Assessing the current solid waste management system and selecting new landfill site using Geospatial Technology: A case of Chole Town, Oromia, Ethiopia

EYOB FURNO

A thesis submitted to the Department of Architecture,
College of Civil Engineering and Architecture
Presented in Partial Fulfillment of the Requirement for the Degree of
Master's in Geo-Informatics Engineering

Office of Graduate Studies

Adama Science and Technology University

May, 2025
Adama, Ethiopia

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ADVISOR: GETACHEW B/MESKEL (PH.D.)

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DECLARATION

I declare here by this research thesis entitled "Assessing the current solid waste management system and selecting new landfill site using Geospatial technology: A case of Chole town, Oromia, Ethiopia" is my own work and has not been submitted to any university for similar purpose. The reference used in this Thesis are dully recognized by proper citations.

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I, the major advisor of this thesis, here by certify that I have read the revised version of the thesis entitled "Assessing the current solid waste management system and selecting new landfill site using Geospatial technology: A case of Chole town, Oromia, Ethiopia" prepared under my guidance by Eyob Furno. Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures.

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We, the undersigned, members of the Board of Examiners of the thesis by Eyob Furno have read and evaluated the thesis entitled "Assessing the current solid waste management system and selecting new landfill site using Geospatial technology: A case of Chole town, Oromia, Ethiopia" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in Geoinformatics.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
FAO	Food and Agriculture Organization
CR	Consistency Ratio
CI	Consistency Index
CSA	Central Statistical Authority
DEM	Digital Elevation Model
FPC	Finite Population Correction
FGD	Focused Group Discussion
GPS	Global Positioning System
GIS	Geographical Information System
IBM	International Business Machines Corporation
LULC	Land Use/Land Cover
USGS	United States Geological Survey
SWM	Solid Waste Management
MCA	Multicriteria Analysis
MCDM	Multi Criteria Decision Model
SPSS	Statistical Package for the Social Sciences

ABSTRACT

This study aims to enhance the solid waste management (SWM) system in Chole Town, Oromia Regional State, Ethiopia, through the application of geospatial technologies. Driven by rapid urbanization, population growth, and increasing wastes generation, Chole Town faces major environmental, infrastructural, and institutional challenges in solid waste management. The research integrates geospatial technologies like Geographic Information Systems (GIS), Remote Sensing (RS), and the Analytic Hierarchy Process (AHP) with socio-economic data and environmental data to identify the best locations for solid waste dumping. 380 household respondents were sampled using stratified random sampling, and data were collected using questionnaires, interviews, field observation, and spatial data. The significant determining factors that were identified as applicable are inadequate institutional coordination, poor public awareness, absence of infrastructure, and proximity to slope, water body, and land use. Multi-criteria decision-making techniques were employed to rank eight crucial spatial factors including land use/land cover, slope, proximity to roads, proximity to built-up, soil type, distance to surface and ground water, and sensitive area proximity. The geospatial analysis indicated that 14% of the study area was highly suitable for landfill development, 28% was moderately suitable, 18% was less suitable, and 38% was unsuitable according to environmental and social limitations. The study confirms that integrating spatial and non-spatial data improves well-informed decision-making for sustainable waste management. It concludes that the application of geospatial tools not only enhances the efficiency of SWM practices but also promotes resource optimization, environmental sustainability, and long-term urban development. It suggests improving institutional capacity, investing in infrastructure, adopting segregation and recycling, and mainstreaming GIS-based planning for future development.

Key Words: Solid Waste Management, Geospatial Technology, Site Suitability,

CHAPTER I: INTRODUCTION

1.1 Background of the study

Solid waste management is defined as the collection, transportation, processing, recycling, and disposal of solid waste materials so as to reduce their effect on health, environment and aesthetics (Anberber, 2021). One aspect of the issue with border urbanization is solid waste management. Daily activities produce garbage, and how this material is collected, processed, stored, and disposed of can have negative effects on the environment and public health (The World Bank, 2019).

Adverse environmental impact of uncollected waste in a city is significant. Uncollected solid waste can end up in drains leading to the blockage of drainage systems e and cause unsanitary conditions that have a direct health impact on residents. (Solomon, 2021) Open burning of uncollected waste produces pollutants that are highly damaging locally and globally. Vectors such as mosquitos usually breed in blocked drainages and blocked drainages also contribute to flooding. In 2015, the Global Waste Management Outlook estimated that at least 2 billion people do not have access to regular waste collection. This is particularly worse in informal settlements. UN-Habitat's report on Solid Waste Management in World Cities Report published in 2010 estimated that only 5% of waste in squatter areas is regularly collected (Dadi et al., 2017).

In order to reduce the spread of illness, lower pollution, improve cleanliness, encourage resource recovery, and generate jobs opportunities urban areas communities must effectively manage their solid waste. Similar to other wastes, solid wastes are produced by human activity. The type of solid waste generated is determined by a number of variables, including the occupation, style of living, and habits of the contributing population, all of which are influenced by the climate and dietary practices. Therefore, the kind and volume of solid waste that will be produced in a given situation are determined by these different criteria. Because of these variations, different strategies are needed for different waste management systems. For instance, the emphasis of the Solid Waste Management process in developing nations should be on the collecting procedure because the waste material in these regions is primarily organic and prone to rapid degradation.

With a focus on defining the essential elements and assessing the existing practices and challenges, in Chole town the study aims to investigate the different geospatial analysis techniques integrated with household in Chole town for the disposal of solid waste. To address the research gap, this study will utilize a multi-criteria Decision model to assess the impact of waste management factors on the methods and components of solid waste disposal in households, considering socioeconomic factors like family size, monthly income, education level, and occupation.

By dumping of huge garbage, drives biodegradable materials to decay and decompose under abnormal, uncontrolled and unhygienic conditions. After a few days of decomposition, it becomes a breeding ground for different types of disease-causing insects as well as infectious organisms. A foul smell is produced and it also spoils the aesthetic value of the area.

The solid wastes collected from different industries include toxic metals, chemicals, and other hazardous wastes. When these wastes are released into the environment, they can produce biological and physicochemical problems to the environment, the chemicals may drain into the soil and pollute the groundwater and also alter the productivity of the soils in that particular area.

In rare cases, the hazardous wastes may get mixed up with the ordinary garbage and other combustible wastes causing the disposal process even harder and risky.

By burning the paper and other scraps along with the hazardous wastes, dioxins and poisonous gasses are produced and released into the air which results in causing various diseases including chronic disease, skin infections, cancer, etc.

A technological approach to solid-waste management began to develop in the latter part of the 19th century. Watertight garbage cans were first introduced in the United States, and sturdier vehicles were used to collect and transport wastes. There are several reasons why this study is important (Babalola & Busu, 2011). As a developing urban area, Chole town faces significant obstacles in effectively handling its garbage and lack of dumping site. It is imperative to conduct further research on the factors that influence the management of solid waste and the socio-economic aspects that impact how solid waste manage using Geospatial technology.

The selection of suitable sites for solid waste management systems is essential for sustainable urban development and minimizing environmental impacts (Sadessa & Balo, 2025). Geospatial tools such as Geographic Information Systems (GIS) and remote sensing are increasingly used to support this process through the integration, analysis, and visualization of spatial data. Advanced techniques like the Analytical Hierarchy Process (AHP), weighted overlay analysis, buffering, and image classification further enhance decision-making by enabling multi-criteria evaluation and accurate land-use assessment. This study applies these geospatial and analytical tools to identify optimal locations for solid waste management system site selection.

1.2 statement of the problem

Challenges in solid waste management are more acute in developing countries than in developed countries (Hoornweg and Freire, 2013). Perhaps one major challenge in developed countries as pointed out by Hoornweg and Freire (2013), is the complexity of wastes generated by their populations. Land space for siting landfills is also a challenge in solid waste management in developed countries. For instance, the United Kingdom will run out of landfill space by 2018 with their current generation rates (UN Habitat (2013a).

The problem of solid waste management is especially acute in developing countries because as Muhammad and Manu (2013) observe, most third world cities do not collect the totality of wastes generated, and of the wastes collected, only a fraction receives proper disposal. This is supported by UNEP‘s (2015) assertion that low- and middle-income countries still face major challenges in ensuring universal access to waste collection services, eliminating uncontrolled disposal and burning and moving towards environmentally sound management for all waste.

Badgie et al. (2012) hold that inadequate municipal solid waste management is certainly one of the contributing factors to the degradation of the environmental quality. Surmounting this challenge is made even more difficult by forecasts that major cities in the lowest income countries are likely to double in population over the next 20 or so years (UNEP, 2015). Guerrero et al., (2013) concludes that solid waste management is a challenge for the cities ‘authorities in developing countries mainly due to the increasing generation of waste, the burden posed on the municipal budget as a result of the high costs associated with its management, the lack of understanding over a diversity of factors that affect the different stages of waste management and linkages necessary to enable the entire handling system functioning.

Despite the growing significance of Solid waste management, there is a research gap in understanding and improving the practices Existing literature primarily focuses on general frameworks and best practices, often overlooking the unique characteristics and challenges faced by individual cities (Wright, 2017). As a result, there is limited knowledge and guidance on evaluating the solid waste management practices in Chole town.

Geospatial technology can play a significant role in minimizing solid waste challenges by providing valuable insights into waste management systems, optimizing processes, and enabling better planning and decision-making. Mapping waste generation hotspots, optimizing waste collection routes, route optimization, monitoring waste disposal sites are some of Geospatial technology a significant role in minimizing solid waste challenges.

The existing practices in the town encounter challenges related to solid waste management. Furthermore, the limited utilization of Geospatial tools restricts the availability and accessing, hindering transparency and collaboration. Addressing these challenges requires a comprehensive research effort that evaluates the current management practices in Chole town, develops a system for efficient solid waste management, and leverages Geospatial tools.

By bridging the research gap and addressing the identified challenges, Chole town can enhance its solid waste management practices.

1.3 Research objective

1.3.1. General Objective.

To improve solid waste management in Chole Town using geospatial technologies and multi-criteria analysis for optimal site selection.

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1.3.2. Specific Objectives:

- To assess current solid waste management practices in Chole Town.
- To identify key factors affecting waste management.
- To apply GIS, Remote Sensing, and AHP for site suitability analysis.
- To integrate spatial and non-spatial data for decision-making.
- To recommend strategies for improving SWM in the town.

1.4. Research Questions

- What is the current status of solid waste management in Chole Town?
- What are the key factors influencing solid waste management in the area?
- How can GIS, Remote Sensing, and AHP be used to identify suitable waste disposal sites?
- How can spatial and non-spatial data be integrated to support decision-making?
- What strategies can be proposed to improve solid waste management in Chole Town?

1.5 Significance of the study

This study holds significant value for improving solid waste management in Chole Town, where rapid urbanization and population growth have intensified the challenges of waste disposal. Improperly located disposal sites can lead to serious environmental degradation, including groundwater contamination, air pollution, and public health risks. By assessing the solid waste management system, the study seeks to enhance the efficiency of solid waste management in Chole town. The utilization of geospatial technology for improved solid waste management is anticipated to streamline processes related to planning. The study provides a valuable opportunity to discern both the strengths and weaknesses inherent in the current solid waste management system. This understanding is pivotal for recognizing areas of success and potential improvement, thereby guiding future enhancements to the system. The comprehensive evaluation facilitates the optimization of resources, ensuring that investments in geospatial technology align precisely with the specific needs and challenges of Chole town. This, in turn, can result in more effective resource allocation, promoting sustainable practices in solid waste management.

Through the evaluation process, there is an opportunity to pinpoint areas requiring knowledge transfer and capacity building. This identification can pave the way for targeted training programs and collaborative efforts aimed at enhancing the skills and capabilities of professionals engaged in solid waste management. In conclusion, the study's evaluation of the solid waste management system and enhancing utilizing of geospatial technology in solid waste management, holds significance by addressing practical challenges, informing decision-making processes, and contributing to broader objectives related to efficient and sustainable solid waste management in the town.

1.6. Scope and limitation of the study

The spatial scope of this study is limited to Chole Town, located in the Oromia Region of Ethiopia. All data collection, analysis, and evaluation are confined within the geographic boundaries of this town. The study does not extend to neighbouring towns, rural areas, or other administrative regions. The focus remains strictly on the urban and peri-urban areas of Chole Town where solid waste generation, management infrastructure, and disposal practices are active and observable.

The thematic scope of this study is cantered on evaluating the effectiveness of the solid waste management system in Chole Town, with a particular emphasis on technical and technological aspects. This includes the examination of processes such as waste generation, segregation, collection, transportation, recycling, and final disposal. The study seeks to understand how modern waste management technologies are being applied and how efficiently the current system functions.

1.7 Organization of the Thesis

This thesis is divided into five chapters. The first chapter provides the introduction to the study including background of the study, statement of the problem, objectives of the study, research questions, scope, significance and limitation of the study. The second chapter presents review of related literatures, mainly including, the concept and types of solid waste management systems, the concept and process of solid waste disposal management, applications of GIS and RS in solid waste disposal management and different criteria for solid waste Suitable site. The third chapter deals with the description of the study area as well as the materials and methods employed in the study. The fourth chapter presents the analysis and the final suitable site selected for the study area. Chapter five presents conclusions and recommendations.

CHAPTER II: LITRATURE REVIEW

2. 1 Global Concepts of Solid Waste Management Systems

Globally, waste volumes are increasing quickly even faster than the rate of urbanization (Hoornweg and Bhada-Tata, 2012). Nevertheless, proper waste management has a major contribution to make in shifting the planet towards a sustainable future (UNEP and UNITAR, 2013). According to Horne and Bhadra-Tata (2012), municipal solid waste management is the most important service a city provides both in low-income countries as well as many middle-income countries.

Wilson (2007) observes that while developed countries exhibit a high degree of sound environmental considerations in their waste management utilizing sanitary landfills, waste treatment and processing, energy and material recovery options, in developing countries waste disposal is uncontrolled and waste treatment, processing, energy and material recovery are rare. Many developed countries have made great strides in addressing waste management, particularly since the environment came onto the international agenda in the 1960‘s (UNEP, 2015).

Global Waste Management Outlook (GWMO) of 2015 reports that the initial focus was on waste after it had been discarded, whereas at present attention has moved upstream, addressing the problem at its source through, for example, designing out waste, preventing its generation, reducing both the quantities and the uses of hazardous substances, minimizing and reusing, and, where residuals do occur, keeping them concentrated and separate to preserve their intrinsic value for recycling and recovery and prevent them from contaminating other waste that still has economic value for recovery (UNEP, 2015).

For instance, in Adelaide City, Australia, waste collection system is highly modernized, and 100 per cent of households in the Adelaide metropolitan area receive a high-quality kerb side waste collection service, usually on a weekly basis (UN HABITAT, 2010). The high standards of collection and street and public place cleaning services and customer care are consistent regardless of the socio-economic status of the area. Here solid waste collection system is by both private sector companies and public company. The majority of collection services operate as three-bin systems for separate collection of recyclables, green organics and residual waste (UN HABITAT, 2010).

In Adelaide recycling and disposal, according to UN HABITAT (2010), is at 54% and 46% of the total waste collected respectively.

Disposal is purely by landfilling carried out to a high standard of environmental protection (UN HABITAT, 2010). The situation is even better in Sweden where according to Research Office of the Legislative Council Secretariat (2014), only1% of municipal solid waste (MSW) end up at landfills while treatment is characterized by an almost equal share of recycling/composting (48%) and incineration (51%) as of 2011. Incineration has developed to such a level that Sweden has been short of feed stock to fuel its incineration plants and started to import waste from its neighboring countries (Research Office, 2014).

In the Czech Republic, Danco (2013), reports that around 70% of MSW generated is landfilled while the MSW recycling rate stands at 16% and municipalities are responsible for MSW management in their administrative territories. The Czech Republic has also implemented a landfill tax where citizens pay a fee for municipal waste services per capita (Danco, 2013).

A typical solid waste management system in a developing country displays an array of problems, including low collection coverage and irregular collection services, crude open dumping and burning without air and water pollution control, the breeding of flies and vermin, and the handling and control of informal waste picking or scavenging activities (Ogawa, 1996). This is consistent with UNEP (2015) assertion that low- and middle-income countries still face major challenges in ensuring universal access to waste collection services, eliminating uncontrolled disposal and burning and moving towards environmentally sound management for all waste. Achieving this challenge is made even more difficult by forecasts that major cities in the lowest income countries are likely to double in population over the next 20 or so years (UNEP, 2015). Abdelhamid (2014), observe that most developing countries lack the technical and financial resources to manage solid wastes safely. As a result, solid waste management service is often inefficient and underperforming in developing countries (World Bank, 2014).

Muhammad & Manu (2013) conclude that most Third World cities do not collect the totality of wastes generated, and of the wastes collected, only a fraction receives proper disposal. Despite the sorry state of affairs in SWM for Asian and Caribbean cities, there are success stories where some countries have recorded improvement in their SWM systems. Singapore for instance, as pointed out by UNEP (2015) in the Global Environmental Outlook, has transformed her waste management strategy from a situation of dumping of wastes in swamps in the 1960's to developing a SWM system with the central idea that waste is a resource. UNEP (2015) expounds that the system involves households paying a flat monthly fee which is less than 0.5% of the average monthly household income. The fees according to UNEP (2015), is collected via monthly utility bill that also includes the fees for electricity, water and gas. As part of the strategy, all combustible waste that is not recycled is treated in energy-from-waste (EfW) plants, whereby the waste volume is reduced by 90% and energy is recovered to produce electricity that meets up to 3% of Singapore 's total electricity demand (UNEP 2015).

2.2 Solid Waste Management Challenges in Africa

UN HABITAT (2014) notes that due to poor policies, 62% of urban populations in Sub-Saharan Africa live in slum areas dominated by uncontrolled informal spatial developments, most often located in environmentally fragile areas, and without access to basic services including waste management systems. According to Simelane and Mohee (2012), in urban centers throughout Africa, less than half of the solid waste generated is collected and 95 percent of that is neither contained nor recycled. Mixing of wastes is another problem facing solid waste management in Africa as observed by Remigios (2010), where dumping is unrestricted and industrial, agricultural, domestic, and medical wastes end up in one site which in most cases is not fenced off.

Another challenge in solid waste management in Africa is lack of data. Simalane and Mohee (2012), observe that the quality and availability of data on solid-waste generation and management in Africa is scanty, a factor that impedes development of program that promote efficient use of solid waste. Okot-Okumu, (2012) in a survey of East African cities, identifies lack of prioritization of waste management in the annual plans of urban councils.

UN HABITAT, (2013b) underscores that SWM services in East Africa are chronically underfunded, with too few vehicles, poor equipment and inadequate maintenance. Public apathy towards solid waste management is also a challenge to solid waste management. In this regard, Ali et al., (2010) identify public misconceptions, attitudes and behaviors as some of the issues greatly contributing to the problems of illegal dumping and uncollected household waste being witnessed in the major cities of the East African region. In conclusion, Waste management problems in Africa vary in nature and complexity ranging from infrastructural, political, technical, socio-economic to organizational/management-related challenges. Moreover, regulatory and legal issues and challenges need to be addressed (UNIDO, 2009).

2.3 Effective Solid Waste Management

According to World Urbanization Prospect (2014), rapid and unplanned urban growth threatens sustainable development, when necessary, infrastructure is not developed or when policies are not implemented to ensure that benefits of city life are equitably shared. Waste generation is increasing in quantity and complexity with urban growth (Hoornweg and Freire, 2013). Thus, cities should implement plans that ensure supply of affordable, serviced land which is probably the most important input for sustainable urbanization. World Bank (2013), notes that planning is fundamental to the provision of most basic infrastructure services water, energy, sanitation, and solid waste management to all residents (urban and peri-urban alike). This is done through allocation of land use in a way that allows for infrastructure improvements.

In this regard, GCIF (2015) suggests that urban planning process should include a diverse set of stakeholders including low income and marginalized groups, national minorities and indigenous people because this allows such plans to leverage on the expertise of the said stakeholders.

Globally, UNDESA (2014) submits that 54 percent of the world‘s population currently reside in urban areas. However, we are living in an increasingly urbanized world, where many cities ‘infrastructure systems are already strained or unable to service existing populations (GCIF, 2015). UNDESA (2014) submits that a holistic approach to urban planning and management is needed to improve living standards of urban and rural dwellers alike. World Bank, (2013) further adds that cities need policies for the provision of public goods and basic infrastructure services including water, sanitation, and solid waste management.

According to UN Habitat, 2013a) cities can achieve this by integrating waste management and spatial planning. Urban planning can help to solve the problem of solid waste management through resource allocation and budgeting exercises. This is achieved by incorporating political visions and values into the physical reality of cities (UN HABITAT, 2010).

In spite of the importance of planning in solid waste management, Dewi et al. (2010) observe that many planners and decision makers in the area of municipal solid waste, lack thorough understanding of the whole chain of waste management system and its impact on environmental quality and public health. City planners ‘involvement in waste management has been largely limited to siting waste management facilities (Dewi et al., 2010). According to Onu et al., (2014) study, the importance of urban planning in solid waste management in Africa is perhaps demonstrated by lack of it.

2.4 Solid waste management practice in Ethiopian

Solid waste management (SWM) in Ethiopia is a sector requiring significant attention. According to UN estimates, Ethiopia‘s urban population will triple between 2010 and 2040. Preliminary citylevel population projections suggest that some of Ethiopia ‘s larger cities will much more than triple their 2010 population by 2040: Hawassa ‘s 2010 population will grow more than six-fold by 2040.

Ethiopia has in the last decade been working to provide adequate collection and disposal for its citizens. It has managed to build some landfills for disposal of the country‘s waste. But increased population in Ethiopia‘s urban centers has strained the capabilities of local governments to manage the solid waste generated. The landfills are not well developed and properly managed.

Moreover, these landfills/dumpsites are a major source of GHG emissions, and the economic value of waste buried in landfills/dumpsites has not been capitalized. In addition, the absence of a coordinated, national solid waste management policy, and a city-level action plan for integrated waste management policies, has hampered the implementation of solid waste management activities. Current tariff structures do not recognize alternative treatment methods (recycling, compost, etc.) as part of the waste management system.

There is evidence of increased solid waste in Ethiopia as a result of the rapidly increasing human population, increased economic status and income, changing consumption patterns, urbanization and industrialization. Pollution is a growing concern as industries and urban areas grow. Many rivers are polluted with urban and industrial waste. There is also a high level of air pollution in urban areas. Pollution has become a health threat for people and livestock. The GE strategy estimates that 40 per cent of solid waste is deposited at landfills in cities with populations from 20,000 to 100,000 people and 70 per cent is deposited in cities with over 100,000 people. The strategy estimates a gas capture rate of 60 percent and 0.756 KgCO2e per kg of waste (CRGE, 2011).

Based on the GE strategy, the urban sector contributes about 4.7 MtCO2e or 3 per cent of total emissions in Ethiopia. Under the BAU scenario, emissions from cities will increase to 10.2 MtCO2e by 2030. The main drivers of emissions increases are urban population growth, expansion of cities and GDP growth. Emissions from the solid waste sector were estimated at 1.2 MtCO2e in 2010. These emissions are expected to grow to 4.5 MtCO2e in 2030.

The projection in increase is from two areas: rapid urbanization that is estimated to grow 4.4 per cent between 2010 and 2030, and increases in the number of urban centers with at least 20,000 people from 86 in 2010 to 237 in 2030. The solid waste generation per capita is also expected to increase from 0.33 kg/per/day in 2010 to 0.44 kg/per/day in 2030, leading to a generation of 1.5 million tons of solid waste annually by 2030 (CRGE, 2011).

There are three key technical barriers that need to be overcome in solid waste management: collection, treatment and disposal Poor collection rates associated with transportation of waste at the secondary level are one of the main problems identified by many municipalities. Waste collection and transport are not available everywhere, especially in small cities.

Waste collection vehicle maintenance budgets are inadequate and there are not enough vehicles overall, or in good condition for use. Fee collection is ineffective and cannot reflect the actual capital cost. Lack of capacity in installing and managing modern treatment facilities are common themes across municipalities. Knowledge of waste treatment system maintenance is also lacking.

The key barriers seen across municipalities in this area are lack of properly designed, implemented and managed disposal or landfill sites. The number of operating sanitary landfills is inadequate, especially those offering full disposal operations. Disposal fees do not cover landfill operating and maintenance costs. Knowledge of disposal system maintenance is lacking.

2.5 Geospatial technological in solid waste management

New prospects are created for the technological development of solid waste management systems, as well as the improvement or the extension of the existing ones (Oosterom et al., 2002). Factors such as legal and technical aspect, historical and cultural background, socioeconomic, political aspect, and institutional existence are some of the parameters which are used to clarify technological development.

Technological development in the solid waste management system supports the meaningful exchange of information. This will encourage the comparative methodologies concerning the cost, duration, taxes, etc., among countries and will provide a sustainable solid waste management information management (Chandel et al., 2024)

These specialized information systems should adapt standardized modern technical and technological solutions arising from the operational requirements of their functionality. Technological progress relates geospatial software and analyzes of geospatial data are some of them (Dawidowicz and Zróbek, 2014). Integrated approach of geospatial technologies such as GPS data, remote sensing imagery, aerial photographs, Google earth and GIS is valuable in the development of modern solid waste management information. This study is only limited to, state valuable roles of GPS, remote sensing and GIS in the development modern cadastral information.

With the continual research and development into GPS, the techniques and systems developed have become more reliable, cheaper, productive that making GPS more attractive technology (Tamrakar, 2012).

The fact that remote sensing imagery is in digital form, making it a fundamental tool, quicker, and accurate technology as compared to others geo-information technology (Ondulo and Kalande, 2006).

Thanks to the integrated use of GPS, remote sensing, and GIS, more and more research problems in resource management and environmental modeling can be tackled with increasing ease (Gao, 2002). The vector datasets derived through GPS and Remote sensing survey are integrated in a GIS environment to generate vector datasets is undertaken to demonstrate the efficiency of the hybrid technology for cadastral map preparation (Parida et al, 2012).

As discussed above technology solutions will continue to offer new ways of organizing and utilizing solid waste management information. The dynamic development of modern technologies such as GPS, remote sensing, and GIS and their integration is directly valuable to the development of solid waste management information systems. Geospatial technology plays a pivotal role in modern solid waste management systems. Researchers emphasize the integration of Geographic Information Systems (GIS) and Global Navigation Satellite Systems (GNSS) for precise mapping.

The use of these technologies enhances the accuracy and reliability of cadastral databases, providing a foundation for effective solid waste management (Rajabifard et al., 2005). The user experience in geospatial cadastral information systems is a critical aspect. Colotelo et al. (2016) explore user-centered design approaches, stressing the significance of involving end-users in system design and advocating for user-friendly interfaces to enhance overall efficiency.

2.6 Solid Waste Reduction Strategies

Reduction of solid waste is the most desirable and crucial step in the waste management hierarchy. It tries to minimize the volume and toxicity of the waste at the source. Urban reduction strategies include supporting responsible consumption, promoting use of reusable and durable products, and promoting public education campaigns in favor of behavior change. Wilson et al. (2012) note that in developing countries, waste minimization needs to be integrated into urban development strategies, as spontaneous growth generates more waste without proper infrastructure. Source separation of organic and inorganic refuse, environmentally friendly packaging, and the use of low-waste products can all go a long way towards minimizing the quantity of municipal solid waste. The application of waste audits in homes and institutions can also help in finding opportunities for reduction. Reducing waste not only lessens the environmental burden of disposal but also reduces the financial and logistical burden on local governments.

2.7. Reuse as a Sustainable Practice

Reuse is a part of sustainable waste management since it lengthens the life cycle of materials and keeps them from the waste stream prematurely. Unlike recycling, where the process is involved, reuse is concerned with using objects in their natural form and size for the same or another use. Examples of common reuse activities include keeping containers, fixing broken items, and recycling the material for new use. Ghosh and Ghosh (2018) highlights the environmental and economic advantages of reuse, especially in poor conditions where second-hand goods are prevalent. Encouraging reuse, besides conserving resources, reduces energy consumption and emissions of new products production. Establishing repair facilities and donation systems for second-hand clothes, appliances, and furniture can significantly enhance reuse. Furthermore, encouraging a culture of reuse favors the circular economy since resource extraction and landfill dependency are minimized.

2.8 Concepts of Recycling and Circular Economy

Recycling transforms waste into new materials, conserving raw materials and reducing energy use. It is also one of the most exercised and visible components of the 3R (Reduce, Reuse, Recycle) approach. Recycling programs, especially if complemented with formal municipal schemes, can be a significant environmental and economic benefit. For Kirchherr et al. (2017), recycling has a central role to play within the circular economy model, which tries to avoid waste by keeping materials in circulation for as long as possible. Successful recycling programs require waste collection, sorting, and processing facilities as well as public participation.

2.9 3Rs under Integrated Waste Management Systems

The 3Rs philosophy of Reduce, Reuse, and Recycle is the foundation for integrated solid waste management and sustainable urban planning. It assists in reducing the environmental footprint through prevention of waste generation, reuse, and recycling of recyclable materials. UNEP (2015) suggests the 3Rs as a broad strategy in both the formal and informal waste management systems, especially in developing nations like sub-Saharan Africa. The implementation of the 3R strategy needs coordination of efforts by households, industries, and municipalities. For example, citizens can witness segregation of waste at the household level, with the supply of recycling infrastructure and policy from local governments. Inclusion of 3R strategies in urban planning ensures a more resource-saving and environment-friendly way of handling waste. Hence, cities adopting the 3R model are adequately prepared to reduce pressure on landfills, harvest valuable materials, and enhance circular economies.

2.10. Obstacles to Implementation of 3R Principles

Despite the clear benefit of the 3R principles, various obstacles to their widespread implementation exist in developing countries. These include a lack of infrastructure for waste segregation, weak policy enforcement, limited financial resources, and limited public education. Zurbrugg et al. (2012) propose that because no formal collection schemes and processing facilities exist, the communities do not have the means to effectively engage in reuse and recycling operations. Informal waste pickers fill this gap, but they do not enjoy protection under the law or access to markets for recyclables. Moreover, inadequate availability of data and poor institutional coordination render attempts at rolling out 3R systems even more daunting. Lack of public interest or disinformation about waste segregation is also among the reasons for low participation in recycling schemes. Solutions to these challenges thus must incorporate a holistic strategy with policy reform, investment in infrastructure, public awareness, and geospatial planning and monitoring incorporation.

2.11 Conceptual frame work Modeling

Conceptual models serve as abstract, psychological representations of how tasks should be carried out. People often use these models subconsciously and intuitively to systematize processes. Conceptual models are abstractions that help us understand how things work. They provide a mental framework for interpreting and interacting with systems. For instance, when creating appointments, our mental model might involve calendars and diaries.

Design Implications: Designers leverage conceptual models to tailor software that aligns withusers' mental models. By echoing these models in interfaces and apps, designers build on existing knowledge, making it easier for users to learn new products.

Development Process: Conceptual models are identified early in the design process and serveas a constant reference for direction and inspiration. They guide designers in creating intuitiveapplications.

User Research: Designers gather information from user research (interviews, surveys, observations).

Visual Representation: Using this data, they create visual representations of how users perceive and interact with a system. These representations can take various forms, such as flowcharts, diagrams, wireframes, or prototypes.

The process of determining what to model is known as conceptual modeling. He acknowledges a balance in getting the right level of detail make it too complex and it may not be possible to complete the model with the time and knowledge available, make it too simple and the results may not be sufficiently accurate.

The conceptual modelling stage in a simulation project is very important and yet is still generally regarded as more of an art than a science. Developing conceptual models is also a key step in developing indicators for sustainable andperformance-based management. Another related page in this section provides a number of links outlining how to develop programmed-based outcomes models, also called interventionlogic models. A number of pages cover related approaches to problem structuring and framing, especially systems thinking, systemic design and systems thinking tools.

2.7. Research gaps

The empirical literatures on solid waste management Systems reflect a growing interest in understanding the impact, challenges, and advancements in the field. Despite the growing body of literature on GIS applications in solid waste management, several critical gaps remain that warrant further exploration. One significant gap is the need for more comprehensive research that systematically identifies and evaluates the determinant factors influencing solid waste management across various geographical contexts, thus providing a more holistic view of the determinants that influence effectiveness of solid waste management.

Another important area is the integration of GIS with data sources, such as remote sensing information. Advances in technology have made it increasingly feasible to gather and analyze vast amounts of spatial data. Integrating these data sources with GIS-based models could significantly enhance the accuracy and responsiveness of solid waste management methodologies, allowing stakeholders to make more informed decisions based on the most current information available. However, these researches lack the integrations of GIS, GPS, and remote sensing for managing solid waste.

Previous studies have primarily focused on examining the overall solid waste management, but they have failed to adequately consider the integrations of technology and comprehensive characteristics of urban quality. As a result, the spatial accuracy and precision of research findings have been relatively low, and the existing studies lack the consideration of solid waste management evaluation from the perspective of urban regeneration. Therefore, this research proposed a comprehensive method for identifying inefficient solid waste management in the study area.

CHAPTER III: MATERIALS AND METHODS

3.1. Description of study Area

3.1.1. location description

Chole town is found in Arsi zone at the southern part of the country at some 180 kilometers away from Addis Ababa City. Geographically it located between 8° 14' 57" North and 39° 53' 32" East in the center of Chole woredas which found in in the Oromia Region of Ethiopia. Chole is bordered on the south by Amigna, on the southwest by Sude, on the northwest by Merti, on the north by Aseko, and on the east by Gololcha #Figure_3.1.

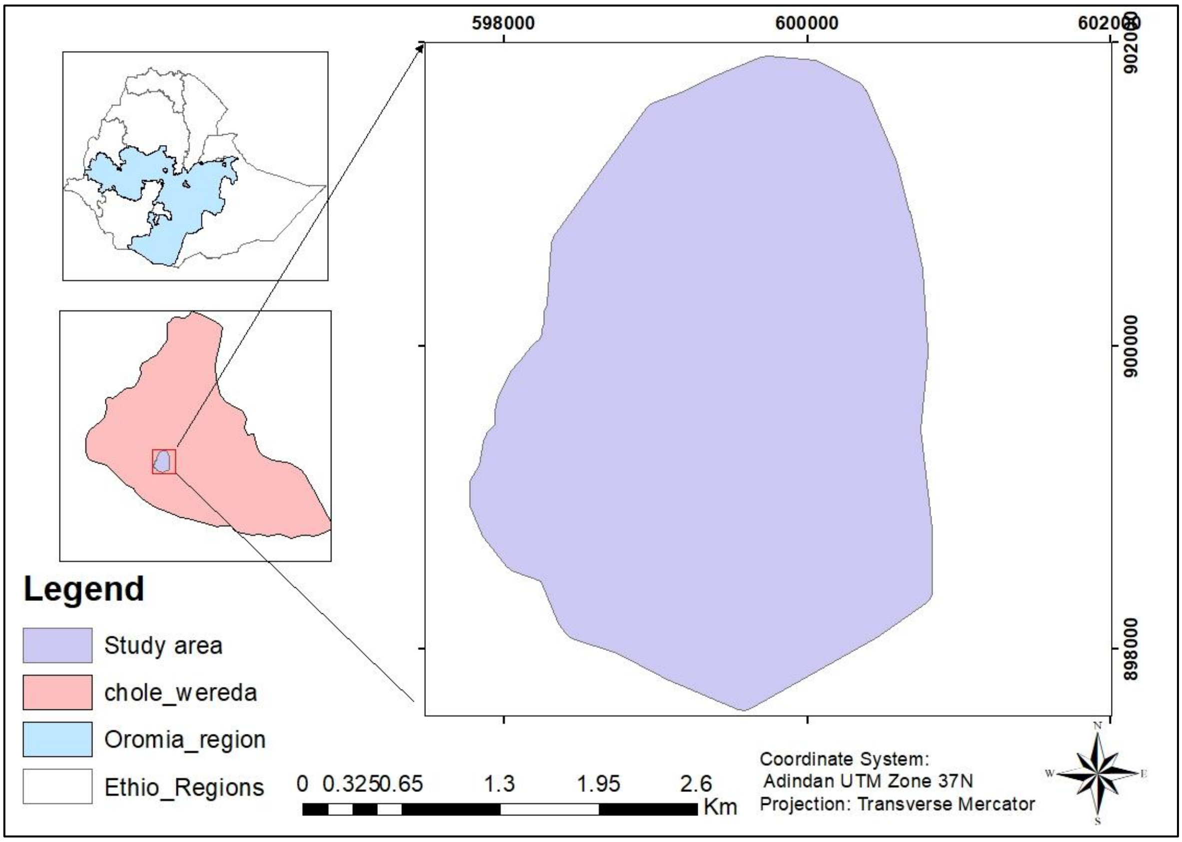


Figure 3.1. Location map of chole town

3.1.2. Topography

Topographically Chole Town, located in the Arsi Zone of the Oromia Region in central Ethiopia, is characterized by a highland topography typical of the Ethiopian plateau. Situated at an elevation of approximately 2,759 meters (9,052 feet) above sea level, the town experiences a temperate climate with relatively cool temperatures year-round. The terrain around Chole is mostly hilly and rugged, interspersed with fertile valleys and cultivated fields. This elevated and varied landscape supports traditional agriculture, particularly the cultivation of barley, wheat, and enset (false banana), and also contributes to the area's scenic beauty.

The surrounding topography is marked by gentle slopes and occasional steep escarpments, which are part of the broader highland system that defines much of Ethiopia's central regions. The figure bellow illustrates the elevation range of Chole Town, derived from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) Digital Elevation Model (DEM) data with a spatial resolution of 30 meters.

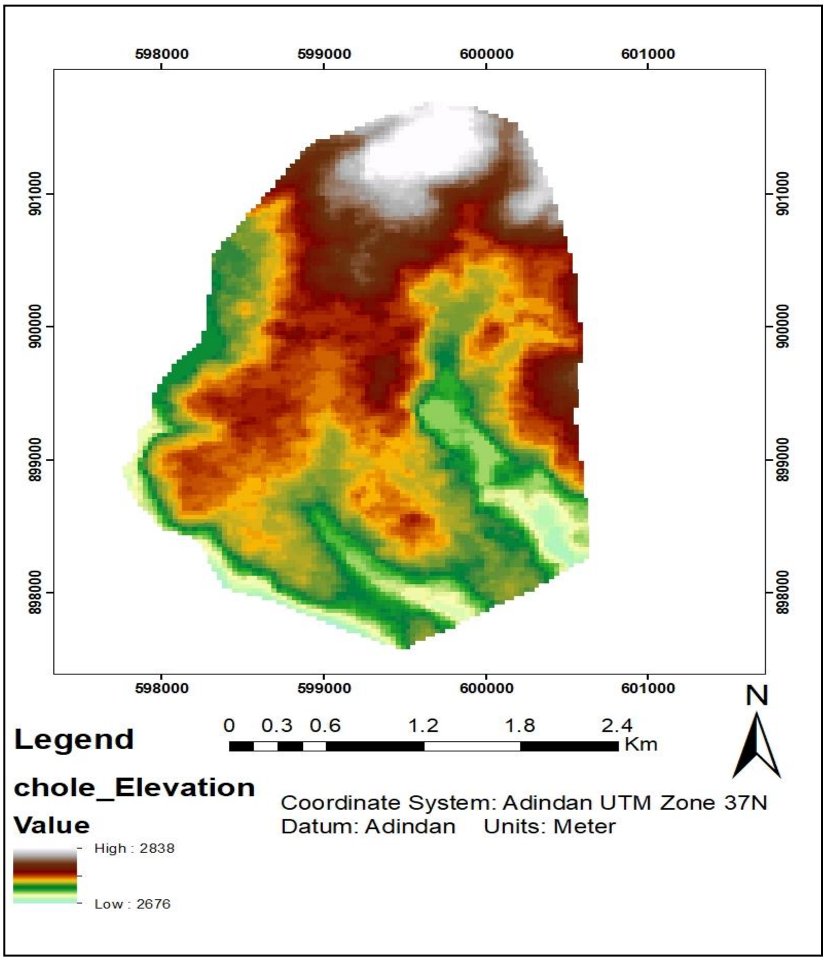


Figure: 3.2. Elevation map of chole town

The above image shows According to the DEM analysis, the altitude in the Chole area varies between a minimum of 2,676 meters and a maximum of 2,838 meters above sea level. This variation in elevation indicates a moderately undulating highland terrain, consistent with the general topographic characteristics of the central Ethiopian highlands. The 30-meter resolution of the aster dem allows for a detailed representation of the area’s topographical features, capturing local variations in elevation that influence land use, water flow, and settlement patterns in and around Chole Town.

3.1.3. Population

According to the 2007 national census, Chole Woreda had a total population of 89,291, with a nearly equal gender distribution and about 7.56% living in urban areas. Earlier estimates from 2005 by the Central Statistical Agency placed the population at 111,831, with 6.76% urban dwellers below the Zone's average urbanization rate of 12.3%. Covering an area of approximately 765.94 square kilometers, the woreda has a population density of around 146 people per square kilometer, which is higher than the Zone average of 132.2. In the context of a study on solid waste, the urban population of Chole Town specifically includes about 31,000 households.

3.2 Research Design

This study was used a mixed-methods research design integrating GIS and Remote Sensing tools with conventional field surveys to assess the solid waste management system in Chole Town. The design is both descriptive and spatial, enabling the study to identify, map, and analyze spatial patterns of solid waste generation, disposal sites, service coverage, and related environmental issues. A community-based cross-sectional study design was used to assess solid waste management practices and to identify its determinant factors in the Chole Town. The population that the samples represent consisted of all households in chole town.

3.2.1. Sampling Techniques

The study employed a combination of purposive and stratified random sampling techniques to gather data. For the qualitative component, purposive sampling was used to select key stakeholders including municipal staff, waste collectors, and community leaders who were identified based on their direct involvement and relevance to the solid waste management system. To ensure broad representation for the quantitative data, a stratified random sampling method was applied, with Chole Town divided into sections. Households were then randomly selected from each stratum to serve as sampling units, allowing for comprehensive and balanced data collection across different areas of the town.

3.2.2. Sample Size Determination

The total sample size was determined according to Cochran’s formula in equation 1:

$$n_0 = \frac{Z^2 \cdot p \cdot (1-p)}{e^2} \quad \text{................................(eq1)}$$

Where; n = (Population size) =31,000

Z= (Confidence level) = 95% → Z = 1.96

E= Margin of error (e) = 5% → e = 0.05

P=Estimated proportion (p) = 0.5 (used when we don't know the true proportion; gives the most conservative, largest sample)

Using the above Cochran's formula (for large/infinite population)

$$n_0 = \frac{(1.96)^2 \cdot 0.5 \cdot 0.5}{(0.05)^2} = \frac{3.8416 \cdot 0.25}{0.0025} = \frac{0.9604}{0.0025} = 384.16$$

So, for an infinite population, we need 384 people in our sample. Adjust for finite population (N = 31,000)

$$n = \frac{n_0}{1 + \left(\frac{n_0 - 1}{N}\right)} = \frac{384.16}{1 + \left(\frac{383.16}{31000}\right)} = \frac{384.16}{1.01236} \approx 379.6$$

Approximately the Sample size ≈ 380 So, to survey a population of 31,000 with 95% confidence and a 5% margin of error, you'd need a sample of about 380 people.

3.3. Methods of Data Collection

Methods of data collection in this study, various GIS spatial operation tools were utilized to effectively achieve the research objectives. The methods employed included buffering and Euclidean distance analysis to assess proximity and spatial relationships, as well as overlay techniques to combine multiple spatial datasets for integrated analysis. Spatial analysis tools were applied to identify patterns and distributions related to solid waste management, while 3D analysis was used to better understand the area's terrain and elevation characteristics. Additionally, other GIS extensions were incorporated to enhance data visualization and support informed decision-making throughout the study.

3.3.1. Questionnaire

For data collection in Chole Town, the primary instrument used by the researcher was a structured questionnaire. This tool included both closed-ended and open-ended questions to gather a wide range of information from respondents. The closed-ended questions were designed for ease of completion, allowing respondents to answer quickly and consistently, which also made the data easier to analyze, interpret, and manage in terms of both time and cost. On the other hand, the open-ended questions offered the opportunity for respondents to provide more detailed, nuanced answers, encouraging a deeper understanding of their experiences and perspectives related to solid waste management. The questionnaire was selected not only for its ability to capture both quantitative and qualitative data, but also for its convenience it allowed respondents the flexibility to complete it at their own pace and time, without needing direct supervision or prompting from the researcher. This approach helped improve response rates and the overall quality of the data collected.

3.3.2 Interview

Interview was conducted for gathered information from the municipalities, administration of the town, sanitary committee, and kebele administrator's office because it is an appropriate tool for the researcher to get responses given as well as to develop follow up questions to gain deeper insights in to the concerns of official. Interview was selected because of its advantages in providing the chance of obtaining in depth data related to the problems.

3.3.3. Observation (site)

The primary purpose of the site observation was to identify and document existing solid waste disposal locations, as well as to record their geographic coordinates using a GPS device. This approach relied on direct observation, which is one of the most widely used techniques for collecting primary data in field research. According to Kothari (2004), the strength of the observation method lies in its ability to capture real-time information, free from the distortions of respondents' memories or future projections.

In this study, the observation method was specifically employed to monitor and evaluate solid waste management practices at the household level within the town. Rather than relying on self-reported data, written documents, or interviews, the method focused on capturing actual behaviors and on the ground conditions. Observations were conducted personally by the researcher using a structured checklist, which was designed to gather systematic data on the state of solid waste disposal and broader environmental issues in the study area.

The checklist served as a practical tool to ensure consistency in data collection and to help identify patterns, deficiencies, or environmental concerns related to waste management. Furthermore, the geographic coordinates collected during the site visits were used to validate and visualize the data spatially through GIS mapping, allowing for a clearer understanding of the distribution and impact of solid waste sites across the town.

3.4. Data Sources, types and materials

3.4.1. Data types

This study utilized both primary and secondary data sources to support the analysis. Primary data were collected through various methods, including unstructured interviews, photographic documentation, ortho-photos, and direct field observation of existing dump sites within Chole Town. These approaches provided firsthand, location-specific insights into current waste disposal practices. Secondary data were obtained from several established sources: information on the town's soil and hydrological conditions was sourced from the Food and Agriculture Organization (FAO), while land use data for Chole Town were collected from the local town administration. Additionally, a base map and a Digital Elevation Model (DEM) with a spatial resolution of 30 meters by 30 meters were retrieved from the United States Geological Survey (USGS). This phase of the research involved collecting both spatial and non-spatial data, which together are essential for conducting a comprehensive and accurate site suitability analysis for optimal solid waste disposal site selection. Geodetic control points in this study are the network of the GPS stations based on the national coordinate systems, which is surveyed to control all subsequent GPS measurements. This GPSsurveying technique is used to fix X, Y, Z control points in the area. The points were established to locate the precise position of cadastral objects in this research. The table below shows types of data used in the study, their sources and data Specifications.

Table 3.1 Data types and their sources.

S/n	Types of Data	format	Sources	Purpose for
1	DEM	grid	USGS	To Drive Slope and Elevation
2	Road network map	shapefiles	Extraction from master plan of chole town	Proximity to
3	Soil map	shapefiles	FAO	
4	Land sat 8/9	raster	USGS	
5	Population	csv	CSA chole woreda, 2021	To assess Socioeconomic data
6	DGPS Data (x,y)	2cm error		Location (x,y)

3.4.2. Software used for study

In the study of solid waste management in Chole Town, a range of software tools was employed to support data analysis, image processing, and overall project organization. Geographic Information System (GIS) software, particularly ArcGIS, was used extensively for mapping, spatial analysis, and identifying suitable sites for waste disposal. Erdas Imagine played a key role in processing satellite imagery, including tasks such as image correction, enhancement, and classification to assess land cover and environmental conditions relevant to waste management.

Google Earth was utilized for time-series verification, allowing the researcher to observe historical changes in land use and track the development of dumping sites over time. For organizing, analyzing, and presenting non-spatial data, Microsoft Office tools especially Excel and Word were used to manage tabular data and prepare documentation.

In addition, SPSS (Statistical Package for the Social Sciences) was applied for the statistical analysis of questionnaire responses. This enabled a deeper understanding of community attitudes, awareness, and practices regarding solid waste management. Together, these software tools facilitated a comprehensive, multi-dimensional analysis integrating both spatial and non-spatial data to inform effective waste management strategies for the town.

Table 3.2 Software used and their purpose

S/N	Name of software	Purpose
1	ArcGIS 10.8	Data processing and thematic map preparation
2	ERDAS Imagine 2015	For processing and analyzing satellite Image
3	Google Earth Pro	Use as a base map in visual image interpretation.
4	MS-Office (word, Power point, Excel)	Report
5	SPSS	For socio-ecomic data analysis

3.5. Method of Data Analysis

Data analysis methods for this study focus on for solid waste management involve the integration of various approaches, including the use of socioeconomic non-spatial data, the application of multi-criteria decision-making models, and spatial analysis tools. These tools include techniques such as Euclidean distance calculations, buffering, and spatial mapping, all of which are supported by Geographic Information System (GIS) technology.

Solid waste management is a critical component of urban planning and environmental sustainability, and effective decision-making in this domain increasingly relies on robust data analysis methods. These methods incorporate a combination of socioeconomic non-spatial data and spatial data to understand, evaluate, and optimize waste collection, transportation, and disposal systems. Socioeconomic data such as population density, income levels, urban growth patterns, and waste generation rates provides essential insights into the factors driving solid waste production and distribution across different area. This type of data helps in identifying high-waste-generating areas and understanding the behavior of various demographic groups in relation to waste disposal practices.

To integrate and interpret these diverse datasets effectively, multicriteria analysis (MCA) models are frequently employed. MCA allows decision-makers to evaluate multiple conflicting criteria such as environmental impact, cost-effectiveness, accessibility, and social acceptability simultaneously. These models help prioritize areas for waste facility siting, optimize waste collection routes, and identify suitable locations for recycling or treatment plants. In particular, MCA is useful for balancing trade-offs between environmental sustainability and economic viability in SWM planning.

Through GIS, spatial tools like Euclidean distance analysis and buffering are used to assess the proximity of waste generation sources to disposal or treatment facilities, identify service coverage gaps, and evaluate accessibility. Buffering, for example, can define zones around landfill sites or waste bins to analyse their service coverage, while Euclidean distance helps determine the shortest path for waste transport, thus improving operational efficiency.

Moreover, remote sensing data significantly enhances the accuracy and scalability of spatial analyses by providing up-to-date, high-resolution imagery of land use and land cover changes. It helps in monitoring illegal dumping sites, assessing landfill expansion, and tracking urban sprawl that impacts waste generation patterns. Integration of remote sensing with GIS mapping enables the visualization of spatial trends and supports predictive modelling for future waste management planning.

Together, these data analysis techniques form a comprehensive framework for sustainable solid waste management, allowing planners and policymakers to make informed, data-driven decisions that are spatially and socially responsive.

3.5.1. Spatial Analysis Buffering

Buffering is a key spatial analysis method within Geographic Information Systems (GIS), often referred to as proximity analysis. This technique involves creating zones or areas around spatial features based on a specified distance, and is particularly useful in applications such as identifying suitable locations for waste disposal. For example, buffers can be created around roads, water bodies, or residential areas to determine how close or far a proposed site is from these critical features. Depending on the type of feature such as lines (roads or streams) or polygons (urban areas) buffers can be generated accordingly using defined distance thresholds for each criterion.

In the context of solid waste management, buffering helps in identifying exclusion or suitability zones by setting minimum distance requirements from sensitive areas. For instance, a buffer around surface water might help ensure a landfill is not located too close to a river, thereby reducing the risk of water contamination. Similarly, buffers around roads can help improve accessibility for waste transport while minimizing disruption to residential areas.

One specific GIS tool commonly used for this purpose is the Multiple Ring Buffer tool. This allows the creation of several concentric buffer zones at different distances, which can be used to categorize areas as more or less suitable for waste facility siting based on how far they are from certain features. This step is vital in narrowing down potential sites by eliminating areas that fail to meet established environmental, regulatory, and logistical criteria.

Overall, siting a solid waste disposal facility involves a complex evaluation process that considers multiple spatial and non-spatial factors. The goal is to identify a location that complies with government regulations while minimizing economic costs and negative impacts on the environment, public health, and surrounding communities.

3.5.2. Euclidean distance

In the study, the Euclidean Distance tool available in ArcGIS Spatial Analyst was also utilized as a critical component for solid waste management site selection. This tool calculates the straight-line distance from each cell in the raster to the nearest source feature, such as roads, built-up areas, or other specified infrastructure. In the context of waste facility siting, the Euclidean Distance tool was used to determine how far potential disposal sites are from key features like roads and urban settlements. Proximity to roads is essential for ensuring accessibility and reducing transportation costs, while maintaining an appropriate distance from built-up areas helps minimize negative impacts on public health, environmental quality, and residential living conditions.

The distance maps generated through this tool enabled the identification of zones that meet regulatory and operational requirements, by helping to exclude areas that are too close or too far from necessary infrastructure or sensitive locations. This spatial analysis was integrated with other criteria, including land use, slope, and water sources, to form a comprehensive suitability model. The use of Euclidean distance, in conjunction with buffering and multicriteria evaluation, provided a more precise and objective approach to decision-making, allowing planners to visualize and quantify spatial relationships that are crucial for selecting optimal waste management sites. This method supports a data-driven strategy that balances logistical efficiency, regulatory compliance, and environmental protection in urban and regional planning.

3.5.3. Overlay Analysis

An overlay operation is an essential technique used to assess areas that meet all the criteria for site selection, while also identifying regions that fail to fulfil these requirements. GIS allows for the integration and comparison of multiple layers of spatial data, facilitating a comprehensive understanding of how various geographic features and network analyses interact. In this study, overlay operations were applied to combine different data sources, enabling the identification of suitable areas for waste management site selection in Chole Town. These input features included a range of spatial layers such as Digital Elevation Models (DEM), soil types, and stream data, all of which were sourced from diverse platforms to create a comprehensive base map of the study area.

The weighted overlay method in ArcGIS was used to perform the final analysis. This approach involves assigning different weights to each input layer based on its relative importance in the decision-making process. By intersecting these layers, the overlay operation created a composite map that highlighted areas that met the required criteria for site selection. The result was a more refined and detailed map, allowing decision-makers to visualize the most suitable locations for waste management facilities. This process is crucial for ensuring that all environmental, logistical, and regulatory factors are carefully considered in the planning process, ultimately aiding in the selection of optimal sites that minimize negative impacts on the community and the environment. The combination of multiple layers of information through overlay operations thus strengthens the accuracy and effectiveness of the decision-making process in GIS-based spatial planning.

3.5.4. Multi-criteria Decision-making

In this study, Multi-Criteria Decision Making (MCDM) was employed as a method to transform geographical data into actionable decisions for solid waste management site selection. MCDM is a set of mathematical tools and techniques, such as weighting, that allows for the comparison of various alternatives based on specific criteria. The primary components of MCDM include human judgment and the evaluation of criteria, which help rank potential landfill sites according to their suitability. This process involves systematically assessing how well each site meets the defined factors, such as environmental impact, accessibility, and regulatory compliance. As highlighted by (Sadessa & Balo, 2025), MCDM is instrumental in integrating both qualitative and quantitative data, allowing for a more informed decision-making process.

In this particular study, MCDM analysis was applied to evaluate eight distinct criteria selected for the solid waste management site selection in Chole Town. These criteria were carefully chosen to address the complex factors involved in site suitability, ranging from proximity to infrastructure to environmental considerations. applying the MCDM approach, the study was able to provide a weighted assessment of each potential site, ensuring that all relevant factors were considered in a balanced and objective manner. The final outcome of this analysis allowed for the identification of the most suitable areas for establishing waste management facilities, guiding the planning process towards locations that meet both technical and regulatory standards while minimizing negative impacts on the community and environment.

3.5.5. Analytic Hierarchy Process (AHP)

In this study, the Analytic Hierarchy Process (AHP) was employed using the AHP extension in ArcGIS to evaluate and prioritize potential sites for solid waste management in Chole Town. AHP is a structured decision-making method that allows decision-makers to compare multiple alternatives based on a set of criteria. The method involves decomposing the problem into a hierarchy, where the goal of the decision-making process is at the top, followed by criteria and sub-criteria at the lower levels. In this case, eight factors, such as proximity to roads, built-up areas, and environmental considerations, were assessed for each potential site. AHP utilizes pairwise comparisons to determine the relative importance of each criterion and assigns weights accordingly.

The process involves calculating a set of normalized weights for each factor, which are then used to score the alternatives. One of the key formulas used in AHP is the calculation of the relative weights, which can be expressed as follows:

$$\lambda_{\max} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} x_i}$$

……………………………………..equation 1

where λ max is the principal eigenvalue of the comparison matrix, wi are the weights assigned to each criterion, and xi represents the scores assigned to each alternative based on the criteria. The final scores for each site are derived by multiplying the weight of each criterion by the score for that criterion, and then summing these weighted scores for all criteria. The site with the highest total score is considered the most suitable.

By applying AHP in ArcGIS, the study was able to systematically evaluate the eight selected criteria for solid waste management, ensuring that each factor was given appropriate weight based on its importance in the decision-making process. This method allows for a transparent, repeatable, and data-driven approach to selecting optimal locations for waste disposal, balancing environmental, logistical, and regulatory considerations effectively (Saaty, 1980).

In the Analytic Hierarchy Process (AHP), Consistency Ratio (CR) and Consistency Index (CI) are essential measures used to evaluate the reliability and consistency of the pairwise comparisons made during the decision-making process. These measures ensure that the judgments made about the relative importance of criteria are consistent and logically sound.

❖ **Consistency Index (CI)**

Consistency Index (CI): The Consistency Index (CI) is a measure that quantifies the consistency of the pairwise comparison matrix. It is calculated using the following formula:

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

……………………………………… equation 2

Where:

- λmax is the maximum eigenvalue of the comparison matrix.

- n is the number of criteria or alternatives being compared.

The value of λmax is derived from the pairwise comparison matrix, and it reflects how consistent the comparisons are. If the pairwise comparisons are perfectly consistent, λmax will equal *n*. Any deviation from nnn indicates inconsistency in the judgments.

❖ **Consistency Ratio (CR)**

The Consistency Ratio (CR) is used to assess whether the pairwise comparison matrix is sufficiently consistent. It is calculated by comparing the CI value to a Random Consistency Index (RI), which represents the average consistency for random matrices of the same size. The formula for CR is:

CR = CI/RI

Where:

- CI is the Consistency Index.
- RI is the Random Consistency Index, which is based on the size of the matrix and can be found in a predefined table. The values for RI are different depending on the number of criteria (n).

Interpretation of CR If CR≤0.1CR (or 10%), the pairwise comparison matrix is generally considered consistent and acceptable. If CR>0.1, the inconsistency is considered too high, and the decision-maker should review and revise their pairwise comparisons.

3.5.6. Solid waste disposal site selection criteria

Numerous studies conducted in different parts of our globe employed a set of criteria for solid waste disposal site selection. Selecting an appropriate site for solid waste disposal requires careful consideration of multiple environmental, social, and technical factors, guided by internationally recognized standards and criteria. Various scholars and planning authorities emphasize that disposal sites must be situated at safe distances from critical features to minimize negative impacts on human health and the environment. One key criterion is the distance from residential buildings, with recommended buffer zones often ranging from 300 to 500 meters to reduce risks related to air pollution, odor, and public disturbance (Chang et al., 2008). Similarly, proximity to major roads is crucial for ensuring accessibility for waste transport vehicles; however, the site should not be located too close to avoid traffic congestion or accidents ideal distances often range between 100 and 500 meters, depending on road hierarchy (Al-Khatib et al., 2010).

Water resources are also critical in landfill siting. It is essential to maintain a safe distance from rivers and streams, typically no less than 200 to 500 meters, to prevent leachate contamination of surface water (Kao and Lin, 1996). In addition, groundwater wells must be considered, with required separation distances of at least 300 meters to avoid polluting local drinking water supplies. Topography and elevation are also important; areas with steep slopes or high elevation are generally avoided due to increased runoff and erosion risk, making flat to gently sloped terrains more suitable (Siddiqui et al., 1996).

Soil type influences the potential for leachate infiltration. Clay-rich soils are often preferred due to their low permeability, which provides a natural barrier to groundwater contamination (Kontos et al., 2003). Furthermore, land use and land cover (LULC) analysis helps identify areas unsuitable for landfills, such as agricultural land, protected forests, or urban zones. Finally, sensitive areas, including ecological reserves, schools, and hospitals, should be avoided, with appropriate buffer distances established to protect both human and environmental health.

These criteria, supported by multicriteria decision-making and GIS-based analysis, ensure that the site selection process is both scientifically sound and aligned with environmental regulations and sustainability goals.

3.5.7. Justification for Spatial Criteria in Solid Waste Site Selection

In the process of selecting suitable solid waste disposal sites for Chole Town, several spatial criteria were carefully considered to ensure environmental sustainability, technical feasibility, and social acceptability. Soil type is a critical factor, as soils with low permeability, such as clay, are ideal for waste disposal because they minimize the risk of leachate contaminating groundwater resources. Additionally, stable soils support the structural integrity of the landfill. Land use and land cover (LULC) analysis is essential to avoid placing disposal sites in ecologically sensitive areas, agricultural lands, or urban zones. This criterion helps to identify degraded or unused lands that are more appropriate for such purposes, thereby reducing land-use conflicts and environmental degradation.

Maintaining a safe distance from streams and other water bodies is necessary to prevent leachate runoff into surface water, which can cause severe pollution and harm aquatic ecosystems. Similarly, proximity to built-up areas must be minimized to reduce health risks, odor nuisances, and potential public opposition. Establishing adequate buffer zones helps protect communities and enhances the social acceptance of the selected site. However, the site must remain reasonably accessible via road networks to allow efficient transport of solid waste. Close proximity to roads reduces operational costs and ensures reliable access throughout the year, particularly during the rainy season.

Topographic slope is another vital consideration; areas with steep slopes are generally unsuitable due to increased risks of erosion, instability, and difficulty in construction. Flat or gently sloping areas provide better conditions for landfill operations. Lastly, the presence of protected areas, such as forest reserves or wildlife habitats, was evaluated to avoid ecological disruption. Ensuring a safe distance from these zones is essential to maintain biodiversity, comply with environmental regulations, and prevent human-wildlife conflicts. Together, these spatial criteria provide a comprehensive basis for selecting solid waste disposal sites that are environmentally sound, technically appropriate, and socially responsible.

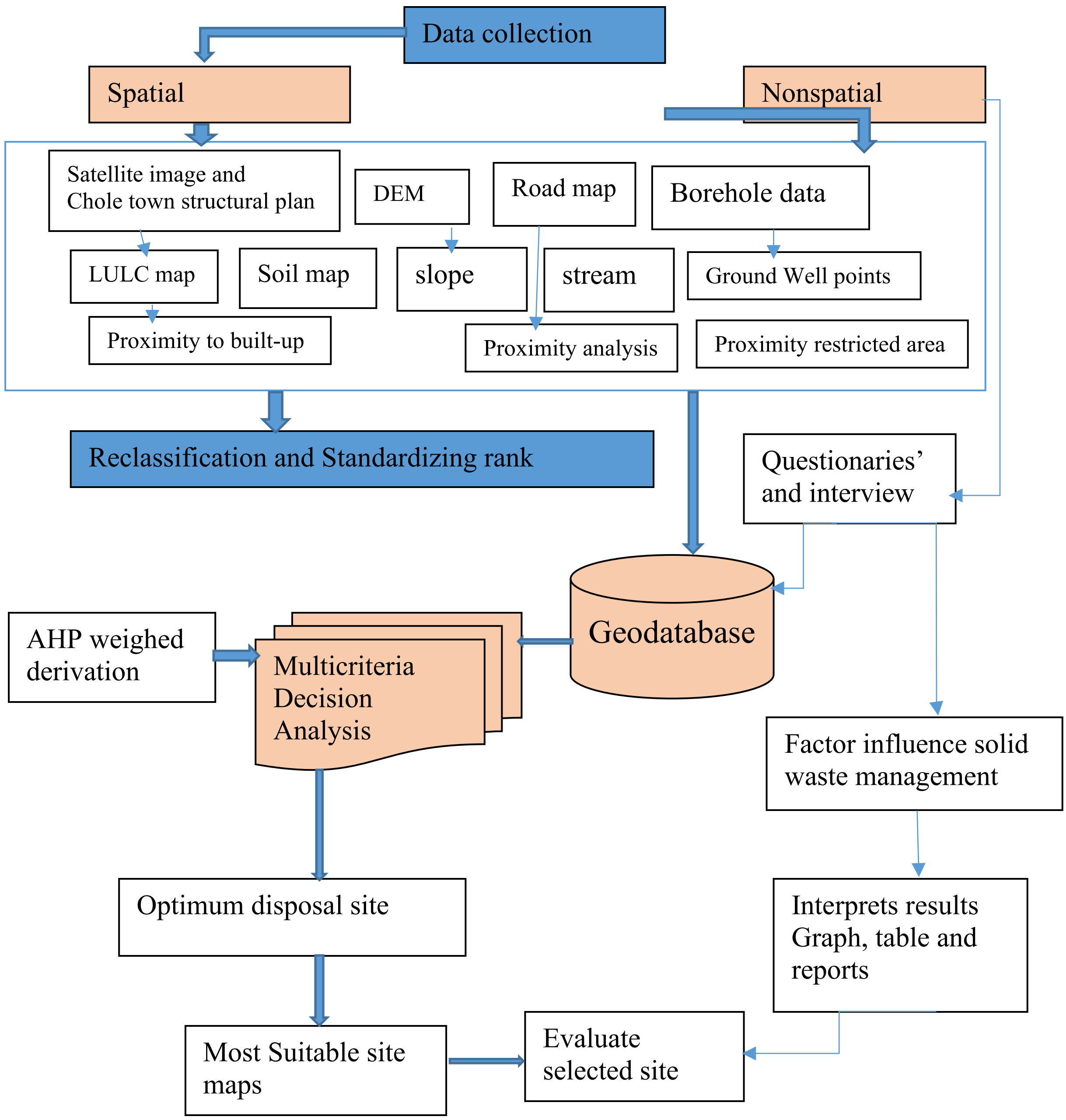


Figure: 3.3 Research Methodological Flowchart

3.6. Validating conceptual framework

Validating the conceptual framework of a involves testing and assessing how well the proposed framework aligns with the real-world requirements, objectives, and outcomes. This process requires a multi-faceted appoach, incorporating both qualitative and quantitative data to determine if the framework can effectively guide the development, integration, and operation of smart city technologies and strategies. The following are the techniques to validate the conceptual framework of Solid waste management:

Ensure the framework adheres to global standards and protocols for smart city development (e.g., ISO/IEC standards on smart cities, sustainable development goals from the UN).

Ensure that the framework is based on well-established theories of urban development, technology integration, and governance. This includes theories in areas like sustainability, urbanism, technology adoption, and innovation systems.

Validate that the framework aligns with current and future urban policies and regulations. This involves checking its compatibility with existing municipal, national, and international regulations and goals related to sustainable development, data governance, and urban planning.

Implementing geospatial solutions in solid waste management can offer significant benefits, including improved waste tracking, better route optimization, and more effective resource allocation. However, several challenges may arise during implementation, such as: Accurate geospatial data is essential for effective mapping and analysis. In many regions, especially in developing countries, data may be incomplete, outdated, or non-existent. Lack of reliable data can hinder decision-making and the accuracy of geospatial solutions, leading to inefficiencies and errors in waste management operations.

Many areas, particularly urban slums or rural regions, may lack the necessary infrastructure (e.g., GPS devices, internet connectivity) to support real-time data collection and analysis. The effectiveness of geospatial solutions can be compromised if the necessary infrastructure for data collection and real-time monitoring is not in place. Geospatial solutions require specialized knowledge and skills, including GIS, remote sensing, and data analysis, which may be lacking in the workforce. Without trained personnel, organizations may struggle to implement, maintain, or optimize geospatial solutions effectively.

3.7. Ethical Considerations and Data Privacy

In the context of solid waste site selection for Chole Town, this study adheres to ethical research standards and principles, particularly concerning data use, community impact, and transparency. The application of geospatial technology often involves the collection and analysis of spatial and socio-demographic data, some of which may be sensitive or related to private land ownership, health, or livelihoods. As such, care has been taken to use publicly available datasets or those obtained through formal agreements with relevant governmental agencies.

Data privacy has been respected by ensuring that any personal or community-identifiable information is anonymized and securely stored.

CHAPTER IV: RESULTS AND DISCUSSION

4.1. Descriptive statistics of sociodemographic characteristics

As a result, show to assess the suitability of existing solid waste management site selection in Chole Town, the researcher employed both descriptive statistics and qualitative spatial data analysis. The first phase of the study focused on collecting and analyzing socioeconomic data.

As part of the data collection process, both interviews and structured questionnaires were administered to a range of stakeholders, including community members and municipal officials. A total of 68 individuals participated in the study. Among them were 5 government employees from the municipal office, 55 community members, and 8 individuals involved in formal and informal waste collection services.

The sociodemographic profile of the respondents revealed that 80.9% were male and 19.1% were female. Regarding age distribution, 14.1% of respondents were between 18–30 years old, 50% were aged 31–45, 19% were between 46–60, and 16.2% were over 60 years old.

These results suggest that a broad age range and a predominantly male group were involved in providing insights into the solid waste management practices in Chole Town. The diversity in age groups contributes valuable perspectives, especially concerning community awareness, participation, and generational attitudes toward waste management. Furthermore, the gender distribution may reflect the local context in terms of labor division and engagement in waste-related activities.

This sociodemographic information provides a foundational understanding of the community's structure, which is essential for evaluating and planning sustainable and inclusive waste management strategies.

Another variable analyzed in the study was the educational background and occupational status of the respondents, which plays a critical role in understanding community awareness and involvement in solid waste management practices. Figure 4.1. illustrate gender and group of respondents.

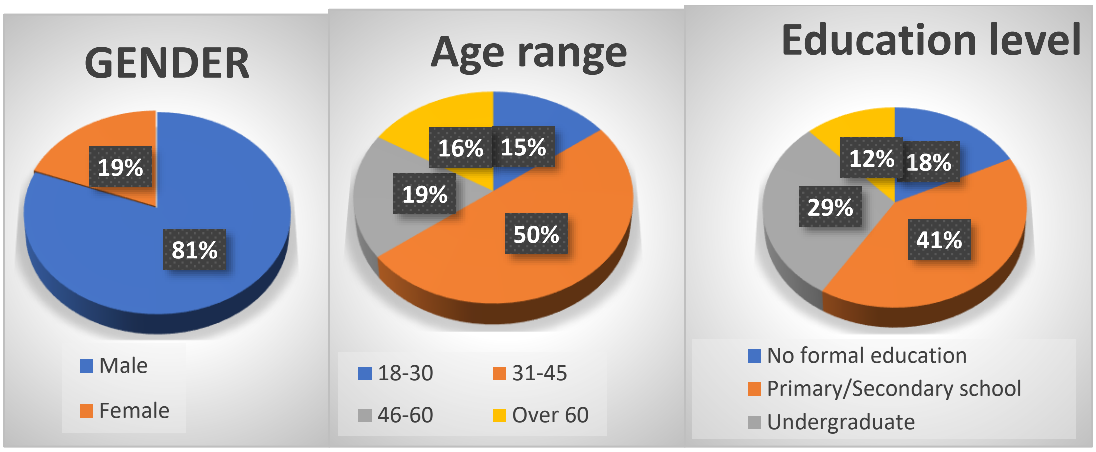


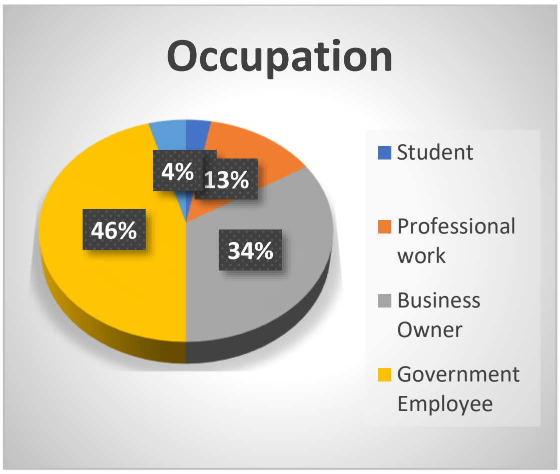
Figure 4.1 gender, age, and education level of respondents.

The findings revealed that 17.6% of participants had no formal education, indicating a segment of the population that may have limited access to environmental information or formal waste disposal training. Meanwhile, 41.2% had completed primary or secondary education, suggesting a moderate level of literacy that could support basic waste management practices and public health awareness. Furthermore, 29% of respondents held undergraduate degrees, and 11.8% had attained postgraduate qualifications. This relatively high proportion of educated individuals provides a valuable knowledge base that can contribute meaningfully to discussions on waste management policy and implementation in Chole Town.

The inclusion of respondents with diverse educational backgrounds enriches the quality of the interviews and ensures a well-rounded understanding of local waste management challenges and opportunities. Education level is, therefore, a crucial factor in selecting participants for this kind of research, as it directly influences perceptions, practices, and potential engagement with sustainable waste solutions.

The results presented in Figure 4.2 illustrate the occupational distribution of respondents in Chole Town. According to the data, 45.6% of participants were government employees, making up the largest share of respondents. Business owners accounted for 33.8%, while 13.2% were engaged in professional work such as teaching, healthcare, or engineering. Students represented a smaller group at 2.9%, and 4.4% of respondents were categorized under 'other' occupations, including self-employment and informal sector work.

This occupational breakdown suggests that employment type significantly influences solid waste management practices in the town. For instance, government employees and professionals are more likely to be informed about municipal regulations and environmental standards, potentially leading to more responsible waste handling behaviours. Business owners, especially those involved in retail or food services, also play a key role, as their waste generation patterns can impact public spaces. The low participation from students and self-employed individuals may point to gaps in awareness or engagement that need to be addressed. Overall, the data indicates that occupation is an important factor in shaping waste management practices and should be considered when designing targeted interventions or educational campaigns in Chole Town.



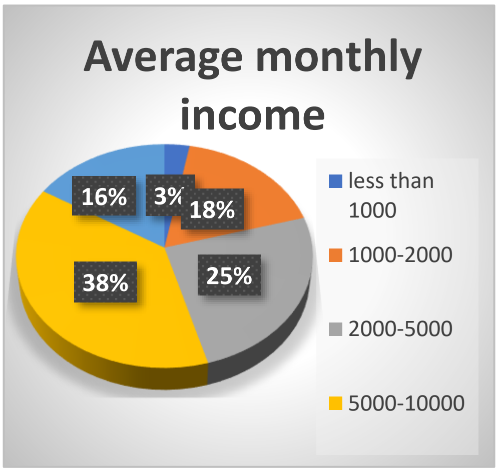


Figure: 4.2 occupation and average monthly income of respondents

The results also highlight the occupational and income status of the respondents, as reflected in Question 3 of the questionnaire. The data on average monthly household income in Chole Town shows significant variation among participants. A small portion, 2.9%, reported earning less than 1,000 ETB per month, indicating a very low-income bracket. About 17.6% of respondents had a monthly income between 1,000 and 2,000 ETB, while 25% fell within the 2,000 to 5,000 ETB range. The largest group, accounting for 38% of respondents, reported monthly earnings between 5,000 and 10,000 ETB, representing the most common income bracket among participants. Additionally, 16.2% of respondents earned more than 10,000 ETB per month, placing them in the high-income category.

These findings suggest that a considerable portion of Chole Town's population earns a moderate to high income, which could influence their ability and willingness to participate in improved solid waste management systems. Occupation and income levels are therefore key indicators for designing effective and affordable waste management strategies tailored to different economic groups within the town.

4.2. Factors influencing the solid waste management in Chole town

4.2.1. Institutional Influence on Solid Waste Management in Chole Town

One of the key factors influencing solid waste management in Chole Town is the role played by institutional structures, particularly the municipal solid waste collection services. To assess the effectiveness of local government efforts, respondents were asked whether they believe the municipality has sufficient policies in place to manage waste effectively. The responses revealed that 44.1% agreed that adequate policies exist, while 32.4% disagreed, and 23.5% were uncertain.

These results indicate a divided perception among residents regarding the effectiveness of the municipality's waste management framework. While a significant portion of the population believes there are sufficient policies, a notable percentage either doubts their adequacy or lacks enough information to form an opinion. This suggests potential gaps not only in policy implementation but also in public awareness and engagement. The relatively high percentage of respondents who are uncertain (23.5%) highlights a possible lack of transparency or communication from the local government regarding waste management initiatives.

Table 4.1: Policies in place to manage sufficient waste effectively

Variables		
Do you think the local government has sufficient policies in place to manage waste effectively?	Frequency	Percent
yes	30	44.1
no	22	32.4
not sure	16	23.5
Total	68	100.0

In summary, while there is a moderate level of confidence in the municipality's efforts, the data suggests a need for improved policy enforcement, community education, and greater institutional accountability to enhance the overall efficiency and sustainability of solid waste management in Chole Town.

Public Awareness of Waste Reduction and Recycling Incentive: An important aspect of effective solid waste management is public awareness of policies and programs designed to encourage environmentally responsible behaviour. In this regard, respondents were asked whether they were aware of any waste reduction or recycling incentives offered by the local government, such as financial rewards, tax reductions, or other benefits intended to promote sustainable waste practices. The results revealed that only 22.1% of respondents reported being aware of such incentives, while a significant majority 72.1% indicated they were not aware, and 5.9% were unsure.

Table: 4.2 Public Awareness of Waste Reduction and Recycling Incentive

Are you aware of any waste reduction or recycling incentives offered by the local government (e.g., financial rewards, tax reductions)?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	15	22.1	22.1	22.1
	no	49	72.1	72.1	94.1
	not sure	4	5.9	5.9	100.0
	Total	68	100.0	100.0	

This overwhelming lack of awareness suggests a critical gap in communication between the local government and the community. Although incentives can play a vital role in motivating residents to participate in recycling and waste reduction efforts, their effectiveness is greatly diminished if the public remains uninformed. The low awareness rate may indicate that either these incentives are not being effectively promoted or, in some cases, may not exist in any practical or accessible form.

Furthermore, the data highlights the need for targeted awareness campaigns, community outreach programs, and the integration of environmental education into public platforms.

Efforts such as informational workshops, posters, community meetings, and the use of local media could help bridge the information gap. Ensuring that residents are both informed and engaged is essential to building a culture of environmental responsibility and to enhancing the success of solid waste management initiatives in Chole Town.

Municipal Involvement in Public Education on Waste Management*:* Public education is a cornerstone of effective waste management, as it empowers residents with the knowledge and tools needed to adopt sustainable practices. To assess the role of the local government or municipality in this regard, respondents were asked whether they believe the municipality is active in educating the public about proper waste management practices. The survey results show that 44.1% of respondents believe the municipality is actively involved in public education, while 30.9% disagreed, and 25% stated that such efforts occur only occasionally.

Table:4.3: Municipal Involvement in Public Education on Waste Management

Is the local government or municipality active in educating the public about waste management practices?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	30	44.1	44.1	44.1
	no	21	30.9	30.9	75.0
	some times	17	25.0	25.0	100.0
	Total	68	100.0	100.0	

These mixed responses indicate that while some residents recognize the municipality's efforts in environmental education, a substantial portion either does not perceive consistent engagement or has not been reached by such initiatives. The fact that only slightly more than one-third of the population perceives consistent educational involvement suggests that the current outreach efforts may be limited in scope, frequency, or effectiveness.

The 25% of respondents who indicated that educational activities occur "sometimes" further reinforce this idea pointing to sporadic or event-based initiatives rather than a sustained and structured public awareness campaign. For waste management practices to be truly effective and widely adopted, educational efforts need to be continuous, well-publicized, and accessible across all segments of the population.

This data highlights the need for the municipality to adopt a more proactive and strategic approach to public education. This could include incorporating waste management topics into school curricula, holding regular community workshops, using local radio and social media platforms for awareness campaigns, and distributing informative materials in public places. Strengthening these efforts can foster a more informed and engaged citizenry, which is crucial for the long-term success of waste management in Chole Town.

The effectiveness of municipal solid waste management in Chole Town is hindered by several interrelated challenges, as identified by local experts surveyed in the study. According to the results presented in Table 4.3, the most frequently cited issue was related to landfill or disposal problems, accounting for 33.8% of responses. This suggests that the town either lacks adequate landfill infrastructure or faces operational and environmental challenges in managing existing disposal sites, such as overflowing landfills, improper siting, or insufficient maintenance.

The second most common challenge reported was a lack of public awareness, which comprised 25% of the responses. This highlights a significant barrier to the success of waste management initiatives, as community participation is crucial for effective sorting, recycling, and disposal. Without a well-informed public, even the best municipal systems can fall short in achieving their goals.

Table 4.4: Main challenges in waste management

Main challenges in waste management		Frequency	Percent	Cumulative Percent
Valid	Landfill or disposal issues	23	33.8	33.8
	Insufficient waste collection services	7	10.3	44.1
	Poor waste segregation	7	10.3	54.4
	Inadequate recycling facilities	10	14.7	69.1
	Lack of public awareness	17	25.0	94.1
	Environmental impact concerns	3	4.4	98.5

	Other (Please specify)	1	1.5	100.0
	Total	68	100.0	

Inadequate recycling facilities were also a major concern, mentioned by 14.7% of respondents. This reflects the limited availability of infrastructure or technology to process recyclable materials, which likely results in a higher volume of waste being sent to landfills and missed opportunities for resource recovery.

Both insufficient waste collection services and poor waste segregation practices were identified by 10.3% of respondents each. These issues point to operational inefficiencies in the collection system, such as irregular collection schedules, lack of coverage in some areas, or inadequate equipment and staffing. Poor segregation of waste at the source further complicates the collection and recycling process, leading to contamination and increased landfill use.

A smaller portion of respondents (4.4%) cited environmental impact concerns, indicating awareness of the broader implications of improper waste management, such as pollution of water sources, soil degradation, and health risks. Meanwhile, 1.5% of respondents mentioned other miscellaneous challenges, which may include funding constraints, lack of political commitment, or institutional coordination issues.

Overall, the data illustrates that Chole Town faces a multifaceted waste management crisis. Addressing these challenges will require an integrated approach that combines infrastructure development, public education, improved service delivery, policy enforcement, and environmental sustainability strategies.

4.2.2. Practical and Infrastructure Factors

An essential component of effective solid waste management is the efficiency and reliability of waste collection services. To assess this in the context of Chole Town, respondents were asked to rate the effectiveness of the town's waste collection services. As shown in Table 4.4, the responses varied, reflecting a range of experiences and perceptions among residents. Only 23% of respondents rated the services as very effective, suggesting that a relatively small portion of the population is fully satisfied with the current system. A slightly larger share, 26.5%, considered the services somewhat effective, indicating that while some basic functionality exists, there are notable areas for improvement.

However, a significant 32.4% of respondents viewed the waste collection services as not effective, pointing to substantial dissatisfaction. This group likely experiences frequent disruptions, delayed or irregular waste pickups, or limited service coverage, particularly in peripheral or underserved areas. The relatively high percentage of dissatisfaction signals systemic challenges in how waste is collected, transported, and managed across the town.

Table:4.5. Practical and Infrastructure Factors Affecting Solid Waste Management in Chole Town:

How would you rate the effectiveness of the waste collection services in your town?		Frequency	Percent	Cumulative Percent
Valid	Very effective	16	23.5	23.5
	Somewhat effective	18	26.5	50.0
	Not effective	22	32.4	82.4
	Not sure	12	17.6	100.0
	Total	68	100.0	

Additionally, 17.6% of respondents stated they were not sure about the effectiveness of the services. This level of uncertainty may stem from inconsistent service visibility, lack of direct interaction with municipal waste services, or general confusion about the roles and responsibilities of local authorities in solid waste management.

Overall, these findings suggest that Chole Town's waste collection infrastructure and practices face serious shortcomings. While a small segment of the population perceives the system as working well, the combined majority either experiences inefficiencies or lacks clear information about how the system operates. This underlines the need for substantial improvements in service delivery, better logistical planning, and enhanced communication between the municipality and the public. Strengthening the reliability, coverage, and transparency of waste collection services is essential to building a cleaner and more sustainable urban environment in Chole Town.

Method by which residents dispose of their solid waste: Another important practical and infrastructural factor to consider in urban planning is the method by which residents dispose of their solid waste. Waste management practices are closely tied to public health, environmental protection, and urban liveability. In the surveyed town, respondents reported a variety of waste disposal methods, indicating a lack of standardized and accessible services. Only 5.9% of respondents use regular municipal waste collection services, suggesting limited government capacity or coverage.

A larger portion, 30.9%, rely on private waste collection services, which may not be affordable or accessible to all residents. Meanwhile, 17.6% of the population practice composting, a more environmentally friendly method, although it is not widespread enough to significantly reduce total waste volume. Alarmingly, 39.7% of respondents dispose of their waste by burning it an unsustainable and hazardous practice that contributes to air pollution and poses health risks. An additional 5% use other unspecified methods, which may include illegal dumping or unregulated practices.

Table 4.6. Method by which residents dispose of their solid waste

How do you dispose of your waste?		Frequency	Percent	Cumulative Percent
Valid	Regular municipal collection	4	5.9	5.9
	Private waste collection services	21	30.9	36.8
	Composting	12	17.6	54.4
	Burning	27	39.7	94.1
	Other (Please specify)	4	5.9	100.0
	Total	68	100.0	

These findings reveal a fragmented and often informal waste disposal system that lacks centralized oversight and sustainable solutions. The high percentage of residents who burn their waste or rely on alternative methods suggests that many are not served by formal waste infrastructure. Therefore, it is critically important to scientifically identify and establish a well-located, properly managed waste disposal site. Such a facility would not only help streamline waste collection and improve environmental conditions, but also support broader public health goals and ensure the town's development is aligned with sustainable urban management principles.

Frequency of Waste Collection: As illustrated in Table 4.6, another important aspect of solid waste management is the frequency of waste collection. The data presented in Table 4.5 reveals that only 2.9% of residents have their waste collected 2–3 times per week, while 22.1% report weekly collection. A larger portion, 30.9%, experience bi-weekly collection, and the majority 44.1% indicate that waste is collected less frequently than every two weeks. These figures clearly demonstrate the absence of a consistent and reliable waste collection system in the town.

Table 4.7 frequency of waste collection

How frequently is waste collected in your area?		Frequency	Percent	Cumulative Percent
Valid	2-3 times a week	2	2.9	2.9
	Weekly	15	22.1	25.0
	Bi-weekly	21	30.9	55.9
	Less frequently	30	44.1	100.0
	Total	68	100.0	

The irregularity in waste collection services is a strong indicator of systemic infrastructural challenges, most notably the lack of an officially designated and accessible waste disposal site. Without a properly located dumping or landfill site, municipal and private service providers face logistical difficulties in maintaining regular collection schedules. This can lead to waste accumulation in residential areas, contributing to environmental degradation, increased health risks due to pests and disease, and overall deterioration of urban hygiene. Addressing this issue requires not only improving collection logistics but also investing in infrastructure specifically, the scientific selection and development of a centralized waste disposal site. Doing so would enhance the efficiency and reliability of waste collection services and ensure better living conditions for the town's residents.

Availability of waste dumping site: Table 4.7 provides insight into the availability of waste disposal points, such as public bins and containers, within the town. According to the responses, only 27.9% of residents believe that sufficient waste disposal points are available in public areas. In contrast, 38.2% reported that such facilities are not available, while 33.8% indicated that they are available only sometimes, often referring to temporary or makeshift containers. This inconsistency in the availability of disposal points suggests a lack of systematic planning and maintenance of public waste infrastructure. The use of temporary containers highlights the town's reliance on ad-hoc solutions rather than a permanent and well-maintained system.

In addition, table 4.7 present respondents were asked to assess the overall condition of the town's waste management infrastructure, including vehicles, bins, and landfill sites. Only 26.5% rated it as good, while 30.9% considered it fair, and a significant 42.6% rated it as poor. These results reflect serious shortcomings in the quality and functionality of essential waste management components. Inadequate infrastructure not only hinders efficient waste collection and disposal but also contributes to public dissatisfaction and environmental pollution.

Table 4.8. Waste site availability in public areas and condition of waste management

Are there sufficient waste disposal points (e.g., bins, containers) available in public areas?		Frequency	Percent	Cumulative Percent
Valid	Yes	19	27.9	27.9
	No	26	38.2	66.2
	Sometimes	23	33.8	100.0
	Total	68	100.0	

How would you rate the condition of the town's waste management infrastructure (e.g., vehicles, bins, landfill sites)?		Frequency	Percent	Cumulative Percent
Valid	Good	18	26.5	26.5
	Fair	21	30.9	57.4
	Poor	29	42.6	100.0
	Total	68	100.0	

The combined data indicates that the town's waste management system is underdeveloped and in need of urgent improvement. There is a clear gap in both the availability and quality of waste disposal facilities and infrastructure. To address these issues, local authorities need to prioritize investment in permanent, strategically placed waste collection points, as well as upgrade existing infrastructure such as collection vehicles, bins, and landfill sites. Doing so would support a cleaner urban environment, promote public health, and enhance the overall efficiency of municipal services.

4.2.3. Environmental and geographical Factors

***Environmental Concerns in Daily Life*:** Table 4.8 highlights the level of importance residents place on environmental concerns in their daily routines. According to the data, 30.9% of respondents consider environmental issues a high priority, while 26.5% assign them a moderate level of importance. However, a larger portion 36.8% view these concerns as a low priority, and 5.9% do not consider them a priority at all.

This variation indicates a general awareness of environmental matters, though many residents may lack the motivation, knowledge, or resources to consistently integrate eco-friendly practices into their daily lives. The relatively low percentage of those who prioritize the environment highly may also reflect the absence of strong public awareness campaigns or limited access to sustainable alternatives, such as recycling programs and green spaces.

Concern About the Environmental Impact of Waste: In contrast to the varied personal prioritization of environmental concerns, the majority of residents express strong worry about the broader environmental effects of waste in their community. According to the survey, 51.5% of respondents are very concerned about the environmental impact of waste in the town, and 42.6% are somewhat concerned. Only 5.9% reported being unsure.

This strong level of concern suggests that while individual environmental practices may be inconsistent, there is significant public recognition of the harmful consequences of unmanaged waste, including pollution, health risks, and degradation of local ecosystems. This awareness presents an opportunity for local authorities and environmental organizations to engage the public through education, community-based initiatives, and policy interventions aimed at improving waste management and promoting sustainable living.

Table: 4.9. Environmental Concerns in Daily Life and Environmental Impact of Waste

How do you prioritize environmental concerns in your daily life?		Frequency	Percent	Cumulative Percent
Valid	High priority	21	30.9	30.9
	Moderate priority	18	26.5	57.4
	Low priority	25	36.8	94.1
	Not a priority	4	5.9	100.0
	Total	68	100.0	
How concerned are you about the environmental impact of waste in your town		Frequency	Percent	Cumulative Percent
Valid	Very concerned	35	51.5	51.5
	Somewhat concerned	29	42.6	94.1
	Not sure	4	5.9	100.0
	Total	68	100.0	

Town's efforts to protect the environment in terms of waste management: The survey results regarding public perception of the town's efforts to protect the environment through waste management reveal a generally lukewarm response from residents. Only 8.8% of respondents rated the town's environmental protection efforts as excellent, while 17.6%

considered them good. The majority 57.4% classified the efforts as fair, suggesting that while there may be some initiatives or systems in place, they are either insufficient, inconsistently implemented, or poorly maintained. Meanwhile, 16.2% of respondents judged the efforts as poor, indicating dissatisfaction and a lack of visible or effective action by the local authorities in managing waste-related environmental concerns.

Table 4.10. protecting the environment in terms of waste management

How would you rate the town's efforts to protect the environment in terms of waste management?		Frequency	Percent
Valid	Excellent	6	8.8
	Good	12	17.6
	Fair	39	57.4
	Poor	11	16.2
	Total	68	100.0

This distribution of responses points to a perception that the town is underperforming in its environmental responsibilities, particularly in waste management. While a small portion of the population acknowledges some positive steps, most people seem to believe that current measures fall short of what is needed to adequately protect the environment. Factors such as irregular waste collection, inadequate disposal infrastructure, lack of public awareness campaigns, and limited recycling options may contribute to this perception.

In summary, the town's waste management efforts are generally viewed as average or below expectations by its residents. With only 26.4% of respondents giving a rating of "good" or "excellent," and a combined 73.6% rating them as merely "fair" or "poor," it is evident that there is a pressing need for improvement. Strengthening the town's commitment to environmental protection through better infrastructure, consistent services, and community engagement would not only improve public satisfaction but also promote a healthier and more sustainable urban environment.

***Geographical layout influences waste management practice*:** The final aspect explored in the survey relates to whether residents believe the town's geographical layout such as the distinction between urban and rural areas, topography, and the availability of space affects waste management practices. According to the responses, only 22.1% of participants agreed that the town's geographic features significantly influence how waste is managed. In contrast, 45.6% of respondents did not believe there was a strong connection between geographical layout and waste management effectiveness. Meanwhile, 32.9% (correcting the 2.95%, which likely refers to a different response group) selected "other," indicating varied or unclear perspectives, possibly pointing to uncertainty or lack of information on how geography plays a role in municipal planning.

Table: 4.11. Geographical layout influences waste management practice

Do you believe the town's geographical layout (e.g., urban vs. rural, availability of space) influences waste management practices?		Frequency	Percent
Valid	yes	15	22.1
	no	31	45.6
	Not sure	20	29.4
	other	2	2.9
	Total	68	100.0

This response pattern suggests that a considerable portion of the population may be unaware of, or overlook, the impact that spatial planning and geographic constraints can have on effective waste management. In reality, the layout of a town whether it is densely urbanized, spread out across rural areas, situated in hilly terrain, or limited in space can greatly influence the logistics of waste collection, the siting of landfill or composting facilities, and the accessibility of waste disposal infrastructure. For instance, remote rural areas may suffer from infrequent collection services due to difficult terrain, while urban centres may struggle with space limitations for temporary storage or permanent disposal sites.

In conclusion, the mixed responses suggest a gap in public understanding about the relationship between the town's geography and its waste management challenges. While only a minority explicitly recognize this influence, the physical layout of the town undoubtedly plays a critical role in shaping waste management strategies. This underscores the need for increased public awareness and integrated urban planning that takes geographical factors into account. By aligning waste management policies with the town’s spatial realities, local authorities can develop more effective, inclusive, and sustainable waste systems.

4.3. Optimum Disposal site screening and identification of each criterion

4.3.1. Land use land cover

Land use/Land cover is one of the criteria used to select optimum sites for solid waste disposal in the Chole town. The land use/land cover of the study area classified into four main classes such as Agriculture land, bare soil land, built up area, Vegetations/grass lands clearly shown in Figure: 4.3. Their suitability is classified according to Kontos *et al.* (2005), Built-up area (road and infrastructure) area are reclassified as not suitable. This is to avoid the adverse effects on human health and the environment. vegetation (greenery) areas are reclassified as less suitable for landfill siting due to their higher ecological value. agricultural land is reclassified as moderately suitable. According to (Kebede et al., 2021) , it is recommended to locate solid waste disposal sites in open bare lands and grasslands or shrubs. Thus, open bare lands are classified as the most suitable, thus bare land including grasslands are reclassified as highly suitable.

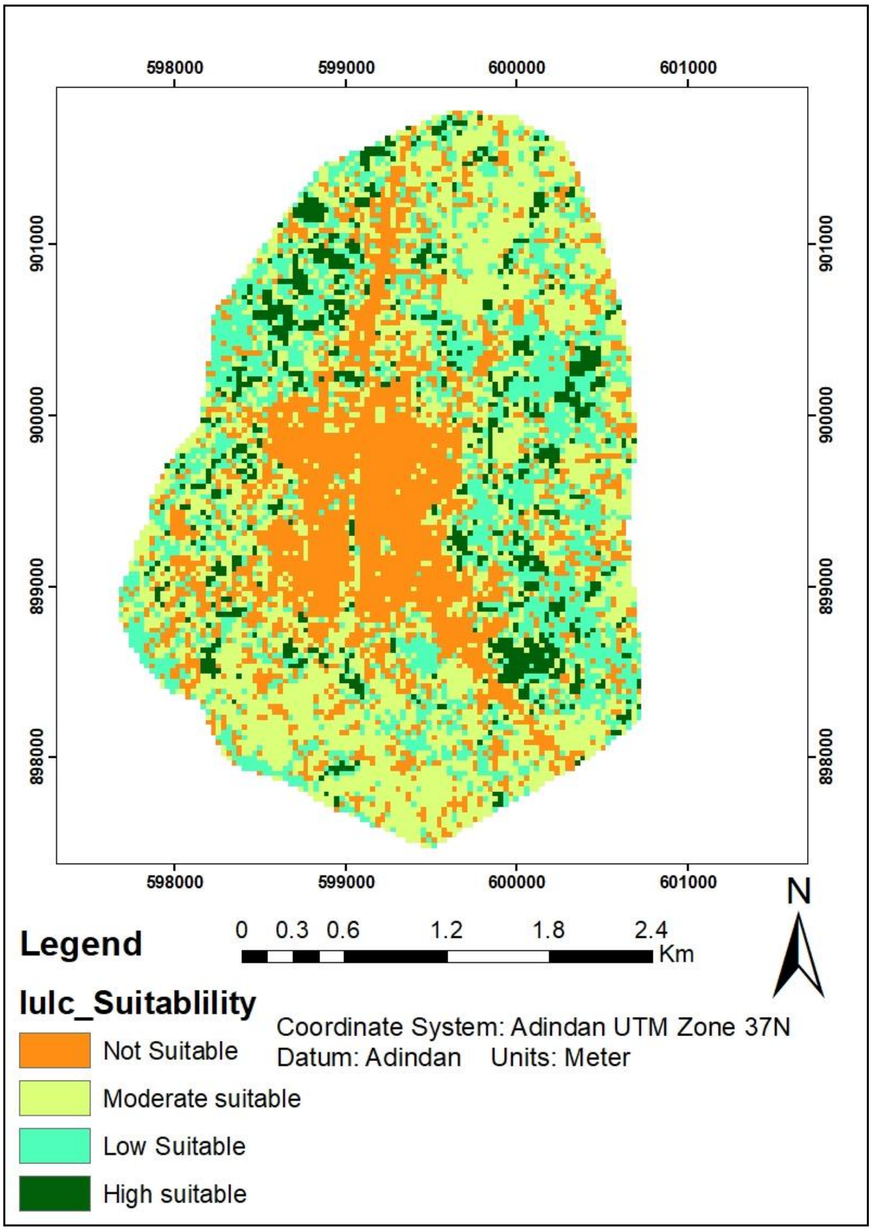


Figure 4.3: LULC suitability map of study area

Sources (Landsat 8-9) images of 2025 and ArcGIS Classification by author, 2025)

The analysis indicates varying degrees of suitability across different land use/land cover types. Built-up areas, covering 293.2 hectares (30.5%), are deemed not suitable for solid waste site selection. Vegetation areas, accounting for 222.76 hectares (23.18%), are classified as low suitability. Agricultural land, with a total of 357.43 hectares (37.2%), falls under moderate suitability. In contrast, bare land represents the most favourable option, with high suitability, covering 87.51 hectares (9.11%) shown in (Table: 4.12). and Figure: 4.3).

Table 4.12: Land use type, area coverage and its suitability for disposal site

LULC_ Class (Types)	Suitability	Rank	Area (ha)	Area (%)
Built-up area	Not suitable	1	293.21	30.51
Vegetation	Low Suitable	2	222.76	23.18
Agriculture	Moderate suitable	3	357.43	37.20
Bare land	High suitable	4	87.51	9.11
Total			960.92	100.00

Source calculations from attribute table of Arc map

Table 4.12 shows that the area which is covered by 293.2 hectares 30.5 % said to be unsuitable and given value 1 and moderately suitable and highly suitable areas covering 37.2 % and 9.1 % respectively. To prevent public health and pollution of surface and ground water built up area and water bodies are unsuitable for best selection of disposal site. Suitability map of LULC is shown in Figure 4.3 from high suitable to unsuitable.

4.3.2. Slope and Elevation (Altitude)

Slope plays a crucial role in landfill site selection. A Digital Elevation Model (DEM) with a 12.5m resolution of was generated and utilized to determine the slope. A Digital Elevation Model (DEM) is a representation of the Earth's surface that captures variations in terrain elevation. It consists of a grid of cells where each cell contains an elevation value. DEMs are widely used in geographic and environmental studies, engineering, and land-use planning. DEMs are commonly derived from satellite imagery, aerial photography, LiDAR (Light Detection and Ranging) technology, or ground surveys. They come in different resolutions, with finer resolutions providing more detailed elevation data.

The permitted slope for solid waste landfill sites depends on various factors, including soil stability, waste composition, and environmental regulations. Generally, landfill slopes are designed to ensure stability and prevent erosion or collapse. Studies suggest that the angle of internal friction for municipal solid waste (MSW) is around 29 degree (Chopra et al., 2009). However, landfill slopes are often designed with lower angles to enhance stability and safety (Ummah, 2019). In some cases, reinforcement techniques like geogrids can be used to allow steeper slopes while maintaining structural integrity. It is classified and ranked into four classes as suggested above in literature and their percentage classifications are shown in Table 4.13 and Figure 4.4.

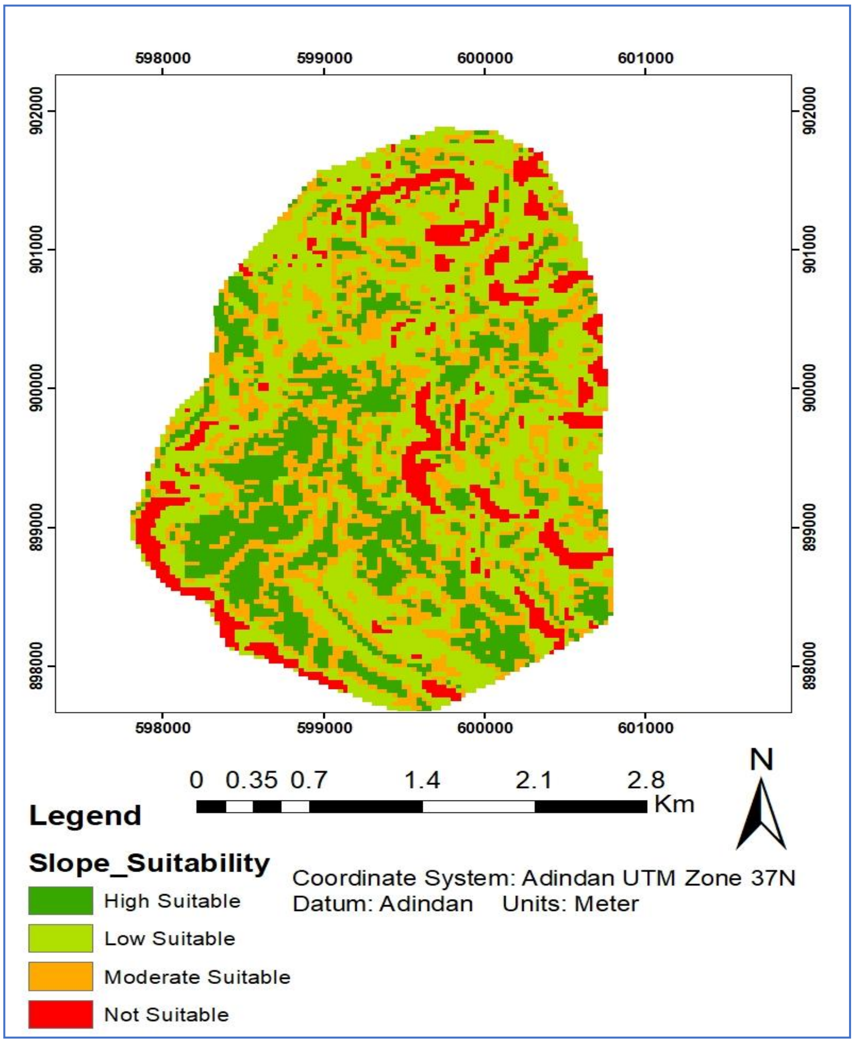


Figure 4.4: Reclassified suitability map of slope

The area which have high slope is not good for solid waste disposal and >13% is not suitable (Chandel et al., 2024). To minimize erosion, water runoff and for easier construction of the site, a low slope is required. Thus according to (Chandel et al., 2024), slope of the land with 0-5% highly suitable, 5-8% moderately suitable, 8-10% low suitable and >10% are classified as not suitable.

Table 4.13: Slope percentage, area coverage and its suitability for disposal site

Slope Degree	suitability Class	Rank	area (ha)	Area (%)
0 - 5	High Suitable	4	211.47	22.78
5 - 8	Moderate Suitable	3	230.46	24.83
8 - 10	Low Suitable	2	393.33	42.38
>10	Not Suitable	1	92.90	10.01
	Sum		928.16	100

Table 4.13 indicates that the unsuitable area covered 10% of the study area and given the value 1 because it is steep slope that increases the costs of construction of landfill and the second ranked low suitable area covering the 42.38% which was followed by the moderately suitable and highly suitable areas covering 24.83% and 22.78% respectively. Based on study area the area 47.61 % is suitable to highly suitable for selection of landfill site to minimize the cost of landfill construction and most of the land of the study area is suitable for disposal of waste selection.

4.3.3. Proximity to main road

A road is one of the criteria that should be considered from economic and social point of views during solid waste Disposal site selection processes. This is because sitting landfill very close to roads may have public health problem as landfill can have hazardous effect to health. Moreover, Waste dispoal site very far from road network is also not recommended due to high transportation cost. Therefore, to minimize such problems, it must not be sited very close to and very far from roads sited in (Kareem et al., 2021).

Chang et al. (2007)sited in (Kenate, 2017) set 75m buffer while Hasan et al. (2009) uses 50-100m buffer from road as a minimum distance within which landfill should not be located. However, 100m buffer distance is mentioned as the safest distance (Kareem et al., 2021). For this study, Multiple Ring Buffer tools were used to create buffer classes around the roads with 0-100m, 100-500m, 500-1000m, 1000-1500m and >1500m distance ranges as we see in the figure below (Fig.4.5).

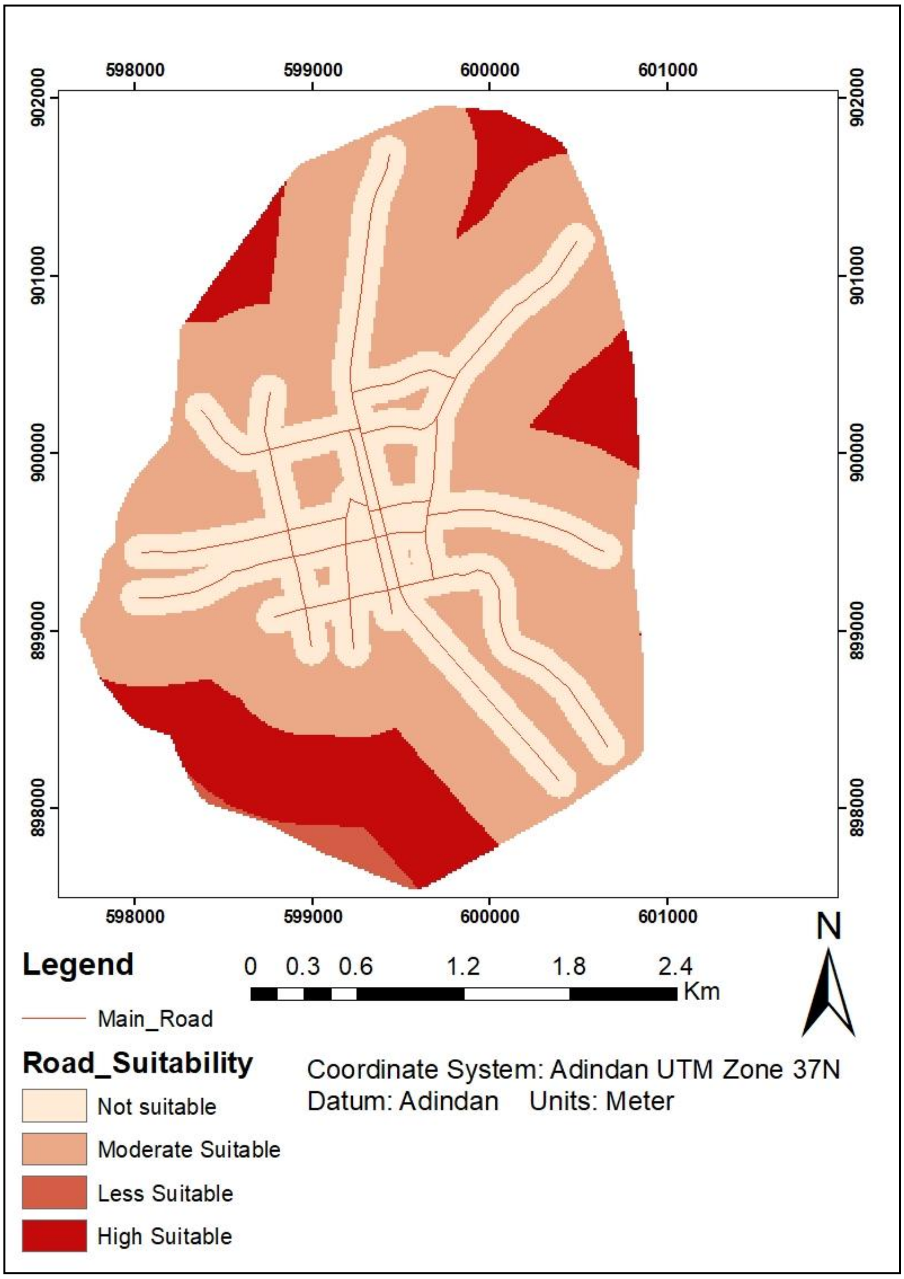


Figure 4.5: Reclassified map of road suitability

Figure 4.5 above presents a reclassified map of the road network, where color gradients ranging from white to red are used to represent varying levels of suitability. In this visualization, white indicates areas of low suitability, while red signifies areas of high suitability. This gradient effectively highlights the spatial distribution of road suitability, allowing for a clear visual interpretation of regions where roads are more or less appropriate based on the criteria used in the analysis.

Table 4-14: distance to road, area coverage and its suitability for disposal site.

Distance (m)	Suitability	Rank	Area (ha)	Area (%)
0 - 100	Not suitable	1	309.91	30.34
100 - 500	Moderate Suitable	3	535.56	52.43
500 - 1000	High Suitable	4	163.1	15.96
>1500	Less Suitable	2	13.0	1.27
Total			1021.57	100.00

The road network buffer map was reclassified and standardized based on the fact that very close and far away sites are unsuitable for landfill and hence excluded from the analysis. Accordingly, a buffer distace from 0 to 100m and greater than 1500m buffer distances were not suitable and less suitable respectively. But, the areas, from 100m to 1500m, were given suitability according to their preference. The highly suitable site is 500-1000m radius from the roads; moderately suitable site is 100-500m. Generally, for areas between 500-1500m suitability decreases with increasing distance. This is due to increased transportation cost and inaccessibility of the area. Table 4.14 summarizes weight assigned and suitability level with their area coverage.

4.3.4. Proximity to built-up area

Maintaining a sufficient distance between solid waste sites and built-up areas is crucial for public health, environmental protection, and property values. Locating solid waste sites further from built-up areas minimizes negative impacts on human health and the environment, reduces nuisance and aesthetics issues, and protects property values. This includes preventing contamination of water and soil, reducing odor and noise pollution, and mitigating the spread of disease vectors (Desta, 2022). Solid waste disposal sites should not be located near to the people, since they might cause different types of pollution. Built up area includes commercial areas, governmental and private institutions, schools, health-centres, religious institutions, educational institutions, residential area and another social services area.

According to Hasan et al. (2009), increasing the distance between potential landfill sites and residential or built-up areas significantly enhances the suitability of a location for waste disposal. To mitigate the negative impacts on public health and preserve the aesthetic and environmental quality of the surrounding land, a minimum buffer zone of 500 meters from built-up areas was established. Beyond this threshold, the suitability of land for landfill development improves with distance.

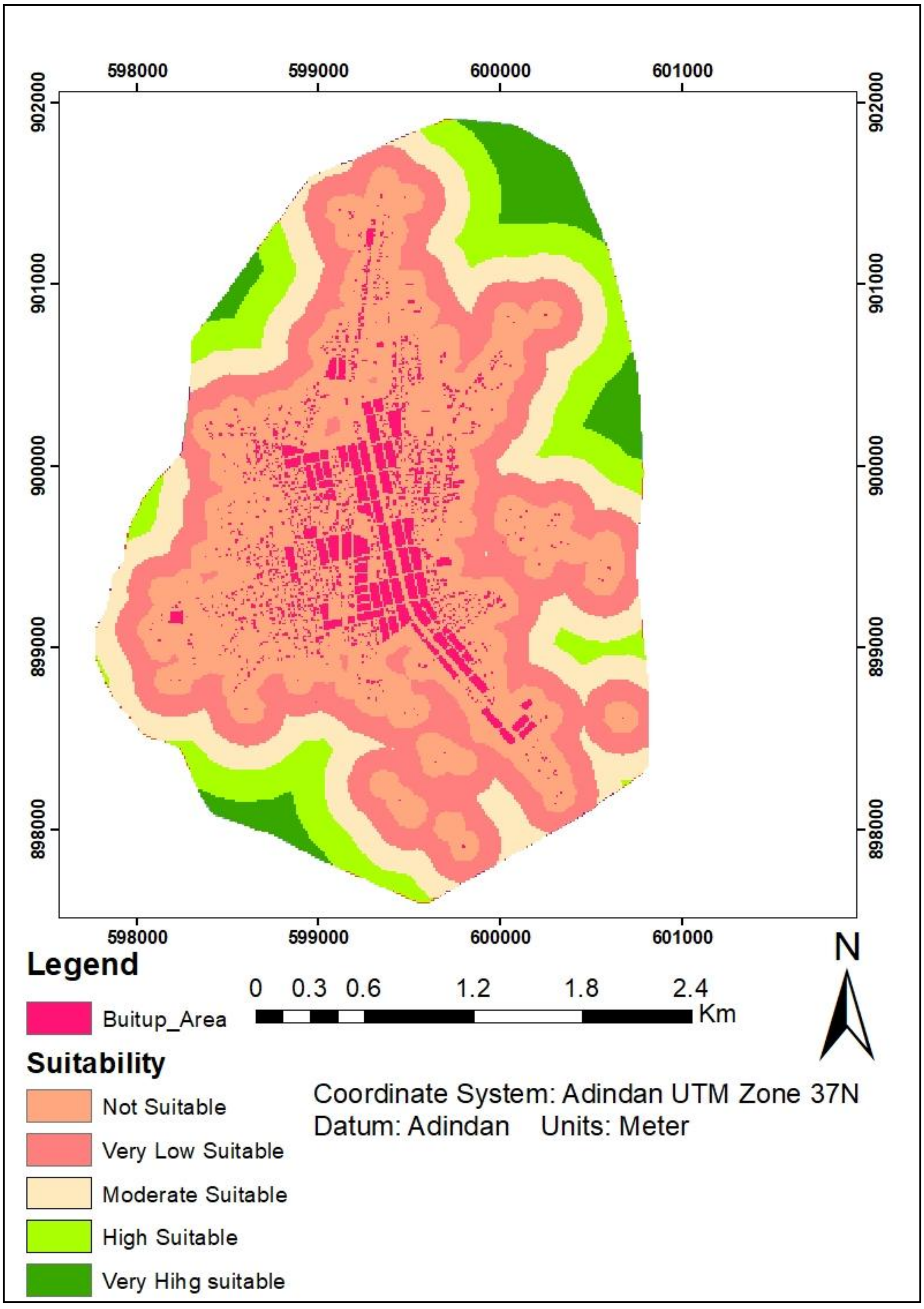


Figure 4-6 map of suitability distance from built-up area

To systematically evaluate suitability, the study categorized the proximity to built-up areas into four distance-based classes: less than 200 meters, 200-500, 500–800 meters, 800–1000 meters, and greater than 1000 meters. Areas located within 500 meters of residential zones were deemed entirely unsuitable and were therefore excluded from consideration. The remaining zones were assessed and ranked based on their relative suitability, using criteria derived from a comprehensive review of existing literature.

The classification scheme for distance from built-up areas, along with its spatial representation, is provided in Table 4-15 and illustrated in Figure 4-6. This method supports informed decision-making in landfill site selection by ensuring that health and environmental concerns are prioritized.

Table 4.15 proximity built-up area coverage and its suitability for disposal site.

Distance (m)	Suitability	Rank	Area (ha)	Area (%)
0 - 200	Not Suitable	1	426.209	44.33
200 - 500	very Low	2	222.672	23.16
500 - 800	Moderate Suitable	3	159.31	16.57
800 - 1000	High suitable	4	103.817	10.80
>1000	Very High suitable	5	49.4158	5.14
Total			961.42	100.00

Table 4-15 shows that unsuitable area covered 44.3 % of the study area and given value 1and low suitable area covered 23.16 % of the study area and given the value 2 and the remaining areas are moderately suitable and highly suitable areas covering 16.57 % and 10.80% respectively. The area that above 1000m which covers 10.81% is highly suitable for selection of landfill site to minimize the risk of pollution of environment and public health.

4.3.5. Geological criteria (soil types of study area)

Soil type significantly impacts solid waste management by influencing how pollutants move, interact with the soil, and potentially contaminate the environment. Different soil types have varying capacities for absorbing, retaining, and filtering contaminants, impacting the fate and transport of pollutants within the soil and potentially into groundwater. Understanding soil characteristics is crucial for selecting suitable landfill sites. Sites with less permeable soils are preferred to minimize the risk of leachate contamination of groundwater. Soil is one of the criteria to select landfill site. Landfill site should not be sited in the area with high permeability soil to minimize the risk of leachate movement.

In the context of solid waste areas, Vertisols are generally considered the most suitable soil type. Vertisols, known for their dark color, high clay content, and tendency to shrink and crack when dry, can be a good choice for landfill construction. while Cambisols are typically considered less suitable. Cambisols, which are typically medium-textured soils with good drainage, may not be ideal for landfill construction due to their higher permeability and lower sealing potential. Luvisols can be suitable depending on their specific characteristics and the intended use of the area.

Thus, in the study area there are three classes of soil types used for solid waste disposal site selection analysis shown in Figure 4-7. These are Vertisols, cambisols, and luvisols.

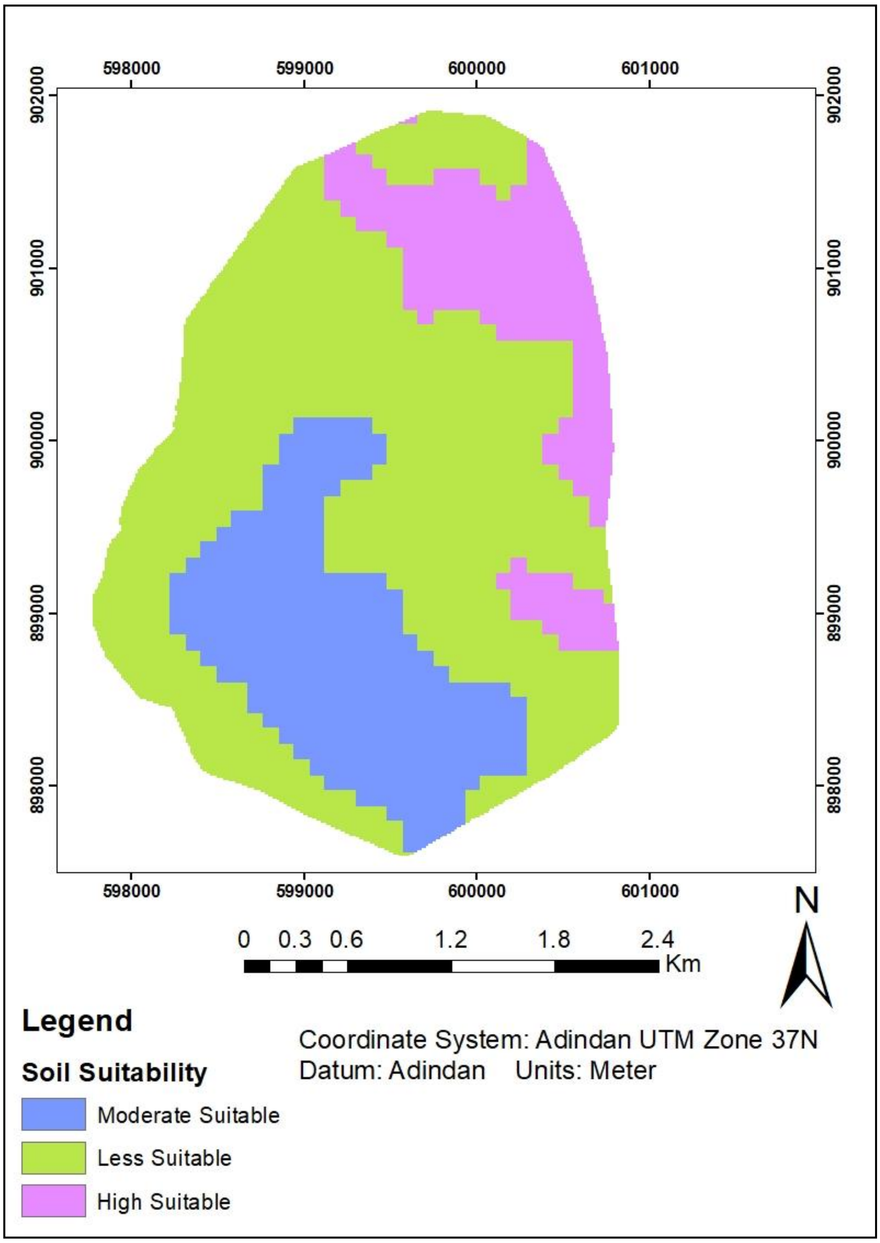


Figure 4.7: soil map suitability of study area

Table 4-16: Soil type, area coverage and its suitability for disposal site

Soil types	Suitability	Rank	Area	Area%
Luvisols Soil	Moderate Suitable	3	237.75	24.73
Vertisols Soil	High suitable	4	157.84	16.42

Cambisol Soil	Less Suitable	2	565.77	58.85
		Total	961.35	100.00

Table 4-16 indicates that 58.85% of the study area covered by Cambisols which has less permeability and ranked as number 2. The third ranked moderately suitable area covering the luvisols 24.73% of the study area and 16.42% of the study area covered by vertisols which is highly suitable areas. vertisols are clay type of soil that have very low permeability and can control the movement of leachate in ground water therefore it is preferable type of soil for solid waste disposal site. Its suitability map is shown in Figure 4-7.

4.3.6. Distance to surface water (rivers and streams)

Waterbody contamination is a significant environmental impact of solid waste. Improper disposal and management of solid waste can lead to the contamination of water bodies such as rivers, lakes, and oceans. When waste is not adequately contained or treated, pollutants can leach into nearby water sources or be carried by runoff during rainy events. Contaminants from solid waste, including chemicals, heavy metals, and organic compounds, can negatively affect water quality and aquatic ecosystems. These pollutants pose risks to aquatic organisms, disrupting their health and habitats.

The distant area from the lake and river stream network is preferable to that of the closer one. The study area river stream was generated from Ethiopian river data and drainages from municipality that resulted in a stream network as shown in Figure 4.8. Solid waste can be carried by surface running water from the upper altitude to the lower part and moves the garbage from the dumped area to the other alongside the river way. There the dumping site should be far from the river network (Molla, 2024).

Landfill should not be located near to surface water sources in order to protect this surface water from pollution, Therefore, to minimize such pollution, (Babalola & Busu, 2011) used 200 m as a minimum distance. According to (Molla, 2024), for this study 100m buffer distance was used as a minimum distance. Multiple ring buffers from analysis tools were used to prepare multiple polygons around each streams and rivers within the following distances: <200 m, 200 - 500m, 500 - 1000m and >1000m. Surface water and the area within 200m considered as not suitable (restricted) and the remained area classified according to their suitability. Distance classification and the rank of surface water as suggested in literature are illustrated in Table 4-17 and Figure 4-8. The more distance from surface water, the more suitable for landfill sitting to reduce pollution of surface water.

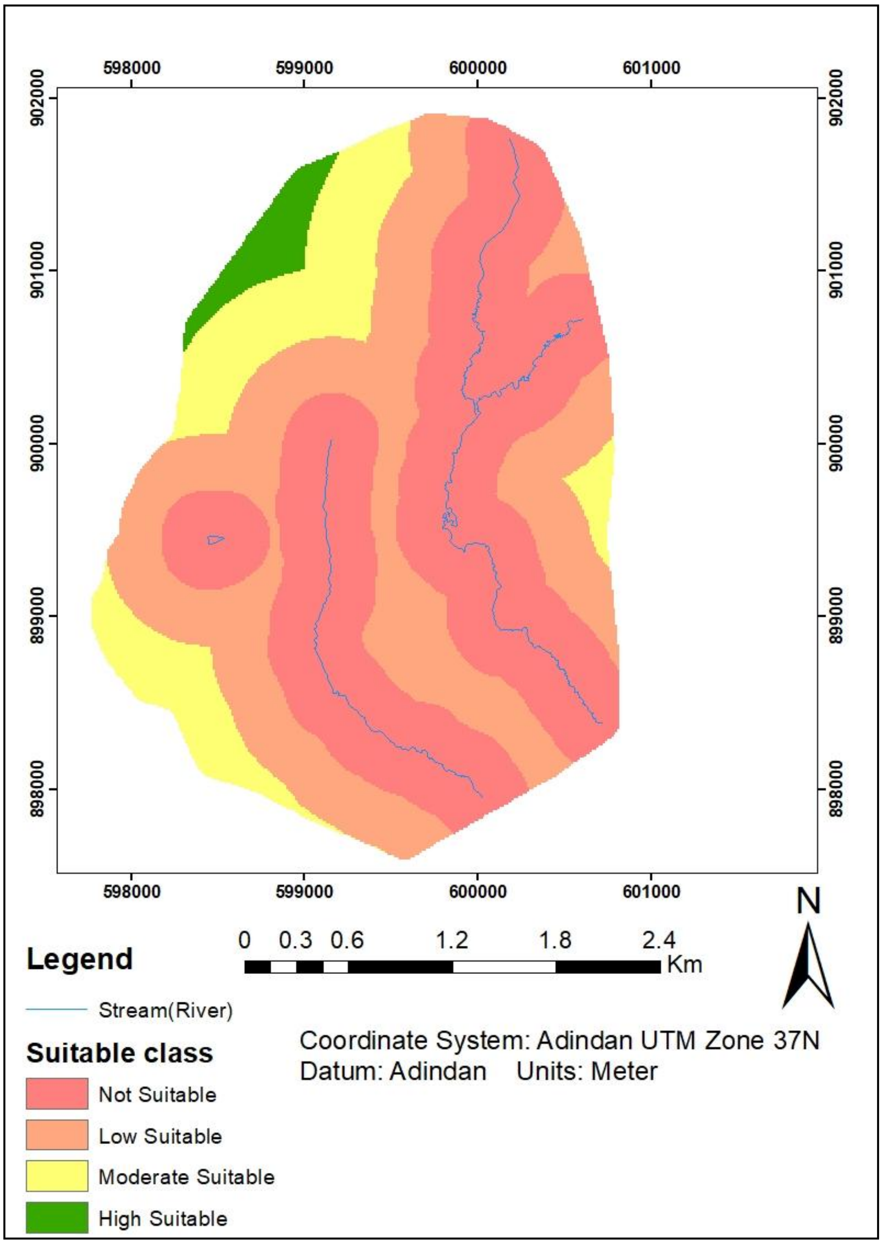


Figure 4-8: Reclassified map of surface water.

Table 4-17: Distance to surface water, area coverage and its suitability for disposal site.

Distance (m)	Suitability	Rank	Area (ha)	Area (%)
<200	Not Suitable	1	442.05	45.98
200 - 500	Low Suitable	2	345.17	35.90
500 - 1000	Moderate Suitable	3	147.26	15.32
>1000	High Suitable	4	26.93	2.80
Total			961.41	100.00

Table 4-17 indicates that unsuitable area covered 45.98% of the study area and given value 1 and low suitable area covering 35.9% of the study area and given the value 2. The remaining areas are moderately and highly suitable areas covering 15.32% and 2.8% respectively. The area beyond 1000m which covered 2.8% is highly suitable for selection of landfill site to minimize the risk of pollution of surface water. The map of suitability of surface water is shown in Figure 4-8.

4.3.7. Distance to ground water well Ground water

solid waste can have significant impacts on underground water quality if not managed properly. However, with proper waste management practices and regulations, we can prevent groundwater contamination and protect this valuable resource for future generations. Groundwater well is one of the criteria in solid waste disposal site selection and it is one of the main which could be leaching into landfill. As a result, solid waste disposal site should be placed away from the water well. Euclidean distance tools were used to prepare classify zones around each well.

In order to minimize ground water pollution coming from leachate, the present study considered 300m distance as minimum distance between the landfill site and ground water well to minimize the movement of leachate in ground water. Because the greater the distance from ground water wells the more suitable for landfill site selection.

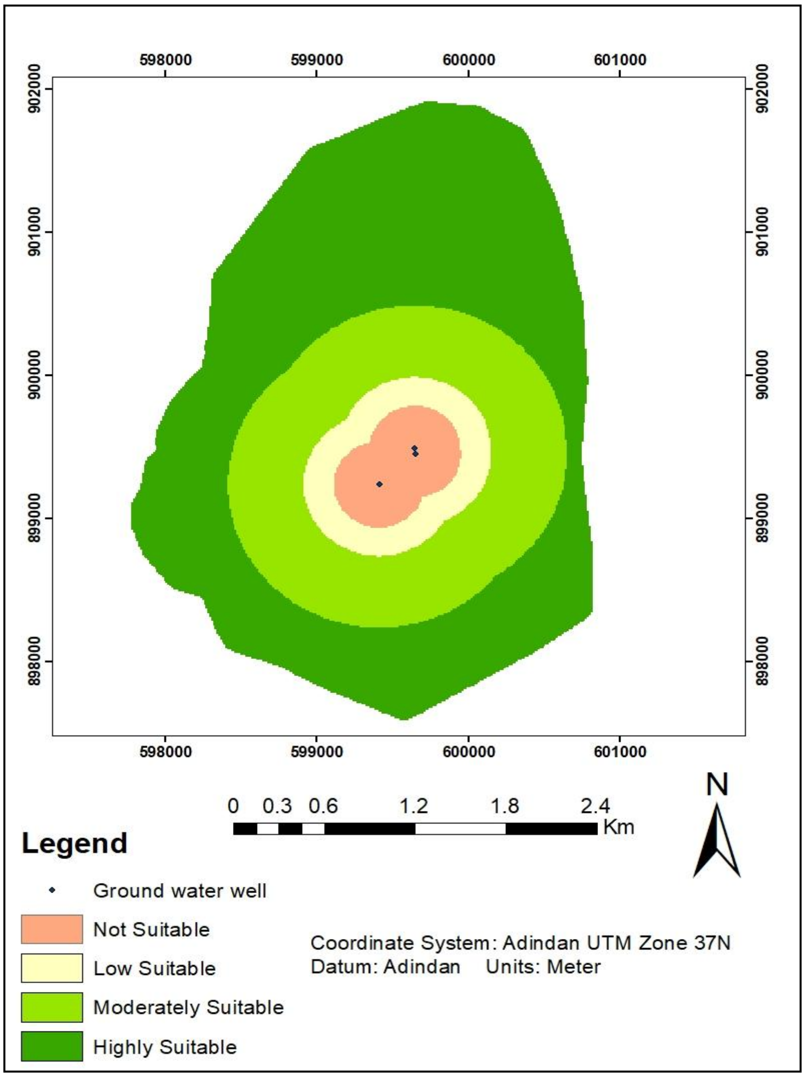


Figure 4.9 map of distance from ground water well

The area was classified into four classes: 0-300m, 300-500m ,500-1000m, and 1000–1500m. Groundwater well and the area within 300m considered as unsuitable (restricted) and the remained area were classified and ranked according to their suitability with the help of literature review. And the distance classification of ground water well is shown in Table 4-9 and Figure 4-18.

Table 4.18 distance from ground water well area coverage

Distance (m)	Suitability	Rank	Area (ha)	Area (%)
0 - 300	Not suitable	1	48.80	5.07
300 - 500	Low Suitable	2	64.76	6.73
500 - 1000	Moderately Suitable	3	271.05	28.18

>1500	Highly Suitable	4	577.11	60.01
		Total	961.72	100.00

Table 4-18 shows that the full coverage of the study area and the area which is said to be unsuitable covered 5% which was ranked number one and the second ranked low suitable area covering the 6.7% which was followed by the moderately suitable and highly suitable areas covering 28.18% and 60.01% respectively. The area is above 1500m which covers 60.01% are highly suitable for selection of landfill disposal site to minimize the movement of leachate. The suitability map of groundwater well was illustrated in Figure 4-9.

4.3.8. Distance from sensitive (protected) area

The protected area in this study includes churches, mosques, schools and health centers. The landfill should not be located in close proximity to sensitive areas listed above to a minimum limit of 300-meter buffer surrounding. The dumping site must be far from these areas (Piyali et.al, 2024). So, to protect the sensitive area, a 3000m buffer has been considered the most suitable buffer for waste dumping. According to (Piyali et.al, 2024) Hakan and Fikri (2009), the distance greater than 3000 m from the site selected as highly suitable for solid waste dumping site and less than 300m from the disposal site considered as unsuitable. When the distance increases from these areas suitabil-ity also increases.

In this study the X, Y coordinates for the above listed protected areas were gathered using GPS during the field survey and buffered using the standards of MUDC, 2012, to locate suitable sites for Solid waste site. Accordingly, four different zones were specified: in which far buffers from protected areas are more suitable while near buffers are less suitable for landfill sitting. The study considered the reclassified distance as unsuitable from 0 to 300meter, less suitable from 300m to 500m, moderate suitable from 500m to 800m and highly suitable above 1000m. The distance classification of protected site is shown in Table 4-19 and Figure 4-10.

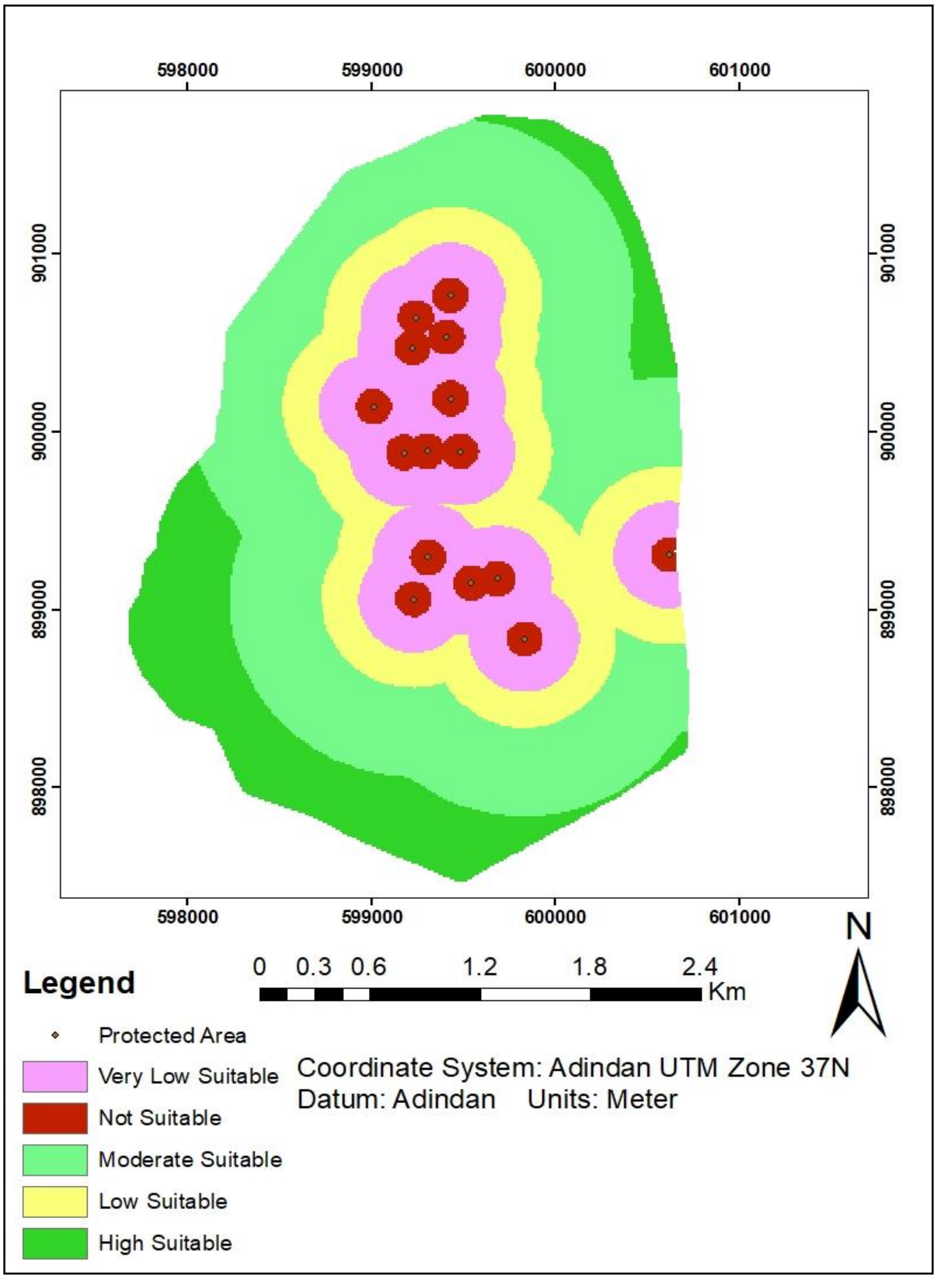


Figure 4.10: distance from protected area suitability map

Table 4.19 distance from protected area and its coverage percentage

Distance	Suitability	Rank	Area_(ha)	Area (%)
100 - 300	Not Suitable	1	219.57	22.83
300 - 500	Low Suitable	2	178.67	18.58
500 - 800	Moderate Suitable	3	398.56	41.44
>1000	High Suitable	4	164.98	17.15
		Total	961.78	100.00

Table 4-19 shows that the covered by 22.83 % which is said to be unsuitable which was ranked number 1 and the second ranked low suitable area covering the 18.58% which was followed by the moderately suitable and highly suitable areas covering 41.44% and 17.15% respectively. The suitability map of Sensitive/protected area was illustrated in Figure 4-10.

4.4. Potential Solid waste Sites Thematic Map

4.4.1. Assigning Criteria Weights

Thematic mapping for identifying potential solid waste disposal sites involves a systematic evaluation of multiple factors through a multi-criteria decision-making process. The site selection for solid waste disposal dumping site involves comparison of different options based on environmental, social and economic impacts. Hence, based on experience and likely impact on surrounding environment, different weights were assigned to all the parameters. The larger the weight, the more important is the criterion in the overall utility.

In this context, the Analytic Hierarchy Process (AHP) was employed to assign relative weights to various criteria influencing site suitability (adefris, 2015). These criteria typically encompass environmental, social, and economic aspects, including proximity to residential areas, groundwater vulnerability, land use/land cover, slope, accessibility, and ecological sensitivity. Based on expert judgment, prior studies, and the anticipated impact of each factor on the surrounding environment and communities, specific weights were allocated to reflect their relative importance (koldba, 2021). This weighted evaluation enables a more objective and informed selection of the most appropriate locations for solid waste disposal, minimizing adverse effects and supporting sustainable waste management planning.

one of the most effective and widely used methods for decision-making is the pair-wise comparison approach, particularly as implemented in the Analytical Hierarchy Process (AHP). AHP is especially useful in multi-criteria evaluation (MCE), where decision-makers need to assign weights to various criteria. In methods like the weighted linear combination, these weights must total exactly 1.0. To facilitate this, the AHP extension in ArcGIS provides a weighting module that employs the pair-wise comparison technique to generate a consistent and normalized set of factor weights (see Table 4.20), ensuring they sum to 1.0. A sample of this process is illustrated in Figure 4.11. The AHP method calculates these weights by deriving the principal eigenvector from a square reciprocal matrix built from the pair-wise comparisons. Each comparison assesses the relative importance of two criteria at a time, contributing to a structured and objective assessment of their influence on overall suitability for the defined goal.

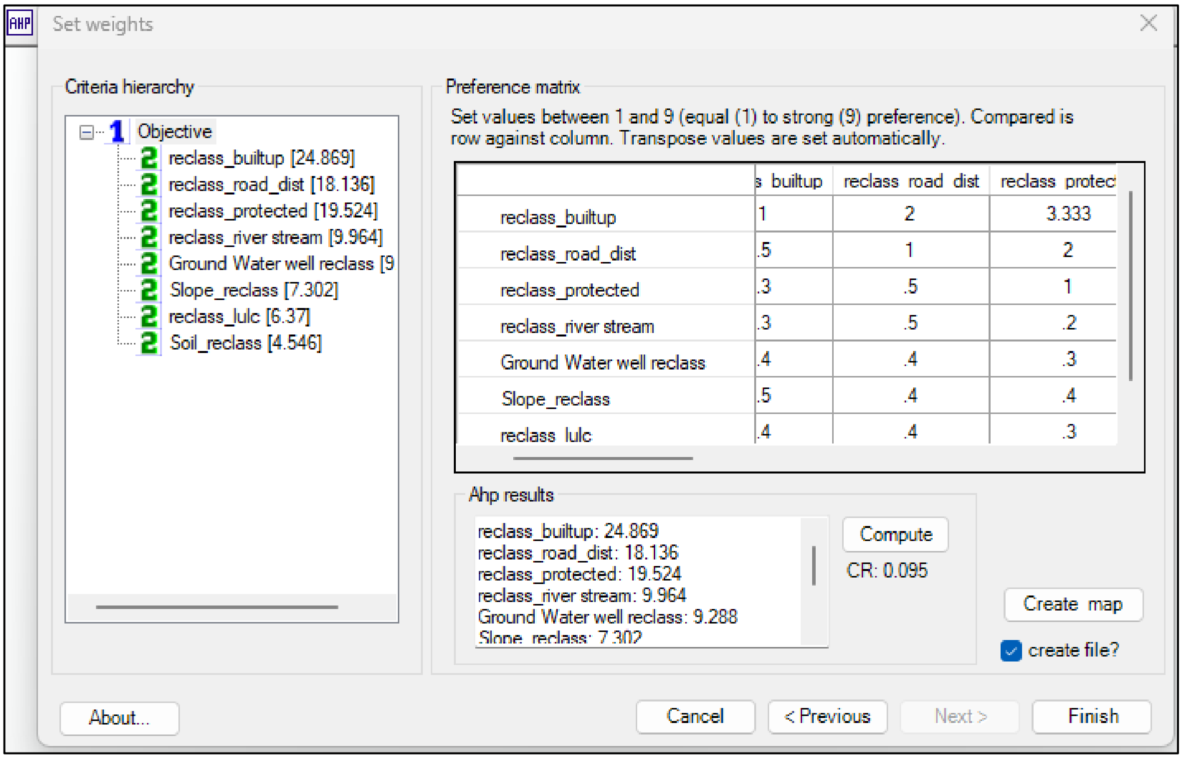


Figure 4.11: AHP weight derivation method considering all factors for solid waste optimum site selection

As part of the analysis, all possible pair-wise combinations of the selected criteria were systematically evaluated using expert judgment to construct a pair-wise comparison matrix. This matrix served as the foundation for calculating a set of relative weights and the consistency ratio (CR) through the Analytical Hierarchy Process (AHP) module (Zemena, 2016). The consistency ratio plays a crucial role in validating the reliability of the judgments made during the comparison process. A low CR indicates a logically consistent set of comparisons, while a high value suggests potential inconsistencies that may need to be revisited. In this study, the AHP weight derivation interface, shown in Figure 4.11, was utilized to determine the factor weights and evaluate the consistency of the input judgments. The resulting consistency ratio was CR = 0.095, which falls within the generally acceptable threshold ($CR \leq 0.1$), confirming that the expert evaluations were consistent and suitable for use in the solid waste site suitability analysis.

Using the AHP weight derivation module, the eigenvectors representing the relative weights of all factors considered in the landfill site selection process were generated. These weights reflect the outcome of the pair-wise comparisons and are presented in Table 4.20, which also illustrates the use of the standard 9-point scale applied during the weighting process.

The Pair-wise Comparison Matrix method calculates factor weights by systematically comparing two criteria at a time, using a rating scale that ranges from 1/4 to 5. A score of 1/4 signifies that the row factor is significantly less important than the column factor, while a score of 5 indicates that the row factor is strongly more important than the column factor. When both factors are deemed equally important, a neutral value of 1 is assigned. Intermediate values, such as 3, represent a moderate or slight preference of one factor over another. This scale allows for nuanced judgment in assessing the relative importance of each criterion. As a result, the computed weights reflect the degree of influence each factor holds within the overall suitability analysis. In general, a higher weight signifies a greater contribution of that factor to the final decision-making model.

Table:4.20. Factors and their eigenvectors weights for solid waste

Factors	Built-up area	Road	restricted area	River stream	Ground Water	Slope	Lulc	Soil	Weight %	Rank
Built-up area	1								24.86	1
Road	0.5	1							18.13	2
restricted area	0.3	0.5	1						19.52	3
River stream	0.3	0.5	0.2	1					10	4
Ground Water	0.4	0.4	0.3	0.5	1				9.28	5
Slope	0.5	0.4	0.4	0.4	0.5	1			7.3	6

LULC	0.4	0.4	0.3	0.5	0.4	0.5	1		6.37	7
Soil	0.5	0.3	0.25	0.5	0.3	0.5	0.3	1	4.54	8
Total									100	

Consistency Ratio=0.095<0.1=acceptable

The consistency ratio of this study indicated that 0.04, which indicates that a reasonable level of consistency in the pairwise comparison. So, it is reasonable accepted and the weights which given for each criterion were reasonable.

In conclusion This structured comparison process enables a transparent and logical derivation of weights, ensuring that expert judgments are effectively translated into quantifiable inputs for the suitability model. The use of the pair-wise matrix in AHP not only prioritizes criteria based on informed reasoning but also enhances the reliability and defensibility of the landfill site selection results.

4.5. Solid waste disposal suitability analysis results

The significance of environmental, hydrological, and topographic factors in determining suitable locations for waste disposal sites varies considerably. Among these, factors related to groundwater and surface water such as soil permeability, distance from groundwater wells, and proximity to rivers or streams carry greater weight in site selection. According to the weight analysis presented in Table: 1.21, these water-related parameters are identified as the most critical due to their direct role in preventing contamination from landfill leachate. Protecting water resources from pollution is a primary concern in waste management planning, as leachate from landfills can pose serious environmental and public health risks if it infiltrates into nearby water sources. In contrast, topographic aspects like slope and land use, while still important, have a comparatively lower impact in determining the environmental safety of a waste disposal site.

In addition, areas located near built-up zones, restricted or protected areas, and major roads are deemed unsuitable for waste disposal. Proximity to urban infrastructure and transportation corridors not only increases the risk of human exposure to pollutants but also raises concerns about land use conflicts, traffic safety, and regulatory compliance. As a result, these locations are systematically excluded from consideration in order to minimize environmental impact and ensure public safety.

Table 4.21: Suitability area level and the percent of total area coverage

Level of suitability	Suitability rank	Area_ha	Area %
Not Suitable	1	323	38.68
Less Suitable	2	157	18.80
Moderate Suitable	3	234	28.02
High Suitable	4	121	14.49

The overall suitability analysis for selecting an appropriate solid waste disposal site in Chole Town revealed that no location meets the criteria for being classified as very highly suitable. This outcome indicates that none of the land parcels evaluated satisfied all eight environmental, social, and economic criteria to the highest standard. Using Geographic Information System (GIS) tools, suitability classifications were determined by first generating raster maps based on various factors and then converting them to vector format to calculate the area coverage of each class.

According to the results, approximately 323 hectares, accounting for 38.68% of the total study area, were deemed unsuitable for landfill development. These unsuitable areas include built-up zones, regions with dense vegetation cover, steep slopes, and locations situated near roads, groundwater wells, rivers, or streams. Such areas were excluded primarily to prevent environmental degradation, safeguard public health, and avoid high construction or transportation costs. These areas pose significant ecological and health risks if used for waste disposal and are economically impractical due to potential infrastructure challenges.

In contrast, 121 hectares (14.49%) of land were found to be highly suitable. These locations satisfy most of the environmental, social, and economic criteria and are considered optimal for waste disposal due to their minimal impact on public health and the environment, as well as their relative cost-efficiency.

A further 234 hectares (28.02%) were classified as moderately suitable. While these areas do not meet all the ideal conditions, they may still be used for landfill development with appropriate management practices, such as installing engineered liners and leachate control systems to mitigate environmental and health impacts. Additionally, 157 hectares (18.80%) were found to be less suitable. These areas fall short in several key criteria and are only marginally viable for landfill siting. Use of these zones would require significant mitigation measures and higher costs, making them less preferable than highly or moderately suitable alternatives. In conclusion, although no location was found to be perfectly ideal, a combination of highly and moderately suitable sites offers practical options for sustainable and safe waste disposal planning in Chole Town.

Figure 4.12 illustrates the levels of land suitability for solid waste disposal, emphasizing the influence of proximity to roads and rivers/streams. Areas near major roads and water bodies are predominantly classified as unsuitable due to the risk of environmental contamination, water pollution, and public health hazards. The map highlights how these two critical factors constrain site selection, underscoring the importance of maintaining safe distances from transportation and water networks when planning landfill locations.

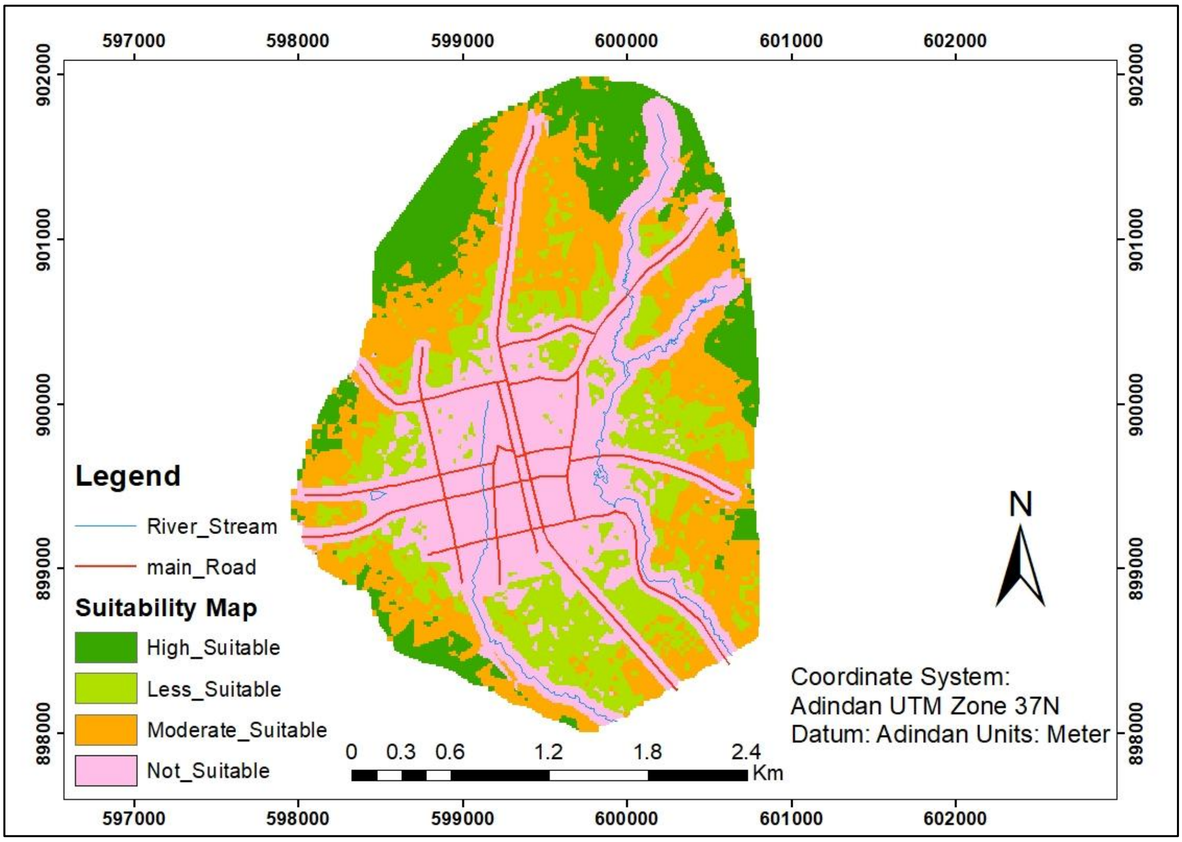


Figure 4.12: Suitability Map for Solid Waste Disposal Site Selection in Chole Town.

The map displays the spatial distribution of land suitability for landfill siting, categorized into four classes: unsuitable, less suitable, moderately suitable, and highly suitable. Areas marked as unsuitable are primarily influenced by proximity to sensitive features such as road networks, rivers, streams, groundwater wells, steep slopes, built-up areas, and vegetation cover. These features are highlighted on the map to show environmental and social constraints, particularly where waste disposal could lead to contamination or disruption. The map was generated using GIS-based multi-criteria analysis, supporting informed decision-making for sustainable waste management.

4.6. Evaluating Suitable Solid waste disposal Sites

In Chole Town, socio-economic factors such as the size of the proposed site, proximity to nearby settlements, and distance from the town center are key criteria in evaluating potential landfill locations. Among these, the landfill site size plays a crucial role in ensuring sustainable solid waste management. The area of land selected directly influences the operational lifespan of the landfill. From both an economic and sustainability perspective, larger sites that can accommodate waste for at least ten years are considered more advantageous. This is because opting for a larger site reduces the frequency and cost associated with future site selection, design, and eventual closure processes.

The assessment of candidate landfill sites in Chole Town considered three critical dimensions: economic feasibility, topographic suitability, and social acceptability. Economically, suitable sites are those located closer to main roads and urban centres, reducing waste transportation and infrastructure development costs. Areas requiring minimal land preparation or located near existing service routes were prioritized to ensure cost-effectiveness. Topographically, the terrain was analysed to avoid steep slopes, which increase the risk of erosion, leachate runoff, and structural instability. Gently sloping or flat areas were deemed more suitable due to their ease of construction and lower environmental risk. Socially, the evaluation excluded areas near densely populated zones, public institutions, or culturally sensitive sites to minimize public opposition and health risks. Buffer zones were applied around settlements to ensure safe distances from human activities, addressing concerns related to odor, pollution, and overall community well-being.

5: CONCLUSION AND RECOMMENDATION

5.1. Conclusions

This study, titled "The Current Solid Waste Management System Using Geospatial Technology: A Case of Chole Town," investigated the effectiveness and challenges of the existing solid waste management practices in Chole Town by integrating both socioeconomic and spatial data. The assessment focused on identifying the key factors influencing waste management, including institutional roles, practical and infrastructural limitations, and environmental and geographical constraints.

Findings revealed that the current waste management system in Chole Town is underdeveloped, with limited institutional capacity, inadequate infrastructure, and lack of proper regulation and coordination. Environmental challenges such as proximity to water bodies, steep slopes, and unplanned urban expansion further complicate waste disposal efforts. The study employed geospatial techniques, specifically the Analytical Hierarchy Process (AHP) and weighted overlay analysis, to evaluate the suitability of potential landfill sites based on a combination of environmental, topographic, and socio-economic criteria.

The spatial analysis results showed that only 14.49% of the study area is classified as highly suitable for landfill development, 28.02% as moderately suitable, 18.80% as less suitable, and 38.68% as not suitable. The most unsuitable areas were found near built-up zones, rivers, roads, and steep terrains, which pose serious environmental and public health risks. Larger and more accessible sites were preferred for their economic and operational advantages, particularly in ensuring long-term service with reduced site development and closure costs.

Overall, the study highlights the value of integrating geospatial tools with multi-criteria evaluation for informed decision-making in urban waste management. It concludes that while Chole Town currently faces several obstacles in its waste management practices, the use of GIS-based analysis provides a strategic approach to identifying sustainable and efficient landfill sites.

To move forward, the town needs to strengthen institutional capacity, improve waste infrastructure, and implement policies that align with environmental and public health standards, using the findings of this study as a foundation for sustainable solid waste management planning.

5.2. Recommendations

In light of the findings from this study, several key recommendations are proposed to improve the solid waste management system in Chole Town. First and foremost, the local government and relevant stakeholders should prioritize the development and implementation of an integrated solid waste management plan that is informed by both spatial and socio-economic data. Strengthening institutional capacity is crucial this includes establishing a dedicated waste management unit with trained personnel, clear operational guidelines, and adequate budget allocation. Investment in waste management infrastructure, such as waste collection vehicles, storage facilities, and designated disposal sites, is also necessary to enhance service coverage and efficiency.

Based on the spatial suitability analysis, it is recommended that landfill development should focus on the identified highly suitable and moderately suitable areas, as these pose the least risk to public health and the environment while offering cost-effective, long-term solutions.

Careful site selection, incorporating environmental protection measures such as proper lining and leachate management systems, should be enforced to ensure that moderately suitable areas are used responsibly. The use of GIS and multi-criteria decision-making tools like AHP should be institutionalized in future urban planning processes, enabling evidence-based decision-making for waste management and other land use planning efforts.

Furthermore, public awareness campaigns should be conducted to educate residents about the importance of proper waste disposal, recycling, and the environmental and health impacts of unmanaged waste.

Community involvement and collaboration with local organizations can significantly enhance the effectiveness and sustainability of waste management initiatives. The chosen landfill site is designated exclusively for non-hazardous solid waste; therefore, hazardous waste should not be disposed of at this location.

- ❖ Hazardous materials from industries, healthcare facilities, and households must be segregated from non-hazardous waste prior to disposal.
- ❖ A separate landfill should be identified for hazardous waste, as the siting criteria and construction requirements for such landfills differ significantly from those for non-hazardous waste disposal.
- ❖ Lastly, regular monitoring and evaluation mechanisms should be established to assess the performance of the system and ensure that solid waste management practices align with environmental standards and the town's long-term development goals.
- ❖ These recommendations, if implemented effectively, will contribute to a cleaner, healthier, and more sustainable urban environment in Chole Town.

REFERENCES

ADEFRIS, A. (2015). Evaluation of Solid Wate Landfill Potential Site Using Gis Based Multi Criteria Evaluation Method: a Case Study of Addis Ababa.

Anberber, A. (2021). Factors Affecting the Performance of Solid Waste Management Practice in Case of Addis Ababa ; Some Selected Sub-City. September.

Assessment of Solid Waste Management Systems in Developing Countries. Waste

Babalola, A., & Busu, I. (2011). Selection of Landfill Sites for Solid Waste Treatment in Damaturu Town-Using GIS Techniques. Journal of Environmental Protection, 02(01), 1–10. https://doi.org/10.4236/jep.2011.21001

Chandel, A. S., Weto, A. E., & Bekele, D. (2024). Geospatial technology for selecting suitable sites for solid waste disposal: a case study of Shone town, central Ethiopia. Urban, Planning and Transport Research, 12(1). https://doi.org/10.1080/21650020.2024.2302531

Chopra, M., Reinhart, D., Vajirkar, M., & Koodhathinkal, B. (2006). Stability of slopes of municipal solid waste landfills with co-disposal of biosolids. WIT Transactions on Ecology and the Environment, 89, 215–222. https://doi.org/10.2495/GEO060221

Dadi, D., Stellmacher, T., Senbeta, F., Van Passel, S., & Azadi, H. (2017). Environmental and health impacts of effluents from textile industries in Ethiopia: the case of Gelan and Dukem, Oromia Regional State. Environmental Monitoring and Assessment, 189(1), 1–30. https://doi.org/10.1007/s10661-016-5694-4

Desta, H. (2022). An overview of solid waste management systems in the city administration of Addis Ababa : past to present. LSE Cities, 01(May), 1–29. https://www.lse.ac.uk/Cities/Assets/Documents/RRR/RRR-field-report-01-Addis-Ababa.pdf

Ghosh, S. K., & Ghosh, S. (2018). Circular Economy and the Role of Reuse in Solid Waste Management. Environmental Progress & Sustainable Energy, 37(6), 1972–1980. https://doi.org/10.1002/ep.12953

Kareem, S., Al-Mamoori, S. K., Al-Maliki, L. A., Al-Dulaimi, M. Q., & Al-Ansari, N. (2021). Optimum location for landfills landfill site selection using GIS technique:

Al-Naja city as a case study. Cogent Engineering, 8(1). https://doi.org/10.1080/23311916.2020.1863171

Kebede, Y. S., Alene, M. M., & Endalemaw, N. T. (2021). Urban landfill investigation for managing the negative impact of solid waste on environment using geospatial technique. A case study of Assosa town, Ethiopia. Environmental Challenges, 4(March), 100103. https://doi.org/10.1016/j.envc.2021.100103

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Krause and T. G. Townsend, (2014.) Rapid Waste Composition Studies for the

Lamessa Kenate. (2017). Suitability Analysis of Solid Waste Disposal Site using GIS Techniques for Sululta Town : Oromia Special Zone Surrounding Finfinne , Oromia , Ethiopia BY LAMESSA KENATE A Project Submitted to the Department of Geography and Environmental Studies Presented.

Memon, M.A. (2010); Integrated solid waste management based on the 3R approach.

Material Cycles and Waste Management, 2010. 12: p. 30-40.

Molla, M. B. (2024). Potential landfill site selection for solid waste disposal using GIS-based multi-criteria decision analysis (MCDA) in Yirgalem Town, Ethiopia. Cogent Engineering, 11(1). https://doi.org/10.1080/23311916.2023.2297486

Piyali Bhowmick, S. Das. (2024). Identification of suitable sites for municipal waste dumping and disposal using multi-criteria decision-making technique and spatial technology: A case of Bolpur municipality, Birbhum district, West Bengal (pp. 250–265). https://doi.org/10.1016/j.wmb.2024.02.001

Resources, 4(2): p.1-6.

Sadessa, Z. H., & Balo, H. T. (2025). Municipal solid waste management strategy selection: Multi-criteria decision making under uncertainty. Journal of Future Sustainability, May 2024, 91–106. https://doi.org/10.5267/j.jfs.2025.4.001

Town, K. (2021). Suitability Solid waste dumping site selection using GIS based Multi-criteria decision analysis and evaluation for.

UNEP. (2015). Global Waste Management Outlook. Nairobi: United Nations Environment Programme. https://www.unep.org/resources/report/global-waste-management-outlook

Wilson, D. C., Velis, C., & Cheeseman, C. (2012). Role of informal sector recycling in waste management in developing countries. Habitat International, 30(4), 797–808. https://doi.org/10.1016/j.habitatint.2011.03.003

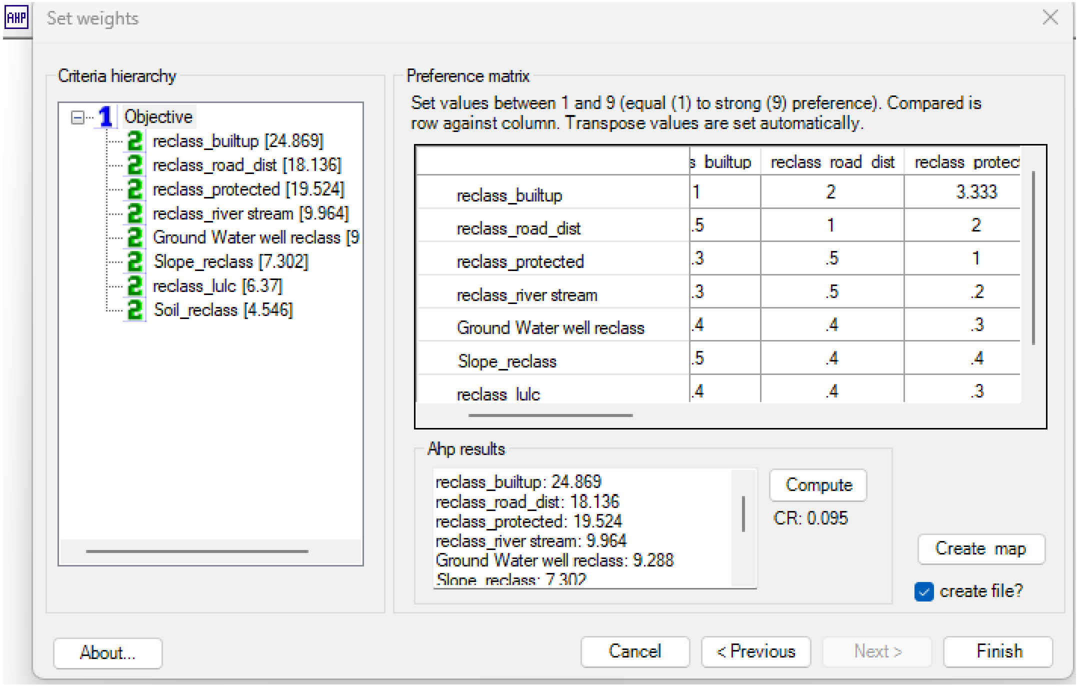
Zemena, G. (2016). Solid Waste Management Practice and Factors Influencing its Effectiveness: The Case of Selected Private Waste Collecting Companies in Addis Ababa. Proceedings of the 8th Multi-Disciplinary Seminar, 133–150.

Zurbrugg, C., Gfrerer, M., Ashadi, H., Brenner, W., & Kühr, R. (2012). Determinants of sustainability in solid waste management – The Gianyar Waste Recovery Project in Indonesia. Waste Management, 32(11), 2126–2133. https://doi.org/10.1016/j.wasman.2012.03.014

APPENDEX

chole restricted area	latitude	Longitude
chole tvet	8.149825912	39.9034227
healthy center	8.148736362	39.90171757
Church kidanemret	8.147182408	39.90152811
kidane,mehric	8.14183842	39.90110708
Chole kedane mhiret ortodox church	8.141902144	39.9022658
Masjidal Nur	8.136506796	39.90228726
Mosque(HK)	8.134364868	39.90156698
cholekidist arsema Church	8.132341969	39.90703937
CHOLE 1APOSTOLIC CHURCH	8.135195813	39.90441447
kidanemiheret orthodox church	8.147725225	39.90323591
Chole kedane mhiret ortodox church	8.14188663	39.90389386
Almesjidutekwa mosque	8.13659958	39.91418106
Chole Primary School	8.144588187	39.90343059
CHOLE 1APOSTOLIC CHURCH	8.13540082	39.90570888
Chole zurya middle school	8.144186246	39.89961811
Chole ground water well	599648	899487.9
Chole ground water well	599652	899448.2
Chole ground water well	599411.4	899238.9
Chole ground water well	599423.1	899241.6

AHP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reclass_river stream [9.964]
Ground Water well reclass [9
Slope_reclass [7.302]
reclass_lulc [6.37]
Soil_reclass [4.546]
Preference matrix
Set values between 1 and 9 (equal (1) to strong (9) preference). Compared is row against column. Transpose values are set automatically.
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Ground Water well reclass .4 .4 .3
Slope_reclass .5 .4 .4
reclass lulc .4 .4 .3
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Ground Water well reclass: 9.288
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CR: 0.095
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Next >
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QUESTIONNAIRE AND INTERVIEW ON RESEARCH ENTITLED ENHANCING THE CURRENT SOLID WASTE MANAGEMENT SYSTEM USING GEOSPATIAL TECNOLOGY: A CASE OF CHOLE TOWN; OROMIA REGIOANAL STATE, ETHIOPIA.

By EYOB FURNO

structured questionnaire designed to gather information on the main factors influencing solid waste management in a town. It includes a mix of closed and open-ended questions that can be used for surveys or interviews with town residents, officials, and stakeholders involved in waste management in chole town.

Dear Respondents

(Please answer all questions and circle your choise/fill/tick where applicable)

SECTION 1: DEMOGRAPHIC INFORMATION OF RESPONDENTS (SOCIOECONOMIC FACTORS)

1. What is your age group?
   - Under 20___ 21-30___ 31-45___ 46-60____ Over 60____
2. What is your occupation?
   - Student____ Professional____ Business Owner___ Government Employee____ Other (Please specify) ___________
3. What is your average monthly household income?
   - Less than 1000_____ 1000-2000_____ 2001-5000_____ 5001-10000_____ Over 10,000____
4. How would you describe your level of education?
   - No formal education
   - Primary/Secondary School
   - Undergraduate
   - Postgraduate
5. How do you prioritize environmental concerns in your daily life?
   - High priority
   - Moderate priority
   - Low priority

- Not a priority

6. In your opinion, how does the local economy influence the amount of waste generated in your area?
   - Strong influence (more waste due to high consumption)
   - Moderate influence
   - Minimal influence
   - No influence

SECTION 2: PRACTICAL AND INFRASTRUCTURAL FACTORS

1. How would you rate the effectiveness of the waste collection services in your town?
   - Very effective___ Somewhat effective___ Not effective___ Not sure___
2. How do you dispose of your waste?
   - Regular municipal collection
   - Private waste collection services
   - Composting
   - Recycling bins
   - Other (Please specify)
3. How frequently is waste collected in your area?
   - Daily
   - 2-3 times a week
   - Weekly
   - Bi-weekly
   - Less frequently
4. Are there sufficient waste disposal points (e.g., bins, containers) available in public areas?
   - Yes_____ No________ Sometimes______
5. How would you rate the condition of the town's waste management infrastructure (e.g., vehicles, bins, landfill sites)?
   - Excellent____ Good____ Fair_____ Poor_____

SECTION 3: INSTITUTIONAL AND LEGAL FACTORS

6. Do you think the local government has sufficient policies in place to manage waste effectively?
   - Yes_____ No________ Not sure______

7. Are there any laws or regulations in your town that require waste segregation, recycling, or disposal in specific ways?
   - Yes_____ No________ Sometimes______

8. Is the local government or municipality active in educating the public about waste management practices?
   - Yes_____ No________ Sometimes______

9. What are the main challenges in waste management in your town? (Check all that apply)
   - Lack of public awareness
   - Insufficient waste collection services
   - Poor waste segregation
   - Inadequate recycling facilities
   - Landfill or disposal issues
   - Environmental impact concerns
   - Other (Please specify)

SECTION 4: ENVIRONMENTAL AND GEOGRAPHICAL FACTORS

10. How concerned are you about the environmental impact of waste in your town (e.g., pollution, landfill overflow)?
    - Very concerned ___ Somewhat concerned____ Not concerned ___Not sure___

11. How would you rate the town's efforts to protect the environment in terms of waste management?
    - Excellent_____ Good_____ Fair_____ Poor_____

12. Do you believe the town's geographical layout (e.g., urban vs. rural, availability of space) influences waste management practices?
    - Yes_____ No________ Sometimes______

13. What do you think are the biggest challenges your town faces in managing solid waste?

____.

____

____

14. What suggestions would you offer to improve the solid waste management system in your town?

____.

____

____.

Comments and suggestions:

____

____

____

____

____

Thanks

Getachew Brhanemeskel

Eyob 21

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Adama Science and Technology University

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