GIS based Multi-Criteria Analysis for Suitable Solid Waste Disposal Site Selection: A Case of Tarcha Town

BY: Getahun Kafe Kareto

A Thesis to be submitted to the Department of Geomatics Engineering in Partial Fulfillment of the Requirement for the Degree of Master's in the Geo-informatics Engineering

School of Civil Engineering & Architecture
Office of Graduate Studies
Adama Science and Technology University

Adama, Ethiopia
November, 2020

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Co-Advisor: Dr. Getachew B/Mesekel

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CANDIDATE'S DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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This MSc Thesis has been submitted for examination with our approval as thesis advisor and co-advisor.

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To: Geomatics Engineering Department

Subject: Thesis Submission

This is to certify that the thesis entitled "GIS based Suitable Site Selection for Urban Solid Waste Disposal Site: A Case of Gessa Town" submitted in partial fulfillment of the requirements for the degree of Master's in Geo-Informatics Engineering, the Graduate program of the department of Geomatics Engineering, and has been carried out by Getahun Kafe Kareto Id. No. PGR/18034/11, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby He can submit the thesis to the department.

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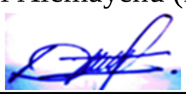
Signature:  ________________

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APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by Getahun Kafe Kareto have read and evaluated his thesis entitled “GIS based Suitable Site Selection for Urban Solid Waste Disposal Site: A Case of Gessa Town” and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Masters in Geo-Informatics Engineering.

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Acronyms and Abbreviations

AHP:	Analytic Hierarchy Process
DEM:	Digital Elevation Model
EMUDC:	Ministry of Urban Development and Construction, 2012.
GCP:	Ground Control Point
GIS:	Geographic Information System
ISWAS	Integrated Solid Waste Administration System
MCDM	Multi Criterion Decision Making
MCE:	Multi Criteria Evaluation
MSWM:	Municipal Solid Waste Management
NGOs:	Non-Governmental Organizations
SNNPR:	South Nation National Peoples Region of Ethiopia
SSWDS	Suitable Solid Waste Disposal Site
SWDS	Solid Waste Disposal Site
SWM	Solid Waste Management

Abstract

New Site selection for municipal solid waste dumping is a great concern for the urban government in most countries worldwide today. In Ethiopia solid waste disposing system is a serious problem in the urban areas including Tarcha Town; because most solid wastes are not dumped in suitable sites and has a problem of waste identification. The current waste disposal system of the Tarcha Town is open dump system as well as the site is filled out and causing social and environmental problems. The General objective of the study is to select the suitable solid waste disposal site by using ArcGIS10.3 and Multi-criteria of evaluation Technique. The SSWDS selection constrains including land use land cover, slope, well point, Soil type, distance from streams/rivers, distance from Major road and Socio-economic criteria (distance from nearby settlements, and center of the town, and size of site) are the determinant criteria to evaluate potential solid waste disposal site. The main data used in this study are scanned existing sketch map of Tarcha Town, and digital elevation model (DEM). The common methods conduct to data analysis are convert from polygon to raster, reclassify and the spatial model will involve geographic modeling functions and coincidence modeling and integration (Weighted Overlay Suitability models) was computed in GIS and as well as creating land slope(counters) from DEM by using Global Mapper19. AHP in which Pair wise comparisons will also be used to determine the alternative in terms of each criterion is one of the most commonly used MCDM tools. The suitability option ranges, not suitable, less suitable, moderately suitable, and highly suitable according to criteria of this study. The results showed that, 192.68ha (1%) of the study area is highly suitable, 8968ha (42%) of the area is moderately suitable, 11535.8ha (55%) less suitable and 413.2ha (2%) of study is not suitable for solid waste dumping site. The finding of the study indicates that 3 candidate solid waste disposal sites in relation to those evaluating criteria. By considering environmentally sound, economically feasible and social sustainability of the residents these sites are ranked as Site1 are the best suitable solid waste disposal site and site 2 and 3are the second and third suitable site with their area coverage of 111ha, 58.2ha, and 23.48ha respectively. The municipality should may use the suggested site looking appropriate sites for the disposal of solid wastes. It is necessary that Further studies recommended by increasing the factors which missed in this study.

Key word: GIS, Analytical Hierarchical Process, Solid waste; Suitability, Tarcha Town

CHAPTER I: INTRODUCTION

1.1 Background

Solid waste disposal site selection is an important part of waste management system, which requires much attention to avoid environmental pollution and health problems. The current global trends of waste management problems are the results of unsustainable methods of waste disposal, which is ultimately a result of inadequate planning and implementation (Abbas, et al., 2011). The generation and dispose of solid wastes are the problems facing both developing and developed countries. Fast expansion of urban, agricultural and industrial activities spurred by rapid population growth has produced vast amounts of solid and liquid wastes that pollute the environment and destroy resources (UNEP, 2005).

In 2016, the worlds' cities generated 2.01 billion tonnes of solid waste. The Organization for Economic Co-operation and Development *(*OECD) countries generate 572 million tons of solid waste pe*r* year. The per capita values range from 1.1 to 3.7 kg per person per day with an average of 2.2 kg*/*capita*/*day. Developing countries thus have solid waste management problems that differ from those found in fully industrialized counters. For instance, it has been noted that low-income countries solid waste generation rates average only 0.165 to 0.6kg/person/day, as opposed to 0.7 to 2.2kg/person/day fully industrialized counters (K.Tassie Wegedie, 2018)

Solid waste disposing is a great challenge in most of municipalities in developing continent like Africa. Largest urban areas as population attracted to cities continues to grow and Solid waste heterogeneous characteristics are a major concern of the government due to the health problems associated with inappropriate solid waste disposal site (Md. Mujibor et al, 2008). The problem is aggravated by the open dump nature of waste especially in the slum areas of most African cities (Meaza Cheru, 2016). This condition is suit for life recycling development of vectors like Files breed which are very effective vectors that speed disease to citizens of low income countries (WHO, 2016 and Ehrogotto, M.Eds. 2005).

Ethiopia like other developing country is experiencing a high urban population growth. Today the country is facing environmental crises as there is no comprehensive plan for waste management. The only way to dispose the waste is to find palace for dumping regardless to its ecological and socio economic potentials (Meaza Cheru, 2016). Tarcha Town is one of the swiftly urbanizing centers and the generation of waste is showing a rapid increase due to socio economic development of the town. the rates of solid waste generation averagely 0.248kg/capital/day or more than 92 kg/year of waste generated in the Tarcha Town (Tarcha municipally office, 2018). However, the municipally has no scientifically criteria based selected solid waste dumping sites; but it was using simple assigned sites and open dumping system. Therefore, the town must need a suitable solid waste disposal sites selection by using Geographic Information Systems (GIS) technology based zoning and multi- criteria Evaluation (MCE). Thus, objective of this study to locate environmentally, socially, and economically friendly solid waste disposal site in Tarcha Town.

1.2 Statements of Problem

New suitable Solid waste disposal Site selection for municipal solid waste is a great concern for the urban government. Rapid increase in population together with rapid development of the town has produced increasing volumes of solid waste and in turn it induced greater infrastructural demand and institutional setup (Karthihea and Yeshodha, 2016). The current solid waste dumping system adopted in Tarcha Town is an open land disposal. The Town has four both solid and liquid waste disposal sites (Mella, wehinbet, Soduwa and Mana zaala) established at about 14 years ago which had simple assigned by the authorities of Tarcha Town and officially adopted through a year. These disposal sites are currently surrounded by squatter settlements and no clearly defined boundaries, and no fenced (Tarcha Town Urban Development office, 2019).

This uncontrolled solid waste dumping affected the public health of Tarcha Town and neighbors' peoples. According to Tarcha Hospital annual report (2018), indicates, 47.5% of people of the Town has affected by air born, severs of vectors (Malaria), acute water Diarrhea, Typhoid and Typhus fever, and Giardia disease accordingly unwise disposal of the solid wastes and it causes peoples to economic loss (medical costs) and other social problems like overcrowdings to the health centers (see in Annex. A). Therefore, it needs immediate measure to overcome this unwise disposal of the solid wastes.

According to Belete Turune (2016), states that, **"**The locally has simply dumping waste on streets, open fields, Residential areas, rivers and water lines. The out parts of the Town and down settlement peoples more exposed to health problems. To solve the environmental pollution and indiscriminate dumping of wastes, that, the solid waste dumping location has needful to Tarcha Municipality.**"** In his study he used land use, slope and nearness from center of Town as a suitable site selection criteria's and not used GIS technology. He also determined only two hectares of land area for all types of Tarcha town Municipal wastes. Therefore, this study fulfills such gaps by using additional suitable site selection criteria's and Geographic Information System (GIS) with considering a minimum recommended area's by reviewed literature in this study.

Several studies have been conducted on different levels of town to find the optimum locations for solid waste disposal sites in different countries by using Geographic Information System (GIS) and Remote Sensing Techniques. But it is not at satisfactory as until; because, many developing countries do not have effective criteria for solid waste disposal site selections and some have regulations of developed countries without modifying to their local conditions. The selection of their ultimate site is complex and it must combine social, ecological, technical and economical parameters (Al-Hanbali et al., 2011). GIS has been found to play a significant role in the domain of sitting of waste disposal sites. Many factors must be incorporated in to solid waste disposal sitting decisions and GIS is ideal for this kind of studies due to its ability to manage large volumes of spatial data from a variety of sources (Karthihea and Yeshodha, 2016).

According to Tarcha Town water service office (2016), states that, "In most parts of the Tarcha Town inappropriate handling and disposal of municipal solid waste. This is the most visible cause of environmental degradation (air pollution, soil contamination, surface and ground water contamination, etc.,). Therefore, the Tarcha Town needs technology supported waste disposal locations to overcome from an improper municipal solid wastes dumping problem." So this description shown that in the study area, there were no studies conducted about municipal solid waste disposal site is selected by using GIS based study. Therefore, the present study employs GIS techniques and Multi-criteria of evaluation approach to appropriate solid waste disposal location for Tarcha Town with considering environmental, economic, social, and public health.

1.3 General and Specific Objectives

The general objective of the study is to identify the suitable solid waste disposal sites in Tarcha Town by using multi-criteria evaluation techniques with Geographic information systems (GIS).

The specific objectives are to:

- Conduct Multi-Criteria Analysis for suitable site selection;
- Evaluate the newly selected solid waste dumping sites
- Recommending the optimal site for solid waste dumping;

1.4 The Research Questions

This study has been focused to answer for the questions raised based on the statements of problem as follows:

1. What factors and criterions are necessary in suitable solid waste disposal site selection?
2. Which site is suitable site for solid waste disposal?

1.5 Significance of the study

This study is expected to select sustainable solid waste disposal site the Tarcha Town. There for the outcome of this study can benefit the following bodies:

- Communities of the Tarcha Town are the most beneficiary by their surroundings will be clean, neat and free from disease causing insects.
- Government institutions: like Tarcha Municipality, Tarcha water service office, and Tarcha Town urban Development offices are benefiters that The findings of the study will serve as for plan and employment the solid waste management, sanitary facilities and other related infrastructures.
- The techniques and procedures used in this study may be used as a reference material for Researchers, Academic and Non-Governmental organization or private sectors for further study to conduct in other places

1.6 Scope of the study

The area coverage of this study is limited with in Tarcha Town administrative location. this study focus on Identifying the suitable solid waste disposal site; prioritizing the new proposed solid waste disposal site and Mapping the new proposed solid waste disposal site.

CHAPTER II: LITERATURE REVIEW

The literature review pointed out that briefly most of the researches work about solid waste management perception on suitable solid waste disposal site selection in developed and developing countries. But extensively solid waste management Study is still inadequate in case of Ethiopia and has been need carried out in solid waste management. The existing study has focused predominantly on the suitable solid waste disposal site selection. It also briefly reviews the GIS technology in used for the suitable solid waste disposal site selection and selection factors like Environmental criteria, Economic and Technical criteria, and Socio-cultural factors for Tarcha Town and associated process which can help in the site selection.

2.1 Solid Waste

Solid Waste is unavoidable by product of daily human activities. It is including any garbage, refuse from households like food, paper, plastic, glass, metals, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material including solid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agriculture operations and various other items (K Tassie Wegedie, 2018).

The total amount of municipal solid waste generated globally reached 2.02 billion tones, representing a7.2% annual increase since 2016 (K.Tassie Wegedie, 2018). According to WHO (2016), estimations, the total health- care waste per person /year in lowest income countries, is anywhere from 0.5kg to 3kg. In African Countries Solid waste was identified as the second most important problem after water quality less than 35% of urban populations have access to proper and regular garbage removal.

2.2 Risk of Open Solid Waste duping

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).

2.3. 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).

The solid waste disposal system should be environmentally 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 Ambaneh (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 Tarcha town, the study area, there is a problem of solid waste disposal.

2.3.1 Solid Waste Disposal Site Selection

Solid waste disposal site is a common solution for the final disposal of wastes in low-income Countries which a large majority of community's practice subsistence solid waste disposal siting or open dumping as their main method of waste disposal (Tsegaye, 2006). Solid waste disposal site selection in an urban area is a critical issue because of its enormous impact on the economy and the environmental health of the region and many sitting factors and criteria should be carefully organized and analyzed. If these solid waste disposal sites are near the individual's work place or living area, it is considered as a negative outcome and it may cause irreparable consequences to human life (Seiied, 2015) cited in Minalu Ambaneh (2016).

2.4 Criteria used for waste disposal site selection

The waste disposal site selection process has become much more complicated, as new procedures and tools have been created. The criteria used in landfill site selection include ecology, environmental, economic and socio-political some of which may contradict to each other (Md.

Mujibor et al, 2008). The factors reviews for landfill site selection used in different countries are as the following.

Environmental criteria: it consisting of Hydro-geological information (ground water, surface water), land cover and ecological character.

Economic and Technical (operational) criteria: consisting of the altitude, slopes, access to roads, and the distance from the main source of waste consumption.

Socio-culture factors: it refers to land use and social value consisting of the distance from settlements, industry, and proximity to major roads and protect places.

A minimum distance of 500 m buffer should be maintained for river suitability dumpsite location (Sam and Steven, 2017). Different research shown that areas with high slopes (the slope class more than10%) will have high risk of pollution and potentially not a good site for dumping (Sener et al. (2011), cited in Tirusew A. and Amare S. (Sep 30, 2013).

2.4.1 Ethiopian Practices for Solid Waste Disposal Site Selection Criteria

Different researchers used different criteria to set suitable solid waste disposal sites as of their existing interest of study, condition, available data and some other factors. Besides, there are also most common criteria that have been used by scholars and institutions (Genemo and Yohannis, 2015). The major important factors considered to locate the best suitable sites for solid waste disposal were distance from protected areas, slope, settlement, land use/land cover, river and lake, distance from main roads to solid waste dumping site according to the towns existing situation identified (MET et al, 2011) cited in Genemo and Yohannis (2015), as bellow table2.1.

Table 2.1 the factors and Criteria that considered for selection of sanitary landfills

No	. Criteria	Distance/time span
1	Distance from gas lines, sewerage lines and water lines	>0.5km
2	Distance from memorial sites, churches and schools	>1km
3	Distance from water bodies	>0.3km
4	Distance from residential areas	>0.4km
5	Distance from main roads	1km-10km
6	Land area and volume	For >10yrs

The criteria found in the above table are used by those researchers were considered to determine suitable solid waste disposal site selection in the study area. Since there are no specified criteria for solid waste disposal site selection developed for Tarcha Town. I have adopted 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, (2016) and EMUDC, (2012) Manual for Solid Waste Management with Respect to Urban Plans, Sanitary Landfill Sites Planning to Addis Ababa city.

i. 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 as environmental sensitive area
ii. 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.
iii. 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.
iv. Areas greater than 85,000-meter square for storage capacity of solid waste disposal site selection based on certain evaluation for analysis of land fill site suitability.

2.5 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).

Analytical Hierarchy Process (AHP), 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. Integrating GIS and MCDA can solve the challenges of landfill site selection which involves highly complex spatial decision-making processes (Eldrandaly et al. (2005) cited in Debishree et al., (2014).

AHP in which Pair wise comparisons will also be used to determine the relative importance of each alternative in terms of each criterion is one of the most commonly used MCDM tools. 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:

$CI = \frac{\lambda max^{n}}{n^{1}}$, Where n is the number of criteria and λmax is the biggest eigenvalue.

To determine if the comparisons are consistent or not, the Consistency Ratio (*C.R.*) is calculated using the formula: CR = CI/ RI

Where *R.I.* is the Random Inconsistency index that is dependent on the sample size.

A 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).

2.6 Application of GIS Technology in Solid Waste Disposal Site Selection

In recent years, GIS has emerged as a very important tool for land use suitability 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 (Karthihea and Yeshodha, 2016).

2.6.1 In Ethiopia Experience of GIS on Suitable Site Selection for Landfill System

GIS is a computer assisted system which It potentially saves time that would normally been spent in selecting an appropriate site, while claim that It is an ultimate method for preliminary site selection as it efficiently acquiesces, stores, retrieves, analysis and displays Geographic information according to user-defined specification (Genemo Berisa, April, 2015). Due to the cause many students and researchers trained to use the GIS supported analysis for determine the vest way of Solid Waste landfill system in Global as well as in Ethiopia.

2.7 Evaluation criteria for newly proposed solid waste dumping sites

Waste dumping suite must be at least 100 meters from public roads, at least 200 meters from industrial developments, at least 500 meters from urban residential, surface water area, at least 1000 meter from rural residential areas (Yaw et al, 2006) cited in Genemo Berisa, April, (2015). At least 200m Distance from memorial sites, churches, settlements, roads, schools and Not suitable to vector spreading which effective to disease transmitting.

2.8 Conceptual Framework of Literature Review

Solid wastes are a complex continuous process by product of daily human activities. The evaluation of new waste disposal site selection is a complicated process, as it requires Considerable criteria. The proposed location must satisfy basic government regulations, and also take into recognizance how to minimize negativity of environmental, economic, public health and social cost. Solid waste disposal site selection criteria represent constraints for sitting range from 1 to 4(i.e. 1 indicates no constrains (Restricted), and a score of 4 indicates a total constraint, see table 2.2).

Table2.2 Attribute scores and criteria weights used in site selection

category	Layer/factor	criteria's	score
Land use Land cover	Commercial area	Not recommended	1
	Residential area	Not recommended	1
	Administration/service area	Not recommended	1
	Manufacturing areas.	Not recommended	1
	Recreational(Green)	Not recommended	1
	Cultural reserve land,	Not recommended	1
	Mixed land use	less recommended	2
	Forest lands	moderately recommended	3
	Special Function area,	highly recommended	4
	Agricultural land	highly recommended	4
Road	Distance to major roads	0–100m, 100–500m, 500-1000m, and >1000	1, 3, 4, 2 respectively
	Distance to Ground water points	<500m, 500 –1000, 1000-1500 >1500m	1, 2, 3, 4 respectively

Geological factors	Soil infiltration rate	High, Medium and low	1, 2, and 3
Topography	slope	>3%, 3 - 8%, <8 - 15% and >15%	1, 4, 3, and 2
	Surface river/stream	<500m, 500 – 1000, 1000 – 1500 and >1500m	1, 2, 3 and 4
Socio-economic criteria	Minimum distance from nearby settlements, Minimum distance from center of the town Minimum size of site	<2500m, <3000m <85,000metsque	

Source: - own conceptual Framework developed

GIS is a significant role in waste disposal site selection; because it can manage large volumes of spatially distributed data from a variety of sources and efficiently store, retrieve, analyze and display information. In Ethiopia, some researchers have used GIS and remote sensing to select suitable solid waste disposal site for municipal solid waste dumping. For instance: Amare Sewnet (2013), Lamessa Kenate (2017), Kumel Beshir (2014), Genemo Berisa and Yohanis Birhanu (2015), Minalu Ambaneh (2016) have conducted studies on solid waste disposal sites selection using GIS and remote sensing for Addis Ababa City, Sululta Town, Bahir Dar, Wolkite, Jigjiga, and Mojo towns respectively.

To optimizing for solid waste disposal process, the first step in the methodology consists of developing a digital network of GIS database in which spatial information will be formed. In this study 6 input map layers including land use, ground water points and surface water, soil information, slope, and roads aspect were evaluated and prepared to be used in the analysis in ArcGIS 10.3 environment. The Final objectives of this study is to be an optimal site will be chosen based on the highest suitability values and the area map will be generated that identifies regions that are most suitable for the location of solid waste disposal site possible with little negative impact to the environment.

CHAPTER III: MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

Tarcha Town is capital of Dawuro Zone Administration in the Gibe- Omo River Basin in southwestern part of SNNP Region of Ethiopia (figure 3.1). Total area of about 211504843msq (21150.48 ha). Its located at about 615 km South West of Addis Ababa and geographical extent is between 07º06ˈ48ˈˈN to 07º12ˈ12ˈˈN latitude and between 37º07ˈ14ˈˈ and 37º16ˈ30ˈˈE longitude. With altitude ranging from 912 to 1990m MSL. Tarcha town consists of six Kebeles are Shaata, Mehali ketema, Addis Mender, Soddo, Bodha and Chere and The total population estimated 38678 of whom 16718 males and 16711 are females (Tarcha municipal office, 2017).

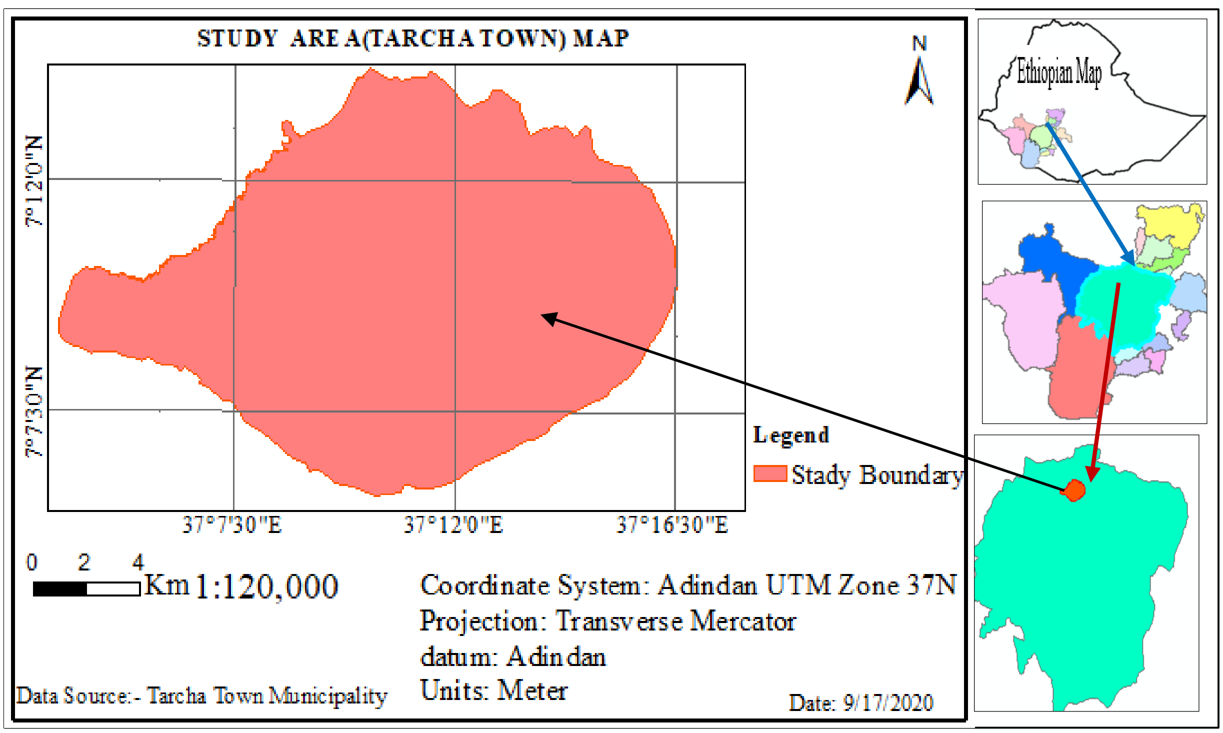


Figure 3.1. Location Map of the Study Area (source: Tarcha Town Map)

3.1.2 Land use and Relief

Most of the residents are comprise mixed land use i.e. residential, commercial, institutional, and agricultural and etc. (Tarcha Town urban development office, 2018). The land surface of the area is dominated by rolling, hills plateaus and plains and mountains, and almost all the town experience

Woine Dega and Kolla (warm to hot type of climate (SNNPRG agricultural bureau agro - extension manual, 2017) cited in SNNPR Urban Development, (2018).

3.1.3 Road network

Tarcha town has 20km asphalt road, 160 km all weathered gravel and cobbles road, and 86km Dry season roads. The town has six entrances road from the neighboring regional towns such as from Hawassa, Soddo to Tarcha, Chida and Jimma. road from Gena karawo to Tarcha and other three local seasonal gravel roads from nearest kebeles to Tarcha Town (Tarcha Town urban development office, 2018).

3.1.4 Soil

The infiltration rate plays an important role in determining potential risk of contamination of the ground water and hence is a key criterion for the solid waste disposal site. Clay is an important component of soil liners due to its ready availability, durable, low infiltration and its tendency to be accommodating to mechanical and other stresses. the hydraulic conductive is less than $1*10^{-7}$cm/sec (S.J.Baban and J.Flannagan, 2003) cited in: Lamessa Kenate, (2017). Central and most part of the study area is dominant Humic AliSols. The Lesly Eastern part of the study area is occupied by Humic NitiSols. Humic AliSols and Humic NitiSols are predominantly low infiltration rate. Leptosols in the FAO world reference base for soil resources is a very shallow soil over hard rock less than 10 cm deep (GSE, 2011) or highly calcareous materials or a deeper soil that is extremely gravelly or stony. This type of soil is found in the Lesly Northern part of the study area (Ethiopian Agricultural Ministry, 2016).

3.2 Materials

Materials have used in this study are as the following. Handheld GPS for collect primary data of the ground water well points truth from field survey, digital camera to be used (see table3.1).

Table 3.1 the Software and Equipment

No	Software and Hardware	purpose
1	ArcGIS 10.3	To Data analysis (data conversion, reclassifying, geographic modeling functions (calculating distances, areas, and generating buffers) and modeling weighted overlay)

2	Global Mapper19	To Download DEM from online source and create contour data from DEM
3	Microsoft Excel 2016	To record field GPS collected data
4	Word Version 2010	Report writing
5	Computer(laptop)	For inscribe
7	IDRISI Selva17 Software	used for Pair-wise comparison
8	Digital camera	To capture photos of existing sites
9	GPS (Garmin36)	To collect ground truth point or Data

3.2.1 Data and Data Sources

The study employed both primary and secondary data. Primary data (field survey data of the coordinates of ground water well points collected directly and photos of existing sites). Whereas the Secondary data (Road network, River line, Soil type, Structural land use and Town Boundary) has obtained from sketched map of Tarcha Town. Land Slope from DEM downloads and Soil data from Ministry of Agricultural and Natural Resource (2016). Another relevant written documents or institutional charts, from the local government Authority such as Tarcha Town urban development office, and Tarcha municipal office.

Table 3.2: data types and sources

No	Data used	Data type	Source	Description
1	Land use land cover class	Raster	Tarcha municipal office	To generate land use land cover class map
2	River/stream	Shape file	Tarcha town urban development office	To generate map of Minimum distance of proposed site from stream
3	G/water well points	Point feature	From field survey directly by hand GPS	To generate map of Minimum distance of proposed site from water well points
4	Boundary	Shape file	Tarcha town urban development office	To generate Boundary map
4	DEM	TIN	download from online sources	To generate elevation and slope

5	Main road(road network)	Shape file	Tarcha town urban development office	To generate Map of closeness distance from the Proposed sites to Road
6	Soil data	Shape file	Ministry of Agricultural and Natural Resource	To generate Soil classification map

3.2.2 Data Collection Techniques

The techniques to be used for Data collection are request letter conduct for selected relevant bodies of above listed offices to procuring secondary data, surveying field data and download the Landsat or DEM image direct from online Earth Explorer.

3.2.3 Data Analysis Methods

Data acquisition, developing a database, and digitizing vector map and optimizing the data to analyzing process are prime importance activities before data analysis. The common GIS tools using in data analyzing are Analysis tools (extract, proximity), conversion tools and special analyst tools.

The common specific activities will be used in this study to analyze the spatial data will be converted from polygon to raster, reclassify and the spatial model will involve geographic modeling functions and coincidence modeling was computed in GIS to generate suitable solid waste disposal site based on the evaluation criteria stetted in literature review introduction part of this study. There are several map combination processes (integration) models in GIS (Frantzis, I. 1993). But in this Study Weighted Overlay Suitability Model will be used to determine an optimal waste disposal site.

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. The Six contributing factors for suitable site selection will developed a common rescaling option which indicates not suitable, suitable, moderately suitable and high suitable range from 1 to 4 (Ozeair A., Mohesn S, 2009). where value of 1 denotes unsuitable and 4 denotes the most suitable for all factors considered. Final an optimal site will be chosen based on the highest suitability values and the area map will be generated. The results of the MCE are used to determine the suitable area is based on the modification and refining of the following flow chart.

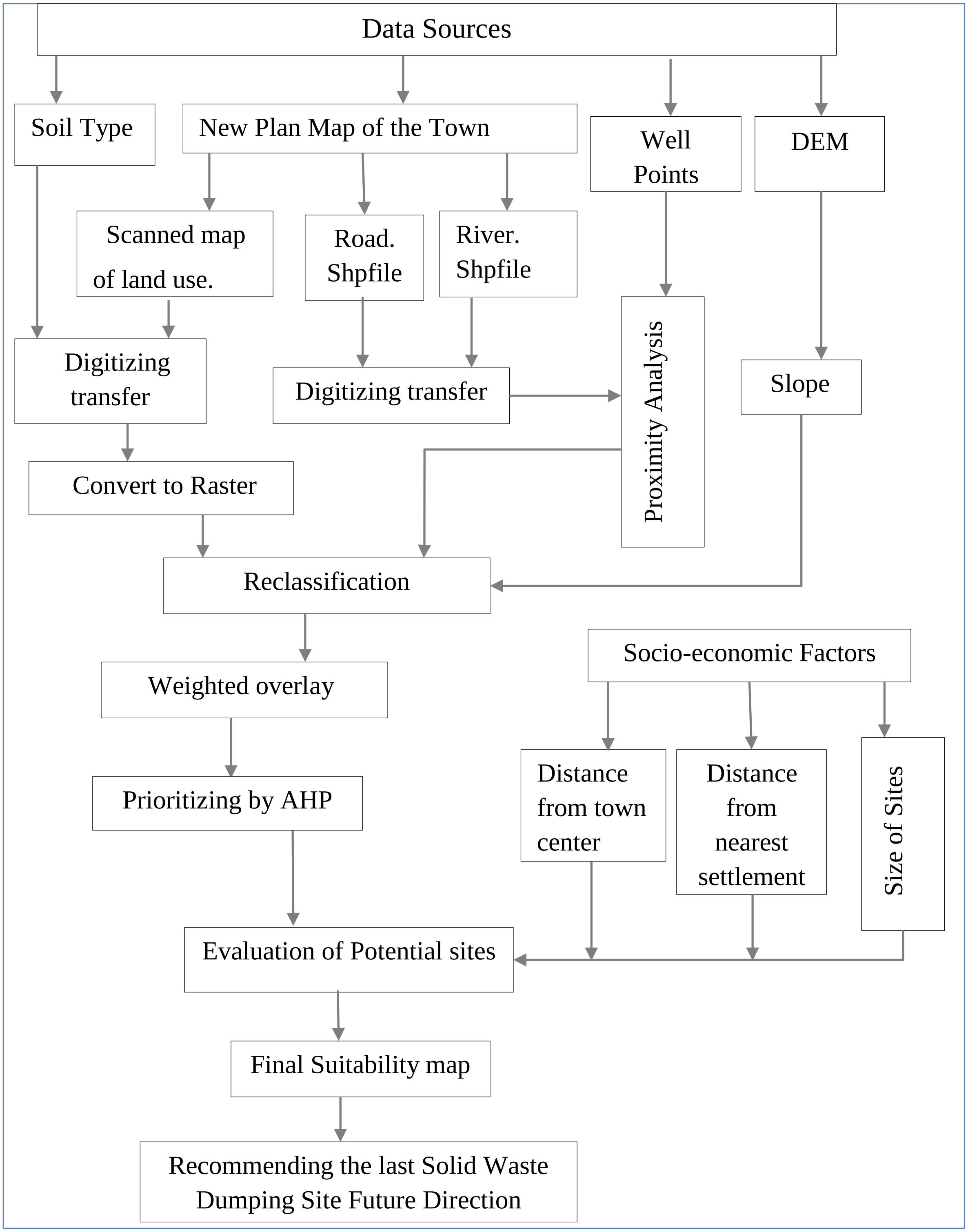


Figure 3.2 Technological scheme of data analysis

CHAPTER IV: DATA ANALYSIS, RESULTS AND DISCUSSION

In this study, suitable solid waste dumping sites were determined for Tarcha Town's by using the GIS tool and weighting product of AHP method. A solid waste disposal site should be kept as far away as possible from Residential, surface water, and water well for reducing impact on public health. On the other hand, the solid waste disposal site should be placed not much far from existing roads for saving transportation and collection costs. Also the difficult or steep terrains and high permeable soil types are not appropriate for solid waste dumping sites. For this study Six suitability contribution factors (main road, surface water, Water Well points, Land slope, Urban land use type and Soil Type) were used based on the relevant criteria(standards) of EMUDC, (2012) and international practices. Maps were created for each suitability criterion and the final composite map was produced by simple weight overlaying of the individual maps. The buffer zones used rankings and layer's weights were summarized using tables.

4.1 The Existing Conditions of Solid Waste Dumping in Tarcha Town

According to field survey in the Tarcha Town currently wastes are generated from commercial area, construction sites, Administrative/service institutions and refuse from households in large amount. Analysis technique of the existing conditions of solid waste dumping in Tarcha Town is reviewed field observation, interview from the relevant Authority information and written documents or institutional charts from the local government are evaluated with suitable solid waste disposal site selection factors like Environmental criteria (ground water, surface water), land cover and ecological character), Economic and Technical(operational) criteria (consisting of the slopes, access to roads) and Socio-culture factors and From sustainability and economical point of views like Size of solid waste disposal and proximity to settlements.

The present waste disposal condition of Tarcha Town is not as such satisfactory because of the solid wastes dumped an open waste disposal system. The existing Solid waste disposal sites does not consider major environmental factors, like distance from water bodies, road network and settlement. These existing open waste dumping sites are selected based on the criteria only distance from center of the town and access of open land surface. Since many of these are very close to the main river/stream, major road, and settlement (see Figure4.1 below). Accordingly, Tarcha Town municipality, waste collection in the town by individual residents of the town from their home and institutional areas with used handcarts, donkey-carts and daily workers to transfer station allowing or open waste disposal places. In the town a community-based group may collect waste from houses to some community container site and it is left at a transfer point for removal to open dump site by municipal vehicles or a private contractor.

Figure 4.1 Existing open Waste Dumping with sidelong of Shata River (Field Survey, Photo)

Some of those open dumping sites are flat land surface and It be clogs drains and creating stagnant water on land surface. Others also at steep slope land surface and it is contaminating the river highly because of runoff and wind since towards the rivers. Waste Collection applied at night shall be avoided, noise, and nuisance to the residents' safety; however, waste Collection in the Tarcha Town is undertaken during daylight hours. In areas of high density housing, with narrow streets, often with poor road conditions, they may not collect solid wastes from all sources. Due to the reason most of the dwellers drop the waste anywhere illegally. This inappropriate dumping of waste is creating opportunity to access for the contaminative pests like flies, mosquitoes, and other animals breeding, and cause public nuisances from odour of open dumped solid waste compost. The residents near to the existing open dump site are suffering from air pollution and due to contamination of the river which they using for different purposes.

Some of the open solid Waste disposed sites found at Mella behind Tarcha high school, wehinbet sefer, Soduwa close to Soduwa Orthodox church and Mana zaala close to Selamber Health Center, and the following photos show open solid waste dumping sites.

a, b, c,

Figure: 4.2 Open dumping site along a. behind Tarcha high school, b. wehinbet sefer, c. fence (Field Survey Photo).

A separation of solid wastes from liquid wastes should be required to help easily in all levels of waste management. What is shown in the above photos is illegal disposal of solid and liquid waste together in an open dumping site that are not easy to manage the effects on health. Solid waste management respect to attend the town sanitation, beautification and green area development, collect the solid wastes with suitable condition are among many responsibilities of the municipality (MUDC, 2012). To carry out such responsibilities Tarcha municipality try by developing different plans from year to year; however, its solid waste management is un satisfactory due to environmentally, economically and socially acceptable. Therefor the negative impacts from open waste dumping can be minimized through selecting an appropriate solid waste disposal site by using GIS techniques and multi- criteria evaluation methods.

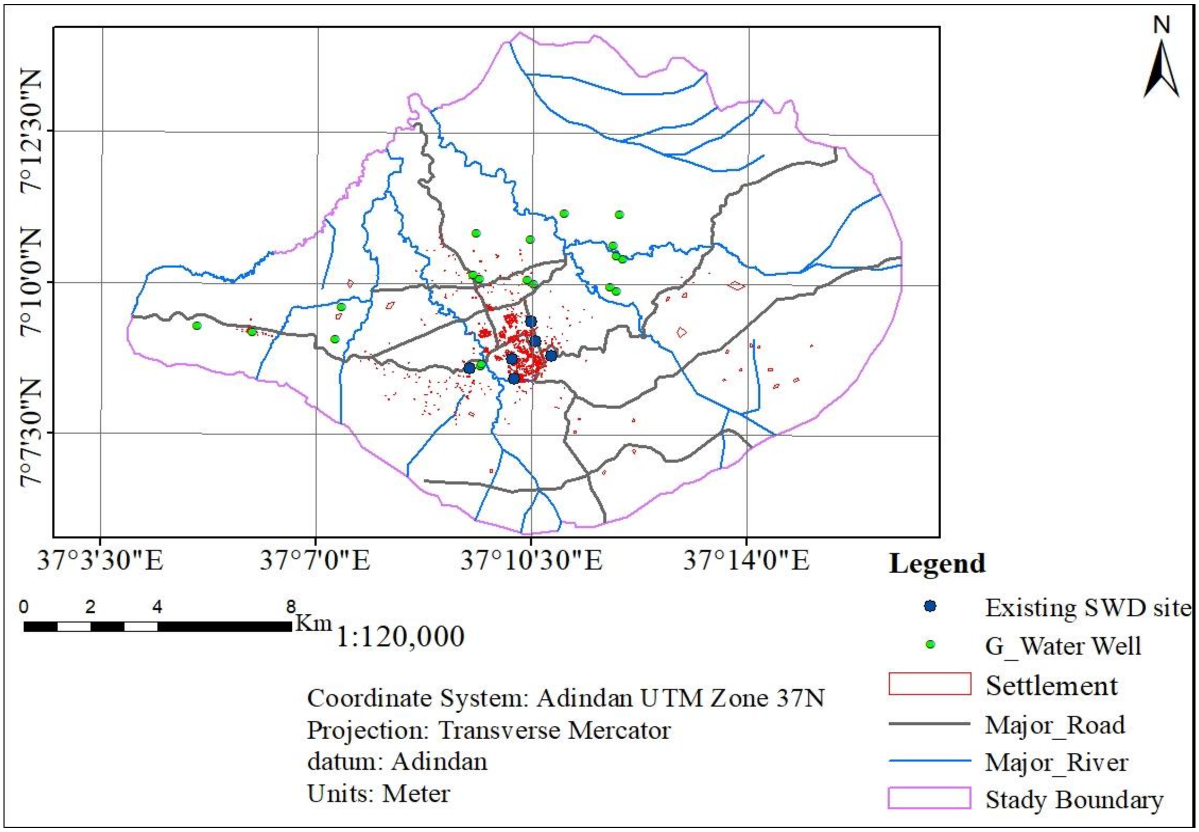


Figure 4.3: Existing open Waste Dumping Site Map

4.2 Solid Waste Disposal Site Selection Criteria

Solid Waste Disposal Site Selection Criteria is a very important process for a successful operation for suitable solid waste disposal site selection. It involves an extensive evaluation process in order to identify the suitable solid waste disposal location. This location must satisfy basically for regulations and recognizance how to minimize factors on health, economic, environmental and social cost. In fact, different researchers have used varying criteria for site selection purposes due mainly to the fact that different criteria applied to different region and all facilities (MUDC, 2012). The following criteria are often used for solid waste disposal site selection. These are Land slope (less than 10%,), from water well and Proximity to surface Water bodies are 300m and 500m buffered distance respectively, Land use and land cover type, and minimum considerable Distance from roads is not be located within 400m (MUDC, 2012).

4.2.1 Distance from Surface Water (River/Stream)

In the study area there are seasonal and perennial streams/rivers that flow towards south west of the town. These streams are used for drinking for humans and animals in the peripheral part of the town. The solid waste disposal site should not be closely placed within seasonal and permanent water resource areas to protect water resource from contamination by leachate and high velocity of the surface runoff (MUDC, 2012).

Different researchers set minimum buffer distance from Stream/River for solid waste dumping site selection. For instance, Hasan et al. (2009) used 100 m buffer distance, Akbari et al. (2008) use 200m buffer distance cited in Gizachew (2011). As Chang et al. (2007), stated the distance away from rivers of not less than 1 km whereas, the standards of EMUDC (2012), claimed to maintain the suitable sites for solid waste disposal is at least 400 m buffered distance surface water. Based on above information, prepare Euclidean distance polygons around each streams and rivers within the following distances: 0 to 500m, 500 to 1000m, 1000 to 1500m, and >1500m. To reduce the effect of solid waste dumping on surface water that, 0 to 500 m buffer area were excluded from suitable sitting. The rest of the areas were analyzed based on the distance from the streams and rivers.

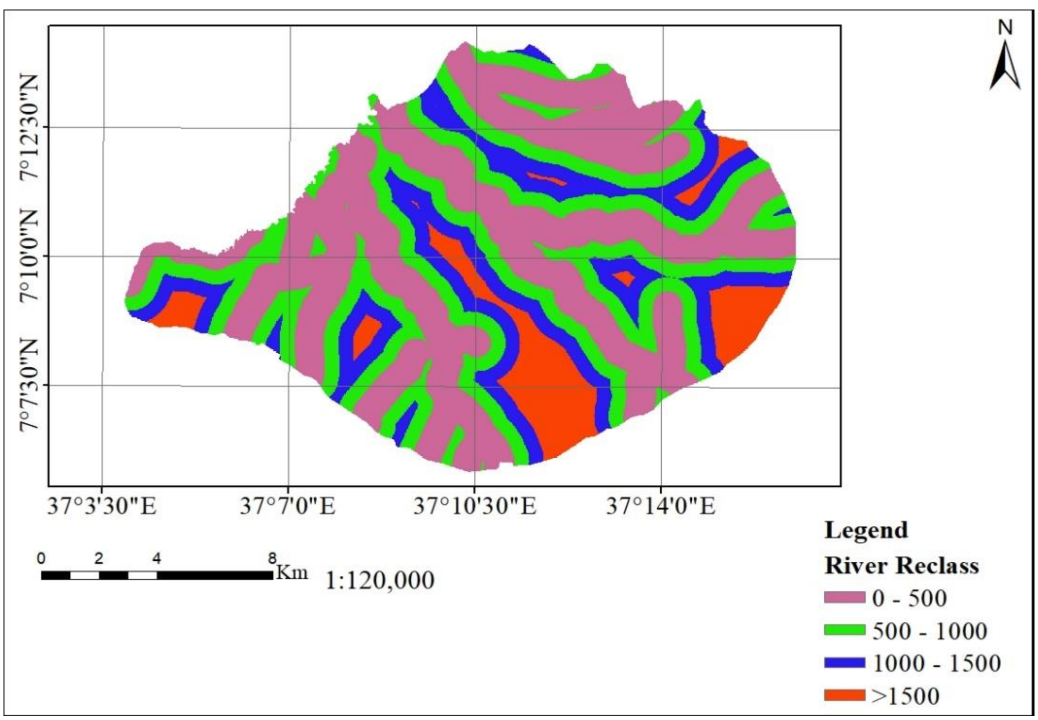


Figure 4.4: Surface Water Distance Re-classification map (Author, 2020)

In this study the analysis results show that 2698.2ha was found highly suitable, 3619.8 ha of the study area is moderately suitable, 5785.8ha was observed as less suitable area and the rest 9046.56 ha of area which is unsuitable for solid waste disposal site. Summary of suitability level with their respective areas are shown as figure 4.5 bellow.

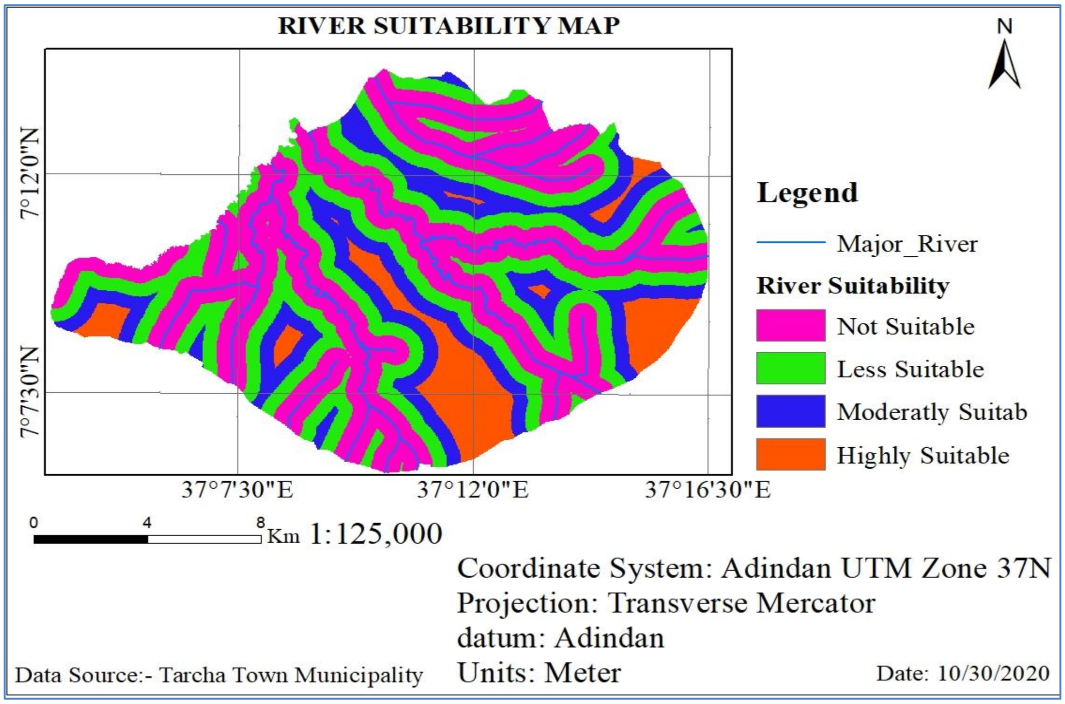


Figure 4.5: Surface Water Distance Suitability Map (Author, 2020)

The figure4.5 shows that an extent of 13% of the area was highly suitable for solid waste disposal sitting, because of the minimum effect on surface water. 17% and 27% of the total areas were moderately and less suitable respectively. Moreover, 43% of the study area was excluded from the suitable site selection processes due to the vicinity to the streams and rivers and hence unsuitable for solid waste disposal site (see Table 4.1).

Table 4.1 Rivers and streams proximity suitability

No	Distance in meter(m)	Suitability	Area Coverage (ha)	% of Area Coverage	Rank by Area Coverage
1	0 - 500	Not Suitable	9046.56	43	1
2	500 - 1000	Less Suitable	5785.8	27	2
3	1000 - 1500	Moderately Suitable	3619.8	17	3
4	and >1500	Highly Suitable	2698.2	13	4
Total			21150.48	100.00	

4.2.2. Ground water Well Proximity

Proximity of a groundwater well to a waste disposal site is an important environmental criterion in the waste disposal site selection. The waste disposal areas should be away from boreholes to protected wells from adverseable environmental effects (runoff and leaching from the solid wastes dumping site). The solid waste disposal site at a high groundwater level or a nearby high river level will cause more risk to the groundwater or river (Gizachew Kabite 2011). The potential location with the lowest groundwater well or river level is more suitable for a waste disposal site. Accordingly, Hasan et al. (2009), used 500- 1000m and Jamjan (2009) used 700m as a minimum distance from which waste disposal can be safely cited in Gizachew (2011). This is also supported EMUDC, (2012), groundwater well points are currently functional, it reserves and buffer zones around each well may not less than 0.5km. For this work, Multiple Ring buffering was performed around the wells in order to identify the best site for waste disposal. Buffer distance of 0 to 500m, 500 to 1000m, 1000 to 1500m and >1500m were prepared around each and every well points. As a result, the map is prepared and show the suitable and unsuitable area based on this criterion.

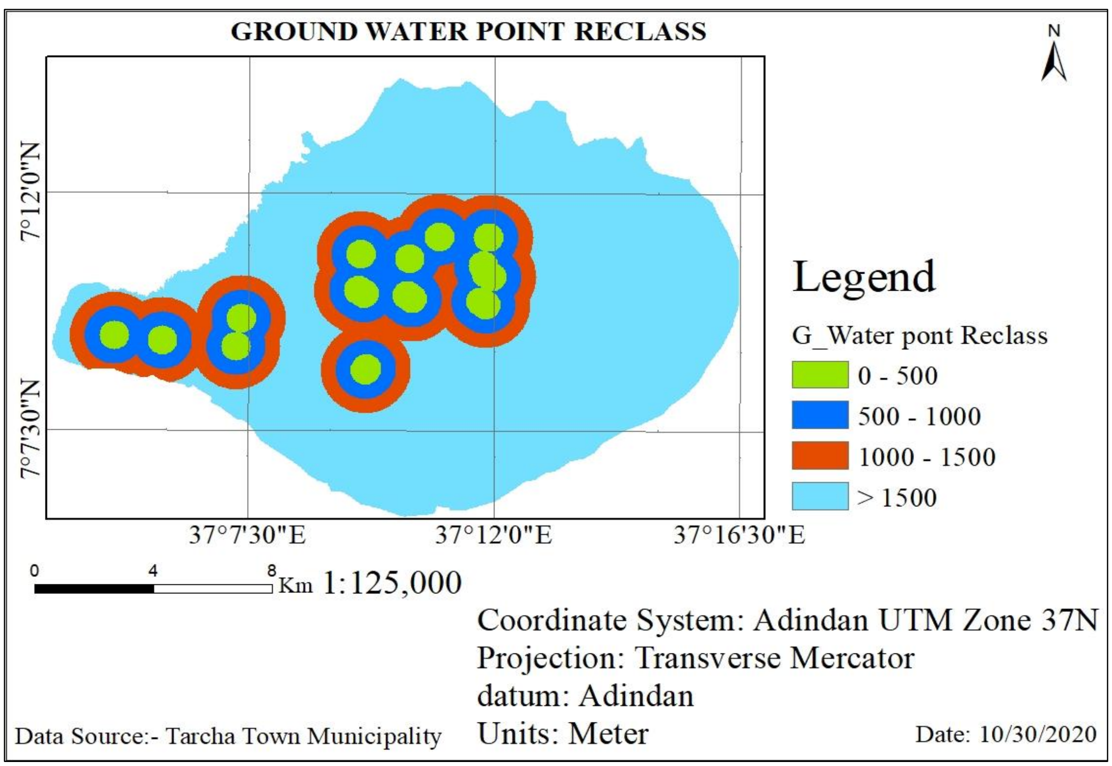


Figure 4.6: Ground water point Re-classification map (Author, 2020)

Solid wastes disposal site more closely the water well, the more probable for ground water to be contaminated. In this study buffer distance from water well point was reclassified into four buffer zone classes. The reclassified buffer distance was ranked with the area coverage between not suitable and the highly suitable for Solid waste disposal site selection (see figure4.7 below).

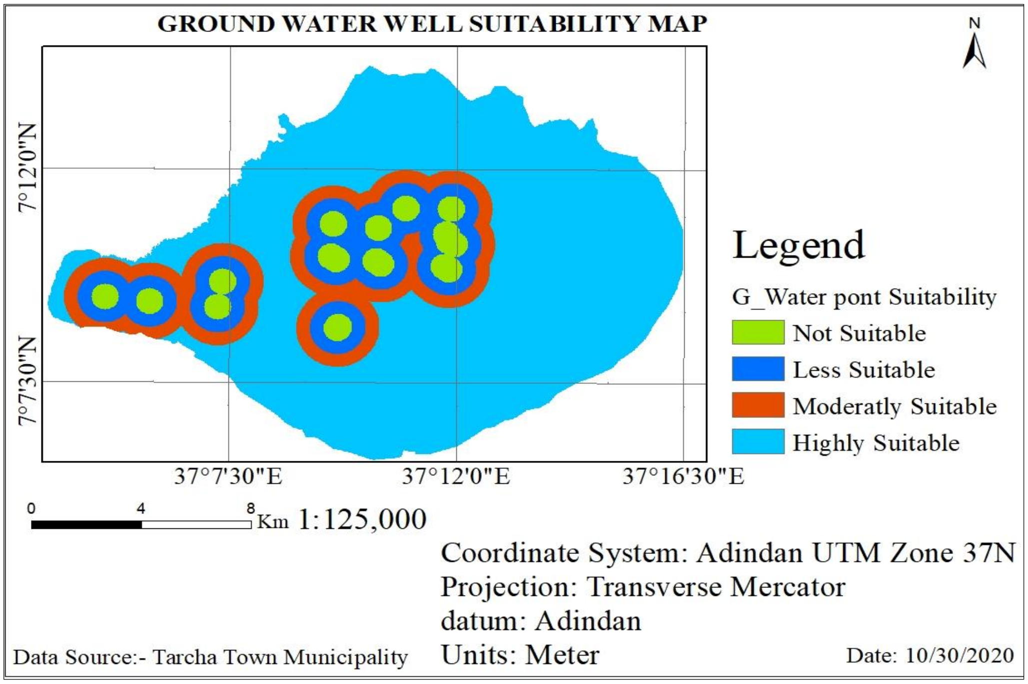


Figure 4.7: Groundwater well buffer map (Author, 2020)

The figure 4.7 shows that 5% of study area is not suitable as it's vicinity of water wells and 72% of the total study area is highly suitable for Solid wastes disposal site from ground water proximity point. In addition, 11%, and 12% of the study area are less suitable and moderately suitable respectively (see table4.2).

Table4.2. Groundwater proximity suitability

No	Distance in meter(m)	Suitability	Area Coverage (ha)	% of Area Coverage	Rank by Area Coverage
1	0 - 500	Not Suitable	1137.46	5	4
	500 - 1000	Less Suitable	2412.16	11	3
3	1000 - 1500	Moderately Suitable	2488.84	12	2
4	and >1500	Highly Suitable	15111.92	72	1
Total			21150.48	100.00	

4.2.3 Distance from the Main Road

In this study the road proximity is one of the criteria that should be considered from economic and social point of views during solid waste disposal site selection processes. This is because solid waste dumping site very close to roads may have public health problem as from odors of dumped solid waste. Also, solid waste disposal sites are not recommended so far from road network to saving transportation and collection cost. Therefore, to minimize such problems, solid waste dumping sites must be not very far from roads and not very closely sited to road. “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 less than 1 km for small landfills serving secondary” (EMUDC, 2012).

Some researchers set minimum distance for solid waste dumping site selection according to road proximity such as Kumel Beshir, (2014) set 300m buffer; While Genemo Berisa, (2015), uses 100m Euclidean distance from road as a minimum distance within which solid waste dumping site should not be located. However, at least 100m far distance is defining as the safest distance (Yahaya, 2010) cited in Kumel Beshir, (2014). Sam and Steven (2017), a minimum distance of 700m buffer should be maintained for road suitability dump site. For this study the Euclidean distance were used to create buffer classes around the roads with 0 to 100m, 100 to 500m, 500 to 1000m, and greater than 1000m distance ranges as shown in the Figure: 4.7 below.

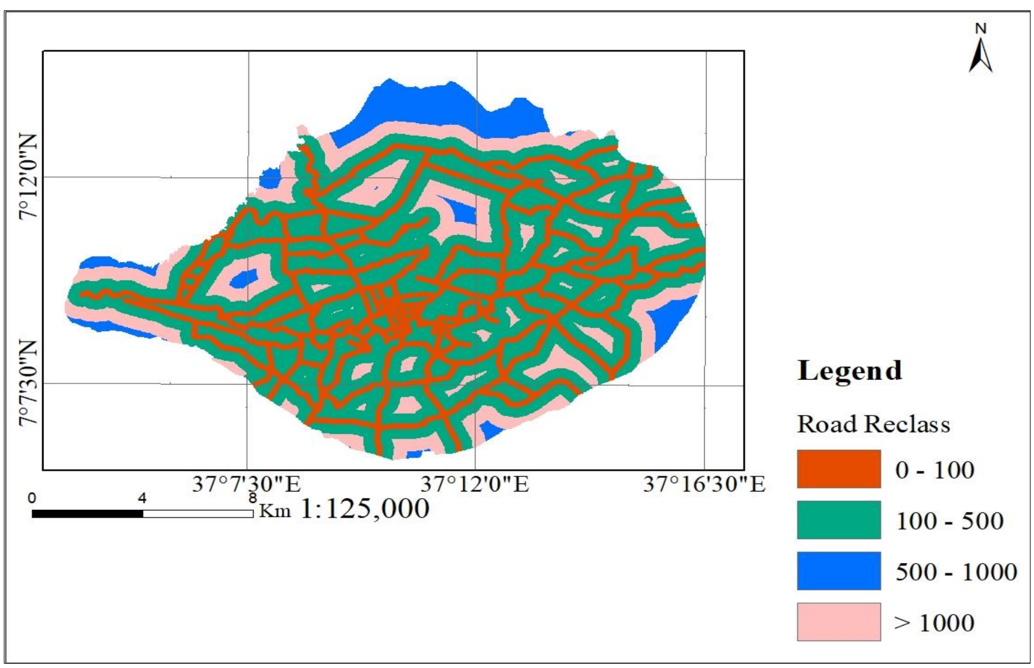


Figure 4.8: Road Distance Re-class map (Author, 2020)

The road Euclidean distance was reclassified based on the fact that very close and far away sites are excluded from the solid waste disposal site suitability analysis. Accordingly, 0 to 100m and greater than 1000m buffer distances were unsuitable and less suitable respectively. But the areas, from 100m to 1000m, were given suitability according to their preference. 100 to 500m radius from the road is moderately suitable site and 500 to 1000m radius from the road is highly suitable site to solid waste dumping. The following Table4.3 summarizes suitability level with their area coverage and weight assigned.

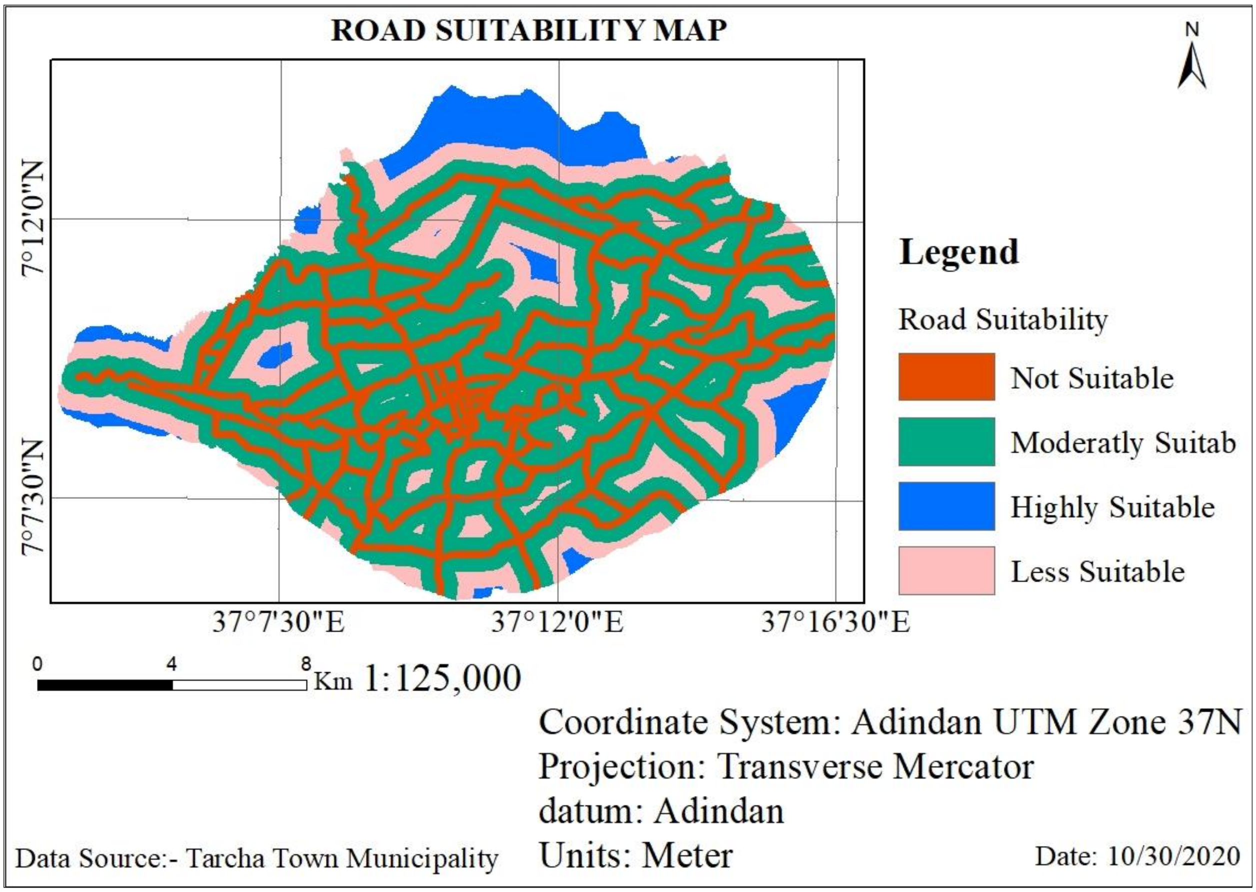


Figure 4.9: Road suitability map (Author, 2020)

In the Table 4.3 the suitability level when considering distance from the main road based above figure4.9 information. The results show that 1618.04ha was high suitable for solid waste disposal site out of the total study area. The moderately suitable area shared 3343.12ha. The less suitable land area accounted for 10778.24ha. The rest area which is 5411.08 ha was evaluated as not suitable for solid waste disposal site.

Table 4.3. Road suitability of the study area

No	Distance in meter(m)	Suitability	Area Coverage (ha)	% of Area Coverage	Rank by Area Coverage
1	0 - 100	Not Suitable	5411.08	26	2
2	100 - 500	Moderately Suitable	10778.24	50	1
3	500 - 1000	Highly Suitable	1618.04	8	4
4	and >1000	Less Suitable	3343.12	16	3
Total			21150.48	100.00	

4.2.4 Urban Land Use

Land use is one of an important criterion in this study for selecting the solid waste disposal site. As it is a matter of considering the high rate of urbanization, the future development plan of the town, current land value and public health concerns are some of the long-term land uses planning to locate the solid waste disposal site. Moreover, the present and future of garbage trucks traffic should be also considered Gizachew Kabite, 2011) cited in Genemo Berisa (2015). The land use land cover was identified to be Agricultural land, Administration area, Recreational(Green) area, service area, cultural reserve land, Forest land, special Function area, Commercial area, Mixed land use, Residential and Manufacturing areas. Usually, land with less political, environmental and socio-economic value or cost is recommended as solid waste disposal site.

The land cover of the town was digitized from Tarcha town new plans sketch and georeferenced to a projection of Universal Transverse Mercator, Grid of UTM Z 37N and datum with Adindan. The land use types were ranked accordingly, on their importance to evaluate suitable solid waste dumping site. In this study the Agricultural land and special Function areas are ranked as a highly suitable, Forest lands area moderately suitable, mixed land use as less suitable, and other identified areas such as near to streams and urban infrastructures are not suitable site to solid waste dumping (see figure4.10).

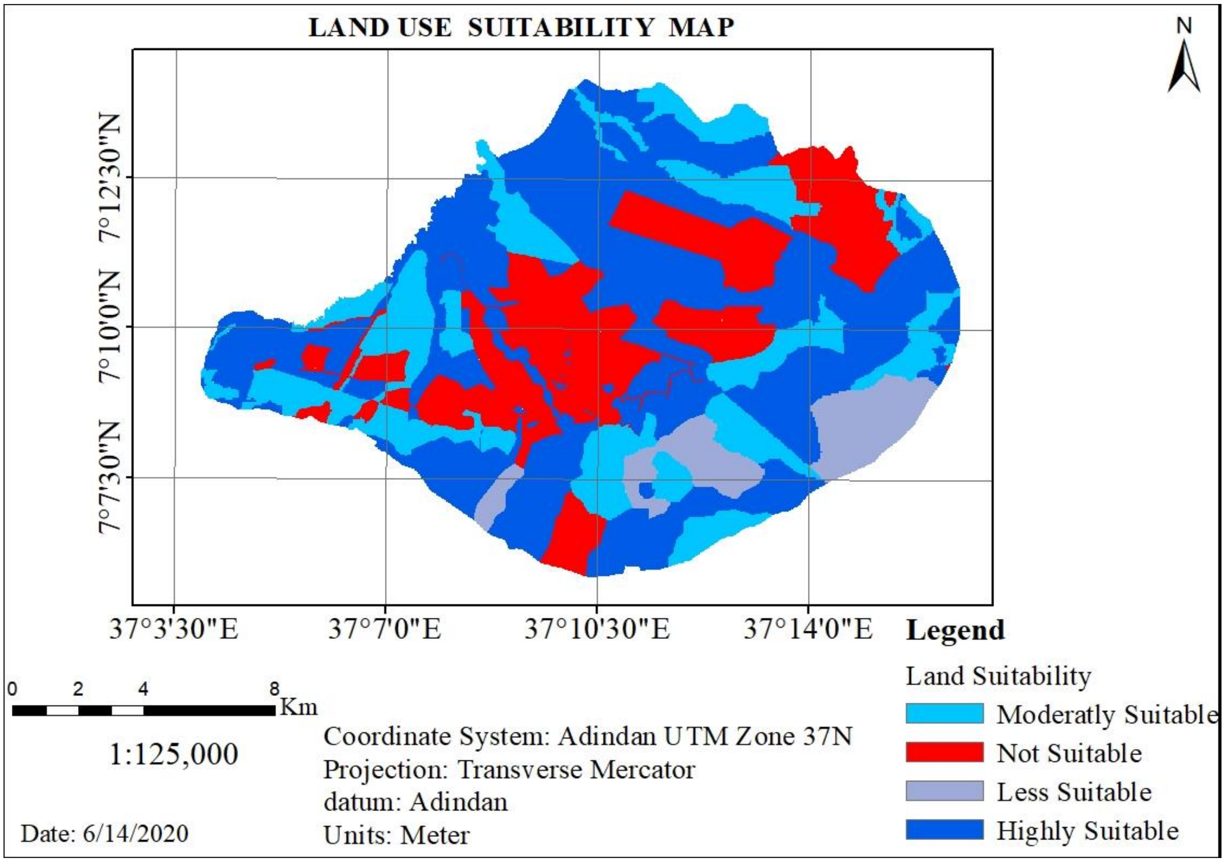


Figure 4.10 Urban Land Use selected Suitability Map

The figure4.10 above show that 3014.84ha was high suitable for solid waste disposal site out of the total study area land cover. The moderately suitable area shared 7007.80ha. The less suitable land area accounted for 4680.80ha and the rest area which is 6446.04ha was evaluated as not suitable for solid waste disposal site (see Table 4.4 below).

Table: 4.4 Land Use Suitability Classes

No	Suitability Level	Area Coverage (ha)	Area Coverage in %	Rank by Area Coverage
1	Not Suitable	6446.04	31%	2
2	Less Suitable	4680.80	22%	3
3	Moderately Suitable	7007.80	33%	1
4	Highly Suitable	3014.84	14%	4
Total		21150.48	100.00	

4.2.5. Land Slope

Slope is topographical factors in determining the suitability of waste disposal sites selection structure integrity, and the flow of floods surrounding a solid waste disposal site. It shows the patterns of land features of the area. The increase or reduce of topography can adverse effects on the environment. This is way it has directly related to site capacity, drainage ways, ultimate land operations and the construction cost. Flat and gently rolling hills that are not subjected to the best sites for waste dumping site; due to water logging problem in downstream surface and ground water pollution. However, steep slope is either not best option for solid waste disposal; because of the difficulty posed in construction or leveling cost, increased risk of landslides and increase leachate movement (Tsegaye, 2006) cited in Kumel Beshir (2014).

Tarcha Town is characterized by Flat topography in the eastern, central, southern, and southwestern. The western part of town has gently rolling topography and the Northern part of the town characterized with rugged land. In this study, slope of the study area was generated from the Digital Elevation Model (DEM) with a resolution cell size of 30m x 30m using Global Mapper19 Software. Then the slope raster was reclassified into four classes of slope percent. Accordingly, 0 to 3%, 3 to 8%, 8 to 15%, and greater than 15% (see figure 4.11).

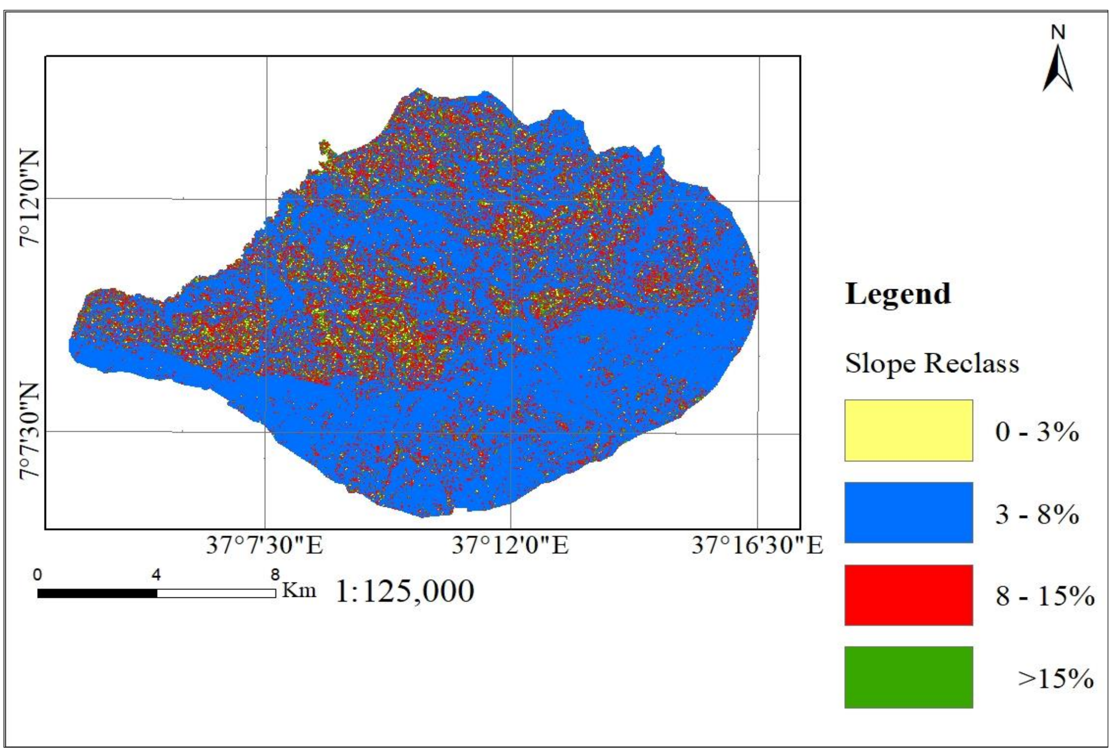


Fig.4.11 Slope Re-class map

According to EMUDC, (2012), the slope becomes steeper (Land with slopes greater than 15%), the area should be considered as least suitable. The type of slope for solid waste disposal site should be gently, less than 10%. But, it is concluded that, the best slope for solid waste disposal should be slopes between 3-15% is found to be an appropriate slope class for solid waste dumping site selection (see figure4.12).

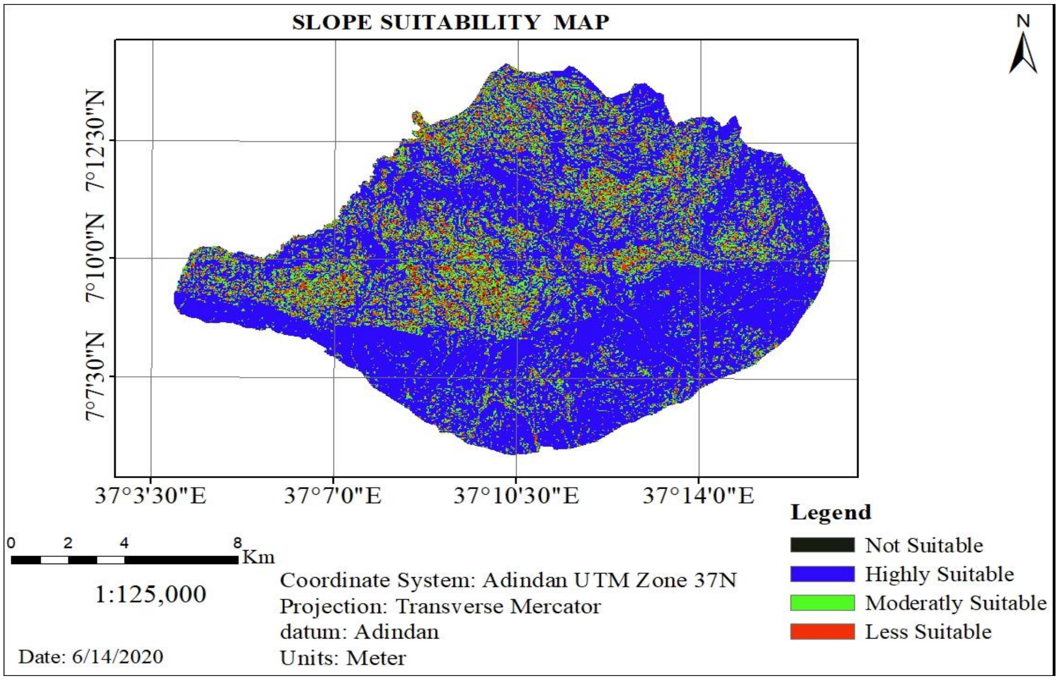


Figure4.12: Slope map of the study area (Author, 2020)

The suitability level of slope in figure 4.12 show, the study area falls under the slope class of 3 to 8%, covering 68% or the majority of study area and 8 to 15%, covering 21% of the study area. Slope >15% covering 9% of the total study area. While slope 0 to 3%, covering 2%. This information shows that most parts of Tarcha town is suitable for solid waste disposal site. Total area coverage and slope classes of the study area are shown in Table 4.6 bellow.

Table: 4.5 Slope Suitability Classes and area coverage of the study area

No	Slope Class	Suitability	Area in (ha)	Area cover (%)	Rank by Area
1	0 - 3%,	Not Suitable	365.20	2%	4
2	3 - 8%,	Highly Suitable	14365.56	68%	1
3	8 - 15%,	Moderately Suitable	4381.26	21%	2
4	and >15%.	Less Suitable	1998.56	9%	3
Total			21150.48	100.00	

4.2.6. Soil Types and it's Characteristics

Soil can vary from place to place due to it's different formation factors. The difference in the nature of soil results difference in water infiltration and holding capacity. The porosity and permeability of a given soil control the vertical as well as horizontal movement of contamination (Tsegaye, 2006) Cited in Minalu Ambaneh, (2016). The soil of the study area is classified in to three major types namely Humic AliSols (19657 ha), Humic NitiSols (174.24 ha) and Lithic Leptosols (1319.24 ha). Accordingly, EMUDC, (2012), "For SWD site selection, the Soil must be above the groundwater's seasonable high table level are relatively impermeable (preferably, less than 10^4cm/s permeability) when undisturbed depth cannot be easily penetrating by water. "

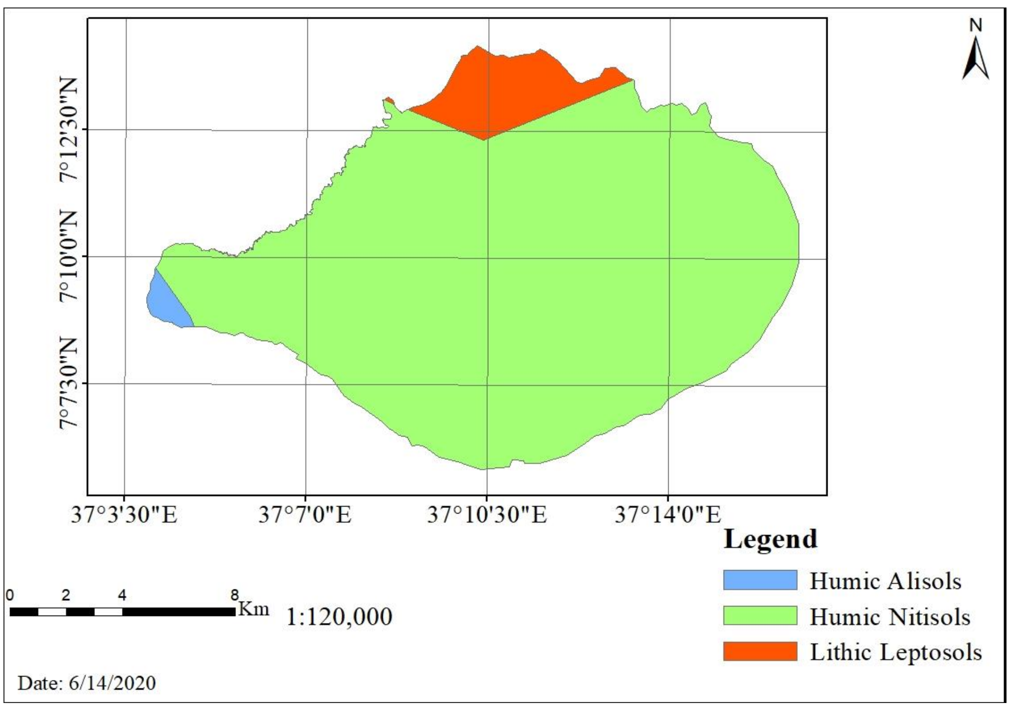


Figure: 4.13 Soil Type of the study area map (Author, 2020)

As shown in Fig:4.13, most part of the study area is dominant Humic NitiSols and the Lesly Western part of the study area is occupied by Humic AliSols. The texture of the Humic AliSols and Humic NitiSols is loam soil. According to the FAO world reference base for soil resources, the Lithic Leptosols is a very shallow soil over hard rock less than 10 cm deep or a deeper soil that is extremely gravelly or stony (GSE, 2011) cited in Minalu A (2016). This type of soil is found in the Lesly Southern part of the study area. The texture of the Leptosols is sandy loam or less developed soil. From its characteristics, the Leptosols is less suitable for MSW disposal site.

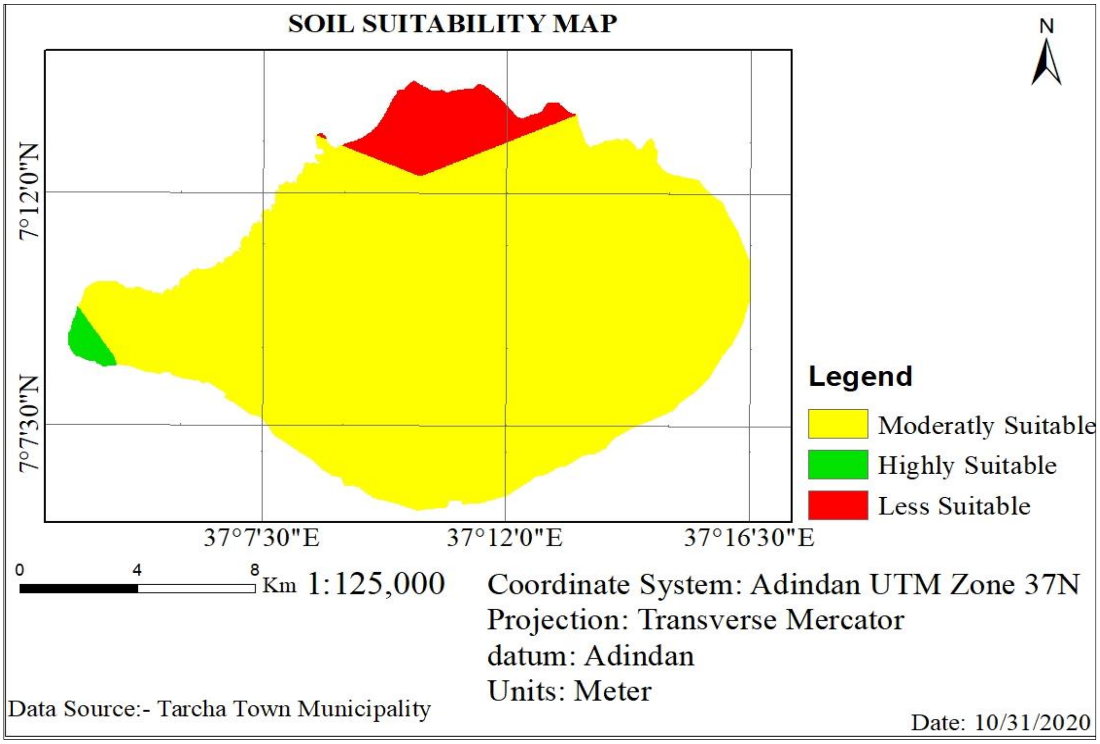


Figure4.14: Suitable soil map of study area (Author, 2020)

Humic AliSols and Humic NitiSols types are covers 1% and 93% respectively. Therefor Humic AliSols and Humic NitiSols are highly suitable and moderately suitable respectively for MSW disposal site and the Leptosols is covers for 6% only as it is Less Suitable (see Table 4.5 blow)**.**

Table: 4.6 Soil suitability of the study area

No	Soil Types	Suitability Level	Area Coverage in (ha)	% of Area Coverage	Rank by Area Coverage
1	Lithic Leptosols	Less Suitable	1319.24	6%	2
2	Humic NitiSols	Moderately Suitable	19657	93%	1
3	Humic AliSols	Highly Suitable	174.24	1%	3
Total			21150.48	100.00	

4.3. Solid Waste Disposal Site Assigning Criteria Weights

The solid waste disposal site selection involves different comparison factors based on environmental, social and economic impacts. In this Study Weighted Overlay Suitability Model were determine suitable solid waste disposal site from several map integration models in GIS. Weighting the different factors in solid waste disposal site selection process is to express the preference of each factor relative to other factor effect on solid waste disposal sitting (Frantzis, I., 1993). The factors and their resulting weights were used as input for the multi-criteria evaluation (MCE) module for weighted linear combination of overlay analysis. One of the most promising is pair-wise comparison developed in context of a decision making process is known as the Analytical Hierarchical Process (AHP) what is a decision-making technique utilized for solving complex problems, with many parameters of concerned criteria.

Accordingly, an IDRISI 17 in AHP, weight can be derived by taking the principal eigenvector of a square reciprocal matrix of pair-wise comparisons of the relative importance of factors to the suitability. 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, 2008) cited in Lamessa K. (2017). The level of each parameter is not equal; some parameters are dominant over others. Different weights can generate the difference in the level of suitability. Accordingly, all possible combinations of two factors were compared based on expert judgment to prepare a pair-wise comparison matrix from which the module calculates a set of weights and consistency ratio. This ratio is very important as shows any inconsistencies that may have arisen during the pair-wise comparison process. The AHP weight derivation interface to derive the weights, with its consistency ratio, for solid waste disposal site selection (Figure.4.15).

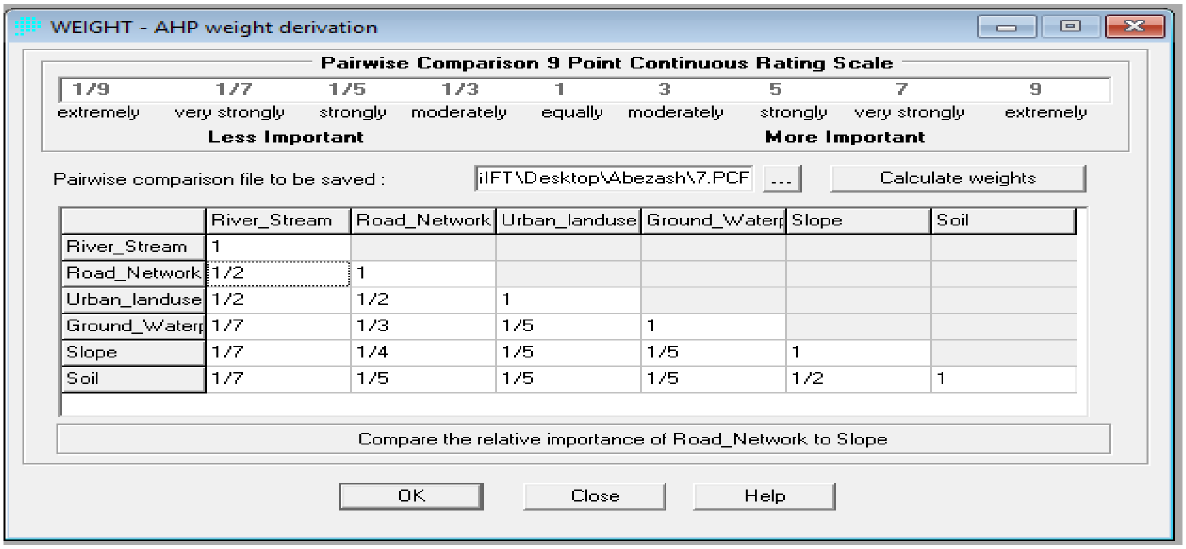


Figure 4.15: AHP weight derivation method of PWC Point Continuous Scale (Author, 2020)

The pairwise comparison matrix consideration is ranked each factor was weighted according to the estimated significance for determining solid waste disposal site. In order to Ranking Method, combine all the layers to process overlay analysis, and standardization to the relative importance has a range from 1/7 to 1; 1 means an equal a very important parameter contribution of the pairwise parameter and A rating of 1/7 indicates that relative to less important parameter (Saaty, 2008) cited in Lamessa K (2017). According to, this AHP weight derivation module, the following eigenvectors of weights for all factors considered for Solid Waste disposal site selection are generated (see Table 4.7).

Table 4.7. Factors and their eigenvectors weights for Solid Waste disposal sitting

Factors	Stream /River	Road Network	Urban LULC	G/Water point	Land Slope	Soil Type	Weight	Percent of Weight
Stream/River	1						0.3820	38
Road N/work	½	1					0.2270	23
Urban LULC	½	½	1				0.2142	22
G/Water point	1/7	1/3	1/5	1			0.1002	10
Land Slope	1/7	1/4	1/5	1/5	1		0.0434	4
Soil Type	1/7	1/5	1/5	1/5	1/2	1	0.0332	3
Total							1.00	100.0

Consistency Ratio = 0.09 <0.1 = acceptable

According to Al-Hanbali A (2011), if the consistency ratio is less than or equal to 0.1, it signifies acceptable reciprocal matrix. The consistency ratio of this study indicated that 0.09 was acceptable. The pair-wise comparison eigenvectors of the AHP weight derivation interface to derive the Weight value provided of suitable solid waste dumping site selection factors shown in Table 4.8 below.

Table 4.8. the Weight of Factors from the pair-wise comparison eigenvectors.

Factors No	Factors	Weight of each factor's	Percent(%) of Weight for each factor
1	Stream or River	0.3820	38
2	Road Network	0.2270	23
3	Urban Land Use Land Cover	0.2142	22
4	Ground Water point	0.1002	10
5	Land Slope	0.0434	4
6	Soil Type	0.0332	3
Total		1.00	100.00

4.4. Solid Waste Disposal Site Suitability Analysis

The Weight of Factors from the pair-wise comparison eigenvectors which analysis in GIS tools and the final map has classified the study area in to the following four classes. This classes rescaling option from 1 to 4 (value 1to Not suitable and 4 to highly suitable). The values 2 and 3 are less suitable and moderately suitable respectively performed. The weight value provided the prioritize factor expressed as a percentage value between 0 and 100%. The result showed out of the total study area 2 %(413.20 ha) fall under Not Suitable area (1) and area which covers 55% (11535.80ha) is under less suitable class (2) for solid waste disposal site. The moderately suitable area (3) covers an area of 42 %(8968ha) and the remaining 1 %(192.68ha) is under highly suitability class (4).

Table 4.9 the Suitability area level and the percent of total area coverage of the study area.

Level of Suitability	Area in (ha)	Percent(%) of Total Area	Rank
Not Suitable	413.20	2	3
Less Suitable	11535.80	55	1
Moderately Suitable	8968	42	2
Highly Suitable	192.68ha	1	4
Total	21150.48	100.00	

According to the stated criteria, suggested suitable areas for solid waste dumping sites fall potentials on the North, North East, North West, and West part of the stud area (Figure 4.16).

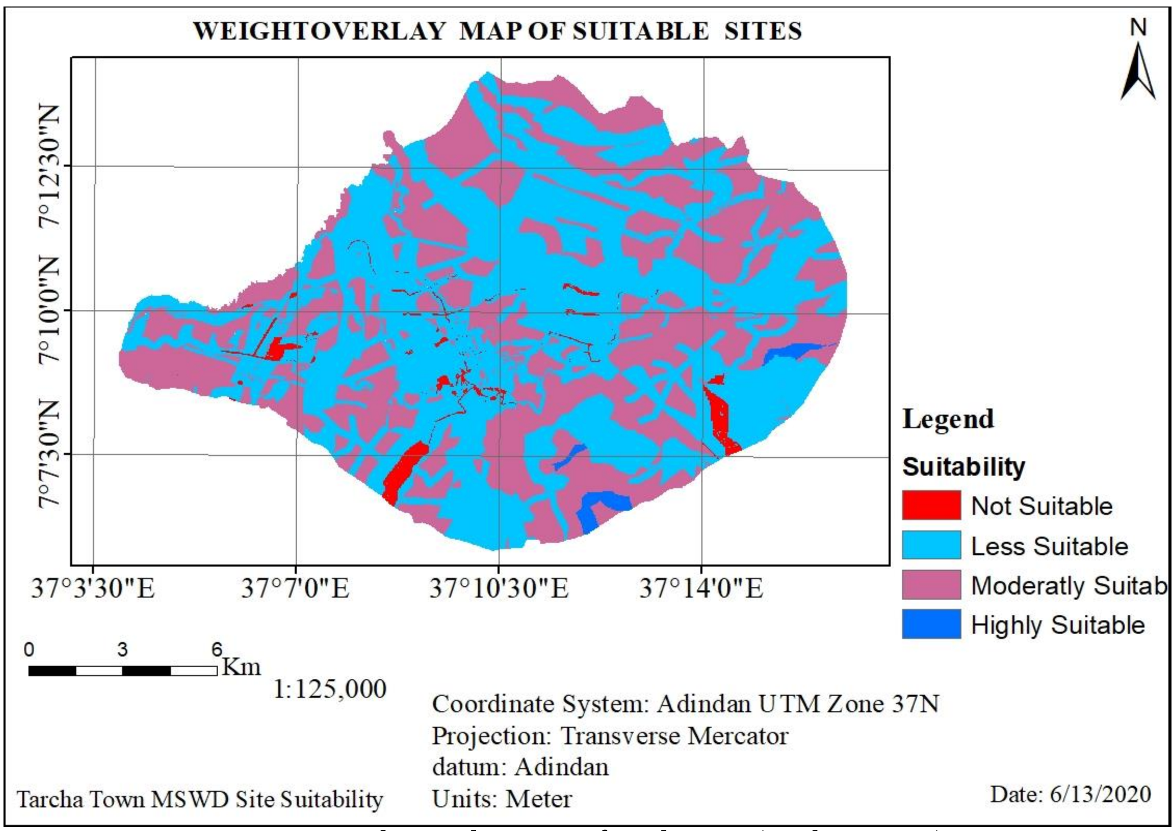


Figure4.16: Weight overlay map of study area (Author, 2020)

The results of the analysis showed in Figure 4.16 that, the suitability level for most of the study area range from moderately to less suitable for solid waste disposal sites except that there is some part of suitable sites that fall in low and high suitability level from those criteria point of views. The Weight overlay map of study area has shown that, three suitable sites from all surface of study area.

4.5. Evaluation of Selected Suitable Sites for Solid Waste Disposal

The Socio-economic criteria like distance from nearby settlements, size of area coverage, distance from the center of the town, the Environmental criteria (surface water), and Economic criteria (access to roads) are the determinant criteria used to evaluate potential solid waste disposal site so as to choose the most suitable site. In this study the three (3) solid waste disposal sites are preferable and selected for further evaluation with criteria of suitable site selection cited in this study. Size of solid waste disposal site is one of the determinant criteria for sustainable solid waste management. From sustainability and economical point of views, larger size of land that will serve for at least ten years are more preferable than small size. This is because selecting large sized solid waste disposal site can minimize the cost of site selection, design and closure that will be performed at the end of its lifespan. Accordingly, the analysis of the suitable solid waste disposal sites in GIS environment, shows that, the suitable site 1 and 2 with area coverage of 111ha and 58.2ha; while suitable site 3 is less area coverage(23.48ha) than site2 and site3.

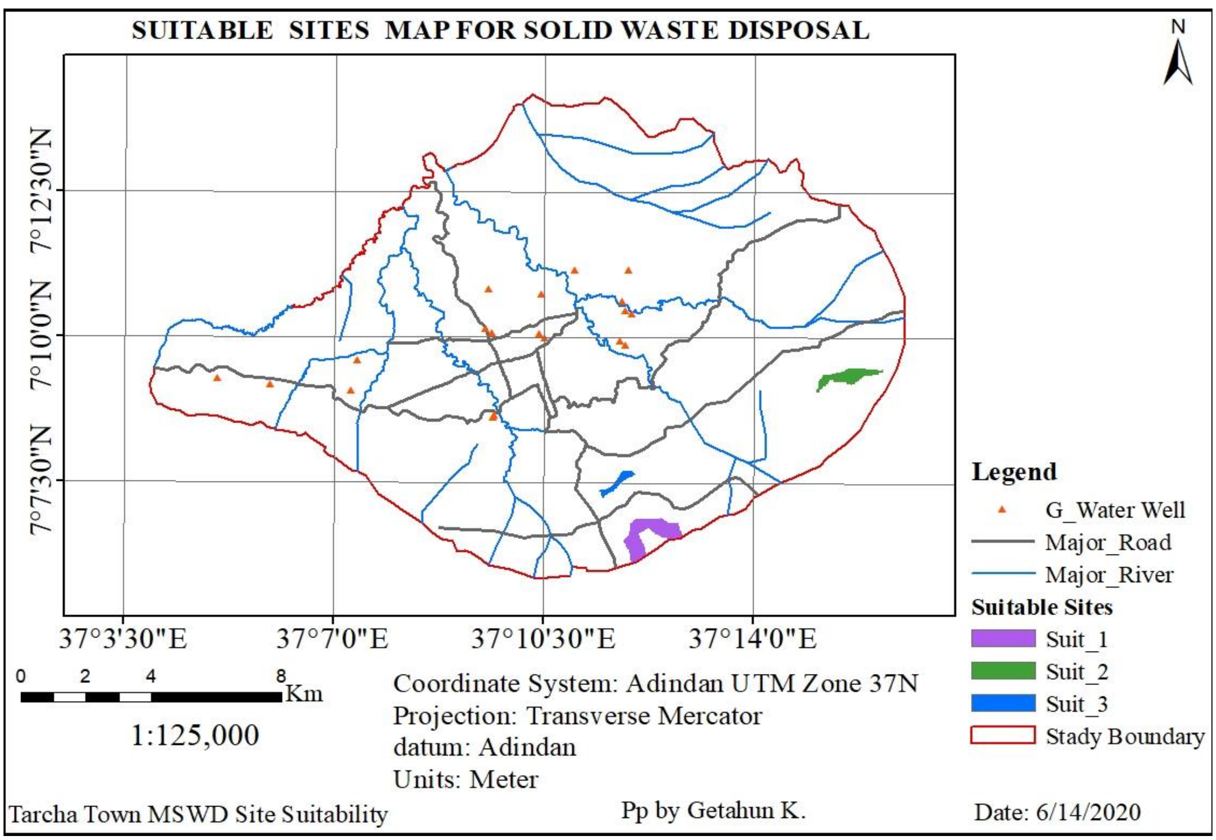


Figure4.17: Suitable sites map of study area (Author, 2020)

Distance from the center of the town is also another very important criterion for evaluating solid waste disposal site from economic point of view. A solid waste disposal site accessible within 30 minutes' travel time (a function of road and traffic conditions) is to be sought, because of the need to avoid adversely affecting the productivity of collection vehicles and transportation cost. Sites close to the center of the town is more preferable than far sites (EMUDC, 2012). Accordingly, the analysis of the suitable solid waste disposal sites in GIS environment, the findings showed that, suitable site 3 is close 3.43km to the center of town than other sites while suitable sites1, and 2 are 6.54km, and 9.35km faraway from the center of the town compared with the suitable site 3. The suitable site 3 is relatively preferable suitable solid waste disposal site from site1 and 2; due to it's closeness to the town center.

In solid waste disposal site selection, the distance from the nearby settlement area is also another very important criterion from socio-economic point of view. Solid waste disposal site should not be located near settlement area as it poses negative impact on human health in urban centers and rural villages (Sener et al. (2011). Accordingly, the analysis in GIS environment show that, suitable sites are ordered by distance from the nearby settlements are site3, 2, and site1 or (0.67km, 2.01km and 2.26km) respectively. Therefor suitable sites according to distance from the nearby settlements, suitable site 1 is more faraway and site 2&3 are following.

Distance of solid waste disposal site from river is also another factor that determines suitable solid waste disposal site. The waste disposal areas should be away from water bodies to protected adverseable environmental effect (Sam and Steven, 2017). As a result, suitability site1 is found in a suitable distance from water bodies by 2.24km than suitable sites 3(2km), and site2 (1.85km) respectively.

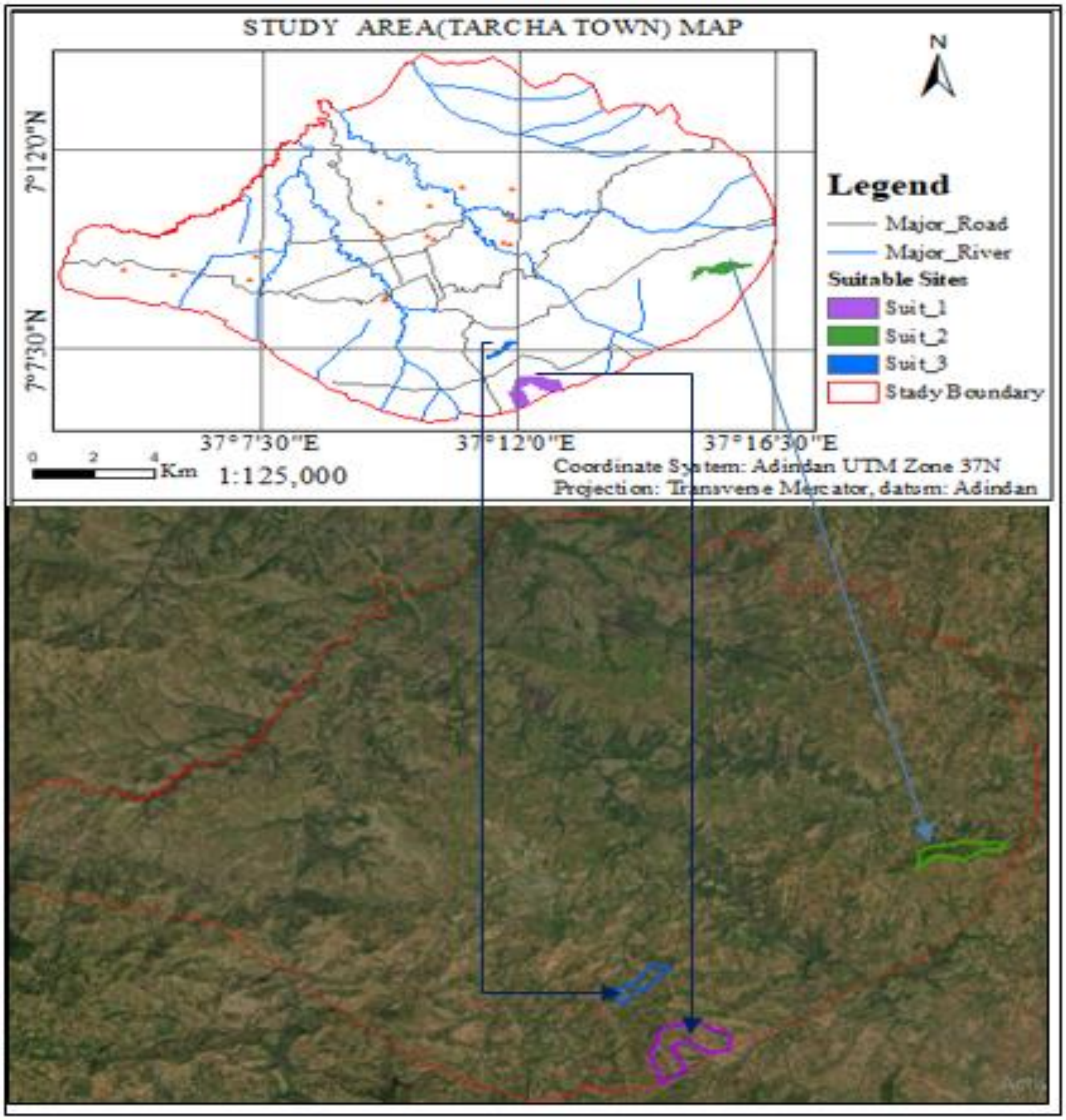
In addition, distance of a suitable solid waste disposal site from the main road is another determinant factor. From the public road into the site, the access road to be constructed should be less than 10 km for large landfills serving metropolitan areas and less than 1 km for small landfills serving secondary cities. 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 to avoid adversely affecting the productivity of collection vehicles and travel time saving (EMUDC, 2012). The analysis of the entire candidate solid waste disposal sites with distance from the roads showed that, suitable solid waste disposal site 1 is 1km optimally preferable compared to other solid waste disposal sites 2 and 3 are faraway 2km and 0.47km respectively with shortest distance following the roads path showed below in table4.10.

Table4.10 Candidate suitable sites with respect to those evaluating criteria value

List of suitable sites	Area (ha)	Distance from town Center(km)	Distance from major road (km)	Distance from nearby settlement (km)	Distance from nearest river (km)
suit-1	111	6.54	1	2.26	2.42
suit-2	58.2	9.35	2	2.01	1.85
suit-3	23.48	3.43	0.47	0.67	2

Therefore, according to the analysis, Suitable Site 1 is the best suitable solid waste disposal site for Tarcha Town from all three candidate sites and the rests suitable site 2 and 3 are the second and third suitable sites; due to its distance from determinant factors, site close to the center of the town, Distance from nearby settlement and area coverages (size of site).

However suitable site 2 and 3 are not the least suitable sites to be used for solid waste disposal site. The suitable site 1 is about 1km close to the major roads, 2.42km away from rivers, 6.54km close to the center of Tarcha town, 2.26km faraway from nearby settlement and it covers 111ha of area (see table4.10 above). The site found in the Northern direction of the study area. the following figure4.18 was indicating the location of the suitable solid waste disposal sites.


STUDY AREA(TARCHA TOWN) MAP
N
Legend
Major_Road
Major_River
Suitable Sites
Suit_1
Suit_2
Suit_3
Stady Boundary
7°12'0"N
7°7'30"N
37°7'30"E
37°12'0"E
37°16'30"E
Km
1:125,000
Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator, datum: Adindan

4.6. Discussion

According to Kumel (2014), states that, many developing countries do not have criteria for solid waste disposal site selections and some have regulations of developed countries without modifying to their local conditions. But the development of engineered solid waste disposals involves really local conditions or criteria and complex engineering design and construction techniques. Sitting criteria for new solid waste disposals is important to ensure that the constructional and operational capabilities of the local communities. According to Seiied (2015), states that, solid waste disposal site selection in an urban area is a critical issue because of its enormous impact on the economy and the environmental health of the region and many sitting factors and criteria should be carefully organized and analyzed.

Therefore, in current study used six site selection criteria including environmental criteria (stream/river water and ground water points, land use), soil types, slope, Economic criteria (access to roads) and the Socio-economic criteria like distance from nearby settlements, size of area coverage, distance from the center of the town are the determinant criteria used to select and evaluate potential solid waste disposal site and prepared to be used in the analysis in ArcGIS 10.3 environment. The final map has shown that, the three suitable sites was selected from all surface of study area. From these three suitable sites; site1 is selected suitable solid waste disposal site for Tarcha town from all three candidate sites and the rests suitable site 2 and 3 are the second and third suitable sites according to the determinant factors.

Accordingly, EMUDC (2012), a solid waste disposal sites are no naturally important area, not municipal or industrial and a minimum distance from groundwater well points are not less than 0.5km. It should be recommended that a minimum distance of 500m buffer maintained for river from suitable Solid waste dumping sites (Sam and Steven, 2017). However, the findings show that, the suitable site1 is 2.42km away from rivers/water points, and site2 and sites3 are faraway1.85km and 2km respectively. According to the review the selected site is the suitable site to solid waste disposal in Tarcha Town.

According to the Indian Government Guidelines for site selection of common waste management facility' prepared Manual Part I (2016), and Integrated Solid Waste administration system and occupational safety control manual for Addis Ababa City (2018), states that, the solid waste disposal sites are not be located an area where the average surface slope is not steep or more flat; must be 300m away from drainage and 500m away from major road; not be selected as environmental sensitive area; and areas greater than 85,000metersquare for storage capacity of solid waste. However, the analyzed result above showed that, from the newly selected suitable Sites, the suitable site 1 is about 1km close to the major roads, it covers 111ha of area; 6.54km close to the center of Tarcha town. The smallest area coverage site 3 is more than 20ha and close from road is more than 0.47km as well as 3.43km far away from the center of the town and the average Land slope of these suitable sites are less than 10%. So as the selected suitable sites are acceptable; because all suitable sites result is above from minimum required criteria set out to solid waste disposal site selection (see table4.10 above).

According to Yenenesh Hailu*, Terefe Hanchiso and Abreham Bereta (2019) stated that a landfill must not be located within 100m Multi-ring buffer zone of any surface streams, lakes, rivers and ground water points. Locating landfill site should not be very near to main road due to public health problem as landfill can have harmful effect to health. Moreover, placing landfill site very far from road network is also not advised because it can hamper transportation and access to the site. Landfill sites are not recommended in proximity to settlement areas. Due to fast expansion of urban settlement, built up area is expanding every time. If waste landfill site is located near to settlements different health problems, like as bad smell, noise, decreased property values and scavenging animal complaints may arise. Landfill site is usually recommended to be one kilometer far from settlement areas. However, the findings of this study show that the closeness distance from the newly Proposed solid waste disposal sites1, 2, & 3 to nearest settlement area is 2.26km, 2.01km and 0.67km and 3.5km, 4.6km, and 3km Multi-ring buffer zoning from ground water point which was greater than a minimum recommended distance to solid waste disposal sites.

According to Minalu Ambaneh (2016), solid waste disposal should be placed away from built-up areas and other social services area. Also MET et al., (2011), states that, the safe distances at least from settlements are determined as 0.40km for urban centers. Otherwise, it can have irretrievable human and environmental effects. Accordingly, the findings show that, the closeness distance from the newly Proposed solid waste disposal sites1, 2, & 3 to nearest settlement area is 2.26km, 2.01km and 0.67km which was greater than a minimum recommended distance to solid waste disposal sites. Therefore, the newly proposed solid waste disposal sites are at safer proximity from settlement areas appropriate solid waste disposal location for Tarcha Town with considering ecological, environmental, economic and social acceptable.

CHAPTER V: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

The open dumps of municipally solid waste, leads to many environmental and public health concerns in study area. The main purpose of this study is locate the suitable sites for solid waste disposal site using GIS and AHP. In this study six important factors (land use type, slope, river/stream, G/water well, road, and, soil types) and the Socio-economic criteria (distance from nearby settlements, size of site, and distance from the center of the Town) are the determinant criteria has taken to select and evaluate potential solid waste disposal site. The findings showed that 0.98% relatively 1% of the entire study area is as suitable to SWD Site. These suitable sites categorized in to three suitable sites (site 1, 2 and 3) with their area coverage of 111ha, 58.2ha, and 23.48ha respectively. Accordingly, the findings of this study showed that, the newly proposed Site1 is the best suitable solid waste disposal site for Tarcha Town among the three suggested sites and suitable site 2 and 3 are the second and third most suitable sites respectively. These Suitable sites are alternatively chooseable in features expansion of the Town. Thus suitable sites also solve the current open solid waste dumping practices in study area. If thus newly proposed suitable solid waste disposal sites should be employed well; that it protect the environmental degradation (air pollution, soil contamination, surface and ground water contamination, etc.,) and save public health from air born, severs of vectors(Malaria), and acute water borne disease accordingly unwise disposal of the solid wastes. Site1 and 2 are found in Northern parts of the study area and site 3 found in North western part of the study area. These sites are far away from determinant factors and easy to access and manage solid waste disposal. Therefore, the Tarcha Town municipality should may use the suggested sites looking appropriately as listed recommendation bellow.

5.2. Recommendation

- All the proposed solid waste disposal sites are more than the minimum requirement for solid waste dumping site selection criteria. According to Land value and transportation cost of solid waste to dumping site, it is possible to choose either of the three proposed solid waste disposal sites. Therefore, the rates of solid waste produced from the Town should be known in order to determine the dimension of the solid waste disposal site.
- The selected Solid waste disposal sites were only for non-hazardous solid wastes. Therefore, the municipality must should be separate hazardous solid wastes from non-hazardous wastes before dumping and should be selected hazardous SWD site.
- The present study considered only some of environmental, social and economic factors for solid waste disposal site selection. Therefore, further study should be recommended in view of highlighting the factors and parameters and combined techniques which missed in this study.

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Annex. A: Ten Top Infectious disease and treated Patients in Tarcha Primary Hospital

No	Disease types	No/ of Patients and other information			Total Patient
		Age < 18	Age b/n 18 &40	Age > 40	
1	Diarrhea	532	420	371	1323
2	Typhoid	620	524	182	1326
3	Malaria	354	245	105	704
4	Amoebic dysentery	468	512	123	1103
5	Giardia	730	437	98	1265
6	Acute febrile illness	968	639	240	1847
7	Eminium speculatum	206	254	64	524
8	Ruta chabepensis	19	26	10	55
9	Urtica pilulifera	45	38	22	105
10	Dyspepsia	220	350	73	643
Total patient					8807

Source: Tarcha Hospital Annual Report of 2018.

Annex. B Existing Solid Waste Dumping Sites Coordinate Points

No	Site Name	Coordinate_X(m)	Coordinate_Y	Elevation(m)
1	Soduwa	296593.455	789942.638	1318
2	Shata	297937.111	789606.187	1376
3	Mehal Meda	297836.569	790214.729	1347
4	Chare	299016.613	790304.688	1375
5	Addis Mender	298556.237	790759.772	1337
6	Bodha	298434.528	791325.982	1310

Field Survey, Author, 2020

Annex. C Ground Water Wells Coordinate Points

No	Water Well Name	Coordinate_X(m)	Coordinate_Y(m)	Elevation_Z(m)
1	WP_1	292538.536	790819.906	1239
2	WP_2	292723.745	791795.559	1218
3	WP_3	290048.372	791042.415	1325
4	WP_4	288413.244	791209.103	1365
5	WP_5	296899.672	789974.164	1290
6	WP_6	299401.485	794638.14	1175
	WP_7	296943.328	790031.105	1284
	WP_8	300969.313	792263.615	1200
	WP_9	301151.699	793239.506	1160
	WP_10	298488.972	792484.939	1220
	WP_11	296855.96	792662.74	1270
	WP_12	300874.768	793645.819	1190
	WP_13	301057.78	794624.511	1266
	WP_14	298393.961	793866.261	1196
	WP_15	296756.848	794041.548	1206
	WP_16	300789.925	792382.682	1200
	WP_17	300972.135	793355.835	1140
	WP_18	298311.172	792603.473	1228
	WP_19	296679.218	792779.157	1260

Field Survey, Author, 2020

Annex. D Newly Selected Suitable Sites Coordinate Points

No	Proposed Site Name	Directions	Coordinate_X(m)	Coordinate_Y	Elevation(m)
1	Suitable site_1	North	301403.169	785562.121	1740
		South	301270.666	786820.9	1680
		East	300873.157	786092.133	1860
		West	302661.948	786622.146	1550
2	Suitable site_2	North	307962.072	791060.999	1920
		South	307763.317	791524.76	1780
		East	306902.047	791326.005	1760
		West	308757.09	791458.508	1820
3		North	300244.894	787449.75	1620
		South	300881.043	788289.466	1600
		East	300117.665	787678.764	1600
		West	301237.286	788187.682	1640

Field Survey, Author, 2020