Geospatial Technology Based Site Suitability Analysis for Abattoir: A Case of Nagele Borana Town, Oromia, Ethiopia

Jateni Molu Liban

A Thesis Submitted to

The department of Geomatics Engineering,

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in

Geo-informatics Engineering

Office of Graduate Studies

Adama Science and Technology University

June, 2022

Adama, Ethiopia

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Declaration

I hereby declare that this Master Thesis entitled "Geospatial Technology Based Site Suitability Analysis for Abattoir: A Case of Nagele Borana Town, Oromia, Ethiopia." The thesis is my original work and has not been presented and submitted to any other university anywhere for the award of any academic degree, diploma or certificate. All sources or materials that I used in this thesis have been duly acknowledged through citation.

Jateni Molu Liban		16/06/2022
Name of student	Signature	Date

Recommendation

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Geospatial Technology Based Site Suitability Analysis for Abattoir: A Case of Nagele Borana Town, Oromia, Ethiopia” prepared under my/our guidance by Jateni Molu Liban submitted in partial fulfillment of the requirements for the degree of Mater’s of Science Geo-informatics Engineering. Therefore, I/we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Tilahun Erduno (PhD) ____	________________	________________
Major Advisor	Signature	Date

Approval Board of Examiners

I, the advisors of the thesis entitled "Geospatial Technology Based Site Suitability Analysis for Abattoir: A Case of Nagele Borana Town, Oromia, Ethiopia" and developed by (Jateni Molu Liban), hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Tilahun Erduno (PhD) ____ ______________________ _______________

Major Advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by Jateni Molu Liban have read and evaluated the thesis entitled "Geospatial Technology Based Site Suitability Analysis for Abattoir: A Case of Nagele Borana Town, Oromia, Ethiopia" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geo-informatics Engineering.

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ACKNOWLEDGMENT

First and foremost, I would like to thanks immensely to Allah for giving me courage, strength, health and patience throughout the complete of all possible to begin and finish my study successfully.

I would like to pass my special thanks to my advisor Dr. Tilahun Erduno (PhD) (Adama Science and Technology University, School of Civil Engineering and Architecture) for his direct supervision, consistence advice, encouragement, invaluable guidance, constructive comments, fruitful discussions on my work and patience during this research. His thoughtful and kind encouragement helped me to learn more and develop my knowledge.

Also, thanks to Mr. Hailu Tare and Bonaya Tuka, Urban land manager leaders, Mr. Doyo Diba and Mr. Nura kete, Environmental protection and climate change management experts, Mr. Abduba Giro and Zerubabel Yewalashet, Urban planning experts all were from Nagele Borana town as all of you being part of this research and provided me your knowledge.

Thank you to the Ethiopian Geological Survey, Nagele Borana town municipality, Central Statistics Agency of Nagele Borana branch, Nagele Borana town Energy and Water resources office for providing me all the spatial and non-spatial data used in this study.

From the bottom of my heart, I would like to thanks for my Wife Gordo Golo, for her supporting and encouraging me day night in my life past and future; your effort that cannot be explain only the word thanks; I love you forever!

Brother Galgalo Dayasa and brother-in-law (Soda) Sora Taro, I would like to thanks for unforgettable supporting and encouraging me during my thesis work.

Brother Mahammad Guyo Shano, I would like to say thanks from bottom of my heart for memorable supporting and encouraging me special during challenge time you're outstanding with me so I haven't word explain your thanks.

My sister-in-law (soddaa) Ware Golo, I would like to thanks for you supporting and heartening me special you advise me as my mother's during sickness challenge faced me.

Lastly and mostly, I would like to thank all of my family father and mother, brothers and sisters; I would not be where I am without your help. I also would like to thank all of my instructors and friends, whom I did not mention their name here, who were always supporting and encouraging me while I was on study during the last two academic years.

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Acronyms

AHP	Analytical Hierarchy Process
CR	Consistency Ratio
DEM	Digital Elevation Model
EIA	Environmental Impact Assessment
EMA	Ethiopia Map Agency
EPA	Environment Protection Assessment
ERDAS	Earth Resource Data Analysis System
ESRI	Environmental System Research Institute
FAHP	Fuzzy Analytical Hierarchy Process
FCC	False Color Composite
GIS	Geography Information System
GPS	Global Position System
LMA	Livestock Market Authority
LULC	Land Use Land Cover
MCA	Multi-Criteria Analysis
MCDAM	Multi-Criteria Decision Analysis Making
MCDM	Multi-Criteria Decision Making
MCE	Multi-Criteria Evaluation
NUPI	National Urban Planning Institute
TFNs	Triangular Fuzzy numbers
USGS	United States Geological Survey
WLC	Weighted Linear Combination

Abstract

The rapidly changing pattern of urban growth is factor that rise new problems for urban planning and development. Land suitability analysis is the process to determine whether the land resource is suitable for some specific uses and to determine the suitability level. Abattoir is urban function that need suitable site to be compatible with the Surrounding geographic features. Hence, this study aimed to select suitable site for an abattoir in Nagele Borana town using geospatial technology based FAHP techniques and multi-criteria decision making analysis methods. Four main criteria namely: geological, environmental, economic and population were identified and split into, fourteen criteria including road, elevation, slope, aspect, existing abattoir site, land use land cover, waterbody (surface water/stream and underground water/borehole), settlement area, high power line, landfill site, geology types, soil types, and population density were considered as criteria factors and eleven constraints namely; administration offices, high voltage station, airport, school, health center, cattle market, military camp, religious area, cemeteries area, and industrial area were identified and prioritized as per judgment of urban planning and land use land management experts. The FAHP derivation showed that fourteen criterion were classified into four pillar such as economic, environmental, geological condition, and population density to derivate there weighted priorities depicted as economic criteria have been highest weighted which (45%) and from the economic factor LULC criteria was ranked highest score (13%) and all criteria consistency ratio were acceptable which means (CR ≤ 0.10). .From final suitability map of study area (11.07%) 4.76 km^2 area was suitable for abattoir allocation. To validate the suitability of the proposed abattoir land use plan of the town, the plan was compared with the final suitability map. The validated result of the study expose 1.59km^2 of proposed abattoir land use plan site_4 high suitable, site_3 (1.06mk^2) moderate suitable, site_2 (0.33km^2) less suitable and site_1 (1.21km^2) as restricted respectively. However, 0.0069 km^2 area covers the existing abattoir site from (43 km^2) areas of study area already developed while 1.21km^2 area was proposed an abattoir land use undeveloped but categorized under restriction areas. Therefore, the final suitability map provides a useful guide for the proposed abattoir land use. The study would support the planning efforts being made to improve abattoir land provision, and also supports the government in formulating effective policies to the context.

KEYWORDS: *FAHP, Geospatial Technology, Abattoir Site, Suitability Analysis, MCDAM, WLC*

CHAPTER I. INTRODUCTION

1.1. Background of the Study

The Abattoir is a place where animals are slaughtered for the purpose of production of meat/protein which are supplied to the public and a service factory place in which cattle and other livestock are slaughtered for conversion into meat (Mamhobu-Amadi, 2019)Abattoir were defined as places where animals are slaughtered for food (LAS99). An abattoir has been defined as a premise approved and registered by the controlling authority for hygienic slaughtering and inspection of animals, processing and effective preservation and storage of meat products for human consumption (Ayling, R.S, 1908) (Codex Alimentarius, 1993). The abattoirs function is produce a good quality meat free from infection at reasonable prices (Mamhobu-Amadi, et, al., 2019). The development of the Abattoir industry varies between countries due to cultural differences, the types of animals slaughtered and wealth. In developed countries such as the USA or the United Kingdom traditional slaughter facilities were small and local to town centers but, in the 20th century they became centralized, large-scale, and mechanized. In developing countries slaughter facilities vary from large abattoir meat processing facilities in cities to small unregulated facilities in rural areas (Elizabeth Anne Jessie Cook, et al., 2017). In abattoir operation, certain prerequisite features have to be considered to provide basic environmental and operating conditions that were necessary for production of nontoxic food. These prerequisite instinctive include good manufacturing practices, good hygiene practices and standard operating system (Enem, S. I., 2017).

Decision making is an important component of investments, logistics, allocation of resources, etc. However location decisions on centralized location for abattoir may be the most critical and most difficult of the decisions needed to realize an efficient waste management system. Sitting abattoir in optimal locations at optimum capacities is a challenging task. Facility location decisions, on the other hand, are often fixed and difficult to change even in the intermediate term. The location of a multi-million centralized abattoir cannot be changed easily as a result of changes in urbanization, transportation costs, or component prices. (Mamhobu-Amadi,et al., 2019).

The establishment of basic facilities and services in cities and neighborhoods is crucial to their sustainability and efficiency. However, the disadvantage of locating abattoir facilities in residential neighborhoods outweighs their advantages. As a result of non-compliance with abattoir laws, residents around abattoir vicinity can be at a greater risk (EPA, 2002). According to Thornton (1968) as cited by (LASISI, 1999) opined that the following conditions are essential for efficient location of abattoir:- Area size to be determined by the size of the available land, the current and projected number of daily kill, adequate parking space and turning allowance for long transport vehicles, buildings, level of intended expenditure and extra land for future expansion, Proximity to the cattle center and meat market, Freedom from human dwelling area such as school, market barns, stores, houses, public offices, hospitals and religious worshipping center, Freedom from laterine, open gutter system and public dumping ground and The place should be screened from public glare by obstacles such as planted trees, fences etc. (LAS99). The numerous waste and microbial organisms obtained during abattoir operation pose a significant challenge to the effective environmental management and are also associated with decreased quality of life of human population residing close to these abattoirs. Air and water qualities within the residential areas are also affected by abattoir activities especially where modern or effective waste disposal system is not practiced (Auwalu Abdullahi, et al., 2015). Urban areas, mainly in developing countries, are growing largely at unprecedented and challenging pace and rapidity by posing serious challenges. Since they are places where challenges and opportunities of development meet, they need to be adequately planned and effectively guided by these plans in order for enabling their expansion, functional specialization and cultural expression and above all sustainability (Engida, 2013).

This growth is associate with increasing pressure on land for human settlements and relates to urban services (Teshome M. , 2O15). Land use planning is to become most complex with a growing desire to integrate the goals related to sustainable development. Thus the modern planning process is evolved into a movement of conflicting and contradicting interests between environmental, economic, and social interests (Abdulnaser Amiin Arafat, et al., 2010).

One of the most useful applications of GIS for planning and management is land-use suitability mapping and analysis. Broadly defined, land-use suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specific requirements, preferences, or predictors of some activities. The GIS-based land-use suitability analysis has been applied in a wide variety of situations including an ecological approach for defining land suitability /habitat for animal and plant species, geological favorability, suitability of land for agricultural activities, landscape evaluation and planning, environmental impact assessment, selecting the best site for the public and private sector facilities, and regional planning (Jacek, 2004).

A different set of problems arises when the present and future location of systems of facilities are considered. Here, all the questions at the single facility-level arise, but also, the facilities complete and supplement each other, so that no two facilities must be too close together, and no client needing service should be too far from the nearest facilities (Aysheshim Melese , 2002)

In the context of land suitability analysis, it is necessary to make distinctions between the site selection problem and the site search problem. Site selection analysis aims to identify the best site for some activity given the set of potential (feasible) sites. In this type of analysis, all the characteristics (such as location, size, relevant attributes, etc.) of the candidate sites are well-known. The problem is to rank or rate the alternative sites based on their characteristics so that the best sites are well identified. If there is not a pre-determined set of candidate sites, the problem is referred to as site search analysis. The characteristics of the sites (their boundaries) have to be defined by solving the problem. The site search analysis aims to explicitly identify the boundaries of the best site. Both the site search problem and land suitability analysis assume that there is a given study area, and the area is subdivided into a set of basic units of observations such as polygons (areal units) or raster. The land suitability analysis problem involves the classification of the unit of the interpretations according to their suitability for a particular activity. The analysis defines an area in which a good site might exist. The explicit site search analysis determines not only the site suitability but also its spatial characteristics such as its shape, contiguity, and compactness by aggregating the basic units of observations according to some criteria (Jacek, 2004). Since the 1990s, multi-criteria decision analysis (MCDA) and geographic information systems (GIS) have been used together as powerful tools to solve some spatial problems in urban planning because of their ability to identify a location using complex criteria. Research regarding land suitability, land use planning, site selection, and disaster mitigation has been widely conducted using GIS-based MCDA (Daniel Hary Prasetyo, et al., 2018).

Land suitability analysis is the process to determine whether the land resource is suitable for some specific uses and to determine the suitability level. In order to determine the most desirable direction for future development, the suitability for various land uses should be carefully studied with the aim of directing growth to the most appropriate sites. Establishing appropriate suitability factors is the construction of suitability analysis (Yang Manlun , 2013).

1.2.Statement of the Problem

In many countries, the abattoirs are not just well managed and the wastes generated are also not treated before disposal. Similarly, the regulatory bodies are never up to their duties to monitor the processing activities and the disposal of the waste. On the other hand, abattoirs could be influenced by certain close-by incompatible activities. Abattoir wastes consist of several pollutants such as faeces, blood, bone, hone, fat, animal trimmings, paunch content and urine from operations, stunning or bleeding, carcass processing and by-product processing (Mamhobu-Amadi, et al., 2019). Abattoirs are a major pollutant of the rural and urban when the slaughter wastes are not properly managed, and especially, discharged into waterways, as such practices can introduce enteric pathogens and excess nutrients into surface water (Ayoade and Olayioye, 2016). (Mamhobu-Amadi, et al., 2019). The activities included in abattoirs pose environmental hazards to the neighboring areas (Dire dawa City Dynamic Planners PLC, 2012). The Abattoir facility has various waste and waste generation points. These are shown as fluid wastes, storm water pollution, solid wastes, airborne wastes, diseases, and noise (EPA, 2002).

Additionally, in Ethiopia some researchers were conducted their study on abattoir suitability site analysis and also these problems stated from abattoir facility on their study including; pollutants from abattoir effects nearby community, affect health and quality of life residents close proximity, around intensive livestock operations, negative effects of gutters and drainages blockage by abattoir waste materials were statistically significant and other waste materials were discharge to the nearby stream without treatment resulting in drainages blockages, pollution of surface and underground water (Aysheshim Melese , 2002; Tesfaye N., 2017; Teshome M. , 2O15).

Finally in Nagele Borana town there was the problem that related with abattoir; the existing abattoir site was not sit on suitable site and it was not constructed with consideration of urban planning, now it come to the center of the town and this was also the problems. Not only this, the existing abattoir site was constructed nearest to the stream, poor standard capacity size, residential/ settlements, nearby others industry area, the waste generated from an abattoir facility was not well managed, the health of community live nearby abattoir facility are affected, there is poor odours smelled from the abattoir facility, facility area do not have fences, the environment disturbed, it was immensely oldest that situated on 1979 E.C in Nagele Borana municipal and it was no existing literature on the site suitability analysis for abattoir establishment in the study area before.

1.3. The objective of the Study

1.3.1. General objective

The general objective of this study is to analysis the optimum suitable site for an abattoir facility at Nagele Borana town based on geospatial technology tools using MCDA method and FAHP techniques.

1.3.2. Specific objective

- ✓ To communicate with the criteria that affect the suitability of an abattoir site.
- ✓ To generate the criteria map of Nagele Borana town for abattoir suitability analysis
- ✓ To calculate weights for the criteria map based on the FAHP method
- ✓ To evaluate the existing abattoir site suitability problems with proposed abattoir area.

1.4. Research question

- ➢ How communicate with the basic criteria that influence the suitability of an abattoir site in Nagele Borana town?
- ➢ What are the algorithms used to produce the criteria map for abattoir site selection?
- ➢ How to calculate weights of criteria priorities for an abattoir site selection based on the FAHP?
- ➢ What are the impacts of the existing abattoir site that considered for proposed new abattoir site suitability?

1.5. Significance of the Study

Firstly, this study would be used to analysis the site suitability of existing abattoir and to propose the new suitable site for Nagele Borana town abattoir facility and also the study findings would be guided the group of people, either directly or indirectly. Secondly, this study would be used to communicate reviewers with in criteria that influence the suitability of abattoir facility of geospatial technology tools. Secondly, the study's final product is a map that shows the suitability of site for an Abattoir area. As a result, urban planners and decision-makers in Nagele Borana Town could use this map as a starting point for deciding which areas abattoirs to be constructed or which area could be suitable for abattoir. Thirdly, if the decision-makers use the result of this study then the investor and community will be benefited. Because, this study was considered physical, environmental, socio-economic, geological, population dense area criteria's and constraints factors for abattoir location. The community will be benefited by getting employment opportunities and maintaining a sustainable clean environment with minimum abattoir pollution and the investor will be profited by the location of abattoir near to road accessibility by reducing the cost spent on transportation of raw materials and finished output. Finally, different researchers may benefit from this research output by using it as a reference for further site suitability studies on abattoir area.

1.6.Scope of the study

This study focused on site suitability analysis for an abattoir using geospatial technology-based multi-criteria decision-making methods and FAHP techniques located on the south-eastern part of Ethiopia at Nagele Borana town.

The geographic scope of this study is delimited to the Nagele Borana Town municipality boundary for the identification of land use suitability for abattoir site. Abattoir site selection was a complex process it requires analysis of different economic, environmental, geological soil, and Constraints factors. Therefore, the thematic scope considered fourteen criteria and eleven constraints for selecting a suitable site for abattoir development such as distance from (major road, the existing abattoir areas, landfill site, high tension line, waterbody (stream and borehole) & geological types, and settlement areas) topographic elevation, aspect, slope, soil type, population density and LULC. Weight was developed for criteria based on the Fuzzy Analytical Process (FAHP). Finally, factors were combined with a weighted linear combination algorithm in Idrisi 32 software.

1.7.Limitation of the Study

The aimed of this study was selecting suitable site for abattoir using FAHP and multi-criteria decision making techniques based on geospatial technology tools. As stated earlier in the statement of the problem section a little study have been conducted in the country regarding abattoir site selection using geospatial technology tools. The researcher health problem was affected on the schedule time proposed to complete the study period. However, this limitation did not affect the result of study.

1.8.Organization of the Thesis

This study was compiled into five chapters. The first chapter deals with the introduction which gives background information about the study, statement of the problems, objective of the study it comprises general and specific objectives, research questions raised, the significance of the study, the scope of the study, limitations of the study and organization of the thesis. The second chapter deals with a review of related literature which includes introduction, definition and concepts of an abattoir area, overview of abattoir in Ethiopia, the concept of geospatial technology, decision support with GIS, GIS and multi-criteria decision making, method of determining a weight for a decision, analytical hierarchy process, fuzzy analytical hierarchy processes, empirical review of related study and lastly conceptual framework of abattoir site selection. The third chapter deals with the materials and methods employed for this thesis research. This embraces; description of the study area, data and software used, the methodology implemented, technical flow chart of the methods and Abattoir site selection criteria and process. The fourth chapter deals with data analysis, result and discussion, which encompasses suitability of economic, environmental, geological and population density criteria and different constraint parameters for abattoir site selection, standardizing factors, calculating weight for main and sub-criteria, weighted linear combination, assessment of the existing abattoir area, validation of the proposed land use plan for abattoir area, and discussion about the finding and result obtained. Lastly, conclusions, and recommendations are provided to improve the analysis of site suitability for an abattoir area for future decisions.

CHAPTER II. LITERATURE REVIEW

2.1.Definition and concepts of an abattoir area

Abattoir are dictionary defined as the word implies slaughterhouse or meat industry that have the similar meaning. An abattoir is a service factory in which cattle and other livestock are slaughtered for conversion into meat. Abattoirs are defined as places where animals are slaughtered for food (Elizabeth Anne Jessie Cook, 2017).

An abattoir has been defined as a premise approved and registered by the controlling authority for hygienic slaughtering and inspection of animals, processing and effective preservation and storage of meat products for human consumption (Ayling, R.S, 1908) (Codex Alimentarius, 1993). The Abattoir is a place where animals are slaughtered for the purpose of production of meat which are supplied to the public (Mamhobu-Amadi, et al., 2019).

Abattoirs often have difficulties in disposing, treating and processing of the wastes in an environmentally acceptable fashion. Due to these reasons, there is high risk of environmental pollutions like underground water pollution, air pollution, nuisance, odour, soil pollution and public health risks through the transmission of zoonotic diseases to humans (Mamhobu-Amadi, et al., 2019), (Auwalu Abdullahi, et al., 2015). The huge amount of wastes generate from an abattoirs and they simply discharge and release their wastes into open environment without any management system or treatment (Fekade, S. T. et al., 2020).

2.1.1. Overview of Abattoir in Ethiopia

Some researchers point out that abattoir activities are causes of the pollution of surface and underground waters as well as air quality which indirectly affect the health of residents living within the vicinity of abattoirs (Tesfaye N., 2017)

There were three abattoirs in 2013, one was privately owned, that were providing slaughtering services to the residents of the city. The main abattoir, namely the Kera Abattoir located in Nefas Silk-Lafto subcity occupies an area of 47,328m^2 and is the oldest of the three. The relatively recent abattoirs, Akaki Kera and Kara Allo, are located in Akaki and Yeka sub-cities respectively.

The main problems related to the provision of abattoir services in Addis Ababa include land use incompatibility, poor waste management and pollution and lack of facilities as well as the proliferation of illegal slaughtering activities (AACPPO, 2017). As (Mustefa Wazir Shafi, 2021) stated that the abattoirs in the country are typically characterized by inadequate waste management facilities, poorly designed and obsolete amenities, unhygienic operations, marshy surroundings due to poor drainages, insufficient government funding, weak policies managements, and environmental pollution particularly of air and water.

The Negative environmental impacts that are anticipated mainly originate from the waste disposed from an abattoir site (Dire Dawa City Dynamic Planners PLC., 2012).

Abattoir activities are one source of pollution since human activities such as animal production and meat processing have been reported to impact negatively on soil and natural water composition and the surrounding environment. These waste streams can be segregated and treated separately (Yunus, 2019).

In Ethiopia, most of the cattle are slaughtered without abattoir area, not only due to religious reasons, but also because of continued traditions and lack of further knowledge about modern slaughter techniques (Gronvall, 2013). Foremost of abattoir facilities in Ethiopia have been lack of monitoring inspection services delivery for customers and lack of control wastes from abattoir site to the surrounding (Abera, 2021).

2.1.2. Environmental Problems Associated with Abattoirs

The characteristics of abattoirs are could be pose serious problems to the environment unless these problems were enough valued and proper measures would be taken. The issue could be examined regarding to liquid wastes, solid wastes, airborne wastes, disease, and noise (EPA, 2002).

Liquid *Wastes:* One essential attribute of abattoirs, in addition to other things, is that they consume spread-out amount of water in their animal processing operation mostly for hygienic reasons. Such circumstance creates an expansive amount of wastewater which must be dispensed.

Effluent Salinity: Effluent created from the dry salting skin protection technique is exceedingly saline, has a high biochemical oxygen demand (VETERINARY, 2007)

Wastewater: Wastewater created in animal butcher areas commonly has a high biochemical oxygen request. It is additionally very saline and has a high level of nutrients, suspended solids, and bacterial pollution (Enem S. I, et al., 2017).

Storm water: Storm water can get contaminated when it comes into contact with animal holding pens, sludge, store, and treated wastewater irrigation area.

Solid *wastes*: Solid wastes produced from inside an abattoir may have distinctive sources Counting animal holding areas, abattoir, and processing areas, waste treatment plants, unwanted hide or skin and pieces, and unwanted carcass and carcass parts.

***Airborne wastes*:** Airborne wastes can refer to smells, tidies (specks of dust), and fuel burning outflows (LMA, 2000).

Dust: a potential source of clouds of dust emissions at an abattoir incorporate unsealed roads, enclosures, deal yards and holding pens, stockpiled products and materials, and construction activities.

Noise: In an abattoir, noise can be produced from various sources including animals, processing activity inside the slaughterhouse, plant machinery, and service vehicles (VETERINARY, 2007).

2.1.3. Land use identifying regulation and control for an abattoirs

Land use plan is the spatial interpretation of the Structure Plan. The different major land use zones are environment (green frame), urban mass transport axes, urban centers, major industrial areas, major street network and major water bodies /swamps are not preferable to abattoir area (AACPPO, 2017). Identification of suitable sites for urban development in hilly areas is one of the critical issues for planning (Mr. Akshay Nidhalkar, et al., 2020). To satisfy the needs of appropriate site in undulating areas, site suitability analysis has become inevitable. An abattoirs are considering that the construction or facilities of abattoirs do not comply with the standards of general abattoirs or simple abattoirs designated by Cabinet Order (Law Abattoir, 2007).

2.1.4. Operations and Requirements of a Standard Abattoir.

The location of abattoir shall be suitable i.e. distant from residential area that will not cause danger, annoyance and damage to the persons and one's property. The location of abattoir shall not be in an area risk of flooding, land collapse, causing construction damages. There shall be enough spaces for lairage, road, parking, office, waste water treatment, and other necessary areas. The road in abattoir area shall be maintained in good working condition and free from dust. Water drainage system shall be in place. The location of the abattoir shall have convenient transportation and adequate public utility. The abattoir shall have fences to protect entrance of person and animals, such as dogs and cats. The abattoir shall not be located in the risk area which can be contaminated with hazardous substances from agriculture and others manufacturing industry (Victor Istifanus and Haruna B. Bwala, 2017). For food safety reasons, the layout of an abattoir must provide for the prevention of cross contamination and adequate separation of incompatible activities. The layout of every approved abattoir shall be such that hanging rail transport for carcasses in the suspended position is provided in such length and arrangement that the total number of animals to be slaughtered in one day can be dressed in one continuous operation without touching or contaminating each other (Law Abattoir, 2007).

2.2. Suitability of municipal abattoirs land and influencing factors

2.2.1. Influencing factors for the suitability of an abattoir areas

Relevant site information should include the closeness to existing and future abattoir developments, and to land zoned to authority abattoir or other land uses not compatible with the proposed development; the site hydrology: flood liability, site drainage and closeness to watercourses and groundwater resources used for domestic, agricultural or town water supply, the prevailing wind conditions, the landform and the likely direction of drift of odour or effects of noise, the adequacy of the land area to house all projected activities, the erosion hazard, the local road network, corridors for power and other services, and suitability of the site for possible land disposal (Department of Agriculture and Rural Development, 2009). The negative effects of an abattoir waste nearby streams without treatment resulting in drainages blockages, pollution of surface and underground water (Auwalu Abdullahi, et al., 2015).

According to (Collins et al., 2001), study states that the complex array of critical factors used for abattoir site suitability drawing from physical, demographical, economic, policies, and environmental disciplines.

(Beyene . M, 2019), was attempted on the related study subject to evaluate the potentiality of land for industrial development by combining spatial and decision making techniques. On this study, researcher was used different criteria that affect the potentiality of land for industrial development these were slope, elevation, and distance from road, landslide, geology, land use, erosion, and distance to river, fault and groundwater.

Administrative and service problems associated with the financial and material capacities of the separate municipalities, abattoirs are located within the municipal boundary. The data on the distance between the abattoir and the various spatial entities is obtained from NUPI (Aysheshim Melese , 2002).

The suitability of topography necessary for construction costs and site drainage, distance to nearest constraints for environmental contamination factor, odour, dust, noise or visual, aesthetic impact, distance to nearest potable water supplies (i.e. artesian, reservoirs, water catchment areas), legal security of an adequate supply of potable water, risk of impacts on groundwater, risk of impacts on surface water quality, access to construction materials (e.g. clay and gravel), absence of archaeological and heritage sites or artefacts, likely impact on threatened or endangered species or ecological communities, risk of flood or bushfire, site access in respect to traffic and road safety, and availability of land and suitability of soil for by-product waste utilization (Peter Watts, 2013)

The criteria that affect the allocation of land, waste disposal and treatment design and construction requirements, of abattoirs should be guided by the standards and regulation of the Ethiopian Livestock Authority. General norms and standards of an abattoirs location are stated as below:

- An abattoir or slaughterhouse cannot be mixed with residence or commerce. This facility should be built only on land reserved for such purpose by the Structure Plan or in industrial zone.
- It should be at least 2km away from sources of water (e.g. deep wells, ponds, lakes, etc.).
- Its location should be against the prevailing wind direction of the town.
- The site should be free from big trees that may harbour scavenging birds.
- It is preferable if the slope is about 5% to protect the facility from rainwater runoff and runoff from the dirty part of the premise.
- It should be accessible at least with a compacted gravel collector road.
- It should be located at least 5km away from runways of airports.
- It should not be located in expansion areas.
- Infrastructures such as water supply, electricity, etc. should be available.
- Minimum 1 – 1.5 (ha) area must be required for small abattoir site standard capacity area (LMA., 2000)& (AACPPO, 2017).

In discussions with resident farmers, MPI, and through information gained from reviewing other feasibility studies, it has been identified that the following considerations need to be taken into account should the project proceed:

- Proximity to cattle: Located closest to the largest supplier of cattle
- Land Ownership: Land could be used 'free of charge' and/or have a pepper corn lease
- Direct road access
- Water availability
- Site size to accommodate plant, a secondary small office building and waste management concrete drying pad and septic system
- Flat, with ideally a gradual slope to enable ease of water drainage
- Suitable distance from other buildings and habitations
- Current usage of site

- Likely level of objections to change of use. Based on the above information it would seem probable that a site on and/or adjacent to the Mabey farm in Okiwi would be a preferred location. An actual site would need further determining (Napier Engineering & Contracting Ltd, , 2014).

Land suitability analysis or assessment is achieved by considering certain criteria of land features such as hydrology, geography, topography, geology etc. in an enabled environment using GIS technologies (Emmanuel C. Chukwuma, et al., 2021).

Land use and land cover:-The differences of the types of land use suitability studies can be credited to the diverse ways the term land use is characterized by different applications and the context of its utilization. Mostly land cover describes as the physical state of the earth's surface and immediate subsurface in terms of the natural environment, (for example, vegetation, soils, and surfaces and ground water) and the man-made structures (e.g. buildings). In addition, the term land use may have a common reference depend upon the spatial scale. At the large scales it is regularly considered as a resource and subsequently land use implies resource use (Chapin and Kaiser , 1979).

Topography: - represents the surface shape and relief of the land. It refers to different landforms (Physical features) which represent to the external shape of the earth. Moreover, elevation, slope and aspect should be considered when selecting site for abattoir construction project (Tesfaye N., 2017).

Elevation: To assess the nature and element of an area making the landscape what areas are appropriate for the determination of abattoir site. It is important to consider the position, angle and stage. As indicated by (Fard, F. A.and Zahraei, S. M., 2012). Abattoirs could be constructed in area lower than the city level to keep the spread of contamination. The elevation classes are evaluated based on the basis of suitability of landscape for urban land use allocation.

Slope: Slope is a vital criteria in hilly landscape for finding suitable sites for urban development. Slope is connected with building cost. Building the abattoir is less expensive on low slope. The slope also closely related to surface drainage characteristics of the site. Desirable slope for abattoir site is recommended to be gently sloping area (LMA., 2000) which ranges from 2 to 10 percent. Slope values less than 2 percent are not reasonable from safe drainage point of view.

Aspect: Aspect generally refers to the horizontal direction of which a mountain slopes faces. It finds the steepest downslope direction from each cell to its neighbors, where, the value of the output raster data set represents the compass direction. Aspect map generally refers to the horizontal direction to which a mountain slope faces (Nayama Valsa Scariah,& M.S.Vinaya, 2016).

Surface water: - Waste water from abattoir is one of the significant source of pollution in river. The wide-ranging amount of water is utilized in abattoir operations. If released to controlled waters it would have an ecological effect by righteousness of volume and quality water run off Pollution and consequent contamination of watercourses. Surface water quality could be influenced by various factors during abattoir operations (EPA, 2002). Abattoir site must not be situated in close proximity to surface water (streams, rivers, lakes, and ocean). In order to avoid possible contamination of river or stream and to keep the abattoir from being overflowed, the site should not lie within 200 meters of rivers or streams (AYSHESHIM MELESE WUBSHET , 2002). The criterion is important from the point of view of both environmental and economic concerns because in addition to causing pollution problems, it may require an effectual drainage system with high expenses (Gemitzi, A.,& Tsihrintzis, V.A., 2007) used minimum of 200 m buffer distance for site selection of abattoir.

Roads: Roads refers to any transportation facility. It is also a critical criteria in site suitability analysis. The need to transport processed meat, remains, slaughter animals, and so on is subject to the nearness to transportation facility. It is fundamental criteria besides the economic or related with the cost of transport facility, all together that at least one sidings might be obtained for bringing animal to the abattoir, to encourage the work of sending away the meat, manure, and so forth (Ayling, R.S, 1908). Besides, keeping in mind the end goal to discover better accessibility to the existing road, buffer zones have been made by taking distances between 20 and 400 meter distance from the existing major road to produce accessibility map (EPA, 2002).

High tension lines: These are power transmission lines. In order to avoid possible accidents that could be encountered as because of big flying birds (e.g. scavengers) floating over the abattoir, the site should be located at least 500 meters from high tension lines.

Abattoir areas: To minimize the effect of neighborhood activities upon the abattoir, polluting industries are considered especially, dust and smoke emitting industries can create chemical and other type of pollution. Abattoir should be situated at least 300 meters from dust emitting industries (AYSHESHIM M., 2002).

Hydro wells: Wells are facilities required by the abattoir in the event that the water supply of the town is not sufficient and they are likewise spatial substances subject to contamination if located close to the abattoir. As per (EPA, 2002) on average, a 300-meter distance should be kept between an abattoir and boreholes with a specific end goal to shield them from being contaminated through ground water stream.

Social services: In order to avoid the disturbance of sounds generated from the abattoir the site should be located at least 300 meters from social services (health services, schools, worship places and recreational areas). Ideally, for site selecting of a slaughterhouse there are no fixed and defined standards in any case, for a large portion of the variables used in the given study, reliable reasons could be found that due to environmental constraints and capability of every area returning of that criteria is a top priority (Fard, F. A & Zahraei, S. M., 2012). In order to locate an appropriate site as a preliminary and starting guideline, the following articles could be followed.

Location in respect to the city: The site location should be inside of the city limit. In addition site selecting must not be on the way of the city development.

Distance to the city: The legal separation from a large slaughterhouse to a town border is around 6 km, for a moderate size one is 3km and for small ones is considered 2 Km.

The position in relation to communication road: The site could be situated close to one of the principal roads or broad link to the arterial road, it is more accurate to choose a place for abattoir close to the major road and if possible make a branch line to be observed.

Prevailing winds: It must not situate on the way of prevailing wind. This may reduce the diffusion of bad smell into the city. The wind direction was considered regarding the prevailing local winds (Adebowale, 2019). The emphasis is on easing conceivable negative effects that the abattoir can pose on the surrounding environment and the vice versa.

Agricultural /Vacant land use: The site should preferably lie on agricultural/empty land use for the purpose of reducing site acquisition cost.

Future land use: The suitability of candidate site for abattoir would at last be assessed taking into account the future expected land utilization of the area.

Required water: It should be developed in area which in the required water can be accessible. Because of high utilization of water, tap water is not recommended. In this task drilling deep or semi-deep wells are favorable.

Location of polluting industries: Abattoir Site should not be exposed to pollution from abattoir operations, dusts, smoke, ash, and so on.

Access to electricity network: In the terms of the necessity of an abattoir to electricity, site selection must be located in a place that the power network is legally permissible and large abattoir required power could be set up by the utilization of a generator rather than power network but it is not suggested except in emergencies (Aysheshim Melese , 2002).

Significant site information should include; the closeness to existing and future housing developments, and to land zoned to allow housing or other land uses not compatible to the area proposed for municipal abattoir development site, hydrology site, drainage and closeness to water courses and groundwater resources used for domestic, agricultural or town water supply, the prevailing wind conditions; the landform and the likely direction of drift of smell or effects of noise, the sufficiency of the land area to house all projected activities, the erosion hazard, the local road network, social services corridors for power and other services; and suitability of the site for possible land disposal (GDARD., 1999).

As stated by (Jacek Malczewski, 2006), the set of criteria that affect the abattoir area includes: protection of groundwater recharge areas, distance to city well heads, erosion-prone area protection, wetland protection, forest interior protection, proximity to surface water, proximity to natural areas, land use protection, protection of property ownership, and visibility of site.

2.2.2. Utilities for Abattoirs

New sites for abattoirs are typically situated on the empty or undeveloped area. In such cases, the dynamic infrastructure, facilities, and utilities must be accommodated for the best possible working of an abattoir. The discussion beneath depends on the guideline provided by (EPA, 2002).

***Water Supply*:** as already discussed, the different operations happening in an abattoir include the utilization of an extensive amount of water.

Power Supply: Among different things, laboratory activities are conducted in an abattoir. In arrange for the laboratory to give consistent services, there ought not to be an interruptible electric supply (EPA, 2002).

Road Accessibility: Access roads to abattoirs ought to be at least compacted gravel road according to the Ethiopian Road Authorities road standard.

Waste disposal and Drainage Systems: It is prescribed that for effective waste transfer and waste system, the topography of the abattoir site preferably be a gentle slope.

2.2.3. Land suitability analysis

The land capability classification system, developed by U.S. soil conservation service, is the oldest and most established system for classifying the ability of land (soil) to support various uses (Shu-Li Huang, 2012). Site suitability is the method of understanding existing site qualities and factors that will determine the location for a particular activity (Mr. Akshay Nidhalkar, et al., 2020). The value of suitability approach to planning of land use and project development was definite as shown by McHarg's suitability approach:

According to suitability approach of (McHarg I.L, 1969), stated that the land-use suitability is the ability or level of land suitable for recommended uses and involves combined physical, socioeconomic, environmental and ecological outlooks which are quantified through set criteria stated. The land suitability term has to do with its features required to support a proposed land use, taking into account social, physical, spatial, and economic factors. The description of land use, at a given spatial level and for a given area, usually includes indicating the mix of land use types, the specific pattern of these land use types, the areal extent and strength of utilization connected with each types. Land use suitability analysis goes for identifying the most suitable spatial pattern for future land use as per determined necessities, preferences, or indicators of some activity (Collins et al., 2001). Land suitability analysis (LSA) is an analysis which is based on a combination of many GIS operations and functions for assessing the land suitability locations for certain developments, in their cases they were used for residential development. Suitability analysis requires clear definition of each individual kind of use to be assessed. The concept of land use suitability is meaningful only in terms of specific kinds of use, each with its own land use needs. The characteristics of the natural environment are compared with the requirements of each use. The output of suitability analysis is a set of maps, one for each use, showing which level of suitability classes each parcel of land contains. Interpretation and analysis of environmental resources are prerequisite to suitability ranking (Shu-Li Huang, 1990). Land suitability analysis is the evaluation and grouping of specific areas of land in terms of their suitability or capability for a defined use (Berhanu Keno Terfa & K.V. Suryabhagavan., 2015).

Certainly, According to (Wang & Hofe, 2007) studies were stated that land suitability analysis examines selected land characteristics to determine the level of suitability and ranks available land accordingly they follows the following eight steps:

(1) Select a land-use type for analysis;

(2) Select factors to be considered and attribute values of each factor;

(3) Determine a score for each factor attribute;

(4) Weigh the factors;

(5) Calculate a composite score from the attribute values and weight it for each factor;

(6) Rank the combined scores to establish suitability levels;

(7) Identify available land-based on existing land uses;

(8) Compare with comprehensive plan, zoning, or other land use controls that further remove unavailable land.

2.2.4. Abattoir Site Selection

Site selection is a critical environmental issue for abattoirs. Careful site selection can greatly reduce the environmental nuisance. The process selection of site means complex multi-criteria analysis which includes a complex array of factors involving environmental, social, economic, technical, and political issues that may result in conflicting objectives (AACPPO, 2017). Abattoirs may be located outside or on the periphery of a city or town and shall be away from an airport. Care should be that are easily accessible to the patrons and do not adversely affect for transport of meat to the market place. In areas expected to be disturbed by construction of the proposed development, the site description should be include data on plants and animals, such as: major plant communities, the status and conservation significance of vegetation, the occurrence of any rare or threatened species, the presence of any introduced species, and the heritage or cultural significance. Ministry of Industry (2015) conducted feasibility studies for selected sub-sector such as coffee processing, corn processing, garment accessories manufacturing, glass packaging, label manufacturing, leather accessories, metal packaging, paper packaging manufacture, plastic and flexible manufacturing, and meat manufacturing. A suitable location for these plants were selected across the country based on a two-stage location and site selection procedure. The first stage involved identifying potential project locations and prioritizing and selecting the appropriate one. Similarly the abattoir plants are incompatible with nearest different urban facility on its relocation. However the abattoir area was located nearby the industry zone in Furi Hana (20ha) being processed. The abattoirs in Yeka and Akaki-Kality sub-cities would continue operation. Moreover, plots would be provided for at least one shoat abattoir together with a shoat market in each Woreda. (AACPPO, 2017). This would be expected to reduce illegal trading and illegal slaughtering along roads and rivers. The project location determining factors considered in the study were the supply of raw material and input, access to market, availability of skilled and unskilled labor, infrastructure such as road, electricity, and telephone line, availability of social service hospital, school, training center residence housing. The second stage of the project location and site selection procedure involved identifying alternative project locations within the selected project location and selecting of optimum project location from the proposed site. From this feasibility study finding, Nagele Borana town was amongst one of the selected town for sub-sector abattoir planting. However, the study emphasizes the selection criteria almost mainly depend on economic, environmental, geological, soil type and population criteria as the main factors for locating a suitable abattoir site. Additionally, the selection process was based on a manual method that was not used any kind of geospatial technology for integrating selected mentioned above criteria factors to support a decision. According to Alvima PLC (2012), a study report on environmental impact assessment of pasta and macaroni project located in Adama Town. The land adjacent to the project site and the neighboring environment were the most impacted area directly or indirectly by the project. Primarily, soils were the natural ecosystem to be impacted by the project. Secondly, there was a landscape form in the project site, which was impacted. To make less severe the listed impact the organization used baseline environmental conditions for the project such as physical environment, biological environment, and socio-economic environment. However, the environmental impact assessment study was conducted after the land for the project was obtained from the Oromia investment board based on a let. This would show that before the allocation of certain urban development, the suitability analysis of selected land was not evaluated in GIS and RS based method. Finally, in the present study, the above-described limitations were used as an input to select a viable site for the abattoir by consistent environmental, geological, population, and economic main criteria factors to find an optimal location for abattoir area using geospatial technology mainly GIS, RS, and Google Earth was used to fill the above indicated manual based selection of land for abattoir.

2.2.5. GIS & Multi-Criteria Decision Making (MCDM)

Identification, appropriateness analysis, and contradictory judgments in comparison analysis are all part of land use planning. Many problems associated with the real world have spatial factors involved in them. With their computational capabilities, MCDM and GIS can address them quickly, implying that they have become a platform for the majority of the problems that are necessary for improved planning. Multi-criteria evaluation which area Multi Attribute Decision Making (MADM) and Multi Objective Decision Making (MODM) are two types of decision making (MODM). The term MCDM is used to refer to both attribute and objective management. The objective of Multi Attribute Decision Making (MADM) analysis is to select the most preferable alternative. To solve MADM challenges, a variety of decision-making procedures can be applied. Additive decision methods are widely accepted to solve the MADM problems along with ideal point methods. Analytical Hierarchy Process (AHP) is one of the additive decision methods, which is used in a lot of real world problems as well as non-spatial problems. Breaking down complex problems into basic forms using a hierarchy or levels system, and then incorporating mathematical calculation for pairwise comparison and normalization to produce priority vectors, also known as criteria weights (Sarath,et al., 2018). AHP measures rely on the judgments of experts to drive the priority of parameters under consideration. The comparisons are made using a scale of absolute judgments that represents how much more one element dominates another concerning a given attribute. The judgments may be inconsistent, and measuring inconsistency and improving the judgments, when possible, to obtain better consistency is a concern of the AHP (Saaty, 1980). The Analytic Hierarchy Process (AHP) was introduced by (Saaty,1980) and is a very popular means to calculate the needed weighting factors with the help of a preference matrix where all identified relevant criteria are compared against each other with reproducible preference factors (Malczewski 1999).

Weighting by Ranking: The simplest method is to rank the criteria in ascending or decreasing order. Ascending means that the most important criterion receives rank 1, the second criterion receives rank 2, and so on until the total number of criteria is reached. The least important criterion receives rank 1 when ranking in descending order, and so on (Flitter et al., 2013).

Weighting by Rating: Another popular method is rating. The ranked criteria are assigned a score based on their respective importance. a) Point allocation: the overall score is to be distributed within the chosen criteria. For example, with a total score of 100, criteria could receive the weights 35, 30, 20, 10, and 5 points with decreasing importance. b) Ratio estimation: each criterion is provided with an arbitrary score from a defined range of values. The most important criterion receives the highest score (e.g. 100) and the insignificant criteria receive a score of 0 (Flitter et al., 2013).

Weighting by Pairwise Comparison: According to Flitter et al., (2013), a pairwise comparison is another method for weighing many factors. It is based on the Analytic Hierarchy Process (AHP), a well-known decision making framework created by an American mathematics professor in the 1960s saaty‘s (1980). This strategy allows you to focus on simply comparing two criteria at a time. As a result, when dealing with a large number of classes, the effort required to compare each criterion with each other grows rapidly (to be exact: with n criteria, there are n (n-1)/2 comparisons). To summarize, many ways of allocating weight to criteria have been presented and discussed earlier. However, as a method, their accuracy and dependability are also very diverse. Furthermore, the three techniques have different underlying scales. They range from ordinal (weighting by ranking) to interval (weighting by rating), to ratio scale (pairwise comparison). While the first two methods lack a theoretical foundation, the last one can be quantitatively validated. Wrong weights lead to incorrect suitability analysis conclusions and, as a result, incorrect judgments

(Flitter et al., 2013). As a result, the focus of this thesis is to identify land use suitability in order to make the best possible abattoir sites decision. Based on the above-mentioned strength toward weighting, weight by pairwise comparison was used to assess the relative importance of the criterion.

2.2.6. Analytical Hierarchy Process

Multiple criteria decision making (MCDM) is a generic term for all methods that exist for helping people making decisions according to their preferences, in cases where there is more than one conflicting criterion. Multi-Criteria Decision Analysis (MCDA) is a set of analytical approaches that aid decision-makers in solving complicated problems by utilizing information provided by the decision-makers. There are several techniques to multi-criteria decision-making that can be successful based on the many concerns. The Analytic Hierarchy Process (AHP) is a decision-making technique for determining the relative relevance of criteria in a given decision-making situation (Hashemi et al., 2017). AHP provides an effective tool to deal with complex decision-making and unstructured problems (Soltani & Marandi, 2011). The AHP is an iterative technique, which consists of a number of stages that can be modified to suit a particular problem (Tsiko & Haile, 2011). It is a tool for evaluating many issues in numerous areas of human requirements, such as political, financial, and several other diverse interests, in order to solve difficult decision problems (Singh Thakur et al., 2018).

2.2.7. Fuzzy Analytical Hierarchy Process

Both FAHP and AHP methods are extremely useful for prioritizing multiple-choice criteria and sorting them into a hierarchical structure. FAHP assesses the relative importance of each criterion and also generates an overall rank of alternatives or weight of factors. In the classic AHP method, the numerical values of linguistic variables are directly used for the evaluation of the criteria. If the environment where the decision-making process takes place is fuzzy, then fuzzy numbers would be used for the evaluation concerning some deviations of the decision-makers (Wijitkosum & Sriburi, 2019). The AHP has been widely used to solve MCDMA problems. Due to the ambiguity and uncertainty in judgments, a crisp, pairwise comparison with a conventional AHP may not be able to effectively describe the decision-makers views. Even while the AHP discrete scale offers the advantages of simplicity and convenience of use, it does not account for the uncertainty associated with mapping one's perception to a number. FAHP is an effective approach for dealing with the fuzziness of data used to determine the preferences of various decision factors (Hatta et al., 2014).

2.3. Determination of Criteria weights in land suitability Analysis.

2.3.1. Fuzzy Analytical Hierarchy Process (FAHP)

The FAHP is an AHP format, which assesses different factors using fuzzy numbers. While AHP is based on using the crisp numbers, FAHP has overcome the imperfections of AHP. Since vagueness is a common characteristic of many decision-making problems, the FAHP technique has been developed to compensate for that limitation (Maddahi et al., 2017). Therefore, the priority weights of each criterion were computed by utilizing the Fuzzy-AHP based methodology in the current study after reclassifying and standardizing the criteria. The comparison of one criterion over another was computed based on previous related research studies and the opinion of different experts. To capture the experience and knowledge of expert's questionnaires were developed in the form of pairwise comparison. Then the collected comparisons through linguistic variables were transformed into fuzzy numbers one by one.

2.3.2. Triangular Fuzzy Numbers (TFNs)

Fuzzy numbers are natural generalizations of ordinary numbers. Triangular fuzzy numbers are frequently used to capture the ambiguity of the parameters which are related to selecting the alternatives (Lee et al, 2013, as cited in Dinade, 2016). In this research study, a triangular fuzzy number was used to rank the suitability of land for industry based on the reclassified value of the map. Triangular fuzzy numbers are expressed with boundaries instead of crisp numbers for reflecting the fuzziness as decision-makers select the alternatives or pairwise comparisons matrix. This property makes FAHP is advantageous over the AHP method for site selection problem.

Table 1 Intensity of TFNs importance.

Linguistic variable	Crisp pairwise value	TFNs	Reciprocal TFNs
Extremely important	9	(9,9,9)	(1/9,1/9,1/9)
Very strong important	7	(6,7,8)	(1/8,1/7,1/6)
Strong important	5	(4,5,6)	(1/6,1/5,1/4)
Moderate important	3	(2,3,4)	(1/4,1/3,1/2)
Equally important	1	(1,1,1,)	(1,1,1)
Intermediate important	2, 4, 6, 8	(7,8,9),(5,6,7), (3,4,5),(1,2,3)	(1/9,1/8,1/7),(1/7,1/6,1/5) (1/5,1/4,1/3),(1/3,1/2,1)

According to Chang (1996), a fuzzy number M or R is called a triangular fuzzy number (TFN), as it is membership function is given by where l is the lowest possible value, m is the middle possible value and u is the highest possible value in judgment interval of decision making.

$$\mu\ddot{a}(x) = \begin{cases} \frac{x}{m-u} - \frac{l}{m-l} x \ \in [l, m] \\ \frac{x}{m-u} - \frac{u}{m-u} \quad x \ \in [l, m] \\ 0 \quad otherwise \end{cases}$$ Equation 2. 1

This approach was adopted for this research, resulting in the uncertain comparison judgements being represented by a special class of fuzzy numbers known as Triangular Fuzzy Numbers (TFNs). When using TFNs, the decision maker‘s judgement is represented as an interval defined by three real numbers or parameters, expressed as (l, m ,u), where is the lowest possible value, is the middle possible value and is the upper possible value in the decision maker‘s interval judgement respectively. Each TFN is associated with a triangular membership function, which describes the TFN domain. Triangular membership functions can be represented mathematically and graphically by Equation (2.1) and Figure (2.1) respectively as follows:

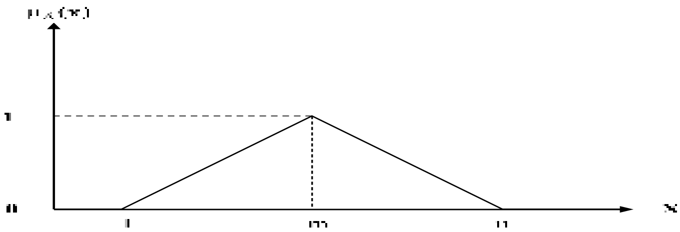

Figure 1 Fuzzy triangular number.

Using Equation (2.1) of the above, TFNs used to represent vague data were then defined in the order .Linguistic variables, which are variables whose values are expressed in linguistic terms, were also used by the decision makers in situations not well defined to be reasonably described by conventional quantitative expressions. In order to utilize TFNs in a fuzzy environment, their basic algebraic operations should be understood. An extensive discussion on these operations can be found in Chang (1996), Kaufmann and Gupta (1988) and Zadeh (1965). However, for the purposes of this research only three operations are illustrated. Consider $that\ \widetilde{M}_1$ and $\widetilde{M}_2$ were two TFNs where; $\widetilde{M}_1$= (l_1, m_1, u_1) and $\widetilde{M}_2$=(l_2, m_2, u_2). The three basic operation used in this study area

$$\widetilde{M}_1 \otimes \breve{M}_2 = (l_1 + l_1, m_1 + m_2, u_1 + u_2)$$ Equation 2. 2

$$\widetilde{M}_1 \otimes \breve{M}_2 = (l_1 + l_1, m_1 + m_2, u_1 + u_2)$$ Equation 2. 3

$$\widetilde{M}_1^{-1} \cong \quad \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l}\right) \qquad \text{Equation 2. 4}$$

Using these three algebraic operations the process of calculating the weights of the evaluation criteria was as follows:

Construct the fuzzy AHP comparison matrix. The aim of the matrix was to clarify an order of preference given a number of evaluation criteria. Central to this is a series of pairwise comparisons, indicating the relative preferences between pairs of evaluation criteria. Since decision makers use linguistic terms or verbal judgements during pairwise comparison, a measurement scale is required to convert these pairwise comparisons into fuzzy numbers by using TFNs, the fuzzy judgement matrices, A$(\ddot{a}ij)$ used to construct pairwise comparisons matrix for Criteria at each level of the hierarchy. In this thesis study, to determine the weight of the criteria fuzzy analytical hierarchy process (AHP) based fuzzy extent analysis method was used.

$$\tilde{A} = (\ddot{a}ij)_{n*m} \begin{matrix} (1, & 1, & 1) & (l_{12}, & m_{12}, u_{12}) & . & . & (l_{1m}, & m_{1m}, u_{1m}) \\ (l_{21}, & m_{21}, u_{21}) & (1, & 1, & 1) & . & . & (l_{2m}, & m_{2m}, u_{2m}) \\ . & & . & . & . & & . \\ . & & . & . & . & & . \\ (l_{n1}, & m_{n1}, u_{n1}) & (l_{n2}, & m_{n2}, & u_{n2}) & . & . & (1, & 1, & 1) \end{matrix} \qquad \text{Equation 2. 5}$$

Where; $\ddot{a}_{ij} = (l_{ij}, m_{ij}, u_{ij}) = (\ddot{a}_{ij})^{-1} = (\frac{1}{uij}, \frac{1}{mij}, \frac{1}{lij})$

The step of chang's fuzzy extent analysis was presented as follow

$$\tilde{s} = \sum_{i=1}^{n} \tilde{a}_{ij} * \left[\sum_{k=1}^{n} \sum_{j=1}^{n} \tilde{a}_{ij}\right]^{-1} \qquad \text{Equation 2. 6}$$

Step 1: normalize the value of row sum, also known as the value of fuzzy synthetic extent where by making use of fuzzy arithmetic operation of the equation. Where *denotes the extended multiplication of two fuzzy numbers. To obtain $\sum_{i=1}^{n} \tilde{a}ij$ the fuzzy addition operation has been applied to the fuzzy numbers in the fuzzy judgment matrices, such that,

$$\sum_{i=1}^{n} \tilde{a}ij = \left(\sum_{j=1}^{n} lj, \sum_{j=1}^{n} mj, \sum_{j=1}^{n} uj,\right) \qquad \text{Equation 2. 7}$$

To obtain $\left[\sum_{k=1}^{n} \sum_{j=1}^{n} \tilde{a}_{ij}\right]^{-1}$ the fuzzy addition operation was applied to column values in the matrix obtained from, followed by computation of the inverse of the resulting vector such that,

$$\left[\sum_{k=1}^{n} \sum_{j=1}^{n} \tilde{a}ij\right]^{-1} = \left(\frac{1}{\sum_{j=1}^{n} uj,}, \frac{1}{\sum_{j=1}^{n} mj,}, \frac{1}{\sum_{j=1}^{n} lj,}\right) \qquad \text{Equation 2. 8}$$

Step 2: This step involved taking two criteria at a time and then using their normalized TFN‘s obtained from Equation (2.6), to determine the degree of possibility of one criterion fuzzy number‘s being greater than or equal to the other criteria fuzzy number‘s ($\tilde{s}_i \geq \tilde{s}_j$). This can be represented by Equation (2.9) as follows.

$$V(\tilde{s}_i \geq \tilde{s}_j) = sup_{x \geq y}[min(\tilde{s}i(x), \tilde{s}j(y))]$$ Equation 2. *9*

This can be equivalently expressed as;

$$V(\tilde{s}_i \geq \tilde{s}_j) = \begin{cases} 1 \text{ if } m_i \geq m_j \\ \dfrac{l_j - u_i}{(m_i - u_i) - (m_j - l_j)} \text{ if } l_j \geq u_i \\ 0 \quad \text{other wise} \end{cases}$$

Where; $\tilde{S}_i = (l_i, m_i, u_i)$ *and* $\tilde{S}_j = (l_j, m_j, u_j)$

In order to compare, $\tilde{S}_i$ and $\tilde{S}_j$, both the values of ($\tilde{S}\ i \geq \tilde{S}\ j$) and V ($\tilde{S}_j \geq \tilde{S}_i$) has been computed. The degree of possibility for a fuzzy number to be greater than n fuzzy number $\tilde{s}_i = (i = 1, 2 \ldots j)$ can be defined by:

$$V(s \geq \tilde{s}_1), S_2 \ldots s_j) = V[(s \geq s_1) \ and\ (s \geq s_2\ ) and \ldots (s \geq s_j)]$$ Equation 2. 10

$$= minV((s \geq s_i),\ i = 1,\ 2, .. j)$$

$$\textit{Assume that } d(\tilde{A}_i) = minV(s_i \geq s_j)\ , j = 1, 2 \ldots n; j \neq i$$

Then the weight vector given by:

$$W' = (d(A'_1), d(A'_2), d(A'_3) \ldots .. d(A'_n))$$ Equation 2. 11

Where $\tilde{A}_i$ were n element via normalizing, the normalized weight vector were

$$W = (d(A'_1), d(A'_2), d(A'_3) \ldots d(A'_n))$$ Equation 2. 12

Where W is non fuzzy number

Step 3: The normalized weight vectors for each fuzzy comparison matrix, $\tilde{A}$, at each level of the hierarchy was determined by normalizing the weight vector, w. In other literature‘s this process is known as defuzification and involves dividing each value in the weight vector, W by their total sum as follows:

$$W_i \frac{V(\tilde{s}_i \geq \tilde{s}_j \quad j = 1 \ldots . n; j \neq i}{\sum_{k=1}^{n} V(\tilde{s}_k \geq \tilde{s}_j \qquad j = 1 \ldots n; j \neq k}$$ Equation 2. 13

Human beings have diverse ways of thinking and making decisions, especially when it comes to determining the suitability of land for various purposes. For example, different degrees of priority are assigned by experts and publications for the identical pairwise comparison of slope and elevation criteria. As indicated in the previous section of this research document weight was determined based on the comparison of one criterion over the other based on literature and expert's suggestion using a fuzzy linguistic variable. Then these linguistic variables were converted into triangular fuzzy numbers. Therefore to overcome the subjectivity limitation of decision making in suitability analysis geometric mean value of different experts and literature suggestions were computed through the below Equation (2.14) then the computed value has been used for final pairwise comparison and weight derivations. Buckley's geometric mean method was used to determine the criterion's fuzzy geometric mean (Mallick, 2021).

$\tilde{r}_i = (\tilde{a}_{i1} * \tilde{a}_{i2} * \tilde{a}_{i3} \ldots \tilde{a}_{in})^{1/n}$ Equation 2. 14

Where $\tilde{a}_{in}$ is fuzzy comparison value of criterion **i** to criterion n, therefore, $\tilde{r}_i$ is geometric mean of fuzzy comparison value of criterion **i** to each criterion, n is the number of involved experts decision-makers and literature suggestion in comparison. Finally, the weights obtained in each hierarchy were combined by multiplying the top major criteria by the lower sub-criteria that were directly related. This was done by multiplying the weight of a factor in the lower level by that of the element/s in the upper level as long as they were directly related as in the hierarchical structure (Dinade, 2016). According to Equations (2.5 and 2.14), the pairwise comparison for major criteria such as economic, environmental, geological and population was matriculated as it can be seen in (Table 2.1).

2.3.3. Consistency Ratio (CR)

The accuracy of pairwise comparisons was evaluated by calculating the consistency ratio (CR) (Abdulhasan et al., 2019). The CR is designed in such a way that if CR < 0.10, the ratio indicates a reasonable level of consistency. However, CR > 0.10 indicates inconsistent judgments (Maddahi et al., 2017). The consistency ratio results tabulated above reveals that each hierarchy level was acceptable for further analysis, which is less than 10%. CR was used to estimate the relative weightings of all criteria on a consistency ratio in which values under 10% are considered acceptable (Abdulhasan et al., 2019).

Table 2 Random consistence index value (RI) (Maddahi, 2017)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0.0	0.58	0.9	1.12	1.24	1.24	1.41	1.45	1.49

$CR = CI / RI$ Equation 2. 15

$CI = \lambda\ max - n / n - 1$ Equation 2. 16

Where: CR- consistency ratio CI - consistency index λ - Average value of consistency vector n - Number of criteria

RI - random index, the consistency index of a randomly generated pairwise comparison matrix, simply obtained from the table of Random Inconsistency Indices (Table 2.2)

2.3.4. Weighted overlay in land suitability analysis

After using the FAHP method to calculate the weights of the criteria in this study, the whole set of criteria maps was superimposed using the weighted linear combination approach (Maddahi, Z., Jalalian, A., Zarkesh, M. M. K., & Honarjo, N., 2017). In this research study to delineate optimal abattoir site standardized factor maps such as major road, aspect slope, elevation, existing abattoir area, LULC, settlement areas, waterbody(stream and borehole), soil type, geological types, high tension line, landfill site and population density were aggregated by using the below algorithm depicted in Equation (2.17) through Idrisi selva software. Forest and water bodies were assigned zero weights, hence these sites are not considered for abattoir development (AACPPO, 2017). Additionally, based on the available literature, rivers/streams and areas within 1000 meters from them were considered restricted for allocating industries (constraint) (Aysheshim Melese , 2002) In the current study, also Water body with in 200m buffer, large trees and area within 500m proximity to heavy power lines were considered as a constraint. The produced constraint maps were combined with a Boolean operation to restrict the overall abattoir site suitability map.

$$S = \sum wi\, xi * \prod cj \qquad \text{Equation 2. 17}$$

Where S is suitability, W is weight of factor i, and x is the criterion score of factor i. C_j is the criterion score of the constraint j.

In Weighted Overlay analysis, a series of tools can complement the Weighted Overlay tool to follow the general overlay analysis steps described above ((ESRI), 2015). The Weighted Overlay tool scales the input data on a defined scale (the default being 1 to 9), weights the input roasters, and adds them together. The more favorable locations for each input criterion will be re-classed to the higher values such as 9. In the Weighted Overlay tool, the weights assigned to the input raster must equal 100 percent. The layers are multiplied by the appropriate multiplier, and for each cell, the resulting values are added together and weighted Overlay assumes that more favorable factors result in higher values in the output raster, therefore identifying these locations as being the best (Baidya et al., 2014).

Overlay analysis always requires many different criteria of a common reference system for analysis. For example, selecting a suitable site for a new abattoir site development needs analyzing of such parameters as land value, proximity to existing utilities, proximity to existing social services slope, and flood frequency. It is impossible to add a raster of land value (dollars) to a raster of proximity to utilities (Kilometers) and obtain a meaningful value.

In addition, the parameters under investigation may not be equally important. It may be that the cost of land is more important in choosing a site than the distance to utility lines ((ESRI), 2020). Some values in a particular raster may be ideal for your purposes (for example, slopes of 0 to 5 degrees), while others may be good, others bad, and still others unacceptable. According to ESRI (2005),

The following lists are the general steps to perform overlay analysis:

1) Define the problem.
2) Break the problem into sub-models.
3) Determine significant layers.
4) Reclassify the data within a layer.
5) Weight the input layers.
6) Add or combine the layers.
7) Analyze. The three main overlay approaches available are Fuzzy Overlay, Weighted Overlay, and Weighted Sum, and each approach has different basic premises and assumptions((ESRI), 2015).

The weighted overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Weighted overlay only accepts integer raster as input, such as a raster of land use or soil types. Continuous (floating point) raster must be reclassified to integer before they can be used. Generally, the values of the continuous raster are grouped into ranges, such as for slope, or Euclidean distance outputs. Each range must be assigned a single value before it can be used in the weighted overlay tool. One can either not worry about the value assigned to each range (but note the range of values the new value corresponds to), and assign weights to the cell values in the weighted overlay dialog box later, or we can assign weights at the time of reclassifying, then with the correct evaluation scale chosen, simply add the raster to the weighted overlay dialog box. The cells in the raster will already be set according to suitability (or preference, or risk, or some similarly unifying scale). The output raster can be weighed by importance and added to produce an output raster ((ESRI), 2015).

2.3.5. Proximity analysis in land suitability

The Proximity toolset of the arc toolbox contains tools that are used to calculate the proximity of features within either one or multiple feature classes. These tools can identify features that are closest to one another or calculate the distances between or around them ((ESRI), 2015). This proximity tool is further classified into two classes based on the types of input data the tool accepts: vector or raster data. The vector-based tools vary in the space of output they create. For instance, the Buffer tool outputs polygon features, which can then be used as input to overlay or spatial selection tools such as Select Layer by Location.

Buffers are created by proximity tools to delineate preserved zones around real-world features or to specify areas of influence. For instance, you might buffer a hospital by two kilometers and use this buffer to select all the people that live within two kilometers and those who live more than two kilometers from the hospital to plan for their transportation to and from the hospital. In the GIS function, buffers can be used to select features from another feature class, or they can be integrated with other features using an overlay tool and find parts of features that fall within the buffer areas ((ESRI), 2020). It is possible to use the multi-ring buffer tools to reclassify the areas around a feature into near, moderate far, and very far distance classes for analysis. Buffers are also used to clip data to a given study area or to exclude features within a critical distance of something from

2.3.6. Boolean overlay in land suitability analysis

Boolean logic which was introduced by the English mathematician and logician, George Boole, generally applies a binary condition to the inputs and evaluates to a binary condition for the output. The Boolean tools evaluate the inputs only as True or False conditions and return the result of the particular tool as a 1 or 0 (True or False) Boolean value((ESRI), 2020). The Combination tools identify unique combinations of input values based on the logic of the particular tool and return a different value for each unique combination. The Relational tools compare the values of one input relative to another and return the result of the particular tool as 1 or 0 Boolean value ((ESRI), 2015). The Logical tools have different ways to apply Boolean logic, such as identifying only the input cells that are No Data or using a logical expression that you define to determine which cells are evaluated as true.

2.4. Geospatial Technology (GST)

Geospatial technology concerned with spatial information about features at a place or, in space, collected in real time. Geospatial techniques is the combination of Remote Sensing (RS), Geographic Information System (GIS), Global Positioning System (GPS), cartography, and spatial statistics that capture, store, manipulate and analyze to understand complex situations of environment and solve the problems for sustainable development.

2.4.1. Geographic Information System (GIS)

GIS is computerized information storage, processing and retrieval systems that have hardware and software specially designed to cope with geographically referenced data and corresponding attribute information (tables, charts and statistics). It is evident that numerous elements must be considered during the decision-making process, making the task of selecting appropriate tools to enable the concentration of data, information, and expertise difficult. New trends in information technologies put Geo-information systems (GIS) in the center of events in abattoir locations science. The siting and placement of a major facility means to satisfy a number of competing objectives and criteria.

2.4.2. Remote Sensing (RS)

Remote sensing is the only means to obtain continuous data over large areas at an effective cost. The products derived from remotely sensed data are typically continuous thematic maps (e.g., land use/land cover). Remote sensing increases the efficiency of the inventory, typically reduces the standard error of the statistical population estimate, and often provides new information, including map products. Using advanced remote sensing data like LiDAR it is possible to make nationwide natural resource inventory in the form of high resolution natural resource maps (T. K. Sen, S. K. Singh, S. Chaterjee, G.P. Obi, P. B. Rajankar and S.N. Das, 2018).

2.4.3. Global Positioning System (GPS)

A GPS is the device, which provides information on the geographic coordinates, altitude, time, direction of movement, the distance covered. Global Positioning System is also called Navigational System with Time and Ranging (NAVSTAR).GPS is the constellation of many satellites. Each satellite receives and stores information from the control segment, maintains very accurate time through onboard precise atomic clocks and transmits signals to the earth (Kushwaha, S. P. S., 2005). Positioning System (GPS), cartography, and spatial statistics that capture, store, manipulate and analyze to understand complex situations of environment and solve the problems for sustainable development. In the study an attempt to analysis suitability of specific area using the application of geospatial techniques in abattoir site selection, analysis, mapping and management (T. K. Sen, S. K. Singh, S. Chaterjee, G.P. Obi, P. B. Rajankar and S.N. Das, 2018).

2.4.4. Google Earth

Google Earth shows the earth as it looks from an elevated platform such as an airplane or orbiting satellite. Most of the high resolution imagery in Google Earth Maps is the Digital Globe Quick bird which is roughly 65cm pan sharpened (65 cm panchromatic at nadir and 2.62 m multispectral at nadir). Google is actively replacing this base imagery with 2.5 m SPOT Image imagery and several higher resolution datasets (Mohammed, et al., 2013).

2.5. Urban Abattoir land suitability index system

The following general principles need to be considered for the urban abattoir suitability analysis index system (LMA., 2000)

1) The evaluation indexes should be a concise and scientific approach. The number of indexes needs to be scientifically set as excessive indexes may result in index overlapping and conflict whereas insufficient indexes may lead to missing of information and thereby wrong decision making;
2) Systematical integrity principle. The indexes should stand independently as well as interrelated to each other and they should be united into an organic evaluative system with the hierarchical order of importance;
3) Comparability, quantification, and feasibility principle. To create a good comparison condition, the indexes must include common features of the evaluative objects under consideration. For a good calculation, qualitative indexes are supposed to be assigned values based on their importance and quantitative indexes can be directly quantified and get their importance score which can be integrated with the former. The feasibility principle needs convenience in the availability and analysis of index data to drive new information for decision support;
4) The principle of objective. The indexes are considered as the fundamental guarantee for an objective under investigation and accurate evaluation

2.6. Proposed abattoir land use suitability validation

Huang et al., (2019) demonstrated that the urban abattoir land suitability analysis is designed to determine and locate the best potential sites for abattoir land planning and it is also aimed to identify the most suitable sites for abattoir development after the land use planning is done. (GDARD., 1999) and (Tesfaye N., 2017) used land suitability analysis for abattoir areas to validate the suitability level of proposed abattoir land use by superimposing the final suitability map with the proposed abattoir layer. Analysis of urban land and identification of optimal areas for future abattoir development is the most important task in urban planning regulations that can be done either before land use planning to prepare land use plan or after the proposed land use is prepared at different time interval to understand the nature and level of proposed land suitability. (EPA, 2002), (LMA., 2000) and (Victor Istifanus and Haruna B. Bwala, 2017) clearly stated that Urban abattoir land use planning by its nature is not a one-time activity. However, it is an ongoing process and should be updated regularly. So proposed land use plan should be timely analyzed and since we are operating in an extremely dynamic environment, the plan should be periodically evaluated and adjusted as the situation on the ground dictates (AACPPO, 2017)

2.7.Empirical Review

2.7.1. Global experience in Abattoir site suitability analysis

This section presents the implementation initiatives and assigns a priority to provide a basis for detailed planning and execution of work elements.

GIS is a computer based system and manages geographic issues, and geospatial data is utilized to analyze in this system (data with its location information, for example, longitude, latitude, height). Choosing an optimal facility location is a multi-criteria decision method, which has been generally utilized in both private and public organizations, with a specific end goal to pick the optimal location and relocate operation sites (Yang and Lee., 1997). Furthermore, along with the advancement of GIS technology, multi-criteria analysis decision making (MCADM) is turning out to be increasingly popular in GIS processing for designing models (Tims, W., 2009). More cases are done by GIS-based technology make GIS become one of the most popular visualization platform site selection studies (Wei., 2008). As said above, both remote sensing and GIS techniques are perfect tools for site selection and land use by managing them accurately and efficiently. In this study, GIS and remote sensing technologies were employed to identify new potential areas to plan abattoir industry in study area and provide an up-to-date geodatabase to assist abattoir security. One of the primary materials in abattoir industry site selection is availability of an up-to-date land cover map. Improving the accuracy of land cover maps would be very significant because these thematic maps are primary sources in many applications such as site selection, management of natural resources, urban planning, etc. The advantage of using GIS-based MCDMA is that it is an open and resettable analysis process. The weights can be changed by the time in different situations, and determine of weights is changeable during different situations as well. The more important purpose behind using MCDMA to do the optimal site selection is the result can be directly used for making a decision in the next researches or upcoming cases.

(Sarath et al., 2018) had presented the combination of a Geographic information system (GIS) and multi criteria decision making (MCDM) to identify distinctly the suitable zone for industries. Six criteria that were used by the researchers for analysis of land suitability for industries sites are LULC, flood, geology, road, DEM and slope. To develop the importance level of criteria for industry location they implemented AHP based pairwise comparison. The high and lower weight were assigned to geology and road respectively. For criteria standardization, they used simple linear transformation by allocating a score value of 1,2,3,4, and 5 for the consecutive influence from unsuitable to highly suitable. Finally, for aggregation of these criteria, they used weighted linear combination methods.

2.7.2 National experience in Abattoir site suitability analysis

The FAO classification model for land suitability index is widely used in the studies of land suitability analysis ((AACPPO, 2017), (Aysheshim Melese , 2002) (Teshome M. , 2O15) (Tesfaye N., 2017). For each criterion, a suitability score was applied using a four-point scale to determine the qualitative rankings of the suitability on each criterion under consideration. The ranking ranges from 1 (unsuitable) to 4 (high suitable). The scores understandable well since the higher the score, the more suitable the site is. Suitability classes are given below: Unsuitable (1): This is attributed to areas with characteristics imposing certain constraints or restrictions, which cannot be overcome or legally excluded for the development of abattoir areas. Moderate suitable (2): areas moderately appropriate for abattoir development. It represents sites with good conditions in relation to a low suitable site, but it needs some improvements to make it better conditions. Suitable (3): it denotes sites with good characteristics but may be slight challenges to develop abattoir areas which can be overcome by least investment. High suitable (4): This is attributed to areas with characteristics imposing no significant constraints for future abattoir development. Optimal lands for the development of areas for abattoir activities.

According to (Tesfaye N., 2017) study entitled “GIS-Based Multicriteria Decision Making Analysis For Abattoir site in Ethoipia, a case of Shashamane town.” Suitable areas for the industry can be selected by seven parameters measured as independent variables such as distance from stream, distance from borehole, distance from constraints areas, land use land cover, distance from urban area, distance from high power line, and proximity to main roads. In order to overcome the uncertainty and flow that originate from Analytical Hierarchy Process (AHP) during the decision-making process Fuzzy Analytical Hierarchy Process (AHP) was employed as a technique for distributing weights. The final result obtained from the analysis depicts that the study area fell under five categories such as exclusively suitable, less suitable, suitable, moderately suitable, highly suitable and extremely suitable and its corresponding study area coverage in percentage was 25.0, 13.5, 15.9, 22.4, 18.0, and 5.2. (Aysheshim Melese , 2002), have been produced a GIS-based model to screen the most suitable location for abattoir site in Ethiopia a cases of Kilito sub-city. As a methodology, initially they used seven sets of criteria that were identified through literature review and consultation of experts including; Land use, water, soil type, wildlife, airport, roads and power line were the selected criteria. For deriving the weight for the criteria, they used AHP methods. The (AACPPO, 2017) is indicates as the minimum requirement for site capacity abattoir was 1 – 1.5 (ha) and they developed a 100 m buffer zone (green belt) for the final suitable zone to minimize the pollution of abattoir area. Lastly, they classified the finding into very high, high, moderate, less suitable and not suitable. Besides to criteria selection limitation of this study also had a strength and the main strength of this study was the inclusiveness of green belt assessment in a final suitability map to minimize the pollution of any industry.

The overall global empirical study related to abattoir site selection reviewed under the present study was summarized in (Table 3).

Table 3 Summarization of experience in abattoir and related industry site selection

No	authors	criteria	methods	country
1	E.C.Chukwuma, et al., (2016)	Settlement, waterbody, slope, elevation, LULC, waste water, etc.	GIS	Nigeria
2	(AYSHESHIM M. , 2002)	Settlement, waterbody, slope, elevation, landfill, high tension line	GIS,	
3	Tesfaye.N., (2017)	Settlement, waterbody, slope, elevation, landfill, high tension line	GIS, AHP, WLC	Ethiopia
4	(TeshomeM.,2O15)	Settlement, waterbody, slope, elevation, landfill, high tension line,	GIS, AHP, WLC	Ethiopia
5	(Watts, 2013)	Road, slope, water surface and ground water, residents	Report on feedlot	Australia
6	(EPA, 2002)	Ground water, main road, stream and river,	Guidelines report	
7	(Abushnaf et al., 2015)	Geomorphology, land cover, ground water, main road and river	GIS, AHP, WLC	India

8	(AACPPO, 2017)	Slope, geological fault, surface water, land use, urban area, and pathway, settlement, soil types etc.	guideline	Ethiopia
9	(Sarath et al., 2018)	LULC, flood, geology, road, settlement area, DEM & slope	GIS, AHP, WLC	India
10	(Fernando et al., 2015)	Power line, road, archeologic site, soil, wildlife, water &LULC	GIS, AHP, WLC	Srilanka
11	(Auwalu Abdullahi, et al., 2015)	Urban area, landfill site, heritage site, airport, river, rural area, industrial area, slope, natural resource, railway, LULC, oil pipe& highway	GIS, AHP, WLC	Malayisa

Finally, as shown in (Table 3) many studies and researches were undertaken at the worldwide level to identify ideal places for the abattoir industry. However, the methods for analyzing independent parameters for final conclusions differ from one researcher to another. There is no universal buffer distance standard for pre-analysis of criteria for decision-making, such as proximity to a road, river, urban area, railway, power line, degree of slope, and existing abattoir. Each researcher utilized a different distance. This property makes on industrial site selection is subjective for instance ((AACPPO, 2017), (Aysheshim Melese , 2002), (Tesfaye N., 2017), (Auwalu Abdullahi, et al., 2015), were used different buffer distance reclassifications intervals. To overcome the subjectivity of abattoir sites selection distance analysis, a new methodology was adopted in this study, which involved taking the average proximity distance of criteria utilized by various researchers as described above. Furthermore, the empirical research shows that road networks, waterbody, topographic slope and elevation, LULC, geology factor and AHP method are the most commonly employed criteria for abattoir site selection.

2.8. Conceptual Framework of the Study

Conceptual framework is summarized how all reviewed literature under this chapter is contextualized to the present study in order to formulate the framework for demarcating land for abattoir site development. Demarcating optimal sites for abattoir development was a complicated process it needs data from the diversified socio-economic, environmental sensitive and geological fields. As indicated in the empirical review part, a few studies have been conducted in the field of abattoir site selection and the most common frequently used independent variable which affects the suitability of land for abattoir development by all scholars are road network, topographic slope, aspect, elevation, Land Use Land Cove (LULC), geological factors. So depending upon the literature, suitability type and study area, major road, elevation, aspect, slope, existing abattoir area, LULC, waterbody (stream and borehole), settlement, landfill site, high power line, geological types line, population density, and soil type independent variable were identified for the current study to enhance the suitability of abattoir sites (dependent variable) by agreeing these factors based on geospatial technology. Therefore, it has been applying in various filed of suitability for instance in the field of abattoir site selection the different researchers applied this technology. Suitable abattoir site selection was not only dependent on independent thematic map criteria but also it is dependent on different moderator variable, which includes spatial analysis, classification, buffer, and geospatial technology and weight allocation. Suitable site selection for the abattoir site is sensitive to the weight influence assigned for factors. Defect and ambiguity were the common characteristics of decision-makers in suitability analysis that was affect the weight influence factors for final decision. Thus, in order to avoid vagueness in the decision making process, the weight was critical and necessary established based on Fuzzy Analytical Hierarchy Process (FAHP). The overall summarized conceptual framework of all reviewed literature under this chapter is contextualized in the current study for selecting suitable land for abattoir site development was shown in below (Figure 2)

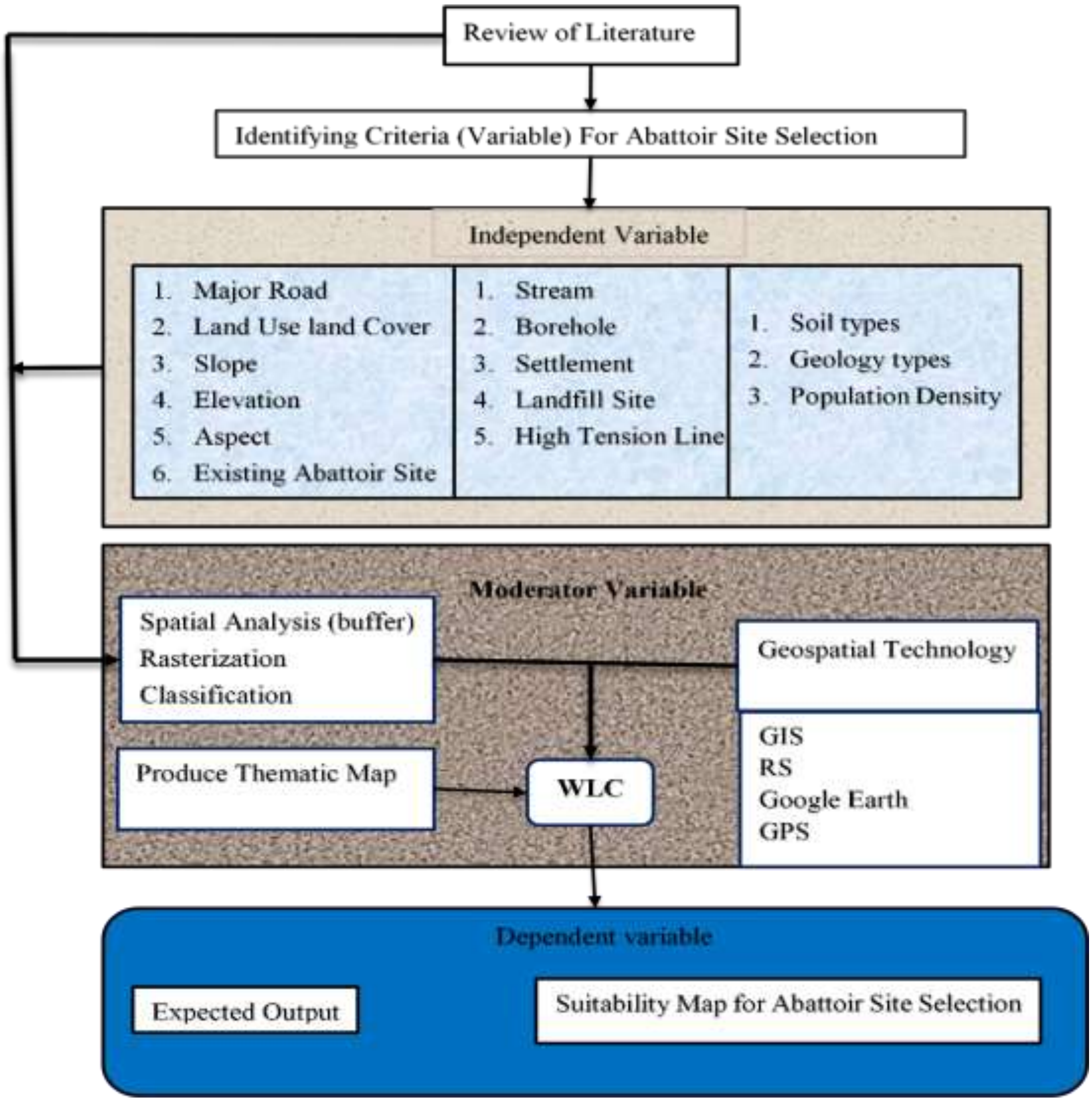

Figure 2*:* Conceptual framework of suitable site selection for abattoir

2.9.Research Gap

Most previous studies were focused on municipal abattoir operation and waste management practices, the hygiene of meat and byproducts, and the majority of cattle diseases in Ethiopia and the world at large. Only a few studies have used the application of GIS for urban planning in Ethiopia with particular reference to abattoir site suitability analysis. For instance (Aysheshim Melese, 2002) studied on the abattoir site suitability analysis for kulito town. His study was mainly based on the urban planning institute experience for abattoir area. However, the study should not considered the multi-criteria decision making analysis and FAHP method. In addition (Tesfaye N., 2017; Teshome M. , 2O15) were studied on Abattoir site suitability analysis by considered multi-criteria decision making techniques on Shashamane town and Wolaita soddo town respectively and both were used Analytical hierarchy process, spatial multi-criteria decision making and weighted linear combination method. But, there were not considered uncertainty and imprecise of idea solution. However, this study would be considered about the uncertainty and imprecise idea solution for abattoir suitable site selection using integration of fuzzy and analytical hierarchy process. As can be noted like most spatial decision-making problems, the land allocation problem associated with an abattoirs is multi-criteria in nature, involving economic, social, environmental dimensions. Moreover, the pattern of geographical features varies from place to place and time to time by nature and artificially. The Nagele Borena town, was different from Shashamane town and wolaita soddo town. Thus, the criteria applied for site suitability analysis of abattoir in Nagele Borena may not be similar to Shashamane town and wolaita soddo town. This study area also varies in slope, elevation, altitudes and geographical location would be difference from those mention town. In addition to this in Nagele Borena town there was the problem that related with abattoir; the existing abattoir site was not sit on suitable site and it was not constructed with consideration of urban planning and it is now come to the center of the town and this was also the problems that seen on the site. Not only this, the existing abattoir site was constructed immensely oldest that situated on 1979 E.C in Nagele Borana municipal when the town stated under borana zone and now a day in the center of the town. There were no existing literature on the site suitability selection for abattoir area in this study area before. The role of geospatial technology was prime importance to make numerous types of work more productive and works most viable; FAHP method was empowers better decision making support and it was used to light data for better analysis. Therefore, this study would be filled the gap and focus on the selection of the appropriate site for an abattoir area in Nagele Borena town considering sustainable development of the town. Not only this, the most of all previous studies did not considered the validation of suitability index of their analysis by comparing with proposed land use plan of their study areas which would have prepared by authorized body for city's spatial development and regulation. From principles of land use suitability analysis, the final results of suitability analysis for land use should be compared with proposed land use plans, comprehensive plan of land use controls that further gives detail pictures of land use control tools and remove unavailable land. This research tried to fill this gap of knowledge by comparing the final suitability map with existing proposed land use plan to validate its suitability. This is not experienced well before in suitability analysis of abattoir land uses for some particular purpose.

CHAPTER III. MATERIAL AND METHODS

3.1.Description of Study Area

3.1.1. Geographic Location

Nagele Borana is a town and separate woreda in southeastern part of Ethiopia. Located in the east Guji Zone of the Oromia Region on the road connecting Addis Ababa to Dolo Odo, it is the largest town in the region traditionally inhabited by the Borana Oromo and nation, nationality peoples of Ethiopia are tolerantly live together. It has a latitude and longitude of 5°20′N 39°35′E coordinates; with maximum altitude of about 1,591 meters above sea level. Nagele borana town is 610 km far from capital city of Ethiopia.

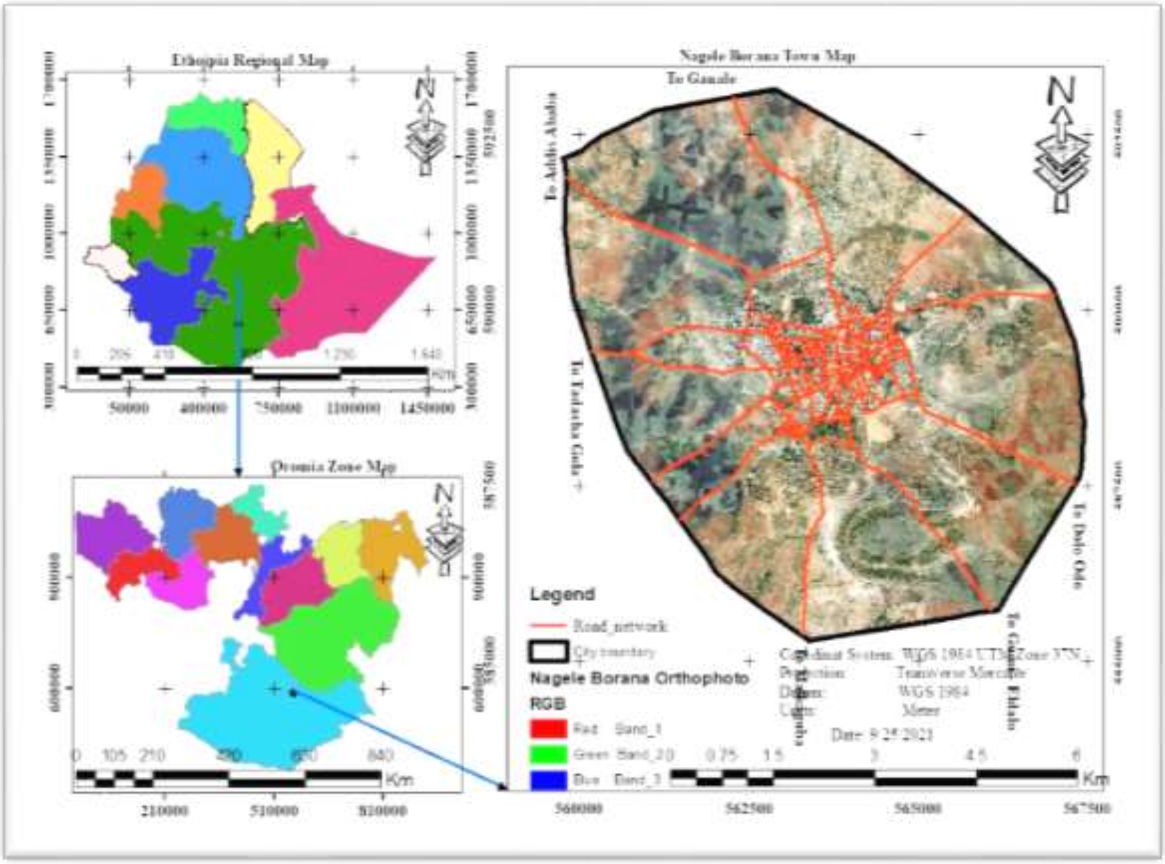

Figure 3 Study Area Map

3.1.2. Demography/population

The size of population of any place was affected by birth rates, death rates and migration. Demographically, Nagele Borana was the one of rapidly growing town both in terms of population and physical areas in the region starting from the outset of its establishment due to ongoing urban spread out, natural growth of population and high level of rural urban migrations. According to 2007 national census reported the total population of the Nagele Borana town were 36,699, of whom 19,081 were male and 17,618 were female (NCA, 2007).

The high concentration of population in urban areas increases the potential of urban crises and risks such as unexpected sprawl urban, fires, car accidents, work-related incidents, food poisoning and various diseases (Ali Soltani, 2019). The 1994 national census reported this town had a total population of 23,997 of whom 12,036 were men and 11,961 women (NCA, 1994).

3.1.3. Climate

The climate in the area was semi-arid climate in most cases as the elevation was mostly below 1600m a.s.l. It has a warm climate in most of the year for most places and fair climate during the rainy period. However, there is areas with over 1600m a.s.l. elevation which has a fair climatic condition.

3.1.4. Temperature

The area above 1500 mean sea level is generally cool and gets more rain than the area below 1500 m, which is dry and hot. The study area has a warm temperate to desert and semi-desert climate and belongs to the desert (Bereha) although there is places with Woynadega climatic zone. The maximum temperature reaches about 28°c in few days but commonly between 24 and 27.5° c. The minimum daily temperature for Nagele borana commonly varies between 11° c to 14° c.

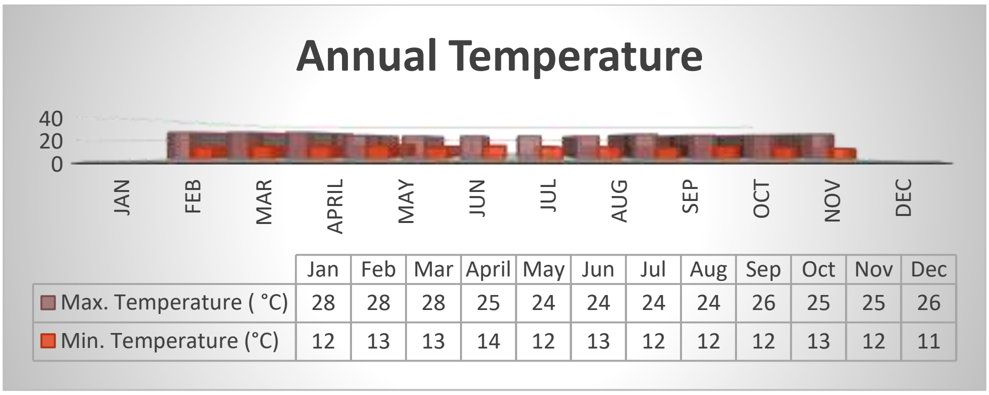

Figure 4 Average annual temperature

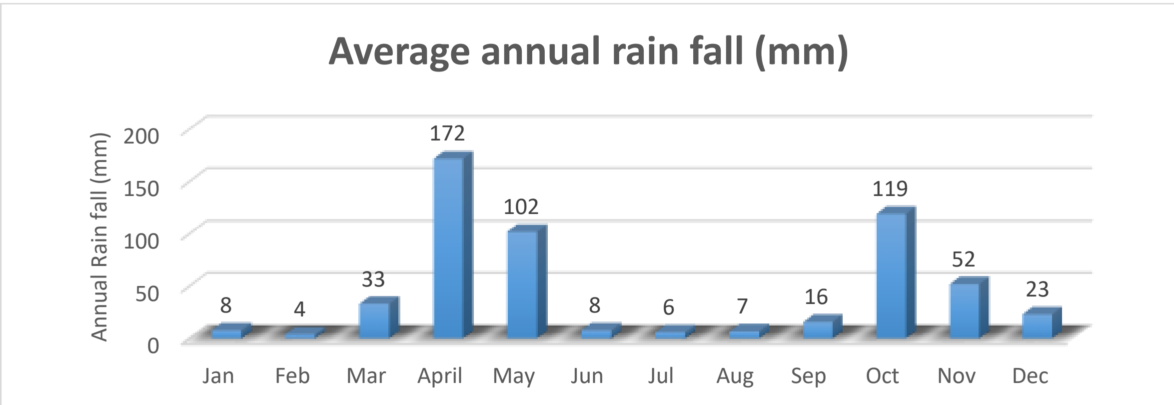

Figure 5 Average annual rain fall

3.1.5. Topography

Nagele Borana town is the eastern Guji Zone Oromia Region Administration town. The town was located on a plateau with an elevation ranging from 1,400 to 1591 meters above mean sea level. Some of the general physical characteristics of the study area, the slope of the area ranges from 0 (Flat) to 55 (steep) degrees (OUPI, 2010).

3.2.Research Methodology

3.2.1. Data Sources

The availability of data was the most important thing to perform any kind of data analysis. Therefore, in this study, spatial and non-spatial data were used to extract fourteen parameter maps for the analysis of suitable site for an abattoir location. These spatial and non-spatial data were organized from different fields; Nagele Borana land use plan, master plan, contour, aerial photo images, population data, soil and geological map data. Additionally, the details of the data used format, their source, resolution and data types were presented in (Table 4)

Table 4 Data source

Data Types	format	Source	Resolution	Year
Point data	Text	Field Survey		2021
Land Use Plan	Shapefile	Nagele Borana Municipal Land Management Office.	1:250000	2019
Structural Plan Map	dwg	Nagele Borana Municipal Land Management Office.	1:250000	2019
Geological Map	jpg	Geological Survey of Ethiopia	1:250000	2011
Orthophoto	Tiff	Nagele Borana Municipal Land Management Office.	15 cm*15cm	2019
Contour	shapefile	Nagele Borana Municipal Land Management Office.		2019
Population Data	text	Statistics Agency (CSA) Nagele Borana branch		2007
Soil Types	shapefile	Ministry of Agriculture	1:250,000	2004

3.2.2. Software Used to Analysis the data and interpretation

As presented their list, version, and purpose in (Table 5), in order to complete, the study effectively different software packages were operated to help a decision such as ERDAS imagine, ARC GIS, Idrisi32, Microsoft word, and Microsoft excel. A number of tools have been used to determine the proper site for capital-intensive infrastructure development facilities. These tools include Expert opinion Systems Geographic Information Systems (GIS), Multi-Criteria Decision Analysis (MCDA) methods FAHP techniques (Ohri & Singh, 2010). In this study, (Environmental Resource Data Analysis System) (ERDAS) imagine software was applied to process the Aerial photo and prepared land use land cover of study area for applied the geometric, stacking corrected image layer and finally, for the classification of existing land use land cover (LULC) map of Nagele Borana town by supervised classification technique and accuracy assessment. ARC GIS was used for preparing criteria to perform spatial analysis like proximity, buffer, rasterization, and digitization. Many GIS analysis tools were used in the study such as buffer zoning, euclidean distance, reclassification, and overlay analysis (Alzamili et al., 2015). A reclassification is an effective tool used in GIS for creating categorical attributes in a dataset by classifying various features based on existing attributes Roy et al., 2019). Idris32 was used for weighted derivation by APH techniques and next, Google earth was undertaking to conduct an accuracy assessment for land use land cover classification map by integrating with Erdas Imagine software.

Table 5 List of software and instrument used

No.	Software	Version	Purpose
1	ArcGIS	10.5	For spatial and non-spatial data processing, analysis, creating geo-database and producing thematic map.
2	ERDAS imagine	2014	For preprocessing and classifying land use land cover land and to extract interest area and stacking different layers
3	Idris	32	To produce thematic map of overlaying each criterion and drive the eigenvector weight and consistency ratio.
4	Handheld GPS	Germin36	To collect ground truth data from the field.
5	Google earth pro	7.3.1	To clarify and validate the classified result with the existing veracity. For collection of online random point and check the accuracy assessment of classification
6	Microsoft word and MS excel	2016	To integrate attribute data and prepared final report. To illustrate the weights of each criteria by using FAHP techniques.

3.3. Data preparation for analysis

3.3.1. Spatial location of environmentally sensitive areas

The spatial location of environmentally sensitive areas as a result of a field survey conducted using handheld GPS including existing health care services, high tension lines, social services, boreholes, existing abattoirs, streams landmarks, cemeteries, nearest industries were identified on digital aerial-photo. Next, each plot of these features were digitized in ArcGIS and incorporated with other constraints to preserve them from the analysis as they were legally restricted to allocate abattoir on their sites. Numbers of Facility and software Purpose

1. ArcGIS 10.5:- used for Spatial data processing, analysis, and output map generation
2. ERIDAS imagine 2014 :-Aerial photo processing and land use land cover preparation
3. Idris32:- to drive the eigenvector weights of each criteria and check consistency ratio
4. GERMIN handheld GPS:- used for collecting point data from the field
5. Google Earth Pro:-. To verify and validate the result with the existing situation
6. Microsoft Word:- used for writing report and composite final thesis
7. MS Excel: - used for integration of attribute data and calculation of each criteria weights using FAHP techniques.

3.3.2. Geo-referencing

Raster datasets which were obtained by scanning maps would have only the grid reference and it do not contain the locational information on the surface of the earth and it was need to be geo-referencing. Geo-referencing is the process of assigning a coordinate system that associates to the data which have a specific location on the earth in real-world coordinate system. In this study, the initial data format of geological data was in the format of jpg and it was not georeferenced. Hence, control points were selected in the input raster dataset and the output location was specified by typing in the known output coordinates. First, eight grid line intersections as control points with uniform distribution were selected on the input raster data and their ground coordinates of grid were recorded. Next, in ERDAS imagine software, using geo-referencing function coordinates of all control points were registered to their respective grid intersection point. Root Mean Square Error (RMSE) for all control points were computed using geo-referencing function to estimate their positional accuracy. Since positions would be determined with millimeter accuracy, the RMSEs standard was set to 0.5 millimeters. Finally, the map was rectified with acceptable root mean square error (RMSE) of each point. The root mean square (RMSE) for geological map was computed as 0.047mm. To achieve the goals, very high spatial resolution imagery (Ortho photo with 0.15m), of 2019 would be used as the basis for land cover data.

3.3.3. *Research Geodatabase Design*

A geodatabase is the physical storage of geographic information (spatial, non-spatial, metadata, and relationship) inside a relational database management system. It contains layers vector data representing features and raster data representing images and grid surfaces. Each layer represents particular types of features that have been used for spatial analysis. In this study, a common personal geodatabase was built using Universal Transverse Mercator projection system world geodetic system 1984 to store, query, and manage both spatial and non-spatial data that could be used for the final analysis to achieve the proposed objectives. Feature datasets were created for the area and line feature geometry in single personal geodatabase. Urban land use, elevation, slope, road, streams, high tension lines, social services, boreholes, abattoir area and existing abattoir are stored in the geo-database in order to store the collected data and the analysis results in a logical arrangement. The factors involves were examined according to their relative importance towards designating areas of high suitability classes and assigning weights. The collected data was automatically (digitizing, and clipping from the study area boundary) and organized into logical groupings of the factors. The factor layers were grouped into five according to their nature as:

- Urban land use factors: built-up area, water bodies, vegetation, Agricultural land and bare lands
- Topographical: elevation, slope, Aspect
- Accessibility: distance from major roads
- Water body: streams/rivers and borehole
- Constraints: location in terms of the distance, high tension lines, social services, boreholes, Abattoir area and existing abattoirs, streams.

Using ArcGIS functions, town boundary, road network, high power lines, rivers lines, and geology types were digitized from Georeferenced maps and aerial-photo and personal Geodatabase which was shown in Figure 6. Next, topology was created and applied for all datasets and digitization errors were corrected

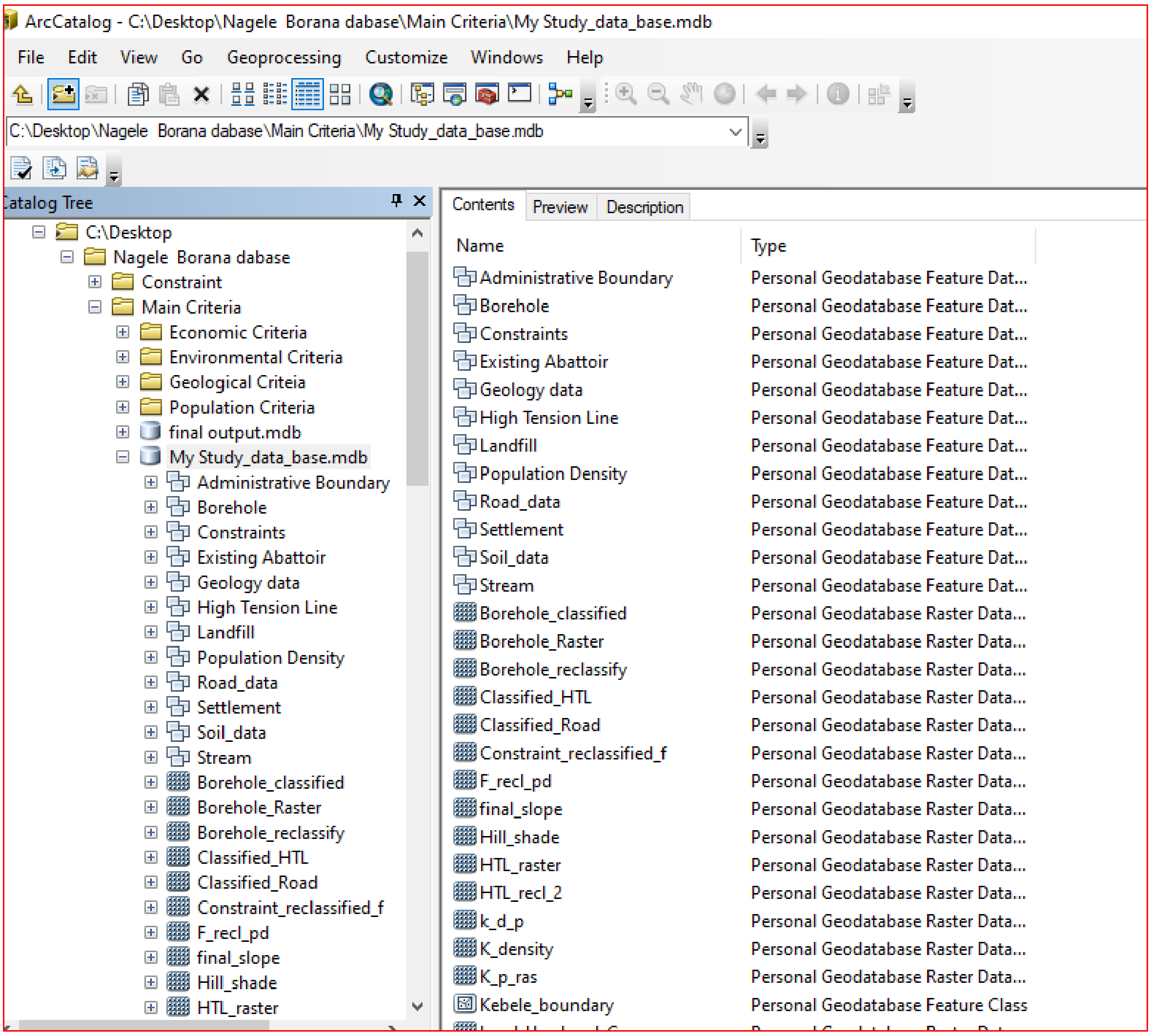

Figure 6 Developed geo-database for the study

3.3.4. *Layer extraction (Digitization)*

Digitization is the process where features on a map or image are converted into digital format for use by a GIS. This can be done by either manual or automation technique. In this study, on-screen digitization was performed to extract layers that represent criteria for decision making. Using ArcGIS functions, stream paths, high power transmit lines, and road networks were digitized from Georeferenced map and aerial-photo and entered into a common personal Geodatabase. Then, topology was created and applied for all datasets, and digitization errors were corrected.

3.4.Methods of Data Analysis

The data analysis process of site suitability analysis for an abattoir areas involves numerous factors with complicated correlations. Therefore, the Geospatial Technology tools with multi-criteria spatial analysis methods and The Fuzzy Analytic Hierarchy Process (FAHP) approach has been used to address the proposed study. The methodological procedure of site suitability analysis for identification of optimal abattoir areas is presented well below on Figure 8.

3.4.1. *Reclassifying values of a set of raster*

The Reclassifying tools are used to allow the researcher to reclassify or change input cell values to alternative values. In this study, all thematic layers were converted to raster, and then raster reclassification using reclassify tool of ArcGIS 10.5 was adopted to reclassify the old value to the new one. The reason behind reclassifying raster data was to:

- ✓ Replace new values with the old ones based on new information;
- ✓ Group certain values and
- ✓ Reclassify values to a common scale of measurement.
- ✓ Identify priority of classes suitability index

3.4.2. *Spatial multi-criteria decision making (MCDM)*

Both FAHP and AHP methods are extremely useful for prioritizing multiple-choice criteria and sorting them into a hierarchical structure. FAHP evaluates the relative importance of each criterion and also generates an overall rank of alternatives or weight of factors. In the classic AHP method, the numerical values of linguistic variables are directly used for the evaluation of the criteria. If the environment where the decision-making process takes place is fuzzy, then fuzzy numbers would be used for the evaluation concerning some deviations of the decision-makers (Wijitkosum & Sriburi, 2019). The AHP has been widely used to solve MADM problems. However, due to the ambiguity and uncertainty in judgments, a crisp, pairwise comparison with a conventional AHP would not be able to effectively describe the decision-makers views. Even while the AHP discrete scale offers the advantages of simplicity and convenience of use, it would not accounted the uncertainty that associated with mapping one's perception to a number. FAHP is an effective approach for dealing with the fuzziness of data used to determine the preferences of various decision factors. It uses a multilevel hierarchical structure of objectives, criteria, sub-criteria, and alternatives uses the fundamental scale of absolute numbers to express individual preferences or judgment below this scale consists of nine points as shown intensity preferences of triangular fuzzy numbers (TFNs) on (Table 2.1). In general, nine objects are the most, which an individual can simultaneously compare and consistently rank. The score of differential scoring assumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7, 1/9) have been used where the row criterion is less important than the column criterion. To ensure the credibility of the relative significance used (Hatta et al., 2014), AHP also provides measures to determine the inconsistency of judgments mathematically. Based on the properties of reciprocal matrices, the consistency ratio (CR) can be calculated. CR< 0.1 indicates that level of consistency in the pair-wise comparison was acceptable. Saaty (1980) Suggested that if CR is smaller than 0.10, then the degree of consistency is fairly acceptable (Table 2.2). But if it is larger than 0.10, then there are inconsistencies in the evaluation process, and the AHP method would not yield meaningful results (Chu & Liu, 2002). In this thesis research, the methodology designed in order to achieve the general and specific objective set for the study was presented in five steps as follow. First, after problem identification various source data layers that affect the location of the abattoir were collected from the field data using handheld GPS, Ministry of Agriculture, Nagele Borana town municipality office, Ethiopian geological survey and USGS earth explorer website. The suitable site selection for an abattoir area was involves many geospatial data layers and related attributes. The FAHP method and Chang's (1996) method, which is a very simple method for generalizing the hierarchical analysis process to the fuzzy space, was used in order to assign weight to the criteria (Maddahi et al., 2017). Also, in present study all main and sub-criteria were priorities organized using hierarchical analysis process structured as shown below (Figure 7).

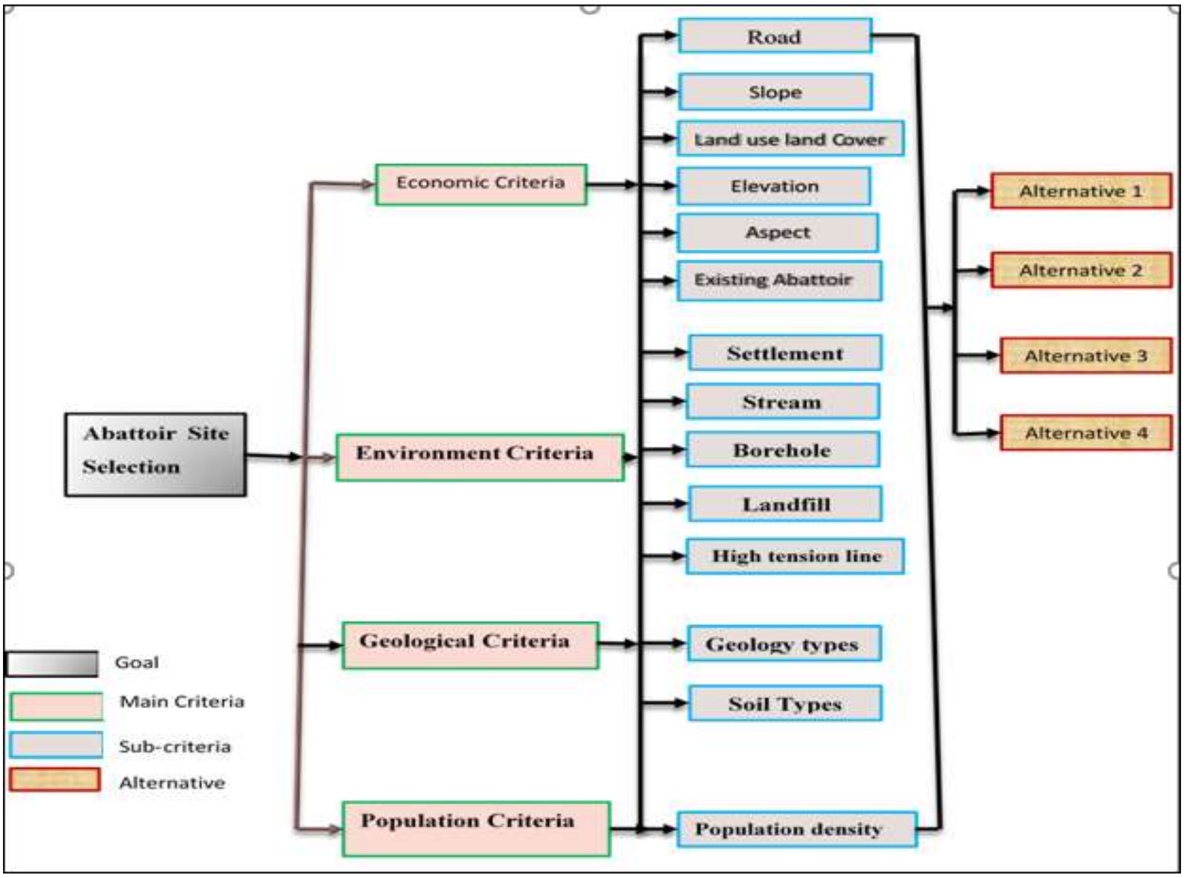

Figure 7 Fuzzy analytical hierarchical structure of the criteria

3.5.Conceptual framework and flowchart of the analysis

In this study, there were six important steps to analyze site suitability maps for abattoir areas.

1. Determining influencing criteria's to be used in the abattoir site analysis for decision making,
2. Generating of all criteria maps for defining the suitability index of each criteria.
3. Delineating constraints by developing a Boolean constraint map to exclude from the analysis;
4. Assigning factor priority, derivate weight, and class weight (ranking) to the criteria involved,
5. Developing weighted overlay analysis and determine overall suitability of the entire study area and
6. Validate the suitability of proposed abattoir location of the study comparing with existing abattoir site suitability. The details of the conceptual framework and each processing steps were shown in Figure 8. MCDA technique was applied to incorporate decision maker's judgment and preferences using the FAHP method. This method includes the selection of the criteria for the spatial Multi-Criteria Decision Analysis making (MCDAM) technique for the suitability analysis of an abattoir site. The final step involved in Both FAHP and AHP methods were extremely useful for prioritized multiple-choice criteria and sorting them into a hierarchical structure. ArcGIS is used to combine the spatial data with the suitability index so that a continuous site suitability map was generated. The output of site suitability map for abattoir location. In general, (Figure 8) was summarizes the overall methods, techniques, and approaches used to carry out in this study, to analyze the existing abattoir site and identify suitable areas for future abattoir area development in Nagele Borana town.

3.6.Technical Flow Chart of the Methods

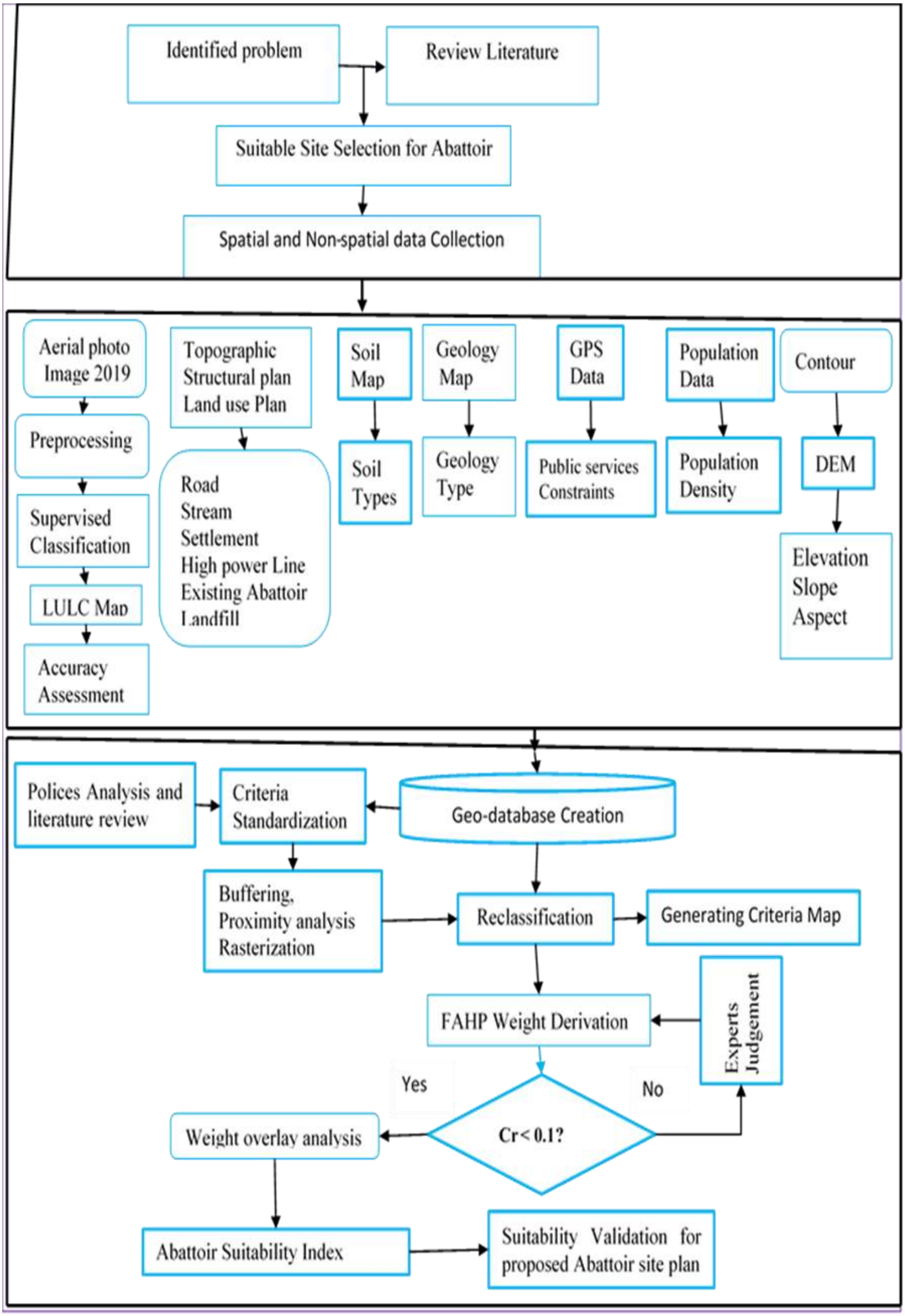

Figure 8 Technical schematic flow chart of the methodology used

CHAPTER IV. RESULT AND DISCUSSION

4.1.Influencing Factors (Criteria and constraints) for Abattoir Suitability Analysis

By amalgamation literature reviews, expert's opinion, and available data, a wide variety of factors (criteria and constraints) have been selected to achieve the objectives of this study. Accordingly, the review literature to determine criteria that influence the suitability of an abattoir study area include: (Sarath et al., 2018), (LASISI, Kamil Oluranti, 1999), (Sina Temsgen Tolera and Fekade Ketema Alemu, 2020), (Codex Alimentarius, 1993; Dire dawa City Dynamic Planners PLC., 2012) (E. C. Chukwuma, 2016) (Naila, 2008) (Emmanuel Chibundo Chukwuma, 2018), (Aysheshim Melese , 2002) (Barter, 2014), (EPA, 2002), (Tesfaye N., 2017), (Teshome M. , 2O15). Seven experts were also selected from Nagele Borana town municipality office. Accordingly, urban planners (Mr. Zerubabel Yewalashet and Mr. Abduba Giro from Nagele Borana town, recommended me to consider accessibility of road network for transportation cost, land use land cover, terrain condition, geological condition, availability of utilities services, proximity distance from waterbody, settlement areas, streams, market centers, and any religious place), while Mr. Doyo Diba and Mr. Nura Kete who were experted from environmental protection and climate change management office were also recommended me to give attention on prevailing wind direction, population density over area, surface water flow direction, proximity distance of others industries, landfill site, underground water, and surface), in addition to those four experts mentioned above the leaders of urban land use and land management Mr. Ayilu Tare and Boneya Tuka where as recommended me as think careful about proximity distance from environmental sensitive including; high tension line, high voltage electric station, Schools, Airport, military camp, health center, government office and repeatedly some criteria were mentioned above experts.

Accordingly, above mention of literature review, experts' opinions and available data in this study four major factors include: economic, environment, geological types, and population density were identified. These factors (criteria and constraints) further classified as follows:

a) Economic criteria like proximity to road, topography condition (slope, aspect, elevation), existing abattoir site, and land use land cover
b) Environmental criteria like settlement, Borehole, Stream, Landfill site, and high tension line

c) Constraints factors proximity like high electric voltage station , industry area, airport, military camp, schools, religious place, governmental office, health center, cemeteries area
d) Availability of utility services like water and electric transmission;
e) Geological characteristics like soil and geology types
f) Population density over the study area.

In relating to the identified factors, fourteen criteria including road, elevation, slope, aspect, existing abattoir site, land use land cover, waterbody (surface water/stream and underground water/borehole), settlement area, high power line, landfill site, geology types, soil types, and population density were considered as criteria factors and eleven constraints namely; administration offices, high voltage station, airport, school, health center, cattle market, military camp, religious area, cemeteries area, and industrial area were also identified (E. C. Chukwuma, 2016), (AACPPO, 2017), (Emmanuel Chibundo Chukwuma, 2018), (LASISI, Location and Environmental Effects of Abattoirs in ibadan, 1999), (Dire dawa City Dynamic Planners PLC., 2012), (LMA., 2000), (Aysheshim Melese , 2002), (Yunus, 2019), (Sharma, 2002), (Tesfaye N., 2017), and (Teshome M. , 2O15). These factors (criteria and constraints) were considered highly specific and relevant for this study area. The factors were selected to identify and evaluate the most suitable areas for an abattoir location development to satisfy the demand for abattoir purposes to utilizing it. So the research question one should be answered.

4.2. Economic Criteria Map Generation for Abattoir Site Selection

In this major economic criteria distance from major road, existing abattoir area, topographic feature such as: slope, elevation, aspect and land use land cover sub-factors were considered to optimize the selected suitable site for abattoir development economically.

4.2.1. Road Networks Factor

Transportation facility is a major concern if the economic aspect is raised for any industrial and manufacturing areas. The suitability decreased as the distance from road network increased. This results in longer distances to be less suitable as transportation costs increase (Reisi et al., 2011). Therefore, the existing road networks of Nagele Borana Town was one of the transportation facility that was considered for this study. The digitized and Produced major roads proximity distance from the study area base map and the topographic map was graded into five classes as unsuitable, less suitable, moderately suitable, suitable and highly suitable. As presented in (Table 6) break values used for the classification of road proximity distance into five classes were based on the suggestions of previous researchers' for major road categorization (Tesfaye N., 2017), (AYSHESHIM M. , 2002), and (Teshome M. , 2O15). However, according to their study were the classified into four score suitability grade. From the suitability index score 1= unsuitable 2= moderately suitable 3= suitable and 4 shows highly suitable. However, in this study the suitability classes were scored into five class level of suitability index; where as S1= unsuitable, S2= less suitable, S3= moderately suitable, S4= suitable, and S5= highly suitable respectively.

Table 6 Suitability index from major road proximity distance in (m)

(Tesfaye. N., 2017)	In this study	Score	Suitability levels	Area in km^2	%
20 - 400	0- 200	5	Highly Suitable	9.66	22.46
400-800	200-300	4	Suitable	6.22	14.46
800-1200	300-400	3	Moderate Suitable	5.53	12.89
>1200	400-500	2	Less Suitable	4.50	10.45
	>500	1	Unsuitable	17.09	39.74
Total				**43**	**100**

As reveals above the table the reclassified main roads vicinity distance suitability levels showed that highly suitable, suitable, moderately suitable, less suitable and unsuitable ranks were graded for the classes of 0 to 200, 200 to 300, 300 to 400, 400 to 500 and > 500. As presented in (Table 6) the coverage of each index in terms of area and percentage were, 9.66 km^2 (22.46%), 6.22 km^2 (14.46%), 5.53 km^2 (12.89 %), 4.50 km^2 (10.45 %) and 17.09 km^2 (39.74%) as its order from highly suitable to unsuitable. As seen from the reclassified result of the major road network map, places near major roads were graded highly suitable for abattoir site selection, with a score of five, but areas too far from road networks were counted unsuitable from an economic viewpoint. (AACPPO, 2017) (Dire dawa City Dynamic Planners PLC., 2012) (AFD, 2019), were also supports the study results. As depicted from the results on (Table 6 & Figure 9) the greater percent of the study area from the class graded 39.74% was not recommended for allocation of abattoir site.

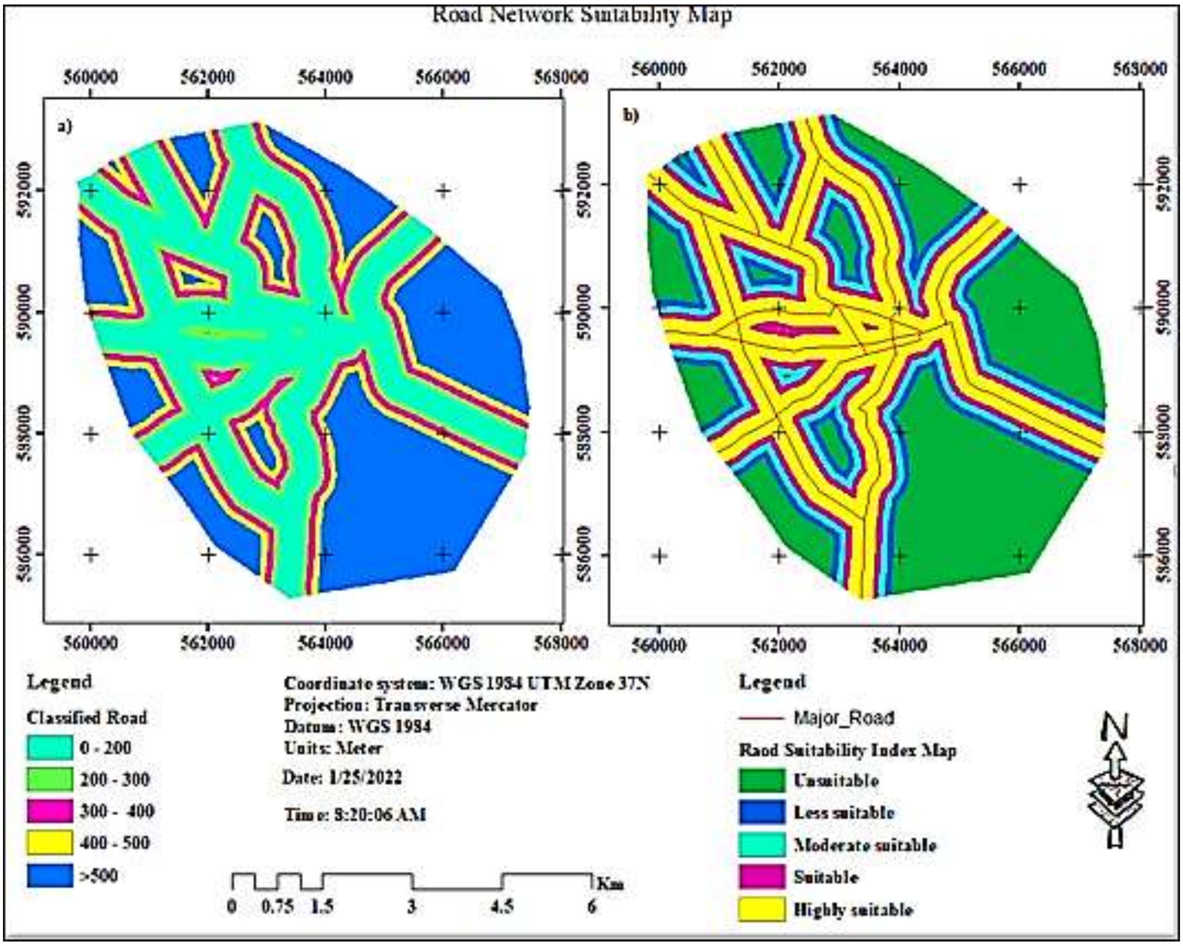

Figure 9 Road suitability index map

4.2.2. Slope Criteria Factor

Topographical features are key factors in construction and output flows (Fataei, et al., 2015). Slope gradient was usually expressed as percent slope or degree slope is used to represent the degree of variability in elevation. Areas with a gentle slope were taken as more suitable for the construction of large structures. Moreover, immovability issues during the construction phase. To lessen the risk of instability during construction, steeper slope locations are often avoided (Sarath et al., 2018). Slope layer obtained from DEM was reclassified, the most suitable sites are the flat areas of the land cover ranked as 1 (E. C. Chukwuma, 2016). But in this study the highly suitable location were given as 5 score classes that shown on the (table 7) of study area. Slope is associated with building cost. Building the abattoir is less costly on low slopes. The slope is also closely related to surface drainage characteristics of the site. Desirable slope for abattoir site is suggested to be gently sloping area which ranges from 2% to 10% (Mengistu TS, Haile AW, 2017). Additionally, as stated by Jiang (2007), always the flat terrain is better to build up plant than sharp terrain. A slope map of the study area was generated from DEM extracted from the contour of the Nagele

Borana town strategic plan. The spatial resolution of the contour was 30 m depends on DEM resolution. ArcGIS 10.5 software was applied to generate a slope from the DEM raster and an extension of the reclassified slope was given a rank value 1 to 5 with the lower value of 1 showing unsuitable, while the higher value of 5 showing highly suitable. Thus, as recommended by (LMA, 2000), (AACPPO, 2017) and other researchers were supporter of this study result. The desirable slope for abattoir site is suggested to be gently sloping area, which ranges from 2 to 10 percent (AYSHESHIM MELESE WUBSHET , 2002). Slope values below 2 percent were not suitable from safe drainage point of view (Table 7).

Table 7 Suitability index of slope value in percent

Slope (%)	score	Level of suitability	Area in km^2	Percentage %
0-4	5	Highly suitable	18.89	43.90
4 –8	4	Suitable	19.20	44.60
8 – 13	3	Moderate suitable	3.72	8.70
13 – 21	2	Less suitable	1.03	2.40
21 – 55	1	Unsuitable	0.16	0.40
Total			43	100

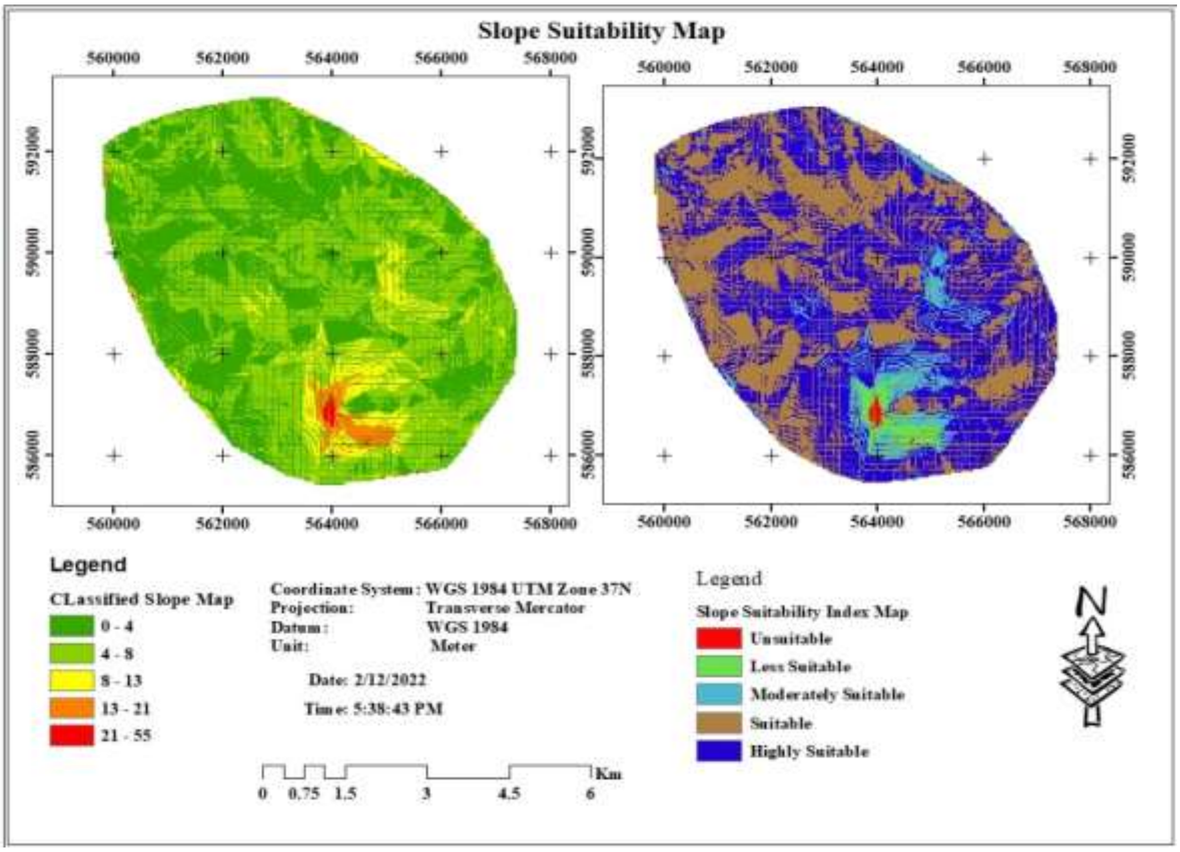

Figure 10: Slope suitability index map

As depicted in (Figure 10) the reclassified topographic slope distributions, the suitability indexes used for slope factor were unsuitable, less suitable, moderately suitable, suitable and highly suitable. As above table shows that the overall share of these suitability indexes in area and percentage for abattoir delineation it accounts about 0.16 km^2 (0.4 %), 1.03 km^2 (2.40 %), 3.72 km^2 (8.70 %), 19.20 km^2 (44.60 %) and 18.89 km^2 (43.90 %) respectively. This results were shown that the study area was primarily highly suitable for abattoir establishment, with a slope ranging from 0 to 4 precent. The maximum slope of the Town, according to the reclassified portray, ranges from 21 to 55 percent-rise and classified as unsuitable area, while the minimum slope ranges from 4 to 8. Thus, as recommended by (LMA., 2000) the desirable slope for abattoir site was suggested to be gently sloping area, which ranges from 2 to 10 percent. Slope values below 2 percent are not suitable from safe drainage point of view. Areas with higher slope values are not suitable for abattoir, whereas areas with a lower topographic slope raised were the right alternative for abattoir sites. The less the slope amount the highly suitable (Fatae, E. et al, 2015).

4.2.3. Aspect Criteria Factor

Aspect map generally refers to the horizontal direction to which a mountain slope faces. The south portion is highly suitable and north is less suitable for abattoir; buildings based on the amount of sunlight available in these parts (Nayama Valsa Scariah,& M.S.Vinaya, 2016). The effect of wind must be taken into account because odors arising from abattoir should not be felt in urban areas. Aspect oriented the direction of the slope and for identified water flow direction on the horizontal direction of land surface. Accordingly, on Nagele Borana town study finding was shows that, the north (N) and Northeastern (NE) direction were highly suitable, east (E) direction was suitable, southeast (SE), south (S) and southwest (SW) direction were moderately suitable, West (W) direction was less suitable and the northwest (NW) was unsuitable respectively. As the result shows the area coverages of the aspect analysis were 6 km^2 (13.95%), 2km^2 (4.65%), 10 km^2 (23.26%), 14 km^2 (32.56%), 11 km^2 (25.58%) from highly suitable to unsuitable respectively. In this study, aspect was computed from DEM data and reclassified into suitability classes by considering experiences of the previous study (Figure 10). As shown below the (Table 8 and Figure 11), the north and northeast direction were depicted highly suitable of the new proposed site of abattoir area with regarding to prevailing wind and water flow direction or slope faces of study area consideration for future expansion of urban plan of the town.

Table 8 Aspect suitability index analysis in degree

Aspect(°)	score	Level of suitability	Area in km^2	Percentage %
N, NE	5	Highly suitable	6	13.95
E	4	Suitable	2	4.65
SE, S, SW	3	Moderate Suitable	10	23.26
W	2	Less suitable	14	32.56
NW	1	Unsuitable	11	25.58
Total			**43**	**100**

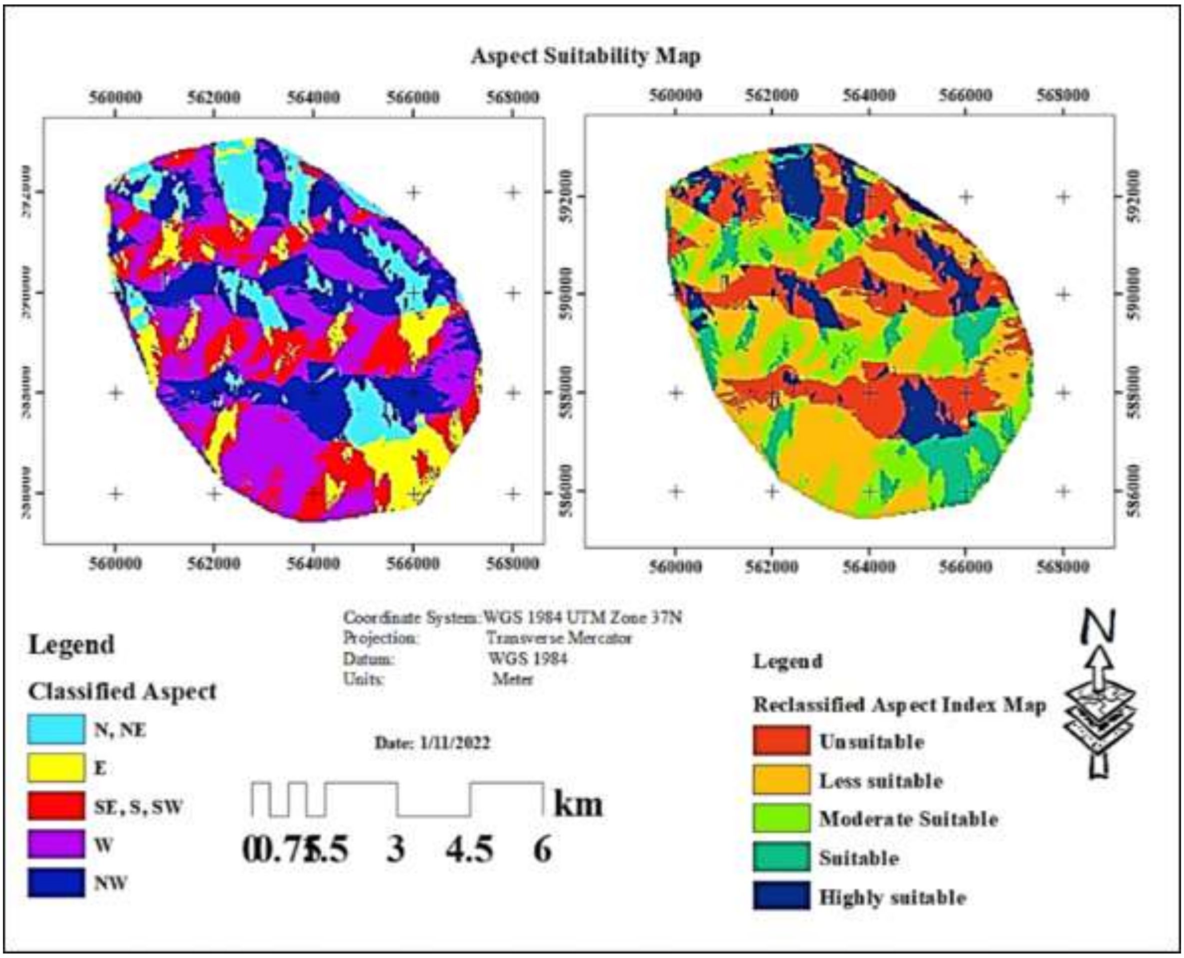

Figure 11: Aspect suitability index Map

4.2.4. Elevation Criteria Factor

The sea level of an area is a very important factor during the identification of potential sites. Sites far above the sea level increase the transportation cost are considered unsuitable (Sarath,et. al 2018). Elevation of the area where potential locations for abattoir was sited to be known for better decision to be taken. DEM was extracted from the contour map of study area with a spatial resolution of 30 m according to the study area and classified based on elevation present at that location. From the digital elevation model map, the maximum and minimum elevations of the study area were 1418 m and 1591 m respectively above mean sea level. The minimum elevations were located at the Northwest, west edge and southeast direction of the town and maximum elevation were shows the northeastern, east and southeastern part of the study area. This means areas with higher elevations were not suitable for optimal location of abattoir site due to economic disadvantages (AACPPO, 2017). Based on this fact topographic elevation of the town was categorized under major economic criteria.

Table 9 Suitability index of elevation value in meter (m)

DEM (above mean sea level)	Score	Level of suitability	Area in km^2	Percentage (%)
1418 – 1452	S5	Highly suitable	10.04	23.35
1452 – 1487	S4	Suitable	10.60	24.65
1487 – 1522	S3	Moderate Suitable	8.38	19.48
1522 – 1556	S2	Less suitable	6.99	16.26
1556 – 1591	S1	Unsuitable	6.99	16.26
Total			**43**	**100**

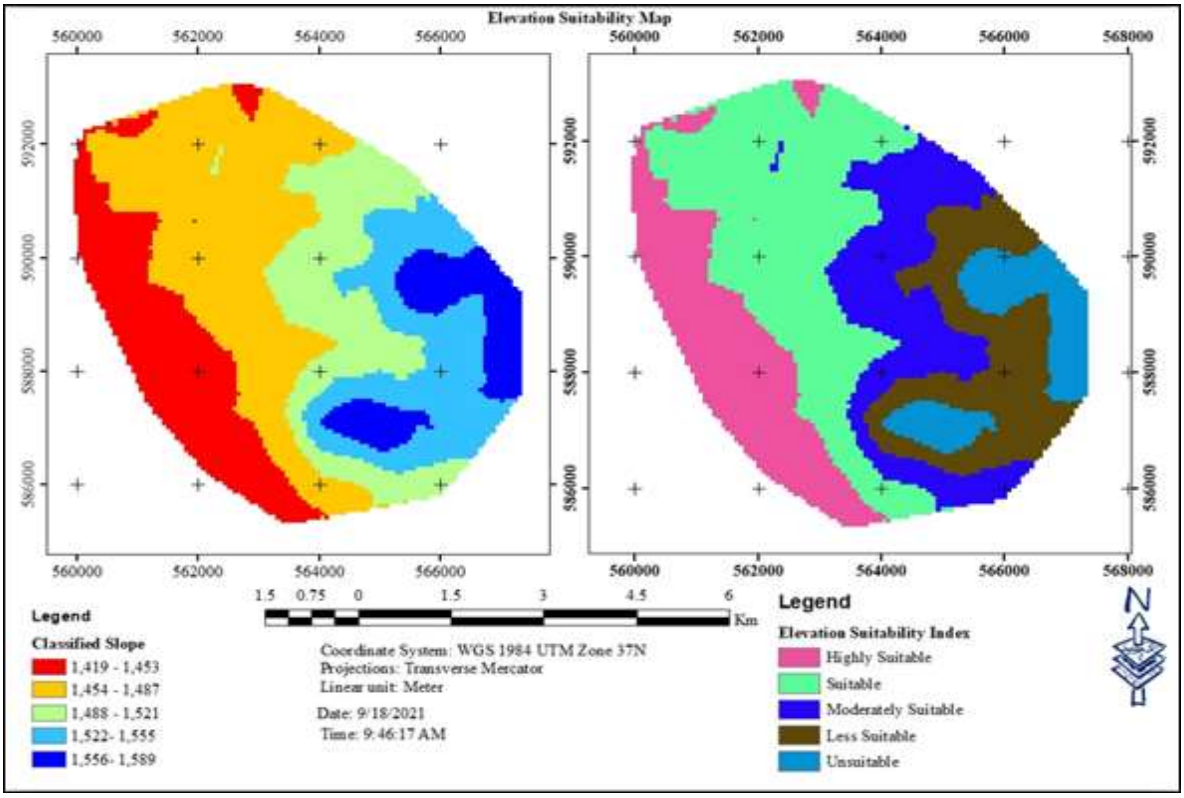

Figure 12: Elevation suitability index map

According to above the (Table 9), the study area's digital elevation model was reclassified into five categories: unsuitable, less suitable, moderately suitable, suitable, and highly suitable, with elevation ranges of 1418-1452, 1452-1487, 1487-1522, 1522-1556, and 1556-1591 meters above sea level. As the reclassified map result was shows the study area were highly suitable, suitable, and moderately suitable, less suitable and unsuitable for identification of an abattoir site, which covers 10.04 km^2 (23.35%), 10.60 km^2 (24.65 %), 8.38 km^2 (9.48%), 6.99 km^2 (16.26%) and 6.99 km^2 (16.26%) of the study area respectively. For the current study aim, the areas with a low elevation value were ranked as highly suitable for abattoir site. As a spatial decision making, site suitability analysis involves several steps or procedures. As shown above the results from (Table 9 and Figure 12) the areas were shows high elevation unsuitable and low elevation areas were shows highly suitable area. (Tesfaye N., 2017), and (Teshome M. , 2O15) study were support this study results.

4.2.5. Existing Abattoir Site Factor

When developing new optimal suitable locations, proximity to other businesses center, commercial area, availability of utilities services, and lending institutions (such as banks, etc.) were all elements would be considerable distance from new plant sites (Negi & Jain, 2008). The centralization effect, according to Jiang (2007), was a significant feature in plant design. Closely, the centralized factories have a greater impact on each other than the far, dispersed factories. Additionally, having a group of firms that produce complementary products and services close to one another cannot enhance the ability of the firms to make cluster wide changes in their product offerings (Jote et al., 2010). The existing abattoir points were taken from the field survey of the study area were buffered and reclassified. As depicted from result illustrated on (Table 10 and Figure13) the suitability of the study area was raised where the new proposed site was far away from the existing an abattoir site. In addition the score of suitability level was implies 1 to 5 unsuitable to highly suitable respectively. Finally most area coverage was indicated as highly suitable 30.43km^2 (70.77%) out of 43 km^2 area. However, the idea of the reviewed researchers were support within this study results.

Table 10: Suitability index of proximity distance in (m) used for the EAA

Distance (m)	score	Level of suitability	Area in km^2	Percentage %
0 – 500	1	Unsuitable	0.78	1.83
500 – 1000	2	Less suitable	2.36	5.48
1000 – 1500	3	Moderate Suitable	3.93	9.13
1500 – 2000	4	Suitable	5.50	12.78
>2000	5	Highly suitable	30.43	70.77
Total			**43**	**100**

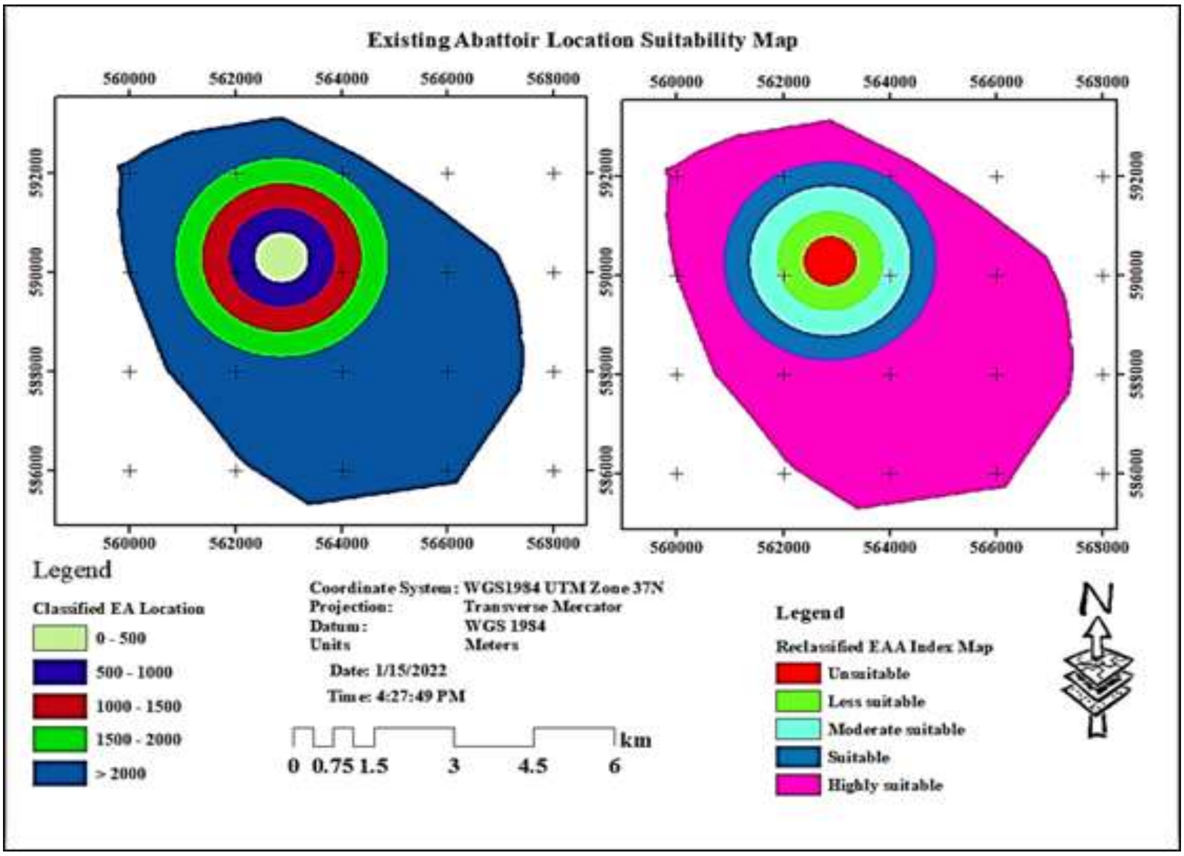

Figure 13. Existing abattoir areas suitability index map

4.2.6. Urban Land use and land cover

The land use of the study area was classified based on the aerial-photo of the study area that acquired in 2019. As shown on supervised classification of aerial-photo image on the study area classified pixels were clustered into the following five general categories: built up lands, agricultural lands, bare land, vegetation lands, and water bodies (Figure 14). The classification of urban land use/cover involves evaluation and grouping of specific areas of land in terms of their suitability for a defined use. Then each of the land use/cover types were reclassified into 5 classes based on their importance to evaluate suitable site to locate abattoir for overlay analysis. According to national urban planning institute experience, bare lands and agricultural lands were more preferable for the location of abattoirs due to the low cost of construction for an abattoir area (Napier Engineering & Contracting Ltd, , 2014), (LAS99), (Teshome M. , 2O15). As shown below (Figure 14) the barren land was ranked as highly suitable, Agriculture land was ranked as suitable, vegetation was ranked as moderately suitable, built-up land and water surface were ranked as unsuitable respectively. Due to the significant impact of these land cover classes on ecosystem balancing, delineating abattoir sites on built-up and water body were not suggested. Water bodies, wetlands, forest covering, and residential regions, according to Johar et al. (2013) were not suitable for industrial establishment. Open spaces, unoccupied lands, and rangelands were good places to put industry zone. Both water bodies and forest land cover were categorized as restricted (BCaD Consulting Management PLC., 2015). As shown in (Table 11) and (Figure 14), whilst waterbodies and built-up, vegetation, agricultural, and bare land were allocated as unsuitable, moderate suitable, suitable and highly suitable, respectively. The overall contribution of each land cover class for abattoir site selection in terms of area coverages were water body (0.42 km^2), built-up (5.46 km^2), vegetation (10.19 km^2), agriculture (16.06 km^2) and bare land (10.87 km^2).

Table 11 Land use land cover class suitability for study area

s/no	Class Name	score	Suitability index	Area (km^2)	Area (%)
1	Water	1	Unsuitable	0.42	1%
2	Built-up	2	Unsuitable	5.46	12.70%
3	Vegetation	3	Moderate suitable	10.19	23.70%
4	Agriculture	4	Suitable	16.06	37.30%
5	Bare land	5	Highly suitable	10.87	25.30%
Total				**43**	**100**

As illustrated from the study result, the score of suitability index from 1 to 5 shows unsuitable to highly suitable for the allocation of new proposed abattoir area. The (Table 11) shows highly suitable class was covered 25.30% of the study area.

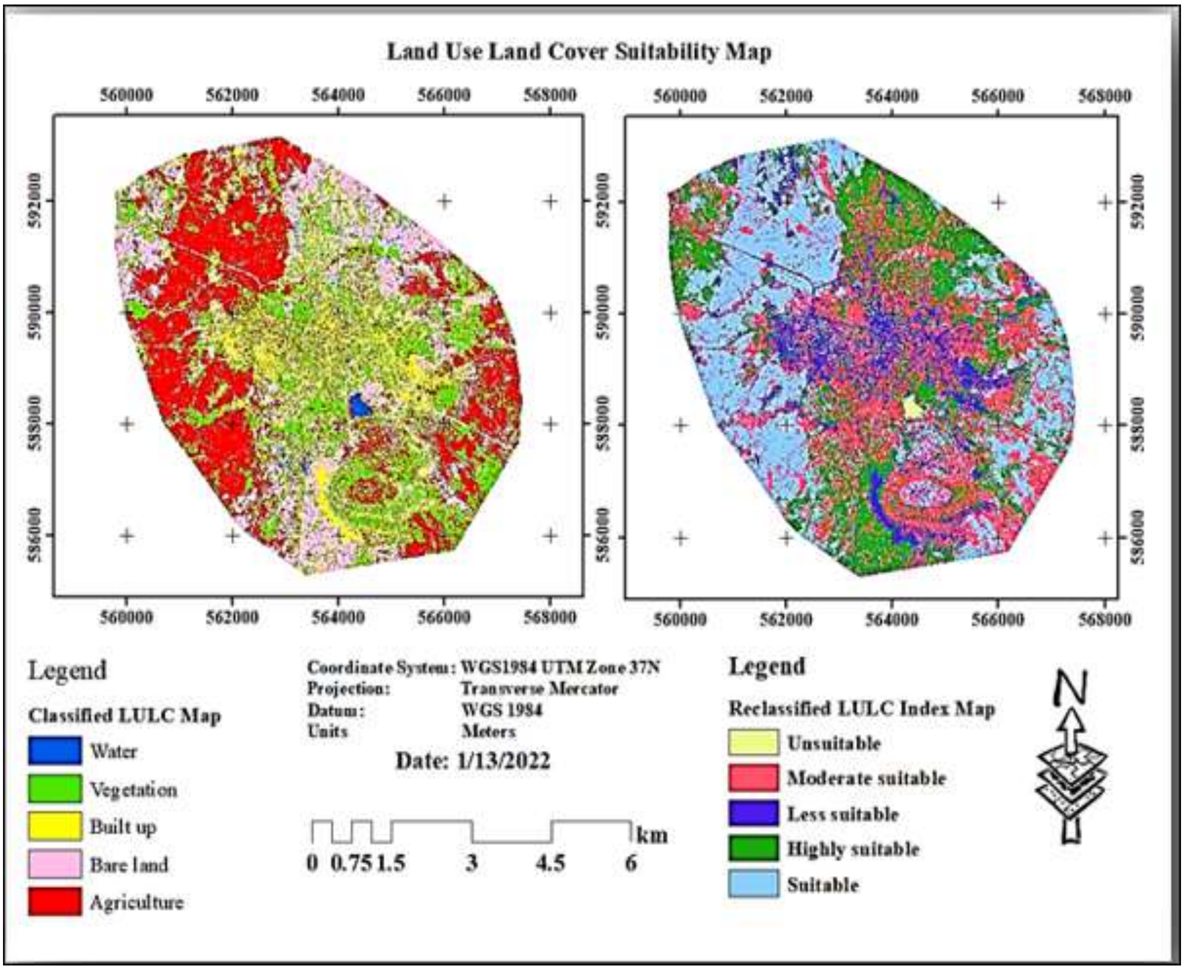

Figure 14 Land Use Land Cover suitability index map

4.2.7. Accuracy assessment

The accuracy assessment technique was made through a confusion or error matrix. A confusion matrix contains information about actual and predicted classifications done by a classification system. The pixel that has been categorized from the image was compared to the same site in the field. The result of an accuracy assessment typically provides the users with an overall accuracy of the map and the accuracy for each class in the map. Besides the overall accuracy, classification accuracy of individual classes was calculated in a similar manner. The two approaches were user's accuracy and producer's accuracy. The producer's accuracy is derived by dividing the number of correct pixels in one class divided by the total number of pixels as derived from reference data. In this study, the producer's accuracy measures how well a certain area has been classified. It includes the error of omission which refers to the proportion of observed features on the ground that was not classified in the map. Meanwhile, user's accuracy is computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category.

Table 12 Error matrix showing classification accuracy of the land cover

Class Name	W	Bu	V	A	BL	Total User's	User accuracy	producer accuracy	Kappa for each class
Water	13	0	0	0	0	13	100%	100%	0.9876
Built-up	0	27	0	0	0	27	100%	93.1%	0.9879
Vegetation	0	0	84	0	0	84	100%	100.0%	0.9876
Agriculture	0	1	0	26	0	27	96.30%	100%	0.9838
Bare-land	0	1	0	0	14	15	93.33%	100%	0.9879
Total Producer's	13	29	84	26	14	166			

Where; W=Water, B= Built-up V=Vegetation, A=Agriculture, and BL=Bare-land Overall classification Accuracy = **98.80**% and Kappa Coefficient (K) = **0.98696.** Where; K was represent kappa coefficient.

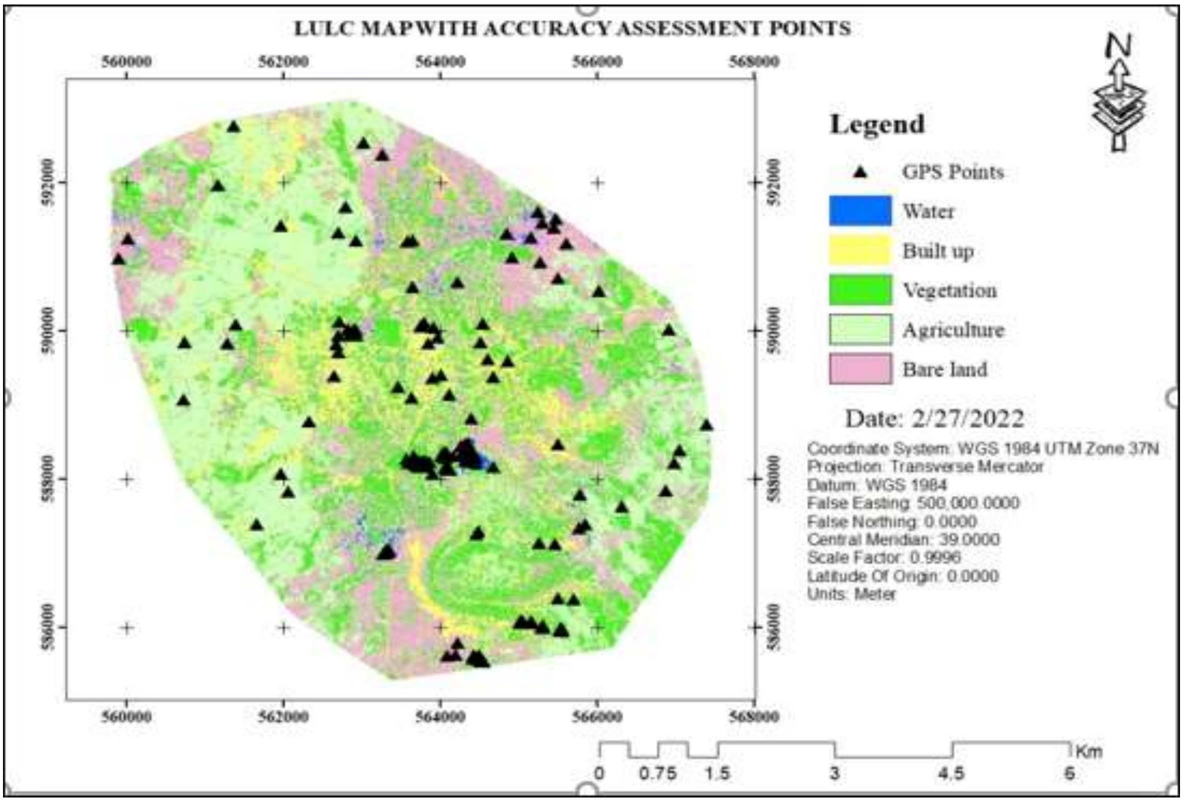

Figure 15: Overall accuracy assessment of GPS point identified map

It is computed by dividing the total number of correctly classified pixels by the total number of reference pixels. It shows an overall result of the tabular error matrix. The overall accuracy performed in this study was 98.80% as shown above (Table 12). As stated by Anderson et al. (1976) for a reliable land cover classification, the minimum overall accuracy value computed from an error matrix should be 85%. Therefore, the overall accuracy for the study area land use/cover map was above 85% based on Anderson's criteria. The 2019 supervised classification with an overall accuracy of 98.80% was achieved with a Kappa coefficient (K) of 0.98690. This value implies a strong agreement, and was often multiplied by 100 to give a percentage measurement of classification accuracy. Therefore, the K value of 0.9870 represents a probable 98.80% better accuracy than if the classification resulted from a random assignment.

4.3.Environmental Criteria Map Generation for Abattoir Site Selection

Under this study, the major environmental criteria factors, were the impact of environment activity on the neighbours industry and the impact of abattoir sites on the environment and the impact abattoir site on the human beings, were also taken into account using the following sub-criteria's: distance from borehole, distance from waterbody (stream, river, and lake), distance from heavy power lines, distance from settlement areas and distance from landfill site were identified as environmental criteria.

4.3.1. Rivers and Streams (water body) Factor

Abattoir site must not be located in close proximity to surface water (streams, rivers, lakes, sea). The criterion is important from the point of view of both environment and economic concerns because in addition to causing pollution problems, it may require an efficient drainage system with high expenses (Tesfaye N., 2017). According to (Gemeda, 2018), the area coupled with the nature of topography were exposed to erosion, gully formation and flood problem for its loosely held soil. The economic cost of allocating land on river banks was pollution caused by open dumping. This condition have its negative impact on the quality of the land or suitability of the land for different urban development. In this study, based on previously mentioned by different researchers abattoir sites should not be built near rivers or powerful streams in order to reduce pollution caused by abattoir waste. However, the existing abattoir in Nagele Borana town was inside the bururi stream on the study area. Thus, the spatial analysis tool was used to calculate the proximity distance from the rivers and streams that were extracted from the aerial photo by referenced strategical plan of the town.

Stream networks were buffered and classed into five classifications, as depicted in (Figure 16), ranging from unsuitable to highly suitable. For buffer distance determination, the average value was taken after related literature were reviewed as indicated below in (Table 13). For this study, areas that were more than 550 meters away from rivers and streams were deemed highly suitable for abattoir site allocation, while areas that were close to rivers and streams considered as unsuitable. Therefore the area covered by each suitability index in square kilometers, were depicted as, unsuitable was (9.38 km^2), less suitable was (8.61km^2), moderately suitable was (7.61 km^2), suitable is (3.91 km^2), and highly suitable was (13.49 km^2) respectively.

Table 13: Suitability index of streams proximity distance in (m)

Stream	score	Level of suitability	Area in km^2	Percentage %
0 – 150	1	Unsuitable	9.38	21.82
150 – 300	2	Less suitable	8.61	20.01
300 – 450	3	Moderate Suitable	7.61	17.69
450 – 550	4	Suitable	3.91	9.10
>550	5	Highly suitable	13.49	31.38
Total			**43**	**100**

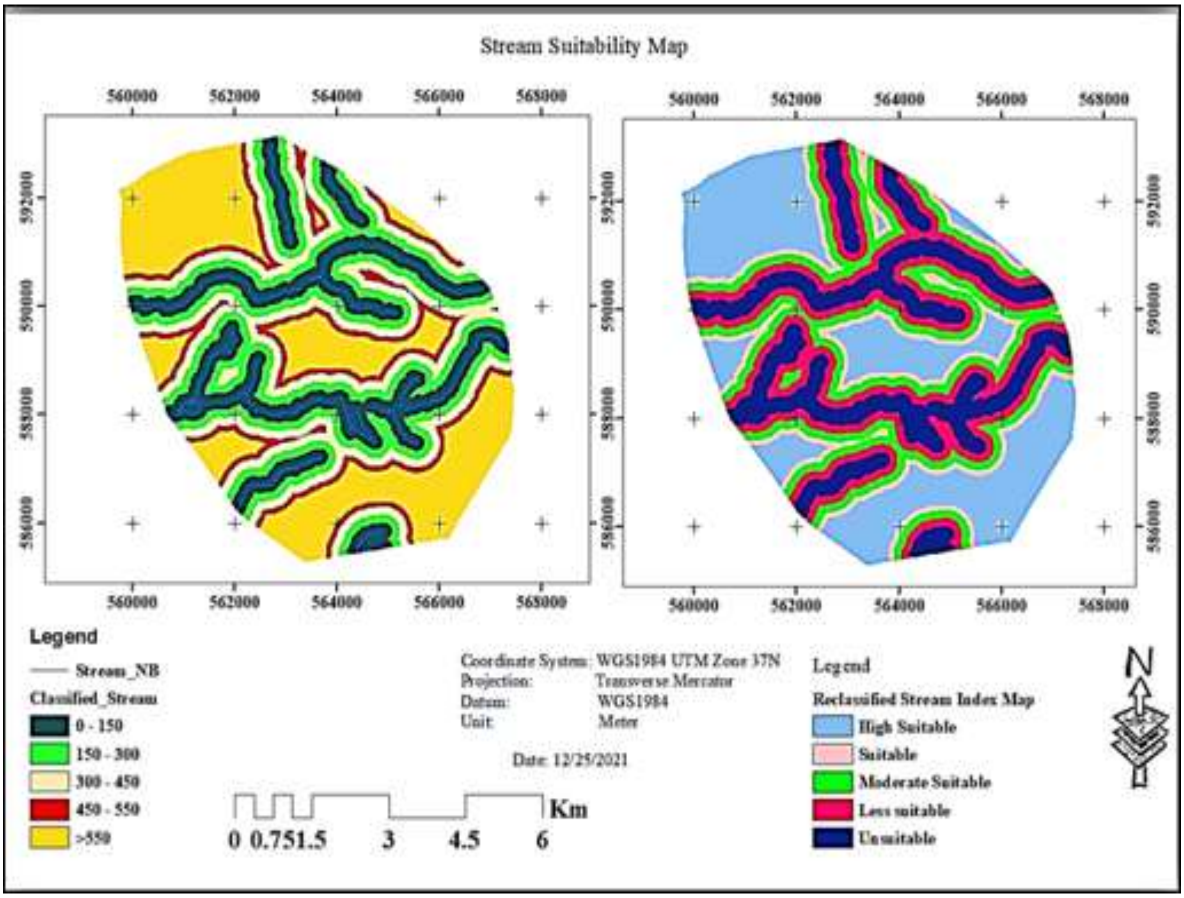

Figure 16: Water body (stream) suitability index map

4.3.2. Settlements or Residential Areas Factor

According to Johar et al. (2013), the availability of wasteland or a suitable construction site was the most important condition for any project development. Furthermore, the main basic development of abattoir sites were primarily due to the dangers from abattoir site, so that such sites would be located distant from communities. The main traditional methods of bringing abattoir industry closer to settlement and cluster were implemented with the goal of enhancing economic growth by increasing job opportunities in the area (Uzma Ajmal & Saleha Jamal, 2021). However, this practice would have an impact on those who live near to abattoir industry, either directly or indirectly. To reduce the negative impact of abattoir site noise, dust particles, and liquid waste released into the surrounding neighborhood, a safe distance should be maintained. Settlement area was extracted from the classified Land Use Land Cover map of the study area (2019). A logical distance should be selected between residential areas and abattoir sites (Fataei, et al., 2015). As a result, the (residential) settlement areas were buffered and reclassified into five groups as shown below (Table 14) using the buffer distance suggested by (Fataei, et al., 2015), and (Johar, et al., 2013),

The results obtained from the study done on abattoir site in four town of Ethiopia like; Adama, Hawasa, Mekele, and kombolcha was depicted that, two of the four abattoirs visited in their study was located in the community residence (Mummed & Webb, 2015). Similar to their study existing abattoir in Nagele Borana town was now locate in the center of community residence and affecting the health of the environment and neighbor community. Additionally, the implications of providing a framework to minimize the negative and maximize the positive impacts of an abattoir sites on economic, environmental and geological factors based on the required police and regulatory requirements of the study area or any town of the country.

For the current study, settlement areas were categorized as unsuitable, less suitable, moderately suitable, suitable, and highly suitable based on the reclassification proximity distance of study area suitability classes. As shown below, (Table 14) distance between 0 and 500 meters were deemed unsuitable, whereas the distance greater than (>1100) meters were considered highly suitable. The more settlement site distance from abattoir sites the higher suitability and would be consistency (Fataei et al., 2015). However the transportation costs for employees to gone be the abattoir site that was too far away from residential regions were not highly suitable. As demonstrated in (Figure 17) to maintain two objectives (health and economic issues). In this study area the boundary was not immensely far away from the settlement site of the study. Accordingly, researcher was chosen highly suitable as the most preferable for abattoir land demarcation. From the reclassified map statistics presented in (Table 14), the area share of each suitability range was 26.81 km^2, 4.37 km^2, 3.44 km^2, 2.84 km^2, and 5.54 km^2 in order from unsuitable to highly suitable respectively. The study findings show that the majority of the study area 26.81 km^2 was not suitable for optimal abattoir site selection and although solely 5.54 km^2 of study area was show the highly suitable for abattoir site development from a settlement aspect.

Table 14: Suitability index of settlement areas proximity distance in (m)

Settlement	score	Level of suitability	Area in km^2	Percentage %
0 – 500	1	Unsuitable	26.81	62.34
500 – 700	2	Less suitable	4.37	10.16
700 – 900	3	Moderate Suitable	3.44	8
900 – 1100	4	Suitable	2.84	6.60
>1100	5	Highly suitable	5.54	12.88
Total			**43**	**100**

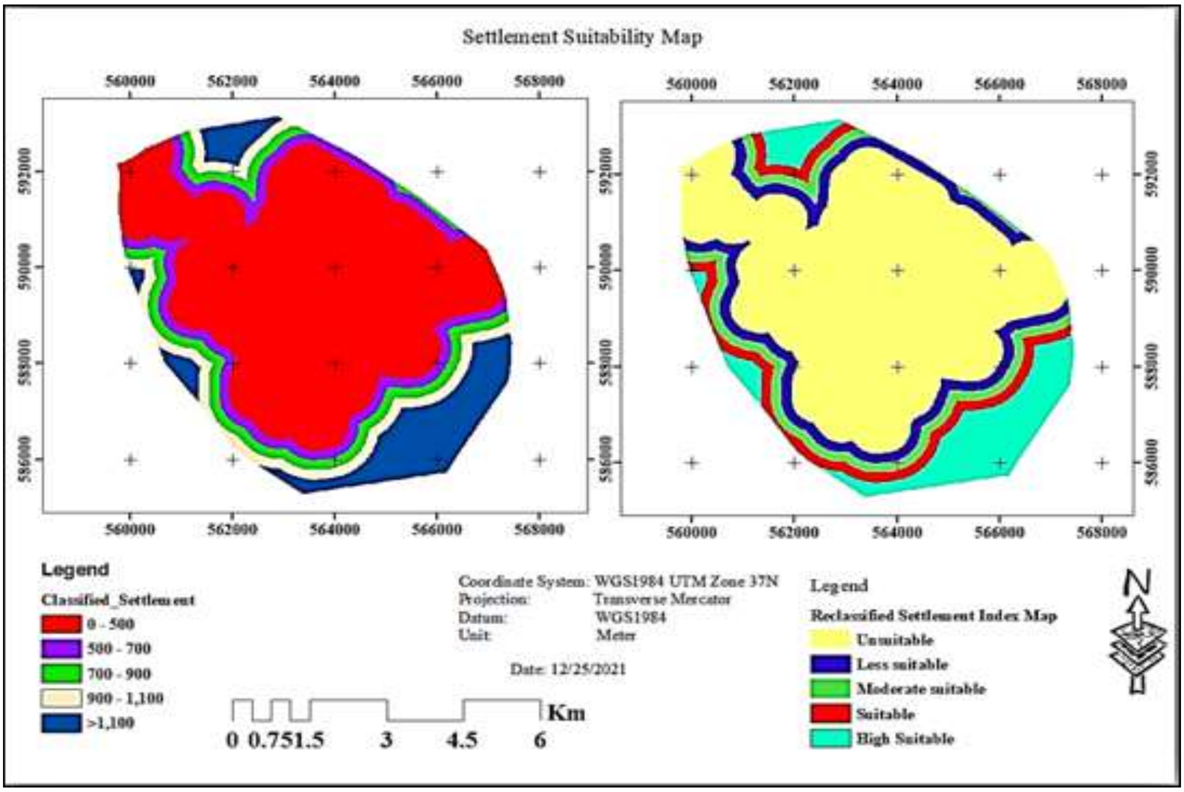

Figure 17: Settlement areas suitability index proximity

4.3.3. Landfill Site Factor

Environmental factors play an important role in today's abattoir setting. To make sustainable an abattoir site various criteria can be considered during the abattoir working, environment plays an important role. With the proper control of the effects of these environmental factors, the Sustainability of an abattoir can be further increased (Singh Thakur et al., 2018). The quality of human health has been impacted by the growth of urban populations, municipal operations, and the ongoing discharge of garbage into the environment. One of the most significant sources of risks to human health and the environment is waste production (Auwalu Abdullahi, et al., 2015). When landfill sites were closed to an abattoir sites, they may dump discarded garbage straight into the Abattoir during wet seasons, posing a major danger to both Abattoir products and the environment. Different types of industry and production, such as food and beverage, materials, and chemical factories, might be found in the abattoir zones. Some of these industries were sensitive to contamination from any source, which lower the quality of the product provided by the facility, either directly or indirectly. According to (Audu, H.A.P, et al., 2020), the abattoir site may include industries that cannot tolerate any contamination rate distance of at least should be kept between 2-5 km. To avoid this sensitivity existing landfill waste disposal site was used as an input spatial information parameter. The existing waste disposal area was extracted from the base map of Nagele Borana Town by utilizing ArcGIS 10.5 software. Because of the lower risk of contamination, areas further away from landfills were more suitable for abattoir plants. So that, a places that was too far away from landfills were not cost-effective since Abattoir site would be travel long distances to dispose of their garbage. As shown below the (Table 15) unsuitable, less suitable, moderately suitable, suitable, and highly suitable were the score ranges used for landfill sites categorization into five classes with intervals of 0-700, 700-1000, 1000-1300, 1300-1600, and >1600. As shows below the (Table 15), the overall contribution of each suitability class landfill for abattoir site demarcation in terms of areas was 1.54 km^2, 1.60 km^2, 2.17 km^2, 2.73 km^2, and 34.96 km^2 based on the reclassified and indexed map of landfill site factor illustrated in (Figure 18) were unsuitable, less suitable, moderately suitable, suitable, and highly suitable ranks were assigned respectively in linguistic variables for landfill factor. To compensate the environmental impact and economic benefit in the current study, would be located at a higher distance from the landfill site were considered highly suitable, while the site was located too distant from the dumpsite were reclassified as suitable for achieving the study's goal. From this viewpoint, the study area was most important suitable for abattoir zoning in regards to area coverages 81.30% and 3.58% indicated highly suitable and unsuitable suitability classes respectively shown on the below (Table 15 and figure 18) respectively results.

Table 15 Suitability index of landfill site proximity distance in (m)

Distance in meter (m)	score	Level of suitability	Area in km^2	Percentage %
0 – 700	1	Unsuitable	1.54	3.58
700 – 1000	2	Less suitable	1.60	3.72
1000 – 1300	3	Moderate Suitable	2.17	5.05
1300 – 1600	4	Suitable	2.73	6.35
>1600	5	Highly suitable	34.96	81.30
Total			**43**	**100**

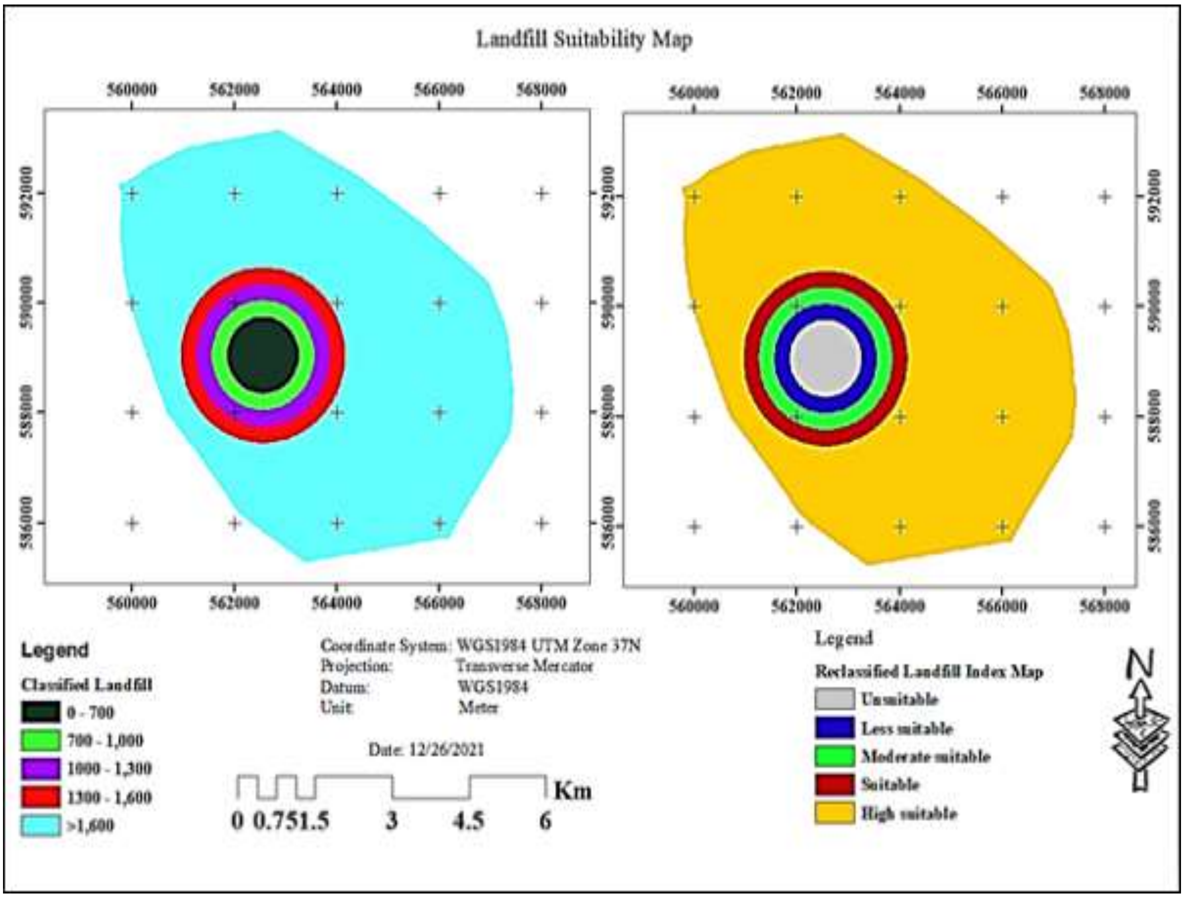

Figure 18: Landfill site suitability index map

4.3.4. Boreholes Criteria factors

Proximity from an abattoir site to a groundwater well is an important environmental criterion in the abattoir site selection so that boreholes may be protected from the runoff and leaching of the waste products from abattoirs (Tesfaye N., 2017). As some sources suggested that the location of abattoir sites should be 300m far from the groundwater wells to increase its importance of protecting the groundwater from pollution (E. C. Chukwuma, et al.,2016) (LMA., 2000).

Table 16 Suitability index of borehole proximity distance in (m)

Distance in meter (m)	score	Level of suitability	Area in km^2	Percentage %
0 – 300	1	Unsuitable	1.54	3.58
300 – 800	2	Less suitable	1.60	3.72
800 – 1400	3	Moderate Suitable	2.17	5.05
1400 – 2000	4	Suitable	2.73	6.35
>2000	5	Highly suitable	34.96	81.30
Total			**43**	**100**

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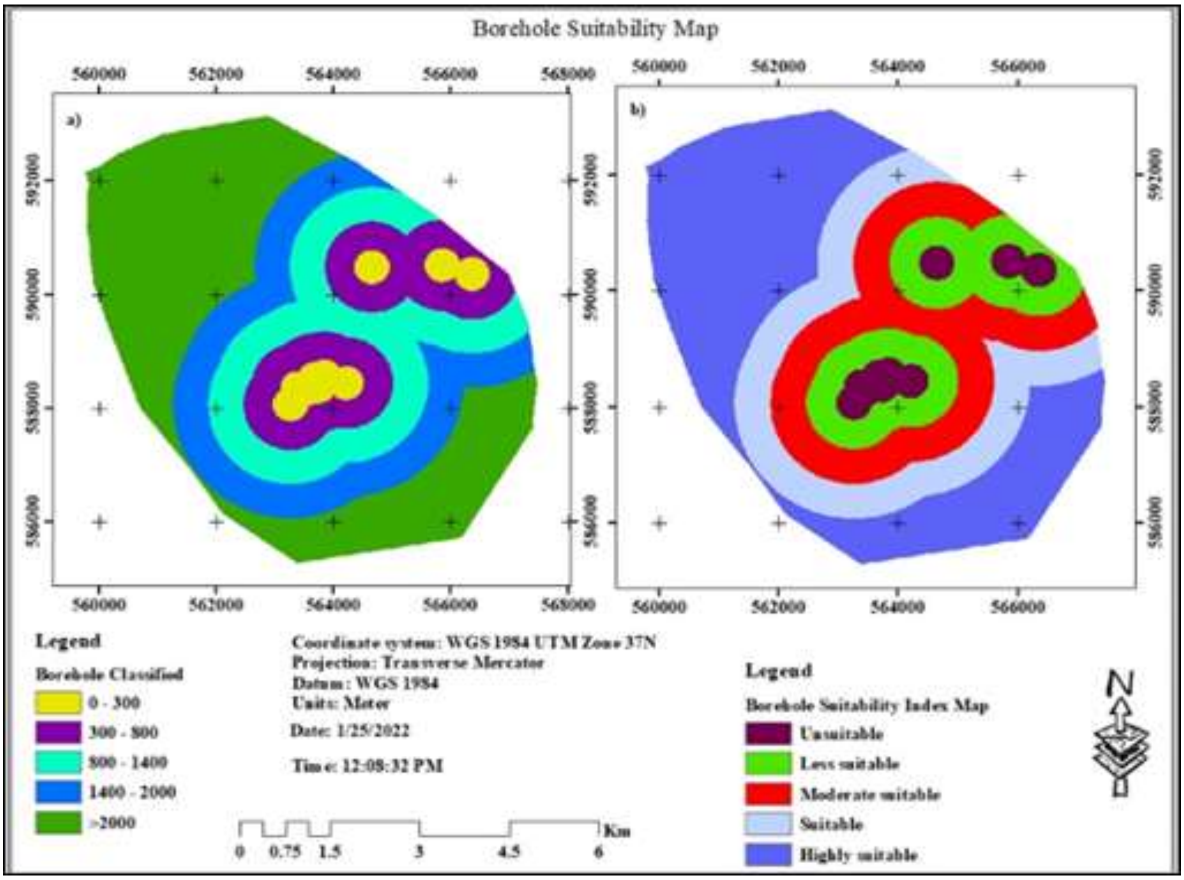

Figure 19 Reclassified borehole Suitability Map

In addition to this, it was directly influence the community neighbored to abattoir site. In each case of the above constraints; areas around all buffer zones are taken as the most suitable and areas within the limit of the least buffer zones were taken as unsuitable for abattoir site location. In this study, as shown below the (Table 16 and Figure 19) the proximity distance of borehole to abattoir area were illustrated from unsuitable to highly suitable,1.54 km^2, 1.60km^2, 2.17km^2, 2.73 km^2, and 34.96 km^2 respectively demonstrated and classified suitability levels from 0 – 300, 300 – 800, 800 – 1400, 1400 – 2000, and > 2000 respectively. As the results of this study shown that, the small areas 1.54 km^2 were considered as unsuitable and immensely large area 34.96 km^2 were shows highly suitable site of study area

4.3.5. High Tension power Line Criteria Factor

Murseli et al., (2014) suggests that areas that are less than 200 meters to electric transmission are the most suitable site, whereas areas greater than 2500 meters are the least suitable for residential areas development. In this study, to lessen possible accidents that could be encountered because of big flying birds (e.g. scavengers) hovering over the abattoir area. Accordingly, the site should be located at least 500 meters from high tension lines (Teshome M., 2O15). In this research, Heavy electric power lines of the study area were extracted from aerial photo with reference to structural plan of municipal. The distance to the electricity grid seems to be highly dependent on the location of the study area. To reclassify the heavy electric power line based on this standard, their euclidean distance was computed using the spatial analysis extension toolbox in ArcGIS 10.5 map and then reclassified with distance ranges of 0-500m, 500m-1000m, 1000m-1500m, 1500m-2000m, > 2000m based on the (AYSHESHIM M. , 2002) (EPA, 2002), (LMA., 2000), (Teshome M. , 2O15), (Tesfaye N., 2017) review. In the linguistic variable, their suitability indexes were unsuitable, less suitable, moderately suitable, suitable, and highly suitable, respectively. As the results shown below the (Table 17 and Figure 20) were a description demonstrating its distance range and suitability index for high electric power lines.

In this study, as shown below (Table 17 and Figure 20) the proximity distance of high tension power lines to abattoir area were illustrated from unsuitable to highly suitable, 9.14 km^2 (21.25%), 8.61 km^2 (20.02%), 8.01 km^2 (18.62%), 7.24 km^2 (16.84%) and 10.00 km^2 (23.27%) respectively demonstrated and classified suitability levels from 0 – 500, 500 – 1000, 1000 – 1500, 1500 – 2000, and > 2000 respectively. As shown above the results, the areas that covered 9.14 km^2 were considered as unsuitable and large areas covered 10.00 km^2 were shown as highly suitable site for abattoir facility of study area.

Table 17 Suitability index high tension power line proximity distance in (m)

Distance in meter (m)	score	Level of suitability	Area in km^2	Percentage %
0 – 500	1	Unsuitable	9.14	21.25
500 – 1000	2	Less suitable	8.61	20.02
1000 – 1500	3	Moderate Suitable	8.01	18.62
1500 – 2000	4	Suitable	7.24	16.84
>2000	5	Highly suitable	10.00	23.27
Total			**43**	**100**

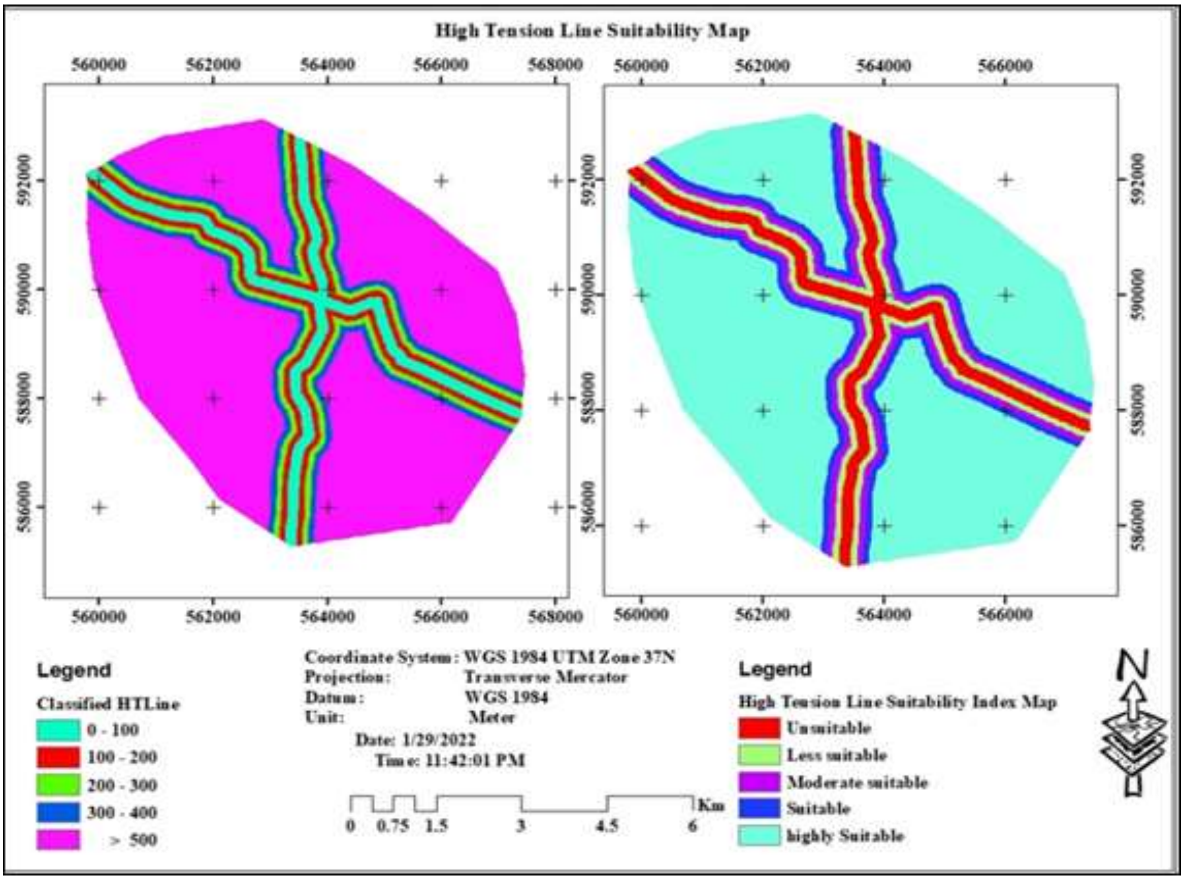

Figure 20 high power line reclassified proximity distance suitability index map

4.4.Geological Criteria Map Generation for Abattoir Site Selection

4.4.1. Soil Types Factor

Soil is defined by Davidson (1980) as a natural body consisting of layers or horizons of mineral and/or organic constituents of variable thickness, which differ from the parent material in their morphological, physical, and chemical properties and their biological characteristics. The lateritic soil and regolith development in Negele seems to be in a high erosional environment and the ferric rete is not thick or eroded by later events from observation in the present field survey. The soil is thin permeable lateritic soil to red clay soil and mixed with black soil of variable thickness as seen in many places of Negele and its surrounding in the present work.

Table 18 .Soil type, texture and infiltration rate (source FAO, 2001)

Soil type	texture	Silt content	Clay content	Sand content	Infiltration rate (mm/h)
Haplic calcisols	Loamy sand	10	9	81	20 – 30
Chromic cambisols	Clay	29	50	21	10 – 20

For this study purpose, the existing soil type of the study area digitized from soil map of Ethiopia was reclassified into highly suitable and less suitable based on the amount of silt and clay content and infiltration rate as presented in (Table 18). Chromic cambisols have high percentages of silt and clay content jointly and less amount of infiltration rate. Therefore, it was grouped under highly suitable classes. The soil with a high percentage of silt and clay particle has high water holding capacity less susceptible for erosion. The infiltration rate of haplic calcisols was less than chromic cambisol and also the silt and clay amount are less. Accordingly, the reclassified of the soil types were as shown below the table indicate that the chromics cambisols were highly suitable and haplic calcisols were less suitable.

Table 19 Suitability index of soil type for abattoir site selection

Soil types	Score	Level of suitability	Area in km^2	Percentage %
Haplic calcisols	2	Less suitable	5.14	11.95
Chromics cambisols	5	Highly suitable	37.86	88.05
Total			43	100

As shown in (Table 19 and figure 21) above, the majority of the study area was highly suitable for abattoir site allocation in terms of soil type spatial information layer, covering 37.86 km^2, while the smallest portion of the study area was less suitable, accounting for 5.14 km^2 of this study area. In this study, as shown above table and figure the soil types and reclassified suitability index map of abattoir area were illustrated they have been only two classes of suitability levels were based on the soil types that shown above on this study area.

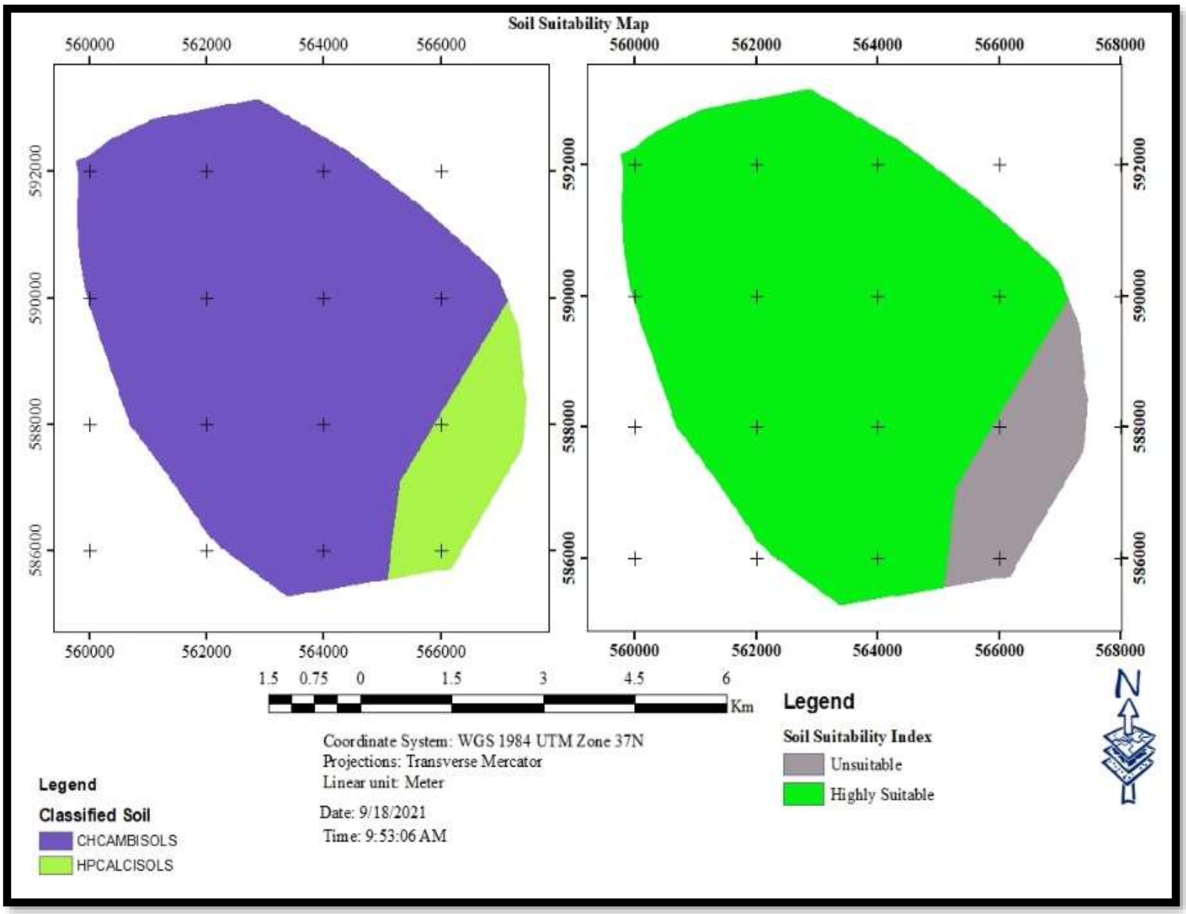

Figure 21 Soil factor map: classified soil type and soil suitability index map

As shown in (Table 19 and figure 21) above, the majority of the study area was highly suitable for abattoir site allocation in terms of soil type spatial information layer, covering 37.86 km^2, while the smallest portion of the study area was less suitable, accounting for 5.14 km^2 of this study area. In this study, as shown above (Table 19 and Figure 21) the soil types and reclassified suitability index map of abattoir area were illustrated and they have been only two classes of suitability levels were based on the soil types that shown above on this study area. Accordingly the level of suitability were depicted less suitable and highly suitable, 5.14 km^2 (11.95%) and 37.86 km^2 (88.05%) respectively. As the results above shows that, the small areas 5.14 km^2 were considered as less suitable and immensely large area 37.86 km^2 were shows highly suitable site of study area.

4.4.2. Geology Types Factor

An abattoir should be located in areas with a low risk of groundwater contamination. The contamination of groundwater primarily depends on the permeability and the depth of the strata beneath the abattoir. High permeability of the strata occurs in karst formations (such as limestone) and sandy soil, low permeability is characteristic for clayey soils, while the clay shales are impermeable (Sekulović D. et al., 2016). This major soil type is common above the limestone units and rocks of low grade belts. The area distribution of the soil types is related to extensive basaltic rock erosion and alteration, transportation and deep weathering of the low grade rocks, and transportation and deposition of soil/sediments from far sources. Despite the presence of patchy and less thick, unmappable eluvial soils developed elsewhere in the peneplained surfaces, over the basement rocks of Negele area, Quaternary eluvial soil cover is restricted to exist over the Jurassic limestone succession, to the east and NNE of Negele town and on top of low grade metamorphic rocks southwest of Negele town (DEMIS A., 2011)

Table 20 Suitability index of reclassified geological types

Geological types	score	Level of suitability	Area in km^2	Percentage %
Eluvium	1	Unsuitable	0.9	2.1
Jerder limestone	2	Moderately suitable	1.3	2.9
Melmel limestone	5	Highly suitable	40.8	95
Total			**43**	**100**

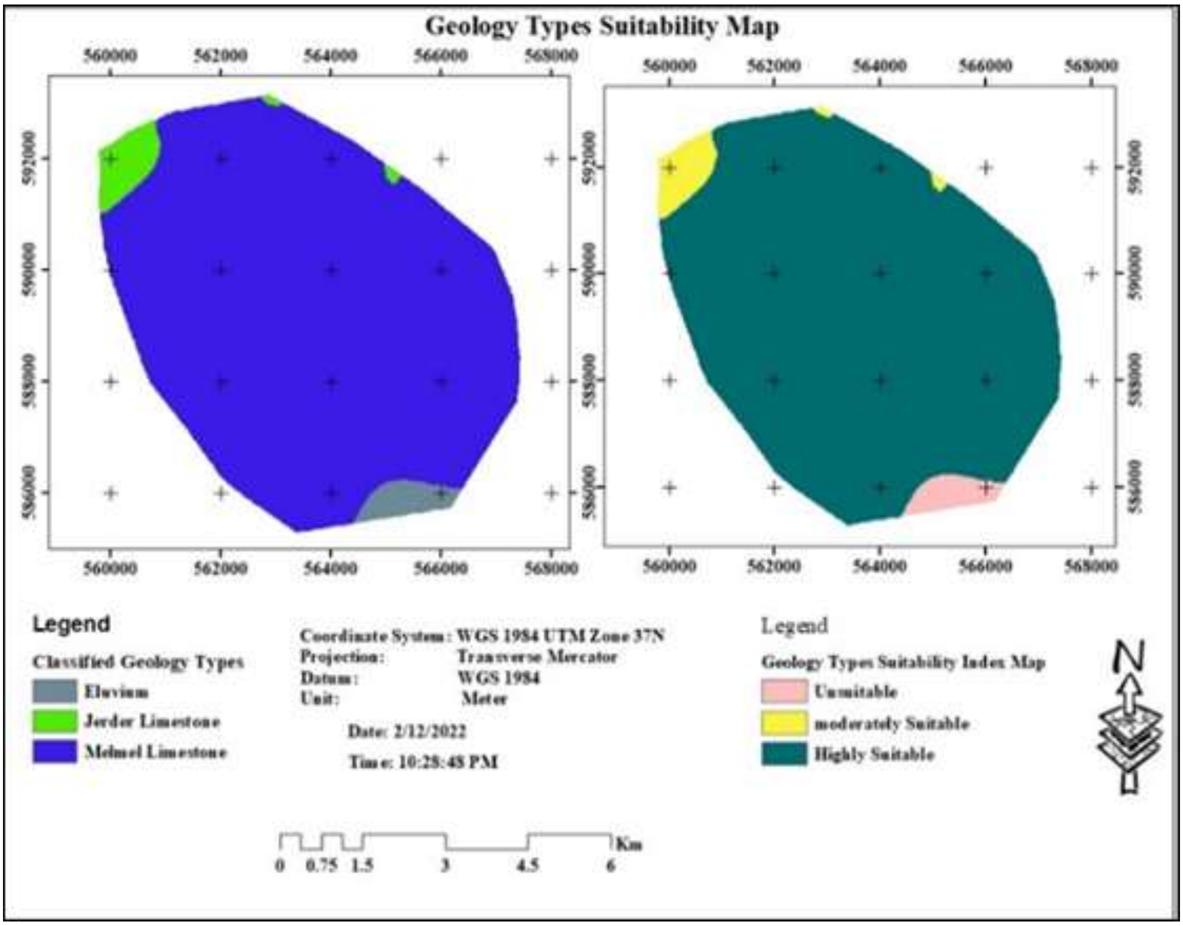

Figure 22 classified geology type suitability index map

In this study, as shown above Table 20 and Figure 22 the geology types and reclassified suitability index map of abattoir area were illustrated under the three classes categories of suitability levels based on the geology types that shown on study area. Accordingly the level of suitability were depicted unsuitable, moderately suitable and highly suitable, 0.9 km^2, 1.3 km^2, and 40.8 km^2 respectively. As the results above shown that, the small areas 0.9 km^2 were considered as unsuitable and immensely large area 40.8 km^2 were showed highly suitable site of abattoir facility area based on the geology types of study area.

4.5.Population Criteria Map Generation for Abattoir Site Selection

4.5.1. Population Density Factor

Urban density is a term used in urban planning and urban design to refer to the number of people living a given urbanized area per given building. Urban density was considered an important factor in understanding how cities function. It was believed that as the number of building increased the built area would be increase and the neighborhood becomes denser. From the ground reality, it was known that most municipal service delivery was related to the population density (Gemeda, 2018). The density of population varies from area to area. According to analysis result, the central parts of the city have high population density in comparison with the urban expansion areas. Densely populated urban areas particularly in low and middle-income countries were vulnerable to the effects of environmental and climate change (Dodman, 2009). Lower population density was considered as more suitable than higher population density for optimal abattoir site selection since the cost of land, property and effects on population decreases with decreasing density. In addition to this, Abattoir waste would be the main source of pollution in the worldwide therefore highly dense population were easily exposed to pollution. For this study population density of the study area was reclassified into five grades as depicted in below (Table 21).

Table 21 Population density suitability analysis of study area

Population density per km^2	score	Level of suitability	Area in km^2	Percentage %
413 – 599	5	Highly suitable	9.14	21.25
600 – 969	4	Suitable	8.61	20.02
970 – 1154	2	Less suitable	7.24	16.84
1155 – 1340	1	Unsuitable	10.00	23.27
Total			**43**	**100**

In this study, as shown above Table 21 and below Figure 23 the population density per area distribution and reclassified suitability index map of abattoir area were illustrated and it have been classified into four classes of suitability levels based on the population density that shown on study area. Accordingly the level of suitability were depicted unsuitable, less suitable, suitable and highly suitable, 10.00 km^2, 7.24 km^2, 8.61 km^2 and 9.14 km^2 respectively.

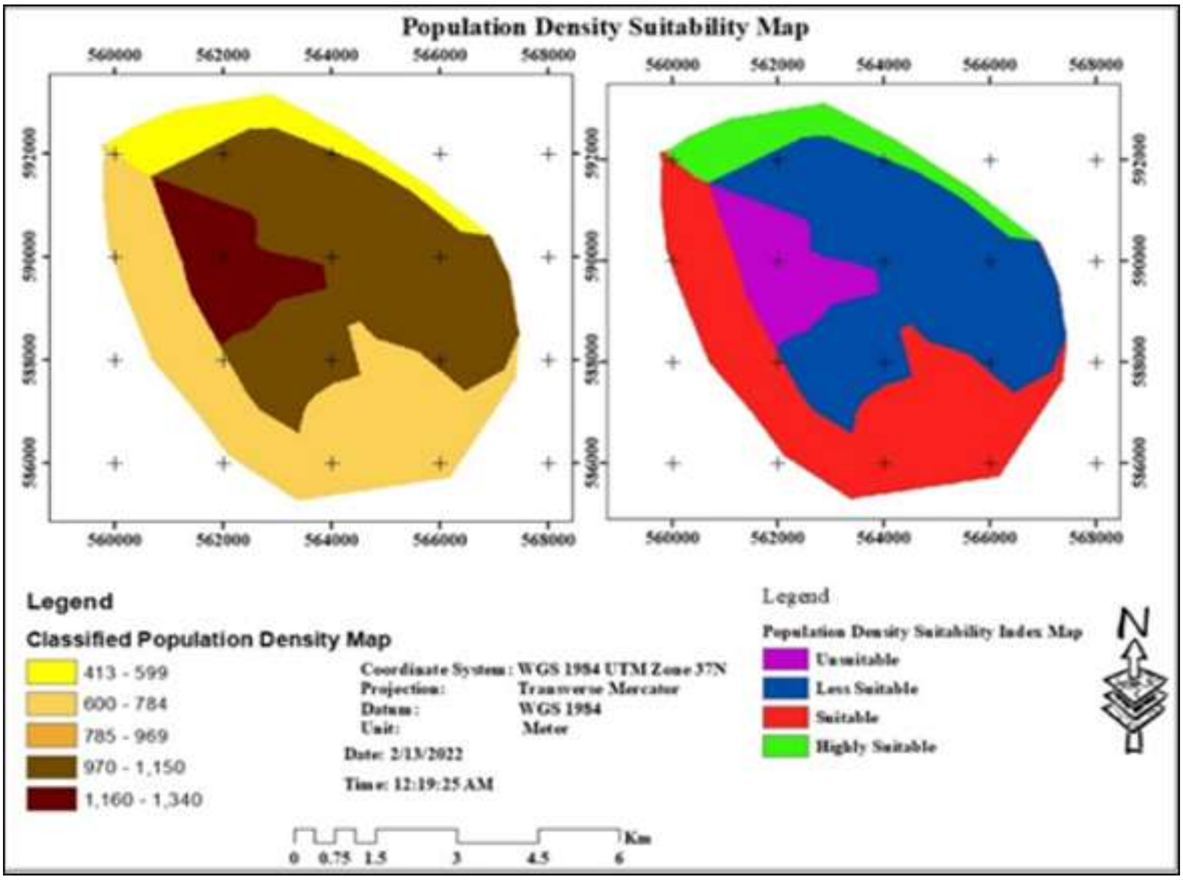

Figure 23 Classified population density suitability index map

As the results above shown that, the areas 10.00 km^2/1155 – 1340 population density of the study area was considered as unsuitable and whereas the area 9.14 km^2/413 - 599 population density of the study area was shown as highly suitable site of abattoir facility.

4.6.Constraints

The constraints in this study include; social services, high tension line, boreholes and abattoir areas. Abattoir should be situated at a significant distance away from these areas. The focused on alleviating possible negative impacts that abattoir can pose on the surrounding environment and vice versa. The impact that the abattoir poses may manifest in the form of liquid wastes, solid waste and airborne wastes (mainly disagreeable odors), large potential for the transmission of zoogenic diseases, noise, traffic congestion, attraction of animals (such as hyenas) and big birds, etc. Therefore, a buffer zone of certain distance should be reserved around the abattoir. Thus, each of these constraints was classified based on the standard criteria using spatial analyst buffer zone distance and the reclassified optimum buffer zone of each factor was taken as suitable site for abattoir site location. According (LMA, 2000), (EPA, 2002) and N U P I experience. Social services: the site should be out of areas of social services such as (Health centers, schools, worship places and recreational areas) in order to reduce sound disturbances. Such areas should also be protected with a 300 meter buffer (Figure 24).Boreholes: Proximity of abattoir site to a groundwater well is an important environmental criterion in the abattoir site selection so that wells may be protected from the runoff and leaching of the waste products from abattoirs. As some sources suggested that the location of abattoir sites should be 300m far from the groundwater wells to increase its importance of protecting the groundwater from pollution, in addition to its direct influence on the community. However, as depicted below the (Figure 24) using Boolean method classification used to identify the constraints factor that shown on the study area. In addition to the results of this study shown that, the area covered by red color was indicated (0) value or restricted area and blue color area covered was denoted (1) value or suitable site for abattoir facility. Finally, as shown below (Figure 24) the result map was generated from Boolean method overlay analysis of all constraints criteria of this study.

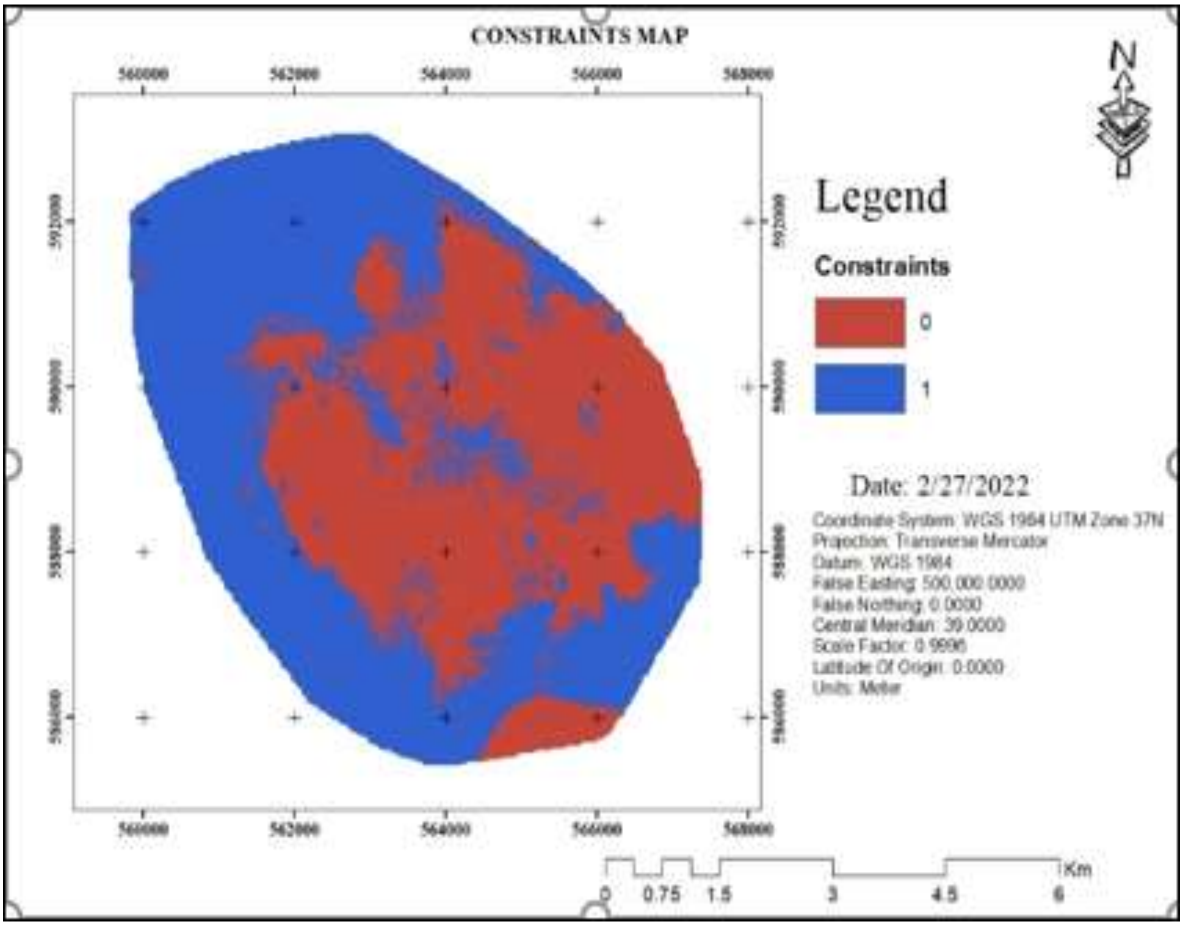

Figure 24 Reclassified Constraints map extracted from topographic map

4.7. Standardizing Factors

After preparation, the factor maps had to be standardized. The values in different input maps may have different meanings and they may include different measurement units (e.g. the slope and aspect map in terms of degree, roads, elevation, and all criteria and constraints were measured in terms of distance, etc.). In order to make the values mutually comparable, it is necessary to standardize them by turning into similar measurement units (Maddahi et al., 2017). Even though different methods can be used to standardize criteria maps, linear scale transformation is the most frequently used technique (Malczewski, 2003). Therefore, in this study for criteria standardization linear scale transformation was implemented to transform heterogeneous factors into uniform measurement scales. To assign scale for the criteria reclassification was done based on different researcher's suggestion then new value was assigned as 5, 4, 3, 2 and 1 for highly suitable, suitable, moderately suitable, less suitable, and unsuitable respectively.

4.8.Determined weight values for influencing criteria in AHP

The ordering of the suitability criteria and the computation of influencing weights were the necessary steps in site suitability analysis. Therefore, the influencing weight of all criteria was generated using 9 class values applied in each factor based on their relative importance (Saaty, 1980). The attributes of all factors were standardized by transforming the original values to a suitability value using a suitability scale from 1 - 9 (Saaty T., 1997). The eigenvector weights of fourteen criteria factors were computed using decision support wizard IDRISI 32 software (Eastman,1995) with the supports of expert judgments (Chandio et al, 2014). Figure 7 show the in-put value of pair-wise comparison using nine point's continuous rating scale and the derived eigenvector of all criteria.

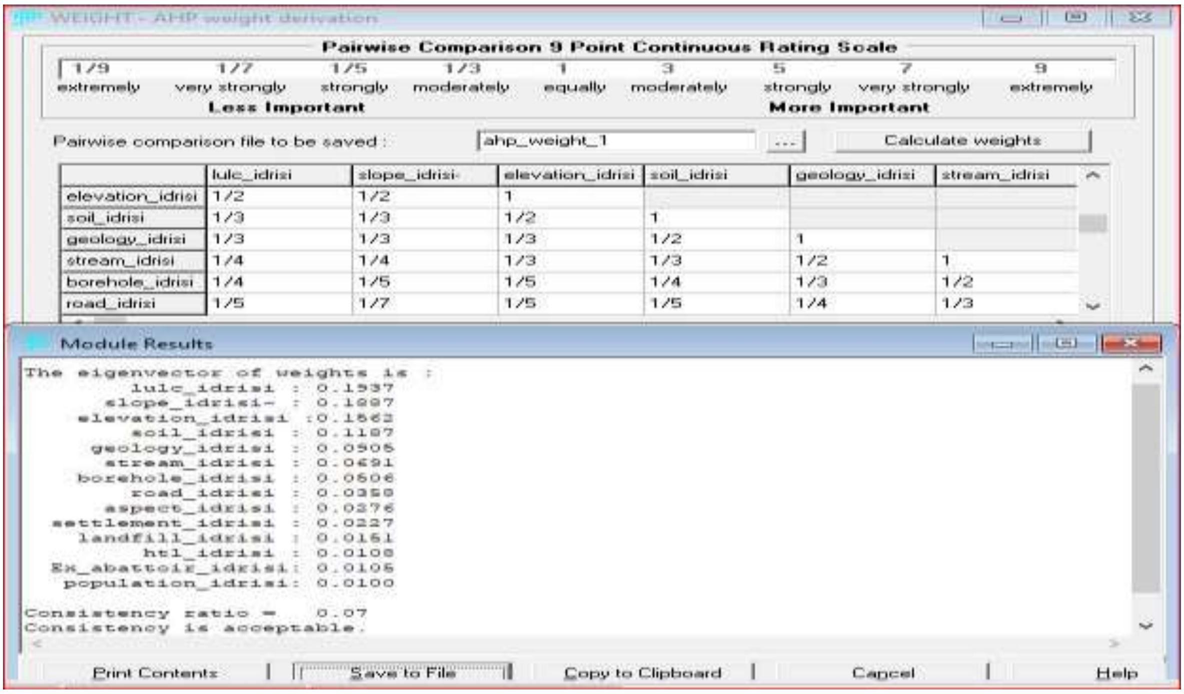

Figure 25. Weight derived by AHP methods

As shows above (Figure 25) results of weight derivate by AHP technique using Idrisi 32 software was acceptable according to the consistency ratio that shown from the finding of their weights. However, this study would be focused on the integrated techniques which means FAHP with multi-criteria decision making analysis.

4.9.Determined weight values for influencing criteria in FAHP

Both FAHP and AHP methods are extremely useful for prioritizing multiple-choice criteria and sorting them into a hierarchical structure. FAHP assesses the relative importance of each criterion and also generates an overall rank of alternatives or weight of factors. In the classic AHP method, the numerical values of linguistic variables are directly used for the evaluation of the criteria. If the environment where the decision-making process takes place is fuzzy, then fuzzy numbers would be used for the evaluation concerning some deviations of the decision-makers (Wijitkosum & Sriburi, 2019).The FAHP method and Chang's (1996) method, which was a very simple method for generalizing the hierarchical analysis process to the fuzzy space, was used in order to assign weight to the criteria (Maddahi et al., 2017).

Table 22 Pairwise comparison matrix of main criteria

Main Criteria																
Criteria	EC			ENC			GC			PC			Row Sum			W
EC	1	1	1	1.5	2	2.5	3.5	4	4.5	2	2.5	3	**8**	**9.5**	**11**	**0.45**
ENC	0.4	0.5	0.66	1	1	1	1.5	2	2.5	2.5	3	3.5	**5.4**	**6.5**	**7.66**	**0.28**

GC	0.22	0.25	0.286	0.4	0.5	0.666	1	1	1	1.5	2	2.5	**3.12**	**3.75**	**4.452**	**0.15**
PC	0.333	0.4	0.5	0.286	0.333	0.4	0.4	0.5	0.666	1	1	1	**2.019**	**2.23**	**2.566**	**0.12**
Column Sum	**1.953**	**2.15**	**2.446**	**3.186**	**3.833**	**4.566**	**6.4**	**7.5**	**8.666**	**7**	**8.5**	**10**	**18.54**	**22**	**25.68**	1.000
CI = (λmax – N)/N – 1																
λmax = 4.208, N = 4, RI = 0.9, CI = 0.069, & CR = CI/RI = 0.069/0.9 = 0.077																

In (Table 22): EC=Economic criteria, ENC= Environmental criteria, GC= Geological criteria, PC= population criteria and W=Normalized weight

According to Equation (2.6), row sum was normalized, also known as the value of fuzzy synthetic extent were conducted for economic, environmental, geological and population major factors based on transformed triangular pairwise comparison matrix

$\tilde{S}_{EC}$ = (8, 9.5, 11)*(1/25.68, 1/22, 1/18.54) = (0.312, 0.432, 0.596)

$\tilde{S}_{ENC}$ = (5.4, 6.5, 7.66)*(1/25.68, 1/22, 1/18.54) = (0.210, 0.295, 0.415)

$\tilde{S}_{GC}$ = (3.12, 3.75, 4.452)*(1/25.68, 1/22, 1/18.454) = (0.121, 0.170, 0.241)

$\tilde{S}_{PC}$ = (2.019, 2.23, 2.566)*(1/25.68, 1/22, 1/18.452) = (0.079, 0.101, 0.139)

To determine the degree of possibility of one criterion fuzzy number‘s being greater than or equal to the other criteria fuzzy number‘s ($\tilde{s}i \geq \tilde{s}j$) Equation (2.9) was applied as follows.

MinV ($\tilde{S}_{EC} \geq \tilde{S}_{ENC}, \tilde{S}_{GC}, \tilde{S}_{PC}$) = min (1.000, 1.000, 1.000) = 1.000

MinV ($\tilde{S}_{ENC} \geq \tilde{S}_{EC}, \tilde{S}_{GC}, \tilde{S}_{PC}$) = min (0.429, 1.000, 1.000) = 0.429

MinV ($\tilde{S}GC \geq \tilde{S}EC, \tilde{S}ENC, \tilde{S}PC$) = min (0.000, 0.199, 1.000) = 0.000

MinV ($\tilde{S}PC \geq \tilde{S}EC, \tilde{S}ENC, \tilde{S}GC$) = min (0.000, 0.000, 0.207) = 0.000

Table 23 Pairwise comparison matrix of economic criteria

Economic Criteria																						
C	**RD**		**LULC**			**SP**			**AP**			**EL**			**AE**				**RS**			**WN**
RD	1.0	1.0	1.0	1.1	1.1	1.2	1.7	2.0	2.5	1.1	1.4	2.0	1.1	1.4	2.0	2.0	2.5	3.3	7.9	9.5	12.0	**0.23**
LULC	0.9	0.9	1.0	1.0	1.0	1.0	2.5	3.0	3.5	1.5	2.0	2.5	3.1	3.6	4.1	2.0	2.0	2.1	10.9	12.5	14.1	**0.28**
SP	0.4	0.5	0.6	0.3	0.3	0.4	1.0	1.0	1.0	2.1	2.3	3.3	2.1	2.3	3.3	1.1	1.8	1.8	7.0	8.1	10.5	**0.19**
AP	0.3	0.3	0.4	0.4	0.5	0.7	0.3	0.4	0.4	1.0	1.0	1.0	0.9	0.9	1.0	1.4	1.7	2.0	4.2	4.7	5.4	**0.11**
EL	0.5	0.7	0.9	0.2	0.3	0.3	0.3	0.4	0.5	1.1	1.1	1.2	1.0	1.0	1.0	1.4	1.7	2.0	4.2	4.7	5.9	**0.12**
EA	0.3	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.9	0.5	0.6	0.7	0.5	0.6	0.7	1.0	1.0	1.0	3.3	3.7	4.3	**0.08**
TCS	3.3	3.8	4.3	3.5	3.7	4.1	6.3	7.4	8.8	7.2	8.4	10.7	8.6	9.8	12.0	8.9	10.6	12.2	37.8	43.6	52.1	**1.00**
	Consistency Ratio (CR) = CI/RI, CI = λmax - N/N-1, where, N=6, λmax= 6.315 RI= 1.24, CI= 0.063, & CR= 0.0508																					

In (Table 23): TCS= Total Column Sum, RS= Row Sum, SP=Slope, LULC=Land Use Land Cover RD=Road, AP=Aspect, EL=Elevation, EA= Existing Abattoir area, C=criteria, and W = normalized weight.

Based on Equation (2.6), row sum was normalized, also known as the value of fuzzy synthetic extent were conducted for economic sub-criteria, based on transformed triangular pairwise comparison matrix depicted above (Table 23).

$\tilde{S}_{LULC}$ = (10.9, 12.5, 14.1)*(1/52.1, 1/43.6, 1/37.8) = (0.158, 0.234, 0.351)

$\tilde{S}_{RD}$ = (7.9, 9.5, 12.0)* (1/52.1, 1/43.6, 1/37.8) = (0.139, 0.197, 0.296)

$\tilde{S}_{SP}$ = (7, 8.1, 10.5)* (1/52.1, 1/43.6, 1/37.8) = (0.138, 0.202, 0.305)

$\tilde{S}_{AP}$ = (4.2, 4.7, 5.4)* (1/52.1, 1/43.6, 1/37.8) = (0.098, 0.139, 0.182)

$\tilde{S}_{EL}$ = (4.94, 5.69, 6.38)* (1/52.1, 1/43.6, 1/37.8) = (0.098, 0.139, 0.182)

$\tilde{S}_{EA}$ = (3.28, 3.67, 4.35)* (1/52.1, 1/43.6, 1/37.8) = (0.065, 0.090, 0.124)

Fuzzy weight obtained through (Equation (2.6) were converted into degree of possibility based on (Equation (2. 9) to determine crisp weight for factor map.

Min$V$ ($\tilde{S}_{LULC} \geq \tilde{S}_{SP}, \tilde{S}_{RD}, \tilde{S}_{AP}, \tilde{S}_{EL}, \tilde{S}_{EA}$) = min (1.000, 1.000, 1.000, 1.000, 1.000) = 1.000

Min$V$ ($\tilde{S}_{SP} \geq \tilde{S}_{LULC}, \tilde{S}_{RD}, \tilde{S}_{AP}, \tilde{S}_{EL}, \tilde{S}_{EA}$) = min (0.789, 0.969, 1.000, 1.000, 1.000) = 0.789

Min$V$ ($\tilde{S}_{RD} \geq \tilde{S}_{LULC}, \tilde{S}_{SP}, \tilde{S}_{AP}, \tilde{S}_{EL}, \tilde{S}_{EA}$) = min (0.821, 1.000, 1.000, 1.000, 1.000) = 0.821

Min$V$ ($\tilde{S}_{AP} \geq \tilde{S}_{LULC}, \tilde{S}_{SP}, \tilde{S}_{RD}, \tilde{S}_{EL}, \tilde{S}_{EA}$) = min (0.103, 0.426, 0.411, 1.000, 1.000) = 0.103

Min$V$ ($\tilde{S}_{EL} \geq \tilde{S}_{LUCL}, \tilde{S}_{SP}, \tilde{S}_{RD}, \tilde{S}_{AP}, \tilde{S}_{EA}$) = min (0.103, 0.426, 0.411, 1.000, 1.000) = 0.103

Min$V$ ($\tilde{S}_{EA} \geq \tilde{S}_{LULC}, \tilde{S}_{SP}, \tilde{S}_{RD}, \tilde{S}_{AP}, \tilde{S}_{EL}$) = min (0.000, 0.000, 0.000, 0.347, 0.347) = 0.000

Table 24 Pairwise comparison matrix of Environmental criteria

Environmental Criteria																			
C	**SR**			**SA**			**BH**			**HTL**			**LF**			**RS**			**W**
SR	**1**	**1**	**1**	**2**	**2.5**	**3**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**1**	**1.5**	**2**	**8.5**	**10.5**	**12.5**	**0.342**
SL	**0.333**	**0.4**	**0.5**	**1**	**1**	**1**	**2**	**2.5**	**3**	**2.5**	**3**	**3.5**	**1.5**	**2**	**2.5**	**7.333**	**8.9**	**10.5**	**0.259**
BH	**0.4**	**0.5**	**0.67**	**0.3333**	**0.4**	**0.5**	**1**	**1**	**1**	**1**	**1.5**	**2**	**1**	**1.5**	**2**	**3.733**	**4.9**	**6.167**	**0.153**
HTL	**0.25**	**0.286**	**0.333**	**0.2857**	**0.333**	**0.4**	**0.5**	**0.667**	**1**	**1**	**1**	**1**	**0.5**	**1**	**1.5**	**2.536**	**3.286**	**4.233**	**0.102**
LF	**0.5**	**0.667**	**1**	**0.4**	**0.5**	**0.667**	**0.5**	**0.667**	**1**	**0.667**	**1**	**2**	**1**	**1**	**1**	**3.067**	**3.833**	**5.667**	**0.144**
TCS	**2.483**	**2.852**	**3.5**	**4.019**	**4.733**	**5.5667**	**5.5**	**6.833**	**8.5**	**8.167**	**10**	**12.5**	**5**	**7**	**9**	**25.17**	**31.42**	**39.07**	**1.000**

CI = (λmax – N)/N – 1

λmax = 5.423, N = 5, RI = 1.2, CI = 0.0885, & CR = CI/RI = 0.0885/1.2 = 0.074

In (Table 24): SR= Streams, SA= Settlement Area, BH= Borehole, HPL= High power line, LF= Landfill site, W= normalized weight

Finally, the minimum values were normalized according to (Equation (2.13) and the normalized weight result obtained was tabulated above.

$\tilde{S}_{SR}$ = (8.5, 10.5, 12.5) * (1/39.07, 1/31.42, 1/25.17) = (0.218, 0.334, 0.497)

$\tilde{S}_{SL}$ = (7.333, 8.9, 10.5) * (1/39.07, 1/31.42, 1/25.17) = (0.188, 0.283, 0.417)

$\tilde{S}_{BH}$ = (3.733, 4.9, 7.167) * (1/39.07, 1/31.42, 1/25.17) = (0.096, 0.156, 0.285)

$\tilde{S}_{HTL}$ = (2.536, 3.286, 4.233) * (1/39.07, 1/31.42, 1/25.17) = (0.065, 0.105, 0.168)

$\tilde{S}_{LF}$ = (3.067, 3.833, 5.667) * (1/39.07, 1/31.42, 1/25.17) = (0.079, 0.122, 0.225)

MinV($\tilde{S}_{SR} \geq \tilde{S}_{SL}, \tilde{S}_{BH}, \tilde{S}_{HTL}, \tilde{S}_{LF}$) = min(1.000, 1.000, 1.000, 1.000) = 1.000

minV($\tilde{S}_{SL} \geq \tilde{S}_{SR}, \tilde{S}_{BH}, \tilde{S}_{HTL}, \tilde{S}_{LF}$) = min(0.796, 1.000, 1.000,1.000) = 0.796

minV($\tilde{S}_{BH} \geq \tilde{S}_{SR}, \tilde{S}_{SL}, \tilde{S}_{HTL}, \tilde{S}_{LF}$) = min(0.273, 0.433, 1.000, 1.000) = 0.273

minV($\tilde{S}_{HTL} \geq \tilde{S}_{SR}, \tilde{S}_{SL}, \tilde{S}_{BH}, \tilde{S}_{LF},$) = min(0.000, 0.000, 0.585, 0.840) = 0.000

minV($\tilde{S}_{LF} \geq \tilde{S}_{SR}, \tilde{S}_{SL}, \tilde{S}_{BH}, \tilde{S}_{HTL},$) = min(0.032, 0.111, 0.791, 1.000) = 0.032

Table 25 Pairwise comparison matrix of geological condition criteria

	Geological Criteria									
Criteria	ST			GT			Row Sum			W
ST	1	1	1	1.5	2	2.5	2.5	3	3.5	0.662
GT	0.4	0.5	0.666	1	1	1	1.4	1.5	1.666	0.338
	1.4	1.5	1.666	2.5	3	3.5	**3.9**	**4.5**	**5.166**	1
CI= **(λmax – N)/N - 1 λmax = 2.02196, N = 2, RI = 0.0, CI = 0.0885, & CR = CI/RI = 0.02196/0.0 = 0.0**										

4.10. Consistency Ratio (CR)

The accuracy of pairwise comparisons was evaluated by calculating the consistency ratio (CR) (Abdulhasan et al., 2019). The CR is designed in such a way that if CR < 0.10, the ratio indicates a reasonable level of consistency. However, CR > 0.10 indicates inconsistent judgments (Maddahi et al., 2017). In this study in order to determine, the comparison of consistent or not in each level of the hierarchy, the consistency ratio was computed using Equation (2.15). The consistency ratio results tabulated above reveals that each hierarchy level was acceptable for further analysis, which was less than 10%. CR was used to estimate the relative weightings of all criteria on a consistency ratio in which values under 10% are considered acceptable (Abdulhasan et al., 2019).

Table 22 Summarization of the overall normalized weights of criteria used

(Hierarchy 1)	Main criteria Weight (W1)	Sub-criteria (Hierarchy 2)	Sub-criteria Weight(2)	Global weight (W1*W2)	Rank
		Road	0.23	0.1035	**2**
		Slope	0.19	0.0855	**3**
		LULC	0.28	0.126	**1**
Economic criteria	0.45	Elevation	0.12	0.054	**4**
		Aspect	0.11	0.0495	**5**
		EAA	0.07	0.0315	**6**
		Stream	0.34	0.0952	**1**
		Borehole	0.15	0.042	**3**
Environment criteria	0.28	HTL	0.10	0.028	**4**
		Landfill	0.15	0.042	**3**
		Settlement	0.26	0.0728	**2**
Geological criteria	0.15	Soil types	0.66	0.099	**1**
		Geology types	0.34	0.051	**2**
Population criteria	0.12	P. Density	1	0.12	**1**
Summation	1			1	

4.11. Weighted Linear Combination (WLC)

After using the FAHP method to calculate the weights of the criteria in this study, the whole set of criteria maps was superimposed using the weighted linear combination approach (Maddahi, Z., Jalalian, A., Zarkesh, M. M. K., & Honarjo, N., 2017). In this research study to delineate optimal abattoir site standardized factor maps such as major road, aspect, slope, elevation, existing abattoir area, LULC, settlement areas, waterbody(stream and borehole), soil type, geological types, high tension line, landfill site and population density were aggregated using the below algorithm depicted in Equation (2.17) through Idrisi selva software. Built-up and water bodies were assigned zero weights, hence these sites were not considered for abattoir development (Johar, et al., 2013). Additionally, based on the available literature, rivers/streams and areas within 1000 meters from them were considered restricted for allocating industries (constraint) (Reisi, et al., 2011). In the current study, also Water body with in 1000m buffer, built-up area within 500m proximity to heavy power lines were considered as a constraint. The produced constraint maps were combined with a Boolean operation to restrict the overall abattoir site suitability map.

The resulting map obtained in the above Equation (17) was summarized in (Table 23) in terms of area and percentage were categorized of each land suitability class. The results shown five suitability index classes were observed in the study area: restricted, unsuitable, less suitable, moderately suitable, and suitable, with percentage coverage of 8.12%, 43.52 %, 36.80 %, 0.49% and 11.07%, respectively.

Table 23 Statistical analysis of abattoir site suitability map

Level of suitability	Area in km^2	Percentage %
Restricted	3.49 km^2	8.12 %
Unsuitable	18.71 km^2	43.52 %
Less suitable	15.82 km^2	36.80 %
Moderate suitable	0.21 km^2	0.49 %
Suitable	4.76 km^2	11.07 %
Column Sum	43 km^2	100 %

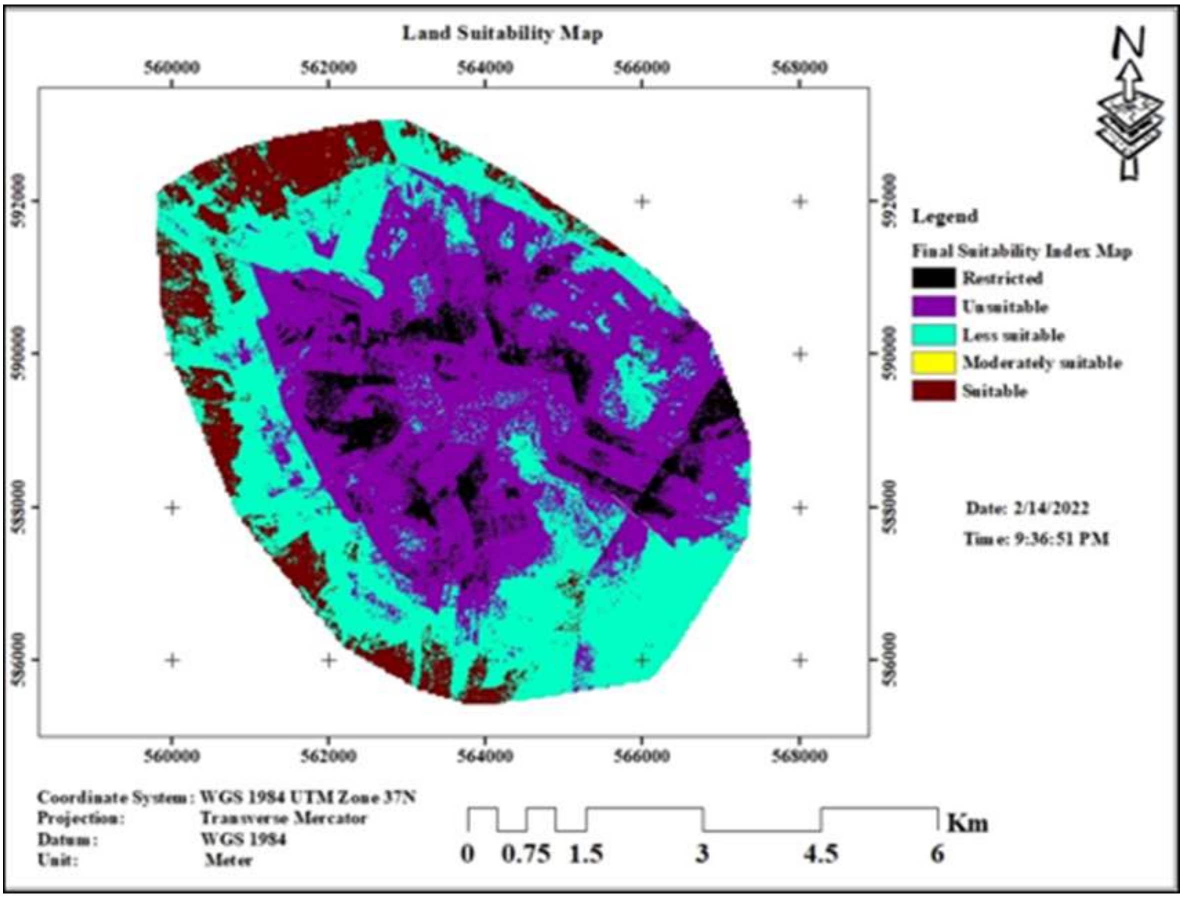

Figure 26 Final suitability map for abattoir sites selection.

The finding obtained by integrating different spatial and non-spatial factor maps reveals that the study area fell under restricted, unsuitable, less suitable, moderately suitable, and suitable classes only out of the expected result from restricted to highly suitable. According to this study's findings, the majority of the study areas were constrained or restricted areas, while the smallest number of areas were suitable for abattoir facility. The area coverage of the suitability indexes from the final result map was 3.49 km^2 (8.12%), 18.71 km^2 (43.52%) 15.82 km^2 (36.80%), 0.21 km^2 (0.49%) and 4.76 km^2 (11.07%) were shown the suitability of classes from restricted, unsuitable, less suitable, moderately suitable, and suitable respectively. According to this study result, the highly suitable class was not found in the study area based on the aggregation of fourteen criteria (factors) and eleven constraints map. The second most suitable land class graded as suitable has been not the prevailing wind directional distribution in the north, northeastern, and some eastern parts of the town, whereas the other suitability classes were spread out in all directions.

4.12. Assessment of Existing Abattoir Area

For the current study, fourteen factors were utilized to assess site suitability for the best abattoir site, including existing abattoir areas. In addition to, those criteria the constraints were superimposed to produce an assessment suitability model map and to evaluate the overall compatibility of the current abattoir areas. The independent input variable, which have been the existing abattoir area, was used as a controlled variable. In order to determine the degree of influence for the others thirteen criteria, the existing abattoir factor was removed from the pairwise comparison matrix. Thus, the weight allotted for this factor map was distributed to others factors. After that, the existing abattoir area polygons were overlapped to the generated evaluation suitability map then their suitability was analyzed using zonal statistics tool extension of ArcGIS toolbox. Then the majority of suitability pixel value fall under polygons were counted and the agreement between the existing abattoir areas and suitability model was analyzed in area coverage as presented in (Table 24). The result of this comparison map shown that the existing abattoir area was fell under restricted suitability class level of study area. Most of the existing abattoir areas were mainly classified under unsuitable areas, whereas it was not identified areas that shown the highly suitability classes from suitability index map of study. According to the depicted findings below (Table 24 and Figure 27), the area of the existing abattoir on the evaluated map was only 0.0069 km^2 area coverage that indicated the unsuitable level of suitability.

Table 24 Comparison of suitability existing abattoir site with proposed area

proposed site suitability		Area in (km^2)	Existing abattoir site area by hectare		Area by (Ha)
Site_1	Restricted	1.21 (km^2)			
Site_2	Moderately suitable	0.33 (km^2)			
Site_3	Suitable	1.06 (km^2)	Existing Abattoir site	Restricted	0.0069 (km^2)
Site_4	Highly suitable	1.59 (km^2)			

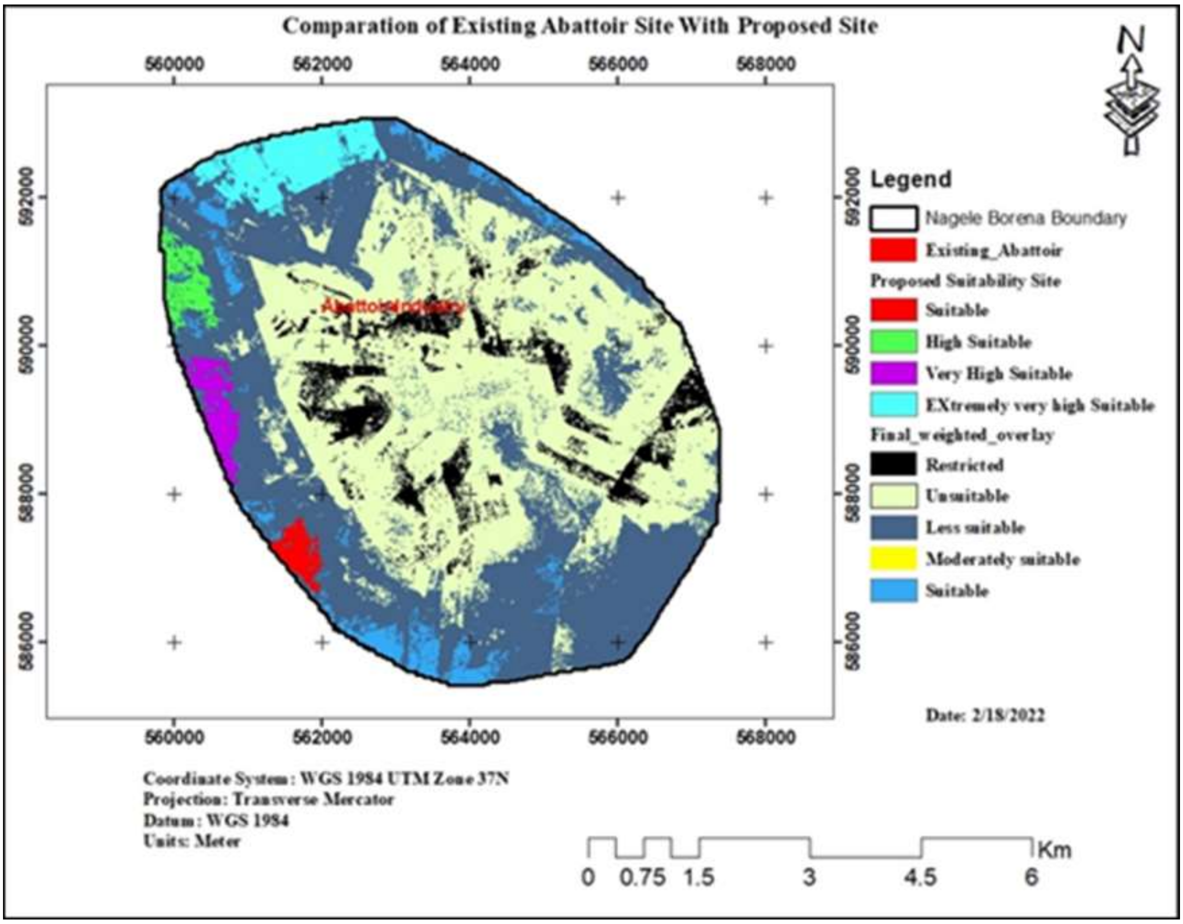

Figure 27 Existing abattoir areas and suitability comparison map

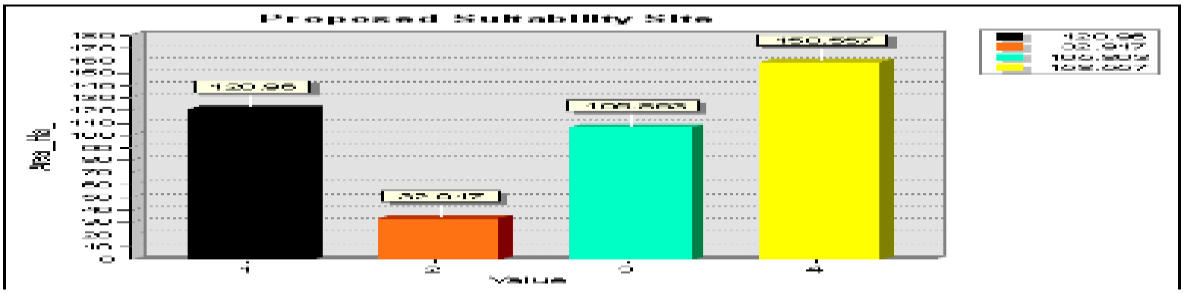

Figure 28 proposed abattoir site land coverage area measured by hectare

Figure 29 existing abattoir land coverage measured by hectare

As depicted results above the (Table 24, Figure 27, 28, and 29) were presented the comparison of the existing abattoir site with the proposed abattoir site capacity of the study area. According to VETERINARY SERVICES, (2007) were suggested that, the site must be large enough to allow the abattoir and related activities to be correctly situated and oriented and it was provided also for future expansions. Site capacity of small abattoirs must be greater than or equal to one hectare (LMA, 2000), (AYSHESHIM M., 2002), (Teshome M., 2O15) (Tesfaye N., 2017). However the existing abattoir site capacity presented on figure 27 is not fulfilled the minimum site capacity that allocated for abattoir facilities. Inversely, in this study there were proposed four sites that have been different capacity of area coverages were identified for abattoir suitable site selection. As the results above (Table 24 and Figure 29) shown that, the existing abattoir area 0.0069km^2 was not suitable. Because the site capacity was under the standards of small abattoir that sited by different researchers. Additionally, above final suitability class on (figure 27) shown that the existing abattoir site was classified under unsuitable class and whereas the proposed area coverage that selected as suitable were ordered, site_1 (1.21km^2), site_2 (0.33km^2), site_3 (1.06km^2), and site_4 (1.59km^2) due to the site capacity size and proposed suitability classes were depicted from restricted, moderately suitable, suitable, and highly suitable that shown above (Table 24) respectively.

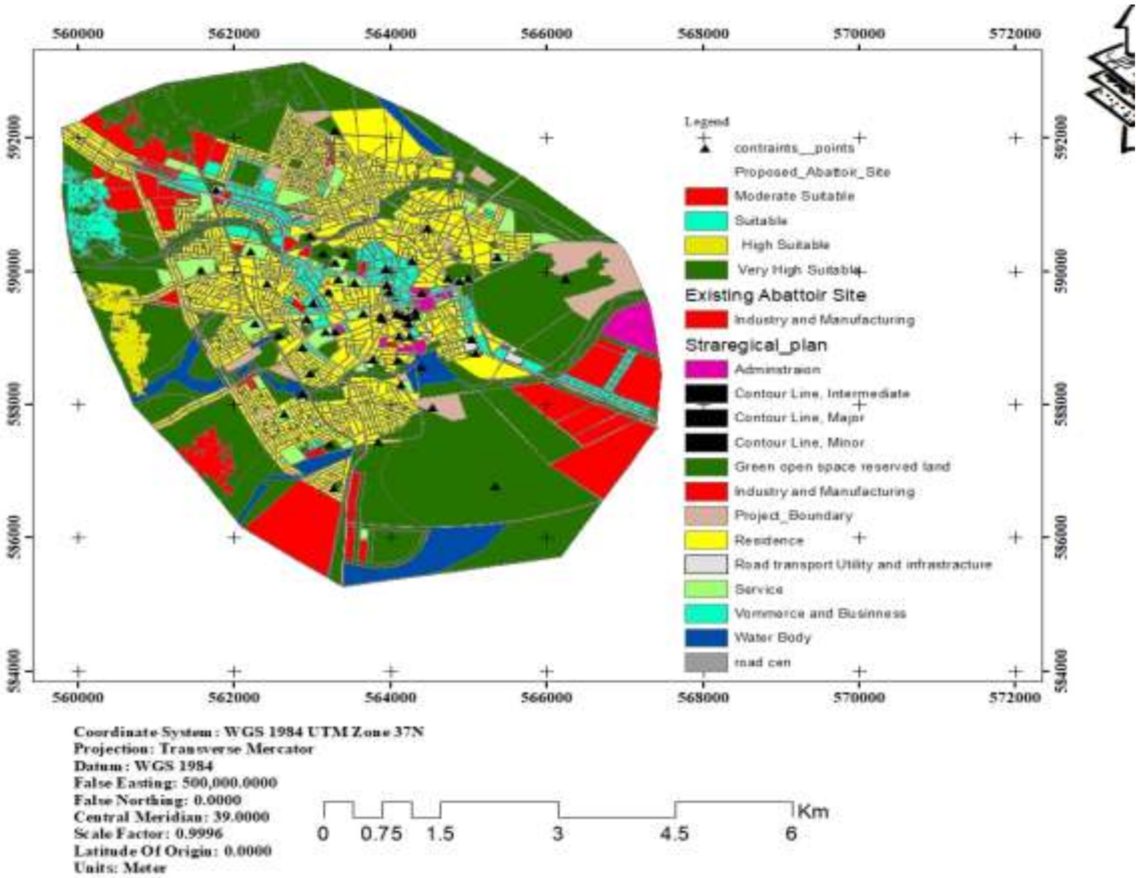

Figure 30 Proposed land-use plan of Nagele Borana town as of 2019 (Source: Nagele Borana town Municipality, 2019).

4.13. Proposed abattoir land use suitability validation

Proposed abattoir land sites were extracted from the proposed land use plan of Nagele Borana town and superimposed with the final suitability map of this study to validate their suitability (Figure 32). The yellow colors area represents the proposed for Abattoir Suitability land of study area that overplayed with the final suitability map (Figure 32).

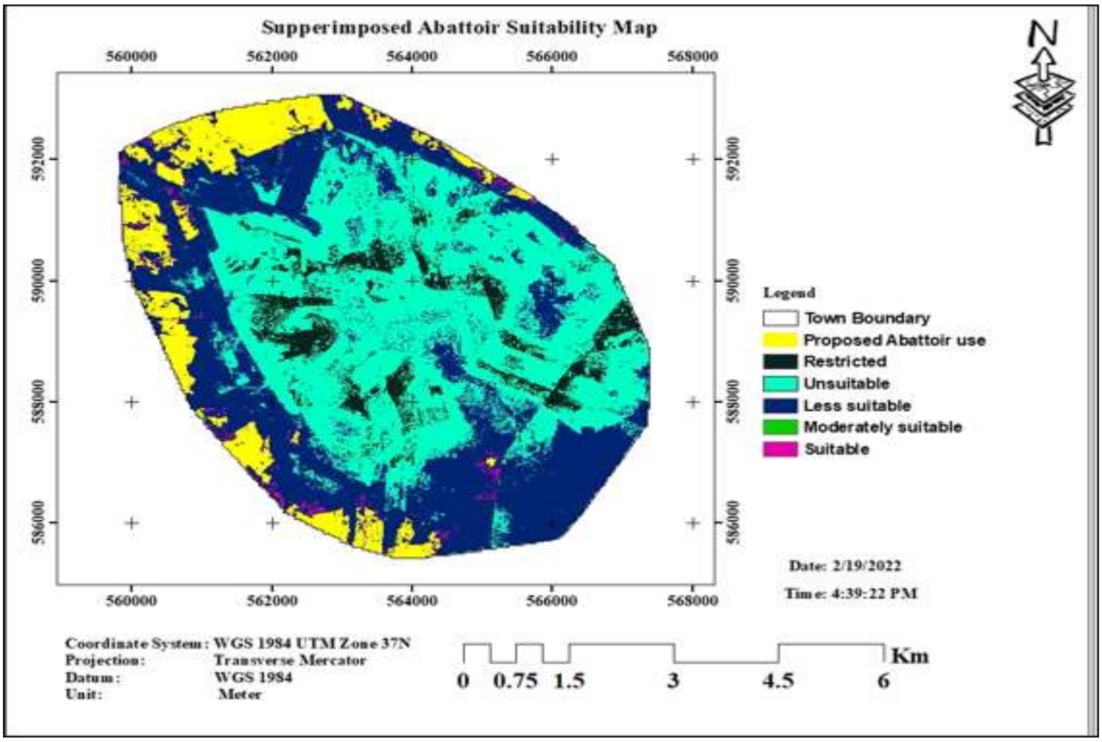

Figure 31 Final suitability map superimposed with proposed abattoir suitability map

The suitability indexes of the proposed abattoir suitability land use were computed (Table 23). The validated result that shown below (Table 25) reveals that 37.905% of proposed abattoir suitability land use was classified as high suitable. Table 24 was also showed that 25.308% of proposed abattoir suitability land use was classified under suitable conditions. The validated result of this study shows that 37.905and 25.308% of proposed abattoir suitability land use plan which were still not constructed or undeveloped exist under high suitable and suitable respectively (Table 25; Figure 32). This indicates that currently, Nagele Borana town was 37.905 % (1.59 km^2) of its remaining proposed abattoir suitability land-use plan will be used for proposed abattoir area for future urban land of Nagele Borana town. The result also shows 0.329% (7.870) exist under less suitability which needs further investigation before the study area only site 1 that was used for slaughtering purposes (Table 24; Figure 27, 29 and 33). Currently, no proposed abattoir suitability land exists under low suitability, whereas 28.917% (1.21km^2), the areas was existed under restriction class of suitability level (Table 25; Figure 32). This was due to either its location under a constraints zone or being constructed or developed before.

Table 25 Suitability levels of proposed abattoir site use plan

Suitability Alternative	Value	Area By km2	Area by %
Restricted	0	1.210	28.917
Unsuitable	1	0	0
Less Suitable	2	0	0
Moderately Suitable	3	0.329	0.7870
Suitable	4	1.059	25.308
Highly Suitable	5	1.586	37.905
Total Column Sum		4.76	100

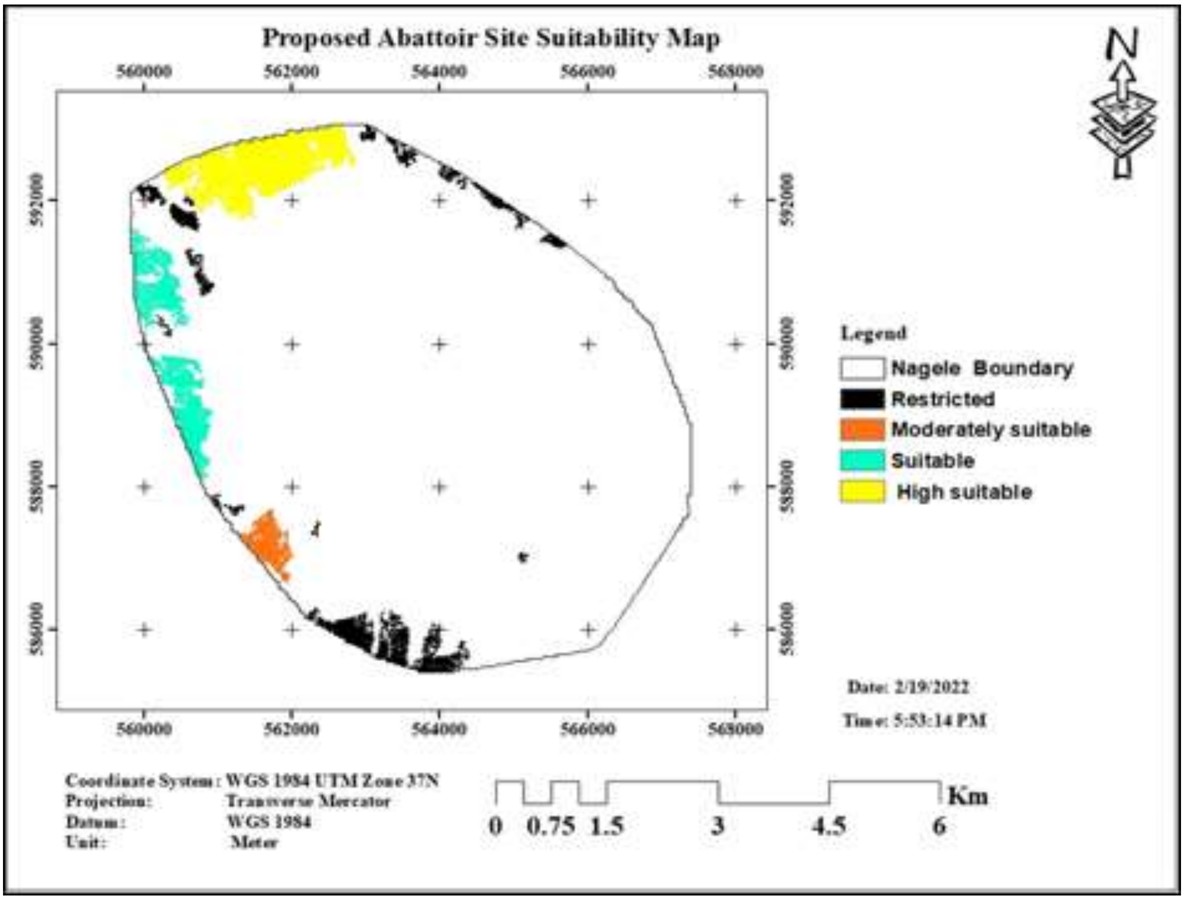

Figure 32 Proposed abattoir site suitability map

The validated result of proposed abattoir site suitability was verified from Google Earth pro and aerial photo of the town. Aerial photo of study area was captured in 2019. It have been 15 cent meter resolution that it had shown the detail spatial resolution of very fine features existed in study area. In the same way Google Earth pro have been 15 cent meter resolution and high temporal resolution with sixteen days revisiting time of the same area. Both Google Earth pro and aerial photo were used to show the current status of proposed abattoir site suitability indexes. Hence the suitability indexes of proposed abattoir site suitability layers obtained in Figure 31 was exported to Google Earth and superimposed with aerial photo and then the following result (Figure 32; Figure 33) were obtained to give the depth picture of proposed abattoir site suitability use status. In comparison of google earth pro with aerial photo of the town, after aerial photo acquired no change was occurred at all from Google Earth pro. So, this study used aerial photo of the town as of 2019 as a field verification to understand the current nature and status of the proposed abattoir site suitability use plan.

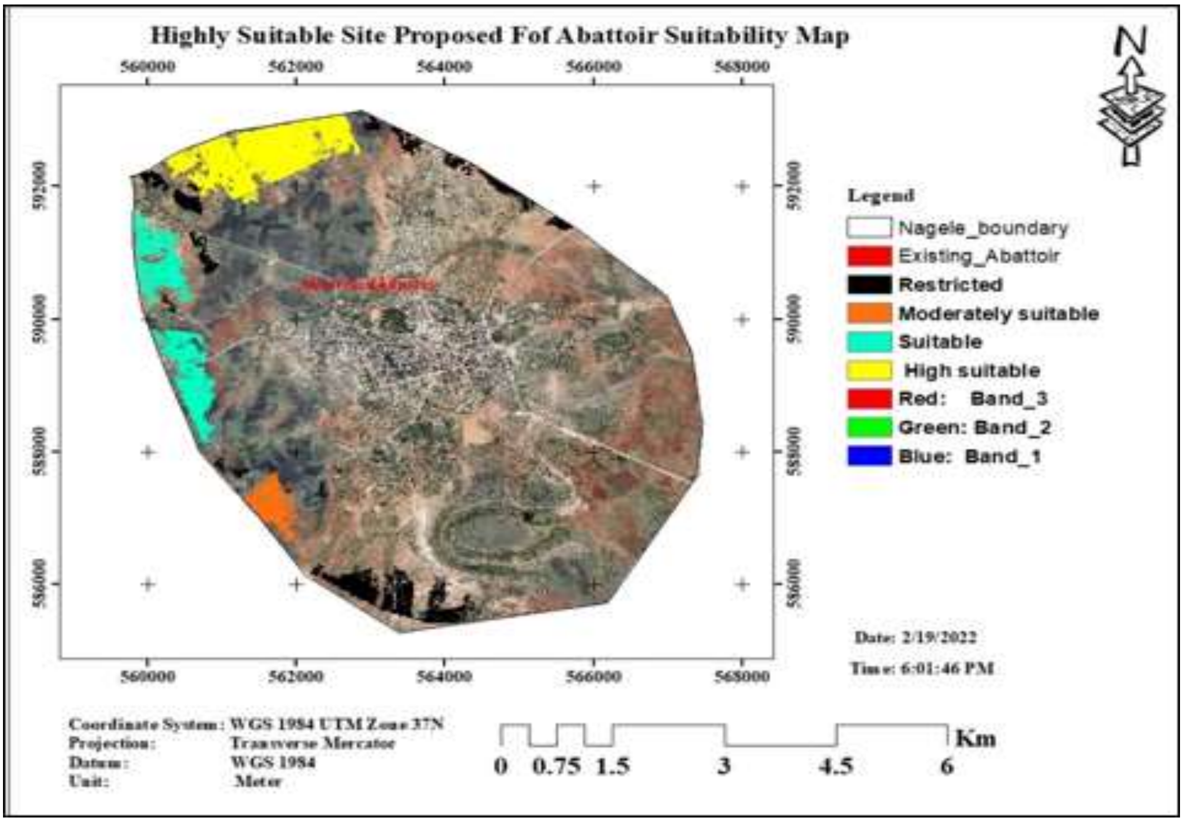

Figure 33 Current status of proposed abattoir suitability

The validated result of this study depicted on (Figure 32; Figure 33) indicated that 1.59 km^2 area of proposed for abattoir Suitability site planned which was still not constructed or undeveloped exist under high suitable site, 1.06 km^2 moderate suitable area that proposed for future abattoir allocated area. Finally the currently Nagele Borana town was 37.905% (1.59km^2) of its remaining proposed abattoir suitability were use plan to allocate for future abattoir area. The finding (Figure 33) reveals 0.33 km^2 exist under less suitability which was not needs for land allocation of abattoir purposes. Currently, no proposed abattoir suitability exists under unsuitable, whereas 1.21km^2, were the area exists under restriction (Figure 33). Finally, the proposed site for future new abattoir facility 1.59 km^2 of study area which proposed as highly suitable site categories for new abattoir location in Nagele Borana town.

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The development of abattoir areas has a substantial good and negative impact on the national economy and environment. The main objective of this study was to analyze an abattoir site suitability area in Nagele Borana town, Oromia, Ethiopia, using geospatial technology tools augmented with MCDA and FAHP techniques for criteria priorities. The rapid progress made in geospatial technologies tools augmented with MCDA and FAHP nowadays have been put forward with a series of functional capabilities and applications to solve conflicts and complexities in any geospatial decision making. Each criterion was standardized, Reclassified, assigned there suitability score. Criterion standardization was based on literature review and policy analysis. All criteria were reclassified to a common scale of measurement. As revealed from the present study, the fourteen communicated criteria result showed that the area classified as minimum proximity distance from the major road, low slope and elevation, maximum proximity distance from water body (stream and borehole), landfill, high power tension line, existing abattoir facility, settlement/residents, geology condition (chromic cambisols soil types and melmel limestone geology types), Bare land class from LULC classified map, North and Northeast aspects of the town and the area classified as low population density were classified as highly suitable site for allocation of abattoir facility. As the result on this study was shown that, the land use land cover classification was determined with the accuracy assessment each classified points were performed as the water, settlement, vegetation, agriculture, and bare-land classes were classified from unsuitable to highly suitable respectively. In addition, the overall accuracy and kappa coefficient results were 98.80% and 0.9822 respectively.

Local experts were offered to order and assign relative importance of each criteria using 9 class values of satty scale and eigenvector weights of fourteen criteria were computed using decision support wizard IDRISI 32 software (AHP) and then the overall consistency ratio (CR) of the module was checked as 7% (0.07) to ensure that the judgments made by experts whether consistent or not and the result fulfilled the tolerable threshold ($CR \leq 0.10$) and as result of FAHP derivation showed that fourteen criterion were classified into four pillar such as economic, environmental, geological condition, and population density to derivate there weighted priorities depicted as economic criteria have been highest weighted which (45%) and from the economic factor LULC criteria was ranked highest score (13%) and all criteria consistency ratio were acceptable which means ($CR \leq 0.10$).

The weighted overlay analysis tool of ArcGIS 10.5 software was adopted to integrate all weighted factors and multiplied by constraint map to produce the final suitability map. The resultant map was computed as all reclassified factors were multiplied by their weights and summed up together then multiplied by a Boolean map which incorporated all constraints under consideration.

As revealed from the final suitability map study areas were categorized under five levels of suitability classes depicted from overall weighted factors were restricted, unsuitable, less suitable, moderately suitable, and suitable respectively. From this output of the study unexpectedly highly suitable class were not detected in the final suitability model map. Their area coverages were 3.49 km^2, 18.72 km^2, 15.82 km^2 0.21 km^2, 4.76 km^2 as its order from restricted, unsuitable, less suitable, moderately suitable, and suitable respectively. Thus, the second suitability index, which covers (4.76 km^2) 11.07% of the study area was considered as the most alternative site for the development of abattoir location. As the assessment result was showed the capacity of the existing abattoir site capacity was 0.69 hectare. As shown from the result, four alternative sites were selected from final suitability classified class which indicated as suitable class and their suitability shown as site-1 (1.21km^2), site-2 (0.33km^2), site-3 (1.06km^2), and site-4 (1.59km^2) based on the area coverage that indicated with the classified as restricted, less suitable, moderately suitable, and highly suitable classes were used to analyze the most appropriated site for abattoir situate.

Assessment of existing abattoir site and validation of proposed site were done and alternative site four (4) which covered (1.59km^2) area was proposed as highly suitable site for abattoir facility allocation.

5.2 Recommendation

Based on the methodology adopted and result obtained through this thesis research the following recommendations were forwarded:-

- The fourth alternative highly suitable abattoir site proposed of this study result was expected to balance the economic factors advantage of an abattoir site, adverse impact of an abattoir on the environment and impact of environment on abattoir (landfill, dust and noise of other industries), population, and impact of geological factor on the abattoir site; therefore, decision-makers can use this zone for further abattoir area development with some extent modification.
- The assessment map of the existing abattoir is situated in center of public settlement, other industry, streams, and site capacity would be under restricted suitability level; so

that, regarding decision-makers, environmental and urban planners will be need to pay attention to those areas.

* Further, in order to lessen issues related to abattoir site impact on the environment, investors, and residence numerous stakeholders from the various field ought to work collaborative.
* This study has been planned to serve for solving of the location problems connected with municipal abattoirs. For export abattoirs, which are relied upon to prosper in the country in the future, some extra factors will probably be required to be considered, depending upon the nature and complexity of such abattoirs based on additional spatial and non-spatial factors including availability of raw materials, availability of workforce, the income of the community and availability of social service.
* Further, future works should be focused on the comparison of AHP and FAHP methods in abattoir site selection used for identified the most considered criteria and to priorities of the site suitability alternative.
* Finally, the abattoir suitable site selected criteria in this study has been expected to be used for towns requiring one abattoir where more than one abattoir is required, additional factors, especially in connection to the spatial distribution of the abattoirs, will be considered due to the particular characteristics of the study area, certain geographic features (such as airplane) are excluded in the study area; however, it considered as constraints in this study area.
* The abattoir site was not located to the direction of prevailing wind this may reduce the dispersal of bad smell into the town.
* The study assured that an abattoir site selection was a spatial problem affected by multiple criteria, which are economic, environmental, geological and social factors. Scientifically abattoir site is critical in protective clean environment and sustainable economic growth. Accordingly, this study provides further understanding to the decision-makers to consider the negative and positive impact of abattoir sites on the environment, investors and residence based on multiple criteria before decisions, in the study area and other regions of the country as well.

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APPENDICES

Field survey using Handheld GPS

Appendix I

Table 26 GPS data collected from the study area using a handheld GPS instrument.

P.#ID	Easting	Northing	Land Identification Infrastructure or feature Category
1.#ID	566241	589886	43 military camp
2.#ID	563019	589521	Bus station
3.#ID	564469	590649	catholic region grave
4.#ID	562879	588858	Cattle market
5.#ID	563986	589696	Commercial Bank of Ethiopia
6.#ID	565091	588773	Drug store
7.#ID	562885	588170	ela oda stream
8.#ID	562978	590530	Existing Abattoir Site
9.#ID	562572	589039	Existing Land Fill site
10.#ID	565377	590217	Shola Primary school
11.#ID	564111	589031	Female Pastoralist students Hostel
12.#ID	563547	589824	Gada Primary school
13.#ID	562423	589821	Garmin Hostel
14.#ID	565345	586784	gobicha Shrub land
15.#ID	563852	587447	gobicha water storage
16.#ID	562268	589216	Gumi Gayo Primary school
17.#ID	561775	591222	HTL
18.#ID	562638	587859	Lega Gula Primary School
19.#ID	562220	590300	Liban Primary school
20.#ID	564317	589403	Liban Woreda Jail House
21.#ID	564231	589214	Makana yesus primary school
22.#ID	563941	590036	Market center
23.#ID	563777	588679	Mosque
24.#ID	563965	589804	Mosque
25.#ID	564279	590167	Mosque Bururi
26.#ID	562981	588465	muslim grave
27.#ID	563296	592110	Muslim Grave
28.#ID	563232	587399	muslim grave place
29.#ID	563425	590256	Muslim Grave Place
30.#ID	563284	586751	muslim tomp place

31.#ID	563298	589089	N /B Rift Vally University
32.#ID	564398	589671	N_B police camp
33.#ID	564249	589030	Nagele Borana Prison
34.#ID	563652	589372	Nagele Borana General Hospital
35.#ID	564083	589374	Nagele Borana Hall
36.#ID	563171	589099	Nagele Borana Health Science College
37.#ID	563870	589333	Nagele Borana Police office
38.#ID	561583	590026	Nagele Borana PoliyTechinc college
39.#ID	563341	589888	Nagele Borana Preparatory school
40.#ID	563298	590134	Nagele Borana Secondary school
41.#ID	563147	590269	Nagele Borana Town Stadium
42.#ID	564409	588568	Nagele Borena small pond
43.#ID	563893	589290	Nile Hotel
44.#ID	565038	588986	OBN Medida Station
45.#ID	563210	589685	Oda Garden Hotel
46.#ID	564332	589336	Ogoba Primary school
47.#ID	564095	588659	old wakefata grave place
48.#ID	564137	588300	Orthodox church
49.#ID	564887	589856	Orthodox church
50.#ID	562933	589294	Orthodox church
51.#ID	564737	589891	Orthodox religions Grave place
52.#ID	565004	589901	orthodox religions grave place
53.#ID	564219	589322	protestant church
54.#ID	565933	588449	Stream
55.#ID	565430	588643	Stream
56.#ID	562998	590448	Stream
57.#ID	564153	589348	Turako Hotel
58.#ID	564540	587954	wakefata grave place
59.#ID	564433	589049	Water Clearing
60.#ID	565079	589556	water storage
61.#ID	565235	588313	water stream
62.#ID	563845	588545	well_point_1
63.#ID	563686	588512	well_point_2
64.#ID	564398	589549	Zone office

Appendix II

Table 27 *Handheld GPS based field survey data for evaluation of accuracy assessment of LULC image classification.*

P .#ID	C	E	N	LULC	P	**P .#ID**	C	E	N	LULC	P
1 .#ID	1	564454	588226	WB	1	**44.#ID**	3	564485	587307	V	3
2.#ID	1	564360	588487	WB	1	**45.#ID**	3	564672	588173	V	3
3.#ID	1	564262	588456	WB	1	**46.#ID**	3	564850	591319	V	3
4.#ID	1	564265	588324	WB	1	**47.#ID**	3	565164	591270	V	3
5.#ID	1	564322	588473	WB	1	**48.#ID**	3	565262	587143	V	3
6.#ID	1	564388	588394	WB	1	**49.#ID**	3	565470	587132	V	3
7.#ID	1	564309	588400	WB	1	**50.#ID**	4	560731	589079	A	4
8.#ID	1	564318	588250	WB	1	**51.#ID**	4	560744	589853	A	4
9.#ID	1	564407	588273	WB	1	**52.#ID**	4	561167	591980	A	4
10.#ID	1	564354	588424	WB	1	**53.#ID**	4	561374	592775	A	4
11.#ID	1	564370	588356	WB	1	**54.#ID**	4	561659	587399	A	4
12.#ID	1	564436	588333	WB	1	**55.#ID**	4	561968	588074	A	4
13.#ID	1	564464	588292	WB	1	**56.#ID**	4	561968	591431	A	4
14.#ID	2	562643	589399	S	2	**57.#ID**	4	562063	587839	A	4
15.#ID	2	562712	590137	S	2	**58.#ID**	4	562330	588779	A	4
16.#ID	2	562704	589945	S	2	**59.#ID**	4	562699	591332	A	4
17.#ID	2	562697	589720	S	2	**60.#ID**	4	562791	591684	A	4
18.#ID	2	562673	589821	S	2	**61.#ID**	4	562930	591223	A	4
19.#ID	2	563648	591227	S	2	**62.#ID**	4	565507	586399	A	4
20.#ID	2	563750	590082	S	2	**63.#ID**	4	565706	586378	A	4
21.#ID	2	563793	590124	S	2	**64.#ID**	4	561398	590088	A	4
22.#ID	2	563919	590049	S	2	**65.#ID**	4	563022	592554	A	4
23.#ID	2	563968	589923	S	2	**66.#ID**	4	565274	590939	A	4
24.#ID	2	564004	589412	S	2	**67.#ID**	4	565509	590718	A	4
25.#ID	2	564112	589141	S	2	**68.#ID**	4	565612	591192	A	4
26.#ID	2	564403	588819	S	2	**69.#ID**	4	566029	590542	A	4
27.#ID	2	564606	589629	S	2	**70.#ID**	4	566317	587632	A	4
28.#ID	2	564674	589383	S	2	**71.#ID**	4	566886	587854	A	4
29.#ID	2	564858	589606	S	2	**72.#ID**	4	566924	590025	A	4

30.#ID	2	563904	588072	S	4	**73.#ID**	4	566988	588231	A	4
31.#ID	2	565501	588482	S	2	**74.#ID**	4	567053	588396	A	4
32.#ID	2	564219	590670	S	2	**75.#ID**	4	567401	588743	A	4
33.#ID	2	561293	589842	S	5	**76.#ID**	5	559894	590989	BL	5
34.#ID	2	563642	589111	S	2	**77.#ID**	5	560018	591259	BL	5
35.#ID	2	563467	589257	S	2	**78.#ID**	5	563260	592392	BL	5
36.#ID	2	563589	591212	S	2	**79.#ID**	5	564091	585619	BL	5
37.#ID	2	563652	590597	S	2	**80.#ID**	5	564195	585639	BL	5
38.#ID	2	564546	590107	S	2	**81.#ID**	5	564230	585801	BL	5
39.#ID	2	563908	589378	S	2	**82.#ID**	5	564918	591005	BL	5
40.#ID	2	563847	589835	S	2	**83.#ID**	5	565247	591613	BL	5
41.#ID	2	563769	590070	S	2	**84.#ID**	5	565304	591474	BL	5
42.#ID	2	564514	589849	S	2	**85.#ID**	5	565457	591407	BL	5
43.#ID	3	564467	587259	V	3	**86.#ID**	5	565477	591524	BL	5
87.#ID	5	565772	587350	BL	5	**132.#ID**	3	564508	585617	V	3
88.#ID	5	565782	587795	BL	5	**133.#ID**	3	564441	585603	V	3
89.#ID	5	565851	587401	BL	5	**134.#ID**	3	563659	588311	V	3
90.#ID	3	562868	589974	V	3	**135.#ID**	3	563600	588227	V	3
91.#ID	3	562884	589970	V	3	**136.#ID**	3	563567	588275	V	3
92.#ID	3	562816	590028	V	3	**137.#ID**	3	563869	588243	V	3
93.#ID	3	562901	590030	V	3	**138.#ID**	3	563785	588222	V	3
94.#ID	3	562926	590017	V	3	**139.#ID**	3	563758	588222	V	3
95.#ID	3	562855	589941	V	3	**140.#ID**	3	563834	588173	V	3
96.#ID	3	562924	589941	V	3	**141.#ID**	3	563826	588208	V	3
97.#ID	3	565023	586088	V	3	**142.#ID**	3	563790	588257	V	3
98.#ID	3	565029	586089	V	3	**143.#ID**	3	563804	588245	V	3
99.#ID	3	565027	586080	V	3	**144.#ID**	3	563729	588257	V	3
100.#ID	3	565038	586084	V	3	**145.#ID**	3	563705	588186	V	3
101.#ID	3	565042	586074	V	3	**146.#ID**	3	563736	588176	V	3
102.#ID	3	565064	586079	V	3	**147.#ID**	3	563660	588219	V	3
103.#ID	3	565026	586061	V	3	**148.#ID**	3	563682	588209	V	3
104.#ID	3	565160	586071	V	3	**149.#ID**	3	564079	588376	V	3
105.#ID	3	565156	586072	V	3	**150.#ID**	3	564177	588323	V	3

106.#ID	3	565154	586066	V	3	**151.#ID**	3	564067	588298	V	3
107.#ID	3	565169	586067	V	3	**152.#ID**	3	564026	588313	V	3
108.#ID	3	565173	586071	V	3	**153.#ID**	3	564029	588328	V	3
109.#ID	3	565161	586068	V	3	**154.#ID**	3	564074	588362	V	3
110.#ID	3	565164	586057	V	3	**155.#ID**	3	564042	588357	V	3
111.#ID	3	565309	586021	V	3	**156.#ID**	3	564060	588162	V	3
112.#ID	3	565301	586011	V	3	**157.#ID**	3	564137	588128	V	3
113.#ID	3	565305	586002	V	3	**158.#ID**	3	564097	588170	V	3
114.#ID	3	565315	586010	V	3	**159.#ID**	3	564088	588136	V	3
115.#ID	3	565310	586017	V	3	**160.#ID**	3	563329	587009	V	3
116.#ID	3	565316	586023	V	3	**161.#ID**	3	563294	587011	V	3
117.#ID	3	565541	585982	V	3	**162.#ID**	3	563282	586995	V	3
118.#ID	3	565529	585972	V	3	**163.#ID**	3	563296	587013	V	3
119.#ID	3	565554	585961	V	3	**164.#ID**	3	563315	587045	V	3
120.#ID	3	565530	585953	V	3	**165.#ID**	3	563344	587039	V	3
121.#ID	3	565525	585956	V	3	**166.#ID**	3	563359	587040	V	3
122.#ID	3	565529	585982	V	3						
123.#ID	3	565554	585981	V	3						
124.#ID	3	564520	585540	V	3						
125.#ID	3	564555	585538	V	3						
126.#ID	3	564427	585587	V	3						
127.#ID	3	564459	585583	V	3						
128.#ID	3	564485	585572	V	3						
129.#ID	3	564448	585615	V	3						
130.#ID	3	564430	585617	V	3						
131.#ID	3	564489	585614	V	3						

P. #ID=Point Identification, E= Eating, N=Northing, LULU=Land Use Land Cover, C=Classified, P =Predicted, 1 or WB=Water body, 2 or S= Settlement, 3 or V= Vegetation, 4 or A= Agriculture, and 5 or BL= Bare land

Appendix III

Questionnaires prepared for experts in different level MSC, Thesis questionnaires paper on Abattoir site suitability analysis in Nagele Borana February 2022

A. For Urban land management and Development of Nagele Borana town Personal Information Name: ____________________ Occupation: ________________ Kebele____________ Sex _________ Age_________ As part of my MSC. Thesis at Adama Science and Technology University, I am conducting a survey that investigates the perceptions of experts about Urban land suitability for abattoir site in Nagele Borana town. Please respond to the following questions that provide inputs for my research. Hence give your idea on space provided

1. What are the criteria you consider during urban land plan preparation special for abattoir site?

____

____

____

____

2. Do you think that, the Nagele Borana existing abattoir site was allocated on the suitable place?

____

____

____

3. What are the suitable criteria considered for abattoir site selection?

____

____

____

4. What are the spatial buffer distances required to separate municipal abattoir from different geographic features (such as settlement areas, streams, boreholes etc.) Nagele Borana town?

____

____

____

B. For Environmental protection and climate change management of Nagele Borana town Personal Information

Name______________________ Occupation; _______________ Kebele___________ Sex ________ Age________ As part of my MSC. Thesis at Adama Science and Technology University, I am conducting a survey that investigates the perceptions of experts about Environmental suitability factors for abattoir site in Nagele Borana town. Please respond to the following questions that provide inputs for my research. Hence give your idea on space provided

1. Are the environmental related problems with Nagele Borena town existing abattoir area?
A. Yes B. Partially C. No please describe

____

____

____

2. What do you recommend to improve the suitability of environment factors for abattoir site of the town for the future?

____

____

____

3. What are the possible recommendations you would be suggest to improve the suitability of abattoir sites and the mechanism to reduce economic crisis and environmental pollution in Nagele Borana town?

____

____

____

5. What problems do you observe from the existing abattoir site plan implementation and regulation?

____

____

____

6. What problems are observed surround the existing of abattoir location in Nagele Borana town?

____
____
____
____

6. What are the site selection gaps and reasons for weaknesses of existing abattoir sites?

A) Plan gaps to encounter the requirement for abattoir area

B) Weak community participation and interference

C) Awareness shortage of residences

D) Municipality weakness in land administration and management

E) Knowledge and capacity shortage of municipality officials

F) The plan preparation doesn’t consider mandate size.

Appendix IV

Interview question and answer responses summarization

Question Number 1: Would you introduce yourself, your position and experience in urban land use and land management sector?

Responses of first Respondent:

Name: - Hailu Tare

Position: - Urban land manager

Experience: - above 5 years

Responses of second Respondent:

Name: - Bonaya Tuka

Position: - Urban land manager

Experience: - above 3 years

Phone: - 0932666437

Responses of third Respondent:

Name: - Arero Galgalo

Position: - Nagele Borana town municipal manager

Experience: - above 4 years

Phone: - 0943947870

Responses of fourth Respondent:

Name: - Doyo Diba

Position: - Environmental protection and climate change management office manager

Experience: - above 7 years

Phone: - 0910047048

Responses of fifth Respondent:

Name: - Abduba Giro

Position: - Urban land use and land management bureau expert

Experience: - above 4 years

Responses of sixth Respondent:

Name: - Zerubabel Yewalashet

Position: - Urban land use and land management bureau expert

Experience: - above 9 years

Responses of seventh Respondent:

Name: - Nura Kete

Position: - Environmental protection and climate change management bureau experts

Experience: - above 3 years

Question Number 2: would you tell me, how the suitability site of municipal abattoir of Nagele Borana town? What are criteria you recommend to select the suitable site for an abattoir?

Responses of first Respondent:

According to his responses the abattoir area and services delivery to the communities are not suitable. Because the site is the center of the town, site capacity is not standard; he said according to new Oromia urban plan the abattoir site must be inner boundary of the town or city and capacity for small abattoir site must 1-1.5 (ha) the Nagele Borana municipal existing abattoir is not suitable for missing of different economic and environmental factors. The road, slope, utilities service, and social services and proximity distance from the settlement area, should be consider during new site selection.

Responses of second Respondent:

According to his responses the existing abattoir site is not suitable. And also many problems present from the site; odour, scavenger (hyenas and different meat birds) are disturb the site and communities around the sites, the site is not have the properly fences to avoid these scavengers. In addition the site is the center of the town, the capacity of the site is not standard. If the future new abattoir site consider criteria such as accessibility of road network for transportation cost, land use land cover, terrain condition, soil condition, geology types, obtainability utilities services, proximity distance from waterbody, residential areas, streams, market centers, and any religious place) the should be suitable for abattoir facility.

Responses of third Respondent:

According to his responses the abattoir area of the town is not suitable. Because the site is the center of the town, community nearest to the sites are affect their health and their always present their complaint to our offices, and also the site capacity is not standard; according to new Oromia urban plan the abattoir site must be inner boundary of the town or city and capacity for small abattoir site must 1-1.5 (ha). So that the existing site was not the standards and still the complain of community nearest to the site was not get the solution. For the future new abattoir site must be consider criteria like; road, slope, utilities service, social services, proximity distance from environmental sensitive including; high tension line, high voltage electric station, Schools, esteem to the airport plan area, military camp, health center, government office for future new site selection.

Responses of fourth Respondent:

According to his retorts the existing abattoir is not suitable by regarding to environmental and socio-economic sides. As his justification the environmental contamination and air pollutions problems are presented around the area because of an properly management of either solid or liquid waste generated form the abattoir area; during burning of bones, carcass and different solid waste the air pollution is occurred not only this there is a bad odour smelled from the site, this also contaminates the environment and also affect the health of resident proximity to the site. As his explanation the existing abattoir site an appropriate distance from surface water line or it an expected nearest to the stream; this also contaminates the surface water and this sites so poorest for producing facility expected to customers. For the future new plan of this facility if those criteria like; (prevailing wind direction, population density area, proximity distance of others industries, landfill site, underground water, and surface) should be consider for appropriate site of abattoir area.

Responses of fifth Respondent:

According to his explanation the existing abattoir site was not suitable for the causes of different factor that could not satisfied and considerable criteria's are present on the site. His suggests that for future site plan will be consider the criteria such as; accessibility of road for reducing the transportation cost, land use land cover, terrain condition, soil condition, geology types, obtainability utilities services, proximity distance from waterbody, residential areas, streams, market centers, and any religious place) those are considerable criteria for suitable abattoir area.

Responses of sixth Respondent:

According to his responses the existing abattoir site is not suitable. As his justified that an abattoir area is the urban function site that generate most wastes of either solid or liquid that are contaminate the environment and pollute the air. By doing so, for the new site selection for abattoir area there are many factors like; (accessibility of road network for transportation cost, land use land cover, terrain condition, soil condition, geology types, obtainability utilities services, proximity distance from waterbody, residential areas, streams, market centers, and any religious place) are to be considerable for suitability of abattoir site.

Responses of seventh Respondent:

According to his explanation the gutters and drainages blockage of abattoir waste were not statistically significant and discharge to the nearby stream without treatment resulting in drainages blockages, pollution of surface and underground water. As his justified that the environmental contamination and air pollutions problems are presented around the area because of an properly management of either solid or liquid waste generated form the abattoir area; during burning of bones, carcass and different solid waste the air pollution is occurred not only this there is a bad odour smelled from the site, this also contaminates the environment and also affect the health of resident proximity to the site. Because of all problems the existing site is not appropriate to give expected facility for customers. However, the future new plan of this facility if those criteria like; (prevailing wind direction, population density area, proximity distance from the environmental sensitive and social services, underground water, and surface) should be consider for suitable site allocation of abattoir area.

Appendix V

Captured photo shows the Nagele Borana Existing Abattoir site suitability used as evidence.

Figure 34 captured photo that shows the existing site suitability


Courante rooms liquid waste storage


Waste drainage line Slaughter Room


Figure 35 Capture photo that shows the proximity of existing abattoir site from settlement

Figure 36 Scattering solid waste generated from abattoir site on surrounding and streams

Liquid waste proximity to stream burning solid settlement

Skin throw into stream over fence liquid waste storage proximity to settlements