JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
ENVIRONMENTAL ENGINEERING CHAIR
MASTERS OF SCIENCE PROGRAM IN ENVIRONMENTAL ENGINEERING

LANDFILL SITE SELECTION USING GEOGRAPHICAL INFORMATION SYSTEM AND REMOTE SENSING TECHNIQUES: THE CASE OF FICHE TOWN, NORTH SHEWA, OROMIYA, ETHIOPIA

By:

Bezu Abera Geresu

A Thesis Submitted to the Chair of Environmental Engineering, Jimma Institute of Technology, Jimma University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Environmental Engineering.

July 2021
Jimma, Ethiopia

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Advisor: Dr. Eng. Feqadu Fufa (Ph. D)

Co-Advisor: Mr. Beekan Gurmessa (MSc.)

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DECLARATION

I declare that this research entitled **"landfill Site Selection by Geographical Information System and Remote Sense, Fiche Town, North Shewa, Oromiya, Ethiopia"** is my original work and has not published as a requirement for the award of any degree in Jimma University or elsewhere.

As research Advisor, I hereby certify that I have read and evaluated this proposal paper under my guidance, by Bezu Abera Geresu entitled "**landfill Site Selection Using Geographical Information System and Remote Sense Techniques on Fiche Town, North Shewa, Oromiya, Ethiopia**" and recommend and would be accepted as a fulfilling requirement for the Degree Master of Science in Environmental Engineering.

Submitted by:

<u>Mr. Bezu Abera Geresu</u> ________________ ______________

Name Signature Date

Approved by:

<u>Advisor: Dr. Eng.Fekadu Fufa (Asso. Prof.)</u> ________________ ______________

Name Signature Date

<u>Co-Advisor: Beekan Gurmessa (MSc)</u> ______________ ________________

Name Signature Date

ABSTRACT

*Unsafe municipal solid waste disposal is the most difficult problem all over the world. Municipal solid waste has different components. Those responsible for global environmental degradation and health issues as a result of improperly dumped waste. This study aimed to select suitable sites for municipal solid waste disposal of Fiche town using GIS and RS tools techniques. Primary data were collected using GPS, while secondary data were collected from the governmental institution and satellite image. Satellite image resolution used was 12.5 m * 12.5 m. During this research, ten parameters were considered which were used to select suitable sites for municipal solid waste. They were: LULC, built-up area, geology, religious institution, soil, slope, road network, groundwater well, groundwater table, and surface water. These parameters were analyzed, pair-wise comparison, and weighted using GIS extension tool AHP. As the result indicated, the suitable area is about 566 ha (19.66%), moderate suitable is 432.8 ha (15.022%), low suitable is about 1830.58 ha (63.54%) and the unsuitable area is about 51.56 ha (1.79%) of the study area. The suitable sites selected for municipal solid waste disposal of Fiche town where: South, South-East, Northerner, and West parts of Fiche town. The area covered was: West direction about 7.28 ha (1.286%), South-East direction 175.42 ha (30.993%), North direction 171.55 ha (30.309%), and South direction 211 ha (37.42%) of the total suitable area. Those areas were far from the main road, built-up area, religious institution, surface water, and groundwater well. Also, the site had: basalt geology, vertosol type of soil, low depth groundwater (> 50 m), and low slope (< 10%). So, the selected site is suitable for solid waste disposal, because, economical, protects environmental pollution, and easily technical operation. Therefore, the selected sites were highly suitable for municipal solid waste disposal of Fiche town for the coming design year.*

Keyword. Geographical information system, Municipal Solid Waste, Site's selection

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ACRONYMS

AHP	Analytical Hierarchy Process
CSA	Central Statistics Agency
CR	Consistency Ratio
DEM	Digital Elevation Model
EPA	Environmental Protection Authority
GIS	Geographical Information System
GPS	Global Positioning System
IDW	Inverse Distance Weight
LULC	Land Use Land Cover
MSW	Municipal Solid Waste
MSWD	Municipal Solid Waste Disposal
OLI	Operational Land Imager
RS	Remote Sense
SWM	Solid waste management
GSE	Geological Surveys of Ethiopia
USGS	United States Geological Survey

1.INTRODUCTION

1.1 Background

Municipal solid waste management in the past and the current issue of the world. As the growth of population or expansion of urban increases the MSW disposal also increases (Cohen, 2006). Municipal trash deposits are higher in under-developing nations than in developed countries because waste control methods differ owing to differences in educated population and financial capacity (Thi, *et* al., 2015). Although they are challenged to control, the developed countries use different techniques to decrease the waste: change the input, change technology, change the system, and avoiding if not possible.

The one thing that just about every city council does for its people is solid waste management (Boadi and Kuitunen,2002). Even though the scope of operation, environmental effects, and costs differ significantly, solid waste management is undoubtedly the most significant public service and functions as a prerequisite for more public activity Municipal solid waste (MSW), one of the most crucial by-products of an urban lifestyle, is rising much faster than the urbanization rate (Hajar, *et* al., 2020). It is expected that rapid global population development, urbanization, economic growth, and an increasing middle class would lead to a corresponding rise in waste production in urban areas of the developing world (Srivastava, *et* al., 2015).

It is complicated by the open dumping nature of waste disposal, particularly in the urban area of most African cities (Yoada, *et* al., 2014). Administrations in African states have historically allowed unregulated dumping in empty landfill sites without sanitary landfills, creating enormous health problems (Thoso, 2007). Insufficient capital and data services for site selection and management are a major part of the issue. Most industrialized countries in Africa do not have an efficient solid waste management system due to a lack of effective governance, public commitment, planning, and technology. Several studies show that a great deal of municipal solid waste is generated in developing countries from households (55 percent - 80 percent), market areas (10 percent - 30 percent), and other institutions (10 percent - 30 percent). (Nabegu, 2010). The waste generation rate in Ghana is 0.47 kg/person/day and only 10% of solid waste produced throughout the country is properly disposed and 30-50 percent of residential waste is dumped near the street, in the drain, and the stream is not properly disposed of (Miezah, *et* al., 2015).

This study aims to analyze, identify and investigate ways to improve solid waste management programs in Ethiopia. Systematic literature reviews of journal articles, official reports, critical legal research, and policies are used to collect data. As research into the waste management system of a country with a better system was carried out to draw comparisons and identify areas of success, case studies provided in depth. For low-income countries, the medium waste generation is (0.32 kg/capita/day) was found to be below the maximum of waste generation. Organic biodegradables, which compensate for 67.4 percent, lead to waste (Gupta, *et* al., 2019). Popular practices are crude open dumping without pre-treatment and conventional open waste combustion. only 5% of waste is recycled in an unsafe informal way (Teshome, 2020). 3 I's (Irregular, insufficient, and ineffective) can be defined as the present waste management system, denoting erratic and inconsistent collection, poor coverage, technological frailties, and lack of law enforcement, respectively. Political will, institutional reform, finance, and most importantly change in behavior are necessary to ensure sustainable waste management (Teshome and Management, 2020). Ethiopia has been a regional leader in the treatment of solid waste in recent years. The Koshe dump site, the only landfill in Addis Ababa, was converted by the country last year into a modern waste-to-energy facility, the first such project on the continent. (https://www.google.com/ 01/01/2021)

1.2 Statement of Problem

In many countries characterized as urban and developing nations, proper management of municipal solid waste (MSW) is a serious problem. which can cause threats to the water-plant-animal-human environments, as a form of waste, typically contains plastic, food, scraps, mineral compounds, glass, paper, construction, and electronic waste, metals, and biological fractions, contributing largely to soil and water contamination by leachates (Vaverková,2019). When MSW comes into contact with water infiltrating via a landfill, leachates are produced. Leachate is a complicated combination of different contaminants, including harmful chemicals, soluble organic and inorganic chemicals, nutrients, and suspended particles (Boateng, *et* al., 2019).

The management of solid waste has been a major problem in Ethiopia. The high amount of solid waste production because of rapid population and construction activities is rising. Poor management and disposal of municipal solid waste posing numerous concerns such as the spread of pathogens, fire risks, odor nuisance, contamination of atmospheric and water, esthetic hindrance, and economic losses (Nikiema, *et* al., 2016).

Whenever most of our country towns had municipal solid waste disposal sites Fiche town hadn't. Choosing an area of disposal without empirical consideration causes various community hazards. All of the problems that came from the unproperly disposal of municipal solids were invited by the town. The people threw the municipal solid waste everywhere in open land, in stream in town, in the forest area, in the hill around, into the stadium, in the water body, in a ditch and unproperly burning without sorting or separating and without selecting the standard site. Those affect the town's economy, future/aesthetic, the health of the community, and the atmosphere of the town. However, this study was given attention to Fiche town to select suitable sites for municipal solid waste disposal to protect or decrease the challenges of unproperly disposal of municipal solid waste using Arch GIS and RS techniques.

1.3 Objective

1.3.1 General Objective

The purpose of the study was to select a suitable municipal solid waste disposal site using GIS and RS on Fiche town.

1.3.2 Specific Objectives

The specific objectives of the study are;

- To determine the weight of influencing parameters considered, to select suitable sites for waste disposal.
- To develop a thematic map of parameters to select suitable solid waste disposal sites using ArcGIS with RS
- To rank suitable disposal sites and select suitable sites.

1.4 Research Questions

- ➢ How to determine weight of influncing parameters considered to a select suitable sites for MSW disposal?
- ➢ How to develop a thematic map of parameters of the study area to select the best suitable site for MSW?
- ➢ How to rank the selected site and select suitable sites?

1.5 The Significant of Study

The study is to decrease the problem raised from the improper disposal of solid waste in the Fiche town. It will support the organization and individual to use the suitable selected sites for landfill of Fiche town that helps the State, population, developers, and other planners are keen to invest in Fiche town in various industries. So, they can invest in the Fiche town without polluting the environment. The community health issue created by solid waste minimises and the esthetic hindrance of the town will also decrease and also ecological damage due to solid waste will decrease. The environmental pollution caused by different sources in all solid waste should be protected.

1.6 Scope of The Study

The study is using ArcGIS and RS to select a suitable site for municipal solid waste disposal of Fiche town. The selection process considered: economic, and environmental parameters.

1.7 Limitation of The Study

The site selection criteria were established based on local legislation and literature.Owing to the unique characteristics of the research region parameters, some of the criteria are not integrated into the solid waste disposal site appropriateness due to a lack of data.

2.LITERATURE REVIEW

2.1 Municipal Solid Waste Production and Its Catalog in The World

Municipal solid waste is generating from different sources. They are point or non-point. Point is the waste which is generated from the specific point such as Industrial area, town, government, and non-government institution. non-point source of solid is the waste which generates from the nonspecific point, for example, agricultural area, from forest, erosion(Joshi and Joshi, 2012).

The configuration of MSW is highly complex and defined by many factors Increased inorganic material intake (such as plastics, and metals) contributes to urbanization. According to a World Bank analysis, 1.3 billion tons of garbage are created globally each year. This figure is expected to rise to 2.2 billion tons by 2025 (Bishoge, *et* al., 2019).

2.2 Municipal Solid Waste Production and Its Catalog in Ethiopia

The amount of waste generated in Ethiopia ranged from 0.17 to 0.48 kg/person/day for urban areas to about 0.11 to 0.35 kg/capita/day for rural areas (Hailu, *et* al. 2019). The range depends on several factors such as income and season. The total generation of municipal solid waste in Ethiopia in 2003 estimated was 2.8 to 8.8 million tons (Rajaeifar, *et* al., 2017). In 2000, the population was 63.5 million; the current population is more than 100 million, the second-largest in African countries next to Nigeria.

2.3 Municipal Solid Waste Production and Its Catalog in Fiche Town

Fiche town population according to Ethiopian statistic census 2007 is about 27,493 and estimated by 2016 is about 42,334. The number of population increasing rapidly, population growth cause for solid waste generation increases and it is unproperly disposal. The town is being the well-known town in the country and its population was increasing from time to time and showing impressive economic growth. One of the swiftly urbanizing centers in Ethiopia has been grappled with an increasingly growing urban waste management problem. The combination of municipal solid waste in the Fiche is inorganic: plastic, metal, ,and Biomedical wastes such as syringes, gloves, glucose materials from hospitals, clinics, and other health care wastes are dumped in different areas of the town. And organic solid waste area scraps food from domestic, Salale university, hotels, commercial areas, and coconut industries.

2.4 Solid Waste Management

Waste management is the monitoring, collection, transportation, processing, or disposal of waste. As urbanization increase, solid waste becomes a major public health and environmental threat in urban areas (Joshi and Ahmed, 2016). Most developing countries in the world use inappropriate handling and disposal of municipal solid waste that leads to environmental degradation, i.e., air pollution, soil contamination, surface and groundwater pollution(Taiwo and Technology, 2011). To control the generation, storage, collection, transfer and transport, processing and recovery, and final disposal of solid wastes in a manner that the term usually relates to materials produced by human activity and to reduce its effect on health, the environment.

2.5 Solid Waste Management in The World

Solid Waste Management (SWM) is one of the main utilities presently attracting universal interest from many developing countries on the urban agenda. An absence of appropriate SWM could lead to environmental health threats and harm the environment. It reaches beyond the city's territorial borders or cities. The most noticeable source of environmental destruction in most cities and towns in the developing world is poor management and disposal of solid waste, i.e. air pollution, soil contamination, pollution of surface and groundwater which is resulting from excessive disposal of municipal solid waste(Forman, 2014).

2.6 Solid Waste Management in Ethiopia

The processing of solid waste management in Ethiopia has negative environmental and public health consequences. The rapid expansion of urbanization, manufacturing operations, agriculture, and population growth has created vast amounts of solid waste that pollutes the environment and affects the issue of public health. Due to changing economic conditions and rapid urbanization, the disposal of MSW in developing countries is difficult (Marshall and Farahbakhsh, 2013). In addition, urban waste management has become a problem for communities and urban councils in developing countries because of inadequate infrastructure, procedural experience, and the limited institutional ability of municipalities (Kirama and Mayo, 2016). In Ethiopia, rapid urbanization with an increasingly urban population over the last decade has had an impact on the increase in the quantity of solid waste, which has placed massive pressure on municipal resources, especially in solid waste management (Hailemariam, *et* al., 2014). The per capita quantity of waste produced in

Ethiopia ranges from 0.17 to 0.48 kg/person/day for urban areas to approximately 0.11 to 0.35 kg/capita/day for rural areas (Birhanu, *et* al., 2015). Generally, solid waste generated in most of Ethiopia is generated from towns and cities not properly disposed of.

2.7 Municipal Solid Waste Management in Fiche Town

Fiche town hadn't municipal solid waste management system and collection system in the town. All the organic and inorganic waste whether from government or non-government institutions collected the municipal solid waste in their compound and improperly burn. Also, domestic waste is handed the same way but most case and dumped to flowing water body, open land, and on the street.

Non-degradable components are plastics, textiles glass, metals, and construction activities consisting of sands, soil stones, metal, and cement concreteare also observed in the town. Such wastes are not properly managed that are disposed of improperly way, outside in streets and open areas. Biomedical wastes such as syringes, gloves, glucose bag and accessaries from hospitals, clinics, and other health care wastes are dumped in different areas of the town. Therefore, since it is hazardous waste, it should be dumped in the selected areas and managed carefully.

2.8 Amount of MSW Generate in Fiche town

When urbanization growth the supply also increases which lead to the amount of waste generated. Fiche town population according to Ethiopian statistic census 2007 is about 274,93 and today around 65000 (Sebsibe, I., *et* al.,2021). Therefore, the amount of solid waste generated is calculated from standard. The amount of solid waste generated in urban Ethiopia ranges from 0.17 to 0.48 kg/person/day. So, the average is 0.325 kg/person/day. Therefore, the amount of solid generate per day of Fiche town is:

0.325 kg/person/day * 65000 person=21125 kg/day.

2.9 Site Selection Guidelines

Suitable landfill siting involves a rigorous assessment process. The selected locations must comply entirely with the standards of current government legislation and must reduce environmetal, financial, health, and social risks at the same time. They should be placed away from private or public drinking, irrigation, or livestock drinking water wells down-gradient of the landfill boundaries to prevent the impact of contamination of groundwater and leachate movement, no housing area is adjacent to the perimeter of the site boundary, soils that have poor resistance, no environmentally significant wetlands of significant biodiversity, no private or public drinking, irrigation or livestock water supply wells down-gradient of the landfill boundaries (Rushbrook and Pugh,1999).

Landfill site requirements are crucial considerations that need to be addressed before determining the suitability of the landfill site. A landfill must be built following specific laws, legislation, factors, and restrictions that differ from location to location or from country to country to be economically and environmentally suitable. The specific rules, regulations, factors, and constraints must cover geomorphology, land value, slope, and proximity to recreational areas. Water supplies, surface water, vulnerable habitats, urban centers, hills, cultural areas, roads, and land use land cover are requirements for specifying the best landfill site (Tercan, *et* al. 2020)..

2.10 Parameters that Affect Sites Selection

During sites, select different parameters were considered. The different variables that directly or indirectly affect the sites selection play a great role in determining the suitable municipal solid waste site. Proper parameters were considered which directly connect to, economic, and environmental.

2.10.1 Ground Water Depth

Groundwater directly affects the solid waste disposal sites because when the groundwater level, it can be infiltrated and easily mixed with physical-chemical and biological parameters of the waste and dissolve some solid (Samadder, *et* al., 2017). Therefore, processes interact simultaneously to bring about the overall decomposition of the wastes. Some material perhaps decomposed by bacterial and formed leachate and mixed with ground easily.

Groundwater pollution is caused by the presence of undesirable and hazardous material and pathogens beyond certain limits (Yates, 2007). Much of the pollution is due to anthropogenic activities like the discharge of sewage, effluents, and waste from domestic and industrial establishments.

Landfills have been identified as one of the major threats to groundwater resources. Waste placed in landfills or open dumps is subject to either underflow or infiltration from precipitation. Areas near landfills have a great possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resources poses a substantial risk to local resource users and the natural environment. Groundwater if once it is contaminated it is difficult to restore the original water, degrades water quality producing an objectionable taste, odor, and excessive hardness so it is irreversible.

2.10.2 Soil Type

The soil type directly affects the site selection of municipal solid waste because during rain time the decomposed waste is directly dissolving with flowing water and passes to open land which means to groundwater. The soil type which easily exposed for leachate not good for the municipal solid disposal site.. Mostly clay soil is favorable because it can hold water or protect leachate (Nanda and Berruti, 2020).

2.10.3 Slope

Slope is one of the major parameters to select a suitable site for municipal solid waste. Because when the land sitting is hill/cliff area it is costly and takes time during construction and technical operation time. Also, can easily form downstream during rain time and has a greater chance to mix with groundwater,surface water, farm area, to town direction which causes environmental degradation, and health problem. Therefore, the standard Slope for solid waste landfill sites is less than 10%. Set areas with a slope between 15% to 20% moderate for landfill ((Barakat, *et* al., 2017). Akbari *et* al., (2008), stated that modest slopes enable easier stormwater control, leachate control, and site stability measures, as well as facilitating the operation of the site.

2.10.4 Surface Water.

Urban solid waste landfills produce a lot of environmental emissions due to the combustion of landfill gas, leaching of leachate, and foul smells (Swati, *et* al., 2018). Recently, several cases have been reported around the world related to pollution of water bodies which were caused by municipal solid waste landfills. The production and usage of heavy metals such as copper, cadmium, and zinc have increased substantially over the years (Wuana and

Okieimen, 2011). The excess quantity of heavy metals disposed of on the land can cause significant damage to the environment and human health as a result of their mobility, solubility, and their ability to transfer in water or plants (Mishra, *et* al., 2019).

The surface water means the flow of water directly on the earth, streamflow, river, lake, and runoff (Worqlul, *et* al., 2015). When the selected site for municipal solid waste is near-surface water, it has a great chance to pollute the water body.

2.10.5 Land Use Land Cover

Land cover describes the physical state of the earth's surface and immediate subsurface in terms of the natural environment (such as vegetation, soils, and surfaces, and groundwater) and the man-made structures (e.g., buildings) and the term Land use itself is the human employment of a land-cover type(Kawy and Abou El-Magd, 2013). Site selection analysis aims to identify the best site for some activity given the set of potential (feasible) sites therefore land-use suitability analysis aims are to identify the most appropriate spatial pattern for future land uses according to specified requirements, preferences, or predictors of some activity. Land use land cover contains bare land, built up rea, an agricultural area, water body (Wijitkosum and Research, 2012).

2.10.6 Sensitive Area

Landfills should typically be avoided in regions where sensitive natural ecosystems might be harmed such as significant wetlands, inter-tidal areas, significant areas of native bush including the forest, recognized wildlife habitats, national/regional and local parks, and reserve lands (for example, cemeteries) and any areas where the release of contaminants from the site could severely affect fish/wildlife/aquatic resources and sites of historical or cultural significance (Kennish, 2002).

2.10.7 Geology

The decomposition of solid waste materials in sanitary landfills produces liquids and gases which are deleterious to human beings, animals, plants, and inorganic geologic materials(Hagerty and Pavoni, 1973). The infiltration capacity, permeability, filtering capability, and absorption potential of the rock at a location are all considered in the evaluation system. (Rahman, *et* al., 2015). Use of the site-evaluation system will improve the quality of site selection and will reduce contamination and pollution problems created by the construction of refuse landfills at unsuitable locations.

2.10.8 Ground Water Well (bore well)

Groundwater is one of the main sources of drinking water. So, it should be better to control groundwater from contamination. The distance municipal solid waste should be far from groundwater well. Also, the downstream should blow the municipal solid site. When the downstream and groundwater are at the same level the distance between them should be greater than > 2500 m (Winter. 2007).

2.10.9 Road Network

Road networks play grate role in municipal solid waste disposal sites. The landfill site is not so far away from the main road and not so close to the main road. Because when far away from the main road it takes time and cost during dump the municipal solid waste also, if near to main road cause odor and unnecessary smell to the community which leads to public health problem(Yukalang, *et* al., 2017).

2.10.10 Built Up Area

Building up areas may be governmental or non-governmental institutions and residential buildings. The municipal solid waste site should far away from this it pollutes the environment and causes health problems.

2.11 Application of ArcGIS

According to Whitish (1977), Remote Sensing involves all ways of collecting pictures or other means of electromagnetic records of the Earth's surface from a distance, as well as the handling and processing of the picture data (Rees, 2013). Remote sensing, in its broadest sense, is concerned with observing and tracking electromagnetic radiation from target locations in the sensor instrument's field of view. Furthermore, its multispectral functionality offers sufficient comparison between different natural features while its repeated coverage provides detail on the complex changes occurring across the earth's surface and natural climate (Dalla Mura, *et* al., 2015).GIS is a versatile technology that can combine various forms of spatial data and conduct several spatial analyses (Jia, *et* al., 2017). It is used to identify environmentally friendly and suitable solid waste and landfill sites. GIS, in particular, used to display, understand, query, analyze, and imagine massive amounts of spatial and nonspatial data in a variety of ways, revealing associations, patterns, and developments in the form of maps, papers, and charts, which would be crucial for critical decision making (Çöltekin, *et* al., 2009).

The use of GIS in the identification of a possible landfill site saves time and improves precision because it allows for the easy capture, storage, and management of spatially referenced data, it allows for the study of spatially referenced input data, it allows for the extraction or classification of spatial features when looking for appropriate locations, it allows for the communication of model outcomes, and it is used in the selection of solid waste site (Gregory and Ell, 2007). It is often presumed in GIS-based land-use suitability analysis that the research field is partitioned into sets of polygons or raster data sets, which are the essential units of observant (Casado-Arzuaga, *et* al., 2014). Satellite remote sensing data and Geographical Information System (GIS) is an intelligent system.

3.MATERIAL AND METHODS

3.1 The Study Area

3.1.1 Location

Fiche is one of the towns of the Oromiya National Regional State, which is located Northerner of the region and 114 km from the capital city of the country. It is the administrative center of the North Shewa Zone of the Oromiya National Regional State and has separate woreda. Fiche town exists between latitude and longitude of 9°764N'-9°812′N and 38°718′E-38°755'E respectively (Figure 3.1) and an elevation of about 2738 m from sea level and the number of populations is around 65000 (Sebsibe, I., *et* al.,2021).

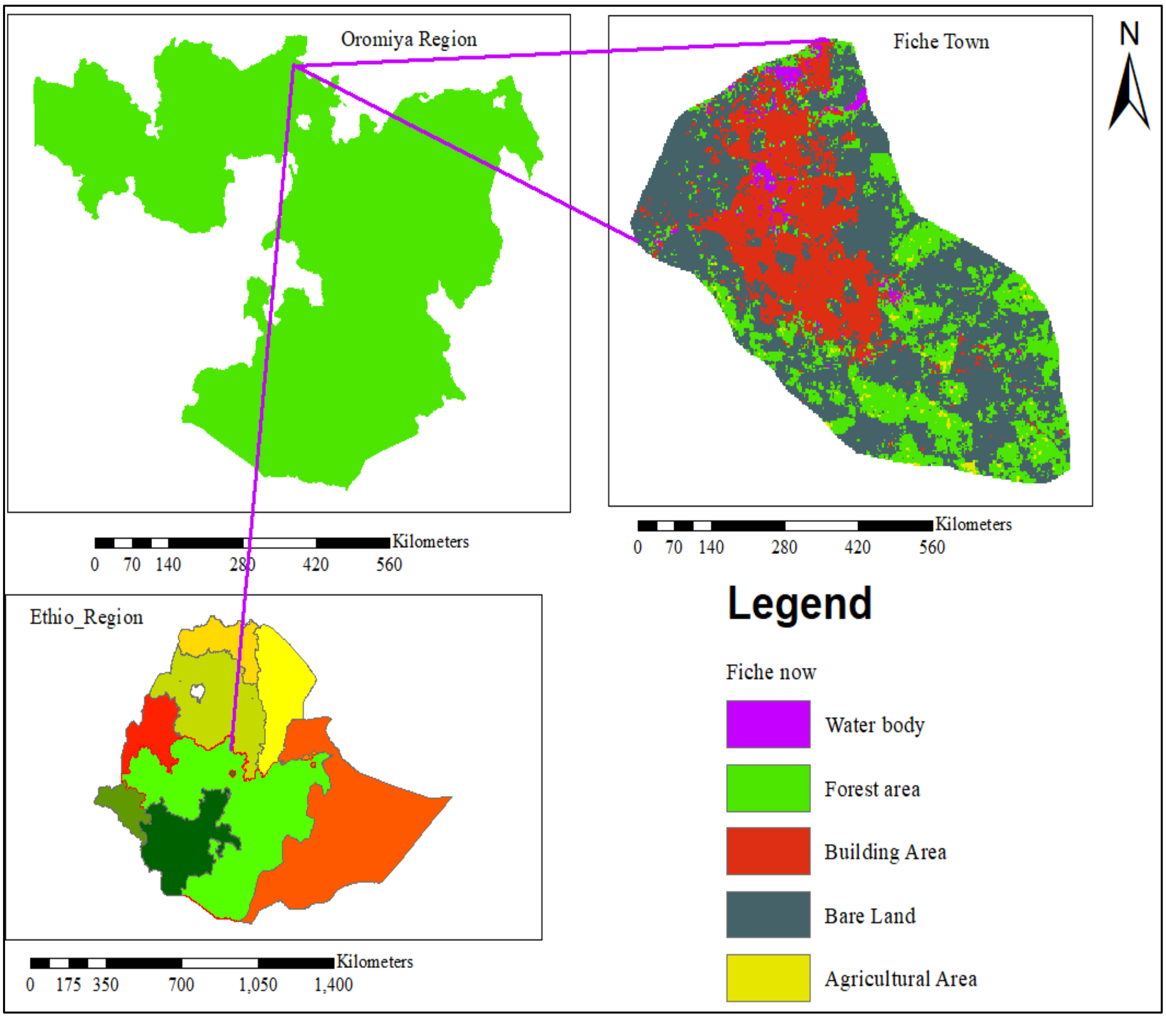

Figure 3.1: Map of the study area

3.1.2 Climate

The zone has heavy rain from June to September and the left months are almost dry season (https://www.google.com/search 1/23/2021). During the rain time, the runoff water collects the waste of the town and mix to the river found around, which danger for the life. The temperature is very high in march (25 ℃) and low temperature (7℃) in December (Belachew, T.A. and Ababu, D.G., 2021). According to Ethiopian local climate classification, the town falls within Wein Degas climatic conditions. Heavy rain occurs in, July and August with precipitation greater than 240 mm, and low rainfall occurs during January and December with average precipitation less than 60 mm.

3.1.3 Topography

The topography of the town is consisting of hills, gentle slope areas, and streams. The elevation of the town is about 2738 m above sea level (Demewoz, Woreta, *et* al.,2017). It has uniform elevation and has a gentle (flat slope) from east to west and elevation is an increase from South-North. But also, there is a hill in the North-West direction of the town.

3.1.4 Geology

The decomposition of solid waste materials in sanitary landfills produces liquids and gases which are deleterious to human beings, animals, plants, and inorganic geologic materials ((Ireaja, *et* al., 2018). The characteristics of the soil and rock at a site are included in the evaluation system through assessment of their infiltration potential, permeability, filtering capability, and absorption potential (Aladejana, *et* al., 2016). The characteristics of the groundwater at a site are taken into consideration through assessment of the substrate potential, buffering capacity, and distributive potential (for contaminants). Use of the site-evaluation system will improve the quality of site selection and will reduce contamination and pollution problems created by the construction of refuse landfills at unsuitable locations. The Fiche town geolog system is uniform and all the towns covered by Aib Basalt which less permeable (Binici and Aksogan,2018).

3.1.5 Soil

The soil type of Fiche town, North Shewa zones are Vertosols and Leptosols. Vertosols are covered most of the Fiche town and heavy clay soil with a high proportion of swelling clays and it is hard in the dry season and sticky in the wet season. It has a high-water holding capacity. It has a 2.5 mm/hr infiltration capacity (Megersa, 2020).

Leptosols are a course and high texture material derived from a wide range of rock, mostly from old rock and large years over layers decomposed materials (Quesada, 2011). They are found in the west part of the town. It is widely used in a variety of agriculture and the steepy land mainly used for grazing and forestry. This type of soil has no stability and poor water holding.

3.2 Study Design

This study was used GIS and RS techniques to select suitable solid waste disposal sites in the Fiche town. Independent data from different organizations and satellite images were collected for this research. Different parameters were considered for selecting appropriate municipal solid waste disposal sites: slope type, geology, soil, groundwater depth, LULC of the town, groundwater well, surface water, road network, religions institution, and structural plan of the town. The study area parameters are categorized into two: Economical, and Environmental. The categorized parameters were, analyzed, reclassified, and overlay weight use AHP, and then determined suitable sites. Detail explained in Figure 3.2.

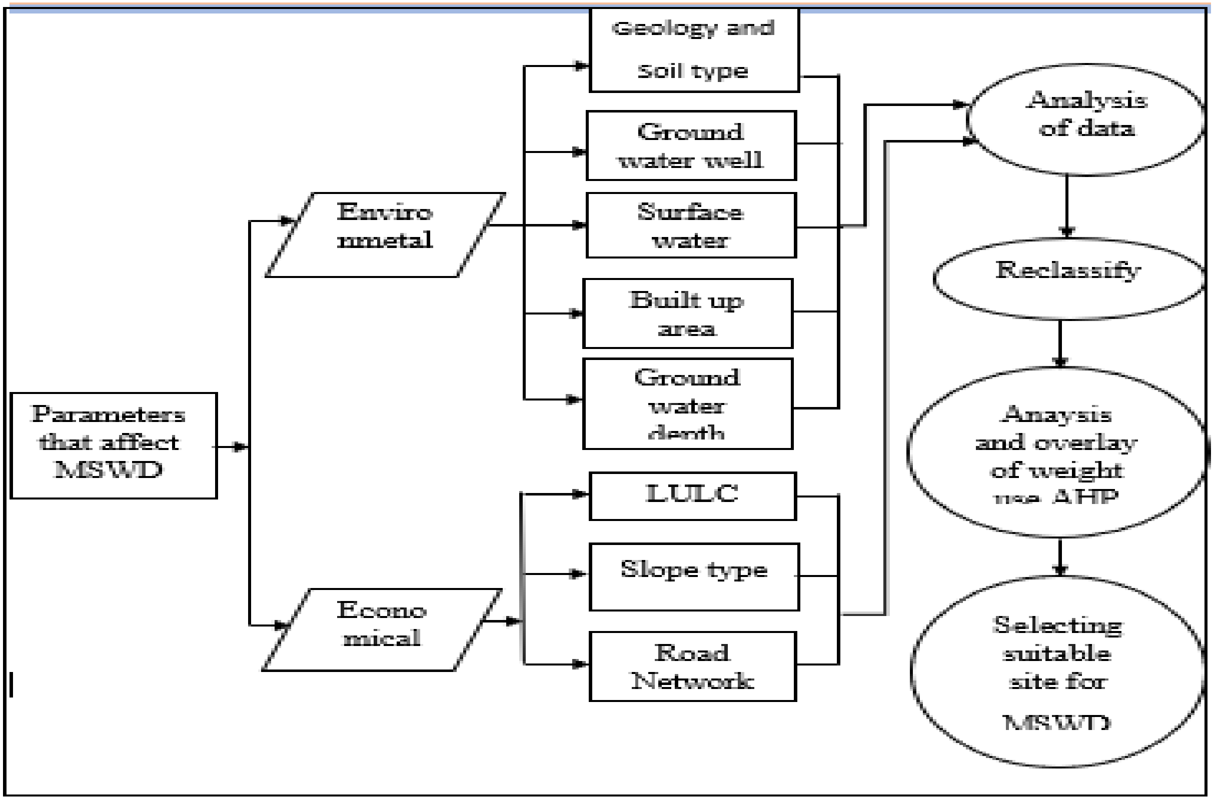

Figure 3.2: Study design

3.3 Study Variables

3.3.1 Dependent

The dependent variable was predicted solid waste disposal sites and it is called dependent since its value depends on the value of the independent parameters. Therefore, the dependent variable of this study was to select suitable sites for solid waste disposal sites.

3.3.2 Independent Variables

The independent variables are the variable that is adjusted or tracked in a statistical experiment to measure the effect of the predictor variables on the basic intent of the study. The independent variables are distance to the main road, soil, land use land cover, lithological formation, distance to the built-up area, distance to the religious institution, distance to surface water, distance to groundwater well, groundwater depth, and slope.

3.4 Data Collection and Data Type

To accomplish the object of this research primary and secondary data were used. Primary data were gathered via a GPS-enabled field survey of the research area, and secondary data were gathered from satellite imagery and government agencies. The data used for this study were, Geological map (2008) were collected from the Geological Survey of Ethiopia, Soil map (2013) were collected from the Ethiopia mapping agency, structural plan of study was collected from North Shewa Zone Urban Development Office. Landsat 8 Operational Land Image (OLI) of March 2021 was acquired for the Fiche town land cover/land-use survey. The OLI picture is used to assess the available area that could be used as a possible location for the MSW landfill. Landsat 8 (LULC) OLI image study area is acquired from US Geological Survey (USGS).and Slope data of the study area is acquired from Ethio-DEM. They are illustrated in Table 3.1.

Table 3.1: Data source and resolution

Data type	Source	Resolution in meter
Landsat 8 OLI	USGS	12.5 * 12.5
Slope	Ethio-DEM	12.5 * 12.5

3.5 Software and Tools

The tools/software used for this study is ArcGIS 10.3.1 used for digitizing, buffering, reclassifying, overlaying, and identifying suitable disposal sites.

3.6 Data Analysis

In this study, integration of GIS and parameters were used to identify appropriate solid waste disposal site areas in Fiche town. GIS and RS methods are recommended for sitting landfills because they are powerful and integrated tools that can solve the problems that arise in landfill site selection (Mat, *et* al., 2017).

3.7 Criteria for Selecting Potential Landfill Site

Identifying the best possible landfill sites possible is to be in position that satisfies the criteria of government legislation and minimizes financial, health, and social costs. The parameters considered were: surface water, slope, geology, built-up area, main road, wells, soil, land use cover, religious institution, and groundwater level. Environmental parameters and economic criteria plays a great role (Chang, *et* al., 2008). The landfill suitability categories were done on several levels, with the assigned grade ranging from most acceptable to unacceptable, and the reclassification was marked by the rating method of 1,2,3,4 where 1 corresponds to unsuitable, 2 low suitable, 3 moderate suitable, and 4 high suitable. (Kapilan and Elangovan, 2018).

3.8 Buffering

A buffer can help with proximity (nearness) analysis. Buffer is a region that drowns around some point, line, or polygon and covers all of the areas within the feature's defined width(Garcia, 2010). In landfill site selection it was carried out for generating areas in a given distance around the specified criteria. The buffering analysis was carried out for surface water, road networks, built-up area, Religion institution, and groundwater well.

3.9 Weight to Evaluation of Factors

Giving weight to evaluation requirements a weight is defined as a value assigned to an evaluation parameter that indicates its importance in comparison to other parameters under consideration (Ali, *et* al., 2009). AHP is one of the best software to compare the parameters and determine the most faced to environmental (Kassar, *et* al. 2008). It is also generally agreed on a decision-making approach for assigning weights to the chosen parameters, which is one of the challenges faced during a multi-criteria judgment study since it is efficient to weight assigning tool and lists the selected places among the most suitable locations (Zhang and Haapala, 2015).

The weights of the parameters were determined using a comparison of scales of 1-9. (Satyr, 1998) indicates that the score of, 1 is of similar significance, 3 is of modest importance, 5 strong, 7 very strong and 9 extreme importance, 2, 4, 6, and 8 are intermediate values and fractions from 1/9 to 1/2 representing the importance of one factor against another in the pair.

Table 3.2: Scale of Comparison (satty,1998)

Scale	Definition	Explanation
1	Equaly important	Who activities contribute equally to objective one
3	Moderaty important	Experience and judgment slightly favor one activity
5	Strongy important	Experience and judgment strongly favor one activity over another
7	Very strongly important	n activity is strongly favored, and its dominance is demonstrated in practice
9	Extremely important	The evidence favoring one activity over another is one of the highest possible order.
2,4,6,8	Intermediate values between the two adjacent judgments	When a compromise is needed

The first step in AHP is a pair-wise comparison matrix is developed after comparing two factors at a time using a scale of 1 to 9 illustrated. The second step is to calculate the weight, which has been obtained by taking the principal eigenvector of a square reciprocal matrix of pairwise comparisons between the parameters. The higher weight has a great impact on the selection of landfill disposal sites. The last significant factor in AHP is the consistent ratio (CR), which was measured to ensure that decision makers' comparison of parameters was consistent. To determine which, one is the most consider among the parameters for municipal solid waste disposal site selection different researchers give different values(weighting). These are considered the high influence parameters to determine the suitable sites for the MSW disposal site. This depends on the weight of parameters already determined by different researchers. It is illustrated in Table 3.3.

Table 3.3: weightings of parameters from different journals

Source	Parameter									
-	LULC	GE	SL	SO	GWW	GWD	SW	BA	RN	RI
(Abate and Goshu, 2017)	32.1	-	2.4	-	-	-	4.93	-	7.3	-
(Ersoy, Bulut, *et* al. 2009)	3.3	7.4	8.7	-	-	-	-	-	5.4	1.7
(Kamdar, Ali, *et* al., 2019)	7.1	-	4.4	9.7	-		15.5	-	2.6	-
(Abuabdou, Ahmad, *et* al., 2020)	-	-	10		15	5	10	-	10	-
(Eskandari, Homaee, *et* al., 2015)	20	-	-	6.7	14.4	-	14.4	-	10	-
(Sashakkuma n and lalwin,2012)	25	22	-	18	-	-	-	-	-	-
(Jayanthi, Emenike, *et* al., 2017)	-	7.5		-	14.4	13. 3	13.3	-	2.4	-
(Issa, Shehhi, *et* al., 2012)	-	15	10	-	15	15		-	10	10
(Birhanu, Berisa, *et* al., 2015),	-	-	-	_	_	_	18	20	20	-
(Ngumom, Terseer, *et* al., 2015)	-	-	-	-	-	-	22.2	16.7	2.78	-
Average (%)	17.5	12.98	7.1	11.5	14.7	11.1	14	18.4	7.8	5.9

LULC=land use land cover, GE=geology type, SL=Slope type, SO=soil type, GWW=ground water well, SW= surface water, BA=building area, RN=road network and RI=religion Institution. This study is considered the guidelines and different researchers who have stated the priority for which need priority among the parameters. The average weight given for each parameter is the amount of influence on the environment (Table 3.3). The pair-wise comparison for this study has done how much influence each parameter on the environment to select suitable sites for MSWD (Table 3.4).

Table 3.4: Pair wise comparison matrix

Parameters	LULC	GWW	SW	BA	SO	GE	GWD	RN	SL	RI
LULC	1	3	5	5	5	5	7	7	7	9
GWW	1/3	1	3	3	3	3	5	5	5	9
SW	1/5	1/3	1	2	2	2	3	3	3	7
BA	1/5	1/3	1/2	1	2	2	3	3	3	5
SO	1/5	1/3	1/2	1/2	1	2	3	3	3	5
GE	1/5	1/3	1/2	1/2	1/2	1	3	3	3	5
GWD	1/7	1/5	1/3	1/3	1/3	1/3	1	2	2	5
RN	1/7	1/5	1/3	1/3	1/3	1/3	1/2	1	2	3
SL	1/7	1/5	1/3	1/3	1/3	1/3	1/2	1/2	1	3
RI	1/9	1/9	1/7	1/5	1/5	1/5	1/5	1/3	1/3	1

After input, this pairwise comparison data into extension tool AHP, its analysis the parameters, output their weight, calculate the Cr value and generate a map of the suitability. For this study, the Cr value is about 0.0463 which is less than 0.1, So the pair-wise comparison is correct and acceptable. The result is calculated by the formula of (Satt, 1980). Those equations are: λmax equation,3.1, consistency index equation,3.2, and Consistency ratio equation is 3.3 which value is 0.0463.

$$\lambda\text{max} = \frac{\text{average ratio}}{\text{n}} \tag{3.1}$$

$$\text{CI} = \frac{\lambda\text{max}}{\text{n}-1} \tag{3.2}$$

$$\text{CR} = \frac{\text{CI}}{\text{RI}} \tag{3.3}$$

CR=0.0463 < 0.1

Where n is the total number of elements being compared. CI is the consistency index of a randomly generated pair-wise comparison matrix, the value of RI varies with nunmber of parameters (Table 3.5). (Satty, 1998) State that if CR ≤ 0.1, it is acceptable but if CR > 0.1, it is not acceptable and need revise.

Table 3.5: Random Inconsistency Indices (RI) For n= 10 (satt,1980)

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

The consistency ratio of the developed matrix is 0.0463 which is less than 0.1. Therefore, it is an acceptable reciprocal matrix. The higher weight has a high influence on the selection of landfills. Hence, for this study built-up area and LULC have a high percentage of weight, that indicates they have a great percentage of influence for selection of landfill site as shown in Table 3.6.

Table 3.6: Criteria weight

Parameters	Weight	Weight in percent
Built up area	0.33466	33.466
Land use land cover	0.19143	19.143
Groundwater well	0.1088	10.88
Distance from surface water	0.09024	9.204
Geology type	0.08017	8.017
Soil type	0.06982	6.982
Groundwater Depth	0.04272	4.272
Slope type	0.03449	3.449
Distance from the main road	0.03004	3.004
Religion institution	0.01584	1.584
Summation	1	100

4.RESULTS AND DISCUSSIONS

4.1 Determinants of Suitable Solid Waste Disposal Site Selection

4.1.1. Soil Suitability

Soil is one of the parameters that affect landfill (MSWD) site selection. Landfill sites should not be sited in the area with high permeability soil to minimize the risk of leachate movement (Abd El-Salam and Abu-Zuid, 2015). Therefore, clay-rich environments are the most preferable sites. There are two types of soil found in the study area. Pellic Vertosol and Leptosols (Figure 4.1).

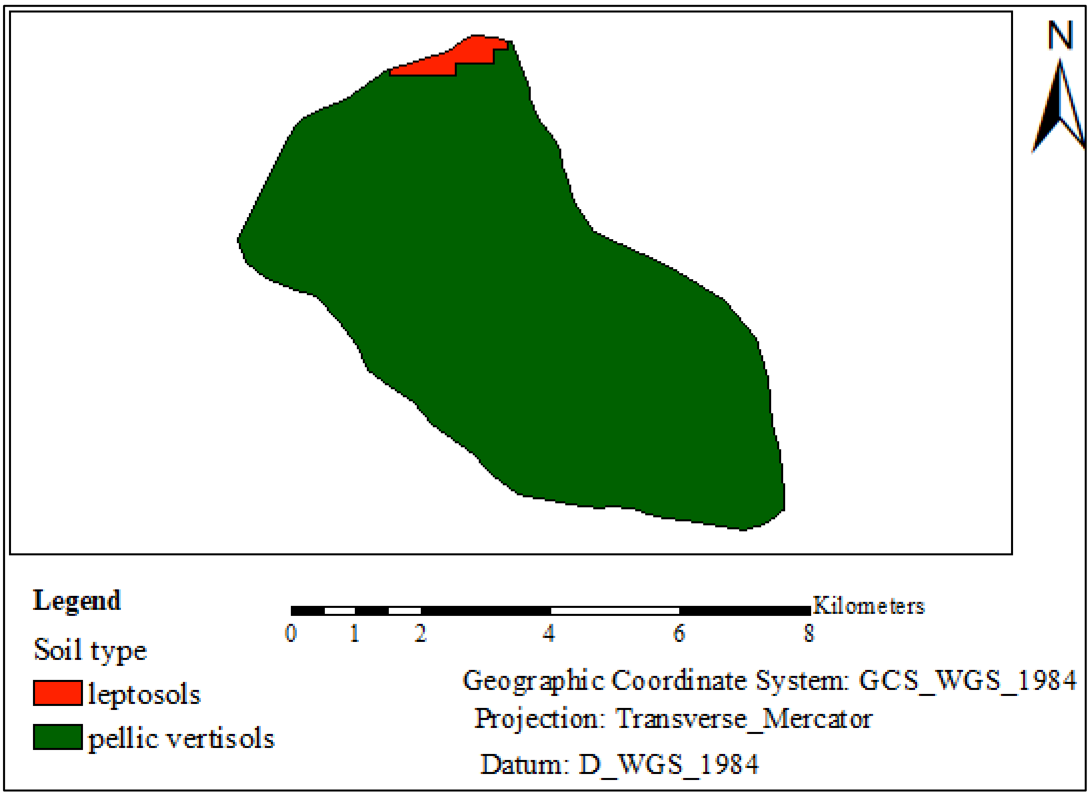

Figure 4.1: Map of soil type

The pellic vertosols have covered most of the study area (98.49%). Since it is clay soil and has low permeability for decomposition leachate organic, and inorganic material by physical, chemical, and biological reaction (Winkler, P., *et* al.,2016). The Leptosols have a grave mix which had high permeability of decomposed material and coverage area is less which means 1.51% of the study area Table 4.1. The suitability of soil is explained in Figure 4.2.

Table 4.1: Soil type, suitability, and their percent coverage

Type of soil	permeability	Suitability	Area		Rank	Weight %
			ha	%		
Pellic Vertosols	Very low	High	3423	98.49	4	6.982
Lepton soils	High	Less	52.47	1.51	1	6.982

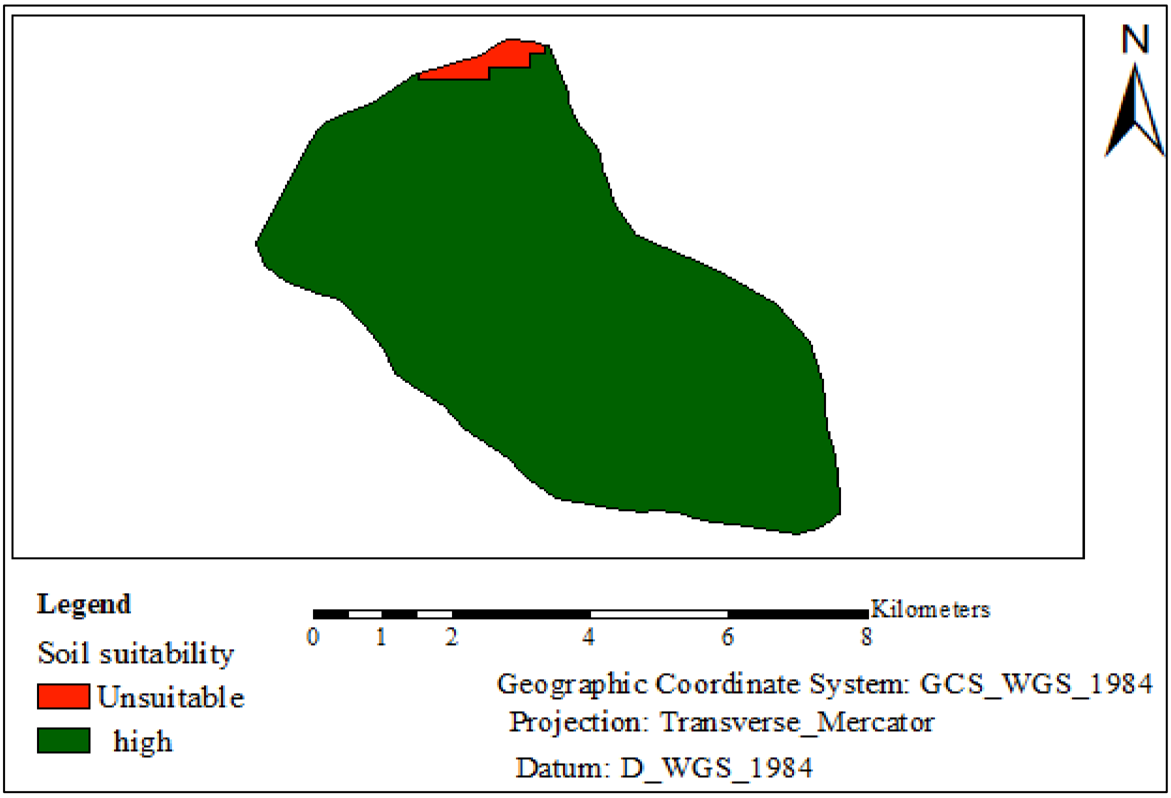

Figure 4.2: Map of soil suitability

4.1.2 Geology Suitability

Geology is a vital factor to consider when selecting a landfill site. The structure of lithology formation influences the movement of leachate. The study area of geology type is uniform according to Ethiopian geological servey data which is Aiba Basalt (Figure 4.3). Aiba Basalt is a type of geology which have Low permeability (Tafesse and Alemaw, 2020). Basalt is suitable for municipal solid waste disposal to protected leachate. Since it has low permeability, it protects the leachate which pollutes groundwater. The suitability of geology is illustrated in Figure 4.3 and all the study was covered by uniform geology type (Table 4.2).

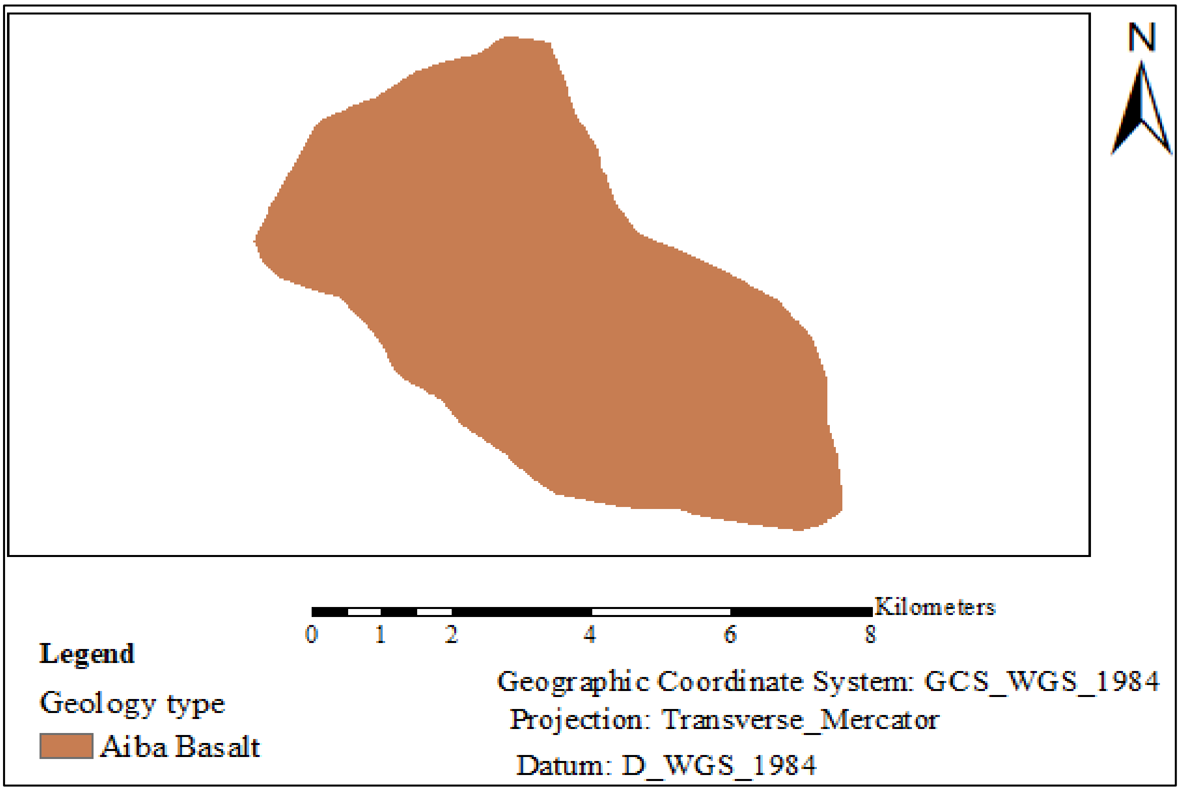

Figure 4.3:Map of geology type

Table 4.2: Geology area coverage, rank, weight and suitability, and permeability

Geology type	Permeability	Suitability	Area		Rank	Weight %
			ha	%		
Aiba basalt	Low	High	3460	100	4	8.017

4.1.3 Slope

According to Akbari et al. (2008) and Senser et al. (2011), the slope of the land with 0-10% extremely appropriate, 10-15% moderately suitable, 15-20% low suitable, and >20% unsuitable. Therefore, slope of study area is classified two four: 0-10%,10-15%,15-20% and > 20%. The lower slope is the most favorable due to safe costs during landfill construction and operation. Figure 4.4 illustrates the slope's type and categorized map.

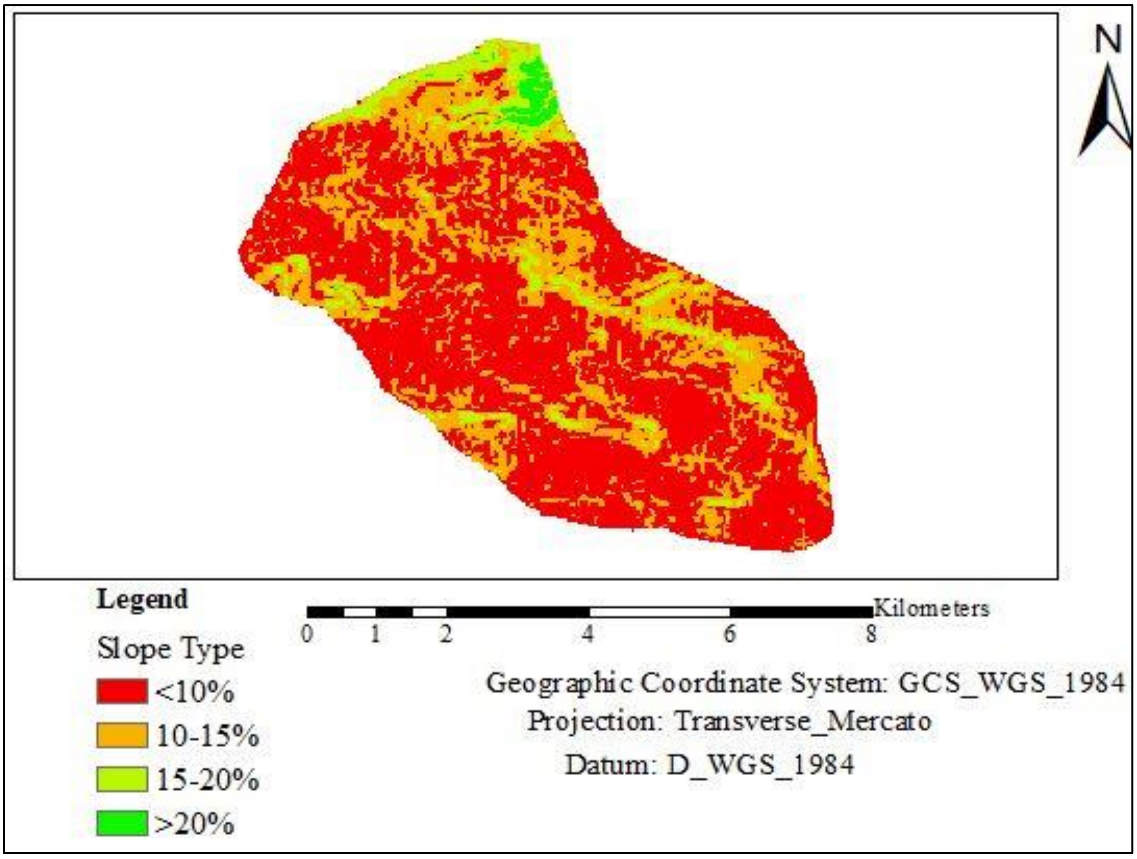

Figure 4.4: Reclassified map of slope type

The slope between 0-10% highly suitable and covers about 50.4% of the total area and the unsuitable slope is > 20% which covers about 1.95% of the total area, whereas 10-15% and 15-20 % are moderate and low suitable respectively (Table 4.3). So, the place which has a high slope is not good for landfill because it is very steep which is difficult during construction and needs high cost whereas an area with less slope is suitable for landfill. According to the result, the high suitable covered high percent (50.4%) had a < 10 % slope of the total area whereas unsuitable coverage is about 1.95% of the total study area had a slope > 20%. So, for the present waste generated and future projection will this area sufficient for the solid waste that would be generated. The suitability of each level illustrated in Figure 4.5.

Table 4.3: Slope Area Coverage, rank, weight, and Its suitability

Slope percentage	Suitability	Area		Rank	Weight
		ha	%		
< 10 %	Highly	545	50.4	4	3.449
10 -15 %	Moderate	370.53	34.3	3	3.449
15 -20 %	Low	145.93	13.5	2	3.449
> 20%	Unsuitable	21.03	1.95	1	3.449

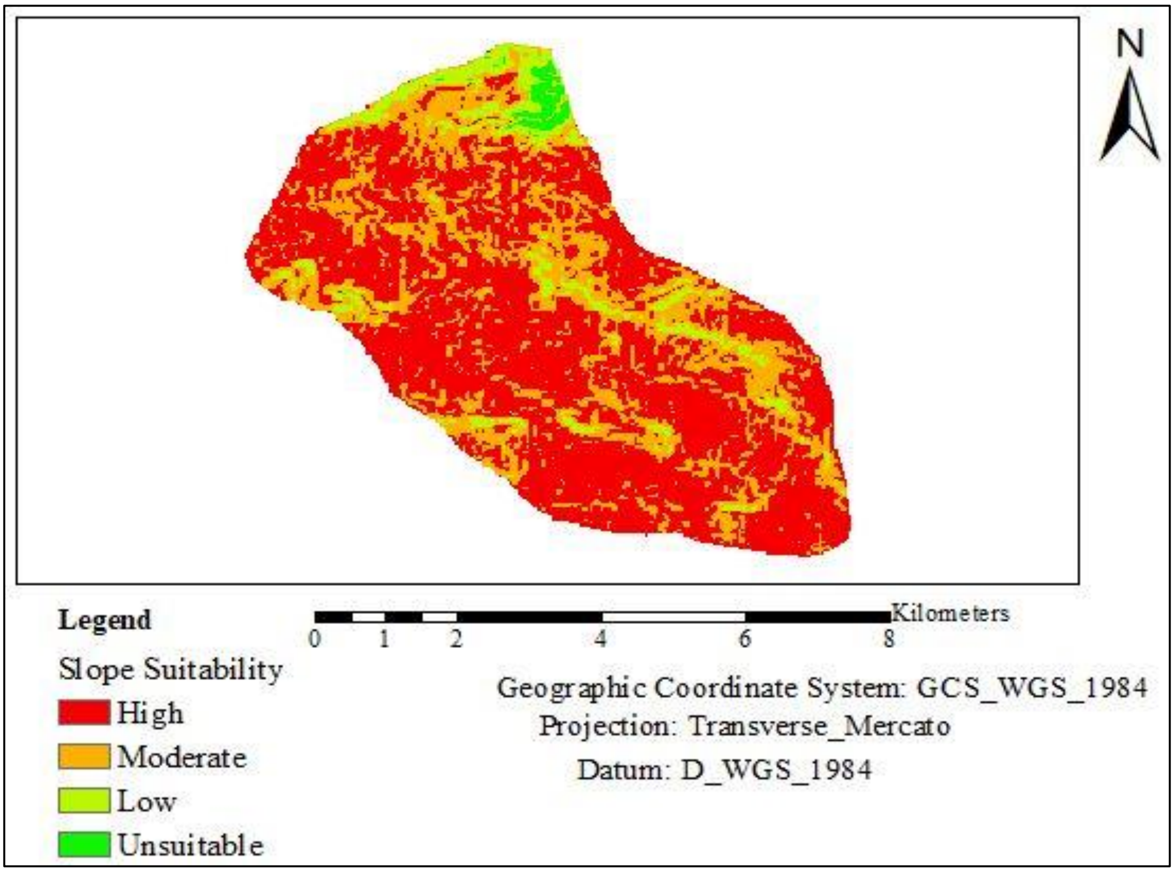

Figure 4.5: Map of slope suitability

4.1.4 Land Use Land Cover

The LULC of the study area is classified into five classes such as forest, agricultural area, bare land, Urban area (built-up), and water body area Figure 4.6. (Olaniyi, *et* al. 2018). Bare land is highly suitable for landfill while water body is unsuitable for landfill (Ebistu, T.A. and Minale, A.S., 2013). The water bodies (swampy areas) and building areas are reclassified as unsuitable areas which covered 548.5 ha (34.38%), agricultural and forest lands are reclassified as moderately suitable with coverage of about 529.45 ha (33.5%) and bare land is reclassified as highly suitable which cover about 503.79 ha (19.143%) Table 4.4.

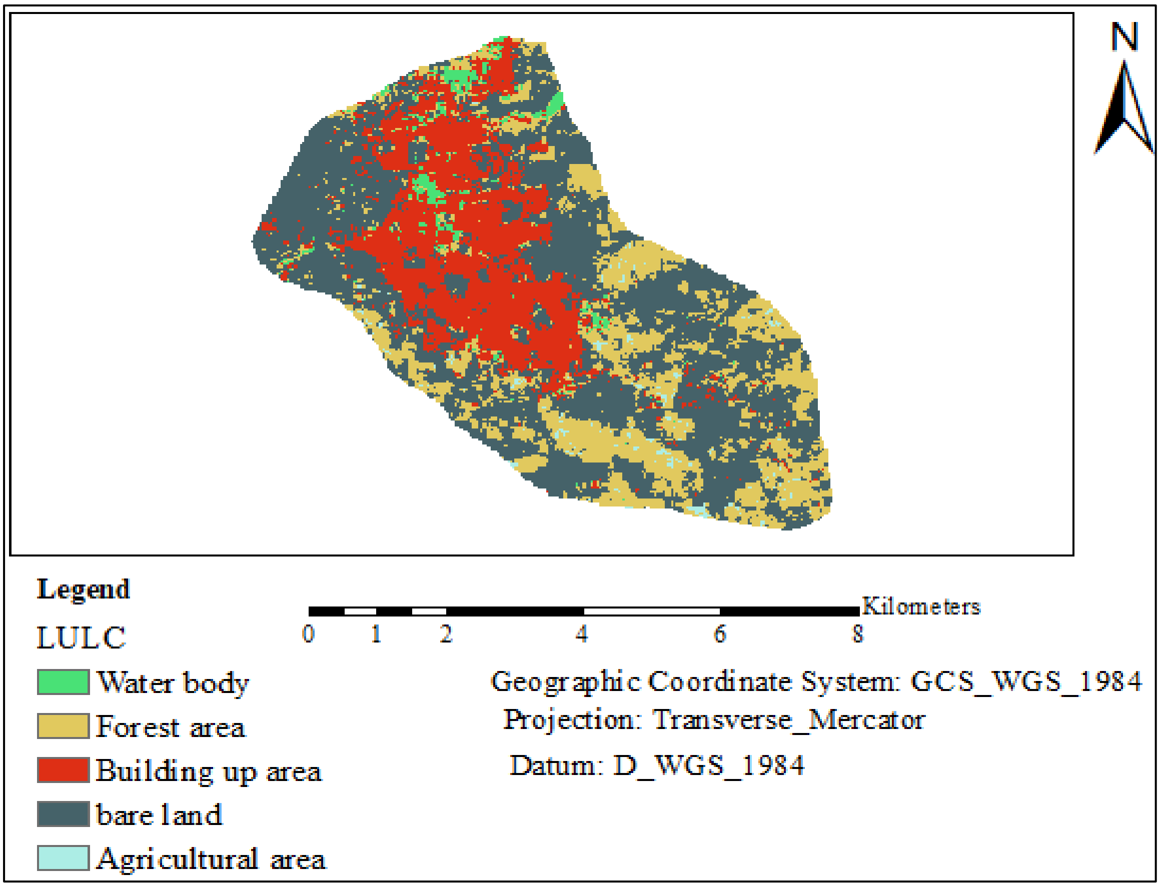

Figure 4.6: Map of land use land cover

Table 4.4: LULC area coverage, rank, weight, and its suitability for disposal site

LULC type	Suitability	Area		Rank	Weight
		Ha	%		%
Building area and waterbody	Unsuitable	548.5	34.68	1	19.143
Forest /Agricultural area	Moderate	529.45	33.5	3	19.143
Bare land	Highly	503.79	32	4	19.143

4.1.5 Distance to Surface Water

Different streams and runoff are flow from several high-slope land and hill surrounding the town. So, to protect from the pollution of surface water by municipal solid waste several Journals use different buffer distances. Accord to (Kidd, 2007) state that a minimum distance of 30 m to surface water while (Akbari, *et* al., 2008) have stated that the minimum distance to surface water about 200 m whereas Allen et al.(2003) has a state that 300-1000 m distance from the surface water. So, by considering, those ideas and guidelines for this research used 500 m as the minimum distance and less this 500 m distance as an unsuitable site. Using multiply ring buffer and buffered around the all the surface water:< 500 m is an unsuitable site,500-1000 m Low suitable,100-2000 m moderate suitable, and > 2000 m is highly suitable for this research (Figure 4.7).

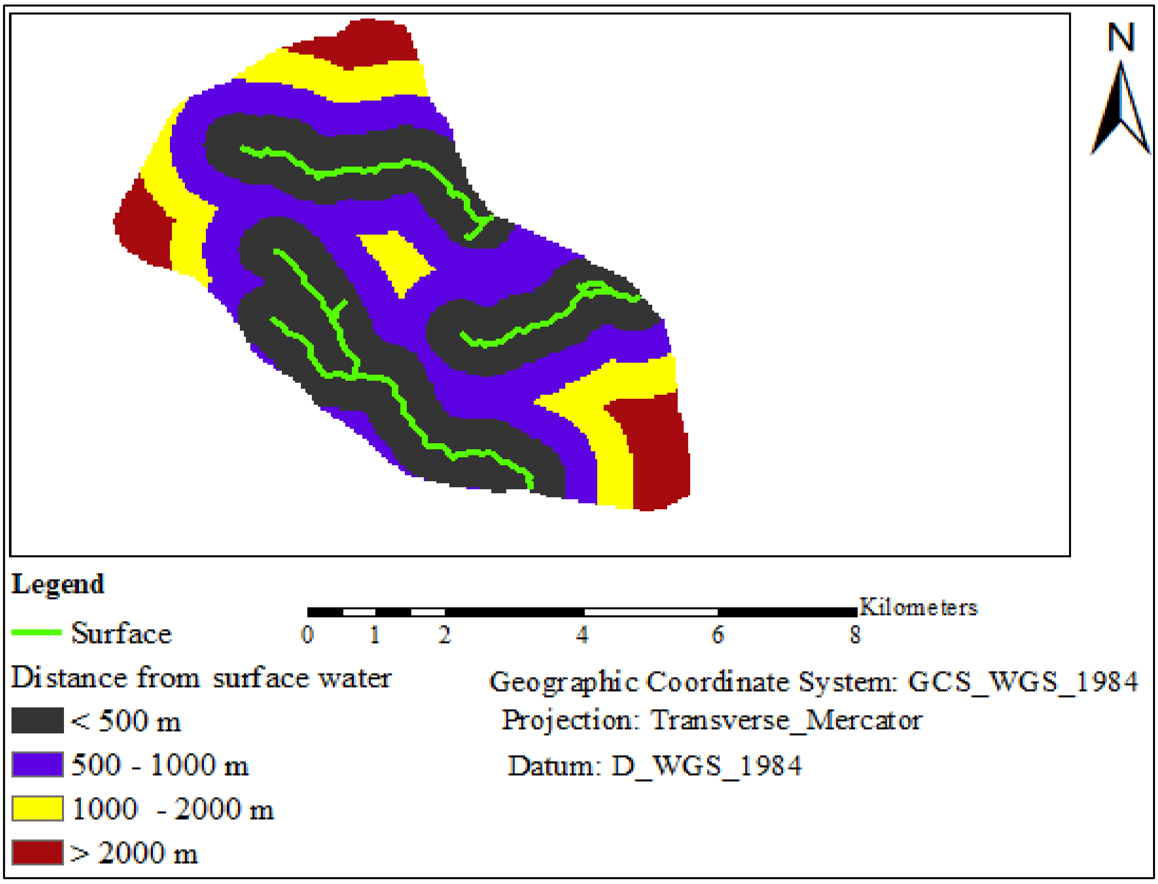

Figure 4.7: Reclassified map of surface water

Unsuitable site of the study area is covered about 43.95%, Low suitable covered about 32.86%, moderate and high suitable area are covered about 13.99% and 19.2% respectively (Table 4.5). The site which covered about 18.1% is greater than 2000 m far from surface water and protected from pollution, So, it is suitable for municipal solid disposal Figure 4.8.

Table 4.5: Surface water, area coverage, rank, weight, and its suitability

Distance (m)	Suitability	Area		Rank	Weight %
		Ha	%		
< 500	Unsuitable	1530	43.95	1	9.204
500-1000	Low	1144	32.86	2	9.204
1000-2000	Moderate	487	13.99	3	9.204
> 2000	High	320	19.2	4	9.204

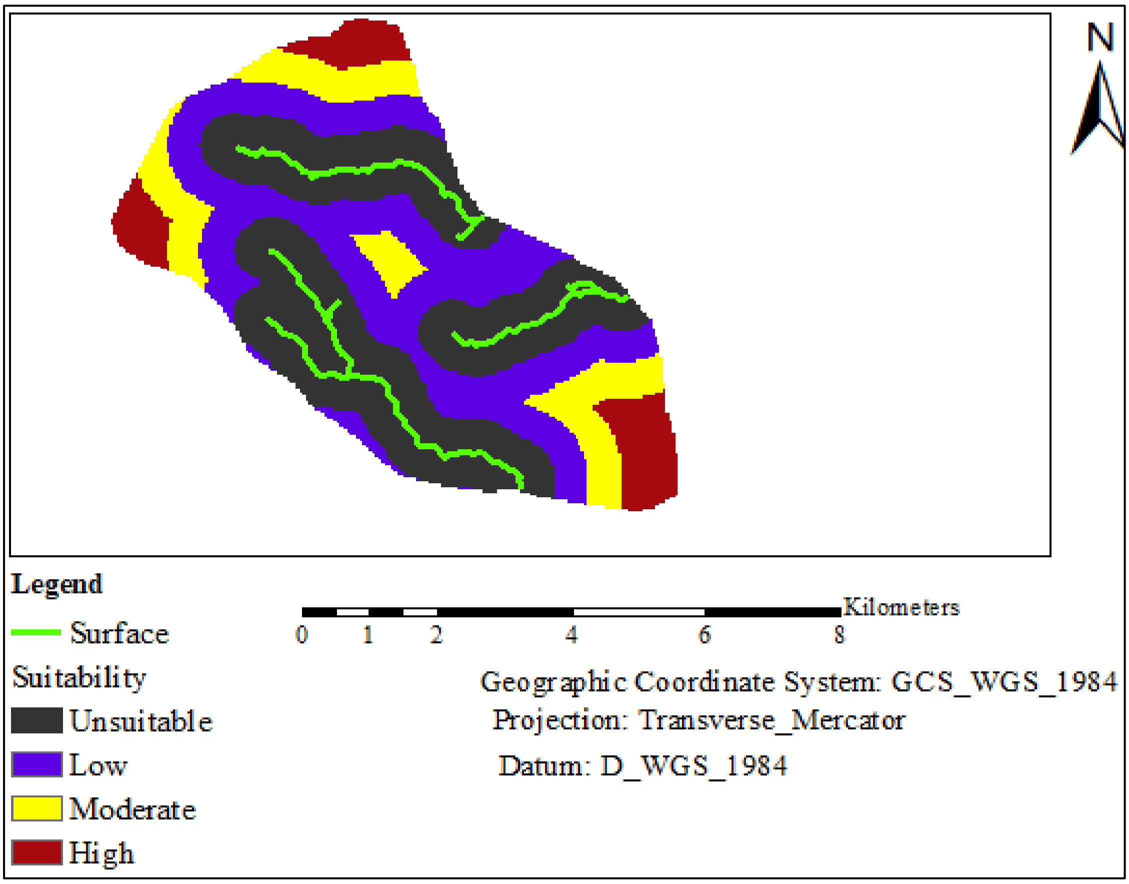

Figure 4.8: Suitability map of surface water

4.1.6 Distance from Groundwater Well

The groundwater well one of the most important to select disposal municipal solid waste sites. Different researchers had state different distances. According to (Josimović, *et* al., 2015), they state that three choices: a.100 - 200 m, downstream of the landfill, or approximately on landfill level b. up to 500 m, downstream of the landfill or on the same level as the landfill c. 500-1000 m, downstream or the same level as the landfill. (Akbari, *et* al., 2008) state that, 400 m is a minimum distance and Allen et al. (2003) set 300 – 1000 m. So, this study is considered the minimum distance of 1000 m to the groundwater well to decrease the leachate which causes groundwater well pollution. The groundwater well of Fiche town is Torben-Ashe, Arat-Mariyam, and Komando near the Komando prison. So, the study using multiply ring buffer to buffer the distance from groundwater well: < 1000 m unsuitable,1000 - 2000 m low suitable,2000 - 2500 m, and > 2500 m is moderately suitable and high suitable respectively (Table 4.6). The reclassified and buffer distance was detailing is discussed in Figure 4.9.

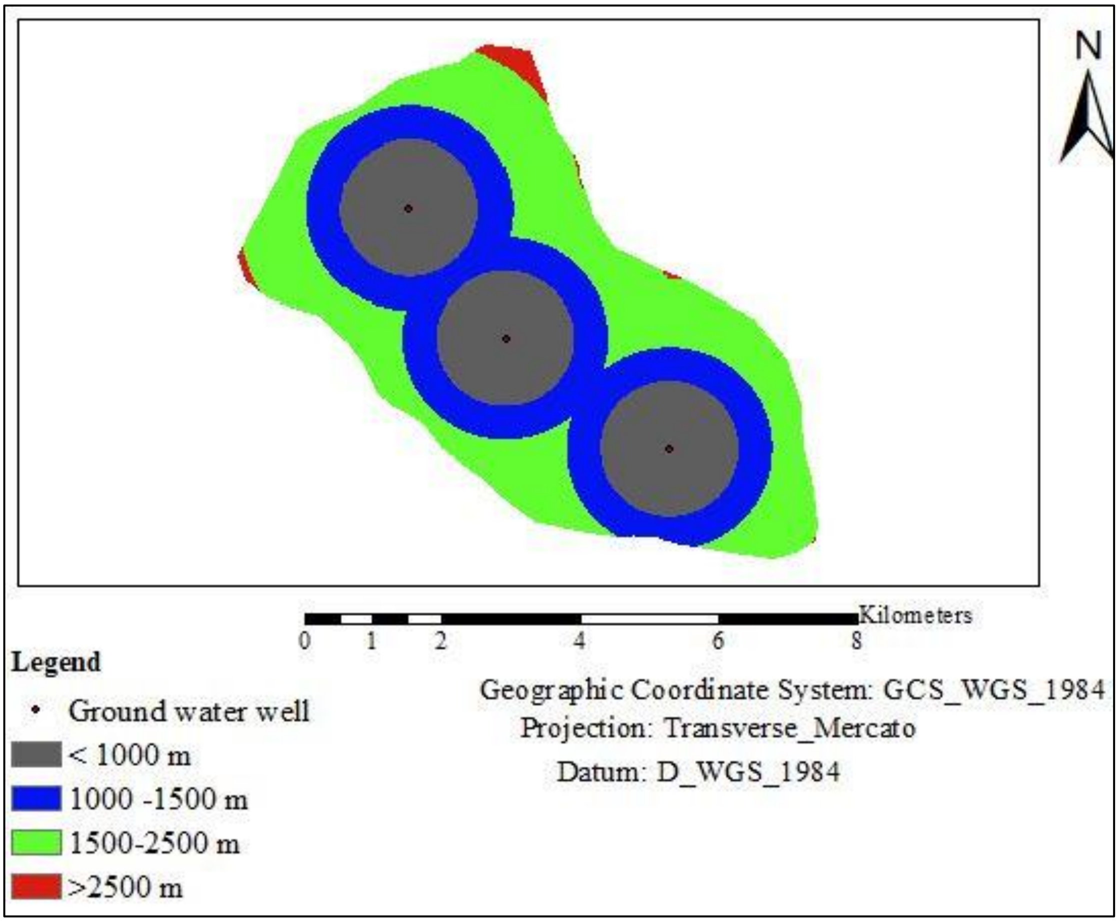

Figure 4.9:Reclassified map of groundwater well

Table 4.6: Groundwater well area coverage, rank, weight, and suitability

Table Distance(m)	Suitability	Area		Rank	Weight %
		Ha	%		
< 1000	Unsuitable	102.952	29.6	1	10.88
1000 – 1500	Low	67.32	19.33	2	10.88
1500- 2500	Moderate	81.774	23.48	3	10.88
> 2500	Highly	96.29	27.65	4	10.88

The < 1000 m buffer area (unsuitable) is covered about 29.6% area of the study area, low suitable is covered about 19.33% area of the study area, moderately suitable and high suitable covered about 23.48% and 27.65% respectively. The area which covered about 27.65% is > 2500 m from selected groundwater well already exist at the study area, so it was highly suitable for disposal of municipal solid because its leachate and runoff can't pollute the water well even if it is on the same level location. The classified and buffered map of a suitable area is explained in Figure 4.10.

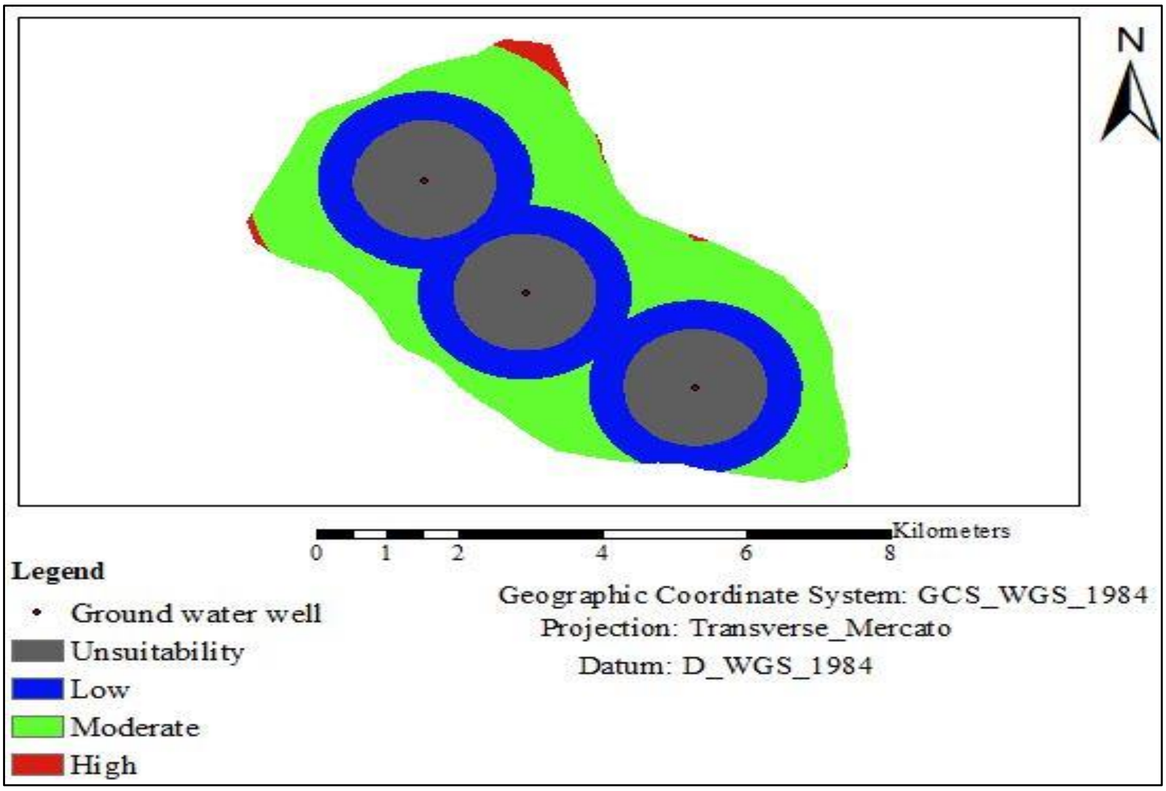

Figure 4.10: Suitability of groundwater well

4.1.7 Distance to The Main Road

The municipal solid waste disposal should far from the main road because to decrease or avoid unnecessary odor and environmental pollution. But also, not be so far from the main road because it is cost and take time to disposal. Some Journals and EPA state different guidelines. According to (Joksimović, 2017) the minimum distance from landfill to the shield main road is about 200 m and the best suitable is > 1000 m without the shield of the main road. (Bahrani, *et* al., 2016) state that the distance of landfill from main road minimum is about 500 m and maximum about 5000 m also (Allen, B., *et* al.2003) state that, the distance landfills from the main road should buffer by 60-600 m. So, this study was considering those Journals and state the distance which < 500 m is an unsuitable area while the distance 2000 -5000 m is highly suitable. Refer to Figure 4.11.

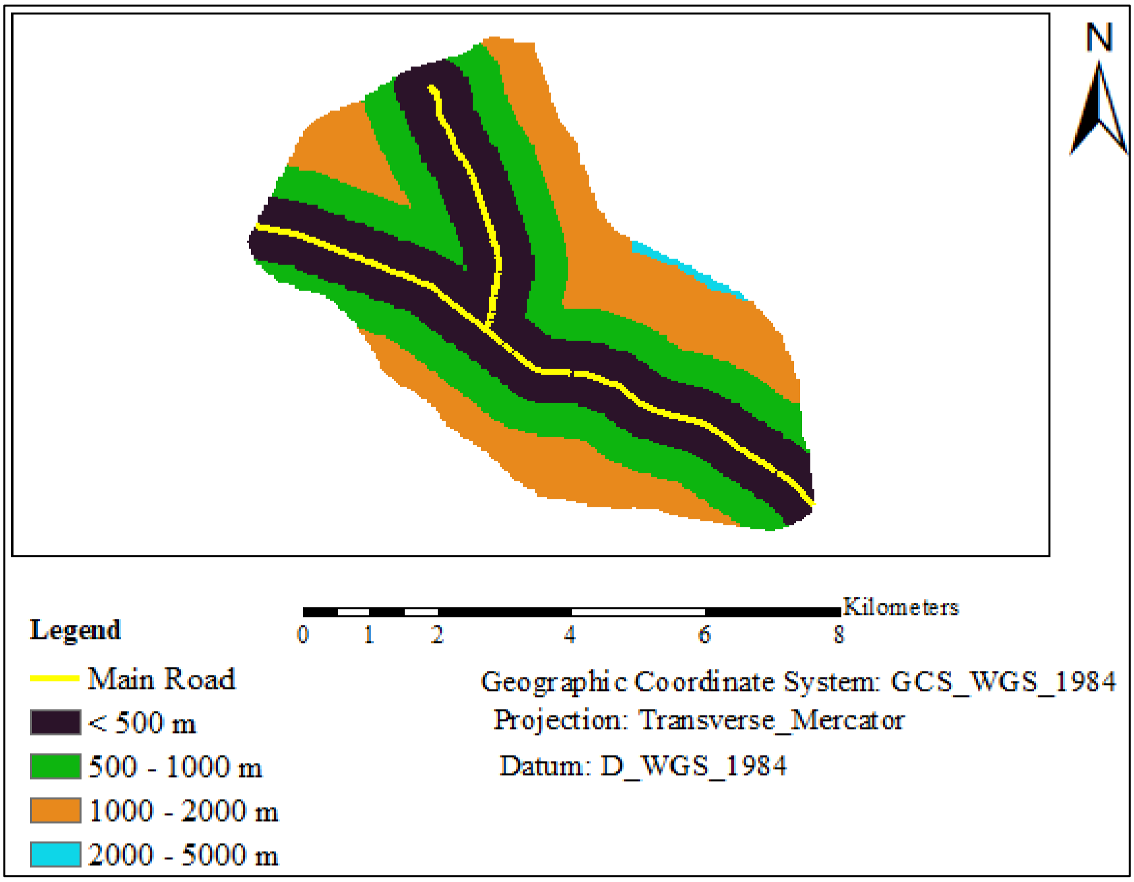

Figure 4.11: Reclassified map of distance to the main road

The buffered a, area coverage, rank, weight, and suitability are illustrated in Table 4.7. The high suitable area covered about 25.93% of the study area while the unsuitable is covers about 24.06% area of the study area, and low suitable and moderate suitable are coveres about 24.65% and 25.31% respectively. Therefore distance 2000 m-5000 m from the main road and area covered about 25.93% of the study area are highly suitable sites. Because it is economical and no pollution to the Environmental. The suitability map is illustrated in Figure 4.12.

Table 4.7: Distance main road area coverage, weight, rank, and suitability

Distance(m)	Suitability	Area		Rank	Weight %
		Ha	%		
< 500	Unsuitable	419.32	24.06	1	3.004
500 - 1000	Low	430.45	24.65	2	3.004
1000 -1500	Moderate	441.17	25.31	3	3.004
2000 - 5000	Highly	451.99	25.93	4	3.004

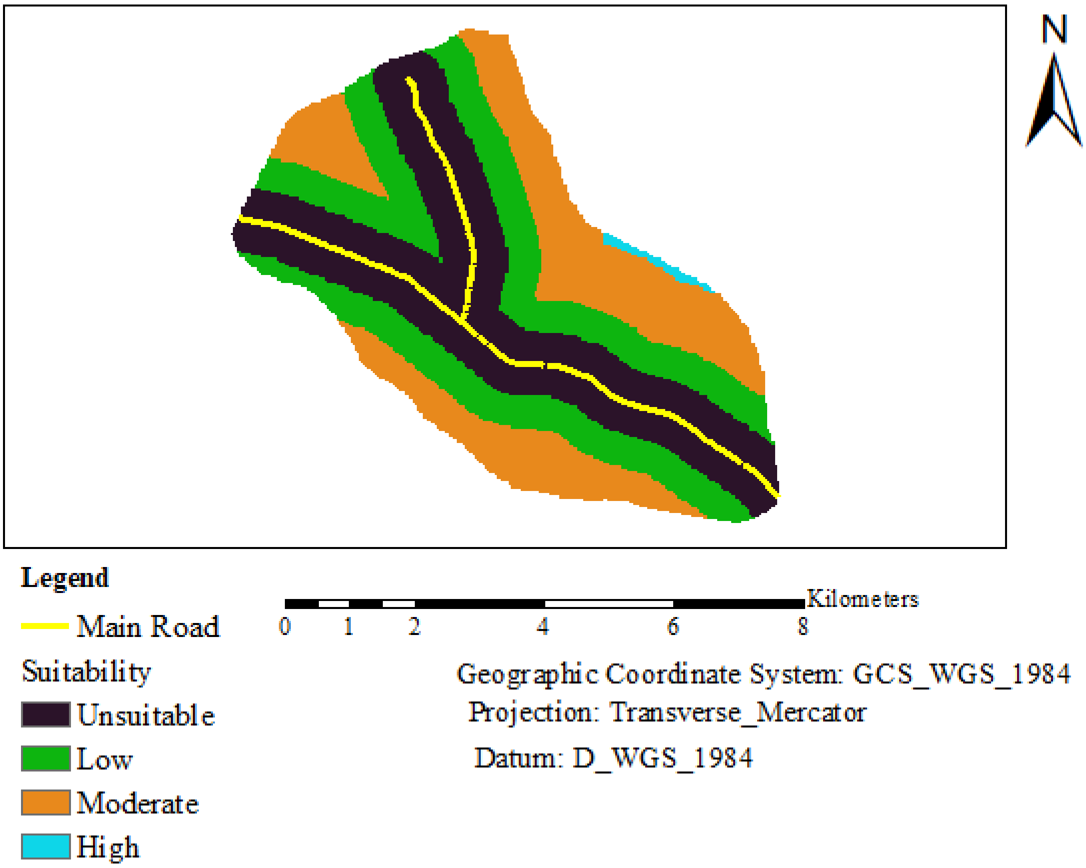

Figure 4.12: Suitability of distance from the main road

4.1.8 Distance from Religiouns Institution

Religioun's institution is the most sensitive area and the most population invite every day so to protect from unnecessary environmental pollution and odor it should be considered. The different researchers have stated that different buffer distances. According to

(Joksimović, 2017) the minimum distance of landfill from the religious institution and sacramental (cemetery) area should be 1000 m. So, for this study, the multiplying buffer minimum is about 1000 m and the maximum is greater than 3000 m the distance which is less than 1000 m from religious institutions unsuitable while the distance greater than 3000 m is the most suitable area Figure 4.13.

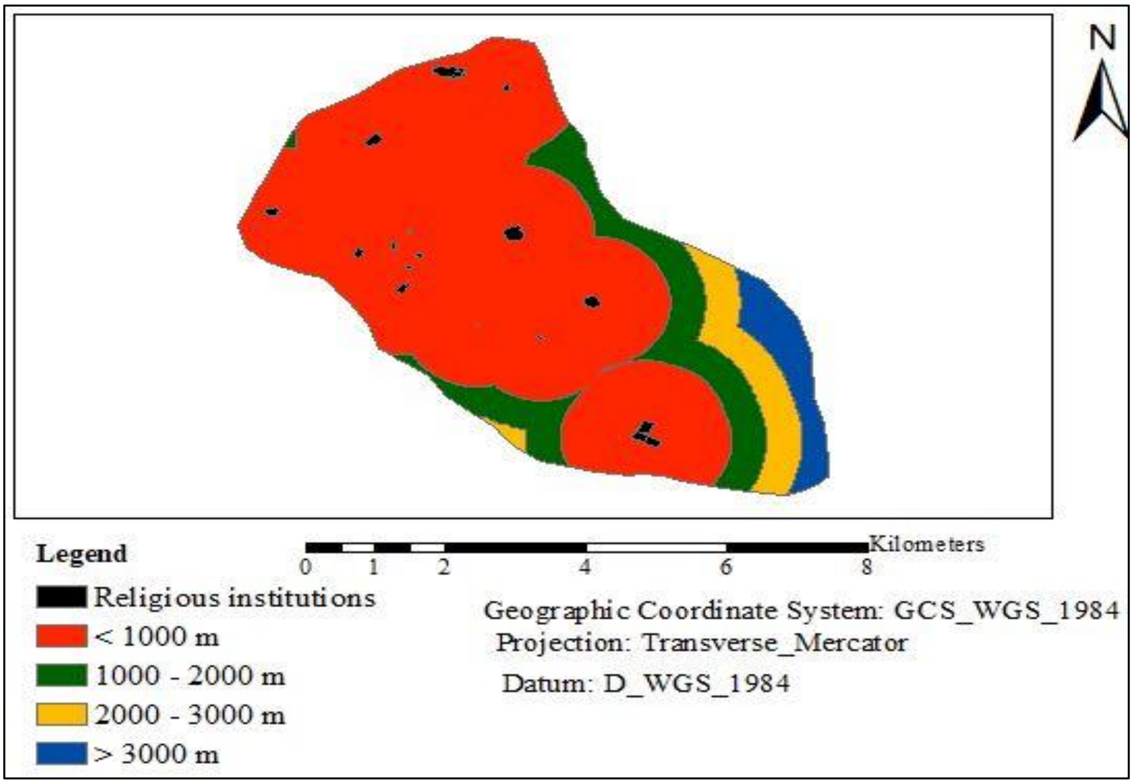

Figure 4.13: Reclassified Map of Religion institution

Table 4.8:Distance to Religion institution, area coverage, rank, weight, and its suitability

Distance(m)	Suitability	Area		Rank	Weight
		Ha	%		%
< 1000	Unsuitable	688.98	23.1	1	1.584
1000 - 2000	Low	936.32	31.3	2	1.584
2000 - 3000	Moderate	918.63	30.75	3	1.584
> 3000	High	443.75	14.86	4	1.584

The percentage, area coverage, and suitability of each buffered study area are in detail described. Among this the high suitable area 14.86% of the study area,23.1% area is unsuitable area and 31.3% and 30.75% are low suitable and moderate suitable respectively. Since the high suitable area is far from the religious institution it is the highly suitable site for disposal of municipal solid waste. The suitability of the study area is illustrated clearly in Figure 4.14.

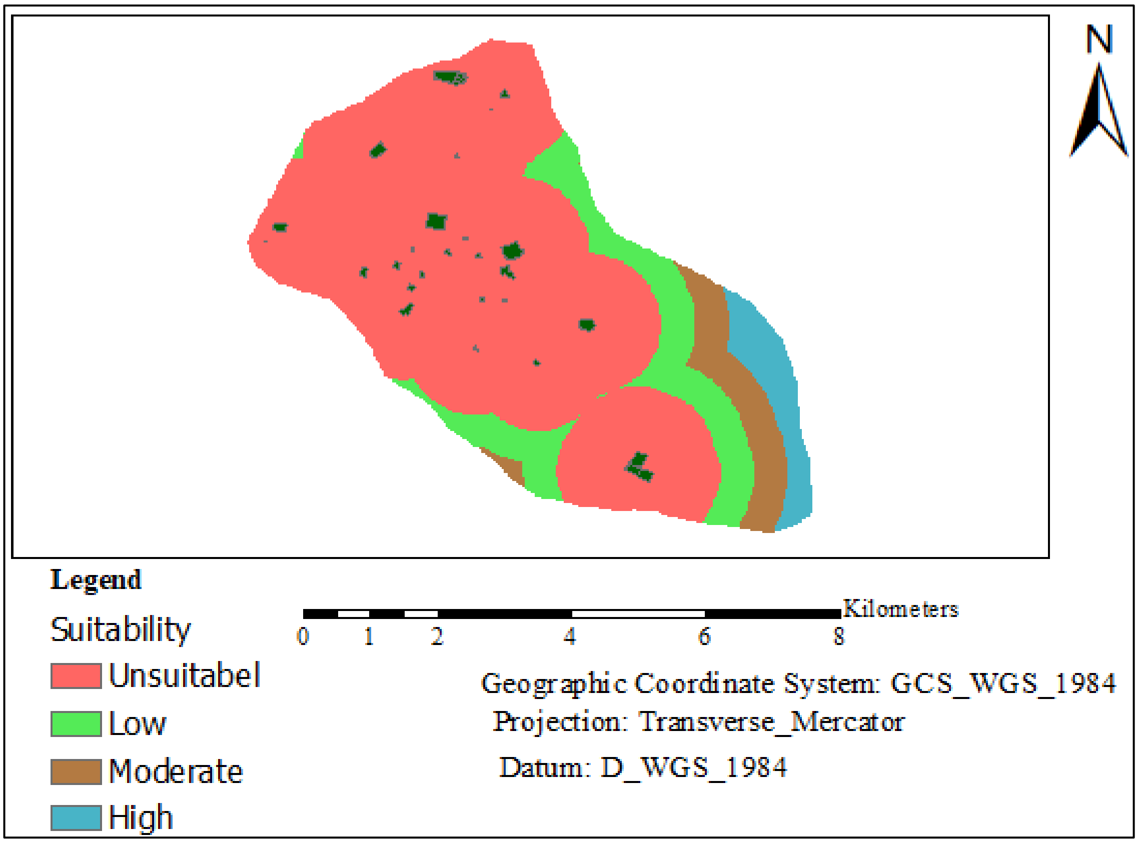

Figure 4.14: Suitability of distance to religions institution

4.1.9 Groundwater Depth

Groundwater table map was prepared using inverse distance weighting (IDW) interpolation technique of water level data. According to (Joksimović,2017) the groundwater level should be > 3 m. The high-water table is an unsuitable area because a flood can form at the site, or leachate easily formed and pollute the groundwater. (Ahmad et al.2011) state that to control groundwater pollution solid waste should be placed on > 50 m depth of water table. The study has taken data from the existing well at the site. The depth 20 – 30 m and 30 – 50 m are Low suitable and moderate respectively Figure 4.15. The depth < 10 m and > 50 m are unsuitable and high suitable respectively (Table 4.9).

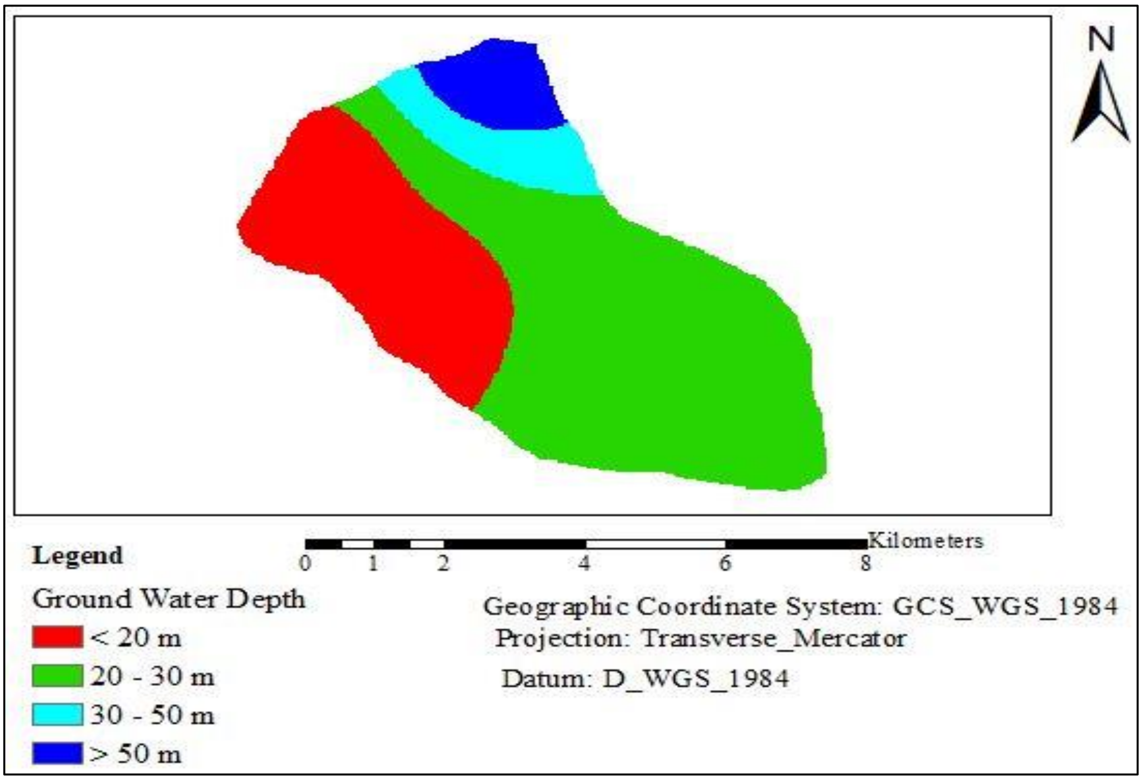

Figure 4.15: Reclassified map of groundwater depth

The 19.5% and 29.7 % of the study area are covered by unsuitable and high suitable respectively and 23.4% and 27.5% are covered by low suitable and moderately suitable areas respectively (Table 4.9). So, to protect the groundwater pollution, a low-depth groundwater table which is > 50 m is high suitable for municipal solid disposal. The suitability of the study area in detail is illustrated in Figure 4.16.

Table 4.9: Depth of water, area coverage, rank, and weight

Depth (m)	Suitability	Area		Rank	Weight %
		Ha	%		
< 20	Unsuitable	2.01	19.5	1	4.272
20 – 30	Low	2.41	23.4	2	4.272
30 – 50	Moderate	2.84	27.5	3	4.272
> 50	High	3.06	29.7	4	4.72

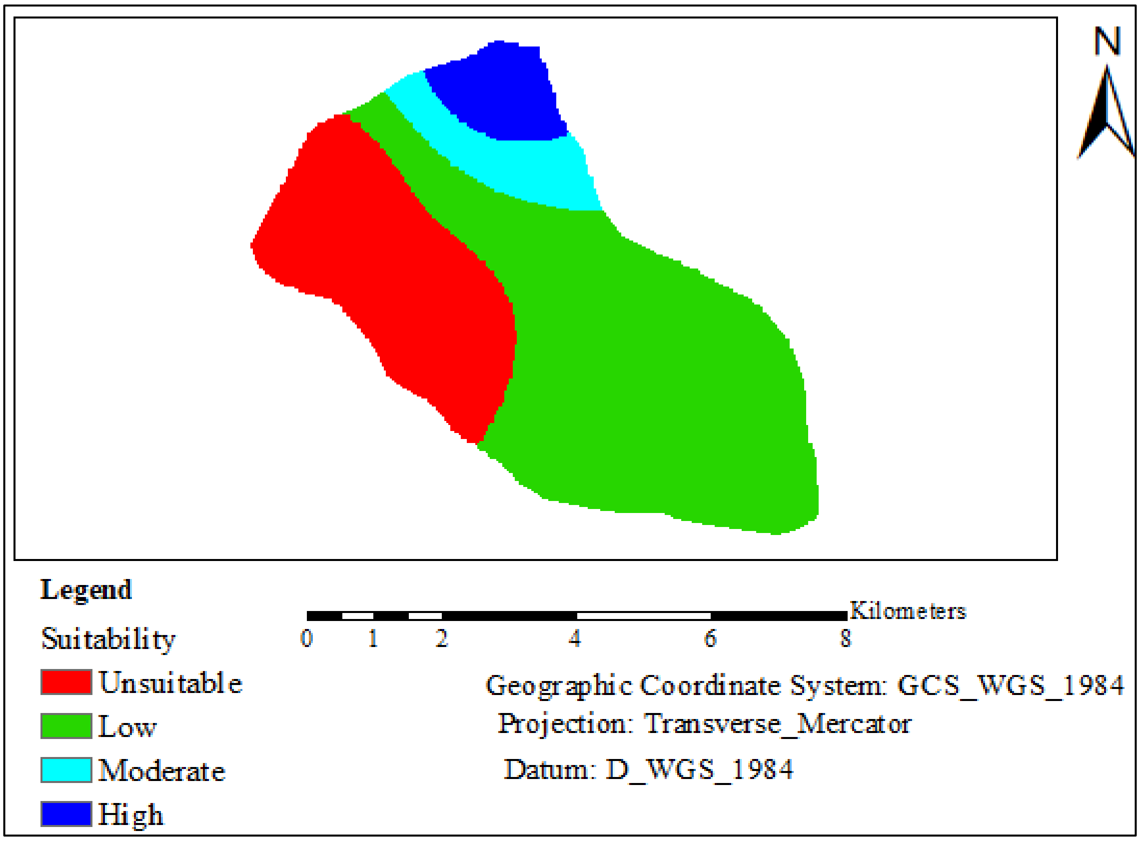

Figure 4.16: Groundwater depth suitability

4.1.10 Built Area

The built-up area is one of the parameters that play a great role to select the best suitable site for the disposal of municipal solid waste. The building contains different institutions governmental or non-governmental such as residential buildings, commercial centers, schools, health, social service center, and utility facilitate centers. According to (Awakener, M. 2016) the distance to the building up area < 500 m is the unsuitable site for MSWD and the distance from the building area > 1000 m is highly suitable (Josimović, *et* al., 2015) had stated that the distance of landfill to building area < 1500 m is unsuitable and when > 5000 m high suitable and EPA, (2007) had stated that the maximum distance to built area 500 m. So, this study has classified the distance to building up area < 500 m unsuitable site,500 m – 1000 m low suitable,1000 – 2000 m moderate suitable, and > 1000 m is highly suitable it is discussed in Figure 4.17.

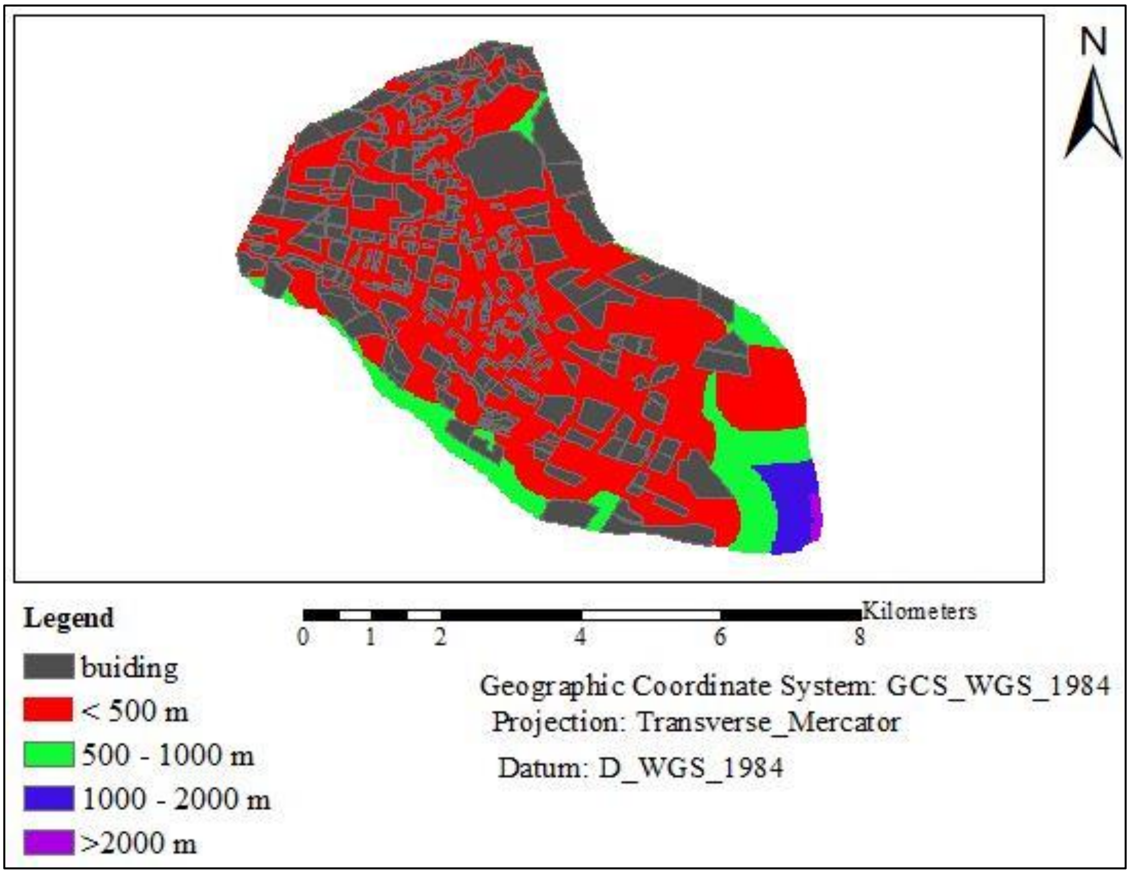

Figure 4.17: Reclassified map of building area

The area 2.4% and 13.83% covered by moderate suitable and low suitable respectively, 83.52 % and 0.32% are covered by unsuitable and high suitable study areas respectively. So, the distance which is >2000 m and covered 0.32 % of the study area is suitable because there less or no environmental pollution and no threat to the health community. A suitable map of building up is illustrated clearly in Figure 4.18.

Table 4.10: Distance, area coverage, rank, weight, and suitability

Distance (m)	Suitability	Area(ha)		Rank	Weight %
		Ha	%		
< 500	Unsuitable	2893	83.52	1	33.466
500 - 1000	Low	479	13.83	2	33.466
1000 - 2000	Moderate	81	2.4	3	33.466
> 2000	High	11	0.32	4	33.466

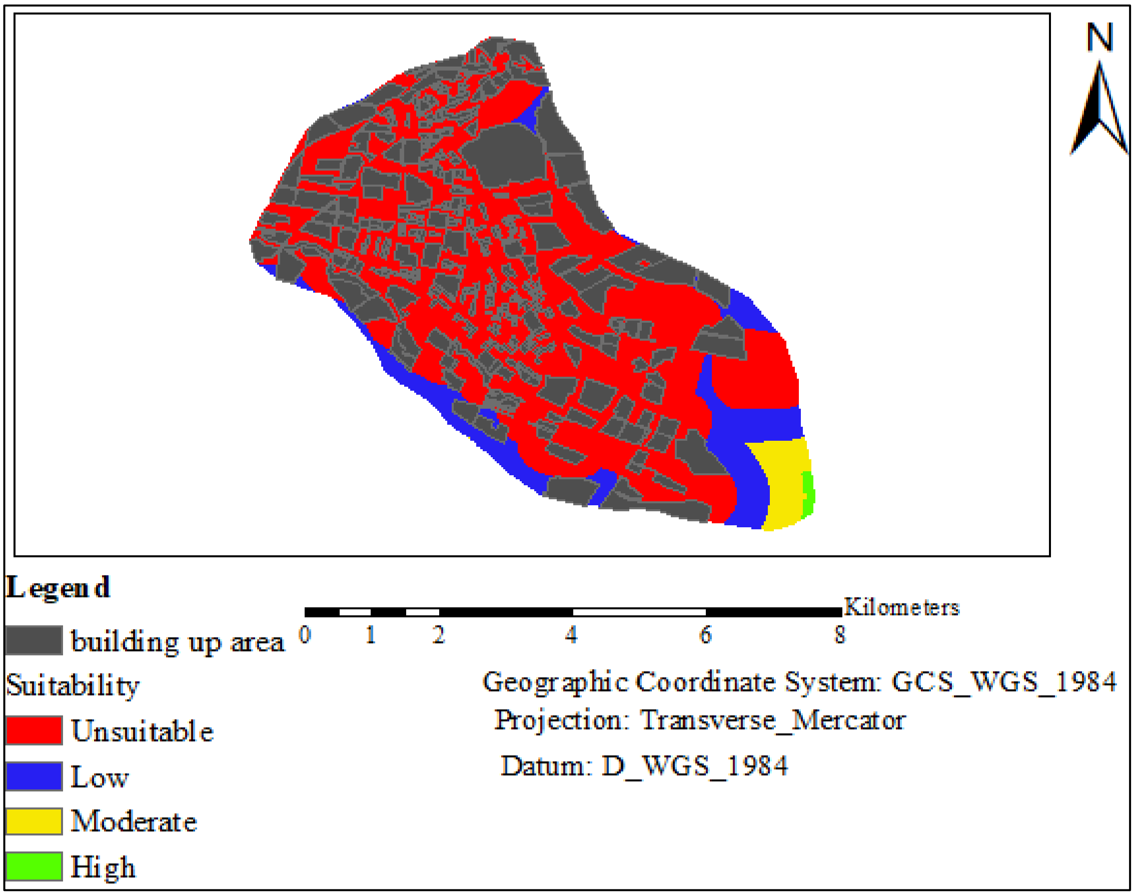

Figure 4.18: Map of suitability building up the area

4.2 Land Fill suitability

The high suitability area is located South-East, South, West, and Northern part of the Fiche town. The highly suitable sites for municipal solid waste disposal have fulfilled the criteria: far from building up area, far from religioun institution, not so far and so near to the main road, the area is covered by basalt type of geology, vertosols, far from well and surface water, low slope, and low groundwater depth. The unsuitable area is covered by lepton soil which has high leachate property, high slope which is > 20% which is costive for landfill construction and technical operation, near to the built-up area, and close to surface water flow. The low suitability area is found central of the town, close to surface and well water drinking, close to the main road which passes in Fiche town, high groundwater depth and, close to a religious institution. Moderately suitable sites are medium good for municipal solid waste disposal relative to others. High suitable sites are highlighted by a slightly green color, the moderate suitable area nearer to the central part of the town relative to high suitability sites which are high light by pink color, the low suitable area is which is located at the central part of the town and highlighted by yellow color and the unsuitable, this area is highlighted red color. All detail illustrated in Figure 4.19.

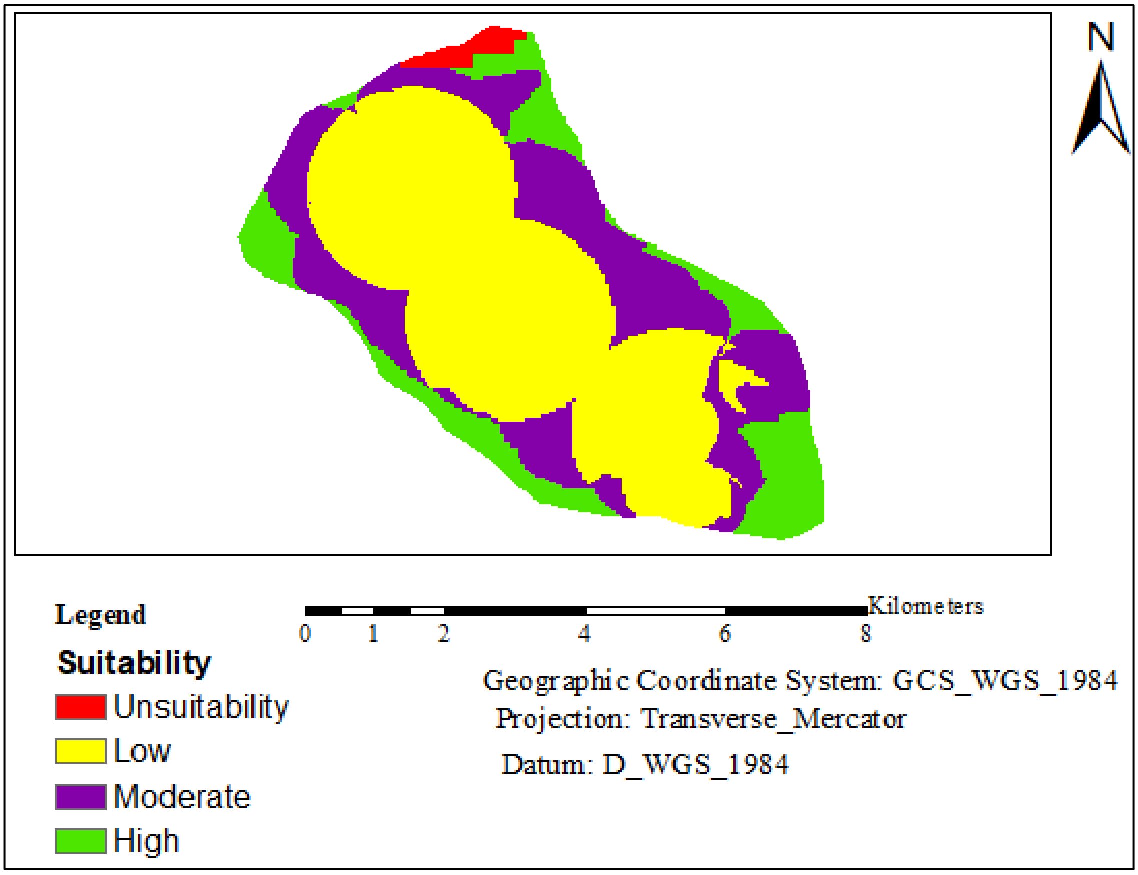

Figure 4.19: Suitability map of the landfill site for Fiche town map

The area coverage unsuitable is 1.79%, the low suitable area is 63.54%, moderatly suitability is about 15.022% and High suitability is about 19.66% (Table 4.11) and detail area coverage is illustrated in Figure 4.20. The rank shows in the 1 represent unsuitably,2 is low suitable,3 is moderate suitable, and 4 is highly suitable. So, the area which covers about 19.66 ha and ranks 4 is the best site for municipal solid waste disposal. Because this result is considered economic, environmental, and technical operation. The area of highly suitable sites for municipal solid waste disposal site is west, North, South, and South-East direction parts of the Fiche town. The part of the south-East direction covers about 175.42 ha (30.993%), the North direction about 171.56 ha (30.309%), the South direction 211.75 ha (37.42%), and the West direction about 7.28 ha (1.286%) Table 4.12. A high suitable site is found in Northern, West, South, and South-East directions which cover a total of about 566 hectares Figure 4.21 and Figure 4.22.

Table 4.11: Suitability, Area, and Rank of landfill

Suitability of landfill	Area		Rank
	Ha	%	
Unsuitable	51.56	1.79	1
Low	1830.58	63.54	2
Moderate	432.8	15.022	3
High	566.36	19.66	4

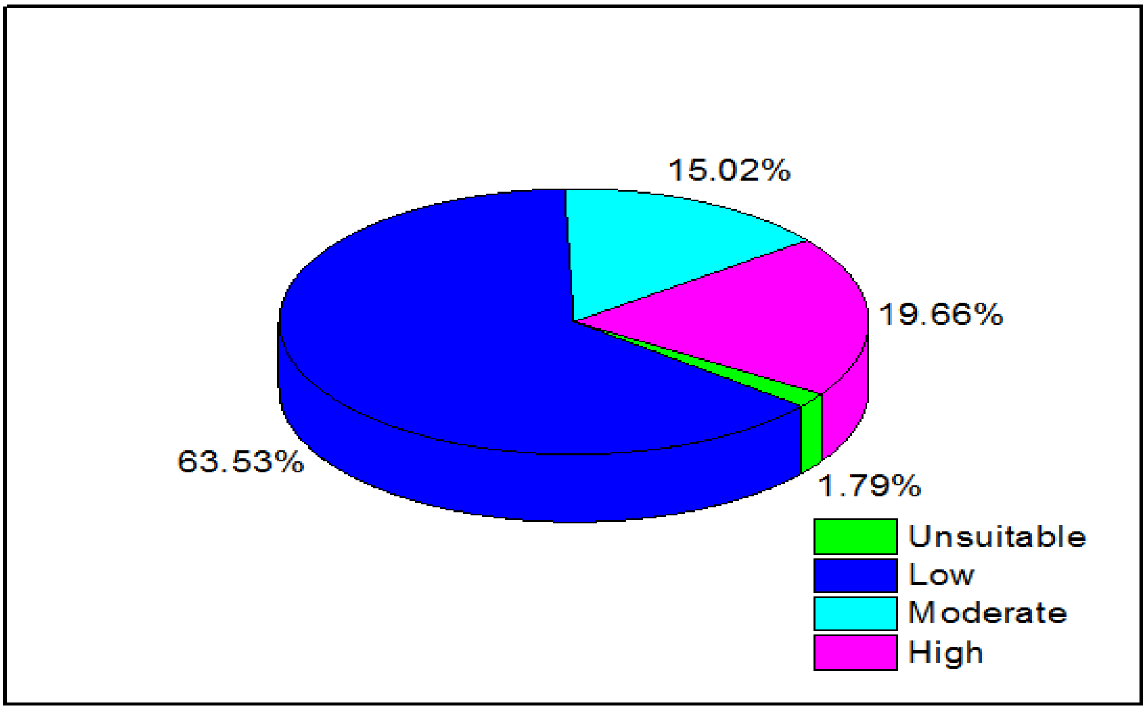

Figure 4.20: Suitability coverage area

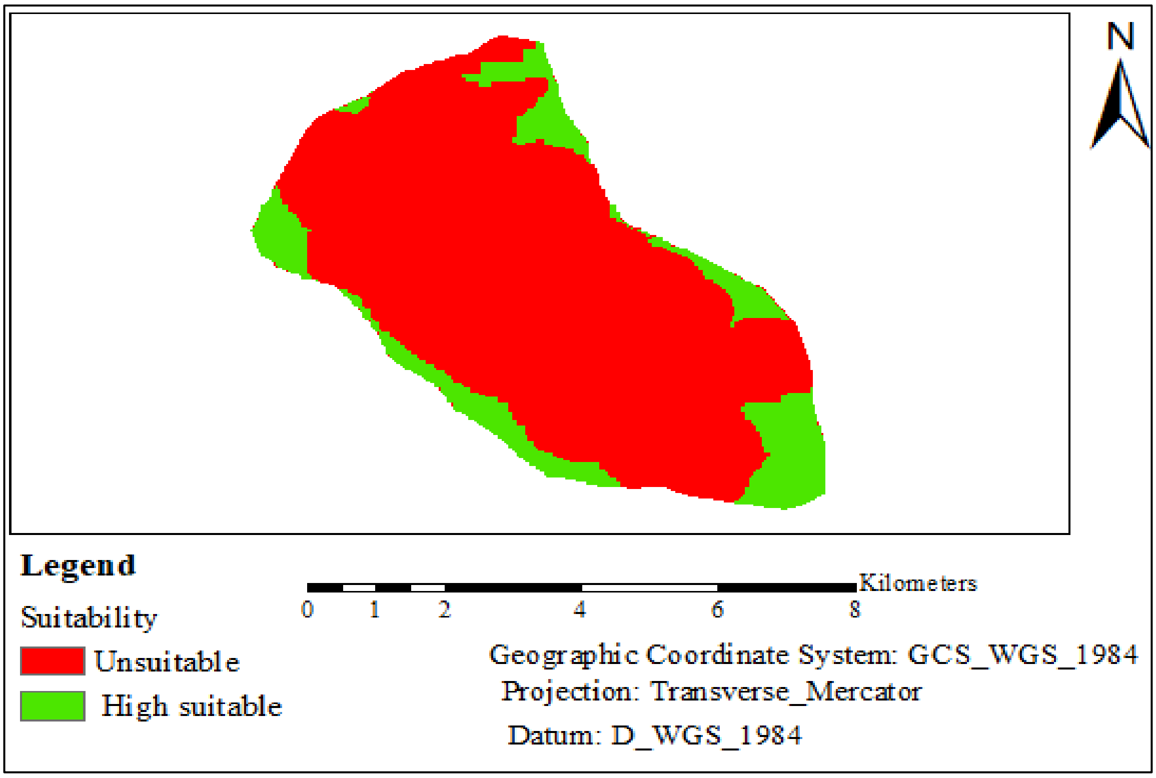

Figure 4.21: High suitability is a map for landfill of Fiche town

Table 4.12: Area, location, and rank of suitability sites.

Direction suitability exist	Suitability	Are		Rank
		ha	%	
South-East (Doyu)	High	175.42	30.993	4
West (Bosoqe)	High	7.28	1.286	4
North (Arat-Mariyam and kidenbrat)	High	171.55	30.309	4
South (Torban Ashe and Ganda Farda)	High	211.75	37.42	4

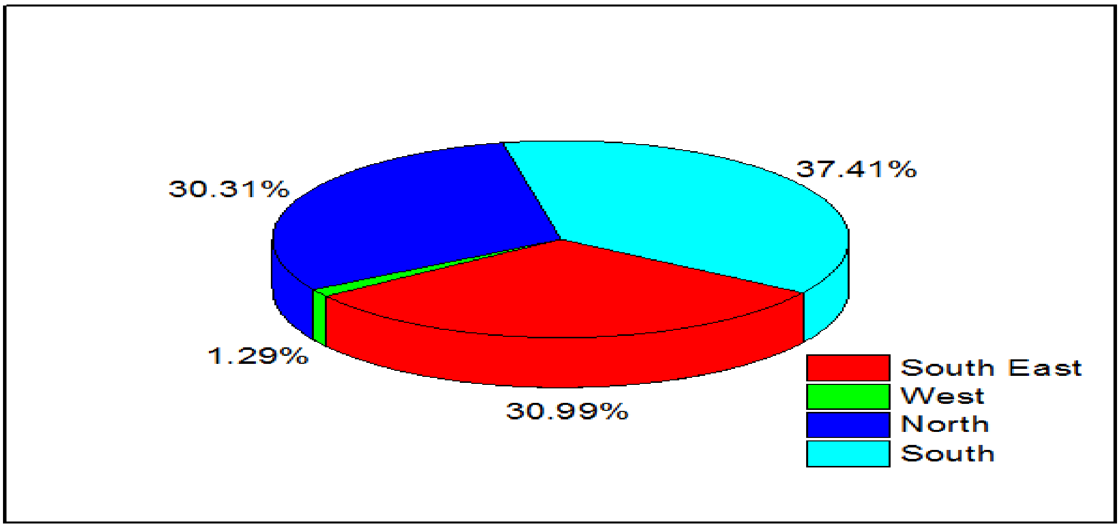

Figure 4.22: High suitability coverage

5.CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This study was done by considering ten parameters to select the high suitable municipal solid waste disposal site for Fiche town. Those parameters are LULC, geology, Soil, Slope, built-up area, road network, religious institution, surface water, groundwater wells, and groundwater depth of the town. These parameters are analyzed by GIS and RS techniques to develop a thematic map. These parameter data used primary which directs from the field using GPS data and secondary data collected from a government institution. The data collected was analyzed by AHP software. The consistency of the study area is 0.0463 which less than 0.1.

The final generated map by AHP has assisted the suitability site for municipal solid waste disposal. Which had four scheme categories: high suitability (19.66%). low suitability (63.54%), moderate suitability (15.022%), and unsuitability (1.79%).The unsuitability is covering the lowest area of the study area while the low suitability of the study area is covering the highest area. According to the result, unsuitable was covered 1.79% (51.56 ha) low suitable was covered 63.54% (1830.58 ha), Moderate suitable cover about 15.022% (432.8 ha) and high suitable 19.66% (566.36 ha). The high suitable selected sites are found South (Torben Ashe and Gand Farda), South-East (Doyu), North (Arat, Mariyam, and Kidenibrat), and West (Bosoqe) part of Fiche town. South covered about 37.42%, South-East covered about 30.993%, North covered about 30.309% and West covered about 1.286% part of the suitability of study area. For each suitability site the geology Aiba basalt, slope < 10%, soli vertosol, LULC bare land, build up distance > 2000, distance to surface water > 2000 distance to groundwater wells > 2500 m, distance to religion institution > 3000 distance to the main road is 2000 - 5000 m and groundwater depth > 50 m.

5.2 Recommendation

For the present and feature design for landfill of Fiche town should incorporate:

- The rates and quantities of solid waste generated by the municipality should be understood to calculate the size of the solid waste disposal site.
- Around municipal solid waste disposal sites, channel should be construct to prevent runoff water mix with waste.
- The chosen solid waste disposal location is solely utilized for non-hazardous trash. Because hazardous trash has distinct parameters, it should be disposed of separately.
- The selected suitable site for municipal solid waste is South (Torben Ashe and Gand Farda), South-East (Doyu), North (Arat-Mariyam and Kidanibret), and West (Bosoqe) parts of Fiche town

REFERENCES

Abate, B. and G. Goshu (2017). Waste management in lake tana basin—Case of rapidly urbanizing Bahir Dar City. Social and ecological system dynamics, Springer: 581-593.

Abd El-Salam, M. M. and G. I. J. J. o. a. r. Abu-Zuid (2015). "Impact of landfill leachate on the groundwater quality: A case study in Egypt." 6(4): 579-586.

. Abuabdou, S.M., Ahmadd, W., Aun, N.C. and Bashir, M.J., (2020). A review of anaerobic membrane bioreactors (AnMBR) for the treatment of highly contaminated landfill leachate and biogas production: effectiveness, limitations, and future perspectives. *Journal of Cleaner Production*, *255*, p.120215.

Akbari, V., Rajabi, M.A., Chavoshi, S.H. and Shams, R., (2008). Landfill site selection by combining GIS and fuzzy multi-criteria decision analysis, case study: Bandar Abbas, Iran. *World Applied Sciences Journal*, *3*(1), pp.39-47.

Aladejana, O.O., Anifowose, A.Y.B. and Fagbohun, B.J., (2016). Testing the ability of an empirical hydrological model to verify a knowledge-based groundwater potential zone mapping methodology. *Modeling Earth Systems and Environment*, *2*(4), pp.1-17.

Ali, H.H. and Al Nsairat, S.F., (2009). Developing a green building assessment tool for developing countries–Case of Jordan. *Building and Environment*, *44*(5), pp.1053-1064.

Allen, B., et al. (2003). A landfill site selection process incorporating GIS modeling. Proceedings of Sardinia.

Bahrani, S., Ebadi, T., Ehsani, H., Yousefi, H., and Maknoon, R., (2016). Modeling landfill site selection by multi-criteria decision making and fuzzy functions in GIS, case study: Shabestar, Iran. *Environmental Earth Sciences*, *75*(4), p.337.

Barakat, A., Hilali, A., El Baghdadi, M. and Touhami, F., 2017. Landfill site selection with GIS-based multi-criteria evaluation technique. A case study in Béni Mellal-Khouribga Region, Morocco. *Environmental earth sciences*, *76*(12), pp.1-13.

Belachew, T.A. and Ababu, D.G., 2021. Statistical Modeling of Farmers' Preference for Adaptation Strategies for Climate Change: The Case of Dera District, Oromia, Ethiopia. *Applied and Environmental Soil Science, 2021.*

Binici, H. and O. J. J. o. B. E. Aksogan (2018). "Durability of concrete made with natural granular granite, silica sand and powders of waste marble and basalt as fine aggregate." 19: 109-121.

Birhanu, Y. and Berisa, G., (2015). Assessment of solid waste management practices and the role of public participation in Jigjiga town, Somali regional state, Ethiopia. *International Journal of Environmental Protection and Policy*, *3*(5), pp.153-168.

Bishoge, O. K., et al. (2019). "The adaptation of waste-to-energy technologies: towards the conversion of municipal solid waste into a renewable energy resource." 27(4): 435-446.

Bloomfield, V. (2009). Probability and Population Genetics. Computer Simulation and Data Analysis in Molecular Biology and Biophysics, Springer: 207-232.

Boadi, K. O. and M. J. E. Kuitunen (2002). "Urban waste pollution in the Korle Lagoon, Accra, Ghana." 22(4): 301-309.

Boateng, T.K., Opoku, F. and Akoto, O., (2019). Heavy metal contamination assessment of groundwater quality: a case study of Oti landfill site, Kumasi. *Applied Water Science*, *9*(2), pp.1-15.

Boateng, T.K., Opoku, F. and Akoto, O., (2019). Heavy metal contamination assessment of groundwater quality: a case study of Oti landfill site, Kumasi. *Applied Water Science*, *9*(2), pp.1-15.

Casado-Arzuaga, I., Onaindia, M., Madariaga, I. and Verburg, P.H., (2014). Mapping recreation and aesthetic value of ecosystems in the Bilbao Metropolitan Greenbelt (northern Spain) to support landscape planning. *Landscape ecology*, *29*(8), pp.1393-1405.

Chang, N.B., Parvathinathan, G. and Breeden, J.B., (2008). Combining GIS with fuzzy multicriteria decision-making for landfill siting in a fast-growing urban region. *Journal of environmental management*, *87*(1), pp.139-153.

Cofie, O., Nikiema, J., Impraim, R., Adamtey, N., Paul, J. and Koné, D., 2016. *Co-composting of solid waste and fecal sludge for nutrient and organic matter recovery* (Vol. 3). IWMI.

Cohen, B. J. T. i. s. (2006). "Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability." 28(1-2): 63-80.

Çöltekin, A., Heil, B., Garlandini, S. and Fabrikant, S.I., (2009). Evaluating the effectiveness of interactive map interface designs: a case study integrating usability metrics with eye-movement analysis. *Cartography and Geographic Information Science*, *36*(1), pp.5-17.

Dalla Mura, M., Prasad, S., Pacifici, F., Gamba, P., Chanussot, J. and Benediktsson, J.A., (2015). Challenges and opportunities of multimodality and data fusion in remote sensing. *Proceedings of the IEEE*, *103*(9), pp.1585-1601.

Demewoz, N.M., Woreta, T.G. and Sodo, E.,(2017). Indoor Radon Concentration and its Associated Health Effect in the Dwellings of Fiche Selale North Shewa, Ethiopia.

Ebistu, T.A. and Minale, A.S., (2013). Solid waste dumping site suitability analysis using geographic information system (GIS) and remote sensing for Bahir Dar Town, North Western Ethiopia. *African Journal of Environmental Science and Technology*, *7*(11), pp.976-989.

Ersoy, H. and Bulut, F., (2009). Spatial and multi-criteria decision analysis-based methodology for landfill site selection in growing urban regions. *Waste Management & Research*, *27*(5), pp.489-500.

Eskandari, M., Homaee, M., Mahmoodi, S., Pazira, E. and Van Genuchten, M.T., (2015). Optimizing landfill site selection by using land classification maps. *Environmental Science and Pollution Research*, *22*(10), pp.7754-7765.

Forman, R. T. (2014). Urban ecology: the science of cities, Cambridge University Press.

Garcia, M. I. (2010). "Assessing annual and seasonal spatial variability of ambient PM10 using linear regression analysis in a United States-Mexico urban sprawl."

Gregory, I. N. and P. S. Ell (2007). Historical GIS: technologies, methodologies, and scholarship, Cambridge University Press.

Gupta, J., Tyagi, B., Rathour, R., and Thakur, I.S., (2019). Microbial Treatment of Waste by Culture-Dependent and Culture-Independent Approaches: Opportunities and Challenges. *Microbial Diversity in Ecosystem Sustainability and Biotechnological Applications*, pp.415-446.

Hagerty, D., and J. J. E. G. Pavoni (1973). "Geologic aspects of landfill refuse disposal." 7(3): 219-229.

Hailemariam, M. and Ajeme, A., (2014). Solid waste management in Adama, Ethiopia: Aspects and challenges. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering*, *8*(9), pp.670-676.

Hailu, Y., Hanchiso, T. and Bereta, A., (2019). Municipal Solid Waste Source Identification, Characterization and Physical Composition Analysis, Case Study Wolkite Town, Ethiopia. *American Journal of Environmental Protection*, *8*(2), pp.48-53.

Hajar, H.A.A., Tweissi, A., Hajar, Y.A.A., Al-Weshah, R., Shatanawi, K.M., Imam, R., Murad, Y.Z. and Hajer, M.A.A., (2020). Assessment of the municipal solid waste management sector development in Jordan towards green growth by sustainability window analysis. *Journal of Cleaner Production*, *258*, p.120539.

Ireaja, N.A., Okeke, O.C. and Opara, A.I., (2018). Sanitary landfills: Geological and environmental factors that influence their siting, operation, and management. *IIARD International Journal of Geography and Environmental Management*, *4*(5), pp.1-9.

Islam, M., et al. (2020). "City and Environment Interactions."

Ireaja, N.A., Okeke, O.C. and Opara, A.I., (2018). Sanitary landfills: Geological and environmental factors that influence their siting, operation, and management. *IIARD International Journal of Geography and Environmental Management*, *4*(5), pp.1-9.

Jayanthi, B., Emenike, C.U., Auta, S.H., Agamuthu, P. and Fauziah, S.H., (2017). Characterization of induced mental responses of bacteria isolates from active non-sanitary landfill in Malaysia. *International Biodeterioration & Biodegradation*, *119*, pp.467-475.

Jia, P., Cheng, X., Xue, H. and Wang, Y., (2017). Applications of geographic information systems (GIS) data and methods in obesity-related research. *Obesity Reviews*, *18*(4), pp.400-411.

Joksimović, M. J. z. (2017). "Pope Pius II's charter of donation of the arm of St John the Baptist to Siena cathedral." (41): 95-105.

Joshi, R. and S. J. C. E. S. Ahmed (2016). "Status and challenges of municipal solid waste management in India: A review." 2(1): 1139434.

Joshi, S. and S. Joshi (2012). Pollution: Point and Non-Point Source Low-Cost Treatment. Encyclopedia of Environmental Management, CRC Press: 2150-2165.

Josimović, B., et al. (2015). "Multi-criteria evaluation in the strategic environmental assessment for the waste management plan, a case study: The city of Belgrade." 36: 331-342.

Kamdar, I., Ali, S., Bennui, A., Techato, K. and Jutidamrongphan, W., (2019). Municipal solid waste landfill siting using an integrated GIS-AHP approach: A case study from Songkhla, Thailand. *Resources, Conservation and Recycling*, *149*, pp.220-235.

Kao, C. J. A. M. M. (2010). "Weight determination for consistently ranking alternatives in multiple criteria decision analysis." 34(7): 1779-1787.

Kapilan, S. and K. J. J. o. C. S. U. Elangovan (2018). "Potential landfill site selection for solid waste disposal using GIS and multi-criteria decision analysis (MCDA)." 25(3): 570-585.

Kassar, M., Kervella, B. and Pujolle, G., (2008). An overview of vertical handover decision strategies in heterogeneous wireless networks. *Computer communications*, *31*(10), pp.2607-2620.

Kawy, W. A. M. A. and I. H. J. A. J. o. G. Abou El-Magd (2013). "Use of satellite data and GIS for assessing the agricultural potentiality of the soils South Farafra Oasis, Western Desert, Egypt." 6(7): 2299-2311.

Kennish, M. J. J. E. c. (2002). "Environmental threats and environmental future of estuaries." 78-107.

Kidd, P. M. J. A. m. r. (2007). "Omega-3 DHA and EPA for cognition, behavior, and mood: clinical findings and structural-functional synergies with cell membrane phospholipids." 12(3): 207.

Kirama, A. and A. W. J. H. I. Mayo (2016). "Challenges and prospects of private sector participation in solid waste management in Dar es Salaam City, Tanzania." 53: 195-205.

Kumar, S. and M. I. J. J. o. t. I. S. o. R. S. Hassan (2013). "Selection of a landfill site for solid waste management: an application of AHP and spatial analyst tool." 41(1): 45-56.

Lumsden, J. and C. Hendtlass (2000). "Landfill Guidelines: Towards Sustainable Waste Management in New Zealand."

Marshall, R. E., and K. J. W. m. Farahbakhsh (2013). "Systems approaches to integrated solid waste management in developing countries." 33(4): 988-1003.

Mat, N.A., Benjamin, A.M. and Abdul-Rahman, S., (2017). A review on criteria and decision-making techniques in solving landfill site selection problems. *Journal of Advanced Review on Scientific Research*, *37*(1), pp.14-32.

Megersa, R. (2020). Modeling Infiltration Capacity of Major Soils: The Case of Upper Awash Sub-Basin, ASTU

Miezah, K., Obiri-Danso, K., Kádár, Z., Fei-Baffoe, B. and Mensah, M.Y., (2015). Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana. *Waste management*, *46*, pp.15-27.

Mishra, S., et al. (2019). Heavy metal contamination: an alarming threat to the environment and human health. Environmental biotechnology: For sustainable future, Springer: 103-125.

Nanda, S. and F. J. E. C. L. Berruti (2020). "Municipal solid waste management and landfilling technologies: a review." 1-24.

Ngumom, T.M., and Terseer, H.W., (2015). Site suitability analysis for solid waste disposal using geospatial technology: a case study of Katsina-Ala township, Katsina-Ala, Benue State. *International Journal of Science and Research*.

Olaniyi, O. E., et al. (2018). "Ecotourism suitability of Okomu and Pendjari National Parks." 29(4): 593-604.

Passos, J., Alves, O. and Brito, P., (2020). Management of municipal and construction and demolition wastes in Portugal: future perspectives through gasification for energetic valorization. *International Journal of Environmental Science and Technology*, pp.1-20.

Rahman, M.A., Imteaz, M.A., Arulrajah, A., Piratheepan, J. and Disfani, M.M., (2015). Recycled construction and demolition materials in permeable pavement systems: geotechnical and hydraulic characteristics. *Journal of Cleaner Production*, *90*, pp.183-194.

Rajaeifar, M. A., et al. (2017). "Electricity generation and GHG emission reduction potentials through different municipal solid waste management technologies: a comparative review." 79: 414-439.

Rees, W. G. (2013). Physical principles of remote sensing, Cambridge university press.

Rushbrook, P. and M. Pugh (1999). Solid waste landfills in middle and lower-income countries: a technical guide to planning, design, and operation, The World Bank.

Samadder, S.R., Prabhakar, R., Khan, D., Kishan, D. and Chauhan, M.S., 2017. Analysis of the contaminants released from municipal solid waste landfill site: a case study. *Science of the Total Environment*, *580*, pp.593-601.

Sebsibe, I., Degaga, B., Feye, G. and Tekle, T.,(2021). Bacteriological and physical quality of Fiche drinking water from households and reservoirs, Oromia, Ethiopia. *Water Practice and Technology*.

Şener, B., Süzen, M.L. and Doyuran, V., (2006). Landfill site selection by using geographic information systems. *Environmental Geology*, *49*(3), pp.376-388

Shukure, R. and T. J. A. i. M. Simegnew (2018). "Knowledge Towards Antenatal Care and Service Utilization Among Women in Fiche Town, North Shewa, Ethiopia." 4(1): 1-5.

Srivastava, V., Ismail, S.A., Singh, P. and Singh, R.P.,(2015). Urban solid waste management in the developing world with emphasis on India: challenges and opportunities. *Reviews in Environmental Science and Bio/Technology*, *14*(2), pp.317-337.

Swati, T.I., Vijay, V.K. and Ghosh, P., (2018). A scenario of landfilling in India: problems, challenges, and recommendations. *Handbook of environmental materials management. Springer, Cham*, pp.1-16.

Tafesse, N. T. and B. F. Alemaw (2020). Groundwater Occurrence, Recharge, and Productivity in Tertiary Volcanic Rocks of Ethiopia and Climate Change Implications. Climate Variability and Change in Africa, Springer: 91-106.

Taiwo, A. M. J. J. o. E. S. and Technology (2011). "Composting as a sustainable waste management technique in developing countries." 4(2): 93-102.

Tercan, E., Dereli, M.A. and Tapkın, S., (2020). A GIS-based multi-criteria evaluation for MSW landfill site selection in Antalya, Burdur, Isparta planning zone in Turkey. *Environmental Earth Sciences*, *79*, pp.1-17.Teshome, F. B. J. J. o. M. C. and W. Management (2020). "Municipal solid waste management in Ethiopia; the gaps and ways for improvement." 1-14.

Thi, N.B.D., Kumar, G. and Lin, C.Y., (2015). An overview of food waste management in developing countries: Current status and future perspective. *Journal of environmental management*, *157*, pp.220-229.

Thoso, M. (2007). The construction of a geographic information system (GIS) model for landfill site selection, University of the Free State.

Vaverková, M. D. J. G. (2019). "Landfill Impacts on the Environment." 9(10): 431.

Wijitkosum, S. J. S. and W. Research (2012). "Impacts of land-use changes on soil erosion in Pa Deng sub-district, the adjacent area of Kaeng Krachan National Park, Thailand." 7(1): 10-17.

Winter, T. C. J. J. J. o. t. A. W. R. A. (2007). "The Role of Ground Water in Generating Streamflow in Headwater Areas and in Maintaining Base Flow 1." 43(1): 15-25.

Winkler, P., Kaiser, K., Kölbl, A., Kühn, T., Schad, P., Urbanski, L., Fiedler, S., Lehndorff, E., Kalbitz, K., Utami, S.R. and Cao, Z., (2016). Response of Vertisols, Andosols, and Alisols to paddy management. *Geoderma*, *261*, pp.23-35.

Worqlul, A.W., Collick, A.S., Rossiter, D.G., Langan, S. and Steenhuis, T.S., (2015). Assessment of surface water irrigation potential in the Ethiopian highlands: The Lake Tana Basin. *Catena*, *129*, pp.76-85.

Wuana, R. A. and F. E. J. I. E. Okieimen (2011). "Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation." 2011.

Yates, M. V. J. W. e. r. (2007). "Classical indicators in the 21st century—far and beyond the coliform." 79(3): 279-286.

Yoada, R.M., Chirawurah, D. and Adongo, P.B., (2014). Domestic waste disposal practice and perceptions of private sector waste management in urban Accra. *BMC public health*, *14*(1), pp.1-10.

Yukalang, N., Clarke, B. and Ross, K., (2017). Barriers to effective municipal solid waste management in a rapidly urbanizing area in Thailand. *International journal of environmental research and public health*, *14*(9), p.1013.

Zhang, H. and K. R. J. J. o. C. P. Haapala (2015). "Integrating sustainable manufacturing assessment into decision making for a production work cell." 105: 52-63.

APPENDICES

Appendix 1: The selected sites for municipal solid waste disposal.

Coordinate(m)	Area coverage		Direction from central of Fiche town	Specific location name
	Ha	%		
469119.579E-473218.184E, and 1080564.197N-1077419.449N	139	24.56	South	Torban-Ashe
468180.625E-468687.362E and 1082084.407N-1080728.141N	73	12.9	South	Ganda Farda
475200.418E-476020.139E and 1077061.753N-1078820.427N	176	31.1	South-East	Doyu
473173.471E-475692.25E and 10811756.518N-1080057.46N	64	11.3	North	Arata Mariyam
471876.822E-472785.967E and 1084349.817N-1082665.663N	107	18.9	North	Kidenibrat
469626.315E-469689.771E and 1083574.808N-1083395.96N	7	1.24	West	Bosoqe

Appendix 2: AHP result.

```
[Suitability analysis with the AHP]

[Analysis context/objective]
No context/objective specified

File created: 6/25/2021 7:37:55 PM

[No of criteria]
10

[Criteria and source layers]
Building Up distance  C:\Users\best\Desktop\GIS data for
R\recom2\BA12
Land Use Land Cover   Reclass_resl7_Resample.RASTER.1
Distance to Water Well     C:\Users\best\Desktop\GIS data for
R\recom2\ww12
Distance to surface water  C:\Users\best\Desktop\GIS data for
R\recom2\SW3
Geology Type    C:\Users\best\Desktop\GIS data for R\NEW
WORK\analysis\wow
Soil type  C:\Users\best\Desktop\GIS data for R\recom2\so12
Ground Water Depth    C:\Users\best\Desktop\GIS data for
R\recom2\Gwd12
Distance Main Road    C:\Users\best\Desktop\GIS data for
R\recom2\Ro12
Slope Suitability     C:\Users\best\Desktop\GIS data for
R\recom2\Slo12
Religion Institution  Feature_RGBF1.RASTER.1

[Criteria hierarchy]
[Objective]
     Building Up distance [0.335] -> [0.335]
     Land Use Land Cover [0.191] -> [0.191]
     Distance to Water Well [0.109] -> [0.109]
     Distance to surface water [0.095] -> [0.095]
     Geology Type [0.08] -> [0.08]
     Soil type [0.069] -> [0.069]
     Ground Water Depth [0.042] -> [0.042]
     Distance Main Road [0.034] -> [0.034]
     Slope Suitability [0.03] -> [0.03]
     Religion Institution [0.015] -> [0.015]

[AHP preference matrices and results]

Parent criterion: Objective

[Preference matrix]
     Building Up distance  Land Use Land Cover   Distance to
Water Well Distance to surface water   Geology Type    Soil Type
     Ground Water Depth    Distance Main Road    Slope
Suitability     Religion Institution
```

```
Building Up distance  1.0   3.0   5.0   5.0   5.0   5.0   7.0   7.0
      7.0   9.0
Land Use Land Cover   0.333 1.0   3.0   3.0   3.0   3.0   5.0   5.0
      5.0   9.0
Distance to Water Well      0.2   0.333 1.0   2.0   2.0   2.0   3.0
      3.0   3.0   7.0
Distance to surface water   0.2   0.333 0.5   1.0   2.0   2.0   3.0
      3.0   3.0   7.0
Geology Type     0.2   0.333 0.5   0.5   1.0   2.0   3.0   3.0   3.0
      5.0
Soil type  0.2   0.333 0.5   0.5   0.5   1.0   3.0   3.0   3.0   5.0
Ground Water Depth    0.143 0.2   0.333 0.333 0.333 0.333 1.0   2.0
      2.0   5.0
Distance Main Road    0.143 0.2   0.333 0.333 0.333 0.333 0.5   1.0
      2.0   3.0
Slope Suitability     0.143 0.2   0.333 0.333 0.333 0.333 0.5   0.5
      1.0   3.0
Religion Institution  0.111 0.111 0.143 0.143 0.2   0.2   0.2   0.333
      0.333 1.0

[Eigenvalues]
10.6244
0.2663
0.2663
-0.1382
-0.1382
-0.094
-0.094
-0.2199
-0.2199
-0.2529

[Eigenvector of largest Eigenvalue]
0.7789
0.445
0.2529
0.2202
0.1857
0.1617
0.0988
0.0799
0.0696
0.0356

[Criteria weights]
Building Up distance  33.4523
Land Use Land Cover   19.1137
Distance to Water Well      10.86
Distance to surface water   9.4586
Geology Type     7.975
Soil type  6.9459
Ground Water Depth    4.2432
Distance Main Road    3.4326
```

```
Slope Suitability     2.9896
Religion Institution  1.5291

[Consistency ratio CR]
0.0463
(A revision of the preference matrix is recommended if CR > 0.1)
```

Appendix 3: Landsat 8 data.

```
GROUP = L1_METADATA_FILE
  GROUP = METADATA_FILE_INFO
    ORIGIN = "Image courtesy of the U.S. Geological Survey"
    REQUEST_ID = "P700ovn2vcurs_00036"
    LANDSAT_SCENE_ID = "LC81680532020355LGN00"
    LANDSAT_PRODUCT_ID =
"LC08_L1TP_168053_20201220_20210310_01_T1"
    COLLECTION_NUMBER = 01
    FILE_DATE = 2021-03-10T07:02:17Z
    STATION_ID = "LGN"
    PROCESSING_SOFTWARE_VERSION = "LPGS_13.1.0"
  END_GROUP = METADATA_FILE_INFO
  GROUP = PRODUCT_METADATA
    DATA_TYPE = "L1TP"
    COLLECTION_CATEGORY = "T1"
    ELEVATION_SOURCE = "GLS2000"
    OUTPUT_FORMAT = "GEOTIFF"
    SPACECRAFT_ID = "LANDSAT_8"
    SENSOR_ID = "OLI_TIRS"
    WRS_PATH = 168
    WRS_ROW = 53
    NADIR_OFFNADIR = "NADIR"
    TARGET_WRS_PATH = 168
    TARGET_WRS_ROW = 53
    DATE_ACQUIRED = 2020-12-20
    SCENE_CENTER_TIME = "07:40:19.8033650Z"
    CORNER_UL_LAT_PRODUCT = 11.16711
    CORNER_UL_LON_PRODUCT = 38.52007
    CORNER_UR_LAT_PRODUCT = 11.16321
    CORNER_UR_LON_PRODUCT = 40.60261
    CORNER_LL_LAT_PRODUCT = 9.06977
    CORNER_LL_LON_PRODUCT = 38.52318
    CORNER_LR_LAT_PRODUCT = 9.06661
    CORNER_LR_LON_PRODUCT = 40.59225
    CORNER_UL_PROJECTION_X_PRODUCT = 447600.000
    CORNER_UL_PROJECTION_Y_PRODUCT = 1234500.000
    CORNER_UR_PROJECTION_X_PRODUCT = 675000.000
    CORNER_UR_PROJECTION_Y_PRODUCT = 1234500.000
    CORNER_LL_PROJECTION_X_PRODUCT = 447600.000
    CORNER_LL_PROJECTION_Y_PRODUCT = 1002600.000
    CORNER_LR_PROJECTION_X_PRODUCT = 675000.000
    CORNER_LR_PROJECTION_Y_PRODUCT = 1002600.000
    PANCHROMATIC_LINES = 15461
    PANCHROMATIC_SAMPLES = 15161
```

```
    REFLECTIVE_LINES = 7731
    REFLECTIVE_SAMPLES = 7581
    THERMAL_LINES = 7731
    THERMAL_SAMPLES = 7581
    FILE_NAME_BAND_1 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B1.TIF"
    FILE_NAME_BAND_2 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B2.TIF"
    FILE_NAME_BAND_3 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B3.TIF"
    FILE_NAME_BAND_4 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B4.TIF"
    FILE_NAME_BAND_5 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B5.TIF"
    FILE_NAME_BAND_6 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B6.TIF"
    FILE_NAME_BAND_7 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B7.TIF"
    FILE_NAME_BAND_8 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B8.TIF"
    FILE_NAME_BAND_9 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B9.TIF"
    FILE_NAME_BAND_10 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B10.TIF"
    FILE_NAME_BAND_11 =
"LC08_L1TP_168053_20201220_20210310_01_T1_B11.TIF"
    FILE_NAME_BAND_QUALITY =
"LC08_L1TP_168053_20201220_20210310_01_T1_BQA.TIF"
    ANGLE_COEFFICIENT_FILE_NAME =
"LC08_L1TP_168053_20201220_20210310_01_T1_ANG.txt"
    METADATA_FILE_NAME =
"LC08_L1TP_168053_20201220_20210310_01_T1_MTL.txt"
    CPF_NAME = "LC08CPF_20201212_20201231_01.07"
    BPF_NAME_OLI = "LO8BPF20201220072521_20201220090414.01"
    BPF_NAME_TIRS = "LT8BPF20201216105400_20201230153218.01"
    RLUT_FILE_NAME = "LC08RLUT_20150303_20431231_01_12.h5"
  END_GROUP = PRODUCT_METADATA
  GROUP = IMAGE_ATTRIBUTES
    CLOUD_COVER = 14.73
    CLOUD_COVER_LAND = 14.73
    IMAGE_QUALITY_OLI = 9
    IMAGE_QUALITY_TIRS = 9
    TIRS_SSM_MODEL = "FINAL"
    TIRS_SSM_POSITION_STATUS = "ESTIMATED"
    TIRS_STRAY_LIGHT_CORRECTION_SOURCE = "TIRS"
    ROLL_ANGLE = -0.001
    SUN_AZIMUTH = 144.43109578
    SUN_ELEVATION = 48.60217644
    EARTH_SUN_DISTANCE = 0.9837989
    SATURATION_BAND_1 = "N"
    SATURATION_BAND_2 = "N"
    SATURATION_BAND_3 = "N"
    SATURATION_BAND_4 = "Y"
```

```
    SATURATION_BAND_5 = "Y"
    SATURATION_BAND_6 = "N"
    SATURATION_BAND_7 = "Y"
    SATURATION_BAND_8 = "N"
    SATURATION_BAND_9 = "N"
    GROUND_CONTROL_POINTS_VERSION = 4
    GROUND_CONTROL_POINTS_MODEL = 353
    GEOMETRIC_RMSE_MODEL = 7.799
    GEOMETRIC_RMSE_MODEL_Y = 5.251
    GEOMETRIC_RMSE_MODEL_X = 5.766
    GROUND_CONTROL_POINTS_VERIFY = 122
    GEOMETRIC_RMSE_VERIFY = 4.512
    TRUNCATION_OLI = "UPPER"
  END_GROUP = IMAGE_ATTRIBUTES
  GROUP = MIN_MAX_RADIANCE
    RADIANCE_MAXIMUM_BAND_1 = 785.30200
    RADIANCE_MINIMUM_BAND_1 = -64.85049
    RADIANCE_MAXIMUM_BAND_2 = 804.15881
    RADIANCE_MINIMUM_BAND_2 = -66.40769
    RADIANCE_MAXIMUM_BAND_3 = 741.02545
    RADIANCE_MINIMUM_BAND_3 = -61.19412
    RADIANCE_MAXIMUM_BAND_4 = 624.87439
    RADIANCE_MINIMUM_BAND_4 = -51.60233
    RADIANCE_MAXIMUM_BAND_5 = 382.39197
    RADIANCE_MINIMUM_BAND_5 = -31.57805
    RADIANCE_MAXIMUM_BAND_6 = 95.09740
    RADIANCE_MINIMUM_BAND_6 = -7.85317
    RADIANCE_MAXIMUM_BAND_7 = 32.05292
    RADIANCE_MINIMUM_BAND_7 = -2.64694
    RADIANCE_MAXIMUM_BAND_8 = 707.18585
    RADIANCE_MINIMUM_BAND_8 = -58.39964
    RADIANCE_MAXIMUM_BAND_9 = 149.44745
    RADIANCE_MINIMUM_BAND_9 = -12.34142
    RADIANCE_MAXIMUM_BAND_10 = 22.00180
    RADIANCE_MINIMUM_BAND_10 = 0.10033
    RADIANCE_MAXIMUM_BAND_11 = 22.00180
    RADIANCE_MINIMUM_BAND_11 = 0.10033
  END_GROUP = MIN_MAX_RADIANCE
  GROUP = MIN_MAX_REFLECTANCE
    REFLECTANCE_MAXIMUM_BAND_1 = 1.210700
    REFLECTANCE_MINIMUM_BAND_1 = -0.099980
    REFLECTANCE_MAXIMUM_BAND_2 = 1.210700
    REFLECTANCE_MINIMUM_BAND_2 = -0.099980
    REFLECTANCE_MAXIMUM_BAND_3 = 1.210700
    REFLECTANCE_MINIMUM_BAND_3 = -0.099980
    REFLECTANCE_MAXIMUM_BAND_4 = 1.210700
    REFLECTANCE_MINIMUM_BAND_4 = -0.099980
    REFLECTANCE_MAXIMUM_BAND_5 = 1.210700
    REFLECTANCE_MINIMUM_BAND_5 = -0.099980
    REFLECTANCE_MAXIMUM_BAND_6 = 1.210700
    REFLECTANCE_MINIMUM_BAND_6 = -0.099980
    REFLECTANCE_MAXIMUM_BAND_7 = 1.210700
    REFLECTANCE_MINIMUM_BAND_7 = -0.099980
```

```
    REFLECTANCE_MAXIMUM_BAND_8 = 1.210700
    REFLECTANCE_MINIMUM_BAND_8 = -0.099980
    REFLECTANCE_MAXIMUM_BAND_9 = 1.210700
    REFLECTANCE_MINIMUM_BAND_9 = -0.099980
  END_GROUP = MIN_MAX_REFLECTANCE
  GROUP = MIN_MAX_PIXEL_VALUE
    QUANTIZE_CAL_MAX_BAND_1 = 65535
    QUANTIZE_CAL_MIN_BAND_1 = 1
    QUANTIZE_CAL_MAX_BAND_2 = 65535
    QUANTIZE_CAL_MIN_BAND_2 = 1
    QUANTIZE_CAL_MAX_BAND_3 = 65535
    QUANTIZE_CAL_MIN_BAND_3 = 1
    QUANTIZE_CAL_MAX_BAND_4 = 65535
    QUANTIZE_CAL_MIN_BAND_4 = 1
    QUANTIZE_CAL_MAX_BAND_5 = 65535
    QUANTIZE_CAL_MIN_BAND_5 = 1
    QUANTIZE_CAL_MAX_BAND_6 = 65535
    QUANTIZE_CAL_MIN_BAND_6 = 1
    QUANTIZE_CAL_MAX_BAND_7 = 65535
    QUANTIZE_CAL_MIN_BAND_7 = 1
    QUANTIZE_CAL_MAX_BAND_8 = 65535
    QUANTIZE_CAL_MIN_BAND_8 = 1
    QUANTIZE_CAL_MAX_BAND_9 = 65535
    QUANTIZE_CAL_MIN_BAND_9 = 1
    QUANTIZE_CAL_MAX_BAND_10 = 65535
    QUANTIZE_CAL_MIN_BAND_10 = 1
    QUANTIZE_CAL_MAX_BAND_11 = 65535
    QUANTIZE_CAL_MIN_BAND_11 = 1
  END_GROUP = MIN_MAX_PIXEL_VALUE
  GROUP = RADIOMETRIC_RESCALING
    RADIANCE_MULT_BAND_1 = 1.2973E-02
    RADIANCE_MULT_BAND_2 = 1.3284E-02
    RADIANCE_MULT_BAND_3 = 1.2241E-02
    RADIANCE_MULT_BAND_4 = 1.0323E-02
    RADIANCE_MULT_BAND_5 = 6.3169E-03
    RADIANCE_MULT_BAND_6 = 1.5709E-03
    RADIANCE_MULT_BAND_7 = 5.2949E-04
    RADIANCE_MULT_BAND_8 = 1.1682E-02
    RADIANCE_MULT_BAND_9 = 2.4688E-03
    RADIANCE_MULT_BAND_10 = 3.3420E-04
    RADIANCE_MULT_BAND_11 = 3.3420E-04
    RADIANCE_ADD_BAND_1 = -64.86347
    RADIANCE_ADD_BAND_2 = -66.42098
    RADIANCE_ADD_BAND_3 = -61.20636
    RADIANCE_ADD_BAND_4 = -51.61265
    RADIANCE_ADD_BAND_5 = -31.58437
    RADIANCE_ADD_BAND_6 = -7.85475
    RADIANCE_ADD_BAND_7 = -2.64747
    RADIANCE_ADD_BAND_8 = -58.41132
    RADIANCE_ADD_BAND_9 = -12.34389
    RADIANCE_ADD_BAND_10 = 0.10000
    RADIANCE_ADD_BAND_11 = 0.10000
    REFLECTANCE_MULT_BAND_1 = 2.0000E-05
```

```
    REFLECTANCE_MULT_BAND_2 = 2.0000E-05
    REFLECTANCE_MULT_BAND_3 = 2.0000E-05
    REFLECTANCE_MULT_BAND_4 = 2.0000E-05
    REFLECTANCE_MULT_BAND_5 = 2.0000E-05
    REFLECTANCE_MULT_BAND_6 = 2.0000E-05
    REFLECTANCE_MULT_BAND_7 = 2.0000E-05
    REFLECTANCE_MULT_BAND_8 = 2.0000E-05
    REFLECTANCE_MULT_BAND_9 = 2.0000E-05
    REFLECTANCE_ADD_BAND_1 = -0.100000
    REFLECTANCE_ADD_BAND_2 = -0.100000
    REFLECTANCE_ADD_BAND_3 = -0.100000
    REFLECTANCE_ADD_BAND_4 = -0.100000
    REFLECTANCE_ADD_BAND_5 = -0.100000
    REFLECTANCE_ADD_BAND_6 = -0.100000
    REFLECTANCE_ADD_BAND_7 = -0.100000
    REFLECTANCE_ADD_BAND_8 = -0.100000
    REFLECTANCE_ADD_BAND_9 = -0.100000
  END_GROUP = RADIOMETRIC_RESCALING
  GROUP = TIRS_THERMAL_CONSTANTS
    K1_CONSTANT_BAND_10 = 774.8853
    K2_CONSTANT_BAND_10 = 1321.0789
    K1_CONSTANT_BAND_11 = 480.8883
    K2_CONSTANT_BAND_11 = 1201.1442
  END_GROUP = TIRS_THERMAL_CONSTANTS
  GROUP = PROJECTION_PARAMETERS
    MAP_PROJECTION = "UTM"
    DATUM = "WGS84"
    ELLIPSOID = "WGS84"
    UTM_ZONE = 37
    GRID_CELL_SIZE_PANCHROMATIC = 15.00
    GRID_CELL_SIZE_REFLECTIVE = 12.5
    GRID_CELL_SIZE_THERMAL = 12.5
    ORIENTATION = "NORTH_UP"
    RESAMPLING_OPTION = "CUBIC_CONVOLUTION"
  END_GROUP = PROJECTION_PARAMETERS
END_GROUP = L1_METADATA_FILE
END
```