JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

RANGELAND SUITABILITY ANALYSIS FOR LIVESTOCK PRODUCTION USING GIS AND MULTI-CRITERIA EVALUATION, DELO MENA WOREDA, BALE ZONE, SOUTH EAST ETHIOPIA

BY: Dejene Kifle

December 2020

Jimma, Ethiopia

JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

RANGELAND SUITABILITY ANALYSIS FOR LIVESTOCK PRODUCTION USING GIS AND MULTI-CRITERIA EVALUATION, DELO MENA WOREDA, BALE ZONE, SOUTH EAST ETHIOPIA

BY: Dejene Kifle

A Thesis Submitted to Jimma University, College of Social Science and Humanities, Department of Geography & Environmental Studies in partial fulfilment of the requirement for the degree of Master of Science (M.Sc.) in GIS and Remote sensing.

ADVISOR: Ajay Babu (PhD)

CO-ADVISOR: Girma Alemu (PhD Candidate)

December 2020

Jimma, Ethiopia

Submitted by

Dejene Kifle ----------------- -------------------------

Signature Date

Approved By:

Ajay Babu (PhD) -------------------------- ----------------------

(Advisor) Signature Date

Girma Alemu (PhD Candidate) ------------------------ ------------------

(Co-Advisor) Signature Date

Internal Examiner

------------------------ ----------------- ------------------

Signature Date

External Examiner

---------------------------- ----------------- ------------------

Signature Date

Head of Department

Mr. Wondafrash Genet ------------------ --------------------

Signature Date

ACKNOWLEDGEMENT

My first thankfulness goes to the almighty God, every challenge and everything in my life could never have been successful without his help and his intervention. Next, my grateful gratitude goes to my adviser Dr Ajay Babu and Co-adviser Girma Alemu (PhD candidate for their deep guidance and support in course of the research undertaking through giving me constructive comments and suggestions that make this thesis succeed.

Mainly, this thesis work was made possible by the precious input of many people and institutions. My gratitude goes to Mr Sintayehu Teka and Derara Kumbi, Delo Mena for their Appreciated contribution in the completion of the course for all their support from starting to the end of the thesis and in completion of M.Sc. program. And also, woreda Rural land administration and land use office expert and livestock development office expert for offering me essential data of accomplishment of my thesis.

Secondly, I am indebted to my wife Serkalem Bekele for her encouragement, support and taking responsibility lonely to care our child in time at the campus and my colleague Bayisa Tamiru, Abebe Bekele, Kalid Rube, Husein Muhamed and Awal Hasen who provide me with all kinds support giving me financial support, advice and motivation from the onset of proposal stage to end of this thesis.

Also, I earn my sincere thanks for my classmate Bayisa Negasa and Dereje Ijasa for their moral help during this study.

ABSTRACT

Rangeland encompasses much of the area where livestock production is the major land use, livestock is an important source of income and livelihood for the rural community and at country level contributing agricultural growth domestic product and national growth domestic product. So thorough knowledge of rangeland bio-physical characteristics is fundamental for an understanding of rangeland management problems and its importance for livestock production. Subsequently, this study aimed to analyze range land suitability for livestock production using geographyical information system and multi-criteria evalution techniques in Delo Mena woreda considering environmental and infrastructural factors such as landuse landcover, slope, rainfall, temperature soil type, access to veterinary service, and access to the market center. These factors were ranked based on their relatives' importance and their weight of influence was computed in the pairwise comparison of the analytical heirarcy process method. landuse landcover of the study area was classified using a supervised classification method in ERDAS 2015 software. The final suitability result indicates that 2%,5% and 7% of the land is highly suitable for cattle, goat and camel respectively, wereas 55%,52% and 66% of land moderately suitable for cattle, goat and camel respectively. Moreover,26% of land marginally suitable for goat and cattle while 11% of the land for camel production. But the insignificant percent of the land of the woreda was not suitable for cattle, goat and camel production. Thus, according to this study, a large part of the study area fell under moderately suitable cattle, goat and camel production. So proper rangeland management and utilization are essential in the woreda to improve the suitability of rangeland for livestock production.

Keywords: Delo Mena woreda, GIS, Livestock production, MCE, Rangeland**.**

Table of content

Contents

Page

ACKNOWLEDGEMENT i

ABSTRACT ii

Table of content iii

List of Table vi

List of Figure vii

ACRONYMS/ABBREVIATION viii

CHAPTER ONE 1

1. Introduction 1

1.1. Background of the study 1

1.2. Statement of the Problem 4

1.3. Objectives of the study 6

1.3.1. General objectives 6

1.3.2. Specific objective 6

1.4. Research question 6

1.5. Significance of the study 6

1.6. Scope of the study 7

1.7. Limitation of the study 7

1.8. Organization of the study 7

CHAPTER TWO 8

2. Review of Related Literature 8

2.1. Concept and definition of Rangeland 8

2.2. Rangeland Development and Livestock Production in Ethiopia 8

2.2.1. Rangeland Development in Ethiopia 8

2.2.2. Livestock production in Ethiopia 10

2.2.3. Spatial distribution of livestock 11

2.2.4. Importance of rangeland for livestock production 12

2.2.5. Current condition of Range Land Resources in Ethiopia 12

2.2.5.1. Bush encroachment 13

2.2.6. Land tenure system 14

2.3. Criteria of rangeland suitability for livestock production 14

2.3.1. Slope 15
3.2.2 Soil 15
2.3.3. Land use /land cover 15
2.3.4. Temperature 16
2.3.5. Rainfall 16
2.3.6. Market access 16
2.3.7. Veterinary service access 17
2.4. Land suitability analysis 17
2.4.1. Land suitability classification 18
2.5. Role of GIS and Remote Sensing in Rangeland Management 19
2.6. Multi-Criteria evaluations 20
2.7. GIS-Based Multi-Criteria Decision Analysis and Land Suitability Analysis 21
2.8. Empirical Literature on Rangeland Suitability Analysis 22
CHAPTER THREE 24
3. Methods and Materials 24
3.1. Description of the study area 24
3.1.1. Location 24
3.1.2. Topography 25
3.1.3. Climate 26
3.1.4. Soil 26
3.1.5. Vegetation 27
3.1.6. Water resource 27
3.1.7. Demographic characteristics 27
3.1.8. Socio-economic characteristics 27
3.2. Material and software 28
3.3. Research design 28
3.4. Data collection 28
3.5. Method of data analysis 29
3.5.1. LULC Classification 30
3.5.3. Accuracy assessment 31
3.6. Multi-Criteria Evaluation 33
3.7. Criteria or Factors selected 34

3.7.1. Criteria rating 43
3.7.2. Standardization of criteria 43
3.7.3. Weighing of criteria 49
3.7.4. Weighted overlay analysis 52
CHAPTER FOUR 54
4. Result and Discussion 54
4.1. Environmental suitability analysis 54
4.2. Socioeconomic (infrastructural factors) suitability analysis 57
4.3. Final suitability analysis 60
4.4. Livestock spatial distribution 64
4.5. Discussion 66
CHAPTER FIVE 68
5. Conclusion and Recommendation 68
5.1. Conclusion 68
5.2. Recommendation 69
References 70
Appendixes 77

List of Table

Table 1:FAO,1985 land suitability classification 19

Table 2: Data type used in conducting the study 29

Table 3: Land use land cover category description 31

Table 4: Error matrix table.. 32

Table 5: Rating factors for livestock production 43

Table 6: Pair Wise Comparison Matrix for cattle 50

Table 7: Criteria weight of Environmental factors calculated by AHP weight derivation method 50

Table 8: Pairwise comparison matrix 51

Table 9: Criteria weight of Rangeland suitability analysis factors calculated by AHP weight derivation method 51

Table 10: Environmental suitability class area for cattle, goat and camel.......................... 56

Table 11: Infrastructural suitability class area for cattle, goat, and camel 58

Table 12: Final suitability area for cattle, goat and camel 62

Table 13: Livestock distribution and density of cattle, goat and camel.............................. 64

List of Figure

Figure 1: Conceptual Framework of the study area 23
Figure 2: Location map of the study area 24
Figure 3: Elevation map of Delo Mena woreda 25
Figure 5: Soil type map of the study area 36
Figure 6: Land use land cover Map of the study area 37
Figure 7: Rainfall Map of the study area 38
Figure 8: Temperature map of the study area 39
Figure 9: Slope map of the study area 40
Figure 10: Market accessibility map 41
Figure 11: Animal health service proximity map 42
Figure 12: Reclassified LULC map for A= Cattle B=Goat and C=Camel 44
Figure 13: Reclassified Slope Map for A=Camel, B=Goat, and C=Cattle 45
Figure 14: Reclassified rainfall map for A=Cattle, B= Goat and C=Camel 46
Figure 15: Reclassified Temperature Map For A=Goat, B=Cattle and C=Camel 47
Figure 16: Reclassified Soil Map of Cattle, Goat and Camel 48
Figure 17:Reclassified Market map for A=Camel, B=Cattle and Goat 48
Figure 18: Reclassified Health service Map for A=Cattle and Goat and B= Camel 49
Figure 19: Methodological flow chart 53
Figure 20: Methodological flow chart of the study area 53
Figure 21: Environmental suitability map for A= cattle, B= goat, C= Camel 54
Figure 22: Environmental suitability scheme to determine rangeland suitability for cattle, Goat and Camel using ArcGIS 10.3.1 model builder. 57
Figure 23: Access to market suitability map for A= camel, B = Goat and cattle 59
Figure 24: Access to veterinary services suitability map A= Cattle and Goat, B= Camel 59
Figure 25: Final suitability map of study area A= Cattle, B= Goat, C= Camel 60
Figure 26: Final suitability scheme used to determine rangeland suitability for cattle, Goat and Camel using ArcGIS 10.3.1 model builder. 63
Figure 27: livestock distribution dot map of the study area 65

ACRONYMS/ABBREVIATION

AHP	Analytical Hierarchy Process
CSA	Central Statistical Agency
DEM	Digital Elevation Model
ESAP	Ethiopia Society Animal Production
FAO	Food and Agricultural Organization
GDP	Growth Domestic Product
GIS	Geographical Information system
GPS	Global Positioning System
IGAD	Intergovernmental Authority for Development
ILRI	International Livestock Research Institute
LU/LC	Land Use Land Cover
Masl	Mean Above Sea level
MCDA	Multi-Criteria Decision Analysis
MCDM	Multi-Criteria Decision Making
MCE	Multi-Criteria Evaluation
MOA	Ministry of Agriculture
MOFED	Ministry of Finance and Economic Development
NMA	National Meteorological Agency
PA	Peasant Association
PCDP	Pastoral Community Development project
PFM	Participatory Rangeland management
PRM	Participatory Rangeland management
RS	Remote Sensing
SRTM	Shuttle Radar Topography Mission
USGS	United State Geological Survey

CHAPTER ONE

1. Introduction

1.1. Background of the study

Rangelands refer to natural ecosystems predominantly occupied by a diversity of vegetation involving grasses, forbs, shrubs, and grass alike plants; and are primarily suited for grazing (Bolo et al., 2019). It is the vast land-use system on the Earth surface, predominating semi-arid tropical areas of the world, in some of these systems, people hinge entirely on livestock for their livelihoods (V.Sejian et al., 2012). Moreover, in Africa, it constitutes 65% which is a major source of feed for all ruminant animals (Mowlid et al.,2018).

Livestock production on rangelands can be a significant contribution to the overall gross domestic product (GDP in developing countries (Angerer, 2012). Livestock production contributes approximately one-third of the value-added of agricultural processes in developing countries (GSARS, 2018). This proportion is expected to increase in the future due to population growth, urbanization, and increases in per-capita income and likely to become an increasingly significant sector of agricultural production over the next few decades, with consumers in developing countries increasingly demanding livestock products (GSARS, 2018; Thornton, 2010).

Livestock has an enormous contribution to the Ethiopian economy and it's a means for providing food, input for crop production, soil fertility management, the raw material for industry, cash income, saving, fuel, social functions and employment (ASL2050, 2018). Therefore, livestock can serve as a vehicle for improving food security, better livelihood and sustainable land management and contribute significantly to agricultural and rural development (Fikadu, 2011; Leta & Mesele, 2014)

Albeit difference among data sources, in Ethiopia, the livestock sector provides 15 - 17% of the total gross domestic product and 30-45% of the agricultural GDP and, also supports about 60 - 70% of the livelihoods of the population in the country (Bekele, 2018; GebreMariam et al., 2013). Livestock production is traditional and one of the most important sources of livelihood of farmers in Ethiopia. And also, play an important role in the household economies of both highland and lowland populations (Asfaw et al., 2017; Dessalegn, 2009).

In Ethiopia, the rangelands are located around the periphery of the country, almost surrounding the central highland mass (ESAP, 2015). Where livestock production remains principal in the economic activity (Belete & Aynalem, 2017; Gebremeskel et al., 2019). The pastoral and agro-pastoral areas of Ethiopia cover between 60 to 65% or around 78 million hectares of the country's surface area (Awgachew et al., 2015; Geta, 2015). Low, variable rainfall means that rangelands, including extensive drylands, is predominant. Pastoralism tracks and utilizes the resulting inconsistent distribution of water and other rangeland resources, so rangeland is the most suitable land-use system for the majority of these areas (Awgachew et al., 2015).

According to Kedu (2019) out of the total area of Bale zone, more than half of the total area included under lowland from which 39.1% of the area falls under rangeland. These areas are characterized by arid and semi-arid environments, diversified vegetation types, livestock and wild animal species as well as untapped mineral, where Sedentary livelihood and mobile livestock production systems are practiced (Belete & Aynalem, 2017). Delo Mena woreda, where livestock rearing is practiced on communal rangeland and it is number is increasing from time to time across all livestock types despite increased pressure on grazing land and conversion of many lands to farming agriculture (Chibssa &Fiona, 2017).

The dependence of the pastoral and agro-pastoral systems on overgrazed natural resource base types them most vulnerable to climate change (FAO, 2019). Because of global climate change and intensive human activities, desertification/land degradation has become the most serious problem in modern society, particularly in the ecologically sensitive arid and semiarid areas. Thus, rangeland resources in Ethiopia face both area decrease and degradation in terms of productivity, these rigorous changes can be observed among seasons within a year and among years and decades (Geta, 2015).

In the past centuries, pastoralists were well adapted and resilient enough to cope with drought events followed by floods. Today, socio-economic and ecological aspects of the pastoral and agro-pastoral production systems are under threat and losing resilience due to rapid population growth annually more than three percent, migration, environmental degradation, land reallocation, the disintegration of rangelands, declining spatial mobility for herds and growing competition in the use of scarce pasture and water resources. Access to land and water rights is not adequately regulated, thus conflicts arise between different competing users especially amongst cross-border communities (IGAD, 2013).

The land comprises the physical environment including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use. It includes the results of past and present human activity (FAO, 1976). So, Land needs careful and appropriate use that is vital to achieve optimum productivity and to ensure environmental sustainability for future generations (Girma and Kenate, 2017).

Providing a suitable management plan for rangelands requires identification of its constraints and potential for various types of exploitation. Therefore, the selection of appropriate land areas is the most important criterion for sustainable livestock production which meets biophysical, environmental and socio-economic constraints. Hence, it is of paramount importance to identify suitable land for livestock production, which enhances the resilience of the environment(Terfa & Suryabhagavan, 2015). So, this study has analyzed rangeland suitability for livestock production using GIS and MCE, in Delo Mena Woreda Bale zone where livestock production means of livelihood was encountering problems due to shortage of land for grazing. It also enables decision-makers and livestock managers to ensure sustainable rangeland management and livestock development.

1.2. Statement of the Problem

Substantial increases in the world's population over the past 50 years have led to extensive overuse of natural resources, with consequent and serious environmental impacts (UN DESA, 2015). One principal concern is the growing and extensive abuse of rangelands in many arid and semi-arid regions of the world, even though rangelands are parts of the world where domestic animals and wildlife graze on native vegetation (Squires, 2010).

In Ethiopia, about 60-70% of the population's livelihoods depend on livestock in one way or another, which are dependent on the success of the livestock sector and in the environmental systems that support livestock production (Belete & Aynalem, 2017). But this environmental system was degrading owing to both natural and man-made factors (Kedu, 2019). Moreover, competing for land-use practices, changing demographics and dynamics in the country and the region as a whole are exacerbating factors. Available evidence indicates that pastoral destitution in Ethiopia is principally driven by feed and water scarcity because the natural resource base in the rangelands is shrinking fast (FAO, 2018).

The rangelands capacity as a source of feed for livestock and the support of sustainable livelihoods for herders has been reduced due to the combination of various factors, including degradation due to overgrazing and expansion of cultivation(Al-bukhari et al., 2018). Inappropriate land-uses lead to inefficient exploitation and destruction of the land resource, leading to poverty and other social problems (Bizuwerk et al.,2005; Terfa & Suryabhagavan, 2015).

Due to its potentially rapid degradation rates and extremely slow regeneration processes land is considered as a limited non-renewable natural resource(FAO, 2007). Where land is degraded, the overall potential to perform its functions is reduced. Therefore, prevention, insurance, and sustainable land management should be at the core of any land use planning. To support body processes and to promote production, animals must receive regular supplies of nutrients. These are broadly defined as protein-energy, minerals, vitamins, and water. Even though under extensive systems of animal husbandry, the animal may not be able to obtain an adequate diet throughout the year, because of the seasonal variation in the quantity or composition of the herbage (FAO, 2007).

As the primary source of cattle feed, rangelands play a vitally important role in sustaining the livelihoods of pastoralists and ensuring long-term food security. But in many rangeland ecosystems in the Ethiopian lowlands, deforestation, rising demand for water resources, overstocking of livestock, uncontrolled grazing and crop agriculture have reduced the availability of dry season grazing and water for livestock and human consumption (Farm Africa, 2017). These factors minimize the current livestock productivity of the country despite a large number of herd available in the country. According to Chibssa &Flintan (2017), the conversion of grazing lands and forest land to cultivation is a common practice and a great threat to livestock production and natural resources in Delo Mena woreda while the number of stocks where increasing in the woreda. Therefore, the proper use of the land for specific purposes could alleviate the existing problem. To get the optimal benefit out of the land, proper utilization of its resources is inevitable, thus considering various factors to analyze land suitability for livestock production is essential.

Locating suitable areas for livestock production using spatial models of Geographic Information systems (GIS) would be indispensable input to improve livestock productivity (Abebe, 2006; Dessalegn, 2009). Few researcher (Abebe, (2006), Dessalegn, (2009), Fikadu, (2011)) were conducted a study on rangeland suitability analysis using GIS and remote sensing applying multi-criteria evaluation method. However, most of the study have considered only environmental factors but socio-economic (infrastructural) factors indicator such market center, animal health service, etc. are determining factors for livestock production so, considering these factors were important in rangeland suitability analysis. In addition to this, the targeted area lacks information on the capability and classification of rangeland suitability for livestock production which led to unwise use and degradation of land resources in the area. Hence, increasing pressure on the highland forest as herder migrate to this area during the dry season. Thus, to identify the alternative solution for the concerned body regarding the problem this study was to analyze the suitability of rangeland for livestock in Delo Mena Woreda using GIS-based Multi-criteria evaluation considering both bio-physical (Environmental) and socio-economic (infrastructure) parameters important to locate the suitable areas for livestock production as area need spatial information on rangeland suitability evaluation for livestock production.

1.3. Objectives of the study

1.3.1. General objectives

The general objective of this study was to analyze rangeland suitability for livestock production using GIS in Delo Mena Woreda, Bale zone Ethiopia.

1.3.2. Specific objective

Specifically, this study aims

1. To evaluate land suitability for cattle, goat and camel.
2. To assess factors of land suitability for cattle, goat and camel.
3. To produce land suitability map for cattle, goat and camel.
4. To map the density of livestock of the study area using a dot map.

1.4. Research question

1. How much area is suitable or not suitable for Cattle, Goat and camel?
2. What are the determining factors of rangeland suitability for cattle, goat, and camel?
3. How can I produce a suitability map for cattle, goat and camel?
4. What is the spatial distribution of the selected livestock in the study area?

1.5. Significance of the study

Analyzing land suitability for specific kinds of use has paramount importance for land use planning, management, and sustainable land development. Thus, analyzing rangeland suitability for livestock is important to ensure the sustainability of rangeland development and the productivity of livestock. Therefore, evaluating land suitability for livestock production in the study area is very important for selecting optimum land use types that will bring sustainable livestock production. Moreover, it allows in identifying the main limiting factors for livestock production and enables stakeholders such as herders/farmers, land-use planners, pastoral development and livestock administration office to develop rangeland and livestock production management, to be able to overcome such constraints and to increase productivity. Although very little study was conducted in the targeted areas on land suitability analysis, this study could be used as a benchmark for further studies, particularly for the study area.

1.6. Scope of the study

Geographically the study was delimited to Delo Mena Woreda, Bale Zone, Oromia Regional National State. These studies mainly focus on rangeland suitability analysis for livestock production using GIS and multi-criteria evaluation in the Woreda. The study has used different methods and techniques such as GIS and RS techniques, multi-criteria evaluation, field observation and secondary data for detailed analysis of land suitability for livestock production. Temporarily, this study has been focused on Landsat 8 OLI image of 2020 with the duration of study time will be until December 2020.

1.7. Limitation of the study

The problem the study faced during the study was a lack of quality data like up-to-date average temperature data and soil data. The study also lacks some factors such as biomass (feed availability), distance to water, road accessibility and chemical properties of soil due to difficulty to access this data due to limited resources and time.

1.8. Organization of the study

This study has five chapters; the first chapter provides the background of the study, limitation of study, objectives, significance and scope of the study while chapter two provides an overview of related literature on rangeland suitability, Application of GIS and Multi-criteria evaluation. Chapter three deals with the method and material used in a study, description of the study area and method of data analysis. Chapter four presents the results of the study on rangeland suitability for cattle, goat and camel production inform of map output and table and discussion. While chapter fives provide a conclusion and recommendation of the study.

CHAPTER TWO

2. Review of Related Literature

2.1. Concept and definition of Rangeland

According to Fajji (2015) Rangeland: is any large area of land that is inhabited by native herbaceous or shrubby vegetation, where domestic or wild herbivores used to graze, rangelands vegetation include tall grass, prairies, steppes or short grass, desert shrub lands, shrub woodlands, savannahs, and tundra. Although ESAP (2015) defined rangeland as primarily arid and semi-arid lands where agriculture is not economically feasible. The term rangelands are much broader than grasslands and include grasslands, desert shrub lands, savanna woodlands and open grassland in forests. Rangelands are the principal source of forage for livestock, and they also provide habitat for a great variety of native plants and animals indigenous to the place. According to FOA (1992), rangeland suitability is defined as the land capability for rangeland exploitation concerning sustainable land use. Livestock" refers to "all animals, kept or reared by the agricultural holdings mainly for agricultural purposes. This includes cattle, buffaloes, horses and other equine animals, camels, sheep, goats and pigs, as well as poultry, bees, silkworms (FAO, 1983).

2.2. Rangeland Development and Livestock Production in Ethiopia

2.2.1. Rangeland Development in Ethiopia

Rangeland includes a large number of economically important species and ecotypes and sustains millions of people, and its resources (grasslands, shrub lands, savannas) also support approximately fifty per cent of the world's livestock and provide forage for both domestic and wildlife populations. Rangelands of Ethiopia consist of mainly native pastures (grass, forbs and woody plant species); they are main feed sources of grazers and browsers covering about 62% of the total land area of the country, and most of them are found at an altitude below 1500m and generally classified as arid and semi-arid (Geta, 2015; Mengistu, et al .2018). Moreover, Cattle, Camel and Goat are prominent domestic animals in this area.

Rangeland development work in Ethiopia started in the early sixties. A pilot project/ pilot rangeland development project (PRDP) in southern Ethiopia (Yabello), which started in 1965, was the antecedent for the rangeland development work in the country. Until this time there was no significant development project in rangeland (ESAP, 2015), the objective of this project is alleviating pressure on wet season grazing and to raise the efficiency of rangeland through pond construction and controlled grazing. But attracting settlement around new water points results in overgrazing and the project has a gap on local support and rangeland condition and trend studies.

Precedent result of this project encouraged MoA to formulate a more comprehensive strategy on pastoral development, which is the Third livestock development project (TLDP). The TLDP, a more comprehensive pastoral development project, was approved in 1975. The project objective was to rehabilitate and develop three major pastoral areas, the Southern Rangeland Development Unit (SORDU), Jijiga Rangeland Development Unit (JIRDU), and Northeast Rangeland Development Unit (NERDU) rangelands of Ethiopia. These projects were intended to develop infrastructures, (road, water, and veterinary service) and natural resource to support livestock production and marketing (Gebremeskel et al., 2019).

Past rangeland development activities were not participatory, top-down, lacked monitoring and evaluation components and had little regard for the cultural and economic differences between the regions and no attempt was made to deal with community problems using a holistic approach. Besides, problems such as frequent conflicts forced sedentary and the huge costs have prevented rangeland development efforts (ESAP, 2015; Gebremeskel et al., 2019). Thus, these development activities failed to improve rangeland and living conditions of pastoral communities.

More recent development initiatives have included the Pilot Project at SORDU in conjunction with the Fourth Livestock Development Project (FLDP) which was initiated in 1988 and the Southeast Rangelands Project (SERP) in the Ogaden, initiated in 1990. These projects were designed to incorporate participatory approaches to pastoral development in addition to providing infrastructure and support services (Fikadu, 2011). Currently, government and non-government organizations are undertaking a development project to improve pastoral society's livelihood. Thus, Development project like Pastoral Community Development Project (PCDP) is a federal government-initiated project being implemented in pastoral areas, having a mission to improve the livelihoods and reduce the vulnerability of the pastoral and agro-pastoral communities in PCDP Woreda through sustainable Community Driven Development interventions (PCDP, 2016).

A non-government organization like FARM Africa and SOS Sahel is currently working in bale eco-region to relieve pressure from bale mountain national park from adjacent pastoral and agro-pastoral Woreda like Delo Mena has developed short and long term project such as participatory rangeland management intending to improve rangeland quality for livestock production through establishing rangeland management co-operatives, introducing rotational grazing, constructing pond to increase water availability for community and their livestock and clear thorny weeds to regenerate grass in rangeland this led to minimizing livestock encroaching endangered forest as herd remain in lowland (FarmAfrica. , 2017).

2.2.2. Livestock production in Ethiopia

In Ethiopia, agricultural development is considered a priority by the government for stimulating overall economic growth, reducing poverty and achieving food security. The agricultural sector of Ethiopia accounts for about 42% of GDP and between 80–85% of employment (MoFED, 2012). Within agriculture, the livestock subsector provides an opportunity for further development. A large number of the national livestock herd, one of the largest in Africa, makes it a resource with the potential to contribute significantly to national development, including poverty reduction (Asfaw, et al.,2017).

In addition to the contribution to national gross domestic product and the agricultural gross domestic product, the livestock sub-sector contributes fifteen per cent of export earnings and thirty percent of agricultural employment, contributing a lot to national economy and livelihoods of many Ethiopia's and still promising to rally round the economic development of the country. Livestock plays vital roles in generating income to farmers, creating job opportunities, ensuring food security, providing services, contributing to an asset, social, cultural and environmental values, and sustain livelihoods (Addis & Dida, 2015; CSA, 2018; Leta & Mesele, 2014).

Approximately 85% of Ethiopia's populations were living in rural areas and livestock supports the livelihoods of about 80% of rural people, the livestock sector a major contributor in poverty reduction by improving the livelihoods of rural people. However, the income of thirty per cent of the rural population is below the poverty line (MoFED 2013). The livestock population in Ethiopia has grown significantly over the last decade since experiencing a major decrease in numbers in the early 1990s. However, in terms of productivity per animal; there has only been a small improvement in dairy cattle and chicken meat. Nevertheless, since 2000, the consumption of both livestock products has started to increase (Asfaw, et al., 2017).

On the whole, the livestock sector has vast potential in terms of food security, accelerating the agro-processing industry and raising export earning is not yet well exploited and the sector's contribution to the previously mentioned areas is not significant and as expected (Leta & Mesele, 2014). This is associated with several complex and inter-related factors such as inadequate feed and nutrition, widespread diseases, the poor genetic potential of local breeds, market problem, and inefficiency of livestock development services concerning credit, extension, marketing, and infrastructure and poor animal productivity that hinders sustainable development of the livestock sector in Ethiopia (FAO, 2018; Leta & Mesele, 2014). To reap the potential of this sub-sector, it needs firm and meaningful intervention that can bring a fundamental change so that the contribution of this sector will continue to be significant at the national level (MOFED, 2013).

2.2.3. Spatial distribution of livestock

Ethiopia is endowed naturally with different agro-ecological zones and a suitable environmental condition makes it a home of many livestock species and suitable for livestock production (Leta & Mesele, 2014). An estimate indicates that the country is a home for about 60.39 million cattle, 30.30 million sheep, 32.72 million goats, and 1.42 million camels. From the total cattle population, 98.24% are local breeds and the remaining are hybrid and exotic breeds. 99.81% of the sheep and 99.97 goat population of the country are local breeds but these livestock population estimates exclude three zones of Afar & six zones of Somali region (CSA, 2018).

In Ethiopia, livestock production and markets vary substantially across space due to different reasons including topographical variations, market access, feed and water availability, and population characteristics and also varies between lowland and highland due to reoccurrence of drought in lowland areas (Leta & Mesele, 2014). According to Helina and Emily (2012) combination of livestock species owned by smallholders varies spatially given the availability of feed, human population density, and intended function of livestock species. This spatial variation in livestock population, coupled with other factors such as population density, grazing land availability, and access to markets has implications in grazing land management and livestock markets. Therefore, understanding spatial variations within the livestock population are crucial to devising a feasible, more geographically targeted livestock policy (Robinson et al., 2014).

2.2.4. Importance of rangeland for livestock production

Rangeland encompassing much of the area where pastoral livestock production is the major land use, of the earth's land area supporting 78% of the global grazing area (Mussa, et al, 2016). Moreover, livestock provides food and income to the majority of the 1.2 billion people living on less than one USA dollar per day and livestock demand is rising to unprecedented levels (FAO, 2008). In addition to supporting livelihoods, rangelands in developing countries provide multiple goods and services of great economic, social, cultural and biological values locally, nationally and globally (Mussa et al., 2016)

In Ethiopia, rangelands were also important for livestock and wildlife production. For instance, the rangelands support 73 % of goats, 25% of sheep, 20-27% of cattle and 100% camel populations (ESAP, 2015). Rangeland ecosystems are ecologically and economically important for livestock production, erosion control, carbon storage, source of medicines, tourism, recreation, source of high-quality water, clean air, wildlife habitat and biodiversity conservation (Farazmand et al.,2019; Gemedo, 2006). The natural resources in the rangelands provide multiple uses that include food, feed, firewood, charcoal, timber for construction, traditional medicine, shade, spices, gums, resins, dyes, etc. (ESAP, 2015).

2.2.5. Current condition of Range Land Resources in Ethiopia

Rangeland resources in Ethiopia are in danger of becoming seriously degrading owing to natural and human-induced factors (Geta, 2015; Kedu, 2019). The rangelands are presently being extensively deteriorated both in quantity and quality. In arid and semi-arid rangelands, heavy grazing pressure and Topographic factors such as elevation can influence forage production and shift composition (Gemedo, 2006), soil erosion and rangeland degradation furthermore increase bush density. Thus rangeland productivity endangers need to be protected for pastoralists to ensure the viability and growth of the pastoral production system as a whole (Geta, 2015).

Several factors affect the success of pastoralists and agro-pastoralist in their attempts to grow their livestock production systems, the most important of these is access to good rangeland as well as mobility, access to markets, access to services (such as animal health care), and severity of climatic shocks (PCDP, 2016).

Nowadays, the Bale lowland ecoregion is seriously challenged by low livestock productivity which results in declining the number of livestock holding per household, severe livestock death during dry periods, increase of cultivated land, and increase of the number of people vulnerable to food insecurity as well as a considerably higher reliance on food aid (Kedu, 2019). The trend analysis suggests that the quantity of grazing land of Delo Mena one of bale zone Woreda has reduced by half, and the quantity of cropland increased although browse availability has also decreased. This is due to the conversion of grassland land to agriculture, population growth, shortage of rainfall and invasion of a thorny bush (Chibssa and flintan, 2017).

2.2.5.1. Bush encroachment

In the process of bush encroached, land vegetation was shifting from herbage to bush, the coverage of herbage decreased and the area of bare land increased with spatial-temporal variability of soil water and nutrients were increased and the process also affects the structure and function of the community ecosystem, which reduced herbage production, declined carrying capacity of indigenous pasture, threaten sustainable progress of livestock production (Fenetahun et al., 2018).

Encroachment of bushy and woody species into rangelands has been linked to increased soil compaction that hinders the proper establishment of herbaceous forage, compromised water infiltration, the reduced build-up of soil organic carbon and reductions in pasture productivity (Bolo et al., 2019).

During the last five decades, rangelands in most pastoral areas of Ethiopia have undergone unheard of changes that manifested in terms of a marked deterioration of conditions. Across all the pastoral areas, an appreciable proportion of the once healthy and productive rangelands have either been reduced to bare ground or completely taken over by invasive plant species of low or none feeding value causing a problem to pastoralists depending on livestock production (ESAP, 2015). In Delo Mena Woreda the health of wet season grazing areas was deteriorating, in particular, the large areas of previously quality grasslands due to the invasion of a thorny bush which has taken over. Previously the community used to destroy it by burning the grasslands three times a year. However, the government has banned the use of fire in this way. Now the bush is taking over, is unpalatable, prevents movement and also harbours wild animals. Thus destroying the grass (Chibssa and Finltan,2017).

2.2.6. Land tenure system

Tenure security in the rangelands, including in Ethiopia, is weak. Due to land use and access in this area is communal and involves various characteristics, the right to tenure, access, and use are not easy to delimit and protect: available policy and legislation fail to sufficiently address these issues. Land use planning is top to down without knowledge, input, and support of rangeland communities (Awgichew et al., 2016).

Key factors in the increased vulnerability of communities living in rangelands are their lack of security of tenure and lack of control over land-use changes that are taking place. To offer a model for better securing of rights to resources, Save the Children USA developed participatory rangeland management (PRM) approach drawing from and building on the well-accepted participatory forest management (PFM) approach now being mainstreamed throughout the country (Flintan, 2014).

2.3. Criteria of rangeland suitability for livestock production

Land suitability analysis is governed by several factors ranging from bio-physical factors to socio-economic factors (FAO, 2007a). The assessment of these parameters provides information about the limitations of the land for agricultural development. Different kinds of land use may have different requirements. The concept of land suitability is meaningful only in terms of specific kinds of land use, each with their requirements, thus Animals have specific environmental (bio-physical) requirements under which they grow and reproduce successfully. These specific biophysical conditions are referred to as optimal environmental conditions (Fikadu, 2011). It is assumed that these optimal conditions have no adverse effect on the growth and production of animals.

Biophysical factors of selected livestock (cattle, goat and camel) refer to the need for favourable climatic, soil, topography, and LU/LC. climatic attributes are including temperature and rainfall whereas topography includes a slope, despite these infrastructures factors that tend to affect livestock productivity and production is access to market and veterinary services etc. But the influence of the above factors may vary from place to place depending on management, development and agroecology of the given area.

2.3.1. Slope

The slope has a great effect on livestock distribution (Melvin et al.,2007). Livestock varies considerably in their willingness to use steep terrain. Large, heavy animals such as mature cattle or camels have difficulty in traversing steep, rocky slopes. Therefore, cattle and camel prefer to use slopes of less than 10% (Melvin et al., 2007). Because of their small size, greater agility, and sure-footedness, goats use these areas more readily. Many rugged ranges can be better used by wild animals than by livestock. Goats can graze or browse on steep slopes unsuitable for cattle and other large animals (Fikadu, 2011). Furthermore, livestock grazing on a high slope not only decreases its performance of grazing but also increases the risk of erosion and flooding this, in turn, causes soil and vegetation degradation.

3.2.2 Soil

All forage plants used as a source of livestock feed are rooted in the soil and it is from the soil that the plants draw the water essential for their growth. Furthermore, the soils are very important to different animal species as a source of natural mineral and sleeping ground in rangelands. It is also one of the most important parameters used by the pastoral community to evaluate the suitability of the rangelands for different livestock as a source of feed, sleeping ground, ease of trekking and livestock disease prevalence (Fikadu, 2011).

2.3.3. Land use /land cover

Land cover is the observed bio-physical cover on the earth surface where as land use being arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO 2007). Vegetation that is tapped by livestock and wildlife is the most important resource in rangeland development. Ranging from major morphological land to individual plant species, the genetic potential of plants to support livestock under extensive grazing is easily noticeable (Fikadu, 2011). Thus, animals have higher preferences for certain vegetation types/cover than for others, causing different vegetation types within a pasture to receive different degrees of use. Assuming that other factors affecting distribution, such as water and terrain, are the same livestock will prefer the vegetation type best meeting their nutritional needs. Open grasslands are preferred by cattle over heavily forested areas. Goats are found in all types of environments, from arid to humid zones. They do well in the drier tropics, where their ability to withstand dehydration and their browsing habit enable them to survive where cattle cannot tolerate (Fikadu, 2011).

2.3.4. Temperature

The overriding environmental factor affecting the physiological functions of domestic animals is the temperature (FAO, 1983). Temperature causes stress to animals in hot, warm and very cool climates. Heat to the body comes mainly from outside and from the metabolism within the body metabolic heat. It costs energy to get rid of excess heat and to maintain body temperature. When body temperature is high, appetite is lost, resulting in a negative energy balance and sometimes heart collapse (Fikadu, 2011). Thus in many parts of tropics and subtropics, its impact is high even for a small increase in average temperature (Thornton, 2010).

2.3.5. Rainfall

Rainfall is important to the agronomist and stockman, as it controls the plant growing seasons and affects the availability of drinking water. More importantly, water availability for feed growth is one of the single most important factors that determine suitability for livestock production. In other words, in areas of sufficient rainfall feed source for livestock availability will increase (Dessalegn, 2009). Thus, the decrease in rainfall not only affects feed availability but of a decrease in the availability of drinking water for livestock. Which makes it difficult for livestock production in rangeland.

2.3.6. Market access

Market centers and their associated infrastructures are important factors that have to be considered in the move to increase the supply of livestock for both domestic and export markets. Due to the wider geographical location of pastoralists, some important sources of livestock are very far from market centers. Pastoralists from the border areas need to travel for a week or more to reach these market areas. This poor access to market influences the marketing behaviour of pastoralists/agro-pastoralist as they keep livestock unsold thus affecting livestock production. To attract such resources to the central markets, there is a need to thoroughly assess these remote areas and open up primary markets with at least dry weather roads connecting them to secondary markets (Addis & Dida, 2015).

2.3.7. Veterinary service access

Diseases and parasites are among the most severe factors that impact livestock production and productivity thus accessibility of veterinary service is essential because its place where livestock takes vaccination and sick animals are treated. There are two major reasons why, despite the high productivity and availability of improved breeds, adoption rates are low due to the lack of distance of veterinary services and increasing problems with feeds and grazing. Summary statistics from the available CSA reports suggest that a small portion of Ethiopian cattle and goats were vaccinated during 2005–09. According to the same reports, fewer than half of sick cattle were even treated by a certified veterinarian (Asfaw et al., 2015)

2.4. Land suitability analysis

Land suitability analysis is the evaluation and grouping of specific areas of land in terms of their suitability or capability for a defined use and used to measure the degree land practicality for current and potential land use based on natural and socio-economic characteristics (FAO,1976). Locating suitable areas for livestock production using spatial models of the GIS would be vital to improving livestock productivity (Terfa & Suryabhagavan, 2015).

Combining land and land use in a land assessment procedure defines land suitability, which is the fitness of a land unit for a land-use type assessed by comparing land use requirements of each land utilization type with the land (FAO, 1976; 2007). Land suitability analysis is an important tool in making locational and sitting decisions in planning studies. Generally defined, land-use suitability analysis aims at categorizing the most appropriate spatial pattern of future land use according to specified requirements, preferences, and analysts of specific activities (Amiri, 2012).

The land is an indispensable resource for the most essential human activities: it provides the basis for agriculture and forest production, water catchment, recreation, and settlement. The range of uses that can be made of land is limited by environmental factors including climate, topography and soil characteristics, and is determined to a large extent by demographic, socio-economic, cultural and political factors such as population density, land tenure, markets, institutions, and agricultural policies (FAO, 2011).

GIS has ascertained to be the best to integrate the different land characteristics that differ spatially and to identify the best suitable land use. To exploit the land resources sustainably, a land-use plan that incorporates the different land characteristics has paramount importance. Furthermore, the surface and overlay analysis capabilities in GIS can successfully facilitate in holding a vast amount of spatial information (Malczewski, 2006).

2.4.1. Land suitability classification

Land suitability classifications were the process of evaluation and combination of specific types of land in terms of their absolute or relative suitability for a specified kind of use. Different kinds of land use may have different requirements. The concept of land suitability is meaningful only in terms of specific kinds of land use, each with their requirements, for example for temperature regime, soil moisture or rooting depth (FAO, 2007).

The common way of determination of land quality from land characteristics is mainly by assessing and grouping the land types in orders and classes according to their natural ability. The order of suitability ranges from suitable (S), that characterizes a land were sustainable use and will give good benefits; to not suitable (N) which indicates land qualities do not allow the considered type of use or are not enough for sustainable outcomes (FAO, 2007).

According to FAO (1985), Land suitability classification is developed by considering different factors of land characteristics. Based on the suitability of each land use, a weight value ranging from 5 (unsuitable) to 1 (most suitable) is given. The weighted value of each factor is reclassified for each land use. Each parameter is given a value based on its suitability for each land-use type. The weighted value of each land characteristic factor is added and the average value of them is taken to determine the suitability of land for each land-use type. The average value of them is categorized into five suitable classes to get the final suitability for each land use.

Table 1:FAO,1985 land suitability classification

Order	Classes	Description
Suitable	S1 (highly suitable)	Land without Significant limitations. Includes the best 20-30% of suitable land as S1. This land is not perfect but that can be hoped for.
	S2(moderately suitable)	Land that is suitable but which has limitations that either reduce productivity or increase the inputs need to sustain productivity compared with those needed for S1 land.
	S3(marginally suitable)	Land with limitations so severe that benefits are reduced and/or the inputs needed to sustain production is increased so that this cost is only marginally justified.
Not Suitable	N1(currently not suitable)	Land with limitations to sustained use that cannot be overcome at a current acceptable cost.
	N2 (Permanently not suitable)	Land with limitations to sustained use that cannot be overcome.

2.5. Role of GIS and Remote Sensing in Rangeland Management

The powerful query, analysis and integration mechanism of GIS makes it an ideal scientific tool to analyze data for land-use planning (Malczewski, 2004). Management of natural resources based on their potentials and limitations is essential for the development of rangeland on a sustainable basis. Nowadays, GIS is a tool that can assist a community to plan and to support information management during the rangeland production process, while ensuring a balance between challenging resource values. It can upgrade the accessibility and flexibility of information and can enhance the linkages and understanding relationships between different types of information (Terfa & Suryabhagavan, 2015).

Sustainable natural resource management has become a fundamental objective in rangeland resource management; thus, the use of spatial information presents a better understanding of the status of natural resources and forms the foundation for the identification of appropriate strategies for sustainable rangeland management. So remotely sensed data play important role in providing update data regarding rangeland disturbances such as loss of palatable grasses, loss of topsoil, bush encroachment and invasion of alien plant species that can take place over a range of spatial scales, from plot level to landscape and regional level (Fajji, 2015).

Remote sensing and GIS are used progressively as tools to assist in rangeland resources inventory and assimilation of data and as an instrument for analysis, modeling and forecasting purposes to support decision making. This technology is a very powerful tool for monitoring natural resources. Many advanced remote sensing methods have been utilized worldwide for estimating biophysical parameters of rangeland vegetation such as pasture quantity, pasture growth rate and primary production among others (Fajji et al., 2018). Furthermore, range conditions can be relatively easily handled with low cost and effort from remotely sensed data.

2.6. Multi-Criteria evaluations

Multi-criteria evaluation is the process in which several criteria are evaluated to meet a specific objective. Taking several criteria into account in an evaluation can be achieved. A decision is a choice between alternatives such as alternatives, actions, and land allocations. The basis for a decision is known as a criterion. In a Multi-Criteria Evaluation, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective, MCE is a useful method in which to identify trade-offs in the decision-making process with the final aim of reaching compromise (Tewodros, 2010)

GIS-based multi-criteria decision evaluation process is practiced by defining goals, determining and standardizing criteria/factors, determining a weight for each factor, aggregating the criteria and validating (Kefelegn et al., 2019). Indeed, GIS is often accepted as a decision support system involving the integration of spatially referenced data in a problem-solving environment. On the other hand, MCDA provides a rich collection of methods and techniques for structuring decision problems, and designing, evaluating and prioritizing alternative decisions (Malczewski, 2006).

Analytical hierarchy process (AHP) technique is one of the most commonly used MCDM techniques in GIS-based suitability procedures (Din &yunusova,2016) because of its appropriateness for making decisions based on multiple factors ranked according to experts' preferences (Kahsay et al., 2018).

GIS-based decision-support systems compromise a single decision-maker, or a group of decision-makers, in evaluating alternatives to enhance decisions and to attain specific objectives.

However, the decision-maker is used to determine the criteria, factors, and constraints that may reduce uncertainty in the decision rules, and finally, it makes the decisions. Therefore, decisions for resolving problems should be based on preliminary simulation on computer-based systems, thus necessitating the use of multi-criteria evaluation methods and GIS technology (Malczewski, 2004; Tewodros, 2010).

Livestock production suitability analysis involves the integration of information from various streams of science due to many criteria which determine land suitability analysis for livestock production. Thus, the rangeland suitability analysis for livestock production is a multiple criterion decision-making processes (Dessalegn, 2009)

2.7. GIS-Based Multi-Criteria Decision Analysis and Land Suitability Analysis

GIS is offering a convenient and powerful platform for performing suitability evaluation. Land suitability evaluation is inherently a multi-criteria problem. Spatial decision problems typically involve a large set of feasible alternatives and multiple, conflicting and disproportionate evaluation criteria. The alternatives are often evaluated by many individuals such as decision-makers, leaders, stakeholders, interest groups. The unique preferences of individuals concerning the importance of criteria among alternative evaluate, accordingly, many spatial decision problems give rise to the GIS-based multi-criteria decision analysis (Malczewski, 2006).

Since the early 1990s, the integration of GIS and multi-criteria decision analysis has gained a growing interest for researchers (Greene et al., 2011; Malczewski, 2006). Furthermore, the purpose of integrating the GIS-based land suitability analysis using the multi-criteria evaluation (AHP) approach is that it is the most suitable method for solving complex problems related to land-use planning and any other kind of development. It has also been recognized as an effective multi-criteria decision support system (Ahmed & Abd, 2011).

GIS is a computer-based system that offers a convenient and powerful platform for performing land suitability analysis and allocation. The integration of multi-criteria methods of suitability assessments and allocation methods into GIS systems improves the spatial capabilities of GIS and the analytical power as a formal decision-making tool (Nyeko, 2012).

In general, one of the most important uses of GIS is the land-use suitability mapping and analysis. As an environmental and resource planning and management point of view, the

Analytic Hierarchy Process is among the fastest-growing decision-analytic techniques (Jafari & Zaredar, 2010). Thus as GIS is capable of handling and combining different types of data both non-spatial and spatial as well as multi-temporal and multiscale in a time-efficient and cost-effective way, there has been a steady increase in interest for using GIS together with MCDA techniques (Myagmartseren et al., 2017).

2.8. Empirical Literature on Rangeland Suitability Analysis

According to FAO (1985), land suitability is primarily the potential biological productivity of land which can be determined by environmental components such as climate, local topography, soil type and existing vegetation. Thus, land suitability evaluation involves the identification of land use patterns, the economic and environmental feasibility of its use. Developments in GIS have led to significant improvements in its capability for decision-making processes in land allocation and environmental management. Land suitability analysis for livestock production provides a bit of information for livestock development and forthcoming planning. The development of GIS and RS, and MCE led the study to be conducted on land suitability analysis for livestock production in Ethiopia considering environmental and socio-economic factors, those researchers are (Abebe, (2006); Fikadu, (2011); Dessalegn, (2009); Berhanu & K.V. Suryabhagavan, (2015)).

Those studys have conducted a study on Borena rangeland to assess suitability using GIS-based MCDM considered various parameter that determines rangeland suitability for livestock production, Fikadu (2011) was outlined biophysical factors such as slope, climate (rainfall and temperature), land use land cover, soil (soil texture), altitude and biomass thus giving high scores for biomass/ feed availability, Dessalegn (2009) in his study considered only four biophysical factors soil, LU/LC, slope and rainfall giving high value for land use land cover next rainfall but Berhanu & K.V. Suryabhagavan (2015) added socio-economic data such, access to veterinary service, access to market and drinking water considering their proximity in addition to a biophysical parameter such as soil, LU/LC, slope and rainfall. And Abebe (2006) was considered only biophysical factors like soil, LU/LC, slope and rainfall giving high rank to land use land cover as the most determining factors among above-traced criteria. Most of them outlined land use and land cover as the major influencing factors for rangeland suitability for livestock production because it is a source of feed for grazers and browsers. From land-use land cover shrubs and grassland ranked as highly suitable for goat, camel and cattle respectively, on their study. Rainfall also important factors as it determines the availability of water and essential for the growth of vegetation in rangeland again slope which influences the distribution of livestock in rangeland but it based on size and weight of animals, accordingly slope less 10% is highly suitable for cattle and camel but for small ruminant, it goes above. According to FAO, (1983)''; the findings of one land evaluation cannot be applied globally, and often not even throughout a region or a country, because of large local variations in the land, management skills, standards of living, capital and labour availability, and demand for livestock products. The principles of evaluation remain the same wherever one is being conducted, but the relevant qualities of the land, and their critical values forming boundaries between classes of land suitability ratings, will vary between countries and regions''. Based on this premise rangeland suitability for livestock production in the targeted area is necessary as most of the study was confined to Borena zone rangeland.

Conceptual framework of rangeland suitability analysis for livestock production.

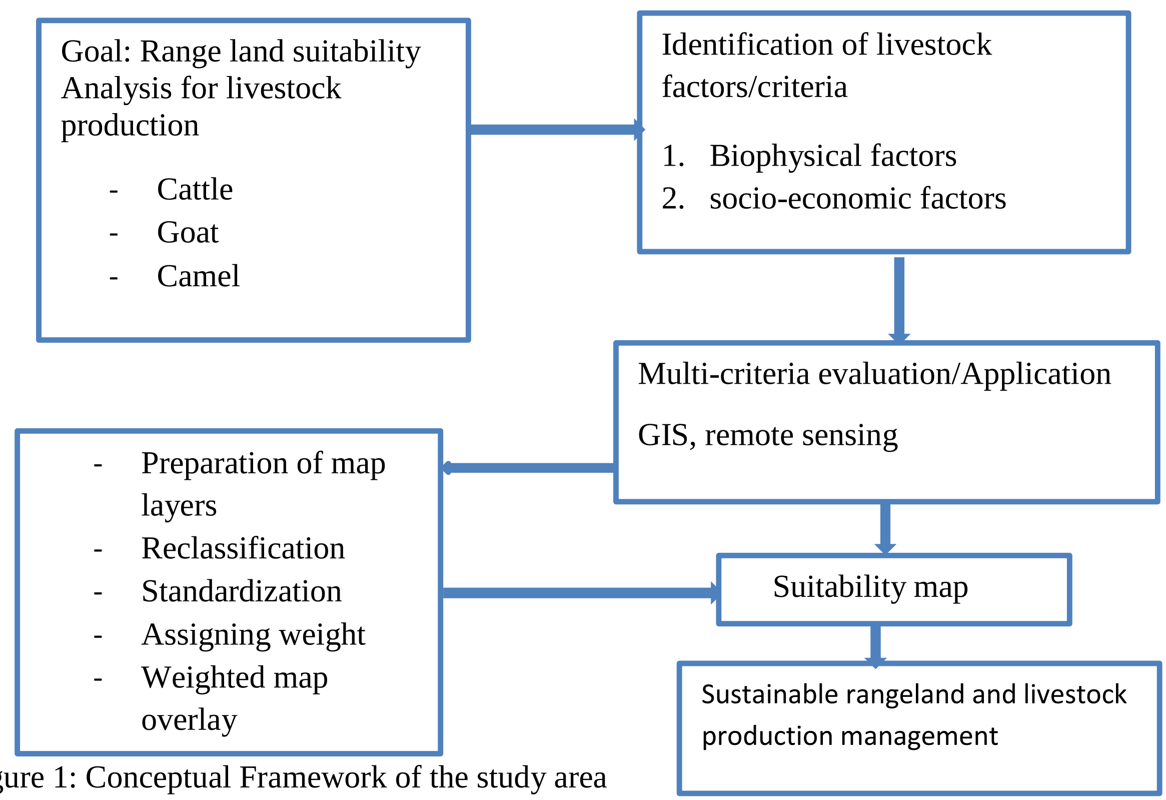

Figure 1: Conceptual Framework of the study area

Adopted from Kefelegn et al,.2019 with modification by a researcher

CHAPTER THREE

3. Methods and Materials

3.1. Description of the study area

3.1.1. Location

The study was conducted in Delo Mena woreda which is located in the Oromia National Regional State in the Bale Administrative Zone, the southeastern part of Ethiopia. The woreda covers an area of 4893.43sq/km. Geographically, it lies between 5˚91' to 6˚45'N latitude and 39˚87' to 40˚26'E longitude. The woreda is bordered in the South by Meda Welabu Woreda and East by Berbere Woreda, in the West by Harena Buluk Woreda, and in the North by Goba Woreda. It is located south of Robe town at the distance of 125 km or it is found at 555 km to the southeast of Addis Ababa, the capital city of Ethiopia (Ayele et al., 2019).

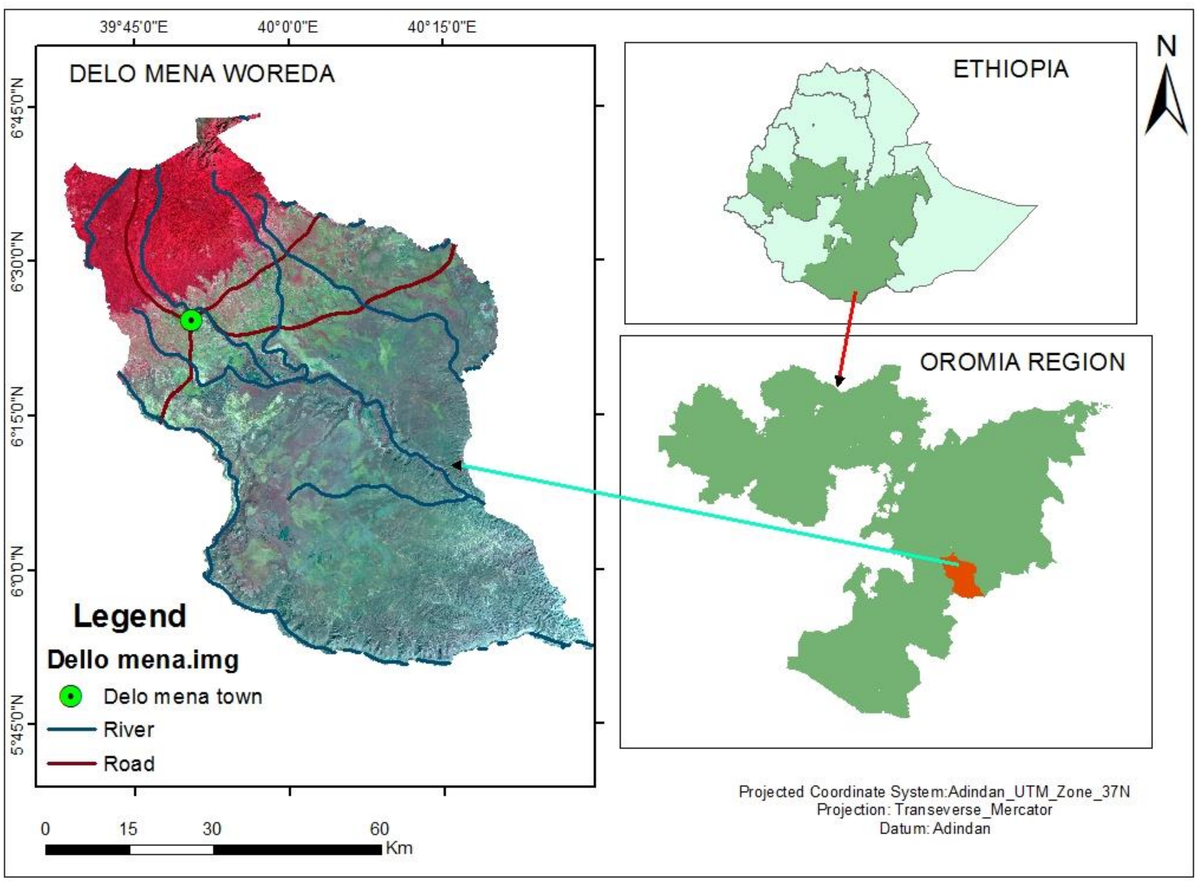

Figure 2: Location map of the study area

3.1.2. Topography

Topography shows the differences in altitude and surface structure of any part of the earth and also, it refers to various physical features or landforms which represent the external shape of a place. The slope represents the gradient of an area expressed either in percent or in degree. It is computed as the vertical increase is divided by the horizontal increase (Kefelegn et al. 2019). The altitude of the woreda ranges from 420 to 3718 meters above sea level and it increases from the south to north and from west to east and the major part of woreda where lowland with an elevation below 1500m a.s.l with percent share of 73% out of the total area. About 64% of the land is characterized as flat with a slope of less than ten percent (Ayele et al., 2019).

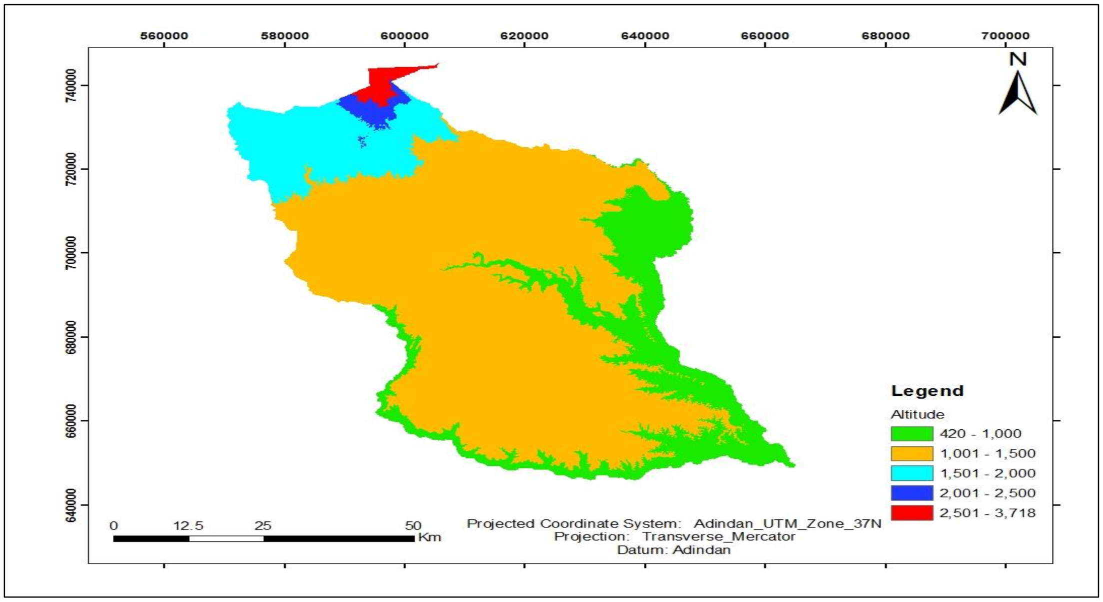

Figure 3: Elevation map of Delo Mena woreda

3.1.3. Climate

The Woreda experiences bimodal rainfall type with a minimum of 628 millimeters and a maximum of 986 millimeters per annum. The first rainfall season is a bit longer and extends from April to June. The second season starts in the middle of September and ends at the beginning of November. The mean annual temperature is 29.5˚C while the minimum and maximum temperatures of 21˚C and 38˚C recorded respectively (Ayele et al., 2019).

3.1.4. Soil

Soil is an output of the impact of organisms, relief, climate, and parent materials interacting over time. The landscape displays a notable range of soil types, resulting from an almost infinite variation in geology, climate, vegetation, and other organisms, topography, and the time for which these factors have combined to influence soil formation (White, 2006). Depending on FAO soil classification Chromic vertisol, Pellicvertisols, Chromic luvisol, and Chromic cambisols are the dominant soil types in the Woreda. The chromic vertisol type of soil covers 44% of the coverage of the Woreda and followed by Pellic vertisols (29%) type which is found in the southern part of the Woreda (Ayele et al., 2019).

A. Vertisols

Vertisols are heavy clay soils with a high proportion of swelling clays and forming deep wide cracks during the dry season. Mostly it occurs in the semi-arid tropics with an average annual rainfall of 500–1 000 mm but also available in moist tropics (FAO, 2015). In the study area, it is available with chromic and pellic qualifiers covering 44% and 29% of total land surface respectively making the area suitable for extensive grazing.

B. Cambisols

Cambisols combine soils with at least an incipient subsurface soil formation. Medium and fine-textured materials are derived from a wide range of rock. Found from level to mountainous terrain in all climates and under a wide range of vegetation types (FAO, 2001). In the study area, it is available with chromic qualifiers covering 8% of the total land surface covering the highland part of the study area.

C. Luvisols

Luvisols have typically a brown to the dark brown surface horizon over a (greyish) brown to strong brown or red argic subsurface horizon (FAO, 2001). Thus, it is fertile soils and suitable for a wide range of agricultural uses. Most Luvisols in subtropical and tropical regions occur on young land surfaces. In the study area, it is available with chromic qualifiers covering 19% of the total land surface (FAO, 2001; FAO, 2015).

3.1.5. Vegetation

Depending on altitudinal differences vegetation of the study area varies from highland to lowland.Thus,the forest of Delo Mena Woreda comprises dominant forest tree species like Podocarpus falcate, Warburgia ugandensis, Celtis Africana, Diospyros abyssinica, Syzgium guineense, Filicium decipiens. Similarly, a woodland forest comprises woody vegetation such as Terminalia species, Combretum molle, Syzgium macrocarpum and Acacia species (Wakjira et al., 2015).

3.1.6. Water resource

There is Major River which crosses the Woreda such as Yadot, Deyu, Helgol, Erbaguda, and Erba Kela. Some of these rivers are used for irrigation while others serve for domestic and livestock services (Ayele et al., 2019). The areas were this river didn't rich use pond for livestock drinking during the wet season.

3.1.7. Demographic characteristics

According to the prediction of Ayale et al. (2019), the population of Delo Mena Woreda was 111,823 people with 56,642 males and 55,181 females. Of the total 96,145 in 2015 people are the dwellers of rural while the remaining dwell in urban areas. With a population density of approximately 21 people per Km^2.

3.1.8. Socio-economic characteristics

According to Mengistu and Asfaw (2016), the dominant farming activities in Delo Mena Woreda is mixed farming systems, livestock, and subsistence crop production farming. They mainly engaged in farm activities such as maize, teff, sorghum, chickpeas, and haricot beans and cash crops like coffee, Chat, and sugarcane. Livestock rearing was mainly practicing in a rural community with cattle, goat and equines were the dominant (Ayele et al., 2019). In terms of livelihood as outlined in Flinton et al. (2017), 18% of the population is pastoral; 45% agro-pastoral; 28% crop farmers; and 9% other. According to Delo Mena woreda livestock office data, 2020 total numbers of livestock in the study area were 621,006, made up of 313,088 cattle, 167,370 shoats, 22,540 equines, and 40,867 camels.

3.2. Material and software

For this, study the following software was used for data acquisition, analysis, design, and presentation of the final result: ArcGIS 10.3.1 for map-making and data analysis, like reclassification, overlay, and accuracy assessment, ERDAS IMAGINE 2015 was used for satellite image processing and classification; Microsoft excel was used to do pairwise comparison analysis. Also, GPS Garmin 60 was used to collect ground control point and point data of features like animal health post or clinic and market center from the field, and a digital camera was used for taking important pictures of the study area during field observation.

3.3. Research design

This study followed the mixed research design (qualitative and quantitative) research method of data collection and analysis. In this study, the quantitative research approach was employed to measure, quantify, and describe collected data while the qualitative design approach was used for field observation and other data collected from different sources. According to (Kefelegn et al., 2019) applying quantitative and qualitative research design makes study and its firm sound and better in quality. In this study GIS-based, Multi-Criteria Evaluation method was used to analyze land suitability for livestock production. Because the technique can effectively be used for suitability analysis in the GIS environment.

3.4. Data collection

To attain the objectives of this study, both primary and secondary data sources were utilized. Primary data used for this study were; own field observation, ground control point, and point data of animal health post and market center. 148 GCP randomly collected through GPS Garmin was used to assess the accuracy of classified land use land cover of study area one of factor map; LULC which was produced by applying supervised image classification technique in ERDAS Imagine 2015 software. Whereas point data (geographical location) of veterinary service and market center were used to calculate proximity to infrastructure and field observation was essential for the study to determine land use class and to scale relatives' importance of factors. Secondary data such as Landsat 8(OLI sensor) satellite image, SRTM DEM data, FAO digital soil map, climatic data (rainfall and temperature) were used. To map land use land cover of woreda the study used Landsat 8, (OLI sensor) satellite images. This sensor offers numerous enhancements than previous Landsat sensors with better radiometric quantization(12bits). Furthermore, to make the study up-to-date, the 2020 satellite image of the study area was used. Besides, reviewing different relevant published and unpublished literature, relevant documents and related studies of different areas was undertaken almost throughout the research period. All the data used in the study were summarized in table 2 below.

Table 2: Data type used in conducting the study

No	Data Type	Path/Row	Resolution(m)	Data Source	Application
1	Landsat 8 OLI sensor	167/56	30m	USGS	To produce a thematic map of the study area
2	SRTM Data	167/56	30m	USGS	Slope and elevation map
3	Digital soil map			FAO Digital soil data	The Soil type map
4	Climatic data	_	_	NMA /Worldclim-2	Rainfall and temperature map
5	Point data			Field survey	For accuracy assessment and proximity map

3.5. Method of data analysis

To analyze the data, the study utilized different methods and applications of ArcGIS10.3.1. and ERDAS imagine 2015. Thus, the study area LULC was classified in ERDAS imagine 2015 from the Landsat8 OLI sensor. The factors map was reclassified using ArcGIS10.3.1. to prepare factors map for overlay analysis. The land suitability analysis was based on LU/LC, climate (temperature and rainfall), Soil type, slope, and Distance to market and veterinary services factor map. Based on available data and literature range those factors were assigned weight before weighted overlay to produce a rangeland suitability map for livestock production. Finally, this study was used in a weighted linear combination method to overlay livestock production influencing factors to come up with final rangeland suitability map for livestock production.

3.5.1. LULC Classification

Image preprocessing which comprises,radiometric correction, image enhancement, layer stacking, false colour combination, resampling, and subsetting were applied to the images to improve image quality, interpretability and extract information from an image. Data types acquired from different sources have possessed different spatial resolution thus, to do overlay analysis it was resampled into the same spatial resolution. Image resampling involves the conversion of satellite imagery at a relatively fine-scale to a coarse spatial resolution by imagery from similar or different satellite sensors with varying spatial resolution. All factors data have been resampled to 30mx30m grid cells using bilinear resampling techniques in ArcGIS 10.3.1 software which is useful for continuous data.

To convert image data to thematic data, image classification is necessary. The present study applied a supervised classification technique with maximum likelihood algorithm using 120 training samples randomly collected from image to train software to categorize the image of the study area into different land use/ land cover classes from the 2020 Landsat 8 image. Thus, multispectral band 2-7 recorded in Landsat 8, OLI sensor layer stacked in ERDAS Imagine 2015 software was masked to the study area to classify the image.

To achieve the goal of this study, the study area was classified into six major LU/LC nomenclatures: Forest, grassland farmland, woodland, built up, and shrub land-based on information obtained from woreda Land use and administration office and field observation. ERDAS Imagine version 2015 software was used for classification, then land use/land cover polygons were made using ArcGIS 10.3.1 to extract and reclassify land use/land cover types of the study area. The description of each class were summarized as follows in table 3.

Table 2: Land use land cover category description

Land categories	Descriptions of Land-Uses and Land-Cover types
Forest	Vegetation with canopy covers greater than 20% with tree height taller than 15meters which occupies greater than 0.5 ha. This comprises forest species of the study area such as Podocarpus falcate, Warburgiau ugandensis, Celtis Africana, Diospyros.
Woodland	Vegetation with canopy covers greater than 15% and a tree height 5 - 15 meters were considered woodland. Woodland tree species in the study area comprisesTerminalia sp., Combretum, molle,
Farmland	This land-use encompasses areas that allocated for the production of perennial and seasonal crops in the rural areas
Shrubland	This Land-cover category includes small woody plants and herbaceous plants
Built-up	Land features such as towns and concentrated small rural villages that roofed with corrugated iron sheets
Grassland	Both communal and\or private grazing lands that are used for livestock grazing. The land is covered by small grasses,

Source : Adopted from Ayele et al.,2019 and Wakjira et al.,2015 with little modification

3.5.3. Accuracy assessment

To determine classification accuracy, an accuracy assessment is necessary to determine the classified output map to meet or not meet certain predetermined classification accuracy criteria. Though, accuracy assessment is considered an integral part of any image classification. This is because image classification using different classification algorithms may classify pixels or groups of pixels to wrong classes. Thus, the error of omission or error of commission will occur while classifying an image. One of the most common methods used to assess classification accuracy is the use of an error matrix and also called a confusion matrix (Congalton, 1991)**.** So, this study was calculated overall, producer and user accuracies and kappa coefficient with the help of ArcGIS 10.3 data management accuracy operation environment for the better quality of land cover classification.

Therefore, for this study producer, overall, users and the Kappa coefficient were calculated from the error matrix table. The error matric table was obtained from sample data (ground control point) with the aids of ArcGIS10.3.1 software, through (extract value to point, frequency, and pivotal table) available in data management extension of accuracy assessment operation. Further Calculation was done using Microsoft Excel 2016. Thus, to assess the accuracy of classified image 148 GCP (31 for cropland.34 woodlands,24 forest,18 built-up areas,21 grasslands,20 shrublands) of all land use were used which were collected randomly during the field survey.

Table 4: Error matrix table

Class category	**Reference (GCP)Data**							**Producer Accuracy (%)**	**User Accuracy (%)**
	Cropland	Woodland	Forest	Built-up area	Grassland	Shrubs land	Total		
Farmland	23	0	0	1	0	1	25	74.19	92.00
Woodland	1	30	1	0	1	1	34	88.24	88.24
Forest	2	1	21	1	1	0	26	87.50	80.77
Built-up area	0	0	1	15	0	0	16	83.33	93.75
Grassland	2	2	0	1	18	3	26	85.71	69.23
Shrubs land	3	1	1	0	1	15	21	75.00	71.43
Total	31	34	24	18	21	20	148		

Overall Accuracy

This is computed by dividing the total correct (i.e., a sum of Major diagonal by the total number of pixels in the error matrix. Which is (23+30+21+15+18+15)/148

Over accuracy =∑ Xii/N---(2)

Where Xii is the number of correctly classified pixel or diagonal values and N is the entire number of pixels in the matrix. Thus, overall accuracy for this classification is (122/148) *100=82.43%

Producer's Accuracy

It is computed dividing the total number correct pixels into categories by total numbers of pixels in that category as derived from reference data (GCP) (i.e., column total). Thus, it indicates the probability of reference pixels being correctly classified and it is a measure of omission error.

User's Accuracy

These measures show the probability that pixels classified on map/image actually represent those categories on the ground. It is computed dividing the total numbers of pixels in a category by the total numbers of pixels that were classified in that category and it is measures of commission error.

Kappa Coefficient

Kappa coefficient can be used as another measure of agreement or assess classification accuracy. It expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification (Congalton, 1991). Computed using the formula provided by congalton, (1991).

$$K = \frac{N\sum_{i=1}^{r} Xii - \sum_{i=1}^{r}(X_{i+} * X_{i\ +1})}{N^2 - \sum_{i=1}^{r}(X_{i+} * X_{i\ +1})}$$ --------------------------------------equation (3)

where r is the number of rows in the matrix, xii is the number of observations in row ì and column ì xi+ and x +ì, are the marginal totals of row ì, and column ì, respectively, and N is the total number of observations. Thus, the kappa coefficient calculated was 0.787.

3.6. Multi-Criteria Evaluation

It is the method in GIS-based multi-criteria decision-making analysis that is accomplished by setting a goal or defining problems, determining factors, standardizing factors, assigning weight for factors, combining factors after weight was assigned and validating the result (Kefelegn et al., 2019). This study used AHP, one of the commonly used methods of multi-criteria decision-making analysis to perform multi-criteria evolution. It is used to derive weight for each factor under consideration.

3.7. Criteria or Factors selected

To analyze rangeland suitability for cattle, goat and camel production first step, were compilations of the livestock production requirements that will be considered in the evaluation. A criterion (factor) remains the basis for a decision that can be measured and evaluated. It is the the evidence upon which a decision is based. Thus, the study identified five environmental factors namely soil map, slope map, temperature map, LULC map, and a rainfall map, and two infrastructure factors; access to veterinary service map and market map. These factors were selected based on their importance to the study area, analysis of different related literature on this topic, previous work and information of experts.

1. **Biophysical (environmental) factors analysis**

This study used five determining environmental factors to analyze environmental rangeland suitability for cattle, goat and camel production such as slope, LULC, Soil type, temperature and rainfall. According to (Fikadu,2011), (Abebe,2006) and (Terfa & Suryabhagavan,2015) assessing these factors offer information about limitation of land for livestock production. Thus, the study used these factors to classify study area according to its suitability for categories of livestock. The ranking and weight of these factors were given based on the above-traced researcher. It is compiled in the table,5 below.

Table 5: Rating factors for livestock production

livestock species	factors/criteria	Range of suitability criteria rating for cattle, Goat and Camel				
		highly suitable(S1)	moderately suitable(S2)	marginally suitable(S3)	not suitable(S4)	Sources
Cattle	Slope (%)	0-8	8-16	16-30	>30	Terfa &Suryabhagavan(2015), Fajji et al,.2018,
	Soil type	Pellicvertisol/ Chromic vertisol	Chromic luvisol	Chromic cambisols	-	Fikadu (2011), Deselegn,2009, FAO,1986
	Rainfall (mm)	>800	500-800	300-500	<300	Terfa &Suryabhagavan (2015), Fiqadu,2011
	LULC	grassland	woodland	farmland	shrubs land	Terfa &Suryabhagavan (2015) and Deselegn,2009
	Temperature(C^0)	13-19	19-23	23-27	>27	FAO,1988 and Fikadu,2011

	Access to market (km)	<10	10-20	20-30	>30	Leta and Mesele, 2014
	Access to veterinary (Km)	<5	5-10	10-20	>20	Terfa &Suryabhagavan (2015),expert
Goat	Slope (%)	0-16	16-35	35-50	50-60	Terfa &Suryabhagavan (2015), Fiqadu,2011
	Soil type	Chromic vertisol/Pellic vertisols	Chromic luvisol	Chromic cambisols	-	Fikadu (2011), Deselegn,2009, FAO,1986
	Rainfall (mm)	600-800	600-400,>800	400-250	<250	Terfa &Suryabhagavan (2015), Fiqadu,2011
	LULC	Shrubs land	woodland	grassland	farmland	Terfa &Suryabhagavan (2015) and Deselegn,2009
	Temperature(C^0)	13-20	20-23	23-27	>27	FAO,1988 and Fikadu,2011
	Access to market (km)	<10	10-20	20-30	>30	Leta and Mesele, 2014
	Access to veterinary (Km)	<5	5-10	10-20	>20	Terfa &Suryabhagavan (2015), expert
Camel	Slope (%)	0-8	8-16	16-30	30-40	Terfa &Suryabhagavan (2015), Fiqadu,2011
	Soil type	Pellic vertisols/chromic vertisol	Chromic luvisol	Chromic cambisols	-	FAO,1988 and Fikadu,2011
	Rainfall (mm)	450-700	350-450	200-350	>700, <200	Terfa& Suryabhagavan (2015), Fiqadu,2011
	LULC	Shrubs land	woodland	Grassland	farmland	Terfa &Suryabhagavan (2015) and Deselegn,2009
	Temperature(C^0)	20-27	27-35	16-20	<16	FAO,1988 and Fikadu,2011
	Access to market (km)	<12	12-24	24-35	>35	Leta and Mesele, 2014
	Access to veterinary (Km)	<5	5-10	10-30	>30	Terfa &Suryabhagavan (2015) ,expert

A. Soil analysis

Soil is an important factor where vegetation essential for livestock feed grows on and also sources of minerals that animals lick to maintain their health. Physical characteristics of soil obtained from FAO digital soil map were considered to interpret and analyze soil suitability of the study area. Though soil type of study area was clipped from FAO digital soil mapping to study area using the clipping tool of ArcGIS 10.3.1. then rasterized and resampled to reclassify into suitability class for goat, camel and cattle production.

.

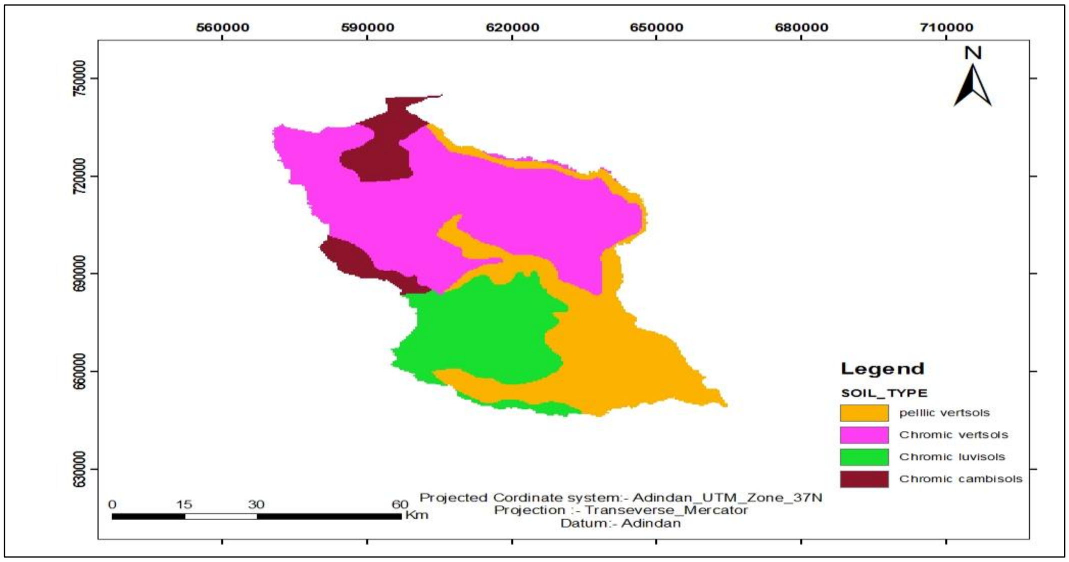

Figure 4: Soil type map of the study area

As indicated in above figure 5 the soil type of study area; chromic cambisols which were found west and south part of the study area covers a small area about 8% (39020he) of the total area, which is marginally suitable for all categories of livestock, other which is found in the southern part and eastern edge was pellic vertisols covering about 29% (139694hec) of total area, chromic vertisols which are dominant soil type of area cover about 44% (215535.6he) almost half other soil type and another soil type which cover 19% (95094he) found south-west to south part of the study area is chromic luvisols.

B. Land use /land cover analysis

According to Jensen (2015) Land cover refers to the features present, on the land surface, for example, water, wetland, forest, and crops, etc. Land use is the activity that people did on land surfaces like settlement, agriculture, mining, and commerce, etc. Land use Land cover map was one of the major factors that affect land suitability evaluation is useful for resource assessment, land use planning, land evaluation, and land use/ land cover change detection, etc. To map the LULC of study area Landsat 8 (OLI sensor) satellite image was used. Accordingly, six major land use land cover were generated: Woodland, forest, farmland, shrubs land, grazing land, and built-up area were used to map the final LULC map of the study area.

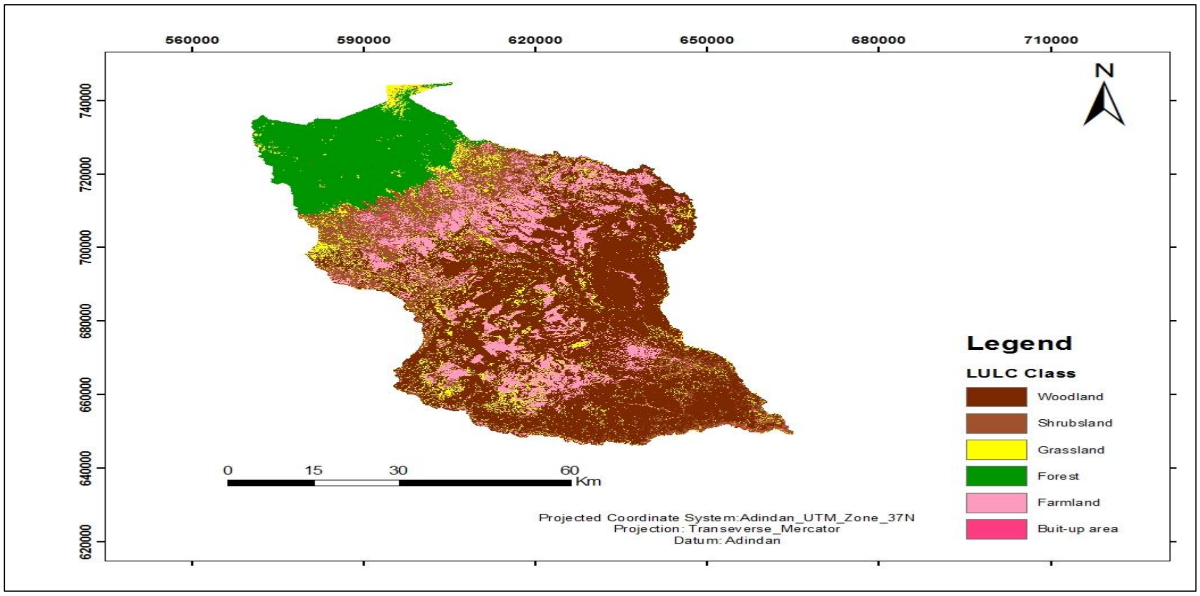

Figure 5: Land use land cover Map of the study area

Map color source: Ethiopia land use land cover classification and coding standard (2018)

As indicated in figure 6 of the LULC map large shares of the study area were covered by woodland which accounts 47% followed by farmland which shares 16% and forest the third-largest LULC cover 15% out of the total share, shrubs land has covered about 13% of the study area with grassland and built-up area share small percent of area coverage which is 8% and 1% respectively. Thus, LULC of study area show that large size of the area is suitable for camel and goat production as both are browser; use woodland and shrubs as source feeding and also farmland and grassland are suitable for cattle production were as forest and the built-up area was restricted from suitability analysis for livestock production.

C. Climate data analysis

Climate is the most important factor in influencing livestock production. Climatic factors such as temperature and rainfall distribution have a great effect on pasture and food resources availability cycle throughout the year and disease outbreak among animals'(Lamy et al., 2012). Thus, considering these factors to analyze rangeland suitability for livestock production was important.

Rainfall data analysis

Rainfall is a source of water for livestock to drink; vegetation and grass animals used as the source of feed need rainfall to grow. Thus, rainfall availability and its distribution and frequency have a significant role in livestock production. The annual average rainfall data of 20 years of the study area was obtained from the National Meteorological Agency (NMA) of Ethiopia. The Rainfall station longitudinal and latitudinal coordinates and the corresponding average rainfall data were entered into Excel, a spreadsheet from which a rainfall station map was prepared for the study area. The seven-station rainfall data were used to produce a rainfall raster map using the inverse distance weighting method of the interpolation tool available in ArcGIS. This map was used to determine rangeland suitability for livestock production. According to (Fikadu, 2011) and (Terfa &Suryabhagavan,2015), rainfall data were ranked into suitability class for this study.

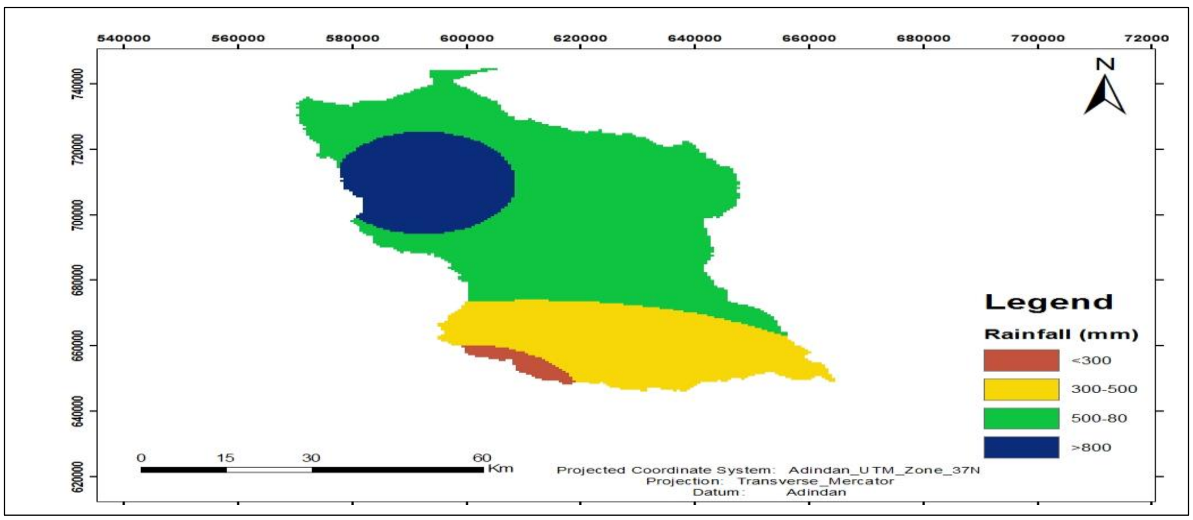

Figure 6: Rainfall Map of the study area

As indicated in above figure 7, of rainfall map 15% of the study area was receiving Average rainfall above 800m covering the northern part of the study area were as 58% was receiving 500-800mm amount of average rainfall covering north to south but, the area around south part study area was receiving average rainfall below 500mm which account 27% of total area. The amount of rainfall area receiving was satisfactory for the production of cattle, goat and camel but the area around the southern of woreda was receiving rainfall below-average rainfall suitable for livestock production facing water shortage for animals drinking and plant growth besides the land was not retained water for a long time due to high amount of temperature on this area.

Temperature data analysis

Temperature is one of the limiting factors for livestock production as they decrease the ability of livestock to maintain their body temperature causing heat stress to animals. Further increase and decrease in temperature will bring temperature beyond the change in heat production will not be sufficient to maintain homoeothermic (FAO,1988). The average monthly temperature was downloaded from WorldClim-2 with 1Km Spatial resolution masked to study area in ArcGIS 10.3.1 and resampled into 30m*30m using bilinear interpolation. Then reclassified into suitability class according to the degree of suitability. Temperature data were classified into a suitability class for goat, camel and cattle based on FAO (19880, (Fikadu,2011) study expert's opinion.

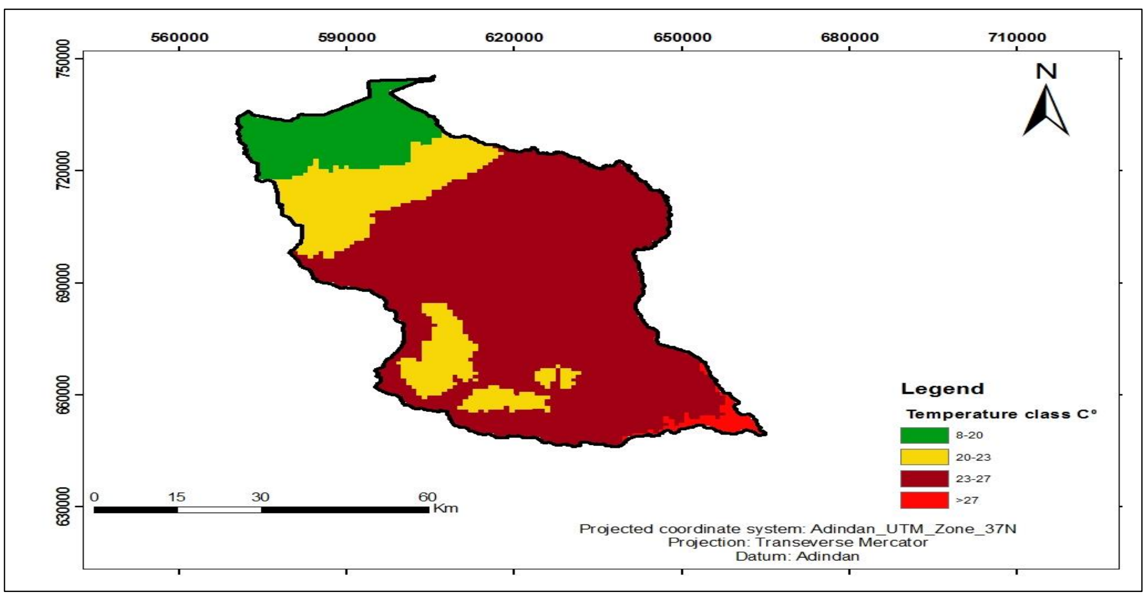

Figure 7: Temperature map of the study area

As indicated in the above figure 8, the temperature map average monthly temperature ranges from 8-20^{0}C (11%) and 20-27^{0}C (87%), which was optimum for cattle, goat, and camel production respectively. This indicates that a large part of the study area was comfort zone camel production while a small area was optimum for cattle and Goat production. Were as about 69% of the total area with an average monthly temperature 23-27^{0}C was very slightly good for cattle and goat production and in moderate condition for camel production. But the insignificant portion of the study area 1% and 2% with average monthly temperature 8-16^{0}C and >27% not comfortable for camel and Goat, cattle production respectively.

D. Slope analysis

According to Fajjii et al. (2018) Topography of the landscape has a great impact on how livestock utilizes vegetation. Thus, the Slope of the terrain influences the accessibility of forage to grazers. For example, cattle and camel is hard to move easily on steep slopes; therefore, utilization of forage by cattle on slopes greater than or equal to 60% is very low but small animals like goats can access this area. The slope of the study area was generated from SRTM data of 30m using ArcGIS 10.3.1 surface analysis tool of spatial analysts' extension. The slope of the study area ranges from 0-72%. According to (Fikadu,2011; Dessalegn,2009 and Terfa & Suryabhagavan,2015) land suitability for livestock production, the slope of the study area is classified into four class.

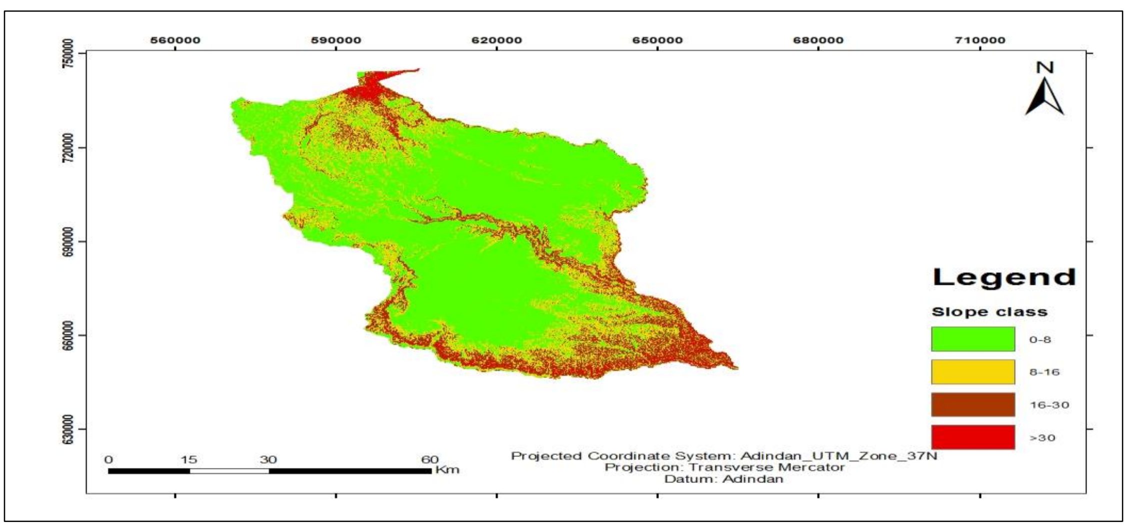

Figure 8: Slope map of the study area

As indicated in above slope map; the land of study area characterized by gentle to the steep slope but most areas were characterized by a flat slope which ranges between 0-15 that account about

86% with the percent share of 0-4 (53%), 0-8 (19%) and 8-15 (14%) whereas small area were range from rolling to hilly with a slope between 15-30 (12%) and >30 (2%) respectively. Accordingly, a large area of study is suitable for cattle, goat, and camel to travel across rangeland to find feed and water.

2. Infrastructural factors analysis

As (Terfa and Suryabhagavan,2015) described in their study 'socio-economic factors that determine rangeland suitability includes road and transport condition, communication system, market outlets, veterinary clinics and services, health centers/health posts, abattoirs, skins and hides collecting and preserving, communication and training system' in case this study was considered only two infrastructural indicators due to some factors data were inaccessible.

A. Access to Market

The market is an essential place where livestock and livestock products are sold. Long distances trekking to markets are major effects for the community to sell their livestock profitably as animals lose their weight during long trekking to market and the community lacks market information; thus, distance from main marketing centers influences the price of animals (Terfa and Suryabhagavan,2015). Thus, assessing distance to market is important to analyze range land suitability for livestock production in addition to this road is very important in market accessibility. Point data of three identified towns were collected by GPS 60 from which proximity to market was done using the Euclidean distance extension tool in ArcGIS 1.03.1 software.

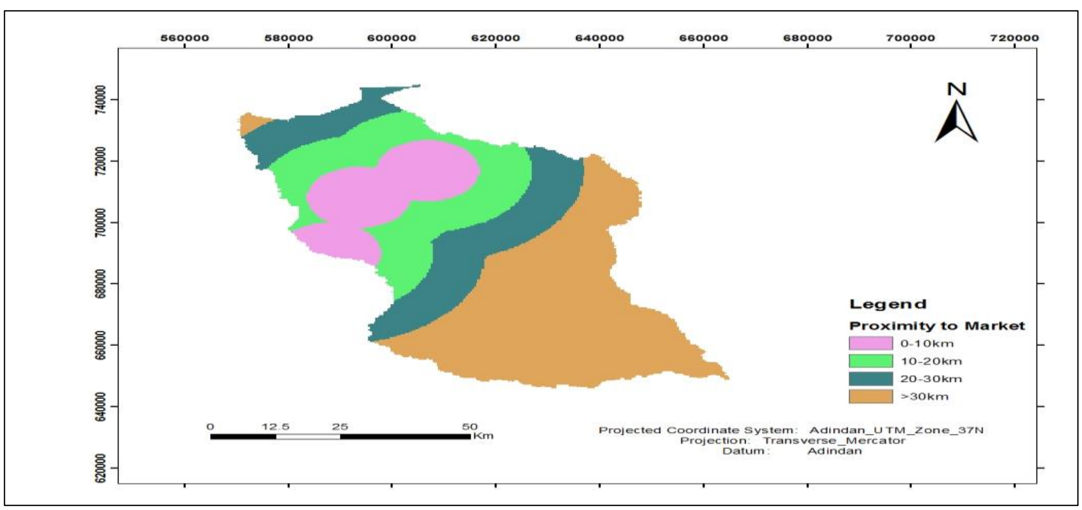

Figure 9: Market accessibility map

As clearly indicated in the market accessibility map in (figure 10),15% and, 4% of the study area is located near market access depending on livestock ability of trekking which is below 10km and 12km were classified as highly suitable for cattle, goat and Camel production respectively. Hence about 44% and 61%of the study area is found out of market accessibility which is far away by above 30km for cattle and goat and 35km for camel was assigned as not suitable for this animal production; while the distance between 10km to 20km and 12 to 24km for camel was classified as moderately suitable. Whereas 20km to 30km and 24 to 35km for marginally suitable for cattle, goat and camel production.

B. Access to veterinary Service

According to Hadush (2015), livestock production and productivity can be improved utilizing effective delivery of quality and affordable veterinary services. Thus, accessing distance to this service was essential because it protects the health of animals and the safety of its products. There are around 9 health posts and 1 clinic that can deliver veterinary services in the study area from which proximity analysis was done and reclassified according to its suitability for cattle, goat and camel production.

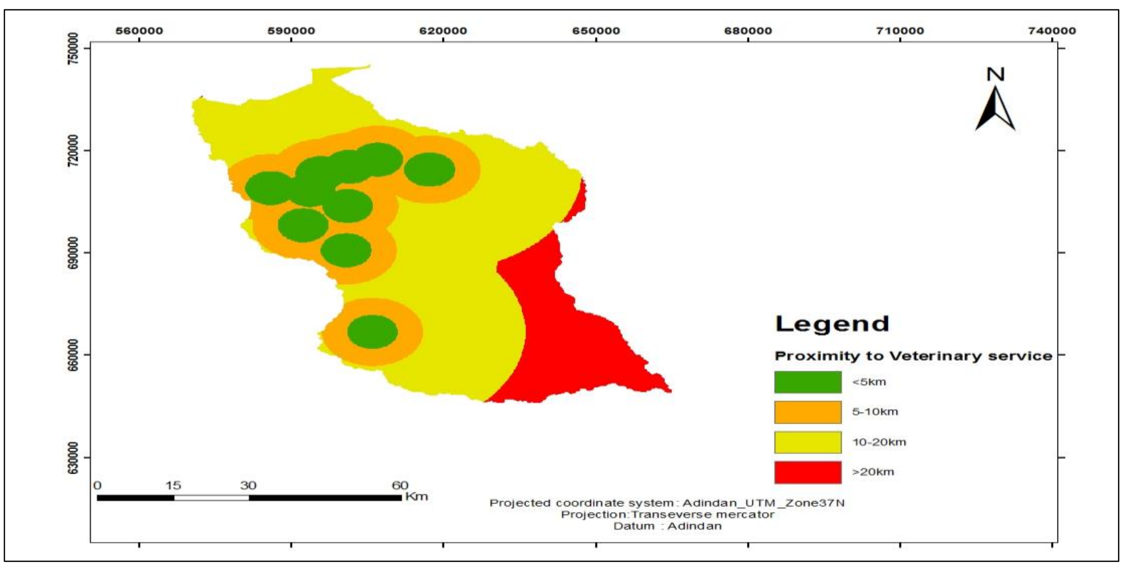

Figure 10: Animal health service proximity map

As indicated in the above figure 11, a large part of the study area was not suitable for cattle and goat, while marginally suitable camel production. Out of the total area of study 14%,21%, and 28% are far away from health service below 5km,10km, and 20km respectively. Otherwise, an area faraway from this infrastructure above 30km is sharing 37 % of the study area which is found in the southern part of the study area. Accordingly, area distant below 5km from veterinary services was highly suitable for cattle, goat and camel. Whereas the distance from 5-10km was assigned as moderately suitable for cattle, goat and camel, while 10-20km was marginally suitable for cattle and goat but for camel, it ranges from 10-30km. Above 20km and 30km distance was assigned not suitable for those categories of livestock.

3.7.1. Criteria rating

Land suitability for livestock production needs the consideration of different factors including; bio-physical (environmental), infrastructural, and social conditions of the area under consideration. These are the most important requirement needed for all livestock production. Compilations of the livestock production requirements that were considered in the evaluation were made and besides, the rating factors for each livestock species were decided. Criteria ratings are sets of values which point out the importance of each factor/criterion in satisfying particular conditions of the corresponding land quality. Factor ratings were made in terms of five classes such as highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1), and permanently not suitable (N2) (FAO, 1985; 1993).

3.7.2. Standardization of criteria

The process of setting the relative importance of each criterion is known as the standardization of criteria. A pair-wise comparison technique is typically used for rating and standardizing the ordinal values. To compare criteria with each other, all values need to be transformed to the same unit of measurement scale (from 0 to 1), whereas the various input maps have different measurement units (Maddahi et al., 2014). Thus, in this study criteria were standardized through transforming each unit of measurement into the same unit, before any weight is assigned, to make standardize and compatible raster features of all factors was reclassified by reclassifying extension tool in ArcGIS so that all factor maps are positively correlated with suitability and the new value is assigned from 1 to 4 where 1 is highly suitable, 2 moderately suitable, 3 marginally suitable 4 not suitable. Thus factors/criteria used in the rating are standardized based on literature FAO and livestock expert opinion.

A. **Reclassified LULC Map**

LULC is an influential parameter for rangeland suitability analysis because land use land cover is the source of palatable biomass that browsers and grazers feed on. Thus, the LULC map was reclassified based on its palatability and preferences by cattle, goat, and camel as a source of feed. Hence, based on previous work and literature grassland was reclassified as highly suitable for cattle, marginally suitable for Goat and suitable camel while woodland is assigned as moderately suitable for goat, Cattle, and camel production; also, shrubs land was reclassified as highly suitable for goat and camel but not suitable for cattle production. Farmland was reclassified as marginally suitable for Cattle, but not suitable for goat and camel production. Forest and built-up areas were restricted for this animal production.

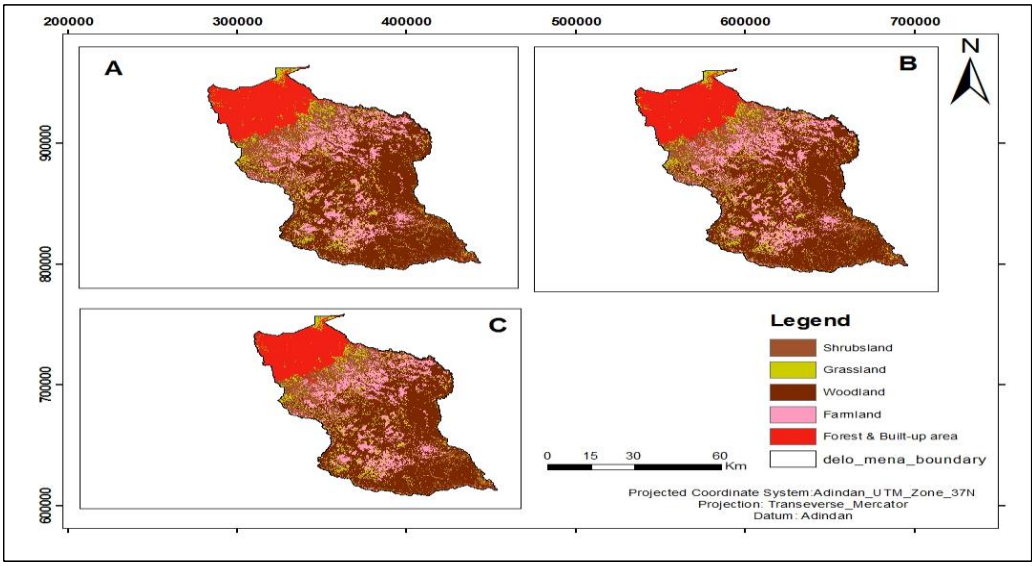

Figure 11: Reclassified LULC map for A= Cattle B=Goat and C=Camel

B. **Reclassified slope map**

Slope map of the study area was reclassified based on the influence of livestock to access grazing land as steep slope impacts animals to utilize vegetation. Thus, it was reclassified into four suitability classes based on available literature and expert opinion. Then it was transformed into the common scale to do weighted overlay analysis which ranges from 1 to 4 whereas 1 represent is highly suitable, 2 moderately suitable, 3 marginally suitable 4 not suitable.to do overlay analysis.

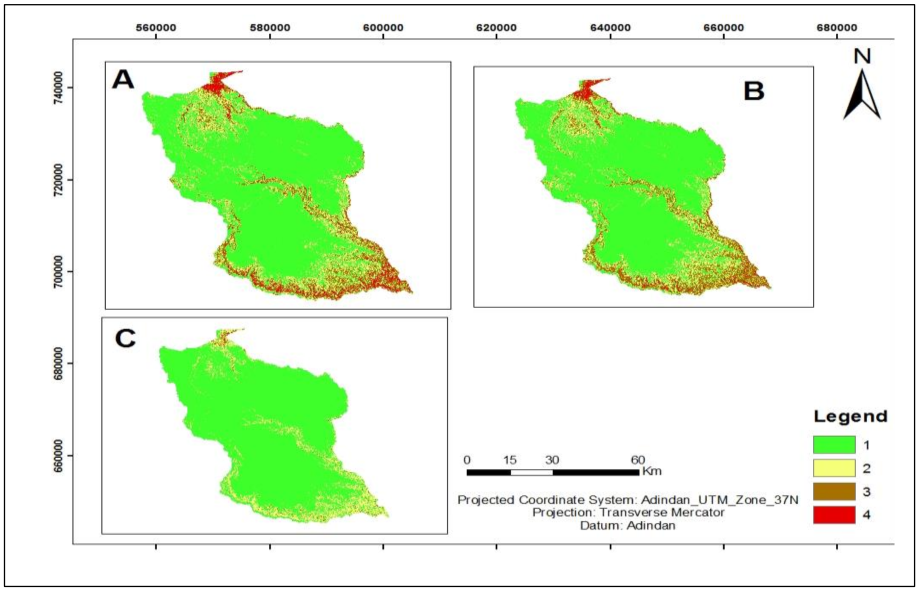

Figure 12: Reclassified Slope Map for A=Camel, B=Goat, and C=Cattle

As indicated in above figure 13 slope class range from 0-8 (72%) ,8-16 (15%), 16-25 (8%) and 16-30 (10%), >25 (5%) and >30 (5%) was classified as highly suitable, moderately suitable, marginally suitable and not suitable for camel and cattle production respectively and slope range between 0-16 (88%) ,16-35 (11%) ,35-50 (1%) and >50 (0.1%) was classified as highly suitable, moderately suitable, marginally suitable and not suitable for goat production respectively.

C. **Reclassified Rainfall map**

The average rainfall of the study area was reclassified into four suitability class based on the amount of rainfall area receive; area receiving a high amount of rainfall were good for livestock and vegetation growth used by animals for feeding. But the area receiving less rainfall was affected by a shortage of water and availability of feed. Accordingly, a new value of 1 to 4 is assigned to convert into the same unit of measurement. whereas 1 represents is highly suitable, 2 moderately suitable, 3 marginally suitable 4 not suitable.

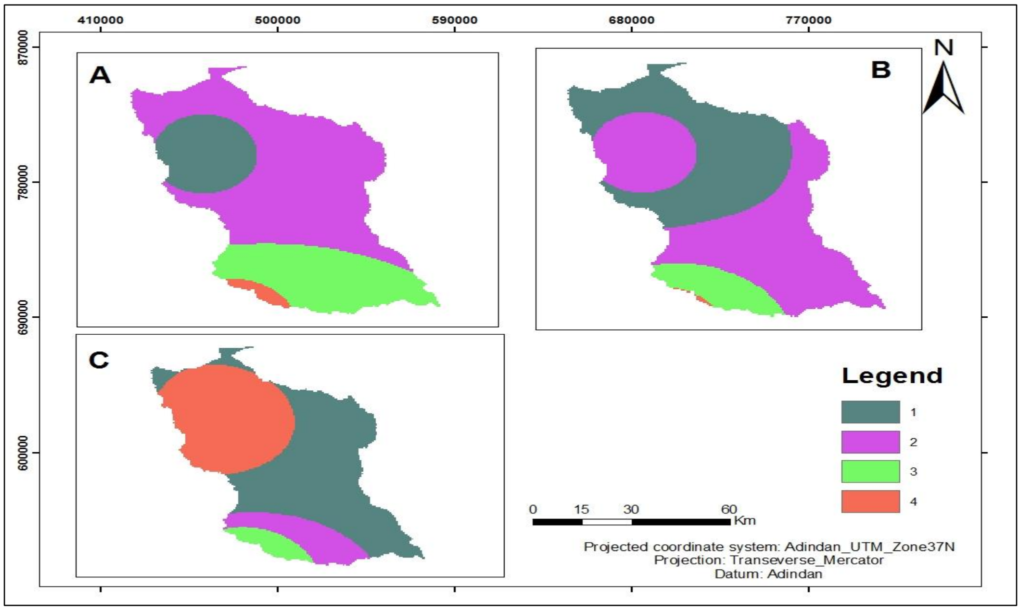

Figure 13: Reclassified rainfall map for A=Cattle, B= Goat and C=Camel

As indicated, in reclassified rainfall map average rainfall above 800mm (15%), 500-800mm (58%),300-500mm (25%), <300mm (2%) was classified as (1) highly suitable, (2) moderately suitable, (3) marginally suitable and (4) not suitable for cattle production respectively. For goat production 600-800mm (38%),400-600mm and >800(53%),250-400mm (8%), <250mm (1%) was classified as (1) highly suitable, (2) moderately suitable, (3) marginally suitable and (4) not suitable for cattle production respectively as well as 450-700mm (50%),300-450mm (11%),230-300mm (4%) and >700mm (35%) was classified as (1) highly suitable, (2) moderately suitable, (3) marginally suitable and (4) not suitable for cattle production respectively.

D. **Reclassified Temperature map**

The average temperature of the study area was reclassified into a common scale according to its suitability for livestock production and adaptability of animals to withstand the hottest or coldest temperature. Temperature map of area reclassified into four suitability class ranging from 1 to 4, whereas 1 represents highly suitable, 2 indicates moderately suitable, 3 represents marginally suitable and 4 not suitable.

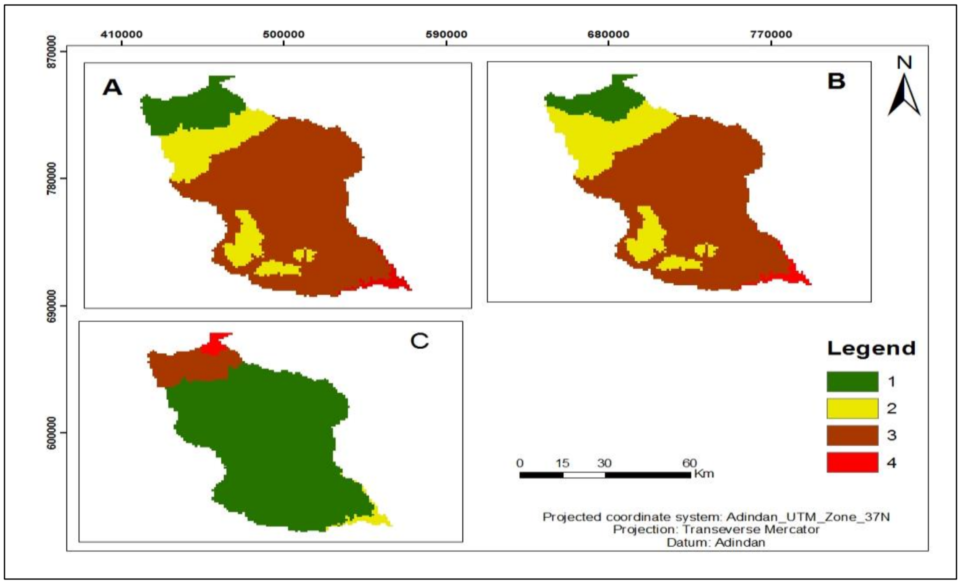

Figure 14: Reclassified Temperature Map For A=Goat, B=Cattle and C=Camel

As indicated in above figure 15, temperature range from 8-20^{0}C (11%) ,20-23^{0}C (18%) ,23-27^{0}C (69%),>27^{0}C (2%) and 8-19 ^{0}C (8%) ,19-23 (22%), 23-2^{0}C 7(69%) and >27^{0}C (2%) was classified as highly suitable, moderately suitable, marginally suitable and not suitable for goat and cattle production respectively and also temperature range between 20-27^{0}C (87%),>27^{0}C (2%) ,16-20^{0}C (10%) and 8-16^{0}C (1%) was classified as highly suitable, moderately suitable, marginally suitable and not suitable for camel production.

E. **Reclassified Soil Map**

Due to the major soil type of study area being in vector format while downloading; to reclassify the soil type it was rasterized by using a vector to raster conversion tool in ArcGIS 10.3.1. After rasterization, it was reclassified into three class based on their degree of suitability for cattle, goat, and camel.

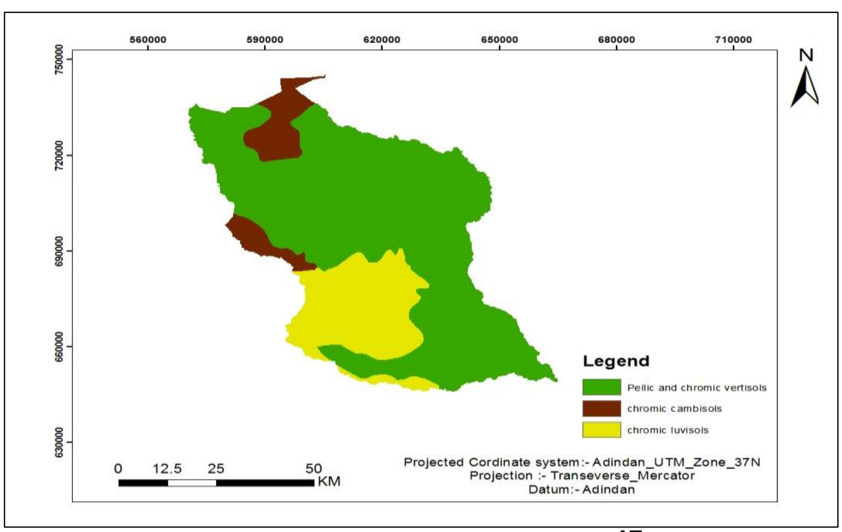

Figure 15: Reclassified Soil Map of Cattle, Goat and Camel

According to figure 16 of the reclassified soil type map, a large part of the study area soil type was classified as highly suitable for cattle, camel and goat which accounts for about 73% which is pellic and chromic vertisols soil type. Similarly, chromic luvisols soil type found in the southwest part of the study area which accounts for 19% of out of the total were moderately suitable for those categories of livestock. Whereas 8% of the study fell into marginally suitable for livestock production which is covered by chromic cambisols soil type. Moreover, the soil type of the study area was favourable for all categories of livestock production.

Reclassified market map

Market accessibility is essential for livestock production serving as a place where communities sell their livestock and its product. Point data of the market center was collected by GPS 60 during the field survey. Then distance was calculated by proximity analysis from this point using Euclidean distance of spatial analyst extension available in ArcGIS10.3.1. and also reclassified into four suitability class. Thus assigning 1 for the nearest place to market below 10km while 4 represent an area far from a market that is above 30km.

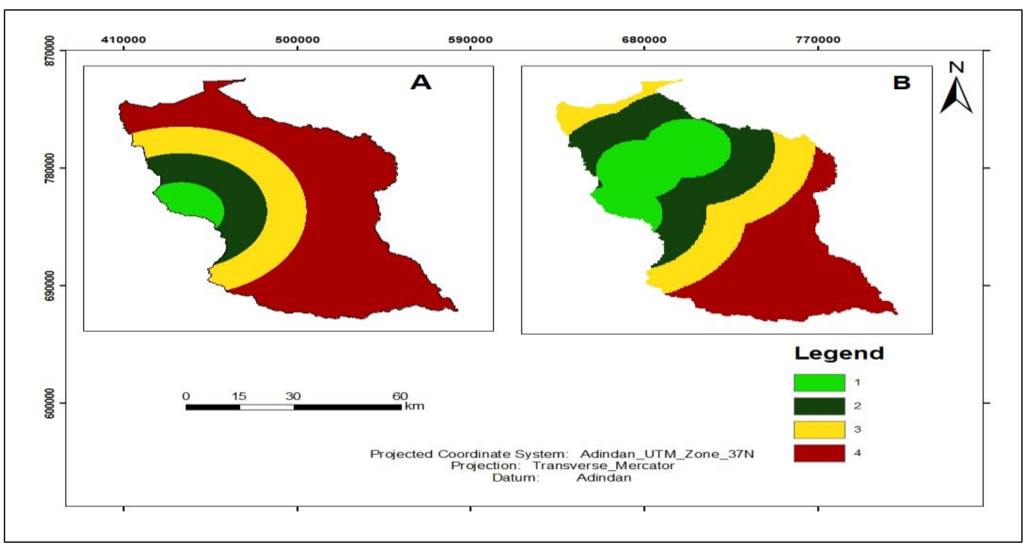

Figure 16:Reclassified Market map for A=Camel, B=Cattle and Goat

F. Reclassified Veterinary Service Map

Point data of woreda animal health clinics and post was collected by GPS 60 during the field survey then the distance from this point was calculated using Euclidean distance of spatial analyst extension tools available in ArcGIS10.3.1. Based on available literature and previous work it was reclassified into four suitability class for cattle, goat, and camel using ArcGIS 10.3.1. Then new evaluation scale of 1 to 4 is assigned were 1 indicates highly suitable,2 moderately suitable, 3 marginally suitable, and 4 not suitable.

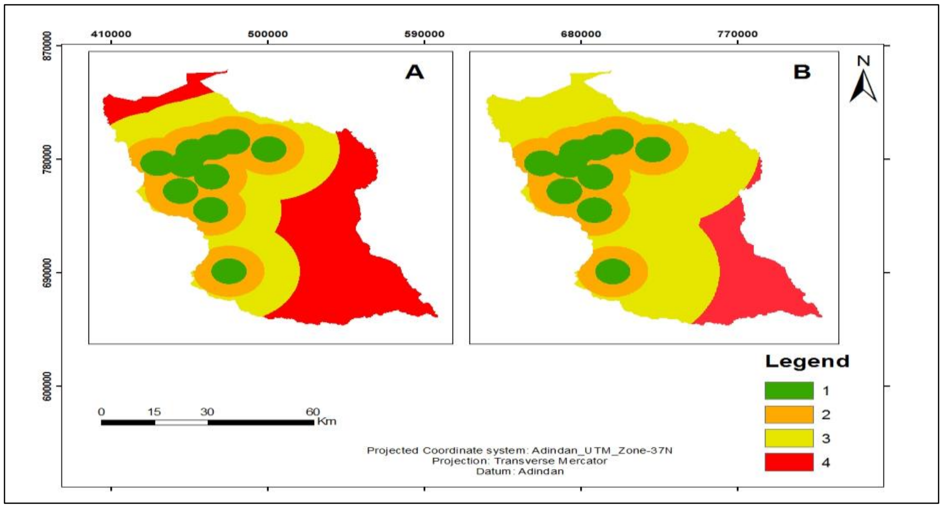

Figure 17: Reclassified Health service Map for A=Cattle and Goat and B= Camel

Veterinary services are essential for livestock production because it is a place where to control, protect, and diagnose of animal disease. Thus, the area nearer to this infrastructure was ranked as the highly suitable and far distance from this service was ranked as not suitable. Accordingly, as indicated in figure 18 area which is found below 5km was reclassified as 1, between 5km-10km was reclassified as 2, from 10km to 30km and 10km to 20km was reclassified as 3 for camel and goat, cattle respectively and above 20km and 30km was reclassified as 4 for cattle, goat, and camel respectively.

3.7.3. Weighing of criteria

Criterion weights are the weights assigned to the objective and attribute maps. Deriving weights for the selected factors map is a fundamental requirement for applying the AHP method. For determining the relative importance of criteria the pair-wise comparison matrix using Saaty's nine-point weighing scale was applied (Maddahi et al., 2014).To assign Weights for each factor maps based on their relevance the study have used a pair-wise comparison of the AHP method and by considering the condition of the study area. Then, prioritizing factor maps (simply factors or criterion) from highest to lowest was arranged according to their suitability value for livestock. The value was derived from the pairwise comparison matrix which was computed in Excel. In a pair-wise comparison matrix, factors are compared two at a time in terms of their importance related to the stated objective. The matrix is symmetrical and only the lower triangle needs to be filled in. The remaining cells are the reciprocals of the lower triangle; accordingly, the weight was assigned to factors.

Table 6: Pair Wise Comparison Matrix for cattle

Environmental Factors	LULC	Rainfall	temperature	slope	soil
LULC	1	2	3	3	5
Rainfall	1/2	1	3	5	5
temp	1/3	1/3	1	3	3
slope	1/3	1/5	1/3	1	3
soil	1/5	1/5	1/3	1/3	1
sum	2.366666667	3.733333333	7.533333333	12.33333333	17

Table 6, indicates that pairwise comparison is used for weight derivation of environmental factors for cattle production suitability analysis. Furthermore, table 7, below is used to indicate the weight of factors and consistency ratio of rangeland suitability for livestock production (cattle, goat, and camel) derived from AHP calculated in excel 2016 for environmental factors.

Table 7: Criteria weight of Environmental factors calculated by AHP weight derivation method

Environmental Factors	Cattle		Goat		Camel	
	Weight	Weight %	Weight	Weight %	Weight	Weight %
LULC	0.378768	38	0.410014	41	0.40453	40
Rainfall	0.315376	31	0.264901	26	0.261741	26
Temperature	0.156518	16	0.183635	18	0.181246	19
Slope	0.099243	10	0.088873	9	0.103785	10
soil	0.050096	5	0.052577	6	0.048688	5
Sum	1	100	1	100	1	100
Consistency ratio	0.073335		0.05346		0.05346	

Consistency Ratio = 0.073, 0.053 and 0.053 for cattle, Goat and Camel respectively thus, CR <0.1 which is acceptable.

Thus as indicated in above table 7 environmental suitabilitymap for cattle, goat and camel was produced by multiplying each factors map with it's assigned weight in ArcGIS software weighted overlay extension.

Table 8: Pairwise comparison matrix

Rangeland suitability Analysis for Cattle, goat, and camel factors	Environmental factors	Animal health service	Market access
Environmental Factors	1	3	5
Animal health service	1/3	1	3
Market access	1/5	1/3	1
Sum	1.533333333	4.333333333	9

Table 8, shows that the pairwise comparison used to derive weight for rangeland suitability analysis for cattle, goat, and camel production considering all factors environmental factors (LULC, Rainfall, Temperature, slope, and Soil) and Infrastructure indicators factors (Animal health service access and Market access. Moreover, Table 9 below indicates the weight derived from AHP calculation for rangeland suitability analysis for livestock production (Cattle, Goat, and Camel) and consistency ratio considering both environmental factors and socio-economic factors (infrastructure indicators). To determine the weight of each factor map, normalization process is needed. To normalize the above pairwise matrix value (Table 9), each cell value is divided by its column total (sum). To get the weight of each class, the mean value of the row were calculated.

Table 9: Criteria weight of Rangeland suitability analysis factors calculated by AHP weight derivation method

Rangeland suitability Analysis for Cattle, goat, and camel factors	Environmental factors	Animal health service	Market access	Weight
Environmental factors	0.652173913	0.692307692	0.555555556	0.6333457
Animal health service	0.217391304	0.230769231	0.333333333	0.260498
Market access	0.130434783	0.076923077	0.111111111	0.1061563
Sum	1	1	1	1

Consistency ratio = 0.047 which less than 0.1 thus if CR< 0.1 it is acceptable.

As mentioned above the weight of all factors was derived and after weight was assigned to all factors based on their relative importance the final range land suitability map for livestock production was computed by multiplying each factor with its weight using weighted overlay techniques of ArcGIS 10.3.1 software extension.

3.7.4. Weighted overlay analysis

The weighted overlay is a technique for applying a common scale of values to diverse and dissimilar input data to create an integrated analysis. GIS can be used not only for automatically producing maps, but it is unique in its capacity for integration and spatial analysis of multisource datasets (Malczewski, 2007). After standardization all criteria and assigning weight to criteria using pairwise comparison method this study has used weighted overlay techniques of analysis that available in the ArcGIS spatial analysis extension tool to combine factors map to produce finally range land suitability for cattle, goat, and camel based on weighted combination formula of Saaty's, (2006) as follows.

$S = \sum WiXi$ ……………………………………………equation 1

Where: S is suitability, $\sum$ is a sum, Wi is the weight of criteria and Xi is the criteria score of factors i

Thus, final suitability map for cattle, Goat and camel production equals 63 (environmental factors) + 26 (access to animal health services) + 11 (access to market center).While running the suitability model using a weighted overlay, the cell values of each input factor maps are multiplied by the estimated weight (percent of influence). The resulting cell values are added to produce the final output raster map. Finally, a raster of overall suitability model is created with four suitability classes; highly suitable, moderately suitable, marginally suitable and not suitable.

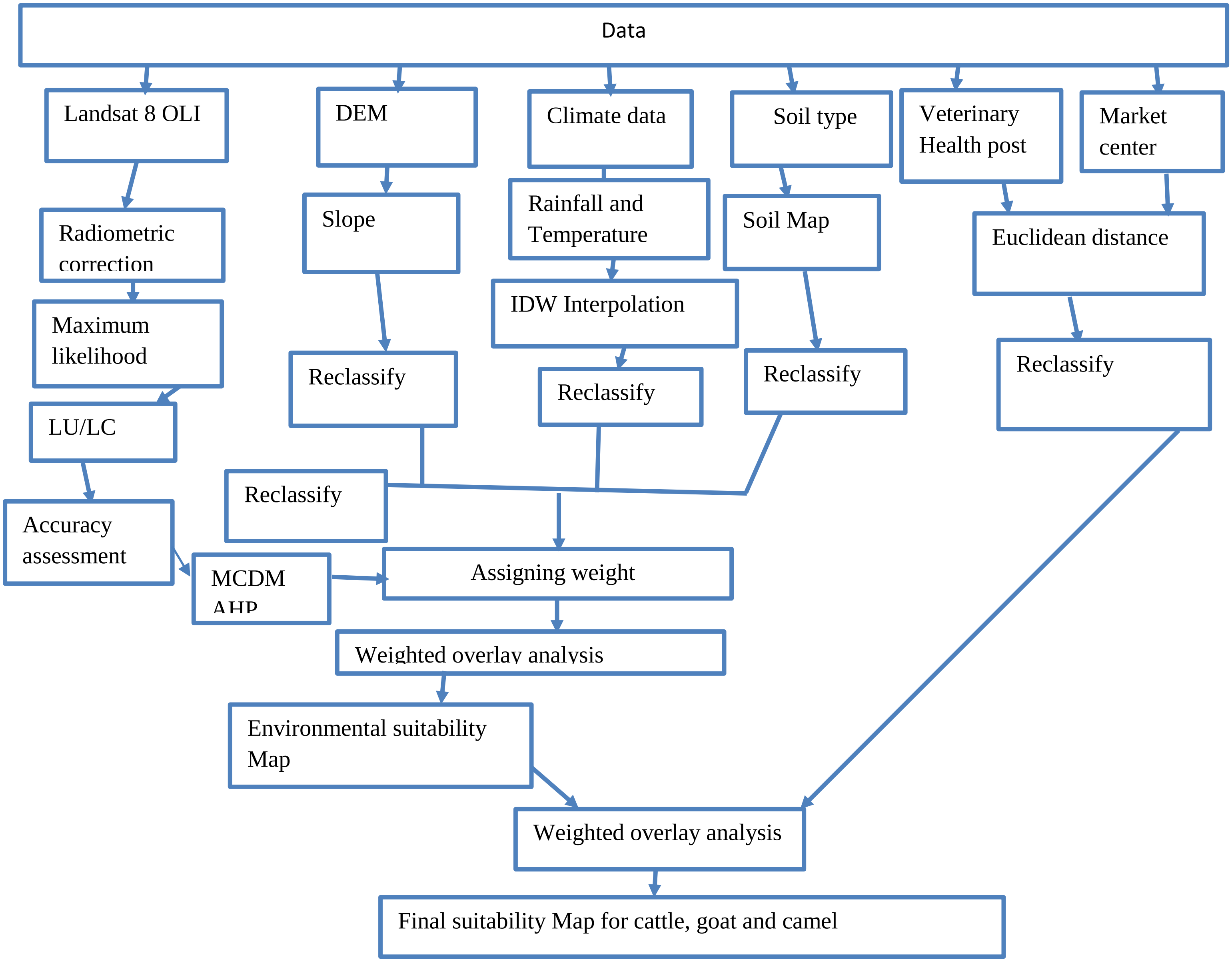

Figure 18: Methodological flow chart

CHAPTER FOUR

4. Result and Discussion

4.1. Environmental suitability analysis

According to the FAO suitability classification study area was classified into four class ranging from most suitable to least suitable for livestock production. Thus, based on the environmental factors of the study area was classified, into four suitability classes.

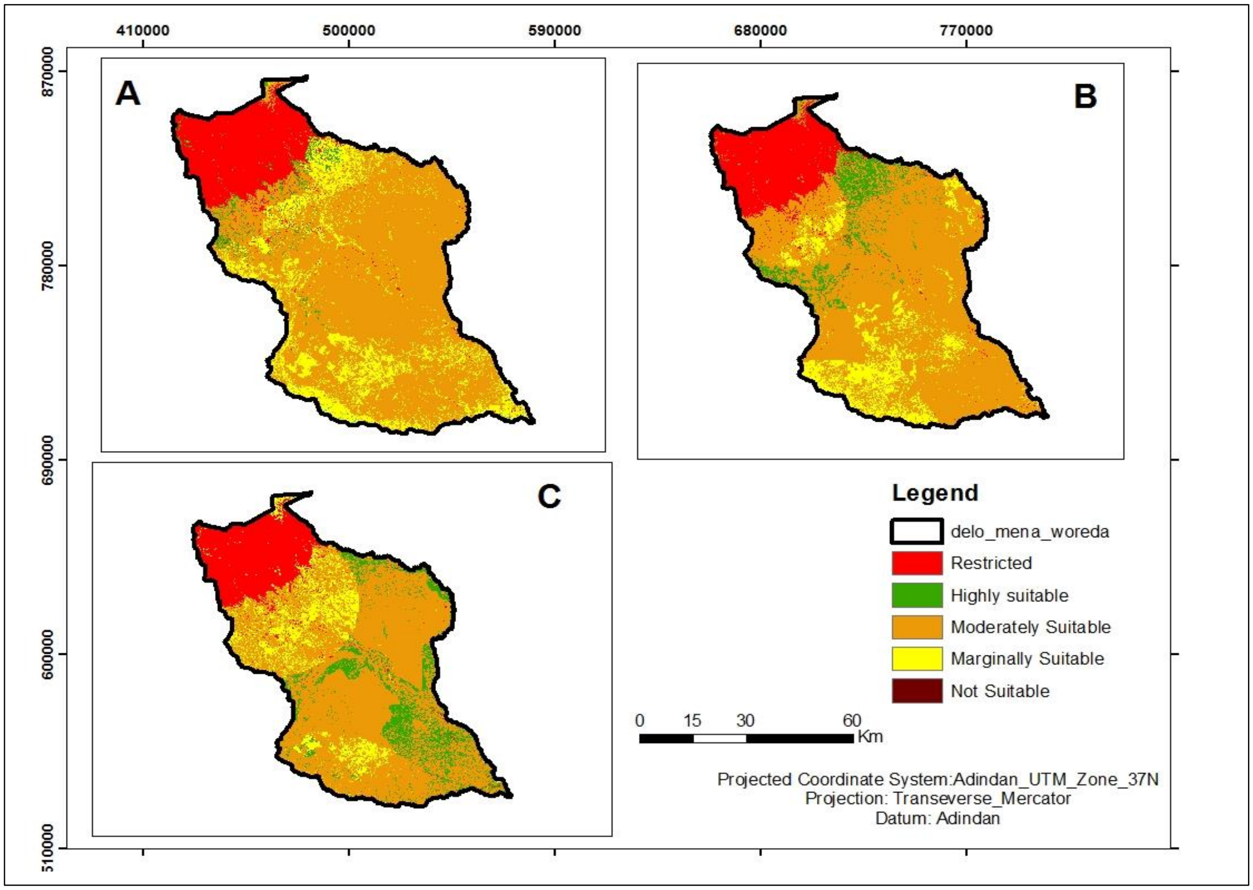

Figure 20: Environmental suitability map for A= cattle, B= goat, C= Camel

As indicated in figure 20 rangeland suitability class map based on environmental factors is produced for cattle, goat, and camel according to FAO four suitability class highly suitable, moderately suitable, marginally suitable, and not suitable beside this restricted area also added due to a large part of the area is restricted for suitability analysis. This suitability class was also used by the different researchers in their study of rangeland suitability analysis for livestock production (Abebe,2006; Dessalegn,2009; Fikadu,2011 and Terfa and Suryabhaguvan,2015).

Rangeland suitability analysis based on environmental factors such as land use land cover, rainfall, temperature, slope, and soil type indicates that land of woreda was moderately suitable for cattle, goat, and camel production. The area that satisfies all group of environmental factors which means; as indicated by (Terfa and Suryabhaguvan,2015) area with high rainfall for feed growth, gentle slope, the minimum temperature for (goat and cattle), grassland for (cattle), and shrubs for (camel and goat) types of LULC was classified as highly suitable livestock production. Thus, as indicated in the above figure 20 area highly suitable for cattle is found in the northern part of the study area were as, for goat in the northwest part and eastern part of the study area but, for camel southern part and a small portion on the western periphery and central part were fell under highly suitable. It accounts 3%, 6% and 11% of the total land of the study area for cattle, goat and camel respectively. Furthermore, large areas of study fell under moderately suitable for livestock production; an area that satisfies medium factors of under consideration which means; moderate water availability(rainfall), moderate slope, LULC types of woodland, moderately fertile soil type.

As depicted in the above figure, south to a central part of the study area is moderately suitable for livestock production which accounts for about 64% for cattle,66% for goats, and 62% for camel production. Similarly, the southwest and northwest part of the study area was classified as marginally suitable for cattle, goat, and camel production which accounts 17%,12% and 11% out of total study area respectively. Besides, this very smallest share of the total land in the study area is not suitable for livestock production; that means an area with low rainfall, steep slope, the minimum temperature for camel, maximum temperature for goat and cattle, shrubs LULC type for cattle, farmland for camel and goat.

Finally, an area occupied by forest and the built-up area was restricted from suitability analysis due to this it is protected area from livestock access; especially forest of the study area is under control or within the boundary of Bale Mountain National Park is a protected area. (Dessalegn,2009 and Fikaku,2011) in their study on rangeland suitability analysis also restrict forest and built-up area from suitability analysis. The total area in hectare and percent share of suitability class is indicated in table 10 below.

Table 10: Environmental suitability class area for cattle, goat and camel

Livestock species	Suitability class	Area_ hectare	Percent%
cattle	Restricted	79325.44	16
	Highly suitable	11383.89	3
	Moderately suitable	315593.26	64
	Marginally suitable	82278.52	17
	Not suitable	762.48	0.0015
	Total	489343.59	100
Goat	Restricted	79325.44	16
	Highly suitable	27766.24	6
	Moderately suitable	324362.86	66
	Marginally suitable	57871.06	12
	Not suitable	18	0.003
	Total	489343.59	100
Camel	Restricted	79325.44	16
	Highly suitable	54047.77	11
	Moderately suitable	301239.23	62
	Marginally suitable	54655.27	11
	Not suitable	45.9	0.001
	Total	489343.59	100

As indicated in the above table 10; 11383.89hec, 27766.24hec and 54047.77hec were identified as highly suitable for cattle, goat, and camel production. But, when compared with a total area of woreda it is small this happen due to the large area of the woreda is covered by woodland, shrubland, high temperature, low rainfall and conversion of grazing land into farmland; this makes difficult for grazer like cattle as they prefer open grassland to feed on and sufficient water availability. For browsers like goat and camel, they need open shrubs land and woodland. As revealed by (Chibssaa and Flinton,2017) most of the study area is covered by thorn bush which is unpalatable for cattle; thus, it needs bush clearance to make it more suitable for cattle production. They also mentioned the situation increased as the government prevents bush clearance by fire. But currently, non-governmental organizations have started bush clearance in

Berak PA and Naniga Dera PA as a pilot test which was used to increase the availability of open grassland for cattle. According to their study local government (Woreda rural land use and administration and Investment office was allocating grazing land to investors for crop agriculture; especially in Beraq, Kale golba, and Nanigadera PA, making pressure on available grazing land and local community due to conflict with an investor. A large part of the study which is 315593.26hec, 324362.86hec, 301239.23hec were identified as moderately suitable for cattle, Goat, and Camel production attributed by woodland large area coverage. Cattle use litter dropped from woodland were as camel and goat feed on woodland but it is not preferable feed for these animals. An insignificant part of the land is not suitable for cattle, goat, and camel which is 762.48hek,18hek, and 45.9hek respectively.

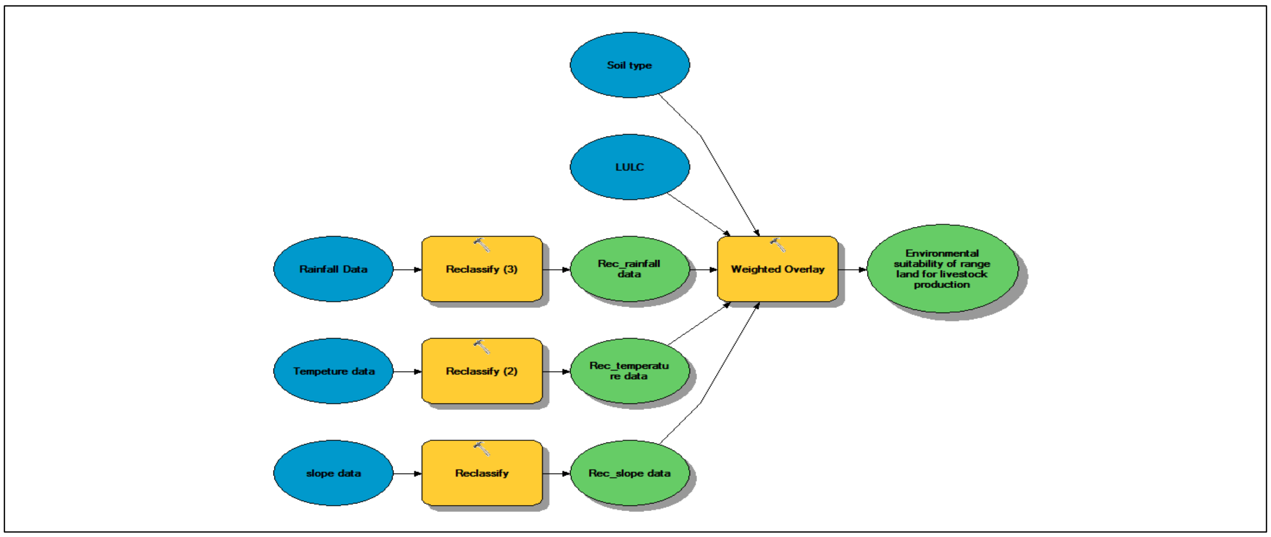

Figure 21: Environmental suitability scheme to determine rangeland suitability for cattle, Goat and Camel using ArcGIS 10.3.1 model builder**.**

4.2. Socioeconomic (infrastructural factors) suitability analysis

Rangeland suitability analysis for livestock production based on infrastructure factors: access to animal health service as indicated in table 11 most of the study area was marginally suitable for camel and not suitable for cattle and goat production. The land of the study area which accounts for 21% (100015hec) was moderately suitable for these categories of animals. Similarly, 28% was marginally suitable for cattle, goat, and 49% (239729.31hec) camel production. Furthermore, 14% of the study area was highly suitable which is a small portion of the study area. Also, 16% and 37% (182223.4hec) of rangeland fell under not suitable for camel and cattle and goat production. This implies the available animal health service center were inaccessible for this livestock due to this center being insufficient in quantity and quality. Moreover, based on access to the market; As table 11 below depicts that small part the study area which was 15% (74343.31hec) and 4% (21843.81hec) highly suitable for cattle, goat, and camel production respectively. Besides, the area which was identified as moderately suitable which accounts 21% (100880.79hec) for cattle, goat, and 13% (62479.89hec) for a camel. Moreover, the rangeland of 20% (100541.48hec) for cattle and goat,22% (105402.51hec) for camel was marginally suitable. But a large part of the area fell under not suitable for livestock production which shares 44% (213645.04hec) for cattle and goat and 61% (299617.38hec) for the camel. Furthermore, in the study area, there is only three and one market center to sell cattle, goat, and camel respectively; for that reason, a large portion of the area fell under not suitable. Thus, the study area based on access to a market is not currently suitable for cattle, goat, and camel.

Table 11: Infrastructural suitability class area for cattle, goat, and camel

Suitability class access to health service	Cattle		Goat		Camel	
	Area(he)	Percent (%)	Area(he)	Percent (%)	Area(he)	Percent (%)
Highly suitable	69881.47	14	69881.47	14	69881.47	14
Moderately suitable	100015	21	100015	21	100015	21
Marginally suitable	137223.7	28	137223.7	28	239729.31	49
Not suitable	182223.4	37	182223.4	37	79717.81	16
Total	489343.59	100	489343.59	100	489343.59	100
Suitability class access to market						
Highly suitable	74326.55	15	74326.55	15	21843.81	4
Moderately suitable	100864.03	21	100864.03	21	62479.89	13
Marginally suitable	100524.72	20	100524.72	20	105402.51	22
Not suitable	213628.28	44	213628.28	44	299617.38	61
Total	489343.59	100	489343.59	100	489343.59	100

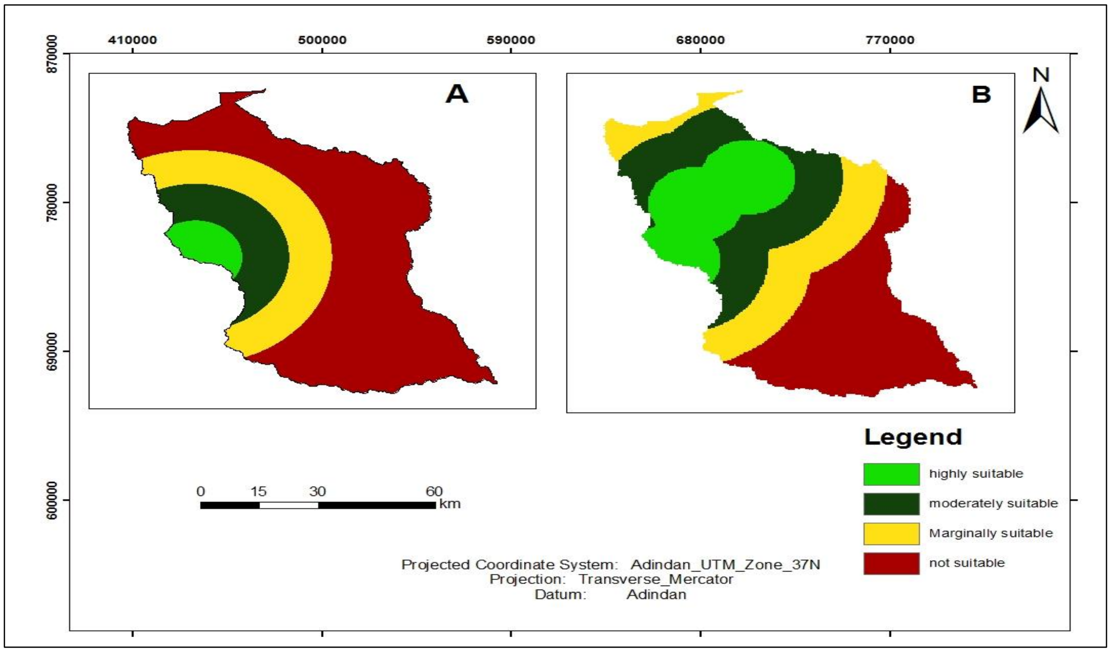

Figure 22: Access to market suitability map for A= camel, B = Goat and cattle

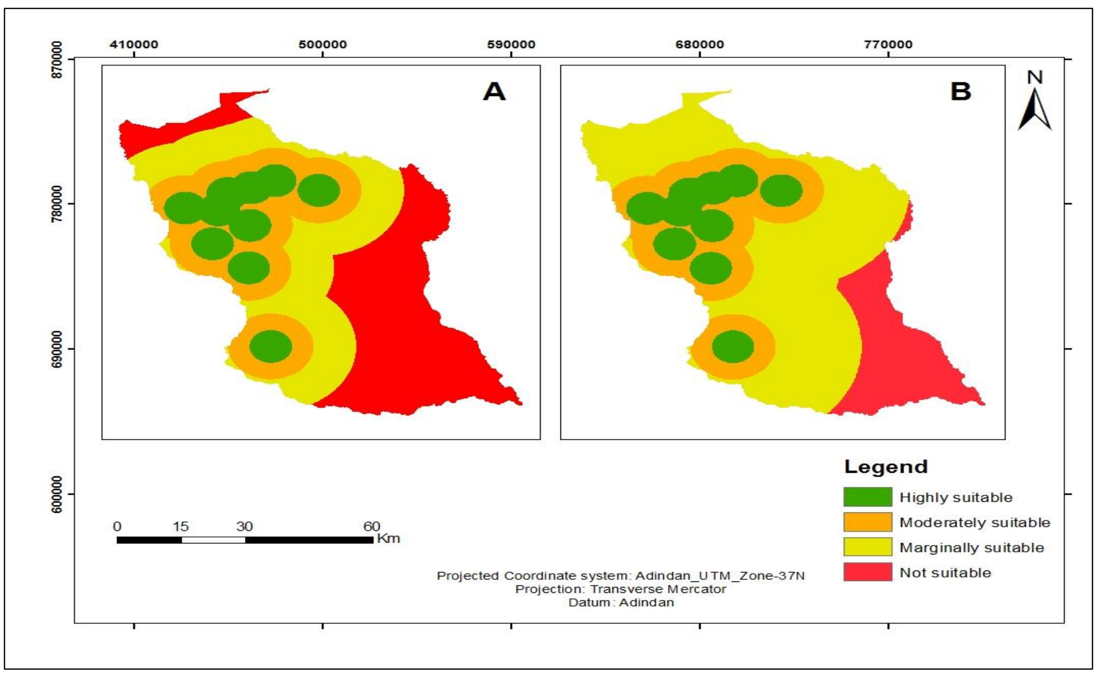

Figure 23: Access to veterinary services suitability map A= Cattle and Goat, B= Camel

As indicated in the figure,22 of the market suitability map highly suitable areas for camel was found at the eastern periphery of the study while for cattle and goat on the northern part of woreda extending from east to west. As the distance from market increases, it is suitability decreases; due to animal losing their weight in long treks this in turn affects the community to sell their livestock at a proper price. Regarding animal health service, as indicated in the figure,23 above it concentrated in the northeastern part of woreda leaving large areas of woreda unsuitable for cattle and goat production. Thus, a large area of woreda constrained animal health service where animals take vaccination, treatment, and diagnosis. Moreover, according to woreda livestock development office and field observation the available animal health post and clinics is not fully giving above service for various reasons such as lack drugs, electric power, budget and professional veterinary expert so it is difficult for woreda to protect and control the outbreak of animal disease.

4.3. Final suitability analysis

Final rangeland suitability model map generated for livestock production (cattle, goat and camel) in the study area concerning two criteria; environmental and infrastructure (socio-economic) combining seven factors (LULC, slope, soil type, rainfall, temperature, access to market, and animal health service).

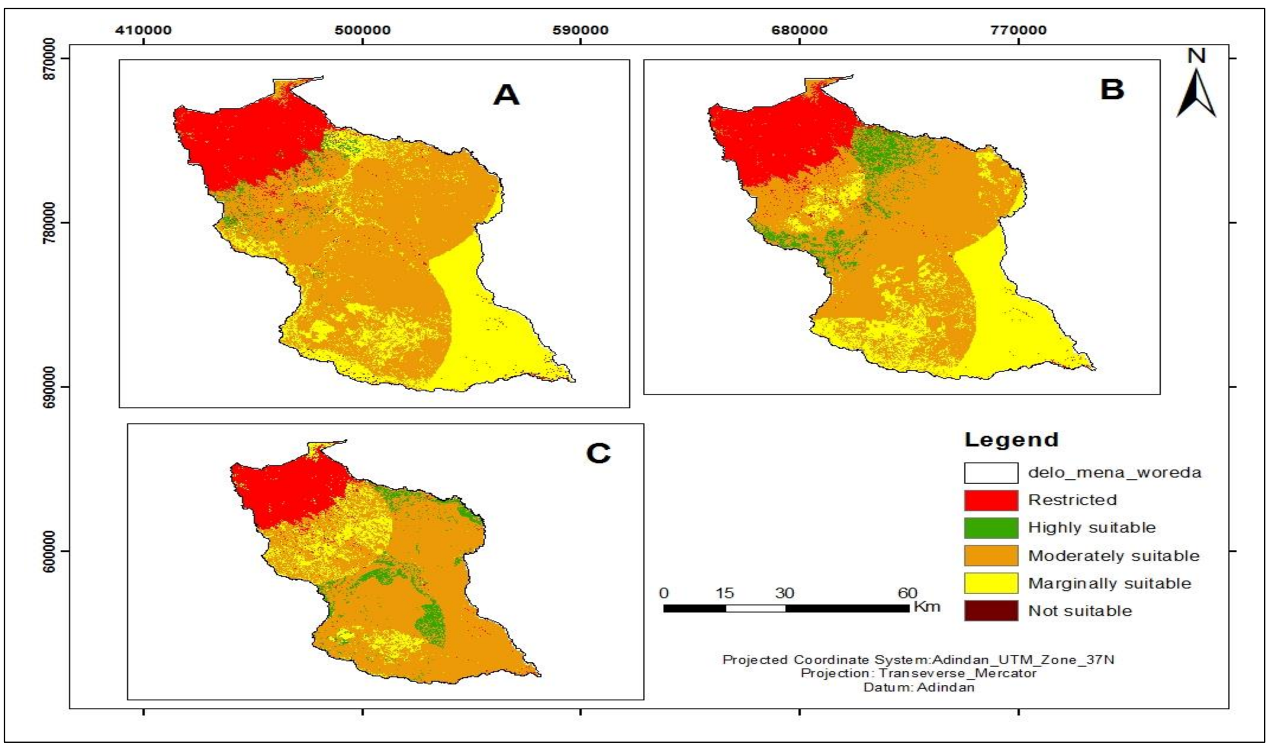

Figure 24: Final suitability map of study area A= Cattle, B= Goat, C= Camel

The result of this study shows as indicated in the above figure,24 central and western part, east to west and north part of the study is highly suitable for camel, goat, and cattle production. These areas were identified as highly suitable due this area satisfies all criteria of suitability analysis for livestock production which means area: that fulfil all environmental factors (gentle slope gradient especially for cattle and camel, high water availability for vegetation growth and drinking, fertile soil type, etc.) and nearer to market center and veterinary service; which account 2%, 5% and 7% for cattle, goat and camel out of total area respectively. But it is the smallest out of the total area of study leaving a large part of the study area under moderately suitable for these categories of livestock. According to the study of (Leta & Mesele, 2014) the area nearer to the market center and all-weather road within 10km for cattle and goat and 12km for camel radius accompanied by the highest livestock population. Which implies market accessibility influences livestock production and productivity.

A parcel of land that fulfils the medium requirement of factors was assigned as moderately suitable for cattle, goat and camel that means an area with optimum environmental factors, medium distance to market and animal health services which is less than 20km, 24km for camel and 10km respectively. Accordingly, a large part of the study area fell under this suitability class locating south to a central part of as indicated in above suitability model map. Similarly, marginally suitability class which account 26% for cattle, goat and 11% for camel production locating north part and insignificant amount on the south part but for cattle and goat production southern part and a small share of central part were identified as marginally suitable.

Furthermore, an area with unsuitable environmental factors and distant from market center and animal health service above 30km, 35km and 20km, 30km respectively were classified as not suitable for Cattle, goat and camel production respectively. But this type of suitability class has insignificant share out of the total area which is around 0.001%. But 16% of the land is restricted from suitability analysis. The suitability class area coverage is indicated in Table 12 below.

Table 12: Final suitability area for cattle, goat and camel

Livestock species	Suitability class	Area_ hectare	Percent %
	Restricted	79297.335	16
Cattle	Highly suitable	10069.245	2
	Moderately suitable	269815.815	55
	Marginally suitable	129403.395	26
	Not suitable	757.8	0.0015
	Total	489343.59	100
	Restricted	79297.4475	16
Goat	Highly suitable	25646.3775	5
	Moderately suitable	256042.1475	52
	Marginally suitable	128339.6175	26
	Not suitable	18	0.003
	Total	489343.59	100
	Restricted	79324.83	16
Camel	Highly suitable	32310.18	7
	Moderately suitable	323004.24	66
	Marginally suitable	54658.44	11
	Not suitable	45.9	0.001
	Total	489343.59	100

As indicated in the above table,12 lands of woreda fell under highly suitable shares small percentage out of the total area which is 10069.25hec,25646.44hec and 32310.2hec for cattle, goat and camel respectively. This implies large parts of the study area were inaccessible to animals' health service and market center and lacks suitable environmental conditions. To improve livestock productivity and to commercialize livestock and its product animal health services and favorable environmental conditions is important. According to 15 years livestock sector strategy of (Asfaw Negassa et al., 2017) only 30% of livestock keeper can reach animal health service, this also a case in the study area in which there is limited animal health service with limited function. They suggest also to overcome the situation animal health strategy is essential to increase access to animal health service through privatization of veterinary clinics and their extension to smaller holder systems is needed.

Additionally, moderately suitable class cover a large area which is 269815.82hec, 256042.37hec and 323004.18hec for cattle goat and camel respectively this show the moderately suitable class area is high for camel when we compare with other animals due to camel inclination or versatility of nourishing is distinctive from cattle and goat too it's capacity to withstand drought as (Tefera and Abebe, 2015) described in their book titled camel in Ethiopia. The area with low environmental suitability,10-20km, and 10-30km distance for animal health service and 20-30km and 24-35km far from the market center was identified as marginally suitable for livestock production which covers the area of 129403.395hec,128339.6175hec and 54658.44hec for cattle, goat and camel production respectively.

Finally, livestock needs suitable environmental conditions, access to veterinary service and market center considering road infrastructure, gentle slope gradient and palatable LULC to increase production and productivity of livestock. Even though livestock plays a significant role in the country's economy and livelihood of rural communities, the government gave little attention to this sector in terms of policy and development especially pastoral area is marginalized from government policy for a long time as mentioned in the various study. Thus, the government have to pay attention to this sector to improve the livelihood of rural community, pastoral and agro-pastoral that are largely dependent on this sector.

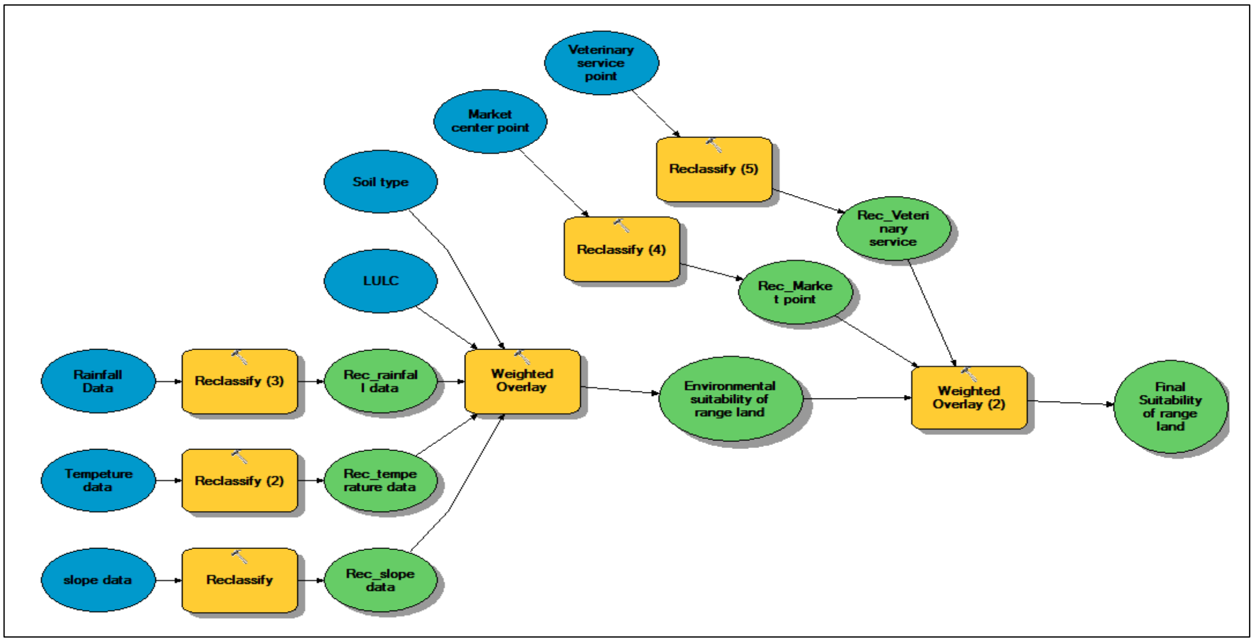

Figure 25: Final suitability scheme used to determine rangeland suitability for cattle, Goat and Camel using ArcGIS 10.3.1 model builder.

4.4. Livestock spatial distribution

Depending on data of livestock collected from woreda livestock development office 2012 dot map and livestock density for cattle, goat and camel was produced for 14 PA of Delo woreda as depicted in the figure,24 and table,13 below. As data gained from woreda shows cattle and goat was found almost in all PA with a variation of number but the camel was found only in 11 PA. Furthermore, cattle and goat were distributed in the area restricted from suitability analysis such as forest but camel somehow found in the area included in suitability analysis.

According to below table,12 Kalegolba PA was the most leading PA in the number of cattle, goat and camel which is 35853,33561 and 9118 respectively; followed by Berak PA with 34051,30492 and 8764 number of cattle, goat and camel respectively. The smallest number of cattle, goat and camel was found in Oda Dima which is 4773, 1087 and 32 respectively. Among the total number of concerned livestock (cattle, goat and camel) distributed camel is the smallest population in the study area. As far as we consider the spatial distribution of this livestock cattle is the prominent animal herded largely in the woreda.

Table 13: Livestock distribution and density of cattle, goat and camel

Id	kebele	Cattle	Cattle density	goat	goat density	camel	Camel density	total	Kebele area_ Km^2	Total density
1	Baraaq	34051	17	30492	15	8764	4	73307	2008.15	37
2	N/dheraa	16045	88	28137	154	3528	19	47710	182.59	261
3	M/Amanaa	32012	333	12543	130	6879	72	51434	96.17	535
4	Gomgomaa	29380	309	14286	150	5318	56	48984	95.14	515
5	Cirrii	31895	112	4872	17	214	0.75	36981	286.06	129
6	Waabaroo	11502	82	4102	29	-	-	15604	140.9	111
7	Burqituu	35061	188	4418	24	-	-	39479	186.35	212
8	H/odaa	9481	94	8984	89	2883	29	21348	100.59	212
9	Irbaa	19744	145	3478	26	86	0.63	23308	135.44	172
10	W/Gudinaa	24449	207	5478	46	1134	10	31061	118.16	263
11	Dayyuu	25787	246	10278	98	4124	39	40189	104.87	383
12	O/Diimaa	4773	31	1087	7	32	0.21	5892	152.39	39
13	Bobiyaa	5986	100	1293	22	-		7279	59.67	122
14	K/Golbaa	35853	29	33561	27	9118	7	78532	1226.86	64
total		316019		163009		42080		521108	4893.34	

Source: Delo Mena Woreda Livestock Development Office,2020

Livestock density is essential to know the carrying capacity of land or the effects of livestock on the environment. Thus, as mentioned by (Leta and Mesele,2014) it is calculated by dividing total livestock available in PA to the total area of PA. Accordingly, the highest density of livestock population is found in Melka Amana PA which is 535 animals per square kilometer followed by Gomgoma PA, 515 animals per square kilometer; the lowest density livestock population goes to Berak and Kale Golba which is less 36 and 64 animals per square kilometer respectively. Hence the main problem in the area regarding the spatial distribution of livestock and density is seasonal migration. As stated by (Chibssaa and Flinton,2017) During the rainy season they migrate to kola PA, s Like Berak and Naniga Dera to escape tseth fly but in dry time the community migrate to forest PA, s like Ciri, Webaro and Burkitu to avoid contraction of disease caused by tortoise bones and shortage of water. In addition to local migration, PA like Berak accommodate livestock of more than three adjacent woredas, during the rainy season, this makes it difficult to express the exact density of livestock.

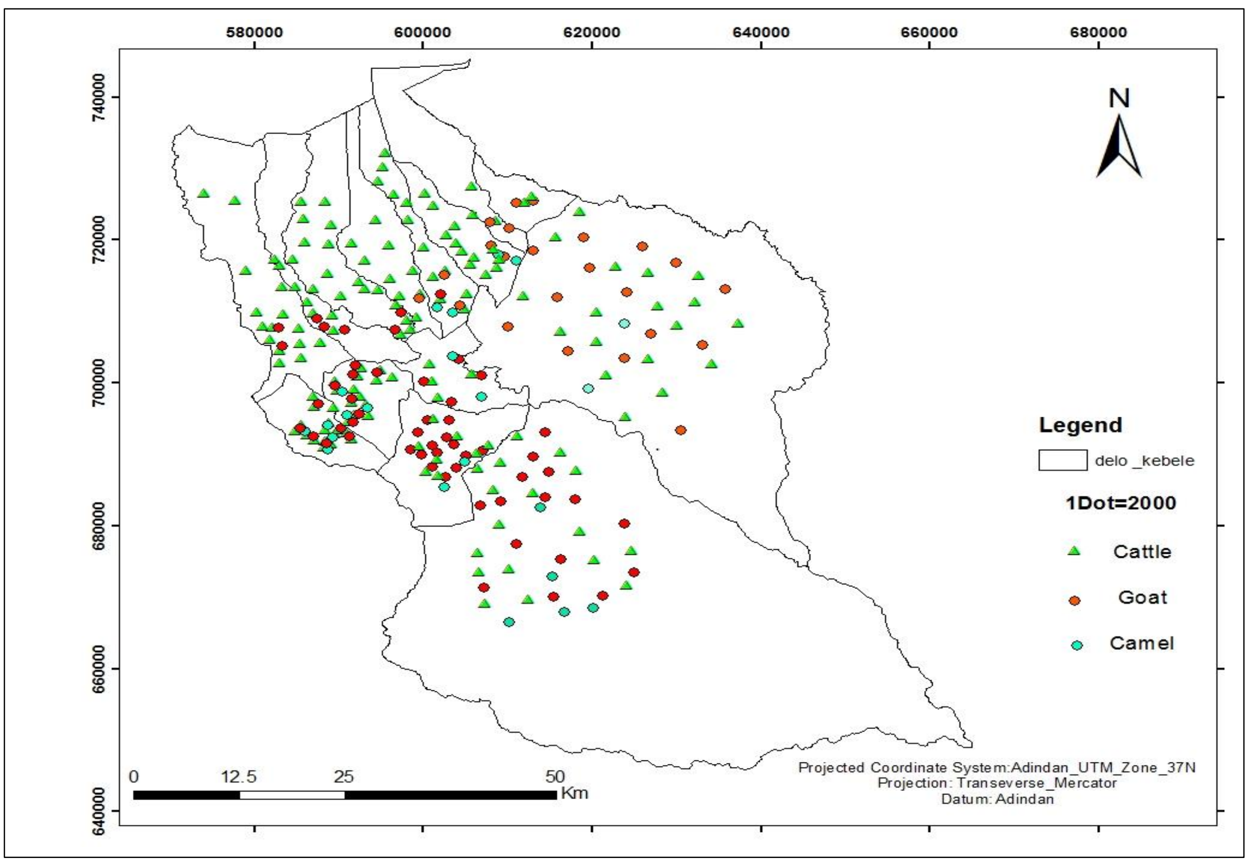

Figure 26: livestock distribution dot map of the study area

4.5. Discussion

In Ethiopia livelihood of agro-pastoral and pastoral community is dependent on livestock directly or indirectly in which its efficiency depends on the environment that supports livestock and the success of the livestock sector. As mentioned by (Terfa and Suryabhagavan,2015), appropriate land-use decisions are vital to achieve optimum productivity of the land and to ensure environmental sustainability.

As stated by (Bizuwerk, et al.,2005), GIS is the best tool to integrate the different land characteristics that differ spatially and to identify the best suitable land use. To exploit the land resources sustainably, a land-use plan that incorporates the different land characteristics has paramount significance. Thus, to identify suitable rangeland for livestock production various study uses GIS with spatial decision making such as (Bizuwerk, et al.,2005, Abebe,2006, Desselegn,2009, Fikadu,2011 and Terfa and Suryabhagavan, 2015) considering different factors. But (Bizuwerk, et al.,2005) uses livestock grazing model of three components which is soil sensitivity to erosion, water quality and quantity and forage production model to determine grazing pressure and land suitability analysis in upland Awash which is a different approach.

Therefore, the study uses GIS with MCE to identify suitable land for livestock production considering two criteria and seven factors such as environmental factors (LULC, Rainfall, Temperature, slope and soil type) and infrastructure factors (access to market and animal health service) which is overlooked by some of the above-traced researchers in their study. To determine the relative's importance of selected factors AHP method was applied which is developed by Saaty, (1980) one of multi-criteria decision-making methods that derive a ratio scale from the paired comparison. All selected factors to analyze land suitability for livestock production have no equal importance for a case MCE is essential to overcome this problem. In this study, pairwise comparison was used to derive weight for selected factors in a way similar to other studies of land suitability. Accordingly, among selected factors LULC gain highest weight and important factors than other factors in identifying land suitability for livestock production. (Abebe,2006 and Dessalegn,2009) in their study of rangeland suitability analysis also gave the highest weight for LULC. But (Fikadu,2011) gives the highest weight for biomass which is calculated from the dry matter of LULC. Considering LULC Delo Mena woreda was marginally suitable for cattle and moderately suitable for goat and camel this because of shrubs and the thorny bush which is not palatable for cattle.

In livestock production ease access to market and animal health service for dispersed rural community is important. AS (Terfa and Suryabhagavan,2015; Leta and Mesele,2014) discussed in their study distance from the market center can influences the prices of animals as long-distance trekking to market was protected herders to sell their stock profitably because animals lose weight during a long journey to market. A large part of the study area was not suitable for camel production based on access to the market because there is only one market center to sell camel. Thus, herders can trek more than 50km on average to access this market and go adjacent woreda which is more than 80km to sell their camel according to the woreda livestock and development office. Access to quality veterinary service is also an important factor; it improves livestock productivity and production and indirectly increases livestock export (live animal and their product) through protecting animal health. But (Shapiro, B.I. et. al,2015) reported that the current provision of animal health services is inadequate both in terms of coverage and quality in Ethiopia. There are very few private veterinary service providers, other than veterinary drug importers and distributors, a few private veterinary pharmacies and too few operational community animal health workers (CAHWs) usually supported by a non-government organization. This problem is also available in the study which is indicated by a small number of animals' health posts and clinics with insufficient animal health workers.

After each factors map were reclassified and standardized into a common scale ranging from 1 to 4;(highly suitable to Not suitable); then the weight is assigned to all factors map to aggregate them using GIS overlay techniques. According to (Malczewski, 2004) the overlay techniques allow the evaluation criterion map layers (input maps) to be combined to determine the composite map layer (output map). This study used the weighted linear combination to aggregate factors map, the method which is widely used in suitability analysis because of it is the simplicity to implement within GIS environment using overlay capabilities of GIS as reviewed by (Malczewski, 2000). Accordingly, a suitability class map was generated for cattle, goat and camel.

CHAPTER FIVE

5. Conclusion and Recommendation

5.1. Conclusion

This study aimed to analyze rangeland suitability for livestock production in Bale zone Delo Mena woreda to support decision making in livestock production development. Rangeland suitability for livestock is essential information for livestock improvement and planning. To achieve the objective this study the study used GIS with multi-criteria evaluation considering seven factors that limit rangeland suitability for livestock production; Namely LULC, slope, soil type, rainfall, temperature, access to the market center and access to animal health service. These factors were reclassified and aggregated based on their importance to generate a suitability map for cattle, goat and camel.

Rangeland suitability analysis for livestock is a piece of very significant information for livestock development on a sustainable basis and future planning which in turn contribute to country economic development, livelihoods of communities and to minimize the environmental impact of livestock. Accordingly, final suitability results show that out of total land of study area 14% lands highly suitable for cattle, goat and camel production due to poor access to the market center, animal health service, minimum area of open grassland especially for grazer (cattle), bush encroachment, conversion of grazing land to cropland and large area coverage of protected forest. But a large part of the study area fell under moderately suitable for cattle, goat and camel production. The smallest portion of the study area is not fulfilling or satisfies factors relatively important for livestock production.

Livestock of the study area is distributed unevenly across the area and also distributed in the protected forest. But this distribution varies between dry and rainy seasons as the community of the area make seasonal migration. This cause degradation to protected forest and overgrazing as most of PA, s livestock migrate toward the same area during migration. To reduce this problem making area suitable on a sustainable base for livestock to stay one area for a long period were essential. Moreover, high density of concerned livestock is found in Malka Amana PA which is 535animal per Km^2 and the lowest density is found in Berak PA 36 animals per Km^2.

5.2. Recommendation

This study only concerned with environmental and infrastructure factors such as slope, temperature, rainfall, soil type, LULC, access to market and veterinary service. But this not only limiting factors for livestock production; so, further research is required to advance the finding from this study in the future by incorporating socio-economic criteria such as, (income, market information, preferences and perception of the community) and Above ground rangeland biomass inventory and grazing land carrying capacity.

Based on the finding of this study, small part study area fell under highly suitable despite large size land in woreda where livelihoods of the most community depend on so, the concerned body has to work on to improve rangeland quality through proper rangeland management.

The government has to implement effective and efficient land use planning policy to help the community in sustainable livestock development as a large percent community depends on livestock to sustain their livelihoods and meanwhile livestock is an important contributor to country economic development.

References

Abebe, A. (2006). GIS applications in suitability modeling for livestock production in Tana sub-basin Blue Nile river basin, Ethiopia. Unpublished MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Addis, B & Dida, K. (2015). Review on Factors Affecting Livestock Market Price in Lowland Area of Ethiopia. *Advances in Life Science and Technology*, *37*, 18–23. www.iiste.org

Alemayehu, M., Gezahagn, K., Fekede, F. (2018). Status of Ethiopian Rangelands: with Special Reference to Southern Rangeland. *International Journal of Agriculture and Biosciences*, 175–181. www.ijagbio.com

Angerer, J. P. (2012). *Technologies, tools and methodologies for forage evaluation in grasslands and rangelands*.

Asfaw, N., Shahidur, R., & Berhanu, G., Adem, K. (2015). *Livestock Production and Marketing in Ethiopia 6 Livestock Production and Marketing*. *August*.

ASL2050. (2018). *Livestock and livelihoods spotlight Ethiopia.FAO, Addis Ababa, Ethiopia*.

Awgachew, S., Flintan, F., & Bekure, S. (2015). *Participatory rangeland management planning and its implementation in Ethiopia "2015 world bank conference on land and poverty."*

Awgachew, S., Flintan, F., & Bekure, S. (2016). Improving security of right to resources through participatory rangeland management Ethiopia. *Paper Prepared for Presentation at the "2016 World Bank Conference on Land and Poverty*.

Ayele, G., Hayicho, H., & Alemu, M. (2019). *Land Use Land Cover Change Detection and Deforestation Modeling : In Delomena District of Bale Zone, Ethiopia*. 532–561. https://doi.org/10.4236/jep.2019.104031

Barry, Sh., Getachew, G., Solomon, D., Asfaw, N., Kidus, N., Aboset, G., & Mechale, H. (2017). Ethiopia livestock sector analysis. *International Livestock Research Institute (ILRI)*, *15 Livestock Sector Strategy*.

Bekele, M. (2018). Determinants of livestock and feed water productivity in the mixed crop-livestock production system of Debre Berhan milk shed central highlands of Ethiopia. *A Dissertation Submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Animal Production*, *34*.

Belete, A., & Aynalem, T. (2017). A Review on Traditional Livestock Movement Systems (Godantu) in Bale Zone : An Implication to Utilization of Natural Resources Open Access Journal of Veterinary Science & Research. *Open Access Journal of Veterinary Science & Research ISSN: 2474-9222 A*, 1–8.

Bengtsson, L. P., Whitaker, J. H., & FAO. (1988). Farm structures in tropical climates*:* A textbook for structural engineering and design. Rome: FAO, 1988.Retrieved from http://www.fao.org/3/s1250e/S1250E10. htm#Animal%20environmental%20requirements.

Bizuwerk, A., Peden, D., Taddese, G., & Getahun, Y. (2005). GIS Application for analysis of Land Suitability and Determination of Grazing Pressure in Upland of the Awash River Basin, Ethiopia. *International Livestock Research Institute (ILRI), Addis Abeba, Ethiopia*.

Bolo, PO., Sommer, R., Kihara, J., Kinyua, M., Nyawira, S., & Notenbaert, A. (2019). Rangeland Degradation : Causes, Consequences, Monitoring Techniques and Remedies. *Working Paper. CIAT Publication No. 478. International Center for Tropical Agriculture (CIAT). Nairobi, Kenya. 23 P. Available at https://hdl.handle.net/10568/102393*.

Canada Centre for Remote Sensing. (2016). *Fundamentals of Remote Sensing*. 258. https://doi.org/10.1016/0301-4207(76)90065-9

Chandio, I.A., & Abdnasir, B.M. (2011). Land Suitability Analysis Using Geographic Information System (GIS) for Hillside Development : A case study of Penang Island. *International Conference on Environmental and Computer Science*, *19*, 1–6.

Congalton, R. G. (1991). A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data. *Remote sens.Environ.*, *46*(April), 35–46.

CSA. (2018). Report On Livestock and Livestock Characteristics (Private Peasant Holdings). *Statistical Bulletin 587*, *II*(April).

Dessalegn, G. (2009). *Remote Sensing and GIS-Based Suitability Analysis For Livestock production In Yabello District Southern Ethiopia.Unpublished MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.*

E.White, R. (2006). *Principles and practice of soil science: The soil as a natural resource* (R. E.White (Ed.); 4th ed.). Blackwell.

Ethiopian Society of Animal Production. (2015). Pasture and Rangeland Research and Development in Ethiopia. *2015*.

Fajji, N. G. (2015). *A remote sensing and GIS scheme for rangeland quality assessment and* *management in the north-west province, South Africa: PhD Thesis, Northwest university, South Africa.*

Fajji, N. G., Palamuleni, L. G., & Mlambo, V. (2018). A GIS Scheme for Forage Assessment and Determination of Rangeland Carrying Capacity. *Journal of Remote Sensing and GIS*, *7*(1), 1–11. https://doi.org/10.4172/2469-4134.1000233

FAO. (1976). A framework for Land Evaluation. FAO Soils Bulletin No. 32, Food and Agricultural Organization of United Nation, Rome 1976.

FAO. (1983). Guidelines : land evaluation for extensive grazing.FAO soils bulletin 58

FAO. (1992). The state of food and agriculture in 1991. *(FAO Agriculture Series, no. 24)*.

FAO. (2001). Lecture notes on the major soils of the world. *World Soil Resources Reports No. 94. FAO, Rome.* (F. Paul Driessen, Wageningen Agricultural University, International Institute for Aerospace Survey and Earth Sciences (ITC), Jozef Deckers, Catholic University of Leuven Otto Spaargaren, International Soil Reference and Information Centre Freddy Nachtergaele (Ed.)).

FAO. (2007a). Gridded livestock of the world 2007, by G.R.W. Wint and T.P. Robinson. Rome, pp 131.

FAO. (2007b). Land Evaluation, Towards a revised framework. *Land and Water Discussion Paper*, *6*. *Food and Agricultural Organization of United Nation*.Rome,Italy.

FAO. (2008). Livestock policy and poverty reduction. Livestock policy brief 04, Rome, Italy. http://www.fao.org/3/a-i0265e.pdf

FAO. (2011). Global livestock production systems.Rome, Food and Agricultural Organization of United Nation and International Livestock Research Institut*e (ILRI), 152 pp.*

FAO. (2018). Ethiopia: Report on feed inventory and feed balance,*2018*.Rome.Italy.160pages

FAO. (2019). Livestock, health, livelihoods and the environment in Ethiopia. An integrated analysis. https://creativecommons.org/licenses/by-nc-sa/3.0/igo/legalcode/legalcode)

Farazmand, A., Arzani, H.Javadi, S. A. Sanadgol, A. A. (2019). Determining the factors affecting rangeland suitability for livestock and wildlife grazing. *Applied Ecology and Environmental Research*, *17*(1), 317–329. https://doi.org/http://dx.doi.org/10.15666/aeer/1701_317329

Farm, Africa. (2017). Farm Africa *Annual impact report 2017*.

Fazel, A., Abdrashid, M. S., & Taybeh, T. (2012). *Monitoring Land Suitability for Mixed Livestock Grazing Using Geographic Information System (GIS)*. https://doi.org/http://dx.doi.org/10.5772/47939.

Fenetahun, Y., Xu, X., & Wang, Y. (2018). *Assessment of Range Land Degradation, Major Causes, Impacts , and Alternative Rehabilitation Techniques in Yabello Rangelands Southern Ethiopia. Review paper*. *July*, 1–19. https://doi.org/10.20944/preprints201807.0198.v1

Fikadu, L. (2011). *Rangeland suitability analysis for livestock production using GIS and Remote sensing : The case of Yabello Woreda, Southern.Unpublished MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia. February*.

Flintan, F. (2014). *Plotting progress: integrated planning in the rangelands of Kenya, Ethiopia, and Uganda*.

GebreMariam, S., Samuel, A., Beker, D., Solomon, A.,& Davies, R. (2013). Study of the Ethiopian live cattle and beef value chain. *ILRI Discussion Paper 23 International Livestock Research Institute (ILRI) This*. http://creativecommons.org/licenses/by-nc-sa/3.0/

Gebremeskel, Esayas, N., Solomon, D., & Girma, K. K. (2019). Pastoral Development in Ethiopia:Trends and the Way Forward''. *Development Knowledge and Learning. World Bank,Washington, DC*.

Gemedo, D. (2006). Rangeland condition and trend in the semi-arid Borana lowlands , southern Oromia,Ethiopia. *African Journal of Range & Forage Science*. https://doi.org/10.2989/10220110609485886

Geta, T. (2015). An Appraisal on Rangeland Resources and Its Current Status in Ethiopia : Challenges and Opportunities. *International Journal of Emerging Technology and Advanced Engineering*, *5*(8), 352–356.

Girma, A & Kenate, W. (2017). GIS Based Land-Use Suitability Analysis for Selected Perennial Crops in Gumay Woreda of Jimma Zone, South West Ethiopia. *Ethiop.j.soc.lang.stud. 4(1),* 3–18. http://www.ju.edu.et/cssljournal/

GSARS. (2018). *Guidelines on methods for estimating livestock production and productivity*.

IGAD. (2013). IGAD Drought disaster resilience and sustainability. *THE IDDRSI Strategy*, *January*, 1–40.

IUSS Working Group WRB. (2015). *World reference base for soil resources 2014 International soil classification system.World Soil Resources Reports No. 106. FAO, Rome.*

Jafari, S., & Zaredar, N. (2010). Land Suitability Analysis using Multi Attribute Decision Making Approach. *International Journal of Environmental Science and Development*, *1*(5), 441–445. https://doi.org/10.7763/ijesd.2010.v1.85

John, R. J. (2015). *Intoductory Digital image processing: a remote sensing perspective* (K. C.Clarke (Ed.); 4th ed.). Pearson series in geographic information science.

Kahsay, A., Haile, M., Gebresamuel, G., Mohammed, M., & Moral, M. T. (2018). Land suitability analysis for sorghum crop production in northern semi-arid Ethiopia : Application of GIS-based fuzzy AHP approach. *Cogent Food & Agriculture*, *4*(0), 1–24. https://doi.org/10.1080/23311932.2018.1507184

Kedu, A. (2019). Causes and Effects of Rangeland Degradation in the Lowland Districts of the Bale Eco-Region , Southeastern Ethiopia. *Journal of Rangeland Science, 2019, Vol. 9, No. 3*, *9*(3), 259–276.

Kefelegn, G., Baykedagn, T., Dessalegn, O.,& Sinteyehu, L. G. (2019). Using Geospatial Techniques in the Selection of Potential Ecotourism. *Ghana Journal of Geography Vol. 11(1), 2019 Pages 201 – 227*, *11*(1), 201–227. https://doi.org/DOI: https://dx.doi.org/10.4314/gjg.v11i1.12

Lamy, E., Harten, S.V., Sales-baptista, E., Manuela, M.,Mendes,G.,& Andre, M. (2012). *Factors Influencing Livestock Productivity* (Issue January). https://doi.org/10.1007/978-3-642-29205-7

Leta, S., & Mesele, F. (2014). Spatial analysis of cattle and shoat population in Ethiopia: Growth trend, distribution and market access. *SpringerPlus, 3*(1), 1–10. https://doi.org/10.1186/2193-1801-3-310

Maddahi, Z., Jalalian, A., Masoud, M., Zarkesh, K., & Honarjo, N. (2014). Land suitability analysis for rice cultivation using multi criteria evaluation approach and GIS. *European Journal of Experimental Biology, 2014, 4(3):639-648 ISSN:*, *4*(3), 639–648.

Malczewski, J. (2000). Review Article On the Use of Weighted Linear Combination Method in GIS : Common and Best Practice Approaches. *Transaction in GIS,200,4(1):5-22*, *4*(1).

Malczewski, J. (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning 62 (2004) 3–65*, *62*, 3–65. https://doi.org/10.1016/j.progress.2003.09.002

Malczewski, J. (2006). GIS-based multicriteria decision analysis: A survey of the literature. *International Journal of Geographical Information Science*, *20*(7), 703–726. https://doi.org/10.1080/13658810600661508.

Melaku, T & Abebe, G. (Ed.). (2015). *Camel in Ethiopia 2012* (Issue January 2012). Ethiopian Veterinary Association.

Melvin, G., Deker, B., Micheal, B., David, G., Gene, S.,&Norm, H. (2007). Factors and Practices that Influence Livestock Distribution. University of California Division of Agriculture and Natural Resources. *Rangeland Management Series,8217,University of Calfornia*.

Ministry of Finance and Economic Development. (2012). *Ethiopia's medium term debt management strategy (2013-2017) Addis Ababa*. *October 2012*, 1–66.

Ministry of Finance and Economic Develpment. (2013). *Growth and Transformation Plan*. *March*.

Mohammed, M., Hakim, H., & Mukeram, T. (2016). Rangeland degradation: extent, impacts, and alternative restoration techniques in the rangelands of Ethiopia. *Tropical and Subtropical Agroecosystems*, *19*, 305–318.

Mowlid, H., Mohamed, A., Mohamud, A., Abdurahman, A., & Apparao, T. (2018). Assessment of Rangeland resource utilization and management practice on pastoralist in Afdem District Of Sitti Zone, Somali State, Ethiopia. *Global Scientific Journals*, *6*(11), 215–233.

Myagmartseren, P., Buyandelger, M., & Brandt, S. A. (2017). Implications of a Spatial Multicriteria Decision Analysis for Urban Development in Ulaanbaatar, Mongolia. *Hindawi Mathematical Problems in Engineering*, *2017*, 16. https://doi.org/https://doi.org/10.1155/2017/2819795

Nyeko, M. (2012). GIS and Multi-Criteria Decision Analysis for Land Use Resource Planning. *Journal of Geographic Information System, 2012, 4, 341-348, August*, 341–348. https://doi.org/http://dx.doi.org/10.4236/jgis.2012.44039

PCDP. (2016). Project performance assessment report Federal democratic republic of Ethiopia pastoral. *IEG Sustainable Development Independent*, *104210*.

Robinson, T. P., Wint, G. R. W., Conchedda, G., Boeckel, T. P. Van, Ercoli, V., Palamara, E., Cinardi, G., Aietti, L. D., Hay, S. I., & Gilbert, M. (2014). Mapping the Global Distribution of Livestock. *PLoS ONE 9(5): e96084*, *9*(5). https://doi.org/10.1371/journal.pone.0096084

Sejian, V., Naqvi, S. M. K., Ezeji, T., Lakritz, J., & Lal, R. (Eds.). (2012). *Environmental Stress* *and Amelioration in Livestock Production*. Springer-Verlag Berlin Heidelberg. https://doi.org/DOI 10.1007/978-3-642-29205-7

Terfa, B. K., & Suryabhagavan, K. V. (2015). Rangeland Suitability Evaluation for Livestock Production using Remote Sensing and GIS Techniques in Dire District, Southern Ethiopia. *Global Journal of Science Frontier Research(H)*, *15*(1).

Tewodros, K. (2010). *Geospatial Approach For Ecotourism Development: A case of Bale Mountain National Park, Ethiopia*.

Thornton, P. K. (2010). Livestock production : recent trends, future prospects. *The Royal Society: International Livestock Research Institute (ILRI), Nairobi, Kenya*, 2853–2867. https://doi.org/10.1098/rstb.2010.0134

United Nation, Department of Economic and Social Affairs, Population Division. (2015). World Population Prospects The 2015 Revision: Key Findings and Advance Tables. *Working Paper No.ESA/P/WP.241*.

Wakjira, D. T., Udine, F., & Crawford, A. (2015). Migration and Conservation in the Bale Mountains Ecosystem. *The International Institute for Sustainable Development*, *August*.

Worku, Chibssa & Fona, F. (2017). Land use change in the bale mountains eco-region of Ethiopia: drivers, impacts and future scenarios. *ILRI (International Livestock Research Institute).*

Appendixes

1. Pair-wise comparison matrix and factor weight calculated for goat

1.1.Pair-wise comparison for goat

Factors	LULC	Rainfall	temperature	slope	soil
LULC	1	3	3	3	5
Rainfall	1/3	1	2	3	3
temperature	1/3	1/2	1	3	3
slope	1/3	1/2	1/3	1	2
soil	1/2	1/3	1/3	1/2	1
sum	2.19999933	5.0333333	6.666666	10.333333	15

1.2. Criteria weight of Environmental factors for goat calculated by AHP weight derivation method

Factors	LULC	Rainfall	Temperature	slope	soil	Weight
LULC	0.454545523	0.633802862	0.398230088	0.285714286	0.277777778	0.410014
Rainfall	0.151515023	0.211267621	0.398230088	0.285714286	0.277777778	0.264901
temperature	0.151515174	0.07042247	0.132743363	0.285714286	0.277777778	0.183635
slope	0.151515174	0.042253524	0.044247788	0.095238095	0.111111111	0.088873
soil	0.090909105	0.042253524	0.026548673	0.047619048	0.055555556	0.052577
	1	1	1	1	1	1

1.3 pairwise comparison matrix for the camel

Factors	LULC	Rainfall	Temperature	slope	soil
LULC	1	3	3	3	5
Rainfall	1/3	1	3	5	5
Temperature	1/3	1/3	1	3	5
Slope	1/5	1/5	1/3	1	3
Soil	1/7	1/5	0.2	1/3	1
Sum	2.009523	4.67619	7.533333	12.33333	21

1.4. Criteria weight of Environmental factors for camel calculated by AHP weight derivation method

Factors	LULC	Rainfall	Temperature	slope	soil	Weight
LULC	0.454545592	0.633802862	0.459183697	0.243243243	0.263157895	0.407866
Rainfall	0.15151504	0.21126762	0.30612246	0.40540540	0.26315789	0.2674936
Temperature	0.15151504	0.07042247	0.15306123	0.24324324	0.26315789	0.1762799
slope	0.15151519	0.04225352	0.05102036	0.08108108	0.15789473	0.0967529
soil	0.09090911	0.04225352	0.03061224	0.02702702	0.05263157	0.0486866
	1	1	1	1	1	1

2. A GPS reading for representatives' land use land cover categories

Number	Easting	Northing	LULC Categories
1	611672	695719	cropland
2	611704	618196	cropland
3	608720	697506	cropland
4	607983	698390	cropland
5	608436	666790	cropland
6	614071	676618	cropland
7	608647	678136	cropland
8	596842	706809	cropland
9	597875	706130	cropland
10	606392	716836	cropland
11	606296	716965	cropland
12	606350	716951	cropland
13	606440	717549	cropland
14	606413	717615	cropland
15	606927	717284	cropland
16	606949	717255	cropland
17	589432	709432	cropland
18	589383	709032	cropland
19	589367	708985	cropland
20	589394	708867	cropland
21	589926	709103	cropland
22	590309	709096	cropland
23	636885	710431	cropland
24	641594	703287	cropland
25	644875	711542	cropland
26	616988	695932	cropland
27	601886	715487	cropland

28	601820	715695	cropland
29	597043	713037	cropland
30	595562	711229	cropland
31	596174	708150	cropland
32	587713	690359	woodland
33	587656	690396	woodland
34	615167	715135	woodland
35	606672	717656	woodland
36	606673	717690	woodland
37	606597	717705	woodland
38	606472	717726	woodland
39	592360	698781	woodland
40	589101	690502	woodland
41	589200	690700	woodland
42	611049	716900	woodland
43	603351	716561	woodland
44	600669	703881	woodland
45	633476	690090	woodland
46	634187	686700	woodland
47	623461	707192	woodland
48	625942	705902	woodland
49	620931	703571	woodland
50	605182	694926	woodland
51	596808	693934	woodland
52	596141	695506	woodland
53	615716	701958	woodland
54	613369	703383	woodland
55	607229	705181	woodland
56	606203	704019	woodland
57	606749	703365	woodland
58	599024	703349	woodland
59	598341	702968	woodland
60	599325	704397	woodland
61	595603	703238	woodland
62	620964	722962	woodland
63	621692	723028	woodland
64	622349	713303	woodland
65	622617	712884	woodland
66	594527	709643	forest
67	594535	709707	forest
68	598503	720500	forest
69	599500	720501	forest

70	599505	720000	forest
71	601002	727500	forest
72	600500	726500	forest
73	590010	716505	forest
74	590005	715500	forest
75	590000	715007	forest
76	589500	714000	forest
77	591000	715000	forest
78	601510	727508	forest
79	602000	727000	forest
80	602500	726500	forest
81	603000	726000	forest
82	604000	725012	forest
83	605007	724003	forest
84	597000	724010	forest
85	598020	724000	forest
86	598000	723000	forest
87	589515	713500	forest
88	590500	714014	forest
89	587554	690581	Built-up area
90	587582	690683	Built-up area
91	587708	690984	Built-up area
92	593754	708973	Built-up area
93	593926	708987	Built-up area
94	593940	708915	Built-up area
95	593877	708861	Built-up area
96	594009	709108	Built-up area
97	594200	709263	Built-up area
98	594594	709966	Built-up area
99	606643	717179	Built-up area
100	594182	709249	Built-up area
101	593833	708847	Built-up area
102	594105	708777	Built-up area
103	594223	708726	Built-up area
104	593534	708832	Built-up area
105	593725	708718	Built-up area
106	593837	708849	Built-up area
107	617322	715051	grassland
108	617342	715101	grassland
109	595155	710668	grassland
110	606953	717354	grassland
111	592286	698186	grassland

112	592333	698369	grassland
113	592391	698331	grassland
114	590470	708938	grassland
115	603801	732105	grassland
116	603730	732100	grassland
117	603804	732200	grassland
118	582372	717406	grassland
119	582475	710582	grassland
120	583089	716960	grassland
121	582309	716418	grassland
122	582429	716741	grassland
123	587384	709240	grassland
124	587312	709257	grassland
125	580798	708399	grassland
126	582525	716795	grassland
127	582251	716918	grassland
128	587665	690292	Shrubs land
129	587707	690310	Shrubs land
130	617216	714974	Shrubs land
131	617147	715050	Shrubs land
132	617158	715103	Shrubs land
133	617474	715230	Shrubs land
134	595087	715574	Shrubs land
135	595138	710734	Shrubs land
136	589450	693011	Shrubs land
137	593415	704616	Shrubs land
138	593436	704588	Shrubs land
139	600208	704215	Shrubs land
140	599464	704835	Shrubs land
141	627247	701865	Shrubs land
142	627029	701545	Shrubs land
143	594049	698761	Shrubs land
144	594168	698007	Shrubs land
145	594882	697451	Shrubs land
146	589532	693444	Shrubs land
147	593739	693310	Shrubs land