JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIROMENTAL ENGINEERING

ENVIROMENTAL ENGINEERING CHAIR

SUITABLE LANDFILL SITE SELECTION USING GEOGRAPHIC INFORMETIOAN SYSTEM AND REMOTE SENSING FOR SOLID WASTE DISPOSAL IN CASE OF SHAMBU TOWN, HORRO GUDURU WOLLEGA ZONE, WESTERN OROMIA, ETHIOPIA

BY

KETEMA DABA DURESA

A Research Thesis Submitted to Environmental Engineering chair, Faculty of Civil and Environmental Engineering, Jimmaa Institute of Technology, in Partial Fulfillment of the requirements for Masters of Science (M.Sc.) in Environmental Engineering

JULY, 2022

JIMMA, OROMIA, ETHIOPIA

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Main Advisor: Dr.Yenealem Mehari (PhD)

Co-advisor: Mr. Million Ebba (MSc)

July, 2022

Jimma, Oromia, Ethiopia

DECLARATION

I declare that this Thesis entitled "Suitable landfill site selection using GIS and RS for solid waste disposal in case of Shambu town, Horro Guduru Wollega zone, Western Oromia, Ethiopia" is my original work and all references used are acknowledged. It also has never been presented in any university for partial fulfillment of any degree, diploma or certificate.

Ketema Daba ______________ _____/____/_____

Name of the student Signature Date

We the under signed supervisor agreed this thesis to be submitted for examination.

Main Advisor: Dr. Yenealem Mehari (PhD) ______________ _____/____/_____

Name Signature Date

Co-Adviser: Mr. Million Ebba (MSc) ______________ _____/____/_____

Name Signature Date

DEDICATION

This Thesis is dedicated to my older brother Diriba Daba Duresa and my wife Gebayinesh Daba Kitila who stood beside me, supported and encouraged me to accomplish this Thesis.

ACKNOWLEDGEMENTS

First and foremost I would like to thank to the Almighty God for all the things he has done for me.

Second I would like to thank my main advisor Dr. Yenealem Mehari for her interesting comments during my Thesis work**.**

Third, I would like to thank heartily my co-adviser Million Ebba for his critical support and interesting comments.

I would also like to express my appreciation to the land administration of Horo Buluk and Horo Buluk administration for allowing me to continue my MSc. in Jimma University.

Last but not least, I am grateful for my wife, parents, brothers and sisters for their spiritually and financial support during the study period.

ABSTRACT

The selection of a suitable landfill site is considered as a complicated task because the whole process is based on many factors and restrictions. The management of collection and disposal site of solid waste existing in shambu town is done through open dumping of waste and the poor quality of the collection process which does not conform to the scientific and environmental criteria applied in the selection of landfill sites. So this study aims to presents landfill suitable site selection for solid waste disposal by using geographic information system and remote sensing with multi-criteria decision analysis. Geographical information system has a large capacity for managing input data and easy to analysis suitability of landfill site. Geographical information system combinations with the Analytical hierarchy process and Multi-Criteria Decision Analysis method were used to derive the relative weighting overlay for each criterion using pairwise comparison. For this study, 5(five) dominant factors were adopted (Geology, soil types, land use land cover, slope and roads) to minimize the negative impacts of landfills in order to find appropriate site for solid waste dumping. Based up on these factors the results have shown that four sites were suggested as highly suitable for solid waste disposal. These sites were site1, site2, site3 and site4 which were found in North, North West, East and South part of 01 and 02 kebele of shambu town. Those sites were easy to access and manage for disposal of solid wastes.

Keywords: *Analytical hierarchy process, Geographical information system and Remote sensing, Landfill, Solid Waste, Multi-Criteria Decision Analysis and Weight Overlay.*

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ACRONMYS

AHP---Analytical Hierarchy Approach

CL--Confidence Level

CSA---Central Statistics Agency

DEM---Digital Elevation Model

DGC---Department Graduate Council

EMA --Ethiopian Mapping Agency

EPA---Environmental Protection Agency

ERDAS--Earth Resource Data Analysis System

FAO---Food Agricultural Organization

GES---Geological Ethiopian Survey

GIS---Geographical Information System

GPS---Global Positioning System

LF--Land Fill

MCDA---Multi-Criteria Decision Analysis

MSW---Municipal Solid Waste

RS--Remote Sensing

SMCE---Spatial Multi-Criteria Evaluation

SRTM--Shuttle Radar Topography Mission

SWM---Solid Waste Management

SSWM---Sustainable Solid Waste Management

SSW--Sustainable Solid Waste

SW--Solid Waste

SWG--Sustainable Waste Generation

U.S--United State

USGS--United State Geographical Survey

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Global rise of population and the consecutive unsustainable practices have caused an enormous increase in the quantity of the generated solid wastes(Alexakis & Sarris, 2014). Solid waste can be classified according to its origin (domestic, industrial, commercial, institutional and construction), according to its potential hazard (toxic, non-toxic, radioactive, flammable and infectious), as well as according to solid waste contents (organic material, glass, metal and plastic paper) (Mehta, 2014). Increasing affluence, improving standards of living, increasing rates of population growth and together with increasing levels of commercial activities in urban areas around the shambu town, are the main reasons for a significant increase in quantities of waste production.

Solid waste disposing is an important part of waste management system, which requires much attention to avoid environmental pollution and health problems (Moeinaddini *et al.,* 2010). Improper solid waste management causes air, soil and water pollution. Solid wastes indiscriminately thrown resulted also in aesthetic problems, nuisance, and pollution of land and water bodies of an area (Hammer, 2003). Management of MSW involves several processes, including reducing quantities of waste, reusing, recycling and recovering energy, as well as the incineration and disposal of waste in landfills (Moeinaddini *et al*., 2010).More effective disposal of solid waste is necessary; even in countries that burn or recycle a large share of their waste and therefore treatment of ashes resulting from burning solid waste remains an issue (Brockerhoff, 2000; Proske *et al*., 2005). The current global trends of waste management problems are the results of unsustainable methods of waste disposal, which is ultimately a result of inadequate planning and implementation (Abbas *et al*., 2011).

The process of a suitable site selection for landfill is considered to be one of the most difficult tasks related to solid waste management systems because it is subject to government regulation, government and municipal funding, increasing population densities, growing environmental awareness, public health concerns, reduced land availability for landfills and increasing political and social opposition to the establishment of landfill sites (Lin and Kao, 1999). Selecting an ideal site for solid waste dumping in a community like Shambu, with limited financial resources and a rapid population growth rate, is more difficult. Identifying landfill sites is a complex process where many factors need to be taken into consideration. Examples of such factors include social and environmental factors, geomorphologic features and technical parameters. Economic factors, which include the cost of acquiring land as well as development and operation costs, owing to the distance from waste production centers and distance from main access roads, are also an important factor (Wang *et al.*, 2009). Waste disposal sites must preserve the biophysical environment and ecology in the surrounding area (Siddiqui *et al*., 1996).

In Ethiopia people are using unsafe solid waste disposal practices, such as open damping, burning and burying. The significant manifestation of inappropriate disposal of solid waste can be contamination of surface and ground water through leaching, soil contamination through direct waste contact, air pollution by burning of waste, spreading of diseases by different vectors like birds, insects and rodents, or uncontrolled release of methane by anaerobic decomposition of waste (Visvanathan and Glawe, 2006). According to Degnet (2008), stated that, like in many other developing countries, the majority of inhabitants in most towns of Ethiopia often use unsafe solid waste disposal practices, such as open dumping, burning and burying. As a result, many households practice uncontrolled open dumping and others employ various households solid waste disposal practices such as burning. However, all self-managed waste disposal practices do not guarantee cleanness and safety. Therefore, locating proper sites for solid waste disposal far from residential areas, environmental resources and settlement is the main issue for the management of solid waste.

Strong squander transfer to landfills could be a significant angle of the squander administration framework, and it requires an extraordinary bargain of care to excuse damage and safety issues. As a result, the essential concern for strong squander administration is choosing fitting destinations for strong squander transfer and selecting fitting landfill destinations absent from private regions, natural assets, and settlement.

Since there are modern, coordinates instruments accessible to handle the issue of dump location choice, the thoughts of topographical data frameworks GIS and a spatial multi-criteria choice examination ought to be connected in landfill siting inquire about. The integrated use of GIS and MCE methodology has been extensively implemented to assess the suitability of an area to host a landfill site (Hatzichristos and Giaoutzi 2006; Delgado et al. 2008;Akbari *et al*., 2008; Sharifietal, 2009; Tavares *et al*. 2011; Nas *et al*., 2008). A MCE methodology can be applied to categorize, analyze and conveniently arrange all available information concerning choice alternatives in landfill site planning. AHP may be a multi-criteria choice making approach and was created by Thomas Saaty in 1980 to bind together these multi-criteria within the prepare of making choice. This methodology can be utilized to address complicated choice issues as well as a decision-making help. It uses a multi-level hierarchical structure of objective criteria and sub-criteria (Eldrandly *et al*., 2009). In landfill siting, GIS is crucial. GIS allows data from a number of sources to be displayed and managed efficiently, saving time and money during the siting process (Kontos *et al*., 2003). GIS may also be used for identifying routes for transporting waste to transfer stations and then to a landfill site and vice versa (Kontos *et al*., 2003; Delgado *et al*., 2008 and Moeinaddini *et al*., 2010).

Geographic Information System and Remote Sensing are computerized systems that can be integrated to get optimal solutions for efficient and effective solid waste management planning. On the one hand, GIS is a system that helps to capture, store, analyze, manage, and present data that are linked to locations. It is the merging of computer aided design/drafting (CAD) systems, statistical analysis tools, and database technology that help informed decision making. It is a tool that allows users to analyze spatial information, edit data, maps, and present the results of any spatial and non- spatial based analysis (MohammedShum, 2014).

1.2 Statement of the Problem

There's no fitting landfill location for strong squander transfer, collection, exchange administrations and no deny dumping holders for feasible strong squander administration frameworks in shambu town (Individual Perception and Nearby Community Meet). This causes transfer of household strong squanders along the street side, on open spaces, in ranch destinations, around the burial destinations, around water banks and inside channels (street canals). Issues related with dishonorable residential solid waste administration within the study area incorporates: issue to squander collecting specialists(foragers), location for breeding of infection causing micro-organisms and creepy crawly vectors which are risk for open wellbeing, contaminate the adjacent water bodies by flooding which comes about water borne maladies, diminished the magnificence of the encompassing environment and so have negative effect on the fascination of venture and expanded rate of climate alter by uncontrolled burning and anaerobic decay of natural squanders which produces carbon dioxide.

In Ethiopia, for some towns, researchers have conducted studies on land fill sites selection using GIS and remote sensing. For example, Tirusew Ayisheshim and Amare Sewnet by 2013, Kumel Beshir by 2014 and Tsegaye Mekuria by 2006 have conducted studies on land fill sites selection using GIS and remote sensing for Bahir Dar, Wolkite and Addis Ababa respectively. In the study area, there were also some studies about assessment of domestic solid waste composition and generation rate which was not selection of suitable solid waste disposal site. That is why this study is planned to use the integrated GIS and remote sensing techniques to select suitable solid waste disposal sites. The selection of suitable solid waste disposal sites using GIS and remote sensing requires many factors that should be integrated into one system for proper analysis. This is because remote sensing can provide information about the various spatial criteria such as land use/land cover, drainage density, slope, lithology whereas GIS aids utilizing and creating the digital geo-database as a spatial clustering process and easily understood ways for solid waste dumping site selection process. In this study the selection criteria include the dominant factors like slope, soil type, geology, land use/cover and road.

1.3 Objectives of the Research

1.3.1 General Objective

The main objective of this study is to select suitable landfill site using GIS and RS for solid waste disposal which is environmentally acceptable in shambu town.

1.3.2 Specific Objectives

- ✓ To asses existing solid waste disposal system in the study area;
- ✓ To identify dominant factors for suitable landfill site;
- ✓ To evaluate suitable landfill sites using GIS with MCDA and
- ✓ To produce map showing suitable landfill sites using GIS and RS.

1.4 Research Questions

1. What does the present solid waste disposal system of the study area looks like?
2. What are the dominant factors that should be identified to select suitable solid waste disposal site?
3. How would the suitable landfill site be evaluated?
4. How can the suitable waste disposal sites be mapped?

1.5 Significance of the Study

This study is expected to select and map suitable solid waste disposal sites to protect the environmental safety of shambu town. Since unsuitable solid waste disposal sites affect the social and economic activities of communities as well as the health of resources of the study area, like water, the final result of this study will help the town to solve the problems. In addition, the study is also expected to give an insight about the application of GIS and Remote Sensing technologies for the selection of suitable solid waste disposal sites.

This study also provides sustainable solid waste management by landfill suitable site selection to monitor environmental hazardous, to assess the source of solid waste, to minimize disposal of domestic solid wastes along the road side, on open spaces, in plantation sites, around the burial sites, around water banks and within drains (road canals) in shambu town. By suitable landfill site selection and by applying awareness to the society it is possible to manage any solid waste to make comfort the surrounding for coming generation and good current environment.

1.6 Scope of the study

This study is aimed to carry out Suitable landfill site selection for solid waste disposal by using GIS and RS software with MCDA at Shambu town. This also recommends, to use proper landfill site for solid waste management strategies in the study area. It focuses on some technical aspects of solid waste disposal site selection. The issue under consideration in this study is only landfill suitability site selection for solid waste management. The study was not included sanitary wastes area, engineering and design part of the construction.

1.7 Limitation of the study

Budget is one of the crucial inputs for research work. In this study because of budget was not paid for self-sponsor it was difficult for transportation and to buy materials required for this thesis.

Another challenge to do this thesis was problem of peace in study area which restricts to move freely for visual and field observation to collect the data.

1.8 Organization of the Thesis

This Thesis has five chapters. Chapter one is an introduction part which consists of the back ground, statement of the problem, the objectives, research questions, significance, scope of the study, limitations and the organization of the study. Chapter two deals with review of related literature obtained from various published and unpublished reference materials. Chapter three describes the study area and the research methodology. Chapter four contains the analysis, results and discussion parts of the study and the fifth chapter presents the conclusion and recommendations of the study.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 General Concept and Definition of Solid Waste

Solid waste means any garbage, refuse, sludge, and other discarded solid materials, including solid waste materials resulting from industrial, commercial, and agricultural operations, and from community activities, but does not include dissolved material in domestic sewage (Tchobanoglous *et al*., 1977). Similarly, according to Sasikumar and Krishna (2009), Solid waste is used to describe non-liquid materials from domestic, trade, commercial, agricultural and industrial activities, and from public services.

A substantial increase in volume of wastes generation began in the sixteenth century when people began to move from rural areas to cities as a result of industrial revolution (Wilson, 2007). The dense population of towns and communities resulted in widespread trash and open landfills. These dumps became breeding grounds for rats and other vermin, posing serious health dangers to the people. The unhealthy waste management practices resulted in several outbreaks of epidemics with high death tolls (Tchobanoglous *et al.,* 1993)**.**

A chemical that one person considers a waste could be a valuable resource for someone else. Therefore, a material can only be regarded as a waste when the owner labels it as such (Dijkema *et al.,* 2000). Despite the subjective nature of wastes, it is critical to define exactly waste. This is because the classification of a material as a waste will form the foundation for the regulations required to safeguard the populace and the environment where the wastes are being processed (Defra, 2009)**.**

Numerous investigaters have utilized multi objective techniques to analyze the area of the squander plant. Utility areas models have too been routinely utilized to find SW landfill locales in arrange to diminish open and biological system presentation. The distinguishing proof of the landfill location utilizing GIS and farther detecting is more viable and productive than conventional strategies. A number of GIS-based strategies for ideal landfill location determination have too been displayed. Some methods for landfill sites integrate MCDA with GIS (Mallick *et al*., 2021)**.**

According to Mallick *et al*., (2021) Multi-Criteria Decision Analysis assists decision-makers rank a set of alternatives by contrasting them with other variables based on how they work with each criterion. Various thematic layers will be utilized for choice of landfill location. This think about covers the investigation of arrive utilize arrive covers, the slant reasonableness, geography, soil sort and road-accessible ranges. The key objective of deciding the best location for landfill sites is to reduce negative environmental, ecological, and economic impact (Mallick *et al*., 2021)**.**

2.2 Quantities of Generated Waste

Numerous analysts' completely different countries have archived the current state of strong squander administration, waste amounts, and strong squander era rates within the writing. The Comprehensive Scope Evaluation Report (2010) states that the total generated waste in Multan/Pakistan was 611 tons/day, and the generation rate of all waste was 0.41 kg/ (capita. day). Annepu (2012), studied the actuality of the solid waste in 366 of India's cities, which represented 70% of urban population in India.

In USA, the Center for Sustainable Systems (2015) found that the annual generation rates of municipal solid waste were 4.40 kg/ (capita. day) in 2013, whilst the total generation quantity of municipal solid waste in 2013 was 254.1 million tons.

According to Hofosha, (2018) study showed that an average of household generates 0.148Kg/cap/day and by taking the total population of the study area in to account, the annual household solid waste generation rate of the town was estimated to be 4296.05 tons in shambu town which is abundantly disposed to unnecessary place like along road side, biuret area, recreational place, and in canal of ditch.

2.3 Solid Waste Management system

Human interactions with the environment (human activities) have always resulted in waste production. However, Giusti (2009) reported that waste production and management was not a major issue until people began living together in communities. Vergara & Tchobanoglous (2012), reported that as population and purchasing power of people increases worldwide, more goods are produced to meet increasing demand, thereby leading to the production of more waste. According to Marchettini et *al.,* (2007) pointed out that, these continuous flows of waste resulting from human activities, overburdened the environment. Indeed in spite of the fact that, people are incomprehensible to live without collaboration with their environment, it is conceivable to oversee strong squander created from human action by arranging squander in to landfill location.

SWM may be defined as that discipline associated with the control of generation, storage, collection, transfer and transport, processing and recovery, and final disposal of solid wastes in a manner that is in accordance with the best principles of public health, economics, engineering, urban and regional planning, conservation, aesthetics, and other environmental considerations which are also responsive to public attitudes (Jaya, 2004).

The goals of MSWM are to generate employment and income promotes the quality of the urban environment, and protects environmental health and support the efficiency and productivity of the economy (Ogwueleka, 2009). Strong Squander administration includes a wide extend of individuals support to assist keep a clean, secure and pleasant physical environment in human settlements.

2.3.1 Solid waste management in developed countries

Developed countries have serious environmental challenges about solid waste management because of fast urban development. The growing of population number and improved standard of living in cities and urban areas has led to the generation of varied categories of wastes (Sciences, 2016). Shortage of land for waste disposal and inappropriate landfill site is one of the biggest problems in most of large urban areas in the world which has its negative impact on human, and environment (Mcfaden 2003). Therefore, more efforts are needed to overcome this problem that leads different agencies and establishments to find common limitations to protect human and environment from these consequences (Berisa & Birhanu, 2015).

2.3.2 Solid waste management in developing countries

Created nations have genuine natural challenges approximately strong squander administration since of quick urban advancement. The developing of populace number and progressed standard of living in cities and urban zones has driven to the era of changed categories of squanders. Because of urbanization, population growth, industrialization, and economic growth, a trend of increase in municipal solid waste generation has been recorded worldwide in major cities (Punjab Pollution Control Board, 2007).

As such, Solid waste management is becoming a big challenge for the cities administrations in many developing countries mainly because of the degree of rapid urbanization and increasing number of population growth which in turn have greatly accelerated the municipal solid waste generation rate in the urban environment (Zhang *et al.*, 2010; Guerrero *et al.*, 2013). Squander era has been rising with expanding riches and financial development. In developing countries, the waste generation is rising rapidly and may keep increasing in quantum as a consequence of improvement in standard of living, economic activities and population growth (Un-habitat, 2010b).

Because of, lack of waste disposal and inappropriate landfill site are one of the biggest problems in most of large urban areas in the world which has its negative impact on human and environment (Mcfaden, 2003). In most urban centers of developing countries, municipal solid waste management (MSWM) is highly unsatisfactory and beyond the capabilities of their economic setup for handling and disposal (Henry *et al*., 2006; WHO, 1996; and World Bank, 1999). Municipalities in developing countries spend 20-50% of their budget on SWM, which cover less than 50% of the total population (Henry *et al*., 2006).

Too, in a few African nations, one to two thirds of the strong squander produced isn’t collected. Since of this uncollected squander, usually end up within the encompassing environment or seepage or open dump. They are confronted with many aspects of problems such as, inadequate service coverage and operational inefficiencies of services, limited utilization of recycling activities and inadequate landfill disposals (Un-habitat, 2010b).

2.3.3 Solid waste management in Ethiopia

Ethiopia currently faces waste management challenges related to over-accumulation on open land, water pollution, and overall public nuisances such as pests, diseases, and odors (Edwards, 2010). Municipal solid waste is any material discarded by the primary user in an urban area, contributes to about 70 percent of total waste generated in Ethiopia (Wakjira, 2007). In many cities of the country, waste management is poor and solid wastes are dumped along roadsides and into open areas, endangering health and attracting vermin (Tewodros *et al*., 2008). According to Environmental Protection Authority (2004), study conducted in per capita amount of waste generated in Ethiopia range from 0.17 to 0.48 kg/person/day for urban area to about 0.11 to 0.35 kg/capita/day for rural area.

According Brike (1999), random survey indicated that, large and medium urban areas of our country shown the status 86.6 percent used open dump to dispose waste, while the rest used holes. Most of the other urban ranges in Ethiopia are accepted to utilize open dump for transfer. Open dumps contaminate surface and ground water, soil and the normal environment as an entirety.

Therefore, Waste management in Ethiopia is important because only a small percentage of the country's inhabitants have access to safe drinking water: 21% in rural areas, 84% in urban areas, and 30% country-wide. Additionally, only 7% of populations in rural areas, 68% in urban areas, and 15% of people country-wide have adequate access to latrines or other improved human waste disposal options (Kuma, 2004).

2.3.4 Solid waste management in Shambu town

Within the past there was no any consideration to determine of reasonable location for landfill in shambu town. This causes improper solid waste disposal in the town.

According to Hofosha (2018), states that the absence of accessibility of household solid waste collection and transfer services, absence of communal dumping containers and insufficient and inappropriate placement of landfill site, discourage the inhabitants to dispose of domestic solid wastes along the road side, in the plantation sites, on open spaces around the residential sites, around burial area and within the road canals which have a major threat for public health and the surrounding environment.

2.4 Landfill

A landfill site, also known as a tip, dump, rubbish dump, garbage dump or dumping ground and historically as a midden, is a site for the disposal of waste materials by burial and is the oldest form of waste treatment. Historically, landfills have been the most common method of organized waste disposal and remain so in many places around the world.

Landfill is an environmentally acceptable disposal of waste on the ground. As Kumel (2014) notes, many developing countries do not have criteria for landfill site selections and some have regulations of developed countries without modifying to their local conditions. But taking regulations of developed countries without considering local conditions is a problem because the development of engineered landfills involves complex engineering design and construction techniques. These sophisticated engineered landfills can occur where the local economy can afford the high level of expenditure required for construction and operation of the landfill and where the technical resources to achieve high standards of construction and operation are made available. It is therefore important to ensure that when new landfills are sited, the construction and operational capabilities of the local communities are considered in developing sitting criteria so that environmental protection objectives can be met. As Laura (2003), noted, in addition to available financial and human resources, the com-position of the waste differs, and the climate of the area should be considered.

Landfill has been recognized as the cheapest form for the final disposal of municipal solid waste and as such has been the most used method in the world. However, sitting landfill is an extremely complex task mainly due to the fact that the identification and selection process involves many factors and strict regulations. For proper identification and selection of appropriate sites for landfills careful and systematic procedures need to be adopted and followed. Wrong sitting of landfill many result in environmental degradation and often time public opposition. The sitting of a solid waste landfill must also involve processing of a significant amount of spatial data, regulations and acceptance criteria, as well as an efficient correlation between them (Sumathi, 2007). GIS has been found to play a significant role in the domain of sitting of waste disposal sites. Many factors must be incorporated into landfill sitting decisions and GIS is ideal for this kind of studies due to its ability to manage large volumes of spatial data from a variety of sources (Debishree, 2014).

Land filling is a common solution for the final disposal of wastes in lower-income countries and a large majority of community's practice subsistence land filling or open dumping as their main meth-od of waste disposal. Recently, due to the growing urgency of urban environmental problems, solid waste management in lower income countries has attracted much attention and there is now a movement toward landfills designed to increase environmental protection (Tsegaye, 2006).

2.4.1 Landfill Sitting

Landfill sitting is difficult task to accomplish because the site selection process depends on different factors and regulations and also because it requires data from diverse social and environmental fields such as slope, soil type, land use land cover sensitive sites geology and road (Kabite *et al*., 2012). These data often involve processing of a significant amount of spatial information which can be used by GIS as an important tool for land use suitability analysis (Zeinhom *et al*., 2010).

Landfill sitting is becoming increasingly difficult due to growing environmental awareness, decreased amount of governmental and municipal funding with extreme political and social opposition. The increasing of population, public health concerns, and less land available for landfill construction adds more difficulties to the problem to overcome. Environmental factors are very important to be considered in such work due to the fact that landfill might affect the biophysical environment and the ecology of the surrounding area. Several techniques can be found for site selection of solid waste disposal. Such sitting techniques combine MCDA and GIS. The result of these techniques is the evaluation of the suitability for the entire study region based on suitability index, which is useful in order to make an initial ranking of the most suitable areas (Mohammad *et al*., 2014).

Landfill site selection in an urban area is a critical issue because of its enormous impact on the economy and the environmental health of the region and many sitting factors and criteria should be carefully organized and analyzed. The integration of GIS and AHP is a powerful tool to solve the landfill site selection problem, because GIS provides efficient manipulation and presentation of the data and AHP supplies consistent ranking of the potential landfill areas based on a variety of criteria (Debishree *et al*., 2014).

2.5 Application of Remote Sensing and Geographic Information System for Solid waste disposal site

According to Campell (1996), Remote Sensing is the practice of deriving information about the earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the earth's surface. On the other hand, Remote Sensing is a small or large-scale acquisition of information of an object or phenomenon, by the use of either recording or real time sensing device(s) that are wireless, or with no physical or intimate contact with the object (Lille *et al*., 2004). Its multispectral capability provides appropriate contrast between various natural features where as its repetitive coverage provides information on the dynamic changes taking place over the Earth surface and the natural environment (Adeofun *et al.*, 2011).

The part of inaccessible detecting is getting to be progressively visit in natural considers. At this time, no serious research of the environment performed without advanced image processing and analysis. One of the most important applications of remote sensing can be found in the case of solid waste landfill site selection where satellite images are used for extracting most of the site selection criteria used for sitting landfill (Oštir *et al.,* 2003) time and cost effectively. Moreover, remote sensing can provide digital data as an input for GIS.

GIS is a computer-based technology and methodology for collecting, processing, managing, analyzing, modeling, and presenting geographic (spatial) data for a wide range of applications (Eldrandaly *et al.*, 2003). The role of GIS in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data. In general, GIS plays a key role in maintaining account data to facilitate collection operations. In this manner, aspects such as customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial customers to transfer stations and from transfer stations to landfills; locating new landfills and monitoring the landfill, are important (Tomlison, 1990). The advantage of a GIS-based approach for sitting arises from the fact that it not only reduces time and cost of site selection, but also provides a digital data inventory for long-term monitoring of the site (Kontos *et al*, 2005). Application of it can help in determining the landfill location in accordance with the technical requirements, with overlay the thematic map to get an appropriate landfill (Akbari *et al.*, 2008).

The role of GIS in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data. In general, GIS plays a key role in maintaining account data to facilitate collection operations (Jamshidi *et al*., 2014). In this manner, aspects such as customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial customers to transfer stations and from transfer stations to landfills; locating new landfills and monitoring the landfill, are important. According to Barron (1995), GIS analysis of waste composition, degree of compaction and resulting density along with volumetric changes during land-filling, can ensure that the most efficient placement method is used and maximum capacity is achieved.

2.6 Multi-Criteria Decision Analysis for landfill site selection

Decision Analysis is a set of systematic procedures for analyzing complex decision problems. These procedures include dividing the decision problems into smaller more understandable parts; analyzing each part; and integrating the parts in a logical manner to produce a meaningful solution (Malczewski, 1999). The main objective of MCDA is the design of mathematical tools to support the subjective evaluation of a finite number of decision alternatives under a finite number of criteria in order to find the best choice (Pournamdarian, 2010). Multi criteria decision analysis techniques can be used to identify a single most preferred option, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities (Clemen, 1996).

Multi criteria decision analysis has undergone an impressive development during the last 30 years, in part because it is amenable to handling today's complex problems, in which the level of conflict between multiple evaluation axes is such that intuitive solutions are not satisfactory (Jamshidi *et al*., 2014). Multi criteria decision analysis isn't a tool giving the correct arrangement in a choice issue, since no such arrangement exists. The arrangement given may well be considered best as it were for the partners who given their values within the frame of weighting components, whereas other stakeholders values may demonstrate another elective arrangement. As a replacement for, it is an aid to decision-making that helps stakeholders organize available information, think on the consequences, explore their own requirements and tolerances and minimize the possibility for a post-decision disappointment (Belton and Stewart, 2002). Analytic Hierarchy Process is one of the most commonly used MCDA tools (Berisa & Birhanu, 2015). This tool is applied in site selection processes as it assists the decision making process by allowing decision-makers to organize the criteria and alternative solutions of a decision problem in a hierarchical decision model (Eldrandaly *et al*., 2005).

2.7 Site Selection Criteria for Landfills

The World Health Organization has a set of general criteria for selecting sites for landfill without determining buffer zones or distance from/around each criterion (Sloan, 1993). These criteria are soil profile and its characteristics, rechargeable ranges, normal assets, structure sort, memorable regions, social assets, characteristic dangers, and built-up ranges. The WHO prescribed that these criteria are considered basic and ought to be connected to make fulfillment, cooperation and endorsement among the populace.

The Environment Protection Authority (Australia EPA, 2016) based on (NSW Department of Urban Affairs and Planning, 1996) has set out restrictive criteria for landfill siting including the following:

- 250 m as buffer zones from landfill sites to "national parks, historic and heritage areas. Conservation areas, wilderness areas, wetlands, littoral rainforests, critical habitats, scenic areas, scientific areas and cultural areas".
- 1000 m as buffer zones from landfill sites to residential zones, schools and hospitals.
- Landfill sites should not located within "with substrata that are prone to land slip or subsidence".

- Landfill sites should not be located within "especially reserved drinking water catchments".

- Landfill sites should not situated within a way of major flood event.

European landfill selection regulations recommend that a landfill site must be situated on a site that does not pose a danger to the environment (Swedish Environmental Protection Agency Handbook, 2004).

The site boundary of a landfill should be located at suitable distances from residential and recreational areas, water bodies, waterways, other agricultural sites and urban sites.

- ✓ Avoid selecting a landfill site in areas of groundwater, coastal water and nature protection zones.
- ✓ Taking into account the geological and hydrogeological conditions of a landfill site area.
- ✓ Avoid selecting a landfill site in areas that are located within the risk of flooding, subsidence, landslides and avalanches.
- ✓ Avoid selecting a landfill site in areas that should be under protection (for natural or cultural heritage).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

Shambu is a capital town of Horo Guduru Wollega Zone of Oromia Regional State which is situated at 315 kilometers to the Northwest of Addis Ababa with a latitude and longitude of 9° 34' 00" N and 37° 6' 00" E (shambu municipality, 2018), respectively. According to shambu municipality (2018), the town was established in 1918 G.C. Administratively it is found in Zone One of the regional administration; and this Zone comprises of twelve woreda namely Horo, Horo Buluk, Jerdega Jerte, Amuru, Abe Dongoro, Jimma Ganati, Jimma Rare, Abbey Comman, Guduru, Ababo Guduru, Comman Guduru and Sulula Finhcha. As a zonal capital, the town has an administrative linkage with all the woredas of its zone. The total area of the study area is 503.52 ha (area calculation using GIS).

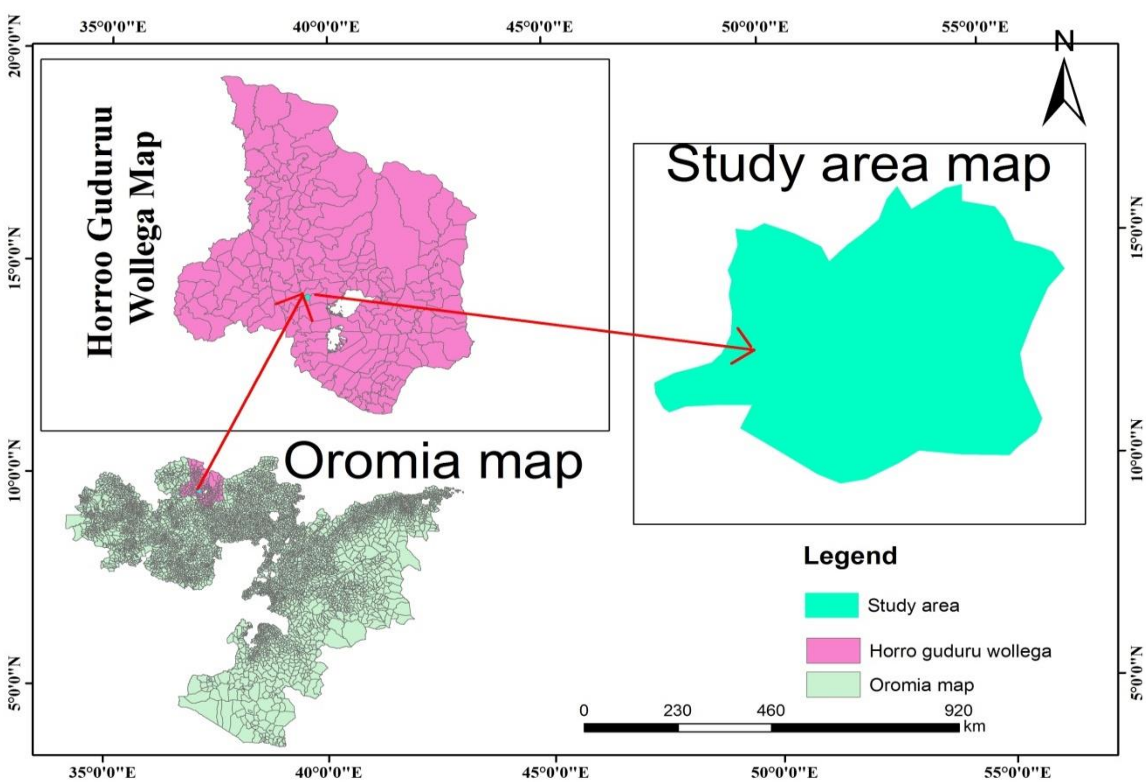

Figure 1. Locational map of the Study area

3.1.2 Climate

According to the data from (Shambu meteorological station, 2018),Shambu town receives an average annual rainfall ranging from 400mm to 2000 mm and an average annual temperature ranging from 15^{o}C to 27^{o}C **.** It has a subtropical high land climate with a unimodal rainfall ranging between 1200mm to 1800mm. The rainy season occurs from April to mid-October where maximum rain is received in months of June, July and August. Maximum temperature of 23-27C^{0} are reached from January to March, and minimum temperature of 7-15C^{0} are normal from October to November (CSA, 2006).

3.1.3. Population of the study area

It is key subject in carrying out any planning activity, having knowledge of population size of any urban center is very important. Based on this according to CSA (2007) the shambu town has a total population number of 38,584 by the year 2015 from which 20,303 are men and 18,281 women with an average family size of 4 persons per house. The average population growth rate of the region was taken for the predication of Shambu town population for the year 2025.

3.2. Sampling Method

The sampling method employed in this study would be Judgmental sampling method based on preference paid to where a lot amount of solid waste were generated area by highlight field observation during the sample collection time.

3.3. Sample Size Determination

A community based cross-sectional study was conducted on 77 sampled households to assess the collection, transportation and disposal of solid wastes produced by population of different socio-economic strata. Systematic and stratified random sampling techniques were used to select household samples from the targeted households, and to identify sampled residents with different socio economic strata. To calculate the number of samples of confidence level on solid waste data, the confidence level is usually set at 80% or 90%(UNEP, 2009).For determining the sample size of households a total of 340 targeted households were considered as a study site and the sample size of the households were determined by using sampling technique formula developed by Yemane (1973), with 90% confidence level and 10% margin error which helps to determine sample size with the degree of precision. The formula is as follows:

$$n = \frac{N}{1+N(e)^2} \qquad 3.1$$

Where n- sample size, N- Total numbers of households in the study site, e- Margin error.

3.4. Data Collection Methods

Data regarding quantity and generation rate of household solid wastes were collected from March 10, 2022 up to April 10, 2022 by administering structured questionnaires to sampled house premises called sample points, by door-to-door waste collection from the sample point (source) and by field survey observation. Data on waste generation were collected per day from each sampled household for seven consecutive days. Each sampled household was given plastic bags labeled with a corresponding house number to store the solid wastes generated per day. In the same way, other plastic bags with the label were given for each household for the next day collection and this process was continued until the last day of data collection for four weeks. Every morning the collected waste was brought to the selected working sites by trained waste sample collectors using hand push cart or horse cart. Finally the collected solid wastes were sorted out physically in to their categories, weighed and recorded.

3.5. Methods of Data Analysis

Data analysis of solid waste generation Per Household Per Day (PHPDSWGR) and Per Capita Per Day Solid Waste Generation Rate (PCPDSWGR) of the sampled households were done by using Statistical Package for Social Studies (SPSS) version 20 Microsoft Excel 2007.

$$\text{PHPDSWGR} = \frac{\text{Total solid waste generated in 7 days}}{\text{7 days X total number of sampled house holds}} \quad \text{---3.2}$$

$$\text{PCPDSWGR} = \frac{\text{Total solid waste generated in 7 days}}{\text{7 days X total family size of 77 sampled house holds}} \quad \text{---3.3}$$

3.6. Methods of suitable site selection

To evaluate study area for selection of a suitable site for landfill, the analytical hierarchy process (APH) together with GIS with its special analysis tools, were used to prepare maps layered according to determinant criteria. The main steps of landfill site, depending on current criteria, can be divided into the following figure 2.

- Selecting suitable criteria for the current study.
- Creating suitable dominant factor around important areas to suit each criterion map.
- Determination of the weights for the sub-criteria based on opinion of experts, environmental and scientific requirements and governmental regulations.
- Determination of the weights for the criteria using AHP model.
- Determination of a suitability index to produce the map of selected sites for landfill.

The following Chart shows that the flowchart of landfill site selection.

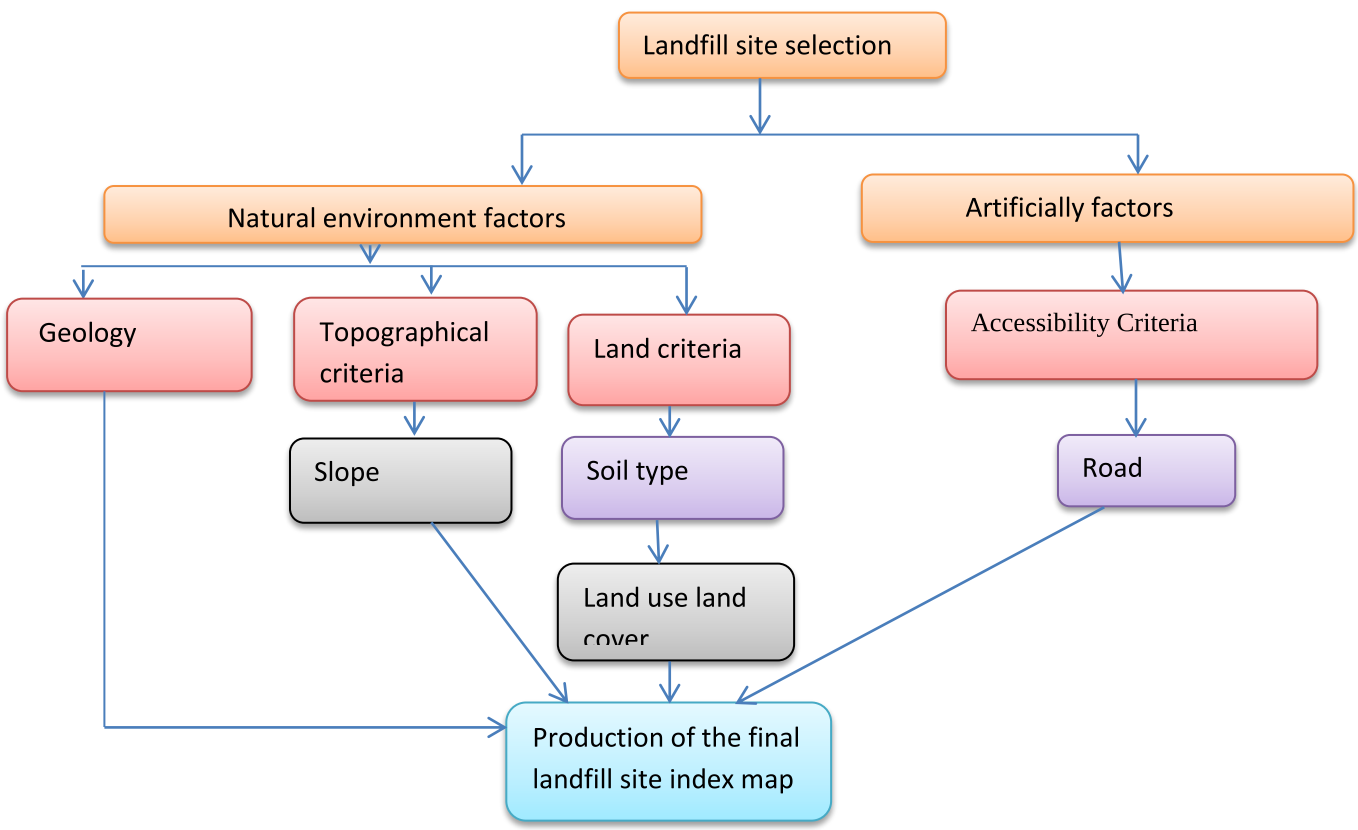

Figure 2. Flowchart of landfill site selection

3.7. Digitizing

This work of GIS is utilized to create highlights such as like soil surface lesson and Lithology were delivered from the soil outline and geologic outline.

3.8. Thematic map preparation

Topical maps are a critical source of GIS data. These are devices to communicate geological concepts within the frame of outline. The topical maps such as soil sort, Arrive utilize arrive cover, topography and street outline were arranged by utilizing digitization, overlay and buffer investigation with the suitable criteria. These thematic maps were used as an input for Analytical Hierarchy Process (sehnaz *et al.*, 2011).

3.9. Weighting criteria

Analytical Hierarchy Process was used as a decision rules to analyze the data for waste disposal site selection using GIS (sehnaz *et at*., 2011). Analytical Hierarchy Process consists of the construction of pair wise comparison matrices and the extraction of weights by means of the principal right eigenvector (Theo, 2010 and sehnaz, 2011). Pair wise comparison matrix is created by setting out one row and one column for each factor in the problem. Therefore, the AHP divides the decision problems based on the factors in to understandable parts; each of these parts is analyzed separately and integrated in a logical manner as suggested by Theo (2010). Analytical Hierarchy Process also facilitates sound decision making though applying both empirical data as well as subjective judgments of the decision maker. It assists to establish priorities among the elements within each stratum of the hierarchy. In AHP, the 9-point scale which is ranging from 1(indifference or equal importance) to 9 (extreme preference or absolute importance) was used in the decision making process for waste disposal site selection in shambu town. In reference to rating scale of 9, Theo (2010) also suggests a 9-point scaling system where, 1 for equal importance, 3 for moderate importance, 5 for strong, 7 for very strong and 9 for extreme importance, integers in between for refinements (2, 4, 6, 8), and reciprocals for the inverse judgments.

Table 1. Scale for pair wise comparison (Saaty, 1980).

Intensity of pair wise comparison	Definition
1	Equal Importance
2	Equal to Moderately Importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extremely importance

3.10. Weighted Index Overlay Analysis

Weighted Overlay could be a procedure for applying a common measurement scale of values to diverse inputs to make a coordinates investigation. The weight is given through subjective judgments by the choice producer. For this consider, utilizing weighted overlay examination of each input layer or components such as geography, arrive use/land cover, fundamental street, slant and soil sort maps, and appropriate location affectability list was arrived. In this prepare, Weight was relegated to diverse topical layers based on their noteworthiness in choosing the location reasonableness. Besides, weighted overlay investigation was utilized for choosing potential area of squander transfer of the ponder zone

3.11. Data source

Data collection would be generated by acquiring primary information and secondary data in this study area. The primary data were collected from field surveys and observation. Whereas, the secondary data for the study was acquired from internet, reports, books, journals, governmental institutions and other documents.

The secondary data used includes Landsat8 for land use/land cover of the study area which was downloaded from U.S Geological Survey Global Visualization Viewer Website without the presence of cloud cover, DEM of (30 m * 30m) to derive slope of the study area, soil map of the study area from FAO for mapping soil texture in the study area. Structural plan of shambu town was obtained from Horo Guduru Wollega Zone urban development office and Geological map of study area from Geological Survey of Ethiopia (GSE) and main Road from Oromia road authority by using clip, extract and export from digitized map and shape file and developed from the GIS environment and structural plan of the study area. In addition, demographic characteristics and related data were gathered from Central Statistics Agency (CSA) and from Administrative Offices in shambu town. All the above data were collected, manipulated and analyzed in GIS environment to be used for further analysis.

3.12. Software

With regard to this study for data preparation and organization, data analysis and output generation computer hardware and software were used for study. The hardware includes Personal Computer, Printer, and digital camera. The software also for preparing and analyzing of data in materials were used to collect and store. The software's used for data pre-processing and preparation, data analysis, editing and output generation were ArcGIS 10.3 and IDRISI Selva 17.0. ArcGIS 10.3 applied for digitizing proximity and overlay analysis and database creation. IDRISI Selva 17.0 software's was used for weighting and rank different factors maps production using Analytical Hierarchy Process method.

3.13. Study Variables

This study would have dependent variable and independent variable

The dependent variable part of the study area was suitability analysis of landfill site selection for sustainable solid waste management using geographical information system and remote sensing and the independent variable part of this thesis were Geology, slope, land use/land cover, Soil type and road.

3.14. Study Design and Period

An experimental study design was conducted from February 2022 up to July 2022 on landfill Suitable site selection for solid waste disposal using geographical information system and remote sensing in case of shambu town.

3.15. Ethical Considerations

Official letter was written to Shambu municipality office and other concerned bodies to communicate about the research and for gathering required data.

The sampled households' society were approached with respect and deeply informed why the landfill site selection was important for the study area.

3.16. Inclusion and Exclusion Criteria of the Study

All solid waste disposed area in the town during sample collection would be included in sampling and solid waste disposed outside the town would be excluded in this study.

3.17. Expected Output of the Study

The following outputs are expected at the end of this study:-

After this research the society living in shambu town would develop their capacity to manage solid waste practically in continues manner by disposing in to landfill site.

This study result would provide information about health effects and advantages for environment within the study area.

The study can provide the prevention of clogging of ditch by SW, deposition of waste to water body and to open space.

This is also input for the responsible government organization especially for shambu town administration to take measures based on the result of this study and makes a suitable town for living by sustainable manage solid waste.

CHAPTER FOUR

4 RESULTS AND DISCUSSION

4.1 Solid waste assessment of the study area

A community based cross-sectional study was conducted on 77 sampled households to assess the collection, transportation and disposal of solid wastes produced by population of different socio-economic strata. Systematic and stratified random sampling techniques were used to select household samples from the targeted households, and to identify sampled residents with different socio economic strata. To calculate the number of samples of confidence level on solid waste data, the confidence level is usually set at 80% or 90%(UNEP, 2009).For determining the sample size of households a total of 340 targeted households were considered as a study site and the sample size of the households were determined by using sampling technique formula developed by Yemane (1973), with 90% confidence level and 10% margin error which helps to determine sample size with the degree of precision.

$$n= \frac{340}{1+3400(0.1)^2}$$

n=77 (sample size of the households).

4.1.1 Availability of storage material at household level

At the study area, solid waste handling practice at household level was mainly the primarily the duty of the moms and girls when compared with other family individuals. Totally, there is no sorting of household solid wastes in to their categories in the sampled community members of the study area .Most of the domestic solid wastes of the study area were not collected properly at household level. The sampled residents are facing problems of waste collection and transfer services before disposal. Table 2 of the following shows the availability of temporarily storage materials at the household from the sampled residents.

Table 2. The availability of temporary storage material at the household level

Availability of storage material	Frequency	Percent
Available	46	59.74
Not available	31	40.26
Total	77	100

According to the data from Table 2 out of the total 77 households; 59.74% of the sampled households have temporary storage materials which include: sacks, plastic bags, baskets and cartons. The rest 40.26% of the sampled households have no temporary storage materials at the household level and so they throw the domestic solid wastes on the street, on the nearby open spaces and within the drains (road canals).

4.1.2 Solid waste collection and transportation methods

As interviewed from the sampled residents there was no any collection system and transportation method took place neither by labor force nor by vehicles to collect and transport the solid waste generated from the residents. Simple the households in that sampled household would be store the SW in temporarily storage materials and then transport by handcart or by renting cart to dispose on the open space which may cause adverse effect on human health and other social problems like nuisance, ugly and hindering economic activities.

4.1.3 Domestic solid waste disposal practices of the sampled inhabitants

The survey analysis and visual observation of the study area also shows that absence of accessibility of household solid waste collection and transfer services, absence of communal dumping containers and inappropriate and insufficient placement of landfills, discourage the inhabitants to dispose domestic solid wastes along the road side, in the plantation sites, on open spaces, near the residential sites, around burial area and within the road canal which are a major threat for public health and the surrounding environment and all of these activities were described by figure as shown from annex. The municipality of shambu town had been facing to problems related to solid waste management. The problem starts from collection to final disposal due to the increased waste generation and scarcity of dumping site.

The visual observation of the existing damping site in shambu town shows that the location of landfill site was along drainage system surrounded by essential areas that had been precipitating adverse effect on human health and other social problems like nuisance, ugly sceneries and hindering economic activities. Furthermore, there were no daily covering of solid waste after disposal to reduce environmental and public health problem.

Figure 3. Existing solid waste disposal site in Shambu town (field observation, 2022)

4.1.4 Generation rate of domestic solid waste in the study area

Total generation rate per household per day is equal to total weight of sampled solid waste in seven days divided by the total sampled households conducted. In this study, the sampled households were classified into three places based up on their income levels of family members per months as shown below in table 3. The average household solid waste generated by the sampled households was calculated with respect to socio economic level and comparative analysis of average waste generation rate would be done.

The total domestic solid waste generation rate survey of households of the study area was estimated depending on the data collected from the sampled households. Results of quantitative data obtained from sampled residential houses through direct measurement of domestic solid waste generated were analyzed using tables, averages, ratios and percentages as the major summarizing tools. Table 3 shows waste generation per day per household and per day per capita of sampled households of the study area.

Table 3**.** Waste generation per day per household and per day per capita

Economic level	No.of HH	Population	Total weight of SW generated (Kg)	Kg/HH/day	Kg/Cap/day
Low	16	85	84.62	0.75553	0.14221
Middle	34	103	104.81	0.44037	0.14536
High	27	152	187.54	0.99227	0.17625
Total average	77	340	376.97	0.69938	0.15839

As the data analysis on Table **3** indicates the total average domestic solid waste generation rate of sampled households of the study area is 0.69938kg/ |HH/| day and the total average daily per capita residual solid waste generation rate is 0.15839kg/cap/ day. Table **3** also depicts that the daily per capita residual solid waste generation rate and per household per day increases from low income groups to high income groups.

According to the data from municipality office (2018), the current total population of Shambu town is estimated to be 38,584. Taking this figure into account, the daily, weekly, monthly and yearly domestic solid waste generation rate of this town is estimated to be 12.87, 64.52, 283.7, 4184.15 tons respectively.

4.2 Assessment of dominant factors for Suitable waste disposal site selection in the study area

4.2.1 Slope

Land slope is an important factor when selecting a landfill site. Slope of the study area was developed from DEM 30*30 m resolutions and used in GIS environment. According to Akbari *et al.,* (2008), areas with high altitude or high slope are not suitable landfill sites. An area with a very steep slope will increase drainage of pollutants from the landfill site to surrounding areas (Lin and Kao, 1999) as well as increasing the risk of leachate flowing from high slopes to flat and low areas or bodies of water.

As shown in **table 4** of the following the study area is dominated with slope of 8-20% which accounts 34.7% of the total area. The second most dominant slope of the study area is 0-8% found in most parts the study area of the town covering 27.5% of total area, the third slope of the study area is 20-32% covering 25% of total area and the slope of the remaining part of the study area is 32-44% covering 7.3% of the total area and the very low part of the study area is 5.5% with slope >44%.

Table 4. Area coverage and Slope Suitability

No	**Slope Classes**	**Suitability Rank**	**Suitability Class**	Area in (ha)	Area in (%)
1	0-8	5	Very high suitable	138.463679	27.5
2	8-20	4	High suitable	174.912478	34.7
3	20-32	3	Moderate suitable	125.968628	25
4	32-44	2	Low suitable	36.623581	7.3
5	>44	1	Very low suitable	27.58238	5.5

Table 4 indicates that 27.5%, 34.7%, 25%, 7.3% and 5.5% of the total area of the study area is very highly suitable, highly suitable, moderately suitable, low suitable and very low suitable for solid waste disposal site respectively. Based on above explanation suitability map of slope was prepared as shown **fig.4**.

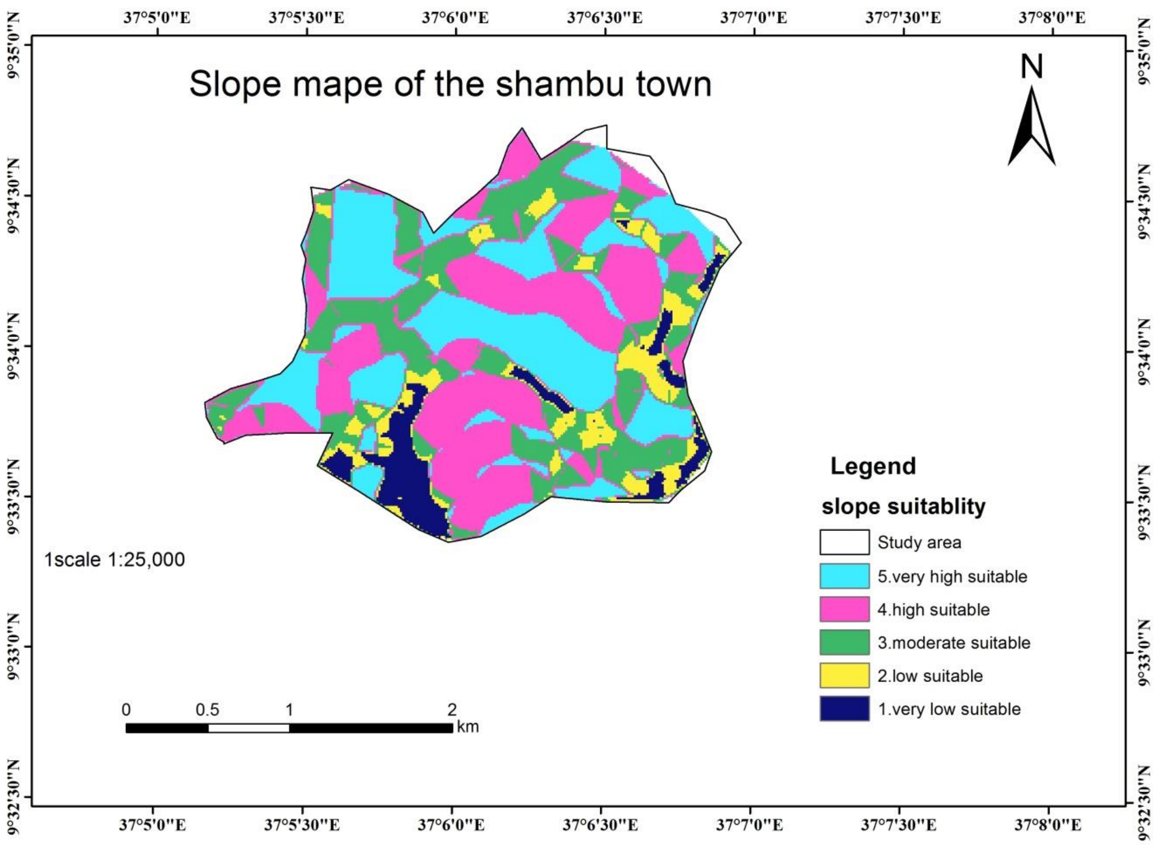

Figure 4**.** Slope Suitability map of the study area.

4.2.2 Soil type

Soil type is one of the criteria used to select potential sites for solid waste disposal in the study area. The soil of the study area was taken from FAO (2007) and was digitized in to polygon type by ArcGIS.

The soil type that was generated in ArcGIS for the delineated study area is as follows and the detail of the soil types is shown by table 5 as well as putted as legend on the right side of the map figure 6. The soil type of the study area was classified in to three categories such as, dystric nitosols, hablic xerosols and orthic solochaks and they have different soil characteristics which were considered for landfill site selection.

Table 5**.** Physical characteristics of soil types

No	Soil type	Physical characteristics
1	dystric nitosols	low permeable
2	hablic xerosols	medium permeable
3	orthic solochaks	high permeable

Source: www.soil.org

According to (Abdoli, 1993), as the amount of soil permeability is increase; the suitability site will decrease, because the very high permeable soil, the most probable to pollute ground water. Therefore, based on the below Table 6, dystric nitosols covers 35.1% of the total of the study area having low permeable which is high suitable for landfill site, orthic solonchaks covers 29.4% of the study area and have medium permeable which is moderately suitable and hablic xerosols have covers 35.5% of the study area and have high permeable which is low suitable for landfill site selection.

Table 6. Classification of soil types

No	Soil type	Suitability Rank	Suitability Class	Area (ha)	Area in (%)
1	dystric nitisols	3	High suitable	180.0065	35.1
2	orthic solonchaks	2	Moderately suitable	150.8413	29.4
3	haplic xerosols	1	Low suitable	182.4847	35.5

Based on above explanation suitability map of soil type for study area was prepared as shown fig.5.

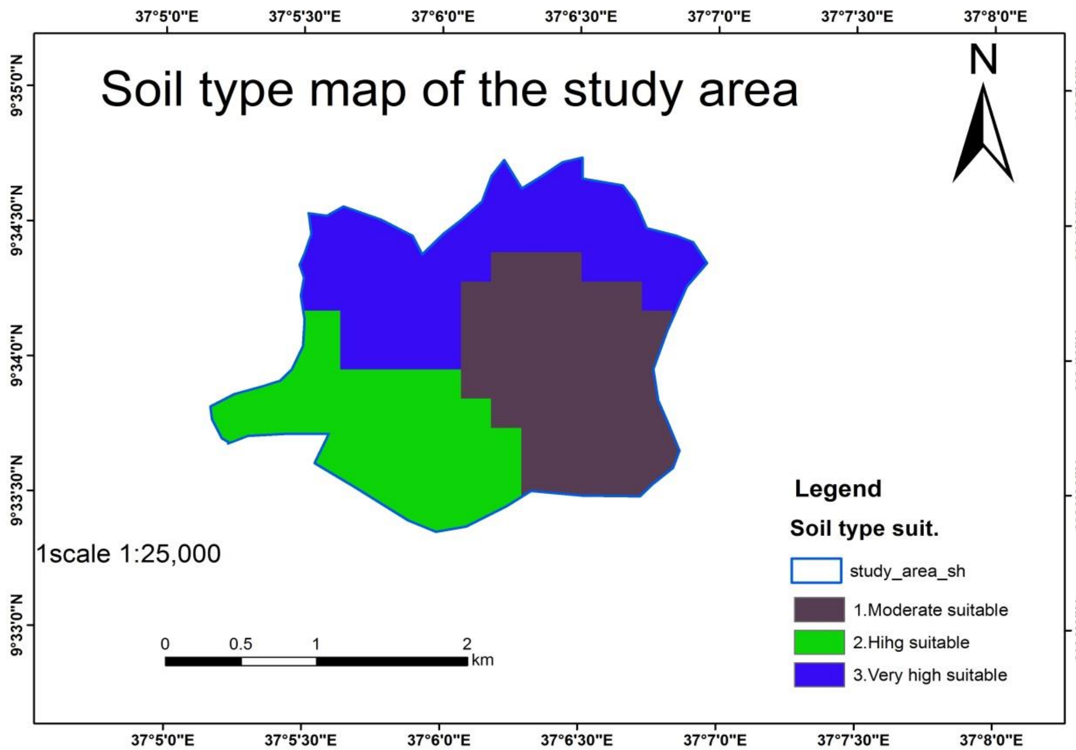

Figure 5. Soil the type suitable map of study area

4.2.3 Land use/Land Cover

Land use/Land cover map of the study area is one of the criteria used to select potential sites for solid waste disposal in the town of shambu. It was downloaded from satellite image 7 of the world map and digitized in to polygon using GIS. In the study area, LU/LC map were produced using extract by mask and classified based on field data by using ERDAS Image 2014. From the land use/land cover of the study area large part covered by residential area which accounts about 40% of the total study area, Agricultural land, vegetable land, wetland and bare land covers 26.9%, 21.2%, 8.6% and 3.2% of the total study area respectively and clearly shown in table 7.

Table 7. Area coverage and Land use/land cover suitability

No	Land use/Land Cover type	Suitability Classes	Suitability Rank	Area in (ha)	Area in (%)
1	Bare land	Very high suitable	5	16.17	3.2
2	Agricultural land	High suitable	4	135.22	26.9
3	vegetable land	Moderate suitable	3	106.58	21.2
4	wetland	Low suitable	2	43.53	8.6
5	Residential land	Very low suitable	1	202.02	40.1
Total				503.52	100

As shown in table 7 the largest part of the study area 40.1% was found as very low suitable for solid waste disposal sites whereas, 26.9%, 21.2% and 8.6% of the area were high suitable, moderately suitable and less suitable, respectively. The remaining 3.2% of the study area was found very high suitable for solid waste disposal site. Land use/land cover of the study area is shown in fig. 6.

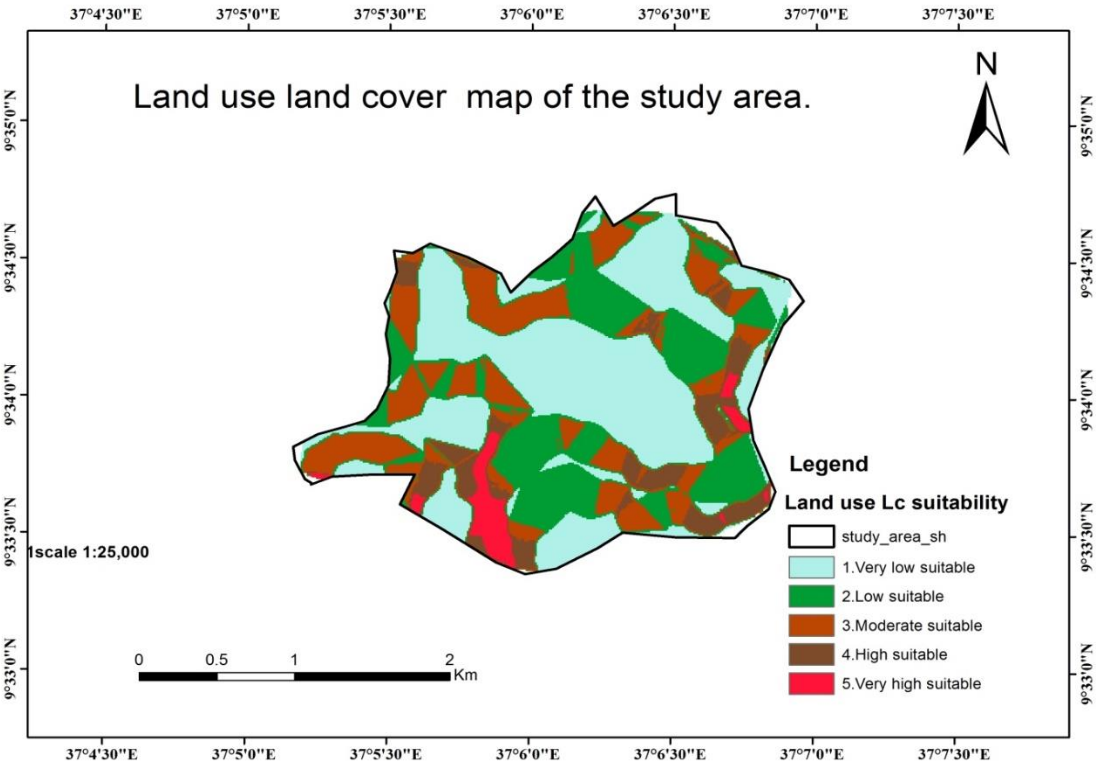

Figure 6. Land use/Land cover Suitability map of the study area

4.2.4 Lithology

For this study to select the suitable landfill site the rock type based on amount of weathered/fracture and porosity is essential. The lithology map of the study area was georefferanced from geology map of the Ethiopia by using GIS environments. The geology of the study area was classified in to five categories such as magmatite, Biotite, hornblende gneisses, granulite and Sandstone.

Table 8. Lithology type information, online

No	Lithology type	Properties
1	Magmatite	Very low weathered
2	Biotite	Low weathered
3	hornblende gneisses	Moderate weathered
4	Granulite	High weathered
5	Sandstone	Very high weathered

Source: www.lithology.wine

Lithology criteria, based on (center for Advance Engineering, 2000) landfill site should be reducing the risk of ground water contamination, more weathered and fracture, more permeable and instable the rock. As shown in Table 9 below most of the study area is covered by magmatite which covers 60.4% of the total study area. They are found in the southern parts of the study area and characterized by very low porosity. Because of this they are very high suitable for landfill site selection. Another lithology classes in the study area are Biotite which is found in the north west part of the study area and have low porosity, hornblende gneisses which is found in the northern part of the study area and have medium porosity, granulite is found at central part of the study area and have high porosity and sandstone have very high porosity.

Table 9. Lithological Classification

No	Lithology type	Lithology Suitability	Suitability Rank	Area in (ha)	Area in (%)
1	Magmatite	Very high suitable	5	304.02	60.4
2	Biotite	High suitable	4	21.8	4.3
3	hornblende gneisses	Moderate suitable	3	30.7	6.1
4	Granulite	Low suitable	2	54	10.7
5	Sandstone	Very low suitable	1	93	18.5
Total				503.52	100

In the study area 60.4% of the area is very high suitable for solid waste disposal potential site, 4.3% was high suitable, 6.1% of the study area was moderately suitable. The remaining 10.7% and 18.5% from the total study area were less suitable and very low suitable respectively for solid waste disposal potential sites fig.7.

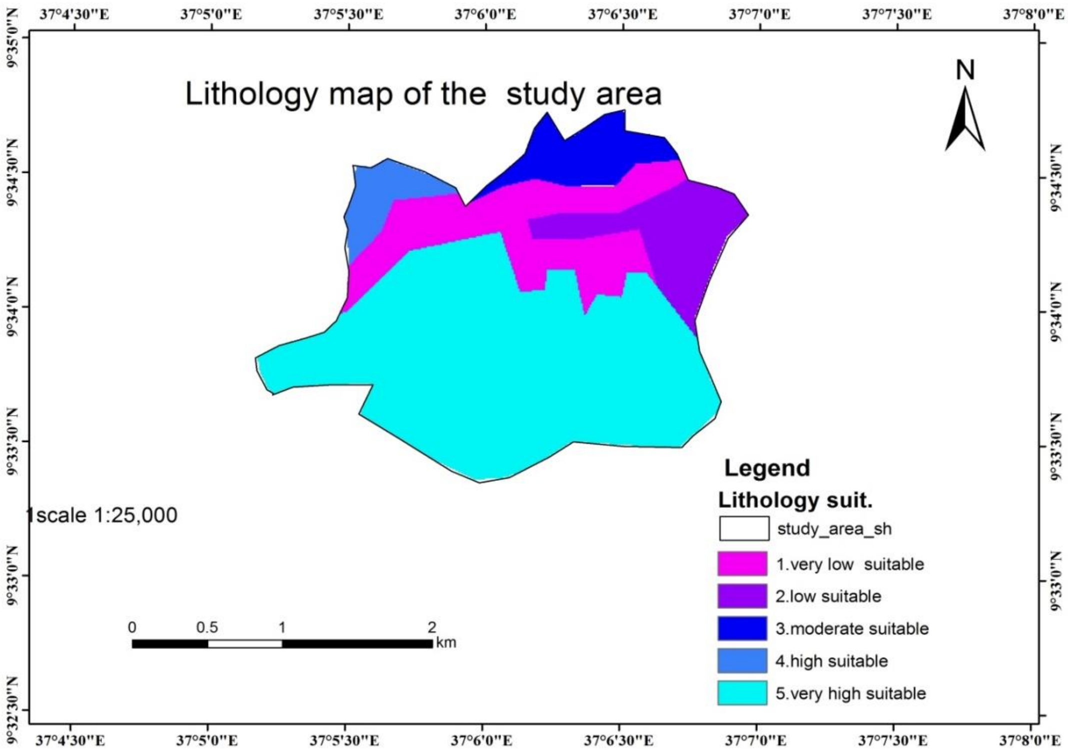

Figure 7. Lithology Suitability map of the study area

4.2.5 Road

Road is one of the important criteria for solid waste disposal site selection processes. Because, solid waste site especially close to roads may have public health problem as landfill can have hazardous effect to health. Moreover, landfill site very far from road network is also not suggested due to high transportation cost. The existing road was obtained from Oromia road authority shape file map by using GIS environment. The road of the study area to its nearby was measured by buffer distance created in the ArcGIS environment using analysis tools. Based on the road network proximity standard Rafiee, *at al*., (2011) and EPA (1995), areas found below 500 m and above 5000 m from a highway were considered as unsuitable. Because of, high proximity to roads can result traffic congestion and when it is too far away from road network access results high cost of transportation. Therefore, for this study road reclassified into five classes as shown in table 10.

Table 10. Classification for Road

Factor	Criteria Value in meter	Road Suitability	Area (ha)	Area in percentage
Road	0-250	Very low suitable	21.5005062455	4.27
	250-500	Low suitable	26.02025959098	5.2
	500-750	Moderate suitable	71.0016961189	14.1
	750-900	High suitable	122.00232855349	24.3
	>900	Very high suitable	263.005034007	52.13
Total			503.52	100

The study area was covered in 52.13% and was concerned also as very high suitable for solid waste disposal potential site, 24.3% was high suitable, 14.1% of the study area was moderately suitable. The remaining 5.2% and 4.27% from the total study area were low suitable and very low suitable respectively for solid waste disposal potential sites fig.8.

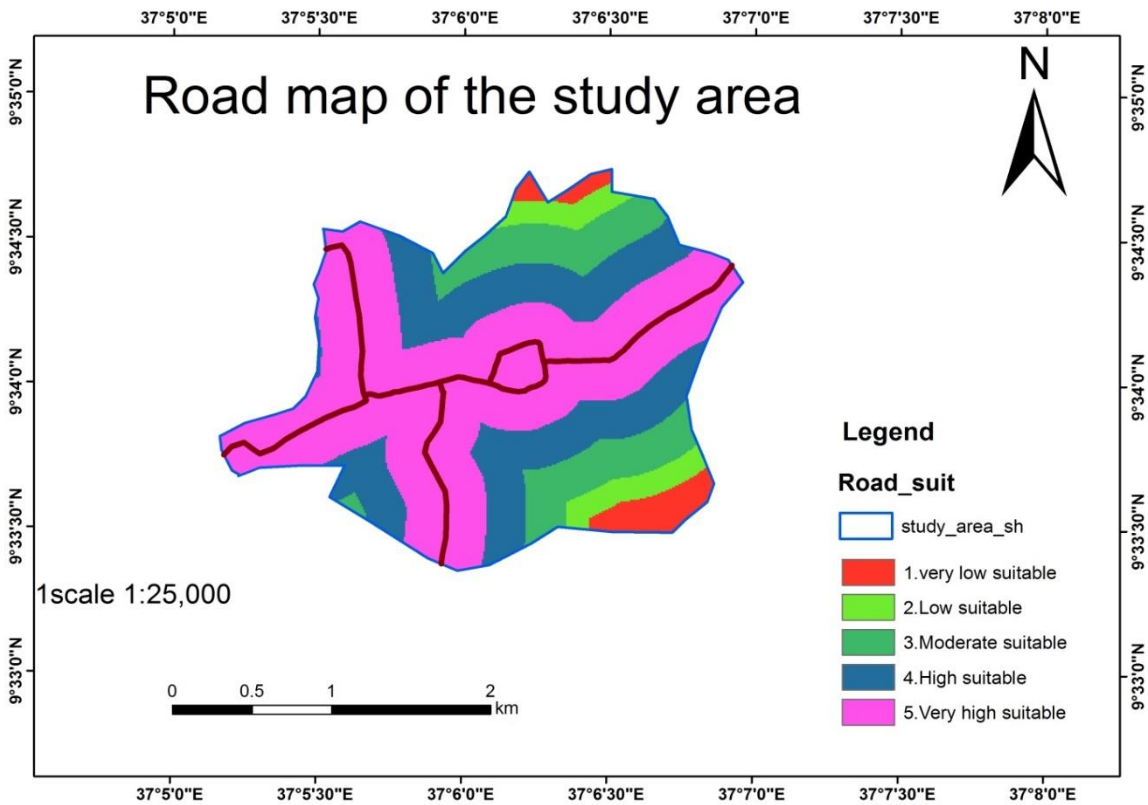

Figure 8. Road Suitability map of the study area

4.3.Evaluation of suitable landfill sites using GIS with MCDA

4.3.1.Calculating factors weight and overlaying identified suitable sites

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. The weights were developed providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights were produced follows the logic developed by Saaty (2005) under the Analytical Hierarchy Process. Weight rates were given based on pair wise comparison 9 point continuous scale. These pair wise comparison were then analyzed to produce of weights that sum to 1. The factors and their resulting weights were used as input for the multi criteria evaluation module for weighted linear combination of overlay analysis.

Table 11. Pair wise comparison, 9-point weighting scales

1/9	1/7	1/5	1/3	0	3	5	7	9
Absolutely	Strongly	More	Slightly	Equally Important	Slightly	More	Strongly	Absolutely

Source: Saaty, 1980

In the process of selection the importance and weight of each criterion was compared with each criterion in this study. It was done through the adoption of the opinions of experts who have worked in this field. Each criterion was given a value of weight that it deserves by adopting the method of "simple additive weighting," which is considered the simplest technique in the decision-making process (Afshari *et al*., 2010). Then these weights have been used and applied in preparing the matrix of AHP to get the right weight for each criterion.

According to Lawal *et al*., (2011), if the consistency ratio is less than or equal to 0.1, it shows acceptable reciprocal matrix. The consistency ratio of this study indicated that 0.027 was acceptable. In order to combine all the layers to process overlay analysis, standardization of each data set to a common scale of 1, 2, 3, 4 and 5 (value 1 = very low suitable, value 2 = less suitable, value 3 = moderately suitable, value 4 = highly suitable, 5=very high suitable) was performed. The factors, their values and weights are summarized below in table 12.

Table 12. Weights of the criteria using pair wise comparison matrices

Criteria	slope	soil type	LULC	Geology	Road	weight	weight %
slope	1					0.263	26.3
soil type	1/2	1				0.214	21.4
LULC	1/3	1/2	1			0.0979	9.8
Geology	1/4	1/3	1/2	1		0.3605	36
Road	1/5	1/4	1/3	1/2	1	0.0647	6.5
total						1.0001	100

Consistency Ratio = 0.027 < 0.1 acceptable.

Table 13. Weight of Suitable Solid Waste Dumping Site Selection Factors

Factors	Class	Value	Level of Suitability	Influence
	0-8	5	very high suitable	
	8-20	4	high suitable	
Slope	20-32	3	moderate suitable	26.3%
	32-44	2	low suitable	
	>44	1	very low suitable	
Soil type	dystric nitosol	3	moderate suitable	
	Hablic xerosol	2	low suitable	21.4%
	Orthic solochaks	1	very suitable	
	Bare land	5	very high suitable	
LULC	Agricultural land	4	high suitable	
	Vegetable land	3	moderate suitable	9.8%
	Wet land	2	low suitable	
	Residential land	1	very low suitable	
	Magmatite	5	very high suitable	
Geology	Biotite	4	high suitable	
	hornblende gneisses	3	moderate suitable	36%
	granulite	2	low suitable	
	Sandstone	1	very low suitable	
Road	>900	5	very high suitable	
	750-900	4	high suitable	
	500-750	3	moderate suitable	6.5%
	250-500	2	low suitable	
	0-250	1	very low suitable	

As shown in table 13 above geology, slope and soil type influences highly the suitability of landfill site selection having influential value of 36%, 26.3% and 21.4% respectively in the study area. Land use land cover and road influences the suitability of landfill site selection slightly having influential value of 9.8% and 6.5% respectively in the study area. The fig.9 of the follow shows the weighted overlay map of suitable landfill sites.

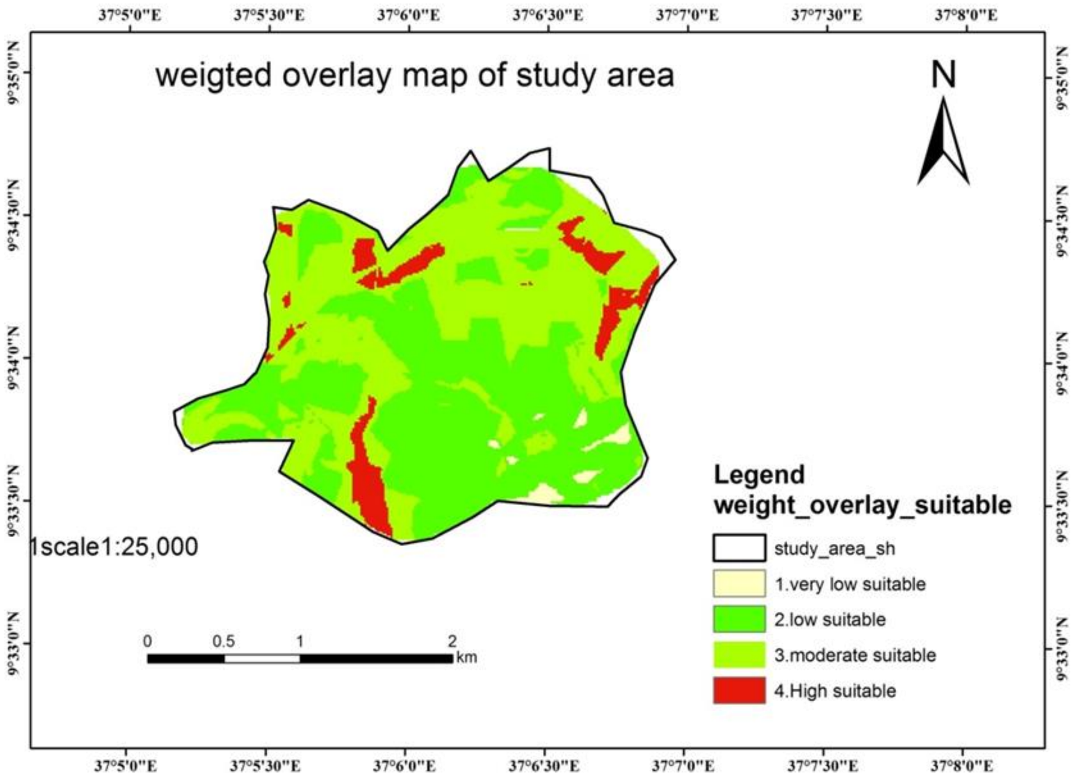

Figure 9. Overall Landfill Suitability Map of the study area

Table 14. Suitability area, level of suitability and the percent of total area coverage

Level of Suitability	Rank	Area (ha)	Percent of total area
very low suitable	1	6.5010772267	1.29
low suitable	2	235.022181172	46.67
moderate suitable	3	225.00117	44.68
high suitable	4	37.000943	7.36
Total		503.52	100

The area of each level of suitability was calculated using GIS. As shown from table 14 above out of the total area of the study site, about 7.36% (37.000943 ha) fall under high suitable categories due to, the region satisfies the environmental, social and economic criteria such as slope, soil type, land use/land cover, geology and road. The moderate suitable area covers an area of 44.68% (225.00117ha), low suitable area cavers 46.67% (235.022181172 ha) and the remaining 1.29% (6.5010772267 ha) falls under very low suitable for solid waste disposal sites.

4.4.Map of suitable landfill site selected

The suitable site selected maps were prepared with the aid of GIS. After all the maps were prepared, a resultant map site was derived using overlay analysis of the ArcGIS Spatial Analyst as shown in fig.10. Those suitable landfill sites were found in 01 and 02 kebele of shambu town at the Northern, Southern, Eastern and North West parts which each of them were assigned as site 1, site 2, site 3 and site 4 respectively as shown in legend of fig.10.

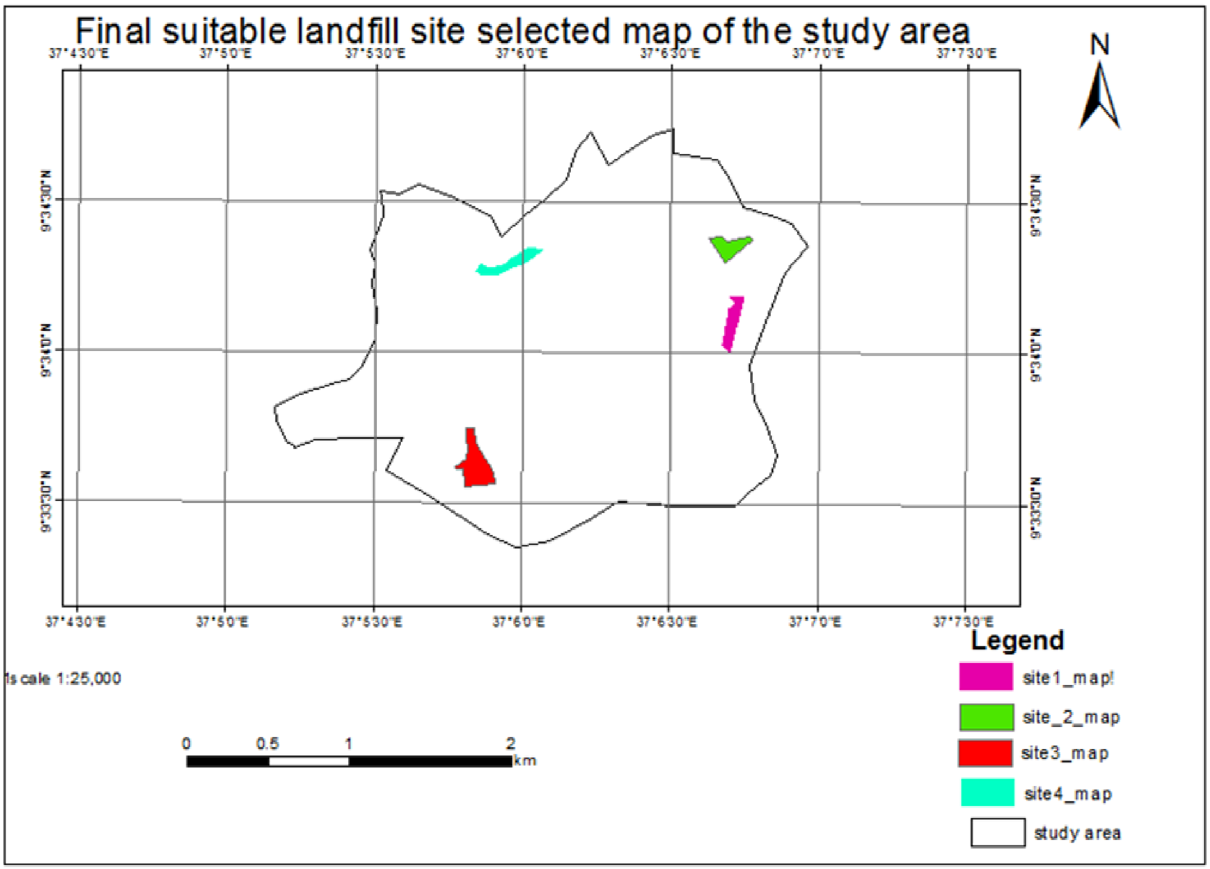

Figure 10. Suitability site selected map of the study area

Table 15. Site selected Suitability area coverage and direction

Site No.	Area in ha	Locations of site selected	
		North direction	East direction
Site 1	12.361555	$9^0 34' 0''$ to $9^0 34' 30''$N	$37^0 6' 30''$ to $37^0 7' 0''$E
Site 2	8.044035	$9^0 34' 0''$ to $9^0 34' 30''$N	$37^0 6' 30''$ to $37^0 7' 0''$E
Site 3	7.270644	$9^0 33' 30''$ to $9^0 34' 0''$N	$37^0 5' 30''$ to $37^0 6' 0''$E
Site 4	4.353617	$9^0 34' 0''$ to $9^0 34' 30''$N	$37^0 5' 50''$ to $37^0 6' 20''$ E

As shown from table 15 of the above, the area of Site1 is 12.361555ha Site2 is 8.044035ha, site3 is 7.270644ha and site4 is 4.353617ha. Table 15 also depicts the location of suitable landfill site (1, 2, 3 and 4) in the study area.

In order to check the suitability of selected site areas field observation was performed to confirm the results. As observed field areas, the site selected are impermeable properties and are located on the bare lands. The slopes of selected sites are also gentle slope which is low for runoff. Additionally, distances to roads of selected sites are quite suitable for landfill. At the end of field study, desired results are obtained and it can be concluded that when the results are compared with field study, the selected sites have suitable properties for landfill in study area.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Landfills are an environmentally acceptable disposal of solid waste on the ground. The main purpose of establishing landfills is to protect the safety of the environment by minimizing effects on resources and community health. Similarly the main purpose of this study was finding suitable sites for landfills using GIS and remote sensing technologies.

As the study shows GIS requires collecting different data from different sources with different formats and the data must be updated to show the current information of the study area. Remote sensing also helps in having information about the study area through satellite images.

The findings also, have shown the ability of GIS and remote sensing as an absolute tool for analyzing the criteria for decision support. The analysis has taken important factors to minimize the negative impacts of landfills. These are land use land cover, slope, soil type, road and geology as determining factor in order to find appropriate site for solid waste dumping site. The results have shown that four sites were suggested as highly suitable for solid waste landfills. The sites are easy to access and manage for disposal of solid wastes. They are located in north, north western, east and south peripheries of the town and are agricultural areas, bare land and grass land with less than 8% slope. Hence, the capacity to use GIS and remote sensing technology for the effective identification of suitable solid waste dumping site will minimize the environmental risk and human health problems.

5.2 Recommendations

The following recommendations are given for more understandings

- ✓ The selected landfill sites by this study are only for non-hazardous solid wastes. Therefore, hazard solid waste should not be deposited at these sites, because it should have different parameters and construction of solid waste disposal sites from non-hazardous waste.
- ✓ This study considers only five factors like slope, soil type, land use land cover, lithology and road to select suitable landfill site but other factors which influence solid waste disposal site should be excluded as evaluating criteria like cost of construction, aspect, area design and others.
- ✓ Further studies are necessary about the design and costs of construction of landfills.

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ANNEX

Annex 1
Survey questionnaires

For assessing availability storage material at household level, sold waste collection and transportation methods and solid waste dump site of sampled residents.

1. Availability storage material at household level

(Available /Not available)

If your answer is available, what is temporary storage material used?------------------------------

2. Methods used to collect and transport household solid waste to the disposal sites-------------
----

3. Accessibility of solid waste collection --

4. Where do you dump household solid waste refuse?---

Is the existing waste management of the municipality satisfactory? Yes------------------------ No---

5.How is the work of the existing municipality services on domestic solid waste management?--
----

6.What measure should have to be taken to improve improper solid waste management?-------
----

-------------------- --

7.What is your suggestion about the final disposal of household solid waste to be environmentally safe and acceptable?---
----

Annex 2

Indicating waste disposal at improper different site.

Solid waste disposal on open space

Solid waste disposal around burial area

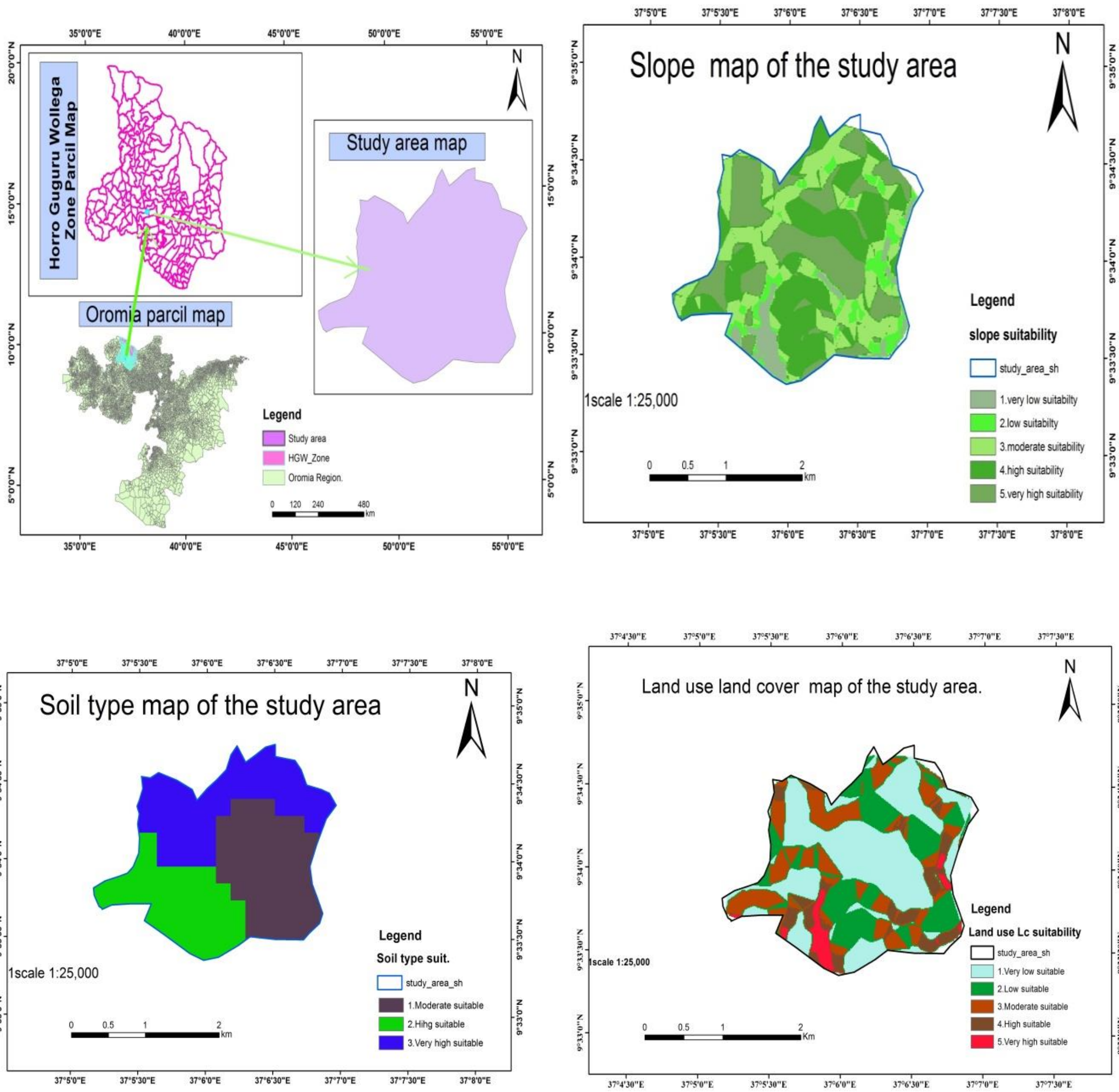
Solid waste disposal in plantation site.

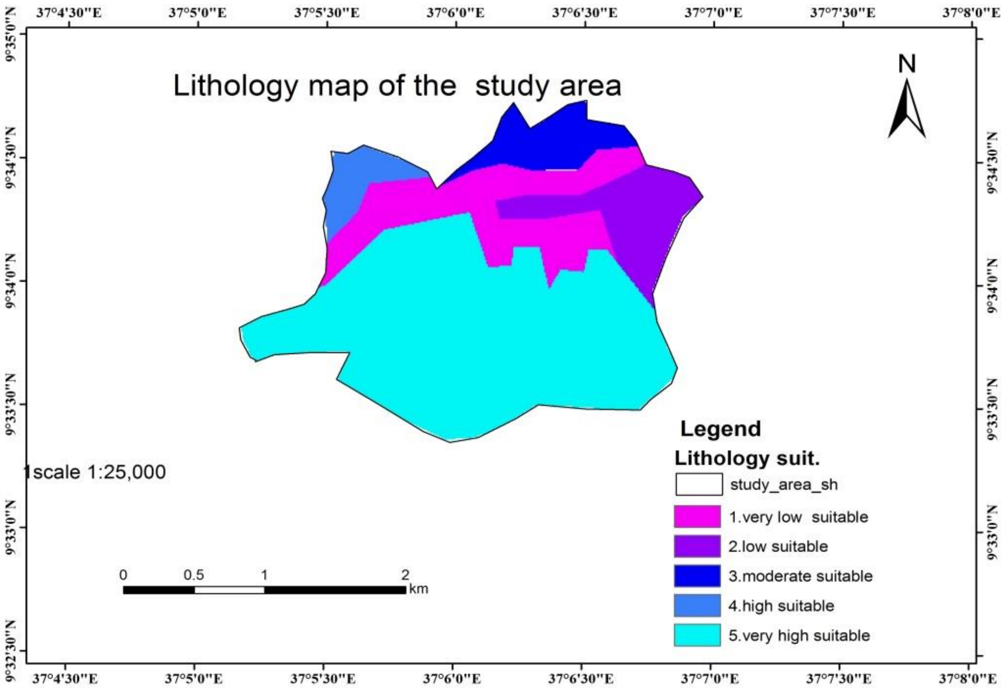
Solid waste disposal along road side.

Solid waste disposal around residential area

Annex 3

Indicating suitability factors map for study area.





Lithology map of the study area
N
37°4'30"E
37°5'0"E
37°5'30"E
37°6'0"E
37°6'30"E
37°7'0"E
37°7'30"E
37°8'0"E
9°35'0"N
9°34'30"N
9°34'0"N
9°33'30"N
9°33'0"N
9°32'30"N
1scale 1:25,000
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Legend
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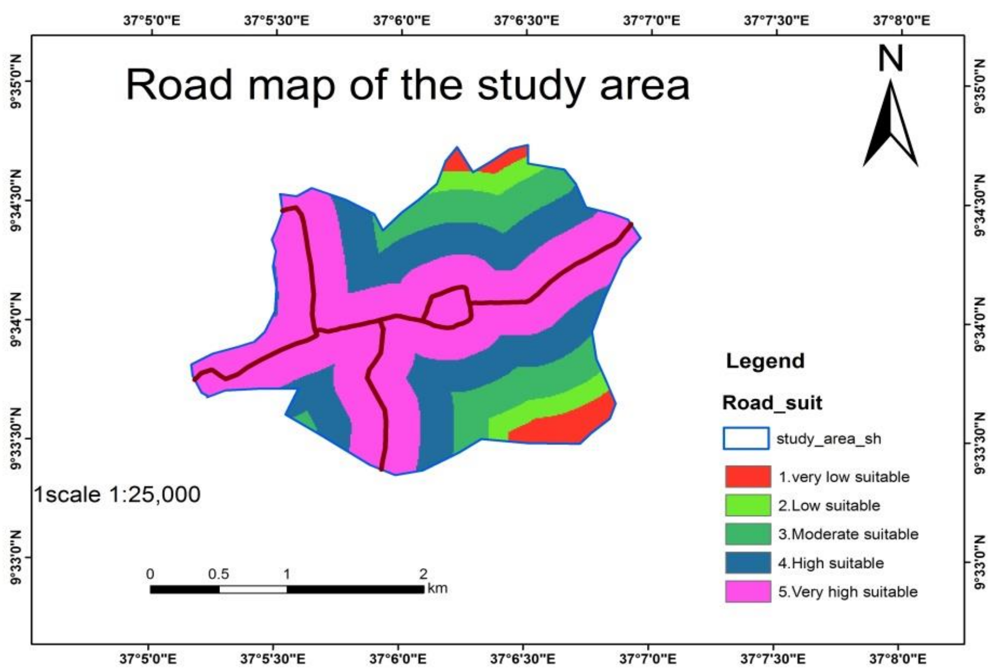
2.low suitable
3.moderate suitable
4.high suitable
5.very high suitable



Road map of the study area
N
37°5'0"E
37°5'30"E
37°6'0"E
37°6'30"E
37°7'0"E
37°7'30"E
37°8'0"E
9°35'0"N
9°34'30"N
9°34'0"N
9°33'30"N
9°33'0"N
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study_area_sh
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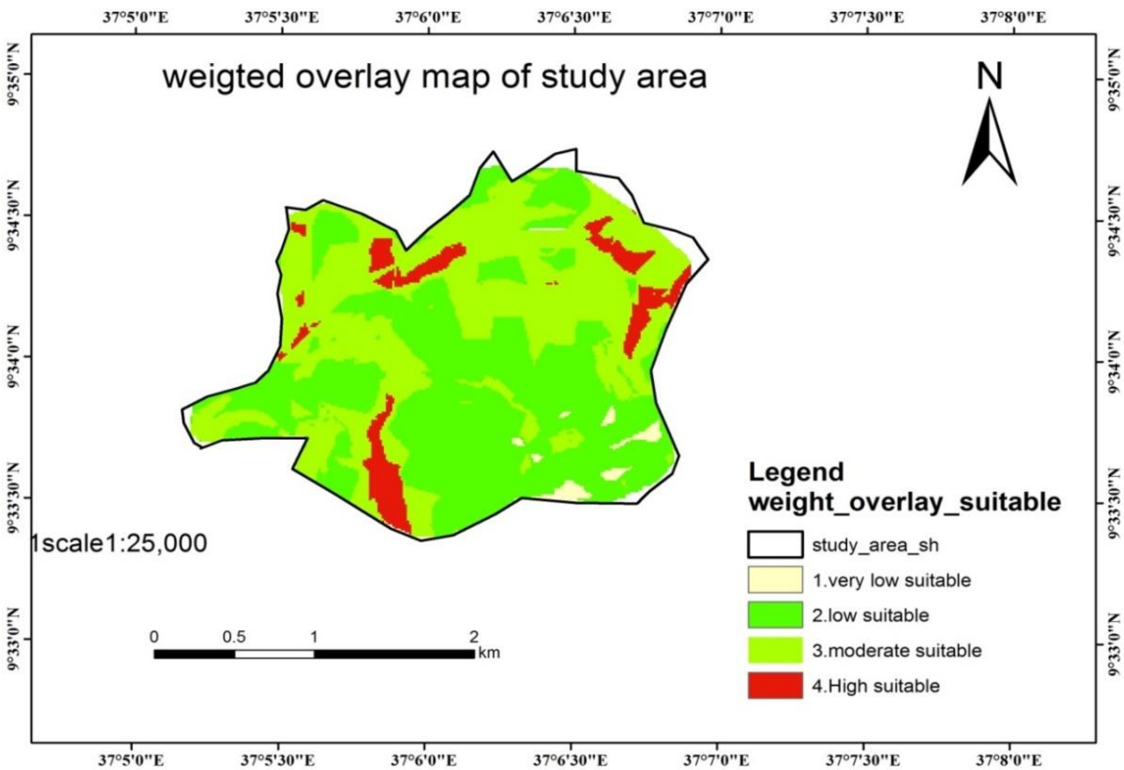
2.Low suitable
3.Moderate suitable
4.High suitable
5.Very high suitable


weigted overlay map of study area
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Legend
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1.very low suitable
2.low suitable
3.moderate suitable
4.High suitable
1scale1:25,000
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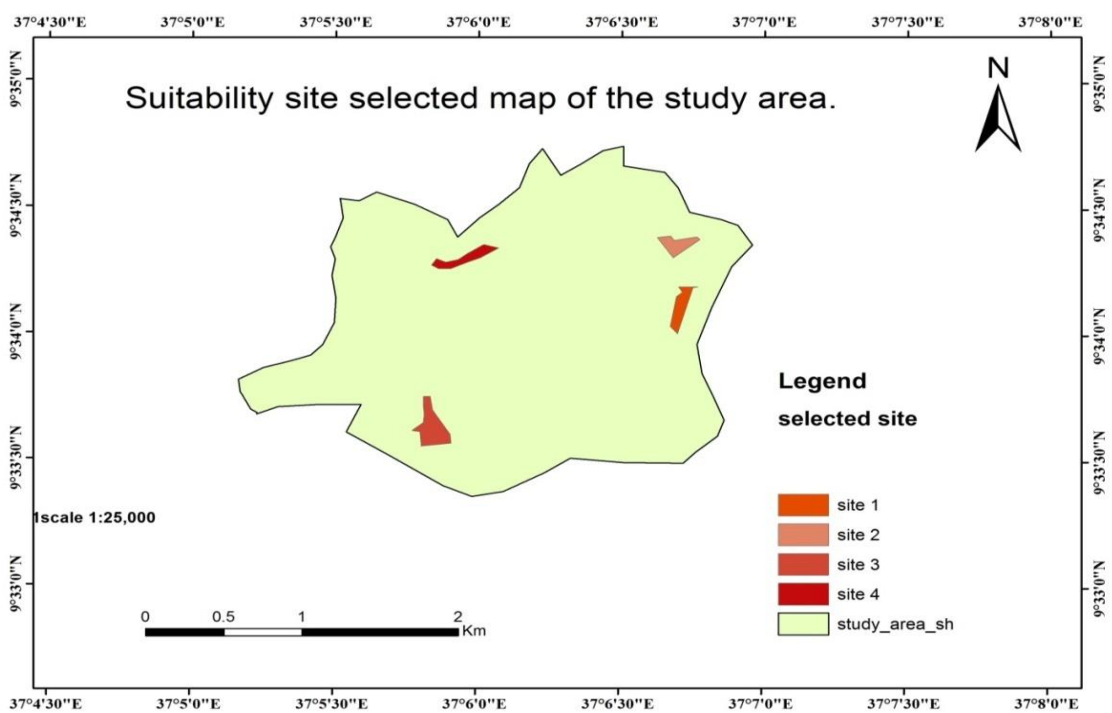
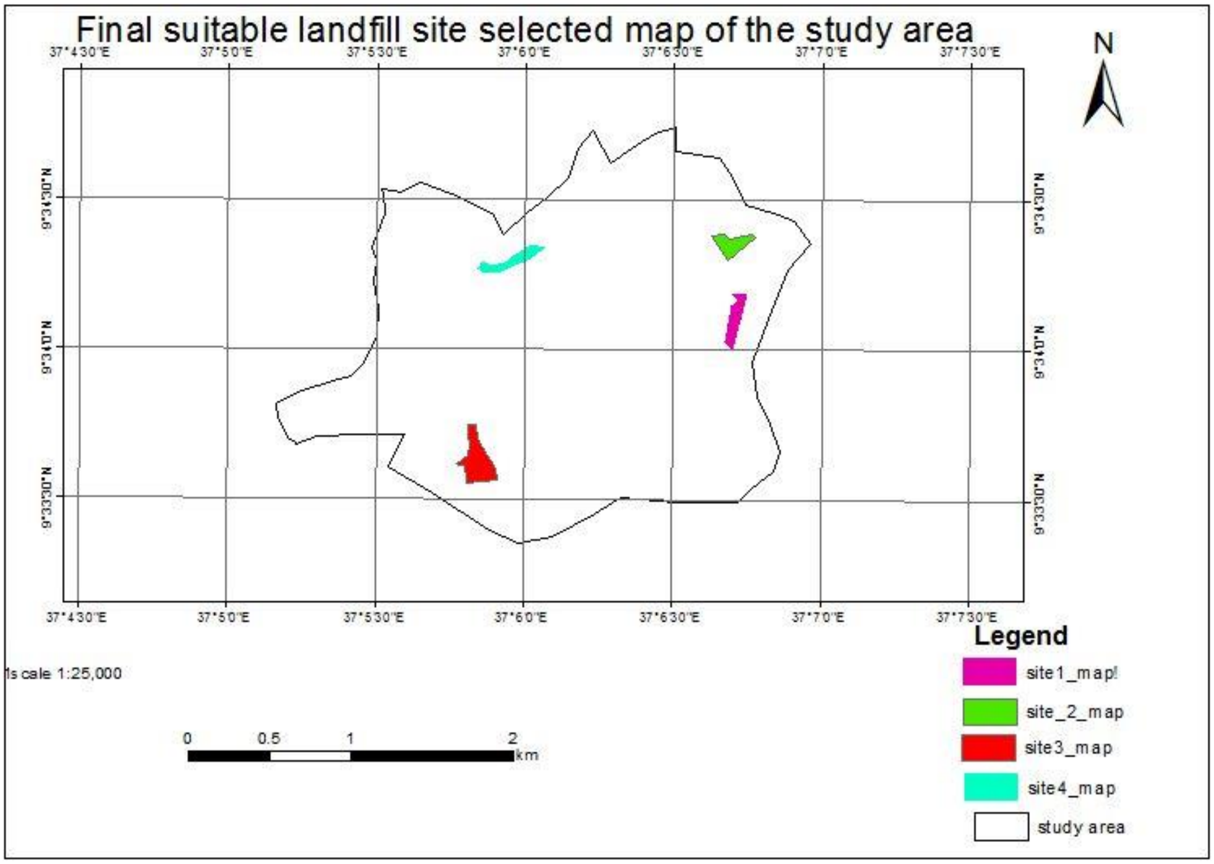
37°5'0"E 37°5'30"E 37°6'0"E 37°6'30"E 37°7'0"E 37°7'30"E 37°8'0"E
9°35'0"N 9°34'30"N 9°34'0"N 9°33'30"N 9°33'0"N


Suitability site selected map of the study area.
N
Legend
selected site
site 1
site 2
site 3
site 4
study_area_sh
1scale 1:25,000
0 0.5 1 2 Km
37°4'30"E 37°5'0"E 37°5'30"E 37°6'0"E 37°6'30"E 37°7'0"E 37°7'30"E 37°8'0"E
9°35'0"N 9°34'30"N 9°34'0"N 9°33'30"N 9°33'0"N


Final suitable landfill site selected map of the study area
N
Legend
site1_map!
site_2_map
site3_map
site4_map
study area
ls cale 1:25,000
0
0.5
1
2
km