Application of GIS and Remote Sensing Using Multi-Criteria Decision Making Analysis for Abattoir Site Selection: the Case of Wolaita Soddo Town, Ethiopia

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MA Thesis Submitted to the Graduate School of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Art in Geographic Information System, Remote Sensing and Digital Cartography

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Declaration

I, the undersigned declare that this 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.

Teshome Matusala Sumamo

Signature _______________

Date ___________________

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Lists of Abbreviations and Acronyms

AHP:	Analytic Hierarchy Process
a.m.s.l:	above mean sea level
CAD:	Computer Aid Drafting
CR:	Consistency Ratio
CSA:	Central Statistics Authority
DEM:	Digital Elevation Model
EIA:	Environmental Impact Assessment
EMA:	Ethiopian Mapping Agency
ERDAS:	Earth Resource Data analysis System
EPA:	Environmental Protection Authority
ESRI:	Environmental Studies Research Institute
ETM+:	Enhanced Thematic Mapper+
FAO:	Food and Agriculture Organization
GIS:	Geographic Information System
GPS:	Global Positioning System
GLCF:	Global Land Cover Facility
GDARD:	Gauteng Department of Agriculture and Rural Development
Ha:	hectare
Km:	Kilometer
LMA:	Livestock Marketing Authority
LU/LC:	Land Use/Land Cover
MCDA:	Multi Criteria Decision Aid
MCE:	Multi Criteria Evaluation
MOE:	Ministry of Agriculture
NUPI:	National Urban Planning Institute
PMGE:	Provisional Military Government of Ethiopia
TGE:	Transitional Government of Ethiopia
USGS:	United States Geological Survey
UTM:	Universal Transverse Mercator
WDU:	Wolaita Development Association
WHO:	World health organization
WLC:	Weighed Linear Combination
WSM:	Wolaita Soddo Municipality
WZFED:	Wolaita Zone Finance and Economy Development

Abstract

Abattoirs are one of important urban functions that need suitable site to be compatible with the surrounding geographic features. However, they are observed being located at inappropriate site posing environmental hazard to their surrounding and are also affected by some nearby activities. The present study was carried out to locate the most suitable abattoir site in Wolaita Soddo town. In order to do this it was found important to go through the experience of national urban planning institute of Ethiopia, and hence reviewing the experience of urban land use planning for sitting critical environmental issues like abattoir was done. An integrated Remote Sensing and GIS approach was found to be very helpful to designate abattoir site in the study area. Factors that were found to be significant in identifying the site in the study area in order of importance were: land use/cover, drainage, elevation, slope, and distance from roads, landfill, power sources, conservation areas and boreholes. These factors were weighted in hierarchical order using the MCE approach to produce suitability map of abattoir site. From the overall suitability map, suitability level of areas was calculated. Major findings of the study revealed that, highly suitable areas and moderately suitable sites are identified within the bare land portion of future land use at south western and south eastern part of the town, suitable and least suitable sites are located at the periphery of built up lands in the west and other different land use portions. The results can be readily interpreted by land-use planners and land managers and should contribute to environmentally sustainable land-use decision making.

Chapter One

1. Introduction

1.1 Background of the Study

The rapidly changing pattern of urban growth has given rise to new problems for urban planning and redevelopment. This growth has been associated with increasing pressure on land for human settlements and related urban services. Thus, immediate attention required for the perspective physical planning of towns and cities due to higher complexity involved in it. A major objective of urban land use planning is to evaluate the advantages and disadvantages of one use of land parcels as compared to another. Cities and towns in most developing countries experience a growing pressure of population on finite resources and a lack of modern economic organization, which might help relieve this pressure (Harris, 1990). The implication on the environment and the quality of life is thus far reaching (Tegegn, 2001). This fact holds true for Ethiopia, as well (Ibid).

Urban planning takes place in a spatial context. Much of this planning has to do with the use of land and how the different types of land uses relate to one another. This means that urban planning must contend with many conflicting goals and circumstances. A desire to provide an amendable and efficient urban environment conflicts with the need to conserve resources. The anticipation of rapid growth calls for the provision of facilities which may not be needed at once. Provisions for the future will require a degree of foresight which is difficult to achieve in a dynamic and uncertain environment (Harris, 1990). Furthermore, most investments in buildings, factories and infrastructures have their physical location in towns and cities. These investments have a long life span and depend for their functioning and efficiency on the urban area to which they belong (Bruijn, 1990).

Harris (1990) stresses that the mixture of problems which must all be resolved together, covering several types of land uses and a lot of public facilities which illustrate the natural complexity in urban planning creates as situation in which many alternatives must be tried, combined, improved, and tested by analysis, by experiment and by public discussion. Bruijn, (1990) also emphasized that the interdependency between investments and their environment, and the need to integrate all groups of dwellers in urban society under decent living conditions, make urban planning at all level of government a prime concern. Such urban planning exercise is no exception in Ethiopia (Solomon, 1999).

Geographic data have been traditionally presented in map form. Land suitability analysis is commonly done with map overlay and it used to be done manually. McHarg (1969) describes how using manual map overlaying can do systematic land use planning. GIS has vast potential, recognized but not fully realized, for solving environmental and human management problems (Antennuci, *et al*, 1990); its application is limited only by the imagination of those who use it (ESRI, 2001). This is why a GIS application for solving real world problems, where geographically-referenced data is needed, is recognized as an important research area of the field (Worboys, 1994).

GIS is used for site selection for many different lands of single facilities with unique location requirements, for which the implications as to traffic, pollution, displacements of other activities, functionality of the new facility, and soon can be explored (Harris, 1990; Bruijn, 1990). A different set of problems arises when the present and future location of systems of facilities are considered. Here, all the questions at single facility level arise, but compete 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 (Harris, 1990).

The effective use of GIS depends on the purposes for which it is applied and the context in which that application takes place (Ibid). Furthermore, a better understanding of GIS technology by users, managers, and decision makers is crucial to the appropriate use of the technology (Aronoff, 1989).

A multi-criteria evaluation (MCE) method can serve to identify, classify, analyze and conveniently arrange the available information concerning choice-possibilities in urban land use planning. It is mainly involved with how to combine the information from several criteria to form a single index of evaluation. It is used to deal with difficulties that decision makers encounter in handling large amounts of complex information. Abattoir site location was determined within the study town through the integration of geographic information system (GIS), weighted linear combination (WLC) analysis, and remote sensing techniques. Several parameters were collected from various sources in vector and raster GIS formats, and then, used within the GIS-based WLC analysis to select suitable abattoir site.

1.2. Statement of the Problem

One of the major tasks performed by National Urban Planning Institute /NUPI/ is, studying important urban functions or services and proposing them at appropriate location. Abattoirs are among the many services which NUPI designs in urban land use development. Abattoirs are livestock processing industries, located near the population and serves (for Ethiopian case, usually within the municipal boundary of the corresponding cities and towns). The activities involved in abattoirs pose environmental hazards to the neighboring areas. These are manifested in the form of (EPA, 2002; WHO, 1984) liquid wastes, storm water contamination, solid wastes, airborne wastes, diseases, and noise. In some other situations such as in Gimbi town, abattoirs are built very close to water supply dams that the liquid waste disposed of joins the water, representing serious hygienic hazard (NUPI, 1999b).

Conversely, abattoirs could be affected by certain nearby incompatible activities. Examples are industrial activities that emit smoke and dust. The most notable ones include; encroaching by other urban land uses (housing and commercial activities) through time dimension, being nearer to waste disposal site and exposed to pollution (typical example is Teppi town (NUPI, 1999c), constructing within the central business center indicating serious incompatibility problems.

According to the NUPI, the duration of plan implementation for a given town ends within ten years and considering the expansion and scope of the service delivery, the revision and modification of the existing plan might be mandatory. In most cases this is either to renew old areas or due to complete utilization of land allocated during the last planning period.

Hence, the establishment of abattoirs at appropriate site considers the identification of large number of factors to make spatial decisions and the extent of the interrelationship among these factors and difficulties in decision making (Malczewiski, 1999), particularly in terms of timeliness, being error free, and labor requirement (both intellectual and physical).

Many researchers had carried out studies on municipal abattoirs operation and waste management practices, suitability of meat and byproducts, and prevalence of cattle diseases in Ethiopia and the world at large. However, Aysheshim (2002) conducted his research on the application of GIS for urban planning in Ethiopia with particular reference to abattoir site suitability analysis for kulito town. The study was mainly based on the urban planning institute experience. However, it did not consider the multi-criteria decision making analysis. The ability to manipulate the spatial data and corresponding attribute information and to integrate different types of data in a single analysis and a higher speed are unmatched by any manual methods (Aronoff, 1989). The current study considered both the experience of NUPI and multi-criteria decision making techniques. As can be noted like most spatial decision making problems, the land allocation problem associated with abattoirs is multi-criteria in nature, involving economic, social, environmental and political dimensions.

Moreover, the pattern of geographical features varies from place to place and time to time. Topographically, the study town, W/Soddo, is typically different from Kulito. Thus, the criteria applied for site suitability analysis of abattoir in W/Soddo may not be similar with Kulito town. For example slope, one of the major criteria in site selection for this study, was not treated in the case of Kulito. Besides, the site selection techniques using GIS had never been conducted to locate abattoirs as well as other urban functions in the study town. Basically, technology in general and geographic information technology in particular, is a means to make many types of work more efficient and works more effective; it enables better decision, based on better information (Antennuci, *et al*, 1990).Therefore, this study fills the gap and seeks to validate the suitable site for abattoir considering sustainable development of the town using GIS as a tool.

This study was focused on abattoir site suitability assessment in Wolayta Soddo town, southwestern Ethiopia. The researcher has been working in the areas of urban development particularly in urban plan preparation and implementation sector of the study town. This exposure created opportunity for the researcher to access town data and see gaps related with abattoir's site. Furthermore, meat consumption is likely to be high. These derived the researcher's attention to carry out the study on the existing abattoir. The problems are further summarized as follows:

1. The present expansion of residential areas, proximity to stream water (on which most urban low income classes depend) for domestic uses, and other urban facilities like power sources, commercial centers likely to make the location of existing abattoir inconvenient.

2. The previous site allocation of abattoir seems out of date against the application of multi-criteria support techniques relevant for specific location of urban facility.

1.3. Objective of the Study

1.3.1. General Objective

The main objective of the study is to develop suitability model for abattoir site selection using GIS and remote sensing for W/Soddo town and provide recommendation for further activities of urban planning.

1.3.2. Specific Objectives

In line with achieving the general objective, the study sets the following specific objectives:

i. To develop a prototype GIS database for the location of abattoir site and other urban services;
ii. To develop a site suitability model in order to select the most suitable site for abattoir.

1.4. Significance of the Study

The research study is expected to produce suitable site location map for abattoir in W/Soddo town. The information generated by this study is believed to provide useful information for urban planners to exercise right judgment on the provision of preferable location for specific urban facilities and organizations working on environmental issues like sanitation problems related with pollution of air, waste water and noise.

1.5. Limitation of the Study

The scope of this study is identifying suitable site for abattoir using multi-criteria decision making techniques in GIS and remote sensing environment. The study focused mainly on municipal abattoir since they are the dominant types in most towns of the country. The site selection criteria were formulated based mainly on NUPI's experience. As to export abattoirs, such requirements should be modified based on the guidelines recently provided by the Livestock Marketing Authority. Because of the specific features of the study area, some of the criteria are not incorporated in the abattoir site suitability model. This mainly include; airports.

1.6. Organization of the Thesis

This thesis is divided into five chapters. The first chapter provides an introduction to the study, which consists of different sections: background, statement of the problem, objectives, significance of the study and its limitations. The second chapter deals on the review of related literatures. Which mainly included the experience of urban development planning, the importance of abattoirs as urban functions including their basic features, undesirable environmental problems abattoirs pose and basic facilities they require to properly function, the application of geographic information system (GIS), its theoretical framework. The third chapter deals with the materials and methods employed in the research. These include; description of the study area, identification of site selection criteria and analytical framework. In chapter four, discussions of the analysis report and final suitable site has been identified for the study area. Chapter five is about conclusion and recommendations.

Chapter Two

2. Literature review

2.1. An Overview of Urban Planning

The urban areas in developing countries have witnessed tremendous changes in terms of population growth and urbanization. In the absence of proper urban management practice, uncontrolled and rapid increase in population pose enormous challenges to governments in providing adequate shelter to the millions of homeless and poor in urban areas (Raghunath, 2006). This has also posed great concern among urban planners. Random urban growth leads to the change of land use and land cover in many urban areas around the world, especially in developing countries (Hauser *et al*, 1982). This is resulting in deterioration of infrastructure facilities, loss of agricultural lands, water bodies, open spaces, and diminution of ground water aquifer zones, water contamination, air pollution, health hazards and many micro-climatic changes.

Urban land-use planning is a multi-component and multi-disciplinary process, which requires more than a single method for reasonable results. The main concern of urban land use planning is the allocation of suitable sites for the appropriate land uses. It is the fundamental work and the essential content of overall land use planning, which requires a scientific approach, in addition to guide development, avoidance of errors in decision-making and over-investment, for sustainable utilization of land resources. Most urban growth falls outside formal planning controls, thus increasing economic and social pressures and exacerbating health and hygiene problems.

In the preparation of environmentally compatible urban development plan it is a prerequisite to understand linkages and interactions that exist between different components of the urban environment. Secondly, the data collected on different aspects of the urban environment has to be translated into useful information for the purpose of urban development. Thirdly, there is also a need to aggregate this information according to administrative/natural and hierarchical units (Das *et al*, 2013). Basic requirement for this is the availability of systematic, detailed, reliable, timely and accurate information on various facets of urban environment (Bhavana, 2013). Urban planning should concern the use of land and design of the urban environment, including air and water and infrastructure passing into and out of urban areas with it.

Planning is a widely accepted way to handle complex problems of resources allocation and decision-making. It involves the use of collective intelligence and foresight to chart direction, order harmony and make progress in public activity relating to human environment and general welfare. In order to provide more effective and meaningful direction for better planning and development necessary support of the organization has become essential. Hence, the need for a suitable information system is increasingly being felt in all planning and developmental activities, whether these are for urban or rural areas. The modern technology of remote sensing which includes both aerial as well as satellite based systems, allow us to collect lot of physical data rather easily, with speed and on repetitive basis, and together with GIS helps us to analyze the data spatially, offering possibilities of generating various options (modeling), thereby optimizing the whole planning process.

2.2. Urban Development Planning Exercise in Ethiopia

Almost all Ethiopian towns and cities were established without proper plans (Tadesse, *et al*, 1997). It was only in the late 1950's that Ethiopia first started giving attention to urban development planning by formulating appropriate development strategies (Solomon, 1999). This means that the history of urban development planning in Ethiopia can be estimated to be only half a century old. The emphasis at that time was largely on the issue of land use control.

A series of three different types of 5-year plans were prepared between 1958 and 1974. The focus of these plans in general was (Solomon, 1999) development of infrastructure, expansion of agriculture and manufacturing industry, and maximization of growth and attainment of better standard of living. In 1964 the first huge planning project with the aim of preparing master plan for forty towns of the country was commenced and completed in 1967. The responsible government arm was Ministry of Interior and the contract was given to three Italian Companies (Tadesse, *et al*, 1997). Later the development and planning aspect of the urban sector was handled by the Ministry of Urban Development and Housing, which was established through proclamation No. 126/1977.

The various plans prepared, however, were not responsive as expected due mainly to lack of integration of the various aspects of urban development planning (such as social, economic, cultural and physical concerns of the towns). Neglect of the interactions of the towns with their corresponding immediate hinterlands was also important factor (Ibid). As urban problems in the country got more and more complex, the concern of the government and the importance of having sound urban planning practice became notable. To that end, the Military Government of Ethiopia established the present National Urban Planning Institute (NUPI), in 1987 (PMGE, 1987).

The proclamation empowers the institute: to prepare different types of plans for towns and cities of the country based on appropriate study and research; to prepare plans for regional urbanization, metropolitan area and urban centers; and; to recruit the required manpower necessary for executing the above mentioned responsibilities.

The traditional planning power of the central government was decentralized to Regional and Local authorities following government change in 1991. Regional governments have been given power to prepare and implement urban plans under their jurisdiction (TGE, 1993). However, for reasons associated with lack of appropriate technical manpower, and equipment's, regional governments would still require technical and other assistances from the central government in preparing, monitoring and implementing urban development plans (Solomon, 1999). The Ministry of Works and Urban Development has also the responsibility of conducting socio-economic studies related to urban areas, preparing master plans for them and providing technical assistance to regional governments during implementation (TGE, 1993). This means that the main actors engaged in urban development planning in Ethiopia are Ministry of Construction and Urban Development, NUPI (Tadesse *et al.*,1997) and some regional governments (to minor extent).

2.3 Current Planning Practice Undertaken by NUPI

NUPI, the chief plan preparation agent of the federal government, has been employing three fundamental approaches to urban plan preparation (for various town of the country). The approaches include master planning, development planning and action planning. In light of the planning practice adopted by NUPI, these basic planning types possess much similarity in essence. The differentiating features, though not sound, are related to the time dimensions the plans are expected to serve, the composition of the professionals involved, the scope and content the plans dwell on. Currently, however, NUPI has almost completely abandoned preparing master plans (Belachew, 2001) for reasons to be clarified shortly. The basic traits of these plan types are briefly discussed here below.

2.3.1. Master Plans

Basic attributes of and major activities involved in master plans include (Tadesse *et al*, 1997; Belachew, 2001): embrace multidisciplinary planning team, involve production of maps with accompanying textual documents, specifying land use categories, road structure, and other physical standards, usually provide a city-level guidance for development activities; and provide long-term (a twenty-year) framework. Such plans, however, are subject to review every five year (though this has been done for no town by NUPI).

According to Belachew (2001), NUPI has terminated (as mentioned a bit earlier) preparing master plans merely in favor of shorter plans apparently to facilitate investment and settlement programs across centers in the country. He further identified some drawbacks related to master plans. These include; taking longer time to prepare, lacking estimate of cost of development; assumptions are not based on realistic evaluations of economic potentials and likely population growth. Generally characterized by longer time perspective, and proposals are aimed at being implemented over longer time period. This makes the plans rather rigid and inflexible to the extent that it would be difficult to control socio-economic dynamics.

2.3.2. Development Plans

Development Plans are medium-term plans intended as an attempt to alleviate the drawbacks inherited in master plans. They are more detailed and relatively more efficient (i.e., in NUPI's context) than master plans. Development plans focus on areas which should be developed and redeveloped. Specifically, they define the sites of proposed roads, buildings and open spaces, allocate land for agricultural, industrial and other uses. They also provide the ground for development coordination. Their drawbacks incorporate the level of detail they propose and definition of broad strategies inherited from master plans (Belachew, 2001). Development plans are not merely implemented immediately once prepared. Instead, NUPI applies further division upon them, resulting in three distinct components. These are district, action area and subject plans that are intended to serve as implementation tools within a broader framework of a city wide structure.

2.4. Abattoirs as Important Urban Functions

2.4.1. Basic Features

Though not accomplished by all, the major activities involved in the operation of an abattoir are: receiving and holding of livestock; slaughter and carcass dressing of animals; chilling of carcass product; carcass boning and packaging; freezing of finished carcass and cartooned products; rendering processes; drying of skins; treatment of wastewater; and transport of processed materials. The ultimate purpose or importance of establishing abattoirs is, thus, (LMA, 2000; ORAAMP, 2001) to provide cleaner and hygienic animal slaughtering services; to ensure proper utilization of animal by-products including hide, skin, horns, bones; to establish and control standards, and to generate income for the services rendered; and to improve impact on the environment by controlling the waste disposal system.

2.4.2. Environmental Problems Associated with Abattoirs

The characteristics of abattoirs are such that they can pose serious problems to the environment unless these problems are adequately appreciated and appropriate measures are taken. The issue could be discussed in terms of liquid wastes, solid wastes, airborne wastes, diseases and noise (EPA, 2002).

1) **Liquid Wastes:** One basic trait of abattoirs, among other things, is that they consume large amount of water in their animal processing operation mainly for hygienic reasons. Such situation produces large amount of wastewater which must be treated. In general, the effect of liquid wastes could be explained in terms of effluent salinity and wastewater as well as storm water qualities.

Effluent Salinity: Effluent generated from dry salting skin preservation method is highly saline and has a very high biochemical oxygen demand. It contains high levels of fluoride. This may lead to salinity problems if the effluent is used for irrigation, and also to fluorosis problems with vegetation.

Wastewater: Wastewater produced in animal slaughter areas typically has a high biochemical oxygen demand. It is also very saline and has high levels of nutrients, suspended solids and bacterial contamination.

Storm water: There is a chance for storm water to get contaminated when it comes into contact with animals holding pens, sludge, store and treated wastewater irrigation area. This contaminated storm water can have detrimental environmental effects on the surrounding eco-system.

2) **Solid wastes:** Solid wastes generated from within an abattoir may have different sources including animal holding areas, slaughterhouse and processing areas, waste treatment plant, unwanted hide or skin and pieces, and unwanted carcasses and carcass parts.

3) **Airborne wastes**: Airborne wastes can refer to odors, dusts and fuel burning emissions.

Odors: potential sources of disagreeable odors in abattoir operation consist of the cooking and rendering process, water effluent treatment plants, slaughterhouses, product storage and handling areas, material drying areas, waste disposal techniques such as burning dead stock, animal holding pens, livestock transport vehicles, holding of carcass before disposal, odors from skin handling and odors from skin sheds.

Dusts: potentials sources of dust emissions at an abattoir include unsealed roads, paddocks, sale yards and holding pens, stockpiled products and materials, and construction activities.

Fuel burning emissions: Fuel burning leads to atmospheric emissions. Materials burned at an abattoir incorporate coal or gas fuel for boilers and steam production, diseased animals, sludge, packaging and unusable skins.

Noise: In an abattoir noise can be generated from different sources including animals, processing activity within the slaughterhouse, plant machinery, and service vehicles.

2.4.3 Utilities for Abattoirs

New sites for abattoirs are usually located on vacant undeveloped area. In such cases, it is important that the necessary infrastructure, facilities and utilities are provided for the proper functioning of an abattoir. The discussion below is based on the guideline provided by LMA (2000).

Water Supply**:** As already discussed, the various operations occurring in an abattoir involve the use of large amount of water. Most of the time such water requirements are satisfied from the corresponding municipal town's water supply system. However, where such water supply system is inadequate or absent, deep wells should be borehole.

Electricity Supply: Among other things, laboratory activities are conducted in an abattoir. In order for the laboratory to provide regular service, there should not to be an interruptible electric supply. For meat examination, the intensity of the light should be 540 lux and in other working places it could be 220 lux or 110 lux depending on the situation.

Road Accessibility: Access roads to abattoirs should be at least compacted gravel road as per the Ethiopian Road Authorities rural road standard. The provision of such facility, of course, depends on the financial capacity of the corresponding municipality.

Waste Disposal and Drainage Systems: It is recommended that for efficient waste disposal and drainage system, the topography of the abattoir site preferably be gentle slope.

2.4.4. Planning Issues

Studies of the causes and effects of soil, water, and air pollution and noise nuisance and risk reveal increasingly that the land use planning should play an important role in the prevention of pollution (Velden, *et al*, 1990). Almost every pollution problem has both a spatial and a temporal dimension. Therefore, appropriate land use planning, taking into account the prevention and solution of environmental problems is essential (Velden, *et al*, 1990; EPA, 2002).

As far as abattoirs are concerned, land use planning could help, among other things, in designating appropriate sites and provision of buffer zones. Site selection is the critical environmental issue for abattoirs (EPA, 2002). Careful site selection can greatly reduce the environmental nuisance. Relevant Site information should include (NUPI, WHO, LMA, 2000; EPA, 2002):

i. The closeness to existing and future housing developments and to land zoned to permit housing or other land uses not compatible with proposed development;
ii. Conformity with civil aviation free corridor regulation;
iii. The site hydrology: flood liability, site drainage and closeness to water courses and ground water resources used for domestic, agricultural or town water supply;
iv. The prevailing wind conditions;
v. the landform and the likely direction of draft of odor or effect of noise;
vi. Directions of major cattle supply inlets and proximity to cattle market;
vii. The erosion hazard; the local road network; corridors for power and other services; and suitability of the site for possible disposal areas.

As can be noted like most spatial decision making problems, the land allocation problem associated with abattoirs is multi-criteria in nature, involving economic, social, environmental and political dimensions. To make things clear, the site characteristics for an abattoir are evaluated (using a manual procedure) based on various suitability aspects including:

Planning suitability: this refers to whether a site is suitable and appropriate for the intended land use. The data needed for evaluation incorporate site capacity, present land use, planned land use (zoning and restriction), ownership/land control, and environmental impact.

Physical suitability: this relates to the physical characteristics that influence the suitability of the site for development. Data are required on general topography, slope, flood hazard, etc.

Infrastructural suitability: this is associated with existing and supplementary physical infrastructures that are important for the proper functioning of the abattoir and include access road, electric power and water supplies.

Locational suitability: this refers to the distance from the intended site to certain geographic features such as rivers/streams, residences, high tension electric lines, airports, etc., and

Financial suitability: this relates to the financial consequences of development of the site. Relevant data comprise acquisition and compensation costs, site development cost, etc.

2.5. The Role of GIS and Remote Sensing in urban planning

Recent technological advances made in domain of spatial technology cause considerable impact in planning activities. The purpose of using GIS is that, maps provide an added dimension to data analysis which brings us one step closer to visualizing the complex patterns and relationships that characterize real-world planning and policy problems (Malczewski, 1999). This domain of planning is of prime importance for a country like Ethiopia with varied geographic patterns, cultural activities etc. It also offers interpretation of physical (spatial) data with other socio-economic data, and thereby providing an important linkage in the total planning process and making it more effective and meaningful (Verma *et al*, 2008).The modern technology of remote sensing which includes both aerial as well as satellite based systems, allow us to collect lot of physical data rather easily, with speed and on repetitive basis, and together with GIS helps us to analyze the data spatially, offering possibilities of generating various options (modeling), thereby optimizing the whole planning process. Thus, GIS is considered as a kind of decision support system in which spatially referenced data are integrated in a problem solving environment. GIS represents an integration of a number of technologies.

The number and type of application that can be performed by a GIS are as large and diverse as the available geographic data sets (Aronoff, 1989). As far as urban development planning is concerned there are many possibilities for the application of GIS. From broader perspective, GIS can be used for planning, analytical, policy-making and management tasks. More specifically, GIS could be applied nearly for all research that involves land-based spatial analysis and modeling (Ottens, 1990). Some these to mention include:

- GIS for allocation of land for housing
- GIS for identifying areas for restoration

- GIS for evaluating public Services
- GIS for assessing suitable site for future development

2.6. Application of Multi-Criteria Decision Making

One of the classic problems in decision theory or multi-parameter analysis (Urban land use survey handbook, 1987) is the determination of the relative importance (weights) of each parameter with respect to the other. This is a problem which requires human judgment supplemented by mathematical tools. Finding an adequate location for urban infrastructure is one of the important subjects in urban development planning. To express the importance of this subject for instance, management and finding a location for urban infrastructure accurately such as landfills, industrial slaughterhouses, are considered as one of the main pillars of sustainable development (Krizek *et al*, 1996).

The integration of MCDM techniques with GIS has considerably advanced the conventional map overlay approaches to the land-use suitability analysis (Malczewski, 1999). GIS-based MCDA can be thought of as a process that combines and transforms spatial data into a resultant decision (output). The MCDM procedures (or decision rules) define a relationship between the input maps and the output map. The procedures involve the utilization of geographical data, the decision maker’s preferences and the manipulation of the data and preferences according to specified decision rules. Accordingly, two considerations are of critical importance for spatial MCDA: (i) the GIS capabilities of data acquisition, storage, retrieval, manipulation and analysis, and (ii) the MCDM capabilities for combining the geographical data and the decision maker’s preferences into multidimensional values of alternative decisions. A number of multi-criteria decision rules have been implemented in the GIS environment for tackling land-use suitability problems.

2.7. Abattoir Site Selection Criteria

Site selection requires consideration of a comprehensive set of factors and balancing of multiple objectives in determining the suitability of a particular area for a defined land use. The selection of abattoir site involves a complex array of critical factors drawing from physical, demographical, economic, policies, and environmental disciplines (Collins *et al*. 2001). The current spatial decision making could benefit from more systematic methods for handling multi-criteria problems while considering the physical suitability conditions. Traditional decision support techniques lack the ability to simultaneously take into account these aspects.

Suitability techniques allow decision makers and environmental managers to analyze the interactions among locations, development actions and environmental elements. This enables analysts to map the interactions in different ways (Collins *et al*. 2001).The process for land-use suitability analysis involves evaluation and grouping of specific areas of land in terms of their suitability for a defined use.

2.7.1 Land use/cover

The diversity of the types of land-use suitability studies can be attributed to the different ways the term land use is defined by various applications and the context of its use. For example, it is likely that the urban planners and the agricultural experts would have different perception of the term. To this end, it is important to make distinction between two notions; land use and land cover (Malczewski, 2004). Broadly speaking, land cover describes the physical state of the earth's surface and immediate subsurface in terms of the natural environment (such as vegetation, soils, and surfaces and ground water) and the man-made structures (e.g. buildings). Furthermore, the term land use may have different connotations depending on the spatial scale. At the large scales it is typically considered as a resource and consequently land use means resource use. In contrast, at the urban scale it is characterized in terms of the potential use of the land's surface for the location of various activities (Chapin and Kaiser, 1979: 4). This connotation of the term land use is understood in the context of urban and regional planning. The description of land use, at a given spatial level and for a given area, usually involves specifying the mix of land use types, the particular pattern of these land use types, the areal extent and intensity of use associated with each type.

One of the most useful applications of GIS for planning and management is the land use suitability mapping and analysis (Collins *et al*., 2001). Land-use suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specified requirements, preferences, or predictors of some activity (Collins *et al*., 2001). In the context of land suitability analysis it is important to make distinctions between the site selection problem and the site search problem. The aim of site selection analysis is to identify the best site for some activity given the set of potential (feasible) sites. The selection of suitable site for abattoir must be based on a set of local criteria to ensure that the maximum cost-benefit ratio for a community is attained.

2.7.2. Topography

Topography describes the surface shape and relief of the land. It refers to various landforms (physical features) which represent the external shape of the earth. It determines the patterns and form of many other landform and land cover features. Furthermore, elevation and slope should be considered when selecting site for abattoir construction project.

Elevation: To evaluate the nature and element of an area making the landscape what areas are suitable for the selection of abattoir site. It is necessary to consider the position, angle and stage. According to Fard, 2012; abattoirs could be constructed in an area lower than the city level in order to prevent 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 an important criterion in hilly terrain for finding suitable sites for urban development. Slope is associated with building cost. Building the abattoir is less expensive 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 (LMA, 2000), which ranges from 2 to 10 per cent. Slope values below 2 per cent are not suitable from safe drainage point of view.

2.7.3. Surface water

Waste water from abattoir is one of the major sources of pollution in river. A considerable amount of water is used in abattoir operations. If discharged to controlled waters it will have an ecological impact by virtue of volume and quality water run-off Pollution and consequent damage of watercourses. Surface water quality could be affected by a number of factors during abattoir operations (EPA, 2002). Livestock will deposit significant amounts of dung and urine during unloading and storage, with the risk of subsequent wash-off into storm drains or local watercourses. Similarly, by-products such as blood and stomach contents pose a risk to surface waters if not properly contained. Abattoir site must not be located in close proximity to surface water (streams, rivers, lakes, sea). In order to avoid possible contamination of the river/ stream and to prevent the abattoir from being flooded, the site should not lie within 100 meters of rivers/streams. Proneness to frequent flooding, not only incurs additional cost but also affects the sanitary condition, both within the abattoir compound and the downstream localities. Furthermore, if abattoirs are constructed near rivers, septic tanks (if not properly lined) may get filled with ground water and ground water pollution may occur, as well.

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 (Gemitz *et al*., 2007) used minimum of 100m buffer distance for site selection for abattoir.

2.7.4. Accessibility

Roads: Roads refers to any transportation facilities, e.g. highways and local roads. It is also an important criterion in site suitability analysis. The need to transport processed meat, carcasses, slaughter animals, etc. is dependent on the proximity to transportation facility. It is essential that the site should be in close proximity to a transport facility, in order that one or more sidings may be obtained for bringing animals to the abattoir, to facilitate the work of sending away the meat, manure, etc. (Ayling, 1908). The newly proposed areas of the town were not facilitated with sufficient road networks. Therefore, effort is made to locate the site nearer to any existing road if possible. Moreover, in order to find out better accessibility to the existing road, buffer zones have been created by taking distances between 20 and 400 meter distance from the existing major roads (LMA, 2000) to generate accessibility map.

2.7.5. Environmental Constraints

These are criteria that constrain, or limit the areas for abattoir site. In this case, the constraints differentiate areas, or alternatives that one can consider suitable for the location of abattoir site, or alternatives that are not suitable. They define areas or alternatives in terms of a continuous measure of suitability and in fact enhance or detract from the alternatives under consideration outside the areas that have been constrained. There are many more criteria/constraints that can be included in the assessment of suitable site for the location of abattoir. Some these to mention here: power sources, waste dump sites, ground wells, conservation areas, and etc. Thus, buffer zones are particularly important as measures to separate conflicting land uses and to minimize any harmful effects of new developments in environmentally sensitive areas. Adequate buffer distances from nearby land users are the best way of avoiding these problems.

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

Waste dump sites: To minimize the impact of neighborhood activities upon the abattoir, at least two activities are considered. These are waste dump and polluting industries. Waste dump is considered mainly from hygienic point of view; particularly, dust and smoke emitting industries can produce chemical and other form of pollution. Abattoir should be located at least 500 meters from waste dump site and 300 meters from dust emitting industries.

Hydro wells: Wells are facilities required by the abattoir in case the water supply of the town is not adequate and they are also spatial entities subject to contamination if located near the abattoir. According to LMA (2002), on average, a 300-meter distance should be kept between an abattoir and boreholes in order to protect them from being contaminated through ground water flow.

Conservation areas: The site should be out of areas needing conservation measure. Such areas should also be protected with a 10-meter buffer.

Preferably, for site selecting of a slaughterhouse there are not any fixed and defined standards but for most of the variables used in a given study, reliable reasons could be found that due to environmental constraints and potential of each area checking back of that criteria is a top priority (Fard *et al*, 2012). In order to locate an appropriate site as a preliminary and initial instruction, the following articles could be followed:

Location relative to the city: The site location should be placed out of the city limits. Moreover site selecting must not be on the way of the city development.

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

The position in relation to communication roads: The site could be located near to one of the arterial roads or a broad link to the arterial road. In cities that are located on the railway track, it is more accurate to choose a place for slaughterhouse near the railway and if it possible create 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 in terms of the prevailing local winds. The focus is on alleviating possible negative impacts that the abattoir can pose on the surrounding environment and vice versa.

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

Future land use: The suitability of a candidate site for abattoir will finally be evaluated taking into account the future intended land use of the area.

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

Waste water treatment: The site should be positioned in order to prepare wastewater treatment and outgoing as well. Thus, the following points are recommended in order to achieve this purpose: For a city with sewage system, the site should be selected on a place that the slaughterhouse wastewater does not flow in to sewer. When a city does not have sewage system and the slaughterhouse is situated somewhere near a river, after treatment of the slaughterhouse's wastewater, the harmless excess water could be directed in to the river. If there is no a river, the slaughterhouse's wastewater should be refined after ensuring that the remaining water to be disposed into adjacent lands in terms of agricultural use.

Location of polluting industries: Slaughterhouse should not be exposed to pollution from industrial operations, dust, smoke, ash, etc.

Access to electricity network: In the terms of the requirement of a slaughterhouse to electricity, site selection must be located in a place that the power grid is legally permissible. In large slaughterhouses the required electricity could be prepared by the use of a generator instead of power network but it is not recommended except in emergencies.

An unsuitable selection of an area that has potential for sustainable activity could cause many environmental, social and economic damages. Hence, it is very important that in the development and operation of urban areas, environmental management and nature conservation be given priority. Thus, site selection is a critical environmental issue for abattoirs. Careful site selection can greatly reduce the environmental nuisance. Relevant site information should include; the closeness to existing and future housing developments, and to land zoned to permit housing 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 odor 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 (GDARD, 1999).

In areas likely to be disturbed by construction of the proposed development, the site description should 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. Much of such environmental problems can greatly be reduced through appropriate sitting of the abattoir (EPA, 2002; Veldon, *et. al*, 1990).

Chapter Three

3. Materials and Methods

3.1. Description of the Study Area

3.1.1. Location

Soddo town is found in Southern Nations and Nationalities Regional State (SNNRS), Ethiopia. It is the capital town of Wolayta zone administration. The total area of the town is about 3200 hectares and from this 78 hectares of the land developed with important infrastructure and waiting for different investment. The geographical location of the town is extended over $6^0$48'30" N to 6^0 53'00" N latitudes and $37^0$43'30"E to $37^0$47'30"E longitudes with altitude ranging from 1800 to 2500m amsl (Ethiopian Demography and Health Organization Institute 2005). Soddo is located Northwest of Bolosso Sore, Northeast of Damot Gale, Southwest Offa Woreda and South of Humbo woreda in Wolaita zone administration of SNNPR of Ethiopia. It is located along the Addis Ababa - Arbaminch high way at a distance of 383kms south west of Addis Ababa, 157kms west of Hawassa town, and the regional capital. Soddo is situated at the foot of mount *Damot*, which is the prominent peak in the study area with 2950m high a.m.s.l.

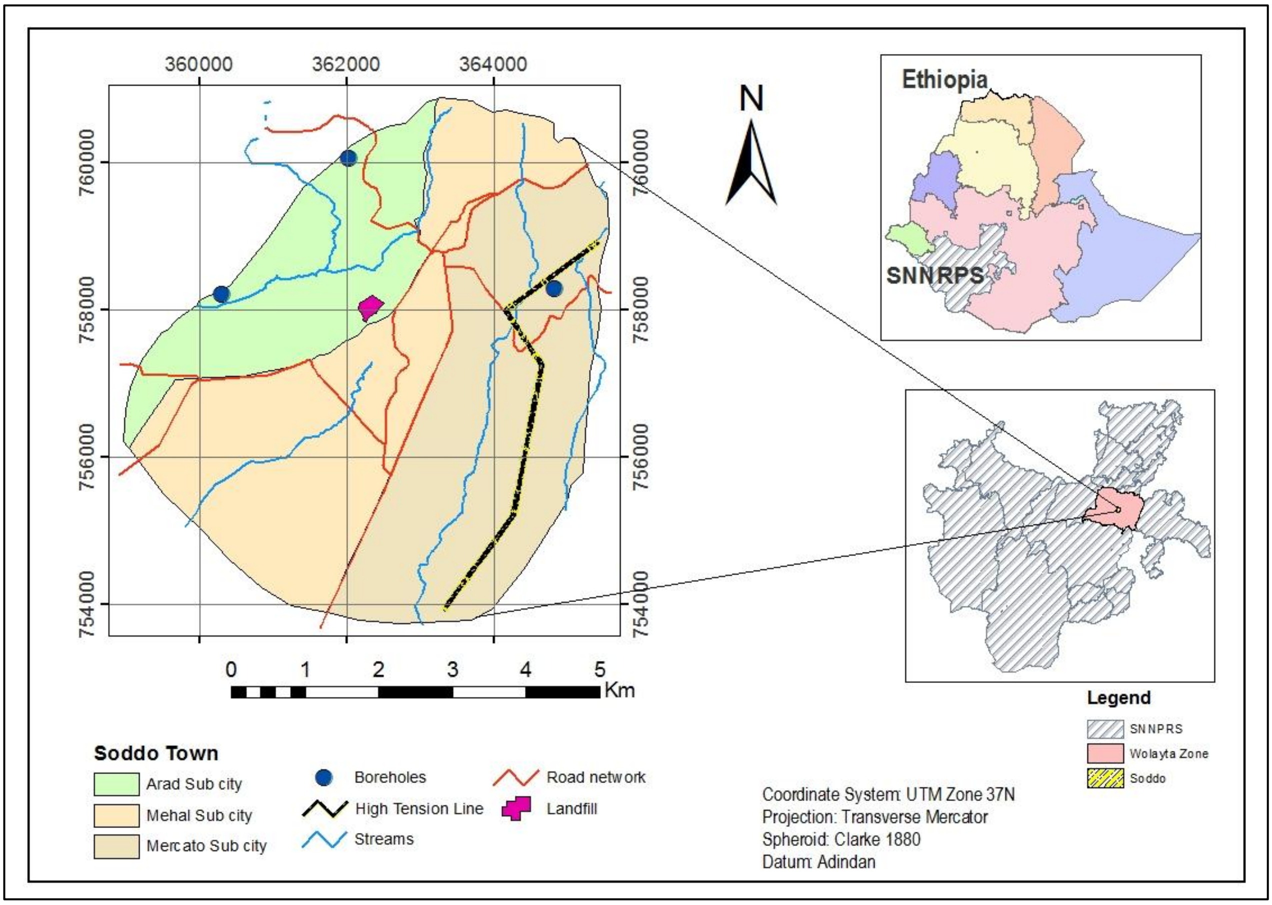

Figure 3.1: Location map of the study Area

3.1.2. Establishment of the city

Wolayta Soddo is one of the oldest and fast growing towns in SNNPR state. For the last 119 and more years Wolayta Soddo has been center of politics, social relations, religious practices, commercial place and symbol of the people of Wolayta. The name of the city was derived from the prominent resident of the village called '*'Mochena Borago Soddo"* (WDA Bulletin, 2008). The town was established during the conquest of *Ase* Menillik towards South of the capital, Addis Ababa. It was since this time that the town has become an important urban center following large scale formal settlement. The town has two main offices, these are the mayor offices led by the mayor and the municipal office which is led by manger that is accountable to the mayor and it is divided in to three sub city administration and eleven kebeles. Currently the town serves as a capital of Wolayta zone, Soddo Town, Soddo Z*uria* district and it has many regional and federal government institutions.

3.1.3. Climate

The climate of Wolayta Soddo town is described based on the type of rain fall and temperature. The mean annual rain fall is greater than 1550mm per year. Most part of the town Soddo experiences Woina dega (warm to cool) type of climate (SNNPR, Bureau of Regional Meteorology Annual Report 2012) except the mt. *Damot* environment of the town, which experiences colder climate. The south and southwest peripheries of the town experience transitional types of climate (warm to hot) (*woina dega* to *kolla*) mainly due to the effect of south east rift valley that crosses the surrounding woreda (*Dellbo Wogen and Humbo Taballa*) and run into the lowlands of lake Abaya and Chamo, the rift valley lakes.

3.1.4. Topography

Topography describes the surface shape and relief of the land. It refers to the various landforms (physical features) which represent the external shape of the earth. It determines the patterns and form of many other landform and land cover features. Topography of the town is predominantly characterized by mountains, steep or hilly, gorges and plain landscapes especially towards southern part of the town. Enjoying a *Woyna-Dega* climate, the town lies on an elevation ranging from 1800 to 2500 meters above sea level and has a sloppy topography. The town is situated at the foot of mount *Damot* in the north and stretching down towards south. Mt. *Damot*, the most prominent feature and symbolic representation of the region, is 2950 meters high. Figure 3.3 illustrates the topography of study area.

Furthermore, elevation and slope of the study area are considered for selecting site for abattoir construction project.

Elevation: Elevation called altitude is the height of a place above or below a reference level such as mean sea level. To evaluate the nature and element of an area making the landscape for the location of suitable abattoir site, it is necessary to consider the position, angle and stage. The elevation factor was generated from the digital elevation model (DEM). The elevation classes were evaluated on the basis of suitability of landscape for urban land use allocation**.**

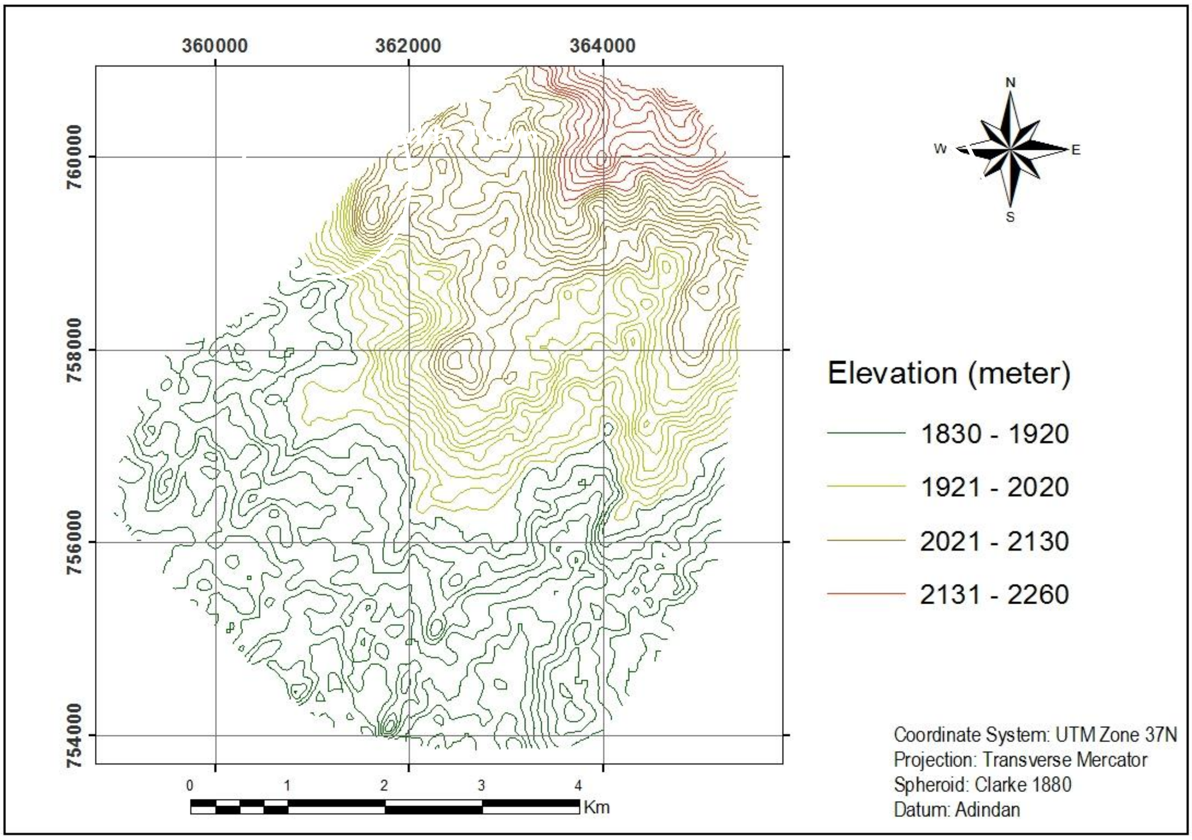

Figure 3.2: Map of elevation

Slope: Slope is an important criterion in hilly terrain for finding suitable sites for urban development. Steep slopes are disadvantageous for construction. Steeper slopes increase construction costs, limit maximum floor areas and contribute to erosion during construction and subsequent use. A slope map was created through the interpretation of DEM that covers the study area.

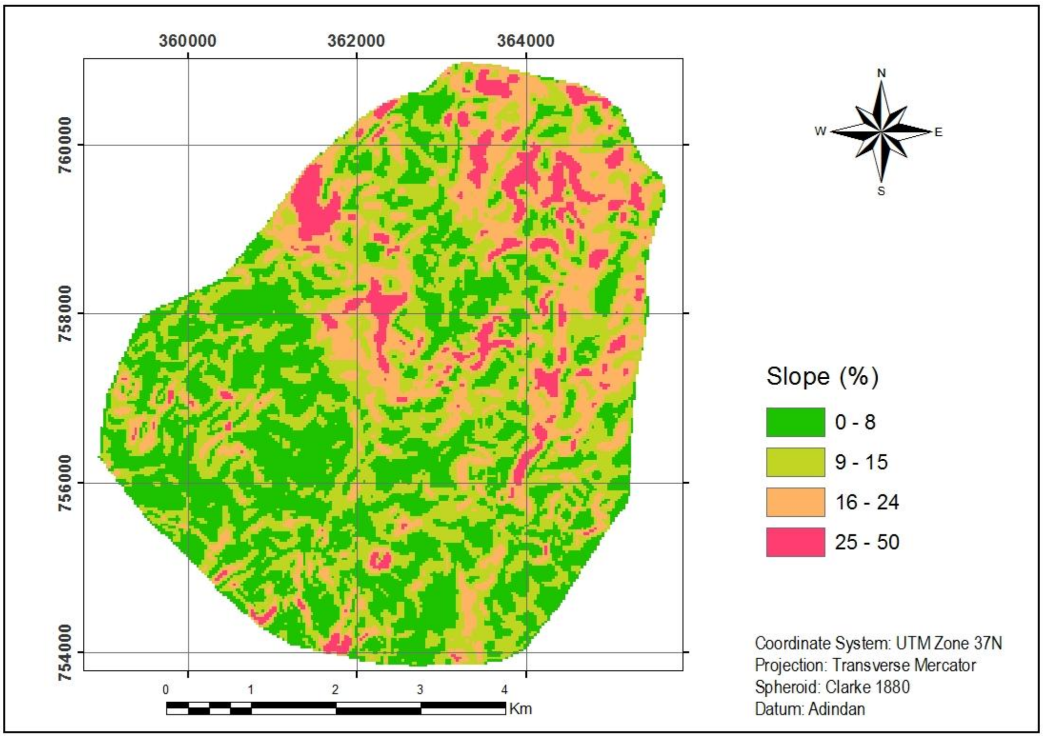

Figure 3.3: Slope Map

3.1.5. Soils of the Study Region

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.

According to the soil classification of FAO (1997), there are three soil types in the study area namely: chromic luvisols, chromic vertisols and dystric nitisols.

Chromic Luvisol: is the dominant type of which covering the northern parts of the study area including the north central part of the town. This part of the town has more elevated and rugged terrain. Most Luvisols have good agricultural potentialities. In soils with a heavy textured B horizon, permeability might be low, and drainage and good root distribution can be hindered.

Chromic Vertisols: This type of soil is dominant in the central area of the town. This kind of soil covered the whole areas of the central town which is highly urbanized and occupied by multi urban infrastructures. Vertisols are heavy clay soils in flat areas. During dry season they shrink and have deep cracks in a polygonal pattern, but on the contrary during the wet season the clay swells and causes pressure in the sub-soil. Chromic vertisols are brownish and better drained. But, in general, vertisols have fairly good, but limited agricultural potentialities. Land preparation is difficult, dry soils are hard and wet soils are sticky. The moisture condition of the surface layer is only during for a short period favorable to prepare land. Another difficulty is that the permeability of the subsoil is very low. Very often these soils are flooded or have stagnant water during the rainy season. The soil has high water retention, but relatively a small amount of water is available for plant growth. Rooting depth might be restricted because of the swelling and shrinking properties of the soil.

Dystric Nitisols: Nitosols are deep, clay red soils with an argillic B horizon. They have rather good potentialities for agriculture. These soils have very good physical properties. They have a uniform profile, are porous, have a stable structure and a deep rooting volume. Their moisture storage capacity is high. This soil covered the southern parts of the study area including most parts of the current expansion areas. Figure 3.4: shows the distribution of major soil types in the study area.

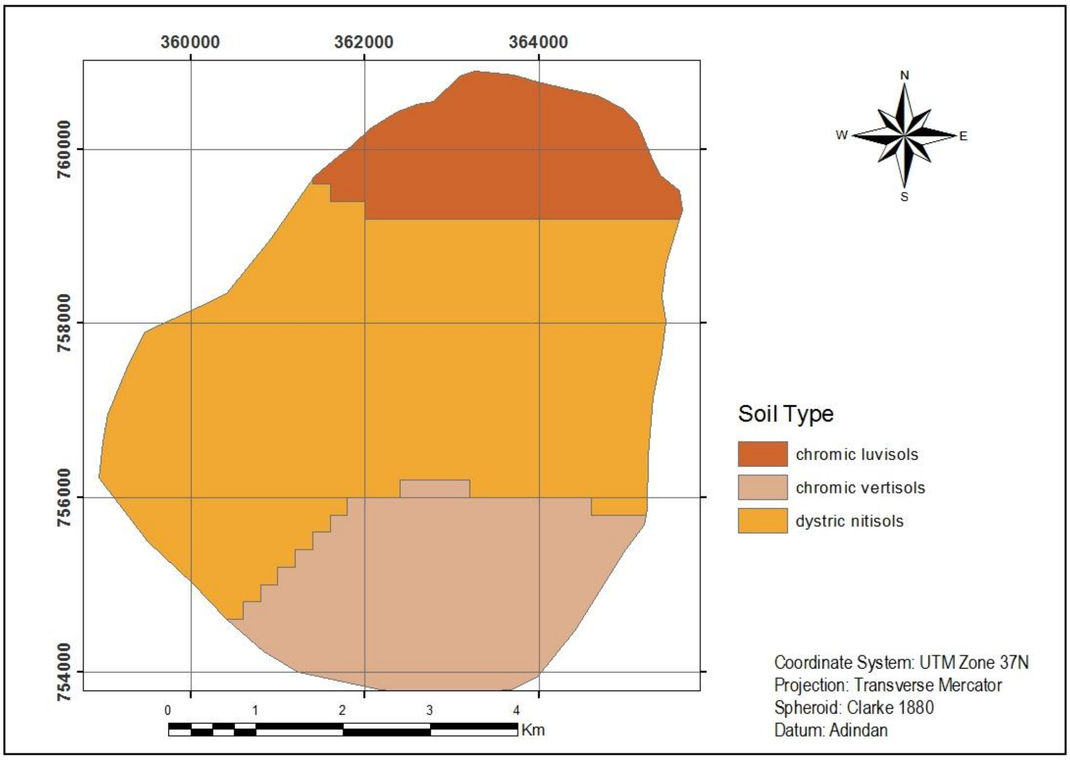

Figure 3.4: Soil map of the Study Area (Source: MOA 2007)

3.1.6. Land use/cover

Based on the remote sensing image, the land use/cover map of the study area was classified into seven categories (Anderson *et al*., 1976), built up area, agricultural land, barren land, forest land, water, scrub vegetation and wetland.

Accordingly, areas occupied by wetland and water surfaces are insignificant whereas built up and agricultural lands covered larger area. Agricultural and barren lands are found at the periphery of the town and follow the pattern of the urban fringes. The other dominant land use/cover types are forest and scattered trees. Forests mainly the '*tid*' tree covered the northern border area of the town where as scattered trees are found mixed with residential lands and are planted by the dwellers. The classification was done on Landsat ETM+ image of the year 2014. The classified land use/cover map of the study area is shown on figure 3.5.

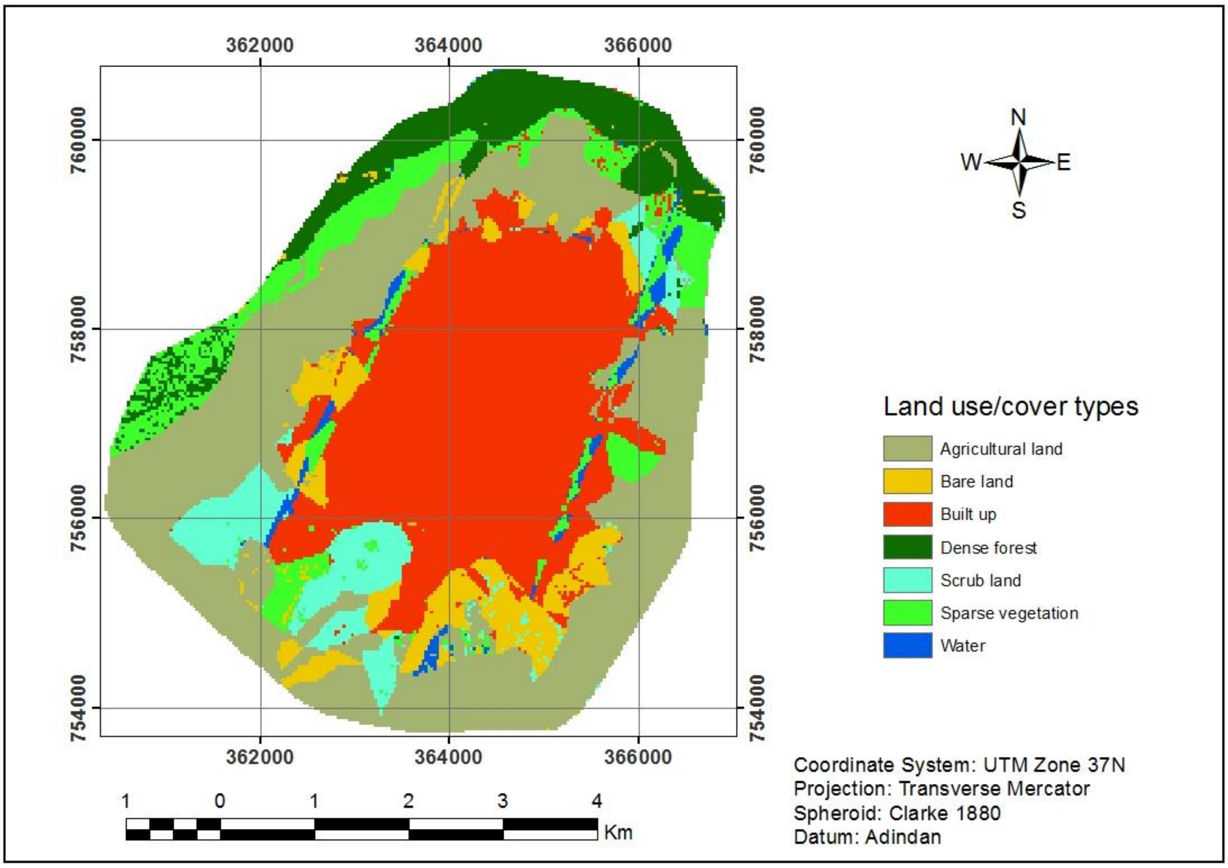

Figure 3.5: Land use/cover types (Source: Land use/cover image, 2014)

3.1.7. Drainage

There are many streams originate from the foot of mount Damot which disseminate into the town in different parts. Among them the main ones include; *Hamassa, Kalte, Kokate, Bichere, Lintala*, *Waja* river, etc. The study region is demarcated in the west and east with two permanent rivers (*Hamassa* and *Waja* River). Most of the rivers are intermittent in nature during dry season except *Hamasa* and *Waja* rivers, which drain into Lake Abaya. As the town is situated at higher elevation, the flood hazard risks remain common and serious in damage particularly during rainy seasons. Figure 3.4: shows drainage network in the study area.

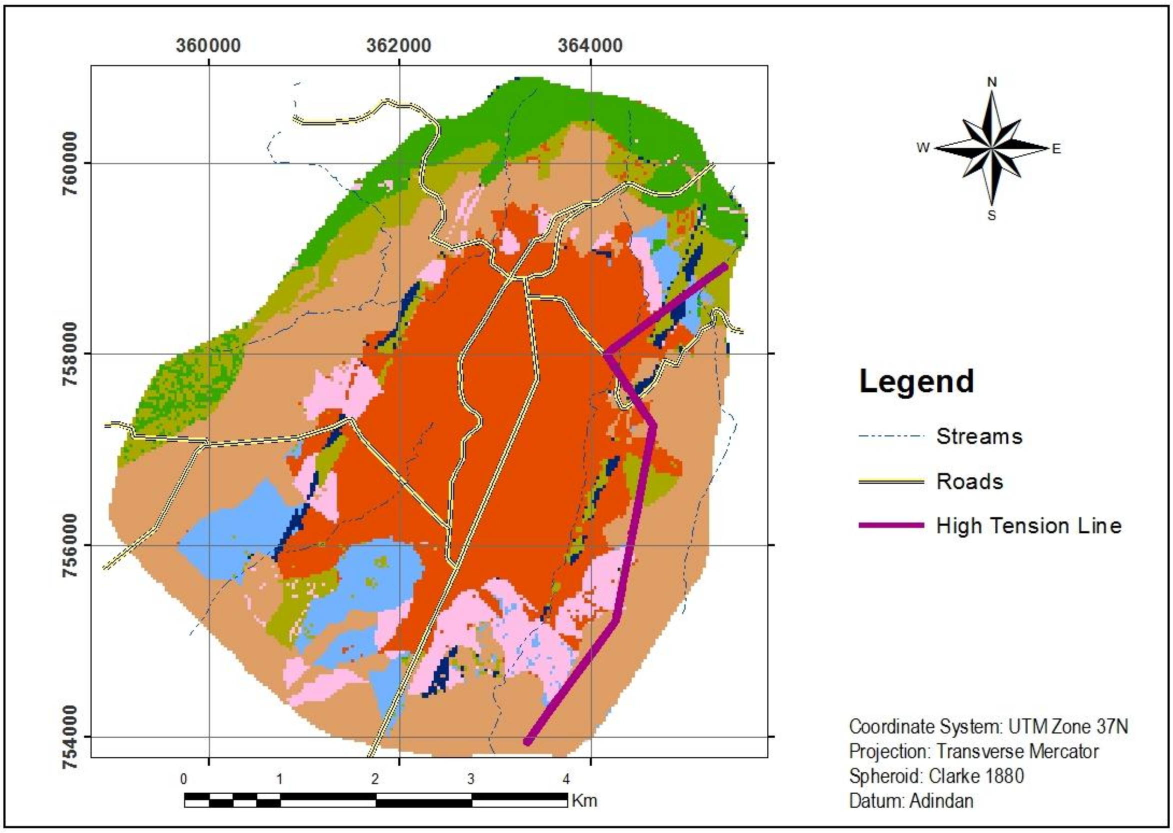

Figure 3.6: Map showing drainage and major road networks

3.1.8. Socio-economic Characteristics

According to Wolayta Zone Finance and Economy Development office (WZFED, 2014) report, the town has estimated total population of 85,514. Of whom 45835 are males and 39679 are females. The sex ratio shows slight difference between males and females which is 112/100. Similarly, the rate of urbanization showed rapid change with annual rate of 2.9%, which by far exceeds the regional urban growth rate. The high rate of rural to urban migration added heavy pressure on the rate of urbanization and the socio economic condition of the town. Economically most of the dwellers are engaged in trade activities except few who are involving in the practice of different economic activities such as agricultural, handcrafts, smith and jewelry, etc. The rate of dependency is relatively low when compared with the county's share. It is 0.5% people in every 100 independent men.

Soddo town is among the few towns in the region endowed with good infrastructure access, for instance, road network, hydro-electric power & cleaned pipe water supply, modern telephone, banking, educational and health facilities. The town has a graveled road network connection with its neighboring towns, fundamental for transportation access. The main highway that stretches from Addis Ababa to Arbaminch - Jinka towns passes across Soddo town.

Currently, the town marked rapid expansion and development mainly in the west, south-west and eastern parts. There was significant change in urban land use pattern mainly in commercial and residential areas where as reduction in agricultural land use because of urban expansion in the fringe areas. The pollution load has increased in terms of air, water, noise, and solid waste generation and disposal, etc.

3.2 Research Methodology

3.2.1. Data Acquisition

This study focuses on site suitability analysis for abattoir in Wolaita Soddo town using GIS based multi-criteria decision support techniques. Data gathering included field surveys and secondary data collection from various organizations and individuals (Table 3.5). Firstly, the primary data were generated from satellite image, field survey, unstructured interviews with experienced experts in urban planning, engineering works and GIS. In addition, a Global Positioning System (GPS) receiver was used in the field survey for the collection of sample points and to identify location of targeted existing urban facilities and infrastructures.

The secondary data were gathered from Department of urban planning which includes; boundary maps and land use land cover map of the town, the demographic and socio-economic figures of 2014, which are based on the population census of 2007. In addition, Ethiopian Geological Survey, and online searching (i.e. http://landsat.usgs.gov) are also contacted of GIS datasets for the collection of necessary information and literatures. Moreover Table 3.5 clarifies sources of data with their format.

Table 3.1: List of data used and their original sources

Data type	**Source**	**Resolution**	**Software used**
Landsat ETM+ image 2014	GLCF	30m	ERDAS Imagine 9.2, Global Mapper 11
DEM	EMA		ArcGIS 10.2
Shapefiles	CSA		ArcGIS 10.2
Soil data 2007	MOA	1:1,500,000	ArcGIS 10.2
Digital maps of urban land use	Soddo Town Municipality		ArcGIS10.2
Meteorological data	Regional Meteorological Service		Microsoft Excel, ArcGIS 10.2
Geological Map	Ethiopian Geological Survey	1:500,000	ArcGIS 10.2
GPS data	Field survey		ArcGIS 10.2

3.2.2 Software used in the Analysis

The thematic maps (Figure 3.5) were prepared and edited, overlaid and visualized on the basis of the site suitability analysis for abattoir using ArcGIS 10.2 software of ESRI. The application of GIS for overlaying thematic layers to establish land databases requires that all the layer maps need to be converted into a common coordinate system. ArcGIS 10.2 advanced (ArcInfo) concurrent use with spatial analyst extension was used for geo-referencing CAD features, proximity analysis and producing maps and graphics. It was also used for statistical manipulation and report generation. ERDAS Imagine 9.2 was used to classify land use/cover map of the study area. Other soft-wares used in this research include Microsoft Internet, word, Excel and power point. During field work Global Positioning System (GPS) receiver, Digital Camera and compass were used to collect field data.

3.2.3. Interview, Meeting and Discussion

As mentioned above, the primary data collection was accomplished by using a survey questionnaire which is one of the important social research methodologies. The discussions were held with experts of urban plan preparation and implementation core work process teams in identifying abattoir site selection criteria and finding out the buffer distance that an abattoir should be separated from relevant geographic features. Direct and indirect unstructured interviews were conducted with the experts during the field survey to gather more information. The information derived from this study was used to identify and develop priority criteria and factors for the selection of abattoir site. It was also used to identify problem in the study area and prioritize the potential abattoir sites in the study town. Additional discussions were made particularly with those experts, who are involved in the development plan preparation of Soddo town, in order to acquire some appreciation of the study area. In particular, the following experts working at Zonal Urban Planning Development were interviewed: *Ato* Kataro Galaso, *Ato* Feleke Dache, *Ato* Daniel Kuma, *Ato* W/Gibrel Folla, and *Ato* Million Shoya.

3.2.4. Methods

1) **Spatial Multi-Criteria Decision Making (MCDM)**

The main goal of this research is using spatial Multi-Criteria Decision Making (MCDM) approach integrated with Geographic Information System (GIS) techniques in order to determine suitable site for abattoir.

Spatial Multi-Criteria Decision Making (MCDM) is a process that combines and transforms geographical data into a decision (Malczewski, 1999). MCDM, combined with GIS data, is a powerful approach to systematically and comprehensively analyze a problem. The fundamental components of a multi-criteria problem are human value judgment and assessments of the importance of criteria. The main purpose of the multi-criteria evaluation techniques is to investigate a number of alternatives in the light of multiple criteria and conflicting objectives (Voogd, 1983).

2) Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a widely used method in MCDM and was introduced by Saaty (Saaty, 1977). It is easily implemented as one of the MCDM techniques. AHP is a decision support tool, which can be used to solve complex decision problems. It uses a multilevel hierarchical structure of objectives, criteria, sub criteria and alternatives. AHP uses a fundamental scale of absolute numbers to express individual preferences or judgment (Table 3.2). This scale consists of nine points. 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, AHP also provides measures to determine 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 is acceptable. Saaty (1980) suggests that if CR is smaller than 0.10, then the degree of consistency is fairly acceptable. But if it is larger than 0.10, then there are inconsistencies in the evaluation process, and AHP method may not yield meaningful results.

Table 3.2: The preference scale for pair wise comparison in AHP

Intensity of Importance	Definition and explanation
1	Equal importance - two activities contribute equally to the objective
3	Moderate importance - Experience and judgment slightly favour one activity over another.
5	Essential or strong importance - Experience and judgment strongly favour one activity over another.
7	Very strong/demonstrated importance – An activity is strongly favoured and its dominance is demonstrated in practice
9	Extreme importance – The evidence favouring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8 Reciprocals of the above numbers	Intermediate values between the two adjacent judgments when compromise is needed.
1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9	Reciprocal values of the previous appreciation

Source: Adopted from Saaty, 1980

3.6. Conceptual Framework and Flowchart of the Analysis

There were four important steps to produce site suitability map for abattoir. These are: (1) finding suitable factors to be used in the analysis, (2) assigning factor priority, weight and class weight (ranking) to the parameters involved, (3) generating land suitability map of abattoir, and (4) determining suitable areas for abattoir. The details of the conceptual framework and each processing step are shown in Figures 3.7.

MCDA technique is applied to incorporate decision maker's judgment and preferences using the AHP method. This method includes the selection of the criteria for the spatial Multi-Criteria Evaluation (MCE) technique for the suitability analysis for abattoir. The final step involved in AHP is the aggregation of the relative weights obtained at each level of the hierarchy to calculate the suitability index. ArcGIS is used to combine the spatial data with suitability index so that a continuous land suitability map is generated. The output is a suitability map for abattoir site.

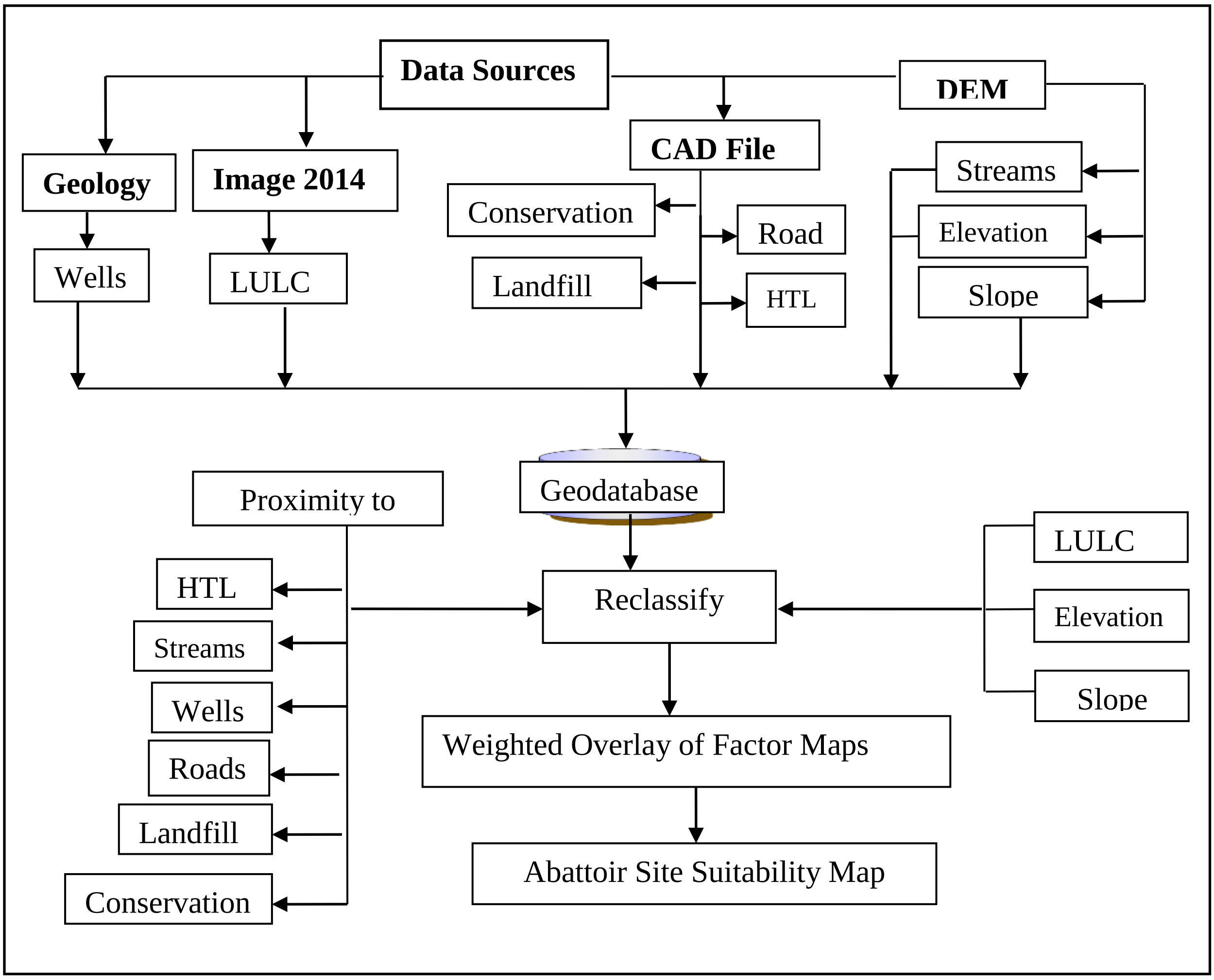

Figure 3.7: General work flow of the study

Chapter Four

4. Data Analysis, Result and Discussion

This part discusses the determination of criteria and classification of factors for the selection of suitable abattoir site and the final results were also presented. The suitability of a site for an abattoir is influenced by the various characteristics of the site. However, each characteristic only reflects an aspect of the overall suitability for the specific land use. The area found suitable for abattoir might be preferable for the other urban land use. Several land uses may compete for the same site however the necessary choices are the subject of the overall urban development planning. A GIS-based spatial analyzing information system for suitable site selection criteria should be identified and integrated in to a GIS database in the form of map layers with associated attributes. The set of spatial analyzing information system criteria for abattoir site selection have been identified based on different literature reviews and relevant expert's opinion. Almost all the criteria identified are geographic in nature so that they reference a particular location.

4.1 Criteria Maps Generation and Classification

As a spatial decision making, site suitability analysis involves several steps or procedures. Among other things, identifying site selection criteria is a critical step. Figure 4.1 shows a diagram that provides a convenient structure of the site selection criteria. The structure could serve as a framework for better understanding of the various specific objectives and spatial entities involved in the overall suitable site designation process for abattoir.

As can be noted from the figure 4.1, the overall objective (the goal) is to designate suitable site for an abattoir. Towards fulfilling this objective, the following more specific objectives are considered.

i. Minimizing the impact of abattoir on the surrounding environment,
ii. Minimizing the impact of nearby activities on the abattoir,
iii. Ensuring the availability of basic facilities that are necessary for the proper functioning of the abattoir, and considering other relevant constraints, factors and targets.

In the following parts the objectives were assessed based on the criteria set for the selection of abattoir site.

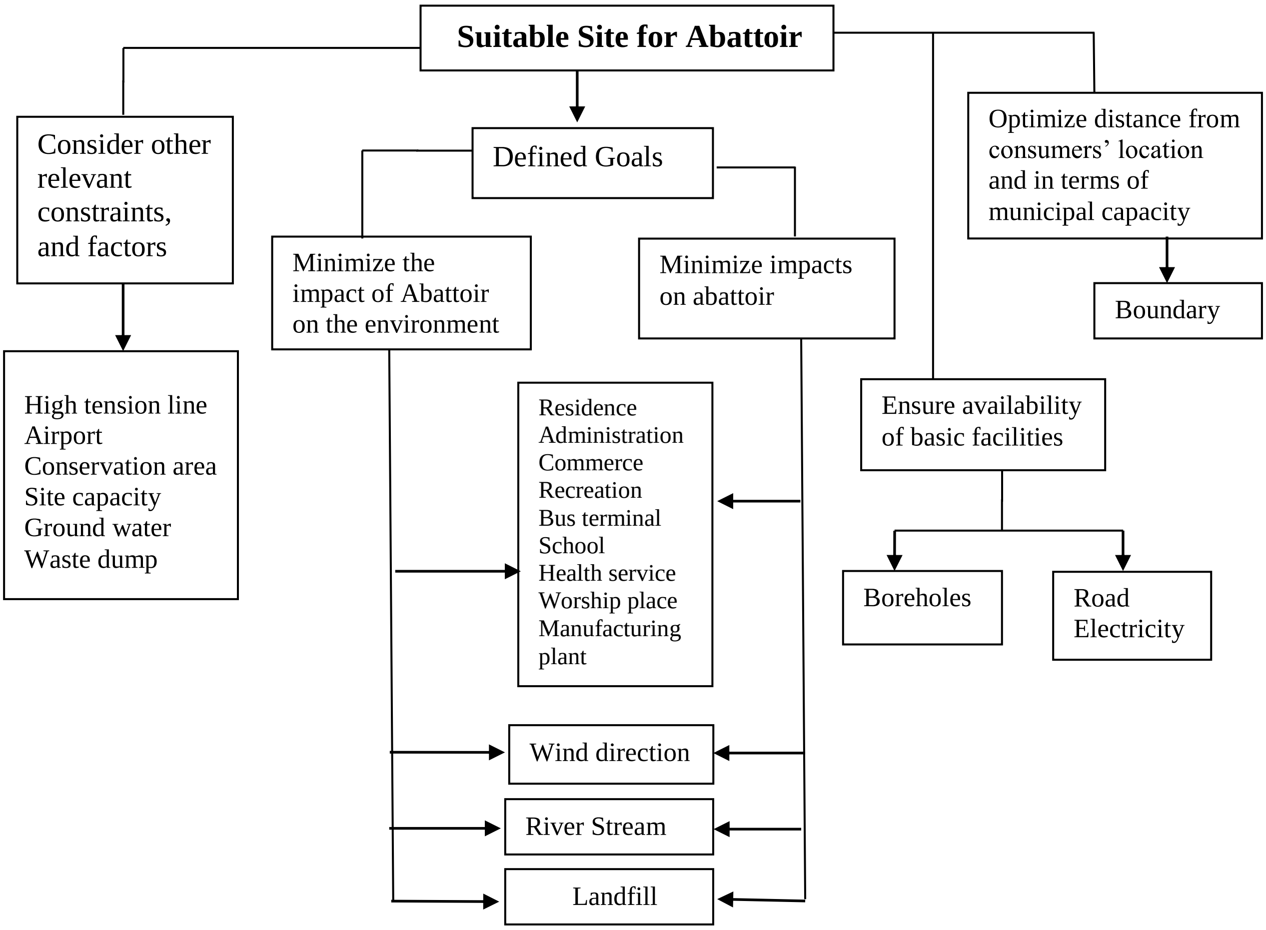

Figure: 4.1 a Diagram Showing the Structure of Abattoir Site Selection Criteria

Table 4.1: Abattoir site Selection Criteria

SN	Spatial Data	Layer Name	Criteria
1	Boreholes	Borehole	300m away from Borehole
2	Waste Dump Site	Waste Dump	500m away from Waste Dump
3	Rivers and Streams	River/Streams	100m away from River/Stream
4	High Tension Line	High/Tension Line	500m away from High/Tension Line
5	Vacant /Agriculture	Vacant/Agriculture	select Vacant/ Agriculture
6	Slope	Slope	between 2-10 per cent slope
7	Road Network(streets)	Road	between 20 and 400 m from existing road
8	Prevailing wind direction	Wind	provide buffer zone (150 to 200m)
9	Future Land use	Future Land use	prioritize
10	Site Capacity	Site Capacity	greater than or equal to one hectare
11	Boundary/Town Area	Boundary	within the municipal boundary

Source: *Environmental protection Agency (2002) and LMA, 2000*

Table 4.1 represents the criteria identified for the analysis of site suitability for the location of abattoir by consulting urban planning experts and referring to the review of related previous works.

4.2. Classification of Criteria Maps

The criteria discussed above can be summarized as constraints and factors. Constraints are those criteria that constrain, or limit the areas for abattoir site. In this case, the constraints differentiate areas, or alternatives that one can consider suitable for abattoir site, or alternatives that are not suitable. Factors, however, are criteria that define some degree of suitability for all geographic regions. They define areas or alternatives in terms of a continuous measure of suitability and in fact enhance or detract from the alternatives under consideration outside the areas that have been constrained. Thus, therefore, five criteria and nine factors/constraints in the form of nine GIS-based layers incorporated for site suitability evaluation for abattoir. Please note that these factor maps were overlaid together for final suitability classification of the study area. However, in this process the data of all the selected factors are kept, displayed, and managed individually. Because the factors have different scales of measurement; they cannot be compared by their raw scores. Therefore, in order to allow comparability, the factor maps were standardized. Standardization allows comparison of criterion scores within one alternative. In order to standardize, the raster features of all the factors were reclassified into a common scale range.

4.2.1. Urban land use/cover

The land use of the study area was classified using Landsat ETM+ acquired in 2014, having path and row of 169/54. The image was geo-referenced to a Projection: Universal Transverse Mercator, Grid: UTM 37 N, Datum: Adindan. The study area was subsetted from the full scene. Then the subsetted image was undertaken supervised classification with the aid of 52 ground control points collected during field survey (Appendix 2). Classified pixels were clustered into the following seven more general categories: built up lands, agricultural lands, forest lands, sparse vegetation, scrub lands, bare lands and water surfaces (Fig 4.2). 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 was reclassified into 4 classes based on their importance to evaluate suitable site to locate abattoir for over lay analysis. These are built-up area, barren lands, open areas, and vegetation. According to national urban planning institute experience, bare lands and agricultural lands are more preferable for the location of abattoirs. This is mainly due to the low cost of acquisitions. Thus, barren lands are ranked as most suitable; open areas, are ranked as moderately suitable; forest lands, are ranked as suitable; urban services and built-up lands, are ranked as least suitable. The result of the reclassified land use/cover map is shown in Figure 4.3.

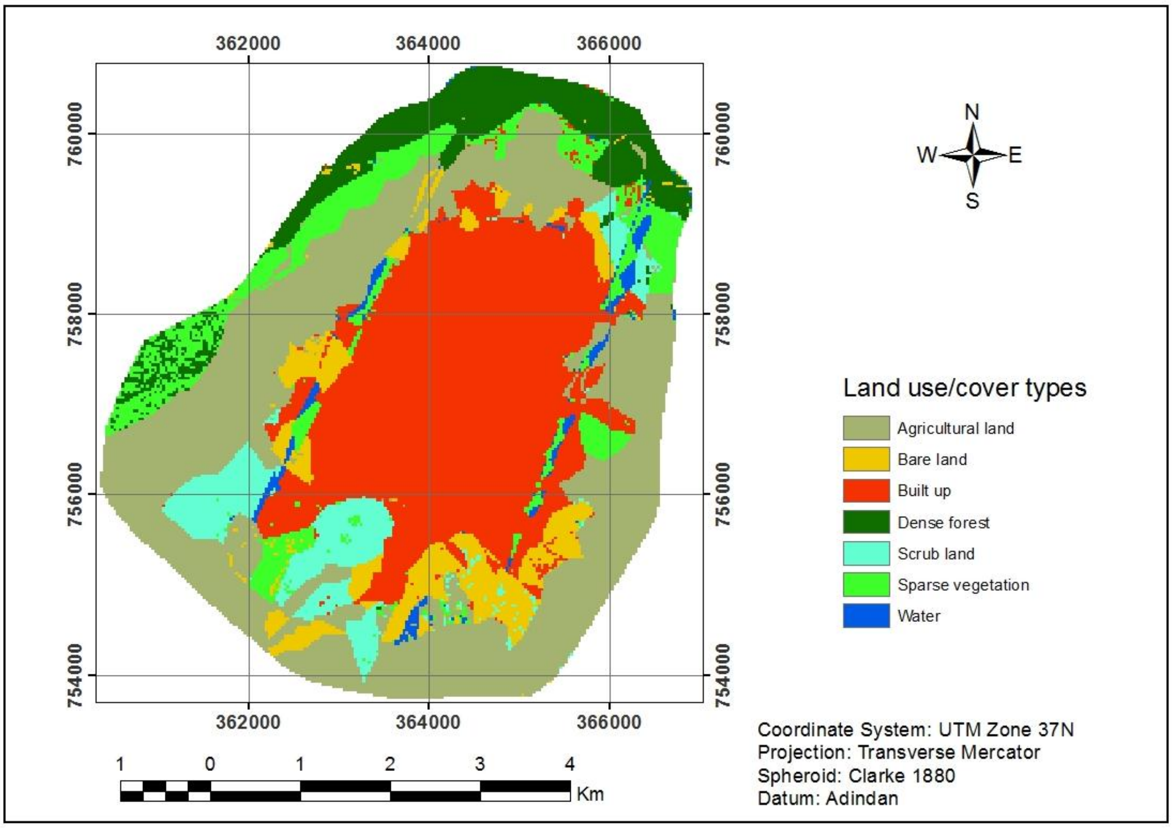

Figure 4.2: Major land use/cover categories (Source: 2014 Landsat ETM+ Image)

i. 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. The percentage of overall accuracy was calculated using following formula:

$$Overall\ accuracy = \frac{Toal\ number\ of\ correct\ samples * 100}{\%\ Total\ number\ of\ samples}$$

Besides the overall accuracy, classification accuracy of individual classes was calculated in a similar manner. The two approaches are 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 is 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 4.2: Error matrix showing classification accuracy of the true land cover

Classified data	Built up	Forest land	Agriculture land	Sparse vegetation	Scrubl and	Bare land	Water body	Total
Built up	**9**		-	1	-	-	-	10
Forest land		**6**	-	1	-	-	-	7
Agricultural land	-	-	**6**	1	-	1	-	8
Sparse vegetation	-	-	1	**5**	-	-	-	6
Scrub land	-	-	-	-	**5**	1		6
Bare land	-	-	1	-	-	**8**	-	9
Water body	-	-	-	-	-	-	**6**	6
Total observation	9	6	8	8	5	10	6	52

Table 4.3 users and producers accuracy

Classified data	**User's accuracy**	**Producer's Accuracy (%)**
Built up	90	100
Forest	85.7	100
Agricultural land	75	75
Sparse vegetation	83.3	62.5
Scrub land	83.3	100
Bare land	88.8	80
Water body	100	100
Overall Accuracy		86.53%
Kappa		0.864

Source: computed by the researcher

ii. Overall Accuracy

It is computed by dividing the total number of correctly classified pixels (i.e., the sum of the elements along the major diagonal) by the total number of reference pixels. It shows an overall result of the tabular error matrix. The overall accuracy performed in the study was 86.53% (table 4.2) during 2014. 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 land use/cover map was above 85% based on Anderson's criteria. The 2014 supervised classification with an overall accuracy of 86.5% was achieved with a Kappa coefficient (K_{hat}) of 0.864. This value implies a strong agreement, and is often multiplied by 100 to give a percentage measure of classification accuracy.

Therefore, the K_{hat} value of 0.864 represents a probable 86.4% better accuracy than if the classification resulted from a random assignment.

Table 4.4: Land use/ cover Reclassification

Urban land use type	Rank	Level of Suitability
Built-up areas	1	Unsuitable
Vegetation	2	Moderate suitable
Open areas	3	Suitable
Barren lands	4	Highly suitable

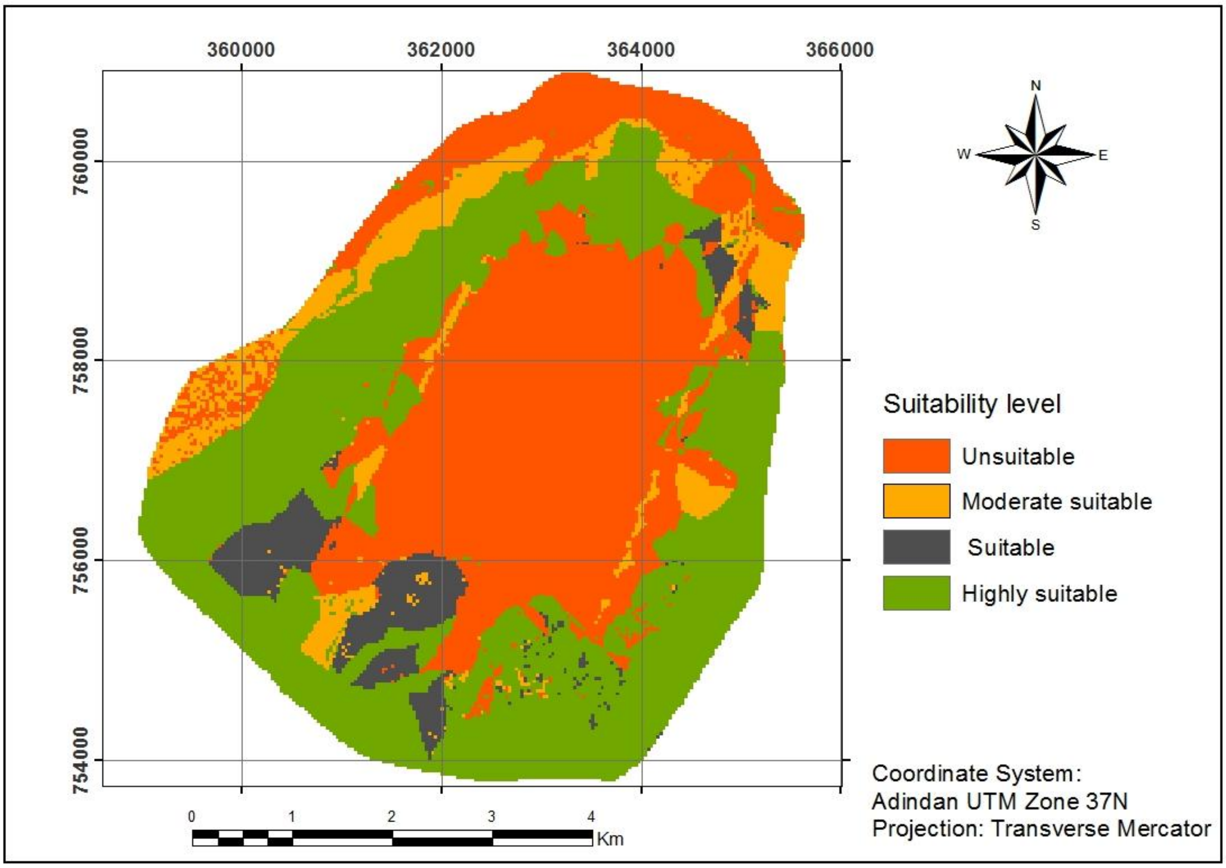

Figure 4.3: The Reclassified land use/cover map of the study area

4.2.2. Topographical factor

Topography describes the surface shape and relief of the land. It refers to various landforms (physical features) which represent the external shape of the earth. It determines the patterns and form of many other landform and land cover features. Furthermore, elevation and slope should be considered when selecting site for abattoir construction project.

Elevation: In this study elevation factor was generated from the digital elevation model (DEM) using the ArcGIS spatial analyst extension of surface module, which enabled to classify the area according to the level of elevation. Then, the elevation raster was reclassified in to four classes by examining the value and the frequency of elevation in the study area (fig 4.4). According to Fard, 2012; abattoirs might be constructed in an area lower than the city level in order to prevent the spread of contamination. It is convenient to locate abattoirs over low laying parts in order to minimize the effect of flooding hazard. Therefore, areas with high altitude ranked as least suitable, and areas with low altitude ranked as highly suitable for site selection. The result of the reclassified elevation map is shown on Figure 4.4.

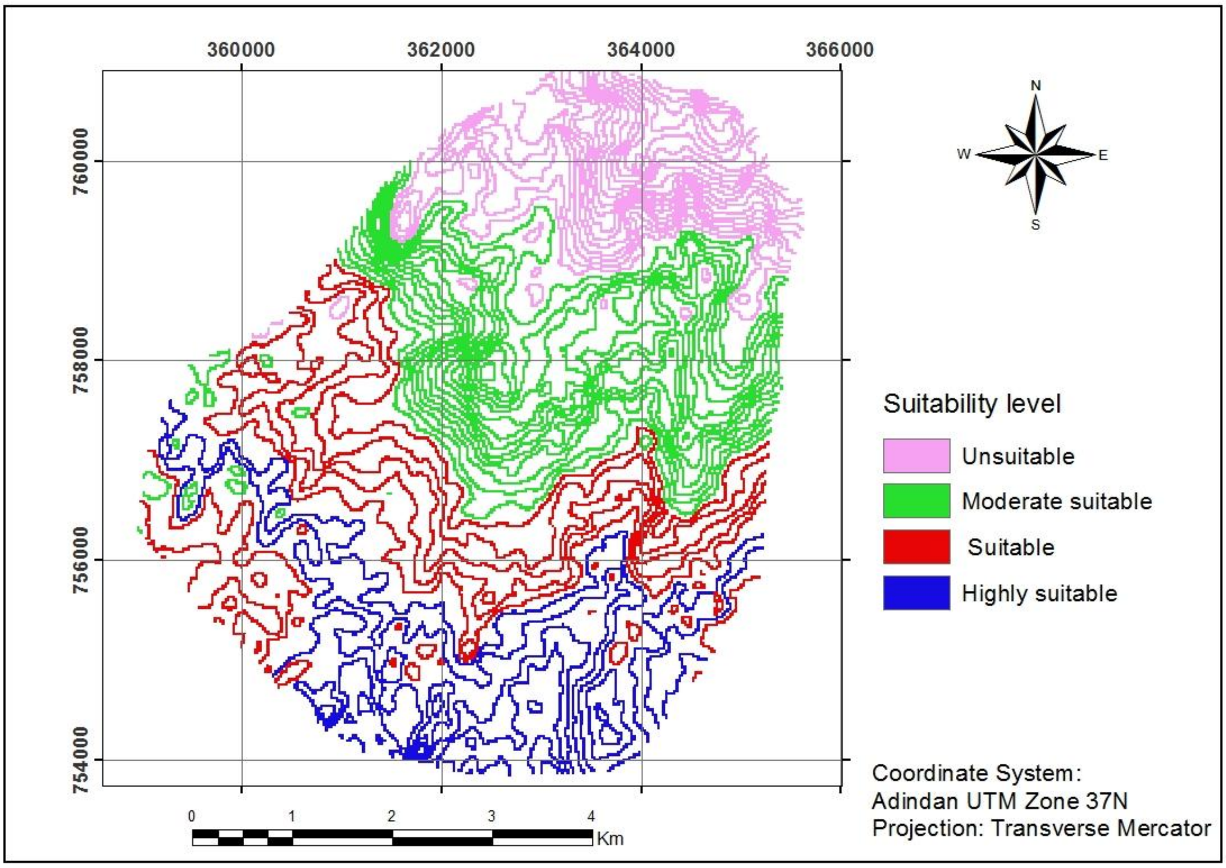

Figure 4.4: The Reclassified map of elevation

Table 4.5: The Reclassified elevation value

Elevation (meter)	Rank	Level of suitability
2160 - 2330	1	Unsuitable
2070 -2160	2	Moderate suitable
1990 – 2070	3	Suitable
1910 – 1990	4	Highly suitable

Source: extracted from reclassified elevation map

Land Slope: Slope is an important criterion in hilly terrain for finding suitable sites for urban development. Steep slopes are disadvantageous for construction. Steeper slopes increase construction costs, limit maximum floor areas and contribute to erosion during construction and subsequent use. In this study slope factor was generated from the digital elevation model (DEM) using the ArcGIS spatial analyst extension of surface module, which enabled to classify the area according to the steepness and the gentleness of the terrain. The Slope function could calculate the maximum rate of change between each cell and its neighbors. Every cell in the output raster had a slope value. The lower the slope value, the flatter the terrain was and the higher the slope value the steeper was the terrain. Then the slope raster was reclassified in to four classes of slope percent by examining the value and the frequency of slope percent in the study area (Fig 4.5). The reclassified slope was given a rank value 1 to 4 with the higher value of 4 showing high influence, i.e. highly suitable, while the lower value of 1 showing low influence, least suitable. Thus, as recommended by (LMA, 2000) the desirable slope for abattoir site is suggested to be gently sloping area, which ranges from 2 to 10 per cent. Slope values below 2 per cent are not suitable from safe drainage point of view.

Table 4.6: The Reclassified slope suitability class

Suitability Class	Rank	Level of suitability
< 10	4	Highly suitable
10 – 15	3	Suitable
15 – 30	2	Moderate Suitable
> 30	1	Unsuitable

Source: extracted from reclassified slope map

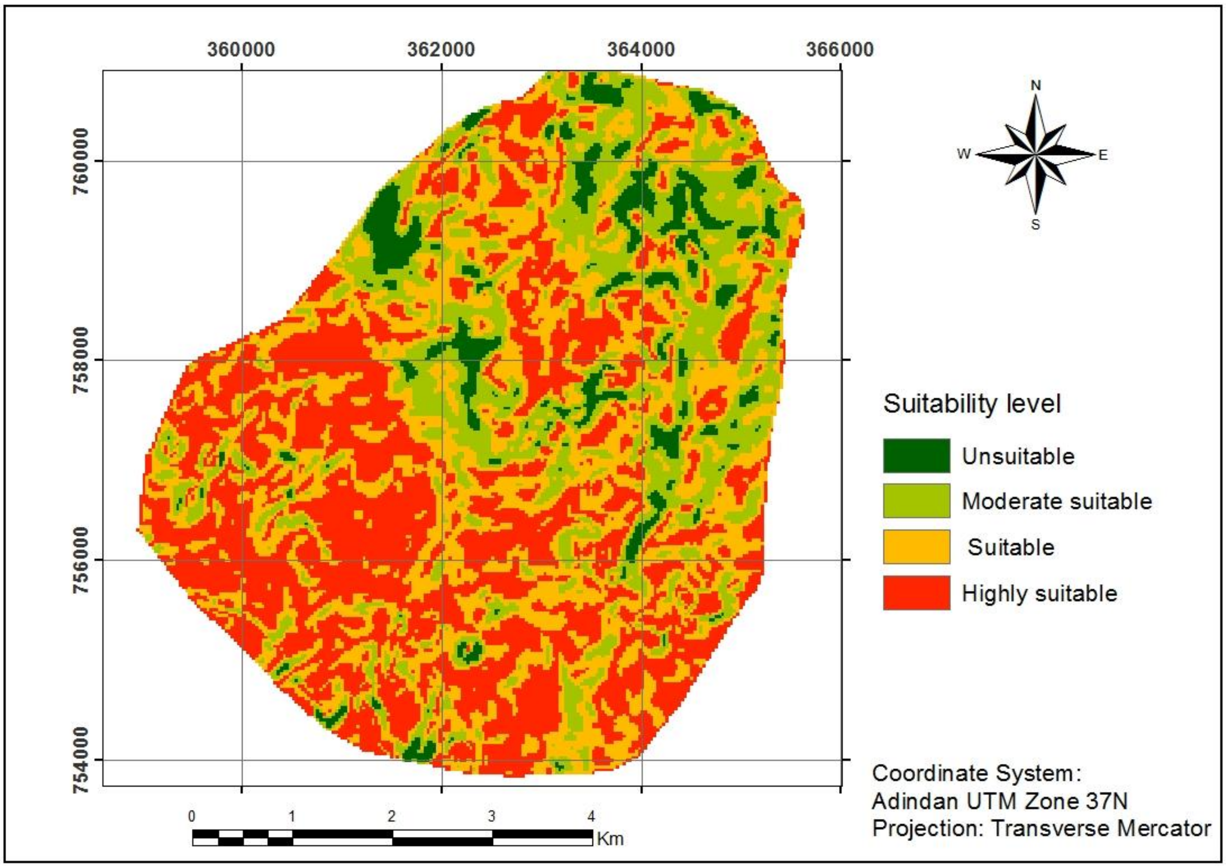

Figure 4.5 Reclassified slope map

4.2.3 Accessibility

Roads: Road is also an important criterion in site suitability analysis. The need to transport processed meat, carcasses, slaughter animals, etc. is dependent on the proximity to transportation facility. The newly proposed areas of the town were not facilitated with sufficient road networks. Therefore, efforts were made to locate the site nearer to any existing road if possible. Moreover, in order to find out better accessibility to the existing road, buffer zones have been created by taking distances between 20 to 400 meter from the existing major roads (EPA, 2002; LMA, 2000) to generate suitable accessibility map. Then the buffer distance zones have been categorized into four levels based on the level of proximity to abattoir site. Accordingly, the low buffer distance ranked as highly suitable whereas the longer buffer distances ranked as least suitable (fig 4.6). Thus, the rank value of 4 was given for highly suitable road buffers and the rank value one was given for unsuitable road buffers (table 4.5).

Table 4.7: Reclassified Distance from the Road Networks

Suitability Class	Rank	Level of suitability
< 400m	4	Highly suitable
400m - 800m	3	Suitable
800m - 1200m	2	Moderate Suitable
1200- 1600m	1	Unsuitable

Source: extracted from the reclassified road network map

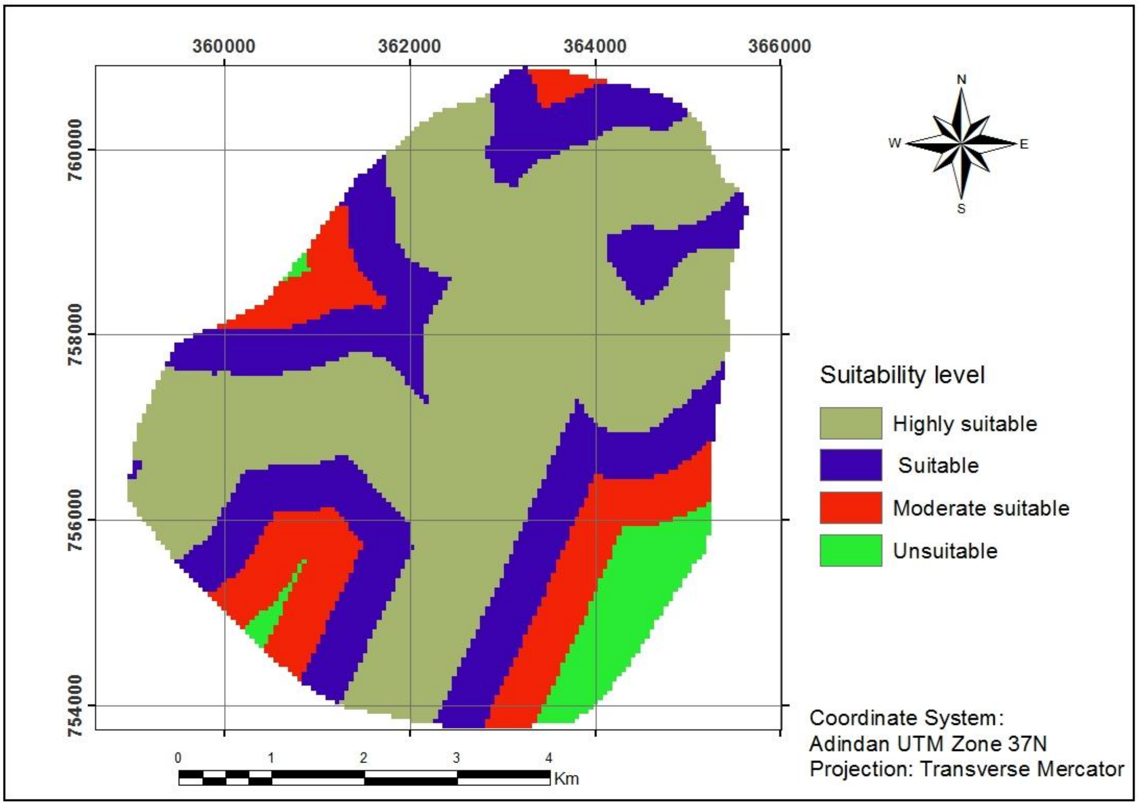

Figure 4.6 Reclassified Road Network map

4.2.4. Surface water

Streams/Rivers: Most of the surface waters in the study area are in the form of streams that occurred during heavy rains in summer season. 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. The streams/river factor was generated from the digital elevation model (DEM) using the ArcGIS spatial analyst extension of hydrology module. Then it was buffered based on the 100m distance standard criteria set by EPA, 2002, to locate abattoirs from critical environmental resources such as streams/rivers. Thus, four buffer zones have been drawn around streams and rivers, and relative suitability rank was assigned; buffers far to rivers are more suitable, while buffers near to streams are unsuitable. A rank value of 4 was given to a distance of > 150 m, while a rank value of 1 was given to distances of ≤ 100 m (table 4.5).

Table 4.8: Reclassified distance from streams

Suitability class	Rank	Degree of suitability
< 100m	1	Unsuitable
100m – 150m	2	Moderately suitable
150m – 200m	3	Suitable
> 200m	4	Highly suitable

Source: extracted from reclassified streams map

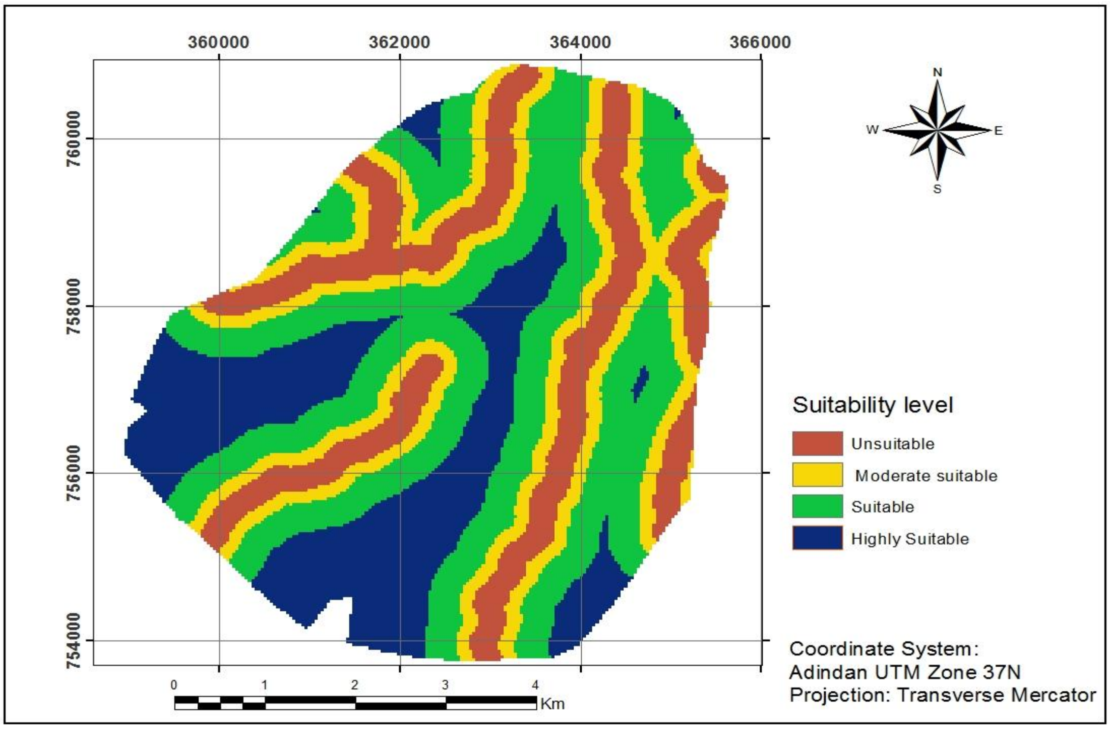

Figure 4.7: Reclassified maps of river/streams

4.2.5. Constraints

The constraints in this study include; areas of conservation, high tension line, boreholes/wells, landfill sites, parks and others. Abattoir should be situated at a significant distance away from these areas. The focus is 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, 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 upper mentioned urban facilities. 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 to LMA, 2000, EPA, 2000 and UPI experience; the high tension line, in order to avoid possible accidents that could be encountered because of big flying birds (e.g. scavengers) hovering over the abattoir, the site should be at least 500 meters from high tension lines. This factor was given a weighting value of 0.06. High tension line: In order to alleviate or avoid possible accidents that could be encountered because of big flying birds (e.g. scavengers) hovering over the abattoir, the site should be at least 500 meters from high tension lines.

Conservation areas: The site should be out of areas needing conservation measure. Such areas should also be protected with a 10meter buffer. This factor was given a weighting value of 0.04.

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. This factor was given a weighting of 0.07 to increase its importance of protecting the groundwater from pollution, in addition to its direct influence on the community. 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 are taken as unsuitable for abattoir site location.

Landfill: To minimize the impact of neighborhood activities upon the abattoir, at least two activities are considered. These are waste dump and polluting industries. Waste dump is considered mainly from hygienic point of view; particularly, dust and smoke emitting industries can produce chemical and other form of pollution. Abattoir should be located at least 500 meters from waste dump site and 300 meters from dust emitting industries. The result of reclassified buffer zone distance map is shown on figure 4.8.

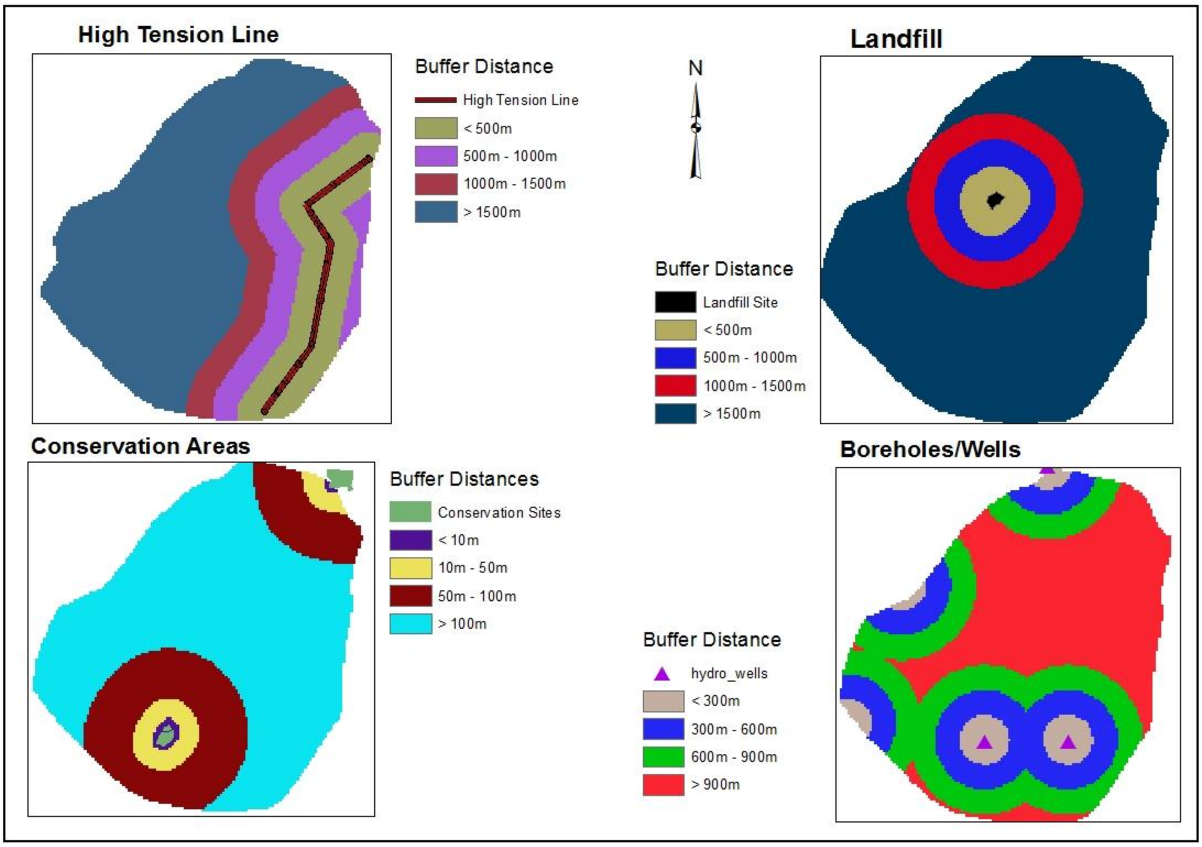

Figure 4.8: A buffer zone distance for selected constraints/factors

Table 4.9: Reclassification of constraints

Distance from wells	Rank	Level of suitability
< 300 m	1	Unsuitable
300m – 600m	2	Moderately suitable
600m – 900m	3	Suitable
> 900m	4	Highly suitable
Distance from conservation areas	Rank	Level of suitability
≤ 10 m	1	Unsuitable
10m – 20m	2	Moderately suitable
20m – 50m	3	Suitable
> 50m	4	Highly suitable
Distance from High Tension Line	Rank	Level of suitability
< 500 m	1	Unsuitable
500m – 1000m	2	Moderately suitable
100m – 1500m	3	Suitable
> 1500m	4	Highly suitable
Distance from Landfill	Rank	Level of suitability
< 500 m	1	Unsuitable
500m – 1000m	2	Moderately suitable
1000m – 1500m	3	Suitable
> 1500m	4	Highly suitable

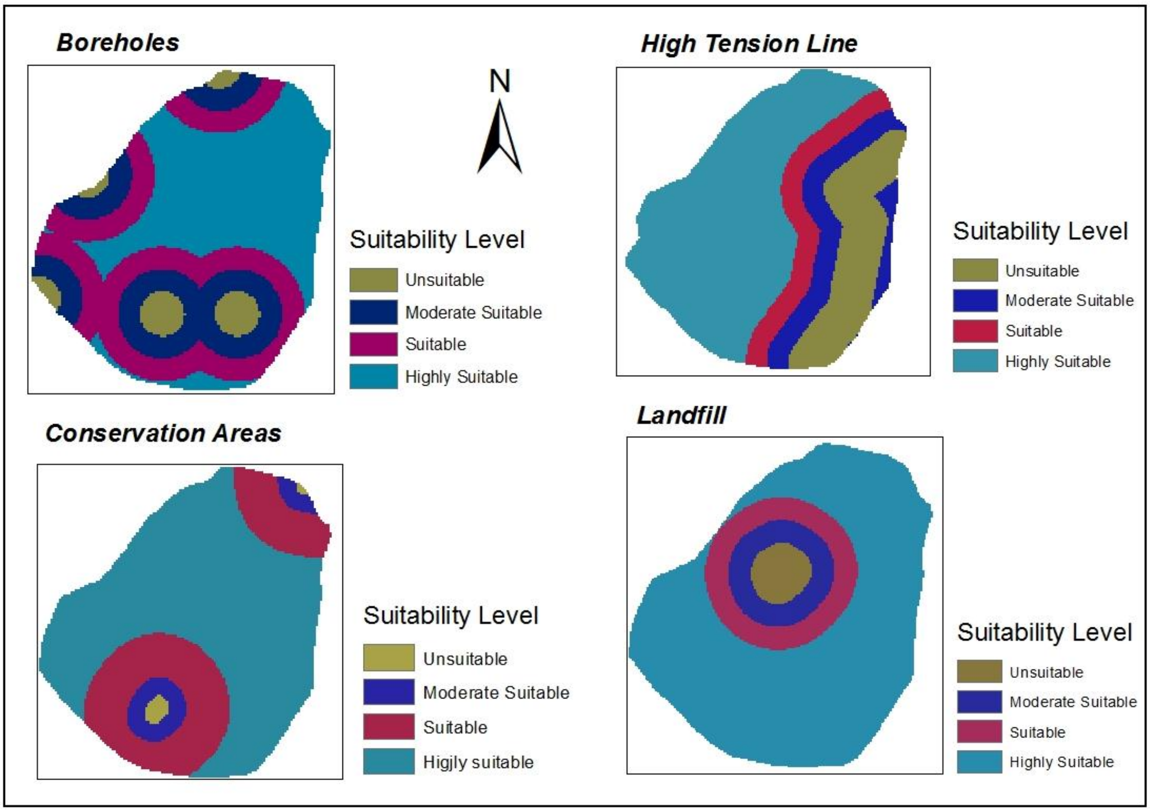

Figure 4.9: Reclassified map of constraints

4.3. Research Geo-Database Design

All the above listed factors were stored in the geo-database in order to store the collected data and the analysis results in a logical arrangement. The factors involved were examined according to their relative importance towards designating areas of high suitability classes and assigned weights. The classes in each factor layers were also compared one another and ranked by their contribution to the output.

The collected data were automated (scanned, digitized, and clipped by the study area boundary) and organized into logical groupings of the factors. The factor layers were grouped into five according to their nature as:

A. Urban land use Factors: built-up area, water bodies, vegetation cover, open areas, bare lands
B. Topographical: elevation, slope
C. Accessibility: distance from major roads
D. Surface water: streams/rivers
E. Constraints: location in terms of the distance landfill, boreholes, conservation areas, high tension lines

The research geo-database was then designed to include the input datasets, their derived datasets, the weighted analysis maps, and the final result. The vector files were exported to the corresponding feature data sets and the raster files were exported as individual raster datasets in the geo-database. The coordinate system selected to be used for analysis was projected coordinate system, UTM. Thus, the geo-database was set to this spatial reference and all the maps were projected to it while exporting to geo-database.

4.4. Calculation of the Criteria and Class Weights

In order to generate abattoir site, nine interrelated components of the environment were used as input data sets (factors). Accordingly the selected input datasets were urban land use, Road network, elevation, slope, wells, streams, high tension line, landfill, conservation area. Each of the factor maps were produced from remote sensing image, topographic maps and different available maps. Before combining them, the following procedures were taken place; first, rasterization was done for the vector data layers in order to produce similar data layers to perform GIS analysis and secondly standardization of each data set to a common scale of 1 to 4 was done in ArcGIS Software. Prior to combining the factors, weights have to be given based on Satty's Analytic Hierarchy Process (AHP), where a pair-wise comparison matrix will be prepared for each map using a nine point importance scale (Table 4.8). Weighting is used to express the relative importance of each factor relative to other factor. The larger the weight, the more important is the factor in overall utility.

Table 4.10: pair-wise comparison, 9-point weighting scale

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very Strongly	Strongly	Moderately	Equally Important	Moderately	Strongly	Very strongly	Extremely
Less Important					More Important			

Source: Adapted from Saaty, 1989 as cited in Malczewsk, 1999

In the process of AHP, the prime task of calculation is the eigenvector corresponding to the largest eigen value of the matrix. Each element in the eigenvector indicates the relative priority of corresponding factor, i.e. if a factor is preferred to another; its eigenvector component is larger than that of the other. A sum/product method is used to obtain the eigen value and the subsequent eigenvector. The weights finally derived by AHP are used for developing the HSI model. To examine the rationality of AHP, it is necessary to determine the degree of consistency that has been used in developing the judgments. In AHP, an index of consistency, known as the consistency ratio (CR), is used to indicate the probability that the matrix judgments were randomly generated.

$$CR = \frac{CI}{RI}$$

Calculating Consistency Ratio (CR)

CR= CI/RI

Where CI = λ-n/n-1

RI=Random consistency index

N=Number of criteria.

λ max is priority vector multiplied by each column total. Where RI is the average of the resulting consistency index depending on the order of the matrix given by Saaty, and consistency index (CI) is defined as:

$$\boldsymbol{CI = \frac{\bar{\lambda}_{max}^{-n}}{n-1}}$$

Where: $\bar{\lambda}_{max}^{-n}$ is the principal Eigen value of the matrix, n is the order of the matrix.

The AHP also provides measures to determine inconsistency of judgments mathematically. The CR, which is a comparison between Consistency Index (CI) and Random Consistency Index (RI), can be calculated using the following formula:

CR= CI/RI

In this process, experts opinions were asked to calculate the relative importance of the factors and criteria involved. It is recommended that the consistency ratio presents values below 0.1. CR* was also calculated and found to be 0.027, which is acceptable to be used in the site suitability analysis.

The computed Eigen vector is used as a coefficient for the respective factor maps to be combined in weighted overlay in ArcGIS environment.

Table 4.11: The Criteria used in abattoir site selection modeling

Class	S1	S2	S3	S4	S5	S6	S7	S8	S9	N^{th} value	weight	Std	Ave
S1	1	2	2	2	3	3	3	3	3	2.32	0.218	2.07	9.0
S2	1/2	1	2	3	2	2	3	3	3	1.90	0.178	1.71	2.28
S3	1/2	1/2	1	1/3	2	2	2	3	3	1.56	0.148	1.17	9.75
S4	1/2	1/3	3	1	2	2	2	3	3	1.48	0.138	1.45	14.5
S5	1/3	1/2	½	½	1	2	2	1/3	3	0.82	0.078	0.77	9.62
S6	1/3	1/2	½	½	1/2	1	2	1/3	3	0.70	0.018	0.66	9.43
S7	1/3	1/3	½	½	1/2	1/2	1	1/3	3	0.57	0.068	0.53	8.83
S8	1/3	1/3	1/3	1/3	3	3	3	1	2	0.95	0.098	1.01	11.2
S9	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/2	1	0.39	0.048	0.37	9.25
Total										10.69	1		83.86

Where: S1= LU/LC; S2 = Streams; S3 = Roads; S4 = Elevation; S5 = Slope; S6 = wells; S7 = High Tension Line; S8 = Land fill site; S9 = Conservation areas

λ_{max}^{-n} = Standardization/n = ∑ave/ N = 83.86/9 = 9.31

Where: N = Number of Criteria

CI = $lamda_{max}$ - N/n-1 = 10.25- 9/8 =0.04

CR = CI/RI = 0.04/1.45 = 0.27

Table 4.12: Classification of factor values and their weights obtained after pairwise comparison

Factor	**Class**	**value**	**level of suitability**	**Influence (%)**
Urban land use	Built-up	1	unsuitable	0.23
	Vegetation	2	Moderately suitable	
	Open areas	3	Suitable	
	Bare lands	4	Highly suitable	
Distance from Streams	< 100m	1	Unsuitable	0.19
	100m – 150m	2	Moderately suitable	
	150m – 200m	3	Suitable	
	> 200m	4	Highly suitable	
Distance from Roads	< 400m	4	Highly suitable	0.12
	400m - 800m	3	Suitable	
	800m - 1200m	2	Moderate suitable	
	1200- 1600m	1	Unsuitable	
Elevation	2160 - 2330	1	Unsuitable	0.10
	2070 -2160	2	Moderate suitable	
	1990 – 2070	3	Suitable	
	1910 – 1990	4	Highly suitable	
Slope	< 10	4	Highly suitable	0.08
	10 – 15	3	Suitable	
	15 - 30	2	Moderate suitable	
	> 30	1	Unsuitable	
Distance from wells	< 300m	1	Unsuitable	0.07
	300m - 600m	2	Moderate suitable	
	600m - 900m	3	Suitable	
	> 900m	4	Highly suitable	
Distance from HTL	< 500m	1	Unsuitable	0.06
	500m - 1000m	2	Moderately suitable	
	1000m - 1500m	3	Suitable	
	> 1500m	4	Highly suitable	
Distance from landfill	< 500m	1	Unsuitable	0.09
	500m - 1000m	2	Moderate suitable	
	1000 - 1500m	3	Suitable	
	> 1500m	4	Highly suitable	
Distance from conservation	< 10m	1	Unsuitable	0.04
	10m - 50m	2	Moderately suitable	
	50m - 100m	3	Suitable	
	> 100m	4	Highly suitable	
Consistency Ratio = 0.027 which is acceptable				

4.5. Integration of criteria maps and preparation of final suitability map

At this stage, all the factor layers are ready to be combined in order to identify suitable site for abattoir location in the study area. If all datasets were equally important, it could be possible to combine them simply. However, from the principal eigenvector calculation, the relative importance of each parameter was determined. Therefore, the higher the weight, the more influence a particular factor will have in the suitable site generation. Accordingly, the factor layers were combined by applying the following formula in the raster calculator of spatial analyst extension in ArcGIS environment. It was done systematically using ArcGIS model builder (Figure 4.11).

[Urban LU/LC] * 0.23 + [Streams] * 0.19 + [Roads] * 0.12 + [Elevation] * 0.10 + [Slope] * 0.09 + [Wells] *0.08 + [HTL] * 0.06 + [Landfill] * 0.09 + [Conservation] * 0.04 = Abattoir Site

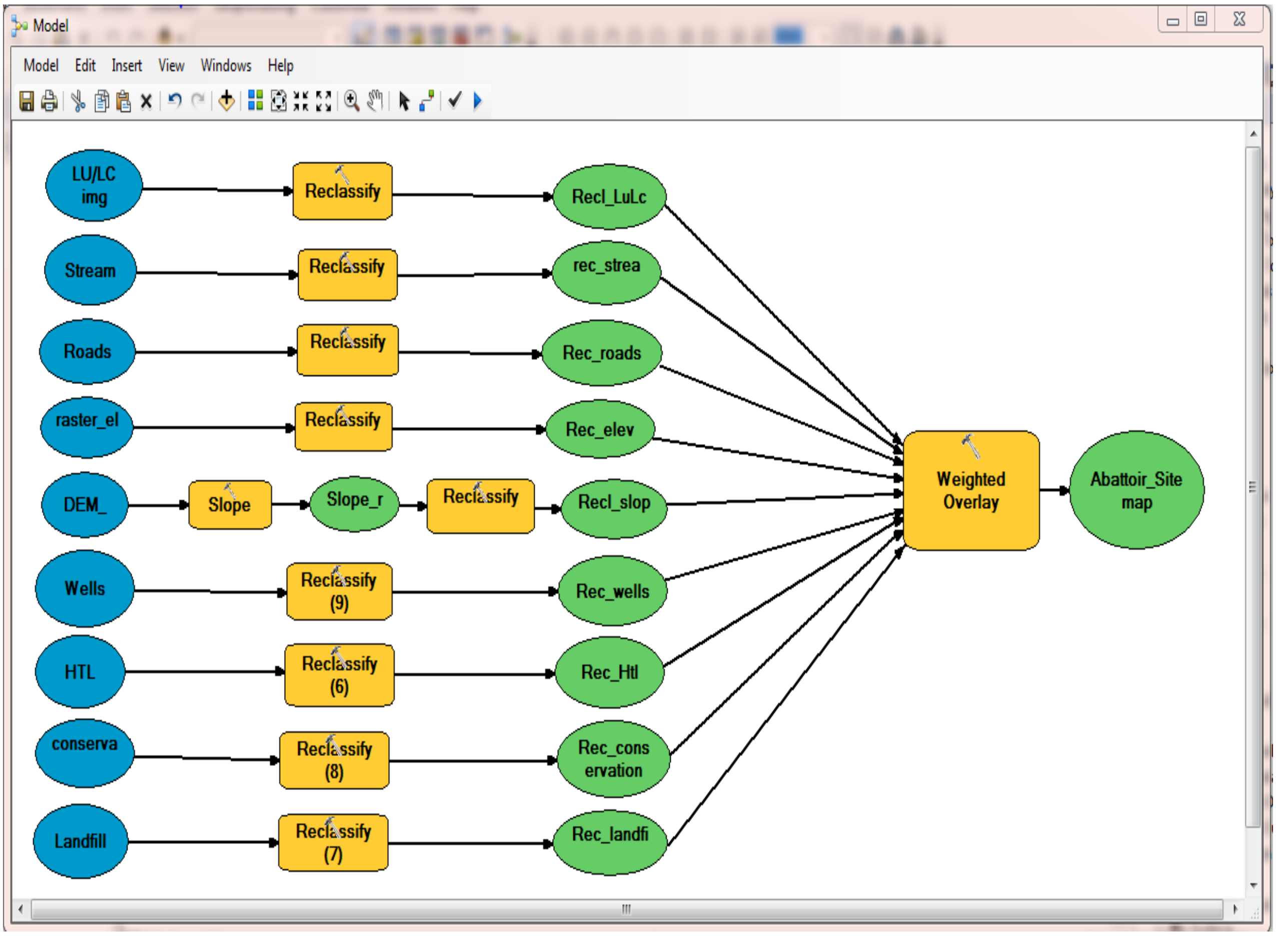

Figure 4.10: Abattoir Site Suitability Analysis Model builders

4.6. Discussions and Results

4.6.1. Abattoir Site suitability Analysis

The site suitability map was divided into four classes: highly suitable, suitable, moderate suitable, and unsuitable. Table 4.11 shows that 18.4% of the study area covers a “highly suitable” class of abattoir site selection, whereas a total of 22.3% and 28.8% of the study areas have “suitable” and “moderately suitable” classes respectively. The “unsuitable” class covers 30.4% of the study area.

Table 4.13: Statistical Analysis for the Abattoir Site Suitability map

Suitability Class	Value	Count	Area (ha)	%
Unsuitable (S4)	1	1276	114.84	30.4
Moderate suitable (S3)	2	1213	109.17	28.8
Suitable (S2)	3	937	84.33	22.3
Highly suitable (S1)	4	775	69.75	18.4
Total		4201	378.09	99.9

Source: Extracted from the Abattoir Site Suitability Map

The value shown on the table above was derived from the site suitability map. The count values represent the number of pixels in each suitability class. Since a pixel has 30m*30m spatial coverage, it represents an area equals to 900m^2 which is about 0.09 hectare when converted. Thus, the total number of pixels multiplied by 0.09 hectare would result 378.09 ha area.

Abattoir site suitability analysis at district level was also assessed. As can be seen from the suitability map (Fig 4.11), the highly suitable areas (S1) are mainly located in the south, south west and south east corner of the town (18.4 %). These areas cover mainly agricultural and bare land uses. Currently these areas are waiting for the distribution of specific urban land use development. The suitable areas (S2) are located following the periphery of built up areas (28.8 %). These areas are free from urban settlements and are occupied by sparse vegetation, agricultural and waste lands. The highly suitable, suitable and moderate suitable areas have an appropriate site for the development of facilities. The areas are also free from any conflicts or restrictions on usage. Finally, the unsuitable areas (S4) for abattoir site selection are also located in the northern mountainous part of the town (30.4 %).

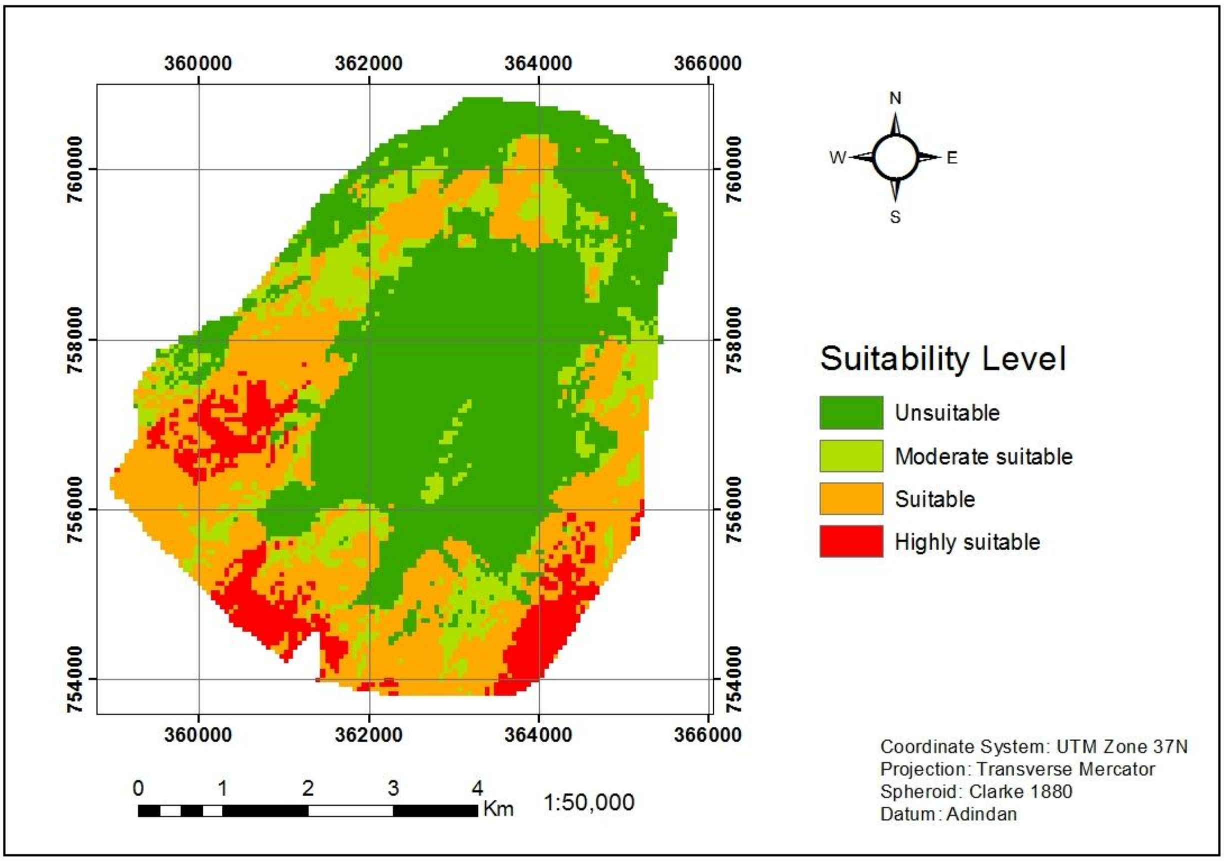

Figure 4.11: Abattoir Site Suitability map

4.6.2. The Overall Suitability Map

The suitability of abattoir site can be expressed in terms of the existing features. Figure 4.12 shows the composite suitability of the constraint map and the factor maps. The areas are labeled as highly suitable (S1), suitable (S2), moderate suitable (S3), and unsuitable (S4). It is still possible to make further suitability differentiation among these areas. Obviously, those parts of the selected areas that are near the existing roads are more suitable than those located further, as far as only the road factor is considered. The highly suitable area appeared at southern part of the town following the main road towards Arbaminch is not preferable for abattoir site due to its residential pressure. The constraints are usually regulations (environmental, land use etc.), which are legal constraints in essence. For example, the local building regulation forbids the construction of an abattoir within 100 meters distance of rivers or streams. Obviously this is a constraining criterion that immediately limits the specified area for development. That is, such constraining criteria are considered as legal constraints and cannot be compromised.

A discussion held with relevant experts supported to prioritize the future land uses of the study areas. Thus, the choice of two alternative sites; moderate suitable and suitable areas are relatively suitable for residential development than for locating an abattoir. If the abattoir is sited either within S2 or S3, the likelihood that it will be relocated earlier than expected (because of residential pressure or encroachment) would be greater. The 4th site, S1, on the other hand, is less suitable for residential development and hence it is selected as the best site for the intended abattoir. This site is located near the boundary of the town and is also bounded in the west, south and south west by conservation areas which could not easily be used for urban land use purpose. It can be therefore observed that, being located within this site, the abattoir will have prolonged life time before it can be relocated. Finally, in order to mitigate the odor pollution that could be generated from some activities within the abattoir, a 200 meter buffer is provided. Based on the suggestion of experienced urban planners, within this buffer, the following activities that are compatible with the abattoir can be undertaken so as to minimize wastage of urban land:

Cattle market: cattle markets are usually recommended to be located close to abattoir so that purchased cattle could immediately be taken to the abattoir without having to cross the town. This reduces possible traffic problems that would otherwise be created; and cattle fattening lots: this type of investment activity exists in most towns of the country. The cattle are usually fattened to be sold later. Thus, it is compatible both with the abattoir and the cattle market.

Generally, highly suitable area of abattoir (S1) can be summarized in terms of the specific objectives set at the beginning of the study. In other words, locating the abattoir within this site ensures minimizing the impact of abattoir on the surrounding environment; reducing the impact of nearby activities on the abattoir, and relatively less probability of being relocated earlier than expected.

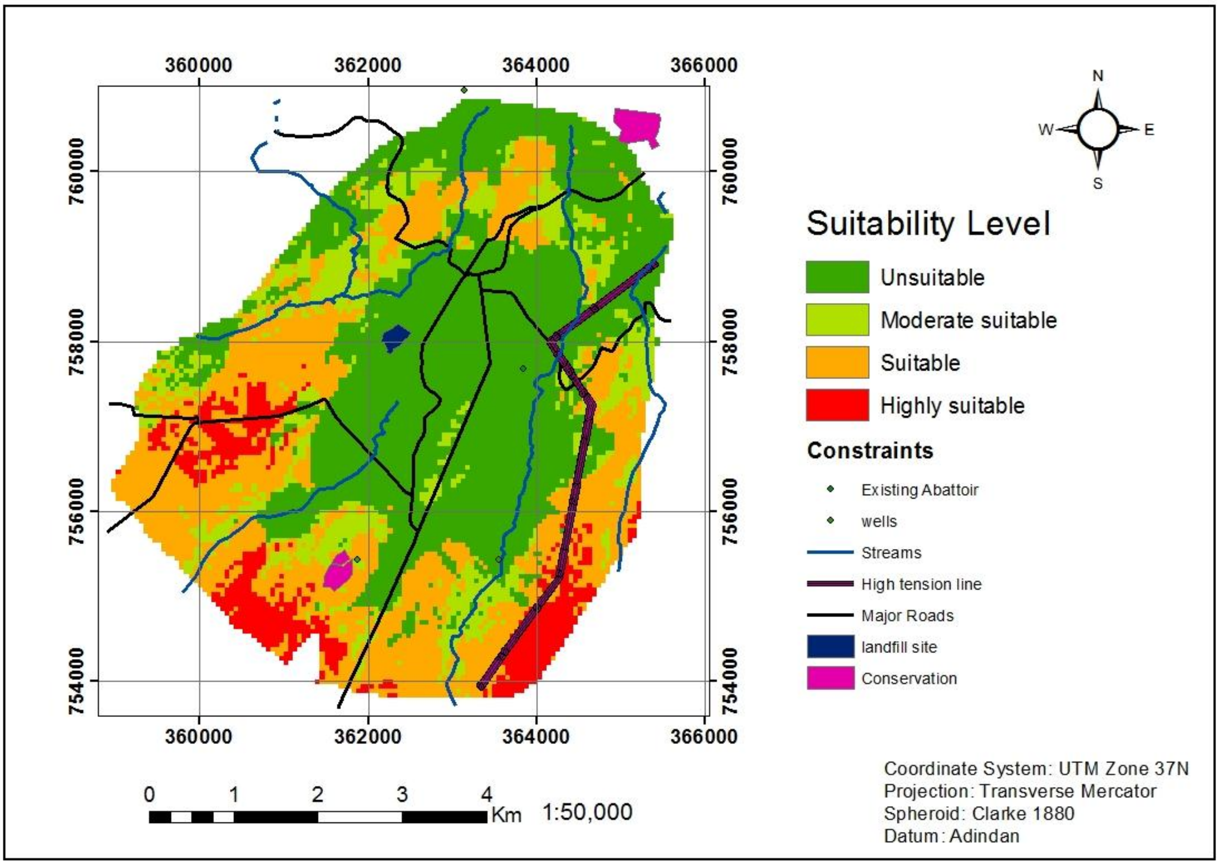

Figure 4.12: The overall abattoir site suitability map

In order to find suitable areas where the abattoir site falls, overlaying the suitability map (Fig. 4.11) with the land use/cover map (Figure 4.3) is important. The land use/cover map indicates that the major land uses are built up area (1031.6 km^2), vegetation (263.34km^2), open areas (1381.7km^2), and bare lands (427.8km^2) of the total study area.

Table 4.14: Summary of land use /cover classification statistics

Land use/cover classes	Count	Area (ha)	Area (%)
Built up area	11462	1031.58	33.2
Vegetation	2926	263.34	8.5
Open areas	15352	1381.68	44.5
Bare lands	4753	427.77	13.8
Total	34493	3104.37	100

Source: Derived from land use/cover map

As expected, the highly suitable and suitable areas were appeared to be over the bare land and open areas segment. The result indicated that 82% of the highly suitable class was distributed over the bare lands, while only 18% of the class was located in the open areas. With respect to the suitability class, 91.70 % of the class was also found in open and bare land section, whereas only 5.52 % of the class was located in the agricultural and built up areas. Finally, the unsuitable class was mainly stretched over the mountainous land and built up areas.

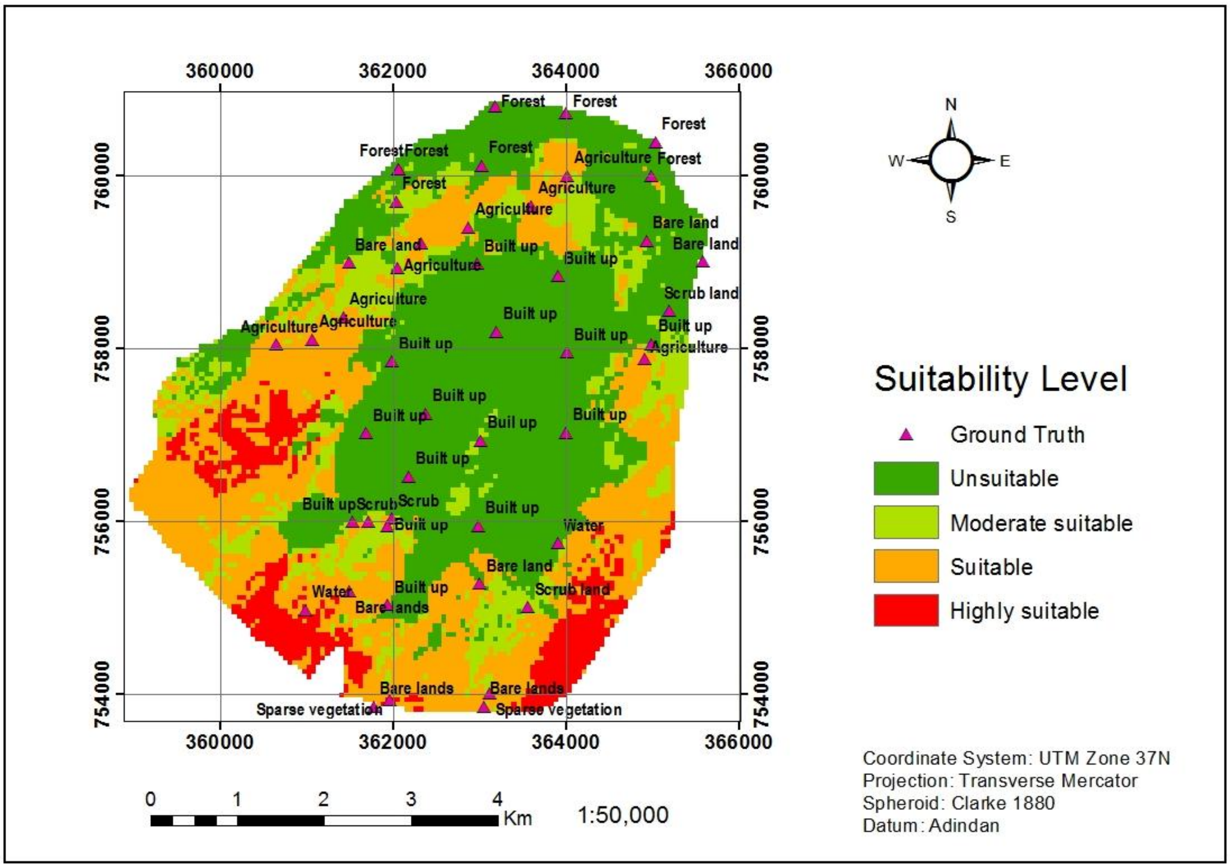

Figure 4.13: Overlay maps of Land use/cover and Site Suitability

A field survey was conducted to check the conditions of the suggested alternative sites. It was found that all the suggested sites, from environmental point of view, can be suitable for a new abattoir site. But, in terms of planning and public opinion there might have different views, which might need further investigations, taking into consideration more detailed engineering, geotechnical, and hydro geological studies.

Chapter Five

5. Conclusions and Recommendation

5.1. Conclusions

Abattoirs are important urban functions that provide livestock processing services for the towns and/or cities they serve. The ultimate purpose of establishing abattoirs is to provide cleaner and hygienic slaughtering services, to ensure proper utilization of animal byproducts, to establish and control standards, to generate income for the services rendered, and to alleviate impacts on the environment by controlling the waste disposal system.

Abattoirs have some basic features that necessitate the search of unique location for them. Such location ought to satisfy some specific objectives including minimizing the undesirable impacts that the abattoir can pose on the surrounding environment and vice versa, ensuring the availability of basic facilities necessary for the proper functioning of the abattoir and so on.

GIS and WLC as analysis tools are valuable tools that can support the decision makers to find best possible abattoir sites. The GIS analysis requires collecting data from different sources with different formats to create a complete uniform database. Thus, the GIS data should be updated regularly in order to reflect the current situation of an area under investigation. Remote sensing data can assist to have updated information of the study area. Also, it can support the decision makers to monitor the investigated area using different dates of satellite images to extract the urban land use/cover class for example.

The findings have shown the ability of GIS and remote sensing as a genuine tool for analyzing the criteria for decision support. The analysis has taken land use/cover, slope, surface water, proximity to main roads and streams and environmental constraints as determining factor in order to find appropriate site for abattoir. The three candidate sites were suggested based on the methodology and available data applied in this research. The results have shown that three sites were selected as suitable. These places are far away from any water sources and other variables put into account in the analysis. The places are located at different parts of the town. The most suitable site was located at south west and south east of the town over bare and open agricultural areas.

Generally, the suggested sites comply with the minimum requirements of the abattoir site selection. However, any GIS model is limited to the available data, which in this study; nine parameters were considered. Therefore, any additional information such as wind direction, land price, detailed soil data, and other social and economic factors can enhance the outputs of the GIS model, and provide more realistic results.

The planners and the decision makers can get useful information about the possible locations of abattoir sites using this methodology. Specially, the site ranking process allows for easily readjustment of the criteria weights in case a sensitivity analysis is required. Nevertheless, defining detailed and standard criteria by the Environmental Agency that comply with the local conditions can enhance the outputs of GIS models used for the purpose of finding a suitable abattoir site. However, getting public agreement on any candidate site is a must, and cannot be avoided. Therefore, the local community should participate in the selection process of abattoir site to avoid any opposition in the future.

5.2. Recommendations

In this study an attempt is made to develop a model for conducting abattoir site suitability analysis for a selected town, i.e. W/Soddo. The study showed that the use of a GIS for land suitability analysis is appropriate and a necessity in urban development planning under Ethiopian context. For further undertaking of the system, the following recommendations are given:

1. The GIS based multi criteria evaluation technique is simple and flexible which can be used to analyze the potential sites for urban development and encourage public participation in the urban decision making process. Thus, planners and authorities to formulate suitable plan for sustained development of the town, need to practice the application of GIS.
2. The abattoir site suitability model developed in this study has been intended to be used for towns requiring one abattoir. Where more than one abattoir is required, additional factors, particularly in relation to the spatial distribution of the abattoirs, have to be considered.
3. Because of the specific characteristics of the study area, certain geographic features (such as airport) are not included in the model. Where such features are present, they need to be incorporated in the analysis.
4. This study has been intended to serve for solving the location problems associated with municipal abattoirs. For Export abattoirs, which are expected to flourish in the country in the near future, some additional factors will probably be required to be considered, depending on the nature and complexity of such abattoirs.

A model builder is a tool for creating and managing spatial models that are automated and self-documenting. A spatial model in a model builder is easy to build, run, save, modify, and share with others. With a model builder the same model can be applied to different geographic areas by changing the input data.

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Appendices

Appendix 1: GPS points

SN	Shape *	X	Y	LU/LC Type
2	Point	363171	760803	forest
3	Point	362035	759701	forest
4	Point	363998	760714	forest
5	Point	365024	760388	Forest
6	Point	362060	760072	Forest
7	Point	362060	760073	Forest
8	Point	363026	760113	forest
9	Point	363594	759648	Agriculture
10	Point	364009	759996	Agriculture
11	Point	364973	759988	forest
12	Point	361491	758991	Bare land
13	Point	361421	758362	agriculture
14	Point	362046	758926	Agriculture
15	Point	362322	759212	agriculture
16	Point	362974	758978	built up
17	Point	362866	759400	Agriculture
18	Point	363897	758837	Built up
19	Point	364924	759248	Bare land
20	Point	365569	759004	bare land
21	Point	360643	758046	agriculture
22	Point	361064	758105	Agriculture
23	Point	361981	757854	Built up
24	Point	363188	758193	built up
25	Point	363083	757811	built up
26	Point	362652	757999	built up
27	Point	364003	757958	built up
28	Point	363489	757754	Built up
29	Point	364979	758053	Built up
30	Point	364897	757879	Agriculture
31	Point	365180	758435	Scrub land
32	Point	361688	757021	built up
33	Point	362181	756526	built up
34	Point	362143	757068	built up
35	Point	362374	757252	built up
36	Point	363011	756940	built up
37	Point	361707	756001	Scrub
38	Point	361981	756036	scrub
39	Point	363897	755750	Water
40	Point	360991	754979	water
41	Point	361937	755041	built up

42	Point	361494	755201	bare lands
43	Point	362999	755287	bare land
44	Point	363555	755014	scrub land
45	Point	361964	753937	sparse vegetation
46	Point	363112	754017	sparse vegetation
47	Point	363046	753864	bare lands
48	Point	361773	753866	Bare lands
49	Point	361956	758227	water
50	Point	362796	759906	sparse vegetation
51	Point	364762	758445	water
52	Point	360721	755974	water

Source: Field Survey, 2014

Annex 2: Criteria for abattoir site selection

SN	Spatial Data	Layer Name	Criteria
1	Residential areas	Residence	250 m away from Residence
2	Administrative areas	Administration	250m away from Administration
3	Commercial areas	Commerce	250m away from Commerce
4	Recreational areas	Recreation	300m away from Recreation
5	Schools	School	300m away from School
6	Health Service	Health	300m away from Health
7	Worship place	Worship	300 m away from Worship
8	Industrial area	Industry	300m away from Industry
9	Conservation areas	Conservation	10m away from conservation
10	Cemeteries	Cemetery	100m away from cemetery
11	Boreholes	Borehole	300m away from Borehole
12	Waste Dump Site	Waste Dump	500m away from Waste Dump
13	Rivers and Streams	River/Streams	100m away from River/Stream
14	High Tension Line	High/Tension Line	500m away from High/Tension Line
15	Vacant /Agricultural Land	Vacant/Agriculture	Select Vacant/ Agriculture
16	Slope	Slope	Between 2-10 per cent slope
17	Road Network (streets)	Road	Between 20 and 400 m from existing road
18	Prevailing Wind direction	Wind	Provide buffer zone (150 to 200m)
19	Future Land use	Future Land use	Prioritize
20	Site Capacity	Site Capacity	Greater than or equal to one hectare
21	Boundary/Town Area	Boundary	Within municipal boundary

Source: EPA, 2002; LMA, 2000

Annex 3: Questions used during discussions with experts

i. What are the criteria employed for abattoir site selection?
ii. What is the spatial buffer distances required to separate municipal abattoir from different geographic features (such as residential areas, rivers, boreholes etc.)?
iii. What are the justifications for the buffer distances provided in (ii) above?
iv. How would you assess the site selected using GIS taking into account all the appropriate criteria and the specific conditions of the study area?