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GIS and Remote Sensing Based Suitable Site Selection for Solid Waste Disposal: A Case Study of Asaita Town, Afar Regional State, Ethiopia

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GIS and Remote Sensing Based Suitable Site Selection for Solid Waste Disposal: a Case Study of Asaita Town, Afar Regional State, Ethiopia

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN REMOTE SENSING AND GEO-INFORMATICS

BY Aden Ali Mohammed

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Addis Ababa University
School of Graduate Studies

This is to certify that the thesis prepared by Aden Ali Mohammed entitled as "**GIS and Remote Sensing Based Suitable Site Selection for Solid Waste Disposal: a Case Study of Asaita Town, Afar Regional state, Ethiopia**" is submitted in partial fulfillment of the requirements for the Degree of Master of Science in Remote Sensing and Geo-informatics compiles with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Declaration

I hereby declare that the thesis entitled "**GIS and Remote Sensing Based Suitable Site Selection for Solid Waste Disposal: a Case study of Asaita Town, Afar Regional Sate, Ethiopia**" has been carried out by me under the supervision of Dr. Getachaw Berhan, Department of Earth Science and Dr. Mekuria Argaw, Department of Environmental Science, Addis Ababa University during the year 2015-2016 as a part of Master of Science Program in Remote sensing and Geo-informatics. I further declare that this work has not been submitted to any other University or Institution for the award of any Degree or Diploma.

Place: Addis Ababa

Date: December, 2016

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CERTIFICATION

This is to certify that the thesis entitled as "**GIS and Remote Sensing Based Suitable Site Selection for Solid Waste Disposal: a Case Study of Asaita Town, Afar Regional State, Ethiopia**" is an authenticated work carried out by Aden Ali Mohammed under our guidance and supervision. This is the actual work done for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and Geo-informatics from Addis Ababa University. Addis Ababa.

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Acronyms

AHP	Analytical Hierarchy Process
ANRS	Afar National Regional Sate
BoFED	Bureau of Finance and Economic Development
CSA	Central Statistical Agency
DEM	Digital Elevation Model
EMA	Ethiopia Mapping Authority
ERDAS	Earth Resource Data Analysis System
GIS	Geographic Information System
HA	Hectares
LULC	Land Use Land Cover
MCDA	Multi-criteria decision analysis
MS excel	Microsoft Office excel
MSWM	Municipal Solid Waste Management
MS Word	Microsoft Office Word
PC	Personal Computer
SRTM	Shuttle Radar Topographic Mission
SWM	Solid Waste Management
USGS	United State Geologic Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WHO	World Health Organization

Abstract

*Solid waste dumping is a serious problem in the Asaita town because most solid wastes are not dumped in suitable area. The main objective of this study is to select suitable disposal site which is economically feasible, environmentally sound and socially acceptable in Asaita town by applying geographic information system and Analytical Hierarchy Process (AHP) methodology. In this research, data from STRM image with a spatial resolution of 30m*30m; topographical map of the study area, land use/land cover map generated from Landsat 8. To achieve the objectives the present study used factor maps as slope, fault, built up area, road, river, land use/land cover, geology and soil map were reclassified in GIS environment followed by preparation of their suitability map. Even if the degree of weight to each factors vary, the factors were considered very important and mandatory in the selection of suitable sites for solid waste disposal. AHP pair wise comparison module was used to achieve weights of factor parameters and finally suitability map was prepared by overlay analyses on Arc Map platform based on Weighted Linear Combination (WLC) analysis to select Suitable solid waste disposal* sites *and leveled as highly suitable, suitable, moderately suitable and unsuitable. The result indicates that from total area 5% is highly suitable; 15% suitable; 4.5% moderately suitable, 1% less suitable and 74.5% unsuitable for solid waste dumping. In general, the selection of highly suitable sites requires further geotechnical and hydro-geological analyses to ensure conformity with stringent standards required for design and construction of facility.*

Key Word: *Solid Waste Disposal Site, Geographic Information System, Remote Sensing, AHP.*

CHAPTER ONE
INTRODUCTION

1.1 Background

An object which discharged and discarded from each stage of human life activities is called waste or waste materials, which leads to adverse impacts on human health and the environment (Bringi, 2007). These includes food remnants, papers, textile materials, bones, ash/dust/stones, dead animals, human and animal excreta, construction and demolishing debris, bio-medical debris, household hardware or electrical appliances, furniture, etc (Sha'Ato et al., 2007; Babatunde et al., 2013).

Waste as the side products of various activities/events in human life and as a result of a natural process often creates serious problems in areas of settlement. Among challenges that most urban areas in the world face management of solid waste. This is a result of an aggregation of human settlements has the potential to produce a large amount of solid waste. Solid waste is global environmental problem in today's world such as developing and developed countries. Increasing population, rapid economic growth and the rise in community living standards accelerate solid waste generation in the world (Elmira et al., 2010).

The significant manifestation of inappropriate disposal of solid waste can be contamination of surface and ground water through leaching, soil contamination through direct waste contact, air pollution by burning of waste, spreading of diseases by different vectors like birds, insects and rodents, or uncontrolled release of methane by anaerobic decomposition of waste (Visvanathan and Glawe, 2006). Solid wastes indiscriminately thrown resulted also in aesthetic problems, nuisance, and pollution of land and water bodies of an area (Hammer, 2003).

Solid waste disposal is an important part of waste management system, which requires much attention to avoid environmental pollution and health problems. For that reason, locating proper sites for solid waste disposal and selecting appropriate landfill site far from residential areas, environmental resources and settlement is the main issue for the management of solid waste.

Along with many, one way to dispose solid waste is to place it in as it should be designed, constructed, and managed landfills, where it is safely contained. African nations (with the exception of South Africa) had the fewest engineered landfills, with the most nations practicing open dumping for waste disposal (Tirusew, Ayisheshim and Amare Sewnet, 2013). In 1960s in Africa rapid urban growth has Place led to increased generation of waste. Solid waste disposal in most African cities, especially the slum areas, the problem is aggregated by the open dump natural disposing waste. Usually, administrations in African states allowed uncontrolled dumping in abandoned quarry site with no condition sanitary landfill, causing huge health problems (Hammer, 2003).

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. Degnet (2008), stated that, like in many other developing countries, the majority of inhabitants in most towns of Ethiopia often use unsafe solid waste disposal practices, such as open dumping, burning and burying.

As a result of rapid population growth in the town, the wastes are increasing from time to time. The suitable site for this waste is not selected due to this reasons the society of the area are dumping the waste anywhere. So to have the time and cost which spent for other purpose, the GIS and RS based suitability site section solid waste disposal is very important to solve that all problems discussed above. Even though the problem is increasing and there is no any research done on this area. So this study is expected to fill this gap to develop socio-economic wellbeing of the society of the area.

1.2 Statement of the Problem

As a result of population growth and development activities, high amounts of household and urban solid wastes are generated. The population of a town is growing due to natural increasing, Tendaho sugar project employee and immigration of people from rural areas to towns (CSA, 2013).

High rate of wastes generation is facing problem of their disposal and very high potential effect to pollute environment such as surface water, ground water, soil, and air. The most common problems associated with improper management of solid waste include diseases transmission, fire hazards, odor atmospheric and water pollution and economic losses (Jilani, 2002).

Public health is also highly affected by uncontrolled solid waste generation and disposal. In Ethiopia most diseases relate to poor environmental cleanliness and water pollution. It is lack of suitable waste disposal site, public latrine and general clean mechanism in the area can affect the community's economic and social activities directly or indirectly (Tsegaye, 2006).

However, finding a good waste disposal area is difficult since land is a scarce resource. An increasing environmental awareness, increasing cost, community and political opposition and public health concerns have made choosing suitable land for landfills quite difficult (Din et al., 2008). Municipal authorities charged with the responsibility of providing municipal solid waste management services have found it increasingly difficult to play this role (Bartone, 1993).

The major sources of solid wastes in the town are homes, hotels and restaurants, barberries, hospitals and private clinics. Due to absence of landfill site, communities have been dumping the wastes around their homes, near to road and other places. Especially there is no any site selection to dispose waste materials in the town including for waste from the sugar project. This leads to high potential environmental, human health risk, beautifulness of town, animals, plants and disruption of wealth. So the people are at risk in their day to day activities because of this problem.

There are no proper site selection criteria for waste disposal in Asaita town. Not only in Asaita but also there is no research done previously in Afar region in order to select waste disposal site for various towns of the region (Personal Observation and Local Community Interview). Therefore, it is very important to select appropriate sites for waste disposal and managing them to solve the existing problems of work management in the region.

1.3 Objectives of the Research

1.3.1 General Objective

The main objective of this study is to select suitable solid waste disposal sites that are economically feasible, environmentally sound, and socially acceptable in Asaita town by applying geographic information system and Analytical Hierarchy Process (AHP) methodology.

1.3.2 Specific Objectives

- ✓ To investigate and implement derived scientific methodology for selecting waste disposal site by examining environmental, social and economic factors using GIS with AHP methods,
- ✓ To produce factor maps that use for landfill suitability analysis, and
- ✓ To evaluate and rank the identified most suitable landfill sites.

1.4 Research Questions

- What methods are scientific methodologies for a waste disposal suitable site selection?
- What are the factors that use for landfill suitability analysis?
- What is the most important criteria's are for identify most suitable landfill sites?

1.5 Significance of the study

Safety of the environment from solid waste hazards is becoming a serious problem. Solid waste disposal site wills should be using scientific criteria to avoid any harmful effect on local communities and the environment. This helps to protect environmental safety of Asaita town, to suggest an appropriate solution for decision makes, to improve the existing solid waste management system of the town and to a guide line for solid waste management decision making process in town by selecting suitable site for waste disposal using remote sensing and geographic information system techniques. The final result sites will help the societies of the area in their day to day activities. Because, the unsuitable waste disposal site may affect the economic, social, natural resources and the environments.

1.6 Scope of the study

The study is limited to suitable solid waste disposal site selection in Asaita town. It focuses on some technical aspects of solid waste disposal site selection. The issues under consideration in this study are only solid wastes. The study is not included sanitary wastes area, engineering and design part of the construction.

1.7 Organization of the Thesis

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

CHPTER TWO

LITERATUR REVIEW

2.1 Concept and Types of solid waste

Solid waste means any garbage, refuse, sludge, and other discarded solid materials, including solid waste materials resulting from industrial, commercial, and agricultural operations, and from community activities, but does not include dissolved material in domestic sewage (Tchobanoglous *et al*., 1977). Similarly, according to Sasikumar and Krishna (2009), Solid waste is used to describe non-liquid materials from domestic, trade, commercial, agricultural and industrial activities, and from public services. It includes of both solid and liquid waste but not include waste water. On the other hand, it comprises all the wastes arising from human and animal activities that are normally solid and discarded as useless or unwanted (Tchobanoglous *et al*., 1977).

A lot of the developing countries, the discharge of solid waste have become part of everyday living, and the countries are faced with the problem of solid waste generation in an almost continual style. The implication is serious taking into explanation the incompetent disposal system in many of these countries, which could finally cause health problems and environmental degradation (Filemo and Uriat, 2008).

Types of solid waste

The solid waste can be categorized same scholars by different ways according to the origins of the waste streams. Based on, United Nations Environment Program (2005), solid waste classified in two main groups. These are Municipal Solid Waste and Homogenous solid waste. Municipal solid waste is referred the solid waste-mix generated and collected in urban areas and it include waste from houses but can sometimes also include waste from industries and small scale businesses in the urban area. On the other hand, Homogenous solid waste is also generated from industries farms, mines etc, in both rural and urban areas. Waste from these sources is in a lot of cases easier to collect because it is concentrated to certain great producers.

The management process itself can also be easier to perform because of the homogeneity of the waste. Additionally, according Penido et al. (2009) solid waste classified three parts such as, hazardous solid waste, non- inert solid waste and inert solid waste depending on potential risk for environmental contamination or its nature and origin criteria. Hazardous solid waste is essentially inflammable, corrosive, reactive, toxic or pathogenic and therefore represents a risk to public health in the form of increased mortality. On the other hand, non-inert solid waste is Combustible, biodegradable represent health or environmental risks and it does not fall within hazardous waste or inert waste. Inert solid waste is solid waste with intrinsic characteristics that do not represent a risk to health or the environment.

2.2 Solid waste management

Solid waste management (SWM) is becoming one of the most serious challenges in Africa face today. Most municipalities are unable to collect the increasing volumes of waste. Solid waste Management (SWM) is critical for protecting urban environments, public health and the image of cities. A rapid urbanization rate means that the challenges relating to the collection and disposal of solid waste will increase in years to come, and therefore there is an urgent need to resolve the current problem (UN-Habitat, 2010a).

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

Municipal Solid Waste Management (MSWM) refers to the collection, transfer, treatment, recycling, resource recovery, and disposal of solid waste generated in urban areas. MSWM is a major responsibility of local government and a complex service involving appropriate organizational, technical, and managerial capacity cooperation between numerous stakeholders in both the private and public sectors (Bernstein, 2004).

The goals of MSWM are to generate employment and income promotes the quality of the urban environment, and protects environmental health and support the efficiency and productivity of the economy (Ogwueleka, 2009). Solid Waste management involves a wide range of people participation to help keep a clean, safe and nice physical environment in human settlements. Especially, in developing countries effective waste management is a growing challenge to all urban governments.

2.2.1 Solid waste management in developed and developing country

Developed countries have serious environmental challenges about solid waste management because of fast urban development. The growing of population number and improved standard of living in cities and urban areas has led to the generation of varied categories of wastes. Because of urbanization, population growth, industrialization, and economic growth, a trend of increase in municipal solid waste generation has been recorded worldwide in major cities (Punjab Pollution Control Board (PPCB), 2007).

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

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

Most of the municipality in developing countries spends the highest proportion of their annual budget on solid waste management. Municipalities in developing countries spend 20-50% of their budget on SWM, which cover less than 50% of the total population (Henry et al., 2006).

Also, in some African countries, one to two thirds of the solid waste generated is not collected. Because of this uncollected waste, usually end up in the surrounding environment or drainage or open dump. They are confronted with many aspects of problems such as, inadequate service coverage and operational inefficiencies of services, limited utilization of recycling activities and inadequate landfill disposals (UN-HABITAT, 2010b).

Therefore, more hard work are needed to overcome this problem that leads different agencies and establishments to find common restrictions to protect human and environment from these consequences (Friedman, 1998). The U.S. Environmental Protection Agency issued a lot of regulations and restrictions to control unfriendly environment projects, like landfill site criteria, and also a lot of agencies were established in different countries of the developed world to control this process (EPA,1996). Developing countries just started to establish such agencies and institutions in this field (PAEA, 2006).

2.2.2 Solid waste management in Ethiopia

Solid waste generation is increasing in Ethiopia environmental and public health problem. The rapid expansion of urban agricultural and industrial activities, stimulated by population growth, has produced vast amounts of solid and liquid wastes pollute the environment and destroy resources. Changing economic trends and rapid urbanization also complicate solid waste management (SWM) in developing countries. Consequently, solid waste is not only rising in quality but also changing in composition (from less organic matter to more paper, packing materials, plastics, glass, metal, and other substances), which is exacerbated by low collection rates (Bartone and Bernstein 1993; Medina 2002).

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

According yami Brike (1999), random survey indicated that, large and medium urban areas of our country shown the status 86.6 percent used open dump to dispose waste, while the rest used holes. Most of the other urban areas in Ethiopia are believed to use open dump for disposal. Open dumps pollute surface and ground water, soil and the natural environment as a whole.

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

2.3 Application of Remote Sensing (RS) and Geographic Information System (GIS) for Solid waste disposal site selection

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

The role of remote sensing is becoming increasingly frequent in environmental studies. At this time, no serious research of the environment performed without advanced image processing and analysis. One of the most important applications of remote sensing can be found in the case of solid waste landfill site selection where satellite images are used for extracting most of the site selection criteria used for sitting landfill (Oštir et al., 2003) time and cost effectively. Moreover, remote sensing can provide digital data as an input for GIS.

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

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

2.4 Multi-Criteria Decision Analysis (MCDA) for landfill site selection

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

Multi criteria decision analysis has undergone an impressive development during the last 30 years, in part because it is amenable to handling today's complex problems, in which the level of conflict between multiple evaluation axes is such that intuitive solutions are not satisfactory. MCDA is not a tool providing the 'right' solution in a decision problem, since no such solution exists. The solution provided might be considered best only for the stakeholders who provided their values in the form of weighting factors, while other stakeholders' values may indicate another alternative solution. As a replacement for, it is an aid to decision-making that helps stakeholders organize available information, think on the consequences, explore their own requirements and tolerances and minimize the possibility for a post-decision disappointment (Belton and Stewart, 2002). Analytic Hierarchy Process (AHP) is one of the most commonly used MCDA tools. This tool is applied in site selection processes as it assists the decision making process by allowing decision-makers to organize the criteria and alternative solutions of a decision problem in a hierarchical decision model (Eldrandaly et al., 2005).

To determine the most proper landfill site for a region, many criteria should be considered. The multi criteria decision analysis is widely used method for site selection process. It is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. Unlike methods that assume the availability of measurements, measurements in MCDA are derived or interpreted subjectively as indicators of the strength of various preferences (Saaty, Thomas. 2005).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

Asaita is a town in northeastern Ethiopia, and before 2007 was the capital of the Afar Region of Ethiopia. Administratively it is found in Zone One of the regional administration; and this Zone comprises of eight woreda namely Asaita, Elidar, Afambo, Mille, Dubti, Kurri, Adaar and Chifra, Asaita wereda shares boundary with the Republic of Djibouti internationally and with Afambo, Dubti and Elidar weredas of Zone One in the region. As a zonal capital, the town has an administrative linkage with all the weredas of its zone. With regard to linkages outside the region, it has strong transport and economic interaction particularly with Dessie town of the Amhara Region. The town has a latitude/longitude of 11°34′N/41°26′E and an elevation of 300 meter (980 ft) asc. Asaita is 655kms far from the capital city of Ethiopia, Addis Ababa and 65kms far from the capital city of Afar, Samara. Topographically, Asaita and its surrounding area consist of basically flat landscape with some hills and small mountains that range in altitude from 350 to 473 m.a.s.l (ATM, 2011). The total area of the study area is 5987 ha.

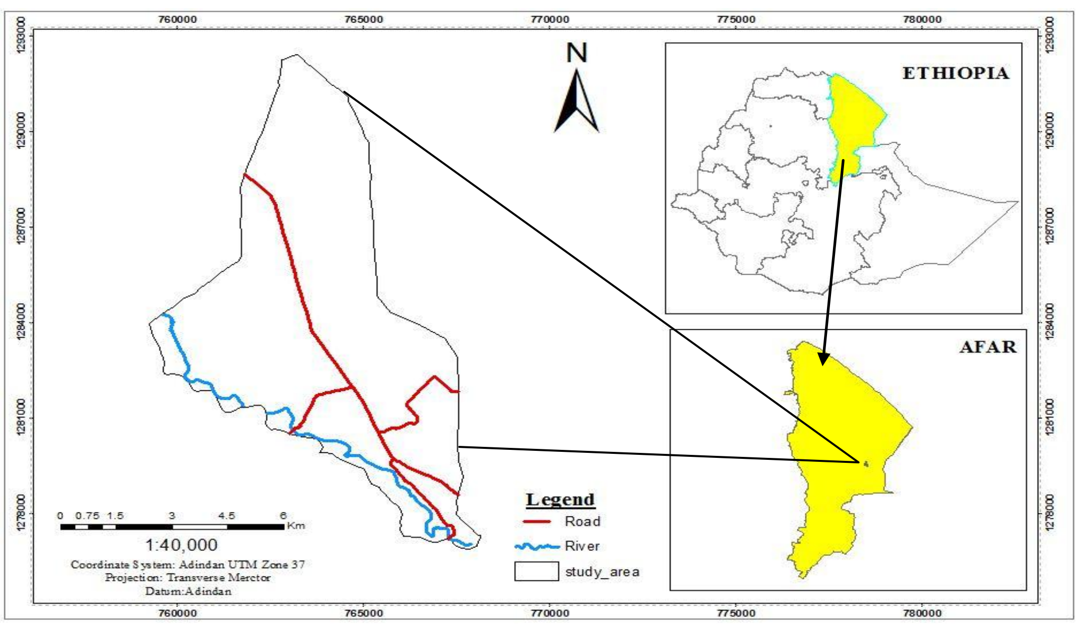

Figure 1. Location Map of the Study area.

3.1.2 Climate

Asaita town is one of the towns in Ethiopia located within the rift valley system. Its location connected with low altitude, makes it to have warm temperature. The temperature very much varies among seasons, and the months of December and January are comparatively cold months while June, July and September are the hottest ones. Bereha is the dominant agro-climatic zone covering 99.33% of the region with an average temperature greater than 27.5C° (ANRS, 2010). Table 1 shows average monthly temperature of the town from 2010-2014.

Table 1. Average monthly temperature of the town from 2010-2014.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max.T°(C)	35.7	36.8	39.2	41.6	44.1	45.6	45.4	43.3	45.3	42.4	38.7	36.0
Min.T°(C)	20.6	21.2	22.3	25.6	27.3	29.1	28.5	26.0	27.6	24.7	23.5	20.0
Average	28.15	29	30.7	33.6	35.7	37.3	36.9	34.6	36.4	33.5	31.1	28.0

Rainfall is bi-modal throughout the region with a mean annual rainfall below 300 mm. The region receives three rainy seasons. The seasonality of Afar region is by large determined by the timing, availability, and performance of the rainfall. The main rain, Karma accounts for most of annual rainfall occurring from mid-June to mid-September. This is followed by rainy showers in mid-December called dada and a short rainy season during March-April called sugum (Getachaw, 2004).

3.1.3 Population

It is key subject in carrying out any planning activity, having knowledge of population size of any urban center is very important. Based on data obtained from Central Statistical Agency of Ethiopia (CSA, 2013), total population of the town was 22,718 of which 12,722 were male and the rest 9,996 were female. At this time in 2013 the total population size of the town is expected to be 64,393 of which male accounts 34,382 and female accounts for the rest 30,011 if the rate is considered to be constant (CSA2013).

3.1.4 Soil

Soil map of the study area is one of the criteria used to select potential sites for solid waste disposal in the study area. The soil of the study area was available from FAO (2007). The study area of soil classified in three categories such as, Eutric Rego Soil, Virtic Ando Soil and No soil and they have different characteristics. Regosols are the family of Eutric Rego soil. They are very weakly developed mineral soil in unconsolidated material. Rego soils are extensive in eroding land. Profile development is minimal as a consequence of young age or slow soil formation. Regosols in medium and fine textured and they used commonly for extensive grazing, best for forest. Andosols found in volcanic area as formed in volcanic tephra. They have a vitric or andic horizon starting with 25cm from the soil surface and having no diagnostic horizons (unless buried deeper than 50cm). Most of Andosols have excellent internal drainage because of their high porosity and their occurrence in predominantly only high terrain position. (WSI, 2016).

3.1.5 Geology

Based on, Geological survey of Ethiopia the study area of geologic map includes Aphanatic basalt, basaltic fissure flow, lacustrine deposit, ryholite and mudflat (silt, clay sand). Basaltic fuser flow of south parts of Asaita with is small areal coverage. The large plains are mudflat which composed of clay, silt and sand covers almost more than half of the study area. Rhyolites (silicics center) is found in the east at Borawli Yeterara Seneselet, it have characterized by high degree of deformation exhibiting faults, folds, fractures, joints and foliations. Its color varies from dark brown to pink alternatively depending on the degree of weathering. It contains quartz, feldspar, plagioclase, and muscovite. Basaltic fissure flows are exposed in the northern parts of study area. It is exposed along fractures and open surface fissures showing gray weathered and black fresh color. It has fine grained texture, highly compacted and resistant for weathering (GSE, 2013).

3.2 Materials

3.2.1 Data sources and types

To achieve the objectives primary data and secondary data were used for this study. The primary data were used Landsat8 current land use/land cover of the study area and it was downloaded from U.S. Geological Survey Global Visualization Viewer Website without the presence of cloud cover. GPS data for verification of land use/land cover map that was produced from image of Landsat 8. SRTM images derived from USGS with spatial resolution of (30 m * 30m) were used to extract Digital Elevation Model (DEM) of Asaita town and it was used to derive slope of the study area.

The secondary data were used includes Topographic map of the Asaita town (1:50,000) from Ethiopia Mapping Agency (EMA), soil map of the study area from FAO for mapping soil texture in the study area. Structural plan of Asaita town was obtained from Asaita Zone urban development office and Geological map of study area from Geological Survey of Ethiopia (GSE). Road networks and built up area are developed from the GIS environment and structural plan of the study area. Additionally, Secondary data for the study was acquired from reliable internet sources, reports, journals and governmental institutions manuals used in the management of waste disposal. In addition, demographic characteristics and related data were gathered from Central Statistics Agency (CSA) and from Administrative Offices in Asaita town. All the above data were collected, manipulated and analyzed in GIS environment to be used for further analysis.

3.2.2 Software

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

3.3 Methods

3.3.1 Data Analysis and Presentation

3.3.1.1 Digitizing

This function of GIS is used to develop features such as like soil texture class; Lithology and fault were produced from the soil map and geologic map.

3.3.1.2 Buffering

Buffering is a spatial analysis tools and also called proximity analysis. It is used to generate areas within a given distance using a specified criterion for waste disposal site selection. The Buffering analysis was executed for roads (0-500m, 501-1500m, 1501-3000m and >3000m), streams/river (0-200m, 201-3000m, 3001-5000m, 5001-7000m and >7000m), fault (0-1000m, 1001-2000m, 2001-3000m, 3001-4000m and >4000m) and built up area (0-500m, 501-2000m, 2001-5000m and >5000m) with the given values in meter. These values for buffering analysis were assigned after referring to different researches and a new value generated based on the geographical characteristics of the Town.

3.3.1.3 Thematic map preparation

Thematic maps are an important source of GIS information. These are tools to communicate geographical concepts in the form of map. The thematic maps such as surface water/river, land use land cover, geology, road network, slope, fault, soil and built up area map were prepared by using digitization, overlay and buffer analysis with the appropriate criteria. These thematic maps were used as an input for Analytical Hierarchy Process (AHP) (sehnaz et al. 2011).

3.3.1.4 Weighting criteria

Analytical Hierarchy Process (AHP) was used as a decision rules to analyze the data for waste disposal site selection using GIS (sehnaz et at, 2011). AHP consists of the construction of pair wise comparison matrices and the extraction of weights by means of the principal right eigenvector (Theo, 2010; sehnaz, 2011). Pair wise comparison matrix is created by setting out one row and one column for each factor in the problem. Therefore, the AHP divides the decision problems based on the factors in to understandable parts; each of these parts is analyzed separately and integrated in a logical manner as suggested by Theo (2010). AHP also facilitates sound decision making though applying both empirical data as well as subjective judgments of the decision maker. It assists to establish priorities among the elements within each stratum of the hierarchy. In AHP, the 9-point scale which is ranging from 1(indifference or equal importance) to 9 (extreme preference or absolute importance) (Saaty, 1980).was used in the decision making process for waste disposal site selection in Asaita town. In reference to rating scale of 9, Theo (2010) also suggests a 9-point scaling system where, 1 for equal importance, 3 for moderate importance, 5 for strong, 7 for very strong and 9 for extreme importance, integers in between for refinements (2, 4, 6, 8), and reciprocals for the inverse judgments. The resultant value is a positives reciprocal n by n matrix.

Table 2. Scale for pair wise comparison (Saaty, 1980).

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

3.3.1.5 Weighted Index Overlay Analysis

Weighted Overlay is a technique for applying a common measurement scale of values to different inputs to create an integrated analysis. The weight is given through empirical methods and subjective judgments by the decision maker. For this study, using weighted overlay analysis of each input layer or factors such as surface water/river, land use/land cover, road network, slope, fault, built up area and soil maps, suitable site sensitivity index was arrived. In this process, Weight was assigned to different thematic layers based on their significance in deciding the site suitability. Moreover, weighted overlay analysis was employed for deciding potential location of waste disposal of the study area.

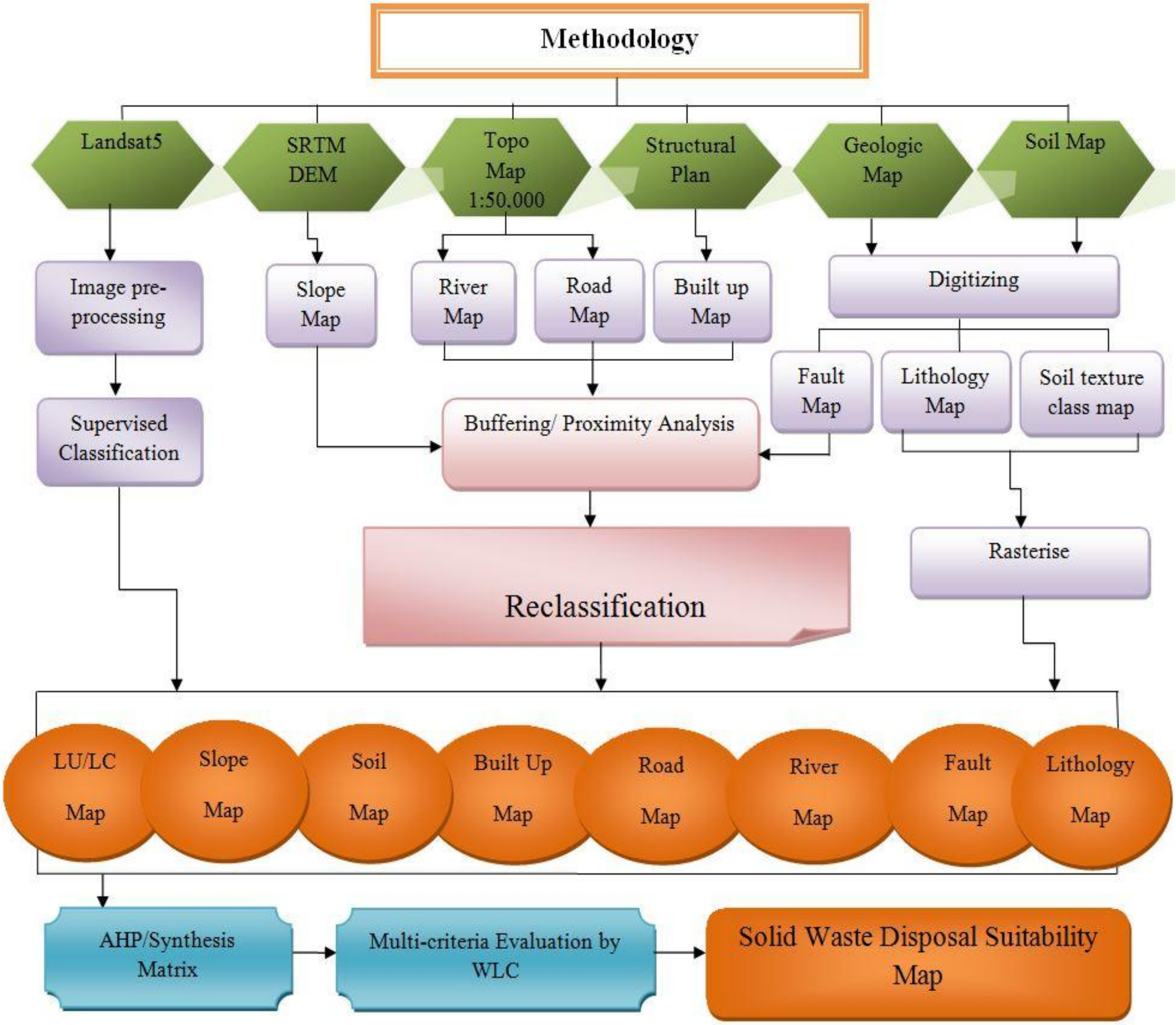

Figure 2. General Methodology Flow Chart

3.3.2 Identification and Reclassifications of criteria

3.3.2.1 Slope

Slope is one of the key criteria to be considered in solid waste disposal site section. Slope of the study area was developed from DEM 30*30 m resolutions and used in GIS environment. According to Akbari et al., (2008), areas with high altitude or high slope are not suitable landfill sites. The best places for solid waste are medium altitude surrounded with no more than 20% slope. The slope affects the amount of water in the soil, the possibility of erosion rate, surface runoff and groundwater pollution. The slope is crucial for the construction of landfill sites, because a higher slope causes higher costs of construction. This is due to huge amount of materials, technology and human power needs high budget. Therefore, for this study slope was reclassified in to three classes: 0-10%, 10-20% and >20%. Fig.3. indicates the slope map of the Town and Table 3 elaborates the slope value and its classification (Akbari et al., 2008).

Table 3. Criteria for Slope

Factor	Criteria Value	Classification
Slope	0-10	Suitable
	11-20	Highly Suitable
	>21	Unsuitable

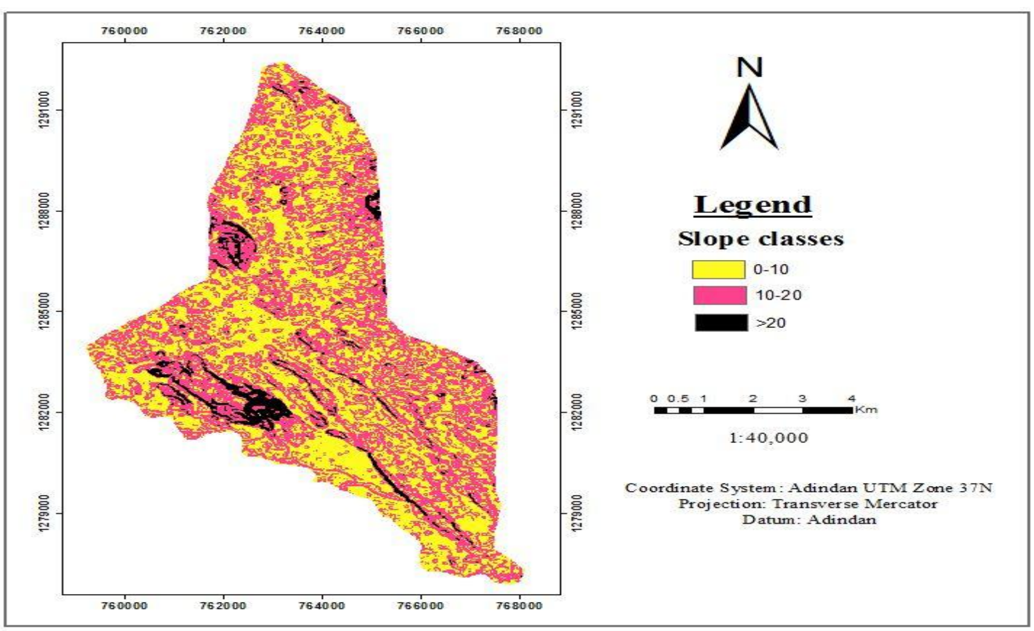

Figure 3 Reclassified Map of Slope

3.3.2.2 River

The River criterion is important the view of environmental and economic concerns due to pollution. Hence, landfill should not be located near surface water body. Surface water used for agriculture and drink to humans and animals in the part of the country sides. Surface water of the study area was generated from topographic map in GIS environment. Therefore, according to, Akbari et al., (2008) used 200 m and Gemitzi et al., (2007) and Hasan et al., (2009) used 100 m buffer distance. In order to reduce vulnerability to ground and surface water pollution from contamination, landfill should not be located near river. In this study area a minimum distance of 200 m was used for site selection process to protect surface water from pollution. Accordingly, buffer tools were used to prepare a buffer zone with 0-200 m, 201-3000 m, 3001-5000 m, 5001-7000 m and >7001 m distance range indicated in Table 4 and fig.4. This buffering was to identify safety site for landfill. The more distant from surface water, the more suitable for sitting landfill to reduce the negative effect on pollution.

Table 4. Criteria for River

Factor	Criteria Value	Classification
River	0-200m	Unsuitable
	201-3000m	Less Suitable
	3001-5000m	Moderately Suitable
	5001-7000m	Suitable
	>7001m	Highly Suitable

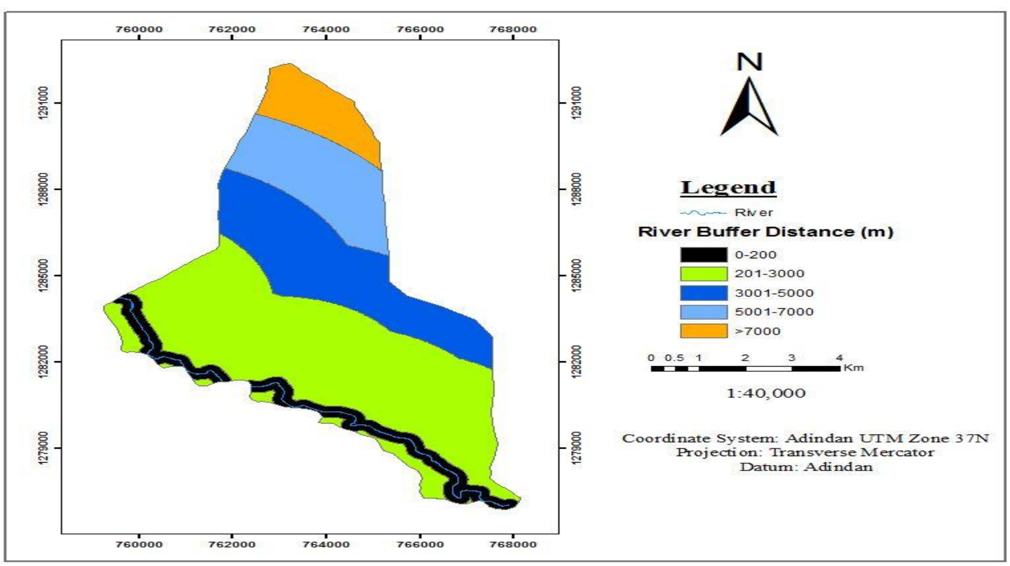

Figure 4. Reclassified Map of River

3.3.2.3 Land use/Land cover (LULC)

Land use/Land cover map of the study area is one of the criteria used to select potential sites for solid waste disposal in the town of Asaita. The land use/land cover of the study area classified into five classes such as farm land, open area, forest, built up and wetland clearly shown in fig.5.

Table 5 Criteria for Land use/Land cover

Factor	Criteria Value	Classification
LU/LC	Open area	Highly Suitable
	Forest	Suitable
	Farm land	Moderately Suitable
	Built up area	Less suitable
	Wetland	Unsuitable

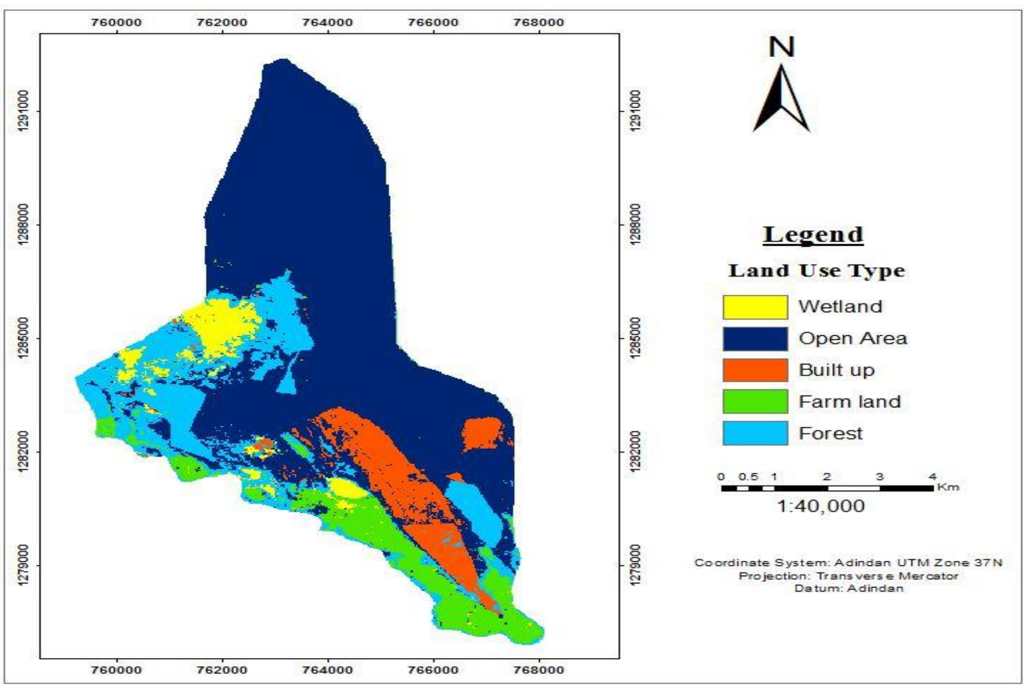

Figure 5 Reclassified Map of Land use/Land cover

3.3.2.4 Lithology

Lithology is the one of the important environmental factors that should be considered for solid waste disposal site selection processes. The Lithology map the study area was obtained from Ethiopian Geological Survey (Bezayit M., et al. 2013). The study area of the map was geo-referenced and digitized at GIS environment .The study area has five Lithology classes, show below in the fig.6. The suitability classification is based on the permeability of the soil and lithology structure (Ismail et al., 2016). Therefore, the degree of permeability decreases from Rhyolite to Basaltic fissure flow, Aphanatic basalt, Lacustrine and Silt, clay and sand. On contrary, the suitability increases from silt, clay and sand, to Rhyolite.

Table 6 Criteria for Lithology

Factor	Criteria Value	Classification
Lithology	Ryholite	Highly Suitable
	Basaltic fissure flow	Suitable
	Aphanatic basalt	Moderately Suitable
	Lacustrine	Less Suitable
	Silt, clay, sand	Unsuitable

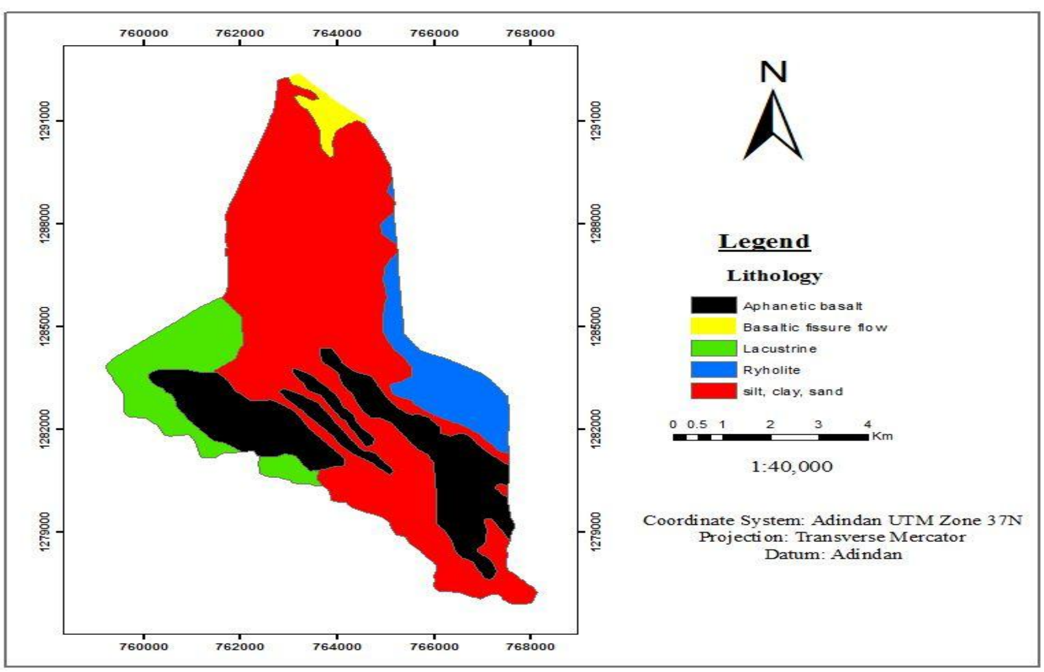

Figure 6 Reclassified Map of Lithology

3.3.2.5 Fault

Fault is one of the criteria that were considered for solid waste disposal site selection. The fault of the study area was digitized from geological map (1:250,000) of Asaita (Bezayit M., et al., 2013). Based on (Rafiee et al., 2011), the study area of fault buffer distance was performed. According to the standard, areas found within 1000 m buffer distance from faults were considered as unsuitable for solid waste disposal site due to high permeability of soil near fault and keep ground water contamination. Additionally waste disposal area should be far from faults. In this study, a minimum distance of 1000 m was used for site selection processes due to the waste can pollute the groundwater or damage the surrounding engineering structures in case of earthquake (Rafiee et al., 2011). Areas which do not have faults or have safe distance from the faults are appropriate for landfill site selection. Accordingly, buffer tools were used to prepare a proximity map from each fault with 0-1000m, 1001-2000m, 2001-3000m, 3001-4000m and >4001m distance ranges fig.7.

Table7 Criteria for Fault

Factor	Criteria Value	Classification
Fault	0-1000m	Unsuitable
	1001-2000m	Less Suitable
	2001-3000m	Moderately Suitable
	3001-4000m	Suitable
	>4001m	Highly Suitable

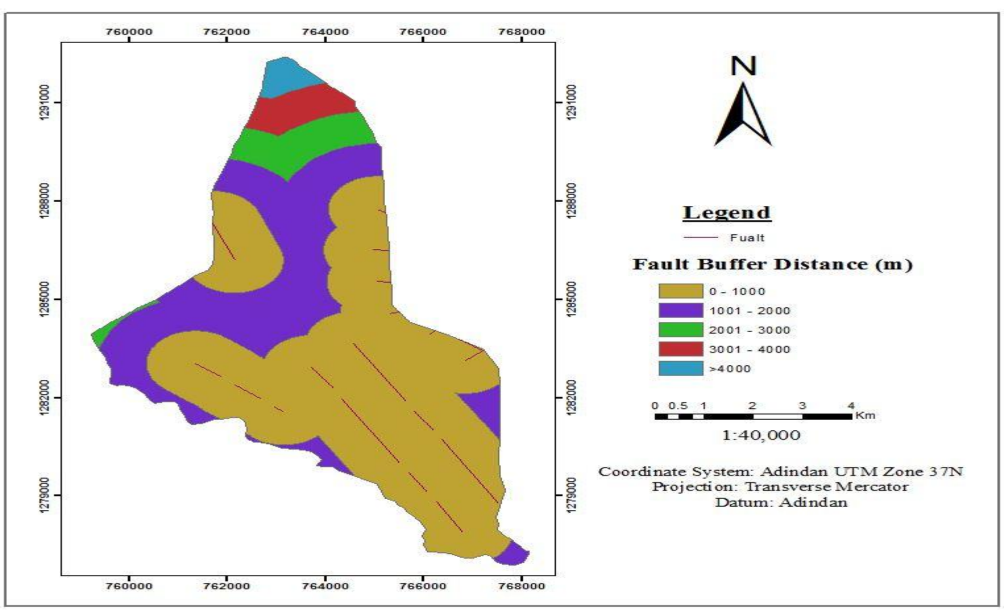

Figure 7 Reclassified Map of Fault

3.3.2.6 Soil

Soil characteristics promote a safe and more economic feasible impletion and operation of a dumpsite. Permeability, effective porosity, and workability are important soil characteristics which were considered for site selection. Therefore, in the study area there are 2 classes of soil types used for solid waste disposal site selection analysis show as below in fig.8 and table 8. Eutric Rego and Virtic Ando soils are classified as suitable and unsuitable respectively. This is due to their formation and permeability. Regosols profile development is minimal and Andosols have high porosity.

Table 8 Criteria for Soil

Factor	Criteria Value	Classification
Soil	Euitric Rego	Suitable
	Virtic Ando	Unsuitable
	No soil	-

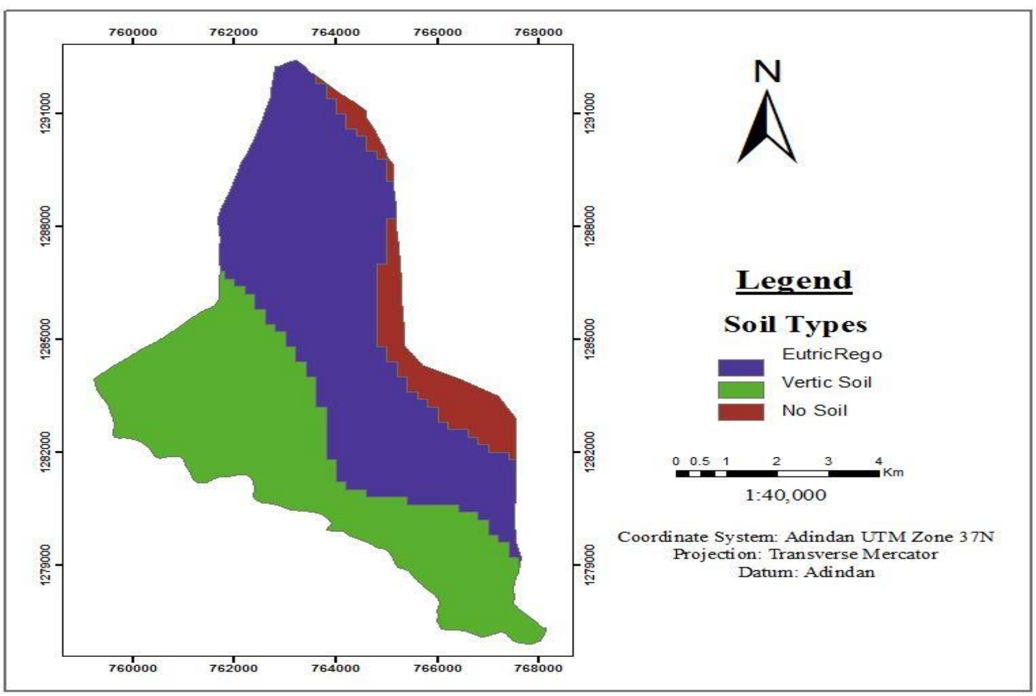

Figure 8 Reclassified Map of Soil

3.3.2.7 Road Networks

Economic and social point of views road network is one of important the criteria for solid waste disposal site selection processes. Because, solid waste site especially close to roads may have public health problem as landfill can have hazardous effect to health. Moreover, landfill site very far from road network is also not suggested due to high transportation cost. The existing road network was obtained from GIS environment. The road network of the study area to its nearby was measured by buffer distance created in the ArcGIS environment using analysis tools. Based on the road network proximity standard Rafiee at al., (2011) and EPA (1995), areas found below 500 m and above 5000 m from a highway were considered as unsuitable. Because of, high proximity to roads can result traffic congestion and when it too far away from road network access results high cost of transportation. Therefore, for this study road network reclassified four classes below fig.9.

Table 9 Criteria for Road Network

Factor	Criteria Value	Classification
Road Network	0-500m	Unsuitable
	501-1500	Highly Suitable
	1501-3000m	Suitable
	>3001m	Moderately suitable

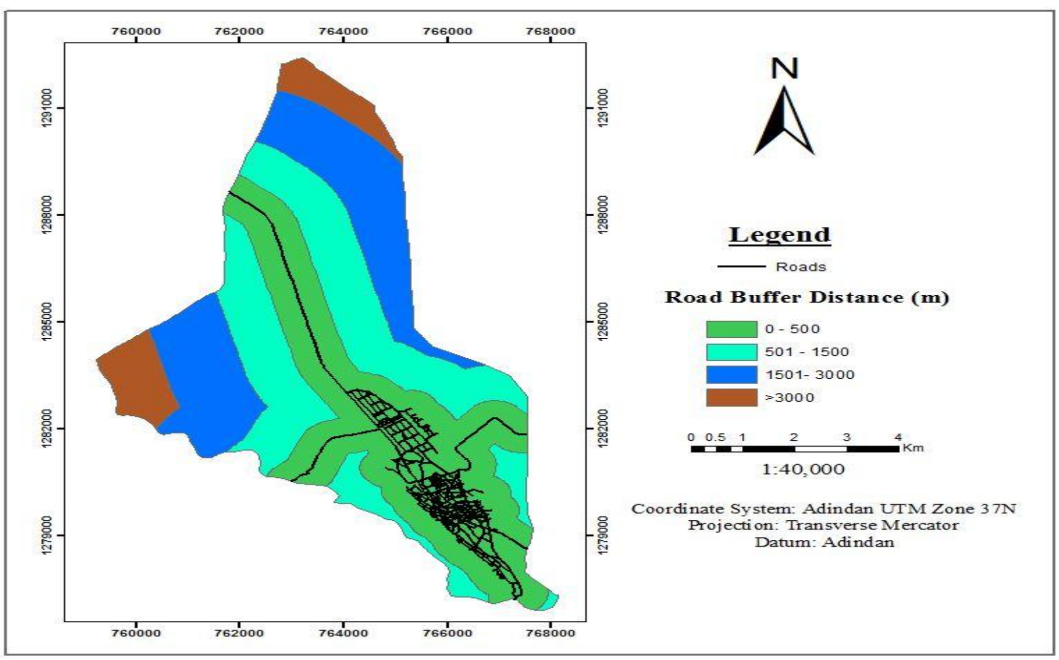

Figure 9 Reclassified Map of Road Network

3.3.2.8 Built Up Area

Built up area is an important view point of environmental criterion in the solid waste disposal site selection. It also includes different services of study area such as commercial area, settlement, school, religious institutions, educational institutions, health centers, governmental and private institution and other social services area. Solid waste disposal site should be far from it because, to avoid any from pollution. Built up area were generated from structural plan of study area. According, Hasan et al., (2009), set built up with distance 500m-2000m as best site for solid waste disposal. In this study Built up area classified four classes: clearly indicated fig.10.

Table 10 Criteria for Built Up Area

Factor	Criteria Value	Classification
Built Up Area	0-500m	Unsuitable
	501-2000m	Moderately Suitable
	2001-5000m	Suitable
	>5001m	Highly suitable

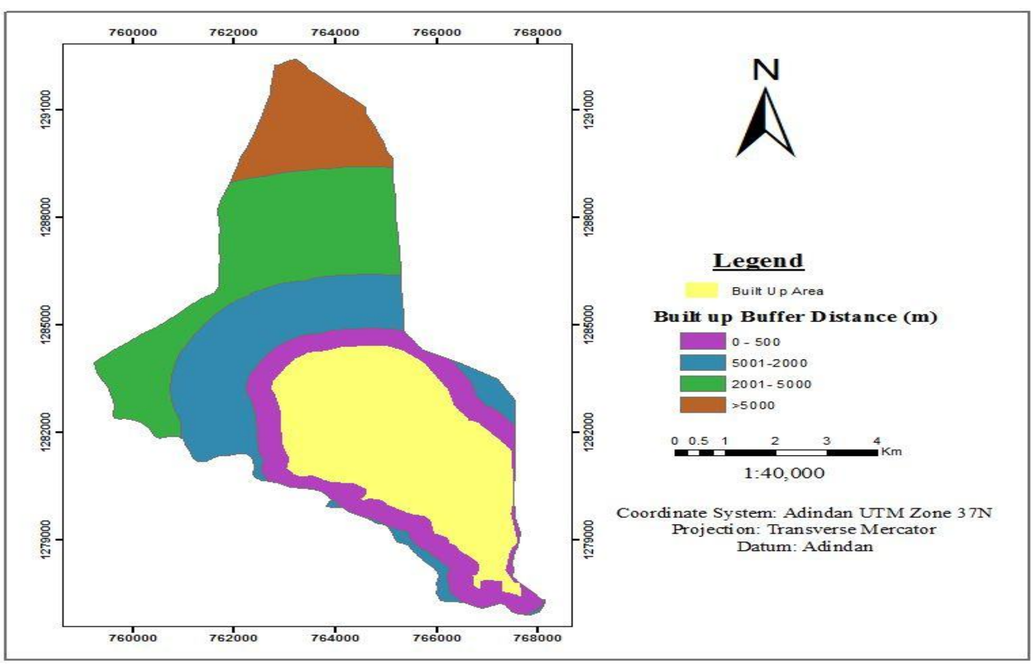

Figure 10 Reclassified Map of Built Up Area

3.3.3 Constraint Maps

Constraint maps are limitations or restrictions which prohibit certain elements to be taken into account the analysis. Constraint (binary) maps are used to distinguish between lands that are suitable for landfill siting and those lands that are restricted. The constraint maps are produced by each individual them with the study area. This procedure creates a constraint map for each theme containing only two classes represented by 1's for suitable land and 0's for unsuitable land.

3.3.3.1 River

According to Akbari et al., (2008), used the surface water (river) constraint map is buffer zone less than 200m are not desirable region to build a landfill nearby. This is due to the possibility of contaminants from a landfill leaching to the ground water and seeping into the river. This is also primarily due to environmental concern, where a location further away from a surface water (river) source would be preferred. The constraint map is then created using the buffer distance less than 200m all areas are given a 0 (unsuitable) and greater than 200m all other are given a 1 (suitable) indicated fig.11.

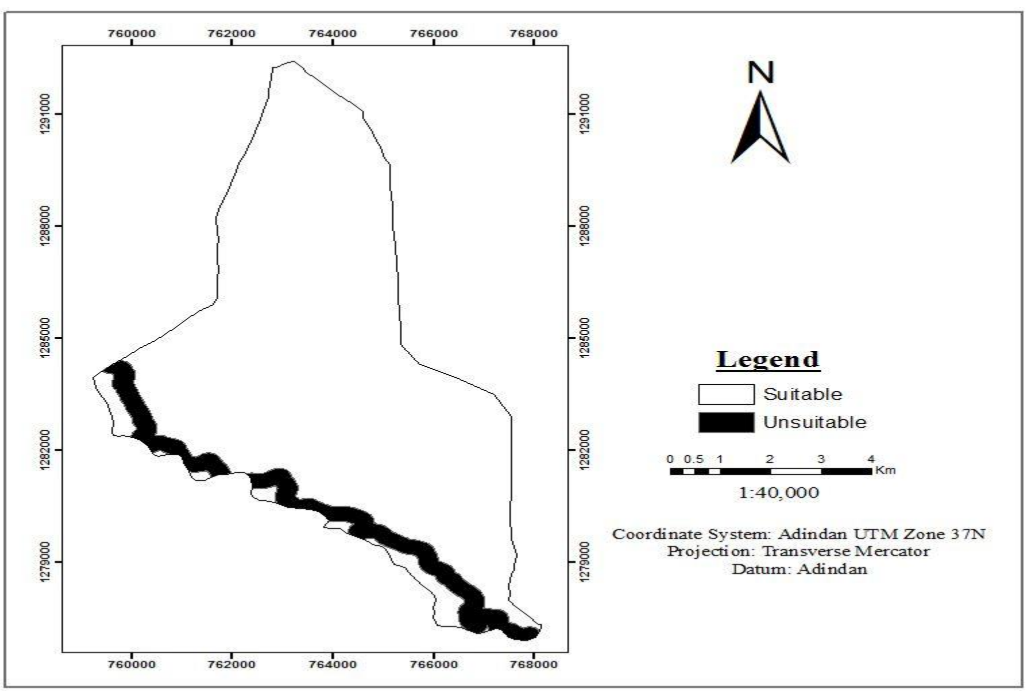

Figure 11 Constraint Map of River

3.3.3.2 Road

For this study, the road constraint map is buffer distance of areas below 500 m were considered all areas as 0 (unsuitable) while, above 500m were also considered all areas 1 (suitable) on the road network proximity standard Rafiee at al., (2011) and EPA (1995). Locating the landfill close to a road would help reduce costs related to transportation and new road access to the site as show fig.12.

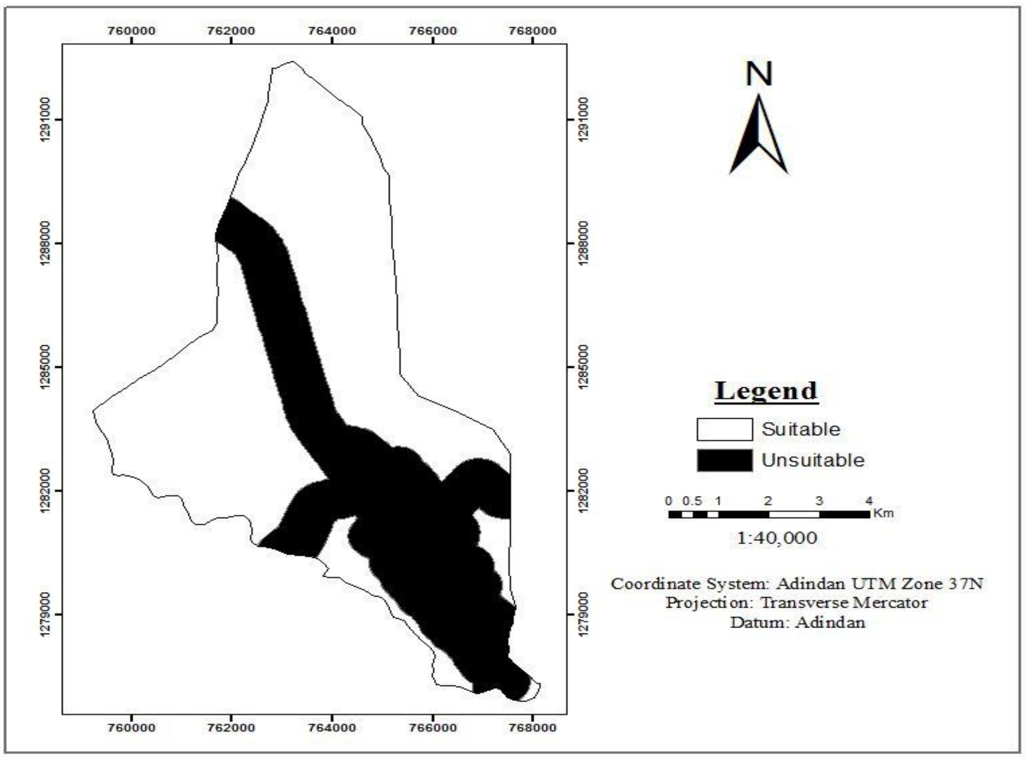

Figure 12 Constraint Map of Road Network

3.3.3.3 Fault

Rafiee et al., (2011), suggested that for solid waste disposal site selection a minimum distance of 1000m should be kept. Also, for current study less than 1000 m buffer distance from faults were considered as 0 (unsuitable) for solid waste disposal site due to high permeability of soil near fault and keep ground water contamination. Other hand, greater than 1000m buffer distance of fault was considered as 1 (suitable) as indicated fig.13.

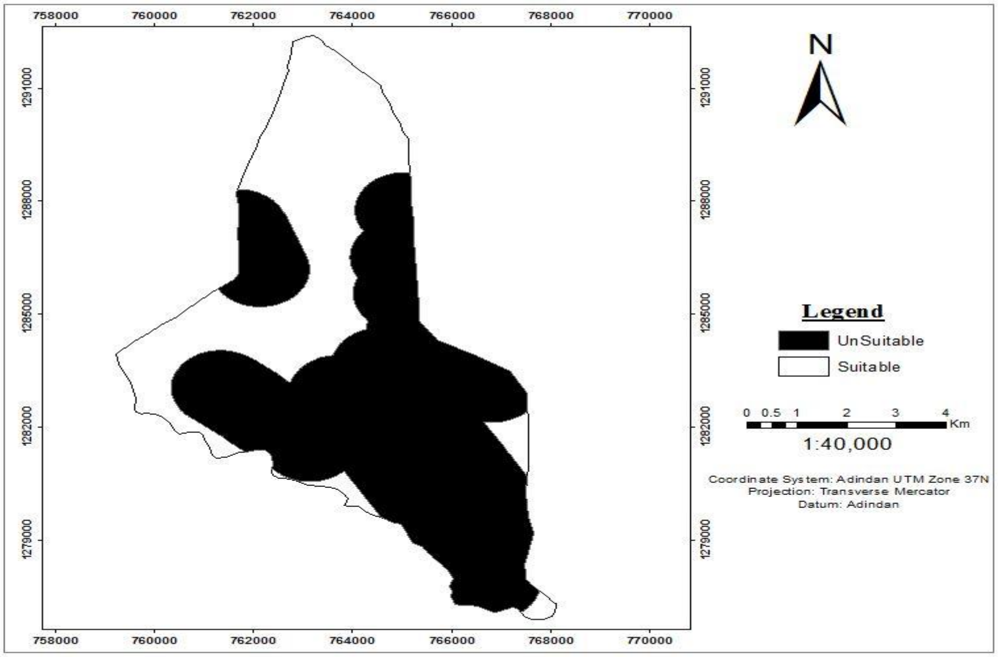

Figure 13 Constraint Map of Fault

3.3.3.4 Built up Area

The built up area constraint map fig. 14 is created in order to define a landfill hazards, such as scavenging animals and unfavorable odor and noise. Based on Hasan et al., (2009), the buffer built up area distance less than 500m were assigned 0 (unsuitable), whilst greater than 500m the considered to be 1 (suitable) for locating a solid waste disposal.

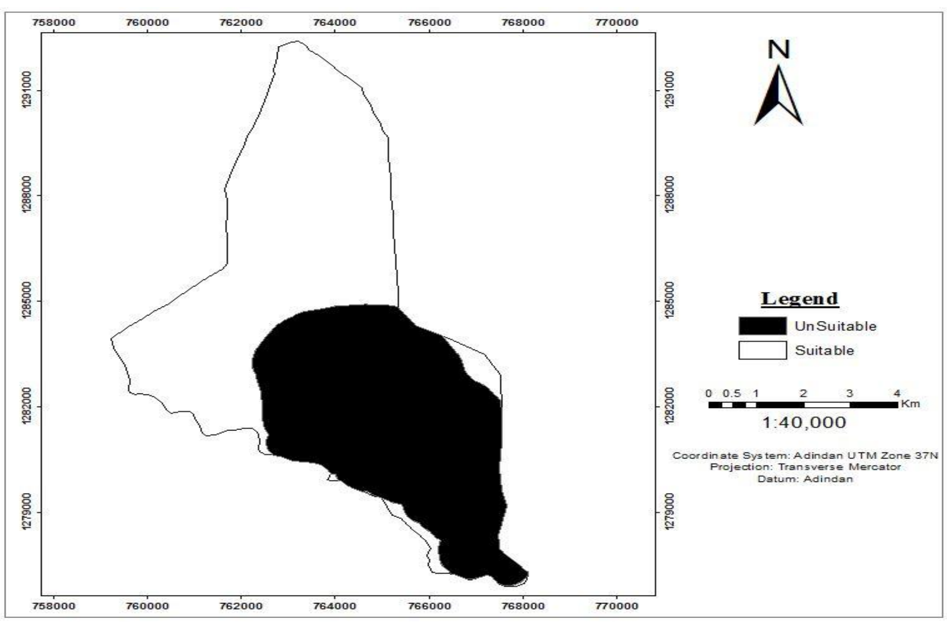

Figure 14 Constraint Map of Built up Area

3.3.4 Aggregation of Suitability Sites

Weighted Linear Combination (WLC) is one the widely used a multi-criteria evaluation (MCE) methods for land suitability analysis. It was chosen as the method of aggregation at this study. The Constraints maps and factors maps had been developed and the associated weights assigned to each input layer, an aggregation stage was undertaken to combine the information from the various factors and constraints. Also, WLC method multiplies each standardized factor map by its factor weight then sums the results. Based on, this it provides better site selection because of its flexibility in selecting the solid waste disposal sites. The WLC analysis was applied using the following equation:

$$S=\sum Wi * Xi \ldots\ldots (1)$$

Where S is the suitability, Wi is a weighting of factor i, and Xi is the criterion score of factor i.

Based on above equation two all factor maps were changed to byte binary format and it multiplied by constraint map to remove out the areas unsuitable for solid waste disposal sites selection. The constraint map was a binary coded image identifying all areas were siting of a landfill was simply not possible due to environmental and economical factors as zero values and the remaining areas were shown as one .Thus Equation 2 was modified as follows,

$$S= \sum (Wi * Xi) * Cj \ldots\ldots (2)$$

Where S is the suitability, Wi is weighting of factor i, and Xi is the criterion score of factor i Cj is constraint.

This equation was a map identifying a number of suitable sites for locating potential of solid waste disposal.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Determinants of suitable waste disposal site selection in the study area

4.1.1 Slope

The topography of the study area is dominated with slope of 0-10% which accounts 85.5 of the total area.. The second most dominant topography of the study area is 10-20% found in most parts the study area of the town covering 14% of total area and the remaining 0.5% of the area is with slope >20%.

Table 11 Area coverage and Slope Suitability

No	Slope Classes	Suitability Classes	Suitability Rank	Area in (ha)	Area in (%)
1	0-10	Moderately Suitable	2	5141	8.5
2	10-20	Highly Suitable	3	835	14
3	>20	Unsuitable	1	11	0.5
Total				**5987**	**100.0**

Table 11 indicates that 14%, 85.5%, and 0.5% of the total area is highly suitable, moderately suitable and unsuitable for solid waste disposal site. Based on above explanation suitability, map of slope was prepared as shown fig.14.

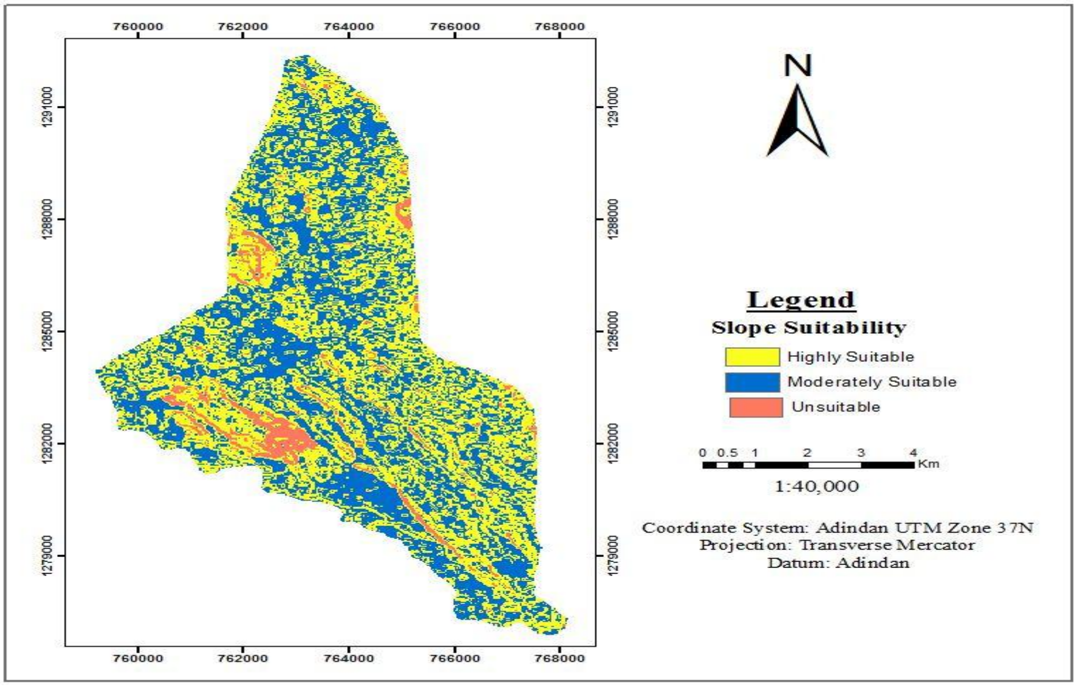

Figure 14 Slope Suitability map of the study area.

4.1.2 River/ Surface water

Solid wastes are been disposed near and in the river which cause ecological problems, that have an extended impact for human and animal that use this water for various activities. Therefore, landfill site should more distant from surface water.

Table 12. Area coverage and River Suitability

No	Suitability Classes	Suitability Rank	Buffer Distance	Area in (ha)	Area in (%)
1	Highly Suitable	5	>7001	497	8
2	Suitable	4	5001-7000	1334	22.5
3	Moderately Suitable	3	3001-5000	2886	48
4	Less Suitable	2	201-3000	832	14.5
5	Unsuitable	1	0-200	432	7
Total				**5987**	**100.0**

The above Table 12 indicated that 7% of the study area was excluded from the sitting processes due to the fact that there is surface water around that area and unsuitable for landfill. On the other hand, 8% of the area was highly suitable due to the fact that there is no impact on the area associated with surface water. Finally, 22.5%, 48% and 14.5% of the total areas were suitable, moderately suitable and less suitable in that order as indicate fig.14.

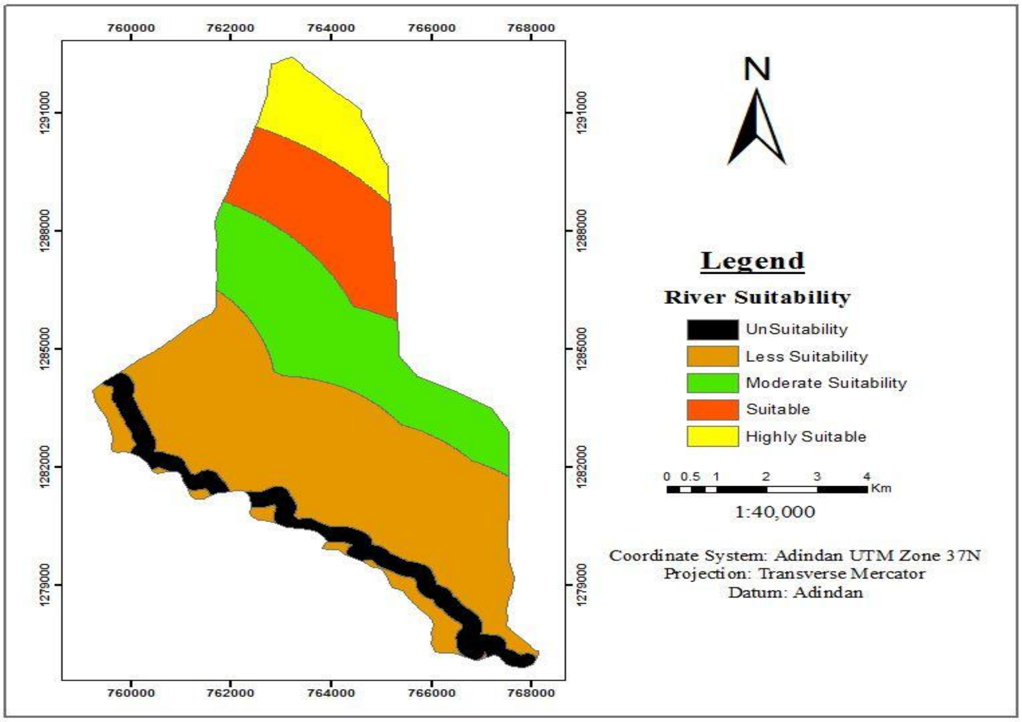

Figure 14. River Suitability map of the study area

4.1.3 Land use/Land Cover

In the study area, LU/LC map were produced using supervised classification and it validated based on field data with over all accuracy of 81.34% by using ERDAS Imagine 2014. The Land use/land cover of the study area Large part covered by open area which accounts about 61%, farm land, wetland, built up area and forest account for 8%, 4%, 9%, and 18% of the total study area, area in that order.

Table 13. Area coverage and Land use/land cover suitability

No	Land use/Land Cover type	Suitability Classes	Suitability Rank	Area in (ha)	Area in (%)
1	Open area	Highly suitable	5	3628	61
2	Forest	Suitable	4	1087	18
3	Farm Land	Moderately Suitable	3	490	8
4	Built up area	Less Suitable	2	520	9
5	Wetland	Unsuitable	1	262	4
Total				**5987**	**100.0**

Based on the above land use suitability Table 13, from the land use suitability point view the largest part of the study area 61% was found as highly suitable for solid waste disposal sites whereas, 18%, 8% and 9% of the area were suitable, moderately suitable and less suitable, respectively. The remaining 4% of the study area was found unsuitable for solid waste disposal site. Land use/land cover of the study area is shown in fig. 16.

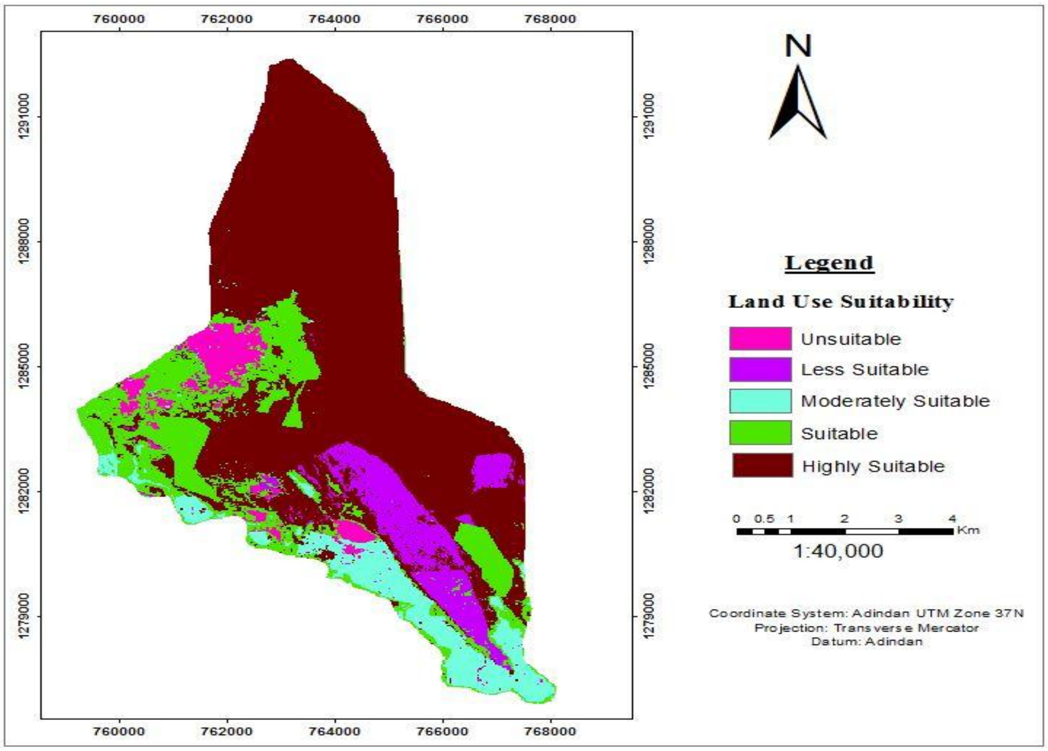

Figure 16. Land use/Land cover Suitability map of the study area

4.1.4 Lithology

For this study to select the suitable rock type, based on amount of weathered/fracture and porosity. Lithology criteria, based on (centre for Advance Engineering, 2000), landfill site should be reducing the risk of ground water contamination, more weathered and fracture, more permeable and instable the rock. Indicate of blow Table 14, most of the flat lands in the study area is covered by silt, clay and sand. They are found in the central and southern parts of the study area and characterized by high porosity. Because of this they are unsuitable for landfill site selection. Most suitable Lithology classes in the study area are Rhyolite which covers 8%. It also found in the eastern part of the study area. It is characterized by no porosity, highly suitable for landfill. Other dominant Lithology classes in the study area are lacustrine basalt, which cover 11% and found in the south west and southern part of the study area. It is suitable for landfill site because of low porosity. The remaining Aphanatic basalt 22% and basaltic fissure flow 2% are found in south west and north east and Northern parts of the study area.

Table 14. Area coverage and Lithology Suitability

No	Lithology Suitability	Suitability Rank	Area (ha)	Area (%)
1	Highly Suitability	5	497.5	8
2	Suitable	4	121	2
3	Moderately Suitability	3	1322	22
4	Less Suitable	2	637	11
5	Unsuitable	1	3409.5	57
Total			**5987**	**100**

The study area was covered in 8% and was concerned also as highly suitable for solid waste disposal potential site, 2% was suitable, and 22% of the study area was moderately suitable. The remaining 11% and 57% from the total study area were less suitable and unsuitable for solid waste disposal potential sites fig.17.

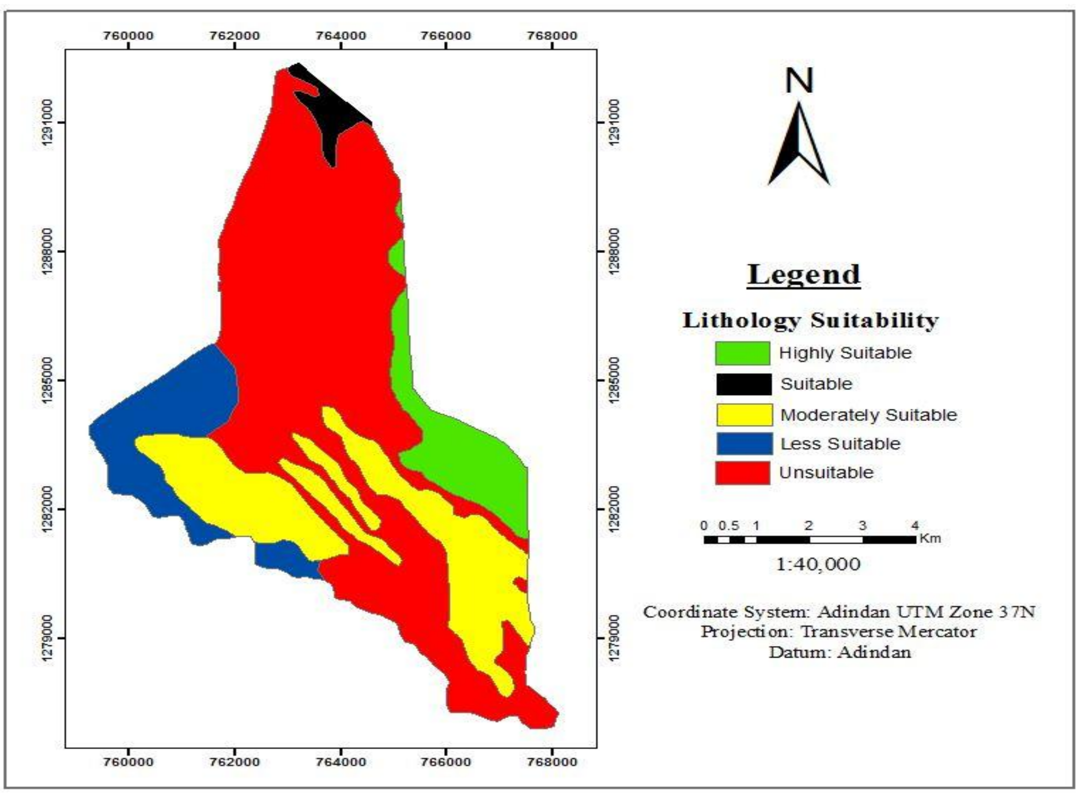

Figure 17. Lithology Suitability map of the study area

4.1.5 Fault

The reclassification of fault was to identify the safety site for landfill the same as other factors. The more distance from fault, the more suitable for sitting land fill to minimize the negative effect of landfill on environment.

Table 15. Area coverage and Fault suitability

No	Suitability classes	Suitability Rank	Buffer Distance in(m)	Area in (ha)	Area in (%)
1	Highly Suitable	5	>4001	95	2
2	Suitable	4	3001-4000	206	3
3	Moderately Suitable	3	2001-3000	333	5
4	Less Suitable	2	1001-2000	1611	27
5	Unsuitable	1	0-1000	3742	63
Total				**5987**	**100**

Fault proximity suitability Table 15, 2% was highly suitable and 3% of the area was suitable whereas, 5%, 27% and 63% of the study area were found as moderately suitable, less suitable and unsuitable for solid waste disposal sites, respectively. During suitability reclassification phase the highest rank was assigned to a buffer distance greater than 4000m and the lowest rank was given to unsuitable areas in the indicated fig.18.

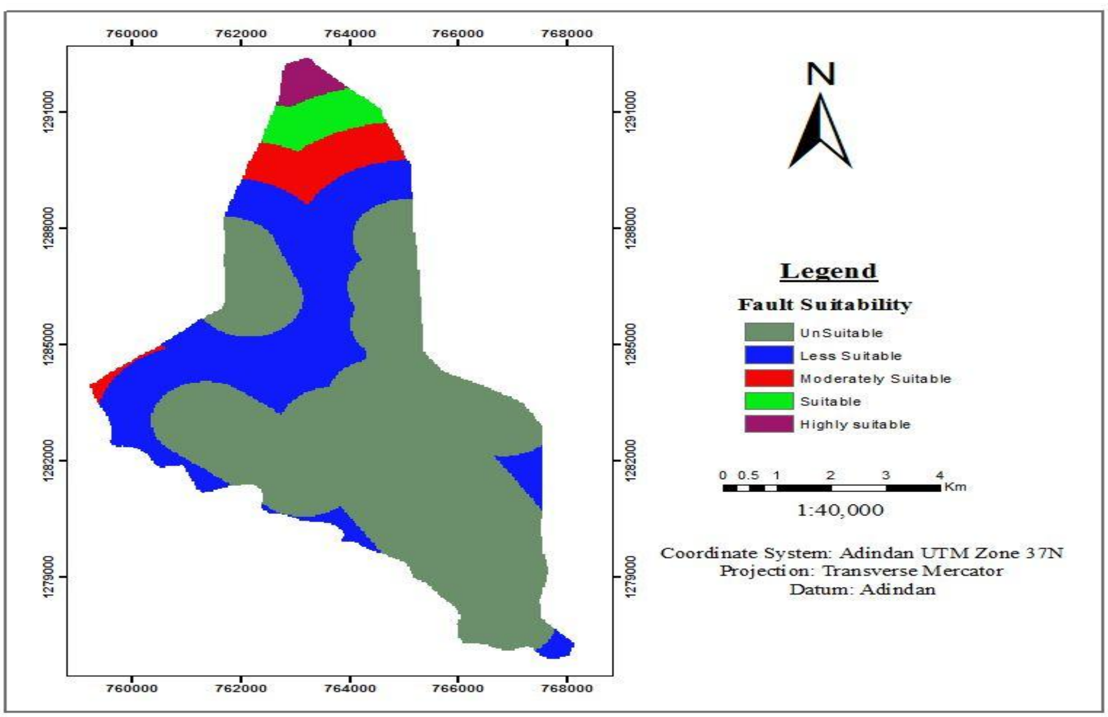

Figure 18. Fault suitability map of the study area

4.1.6 Soil

The study area of the soil type is largely dominated by Eutric Rego soil, which is covered by 49% and found in the northern, central and southern part of the study areas. The second type of soil is Virtic Ando Soil 42% is the dominated in the western and northern part of the study area that at mountain places. The remaining No soil type, which is covered by 8.5% and found in north east and Eastern part of the study area.

Table 16 Area Coverage and Soil Suitability

No	Suitability classes	Suitability Rank	Area in (ha)	Area in (%)
1	Suitable	3	2958.5	49
2	Unsuitable	2	2519.5	42.5
3	No Soil	1	509	8.5
Total			**5987**	**100**

The physical characteristic of the study area is one of the main criteria to select potential site for solid waste disposal. According to (Abdoli, 1993), the amount of soil permeability is increase; the suitability site will decrease, because the very high permeable soil, the most probable to pollute ground water. Therefore, based on above Table 16, about 49% of the total area is Suitable, 42.5% unsuitable and 8.5% No Soil for solid waste disposal site indicate below fig.19.

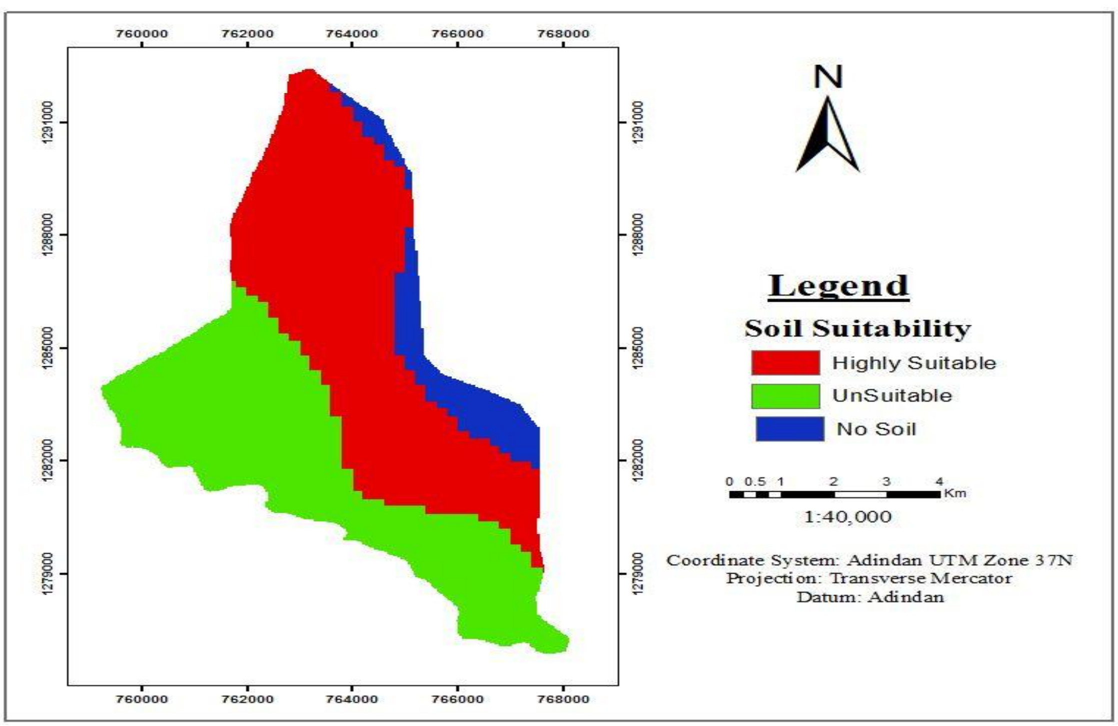

Figure 19. Soil Suitability map of the study area

4.1.7 Road Network

Solid waste dumping site should be located at suitable distance from roads to facilitate transportation and consequently to reduce relative costs. Multiple ring buffers created following road network suitability road distance interval, total four suitability classes were developed.

Table 16. Area Coverage and Road Network Suitability

No	Suitability classes	Suitability Rank	Buffer Distance in (m)	Area in (ha)	Area in (%)
1	Unsuitable	1	0-500	446	7
2	Moderately Suitable	2	501-1500	1450	24
3	Suitable	3	>3001	2205	37
4	Highly Suitable	4	1501-3000	1886	32
Total				**5987**	**100**

Based on the above table 16 road network suitability table, from the total study area 32% and 37% were found highly suitable and suitable respectively while, 7% of the area was unsuitable. The remaining 24% of the study area road proximity is moderately suitable for solid waste disposal potential sites. The road network proximity suitability map of the study area is clearly indicated in the fig.20.

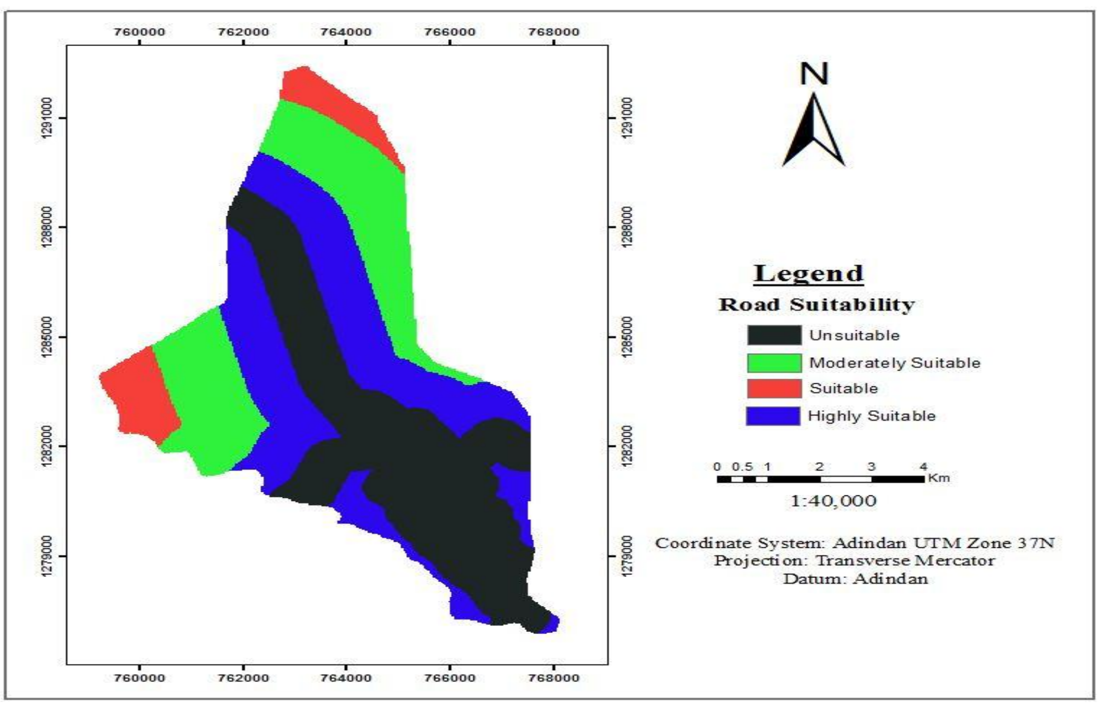

Figure 20. Road Network Suitability map of the study area

4.1.8 Built Up Area

The any type of waste disposal should be at a safe distance from built up area. Because, the built up area as a high determinant of solid waste disposal, disposal site far from built up area to reduce bad odors and health risks.

Table 17 Area coverage and Built up Suitability

No	Suitability classes	Suitability Rank	Buffer Distance in (m)	Area in (ha)	Area in (%)
1	Unsuitable	1	0-500	2664	44.5
2	Moderately Suitable	2	501-2000	1206	20
3	Suitable	3	>5001	1507	25
4	Highly Suitable	4	2001-5000	610	10.1
Total				**5987**	**100**

Indicate above table 17 shows 44.5% of the total area unsuitable while, 20% moderately suitable for solid waste disposal site selection. The other 25% and 10.1% are suitable and highly suitable for solid waste disposal site selection in that order indicated fig.21.

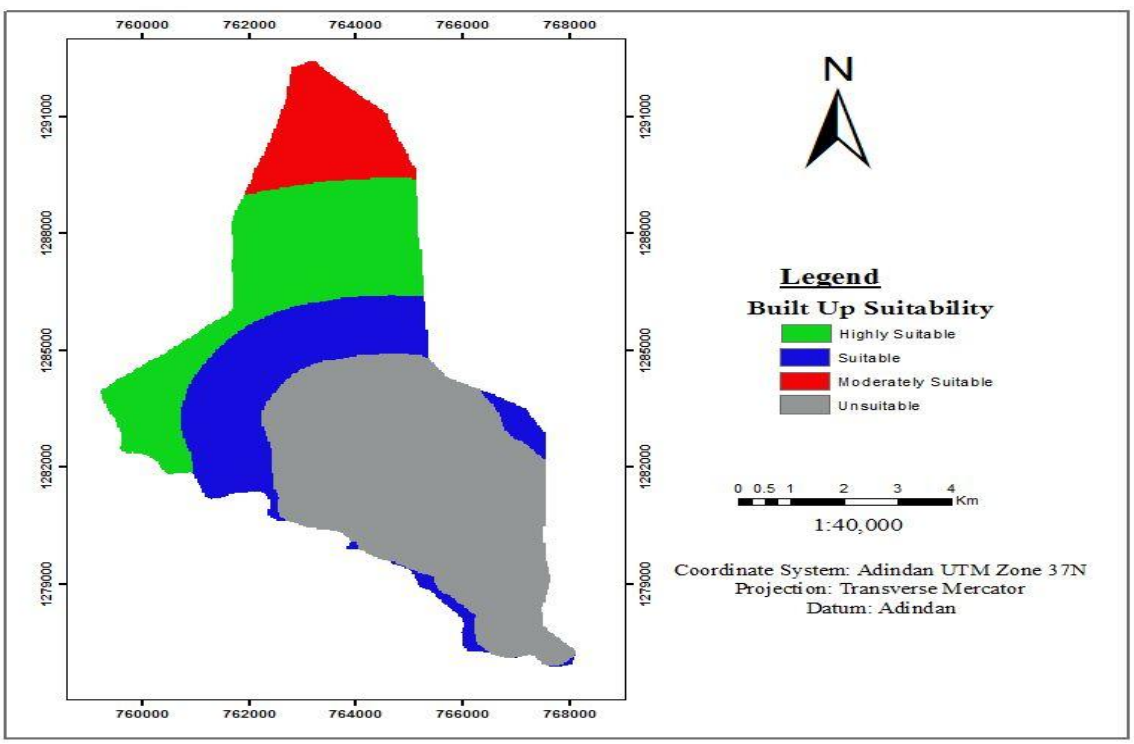

Figure 21. Built-up Suitability map of the study area

4.2 Result of Final Constraint Map

The constraint maps were produced by merging each individual theme within the study area. This procedure created a constraint map for each theme containing only two classes represented by 1's (for suitable land) and 0's (for unsuitable land). The four constraint maps such as river, road, fault and built up area were combined using overlay function (using direct multiplication of binary integer values) to create the final constraint map. Finally, from the total of study area constraints area are cover 4441 ha and the remaining suitable of the study area cover 1546 ha clearly below fig.22.

Table 18 Constraint Criteria

Criteria's	Buffer around constraints in m
River	200 around river
Road	500 around roads
Fault	1000 around fault
Built up Area	500 around built up area

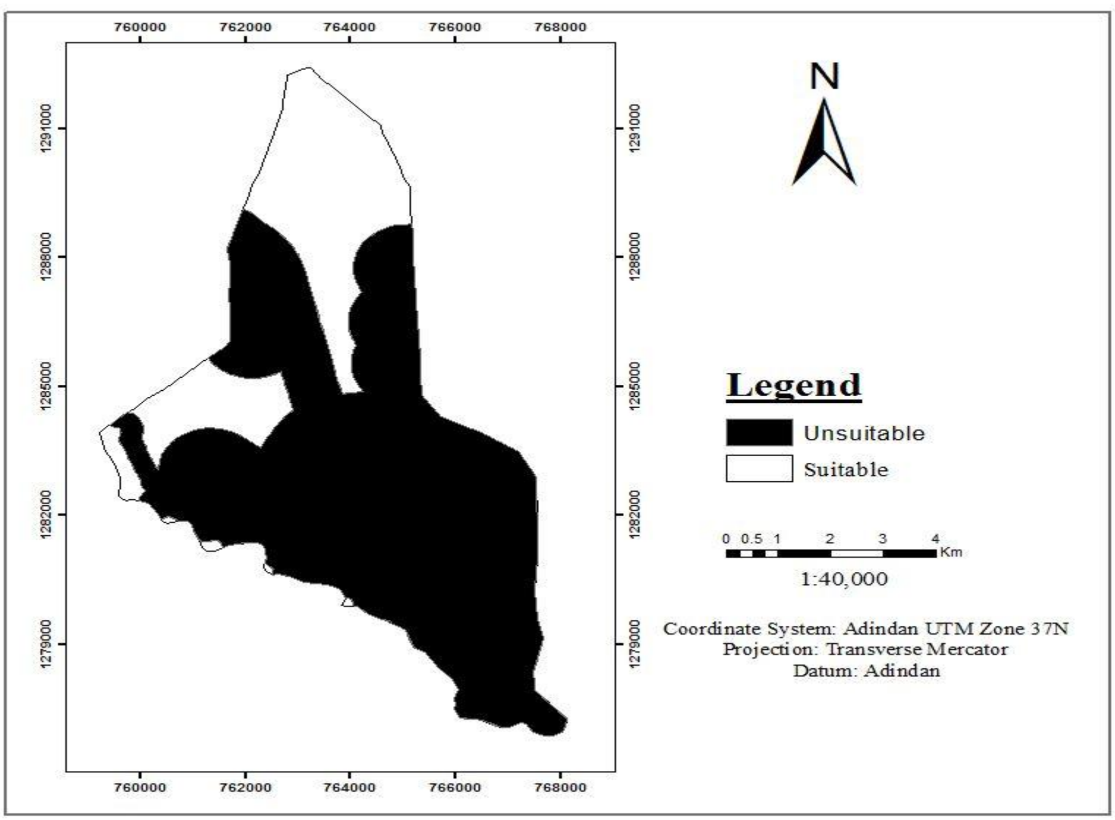

Figure 22 Combined Constraint Map of Study Area

4.3 Result of Weight criteria's

Based on IDRISI, the weight module develops the pair wise comparison technique to help derive the weights and its consistency ratio for solid waste disposal site selection of the study area. According to Lawal et al., (2011), if the consistency ratio is less than or equal to 0.1, it shows acceptable reciprocal matrix. The consistency ratio of this study indicated that 0.03 was acceptable. The factors, their values and weights are summarized below in (table 19).

Table 19. Weights of the criteria using pair wise comparison matrices

Criteria	LU/LC	GE	FA	RI	SO	RO	BU	SL	Weight	Weight (%)
LU/LC	1								0.3329	33
GE	1/2	1							0.2346	23
FA	1/3	1/2	1						0.1559	16
RI	1/4	1/3	1/2	1					0.1049	11
SO	1/5	1/4	1/3	1/2	1				0.0702	7
RO	1/6	1/5	1/4	1/3	1/2	1			0.0472	5
BU	1/7	1/6	1/5	1/4	1/3	1/2	1		0.0324	3
SL	1/9	1/7	1/6	1/5	1/4	1/3	1/2	1	0.0220	2
Total									**1.00**	**100.0**

Consistency Ratio = 0.03 < 0.1 ⟹ acceptable.

(Note: LU/LC= Land use/land cover, GE=Geology, FA=Fault, RI=River, SO= Soil, RO= Road, BU= Built up area, and SL= Slope).

4.4 Aggregation (WLC) of Landfill Suitability Analysis Result

In order to select appropriate solid waste disposal site selection for the study area a comparison of the different potion based on environmental, social and economic impact was done. From the weight calculation, the relative importance of each parameter has been determined for all parameters slope map, geological map, soil map, road map, river map, built up area map, fault map and land use/land cover maps. Hence, based on impact on surrounding environment, different weights were assigned to all parameters. The larger weight, the more important is the criterion in the overall utility. The weights were developed by providing a series of pair wise comparisons of the relative importance of the factors to the suitability of pixel for the activity being evaluated. The procedure by which the weights were produced follows the logic which developed by Saaty (1980) under the Analytical Hierarchy process (AHP). Weight rates were given based on pair wise comparison 9 point continuous scale. These pair wise comparison were analyzed to produce the weights that sum to 1 (table 2). The factors maps were more importance; land use/land cover factors were more importance to have overall suitability map (Ahmed etal., 2011). After the overlay analysis and Weighted Linear Combination method of aggregation result showed five classes of suitability levels such as highly suitable, suitable, moderately suitable less suitable and unsuitable.

Table 20. Area coverage and Landfill suitability

No	Landfill Suitability	Suitability Rank	Area (ha)	Area (%)
1	Highly Suitability	5	300	5
2	Suitable	4	916	15
3	Moderately Suitable	3	269	4.5
4	Less Suitable	2	61	1
5	Unsuitable	1	4441	74.5
Total			**5987**	**100**

Out of the total area of the study site, about 5% (300 ha) fall under highly suitable categories due to, the region satisfies the environmental, social and economic criteria Such as fault, built up are, surface water, geology, land use/land cover, soil, slope and road network. High suitable landfill site were found in the northern parts of the study area. The suitable area covers an area of 15% (916 ha), moderately suitable class covers 4.5% (330 ha), less suitable area cavers 1% (61 ha) and the remaining 74.5% (4441 ha) falls under Unsuitable for solid waste disposal sites indicate fig.23.

By using the stated criteria, the suitable area for solid waste dumping may facilitate transportation and reduce the cost transport. Moreover, suitability for slope analysis had shown that less than 20% are more suitable in order to minimize environmental impacts and the suitable area was far away from fault, river, settlement and urban center and is covered by bare land. Highly suitable area for land fill site is located in northern part of the town (fig. 23). Considering the effect of solid waste for health, economy and other aspects, the selected site most preferable and can be accessed by the road. A study conducted by Olusina and Shyllon (2014) in Lagos, Nigeria indicated that, the land fill sites generated based on the criteria sets are found to be accessible by road.

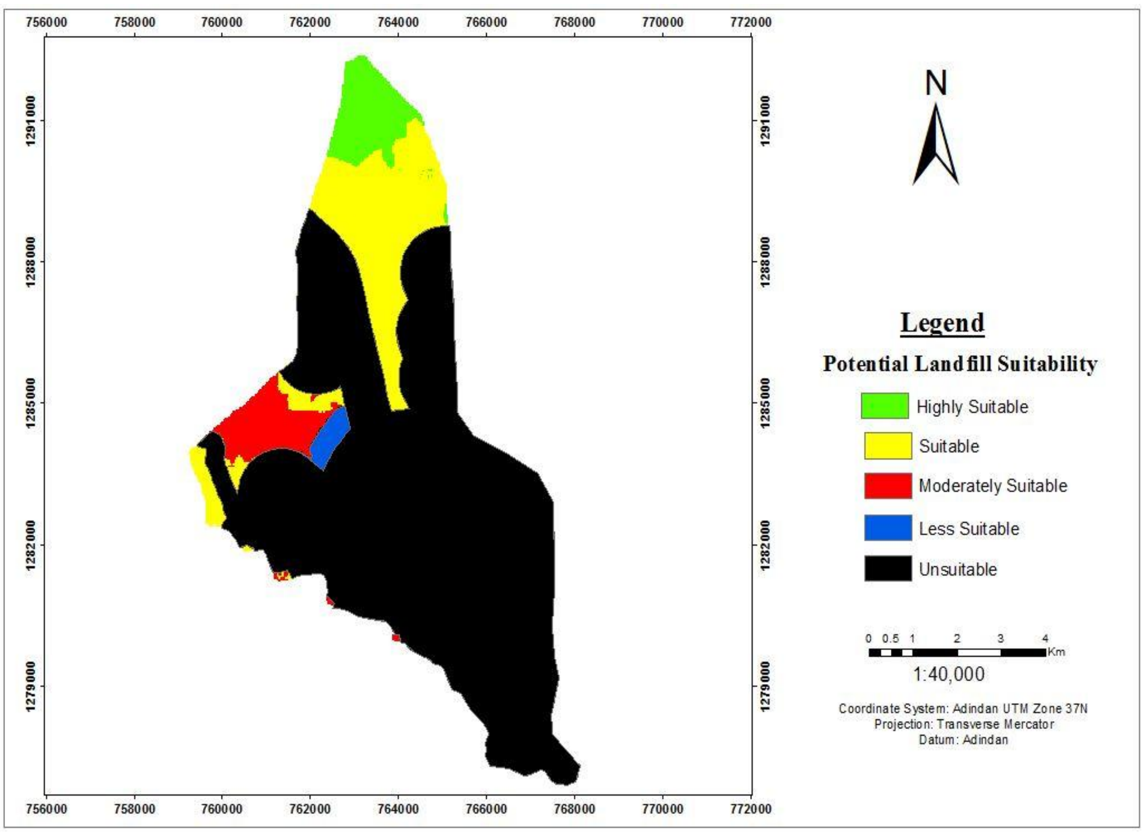

Figure 23. Potential Landfill suitability map of study area

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study has examined the problems of the waste disposal sites in Asaita and its implications on the residents of the town. The study revealed that the town has grown in population as well as spatial extent over the years. The findings have shown the application of the GIS and AHP methods as a viable tool for analyzing the criteria for decision support. The analysis has taken land use/land cover, fault, slope, geology, river, road, built-up area and soil as determining factor in order to find appropriate site for solid waste dumping site. The results have shown that one site was selected as most suitable. The sites are easy to access; manage for disposal of solid wastes. This place is far away from any water sources and other variables put into analysis. It is located in northern part of the study area. The integration of multi-criteria decision analysis is a useful tool in solving landfill site selection problem, because it provides efficient spatial data manipulation and presentation. Hence, the capacity to use AHP with GIS and remote sensing technology for effective identification of suitable solid waste dumping site will minimize the environmental risk and human health problems. Therefore, the result of final suitability map indicate that 5% of the study area has highly suitable for solid waste disposal site, 15% suitable, 4.5% moderately suitable, less suitable 1% and 74.5% the total of the study area under unsuitable.

5.2 Recommendations

For proper waste disposal systems and management to be maintained in the town, the following recommendations were suggested.

- As result of population growth solid waste generation in the town has been increasing and becomes complex. Other hand, the town does not have solid waste disposal sites selection. Therefore, the concerned body should formulate for solid waste disposal sites by considering social, economic and environmental aspects to improve the status of solid waste management system of the town.
- In this study considers eight social, economic and environment criteria were used to select the potential solid waste disposal sites, but other factors are influence for solid waste disposal site selection should be included as evaluating criteria like cost of construction, aspect, and others.
- The selection of the final sites requires further hydro-geological analyses to ensure conformity with the stringent standards required for design and construction of such facility.
- The present study of final solid waste disposal site was only for non-hazard solid wastes. Therefore, hazard solid waste should not be deposited at his sites, because it should have different parameters and construction of solid waste disposal sites from non-hazardous waste.

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