2022-07

Solid Waste Disposal Site Selection Using Integrated Multi-Parametric AHP and GIS Techniques: The case of Gish Abay Town, Ethiopia

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Institute of Land Administration

Department of Land administration and Surveying

Post Graduate Program

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By

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July, 2022

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By

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A Thesis Submitted to the Department of Land Administration and Surveying, Bahir Dar University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Geomatics.

Advisor:

Abebe M. Wubie (PhD) - Institute of Land Administration, Bahir Dar University

July, 2022

Ethiopia, Bahir Dar

DECLARATION

I declared that this master's thesis entitled '**Solid Waste Disposal Site Selection Using Integrated Multi-Parametric AHP and GIS Techniques: The case of Gish Abay Town, Ethiopia'** is my original research work and has not been submitted for the award of a degree at any other university or college. The assistance and help I received during the course of this investigation have been duly acknowledged.

Tadegew Sega Necho	.__________.	14/08/2022
Name of the Student	Signature	Date

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Advisor Approval

I hereby certify that I have advised, read, and evaluated this thesis titled **'Solid Waste Disposal Site Selection Using Integrated Multi-Parametric AHP and GIS Techniques: The case of Gish Abay Town'** by **Tadegew Sega**, prepared under my advice. I approved the thesis for fulfilling the requirements for the award of the degree of Masters of Science in Geomatics.

Abebe M. Wubie (PhD) ________________
20/07/2022

Advisor Signature Date

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THESIS APPROVAL

As members of the board of examiners, we examined this thesis titled 'Solid Waste Disposal Site Selection Using Integrated Multi-Parametric AHP and GIS Techniques: The case of Gish Abay Town, Ethiopia' by Tadegew Sega. We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Science in Geomatics.

Board of Examiners

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Name of Internal Examiner	Signature	Date
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Acknowledgement

Above all I would like to express my deepest gratitude to the almighty God, whose mercy allowed me to prepare and complete this paper.

Secondly, I would like to thank my advisor Abebe M. Wubie (PhD) for his constructive advice, support and fruitful guidance to accomplish this work.

Thirdly, my special thanks and deepest gratitude goes to my friends and classmates; for their precious and fertile moral supports and encouragement in every situation to accomplish my paper.

Finally, special words of thanks to my beloved families for their moral and financial supports.

Acronyms and Abbreviations

AHP: ---------- Analytical Hierarchy Process

CPHEEO ----- Central Public Health Environment and Engineering Organisation

CPCB --------- Central Pollution Control Board

CI: ------------- Consistency Index

CR: ------------ Consistency Ratio

DEM: ---------- Digital Elevation Model

MUDC: ------ Ministry of Urban Development and Construction

FGD: ---------- Focus Group Discussion

FEDO: --------- Finance Economy and Development Office

GATM: -------- Gish Abay Town Municipality

GIS: ------------ Geographical Information System

HHs: ------------ House Holds

IUP: ------------- Institute of Urban Planning

KII: ------------- Key Informant Interviews

MCDA: --------- Multi Criteria Decision Approach

MCDM: --------- Multi Criteria Decision Method

MCE: ------------ Multi Criteria Evaluation

OECD: ---------- Organization for Economic Co-operation and Development

SWAO: ---------- Sekela Woreda agriculture Office

UNEP: ----------- United Nations for Environmental Protection

USGS: ----------- United States Geological Survey

WHO: ------------ World Health Organization

Abstract

The generation and dispose of solid wastes are becoming the problems facing both in developing and developed countries. The rapid growth of population and urbanization are connected with high discharge of solid wastes in which the management of solid waste becomes the challenging tasks both at the emerging and mega cities of Ethiopia. This calls the selection of appropriate waste disposal site by considering both the socio-spatial and environmental factors. Thus, the main objective of this research is to assess the potential suitable solid waste disposal site by customizing the major determinant factors using integrated multi-parametric AHP and GIS techniques. It also assesse to what extent the existing solid waste dumping sites affect the environmental and socio-economic phenomenon in Gish Abay Town, Ethiopia. The study used both spatial and socio-economic primary and secondary data. Primary socio-economic data were collected through survey questionnaires, focus group discussion (FGDs) and key informant interviews (KIIs).The socio-economic empirical data were analyzed using descriptive statistics whereas; qualitative data were analyzed in a content-wise. The spatial data were analyzed using spatial data analysis software. The study result shows that the current waste disposal practices and the existing disposal sites create social and environmental problems. This is because the existing disposal sites are located randomly without any characterization of the socio-economic and environmental parameters. Of the entire study area only 1.13% is highly suitable, 4.88% of the area is moderately suitable, 1.95% is less suitable and that of 91.34% of study is not suitable for solid waste dumping site. Of the suitable areas, the two sites namely 'Ganua' with areal area coverage of 12.84ha and 'Gerelta' area coverage of 1.89ha are the first and the seconded potential suitable solid waste disposal site respectively. As a conclusion, this research suggests the reconsideration and relocation of the existing solid waste disposal sites by adopting the proposed potential suitable areas for the sustainability of the town development.

Key words; Solid waste; Suitable Desposal Site; GIS; Analytical Hierarchical Process, Gish Abay town

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CHAPTER ONE:

1. INTRODUCTION

1.1 Background of the Study

A solid waste refers to a non-liquid and non-gaseous product of human activities, regarded as being useless (Babayemi and Dauda, 2009). Solid wastes are mostly discharging from households, municipals and construction sectors on each stage of daily human life activities (Munier, 2005). It includes leaves (twinges), food remnants, papers (cartons), textile materials, bones, dust (stones), dead animals, animals excreta, and demolished debris, biomedical debris, electrical appliances (Babatunde et al., 2013). The generation and dispose of solid wastes are the problems facing both developing and developed countries; pollute the environment and destroy resources (UNEP, 2005). The most common problems occurring with the result of unplanned disposal municipal solid wastes are transmission of diseases, fire hazards, unpleasant odors, atmospheric and water pollution problems, urban aesthetic problems as well as huge economic loses (Bedassa and Wondwesen, 2020).

The rapid urbanization, industrialization and population growth have produced vast amounts of solid and liquid wastes (Salemi and Hejazi 2017). As the world hurtles toward its urban future, the amount of municipal solid waste is growing even faster than the rate of urbanization. The world's cities are generating 2.01 billion tonnes of solid waste per year, and this volume is expected to increase to 2.2 billion tonnes by 2025 (World Bank, 2012). On average, 0.74kg of waste are releasing per capita per day (World Bank, 2019).

According to World Bank (2019) report solid waste is a problem both in developing and developed countries. However, the amount of solid waste generation in developed and high income countries are much higher than developing and low income regions. For instance, the Organization for Economic Co-operation and Development (OECD) countries generate 675 million tonnes of solid waste per year with an average of 2.21 kg/capita/day. On the other hand, South Asia regions generate approximately 374 million tonnes per year with an average of 0.52 kg/capita/day and in East Asia and Pacific Region is 478 million tonnes per year with an average of 0.95 kg/capita/day. However, low and middle-income nations generate the lowest amount of solid waste per capita: annually generated solid wastes in Sub-Saharan Africa countries were approximated to 174 million tonnes per year with an average of 0.46 kg/capita/day, and also in the Middle East and North Africa, solid waste generation is 129 million tonnes per year with average of 0.56 kg/capita/day (World Bank, 2019).

In Ethiopia, the country's recent strong economic growth has been accompanied by rapid urbanization; this has put pressure on cities' for municipal solid waste management. For instance in Addis Ababa, urban solid waste generation is rising at a rate of 5% each year (World Bank, 2019). And the country's per capita amount of waste generated ranges from 0.28 to 0.83 kg/capita/day (Selamawit et al., 2020).

The other critical issue is the management of generated solid wastes. This is because of the municipal solid waste collection is an important aspect in maintaining the environments and public health in cities around the world. The amount of municipal solid waste collected varies widely by region and income level; collection within cities can also differ greatly, collection rates ranges from a low of 41% in low-income countries to a high of 98% in high-income countries (World Bank, 2012).

Waste disposal site is an integral part of waste management system which requires much attention to avoid environmental pollution (Mijibor et al., 2008). In this regard, landfilling and thermal treatment of waste are the most common methods of municipal solid waste disposal in high-income countries. Although several middle-income countries have poorly operated landfills; disposal should likely be classified as controlled dumping, most low- and lower middle-income countries dispose of their waste in open dumps (World Bank, 2012), which tells that, urban solid waste management is considered as one of the most urgent and serious environmental problems facing municipality authorities in developing countries particularly in Africa (Bedassa and Wondwesen, 2020).

According to World Bank (2012) solid waste should be disposed at a "controlled dump", which includes site selection, controlled access, and where practical, compaction of waste. Incineration requires a complimentary sanitary landfill, as bottom ash, non-combustibles and by-passed waste needs to be landfilled. A suitable solid waste disposal site selection must have characterized environmental and socio-economic factors that will enable the waste to be isolated so as to reduce its negative impacts (Bedassa and Wondwesen, 2020). However, selecting appropriate site and managing the solid waste dumping in countries like Ethiopia with limited financial and rapid population growth rate is more severe (Minalu, 2016). Like in many other developing countries, most Ethiopia town municipals assigned sites for solid waste disposal have been normally carried by in traditional approaches; throwing it at all types of free land and the majority of inhabitants often use unsafe solid waste disposal practices, such as open dumping, burning and burying in or around the town (Mijibor et al., 2008; Degnet, 2008).

Similarly, Gish Abay town as one of the urban areas of Ethiopia has faced problems in solid waste disposal sites. Even if most of the solid wastes are collected from the source using push carts ("kareta") to the temporary transfer stations, there are no scientifically approved suitable sites. All residents (hotels, domestic households, service areas and commercial centers) follows their way of removal of waste, while some others dispose it to the nearby water body (Abay river), streets and ditches. The temporal open dump sites are not well planned, and they are open field disposal (no sanitary landfill). The existing sites are close to residential area and not at appropriate distance from the center of public services (IUP, 2020).

Analytical Hierarchy Process, one of the methods of MCDA, is a conventional land suitability analysis method that provides right decision-making approach for site selection. AHP has been integrated with GIS for land suitability modeling when selecting the best alternatives from a pool of various possibilities in the presence of multiple criteria. The subjective evaluations are converted into numerical values that are ranked on a numerical scale (Debishree et al., 2014). Therefore, the role of MCDA in solid waste disposal site selection can be completed by integrating it with GIS which can solve the challenges of landfill site selection which involves highly complex spatial decision-making processes (Genemo and Yohannes, 2015).

Hence, this study ties to fill the above mentioned gaps by selecting the potential suitable disposal site using integrated multi-parametric AHP and GIS techniques.

1.2 Statement of the Problem

The generation and dispose of solid wastes are the problems facing both developing and developed countries. These challenges are the main concern for many urban municipalities. This is because of a rapid urbanization and rapid increase in population together with rapid development (i.e. rapid economic growth with rise in community living standards) accelerates solid waste generation in urban areas (Elmira et al., 2010). According to Aeden, (2016), high rate of wastes generation is facing problem of their disposal and improper waste disposal high potential effect to pollute environment such as surface water, ground water, soil, and air as well as aggravating public health problems. The most common problems associated with improper management of solid waste include diseases transmission, fire hazards, odor atmospheric and water pollution and economic losses (Palomar et al. 2019; Omoloso et al. 2020.

The current solid waste dumping system adopted in Gish Abay town is open land disposal site located at the Shore of Abay River. Indiscriminate dumping of wastes contaminates surface and ground water supplies. It clogs drains, creating stagnant water for insect breeding and floods during rainy seasons. Specially; as the study area is located on the upper stream side of Lake Tana, the town solid wastes are directly drained to the river Nile. According to the Urban Plan Institute (IUP, 2020) report, the locals have been habituated to simply dumping waste on streets, open fields (near to recreation areas), residential areas and rivers shores, water distributing lines and sewerage canals. This leads to air, soil, and water pollutions. This calls the selection of appropriate waste disposal site by considering both the spatial, social and environmental factors.

An integrated system for solid waste disposal site selection is desirable to reduce the growing challenge of municipal solid waste management problems (Yenenesh et. al., 2020). Therefore, the present study employs Multi-criteria evaluation approach (a multi-parametric analytical hierarchy process) using GIS techniques to select appropriate solid waste disposal site for Gish Abay town by considering environmental, economic and socio-cultural factors.

1.3 Objectives of the Study:

1.3.1 General Objective

The general objective of the study is to assess the potential suitable solid waste disposal site by customizing the major parameters/factors of AHP to the local conditions using integrated multi-parametric AHP and GIS techniques.

1.3.2 Specific Objectives

Under the umbrella of the above general objective, this research attempted to address the following specific objectives:

- To examine the existing solid waste dumping situations in the study area,
- To evaluate the socio-economic and environmental impacts of the existing solid waste dumping system,
- To identify and customize the major parameters/factors of AHP to the local conditions.
- To prepare and map potential site for solid waste dumping through the proposed multi- parametric AHP and multi-criteria analysis.

1.4. Research Questions:

The following research questions are forwarded to achieve the stated objectives.

1 How is the situation of the existing solid waste dumping site in the study area?

2 What are the socio-economic and environmental impacts of the existing solid waste dumping system?

3 What are the main factors for suitability analysis for solid waste dumping site selection in Gish Abay Town? and

4 Which areas are highly suitable site for solid waste dumping?

1.5 Significance of the Study

The study is aimed to assess the potential suitable solid waste disposal site in Gish Abay Town of Ethiopia by customizing the major parameters/factors of AHP to the local conditions using integrated multi-parametric AHP and GIS techniques, Hence, the results of this study will helps the town administrators and the governments for policy and decision-making. Moreover, in these study the researcher have tried to customized the suitability parameters/factors and standards to the local condition so the local governmental offices and experts can use these customized parameters and standard for further related suitability works. Simultaneously, this research may also use as secondary data source for researchers within the related area.

1.6 Delimitation of the Study:

Spatially, this research was conducted in Gish Abay town, west Gojjam zone, Amhara National Regional State, located in the Blue Nile Basin in northwestern part of Ethiopia. Thematically, this research attempted to assess the existing solid waste disposal practices and the research limited to the suitable solid waste disposal site selection for Gish Abay town, but not for liquid and hazardous wastes.

CHAPTER TWO:

LITERATURE REVIEW:

2.1 Solid Waste

Solid waste refers to non-liquid and non-gaseous products of human activities which regarded as being useless (Babayemi and Dauda, 2009). Solid waste are mostly discharged from households, municipals and construction sectors on each stage of daily human life activities (Munier, 2005) which leads to impose impacts on human health and on the natural environment. Solid wastes includes leaves (twinges), food remnants, papers (cartons), textile materials, bones, dust (stones), dead animals, animals excreta, and demolished debris, biomedical debris, electrical appliances (Babatunde et al., 2013). The generation and dispose of solid wastes are the problems facing both developing and developed countries; pollute the environment and destroy resources (UNEP, 2005). The most common problems occurring with the result of unplanned disposal municipal solid wastes are transmission of diseases, fire hazards, unpleasant odors, atmospheric and water pollution problems, urban aesthetic problems as well as huge economic loses (Bedassa and Wondwesen, 2020)

Rapid urbanization and industrialization, agricultural activities spurred by rapid population growth have produced vast amounts of solid and liquid wastes (UNEP, 2020; Salemi and Hejazi 2017). As the world hurtles toward its urban future, the amount of municipal solid waste is growing even faster than the rate of urbanization; in 2012 the world’s cities were generating 1.3 billion tonnes of solid waste per year, and this volume is expected to increase to 2.2 billion tonnes by 2025 (World Bank, 2012). However; overall, the estimated global average for 2016 is 0.74 kilogram of waste per capita per day and total generation of solid waste is about 2.01 billion tonnes in 2016, this number will continue to grow (World Bank, 2019).

According to World Bank, (2019), there is a vast amount of solid waste generation in developed and high income countries than developing and low income regions. The Organization for Economic Co-operation and Development (OECD) countries generate 675million tonnes of solid waste per year with average of 2.21 kg/capita/day. On the other hand, South Asia regions generate approximately 374 million tonnes per year with an average of 0.52 kg/capita/day and in East Asia and Pacific Region is 478 million tonnes per year with an average of 0.95 kg/capita/day.

However, low and middle-income nations generate the lowest amount of solid waste per capita: annually generated solid wastes in Sub-Saharan Africa countries were approximated to 174 million tonnes per year with an average of 0.46 kg/capita/day, and also in the Middle East and North Africa, solid waste generation is 129 million tonnes per year with average of 0.56 kg/capita/day (World Bank, 2019).

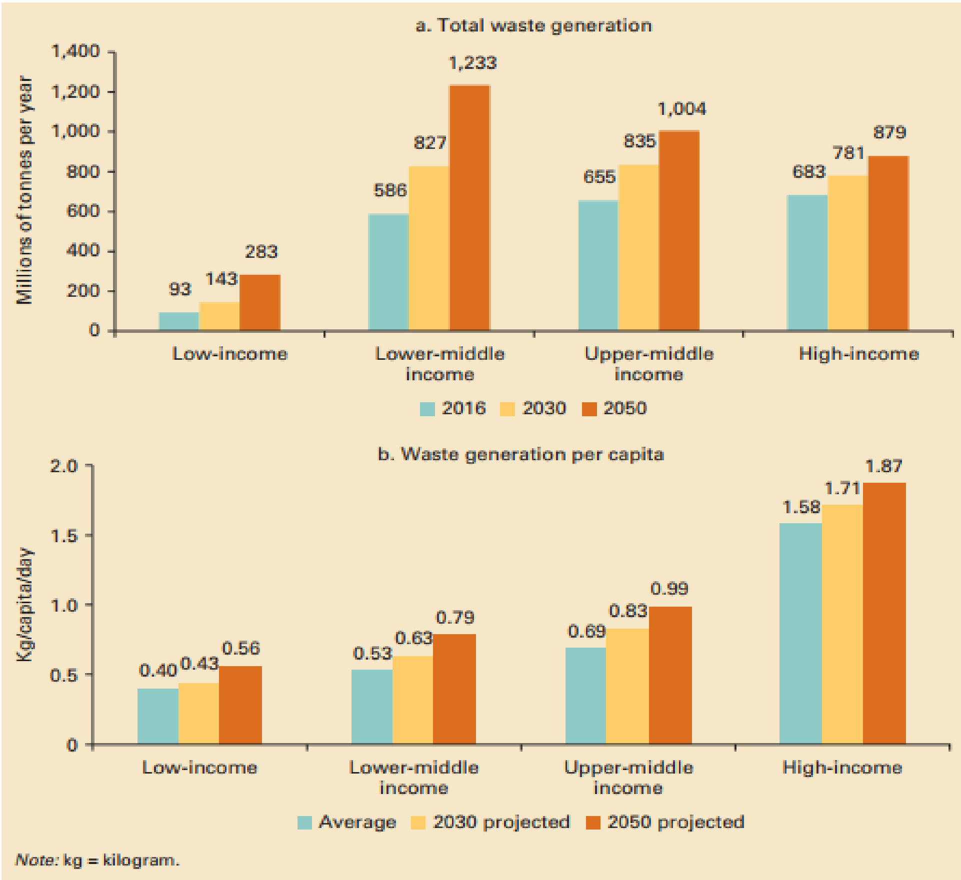


Figure 2-1: World waste generation

Source: (World Bank, 2019: What a waste 2.0: Global review of SWM):

2.1 Solid Waste Management:

Waste disposal is an important part of waste management system, which requires much attention to avoid environmental pollution (Mijibor et al., 2008). Managing solid waste is required to monitoring (handling and storage), collection, transport, processing and disposal of solid wastes. These activities should be in line with principles of waste management hierarchy (Figure 2.1) that seeks to minimize waste generation, maximize waste recycling and reuse, and ensure safe and environmentally sound disposal of waste (Yenenesh et al., 2020).

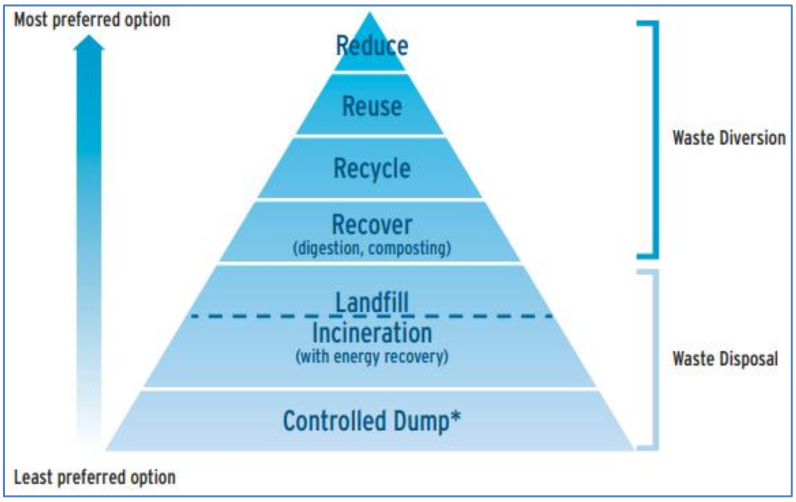


Figure 2-2: Waste management pyramid:

Source: (Yenenesh et al., 2020; World Bank, 2019)

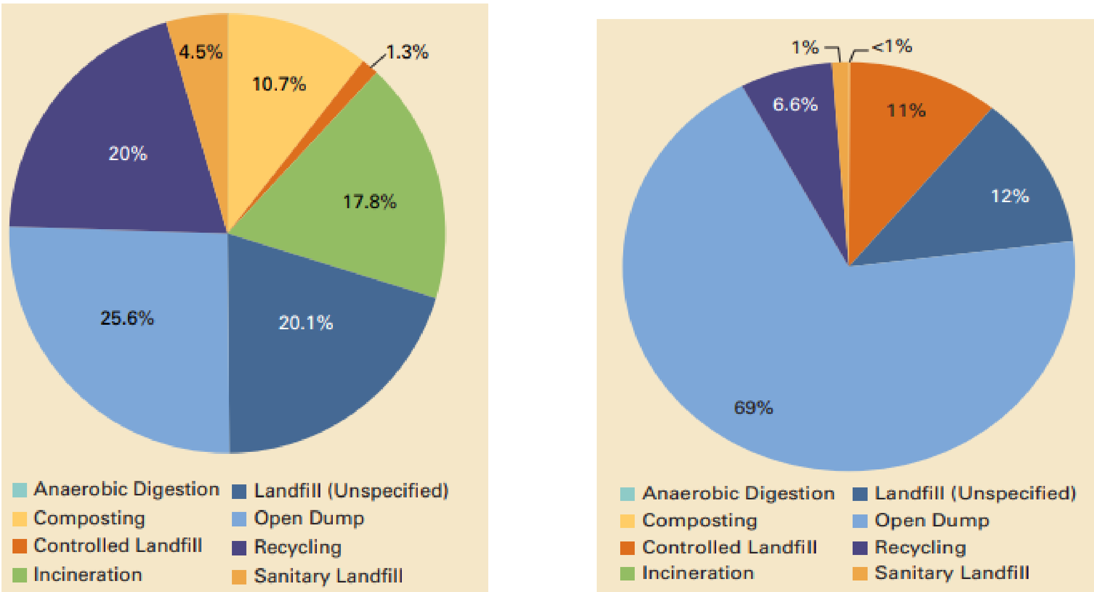
In accordance of waste management, landfilling and thermal treatment of waste are the most common methods of municipal solid waste disposal in high-income countries. Although several middle-income countries have poorly operated landfills; disposal should likely be classified as controlled dumping, most low- and lower middle-income countries dispose of their waste in open dumps (World Bank, 2012). And also urban solid waste management is considered as one of the most urgent and serious environmental problems facing municipality authorities in developing countries particularly in Africa (Bedassa and Wondwesen, 2020).

Table 2-1: Municipal solid waste disposal in two contrasting regions:

Waste disposal models	**Africa (Low income) (Million tonnes)**	**OCED (High income) (Million tonnes)**
Dumps	2.3	-
Landfills	2.6	242
Compost	0.05	265
Recycled	0.14	125
Incineration	0.05	120
Other	0.11	20

Source: World Bank (2012) Global review of solid waste management:

The World Bank stated that, as a minimum, solid waste should be disposed at a "controlled dump," which includes site selection, controlled access, and where practical, compaction of waste. Incineration requires a complimentary sanitary landfill, as bottom ash, non-combustibles and by-passed waste needs to be landfilled (World Bank (2019). A suitable solid waste disposal site selection must have characterized environmental and socio-economic factors that will enable the waste to be isolated so as to reduce its negative impacts (Bedassa and Wondwesen, 2020).



(a) (Europe and Central Asia) (b) in Sub-Saharan Africa

Figure 2-3: Waste Disposal Practices:

(Source: World Bank, 2019: What a waste)

However, selecting appropriate site and managing the solid waste dumping in countries like Ethiopia with limited financial and rapid population growth rate is more severe (Minalu, 2016). Like in many other developing countries, most Ethiopia town municipals assigned sites for solid waste disposal have been normally carried by in traditional approaches; throwing it at all types of free land and the majority of inhabitants often use unsafe solid waste disposal practices, such as open dumping, burning and burying in or around the town (Mijibor et al., 2008 and Degnet, 2008).

Similarly, as one of the urban areas of Ethiopia, Gish Abay town, there are problems in solid waste disposal sites. Even if most of the solid wastes are collected from the source using push carts ("kareta") to the temporary transfer stations, there are no scientifically approved suitable sites. All residents (hotels, domestic households, service areas and commercial centers) follows their way of removal of waste, while some others dispose it to the nearby water body (Abay river), in to streets and ditches. The temporal open dump sites are not well planned, and they are open field disposal (no sanitary landfill), are close to residential area and not at appropriate distance from the center of public services (IUP, 2020).

2.2 Solid Waste Disposal Site

Solid waste disposal is a technique for the final disposal of solid waste in the ground that causes no nuisance or danger to public health or safety neither does it harm the environment during its operations or after its closure. This technique uses engineering principles to confine the waste to as small areas as possible, covering it daily with layers of earth and compacted to reduce its volume. A solid waste disposal site is also known as a tip, dump, rubbish dump, garbage dump or dumping ground and is a site for the disposal of waste materials by burial. It is a carefully designed structure built into or on top of the ground, in which trash is separated from the area around it (Tchobanoglous, 1993).

Solid waste disposal system should be environmentally sound and socially acceptable to protect the environment and the safety of public health. But selecting appropriate site and managing solid waste dumping in countries like Ethiopia with limited finance and rapid population growth rate is more severe. According to Minalu (2016), stated that, like in many other developing countries, the majority of inhabitants in most towns of Ethiopia often use unsafe solid waste disposal practices, such as open dumping and burning. Similarly, in Gish Abay town, the study area, there is a problem of solid waste disposal.

2.2.1 Criteria used for waste disposal site selection

Waste disposal site selection process has become much more complicated, as socio-spatial sustainability is a critical agenda so and the site selection process needs to consider relevant and desirable guidelines to optimize contradictions among socio-spatial suitability factors (Mijibor et al, 2008). The main criteria considered for waste disposal site selection are discussed as follows.

i) Environmental criteria:

Consisting of the natural spatial features including topographical relief (slope) geological (faults and soil), hydrological information (wetlands, natural drainages, surface water/rivers and sub-surface water), and ecological character. Different research shown that areas with high slopes (slope ranges more than 10%) will have high risk of pollution and potentially not a good site for dumping (Ebistu and Minale, 2013). landfill site should have a gentle incline to avoid soil erosion and limit expenditure on cleaning and maintaining drainage system components. The land with a slope less than 10% is highly suitable for solid waste dumping (MUDC, 2012; Debebe, 2017). And the other issue is proximity to Water bodies to maintain the environmental health of water sources at least 500 m buffered distance should be ringed through straight line calculation (MUDC, 2012). Also soil type should be taken in consideration that the soil of the selected site has good nature of impermeability in order to reduce the possibility of aquifer contamination. The soil of the selected site should be clayey (MUDC, 2012)

ii) Socio-economic or Socio-culture factors:

It refers to spatial entities directly influences social value consisting of the distance from settlements, the landfill site should not be placed near a residential or an urban area, to avoid adversely affecting land value and future development and to protect the general public from possible environmental hazards released from landfill sites. In the same time, it should not be located too far to avoid extra transportation costs and environmental pollution. In most case 1500m distance from residences is determined as a safe buffering distance (MUDC, 2012; Debebe, 2017). In regarding of proximity to protect and major socio-cultural service areas, the landfill should not be located within 1000m distance of sensitive areas like churches, mosques, parks, schools/health centers and memorial sites schools (MUDC, 2012). And the other determinant factor which facilitates the disposing system is a road network; landfills shall not be located within 400 m of any major highways and city streets and also should not be placed too far from existing road networks, to avoid the expensive cost of constructing connecting roads (MUDC, 2012).

2.2.2 Risk of Open Solid Waste Dumping

Poorly managed waste is contaminating the world's oceans, clogging drains and causing flooding, transmitting diseases via breeding of vectors, increasing respiratory problems through airborne particles from burning of waste, harming animals that consume waste unknowingly, and affecting economic development such as through diminished tourism. Unmanaged and improperly managed waste from decades of economic growth requires urgent action at all levels of society (World Bank, 2019, What a Waste 2.0).

Unsuitable Solid waste management has long been a worldwide environmental problem. These Unsuitable dumpsites become increases risk of infection like malaria, and other vector transmitted diseases in the society and there are at least 300million acute cases of malaria each year resulting in over one million deaths (WHO, 2016).

2.2.3 Ethiopian Practices for Solid Waste Disposal Site Selection Criteria

Different researchers used different criteria to select suitable solid waste disposal sites as of their existing interest of study, condition, available data and some other factors. There are also most common criteria that have been used by scholars and institutions (Genemo and Yohannis, 2015; CPHEEO, 2016). An area where the average surface slope is not steep or (less than 10%) and where there is no naturally important area, is not municipal, industrial, or not be selected and assumed as environmental sensitive area.

The area is accessible by a competent paved public road which can accommodate the additional truck traffic without significant effect on traffic flow rates. From the public road into the site, the access road to be constructed should be less than 10 km for large landfills serving metropolitan areas and less than 1 km for small landfills serving secondary cities. Hence, preferably, a site accessible within 30 minutes' travel time (a function of road and traffic conditions) is to be sought, even if it means buying land, because of the need to avoid adversely affecting the productivity of collection vehicles. And also areas greater than 85,000 square meters for storage capacity of solid waste disposal site selection based on certain evaluation for analysis of land fill site suitability (MUDC, 2012; Aeden, 2016).

2.2.4 Customized Criteria for Proposed Solid Waste Dumping Sites:

There are no specified criteria and standards for solid waste disposal site selection developed for Gish Abay Town. Thus, based on different scholar experiences and by using some of the criteria from a document series called Guidelines Manual Part-I prepared for site selection of common waste management facility' Government of

Indian, (CPHEEO 2016) and Solid Waste Management Manual with Respect to Urban Plans, Sanitary Landfill Sites Planning to Addis Ababa city (MUDC, 2012) the researcher were localized/customized solid waste disposal site suitability criteria for the study area. As possible as dumping sites shall be not suitable to vector spreading which effective to disease transmitting for this at least 500m buffering distance from memorial sites, churches, settlements, roads, and schools were assumed as preferable classes for this study.

Table 2-2: Factors and criteria that considered for selection of sanitary landfills:

No	Criteria (considerable parameters)	Buffering Distance
1	Distance from protected and memorial sites, (churches and schools, health centers)	>0.5km
2	Distance from natural drainages and surface water bodies	>0.5km
3	Distance from residential (Settlement) areas	>0.5km
4	Distance from main roads	>300 and <1km
5	Slope	>2% and < 10%
6	Land area and volume	At least an area which has a capacity to hold 10 years disposed wastes

Source: MUDC (2012), CPHEEO (2016) and Minalu (2016)

2.3 Multi-criteria Decision-Making:

Multi-criteria evaluation (MCE) technique is used to deal with the difficulties that decision makers encounter in handling large amounts of complex information. MCE consists of a series of techniques such as weighted summation or concordance analysis that permit a range of criteria relating to a particular issue to be scored, weighted and then ranked by experts, interest groups and/or stakeholders according to their degree of suitability or importance for locating/sitting a particular facility/service (Malczewski, 2004).

The subjective evaluations are converted into numerical values that are ranked on a numerical scale; therefore, the role of MCDA in solid waste disposal site selection can be completed by integrating it with GIS. Integrating GIS and MCDA can solve the challenges of landfill site selection which involves highly complex spatial decision-making processes (Debishree and Samadder, (2014). A multi-parametric analytical hierarchy process (AHP), one of the most commonly used methods of MCDA tools, is a conventional land suitability analysis method that provides right decision-making approach for site selection used to determine the relative importance of each alternative in terms of each criterion. AHP has been integrated with GIS for land suitability modeling when selecting the best alternatives from a pool of various possibilities in the presence of multiple criteria.

A measure of how far a matrix is from consistency is determined by computing the Consistency Ratio (C.R). This is obtained by calculating the matrix product of the pair-wise comparison matrix and the weight vectors, and then adding all elements of the resulting vector. After that, a Consistency Index (C.I.) is computed using the following formula (Ouma and Tateishi, 2014):

$$\textbf{Consistency index (CI)} = \frac{\boldsymbol{\lambda_{max} - n}}{\boldsymbol{n - 1}}$$

(Where *n* is the number of criteria and λ_{max} is the biggest eigenvalue).

$$\textbf{Consistency Ratia (CR)} = \frac{\boldsymbol{CI}}{\boldsymbol{RI}}$$

(*RI* is the Random Inconsistency index and which is dependent on the sample size).

Table 2-3: Random index (RI) used to compute consistency ratios (CR):

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Source: Ouma and Tateishi (2014)

Reasonable level of consistency in the pair-wise comparisons is assumed if *C.R.*< 0.10, while *C.R.* ≥ 0.10 indicates inconsistent judgments (Malczewski, 2004).

2.4 Application of GIS Technology in Solid Waste Disposal Site Selection

Technological development in computer science has introduced Geographic Information System (GIS) as an innovative tool in landfill process (Kontos et al, 2005). In recent years, Geographic Information System has emerged as a very important tool for land use spatial analysis such as suitable site selection for landfill system. In addition, GIS can recognize, correlate and analyze the spatial relationship between mapped phenomena, thereby enabling decision-makers to link disparate sources of information, perform sophisticated analysis, visualize trends, project outcomes and strategize long-term planning goals (Debebe, 2017).

GIS data manipulation and analysis subsystem allows the user to define and execute spatial and non-spatial procedures to generate derived information. This subsystem is commonly thought of as the heart of a GIS, and usually distinguishes it from other database information systems and Computer-Aided Drafting (CAD) systems. Each layer, containing specific monothematic information, can be combined with others to produce new layers by query (Darling & Fairbairn, 1997)

Landfill siting is a complicated process that requiring a detailed assessment over a vast area to identify suitable location for constructing a landfill subject to many different criteria. Even though landfill sitting is complex, tedious and costly as it requires multiple criterions from environment, social and economic point of view, the development of technology in computer science provide an opportunity. GIS application can help in determining the landfill location in accordance with the technical requirements. Therefore, GIS offers the spatial analytical capabilities to quickly eliminate parcel of land which is unsuitable for landfill site and hence reduce cost and time of siting processes (Debebe, 2017).

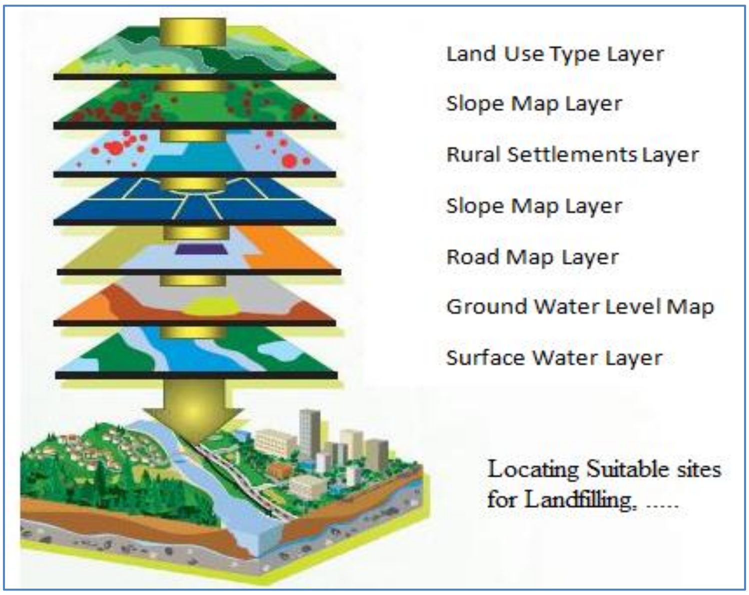


Figure 2-4: GIS data organization in thematic layers:

(Modified from: Darling & Fairbairn, 1997)

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 Description of the study area

3.1.1 Location:

Gish Abay has established before 75 years ago in 1947 and formerly the town was named by ‘Yidib’. Currently the town – Gish-Abay is the administrative center of Sekela wereda in west Gojjam zone of Amhara National Regional State. The town is located at 461 km away North West from Addis Ababa, 174 km away south east from Bahir Dar, and 81 km away north east from its zonal administration, Finote-Selam town.

Geographically, the study area is situated within 10^{0} $57^{'}$ $38^{''}$ N to 11^{0} $0^{'}$ $05^{''}$ N and 37^{0} $11^{'}$ $20^{''}$ to 37^{0} $12^{'}$ $37^{''}$ E in in the Blue Nile River catchment which covers about 1,301 hectare (Figure 3.1). The town Gish Abay shared a boundary to Swusa kebele in east, Abay-Sangib kebele in west and north and to Rebu-Gebaya kebele in south direction.

Topographically, Gish Abay town is lies in altitude ranges from 2621 meter to 2780 meter above mean sea level. According to the traditional agro-climatic classification, the study area lies within dega (cool to cold humid) as the climate is humid with an average annual rainfall between 6 - 210 millimeter per year with the average annual temperature of 8 - 17 degree centigrade. In the study area clay soil the most abundant soil type with 30% black cotton, 65% red clay and 5% brown clay soil type (SWAO, 2020). The town is the source of Abay River, the largest river in world, known by Blue Nile River and other perennial Rivers and seasonal streams are found in the study area CSA, 2010 and SWWRO, 2020).

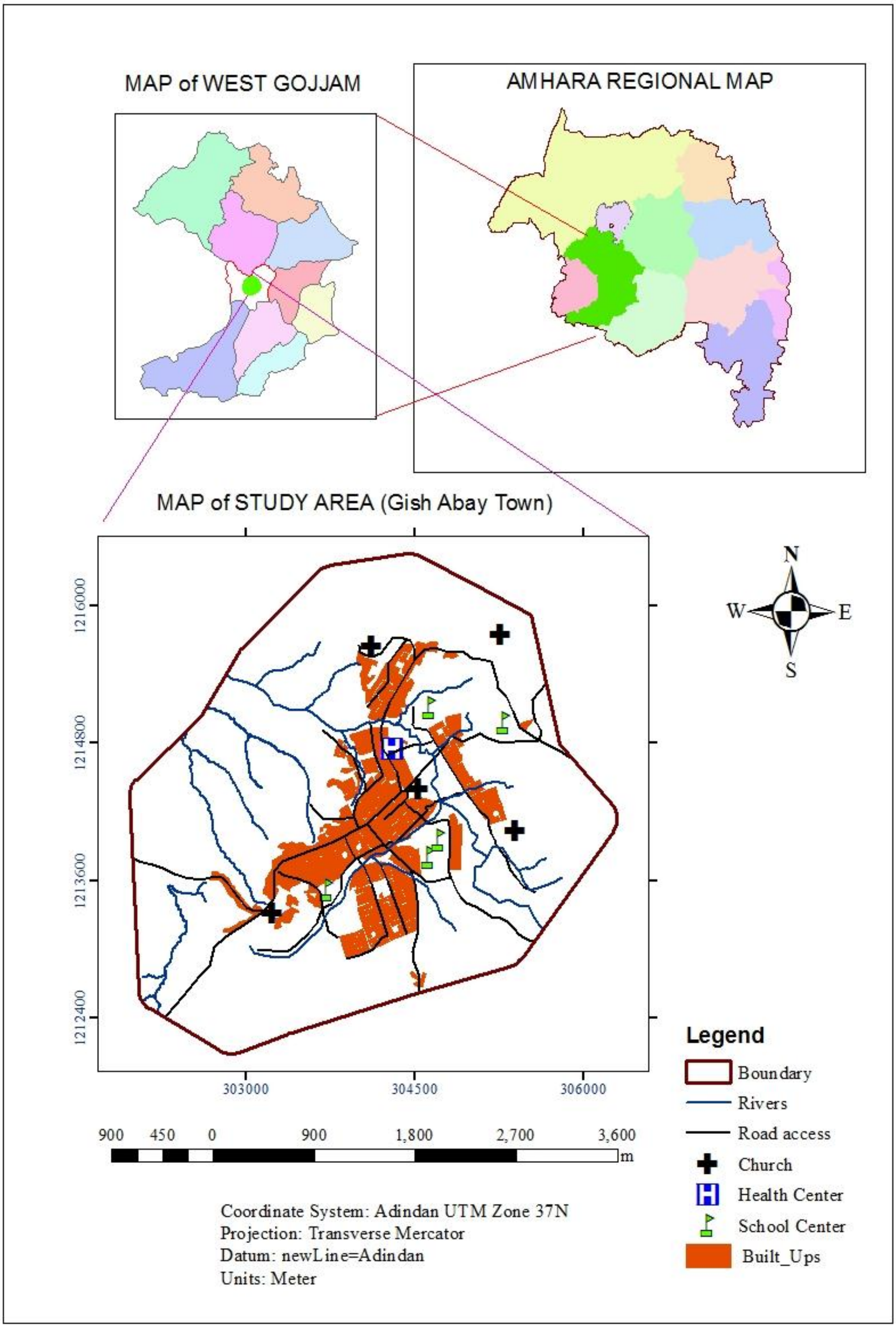


Figure 3-1: Location map of the study area:

3.1.2 Population and Economic Activities

According to Sekela woreda finance economy and development office (FEDO, 2012) the total population of Gish Abay town is estimated 27,892 of whom 13,239 males and 13,653 are females. All households in the Gish Abay town are 7,179, with this bench mark a per regional urban population growth rate (that an average household size of 4.2% and growth rate of the town) the study area might have an estimated 43,234 population at the end of 10 years urban plan time, which is 2.9%, per annual (IUP, 2020).

The main economic activities of the town are trade, public services, manufacture, urban and peri-urban agriculture and labor work. Among these activities services, hotel and restaurants are the main ones. Gish Abay has access to all weathered roads that links the town with all rural kebeles and to the other surrounding adjacent weredas; Tillili, Kuarit and Adet, transportation and trading are the main economic activities.

3.1.3 Infrastructures and Public Services

The town is connected by a 35 km gravel road to Tilili wereda, which is located on the main Addis Ababa - Bahir Dar road. There is also another road (under construction), which connects Gish Abay to Bahir Dar through Adet town. The town also has different urban utilities like; post office (since 1967), water supply, and telecommunication. As the town is the administrative center of Sekela wereda, there are different public services in the town like; one health center, two elementary and secondary schools, one general secondary and preparatory school. Besides to this, there is one technical vocational educational training institute (IUP, 2020).

3.2 Research Approach and Design:

The assessment of a potential waste disposal site selection requires both qualitative and quantitative data. Hence, this research was relied on a convergent mixed research approach. Convergent mixed approach is a form of research approach in which the researcher collects and merges or converge both quantitative and qualitative data in order to provide a comprehensive analysis of the research problem (Creswell, 2014).

Regarding the design, the study was predominantly relied on survey research designs. And cross-sectional research was involved for to collect both quantitative and qualitative data at a time and generalized from the sample to population.

3.3 Sources of Data:

Both primary and secondary data were employed to evaluate the existing solid waste disposal sites and to newly selected disposal site.

Primary data like existing situation (current solid waste disposal sites) were obtained through onsite observation, interview, focus group discussion, and questionnaires. Whereas; relevant secondary data were obtained from different sources; such as, proclamations concerning on urban planning and environmental protections, and annual report files from concerned offices.

Table 3-1: Data Types and Data Sources:

No	Data used	Format	Source	For what?
1	Study area boundary	Shape file	Gish Abay municipality	To generate the analysis extent of all variables.
2	DEM	Raster	From online sources	To get slope and stream net.
3	Land use land cover	Raster	Gish Abay municipality	To carryout separated suitability and constrain map from the perspective of each suitability variables.
4	Water well points	X,Y pt. location	Sekela woreda water office and from field survey directly by hand GPS	
5	Road network	Shape file	Gish Abay municipality and ArcGIS online base map	
6	Rural Settlements	Shape file	Gish Abay municipality and ArcGIS online base map	
7	Existing disposal site and practices	Image	Direct field observations and annual office reports	To evaluating the existing practices of dumping sites and their socio-natural impacts
8	Current impacts	Text and sound records	Observations, interview, FGD, and reports	

3.4 Population, Sample Size and Sampling Technique:

i) Population:

Population is the total collections of elements about which we wish to make some inference; the aggregate or entire group/class/units/variables to be studied from which a sample can be drown and the research results can be generalized (polit and Hungler, 1999). On this regard the population for this research consisted of the whole house hold owners within Gish Abay town (7,179 HHs with 27,892 estimated total populations).

ii) Sampling Size

To assess the current solid waste disposal practices and to evaluate the status of existed desposal sites and their socio-natural impacts, the relevant socio-economic data were collected from a sample of the total population (HHs). Hence, the sample size was determined by using Yamane's simplified sample size determination formula (Yemane, 1967); calculated as:

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

Where: N = the population size, n = required sample size, and

e = the degree of precision (***confidence level)***

The study needs to deduce solid waste disposal trends in exploratory manner with ground evidences and a population not huge. So, setting **90%** confidence level is preferable (Mokonnen, 2019). Therefore the sample size for this study is:

$$n = \frac{7179}{1+7179*(0.1)^2}$$ = 98 respondents (participants) will employ.

iii) Sampling Techniques:

For this study both probability and non-probability sampling techniques were involved. Stratified random sampling technique will be used by grouping the total households in to five separate classes as hotels, services, residence (domestic), shops and mini cafeterias. After that the samples were selected randomly from each stratum.

And also concerned respondents (experts) including urban beauty and urban planner experts from municipality office, environmental protection expert from land administration office, community health officer from health office, water resource experts from water development offices were selected purposively for interviews and focus group discussion.

3.5 Methods of Data Collection and Instruments:

3.5.1 Spatial Data:

The relevant spatial data constitute in this research were obtained from different sources as described before in data source part were selected based on different literatures by considering the study area to develop relevant factor maps for the analysis of potential suitable disposal site. Collection of those spatial data type follows secondary data techniques; direct downloading and through requesting letters.

Digital Elevation Model was downloaded from https://earthexplorer.usgs.gov/ portal and from this the slope and stream nets will be extracted. The soil data will be obtained from bureau of agriculture, the land use, household and road net data will be digitalized from the town master plan map. And also the water resource data will be obtained from woreda water office and through field observations.

3.5.2 Socio-economic Data:

To assess the status of the existed solid waste damping sites conditions and to evaluate and describe the socio-environmental feasibility, relevant survey data was collected in the following ways.

i) Observation

Personal observation was vital to inform the facts on the ground and helps to gain relevant data, which supplement the information during gathering, analyzing and writing the data. Direct field observations were done through transect walks around the existed solid waste disposal sites and necessary images will be taken to show how the current situation looks like. Field observations were conducted by visiting of the current waste disposal sites and other illegal and uncontrolled desposal practices in the town. Also, observation was important to assess distance from main suitability factors/features to open landfill site.

ii) Interview

To obtain information which are relevant to the research objectives from concerned officials (managers), experts and within key informants (knowledgeable persons) structured and semi structured interviewing will conduct and their answers will recorded in their own words.

iii) Questionnaires

Both open and closed ended type questionnaires were used to get relevant information on the existing solid waste dumping practices and to evaluate and describe their socio-natural feasibility. Likert scale values were used to code the data for collecting and analyzing of the socio-economic data to assess the status of existing solid waste disposal sites; 4 (highly appropriate), 3 (appropriate), 2 (moderately appropriate), and 1 (not appropriate), also to evaluate the impacts of existed waste disposal sites on socio-environmental indicators the Likert scale were assigned as; 4 (very high impact) 3 (high impact), 2 (moderate impact), and 1 (low impact).

iv) Focus Group Discussion:

Two focus group discussions were conducted by careful selection of participants from purposively selected offices, school centers, student representatives, kebele administrators, and communities resided around the current disposal sites. Checklists were organized to lead the discussions.

Table 3-2: List of participants for FGDs and interview

Individuals (participants) from		**For FGDs**	**For KI interview**
From Concerned Offices	• Education office and schools, • Municipal office, • Land administration office, • Water resource office, • Health office (Health post)	**group-one FGD 12 plus 1 moderator**	Two persons From each offices
	• Two Kebele administrators, • Communities resided around Gomata, Gudera-ber and Zeleke-desta solid waste disposal sites	**group-one FGDs 11 plus 1 moderator**	
Total			**12 samples**

3.6 Methods of Data Analysis and Interpretation:

i) Data Analysis

To describe the existing situation of solid waste disposal site of the study area all qualitative and quantitative data those are digitally captured (electronically recorded) documents will transcribe into written forms. Then field notes and the transcribed information will translate into English language. Moreover, all collected data were organize, summarize and coded as per guiding research questionnaires and based on their relevance to the research objectives.

Whereas; to suggest the newly proposed suitable solid waste disposal site GIS spatial analyst tools (conversion, proximity, reclassification, overlay analyst), were used. A multi-parametric analytic hierarchy process (AHP) in which Pair wise comparisons was used to determine the relative importance of each alternative in terms of each criterion is one of the most commonly used MCDM tools.

Each factor maps for suitable site selection was developed a common rescaling option which indicates unsuitable, less suitable, moderately suitable and high suitable and very highly suitable class ranges from 1 to 5. Where value of 1 denotes unsuitable and 5 denotes very highly suitable classes for all decision factors (parameters) participate in the suitable site selection process.

Finally an optimal solid waste disposal site was chosen based on the highest suitability values and the area map was generated through weighted overlay analyst tool using GIS environment. To find out the most (final) suitable disposal site among the alternative choices resulted from the weighted overlay analysis the researcher was consider modifying (refining) factors like size of alternative sites and the distance to the rural settlements.

ii) Data presentation techniques

Collected data from the interview, questioners and observation were qualitatively narrated and analyzed quantitatively and presented in percentages, tables, charts and graphs. Whereas; spatial data (spatial factors) were processed and analyzed using GIS environment and outputs presented using maps, charts, graphs and tables.

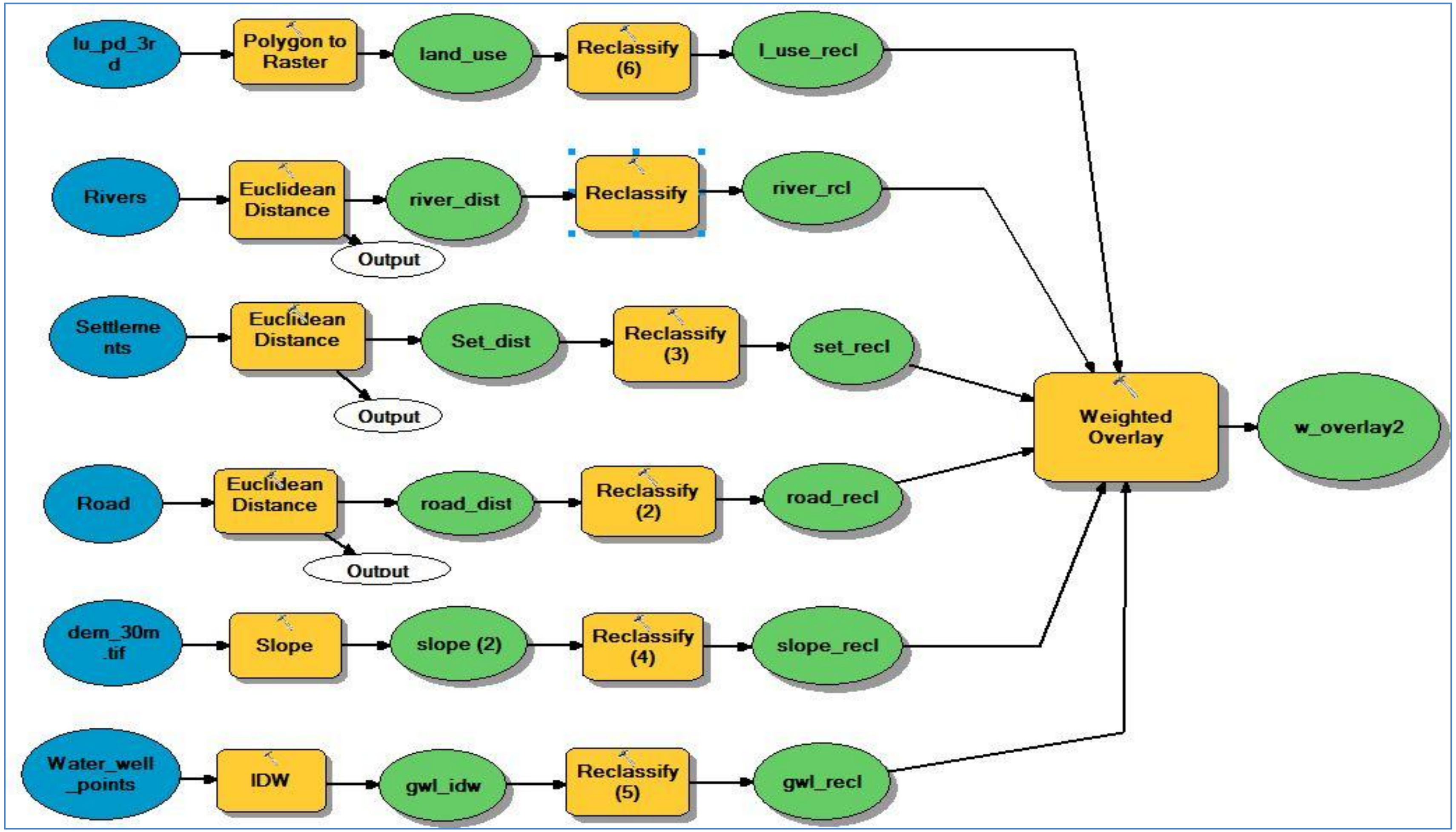


Figure 3-2: Suitability Weighted Overlay Model

iii) Flow Chart of Research Methodology:

The study starts by assessing/evaluating the existing solid waste disposal situations in the study area. And to suggest the newly appropriate disposal site needs identifying spatial factors and producing maps for each factors based on the existing evaluations and literatures. AHP was employed to generate the optimal suitability landfill map through Weighing overlay analysis.

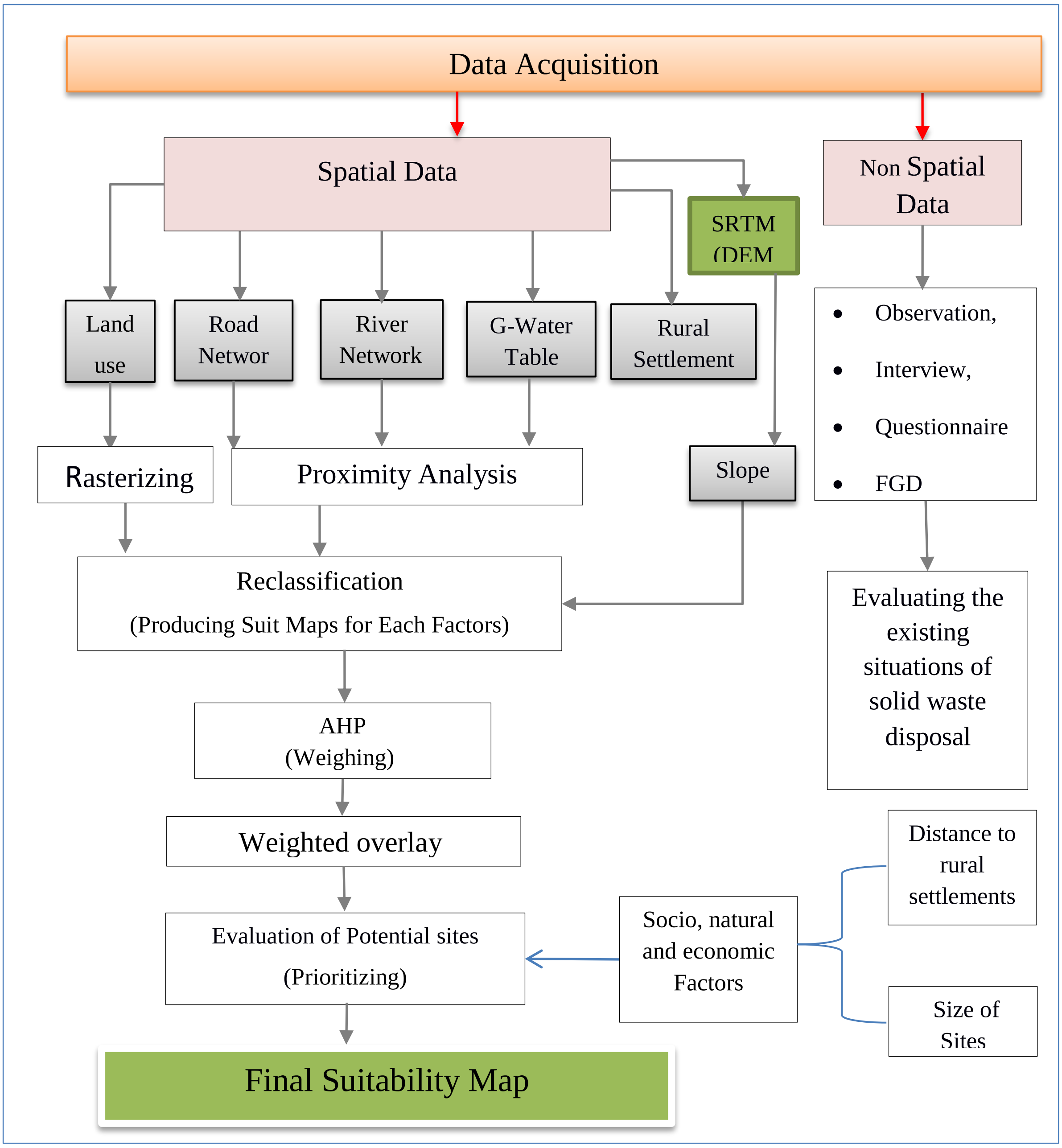


Figure 3-3: Conceptual frame work of the study:

CHAPTER FOUR

RESULTS and DISCUSSION

This chapter presents the results and discussion of the study. It constitute five main sub-sections which presents in a content-wise in line with the data collection techniques. The first sub-section presents general demographic characteristics of the respondents. The second sub-section discusses regarding the existing solid waste disposal sites in Gish Abay town. The Third sub section discusses the impacts of the current solid waste practices and the existing solid waste dump sites on the socio-natural environments. The fourth sub-section discusses that the factor/parameter development and their suitability analysis, whereas; the last sub-section, fifth sub-section discusses on potential landfill site analysis by ranking and weighing formerly developed suitability factors.

4.1. General Demographic Characteristics of the Respondents:

Table 4-1: General demographic characteristics of the respondents:

Characteristics of the Respondents (n = 98)		Frequency	(%)
Sex	Male	54	55.1
	Female	44	44.9
Marital status	Single	23	23.5
	Married	75	76.5
Education level	Illiterate	17	17.3
	Primary school complete	38	38.8
	Secondary school complete	24	24.5
	Graduated	19	19.4
Occupation level	Farmer	11	11.2
	Governmental employer	28	28.6
	Merchants/Traders	36	36.7
	Unemployed	23	23.5
Family size	1 up-to 3	24	9.2
	4 up-to 7	57	58.2
	> 7	17	17.3

4.2. Existing Solid Waste Disposal Sites in Gish Abay Town:

According to the key-informants and the onsite observations the solid wastes discharged from different sources of the town (from: hotels (cafeterias), community market areas, service areas and residential houses) including non-decomposed (water containers, plastics and cloths) were disposed on open spaces everywhere including on environmental and socially sensitive areas without any socio-environmental characterization. Although, the town municipality allocated open solid waste disposal sites in two kebeles, the areas are not suitable and sound in the perspective of environmental and socio-economic criteria.

In addition to those assigned waste disposal sites the community disposes the waste along the rivers sides, on streets and drainage canals and anywhere without restrictions; hence it contribute for environmental contamination and creates socio-economic problems.

As illustrated in Figure 4.1, the existing solid waste disposal sites are not sound under the socio-economic and environmental considerations. The onsite spatial observation analysis results shown that all the existed solid waste disposal sites are not appropriately located. The existed disposal sites Touches Rivers and road networks with 50m and 100m buffering distances. Also social memorials (religious service areas) and protected features (schools and recreational areas) are within 200m distances from the current disposal sites (Figure 4.1 and Annex 2).

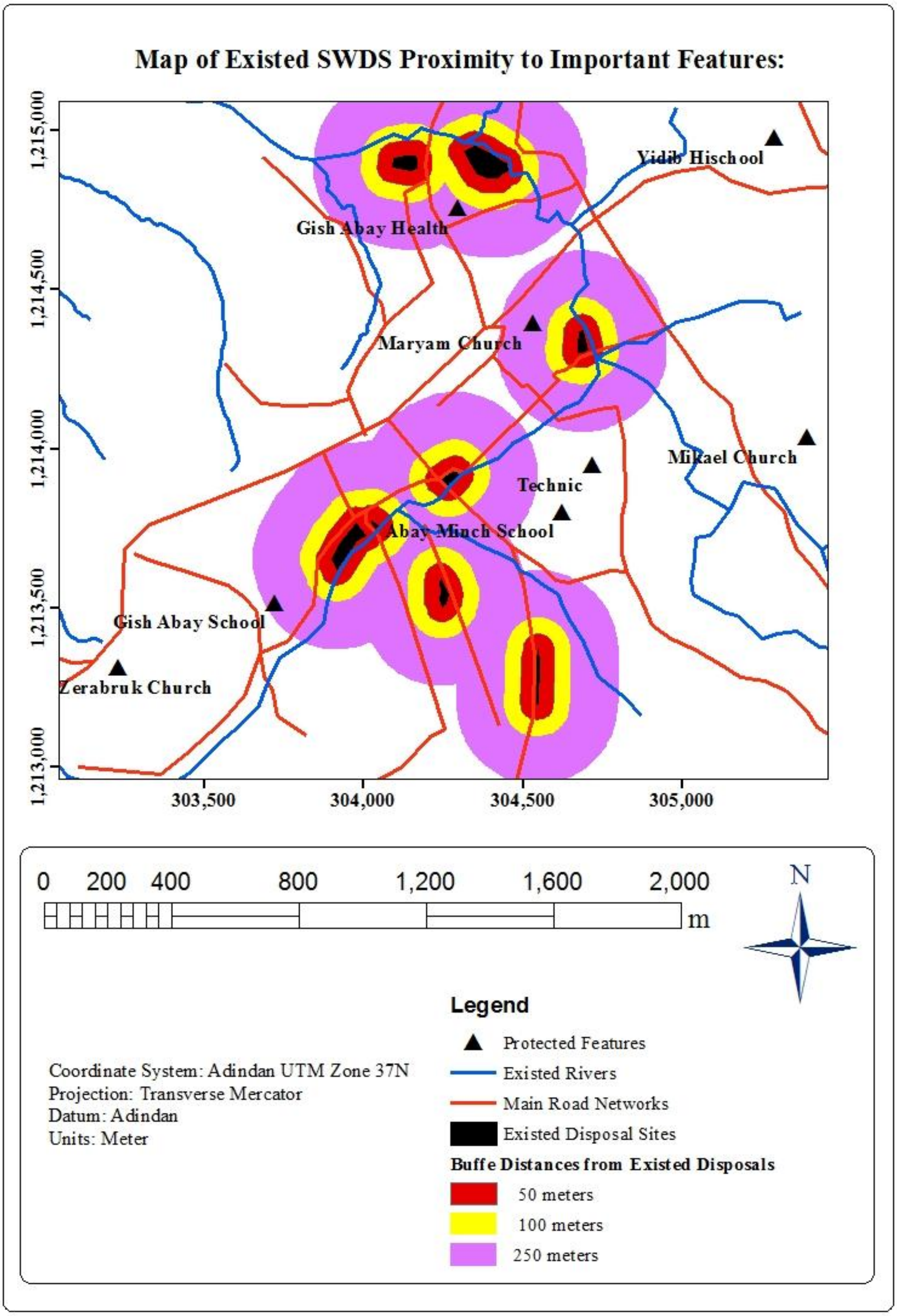


Figure 4-1: Existed open solid waste disposal site map:

Empirical data were also obtained from the sampled household respondent through a questionnaire survey to assess whether current solid waste disposals are socially, economically and environmentally accepted or not.

Based on the empirical data analysis, due on the environment, most (82.7%) of the respondents reported that the existed solid waste disposal sites are not appropriately selected through due consideration of environmental factors. Only 3.1% of respondents claimed that the existed disposals sites are located at appropriate places. The remaining, 8.2% and 6.1% of the sample household respondents reported that the existed disposals are sited at moderately appropriate and less appropriate sites respectively. Whereas, regarding on the socio-economic characterization 75.5% of the respondents reported that the existed solid waste disposal sites are not appropriately selected through due considering of socio-economic factors. Only 7.1% of respondents claimed that the existed disposals sites are located at appropriate places. The remaining, 8.2% and 9.2% of the sample household respondents reported that the existed disposals are sited at moderately appropriate and less appropriate sites respectively.

Similarly, FGD discussants forwarded different views regarding the appropriateness of the existing waste disposal sites. However, most of the discussants mentioned that the existed open dumps sites are not environmentally and socially sound. The discussants stated that the existed solid waste disposal sites in the town were selected without considering desirable environmental and urban planning guidelines (no characterization of environmental, economic and socio-cultural factors) due to this existed open dump sites have not properly situated.

The discussants mentioned different reasons for the inappropriateness of the dump sites. Some of the major reasons are 1) the sites are located near to rivers, schools, etc., 2) the sites are located in open spaces, 3) the sites are located very near to living areas and roads, 4) the discharges are uncontrolled and unmanageable etc.

This implies that lack of effective municipal solid waste management and improper allocation of solid waste disposal sites poses a several challenges to the communities resided around. The result of this study supports other related studies conducted in other areas in Ethiopia. For instance, related studies conducted in Wolkite town by

Yenenesh et al. (2019), and similarly, another study conducted in India by Hazarika and Saikia (2020) indicated that many of the municipalities assign solid waste disposal sites which are not environmentally sound and socially accepted, consequently which poses environmental as well as socio cultural problems.

4.3 Impacts of the current solid waste disposal sites:

From the surveyed data analysis results, the majority (70.4%) of the sample household respondents perceived that current uncontrolled waste discharging practices and the existed open disposal sites poses very high negative impact on the natural environment. Only 5.1% of respondents claimed that the existed open disposal sites poses low negative impact on the environment. And the remaining 13.3% and 11.3%, 4.1% of respondents reported that the existed disposal sites pose high and moderate high impacts respectively. Regarding on socio-economic impacts, about 56.1% of the sampled household respondents perceived that that current uncontrolled waste discharging practices and the existed open disposal sites poses an extreme negative impact on socio-economic features. Only 9.2% of the sample household respondents stated that there is a low negative impact while, 19.4% and 15.3% of respondents reported as the existed open dump sites poses a high and moderately high impacts on the socio-economic features respectively.

Similarly, in FGDs, the discussants summary shown that the current waste disposal practices and the existed solid waste disposal sites poses serious impacts on the socio-spatial environment in the study area. Most of the discussants outlined some practical evidences by examining the waste disposal models of the town community as: 1) most of the peoples dumped the household waste in open places, 2) commercial and service centers (textiles, shops and barber houses) burned the waste on commercial areas, 3) mini cafeterias dumped (through) their waste onto the road side and into channels and 4) most of the communities and commercial areas through their wastes into the road channel and rivers shores specially in rain seasons. Likewise, KIIs agreed that there were high negative impact on natural environment as well as on socio economic features.

This implies that the current solid waste practices and the existed waste disposals in the study area poses very high negative impacts on the natural environment and on the socio-economic affairs. This context supports contemporary studies conducted in Ethiopia and other developing countries. For instance, a study conducted by Yenenesh et al. (2019) in Wolkite town and other studies conducted by Abul (2010) in Manzini (Swazland) and a research studied by Hammer (2003) indicated that uncontrolled solid waste disposal practice creates massive environmental and social problems. Similarly, another study (Palomar et al., 2019) and (Omoloso et al., 2020) indicated that improper waste disposals poor management of municipal solid waste and improper siting of solid waste disposals may results a serious social and environmental problems such as urban sanitary (low aesthetic values), unpleasant odor (air pollution), risk of explosion in landfill areas (economic losses), as well as groundwater contamination because of leachate percolation. In addition to the overall impacts of existed disposal sites, the respondents shown that impacts of existed waste disposal sites on socio-spatial features/indicators.

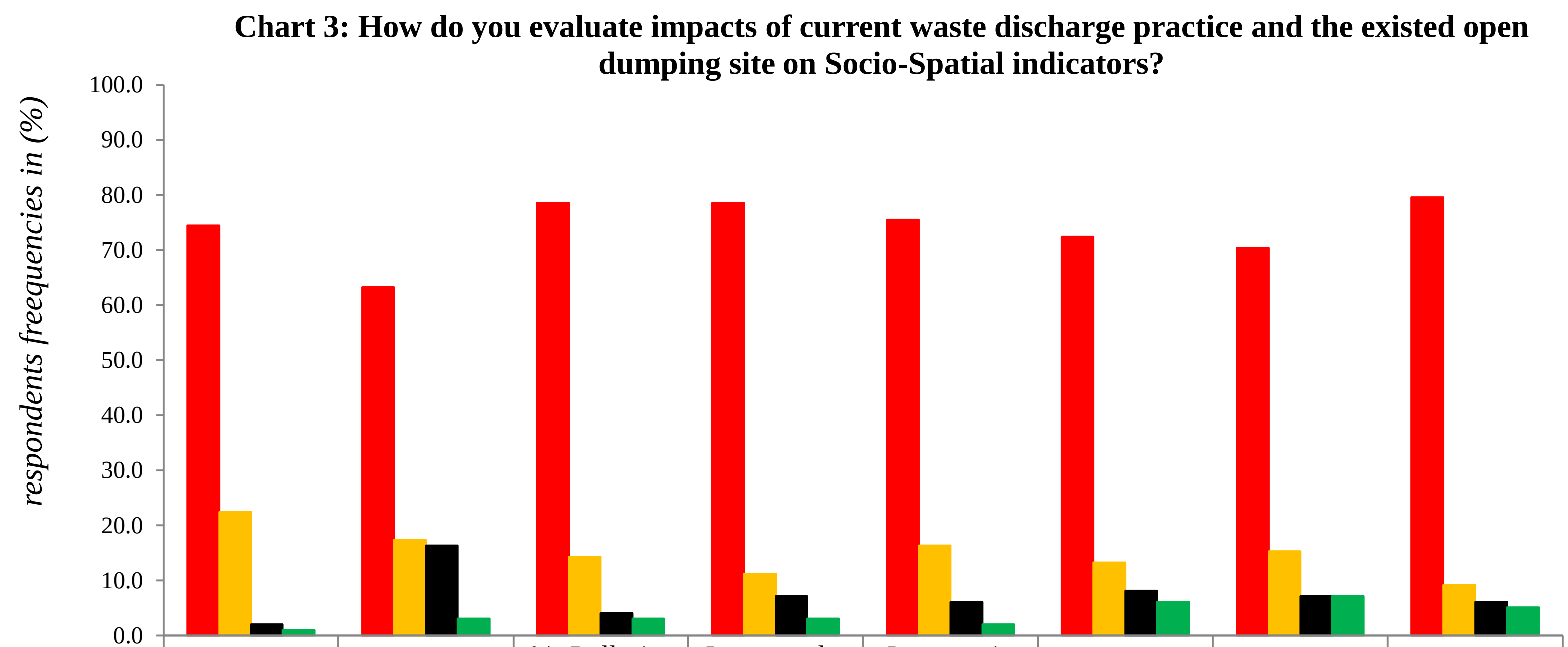
Table 4-2: HH response on the impacts of existed WDS on socio-spatial indicators:

Socio-spatial indicators	**Severity of the impacts Frequencies of Respondents**				
	Very high	**High**	**Moderately High**	**Low**	**Total**
Contaminate rivers and wetlands	73	22	2	1	98
Contaminate the downstream environment	62	17	16	3	98
Air pollution (spreading unpleasant odor and dusts)	77	14	4	3	98
Increase the incidence of sickness among students	77	11	7	3	98
Increase in the incidence of sickness for communities	74	16	6	2	98
Affects livestock	71	13	8	6	98
Damages the town drainage ditch	69	15	7	7	98
Causes for urban flood on roads	78	9	6	5	98

Likewise, the FGDs, discussants mentioned that the current waste disposal practices and the existed solid waste disposal sites poses serious impacts on the socio-spatial environment in the study area. Moreover, the discussants agreed that Abay River and natural drainages were highly affected. They also concluded that, the downstream environment and communities might be affected as the town topographical appearances and flood were causing wastes to be washed into Abay River. Key-informants from water, education and health sectors are also highly emphasized the impacts of the current disposal sites on Abay River and lives of the local communities.

This result implies that the current solid waste practices and the existed waste disposals in the study area poses very high negative impacts on the natural environment and on the socio-economic affairs. This context supports contemporary studies conducted in Ethiopia and other developing countries. For instance, a study conducted by Yenenesh et al. (2019) in Wolkite town and other studies conducted by Shah et al. (2019) in Karachi city (Pakistan) indicated that inadequate and inappropriate collection, transportation and disposal of municipal solid waste results, the sanitary and environmental circumstances have further worsened, as well as public is suffering from passing their lives in polluted situation.

And also an other related study conducted by Williams and Kumar (2016) in Tamil Nadu (India) indicated that improper disposal of solid waste becomes a major threat to the urban area and their surroundings; Solid waste produces foul smell, breeds insects and mosquitoes besides weakens the aesthetic value of land. Inappropriate disposal and burning of solid waste may release of a number of toxic gases into the atmosphere which causes air pollution, acid rain etc., and changes the properties of air, soil and water.



	Contaminate rivers and wetlands	Contaminate the downstream environment	Air Pollution (spreading unpleasent odor and dusts)	Increase the incidence of sickness among students	Increase in the incidence of sickness for communities	Affects livestock	Damages the town drainage ditch	Causes for urban flood on roads
Very High	74.5	63.3	78.6	78.6	75.5	72.4	70.4	79.6
High	22.4	17.3	14.3	11.2	16.3	13.3	15.3	9.2
Moderately High	2.0	16.3	4.1	7.1	6.1	8.2	7.1	6.1
Less	1.0	3.1	3.1	3.1	2.0	6.1	7.1	5.1

Figure 4-2: Perceptions of respondents on evaluating impacts of existed solid waste disposal sites on socio-spatial indicators:

4.4 Factor Development and their Suitability Analysis for Disposal Site:

Development of AHP decision making needs setting factor elements (variables) and analysis. The choice of criterions that has a spatial reference is an important and profound step in multi-criteria decision analysis. Hence, the criteria characterized in this study were chosen based on MUDC standards and guidelines, from different countries experiences for landfill site selection, empirical data analysis results, FGDs /and or KIIs suggestions and on their susceptibility to the impacts of improper solid waste dumping sites.

Thus environmental factors (slope, rivers/drainage and water well points) and socio-economic factors (road network, rural settlements and urban land-use), were considered in this research. In addition, during factor map analysis all variables will be reclassified in five suitable classes and 1 to 5 ranks were given for each factor classes, rank 1 belongs to unsuitable class, rank 2 for low suitable class, and rank 3 belongs to moderately suitable class whereas rank 4 and rank 5 were given for high and very high suitable classes respectively.

4.4.1 Distance from Surface Water (River/Stream):

Most of the surface waters in the study area are streams and rivers. The world largest river, Abay River is discharged within the study area, there are also natural springs, seasonal and perennial streams that flow towards to Abay and Damote rivers. These springs/streams are used for drinking for humans and animals, for bathing (sanitation), for irrigation purposes in the peripheral part of the town and to the downstream communities. So the proposed landfill must not be near to surface water bodies. To avoid the high probability of contamination due to leachate and runoff as pollution in water resources causes severe problems in environment, public health as well as economy (Bedassa and Wondwesen, 2020; MUDC, 2012).

Different scholars set a minimum buffer distance from Stream/River for solid waste dumping site selection. For instance, Minalu (2016) sets 500m buffering, Hasan et al. (2009) used 100m buffer distance, Bedassa and Wondwesen (2020) used 300m buffering, Akbari et al. (2008) use 200m buffer distance. A disposal sites shall be situated at distance of 92m away from permanent rivers whereas, standards of MUDC (2012), claimed to maintain the suitable sites for solid waste disposal is at least 400m buffered distance surface water. Based on above scholar experiences and FGDs suggestions and by considering the existing disposal site impacts on the river sides in this study a region within 200m buffering zone were assumed as restricted area to reduce the effect of solid waste on surface water, and the other suitability levels were prepared through Euclidean distance analysis tool 500m distance from rivers and streams considered as unsuitable area and 500m to 750m, 750 to 1000m, 1000m to 1300 and >1300m distances were assumed as less, moderate, high and very high suitable areas, respectively.

Based on the values of the criteria, surface water factor spatial analysis result shown that the majority (57.63%) of the total area is shown as restricted and only the 0.19% of the area is a very highly suitable, 0.48% is found highly suitable 1.62% of the study area is moderately suitable, 10.81% is less suitable area. The remaining 928.7ha (29.97%) of the study area is unsuitable for solid waste disposal site (Figure 4.5).

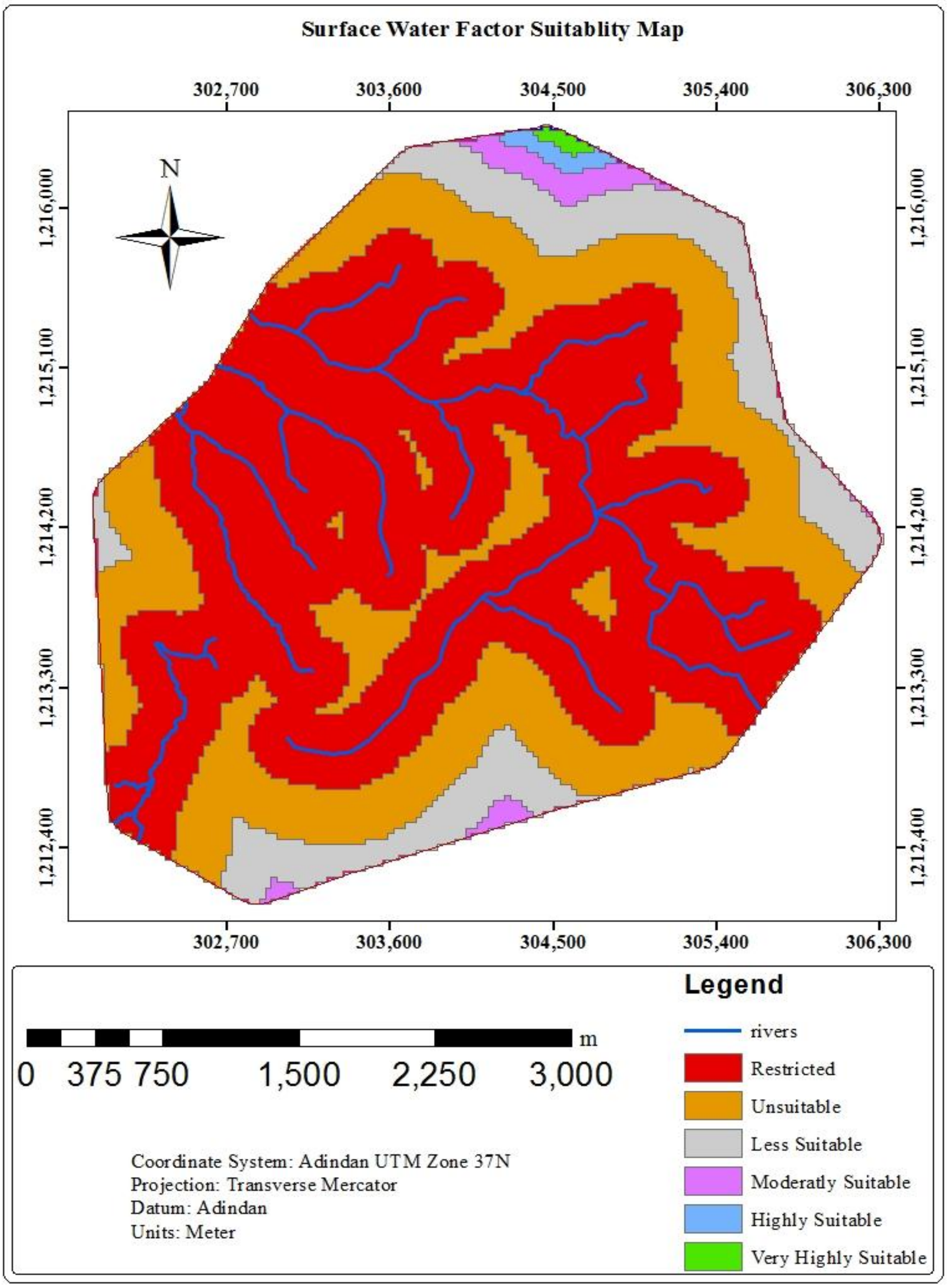


Figure 4-3: Proximity to Surface Water Variable Suitability Map:

(Source: Own analysis result, 2022)

4.4.2 Distance from Road networks:

The proposed disposal site should be feasible and acceptable in socio-economic perspective for this, proximity to roads were considered selection processes. This is because solid waste dumping site very close to roads may have public health problem from unpleasant odors and unsafe psychological views of dumped solid waste. Also, waste disposal sites at so far distant from road network are not recommended to saving transportation and collection cost. Therefore, to minimize such problems, and to perform feasible and socially acceptable analysis different countries and researchers experiences were investigated. Some researchers set a minimum buffer distance such as Bedassa and Wondwesen, (2020) sets 300m buffer; while according to Genemo, (2015), 100m Euclidean distance from road were defined as the safest buffer zone distance and Minalu, (2016) used 500m as a minimum buffer distance for Bahir Dar city solid waste disposal site selection.

From these experiences and FGDs suggestions and by considering the existing disposal site impacts on the river sides in this study a region within 200m buffering zone from existed roads were assumed as restricted area and greater than 900m distance from road net were considered as unsuitable zone (MUDC, 2012). Whereas, buffer classes with a radius of 200m to 400m, 400 to 600m, and 600m to 700m and 800m to 1000m distance form main roads were assumed as very highly, highly, moderately, and low suitable areas respectively.

From the road factor suitability analysis result we as mapped on figure 4.6, the majority of an area (about 54.61%) is considered as restricted area and the suitability level that of very highly and highly suitable were covers 21.68% and 13.08% out of the total study area for solid waste disposal site respectively and moderately suitable and less suitable were shared an area coverage of 5.68% and 3.71% whereas, the unsuitable area accounted for only 0.65% of the study area.

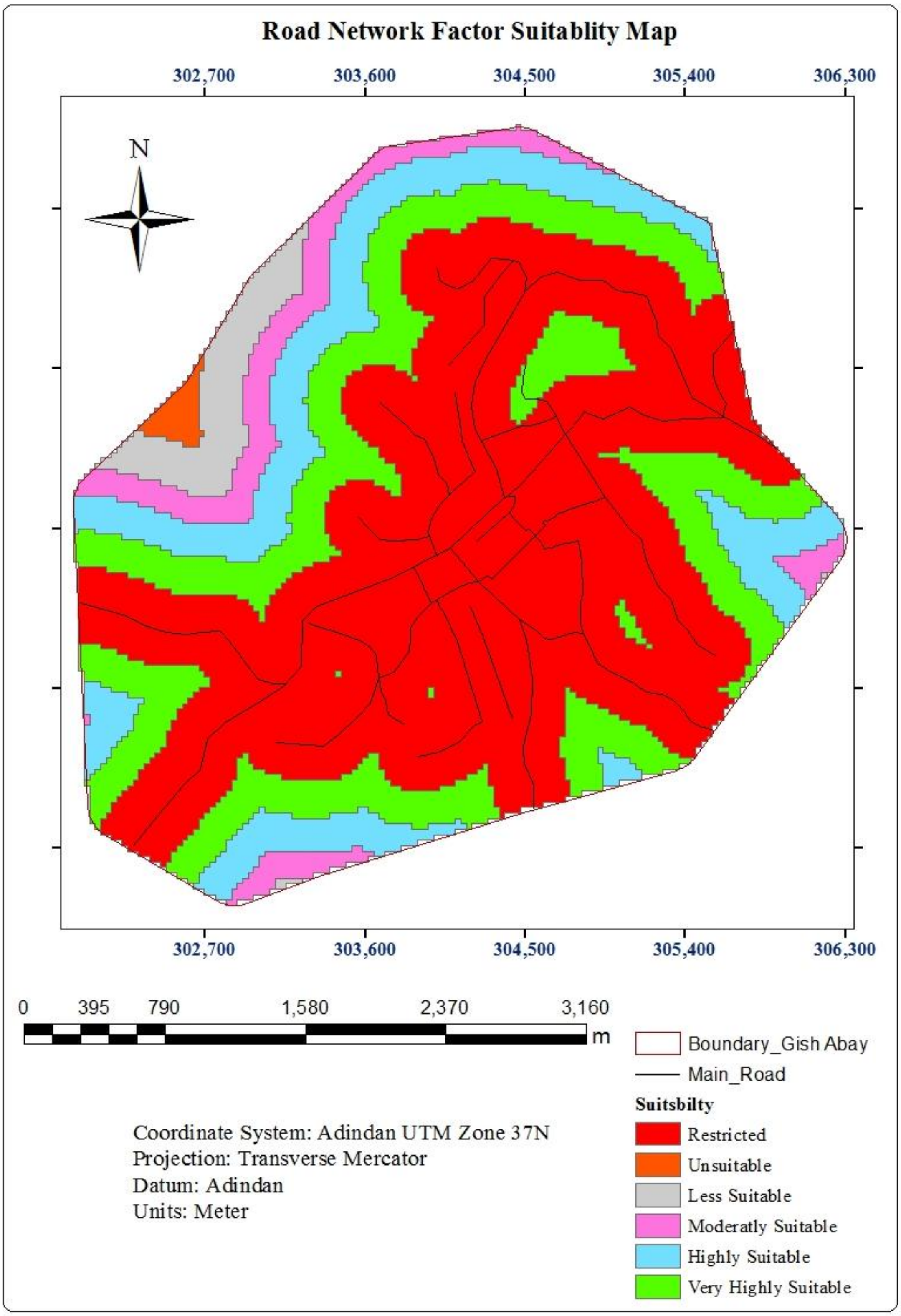


Figure 4-4: Road suitability map:

(Source: Author, 2020):

4.4.3 Urban Land Use Variable Suitability Analysis:

The necessity of municipal waste management and siting appropriate disposals is to create aesthetic urban environment and to maintain natural sustainability to the downstream one. From the main socio-economic criteria that should be give serious attention in solid waste disposal site selection land use is the most one. This is for the reason that, as solid waste disposal sites poses very severe effects related to public health as well as on economic growth by reducing economic values of the land on the neighborhood land use (Bedassa and Wondwesen 2020). To avoid such conflicts land with less political, environmental and socio-economic value covered by bare and grass lands usually recommended as the most suitable solid waste disposal site.

The land use land cover of the town was obtained from Gish Abay town municipal office; identified to be open lands (bare and grass) agricultural land, built-up areas (residential, commercial, administrative, manufacturing and transportation facilities), protected areas (river embankments, schools, health centers, religious and cultural reserve memorial areas), forest land. Based on different scholars experiences and on their importance the study area land use types were rasterized and ranked. Therefore, very high suitable rank were belongs to open lands (bare and grass lands), forest lands are considered as high suitable class, agricultural lands are ranked as moderately suitable class.

However; based on existing disposal site evaluating analysis results; environmentally sensitive and socio-cultural memorial areas were assumed as restricted areas by making a buffer zone with minimum recommended radius. Hence, according to MUDC (2012) and Minalu (2016) in this study the researchers used 300m radius as the minimal closest distance from waste disposal sites to currently functional water well points and for other socio-cultural and memorial features like health and school centers, religious institutions; to be considered as restricted areas (not allowed for disposal site) on the urban land use factor map.

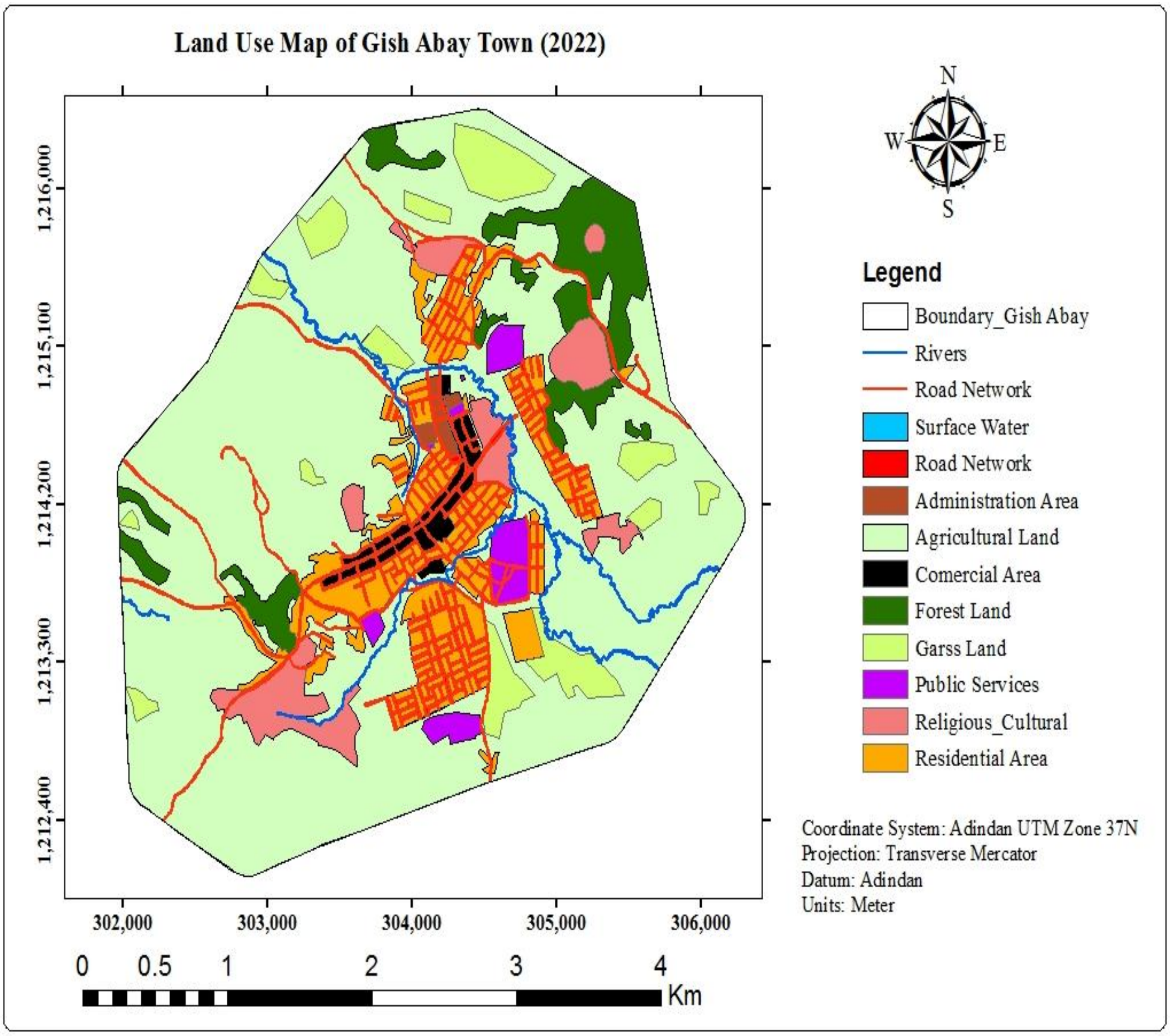


Figure 4-5: Urban land use map: Source:

(Source: Gish Abay Town Municipality, 2022):

Therefore, based on land-use variable spatial analysis result as shown on figure 4.8 from the total area bare (grass) takes 5.81% and forest land 5.67% which are assumed as very highly and highly suitable sites respectively and the majority of (50.41%) which is agricultural land cover is considered as moderately suitable site for solid waste disposal. Whereas, the other cumulative built-ups area (residential, commercial, administrative, manufactures and transportation facilities) covers 12.64% and protected areas (river embankments, schools, health centers, religious and memorial areas) counts 25.47% classed as unsuitable and restricted sites respectively.

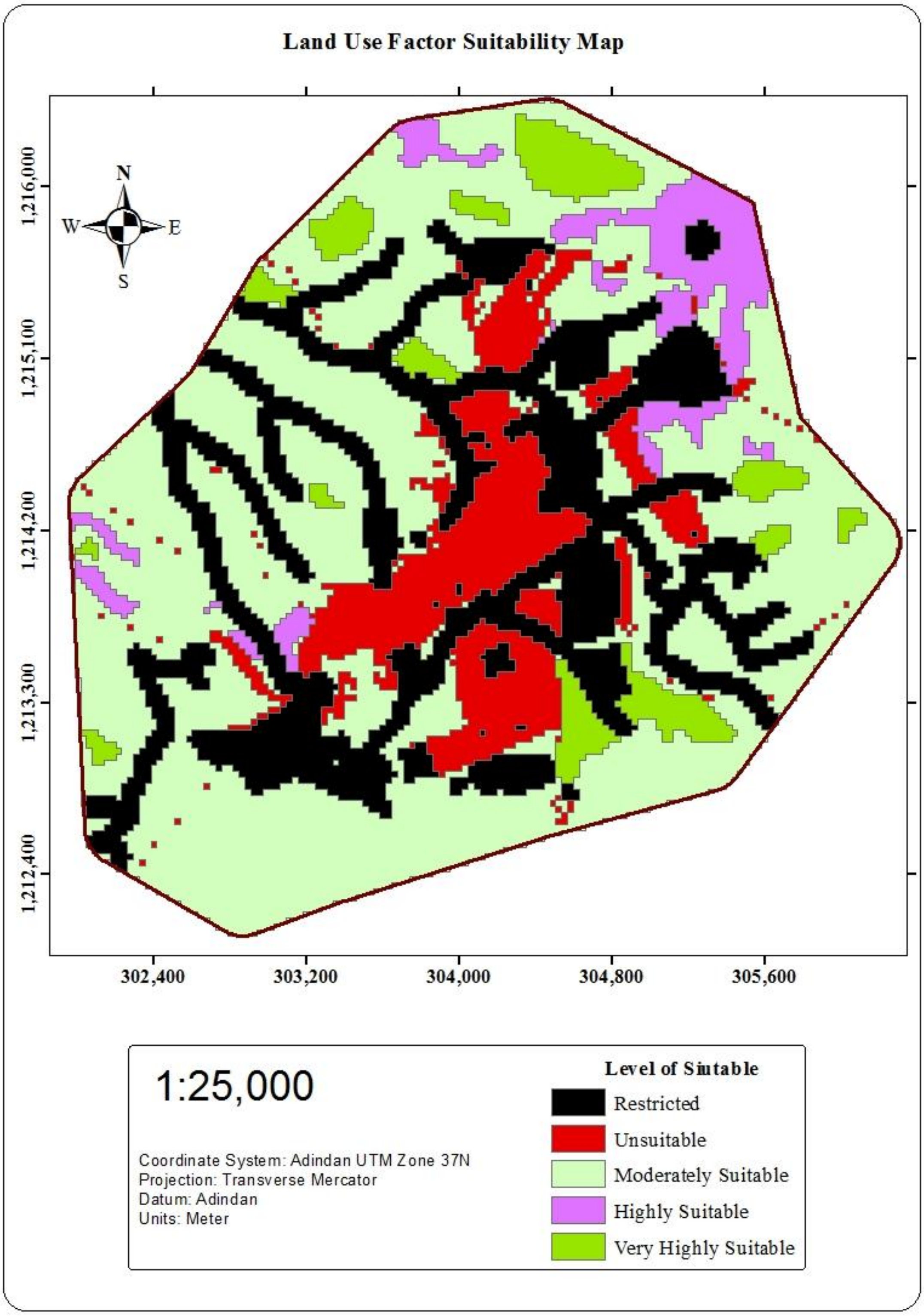


Figure 4-6: Urban land use suitability map**:**

(Source: Own analysis result, 2022)

4.4.4 Slope Factor Suitability Analysis:

Slope is an important topographical factor in determining suitable waste disposal site because slope determines the amount of runoff in the site. Many of scholars; kontos et al (2005), Bedassa and Wondwesen (2020) and Minalu (2016), stated that, areas with high slopes will have high risk of pollution and potentially not a good site for solid waste disposal establishment. As Yenenesh et al (2019) stated on their research finding, landfill area should not be located on a hill with an unstable slope and land slide areas.

Areas located on the gently sloping areas are preferred than level ground and steep sloping areas because of highly sloping areas could cause a fatal avalanche especially when there is rain or high water seepage. And also according to MUDC (2012) and Minalu (2016) the land with a slope less than 10% is highly suitable for solid waste dumping. But, from most researchers experiences it is concluded that, the slope classes between 2 to 15% is considered as an appropriate site for solid waste dumping selection. Depending on this, the slope generated from 30m SRTM DEM were reclassified five suitable classes and as tabulated bellow ranked from 1 to 5; rank 5 is very highly suitable, rank 4 belongs to high suitable class, and rank 3 and rank 2 are assumed as moderately and less suitable classes, whereas rank 1 is for the unsuitable slope because water logging or flood plain and steep slope are not recommended for landfill siting.

Regarding on the slope factor spatial analysis result stated that of 19.23% of the study area (250.41) is unsuitable area (not preferable) for solid waste disposal and 30.96% of the study area (402.25) is very highly suitable for solid waste disposal site. Whereas, the rest area overages, 15.07%, 23.58%, and 11.2% of the study areas were showed as low, moderately, and highly suitable sites for solid waste disposal (see figure 4.7 billow).

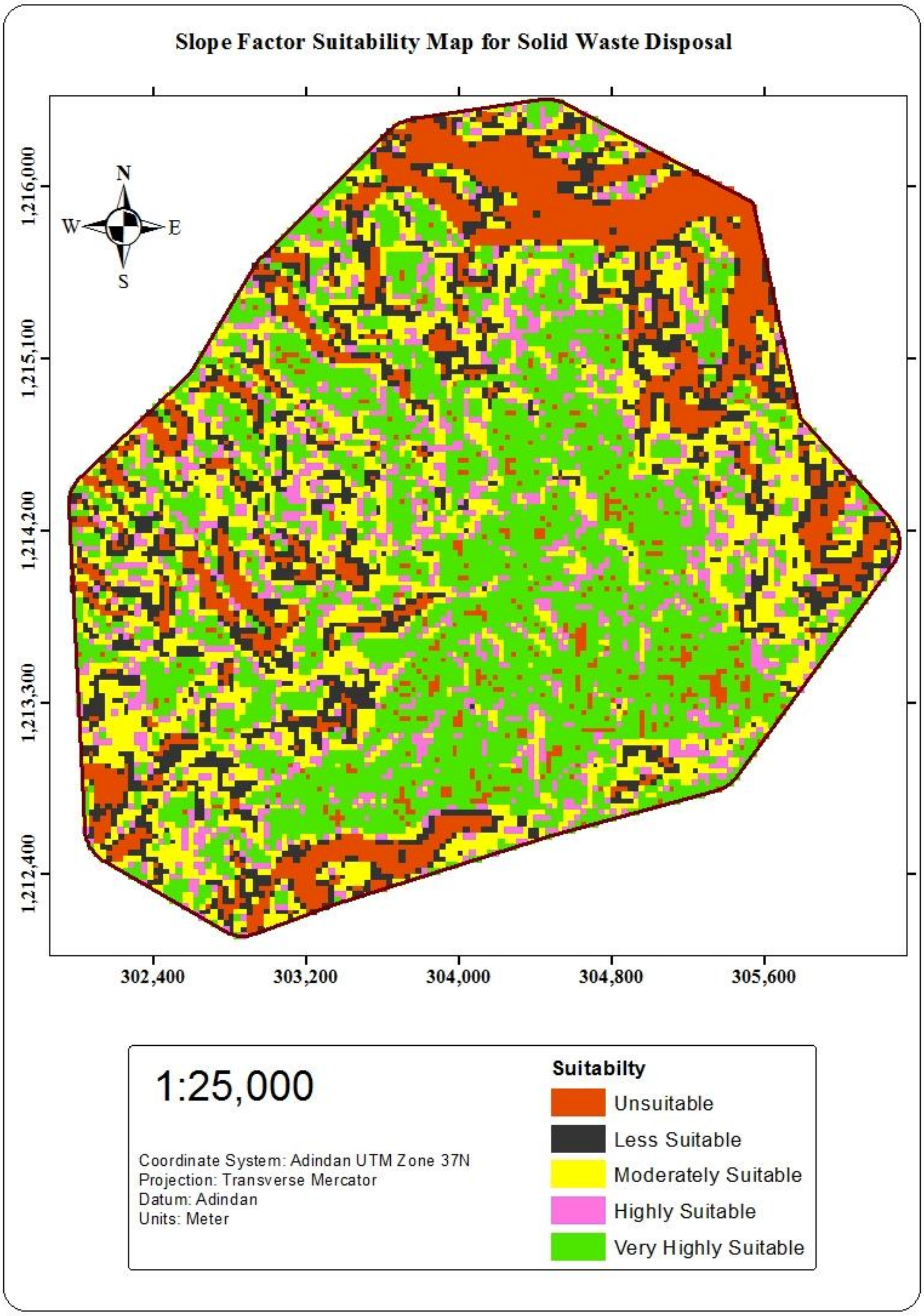


Figure 4-7: Slope factor suitability map:

4.4.5 Ground Water Table Suitability Analysis:

The ground water circulation and infiltration of pollutants depends on hydrogeological condition of surface and subsurface materials more specifically hydraulic properties such as porosity and permeability. Thus, an areas having potential location of shallow water well level are not preferable for waste disposal site, but an area with the deepest groundwater table were assumed as more suitable site for a solid waste disposal site. This is because of solid waste disposal site at a high groundwater level or a nearby high river level will cause more risk to the subsurface water resources (Gizachew et al., 2012; Bedassa and Wondwesen, 2020).

For this study the existed ground water well points were used to define the estimated ground water table for the study area. The available boreholes x, y position and their water level were obtained from Sekela wereda water office and additional water well point data were taken from well distributed individual households through ground survey method using handy held GPS instruments. And then the whole study area ground water level was estimated using GIS IDW spatial analyst tool. The suitability ranks for ground water table factor classes were defined based on the focus group discussant suggestions and by localizing different scholar experiences. Thus an area having less than 8m ground well levels were assumed as restricted zone for dumping sites and the remaining area were classified as 8-12m (unsuitable), 12-15m (less Suitable), 15-20m (moderately suitable), 20-25m (high suitable) and an area with greater than 25m ground water level were considered as very highly suitable class.

From ground water table spatial suitability analysis results 11.43% of an area was found as very highly suitable, 12.57% highly suitable, 8.87% of the study area is moderately suitable, 16.02% was observed as less suitable area and the majority coverage (36.82%) of the study area is unsuitable class. Whereas the rest 13.74% of the study area were assumed as restricted for solid waste disposal site (Figure 4.8).

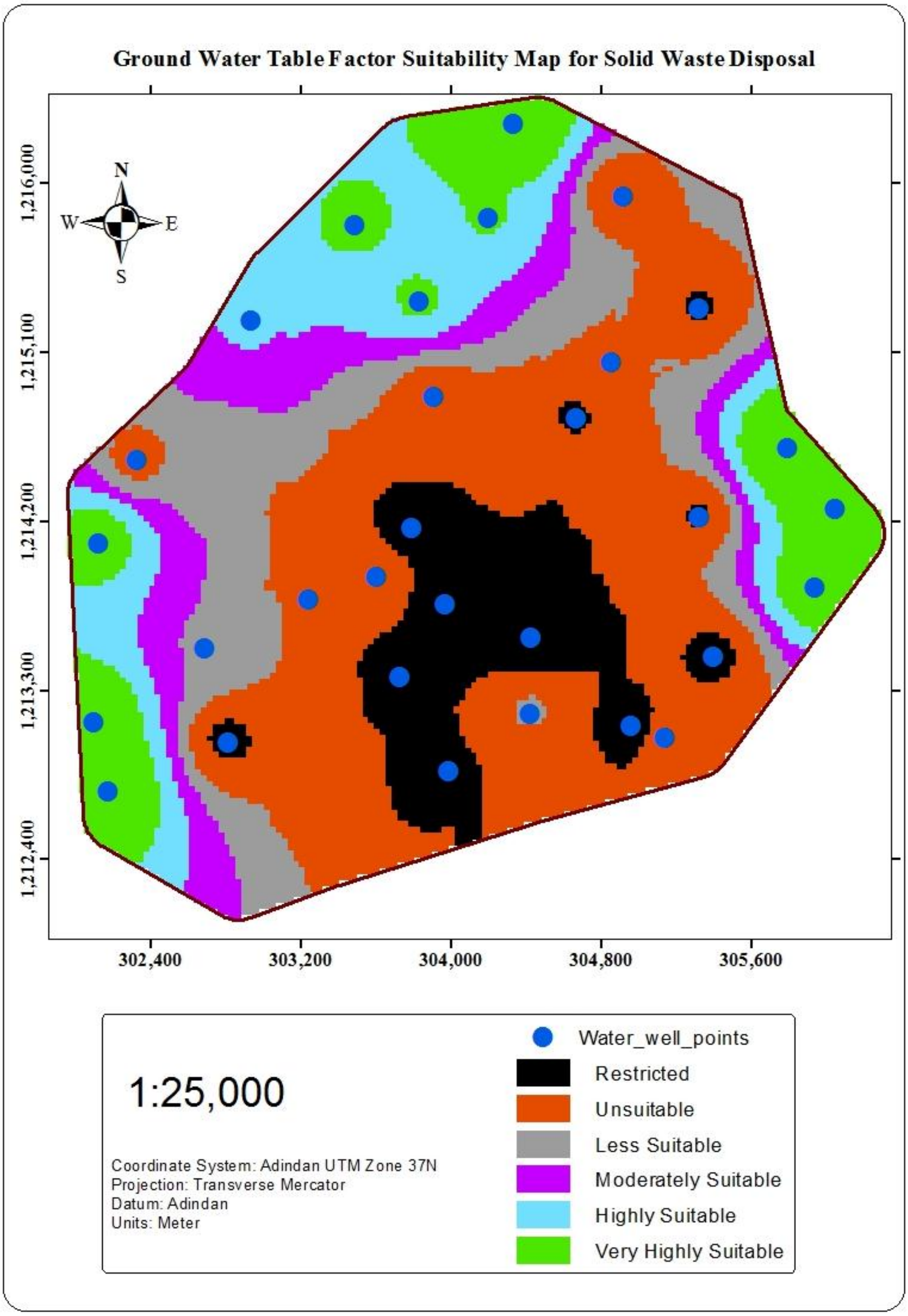


Figure 4-8: Ground water table depth suitability analysis Map:

(Source own Analysis result, 2022):

4.4.6 Rural Settlement Factor Suitability Analysis:

In addition to considering the urban residential areas the rural settlements should be taken in to consideration as one of the determinant factor for solid waste disposal site selection. Different scholars sets a minimum buffer distance for rural settlements to locate waste disposal sites for instance, 750m and 400m are recommended by Minale (2016), and Debebe (2017) respectively. Based on different scholar experiences, from FGDs suggestions and by considering the existing situations in this study from 0 - 200meter distance 200m to 500m were considered as restricted and unsuitable areas, respectively. And the remaining Euclidian distances reclassified as 500m to 750m less suitable, 750m to 1000 moderate suitable, 1000m to 1500m highly suitable, and an area greater than 1500m distance from settlements assumed as most suitable area.

In terms of rural settlements only 0.59% of an area was found as moderately suitable, 12.43% of the study area is less suitable, 19.07% of the study area is unsuitable and the majority (67.91%) of the study area is restricted area for solid waste disposal site.

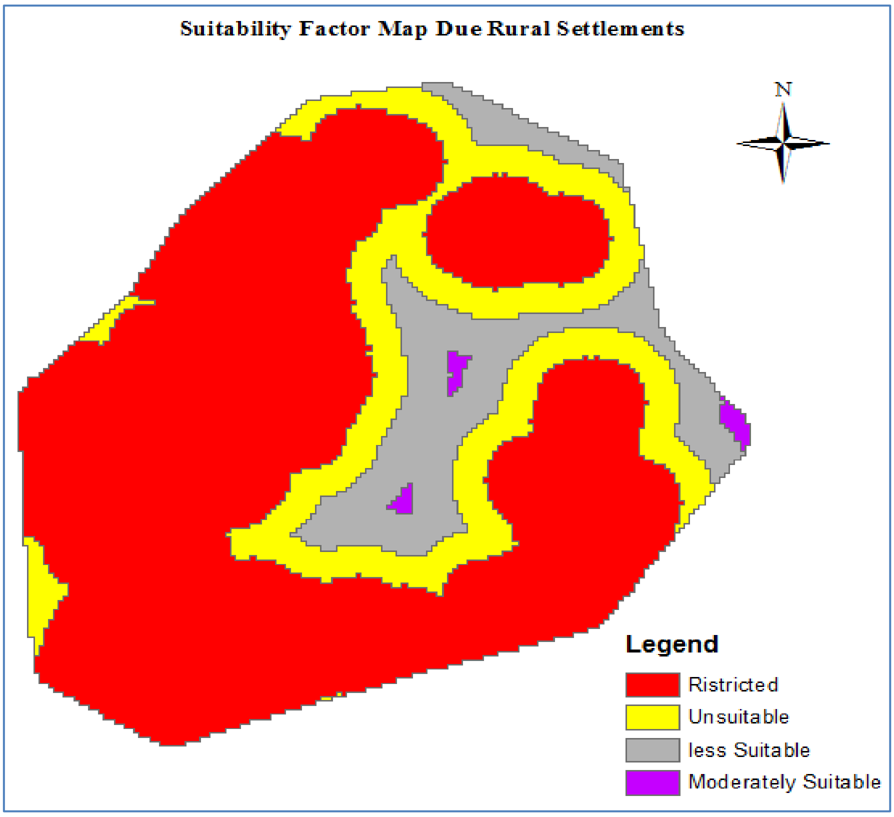


Figure 4-9: Rural settlements suitability analysis Map:

(Source own analysis result, 2022):

4.5 Restriction Map Development (Constraint Maps):

Restrictions in raster exposed here through Boolean expression containing only two classes represented where restricted cell is shown with 0 (for unsuitable land) and viable cell is represented with 1 (for suitable land) to develop a waste disposal site (Aeden, 2016). The constraint (restriction) maps were produced for environmental sensitive and for socio-cultural memorial features by recommended buffering distances within the study area. The critical features involved in constraint ma analysis in this study includes rivers, road-nets, rural settlements, ground water levels and built-ups and socio cultural features (includes areas religious service areas, schools and health centers). Also the waste dumping sites should not be near to the road networks and not located near to swamp and high sub surface water level zones to the reduces a possibility of contaminants from a landfill leaching to the ground water areas (Shah et al., (2019).

According to Akbari et al., (2008), the waste dumping areas should be away from rivers, lakes, or swamp areas; this is because as rivers have an excessive discharge and cause to downstream impact. Therefore solid waste disposal sites should not be placed in the floodplains of main rivers. In addition for the sake of siting social feasible disposal sites there should be a considerable buffering zone from rural settlements and urban built-up areas to prevent the locals from waste borne risks and problems (MUDC, 2012; Aeden, 2016; Genemo and Yohannes 2015). Consequently, based on the KIs responses and FGDs suggestion and by considering the study area situations buffering analysis was applied for each thematic feature as summarized table 4.3, bellow.

Table 4-3: Recommended restriction buffering zone

Restriction Source	**Minimum Buffer Distance**	**Analysis Buffer Distance used**	**Restricted area (ha)**	
			(Value = 0)	**(Value =1)**
Rivers	30	200m	405.45	894.89
Roads	50	200m	440.33	860.02
Built-ups	500	500m	803.09	497.26
Total aggregated constraint map result			967.56	332.79

Source: MUDC, (2012), Aeden, (2016), (Shah et al., (2019) As shown in Table 4.3, in regarding of road and river layers from the total study area 31.15% and 33.83% is highly restricted zone within 200m buffering distance respectively and that of 68.58% and 66.17% is viable site for further suitability class in river and road layers respectively. However in terms of built-up layer constraint map the majority (61.69%) of the study area are a high restricted zone and the rest area (about 38.30%) is less restricted area. Finally the combined constraint map results that the majority (74.32%) of the study area is highly restricted area and the rest 25.67% is considered as less restricted area (see Figure 4.10).

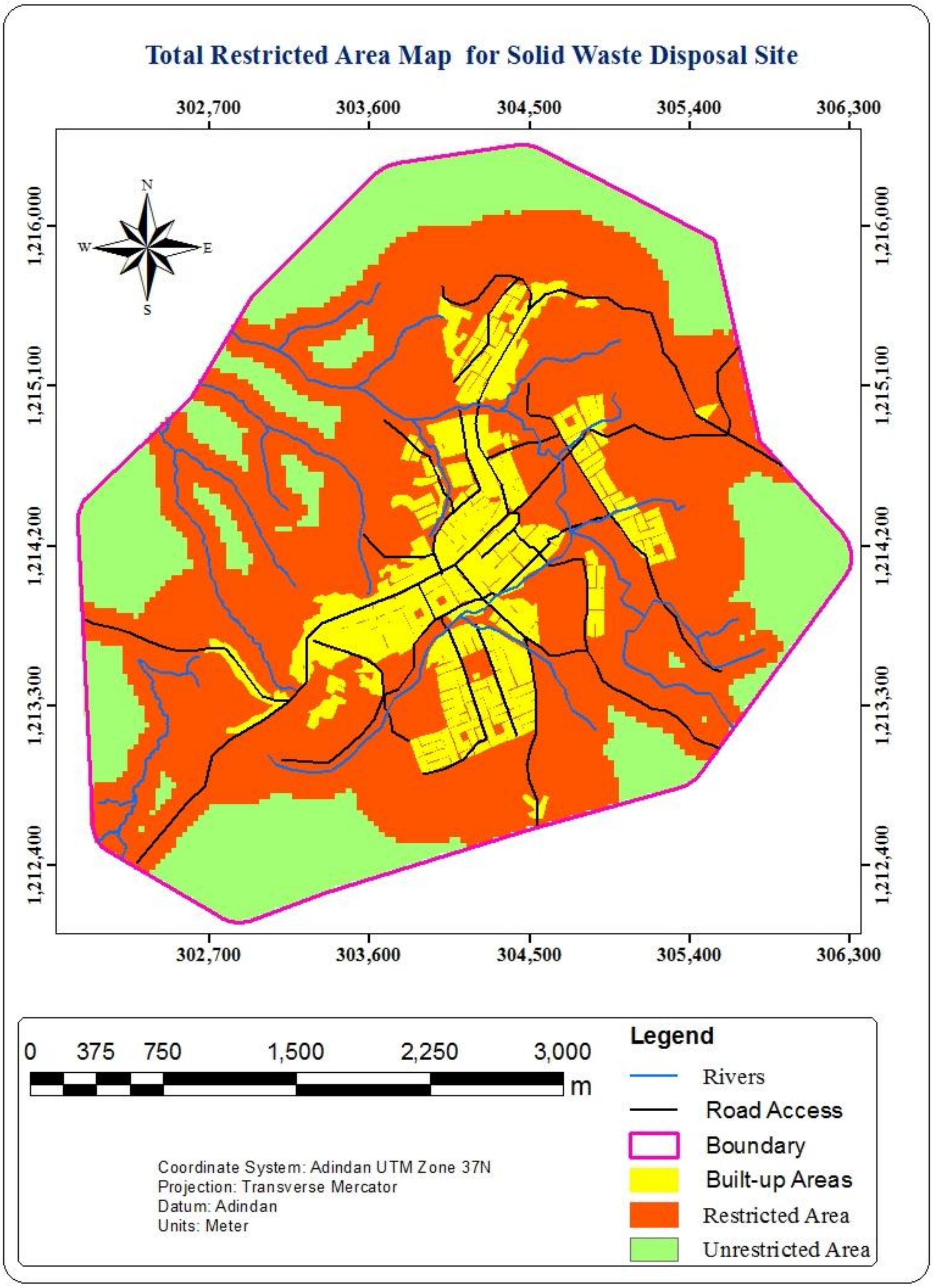


Figure 4-2: Total restricted area map for solid waste disposal site

4.6 Potential Landfill Site Analyses:

4.6.1 Weighting and Ranking of the Model Input Factors (Variables):

Weighting among suitability factors is to express the preference of each factor relative to other factor (Frantzis, 1993). In the weight and ranking calculation step, the pairwise comparison matrix; analytical hierarchical process and factor maps are used.

The principal eigenvector of the pairwise comparison matrix is figured out to produce best fit to the weight set; weight values are absolute numbers between zero and one represent the priorities of factors Weight values represent the priorities which are absolute numbers between zero and one, it implies that the weights sum to one (Ouma and Tateishi, 2014). The factors and their resulting weights were used as input for the multi-criteria evaluation (MCE) module for weighted linear combination of overlay analysis. These pair wise comparison were then analyzed to produce of weights that sum to 1 and the total weight should be added up to 100% in order for the output map to be meaningful and consistent (Saaty, 1980). In this study, nine-point intensity of importance (Satty's scale for pair-wise comparison causative factors) was used to formulate the multi criteria decision making process.

Table 4-4: Satty's (1980) scale (weight) for pair-wise comparison of factors:

Importance	**Definition**	**Description**
1	Equally important	Two factors contribute equally to the objective.
3	Moderately more important	Experience and judgment slightly favor one over the other.
5	Strongly more important	Experience and judgment strongly favor one over the other.
7	Very strong more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice.
9	Extremely more important	The evidence favoring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate values	When compromise is needed

Source: Hazarika and Saikia *(2020)*

Based on the above satty's (1980) scale table and by considering their susceptibility of spatial decision factors the scale of importance is given as follows:

Table 4-5: Ranking of criteria to obtain the pairwise comparison matrix:

Criteria	Land Use	Surface Water	Rural Settlements	Road Factor	Slope	G-Water Table
Land Use	1					
Surface Water	$\frac{1}{2}$	1				
Rural Settlements	$\frac{1}{5}$	$\frac{1}{2}$	1			
Road	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	1		
Slope	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
G-Water Table	$\frac{1}{7}$	$\frac{1}{7}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	1

Table 4-2: Factors Weights derived from the pair-wise comparison eigenvectors

Criteria	Priority Vector (Relative Weights)	Factor Weight (%)
Land Use	0.3879	38.79
Surface Water	0.2394	23.94
Rural Settlements	0.1358	13.58
Road	0.1094	10.94
Slope	0.0866	8.66
G-Water Table	0.0409	4.09
Total	**1**	**100**
Consistency ratio=0.039		

From the comparison matrix inputs and the AHP output the calculated consistency ratio (CR) = 0.039, which is much lower than the threshold value of 0.1 indicated a reasonable level of consistency in the pairwise comparisons judgments, implies that the determined weights obtained are acceptable. Then, computed eigenvector (weight) is used as a coefficient for the respective factor maps to be combined in the weighted overlay.

A summary of solid waste disposal site suitability causative factors or variables development showing hierarchal arrangement of all used determinant factors, their respective weights and how they are ranked according to their susceptibility due to uncontrolled and unprofitable waste disposal sites in the study area is presented in table 4.7; which is used as input for weighted overly analysis.

Table 4-3: Attribute scores and criteria weights used in site selection:

Decision spatial Factors	Relative weight	Decision sub spatial Factors	Sub factors Spatial Suitability Decision	Rank
Land use Land cover	0.3879 (39%)	Buildup Areas	Unsuitable	1
		Protected Areas	Not suitable	Restricted
		Agricultural land	Moderately suitable	3
		Forest lands	Highly suitable	4
		Bare (grass lands)	Very Highly suitable	5
Surface water Buffer analysis	0.2394 (24%)	0 – 200m	Unsuitable	Restricted
		0 – 500m	Unsuitable	1
		500 –750m	Low suitable	2
		750 – 1000m	Moderate suitable	3
		1000 – 1300m	High suitable	4
		>1300m	Very high suitable	5
Proximity to Rural Settlement	0.1358 (13%)	< 200m		Restricted
		200 – 500m	Unsuitable	1
		500 –750m	Low suitable	2
		750 – 1000m	Moderate suitable	3
Road access Buffer analysis	0.1094 (11%)	< 200m	Unsuitable	Restricted
		200 – 400m	Unsuitable	1
		400 – 600m	Very Highly suitable	5
		600 -750m	Highly suitable	4
		700 – 1000m	Moderately suitable	3

Decision spatial Factors	Relative weight	Decision sub spatial Factors	Sub factors Spatial Suitability Decision	Rank
		>1000m	Low suitable	2
Slope	0.0866 (8.9%)	< 2% and > 20%	Unsuitable	1
		2-8%	Very high suitable	5
		8-10%	High suitable	4
		10-15%	Moderate suitable	3
		15-20%	Low suitable	2
Ground Water Table	0.04096 (4%)	< 8m		Restricted
		8 – 12m	Unsuitable	1
		12 –15m	Low suitable	2
		15– 20m	Moderate suitable	3
		20 – 25m	High suitable	4
		>25m	Very high suitable	5

4.6.2 Suitable Solid Waste Disposal Site Mapping for Gish Abay Town:

The computed Eigen Vector values (weight) were used as coefficient for the respective waste disposal site factors. Once the weights for the factors are determined, a multi-criteria evaluation is performed by utilizing the specific weights for each factor; land use, proximity to road, Proximity to rural settlements surface water (proximity to river), slope, and sub-surface water level (ground water table depth).

From the weighted overlay result majority (91.34%) of the study area is resulted as unsuitable for municipal solid waste landfill, and 1.95 % (25.39ha) of the study area considered as less suitable class for solid waste disposals. Whereas, 1.13% (14.73ha) of the study area showed as highly suitable class and the rest 4.88% (63.54ha) of the study area is moderately suitable are for solid waste disposal sites (Figure 4.11).

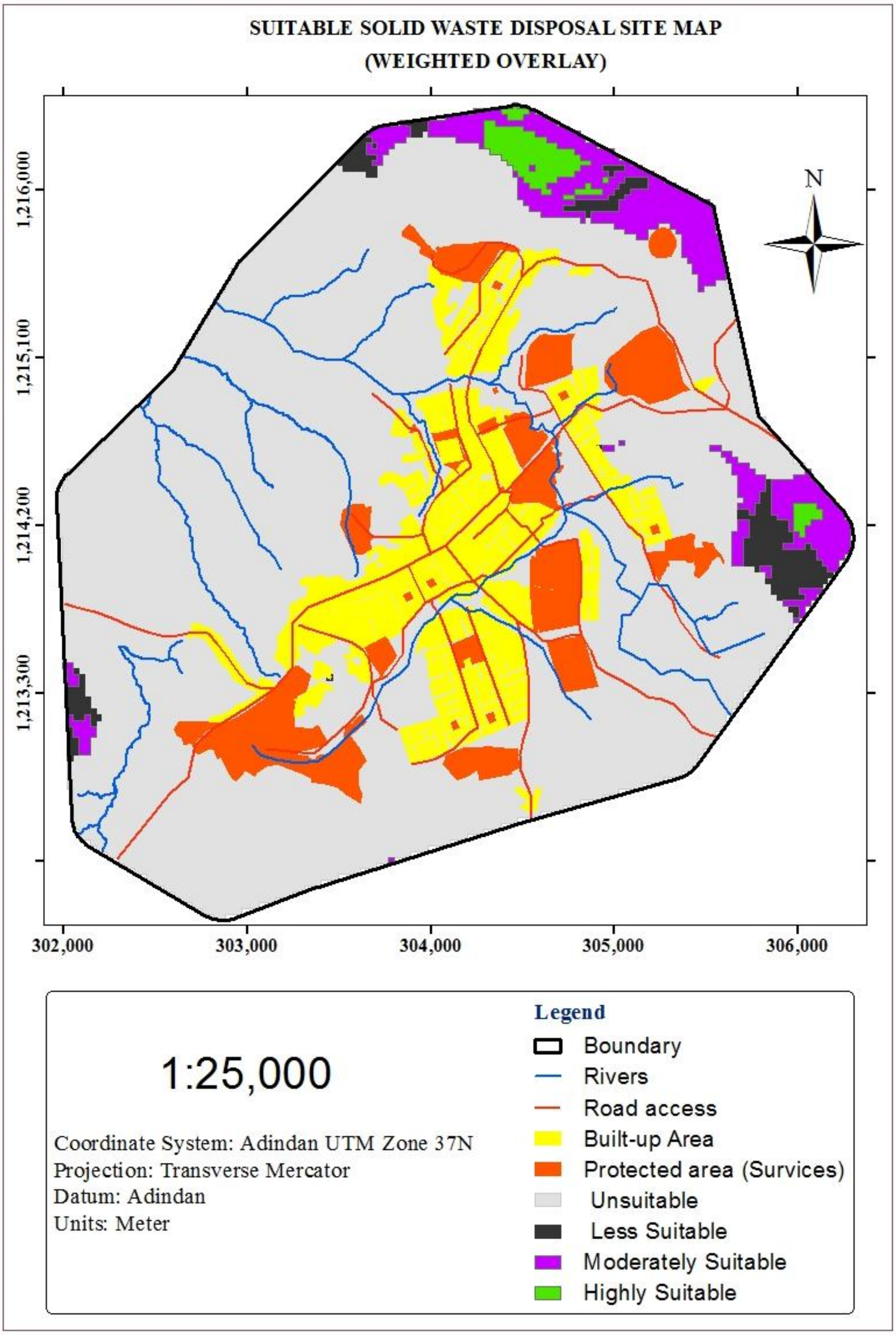


Figure 4-3: Summary of suitability overlay for solid waste disposal site selection:

4.6.3 Result Validation (Evaluation of a Newly Proposed Suitable Solid Waste Desposal Sites)

Spatial decision support systems (SDSS) provide a platform for GIS specialists to provide a service to all levels of decision makers and in all phases of a decision-making process. GIS is capable of generating a set of alternative decisions based on the spatial relationship principles of connectivity, contiguity, proximity and the overlay methods.

The third process of decision making, the choice phase, involves selecting a particular alternative from those available choices. In this phase, specific decision rules defined by the decision maker are used to evaluate and rank these alternatives (Malczewski, 1997). Decision-making methods used in geospatial decision making are computationally complex prescriptive methods, the details of which are rarely transparent to the decision maker. Moreover, it provides the means to analyze and compare the outcomes of different scenarios and decision paths.

The alternatives are defined in the design phase and in the choice phase they are evaluated, whereby the most appropriate alternative or set of alternatives is selected. Informed choice requires the more extensive use of visualization with a high degree of user (socio-spatial) interactivity, thus enabling the decision maker to see how the recommended solution is positioned both in geographical and in attribute space (Milutinovic et al., 2021).

Based on this, the weighed overlay results shown that there are different alternative suitable site to allocate solid waste disposal sites, so it needs further evaluating those spatial choices by setting critical socio-spatial criteria to select the most potential suitable site. In this study two alternative suitable sites are preferable and selected for further evaluation and to perform the evaluation and validation of the suitability zonation results, size of the alternative suitable landfill sites, distance to the rural settlements parameters, distance to urban centers, and road access of the study area were used to compare among suitable areas derived from weighted overlay map.

In accordance to size of sites, from sustainability and economical outlooks, a suitable alternative with larger size that will serve for at least ten years are more preferable than other small size suitable alternatives. This is because of selecting large sized solid waste disposal site can reduce the selection, design and construction costs and for effective land recovery programs that will be performed at the end of its lifespan. In this regard, among the two alternatives suitable Site-2 have an area 1.89ha less than the minimum landfill size recommended by urban development and construction minster (MUDC, 2102). On the other hand, the other alternative; suitable Site-1 have an area coverage of 12.84ha; which is an excellent size to serve for a minimum of 10 years design period for average expected discharge of solid waste from a projected population of the study area.

Table 4-4: Candidate suitable sites with respect to those evaluating criteria value:

Alternative suitable sites	Area (ha)	Distance to urban center	Rural dwellings (Protected areas)	Suitability
Suit_1	12.84	2.5km	No	1st Most Suitable
Suit_2	1.89	1.67km	No	2nd Most Suitable

So from the perspective of these critical evaluating parameters Suit_1 (“Ganu-site”) alternative suitable site is the most potential and suitable solid waste disposal site for Gish Abay town municipality (table 4.8 and figure 4.12).

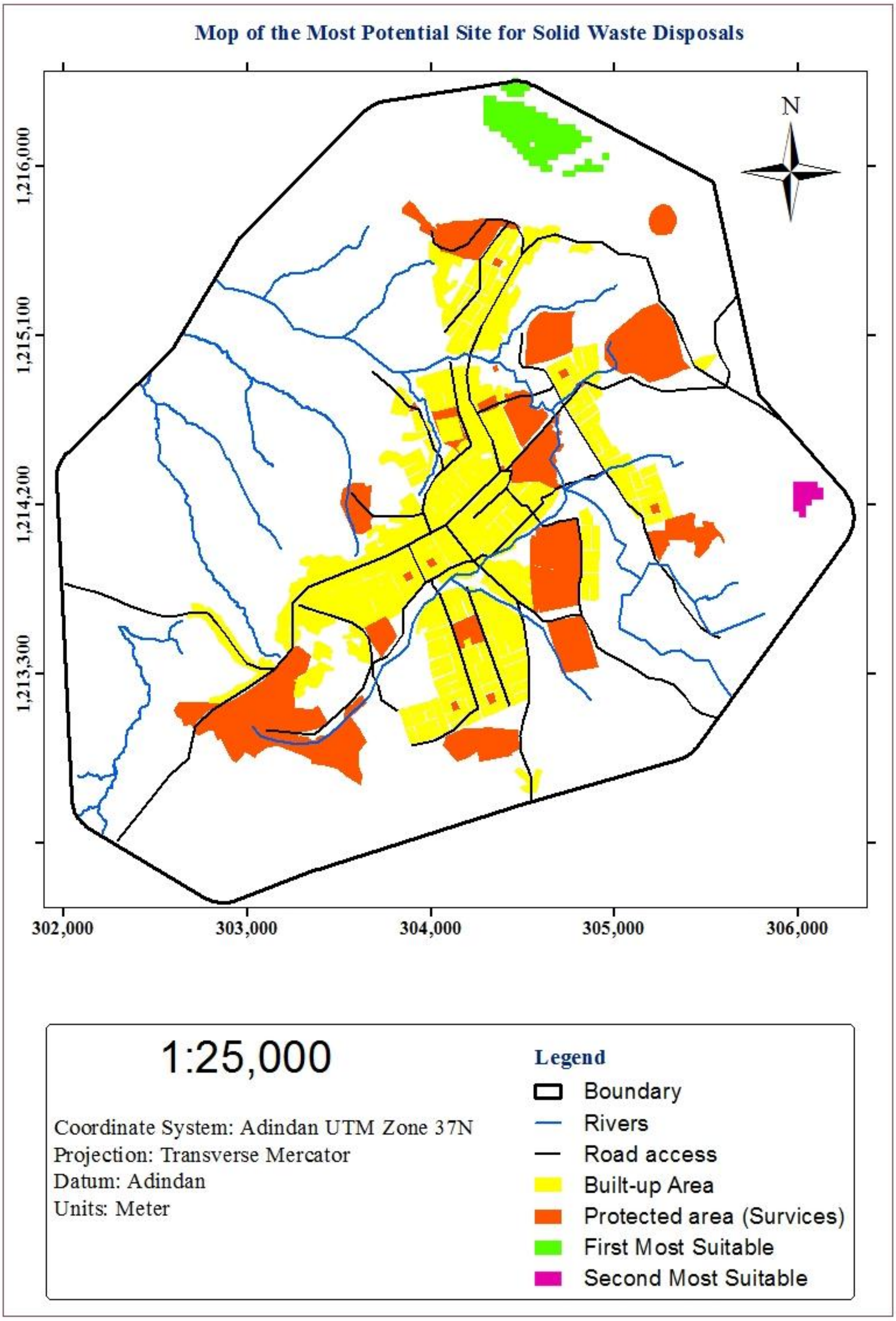


Figure 4-4: The most potential suitable solid waste disposal site map:

CHAPTER FIVE

5. Conclusions and Recommendations:

5.1. Conclusions:

The main objective of this study was to evaluate the current waste disposal practices and to assess the potential suitable solid waste disposal site by customizing the major parameters/factors of AHP to the local conditions using integrated multi-parametric AHP and GIS techniques for Gish Abay town. This study has examined the problems of the current waste disposal. The findings shows that the communities of Gish Abay are habituated inadequate and uncontrolled waste disposal practices, the peoples are simply dumping the waste in the open spaces everywhere and burn within the town. The town municipal did not have appropriate solid waste disposal site. As a result, the existed waste disposal sites are not environmentally and socially sound, results environmental and social problems. This implies that solid waste management is becoming a serious problem for Gish Abay.

Based on the findings, a landfill site for municipal solid waste disposal is sought for Gish Abay town using multi-parametric MCDA-AHP method and GIS techniques. MCDA-AHP enables to compare their importance among many variables and weighing them through comparison matrix. Six environmental and socio economic criteria; namely land use, proximity to rivers, proximity to roads, slope, rural settlements and ground water level were used as determining factors for selecting appropriate (potential) site for municipal solid waste disposal. In this regard, the result of the final suitability map designate that 1.13% of the study areas are highly suitable for solid waste disposal site, 4.88% moderately suitable, 1.95% is less suitable and the majority (91.34%) of the total study is unsuitable area for solid waste disposal site. After validation of the results, only two sites namely ‘Ganua’ with an area coverage of 12.84ha and ‘Gerelta’ area coverage of 1.89ha are identified as the most potential suitable solid waste disposal sites. From the results of the study, this researcher concludes re-consideration and relocation of the existing solid waste disposal sites by adopting the proposed potential suitable areas for the sustainability of the town development.

5.2. Recommendations:

The following recommendations are forwarded based on the findings of the study.

- The existing/current solid waste disposal practices and the existed open dumping sites have impacts on health, economic, social and ecological aspects. Hence, the town municipal should set restrictions and standards in relation to waste disposal system.
- The municipality should put temporary waste collection containers around major waste generating areas which may reduce the habit of waste dumping anywhere and it should be take a great initiation to stop disposing of the solid waste on the existed disposal sites.
- The study results indicate that there is a need of selecting environmentally and socially sound solid waste disposal sites. Hence, the town administration should re-consider and relocate the existing solid waste disposal sites by adopting the proposed potential suitable areas for the sustainability of the town development.
- The local government should create awareness and rehabilitate those existed disposal sites.
- This study considered only some of environmental, socio-economic factors for solid waste disposal site selection. Therefore, further study should be recommended in view of highlighting the factors (parameters) which are not included in this study. For instance, spatial parameters like soil type and socio-economic parameters like population density and income level of the town population are among the causative factors of suitability analysis for solid waste disposal site selection.
- Nevertheless, due to unavailability of updated data those are not incorporate in this study. The town municipality shall need further considerations in accordance of those missed parameters in design phase of landfill for solid waste disposal.

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Annexes:

Annex 1: Onsite Observation of Current Disposal Sites and Practices

Figure 1 Open field solid waste disposal site along the main road near to Abay River (Own)

Figure 2: Open solid waste disposals along to Abay River near to recreational area (Own)

Figure 3: Illegal solid waste disposals along the main road near to Abay River (Own)

Figure 4: Illegal solid waste disposals at the recreational area near to Abay River (Own)

Figure 5: firing of solid wastes on the commercial area at the center of the town:

Figure 6: Solid wastes Disposals near to sensitive areas without restriction