rapid urbanization on the burnt method of waste disposal by households)

Model		Sum of Squares	df	Mean Square	F	Sig.	R	R Square
1	Regression	205910484841.457	7	29415783548.780	18.673	.000[b]	.925[a]	.856
	Residual	34656164589.210	22	1575280208.600				
	Total	240566649430.667	29					

a. Dependent Variable: Burnt_HH

b. Predictors: (Constant), Av_HH_Size, Pop15y_Nli, Pop15y_Uem, Pop15y_Emp, Hhpop, No_of_HH, Pop15yr_L

ANOVA test was used to determine the effect of rapid urbanization on the burnt method of waste disposal by households. The results showed that the F-statistic ($F = 18.673$, $df = 7$, $p<0.05$) is significant and that the study's linear regression model is adequate for explaining the effect of rapid urbanization on the burnt method of waste disposal by households. The r square value of .856 revealed that 85.6% of the variance in the dependent variable (burnt_HH) is influenced by the independent variables. Table 3.6 Coefficients (effect of rapid urbanization on the burnt method of waste disposal).

Table 3. 6 the coefficients of the regression analysis.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-53517.409	68154.495		-.785	.441
	Hhpop	-.006	.012	-.105	-.494	.627
	No_of_HH	.256	.085	1.062	3.017	.006
	Pop15y_Nli	.057	.060	.128	.938	.358
	Pop15yr_L	.123	.079	1.096	1.554	.134
	Pop15y_Emp	-.219	.069	-1.211	-3.193	.004
	Pop15y_Uem	-.120	.238	-.094	-.505	.618
	Av_HH_Size	16738.260	14047.734	.224	1.192	.246

a. Dependent Variable: Burnt_HH

The coefficients shown in Table 3.6 for the regression analysis showed that the household population (Hhpop), Population 15 years and above who are illiterate (Pop15y_Nli), Population 15 years and above who are literate (Pop15y_L), Population 15 years and above who are unemployed (Pop15y_Uem) and Average household size (Av_HH_Size) does not have a significant relationship with the burnt method of solid waste disposal. This is because each of these variables has p values greater than 5% alpha level. However, the study showed that the number of households, a Population of 15 years and above who are employed significantly predicts the burnt method of waste disposal. Specifically, the number of households has a significantly positive ($\beta = 0.256$, $p < 0.05$) effect on the burnt method of solid waste disposal. Also, the Population of 15 years and above who are employed has a significantly negative ($\beta = -0.219$, $p < 0.05$) effect on the burnt method of solid waste disposal. Thus, a unit increase in the

number of households will increase the burnt method of solid waste disposal by 0.256 and vice versa. Again, a unit increase in the population of 15 years and above who are employed will reduce the burnt method of waste disposal by -.344 units and vice versa.

The study showed that the number of households and population 15 years and above who are employed, influenced the burnt method of disposing of waste substances in the region. Specifically, an increase in the number of households increases the possibility of burning waste as a means of disposing of waste while an increase in the population 15 years and above who are employed reduces the possibility of burning waste substances. This is not surprising as people who are employed in the region mostly leave for work early in the morning around 5 to 7 am to avoid traffic and get to work early and they mostly return late at night thereby making it difficult for them to burn their waste substances. This group of individuals will resort to using other means of disposing of solid waste rather than burning it. It was also seen that the total number of households increases the chances of burning waste substances. This is not a surprise as some households turn their backyards into places to gather waste and burn it over a period. Though this unsustainable SWM could result in contamination of the water, air, and soil, dangers to human health and safety, potential for global warming (GWP), and marine pollution (Ferronato & Torretta, 2019), this might be an attempt to reduce expenses by the households given that no expenses are incurred in burning waste in one's backyard in contrast to paying individuals who gather and dispose of waste at designated waste disposal locations or landfill sites

.

Table 3. 7 ANOVA (effect of rapid urbanization on indiscriminate dumping of waste disposal by households).

Model		Sum of Squares	df	Mean Square	F	Sig.	R	R Square
1	Regression	24646363583.937	7	3520909083.420	8.833	.000[b]	.859[a]	.738
	Residual	8769798652.229	22	398627211.465				
	Total	33416162236.167	29					

a. Dependent Variable: Dumped Indiscriminately

b. Predictors: (Constant), Av_HH_Size, Pop15y_Nli, Pop15y_Uem, Pop15y_Emp, Hhpop, No_of_HH, Pop15yr_L

Table 3.7 showed the ANOVA test used to determine whether the model for measuring the effect of rapid urbanization on indiscriminate methods of waste disposal is fit for the study. The model is said to be fit for the sample if the p-value of the F-statistic is less than the significance value of 0.05. Similarly, the model is considered unfit for the sample if the F-statistic p-value exceeds the significance level of 0.05. From Table 3.7, the F-statistic ($F = 8.833$, $df = 7$, $p<0.05$) leads to the inference that the study's linear regression model is adequate for explaining the effect of rapid urbanization on indiscriminate methods of waste disposal. The *R square* value of .738 revealed that 73.8% of the variance in the dependent variable (dumped indiscriminately) is influenced by the independent variables. Table 3.8 showed the coefficients of the regression analysis.

Table 3. 8 Coefficients (effect of rapid urbanization on indiscriminate dumping of waste disposal)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	56689.248	34284.598		1.653	.112
	Hhpop	-.002	.006	-.098	-.341	.736
	No_of_HH	-.003	.043	-.036	-.075	.941
	Pop15y_Nli	-.005	.030	-.031	-.166	.870
	Pop15yr_L	-.103	.040	-2.469	-2.595	.017
	Pop15y_Emp	.136	.035	2.012	3.932	.001
	Pop15y_Uem	.150	.120	.312	1.249	.225
	Av_HH_Size	-6423.332	7066.605	-.231	-.909	.373

a. Dependent Variable: Dumped_Indisc

The coefficients shown in Table 3.8 for the regression analysis showed that the Population 15 years and above who are literate (Pop15y_L) ($t = -2.595$, $p < 0.05$) and the Population 15 years and above who are employed (Pop15y_Emp) are significant predictors of indiscriminate waste disposal since both variables had p-value less than 5% alpha level. Using the unstandardized coefficients showed that the Population 15 years and above who are literate (Pop15y_L) had a significantly negative ($\beta = -0.103$, $p < 0.05$) effect on the indiscriminate method of waste disposal. Also, the Population of 15 years and above who are employed (Pop15y_Emp) has a significant positive ($\beta = 0.136$, $p < 0.05$) effect on the indiscriminate method of waste disposal. Thus, a unit increase in the number of the population 15 years and above who are literate will cause a decrease in the indiscriminate dumping of waste by 0.103 while an increase in the

Population 15 years and above who are employed will be caused an increase in indiscriminate dumping of waste by 0.136. Similarly, a unit decrease in the number of the population 15 years and above who are literate will cause an increase in the indiscriminate dumping of waste by 0.103 while a decrease in the Population 15 years and above who are employed will cause a decrease in indiscriminate dumping of waste by 0.136.

This analysis revealed that only two variables affect the indiscriminate methods of dumping waste in the region. These variables are the population 15 years and above who are literate and the population 15 years and above who are employed. The study showed that the population 15 years and above who are literate is negatively affected by the indiscriminate dumping of waste in the regions. This was not surprising as those who are educated mostly know the consequences of dumping waste indiscriminately. This brings into bare the significant role education can play in solid waste disposal practices due to increasing awareness of the substantial impact of solid waste generation and its disposal which leads to the promotion of sustainable waste management practices (Babaei et al., 2015).

However, the population 15 years and above who are employed positively contribute to the indiscriminate disposal of waste. People who are employed constitute both the educated and illiterate. The nature of work, businesses, and requirements for working in the region guaranteed that both literate and illiterates qualify to work. In certain situations where working conditions in the region, including traffic jams, demand most workers leave home early and return late. Also, in instances where people work long hours or many jobs, forces most of these workers buy food at the roadside, in cars, and in “take-away” packs. These employed persons may end up disposing of their waste indiscriminately mainly because they might not have the time or energy to segregate waste appropriately into recyclable and non-recyclable items. Therefore, causing

employment is one of the socioeconomic factors that contribute to the waste disposal of waste indiscriminately in the region.

Table 3. 9 ANOVA (effect of rapid urbanization on the buried method of waste disposal by households)

Model		Sum of Squares	df	Mean Square	F	Sig.	R	R Square
1	Regression	1707298758.153	7	243899822.593	3.985	.006[b]	.748[a]	.559
	Residual	1346502325.314	22	61204651.151				
	Total	3053801083.467	29					

a. Dependent Variable: buried_HH

b. Predictors: (Constant), Av_HH_Size, Pop15y_Nli, Pop15y_Uem, Pop15y_Emp, Hhpop, No_of_HH, Pop15yr_L. *p<0.05.*

Table 3.9 The model is statistically significant. Table 8, ($F = 3.985$, $df = 7$, $p<0.05$) leads to the inference that the study's linear regression model is adequate for explaining the effect of rapid urbanization on the buried method of waste disposal. The *R square* value of .559 revealed that 55.9% of the variance in the dependent variable (Burnt Method) is influenced by the independent variables. Table 3.10 showed the coefficients of the regression analysis.

Table 3. 10 Coefficients (effect of rapid urbanization on the buried method of waste disposal)

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	43644.115	13434.076		3.249	.004
	Hhpop	-.002	.002	-.240	-.646	.525
	No_of_HH	-.022	.017	-.809	-1.313	.203
	Pop15y_Nli	.032	.012	.649	2.718	.013
	Pop15yr_L	.021	.016	1.675	1.358	.188
	Pop15y_Emp	-.017	.014	-.808	-1.219	.236
	Pop15y_Uem	-.016	.047	-.114	-.350	.729
	Av_HH_Size	-6040.871	2768.979	-.718	-2.182	.040

a. Dependent Variable: buried_HH

The coefficients for the regression analysis as indicated in Table 3.10 revealed that only the Population 15 years and above who are illiterate (Pop15y_Nli) and Average household size (Av_HH_Size) significantly predicted the buried method of waste disposal. Specifically, the population of 15 years and above who are not literate has a significant positive ($\beta = 0.032$, $p < 0.05$) effect on the buried method of waste disposal while average household size had a significant negative ($\beta = -6040.871$, $p < 0.05$) effect on the buried method of waste disposal. Thus, for every 1 unit increase in the population 15 years and above who are not literate (Pop15y_Nli), there will be a 0.032 increase in the buried method of waste disposal and vice versa. Again, a unit increase in average household size will reduce the buried method of waste disposal by 6040.871 units and vice versa.

This analysis revealed that the population 15 years and above who are not illiterate positively affects the buried method of disposing of waste substances while the average household size negatively affects the buried method of disposing of waste substances in the region. People who are not educated do not know that the traditional burial of waste substances leads to the production of ions, bacteria, fungi, and viruses, that spread along with the soil and underwater. This impacts the quality of soil for plant growth and affects water bodies. Thus, as people increase, and more people are not educated there is an increase in the burial of solid waste in the region. Again, an increase in the average household size reduces the burial of waste substances in the region.

3.5.1 Limitations of the study

Despite the meticulous planning that went into the study, the researcher encountered some unavoidable limitations. The Ghana Statistical Service (GSS) gave its census report with much emphasis on the regional level. Even though in the years 2000 and 2010, there were only 10 regions in Ghana. In 2018, a referendum was proposed for the creation of new regions which was voted on December 27, 2018, which led to the splitting of four existing regions making the current number of regions in the country to be 16. These newly created regions were inculcated into the old ones to make the data reliable. Additionally, the GSS does not have a reliable data management system. Due to the absence of data at the district level, the study utilized country-level data to present findings solely for the Greater Accra region. However, the information gathered became adequate to develop an opinion about the present status of solid waste disposal as part of solid waste management and the challenges involved in the Greater Accra region of Ghana.

3.6 Conclusion

The management of municipal solid waste should be considered a vital component when it comes to issues of sustainable development, especially at the local level through to the national level. With the dearth of suitable systems and effective solid waste management approaches especially towards a successful contribution and the achievement of the SDG. This study focuses on the impact of the rapid rate of urbanization on solid waste management in the Greater Accra region of Ghana. Based on the findings of this research question, the study concluded that rapid urbanization affects waste disposal in the Greater Accra Region of Ghana. Specifically, the number of households, the population 15 years and above who are illiterate, and the average household size affect the "collected" method of waste disposal in the region. Again, the number of households and population 15 years and above who are employed affect the burnt method of waste disposal whereas the population 15 years and above who are literate and employed affect the indiscriminate dumping of waste. Finally, the average household size and population 15 years and above who are not literate affect burial methods of waste disposal. Even though government officials in the country have been contemplating ways to improve the current situation of Greater Accra's municipal solid waste management which has become burdensome before conditions deteriorate to the point when resource planning and efficiency are compromised, there should be effective policies and allocation of resources to advance solid waste generation, collection and transportation, and disposal and treatment in addition to the use of advanced technological mechanisms while taking into consideration specific socioeconomic factors. Therefore, the study proposes that rather than using political influences to address the challenges of solid waste management, it should be handled by competent technical services,

educational programs, and technological innovations. Also, effective measures should be put in place to check population growth, especially rural-urban migration in the Greater Accra region. This information can be useful for designing outreach and education campaigns that are targeted toward specific groups within Greater Accra, such as low-income households or households with limited access to education. Overall, the population and housing census report can be improved upon to serve as a valuable source of data for developing effective solid waste management strategies that are tailored to the specific needs and circumstances of the Greater Accra region in specific and the country in general.

3.7 Reference

Abila, B., & Kantola, J. (2017). Proposed solutions in municipal solid-waste management. *International Journal of Environment and Waste Management*, *19*(4), 297–317. https://doi.org/10.1504/IJEWM.2017.084639

Abir, T. M., Datta, M., & Saha, S. R. (2023). Assessing the Factors Influencing Effective Municipal Solid Waste Management System in Barishal Metropolitan Areas. *Journal of Geoscience and Environment Protection*, *11*(1), Article 1. https://doi.org/10.4236/gep.2023.111004

Acquah, K. A. (2021, October 26). My Green Piece of Mind: Accra, Ghana - Circle floods in pictures. *My Green Piece of Mind*. https://landghana.blogspot.com/2011/10/accra-ghana-circle-floods-in-pictures.html

Ahmed, F., Hasan, S., Rana, M. S., & Sharmin, N. (2023). A conceptual framework for zero waste management in Bangladesh. *International Journal of Environmental Science and Technology*, *20*(2), 1887–1904. https://doi.org/10.1007/s13762-022-04127-6

Amano, K. O. A., Danso-Boateng, E., Adom, E., Kwame Nkansah, D., Amoamah, E. S., & Appiah-Danquah, E. (2021). Effect of a waste landfill site on surface and ground water drinking quality. *Water and Environment Journal*, *35*(2), 715–729. https://doi.org/10.1111/wej.12664

Ayuba, K. A., Manaf, L. A., Sabrina, A. H., & Azmin, S. W. N. (2013). Current Status of Municipal Solid Waste Management Practise in FCT Abuja. *Research Journal of Environmental and Earth Sciences*, *5*(6), 295–304. https://doi.org/10.19026/rjees.5.5704

Babaei, A. A., Alavi, N., Goudarzi, G., Teymouri, P., Ahmadi, K., & Rafiee, M. (2015). Household recycling knowledge, attitudes and practices towards solid waste management. *Resources, Conservation and Recycling*, *102*, 94–100. https://doi.org/10.1016/j.resconrec.2015.06.014

Batool, S. A., & Ch, M. N. (2009). Municipal solid waste management in Lahore City District, Pakistan. *Waste Management*, *29*(6), 1971–1981. https://doi.org/10.1016/j.wasman.2008.12.016

Boadi, K., Kuitunen, M., Raheem, K., & Hanninen, K. (2005). Urbanisation Without Development: Environmental and Health Implications in African Cities. *Environment, Development and Sustainability*, *7*(4), 465–500. https://doi.org/10.1007/s10668-004-5410-3

Boadi, K. O., & Kuitunen, M. (2003). Municipal Solid Waste Management in the Accra Metropolitan Area, Ghana. *The Environmentalist*, *23*(3), 211–218. https://doi.org/10.1023/B:ENVR.0000017283.09117.20

Boadi, K. O., & Kuitunen, M. (2005). Environment, wealth, inequality and the burden of disease in the Accra metropolitan area, Ghana. *International Journal of Environmental Health Research*, *15*(3), 193–206. https://doi.org/10.1080/09603120500105935

Buenrostro, O., Bocco, G., & Bernache, G. (2001). Urban solid waste generation and disposal in Mexico: A case study. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, *19*(2), 169–176. https://doi.org/10.1177/0734242X0101900208

Chaerul, M., Tanaka, M., & V. Shekdar, A. (2007). MUNICIPAL SOLID WASTE MANAGEMENT IN INDONESIA: STATUS AND THE STRATEGIC ACTIONS. 岡山大学環境理工学部研究報告, *12*(1), 41–49. http://eprints.lib.okayama-u.ac.jp/11432

Cheng, J., Shi, F., Yi, J., & Fu, H. (2020). Analysis of the factors that affect the production of municipal solid waste in China. *Journal of Cleaner Production*, *259*, 120808. https://doi.org/10.1016/j.jclepro.2020.120808

Cheremisinoff, N. P. (2003). *Handbook of Solid Waste Management and Waste Minimization Technologies*. Butterworth-Heinemann.

Cogut, A. (2016). *OPEN BURNING OF WASTE: A GLOBAL HEALTH DISASTER*.

Cruvinel, V. R. N., Marques, C. P., Cardoso, V., Novaes, M. R. C. G., Araújo, W. N., Angulo-Tuesta, A., Escalda, P. M. F., Galato, D., Brito, P., & da Silva, E. N. (2019). Health conditions and occupational

risks in a novel group: Waste pickers in the largest open garbage dump in Latin America. *BMC Public Health*, *19*(1), 581. https://doi.org/10.1186/s12889-019-6879-x

Dawda Badgie, Mohd Armi Abu Samah, Latifah Abd Manaf, & Azizi B. Muda. (2012). Assessment of Municipal Solid Waste Composition in Malaysia: Management, Practice, and Challenges. *Polish Journal of Environmental Studies*, *21*(3), 539–547. http://www.pjoes.com/Assessment-of-Municipal-Solid-Waste-r-nComposition-in-Malaysia-r-nManagement-Practice,88782,0,2.html

Debrah, J. K., Vidal, D. G., & Dinis, M. A. P. (2021). Raising Awareness on Solid Waste Management through Formal Education for Sustainability: A Developing Countries Evidence Review. *Recycling*, *6*(1), Article 1. https://doi.org/10.3390/recycling6010006

Deku, P. S. (2020). *AN assessment of sustainable solid waste management in Accra- Ghana.* [MASTERS THESES]. Southern Illinois University.

Douti, N. B., Abanyie, S. K., Ampofo, S., & Nyarko, S. K. (2017). Solid Waste Management Challenges in Urban Areas of Ghana: A Case Study of Bawku Municipality. *International Journal of Geosciences*, *08*(04), 494–513. https://doi.org/10.4236/ijg.2017.84026

Faten Loukil & Lamia Rouachad. (2020). *Waste collection criticality index in African cities | Elsevier Enhanced Reader*. https://doi.org/10.1016/j.wasman.2019.12.027

Ferronato, N., & Torretta, V. (2019). Waste Mismanagement in Developing Countries: A Review of Global Issues. *International Journal of Environmental Research and Public Health*, *16*(6), Article 6. https://doi.org/10.3390/ijerph16061060

Gajalakshmi, S., & Abbasi, S. A. (2008). Solid Waste Management by Composting: State of the Art. *Critical Reviews in Environmental Science and Technology*, *38*(5), 311–400. https://doi.org/10.1080/10643380701413633

Ghana Statistical Service. (2021). *2021 Population and Housing Census*. https://census2021.statsghana.gov.gh/presspage.php?readmorenews=MTY4OTA1MDkwNC4wOTY=&Presentation-on-the-General-Report-Volumes-3A-3B-and-3C

Ghosh, A., & Kartha, S. A. (2022). *Simulation of Heavy Metals Migration in Groundwater from a Non-Engineered Landfill to an Ecosensitive Wetland* [Preprint]. Preprints. https://doi.org/10.22541/essoar.167252706.69360449/v1

Gutiérrez, Coria, & Tejeida. (2019). A Study and Factor Identification of Municipal Solid Waste Management in Mexico City. *Sustainability*, *11*(22), 6305. https://doi.org/10.3390/su11226305

Hagan, K. (2015, May 12). IN PHOTOS: All-Round Filthy Gutters in the Capital | Why Accra Still Records the Highest Cases of Cholera in Ghana in this 21st Century. *GhanaCelebrities.Com*. https://www.ghanacelebrities.com/2015/05/12/in-photos-all-round-filthy-gutters-in-the-capital-why-accra-still-records-the-highest-cases-of-cholera-in-ghana-in-this-21st-century/

Hasan, M. M., Rasul, M. G., Khan, M. M. K., Ashwath, N., & Jahirul, M. I. (2021). Energy recovery from municipal solid waste using pyrolysis technology: A review on current status and developments. *Renewable and Sustainable Energy Reviews*, *145*, 111073. https://doi.org/10.1016/j.rser.2021.111073

Hettiarachchi, H., Ryu, S., Caucci, S., & Silva, R. (2018). Municipal Solid Waste Management in Latin America and the Caribbean: Issues and Potential Solutions from the Governance Perspective. *Recycling*, *3*(2), Article 2. https://doi.org/10.3390/recycling3020019

Hoang, T.-D., Ky, N. M., Thuong, N. T. N., Nhan, H. Q., & Ngan, N. V. C. (2022). Artificial Intelligence in Pollution Control and Management: Status and Future Prospects. In H. L. Ong, R. Doong, R. Naguib, C. P. Lim, & A. K. Nagar (Eds.), *Artificial Intelligence and Environmental Sustainability: Challenges and Solutions in the Era of Industry 4.0* (pp. 23–43). Springer Nature. https://doi.org/10.1007/978-981-19-1434-8_2

Humaid, M., Asad, J., Aboalatta, A., Shaat, S. K. K., Musleh, H., Ramadan, Kh., Alajerami, Y., & Aldahoudi, N. (2023). Gamma and neutron shielding properties of lead-borosilicate shielded glass; novel technique of solid waste recycling. *Construction and Building Materials*, *375*, 130896. https://doi.org/10.1016/j.conbuildmat.2023.130896

Kamaruddin, M. A., Norashiddin, F. A., Hanif, M. H. M., Shadi, A. M. H., Yusoff, M. S., Wang, L. K., & Wang, M.-H. S. (2021). Characterization and Measurement of Solid Waste. In L. K. Wang, M.-H. S. Wang, & Y.-T. Hung (Eds.), *Solid Waste Engineering and Management: Volume 1* (pp. 209–295). Springer International Publishing. https://doi.org/10.1007/978-3-030-84180-5_4

Kanhai, G., Fobil, J. N., Nartey, B. A., Spadaro, J. V., & Mudu, P. (2021). Urban Municipal Solid Waste management: Modeling air pollution scenarios and health impacts in the case of Accra, Ghana. *Waste Management*, *123*, 15–22. https://doi.org/10.1016/j.wasman.2021.01.005

Kashyap, P., & Visvanathan, C. (2014). Formalization of Informal Recycling in Low-Income Countries. In A. Pariatamby & M. Tanaka (Eds.), *Municipal Solid Waste Management in Asia and the Pacific Islands: Challenges and Strategic Solutions* (pp. 41–60). Springer. https://doi.org/10.1007/978-981-4451-73-4_3

Kawai, K., & Tasaki, T. (2016). Revisiting estimates of municipal solid waste generation per capita and their reliability. *Journal of Material Cycles and Waste Management*, *18*(1), 1–13. https://doi.org/10.1007/s10163-015-0355-1

Kaza, S., Yao, L., Bhada-Tata, P., & Woerden, F. V. (2018). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. World Bank Publications.

Khajevand, N., & Tehrani, R. (2019). Impact of population change and unemployment rate on Philadelphia's waste disposal. *Waste Management*, *100*, 278–286. https://doi.org/10.1016/j.wasman.2019.09.024

Khanal, A., Giri, S., & Mainali, P. (2023). The Practices of At-Source Segregation of Household Solid Waste by the Youths in Nepal. *Journal of Environmental and Public Health*, *2023*, e5044295. https://doi.org/10.1155/2023/5044295

Khandelwal, H., Dhar, H., Thalla, A. K., & Kumar, S. (2019). Application of life cycle assessment in municipal solid waste management: A worldwide critical review. *Journal of Cleaner Production*, *209*, 630–654. https://doi.org/10.1016/j.jclepro.2018.10.233

Kumar, A., & Agrawal, A. (2020). Recent trends in solid waste management status, challenges, and potential for the future Indian cities – A review. *Current Research in Environmental Sustainability*, *2*, 100011. https://doi.org/10.1016/j.crsust.2020.100011

Kumar, S. (2016). *Municipal Solid Waste Management in Developing Countries* (0 ed.). CRC Press. https://doi.org/10.1201/9781315369457

Leao, S., Bishop, I., & Evans, D. (2001). Assessing the demand of solid waste disposal in urban region by urban dynamics modelling in a GIS environment. *Resources, Conservation and Recycling*, *33*(4), 289–313. https://doi.org/10.1016/S0921-3449(01)00090-8

Lissah, S. Y., Ayanore, M. A., Krugu, J. K., Aberese-Ako, M., & Ruiter, R. A. C. (2021a). Managing urban solid waste in Ghana: Perspectives and experiences of municipal waste company managers and supervisors in an urban municipality. *PLOS ONE*, *16*(3), e0248392. https://doi.org/10.1371/journal.pone.0248392

Lissah, S. Y., Ayanore, M. A., Krugu, J. K., Aberese-Ako, M., & Ruiter, R. A. C. (2021b). Managing urban solid waste in Ghana: Perspectives and experiences of municipal waste company managers and supervisors in an urban municipality. *PLOS ONE*, *16*(3), e0248392. https://doi.org/10.1371/journal.pone.0248392

Marshall, R. E., & Farahbakhsh, K. (2013). Systems approaches to integrated solid waste management in developing countries. *Waste Management*, *33*(4), 988–1003. https://doi.org/10.1016/j.wasman.2012.12.023

Miezah, K., Obiri-Danso, K., Kádár, Z., Fei-Baffoe, B., & Mensah, M. Y. (2015). Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana. *Waste Management*, *46*, 15–27. https://doi.org/10.1016/j.wasman.2015.09.009

Ministry of Sanitation and Water Resources. (2021). Projects—Solid Waste. *Ministry of Sanitation and Water Resources*. http://mswr.gov.gh/projects-solid-waste/

Ministry of Sanitation and Water Resources , Ghana. (2019). Ministry of Sanitation and Water Resources_Medium Term Expenditure Framework (MTEF) 2019-2022. *Ministry of Sanitation and Water Resources*. http://mswr.gov.gh/publications-solid-waste/

Ministry ofHousing and Urban Affairs India. (2019). *SOLID WASTE MANAGEMENT INITIATIVES IN URBAN INDIA A COMPENDIUM.pdf*. Google Docs. https://drive.google.com/file/d/1bC0FgKlnOyDzBHtiBwtmo4cyWML-NQUs/view?usp=embed_facebook

Momodu, N. S., Dimuna, K. O., & Dimuna, J. E. (2011). Mitigating the Impact of Solid Wastes in Urban Centres in Nigeria. *Journal of Human Ecology*, *34*(2), 125–133. https://doi.org/10.1080/09709274.2011.11906377

Mor, S., Ravindra, K., Dahiya, R. P., & Chandra, A. (2006). Leachate Characterization and Assessment of Groundwater Pollution Near Municipal Solid Waste Landfill Site. *Environmental Monitoring and Assessment*, *118*(1), 435–456. https://doi.org/10.1007/s10661-006-1505-7

Muheirwe, F., Kombe, W., & Kihila, J. M. (2022). The paradox of solid waste management: A regulatory discourse from Sub-Saharan Africa. *Habitat International*, *119*, 102491. https://doi.org/10.1016/j.habitatint.2021.102491

Nabegu, A. B. (2010). An Analysis of Municipal Solid Waste in Kano Metropolis, Nigeria. *Journal of Human Ecology*, *31*(2), 111–119. https://doi.org/10.1080/09709274.2010.11906301

Nagabooshnam, J. K. (2011). *Solid Waste Generation & Composition in Gaborone, Botswana. Potential for Resource Recovery.* 67.

Oduro-Kwarteng, S. (2011). *Private Sector Involvement in Urban Solid Waste Collection: UNESCO-IHE PhD Thesis*. CRC Press.

Ogbonna, D. N., Amangabara, G. T., & Ekere, T. O. (2007). Urban solid waste generation in Port Harcourt metropolis and its implications for waste management. *Management of Environmental Quality: An International Journal*, *18*(1), 71–88. https://doi.org/10.1108/14777830710717730

Ojha, C. S. P., Goyal, M. K., & Kumar, S. (2007). Applying Fuzzy logic and the point count system to select landfill sites. *Environmental Monitoring and Assessment*, *135*(1), 99–106. https://doi.org/10.1007/s10661-007-9713-3

Okot-Okumu, J. (2021). *Solid Waste Management in African Cities – East Africa | IntechOpen*. https://www.intechopen.com/chapters/40527

Omona, K., & Maderu, P. (2022). Assessment of Solid Waste Management at Source in Compliance With Guidelines Among Residents of Kawempe Division, Kampala, Uganda. *Journal of STEAM Education*. https://doi.org/10.55290/steam.1079136

Pazoki, M., Delarestaghi, R. M., Rezvanian, M. R., Ghasemzade, R., & Dalaei, P. (2015). Gas Production Potential in the Landfill of Tehran by Landfill Methane Outreach Program. *Jundishapur Journal of Health Sciences*, *7*(4), Article 4. https://doi.org/10.17795/jjhs-29679

Phuttharak, T., & Dhiravisit, A. (2014). Rapid Urbanization-Its Impact on Sustainable Development: A Case Study of Udon Thani, Thailand. *Asian Social Science*, *10*(22), p70. https://doi.org/10.5539/ass.v10n22p70

Pörtner, H.-O., & Roberts, D. C. (2021). *Climate Change 2022: Impacts, Adaptation and Vulnerability*. 167.

Prime News Ghana. (2018, February 24). *Accra's waste reduced by 30%-AMAÂ*. Prime News Ghana. https://www.primenewsghana.com/general-news/ama-waste.html

Rahman, M. A. (2013). Revisiting Solid Waste Management (SWM): A Case Study of Pakistan. *M. A.A International Journal of Scientific Footprints, 1(1), 33-42.*

Rana, R., Ganguly, R., & Gupta, A. K. (2017). Indexing method for assessment of pollution potential of leachate from non-engineered landfill sites and its effect on ground water quality. *Environmental Monitoring and Assessment*, *190*(1), 46. https://doi.org/10.1007/s10661-017-6417-1

Rockson, G. N. K., Kemausuor, F., Seassey, R., & Yanful, E. (2013). Activities of scavengers and itinerant buyers in Greater Accra, Ghana. *Habitat International*, *39*, 148–155. https://doi.org/10.1016/j.habitatint.2012.11.008

Schindler, S., & Demaria, F. (2020). "Garbage is Gold": Waste-based Commodity Frontiers, Modes of Valorization and Ecological Distribution Conflicts. *Capitalism Nature Socialism*, *31*(4), 52–59. https://doi.org/10.1080/10455752.2019.1694553

Segbefia, S. (2021, December 15). Engineered landfill site underway in Accra—Sanitation Minister. *The Business & Financial Times*. https://thebftonline.com/2021/12/15/engineered-landfill-site-underway-in-accra-sanitation-minister/

Serge Kubanza, N., & Simatele, M. D. (2020). Sustainable solid waste management in developing countries: A study of institutional strengthening for solid waste management in Johannesburg, South Africa. *Journal of Environmental Planning and Management*, *63*(2), 175–188. https://doi.org/10.1080/09640568.2019.1576510

Shah, W. U. H., Yasmeen, R., Sarfraz, M., & Ivascu, L. (2023). The Repercussions of Economic Growth, Industrialization, Foreign Direct Investment, and Technology on Municipal Solid Waste: Evidence from OECD Economies. *Sustainability*, *15*(1), Article 1. https://doi.org/10.3390/su15010836

Shaker, A., & Yan, W. Y. (2010). *TRAIL ROAD LANDFILL SITE MONITORING USING MULTI-TEMPORAL LANDSAT SATELLTE DATA*. 6.

Sharma, A., Ganguly, R., & Gupta, A. K. (2019). Characterization and Energy Generation Potential of Municipal Solid Waste from Nonengineered Landfill Sites in Himachal Pradesh, India. *Journal of Hazardous, Toxic, and Radioactive Waste*, *23*(4), 04019008. https://doi.org/10.1061/(ASCE)HZ.2153-5515.0000442

Sharma, K. D., & Jain, S. (2020). Municipal solid waste generation, composition, and management: The global scenario. *Social Responsibility Journal*, *16*(6), 917–948. https://doi.org/10.1108/SRJ-06-2019-0210

Shekdar, A. V. (2009). Sustainable solid waste management: An integrated approach for Asian countries. *Waste Management*, *29*(4), 1438–1448. https://doi.org/10.1016/j.wasman.2008.08.025

Singh, E., Kumar, A., Mishra, R., & Kumar, S. (2022). Solid waste management during COVID-19 pandemic: Recovery techniques and responses. *Chemosphere*, *288*(Pt 1), 132451. https://doi.org/10.1016/j.chemosphere.2021.132451

Sondh, S., Upadhyay, D. S., Patel, S., & Patel, R. N. (2022). A strategic review on Municipal Solid Waste (living solid waste) management system focusing on policies, selection criteria and techniques for waste-to-value. *Journal of Cleaner Production*, *356*, 131908. https://doi.org/10.1016/j.jclepro.2022.131908

Song, J., Feng, R., Yue, C., Shao, Y., Han, J., Xing, J., & Yang, W. (2022). Reinforced urban waste management for resource, energy and environmental benefits: China's regional potentials.

Resources, Conservation and Recycling, *178*, 106083. https://doi.org/10.1016/j.resconrec.2021.106083

Staley, B. F., & Barlaz, M. A. (2009). Composition of Municipal Solid Waste in the United States and Implications for Carbon Sequestration and Methane Yield. *Journal of Environmental Engineering*, *135*(10), 901–909. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000032

Sujauddin, M., Huda, S. M. S., & Hoque, A. T. M. R. (2008). Household solid waste characteristics and management in Chittagong, Bangladesh. *Waste Management*, *28*(9), 1688–1695. https://doi.org/10.1016/j.wasman.2007.06.013

Tan, S. T., Ho, W. S., Hashim, H., Lee, C. T., Taib, M. R., & Ho, C. S. (2015). Energy, economic and environmental (3E) analysis of waste-to-energy (WTE) strategies for municipal solid waste (MSW) management in Malaysia. *Energy Conversion and Management*, *102*, 111–120. https://doi.org/10.1016/j.enconman.2015.02.010

Tchobanoglous, G., & Kreith, F. (2002). *Handbook of Solid Waste Management* [Book]. AccessEngineering | McGraw-Hill Education - Access Engineering; McGraw-Hill Education. https://www.accessengineeringlibrary.com/content/book/9780071356237

Tong, Y. D., Huynh, T. D. X., & Khong, T. D. (2021). Understanding the role of informal sector for sustainable development of municipal solid waste management system: A case study in Vietnam. *Waste Management*, *124*, 118–127. https://doi.org/10.1016/j.wasman.2021.01.033

Tutu, R. A. (2014). Dilemmatic experiences of young migrants in Accra, Ghana: The merciless hands of pirate urbanization and landlordism. *Journal of Housing and the Built Environment*, *29*(4), 637–656. https://doi.org/10.1007/s10901-013-9371-4

Udomsri, S., Petrov, M. P., Martin, A. R., & Fransson, T. H. (2011). Clean energy conversion from municipal solid waste and climate change mitigation in Thailand: Waste management and

thermodynamic evaluation. *Energy for Sustainable Development*, *15*(4), 355–364. https://doi.org/10.1016/j.esd.2011.07.007

Ugwuanyi, R., & Isife, T. (2012). URBANIZATION AND SOLID WASTE MANAGEMENT CHALLENGES IN NIGERIA. *Technoscience Review*, *3*, 3–14.

UNDP. (2015). *Goal 12: Responsible consumption and production | Sustainable Development Goals | United Nations Development Programme*. UNDP. https://www.undp.org/sustainable-development-goals/responsible-consumption-and-production

United Nations Habitat. (2016). *Waste Wise Cities | UN-Habitat*. https://unhabitat.org/waste-wise-cities

US EPA, O. (2014, February 7). *National Service Center for Environmental Publications* (United States, Great Plains, Mid-Atlantic, Midwest, Northeast, Pacific Northwest, Rocky Mountains, South Central, Southeast, Southwest, States, Territories, Water Bodies, Chesapeake Bay, Great Lakes, Gulf of Mexico, Lake Champlain Basin, Long Island Sound, Puget Sound) [Reports and Assessments]. https://www.epa.gov/nscep

US EPA, O. (2016, March 24). *Municipal Solid Waste Landfills* [Overviews and Factsheets]. https://www.epa.gov/landfills/municipal-solid-waste-landfills

Vergara, S. E., & Tchobanoglous, G. (2012). Municipal Solid Waste and the Environment: A Global Perspective. *Annual Review of Environment and Resources*, *37*(1), 277–309. https://doi.org/10.1146/annurev-environ-050511-122532

Wilson, D. C., & Velis, C. A. (2015). Waste management – still a global challenge in the 21st century: An evidence-based call for action. *Waste Management & Research*, *33*(12), 1049–1051. https://doi.org/10.1177/0734242X15616055

World Bank. (2022). *Solid Waste Management*. World Bank. https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management

World Urbanization Prospects. (2018). *World Urbanization Prospects—Population Division—United Nations*. https://population.un.org/wup/

Yankson, P. W. K., & Gough, K. V. (1999). The environmental impact of rapid urbanization in the peri-urban area of Accra, Ghana. *Geografisk Tidsskrift-Danish Journal of Geography*, *99*(1), 89–100. https://doi.org/10.1080/00167223.1999.10649426

Zohoori, M., & Ghani, A. (2017). Municipal Solid Waste Management Challenges and Problems for Cities in Low-Income and Developing Countries. *International Journal of Science and Engineering Applications*, *6*(2), 039–048. https://doi.org/10.7753/IJSEA0602.1002

Zurbrugg, C. (2003). *Solid Waste Management in Developing Countries*.

Chapter 4

Comparing the Effectiveness of Solid Waste Management Practices in Greater Accra and Nairobi: A Study of Policies, Strategies, and Implementation

4.1 Introduction

Solid Waste Management (SWM) has a multifaceted perspective and an associated effect on several sectors that are essential for sustainable growth (Ogutu, 2019). The world is rapidly urbanizing, but the quantity of waste produced is growing faster than population growth resulting in a looming environmental crisis (Cohen, 2006). Globally, about 1.3 billion tons of solid waste are produced annually, and this is anticipated to increase to about 2.2 billion tons in 2025 (Bhada-Tata & Hoornweg, 2012; Moya et al., 2017; Ouda & Raza, 2014) consequentially, the present cost associated with the management of waste will also increase from $205.4 billion to about $375.5 billion in 2025 (Bhada-Tata & Hoornweg, 2012). It is important to note that, as countries develop, the circumstances surrounding their waste management equally evolve (Kaza et al., 2018a). Therefore, the management of waste regularly with a careful consideration of its environmental effects, technological implementations, and administrative expenses associated with the various treatment and disposal techniques should be prioritized by all countries, especially developing countries (Consonni et al., 2011).

The management of solid waste is essential for towns and communities that aspire to be sustainable, healthy, and inclusive, especially in the period of rapid urbanization and population expansion. Unfortunately, when it comes to urban growth, solid waste management is often not given the maximum attention unlike education and health care. But recently, the issue of sanitation has expanded from being a "city" challenge to one that affects an “economy-wide” (Adzawla et al., 2019). This means that challenges associated with sanitation have evolved from being a problem that affects only urban areas to an issue that impacts an entire economy

including a negative impact on public health, the environment, and economic productivity. Therefore, making it a widespread concern for all sectors of a given society.

Municipal Solid Waste (MSW) management follows the same hierarchy of source reduction, reuse, recycling/composting, recovery/energy from refuse, and disposal/landfill (Flávia Tuane Ferreira Moraes et al., 2022). The current state of (MSW) management techniques differs from country to country since its administration is influenced by several variables which usually vary for every nation (Mian et al., 2017). A report from the United Nations 2018 Development Program reveals that a worldwide population of 2.3 billion people still lacked basic sanitation as of 2015 (UNDP, 2018). Hence, making it is crucial to recognize the need to create pertinent strategies for incorporating basic sanitation services including solid waste management into a country's growth approach. For instance, the achievement of goal 6 (clean water and sanitation) of the SDG particularly as a nation, could be aided by developing improved solid waste management strategies. Therefore, any variable that may have an impact on MSW management either directly or indirectly including issues about the physical environments, social standards, economic circumstances, political settings, local, regional, and national laws, institutions, educational systems, finances, human resources, and technology, should be prioritized.

In East Asia and the Pacific, Latin America and the Caribbean, and Sub-Saharan Africa, it has been estimated that about 468, 289, and 231 million metric tons of waste are produced yearly (Statista, 2019). It is significant to understand that the creation of solid waste is an inevitable consequence of human existence (Shekdar, 2009). All individuals, corporations, and governments must take responsibility for waste management to decrease their environmental footprint to secure a sustainable future. In 2012, Africa alone produced 125 million tons of urban

solid waste, and this is expected to increase to 244 million tons in 2025. Sub-Saharan Africa which includes Ghana accounted for 81 million tons (65%) of the total waste generated in Africa in 2012 (Edomah, 2020). Out of the total waste produced in Africa in 2012, 55% of it is collected and this is expected to increase to 69% by 2025 (Godfrey et al., 2019). Sadly, the remaining uncollected waste usually ends up being deposited onto streets, open fields, stormwater ditches, and waterways within towns and cities (Edomah, 2020). Also in Sub-Saharan Africa, the average MSW collection rate is just 44% and this is anticipated to rise to 69% by 2025 (Edomah, 2020). Here, the waste collected differs widely across urban areas, varying between a mere 20% to an average of above 90% (Edomah, 2020; Godfrey et al., 2019; Muniafu & Mutiso, 2022). In Africa, good waste collection services are often found in the city centers, while poor rural areas typically receive inadequate services (Achankeng, 2003). Africa generates about 80-90% of recyclable waste but only 4% of it has been recycled, and this is frequently done by extremely active, but sometimes marginalized, informal reclaimers (Godfrey et al., 2019).

In developing countries, the organic content of MSW is higher than that of paper and packaging. In Africa, various factors, including consumer sentiments, economic status, and culture, influence MSW composition (Alaya, 2022). Generally, in Sub-Saharan Africa, MSW typically contains 57% organic material, 9% paper/cardboard, 13% plastic, 4% glass, 4% metal, and 13% miscellaneous materials (Alaya, 2022; IETC, 2019). The issue of solid waste management has been a crucial problem, especially in many urban areas in developing countries around the world. The use of antiquated solid waste treatment technologies as well as disposal techniques, low collection coverage, and irregular and reliable services for solid waste collection, absence of political allegiance, public literacy regarding effective waste management techniques, the proliferation of insects and vermin as a result of poor SWM practices, and insufficient

management and regulation of informal waste collection activities are the most frequent issues that less developed and developing countries face (Guerrero et al., 2013; Mmereki et al., 2016). All of these are associated with the limitations of the long-term strategic approach and monetary investment (Kamran et al., 2015). It is not surprising to realize that the lack of effective administration is at the root of Africa's solid waste management problems (Edomah, 2020). Consequently, the majority of African countries' current MSW collection systems are wholly insufficient, leading to the careless disposal of solid waste into the environment (Godfrey et al., 2019; UNDP, 2018).

When it comes to waste disposal, Africa is well recognized for its historical and political backdrop. Several African countries are assumed to be dumping sites for harmful and toxic waste generated primarily in some industrialized countries. Africa is being inundated with second-hand products (particularly technological scrap), some of which are already obsolete or nearing the end of their useful existence when they arrive (FOEN, 2011). In some instances, the export of used goods to African countries like Ghana, Benin, Liberia, Nigeria, and Cote d'Ivoire is used to get around laws regulating waste dumping and transboundary movements to dispose of waste products in these developing countries at a reduced cost. Used tires, end-of-life cars (ELVs), and utilized and dying electronic devices are a few examples of traded commodities and this can be attributed to the need for cheap access to high-quality used tools in the importing African countries (Schluep et al., 2012). To a certain extent, this can be ascribed to a tradition of economic dependency of Africa on these developed countries and the fundamental belief that Africa can be used for virtually anything, despite the continent's pervert customs and practices that eventually influence all aspects of the continent's ways of life, in addition to its practices regarding environmental management (Simelane, 2011). This shows the level of regard Africa

has, particularly given the possibilities presented by waste as a supplementary resource (Azubuike et al., 2022).

In most African cities, including Accra (Ghana), Nairobi (Kenya), Lagos (Nigeria), Cairo (Egypt), and Johannesburg (South Africa), population development patterns are being driven by rapid urbanization. As a result, these cities now produce more solid waste, which has caused some of them to lose their appealing qualities as a result of the ineffectiveness of their waste collection systems (Simelane, 2011). However, with challenges like insufficient infrastructure, deficient financing, and a lack of public knowledge, solid waste management in these cities is becoming a major problem that needs urgent attention. Even though almost every African country has policies dictating how its waste should be managed, there are still a lot of variables that limit the waste management system in most of these nations. To safeguard both human health and the environment, appropriate solid waste management has long been encouraged. Traditionally, solid waste can be recycled to improve the lives of casual waste reclaimers while also generating new employment and business possibilities in Africa. To control waste, the government, industries, and civic society must all work together (Edomah, 2020). In addition to that, all individuals must see solid waste as a resource that should be integrated into the goals for public growth and human development but not as a mere discarded material.

Consequently, this study aims to lay the groundwork for future research on Municipal Solid Waste Management, to develop effective strategies for tackling SWM issues, and to reduce the effects of uncontrolled SW in Ghana's Greater Accra region. Given this, a comparative study will be done to analyze the Solid Waste Management Strategies in the Greater Accra region of Ghana and Nairobi, Kenya purposely to draw practices and implementations from Nairobi, Kenya. The comparison will be conducted between Nairobi and Greater Accra because Nairobi

also happens to be one of the most populous and rapidly urbanizing cities in Kenya with a near equivalent population like Greater Accra. The study hypothesizes that, while Greater Accra and Nairobi may have certain solid waste management concerns in common, there are likely to be substantial contextual factors that influence how the problems are addressed and managed in each region. Most significantly, a comparative study may reveal the fundamental variations in method and outcomes, as well as insights into what aspects are most crucial for effective solid waste management in each region. By taking these aspects into account, it may be feasible to establish a more nuanced understanding of the similarities and variations in waste management strategies and outcomes across the Greater Accra region and Nairobi city county.

One aspect of environmental management that directly affects a city's appeal as well as its social, political, and fiscal growth is MSW. Every government should legally offer MSW management services to its people (Fahmi & Sutton, 2010). Even though the results of this comparative urban study of Greater Accra (Ghana) and Nairobi (Kenya) are unlikely to be relevant throughout major urban centers, especially in the entire African continent, the researcher is optimistic that the study will encourage further studies on other urban areas in African nations. However, societies globally must uphold human rights to sanitation and strengthen hygiene standards as a means of creating a healthier and more sustainable world for all while ensuring a better future for generations to come.

4.2. Method

This research aims to compare the effectiveness of solid waste management in Greater Accra and Nairobi, focusing on three key factors: policies, strategies, and practices. To test the study’s hypothesis, the study will conduct several steps to get to the end. Firstly, the key demographic and socio-economic characteristics of Greater Accra and Nairobi will be identified through an extensive review of existing literature, and other secondary data sources like

population and housing census reports, policies, and among others. Secondly, their solid waste characteristics comprising sources, composition, method of storage and disposal, solid waste policies, and measures put in place for solid waste management will be captured. A qualitative comparison will be done using collected secondary data from websites and reports. Also, discussion and conclusion are drawn from the analysis, summarizing the key findings and implications for solid waste management in Nairobi and Greater Accra region. An interpretation of the results will be done highlighting the strengths and weaknesses of the various strategies, policies, and implementation. and recommendations for improving them.

4.2. Comparative Analysis of Solid Waste Management in Greater Accra, Ghana, and Nairobi, Kenya

4.2.1. Demographic and Socio-Economic Characterization

The generation of MSW is aided by rising populations and urbanization (Cheng et al., 2020). Therefore, determining the best tools and management techniques requires an understanding of the relationship between socioeconomic variables and MSW composition (Nguyen et al., 2020). The major variations between countries in terms of economic status and activities, education level, age distribution, family size, marital status, and gender can help to understand some of the changes in solid waste management between countries (Tadesse, 2009). The various demographic and socio-economic characteristics of Greater Accra and Nairobi in the year 2021 are represented in (table 4.1).

Table 4. 1 Demographic and Socio-economic Characteristics of Greater Accra and Nairobi

Demographic/Socio-Economic Characteristics	*Greater Accra (2021) census year*	*Nairobi (2019) census year*
Total Population	5,455,692	4,397,073

Male Population	2,679,063	2,192,452
Female Population	2,776,629	2,204,376
Intersex	Not captured	245
Total Household Population	5,384,268	1,506,888
Average Household Size	3.2	2.9
Population Growth Rate	2.9 annually	3.4 % annually
Population Density	129 persons per square kilometers	6,247 persons per square kilometers
Total Land Area	3245km²	703.9km²

Source: Ghana Statistical Service 2021 Population; Housing Census Report (Ghana Statistical Service, 2021) *and the* Kenya National Bureau of Statistics 2019 census report (Kenya National Bureau of Statistics, 2019).

4.3. Solid Waste Composition in Greater Accra, and Nairobi

4.3.1 Solid Waste Sources and Characteristics in Greater Accra and Nairobi

To improve MSW management, particularly in developing countries, it is crucial to understand the reasons behind compositional variations in waste. Economic development in a particular region is closely linked to shifts in its waste composition (Kieu Lan Phuong 2020). Waste composition is the proportion of waste produced as a percentage of total mass produced (Kaza et al., 2018b). The complexity of MSW's composition and amount of waste produced generally increase as cities and nations become wealthier, more populous, and able to provide their citizens with more readily available goods and services, even though each nation employs different strategies that have developed over time (Kaza et al., 2018b). The various solid waste

characteristics and solid waste composition of Greater Accra and Nairobi are presented in (table 4.2.) figure (4.1) and figure (4.2) respectively.

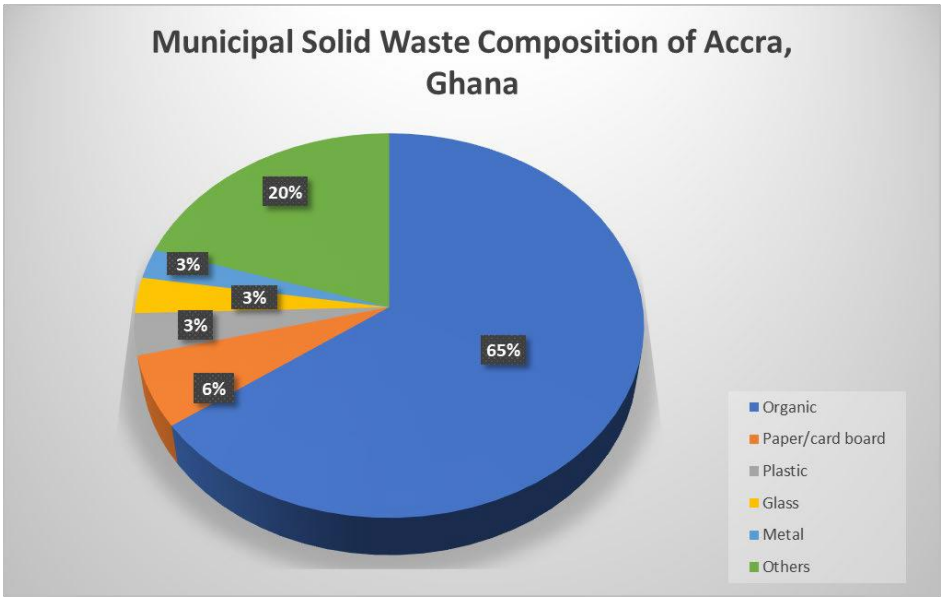
Table 4. 2 Solid waste characteristics of Greater Accra and Nairobi

Solid Waste Characteristics	Greater Accra	Nairobi
Source	Institutional, Industrial, commercial, and domestic	Residential households: Commercial and institutional establishments, Construction and demolition waste, Street litter
Composition	Organic, Paper/ cardboard, plastic, metal, glass, and others	Organic, Paper/ cardboard, plastic, metal, glass, and others
Means of solid waste storage	Standard Waste Receptacles, (covered and uncovered standard waste bin) Improvised waste receptacles (covered and uncovered container, covered or uncovered basket), disposable waste receptacles (sack, polythene bags, others), none (no receptacles)	Household bins, dumpsites, compactor trucks, dump sites, transfer stations, skips, and containers
Method of solid waste disposal	Collected by (compaction trucks, tricycles, central containers, push carts/walk-intendants, bicycles, wheelbarrows), burnt, public dump/open spaces, dumped	Collected by rucks, open dumping, open burning, incineration, composting, and landfilling.

	indiscriminately, buried in the ground, others	

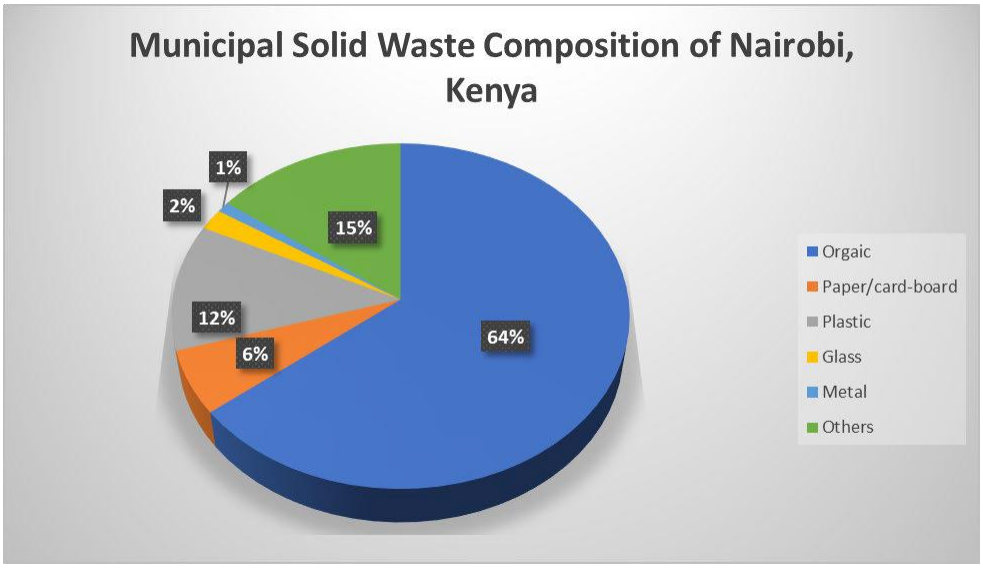
Source: Population and Housing Census Reports for both Ghana and Kenya.

Figure 4. 1 Waste Composition of Accra, Ghana.



Source of data: (Edomah, 2020).

Figure 4. 2 Waste Composition of Nairobi, Kenya



Source of data : (Edomah, 2020)

The composition of waste is essential for determining the most significant issues as well as the most effective waste control techniques. Depending on the circumstances present in a local area, the composition of waste can differ considerably (Vinti & Vaccari, 2022). Figure (4.1) shows the waste composition of Accra, the capital of the Greater Accra region and the capital of Ghana and Figure (4.2) shows the solid waste composition of Nairobi the capital of Kenya. Organic waste represents the predominant fraction of solid waste produced in the two cities as seen in the two figures as 65% and 64% for Accra and Nairobi respectively. This supports recent scientific findings that organic waste is always the most prevalent portion of solid waste and it's usually above 50% in urban areas (Asgari et al., 2019; Bernardes & Günther, 2014; Rajpal et al., 2020; Taboada-Gonzalez et al., 2011). Even in rural areas, the rate can approach 90% (Bernardes & Günther, 2014). However, some literature has also recorded lower values of organic waste tallying around 40% (Kerdsuwan et al., 2015; Taboada-Gonzalez et al., 2011) and the proportion may have been affected by variables like the use of food as livestock feed (Viljoen et al., 2021; Vinti & Vaccari, 2022). Both cities recorded 6% paper/cardboard waste.

Plastic typically makes up the second largest portion of trash, with numbers varying from 4% to 20% (Vinti & Vaccari, 2022). However, Nairobi fell into this norm by recording 12% plastic waste even though Accra recorded 3% for its plastic waste, hence deviating from the norm by 1%. This could be a result of the shift from the use of plastics for food packaging to the use of Katemfe leaves which are locally known as "Ahaban" by average food vendors in the region. The "Ahaban" is known to possess qualities that offer a mild but highly desirable medicinal value for lowering fats and cholesterol in the blood. Also, the leaf is known to improve the flavor of meals. Accra recorded 3% each for metal and glass while Nairobi recorded 2% for glass and 1% for metal. Therefore, this confirms the (Vinti & Vaccari, 2022) observation that,

usually there is a significant difference between metals and glass, ranging from 0.34% to 6.32% for metals and from 0.40% to 4.42% for glass. Nonetheless, the proportion of metals and glass that end up in waste may also be influenced by unauthorized trash collectors or regional marketplaces for such potentially valuable recyclables (Schenck & Blaauw, 2011). In addition, the other composite of waste recorded 20% and 15% for Accra and Nairobi respectively. A study conducted (by Edjabou, 2012) subcategorized the other components of waste as soil, sand, and dirt, and were found to have predominant fractions.

4.3.2 Solid Waste Management in Nairobi, Kenya, And Greater Accra, Ghana.

The execution of policy and its regulation has been difficult for environmental administration in Nairobi's solid waste management (NEMA, 2014). The generation of solid waste in Kenya has been increasing due to the country's rapid rate of urbanization with their annual waste generation of 4 million tons expected to double by 2030 (Njoroge et al., 2014). In Kenya, the National Environment Policy outlines the government's responsibilities to protect the environment and the Constitution with the main goal of improving SWM and enhancing environmental governance (National Environment Policy, 2013). With the development of various SWM policies and policy framework analysis, Kenya has been able to tackle several of its SWM challenges (Ogutu et al., 2021a). Comparably, solid waste management continues to exist as a problem in Ghana due to the significant gaps that exist in stipulating distinct SWM policy strategies and control frameworks for the execution of SWM policy. The case of the Greater Accra region is very crucial because, for some time, there has been much discussion about how to improve a situation while it is still manageable, rather than waiting until it reaches the point of emergency, when resource management, planning, and sustainability are all put at risk (Mudu et al., 2021).

In 2010, 3286 cholera cases with 54 deaths and an unprecedented fatality rate of 1.6% were recorded in Accra by the Ghana Health Service, This was attributed to the effect of poor waste management, therefore, putting strain on the city officials to achieve significant advancements in waste management (Oteng-Ababio et al., 2013a). Accra's daily average of 2,200 metric tons of waste is produced, with private service companies projected to collect 1500–1800 of the total waste generated (Oteng-Ababio et al., 2013b). The Accra Metropolitan Assembly (AMA) spent 450,000 Ghanaian Cedis (GHC, about US$ 307,340) every month on solid waste hauling alone, with an additional GHC 240,000 (US$ 163,910) spent on the upkeep of dumpsites (Oteng-Ababio et al., 2013b). Despite all these efforts, urbanization and a lack of available land area are increasing the production of MSW and biodegradable waste streams in the area (Oduro-Appiah & Afful, 2020). However, urgent attention from researchers, decision-makers, government, and non-governmental organizations, funding organizations and individual citizens to work collaboratively towards effective solid waste management (SWM) systems in the region and beyond is needed.

4.3.3 Common Problems Associated with Greater Accra and Nairobi's solid waste management.

1. Inadequate or ineffective laws and implementation: Even though Ghana has established some legislation on waste management, they are not successfully implemented. However, conflicting requirements or the failure to implement this legislation fosters an attitude of lawlessness and reduces the efficacy of waste management in the country. As a result, most citizens, especially the urban poor generate and dispose of their solid waste anyhow without authorization. This is usually done due to weak solid waste management systems.

2. Low public awareness and negative attitudes: A significant barrier to effective solid waste management in the Greater Accra region to be specific and Ghana in general is the low level of public knowledge of appropriate solid waste processing and recycling techniques, as well as the negative views that many households have toward waste reduction and reuse as a means of solid waste management. Because so many people are ignorant of the negative effects that improper waste disposal has on the ecosystem and human health, they continue to participate in bad habits like littering and unlawful dumping.

3. Weak and unstable system of governance: Poor institutional ability and administration by the government towards the provision of adequate and efficient basic solid waste management facilities and resources and diverse ruling objectives or focus by various ruling political parties.

4. Inadequate monetary support for management services: Although waste management demands substantial financial resources, financing is frequently insufficient in Greater Accra. This restricts the government's ability to spend money on waste management facilities and tools, as well as on educating the public about good waste management techniques.

5. Insufficient and malfunctioning operation equipment: For waste management activities to be efficient and effective, the machinery used for its gathering, transportation, processing, and disposal is essential. However, faulty, or inadequate technology can cause delays, safety risks, and higher expenses. For instance, if there aren't enough refuse collection trucks, trash could build up on the streets and present a risk to people's health and safety. Inadequate processing tools can also result in dangerous and ineffective waste management, possibly subjecting staff members and nearby area too hazardous gases and pollutants. Ineffective waste management practices and safety risks could also result from improper machinery upkeep and repair.

6. Unavailability of adequate and reliable data: For efficient waste management planning and execution, it is essential to have access to precise and current waste management data. However, there is frequently little information on waste generation, composition, and administration in Greater Accra, which makes it challenging to create programs and policies that are founded on facts.

4.3.4 Nairobi's Solid Waste Policies and Strategies

Solid waste management in Nairobi is governed by several laws and rules, some of which are particular to the Greater Accra region, and these include:

1. Environmental Management Coordination Authority Act 1999 (EMCA): This act was passed as the framework of Kenyan environmental laws which included waste production and administration. The EMCA allowed for the creation of several subsidiary laws and rules that regulate SWM and environmental management. It advocates for increased stakeholder collaboration and coordination, as well as increased citizen participation in environmental preservation (Gakungu et al., 2012; Nderitu, 2010; NEMA, 2014).

2. The National Environmental Policy (2013): The Ministry of Environment, Water, and Natural Resources formulated this policy statement on the waste management approach comprising the creation of a comprehensive national waste management plan, encouraging financial rewards for waste management, and promoting facilities and rewards for environmentally sustainable production, waste recovery, recycling, and reuse are all important steps (Haregu et al., 2017).

3. The Solid Waste Management Regulations of 2006: To maximize the function of alliances, the regulation enacts laws that are specifically tailored to the SWM system, which consists of solid waste collection, segregation, disposals, waste management (both hazardous and non-hazardous waste), and the persons participating, such as waste producers and carriers (NEMA, 2014).

4. The National Solid Waste Management (NSWM) Strategy of 2015: the strategy is aimed at achieving sustainable waste management through an integrated approach that puts the preservation of both the ecosystem and human health beforehand. The strategy ensures that despite the negative connotation associated with solid waste, it can be repurposed to be valuable because a new approach to waste reduction is discovered. The strategy came along with the introduction of revenue production, job creation, and economic assistance for the people. Additionally, the strategy aimed at cooperation among stakeholders and private individuals which will contribute to the reduction of pollution in the environment (NEMA, 2014; Ogutu et al., 2021b).

5. The Nairobi City Council (NCC) Solid Waste Management Act 2015: The acts offer a lawful foundation for the execution of a comprehensive waste management plan and promote partnerships between different actors who control SWM in the county and public involvement (Nairobi City Council, 2015). The Council collaborates with groups and organizations involved in managing solid waste in the county, including services providers, NGOs, and community-based groups to offer its SWM services in partnership with the Department of Environment.

6. The Nairobi Metro 2030 Strategy (2008): According to projections made by the Ministry of Nairobi Metropolitan Development, the city's annual production of solid waste would rise to 1.83 million tons in 2030 as it strives to become a world-class African metropolis. Utilizing waste in energy systems and technology, as this concept suggests, gives a beneficial opportunity for SWM. This strategy signifies that Incorporating waste in energy mechanisms and technology presents an effective prospect for SWM (Haregu et al., 2017).

4.3.5 Measures of Solid Waste Management in Kenya and the Nairobi City County

To address the issue of SWM in Nairobi, the Kenyan government has put adverse measures in place including.

1. Banned of the use of plastics: Kenya is emerging as a pioneer in the battle against plastic pollution and was one of the first nations in East Africa to put limitations on single-use plastics (UNEP, 2021). In 2017, the Kenyan government banned the use of single-use plastic bags in the country which was followed by the ban on the use of plastic bottles, cups, and cutlery in the country's national parks in June 2020 (UNEP, 2021).

2. The formation of Kenya Green University Initiative Network (KGUN): This network was established in 2016 by the UN Environment Program (UNEP) to encourage environmental and sustainable practices in Kenyan institutions. The network will operate as a center for information and innovation and encourage the exchange of best practices to help meet the Sustainable Development Goals (SDGs) and obligations made under the Paris Climate Agreement (UNEP, 2016, 2017, p. 2017).

3.Kenya's participation in the Clean Sea Initiative: Kenya has been battling with littering of its plastic waste which dots its Indian Ocean shoreline and even overflows its lakes. Due to that, in 2017, the country signed the Clean Sea Initiative which aims at educating people about the need to improve human connections with the ocean and ocean health, the problems brought on by plastic pollution and the best methods for improving one's actions. Consequentially, serving as a means of enhancing the country's revenue generated from the sea (UNEP, 2021).

4.Construction of waste-to-energy plant- The Kenya Electricity Generating Company PLC (KenGen) in conjunction with the Nairobi Metropolitan Services (NMS) has planned on constructing a waste-to-energy plant which is a 40-megawatt (MW) project in Dandora located

in Nairobi. Upon completion, the plant is expected to supply electricity from waste for the Nairobi metropolitan area through the national grid while giving KenGen a chance to diversify its energy sources. The project will also serve as a source of revenue for the Nairobi City Hall (African Energy, 2020).

5.Recycling of plastics into building materials: Currently, several businesses in Kenya are expanding their prospects in environmentally friendly industries. For instance, Nzambi Matee, a 29-year-old woman, an entrepreneur, and an inventor has established a social business named Gjenge Maker's Ltd. A business that recycles discarded plastics in addition to sand to create alternative construction materials like paving stones and paving stones that are stronger than concrete and affordable (The World Bank, 2021).

4.3.6 Solid Waste Management Policies and Strategies in Ghana and the Greater Accra Region

Solid waste management in Ghana is governed by several laws and rules, some of which are particular to the Greater Accra region, and these include:

1. National Environmental Sanitation Policy (1999): The scope of this policy encompasses all facets of environmental health with solid waste management inclusive. It assigns responsibilities to different stakeholders, ranging from individuals and community organizations to the Ministry of Local Government and Rural Development (MLGRD), Metropolitan, Municipal, and District Assemblies (MMDAs), Ministries of Environment Science and Technology, Healthcare and Education, and the corporate world (MLGRD, 2010).

2. Environmental Protection Agency (EPA) Act 1994: The EPA Act designates the EPA as Ghana's primary agency responsible for ensuring that air, land, and water are well sustained so that future generations inherit a more hygienic and healthier environment. The EPA also

oversees the implementation of environmental laws and keeps track of how well those laws are followed (EPA Ghana, 2022).

3. Local Government Act of 2016, Act 936: The act is responsible for providing for local governance by the Constitution; establishing a Local Government Service; establishing and administering the District Assemblies Common Fund; providing for a National Development Planning System; defining and regulate District Assemblies' planning procedures; to coordinate, facilitate, observe, and manage the operations of internal audits within District Assemblies; and for similar purposes. All these include the management of solid waste at the local level (Local Government Service -Ghana, 2016).

4. Environmental Sanitation Policy, revised (2009): the policy was formulated to rectify the shortcomings of the 1999 policy. It happened as an outcome of a countrywide consultation with stakeholders in various sectors across the country. The strategy has directed its efforts for the next five years towards the achievement of the Millennium Development Goals (MDGs) target year of 2015. All these were done to fulfill recent development objectives and the aspirations of individuals involved in the sector (UN LEAP, 2009).

5. National Plastics Management Policy (2021): The goal of the policy is to enable a transition to a circular economy for plastics by using holistic approaches that encompass all stages of their lifecycle and the value chain is seen as a means for achieving sustainable development. The Policy also establishes the groundwork for the development of a brand-new industry to modify, retrieve, and reuse, reducing environmental and community contamination, and generating job opportunities arising in an environmentally friendly economy (MESTI, 2019).

6. The establishment of the Accra Compost and Recycling Plant (ACARP): ACARP is an integrated waste processing and recycling enterprise founded and commissioned by the

government of Ghana in 2021 to collect and treat solid and liquid waste while also generating organic manure for agronomic uses in Ghana and the West African Sub-Region. Through the sorting, processing, and recycling of such material, the facility also addresses the issue of plastic waste. Also, high-quality plastic pellets that are produced by the company are used as raw materials by regional businesses to make a variety of plastic products. Additionally, the company is noted for the provision of information as well as technical and scientific skills in the field of integrated waste management and research to provide effective waste processing and recycling (ACARP, 2021).

7. The One Million Waste Bin Project of the Ministry of Sanitation and Water Resources: The project was launched in December 2019 by the Universal Plastic Products and Recycling (UPPR) Ghana Limited in partnership with Ecobank Ghana Limited and the Environment Service Providers Association in Accra, Ghana. The goal of the project is to reduce "indiscriminate disposal" of waste in the country as a means of contributing to the Sustainable development goals. However, this was supported by the view that supporting a clean environment is impossible without the usage of waste bins (GhanaWeb, 2019).

The Greater Accra region and the whole of Ghana are covered by these laws and policies, which also serve as the regulatory foundation for solid waste management. However, successful execution and enforcement of these laws in the area continue to be difficult and call for cooperation between various stakeholders, including the public sector, the business community, civic society, and citizens.

4.4 Discussion and Conclusion

Understanding modern development requires comparative urban studies. Ghana is more urbanized than Kenya, and it also has a more dispersed urban structure and a bigger indigenous urban footprint. Urban patterns in these nations are both merging and diverging, and

this is related to their common experiences with colonization, nationalism, and globalization (Otiso & Owusu, 2008). When it comes to solid waste management, Ghana, and Kenya both confront comparable difficulties, but Kenya has made significant advancement in recent years while Ghana has lagged. For Greater Accra to meet its rapid population growth demands, it needs to develop and maintain standards for aesthetics and public health while prioritizing solid waste management (MSW) networks. In this study, the MSWM system in Greater Accra and Nairobi Kenya was successfully reviewed. The comparative study of solid waste management policies, strategies, and implementation in Greater Accra and Nairobi confirms the studies hypothesis that when it comes to waste management concerns, the two cities may have some similarities, but there are also significant contextual differences that influence how the issues are addressed and managed. Socioeconomic conditions like demographic composition, political will, institutional capability and commitment, and public awareness are all important variables that bring about the differences in solid waste management in these two cities.

The MSWM system in the Greater Accra region is limited by weak enforcement of existing laws and policies, strategies, and implementations about solid waste management. Also, poor government implementations of solid technological innovations relating to solid waste management are all significant contributors to the poor management of solid waste in the Greater Accra region. For instance, the banning on the use of single-use plastic bags by the Kenyan government which was followed by the ban on the use of plastic bottles, cups, and cutlery in the country's national parks is a stricter policy that is critical for preserving public health, fostering sustainable practices, and supporting the economy while meeting international commitments. Additionally, that policy contributes to the reduction of solid waste generated in Kenya. Consequentially, minimizing the quantity of solid waste transported to landfills in the country,

therefore serving as a means of alleviating climate change while demonstrating a commitment to environmental sustainability in Kenya. In contrast, in 2018, Ghana launched the "National Plastic Management Policy" to regulate the use and disposal of plastic products in the country. This initiative brought forth the one million waste bin project by the Ministry of Sanitation and Water Resources. By taking these steps, Ghana is also contributing to solid waste management and helping to reduce its negative impact on the environment and human health.

To add to the above, comparing Kenya's recycling of plastics into building materials, Ghana has also undertaken efforts to promote the use of environmentally friendly building materials. For instance, in 2018, the Government of Ghana established the "Green Ghana Housing Project" (Ministry of Lands and Natural Resources, 2021). This was purposely to encourage the use of sustainable materials for the building and construction of housing units in the country. It was also a means to lower the impact of carbon on the housing sectors in the country while promoting environmental sustainability. In contrast, there are no known businesses in Ghana like Gjenge Maker's Ltd of Kenya, which recycles plastics and sand to make alternative construction materials. Therefore, Ghana might learn from Kenya in this area by encouraging or establishing businesses that adopt innovative recycling processes to help improve sustainability.

Also, Kenya's Green University Initiative Network (KGUN) is something Ghana lacks. Currently, the country has no formal program for promoting environmental sustainability in institutions, especially those at higher educational levels. On the other hand, Ghana has made diverse efforts to promote environmental sustainability through initiatives like the "National Sanitation Campaign" and the "National Plastic Management Policy," both of which aim to improve sanitation through the regulation of the use and disposal of plastic products in the country and promotion of good hygiene practices. Despite these efforts, Ghana could take steps

towards the induction of such Green Innovative initiatives in its educational institutions to encourage sustainable environmental practices at various educational levels.

Also in comparison, Ghana has no known waste-to-energy plants that exist in a country like Kenya. However, the country has made some efforts towards promoting renewable energy through the implementation of the Renewable Energy Act in 2011 (Ghana Energy Commission, 2011). The act aims to increase the share of renewable energy in the country's energy mix. Additionally, there are some private companies like Jekora Ventures Limited, that engage in waste-to-energy projects which produce biogas from organic waste in the city of Accra, Ghana. This could also be considered by the government of Ghana to help complement the country's only hydroelectric dam, the Akosombo Dam which is the only reliable source of electricity for Ghana.

Furthermore, the limited allocation of financial resources for research in the country adversely constrains the capacity of local innovators and entrepreneurs to develop and scale up new solutions in dealing with the solid waste management situation in the country. Additionally, the lack of public awareness and education on solid waste management has consequentially limited public support for technological innovations regarding the management of solid waste in Greater Accra and the country at large. Even though the government of Ghana has made several strides in adopting and implementing technology in various sectors of the country, there is still a substantial gap between innovations in waste management, energy, and infrastructural deployment. As a major producer of solid waste in Ghana, Greater Accra's MSWM must consider some of the best MSWM practices used by other nations like Kenya to overcome its limitations.

However, there are differences in the current state of MSWM techniques between various industrialized countries or the top MSWM nations. A concerted effort is required to enhance several variables, including institutional arrangements, budgetary resources, technology, operational administration, development of human resources, and public involvement and knowledge of SWM systems (Fernando, 2019). Therefore, the following suggestions are made to enhance the MSWM in the Greater Accra region considering Ghana's MSWM hierarchy in general and the comparative study. These measures were proposed for implementation in the Greater Accra region to be specific and Ghana in general. Synchronizing these in the region's plans and administration amid the rapid population growth will help promote sustainable development while maintaining its aesthetic value.

There is, however, hope for development because Ghana commits to the SDG of the United Nations, which includes supporting Sustainable Consumption and Production, and Sustainable Cities and Communities. For the country to fulfill its commitment to the UN Sustainable Development Goals and ensure a sustainable future, Ghana must give top priority to technology advancements in waste management, energy, and infrastructure. However, to safeguard the environment, public health, and the stability of the economy, both Greater Accra and Nairobi, as well as their respective countries, Ghana and Kenya must continue to place a higher urgency on sustainable waste management techniques. All these could be achieved with a strong alignment between effective policies, strategies, and implementations and a collaborative effort between citizens and the government.

4.5 Recommendation

4.5.1 Solid Waste Management Recommendations for Greater Accra Region

After comparing the current solid waste management practices, policies, and strategies of both Nairobi and the Greater Accra region, it can be concluded that the proposed recommendations for solid waste management in Greater Accra will have a higher likelihood of being effective and sustainable in the long term if they are specifically tailored to meet the region's unique needs about SWM.

1. Policy interventions and legal framework: Sensitization of city dwellers is significant for the successful execution of policies. However, participatory strategies and the dedication of governments to issues about solid waste management should be prioritized (Muheirwe et al., 2022). Policies and interventions which encompass the various forms of solid waste management should be established in the region and the country at large while being consistent with the existing environmental policies. For instance, there should be specific laws to discourage unsustainable means of waste disposal like dumping indiscriminately, burying waste in the ground, and open burning, among others.

2. Establishment of appropriate waste management system: The creation of solid waste management systems that takes a technological approach encompassing waste reduction and collection, waste sorting, recycling, and transportation and disposal plans could help solve the region’s solid waste management challenges. Also, establishing new landfill sites associated with better management and regulatory frameworks as well as waste management planning and coordination could help improve solid waste disposal.

3. Extension of solid waste management services to all parts of the region: National solid waste management policies should acknowledge the urban poor communities' entitlement to a clean and healthy atmosphere. Solid waste management services, especially disposal, collection, and transportation must be extended to the urban poor neighborhoods that are often not able to afford

the cost of waste disposal and collection usually by private waste collection entities. In addition, infrastructure like roads in such areas which are usually not accessible by waste collection vehicles and trucks must be considered for construction to provide flexibility in waste handling and disposal options.

4. Availability of reliable solid waste data: Solid waste data at the local and national levels should be made accessible in the country. Even though the Ghana Statistical Service provides data on methods of solid waste storage and disposal at the regional level in its decadal census report, there is still a dearth of information on solid waste data in the country. Data related to the quantity and composition of solid waste from the local to the national level should be available openly.

5. Financial investment: the government should allocate funds for the management of solid waste at various levels of the country. This could enhance the provision of machinery, awareness creation on the importance of solid waste management, and training of people who offer solid waste management services to employees, among others. Also, an exemption of taxes on solid waste goods and services could help contribute to the management of solid waste in the country.

6. Public-Private Partnerships: To improve the management of solid waste through collection and disposal services in the region, the Ministry of Sanitation and National Resources must partner with waste management firms using collaborations between government and private entities. This will help increase the efficacy and efficiency of solid waste management services. These suggestions, if implemented in Greater Accra Region will take the city to the next level of sustainability and make it much easier to follow the SDG goals. The government has to invest more money and time to make this possible, keeping in view the long-term impact on the health,

and well-being of people residing in the Greater Accra region as well as overall environmental improvement.

Chapter 5: Summary and Conclusion

5.1: Summary of the Findings: The overall objective of this study was to provide an overview of the rapid rate of urbanization and its impact on municipal solid waste management in the Greater Accra region of Ghana. The study was meant to achieve three different objectives. These include analyzing how much the Greater Accra region of Ghana has grown over time, identifying how Greater Accra's rate of urbanization has impacted solid waste management in the region, and giving suggestions on how solid waste management in the Greater Accra region can be improved and incorporated into urban planning and development.

5.1.1. The Growth of Greater Accra Region Overtime: As part of the study, the researcher employed remote sensing technology like ERDAS Imagine 13, Arc GIS 10.1, and Google Earth Pro to examine and track changes in land use and land cover of the Greater Accra region from 2000 to 2021 using satellite imagery. The study helped to reveal both the spatial and physical changes of the region within the three decades study period. Four land cover classes namely water bodies, bare land, built-up, and vegetation were considered in this study. The study showed that built-up areas and bare land in the region have increased significantly with an inverse decline in vegetation drastically. The most dominant land cover of the Greater Accra Region was built-up features. This is a result of the rapid population growth coupled with the rate of urbanization in the region which has caused a great demand for built-up features mainly for residential and commercial purposes. Also, the analysis found that improper solid waste management, traffic congestion, perennial flood hazard, pollution of water bodies, and the creation of slums as the major problems associated with the region's rate of urbanization.

5.1.2. The Impact of Urbanization on Solid Waste Management: In the second part of the study, the impact of urbanization on solid waste management in the Greater Accra Region was analyzed.

Based on the degree of the current obstacles and advantages the region is facing regarding SWM, the research was also intended to determine the strategies that should be pushed for effective solid waste management in the region before the problem spirals out of control. The findings revealed that the current situation of solid waste management in the region is due to inadequate waste management infrastructure and practices. According to the study, storage of waste in disposable waste receptacles which happens to be the unsustainable means of storing solid waste happens to be more dominant in the region than the other methods of storing solid waste. Also, the study revealed that there has been a massive improvement in the sustainable means of solid waste disposal over the years. Gradually, the collection of generated solid waste by households in the Greater Accra region has improved from 10% in 2000 to 55% in 2021. Comparatively, it was noticed that there is an increment in the burning method of solid waste disposal from 15% in 2000 to 55% in 2021, therefore making burning the major means of disposing of uncollected solid waste.

More importantly, there has been a significant decline in the percentage of households who either buried their generated waste or dumped their solid waste indiscriminately from 70% in 2000 to 15% in 2021 and 55% to 10% respectively whereas public dump has dropped from 60% in 2010 to 10% in 2021. Additionally, the study's statistical analysis revealed that the Population 15 years and above who are illiterate, and the Average household size have an influence on collection as a method of solid waste disposal in the region. Again, the findings of the study indicated that the number of households, and the Population of 15 years and above who are employed significantly predicts the burnt method of waste disposal. Also, the Population 15 years and above who are literate and the Population 15 years and above who are employed (Pop15y_Emp) are significant predictors of indiscriminate solid waste disposal in the region. Additionally, the population 15 years and above who are illiterate (Pop15y_Nli) and Average household size (Av_HH_Size) was

realized to be significant users of the buried method of waste disposal by households in the Greater Accra region.

5.1.3 Enhancement and Incorporation of Solid Waste Management into Urban Planning and Development: The research findings revealed that the Greater Accra region's MSWM system is constrained by poor solid waste management laws, policies, strategies, and implementations. All of these issues are consequences of a lack of proper planning for solid waste management, insufficient government policies and lack of stringency in the government's approach to solid waste management, limited allocation of financial resources, human resource development, lack of awareness, and irresponsible attitudes towards solid waste storage and disposal. Also, inadequate government implementations of substantial technological advancements and innovations linked to solid waste management were discovered to be major factors in the poor management of solid waste in the Greater Accra region. The study's findings revealed these after a comparative analysis has been made between the solid waste management strategies, practices, and policies between Nairobi, Kenya, and the study area, the Greater Accra region of Ghana. Based on the study's findings, the following recommendations were proposed, policy interventions and legal framework by the government, the establishment of an appropriate solid waste management system, an extension of solid waste management services to all parts of the region, especially in the urban poor neighborhoods, the availability of reliable solid waste data, financial investment, and public-private partnerships.

5.2 Conclusion

Ghana's Greater Accra region is rapidly urbanizing, counting as one of the fastest-growing urban areas in West Africa. The growth of the Greater Accra region has seen an increase in human activities and associated solid waste mismanagement. With this, the enhancement and

incorporation of solid waste management into urban planning and development are critical for the region's sustainability. The region has been experiencing urbanization after the Christiansburg Castle was chosen as the seat of the British administration of the Gold Coast in 1877 (Yankson & Gough, 1999). Today, the region's land cover is changing drastically, especially with a significant decline in the vegetative cover which is replaced with built-up features and bare land. The study revealed how the integration of GIS and remote sensing offers a strong tool for monitoring spatial and temporal changes in land use and land cover in a particular area within a specified period. The primary change trajectories in the Greater Accra region were identified by the LULC change analysis results, notably the growth of built-up areas.

In addition, the Greater Accra region's urbanization is almost completely encroaching into neighboring regions. Accordingly, it is impossible to ignore how these areas will affect Greater Accra's upcoming urban growth. Even though the government has put in efforts toward solid waste management in the region, there is still much more to be done to achieve sustainable and effective management of solid waste in the region. Overall, Greater Accra should tackle solid waste management issues holistically by inculcating issues of solid waste management into urban planning and developmental objectives. This could be done by integrating efficient solid waste management approaches like the development of a comprehensive waste management plan and infrastructure, Overall, effective solid waste management amid urbanization is crucial for public health protection, environmental preservation, resource conservation, promotion of economic and social benefits, and creating a sustainable future.

5.3 References

ACARP. (2021). *Accra Compost and Recycling Plant Limited (ACARP)*. http://acarpghana.com/index.php/about-us

Achankeng, E. (2003). *Globalization, Urbanization and Municipal Solid Waste Management in Africa*. https://www.semanticscholar.org/paper/Globalization%2C-Urbanization-and-Municipal-Solid-in-Achankeng/f234b5b4f116bc13398071519f8785df5133480d

Adzawla, W., Tahidu, A., Mustapha, S., & Azumah, S. B. (2019). Do socioeconomic factors influence households' solid waste disposal systems? Evidence from Ghana. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, *37*(1_suppl), 51–57. https://doi.org/10.1177/0734242X18817717

African Energy. (2020). *Kenya: KenGen to study the waste-to-energy plant in Nairobi | African Energy*. https://www.africa-energy.com/news-centre/article/kenya-kengen-study-waste-energy-plant-nairobi

Alaya, H. (2022). Applications of Transportation Models in Africa. In H. Masri (Ed.), *Africa Case Studies in Operations Research: A Closer Look into Applications and Algorithms* (pp. 139–158). Springer International Publishing. https://doi.org/10.1007/978-3-031-17008-9_7

Asgari, A. R., Ghorbanian, T., Dadashzadeh, D., Khalili, F., Yari, A. R., Bagheri, A., Yousefi, N., Ghadiri, S. K., & Talebi, S. S. (2019). Solid Waste Characterization and Management Practices in Rural Communities, Tehran and Alborz (Iran). *The Journal of Solid Waste Technology and Management*, *45*(1), 111–118. https://doi.org/10.5276/JSWTM.2019.111

Azubuike, S. I., Asekomeh, A., & Gershon, O. (Eds.). (2022). *Decarbonisation Pathways for African Cities*. Springer International Publishing. https://doi.org/10.1007/978-3-031-14006-8

Bernardes, C., & Günther, W. M. R. (2014). Generation of Domestic Solid Waste in Rural Areas: Case Study of Remote Communities in the Brazilian Amazon. *Human Ecology*, *42*(4), 617–623. https://doi.org/10.1007/s10745-014-9679-z

Bhada-Tata, P., & Hoornweg, D. A. (2012). *What a waste? : A global review of solid waste management*. https://policycommons.net/artifacts/1513146/what-a-waste/2185670/

Cheng, J., Shi, F., Yi, J., & Fu, H. (2020). Analysis of the factors that affect the production of municipal solid waste in China. *Journal of Cleaner Production*, *259*, 120808. https://doi.org/10.1016/j.jclepro.2020.120808

Cohen, B. (2006). Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. *Technology in Society*, *28*(1), 63–80. https://doi.org/10.1016/j.techsoc.2005.10.005

Edomah, N. (2020). *Regional Development in Africa*. BoD – Books on Demand.

EPA Ghana. (2022). *Integrity, dedication, service, teamwork... | Environmental Protection Agency, Ghana*. http://www.epa.gov.gh/epa/

Fernando, R. L. S. (2019). Solid waste management of local governments in the Western Province of Sri Lanka: An implementation analysis. *Waste Management*, *84*, 194–203. https://doi.org/10.1016/j.wasman.2018.11.030

Flávia Tuane Ferreira Moraes, Andriani Tavares Tenório Gonçalves, & Josiane Palma Lima, Renato da Silva Lima. (2022). *Transitioning towards a sustainable circular city: How to evaluate and improve urban solid waste management in Brazil -*. https://journals.sagepub.com/doi/full/10.1177/0734242X221142227

FOEN, F. O. for the E. S. (2011). *Topic Waste*. https://www.bafu.admin.ch/bafu/en/home/themen/thema-abfall.html

Gakungu, N. K., Gitau, A., Njoroge, B. K., & Kimani, M. (2012). *SOLID WASTE MANAGEMENT IN KENYA: A CASE STUDY OF PUBLIC TECHNICAL TRAINING INSTITUTIONS*. https://www.semanticscholar.org/paper/SOLID-WASTE-MANAGEMENT-IN-KENYA%3A-A-CASE-STUDY-OF-Gakungu-Gitau/136278497a692f7e59d0068b8b45f22d3a3e2007

Ghana Energy Commission. (2011). *Energy Commission, Ghana*. http://www.energycom.gov.gh/

Ghana Statistical Service. (2021). *2021 Population and Housing Census*. https://census2021.statsghana.gov.gh/presspage.php?readmorenews=MTY4OTA1MDkwNC4wOTY=&Presentation-on-the-General-Report-Volumes-3A-3B-and-3C

GhanaWeb. (2019, December 3). *1 million waste bin project launched in Accra*. GhanaWeb. https://www.ghanaweb.com/GhanaHomePage/business/1-million-waste-bin-project-launched-in-Accra-805081

Godfrey, L., Ahmed, M. T., Gebremedhin, K. G., Katima, J. H. Y., Oelofse, S., Osibanjo, O., Richter, U. H., Yonli, A. H., Godfrey, L., Ahmed, M. T., Gebremedhin, K. G., Katima, J. H. Y., Oelofse, S., Osibanjo, O., Richter, U. H., & Yonli, A. H. (2019). Solid Waste Management in Africa: Governance Failure or Development Opportunity? In *Regional Development in Africa*. IntechOpen. https://doi.org/10.5772/intechopen.86974

Haregu, T. N., Ziraba, A. K., Aboderin, I., Amugsi, D., Muindi, K., & Mberu, B. (2017). An assessment of the evolution of Kenya's solid waste management policies and their implementation in Nairobi and Mombasa: Analysis of policies and practices. *Environment and Urbanization*, *29*(2), 515–532. https://doi.org/10.1177/0956247817700294

IETC. (2019, March 25). *Africa Waste Management Outlook*. International Environmental Technology Centre. http://www.unep.org/ietc/resources/publication/africa-waste-management-outlook

Kaza, S., Yao, L., Bhada-Tata, P., & Woerden, F. V. (2018a). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. World Bank Publications.

Kaza, S., Yao, L., Bhada-Tata, P., & Woerden, F. V. (2018b). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. World Bank Publications.

Kenya National Bureau of Statistics. (2019, November 4). 2019 Kenya Population and Housing Census Results. *Kenya National Bureau of Statistics*. https://www.knbs.or.ke/2019-kenya-population-and-housing-census-results/

Kerdsuwan, S., Laohalidanond, K., & Jangsawang, W. (2015). Sustainable Development and Eco-friendly Waste Disposal Technology for the Local Community. *Energy Procedia*, *79*, 119–124. https://doi.org/10.1016/j.egypro.2015.11.493

Local Government Service -Ghana. (2016). *Local Governance Act of 2016, Act 936 – LOCAL GOVERNMENT SERVICE*. https://lgs.gov.gh/local-governance-act-of-2016-act-936/

MESTI. (2019, September 19). National policy to fight plastic pollution. Ministry of Environment, Science, Technology & Innovation -Ghana. *Ministry of Environment, Science, Technology & Innovation*. https://mesti.gov.gh/national-policy-fight-plastic-pollution-launched-oct-1/

Mian, M. M., Zeng, X., Nasry, A. al N. B., & Al-Hamadani, S. M. Z. F. (2017). Municipal solid waste management in China: A comparative analysis. *Journal of Material Cycles and Waste Management*, *19*(3), 1127–1135. https://doi.org/10.1007/s10163-016-0509-9

Ministry of Lands and Natural Resources. (2021). *Green Ghana Project – Operation 5000000 Trees*. https://greenghana.mlnr.gov.gh/

MLGRD. (2010). *Environmental sanitation policy [Ghana, 2010]*. Ghana, Ministry of Local Government and Rural Development.

Moya, D., Aldás, C., López, G., & Kaparaju, P. (2017). Municipal solid waste as a valuable renewable energy resource: A worldwide opportunity of energy recovery by using Waste-To-Energy Technologies. *Energy Procedia*, *134*, 286–295. https://doi.org/10.1016/j.egypro.2017.09.618

Mudu, P., Nartey, B. A., Kanhai, G., Spadaro, J. V., & Fobil, J. (2021). *Solid waste management and health in Accra, Ghana*.

Muheirwe, F., Kombe, W., & Kihila, J. M. (2022). The paradox of solid waste management: A regulatory discourse from Sub-Saharan Africa. *Habitat International*, *119*, 102491. https://doi.org/10.1016/j.habitatint.2021.102491

Muniafu, L., & Mutiso, N. (2022). Contextualising Waste Management Operations Towards Low-Carbon African Cities. In S. I. Azubuike, A. Asekomeh, & O. Gershon (Eds.), *Decarbonisation Pathways for African Cities* (pp. 37–49). Springer International Publishing. https://doi.org/10.1007/978-3-031-14006-8_3

Nairobi City Council. (2015). *The Nairobi City County Public Participation Act,2015 | Nairobi City County*. https://nairobi.go.ke/download/the-nairobi-city-county-public-participation-act2015/

National Environment Policy. (2013). *National Environment Policy 2013—Kenya—Climate Change Laws of the World*. https://climate-laws.org/geographies/kenya/policies/national-environment-policy-2013

Nderitu, M. (2010). *External Communication at the National Environmental Management Authority (NEMA) in Kenya*.

NEMA. (2014). *National Environment Management Authority (NEMA)—Home-KENYA*. https://www.nema.go.ke/

Nguyen, K. L. P., Chuang, Y. H., Chen, H. W., & Chang, C. C. (2020). Impacts of socioeconomic changes on municipal solid waste characteristics in Taiwan. *Resources, Conservation and Recycling*, *161*, 104931. https://doi.org/10.1016/j.resconrec.2020.104931

Njoroge, B. N. K., Kimani, M., & Ndunge, D. (2014). *Review of Municipal Solid Waste Management: A Case Study of Nairobi, Kenya*.

Oduro-Appiah, K., & Afful, A. (2020). *Sustainable Pathway for Closing Solid Waste Data Gaps: Implications for Modernization Strategies and Resilient Cities in Developing Countries*. https://doi.org/10.5772/intechopen.94384

Ogutu, F. A. (2019). *Assessment of the Effectiveness of the Policy Framework on Solid Waste Management in Nairobi, Kenya* [Thesis, University of Nairobi]. http://erepository.uonbi.ac.ke/handle/11295/107189

Ogutu, F. A., Kimata, D. M., & Kweyu, R. M. (2021a). Partnerships for sustainable cities as options for improving solid waste management in Nairobi city. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, *39*(1), 25–31. https://doi.org/10.1177/0734242X20967735

Ogutu, F. A., Kimata, D. M., & Kweyu, R. M. (2021b). Partnerships for sustainable cities as options for improving solid waste management in Nairobi city. *Waste Management & Research*, *39*(1), 25–31. https://doi.org/10.1177/0734242X20967735

Oteng-Ababio, M., Melara Arguello, J. E., & Gabbay, O. (2013a). Solid waste management in African cities: Sorting the facts from the fads in Accra, Ghana. *Habitat International*, *39*, 96–104. https://doi.org/10.1016/j.habitatint.2012.10.010

Oteng-Ababio, M., Melara Arguello, J. E., & Gabbay, O. (2013b). Solid waste management in African cities: Sorting the facts from the fads in Accra, Ghana. *Habitat International*, *39*, 96–104. https://doi.org/10.1016/j.habitatint.2012.10.010

Otiso, K. M., & Owusu, G. (2008). Comparative urbanization in Ghana and Kenya in time and space. *GeoJournal*, *71*(2), 143–157. https://doi.org/10.1007/s10708-008-9152-x

Ouda, O. K. M., & Raza, S. A. (2014). Waste-to-energy: Solution for Municipal Solid Waste challenges-global perspective. *2014 International Symposium on Technology Management and Emerging Technologies*, 270–274. https://doi.org/10.1109/ISTMET.2014.6936517

Rajpal, A., Kazmi, A. A., & Tyagi, V. K. (2020). Solid waste management in rural areas nearby river Ganga at Haridwar in Uttarakhand, India. *Journal of Applied and Natural Science*, *12*(4), Article 4. https://doi.org/10.31018/jans.v12i4.2394

Schenck, R., & Blaauw, P. F. (2011). The Work and Lives of Street Waste Pickers in Pretoria—A Case Study of Recycling in South Africa's Urban Informal Economy. *Urban Forum*, *22*(4), 411–430. https://doi.org/10.1007/s12132-011-9125-x

Schluep, M., Terekhova, T., Manhart, A., Müller, E., Rochat, D., & Osibanjo, O. (2012). Where are WEEE in Africa? *2012 Electronics Goes Green 2012+*, 1–6.

Shekdar, A. V. (2009). Sustainable solid waste management: An integrated approach for Asian countries. *Waste Management*, *29*(4), 1438–1448. https://doi.org/10.1016/j.wasman.2008.08.025

Simelane, T. (2011). Interpreting the transformation of the city centres of South Africa through system dynamics—How different are they from other African cities? *Africa Insight*, *40*(4), 168–186. https://doi.org/10.10520/EJC17668

Statista. (2019). Global waste generation will nearly double by 2050. *The Economist*. https://www.economist.com/graphic-detail/2018/10/02/global-waste-generation-will-nearly-double-by-2050

Taboada-Gonzalez, P., Aguilar-Virgen, Q., Ojeda-Benitez, S., & Armijo, C. (2011). Waste Characterization and Waste Management Perception in Rural Communities in Mexico: A Case Study. *Environmental Engineering and Management Journal*, *10*(11), 1751–1759. https://doi.org/10.30638/eemj.2011.238

Tadesse, T. (2009). Environmental concern and its implication to household waste separation and disposal: Evidence from Mekelle, Ethiopia. *Resources, Conservation and Recycling*, *53*(4), 183–191. https://doi.org/10.1016/j.resconrec.2008.11.009

The World Bank. (2021). *Battling Kenya's Plastic Waste: Young Kenyan Woman is Transforming Waste into Sustainable and Affordable Building Materials*. World Bank. https://www.worldbank.org/en/news/feature/2021/03/11/battling-kenya-plastic-waste-young-kenyan-woman-transforming-waste-into-sustainable-and-affordable-building-materials

UN LEAP. (2009). *Environmental Sanitation Policy (Revised 2009). | UNEP Law and Environment Assistance Platform*. https://leap.unep.org/countries/gh/national-legislation/environmental-sanitation-policy-revised-2009

UNDP. (2018). *Goal 12: Responsible consumption and production | Sustainable Development Goals | United Nations Development Programme*. UNDP. https://www.undp.org/sustainable-development-goals/responsible-consumption-and-production

UNEP. (2016). *UNEP launches Kenya Green University Network | UNESCO*. https://www.unesco.org/en/articles/unep-launches-kenya-green-university-network

UNEP. (2017, October 12). *Kenya Green University Network*. UNEP - UN Environment Programme. http://www.unep.org/explore-topics/education-environment/why-does-education-and-environment-matter/green-university-0

UNEP. (2021, February 18). *Kenya emerges as leader in fight against plastic pollution: United Nations Environment Programme*. UNEP. http://www.unep.org/news-and-stories/story/kenya-emerges-leader-fight-against-plastic-pollution

Viljoen, J. M. M., Schenck, C. J., Volschenk, L., Blaauw, P. F., & Grobler, L. (2021). Household Waste Management Practices and Challenges in a Rural Remote Town in the Hantam Municipality in the Northern Cape, South Africa. *Sustainability*, *13*(11), Article 11. https://doi.org/10.3390/su13115903

Vinti, G., & Vaccari, M. (2022). Solid Waste Management in Rural Communities of Developing Countries: An Overview of Challenges and Opportunities. *Clean Technologies*, *4*(4), Article 4. https://doi.org/10.3390/cleantechnol4040069