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RANGELAND SUITABILITY EVALUATION FOR LIVESTOCK PRODUCTION USING REMOTE SENSING AND GIS TECHNIQUES IN DIRE DISTRICT, SOUTHERN ETHIOPIA

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Remote Sensing and GIS

By
Berhanu Keno

Under the guidance of

Dr. K.V. Suryabhagavan

AAU
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June, 2013

D E C L A R A T I O N

I hereby solemnly declare that the dissertation entitled “Rangeland suitability Evaluation for livestock production using Remote sensing and GIS Techniques in Dire District, Southern Ethiopia” has been carried out by me and that, to the best of my knowledge, under the supervision of Dr. K.V.Suryabhagavan, Addis Ababa University, School of Earth Sciences during the year of 2012-2013 as a part of Masters of Science Program in Remote Sensing and GIS. It contains no material previously published or written by another person and has not been previously submitted to any other University or educational institute for an academic qualification or any other degree. The work I am submitting does not contravene any copyright.

Berhanu Keno

Place: Addis Ababa
Date: June 10/2013

C E R T I F I C A T E

This is certified that the dissertation entitled "Rangeland suitability Evaluation for livestock production using Remote sensing and GIS Techniques in Dire District, Southern Ethiopia" is a bona fide work carried out by Berhanu keno under my guidance and supervision. This is the actual work done by Berhanu keno for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University, Addis Ababa.

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Place: Addis Ababa
Date: June 10/2013

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Acronyms

ASAL	Arid and Semi-Arid Land
AVHRR	Advanced Very High Resolution Radiometer
BLPDP	Borana Low Land Pastoralist Development Program
CDD	Community Driven Development
CSA	Central Statistical Agency
DEM	Digital Elevation Model
DM	Decision Making
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resource Data Analysis
FAO	Food and Agriculture Organization
FLDP	Fourth Livestock Development Project
GCP	Ground Control Point
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
IDW	Inverse Distance Weighted
ILCA	International Livestock Center for Africa
KM	Kilometer
LQ	Land Quality
LSA	Land Suitability Analysis
LU/LC	Land use/ Land cover
LUR	Land Utilization Requirement
LUT	Land Utilization Type
MCDA	Multi-criteria Decision Analysis
MCE	Multi-Criteria Evaluation
MOA	Ministry of Agriculture
M.A.S.L	Meters above sea level
MWR	Ministry of Water Resources
NMSA	National Meteorological Stations Agency
NOAA	National Oceanic and Atmospheric Administration
OWWDSE	Oromia Water Works Design and Supervision Enterprise
PA	Peasant Association

PCDP	Pastoral Community Development Project
RRC	Relief and Rehabilitation Commission
SERP	South Eastern Rangeland Project
SERP	Southeast Rangelands Project
SMCDM	Spatial Multi-criteria Decision Making
SORDU	Southern Rangelands Development Unit
SRTM	Shuttle Radar Topography Mission
TLDP	Third Livestock Development Project
TLU	Tropical Livestock Unit
TM	Thematic Mapper
UET	Ultimate Environmental Threshold
UN-EUE	United Nations Emergencies Unit for Ethiopia
UN-OCHA	United Nations-Office for the Coordination of Humanitarian Affairs

Abstract

One of the important issues in practical and sustainable rangeland management is the study of range suitability. Rangelands are complex ecosystems with balanced and accurate relationships among its parts. Correct management of these ecosystems needs adequate knowledge of the various parts to be able to consider their capability for suitable utilizations. Dire district is one of the pastoral districts in southern part of Ethiopia. For many centuries, the rangelands in Dire district were productive. However, high population growth which resulted in increasing demand for arable land, landuse changes, increasing landuse conflicts and bush encroachments led to reduced amount of land for grazing and livestock production. Improper land use results in land degradation and decline in agricultural productivity. Hence, in order to get maximum benefits out of land, proper utilization of its resources is inevitable. Land suitability analysis is needed in order to make proper land use planning. GIS and Remote Sensing offers a convenient and powerful platform to integrate spatially complex and different land attributes for performing land suitability analysis. The present study was intended to analyze and map suitable areas for livestock production in Dire district using GIS and Remote Sensing techniques. Besides, it was aimed at identifying the landcover changes in the study area in the last 25 years and determines the extent and direction of change that has occurred. The study made use of Landsat TM 1986 and 2011 Remote Sensing Satellite Image for analysis to determine the extent and pattern of rangeland change, and Multi Criteria Evaluation in a GIS environment to come up with the final suitability map. In this study, seven suitability factors; rainfall, landuse/landcover, soil, slope, access to water, veterinary service and livestock market center were considered. To arrive at final suitability result for each livestock, weighted overlay technique of Multi-criteria evaluation in a GIS platform was used. The result of the suitability analysis revealed that, 5.6%, 4.9%, 5.4%, and 10.1% of study area is highly suitable for cattle, sheep, goats and camels, respectively. Furthermore 44.75%, 44.15%, 45.5% and 58.6% of the land was classified as moderately suitable for cattle, sheep, goats and camels, respectively. Furthermore, 45.7%, 46.5%, 51% and 31% of the land was classified as marginally suitable for cattle, sheep, goats and camels, respectively. While, 4%, 4.5%, 1.1% and 0.4% were currently not suitable for cattle, sheep, goats and camels, respectively. There is no parcel of land classified as permanently not suitable. Thus, the study showed that the large area of rangeland in Dire district is marginally suitable (with major limitation) for livestock production. The results of the landuse/landcover change detection showed that in the last 25 years, 3 major changes were observed, grass land and open shrub land resource significantly decreased at a rate of 17.1km^2/year and 12 km^2/year/, respectively. On the other hand in 25 years dense bushland, open bush land, dense shrubland and cultivated land has shown increment in size at a rate of 0.23km^2/year, 13.5 km^2/year, 6.3 km^2/year and 0.2 km^2/year, respectively within 25 years. Small area of the district rangeland is highly suitable and wide area of the rangeland is marginally suitable for livestock production. Therefore, implementation of appropriate rangeland management plans in the district is essential. The expansion of unpalatable woody species significantly reduced the rangeland size and availability of grasses. The consequence of the decrease in herbaceous biomass production might result in high risk of food insecurity in the area unless proper interventions are made in time.

Keywords: *GIS and Remote Sensing techniques, Dire District, Rangeland, Suitability analysis, Multi criteria Evaluation, Livestoc*

INTRODUCTION

1.1. Background

Agriculture is the mainstay of Ethiopian's economy and also the major source of employment. Agriculture account 43% of the Gross Domestic Product (GDP) and 86% of the export earnings, and the sector employs about 85% of the population (CSA, 2009). Livestock production is an integral part of the country's agricultural production system. A recent study by CSA (2009) indicated that livestock sector contributes 26% of the agricultural GDP and 12% to the national GDP.

Livestock production is traditional and one of the most important sources of livelihood of farmers in Ethiopia. Livestock play an important role in the household economies of both highland and lowland populations. The most important contributions of livestock in the highlands are traction power for cultivation and haulage and manure. Livestock production is essential for household food security as the pastoralists uses their products directly and to exchange them with other household commodities. In addition, livestock are the most important source of income and widespread form of asset accumulation for rural residents, particularly assets used as hedges against risk and disaster (Hesse and MacGregor, 2006).

Ethiopia has the majority of the pastoralists in the horn of Africa and the major pastoral communities are the Somali (53%), Afar (29%) and Borena (10%) and (8%) is found in Southern Nation and Nationalities, Gambella, Benishanguel Regions (PADS, 2004). The Borana are semi-sedentary pastoralists who are specialized in cattle-keeping, though they may also keep camels and small ruminants Sheep and goats). Recently, increasing number of the Borana communities have also been practicing agriculture, although it is unreliable in dry years. Rainfall in the area is bimodal, with annual averages varying from 450 mm to 700 mm, and drought in the region is recurrent (Ayana Angass, 2007). The area is environmentally heterogeneous. For many centuries, the Borana pastoralists were able to manage their rangelands based on their own experience and traditional knowledge. Their management system involves the interaction between plants, grazing animals, abiotic components and the anthropogenic factors.

The Borana pastoralists and agro-pastoralists in southern Ethiopia have well established traditional systems of range and water management. They use their indigenous knowledge to categorize landscapes not only in terms of seasons of use, but also in terms of grazing capacity (Oba, *et al.,* 2000). The Borana pastoralists classify their rangelands into Kalo, Worra and Foora land use units (Kalo is grazing land for calves, Worra for lactating livestock and Foora for dry livestock). Encroachment of woody plants might vary with these landuse units and/or sites across different districts in the Borana low lands (Gemedo, *et al.,* 2006).

Land suitability analysis is the evaluation and grouping of specific areas of land in terms of their suitability or capability for a defined use. It involves the application of criteria to the landscape to assess where land is most and least suitable for a particular purpose. The suitability of a given piece of land is its natural ability or the biological productivity of the land and its applied management to support a specific purpose. Analyzing suitability is mainly based on the land qualities satisfying the requirements of the landuse (FAO, 2007). Thus, the common way of determining land quality from land characteristics is mainly by assessing and grouping the land types in order and classes according to their values (Atesmachew, *et al*., 2005).

A number of technological developments have facilitated the implementation of land evaluation principles and models. In order to incorporate the different land attributes that differ spatially and to identify the best suitable land use, Geographic information System (GIS) has proved to be the best tool (Bizuwork, *et al.,* 2006). The powerful query, analysis and integration mechanism of GIS makes it an ideal scientific tool to analyze data for land use planning. Management of natural resources based on their potentials and limitations is essential for development of rangeland on a sustainable basis. Today, GIS is a tool that can assist a community to plan and to support the information management during the rangeland production process, while at the same time ensures the proper balance between competing resource values. It can enhance the accessibility and flexibility of information and can improve the linkages and understanding of relationship between different types of information (Baniya, 2008).

1.2. Problem Statement

Land resource is limited in nature and its use is not only determined by the user but also by the land, its characteristics to sustain the production of required goods and services. Inappropriate land use leads to inefficient exploitation of natural resource, destruction of the land resource, poverty and other social problems. Society must ensure that land is not degraded and that it is used according to its capacity to satisfy human needs for present and future generations while also maintaining the earth's ecosystems. Part of the solution to the land-use problem is land evaluation in support of rational land use planning and appropriate and sustainable use of natural and human resources. Most pastoralists occupy a naturally dry environment, which is unsuitable for conventional rain-fed agriculture (Save the Children USA, 2007). Yet, this very same land is ideal for extensive livestock production, the kind of life style that pastoralists are so familiar at managing. In such a fragile setting, proper land management is an absolute necessity.

Ethiopia has great agricultural potential because of its vast areas of fertile land, diverse climate, generally adequate rainfall, and large labor pool. Despite this potential, however, the Ethiopian agriculture has remained underdeveloped because of drought, a poor economic base, and low level of technologies on agricultural application (MOA, 2000). As part of the agricultural activities, livestock production plays a vital role, adding to stability of farm incomes, food security and farming systems. Besides, livestock are kept as a form of insurance and a means of storing savings (Winrock, 1992). However, the emphasis given to livestock production in Ethiopia is still inadequate.

The Borana rangeland, which covers about 95000 km^2 area, was considered until the early 1980s as one of the few remaining productive pastoral system with a remarkable social organization that have been cited as a model of pastoralism in sub-Saharan Africa (Hogg, 1997) and had good ecological potentials for livestock production (Cossins and Upton, 1987). Until very recently, the Borana rangelands of Southern Ethiopia were considered to be one of the best grazing lands in east Africa (Coppock 1994). Since the early 1980s there is evidence that the system in the Borana rangeland is experiencing a decline in productivity, associated with periodic losses in cattle populations (Ayana Angassa, 2007). This was probably related to extreme climate change and variability, changes in land use, animal diseases, bush encroachment, suppression of fire that resulted in the proliferation of bush encroachment and a general decline in forage production overestimation of the grazing capacity (Ayana Angassa and Oba, 2007). In line with this fact, in the past three decades, the Borana rangelands have faced many problems and the threats are getting severe as time goes (UN-OCHA, 2008) which necessitates interventions based on land suitability evaluation.

The Dire district is one of the Borena Zone, which is situated in arid and semi-arid lands (ASALs), experiences low and erratic rainfall and high temperature that hinder any significant crop production. However, high population growth has resulted in increased demand for arable land in the study area leading to reduced amount of land for natural grazing and forage production. Increasing landuse conflicts which could lead to fast depletion of land resources, land degradation and bush encroachment are also the problems responsible in addition to high population growth and activities have exerted pressure on the extents of grazing lands. Rapidly of bush encroachment and expansion cultivation land are great threats for livestock production in the district, which have caused increasing concern among managers and revealed the importance of land suitability analysis. A few studies have been carried out in the field of presenting suitability model of the range land for livestock production in Yabello district by (Dessalegn Gurmessa, 2006 and Fikadu Lemessa, 2011) considering only biophysical factors. However, no research has been reported on the range land suitability evaluation in Dire district by recognizing both environmental and socio-economic factors affecting land suitability for livestock production and designed to determine the kind and rate of the landuse/landcover changes for proper grazing plan.

1.3. Significance of the study

Locating suitable areas for livestock production using spatial models of Geographic Information systems (GIS) would be indispensable to improve livestock productivity (AlemayehuMengistu, 2006). To get the maximum benefit out of the land, proper use of it for specific purposes is inevitable. Therefore, the most important criterion for sustainable animal production is the selection of appropriate land areas, which meet several biophysical, environmental and socio-economic restrictions. Hence, it is of paramount importance to identify suitable land for livestock production which enhances resilience of the environment.

Although livestock production is a vital component of the agricultural systems, it has so far been overlooked in integrated land and water management for food security in poverty alleviation strategies. There is a need for research and capacity building to understand the complex issues of water, livestock and land management of the district, so as to enhance national and local capacity to deal with water and livestock issues to enhance food security, reduce poverty and speed up national economic development. In addition, acquiring of range land information can help in understanding historical variations of grazing land resources and thereby contribute to its proper management. In fact, vegetation types form one of the main resources of pastoral area. Sound decision on range management depends upon reliable information of the past and present vegetation resources (Herlocker, 1999).

The findings from the present study will primarily benefit the district land managers and NGOs who have implemented land resource management programs in the district, as it evaluates the impact of their programs on the well-being of the land and will suggest some key issues for redesigning.

1.3. Objectives

The main objective of the present study has to evaluate and map suitable land areas for livestock production in Dire district using GIS and Remote Sensing techniques.

1.3.1. The specific objectives

- ❖ To develop suitability model for each of the parameters that determine rangeland suitability for livestock production in the Dire district.
- ❖ To produce environmental and socio-economic suitability maps for livestock production in the district
- ❖ To determine the temporal changes of landuse/cover dynamics and quantify the rate and direction of these dynamics in the study area.
- ❖ To establish the relationship between the rangeland status and livestock number and produce spatial distribution map of the livestock population in the study area

1.4. Research Questions

- What are the major factors and constraints for land suitability for livestock production in Dire district?
- How is the magnitude and the rate of landcover changes that have occurred in the district between 1986 and 2011?
- What percent area of the district is currently suitable and not suitable for cattle, sheep, and goat and camel production? Why?
- What amount of land is accessible and not accessible for cattle and sheep production from infrastructure point of view and why?

LITERATURE REVIEW

2.1. GIS applications on Rangeland Management

One of the most useful applications of GIS for planning and management is the land use suitability mapping and analysis. Broadly defined, land-use suitability analysis aims at identifying the most appropriate spatial pattern for future landuses according to specify requirements, preferences, or predictors of some activity (Malczewski, 2003). Furthermore, a GIS is a computer based system, which is used to digitally reproduce and analyze the future at present on earth surface and the events that take place on it (Alemayehu Abebe, 2006).

The GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habit for animal and plant species, geological favorability, suitability of land for agricultural activities, landscape evaluation and planning, environmental impact assessment, selecting the best site for public and private sectors, and for regional planning (Malczewski, 2003).

GIS provides an environment where collected information and data can be used in a spatial framework to predict the behavior of animals over several periods of time. Models designed to mimic real world applications, in a controlled environment, allow manageable analysis of data tied to spatial locations resulting in a better understanding of the landscape than field observations alone (Amiri, 2012). Using GIS to analyze grazing capability at a landscape scale is not a new concept. GIS was used to assist in the development of suitable areas for sheep grazing across the Awash River Basin, located in Ethiopia, as an attempt to identify how efficiently land managers were utilizing the land (Bizuwerk *et al.*, 2005). The study used Digital Elevation Models (DEM) to find slope values for the study area as well as water data layers to show areas within a close proximity to water within a GIS. Areas were given weighted values based on erosion levels, average rainfall, distance from water, and slope gradient and analyzed to determine overall suitability. Results concluded that 33% of the basin was found suitable for grazing. However, a large portion of suitable area was being used for agriculture crop production. Conclusions revealed either a reduction in crop production or moving crops to other locations so as to allow for optimization of suitable areas for grazing reducing grazing pressure in overused areas (Bizuwerk *et al.*, 2005).

Another study utilizing GIS to depict rangelands suitable for sheep grazing was conducted in the semi-arid landscapes of Iran (Amiri, 2009). Utilizing rangeland to graze sheep is a monitories and culturally entwined process for Iranians. Therefore, the study identified areas suitable for such use in order to design grazing management plans in a sustainable way. Slope gradients, highly erosive areas, and areas within close proximity to water were all used to generate an output of suitable grazing areas classified into three categories moderately suitable, marginally suitable, and unsuitable.

Another research also describes the use of a geographical information system (GIS) to construct land suitability models for livestock grazing in the Ghara-Aghch region, Iran (Amiri, *et al.*, 2012) . Based on FAO method and the source data, sub-models were created focusing on three different themes: sensitivity of the soil to erosion, water resources and available forage. Models recognized important factors affecting model suitability for livestock use of the rangeland, and also determining the kind and rate of the limitations and factors reducing the suitability with the aim of gaining an adequate plan for grazing. In assessing site considerations, these general models identified wider resource management options and solved conflicts of rangeland allocation and livestock grazing between pastoral and rancher. The results of the final suitability outcome of the model revealed (a) none at the high suitability category (unlimited), (b) 694.36 hectares (9.7%) in the moderate suitability category (with minor limitation), (c) 5439.35 hectares (75.9%) in the marginal suitability category (major limitation), and (d) 1025.81 hectares (14.3%) in the unsuitable category.

2.3. Remote Sensing and its role in Rangeland Management

Remote Sensing is the science and art of acquiring information (spectral, spatial, and temporal) about material objects, area, or phenomenon, without coming in to physical contact with the objects, or area, phenomenon under investigation. Without direct contact, some means of transferring information through space must be utilized. In remote sensing, information transfer is accomplished by use of electromagnetic radiation (Lillesand and Kiefer, 2004). Hence it offers an efficient and effective means of collecting the information required in order to map land suitability. Remote sensing has been used extensively over the years as a resource in land management with the premise being the use of high-resolution satellite imagery to identify areas where “greenness,” i.e. vegetation, occurs (Knight *et al*, 2006).

One of the most important uses of remote sensing in rangeland management is the detection change over time. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multi-temporal data sets. Satellite remote sensing data can provide alternative data sources for large areas, allowing classification of the landcover types and estimations of above-ground biomass and primary production. In general, changes in vegetation are the most direct indicator of land degradation (Yang *et al*., 2005). Satellite-based remote sensing data have been applied to monitoring of desertification in Northeast Asia, mapping of land use and land cover (LULC) and the ascertainment of desertification indicators. One of the major applications of remotely sensed data obtained from Earth-orbiting satellites is change detection because of repetitive coverage at short intervals and consistent image quality. Change detection is useful in such diverse applications as land use change analysis, seasonal changes in pasture production, assessment of deforestation, study of changes in vegetation phenology and other environmental changes.

Keeping the limits imposed by scale and image resolution, remote sensing application in rangeland management has got wide acceptance. One of the primary applications of remote sensing in the rangelands is prediction of production potential of a ranch (Palmer and Fortescue, 2003). Using different imageries that have varying spatial and temporal resolution, it is possible to estimate grass biomass. Satellite imageries have been used since the earliest times for the preparation of base maps for rangeland inventory. Integrated with GIS, the system provides spatial and temporal information, which are valuable for inventory. Furthermore, range conditions can be relatively easily handled with low cost and effort. Satellite image like National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer (NOAA AVHRR) have high temporal resolution which can capture information on the condition and health of rangelands on daily basis supported with ground truth. Satellite derived imageries have provided the opportunity to describe the spatial extent of floristically and structurally defined unit (Palmer and Fortescue, 2003). Invasion of rangeland by alien species remains a major problem throughout the world. Attempts to monitor the extent of this invasion based on ground investigation and assisted with the planning of the control and eradication program have met with limited success. The development of spectral libraries, which archive the signature of each species, would improve the efficiency of this application. Change detection using high resolution imagery is another application provided by remote sensing. Ground based change detection is expensive and requires more manpower, resources and time input. In addition, previous data should be available at the appropriate scale and level. However, for example, using Landsat imageries of the past three decades which are freely available, valuable information can be extracted using remote sensing. Rangelands change frequently and their succession favor woody plants domination (Miller, 2012).

2.4. An Overview of Rangeland Development and Livestock production in Ethiopia

Rangeland has been defined as a land where the potential natural vegetation is predominantly grass, grass-like plants, forbs, or shrubs (Lillesand and Kiffer., 2004). Rangelands provide forage for domestic and wild animals. They also represent areas potentially supporting landuses as varied as intensive agriculture, recreation, and housing. The Ethiopian lowlands occur below 1500 m.a.s.l and comprise 61% of the national land area. The climate in the lowlands comprises arid (64%), semi-arid (21 %) and sub-humid (15%) zones largely defined by four rainfall and temperature regimes. These zones vary markedly in terms of number of plant growing days per year, forage production, common plant associations, livestock and human carrying capacity and incidence of important livestock diseases (Coppock, 1994).

According to CSA (2009), Ethiopia has owner 80 million people and over 104.505 million head of livestock. Among 49.3 million are cattle, 25.02 million sheep, 21.88 million goats and 760,000 million camels. The lowlands are home to 12% of the human population and 26% of the livestock. Landuse by the 29 ethnic groups of the lowlands is dominated by various forms of pastoralism and agro-pastoralism. According to Coppock (1994), livestock depend upon rangelands consisting of native vegetation, with crop residues increasing in importance as livestock feed as the annual rainfall increases. Although lowlands have a lower abundance of animals than the highlands, the lowlands still play a crucial role in the national livestock economy. Besides supporting rural and urban lowlanders with milk, meat, employment and investment opportunities, lowland breeds of cattle and sheep made up over 90% of legal exports of live animals. Lowland cattle may also provide around 20% of the draft animals for the highlands, particularly to the east, and smaller numbers are supplied for finishing on crop residues and cross-breeding in smallholder dairy programs. Lowlands are thus important sources of livestock supply to the nation. Coppock, (1994) noted that this situation results, in part, because there are three times as many TLUs per person in the lowlands than in the highlands.

2.4.1. Past and recent rangeland development efforts in Ethiopia.

Although some developmental projects were targeted for lowland livestock systems in the 1950s, large-scale development efforts did not occur regularly until after 1965. These projects were generally intended to foster greater integration among lowland and highland production systems. The First Livestock Development Projects (F1LDP) was aimed to improve the dairy sector of the country. This was achieved through the establishment of dairy farms, milk collection and distribution centers in and within a radius of 100 km of Addis Ababa. Thus, it has played no contribution for pastoral areas (MWR, 2007). The Second Livestock Development Project (SLDP) was market oriented project designed to establish a market outlets for the surplus livestock in the pastoral areas to meet the needs of domestic consumers and export requirements. The main objective of the project was to develop a marketing and infrastructure network to promote the sale and processing of livestock. The main components included establishment of stock routes, staging stations, construction of livestock markets, slaughter houses, hides and skins shades as well as the provision of livestock trucks. The project was active until 1981, but could not continue due to insecurity in the area. The accomplishment of the project included: construction of 470 km of stock routes, 10 staging points and 10 grazing areas, 11 primary and 3 terminal markets and159 slaughter houses. Most of the established infrastructures in the eastern part of the country were destroyed in the 1977/78 Ethiopia/Somalia war. When the project was phased out, it could utilize only 49% of the allotted funds (MWR, 2007).

The Third Livestock Development Project (TLDP) has been the dominant force in development of the pastoral livestock sector since 1975. TLDP has provided infrastructural improvements (roads, markets, water) and support services (veterinary and facilitation of inter- regional trade) to around one million pastoralists residing in 27% of the lowlands in the north, south and east of the country. The primary goal was to stimulate livestock commercialization. These regions were targeted because of proximity to national markets and infrastructure, the quality of indigenous livestock breeds and their higher ecological potential compared to other lowland areas. Despite chronic problems with regional security and the national economy, TLDP has made a notable contribution, particularly in terms of infrastructure. As one of three subprojects of TLDP, the Southern Rangelands Development Unit (SORDU) has been most successful in implementing programs in the Borana pastoral system. In large measure this has been due to the enhanced security situation in the south during the 1980s compared with lowland development regions in the north and east

(Coppock, 1994). 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 developments in addition to provision of infrastructure and support services (Azage Tegegne *et al.*, 2010).

Research and development organizations collaborated in the lowlands during 1982-90 to better understand the pastoral systems and design appropriate production interventions. These efforts of the different organizations included TLDP, ILCA, CARE-Ethiopia, the Institute of Agricultural Research and the Relief and Rehabilitation Commission (RRC) working in the SORDU sub-project area since 1985 (Coppock, 1994).

Currently, there are many development activities undertaken in the area to improve the livelihood of the pastoral society. These are short term to long term development plans which could transform the livelihood of the society to a better future. These projects are implemented by both government and non-government organizations. Oromia South development corridor is one of the five development corridors which are being implemented by Oromia regional government. This project is currently under taking construction activities to provide water for pastoralists and their livestock. 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 vulnerability of the pastoral and agro-pastoral communities in PCDP districts through sustainable Community Driven Development (CDD) interventions (PCDP, 2010). CARE and GOAL are the most important NGOs which have been working in the area to improve the livelihood of the pastoral and agro-pastoral community.

Currently, CARE launches a project called Conservation of Borana Eco-Systems in collaboration with the Ministry of Agriculture. This project helps 30,000 Borena pastoral families to gain access to a permanent supply of food and water. CARE works with project participants to develop sustainable methods of raising livestock, constructing water tanks and water holes, as well as purchasing and storing food. CARE trains people in each community in basic veterinary practices, supplies medicines and equipment to combat disease. The project also helps women to develop income-generating activities such as handicraft production and monetization of food grains. GOAL is also providing water for pastoralists and agro-pastoralists in order to cope up with shortage of water existing in the area interventions (PCDP, 2010).

2.4.2. Pastoral land tenure

Pastoral adaptations in the lowlands of Ethiopia depend entirely on access to wide tracts of land to make full use of a resource base. Although there is little specific information available about the different pastoral tenure systems, it is assumed that they display a number of differences. Land tenure systems must be linked to a number of organizational features (social, political, economic) of pastoral society. On the other hand land tenure arrangements are also assumed to have evolved in response to the nature of the resources involved. While agricultural tenure systems attach specific rights over specific parcels of land to specific individuals over long periods of time, pastoral tenure may be a matter of more vaguely defined rights over large tracts of land vested in a widely defined group. Tenure rights may, for instance, not be attached to the ephemeral pastures, but to the more stable and crucially important water resources, or to more limited areas containing strategic key resources (Helland, 2006).

2.4.3. Bush encroachment

According to Ward (2005), bush encroachment means the suppression of palatable grasses and herbs by encroaching woody species often unpalatable to domestic livestock. Ahmad and Florian (2000) defined bush encroachment as the invasion of shrub and bushes/trees into former grassy rangelands. An expansion of bushland, dominated by unpalatable thorny shrubs, is a common feature of overgrazed pastures in Africa (Rhignos and Hofman, 2003). In semi-arid ecosystems, there has been a general increase in the density of woody plants beyond a critical density, suppressing herbaceous plant production (Oba *et al.*, 2000). The Borana lowlands cover an estimated area of about 95,000 km^2, being the major pastoral rangeland in southern Ethiopia (Gemedo *et al*., 2005). Encroachment of woody plants has been the major threat to the livelihoods of Borana pastoralists and their ecosystem (BLPDP 2004; Gemedo *et al.*, 2006).

The Borana pastoralists in southern Ethiopia have a well-established traditional system of range and water management (Gemedo *et al.*, 2006). Their management system integrates plants, animals and human factors. Their range allocation system considers the carrying capacity of the rangelands, rotational grazing system between wet and dry season grazing areas and drought season grazing reserve areas used to regulate the grazing pressure. Also the Borana pastoralists were obliged by their Gada (traditional and cultural Oromo's management system) to move to other areas when an area is overgrazed. However, this indigenous rangeland management system has been weakened in the recent years, by external influences and interventions as well as internal factors (Ahmed and Florian, 2000).

Bush encroachment seems one of the consequences that happened following the depreciation of this indigenous rangeland management system. There are different factors, which are stated as causes of bush encroachment in this area. These factors combined together, resulted in wide bush coverage, which expands through time. These causes include over grazing, the utilization of rangelands beyond their carrying capacity and optimum grazing frequency. Overgrazing of the rangelands is one of the main causes of bush encroachment. It is associated with the increasing number of both human and livestock population. The degree of grazing strongly affects the structure, composition, quality and productivity of rangeland vegetation (Alemayehu Mengistu, 2006).

The Borana pastoralists have traditionally used controlled burning as a range management tool. During early growth, the encroachers were treated with fire and killed by repetitive burning. Fire limits tree recruitment, allowing adult mortality to remain low (Ward, 2005). Burning also helps to stimulate the growth of new grass shoots, and destroys unpalatable dried and very mature grasses and undesired bushes. However, the continuity of this traditional indigenous range management system ceased due to the implementation of the law that prevented rangeland burning. Since 1970, the Dergue regime banned rangeland burning and unpalatable grass/herb/shrub/bush species got the chance to grow. Less application of indigenous knowledge of the pastoral community also attributed to conversion of rangeland to bushland (Gemedo *et al.*, 2006). Considering the indigenous knowledge and traditional pastoral system as backward by decision makers, government institutions neglected it, and weakened the range management system. The "Gada" system of the Borana people is known to control human and livestock population. Recurrent drought occurring in the area also created a suitable environment for the encroachers. Hence, they do not have a deep root, which traps water from the deep soil, shortage of rainfall limits the growth of grasses. Rainfall frequency is also a necessary condition for bush encroachment (Ward, 2005).

Directly or indirectly land tenure is another factor that has a negative or positive implication on rangeland management. Its negative impact reflected in Borana rangelands is that depreciation of local governance structures to effectively and adequately participate in the management of natural resources and the environment. Land tenure issues have not been adequately addressed to ensure that ownership and utilization of rangelands is clear and effective (Sora Adi, 2007). To have guaranteed access to grazing and water in times of scarcity, more affluent livestock owners fenced-off grazing lands. Existing alongside the no-fenced community grazing land, still is used by all livestock keepers, these areas become depleted. The above mentioned causes are not the only factors, which caused and aggravated bush encroachment in the area. There are different factors, which are considered as minor. However, overgrazing, ban of rangeland fire and less application of indigenous knowledge are major factors that most of the pastoralists agreed with and supported by different studies. Bush encroachment has an adverse effect on the ecosystem and the environment. Herbaceous biomass production and bush encroachment are negatively correlated in the study area (Gemedo *et al.*, 2006). The expansion of unpalatable woody species significantly reduced the rangeland size and availability of grasses.

The consequence, of the decrease in herbaceous biomass might result in high risk of food insecurity in the area. In addition, the bush prohibits access of livestock to the underlying grass and as the canopy closes the grasses and herbs disappear letting the ground susceptible to water erosion. Most studies showed that there is an increasing trend in bush coverage. A study undertaken on Bush crow (*Zavattariornis stresemanni*) in Yabello Sanctuary and its immediate surroundings, south to the town of Mega showed that 8% increase in dense bush cover between 1986 and 2002 (Borghesio and Gainnetti, 2005).

2.5. Suitability Analysis and Multi-criteria Decision Making (MCDM)

Land Suitability Analysis (LSA), conceptualized as Multiple Criteria Decision Making (MCDM) problem, implies the assignment of values to alternatives that are evaluated along multiple decisions or criteria (Pereira *et al.*, 1993). In this regard, for LSA in a raster environment, each grid cell in the database is taken as an alternative to be evaluated for its quality or appropriateness for specific purposes. Therefore, land suitability is a biological productivity of an area for a given set of uses. Livestock production suitability analysis involves integration of information from various streams of science. There are many criteria that are detrimental to land suitability analyses for livestock production. The suitability analysis evaluates many alternative landuse types under various criteria from various disciplines. Criteria are both qualitative and quantitative. Decisions have to be taken at various levels starting from selecting, for instance, different livestock groups until the allocation of these groups for area that suite best. So, the suitability analysis is a multiple criteria decision making process.

FAO (1985) analyzed suitability mainly based on land qualities. Land quality is a complex attribute of land that has a direct effect on landuse (FAO, 1993). These attributes are availability of water and nutrients, rooting conditions of plan and soil erosion hazard. Most land qualities are determined by interaction of several land characteristics, which are measurable attributes of the land. For example, availability the quality of water are determined by a balance between water demand and water supply. The demand is the potential evaporation from the native vegetation, crops and soil. On the other hand, the supply is rainfall, infiltration storage of water in soil, ability of native vegetation and crops to extract the stored water. This inherent characteristic of availability of water enables the calculation of quantitative values of land quality. The value of land quality is the function of the assessment and grouping of land types into orders and classes in the framework of their fitness. Generally, land suitability is categorized as suitable (S) and not suitable (N). Whereas S features lands suitable for use with good benefits, N denotes land qualities which do not allow considered type of use, or are not enough for suitable outcomes (FAO, 1985).

2.6. Land suitability analysis

Land suitability is the fitness of a given type of land for a defined use (FAO, 1976). Broadly defined, land-use suitability analysis aims at identifying the most appropriate spatial pattern for future landuses according to specific requirements, preferences, or predictors of some activities (Malczewski, 2003) / FAO (1976) defined it as the adaptability of a given area for a specific kind of land use. The land may be considered in its present condition or after improvements. Thus, the process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses (FAO, 1976; 2007).

According to FAO (1985), land suitability is primarily the potential biological productivity of land and productivity can be determined by environmental components such as climate, local topography (roughness, steepness, and exposure), soil type and existing vegetation. Land suitability evaluation involves identification of land use patterns, the economic and environmental feasibility of its use. Land suitability classification is developed by considering different factors of land characteristics. Based on suitability of each land use, a weighted value ranging from 5 (unsuitable) to 1 (most suitable) are given (Table 1). The weighted value of each land characteristics was 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 characteristics factors 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 in to five suitable classes to get the final suitability for each land uses.

GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habitat for animal and plant species, geological favorability, suitability of land for agricultural activities, landscape evaluation and planning, environmental impact assessment selecting the best site for the public and private sector facilities and regional planning (Malczewski, 2003).

Table 2.1. Suitability Classes for Range Land

Order	Class	Description
	Suitable (S)	Land on which sustained use of the kind under consideration is expected to yield benefit justify the inputs, without unacceptable risk or damage to land resources
Suitable (S)	S1 (Highly Suitable)	Land having no significant limitations to sustained applications of a given use or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable levels
	S2 (Moderately Suitable)	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations which reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use although still attractive will be appreciably inferior to that expected on class S1 land.
	S3 (Marginally Suitable)	Land having limitations which in aggregate are severe for sustained applications of a given use and will so reduce productivity or benefits or increase required inputs that this expenditure will be only
	Not suitable (N	Land which has qualities that appear to preclude sustained use of the land under consideration
Not suitable (N)	N1 (Currently not Suitable)	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost, the limitations are so severe as to preclude successful sustained use of the land in the given manner
	N2 (Permanently not Suitable)	Land having limitations which appear so severe that as to preclude any possibilities of successful sustained use of the land in the given manner with the existing knowledge

Source: (FAO, 1993)

SOCIAL AND PHYSICAL ATTRIBUTES OF THE STUDY AREA

3.1. Location and Topography

Dire is one of the former districts of Southern part of Borena None, which is located in south west of Oromiya Regional State. It has an international boundary with Kenya in the south, regional boundary with Somali Regional State in the east, and a district boundary with Moyle district in the south east, Dilo at the west, Yabello in the north, and Arero at the east. Mega town is the capital city of the district which is located about 665 kms far from Addis Ababa on the Moyale road. Dire District is bounded by latitude 4° 37' 0" - 4° 37' 10"N and longitude 37° 56' 0" - 38° 31' 0" E and covers a total area of 3921 km^2 (Figure 3.1). Most of the lowlands of Ethiopia are characterized by plain topography.

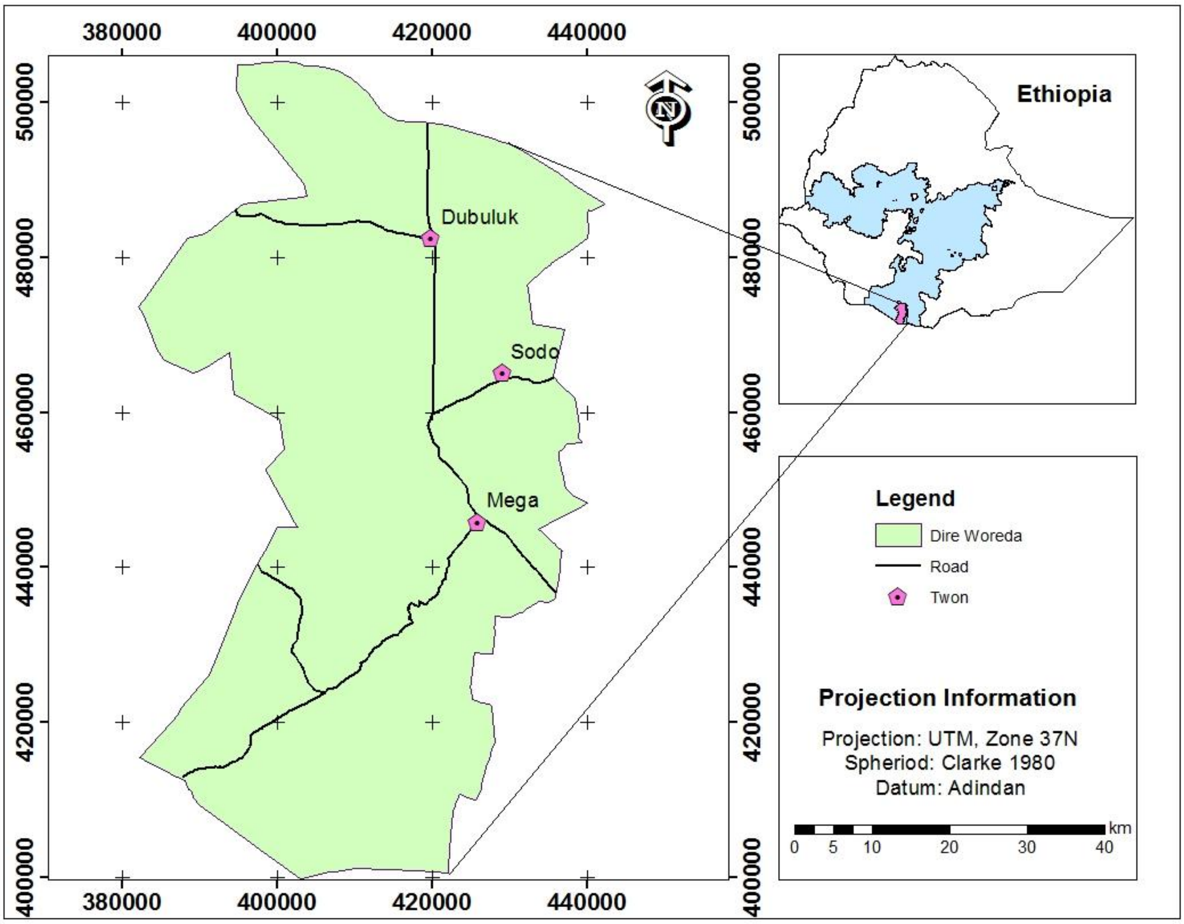

Figure 1. Location map of the Study Area.

By Berhanu keno, E-mail: berekeno@yahoo.com

3.2. Climate

Climatic condition in the lowlands of Ethiopia is largely a result of altitude/altitude of Dire district ranges between 750-1870 m.a.s.l. Based on the climatic map of Ethiopia, the area is characterized by semi-arid lowlands with some mid-altitude areas. The semi-arid lowlands are predominantly occupied by pastoral and agro-pastoral population, whose livelihood is mainly dependent on range-livestock production.

Seasons in the study area are classified by the local people into four sets according to climatic variations and the uses of the range. In line with this the study area comes under the influence of a bi-modal monsoon rainfall type, where 60% of the 300-900mm annual rainfall occurs during March to May (Ganna) and 40% between September and November (Hagaya) (BLPDP, 2004). The period from June to September is characterized by heavy cloud cover, mist and occasionally short showers, while the main dry season (Bonna Hagaya) occurs from November to March with high evaporation (BLPDP, 2004). A prominent feature of the Borena ecosystem is the erratic and variable nature of the rainfall, with most area receiving between 238 mm and 896 mm annually, with a high coefficient of variability ranging from 18% to 69% (Ayana Angassa and Oba, 2007). Figure 3.2 shows sixteen years annual rainfall of Dire district. The ecological environment of the Borana rangelands is more suitable for extensive grazing than for crop production, which is unreliable due to the erratic nature of rainfall. The regional variation in climate influences the agricultural production potential of the region. The Borana rangelands are exploited mainly by mobile herd management system. Pastoralism is the primary mode of life (Ayana Angassa, 2007) though agro-pastoralism is recently emerging as mode of life in some peri-urban areas.

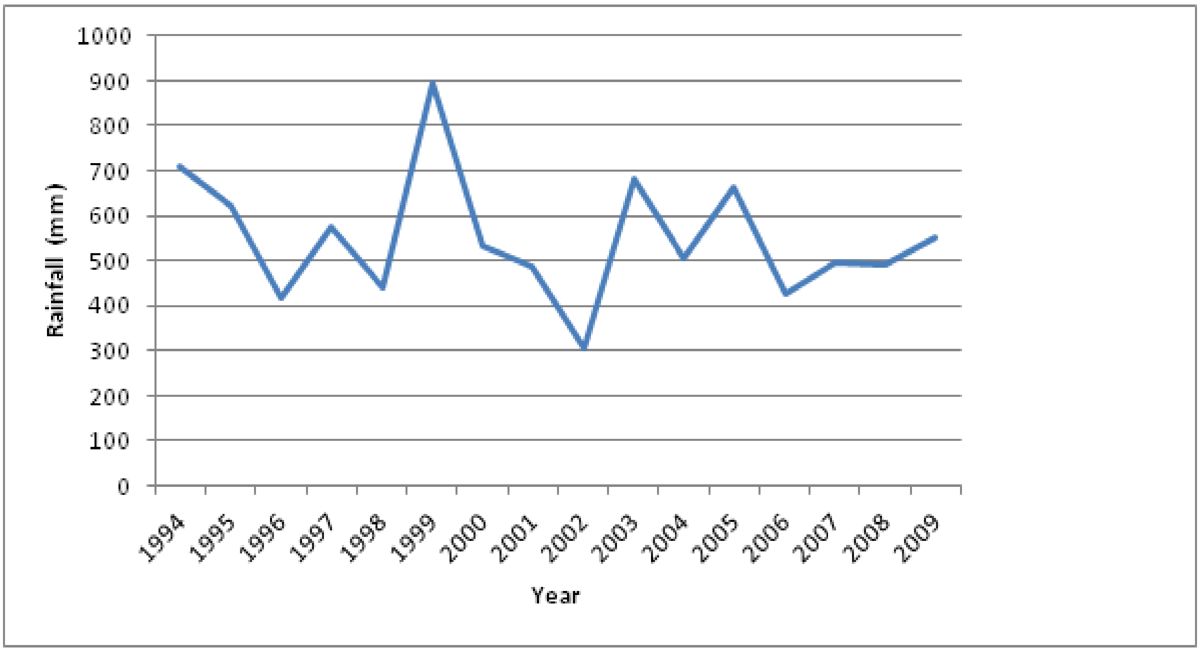

Figure 3.2. Annual Rainfall of Dire District (1994-2009)

The overall average temperature ranges from an annual mean minimum of 13.3^{o}C to annual mean maximum of 29.5^{o}C. Figure 3.3. shows ten years (2000-2010) average mean monthly temperature of Dire district.

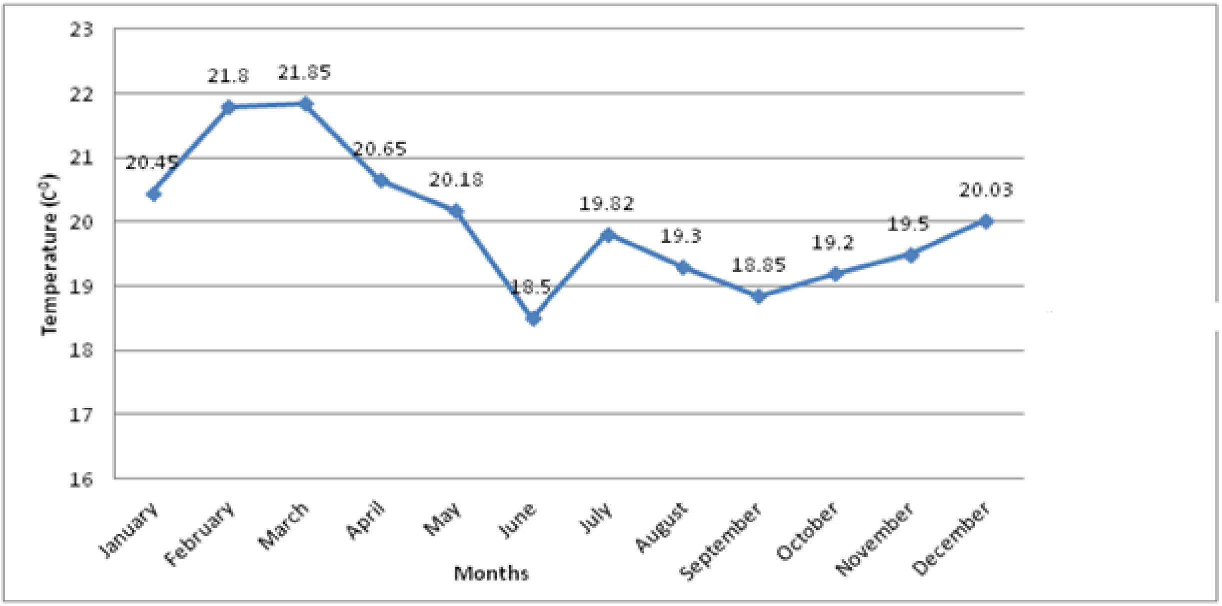

Figure 3. Mean monthly temperature (2000-2010)

3. 3. Soil

According to Ayana Angassa (2000), soils in the study sites are shallow red sandy loam in the uplands and vertisols in the bottomlands. The predominant soil types of the area include red soil (*wayama*), black soil (*koticha*), white or gray soil (*biyye adii*) and sandy soil (*mansa*).

In most cases, the soil is well-drained red sandy loam type. In the valley bottoms with impeded drainage, lava soil and volcanic light colored silty clays predominate, with relatively higher fertility (higher content of nitrogen, phosphorus and organic matter) and higher water holding capacity than the upland soils. The upland soils are shallower, well-drained red sandy soils that are widespread on flat lands and hills with relatively lower fertility and lower ability to retain water and nutrients as compared with the Vertisols in the bottomlands (Coppock, 1994).

3. 4. Vegetation

The pastoral rangelands of Ethiopia are mostly characterized by sparse vegetation composed of mainly grasses, bushes, shrubs, small trees and bare land (Alemayehu Mengistu, 1998). Soil type and topography are among the main factors that control the vegetation type of an area. As the altitude increases from sea level, the vegetation type changes accordingly. This is evident in Dire district. Most of the central mountain vegetation is composed of *Juniperus procera*, *Olea europaena* sub-spp. *cuspidata* and Podocarpus *falactus*, whereas, the lowland vegetation is mainly composed of Acacia spp. The general vegetation type of the study area is Acacia savannah, the major trees being *Acacia drepanolobium* in black cotton soil, and *Acacia brevispica* and *Acacia horrida* on the slopes. According to Gemedo Dalle (2005), *Commbertum Terminalia* and *Acacia Commiphora* woodlands characterize the lowlands of Borana zone. Bushlands and thickets, which cover major parts of the lowlands, are dominated by *Acacia* and *Commiphora* species. Besides, species of the genera *Boscia, Maerua, Lannea, Balanites, Boswellia* and *Aloe* are common in the study area (Gemedo, *et al.,* 2006).

3. 5. Water Resource Potential

Water is one of the most important natural resources, which the Borana pastoralists depend up on. The Borana rangelands in general and the Dire district in particular are characterized by a general scarcity of surface water and perennial rivers. There are no known perennial rivers, streams and lakes in Dire. The main water sources for human and livestock consumption in the district are deep wells (*Eelaas*) and hand-dug ponds (*Haros*).

3. 6. Socio-economy

3. 6.1. Human population and settlement pattern

The dominant ethnic group in the study area is Borana Oromo amalgamated with a few Guji Oromo, Amhara and Burji peoples. The production and livelihood system is based on traditional Gada system, an approximately 550 years democratic, economic and sociopolitical system, which is more or less common for all Oromo tribes (BLPDP, 2004). The Gada council, which divides the entire rangelands into traditional grazing based administrative units called “madda”. The madda on their part are centered-around permanent water sources, usually traditional deep wells. All economic and social lives revolve around the wells. The madda is further sub-divided into sub-grazing units called “arda”, which consists of a few encampments that have jurisdiction over some form of grazing area, cultivated land and to a lesser extent, on water resources (Kamara *et al.,* 2002). The encampments or Ollas, which comprise about ten households, are the smallest administrative units in the traditional system. The Borana household unit consists of one household head, one wife or more depending on the number of animals one has, and three to seven children depending on the number of wives (BLPDP, 2004). The total population of the district was 63, 868 out of which females and males were 31632 and 32036, respectively (CSA, 2009).

3. 6.2. Livestock population

The Borana pastoralists traditionally depend mainly on cattle, but also on goat and sheep for household food security and a few donkeys and camels for transport. The local Zebu known as the Borana cattle breed is bred and kept in Borana rangeland and plays a major role in the traditional Borana pastoralist production and livelihood system (BLPDP, 2004). This breed has good milk and meat production potential besides adaptability is adverse environmental condition under arid and semi-arid environmental conditions, developed through time and selection. Goat has the largest number 83161. Cattle, sheep and camels were 81803, 52743 and 3858, respectively, in 2012 (Dire District Pastoral Development office).

3. 6.3. Farming System

It is known that agriculture is the basis of the Ethiopian economy and in Borana rangelands livestock production is the main source of food and money. Beyond this, it plays a major role as being a symbol object of a Borana identity and culture as well as being a central element of their social and political organization, the Gada system (BLPDP, 2004). In some of the pastoralist Association (Pas), there are small tracts of lands, which are tilled only to satisfy household grain requirement. Cultivated land is estimated to cover 6.6 ha, which is 0.17% of the district. Agro-pastoralism is a newly emerging phenomenon in Borana rangelands and could be described or defined as an activity based on a gambling system spearheaded by those individuals who had lived in the pastoral areas and due to one reason or another became destitute and are forced to cultivation as opportunistic farmers (Sora Adi, 2007).

MATERIALS AND METHODS

4.1. Study materials

The following softwares were used in study. These were ArcGIS 10.1, ERDAS Imagine 9.2, IDRISI Andes 15.0, Global Mapper, 3DEM, Microsoft office 7 and the source of this softwers was Remote Sensing and GIS laboratory of Addis Ababa University. In addition, topographic maps of 1:50000 scale from Ethiopian Mapping Agency, time series satellite imageries and diverse ancillary data were used in order to identify historical and recent landuse/ landcover of the study area. Digital soil map and shape files of district and kebele were obtained from FAO and CSA, respectively. In addition, GPS and Digital camera were also used in the present study.

4.2. Methods

4.2.1. Data Collection

The success of any GIS application depends on the quality of the geographic data used (Lo and Yeung, 2002). Collecting high quality geographic data for input to GIS, therefore, marks a critical stage. Data collection is one of the most time consuming and expensive, yet important for GIS based studies. GIS can contain a wide variety of geographic data types originating from many diverse sources. For this study, both primary and secondary raster and vector data were used. Primary data were generated from the analysis of satellite image and also using GPS in the field. Secondary data were collected from published and unpublished materials including books, journals, research articles and census reports. Secondary data collections were made from various sources. Background information of the study areas were obtained from previous research works in the study area, river, Digital copy maps of pastoral association (kebele) boundaries and various road category networks and water resources data from Central Statistical Agency (CSA). Rainfall and temperature data was collected from National Meteorological Services Agency (NMSA). The relevant data for this study are: landuse/landcover, water resources, digital elevation model, soil classification, livestock density, Landsat TM satellite images, rainfall, market and veterinary service access. Landuse/landcover data were extracted from landsat TM images using ERDAS Imagine 9.2. Topographic maps of the scale 1:50000 of the study area were purchased from the Ethiopian Mapping Agency (EMA).

4.2.1.1. Satellite imagery

The most popular form of primary raster data source is remotely sensed imagery (Lo and Yeung, 2002). Hence, to make the multi-temporal analysis and Landuse/landcover types at various times extraction Cloud free Landsat TM imageries (path 168 and row 57) that were acquired on January 1986 and 2011 were analyzed to classify the landuse/ landcover change of the study area. All were acquired in the month of January during the dry season. Geometric correction and image enhancement were conducted using ERDAS Imagine 9.2. Discriminating the features that were presented on the ground from the scene (Lillesand and Kiefer, 2000) and hence, it facilitated the change detection process by increasing the image classification.

3.3.1.2. Digital Elevation Models (DEM)

Furthermore, topography is essential for land suitability modeling. DEM data was derived from 30 meter resolution SRTM (Shuttle Radar Topographic Mission) abroad the space Shuttle Endeavour, launched in February 2000. A DEM (Digital Elevation Model) is helpful for visualizing the area, for various data generation, (contour line generations, basin area delineation, slope, etc). Then, slope data and subsequent derivations like elevation were calculated from the Digital Elevation Model (DEM) using spatial analysis tools. FAO Soil Classification was used in the Suitability Modeling (FAO, 1997). Figure 4.1 shows the methodology flow charts of the study.

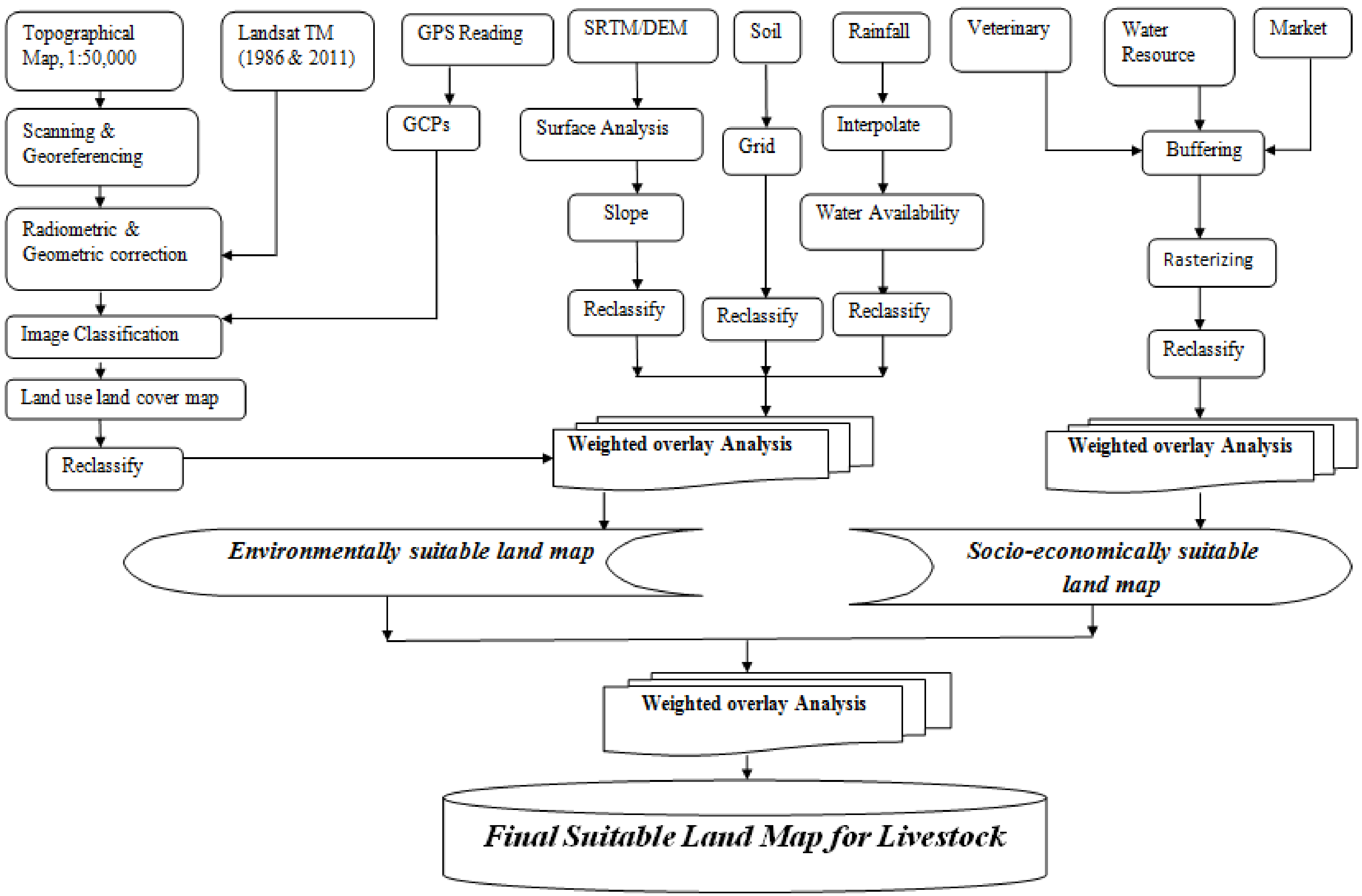

Figure 4. 1. Methodological flow chart

4.2.1.3. Field Survey

Field investigations either to collect training data for digital classification or for ground verification or validation is part and parcel of applied remote sensing (Bedru Sherefa, 2006). Digital signature of each land cover class is a function of its spectral property. Subsequently, these signatures may be used to train software algorithms/classifiers to facilitate accurate automatic classification. Therefore, landuse/landcover classification/mapping activities without the support of field investigation are most likely prone to incorporate errors (Dessalegn Gurmessa, 2009). Accordingly, primary data on the dominant landuse/landcovers of the study area were collected in February, 2013. The collection procedure included identifying the dominant landuse/landcover types in the area and selecting sample Kebeles and relevant areas to be visited. Based on their abundance and coverage, the main land use/land cover types identified were as forest, bushland, grassland, cultivated land, bareland and shrubland. Secondary data were collected from Dire District Pastoralist Development Office. The following definitions were applied as a baseline for the classification.

Forest: refers to an area naturally covered by closed stands of large trees of indigenous species like *Juniperous procera, Olea european* sub-spp. *cuspidata* and *Podocarpus falcatus* with more or less a continuous canopy cover and 7 to 30m height (Zemenu Mintesnot, 2009).

Bushland: refers to open to closed stands of mainly Acacia trees 2 to 5m tall and canopy cover greater than 20%. This land-cover class dominantly refers to those species identified by the local people as invasive and mostly unpalatable to livestock. Most of them are thorny Acacia species forming a patch that prohibits human and livestock movement. Dominant species belonging to this category are *A. brevispica* (Hammaresa), *A. bussie* (Hallo), *A. drepanolobium* (Fillensa), *A.melifera* (Saphansa), *A. reficiens* (Sigirsa), *A. seyal* (Wachu) *and Commiphora africana* (hammessa) (as cited in Zemenu Mintesnot, 2009).

Grassland: is an area dominated by local or introduced grasses and forbs species, including grass-like plants such as sedges and rushes, and small flowering and non-flowering plants or herbal vegetation with trees found scattered along the landscape is included in this category (as cited in Zemenu Mintesnot, 2009).

Crop/Cultivated land: refers to agricultural lands that are seasonally cultivated by the local people for the production of mainly grains like wheat, sorghum, maize and teff. This category mainly includes fragmented or scattered areas that are cultivated mainly for subsistence. Perennial crops and irrigated lands are not significant and thus were not included in this category (as cited in Zemenu Mintesnot, 2009).

Shrubland: refers to scrub vegetation dominated by shrubs greater than 0.5 meters and typically less than 4 to 5 meters in height. It can be dense or open, depending on the canopy cover of the vegetation (as citied in Zemenu Mintesnot, 2009).

Bareland: These categories include non-forested, non –vegetated, non-agricultural land that has less than 60% herbaceous cover. Lands were formally agricultural, but now due to erosion and overuse became worthless or also classified under this category. In the image they were easily identified due to their high reflectance value appear whiter than the surrounding areas.

3.3.2. Satellite Image Processing

Pre-processing operations sometimes referred to as image restoration and rectification, area intended to correct for sensor and platform specific radiometric and geometric distortions of data (Lillesand and Kiefer, 2004). Hence, the image used for the present study was subject to several procedures to correct for radiometric and geometric distortions.

A. Radiometric corrections

Radiometric corrections may be necessary due to variations in scene illumination and viewing geometry, atmospheric conditions, and sensor noise and response (Lillesand and Kiefer, 2004). Each of these will vary depending on the specific sensor and platform used to acquire the data and the conditions during the data acquisition.

B. Geometric correction

Geometric distortions may be due to several factors such as the perspective of the sensor optics, the motion of the scanning system, the motion of the platform, the platform altitude, and velocity, the terrain relief and the curvature and rotation of the Earth (Lillesand and Kiefer, 2004). Geometric corrections are intended to compensate for these distortions so that the geometric representation of the imagery will be as close as possible to the real world.

The geometric registration process involves identifying the image coordinates (i.e. row, Column) of several clearly discernible points called ground control points (or GCPs), in the distorted image and matching them to their true positions in ground coordinates (e.g. latitude, longitude). The true ground coordinates are typically measured from a map, either in paper or digital format. This is image-to-map registration. Once several well-distributed GCP pairs have been identified, the coordinate information is processed by the computer to determine the proper transformation equations to apply to the original (row and column) image coordinates to map them into their new ground coordinates. TM image of the study area was geocoded (georeferenced) to a UTM coordinate system with a pixel size of 28.5 meters using a first order transformation and nearest neighborhood resampling. A root-mean- square error of approximately 1.5 pixels was achieved for the fit between TM image of the study area and the 1:50,000 scales topographic maps using 4 ground control points (GCPs) gathered from the topographic maps the environment of ArcGIS 10.1 system was used for this task.

4.2.3. Data Analyses

4.2.3.1. Image classification

Image classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to those criteria. Image classification serves a specific goal, i.e., converting image data into thematic data. Thematic characteristics such as landuse/land cover can be used for further analysis and input into GIS based models. In addition image classification can also be considered as data reduction: the *n* multi-spectral bands result in a single band raster file. As far as classification of image is concerned, there are two common classification types (Lillesand and Kiefer, 2004). Accordingly, both types of classification systems in this study, i.e., the unsupervised classification before field visit and the supervised classification after field survey were used.

Unsupervised classification of the study area was performed prior to field visit and representative points thought to represent the various land cover classes were marked using GARMIN GPS during field visit. These points were used to sample representative signatures for the various landcover types identified during field visit. Following this, supervised landuse/landcover classification was carried out using ERDAS Imagine 9.2 software.

4.2.3.2. Land cover change Analysis

Multi-temporal satellite imageries of 1986 and 2011 have been used and the method used to classify the Landsat images according to land cover using ERDAS Imagine 9.2 image processing software. Pixels were clustered into the categories of forest, open bushland, dense bushland, dense shrubland and open shrubland, grassland and bareland. Post classification comparison was carried out for two independent images (thematic maps), which is the most proven technique to deal with change detection (Shalaby, 2007). Difference or change information was generated by comparing image values of one data set (TM 1986) with those of the corresponding layer of the second data set (TM 2011). The ERDAS modeler was used to detect landcover change between the two datasets (ERDAS Imagine 9.2). Conversion matrix between TM 1986 *versus* TM 2011 was compiled in the form of a contingency table. This conversion matrix was used to quantify land cover change in terms of pixel values, km^2 or percentage of area coverage.

4.2.3.3. Assessment of Classification Accuracy

Landcover maps derived from remote sensing imagery always contain some sort of errors due to several factors which range from classification technique to method of satellite data capture. One of the most common methods of expressing classification accuracy is the preparation of a classification error matrix or a confusion matrix (Congalton, 1991; Lillesand and Kiefer, 2004). It is a very effective way to represent accuracy because each category is evidently described. Most assessment was conducted using the same data set which was used to train the classifier. These trainings and testing on the same data set resulted in overestimate of classification accuracy (Congalton, 1991). It is to be noted that producer's accuracy is calculated as the total number of correct pixels in a category divided by the total number of pixels of that category as derived from the reference data (i.e. the column total). This accuracy measure indicates the probability of a reference pixel being correctly classified. On the other hand, if the total number of correct pixels in a category is divided by the total number of pixels that were classified in that category, it is said to be user's accuracy or reliability. The rate of land use/land cover change for each class was calculated as follows:

Rate of change (ha/year) = (A-B)/C

Where, A= recent land use/ land area in ha, B= previous area of land use/ land cover in ha, C= interval between A and B in years

4.2.3.4. Rangeland suitability analyses

4.2.3.4.1. Environmental Factor analyses

Land suitability analysis is governed by several factors ranging from bio-physical factors to socio-economic factors. In the present study, four environmental land parameters were considered. These are soil, slope, rainfall and land use/land cover. The assessment of these parameters provides the information about the limitations of the land for agricultural development. All the above mentioned parameters have been considered for the analysis towards the identification of suitable areas for livestock production and they are mapped separately. Each criteria map displays land suitability measured on ordinal scale, that is, parcel of land were assigned values of high, medium and low suitability depending on land attributes.

The criteria maps are the input data to the GIS based decision making procedure. Given these maps, the next step is to combine the maps so that one can identify suitable areas for livestock production. The combination procedure follows the conventional scheme for GIS based MCDA (Malczewski, 1996). It involves three main steps. First, the criterion maps were standardized/ reclassified using Spatial Analyst's Reclassify tool. This step is necessary because the criterion maps contain the ordinal values (high, medium and low) that indicate the degree of land suitability with respect to a particular criterion (criteria standardization). Second, *derivation* of the relative criterion importance using the pairwise comparison method. The criterion weights are automatically calculated once the pairwise comparison matrix is entered in IDRISI-AHP weight derivation module. Third, the criterion weights and the standardized criterion maps were combined/ aggregated by means of weighted overlay technique analysis. Table 4.1 shows requirements of rangeland suitability for Borena livestock production.

Table 4.1. Environmental & socio-economic requirements of Borana Cattles, Sheep, Goats and Camels

Animal	**Criterion**	**Range of suitability**				
		Highly Suitable (S1)	**Moderately Suitable (S2)**	**Marginally Suitable (S3)**	**Currently not Suitable (N1)**	**Permanently Not Suitable (N2)**
Cattle	Soil	SNcc,VReu,VRpe	CMcr,LVcr,CMeu,NTtro	FLca,LPel,FLeu,CLha,Lp		
	Rainfall	>800	500-800	300-500	<300	
	Slope	0-8	8-16	16-25	>25	
	Land use land cover	OGL	OBGL, OSGL	OSL, CL, OBL	DSL, DBL	WB,FR,BA
	Water availability (Km)	< 8 km	8-15	15-20	>20	
	Animal health services(Km)	<5	5-10	10-15	>15	
	Market service (Km)	15	20	25	>25	
sheep	Soil	FLca,CLha	CMcr,LVcr,CMeu,NTro	SNcc,LPel,FLeu,VReu, Lp,VRel		
	Rainfall	>800	500-800	300-500	<300	
	Slope	0-16	16-30	30-40	>40	
	Land use land cover	OGL	OBGL, OSGL	OSL, CL, OBL	DSL, DBL	WB,FR,BA
	Water availability (Km)	<5 km	5-7 km	7-10	>10	
	Animal health services(Km)	<5	5-8	8-10	>10	
	Market service (Km)	<7	7-15	15-20	>20	

Source: Abule Ebro, (2009).

Animal	Criterion	Range of suitability				
		Highly Suitable (S1)	**Moderately Suitable (S2)**	**Marginally Suitable (S3)**	**Currently not Suitable (N1)**	**Permanently Not Suitable (N2)**
Goat	Soil	FLca,CLha	CMcr,LVcr,CMeu,NTro	SNcc,LPel,FLeu,VReu,Lp, VRel		
	Rainfall	600-800	400-600, >800	250-400	<250	
	Slope	0-16	16-35	35-50	>50	
	Land use land cover	OSL	OSGL	DSL,OGL,CL,DBL,OBGL		WB,FR,BA
	Water availability (Km)	<5 km	5-7 km	7-10	>10	
	Animal health services(Km)	<5	5-8	8-10	>10	
	Market service (Km)	<7	7-15	15-20	>20	
Camel	Soil	FLca,LPel,FLeu,CLha,LP	CM			
	Rainfall	400-700	350-450	200-350	<200, >700	
	Slope	0-8	8-16	16-25	>25	
	Land use land cover	OBL	OSL	OGL, CL, DBL	Bare land	WB,FR,BA
	Water availability (Km)	<10 km	10-20	20-25	>25	
	Animal health services(Km)	<5	5-10	10-15	>15	
	Market service (Km)	20	25	30	>30	

Note:

WB Water body
DSL Dense shrub land
OGL Open grassland
FR Forest
OSGL Open shrub grass land
BA Built up areas
OBL Open bush land
OBGL Open bush grass land
OSL Open shrub land
DBL Dense bush land
CL Cultivated land

T1 Thermal zone 1
T2 Thermal zone 2
T3 Thermal zone 3
T4 Thermal zone 4

FLca: Calcaric Fluvisol
SNcc: Calcic Solonetz
CMcr: Chromic Cambisol
LVcr : Chromic Luvisol
LPel: Epileptic Leptosol
CMeu: Eutric Cambisol
FLeu: Eutric Fluvisol
VReu: Eutric Vertisol
CLha: Haplic Calcisol
VRpe: Pellic Vertisol
NTro: Rhodic Nitisol

Source: Abule Ebro, (2009).

A. 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 source of natural mineral and sleeping ground (Chiisaa) in the Borana rangelands (Abule Ebro, 2009). It is also one of the most important parameter, 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. Thus, the inclusion of soil parameter as a land quality is very important both for the plants which are the source of animal feed. For this study, soil mapping unit of Dire District was used as one of the parameters for suitability analysis. Physical properties of soil, specifically textural classes were considered for interpretation and analysis.

The major soil types in the study area are indicated in Figure 4.5 and include Calcaric cambisols, Chromic Cambisol, Epileptic leptosol, Lava, Eutric Cambisol, Dystrict cumbisols, Haplic Calcisol, Leptosols, Pellic Vertisol and Virtic Andosols (OWWDSE, 2013).

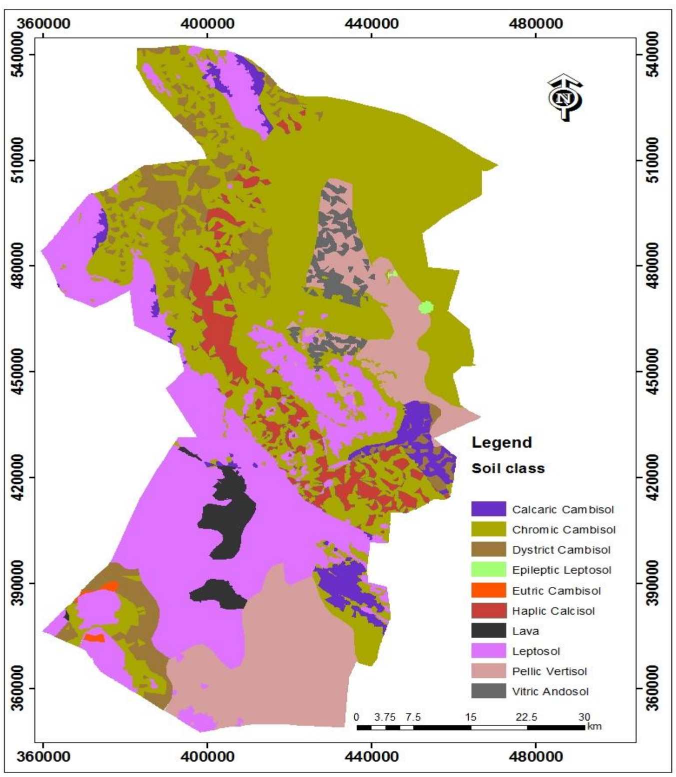

Figure 4.5. Soil map of Dire district

B. Moisture availability (Rainfall)

Food and water are important determining factors for landuse decision for livestock development. Moisture in the Borana rangeland is one of the major factors dictating livestock production of the area (Abule Ebro, 2009). More importantly, water availability for feed growth is one of the single most important factors that determine suitability for livestock production. Feed source is abundant in areas of high rainfall. The mean monthly average rainfall of 6 stations (1 within the study area and 5 from the adjoining districts) for 16 years was collected from National Meteorological Services Agency (NMSA) (Figure 4.6), Ethiopia. Subsequently, a surface was interpolated from the point's data in a GIS platform using Geostatistical Analyst's ordinary kriging technique (Fig. 4.7).

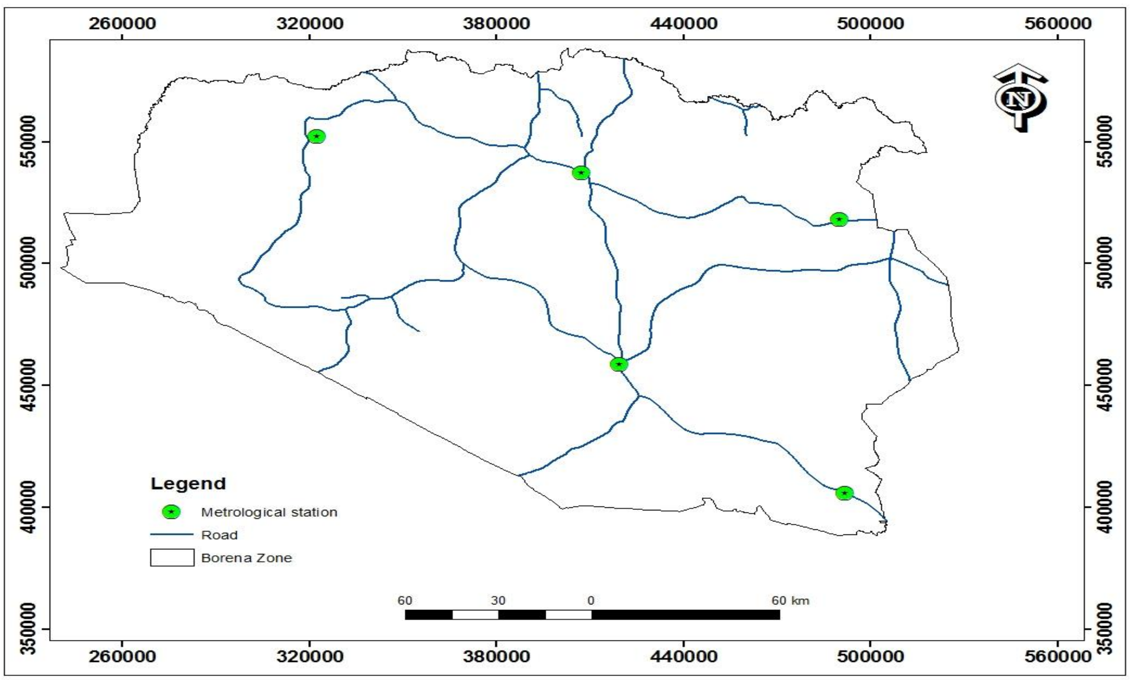

Figure 4. 6. Distribution of the meteorological stations of Borena Zone

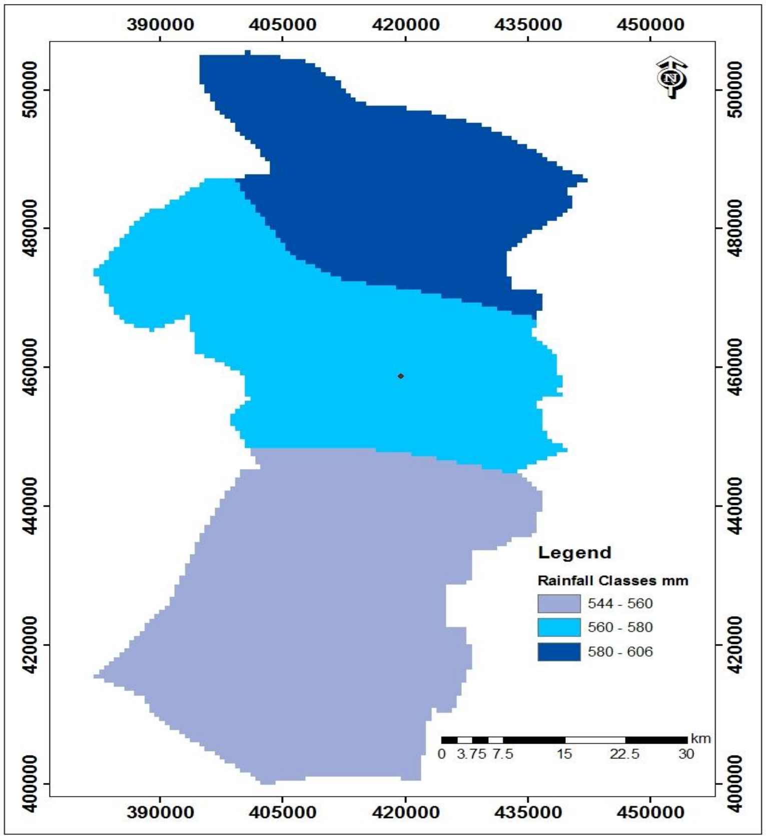

Figure 4.7. Mean annual rainfall map Of Dire District

C. Landuse/ Landcover

In rangeland development, the most important resource is the vegetation that is exploited for livestock and wildlife. Extending from major morphological realms to individual plant species there are marked differences in the genetic potential of plants to support livestock under extensive grazing. All animals have higher preferences for certain vegetation types/cover than for the others. This causes 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 or sheep cannot (Abule Ebro, 2009).

According to the current land use/landcover analysis, there were classified in to 8 classes (table4.3). Figure 4.8 shows Land/use landcover types of the district and their spatial distribution.

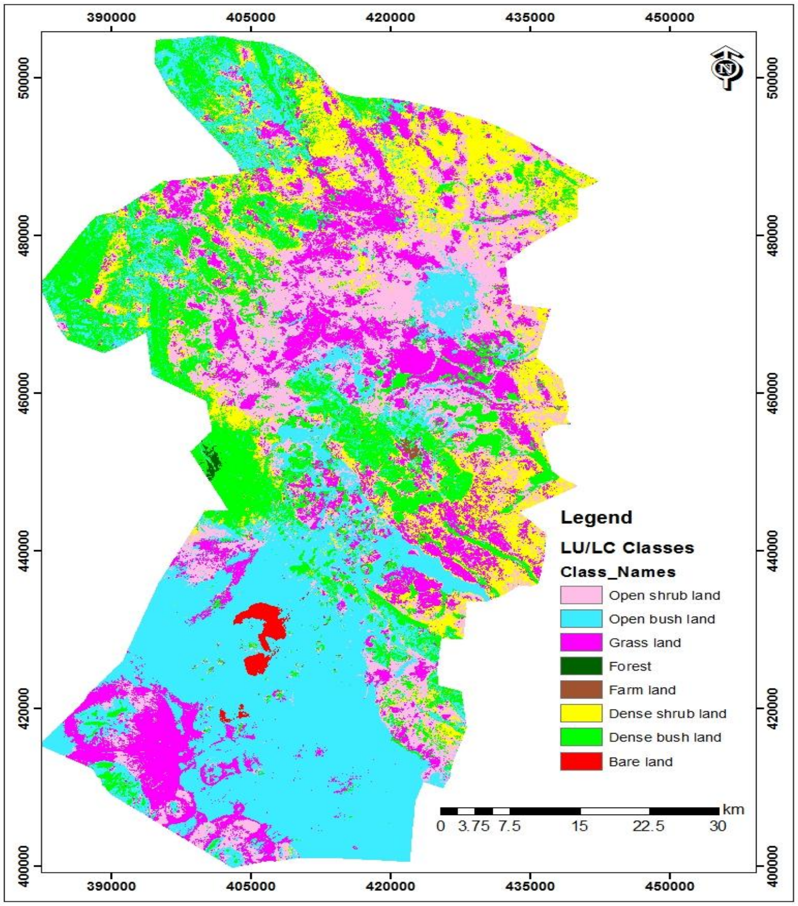

Figure 4.8. Landuse / landcover map

D. Slope

Rugged topography is one of the most important causes of poor livestock distribution on rangelands. The reluctance of livestock to use steep slopes is not entirely undesirable, since these areas are often fragile and valley bottoms can better withstand grazing. However, in many cases slopes serve as barriers to the use of benches and ridge tops above valley bottoms. The different slope categories are 0-2 % flat, 2-5% gentle undulating, 5-8 undulating, 8-15% rolling, 15-30% moderately suitable, 30-60% steep and greater than 60% very steep (Abule Ebro, 2009). Livestock vary considerable 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 camels make little use of slopes with more than a 10% gradient. Because of their small size, greater agility, and surefootedness, sheep and goats use these areas more readily. Many rugged ranges can be better used by wild animals than by livestock. Sheep can graze on steep slopes unsuitable for cattle and other large animals. For the present study slope was generated from SRTM data in GIS platform using Geostatistical Analyst's surface analysis technique figure 4.9 shows the slope map of the study area.

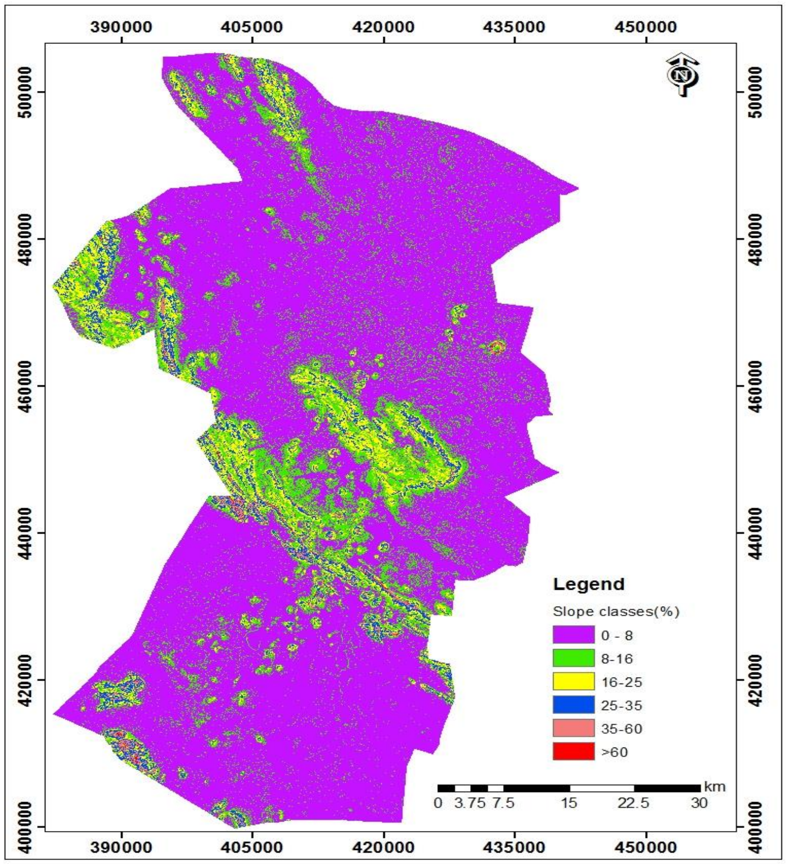

Figure 4.9. Slope map of Dire District

4.2.3.4.2. Socio-economic Factor Analyses

Socio-economic factors in the rangeland includes road and transport condition, communication system, market out lets, veterinary clinics and services, health centers/health posts, abattoirs, skins and hides collecting and preserving systems, communication and training systems. The highly managed rangelands need to have an air field and range management station office to serve in case of emergencies such as disease out breaks, executing, monitoring and reporting day to day activities. In this study, three infrastructural indicators were used namely access to drinking water, access to veterinary services and access to market.

I. Distance to Drinking water resource

The influence of water on range land potential for cattle grazing has been indicated to be of paramount importance (Cowling and Richardson, 1997). Poor water distribution is the chief cause of poor livestock distribution on most rangelands. In arid regions of the world, water is in short supply and poorly distributed. Where available water points are infrequent, large sacrifice areas around water points have often occurred. Although livestock will travel great distances to water, this is not in the best interest of the animal or the range resources. Travel increases energy expenditure by the animal that otherwise would have go into production (weight gain and milk production) and takes away from grazing and resting time. If animals must travel large distances between water and available forage, a series of trails will be created that gradually become larger and more numerous. These trails become water channels that cause severe erosion.

The proportion of land in livestock trails on a range is a good indicator of grazing severity. Recommendations on distances from water points vary with terrain, type of animal and breed of livestock. Any form of water development might be expected to improve the living standard of the pastoral people in normal years and their chances of survival in times of drought if only properly planned. Grazing potentials decline with distance from watering point (Andrew, 1988). It was, therefore, deemed necessary to evaluate and correct for the effect of spatial distribution of water supplies on forage accessibility in the evaluation process. Several distance range (kilometers) away from watering points beyond which forage becomes inaccessible have been used in range land studies, 0-15, 0-10 and 0-25, by Bartles *et al.(*1993); Toxopeus (1999) and Abule Ebro (2009), respectively. In this study, a range of classes (0-25) were used. A map of distance to water was obtained first by combining artificial water point in water map Figure 4.10. The water map was rasterized and then a distance map was calculated from it. Permanent, abundant sources of water should be kept to the minimum possible and should be located no close than 7-10 km apart as in the case of cattle, 3-5 km in the case of sheep and goats and 10 km in the case of camels Abule, (2009).

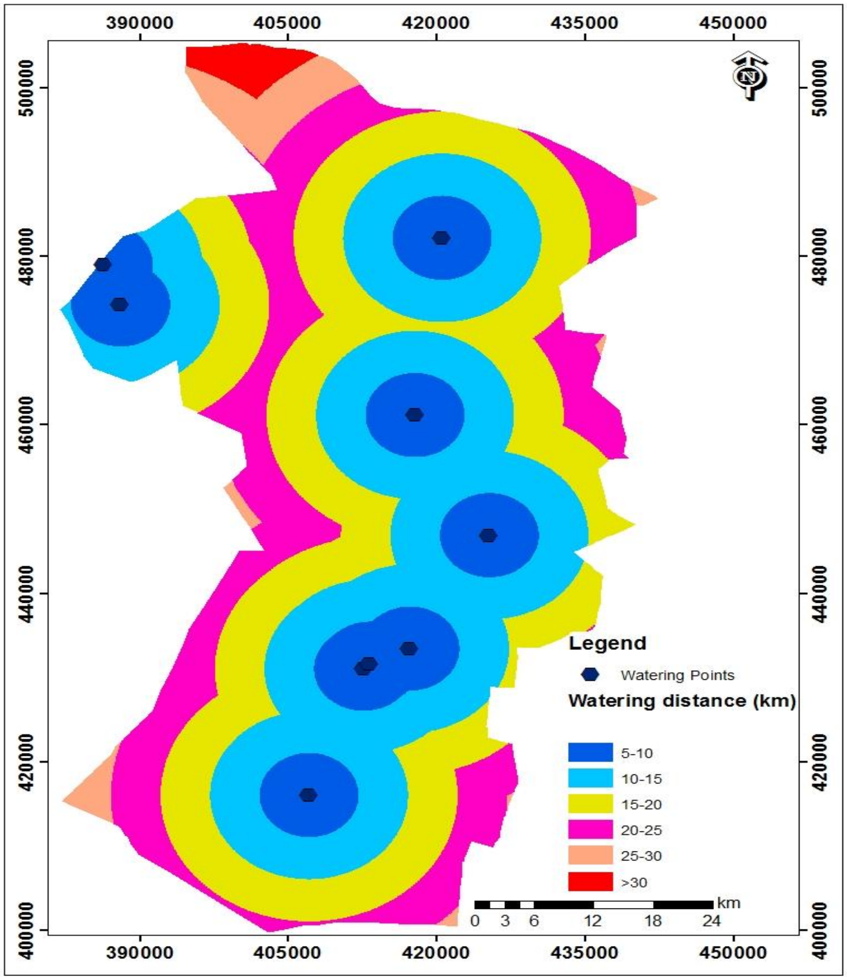

Figure 10. Drinking water Resource map in Dire dirstrict

II. Veterinary services

The distance from veterinary service was calculated by buffering from the veterinary center points and rasterized to reclassify then a distance map was calculated from it. Figure 4.11 shows access to veterinary services map of the study district.

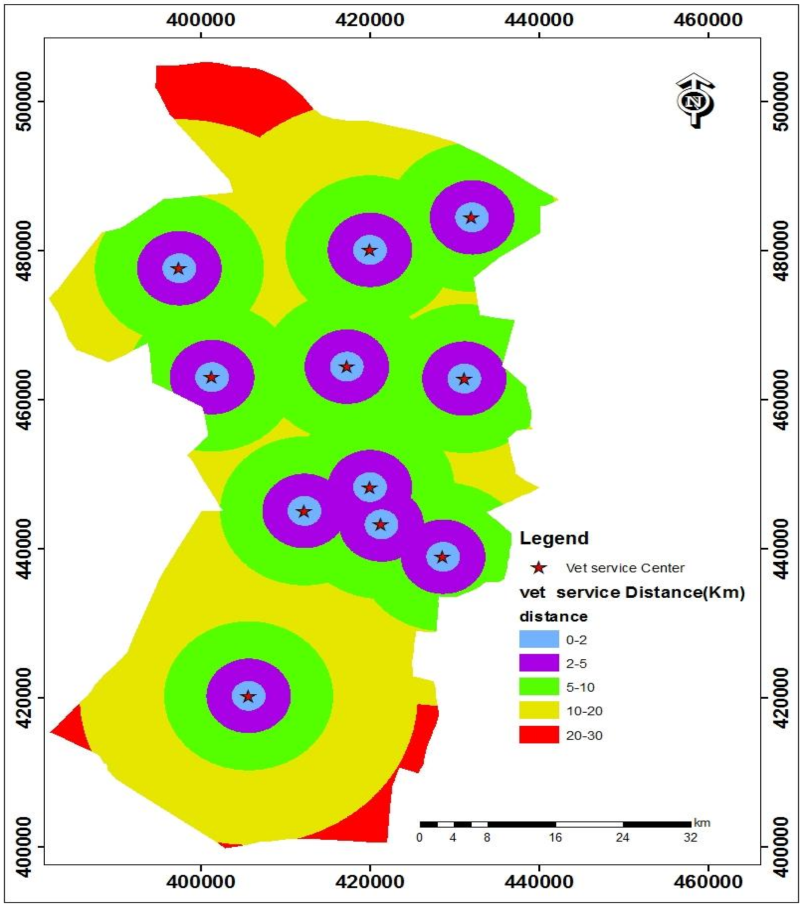

Figure 4.11. Animal Health Service Map

III. Livestock market

Efforts aimed at addressing livestock market distance suitability in the district are increasingly seen as a meaningful way of reducing pastoralists' vulnerability to drought. Because long trekking distances to markets is a significant impediment to pastoralists' ability to profitably sell their livestock. During drought periods, animals lose weight on the journey to market, which significantly lowers their value. In some cases, animals are too weak to embark on the homeward journey, forcing producers to sell at very low prices or even barter animals for food. The distance from market center was calculated by buffering from the market center points and rasterized then a distance map was calculated from it. Figure 4.12 shows map of livestock market center in Borena zone while, Figures 4.13 shows Access to livestock market map of Dire district.

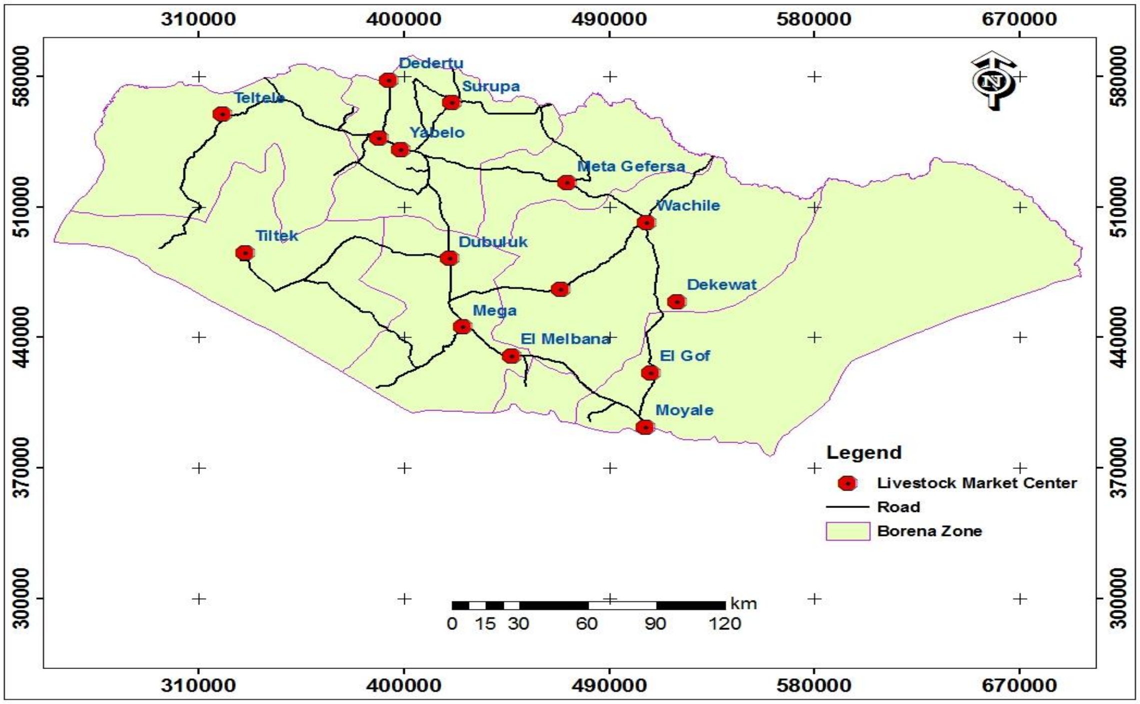

Figure 4. 12. Borena livestock market centers map

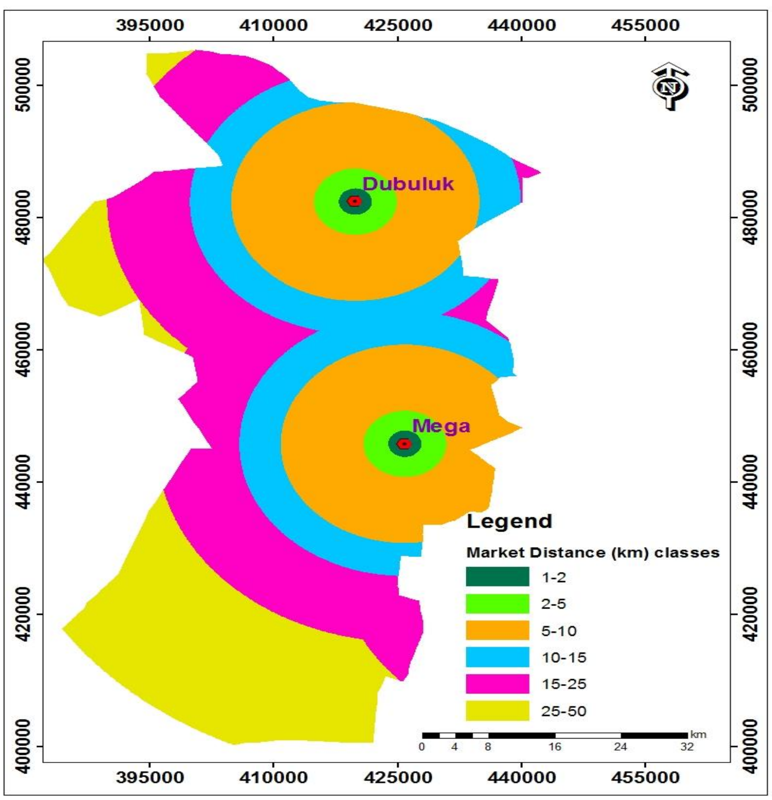

Figure 4.13. Livestock market centers map of Dire district

4.2.3.5. Factor/Criteria rating

Factor ratings are sets of values which indicate how well each factor/criterion is satisfied by particular conditions of the corresponding land quality. Thus, as a first step, compilations of the livestock production requirements that will be considered in the evaluation were made. In present study, both bio-physical and infrastructural parameters of the area were used as factors for suitability analysis. Then, the second stage is to decide on the factor ratings for each livestock species Factor ratings were made in terms of five classes: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1), and permanently not suitable (N2).

4.2.3.5.1. Criteria Standardization

The module named reclass (in ArcGIS environment) for standardization/reclassification of the factors was used. Thus, each factor has an equivalent measurement basis before any weights are applied. Accordingly, all the factors used for this study were reclassified into five classes (S1, S2, S3, N1 and N2) with the range of values 1 to where the values of 1 takes the most suitable and 5 takes the least suitable for all factors considered.

4.2.3.5.2. Assigning criterion weights

The purpose of weighting in land suitability analysis for livestock is to express the importance or preference of each factor relative to other factor effects on animal production. In the procedure for Multi-criteria evaluation (MCE), it is necessary that the weights sum to 1. Accordingly, in IDRISI, the weight module utilizes the pairwise comparison technique to help develop a set of factor weights that will sum to 1.0 (Table 4.2). In pairwise comparison matrix, factors are compared two at a time in terms of their importance related to the stated objective.

In developing weights, an individual or group compares every possible pairings and enters the rating into a pairwise comparison matrix or ratio matrix (Eastman, 2006). The matrix is symmetrical, only the lower triangle actually needs to be filled in. The remaining cells are then simply the reciprocals of the lower triangle. After all possible combinations of two factors are compared; the module calculates a set of weights and importantly, a consistency ratio. This ratio indicates any inconsistencies that may arise during the pairwise comparison process. The module allows repeated adjustments to the pairwise comparisons and reports the new weights and consistency ratio for each iteration. Table 4.2, 4.3 & 4.4 show both factor weights as well as consistency ratios calculated for the factors for livestock production in IDRISI Andes AHP weight derivation module for all livestock species.

Table 4.2. Environmental Suitability classes of each factor calculated by AHP weight derivation module with their respective area coverage for cattle

Factors	Land cover	Rainfall	Slope	Soil	**Total**	**Weight (%)**
Land cover	1				0.5083	50.83
Rainfall	1/3	1			0.2653	26.53
Slope	1/3	1	1		0.1512	15.12
Soil	1/5	1/3	1	1	0.0752	7.52
Total					***1***	***100***
Consistency Ratio					***0.07***	***7***

Table 4.3. Socio-economic Suitability classes of each factor calculated by AHP weight derivation module with their respective area coverage for cattle

Factors	Water access	Veterinary service	market	**Total**	**Weight (%)**
Water access	1			0.4126	41.26
Veterinary service	1	1		0.3275	32.75
market	1/2	1	1	0.2599	25.99
Total				***1***	***100***
Consistency Ratio				***0.05***	***5***

Table 4.4. Criterion weights derived by AHP for Cattle, Sheep, Goats and Camels.

Factors		cattle		sheep		goats		Camels	
		Weights	**Weights (%)**	**Weights**	**Weights (%)**	**Weights**	**Weights (%)**	**Weights**	**Weights (%)**
Environmental factors (53%)	Land cover	0.5083	50.83	0.5495	54.95	0.5272	52.72	0.5255	52.55
	Rainfall	0.2653	26.53	0.2476	24.76	0.2409	24.09	0.2098	20.98
	Slope	0.1512	15.12	0.1293	12.93	0.1295	12.95	0.1579	15.79
	Soil	0.0752	7.52	0.0736	7.36	0.1024	10.24	0.1069	10.69
	Total	***1***	***100***	***1***	***100***	***1***	***100***	***1***	***100***
	Consistency Ratio	***0.07***	***7***	***0.07***	***7***	***0.03***	***3***	***0.04***	***4***
Socio-economic factors (47%)	access to water	0.4126	41.26	0.4934	49.34	0.4934	49.34	0.4434	44.34
	Veterinary service	0.3275	32.75	0.3108	31.08	0.3108	31.08	0.3874	38.74
	Livestock market	0.2599	25.99	0.1958	19.58	0.1958	19.58	0.1692	16.92
	Total	***1***	***100***	***1***	***100***	***1***	***100***	***1***	***100***
	Consistency Ratio	***0.05***	***5***	***0.05***	***5***	***0.05***	***5***	***0.02***	***2***

4.3. Spatial distribution of livestock population

The recent 2013 total livestock population (cattle, sheep, goat and camel) of the 14 pastoral association (PA's), of Dire district was collected from Dire district pastoral development office and produce spatial distribution of livestock using ArciGIS Dot density modules.

RESULTS

5.1. Land Suitability Analysis

The suitability analysis result shows four classes of land suitability. These are, highly suitable, moderately suitable, marginally suitable and currently not suitable. There is no land that is classified as permanently not suitable for the four livestock species considered in this study because the final suitability is the cumulative effect of the weighted overlay of all factors. The output of the analyses was shown in (Table 5.2 & 5.3). Thus, the results portray biophysically that areas with flat to gentle slope, grassland, mean annual rainfall greater than 800mm are identified as highly suitable areas for cattle and sheep production.

Availability of water, animal health and livestock market service within a distance of less than 10, 5 and 15 kms, respectively, for cattle was highly suitable while distance of less than 5 kms of water and veterinary service availability and a distance less than 7 kms of market service are identified as highly suitable areas for sheep and goat production. The results of each factor for rangeland suitability evaluation are illustrated as follows:

Landuse/landcover: The major factor in reducing the suitability of the rangeland of the study area was the domination of the area by dense bushland and dense shrubland which is low in palatability for cattle and sheep. Dense busland and dense shrubland also limit the movements of livestock for searching their feed. The results of the landuse/landcover suitability revealed that the large portion of the area 33 % (1299 km^2) is marginally suitable for grazers (cattle and sheep) and 47.4% (1856 km^2) for browsers (Goat and camel). Small area of the range land about 17% for cattle, sheep and goats and 32 % for camels is highly suitable. Out of the total rangeland area of the district, 17% (663 km^2) for grazers (cattle and sheep), 32.4% (1269 km^2) for goats and 19.6% (769 km2) for camels were moderately suitable. Furthermore, of the rangeland area, 30.3 % (1187 km^2) for cattle and sheep while 0.3% (24 km^2) for goats and camels fell into the currently not suitable (N1) suitability category, and only 0.01% (4.17 km^2) of the rangeland fell in to the permanently not suitable (N2) category for all of the livestock species (Table 5.1 & 5.2).

Table 5.1. Suitability classes of each factor with their respective area coverage for cattle and camels.

Species	Suitability	Factors													
		LU/LC (km^2)	**%**	**RF (km^2)**	**%**	**Slope (km^2)**	**%**	**Soil (km^2)**	**%**	**Access to Water**	**%**	**Access to veterinary service**	**%**	**Access to Market**	**%**
Cattle	S1	662.83	16.9			3137.7	80	2140.5	54.6	1560.7	39.8	819.5	20.9	1329.1	33.9
	S2	768.52	19.6	3921	100	382	9.74	395.6	10.1	1703.5	43.44	1573.8	40.1	1348.7	34.4
	S3	1298.7	33.12			134	3.42	1303.6	33.24	489.4	12.5	873.8	22.3	702.5	17.9
	N1	1186.8	30.27			147.7	3.75	81.3	2.1	167.4	4.27	653.9	16.7	540.2	13.8
	N2	4.15	0.11			119.6	3.1								
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**
Camels	S1	1268.5	32.35	3921	100	3137.7	80	2139.7	54.6	2161.4	55.1	819.5	20.9	1349.1	34.4
	S2	768.52	19.6			382	9.74	396.7	10.12	1101.7	28.1	1572.8	40.1	1338.7	34.14
	S3	1856.13	47.34			137.4	3.51	1303.4	33.24	607.6	15.5	874.8	23.3	706	18
	N1	23.7	0.6			124	3.16	81.2	2.1	49.3	1.3	653.9	16.7	527.2	13.44
	N2	4.15	0.11			139.9	3.8								
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

Note:

S1: highly suitable, S2: Moderately suitable, S3: Marginally suitable, N1: Currently not Suitable, N2: Permanently not Suitable,

LU/LC: landuse/landcover, RF: Rainfall

Table 5.2. Suitability classes of each factor with their respective area coverage for sheep and goats.

Species	Suitability	Factors													
		LU/LC (km^2)	**%**	**RF (km^2)**	**%**	**Slope (km^2)**	**%**	**Soil (km^2)**	**%**	**Access to Water**	**%**	**Access to veterinary service**	**%**	**Access to Market**	**%**
Sheep	S1	662.83	16.9			3137.7	80	2139.7	54.6	698.6	17.8	819.2	20.9	635.7	16.21
	S2	768.52	19.6	3921	100	420.8	10.73	396.7	10.12	862.1	22	1573.3	40.1	713.4	18.2
	S3	1298.7	33.12			135	3.44	1303.4	33.24	601.8	15.35	874.1	22.3	716.3	18.27
	N1	1186.8	30.27					81.2	2.1	1758.5	44.85	653.7	16.7	1855.6	47.32
	N2	4.15	0.11			227.5	5.85								
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**
Goats	S1	768.52	19.6			3137.7	80	2139.7	54.6	698.6	17.8	819.2	20.9	635.7	16.21
	S2	1268.5	32.35	3921	100	516.5	13.17	396.7	10.12	862.1	22	1573.3	40.1	713.4	18.2
	S3	1856.13	47.34			107	2.73	1303.4	33.24	600.8	15.35	874.1	22.3	716.3	18.27
	N1	23.7	0.6					81.2	2.1	1758.5	44.85	653.7	16.7	1855.6	47.32
	N2	4.15	0.11			150.8	4.1								
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

Note:

S1: highly suitable, S2: Moderately suitable, S3: Marginally suitable, N1: Currently not Suitable, N2: Permanently not Suitable,

LU/LC: landuse/landcover, RF: Rainfall

Rainfall suitability: Rainfall determined the amount of water available for rangeland plant growth. Minimal rainfall for rangeland plant growth is not so inadequate. Usually annual rainfall of 400 mm is considered suitable. The results of rainfall suitability showed that 100% of the rangeland of in the district investigation fell under the S1 suitability category for camels while 100% of the rangeland area fell in the S2 suitability category for cattle, sheep and goat (Tables 5.1 & 5.2).

Soil and slope suitability: Both variables are usually allocated deep and heavy soils to agriculture and soils with medium to coarse gravel or rubble stone and semi-evolved with moderate deep to shallow for rangeland. The final outcome of the analysis on the soil suitability showed that the district in question had fewer problems regarding soil suitability for all livestock species (cattle, camels, sheep and goats). Thus, more than 54% of the range land area is highly suitable (Tables 8 & 9). Furthermore, the results showed that 54.6%, 10.2%, 33.4% and 2.1% of the rangeland area fell in the S1, S2, S3 and N1, respectively, for all livestock species. No rangeland area fell into the N2 suitability category. The result of the slope suitability analysis showed that the large area of the district is relatively flat. Thus, more than 80% of the rangeland area is highly suitable for all livestock species and out of the rangeland area about 6.9%, 5.9%, 4.1% and 7 % are unsuitable (N1 & N2) for cattle, sheep goats and camels, respectively while about 3 % of the area can be only for the purpose of tourism and wildlife (Tables 5.1, 5.2 & Figure 5.1).

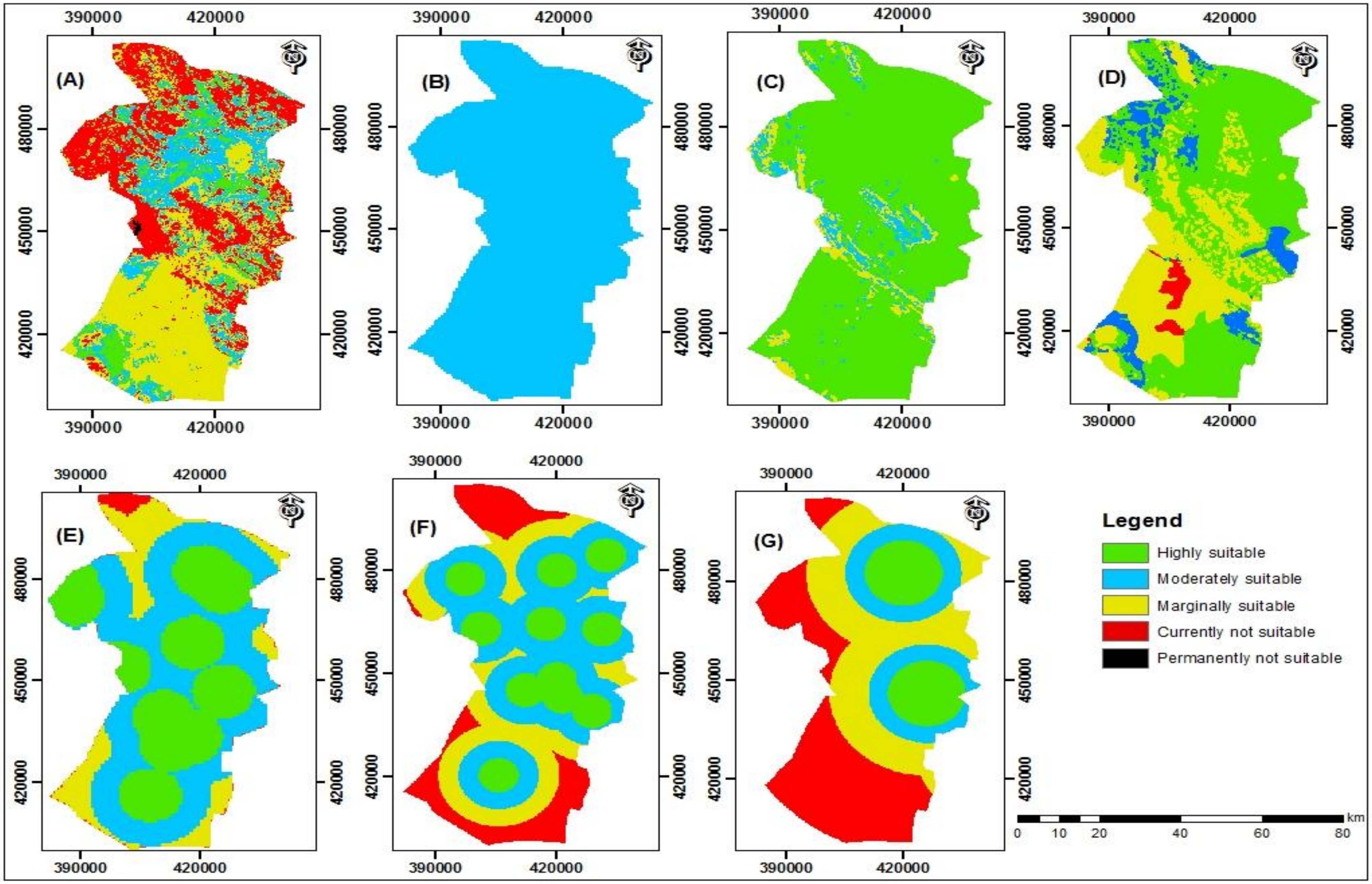

Figure 5.1. Suitability maps of each factors map for Cattle suitability analysis (A. LU/LC, B. Rainfall, C. Slope, D. Soil (texture), and E. Water availability, F. Animal health service and G. Market Access

Distance from water resources, livestock market and veterinary services: The suitability analysis of distance from water resources for different livestock species revealed that a 39.8% and 55.1% of the rangeland area is highly suitable for cattle and camels, respectively, while small proportion 17.8% for sheep and goats. Furthermore, 43.4% of the area is moderately suitable for cattle Tables 7 and 8. Large portion of the total area, about 44.9% for sheep and goats was found to be currently not suitable. The district in question had problems regarding distance from water resources, especially for sheep and goats that mainly constrained the suitability of the rangeland with respect to water resources.

The results of the distance from livestock market suitability analysis showed that, of the rangeland area about 34% fell in moderately suitability category for cattle and camels, while 47.32% (1855.6 km^2) of the rangeland fell into the currently not suitable (N1) category. The final outcome of the model on livestock market suitability showed that the Dire district had problems regarding the access to market center especially for sheep and goats, which covers about 47% of the area is currently not suitable.

The results of the sub-model revealed that about 40% of the district is moderately suitable regarding veterinary service for all livestock species. Furthermore, about 20.9%, 40.1%, 23.3% and 16.7% of the rangeland area fell in the S1, S2, S3 and N1 suitability categories for all livestock (cattle, camel, sheep and goat). About 17% of the area is currently not suitable The final outcome of the model on livestock animal health suitability showed that the Dire district had problems regarding distance from animal health center for all of livestock species (cattle, camel, sheep and goat) that covers about 17% of the district is currently not suitable.

5.2. Environmental and socio-economic suitability analysis

Based on environmental factors (landcovers, rainfall, soil and slope) analysis, the district is marginally and moderately suitable for livestock production (Table 5.3 & Figure 5.2). Furthermore, the result showed that 40.4%, 40.3%, 40.2% and 33.3% is moderately suitable for cattle, sheep, goats and camels, respectively. Out of the total area about 41.6%, 41.6 %, 51.7% and 45.5% of the area is marginally suitable for cattle, sheep goats and camels, respectively. Small area of the district is highly suitable for cattle (8.2%), sheep (8.4 %), goats (7.4%) and camels (20.8%). The area also classified under unsuitable classes (currently not suitable &

permanently not suitable) for all livestock species but the range is small and this is lower for the browsers (goats and camels) than grazers (cattle and sheep).

The suitability analyses results based on socio-economic factors (access to water, livestock market and veterinary service) revealed that the district is moderately suitable for camels while marginally suitable for cattle, sheep and goats (Table 5.3 and Figure 5.3). Small area of the district (8.3%) for small ruminant (sheep and goats), 13.8% for cattle and 26.2 for camels is highly suitable. Furthermore, area of the range 36.3% and 44.3% in the district is moderately suitable for cattle and camels, respectively while 27% for sheep and goats, respectively. Large proportion area of the district, 37.5 % (cattle), 38.6% and (sheep and goats) is marginally suitable. Finally, 25% of the area for small ruminants (sheep and goats) while 12.3% for cattle and 6.5% for camels are currently not suitable.

Table 5.3. Land suitability classes for livestock production based on environmental & socio-economic factors

Suitability factors	Suitability Classes	Livestock Species							
		Cattle		**Sheep**		**Goats**		**Camels**	
		Area (km^2)	**Area (%)**	**Area (km^2**	**Area (%)**	**Area (km^2**	**Area (%)**	**Area (km^2**	**Area (%)**
Environmental factors	Highly suitable	321.75	8.21	329.38	8.4	291.11	7.42	814	20.76
	Moderately suitable	1583.5	40.39	1579.7	40.29	1578.02	40.24	1306.85	33.33
	Marginally suitable	1629.9	41.57	1629.71	41.56	2026.94	51.7	1782.35	45.46
	Currently not suitable	385.85	9.84	382.21	9.75	24.93	0.64	17.8	0.45
	Permanently not suitable	0.58	0.01	0.63	0.02	0.46	0.01		
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**
Socio-economic factors	Highly suitable	539.8	13.8	323.4	8.25	323.4	8.25	1029.2	26.2
	Moderately suitable	1423	36.3	1093.2	27.9	1093.2	27.9	1741	44.3
	Marginally suitable	1476.7	37.5	1514.3	38.6	1514.3	38.6	897.9	23
	Currently not suitable	481.5	12.3	990.1	25.25	990.1	25.25	252.9	6.5
	Permanently not suitable								
	Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

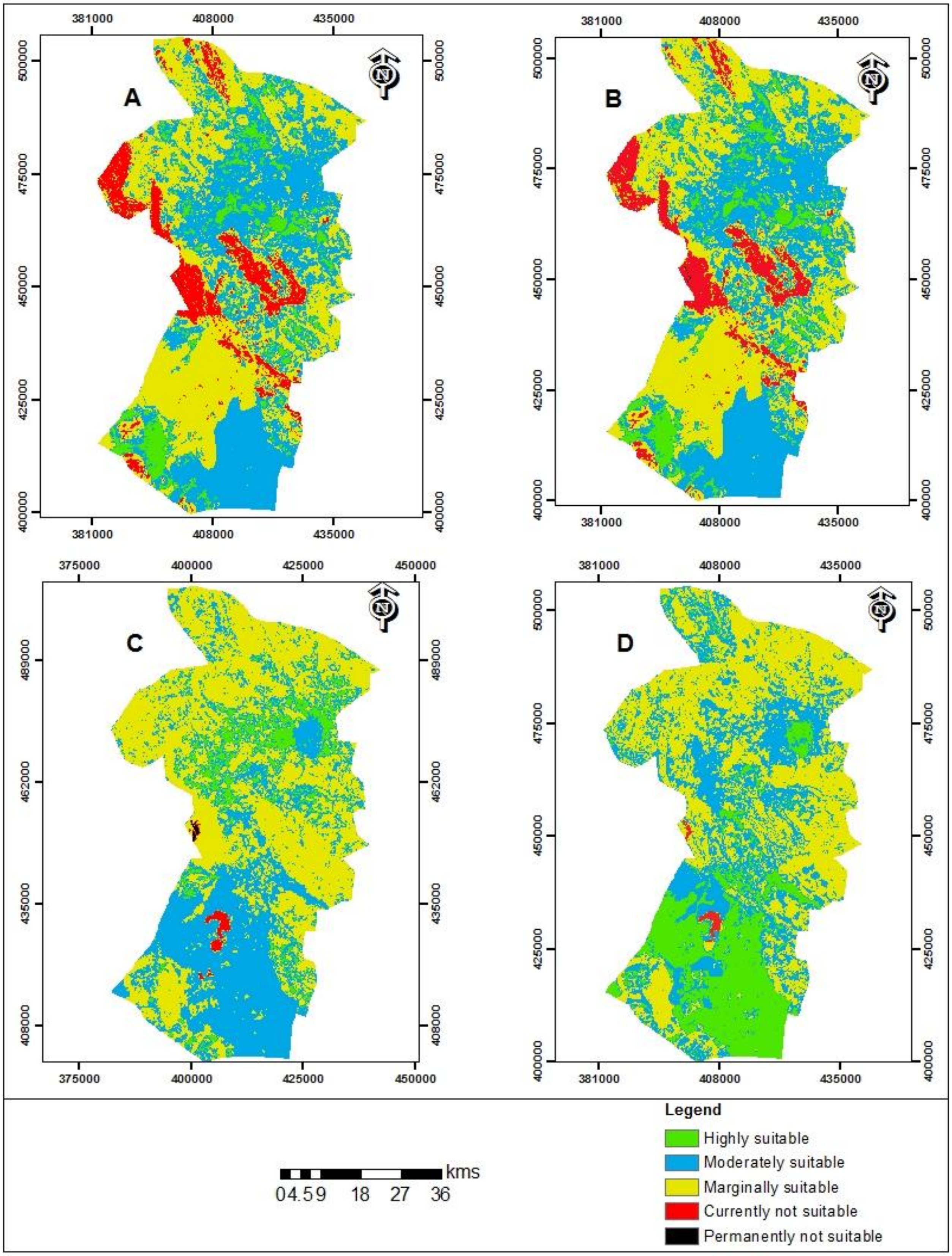

Figure 5.2. Land suitability map based on Environmental parameters of A) Cattle, B) sheep, C) Goats and D) camels.

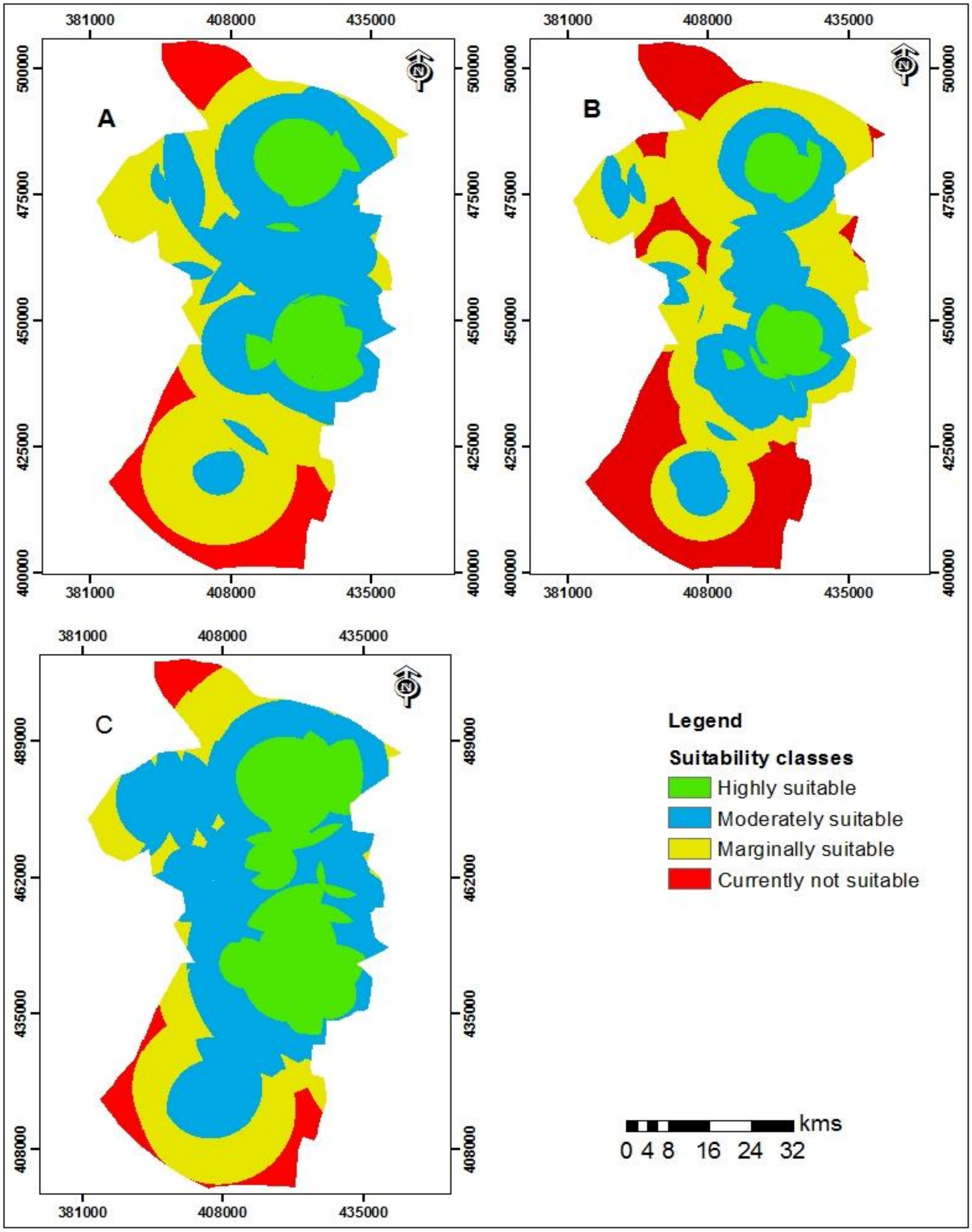

Figure 5.3. Land suitability map based on Socio-economic parameters of A) Cattle, B) sheep & Goats, and C) camels.

5.3. Final application for livestock Production

The final outcome of the suitability analysis for livestock production was derived from the combination of environmental and socio-economic suitability sub-models (Tables 5.3). The result obtained from this study showed that the proportion of highly suitable areas was small which is 5.6% for cattle and 10.1% for camels while sheep 4.9% and goats 5.4%, respectively of the whole area. The amount of land which fell under high suitability class for cattle, sheep and goats is small compared to the total area as well as to that of the area for camels (Table 5.4, Figures 5.4 & 5.5).

Areas having slope between 8-16, grassland, and rainfall of 500-800mm and >1700mm are found to be moderately suitable for cattle. The above conditions also hold true for sheep suitability except the slope class that is between 16-30 have moderately suitable. This is because; sheep can manage themselves better than larger animals because of their smaller body weight. In the utilization of slope, smaller animals like sheep and goats are more tolerant to steeper slope than cattle and camels. Concerning landuse/landcover and temperature parameters, camels and goats have more or less the same preference except slight differences.

A wide area of the range land in the district was classified under marginally suitable for cattle, sheep and goats, while about half of the area is moderately suitable for camels. Furthermore, 45.7%, 46.45%, 51% and 30.9% of the rangeland area is marginally suitable for cattle, sheep, goats and camels, respectively. Of the rangeland areas, 44.75 %, 44.17%, 42.52% and 58.6% of the land is moderately suitable for cattle, sheep, goat and camels, respectively, while 4%, 4.48%. 1.1% and 0.38% of the land is currently not suitable for cattle, sheep, goat and camels, respectively (Figures 5.4, & 5.5). The study does not show areas which is classified as permanently not suitable even though there are factors in which permanently not suitable classes were observed.

Table 5.4. Final land suitability classes for livestock with their respective area coverage

Suitability Classes	Livestock Species							
	Cattle		Sheep		Goats		Camels	
	Area (km^2)	Area (%)	Area (km^2	Area (%)	Area (km^2	Area (%)	Area (km^2	Area (%)
Highly suitable	218.77	5.6	192.25	4.9	211.52	5.4	396.84	10.12
Moderately suitable	1754.7	44.75	1732.01	44.17	1667.72	42.52	2298.3	58.6
Marginally suitable	1791.8	45.7	1821.29	46.45	1998.14	51	1211.02	30.9
Currently not suitable	155.73	4	175.45	4.48	43.62	1.11	14.84	0.38
Permanently not suitable								
Total	**3921**	**100**	**3921**	**100**	**3921**	**100**	**3921**	**100**

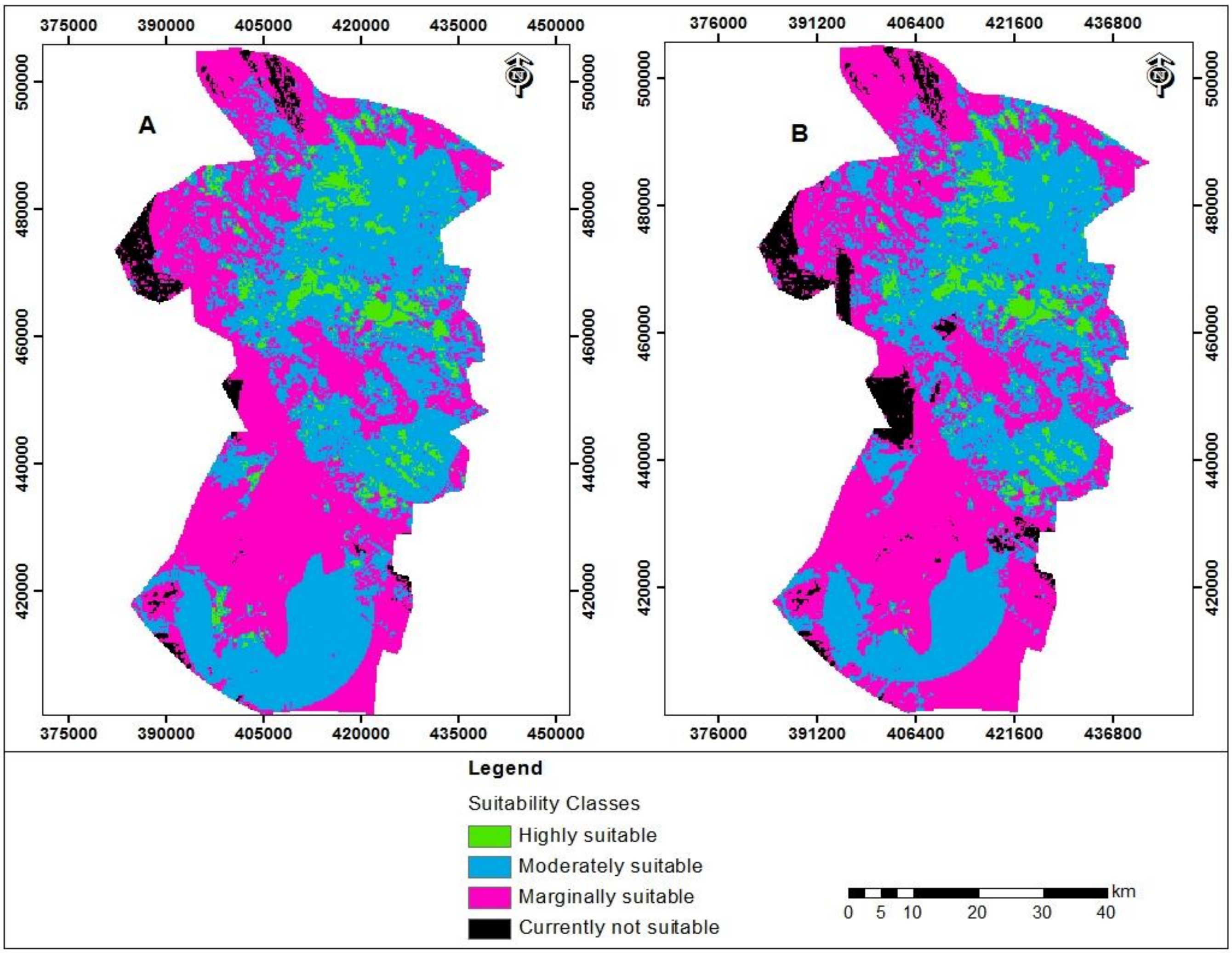

Figure 5.4. Final suitability map based on both environmental and socio-economic factors of A) Cattle and B) Sheep

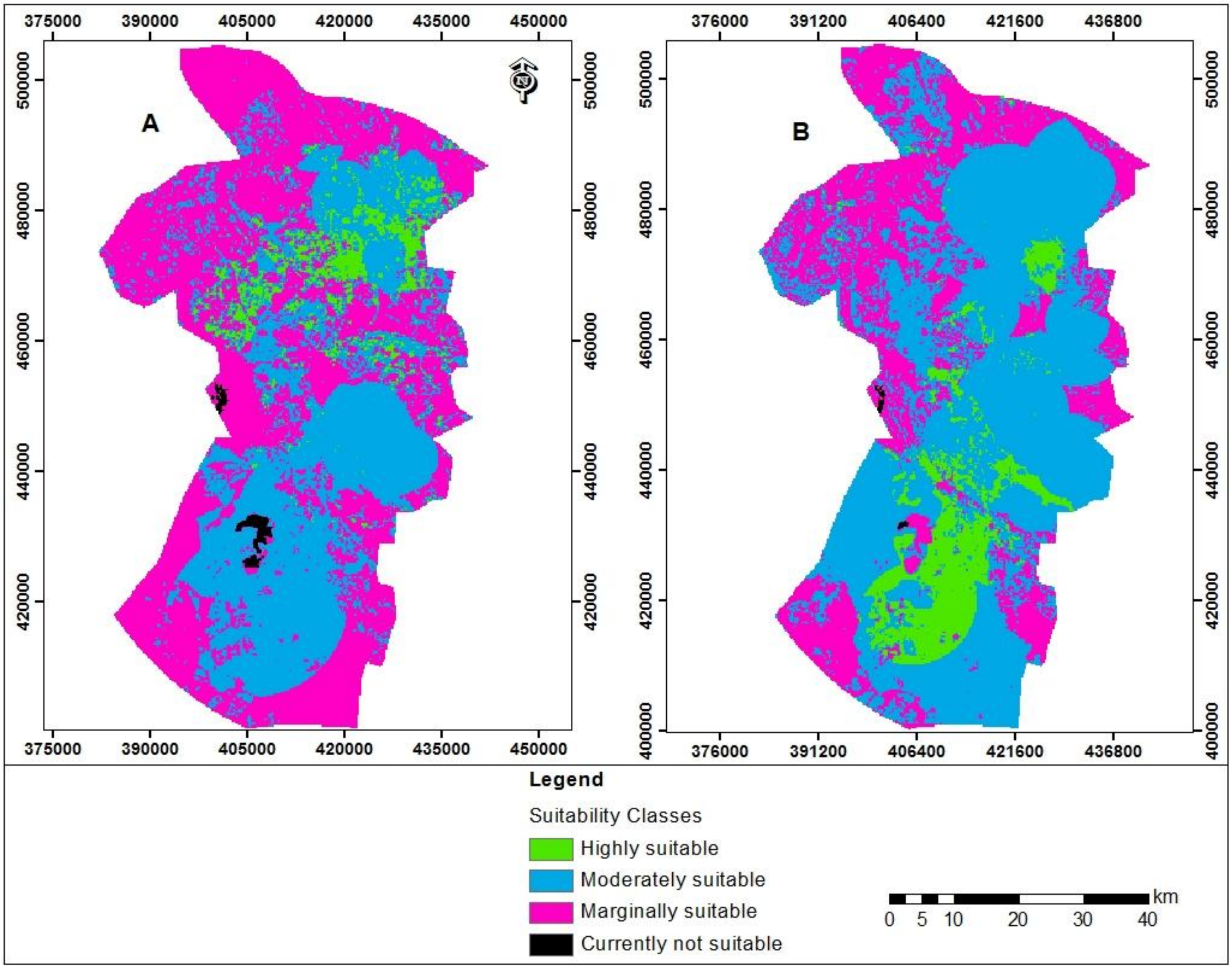

Figure 5.5. Final suitability map based on both environmental and socio-economic factors of A) Goats and B) Camels

5.4. Landuse/landcover change

The landuse/landcover units of the study area were classified in to eight types; these are: forest, open bushland, dense bushland open shrubland, dense shrubland, grassland, farmland and bareland. The major portion of the landuse/landcover was dominated by grassland and open shrubland before 25 years but in 2011 it is dominated by open and dense bushland (Table 5.5 and Figure 5.6). The result of classification accuracy assessment is shown in Table 5.6. The overall accuracy and the Kappa value of field data *versus* automated classification results were 86.05% and 0.84, respectively. The accuracy level of each true land cover category is indicated in Table 5.7.

The results of land use/ land cover map (Figure 5.6 & Table 5.5) showed that the area of grassland and open shrubland and bareland has declined. The rate of change was greater in the grassland and shrubland than bareland classes. The area of open bush, dense bush and dense shrubland has increased rapidly while farmland and forest showed a general trend of increase in area coverage.

Table 5.5. Landuse/landcover classes and changes from 1986 to 2011 in Dire District of the Borena Zone.

Classes	**1986**		**2011**		**Change (km^2)**	**Change (%)**
	Area		**Area**			
	km^2	**%**	**km^2**	**%**		
Forest	3.4	0.1	4.16	0.11	0.76	0.01
Open bush land	931.67	23.76	1270	32.39	338.33	8.68
Dense bush land	459.1	11.7	684.52	17.46	254.42	5.76
Open shrubs land	1068.8	27.26	769.87	19.63	-298.93	-7.63
Dense shrub land	341.3	8.71	498.76	12.72	157.46	4.01
Grass land	1090.17	27.8	663.35	16.92	-426.82	-10.88
Farm land	2.11	0.05	6.64	0.17	4.53	0.12
Bare land	24.45	0.62	23.7	0.6	-0.75	-0.02
Total	**3921**	**100**	**3921**	**100**		

Significant spatial expansion in open bushland, dense bushland and dense shrubland and the rapid decrease in grassland and open shrubland were observed in the 2011. The major cover changes observed during this period had been the reduction in the area of grassland from 27.8 % (1090 km^2) in 1986 to 17% (663.4 km^2) in 2011 with a rate of 17 km^2/year while open shrub-land from 27% (1068.8 km^2) in 1986 to 20% (770 km^2) with a rate change of 12 km^2/year (Table 13). The area of open bushland, dense bushland and dense shrubland were showed increasing pattern in study area over the analysis period. Of the total land area, the landcover by open bushland in Dire district was 24% (932 km^2) in 1986. A consistent increase to 32% (1270 km^2) with a rate change 13.5 km^2 /year throughout the analysis period while dense bushland from 11.7% (459 km^2) to 16.5% (684.5 km^2) with a rate of 0.23 km^2 /year. Dense shrubland increased from 8.7% (341.3 km^2) to 12.7% (498.8 km^2) with the rate of 6.3 km^2 /year. General patterns of land use/landcover identified in the two images were largely dominated by shrubland, bushland and grassland, areas (Table 5.6).

Table 5.6. Landuse/landcover class change rate (1986-2011).

Classes	1986		2011		Rate of change in (km /year)
	Area		Area		
	km^2	%	km^2	%	
Forest	3.4	0.1	4.16	0.11	0.03
Open Bush land	931.67	23.76	1270	32.39	13.53
Dense bush land	459.1	11.7	684.52	17.46	0.23
Open Shrubs land	1068.8	27.26	769.87	19.63	-11.96
Dense shrub land	341.3	8.71	498.76	12.72	6.3
Grass land	1090.17	27.8	663.35	16.92	-17.1
Farm land	2.11	0.05	6.64	0.17	0.18
Bare land	24.45	0.62	23.7	0.6	-0.007
Total	**3921**	**100**	**3921**	**100**	

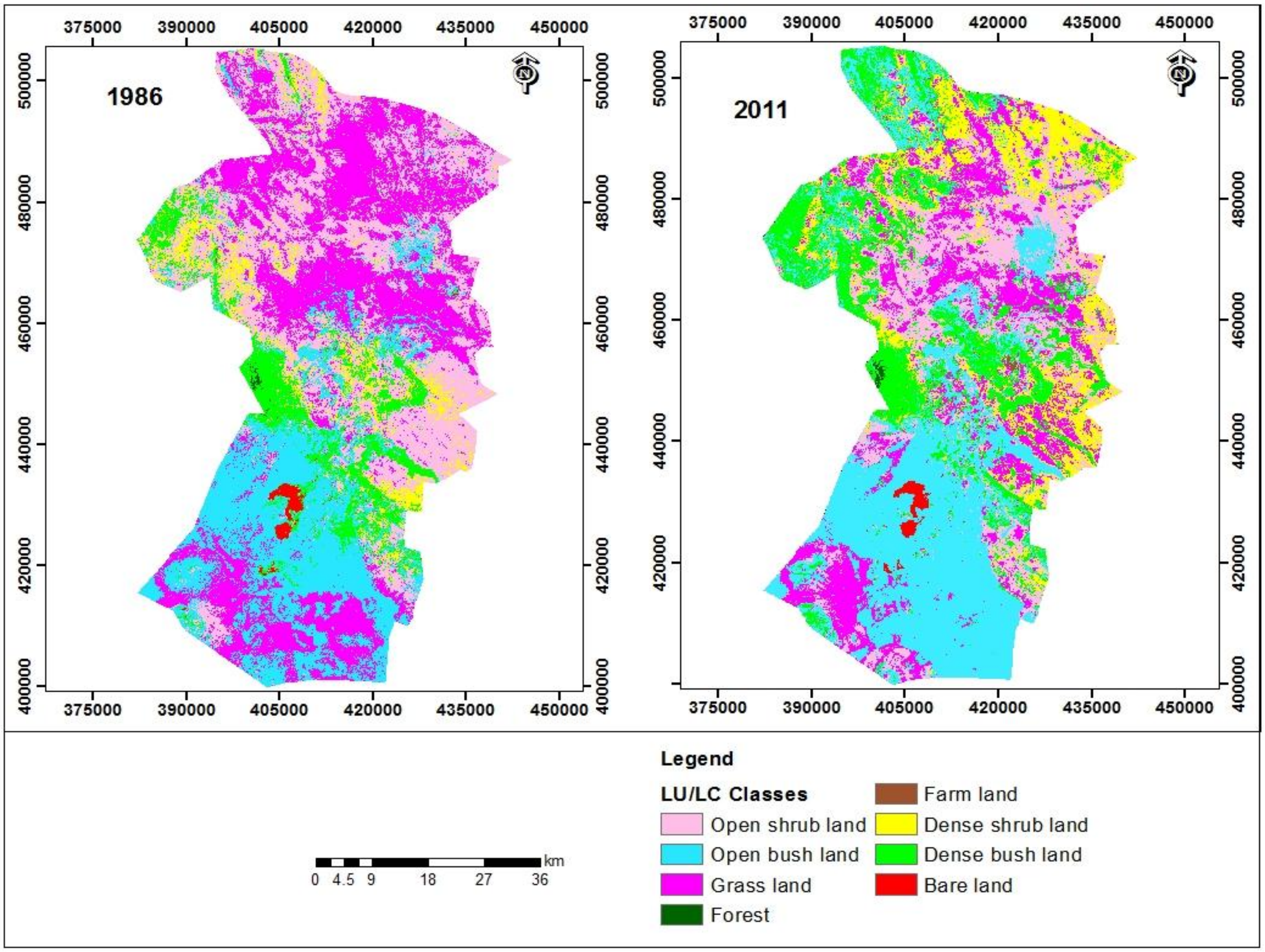

Figure 5.6. Landuse/landcover maps of the study area (1986 - 2011)

The overall accuracy and Kappa values were 86.05 and 0.84, respectively (Table 5.8). The classification of forest and farm land showed that 100% producer's accuracy, which means no pixel, was incorrectly excluded from its category. However, dense bushland, dense shrubland, open bushland, open shrubland, grassland bareland and showed the omission of 22.22%, 16.67, 25%, 20%and 14.29 %, respectively. Forest, dense bushland and bareland showed 100% user's accuracy indicating accurately automated classification was bush land carried out, whereas open bushland and farmland is less accurately classified (75%) in automated classification. Error matrix for each land use/land cover is shown in table 5.7.

Table 5.7. Error matrix of TM 2011 showing classification accuracy of the true landcover

Classified data	**Forest**	**Dense Bush land**	**Dense shrub land**	**Open bush land**	**Open Shrubs land**	**Grass land**	**Farm land**	**Bare land**	**Total**
Forest	2		-	-		-	-	-	2
Dense bush land	-	7	-	-		-	-	-	7
Dense shrub land		-	5	1		1			7
Open bush land	-	2	-	5		-	-	-	7
Open Shrubs land	-	-	-		3	-	-	-	3
Grass land	-	-	-	-	1	4	-	-	5
Farm land	-	-	-	-		-	4	1	5
Bare and	-	-	-	-		-	-	6	**6**
Total observation	**2**	**9**	**5**	**6**	**4**	**5**	**4**	**7**	**42**

Table 5.8. The accuracy level of each Landcover category TM 2011

Class Name	**Reference total**	**Classified Total**	**No. of corrected**	**Producers Accuracy (%)**	**Users Accuracy (%)**
Forest	2	2	2	100	100
Dense bush land	9	7	7	77.78	100
Open Shrubs land	5	7	5	100	71.43
Dense shrub land	6	7	5	83.33	71.43
Open bush land	4	3	3	75	100
Grass land	5	5	4	80	80
Farm land	4	5	4	100	80
Bare and	7	6	6	85.71	100
Totals	**42**	**42**	**36**		
Over all accuracy (%)		***86.05***			
Over all kappa value		***0.84***			

5.6. Spatial distribution of livestock population

According to (Table 5.9 and Figure 5.7) all kinds of livestock species were found in all PA's except in Kebena PA where camels were not found and the variations in number and density among them.

Table 5.9. Livestock population of the study area

No	Kebele/Locality	Livestock population					Percent	Area (km^2)	Density
		Cattle	Goat	sheep	camel	Total			
1	Denbela bedano	11500	7010	500	350	19360	8.7	603.92	32
2	Dida mega	2000	4223	1198	155	7576	3.4	67.93	111.5
3	Dokale	6010	7020	5000	390	18420	8.3	369.67	49.8
4	Dubluk	6250	4050	2500	200	13000	5.9	50.98	254.9
5	Gololcha	6022	8691	6409	255	21377	9.7	228.31	93.6
6	Haralo	6586	10153	3847	305	20891	9.4	108.79	192
7	Higo	8631	7580	6987	387	23585	10.6	223.5	105.5
8	Semero	6203	6050	3150	290	15693	7.1	173.91	90.2
9	Kebena (Mega)	702	400	250	0	1352	0.6	3.24	417.3
10	Medacho	12484	8664	7820	574	29542	13.3	391.73	75.4
11	Magado	7200	10000	8002	466	25668	11.6	1346.85	19.1
12	Manasoda	4650	4420	3980	196	13246	6	164.08	80.7
13	Romso	3565	4900	3100	290	11855	5.4	188.05	63.04
14	Total	81803	83161	52743	3858	221565	100	3920.96	56.5

Source: Dire District Pastoral Development Office (2013)

There were a total of 81803, 83161, 52743 and 3858 of cattle, sheep, goats and camels, respectively, in the study area. The highest population of livestock was found in Medacho PA, which is 29,542 (13.3%), followed by Megado PA having 25668 (11.6%) population of livestock. The smallest was found in Kebena PA 1,352 (0.6%). The highest number of cattle is found in Medacho 12,484 and the lowest in kebena 702. The highest number of sheep is found in Megado 8,002 and the lowest in kebena 250. The highest number of goat is found in Haralo, 10,153 while the lowest in kebena 400. Compared to the other livestock species, the number of camels' population is small in the district. The variation in the number of camels was very high among some PAs. For example, the number was as high as 466 in Megado and 0 in Kebena. The spatial distribution of livestock populations is shown in Figure 5.7.

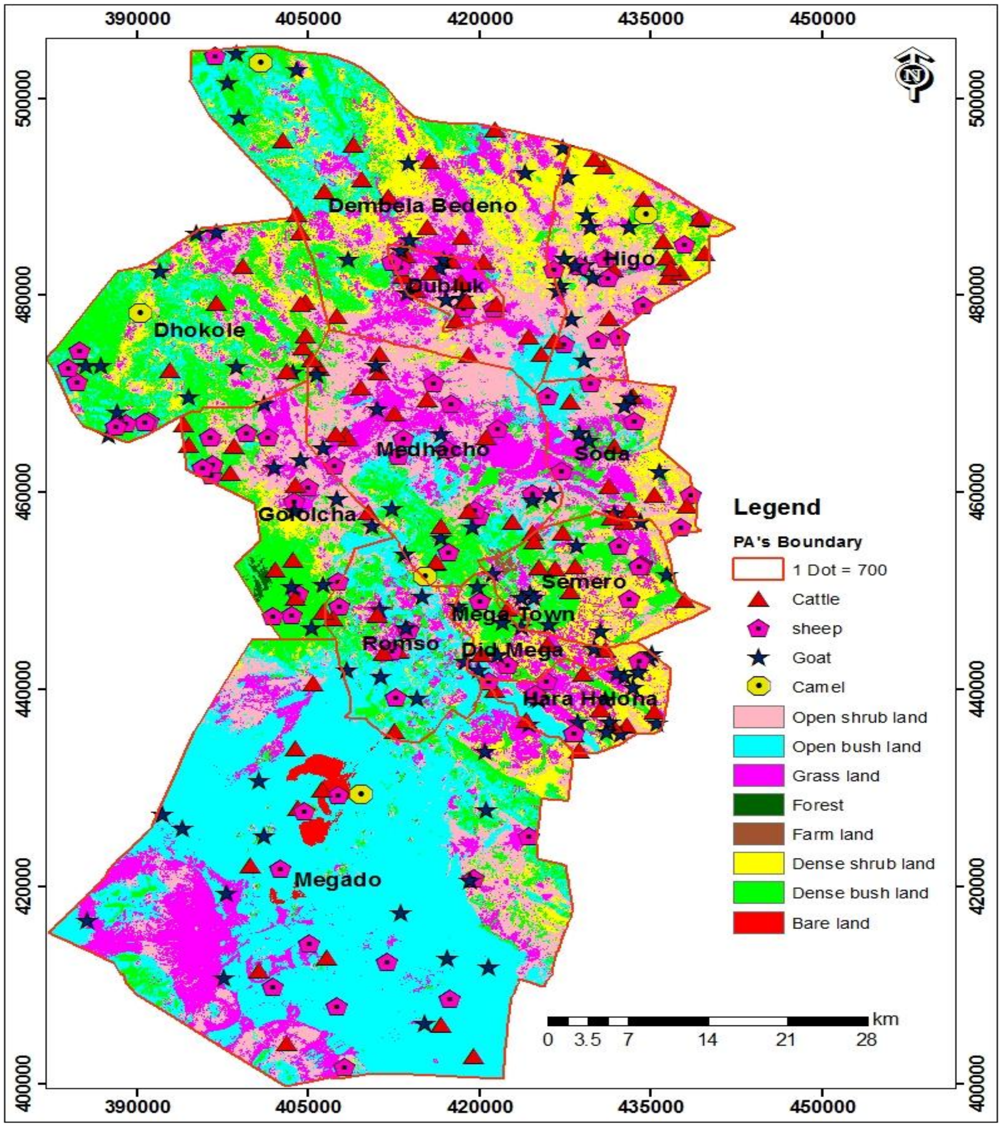

Figure 5.7. Livestock distribution map of the Dire district

Discussion

Rangelands and animal husbandry have been important economic activity in Ethiopia for a very long time. The degree of importance attached to a specific rangeland area reflects its productivity, land scarcity and the availability of alternative sources of income. Appropriate landuse decisions are vital to achieve optimum productivity of the land and to ensure environmental sustainability. In Ethiopia as in most parts of the world, animal husbandry is the most productive use of semi-arid zones bordering the desert. Therefore, the objectives of this study, was to apply the concept of range inventory in the recognition and evaluation of potential and actual production for optimal utilization of this valuable natural resource for domestic livestock production.

In adapting the grazing suitability analysis for the rangelands due consideration was given to the landuse/landcover, rainfall, topography, soil, water availability, access to market and animal health services and the factors were found to be effective to different degrees. Therefore, recognizing the factors effective in the suitability and determining the amount of limitations they impose was important for analyzing and assessing rangelands. Arzani *et al.* (2006), Amiri (2009) and Alizadeh *et al.* (2011) determined rangeland suitability for sheep and goats grazing using a livestock grazing model with the three components, namely forage production, water resources, and the sensitivity of the soil to erosion. Dessalegn Gurmessa (2006) and Fikadu Lemessa (2011) also determined rangeland suitability for cattle, sheep, goats and camels in Yabello district, Southern Ethiopia using only biophysical factors including feed availability altitude, land use/land cover, temperature, rainfall, slope, and soil texture.

The suitability analysis recognized the important factors affecting suitability for livestock use of the rangeland, and also determining the kind of the limitations and factors reducing the suitability with the aim of gaining an adequate plan for grazing and browsing. In assessing site considerations this general suitability analysis identified wider resource management and conflicts of rangeland allocation and livestock production within pastoral communities.

The suitability of the range land for each factor in line with livestock production is discussed below:

A. *Landuse/landcover suitability*

Rangeland is in conflict with industrial development but in compatible with forestry (in condition of compliance of management and control principles) (Jafari and Zaredan, 2010). Land cover is a product of human activities altering the terrestrial surface. In turn, it also governs the kind of activities that can take place over a given piece of land. Because it may not represent the true potential of the land, land cover, as an important element in a complex ecological and economic system, needs to be evaluated periodically. By comparing this potential with the current use, it is possible to know whether land resources have been utilized optimally, and if not, how the current allocation can be modified to achieve optimal or the best use, defined as generating maximum return from the land with minimum detrimental effect on it. Land cover is one of the most important factors affecting the land suitability classification for rangeland because it determines vegetation type and density. Whatever land is rich and diverse regarding palatable species for livestock will definitely have more suitability for rangeland use. A wide area of Dire rangeland is the marginally suitable (major limitation) in landuse/landcovers for all livestock species Small area of the rangeland is highly suitable for livestock production because the area was dominated by bush and shrubs than grasses which is unpalatable for cattle and sheep.

B. *Slope, soil and rainfall suitability*

Slope is very important factor for land suitability analysis of rangeland. This is because, slope is the factor which makes this portion of the land suitable because animals can easily grazing on flat and gentle slope and they can utilize most of the available feed without the loss of much energy. Places with high slope (more than 30%), is not suitable for livestock grazing due to being impassable. On the other hand, the very sharp slopes as a result of low soil depth and lack of evolved soils have not been appropriate condition for growth and diversity of palatable rangeland plants. Grazing on steep slopes will cause movement of the soil and consequently, will make it difficult for plants to remain stable. Furthermore, the livestock will spend lots of energy in walking on the steep slopes (for grazing and reaching water sources) and as a result their function will decrease. Gavili *et al.* (2011) explained that the slopes with more than 60% as useless for all kinds of livestock. On such steep slopes wild animals would graze better than livestock. The slope suitability analysis result showed that about 80% of the rangeland is gentile slope and it is highly suitable for all livestock production while about 6.75%, 5.75%, 4.1% and 6.95 % of the area are unsuitable for cattle, sheep, goats and camels, respectively. This area is used only for the purpose of tours and wild life production. The soil texture is also the animals' preference. But in cases where soil is less suitable, the area still can fall under moderately suitable area as far as the other aforementioned suitability factors are fulfilled. This is because; the weighted value factors outweigh that of the value of soil. But, this does not mean that soil has not influenced the suitability analysis, but its effect is masked by the other factors which have more weight. About 54% of the area is highly suitable in soil texture and 33% of the area is marginally suitable for all livestock species while 2.1% of the area is unsuitable. Regarding rainfall the district is (100%) moderately suitable for cattle, sheep and goats while (100%) of the area is highly suitable for camels.

C. Distance to water suitability

Water availability is an important issue due to the seasonal nature of water throughout the southern Ethiopia. Rangeland management system in southern pastoral areas of Ethiopia is strongly based on the management of water. There are two major water sources in these areas, namely deep wells (local name *eel*aa) and water ponds. Eelaa wells and rangelands that surround them are intensively used during the dry season. Water-ponds are a mechanically excavated seasonal source of water. Rangelands characterized by different systems of grazing resource usage and management of the communal grazing lands based on the water resources, can offer an opportunity to study changes in species composition and response of grasses to prolonged and intensive disturbance (Abule Ebro *et al.,* 2005; Gemedo Dalle *et al.,* 2006). Dire district is currently not suitable regarding water access for small ruminants (sheep and goats) and moderately suitable for cattle while highly suitable for camels. One use of this range suitability analysis is to determine optimal placement of additional water sources to increase cattle distribution. The placement of new water sources in these previous "unsuitable" areas could increase the areas available for grazing.

D. ***Market and veterinary service centers suitability***

The sale of livestock and livestock products is the main source of cash income. The distance from the main marketing centers influence the price of animals. Long distances trekking to markets are a significant impediment to pastoralists' ability to profitably sell their livestock. During drought periods animals lose weight on the journey to market, which significantly lowers their value. In some cases, animals are too weak to embark on the homeward journey, forcing producers to sell at very low prices or even barter animals for food. Regarding distance to market center suitability, the area is moderately suitable for cattle and camel while almost about half of the area is currently not suitable for sheep and goats. The area is moderately suitable in access to veterinary service for all livestock species and about 17% of the area is currently not suitable for all livestock species.

6.1. Environmental suitability analysis

A comprehensive analysis of the physical settings for the Dire district rangeland revealed four major environmental variables (Landcover, rainfall, topography and soil) for land suitability assessment. Rainfall determined the amount of water available for plant growth. Terrain was important for maintaining slope stability and was critical to the distribution of other variables at a local scale ***(****e.g.*, a steep terrain should not be tilled to prevent soil erosion). Soil governed the type of vegetation that could grow most productively in that area and vegetation *(e.g.,* its presence and health conditions) showed whether the land could be used productively. The role of these factors in the environment varied with landcover. Therefore, due to its changing dominance in different areas, the same environmental factor could have different influences. Many researchers (Bizuwerk *et al*., 2005; Dessalegn Gurmessa, 2006, Jafir and Zaredar, 2010 Fikadu Lemessa, 2011 Amir *et al.*, 2012) adapted the same method to analysis rangeland suitability using GIS techniques at different study area. Based on environmental parameter analyses rangeland of the Dire district is marginally suitable (major limitation) for all livestock species because the area is dominated by bush encroachment which limit the suitability of the range land for livestock production.

6.2. Socio-economic suitability analysis

The rangeland management system in southern pastoral areas of Ethiopia is strongly based on the management of water. The availability of surface water sources such as ponds and *eelaa* in order to supply the water needs of plants and livestock as well as veterinary service are essential for live tock production. On the other hand, distance from the main marketing centers influence the price of animals. Long distances trekking to markets are a significant impediment to pastoralists' ability to profitably sell their livestock. Generally, the area is marginally suitable for cattle, sheep and goats while moderately suitable for camels based on socio-economic (distance to water, market and veterinary service) rangeland suitability analyses for livestock production but about 25% of the area is currently not suitable for small ruminants (sheep and goats) while about 12% for cattle and 6.5% for camels because the area is far from access to water, veterinary service and market canter which is greater than 15 km away from veterinary service center, 10-25 km from watering point and 25 km from market center were classified under currently not suitable for livestock production. Similar method was adapted by Jafir and Zaredan (2010) to analysis suitability of land using multi attribute decision making approach.

The final outcome of the suitability result showed that the main part of the rangeland area fell within marginally suitable (major limitation) and moderately suitable (minor limitation) suitable categories. Small areas of the range land, i.e. 5.6%, 4.9%, 5.4% and 10.1% fell in the S1 suitability categories (limitless) for cattle, sheep, goats and camels, respectively, while about 44.8%, 44.2%, 46.5%, and 58.6% of the range land was within moderately suitable. The main part of the rangeland area which is about 45.7%, 45.5%, 51% and 30.9% fell in marginally suitable (high limitations) for cattle, sheep, goats and camels, respectively while 4 %, 4.5%, 1.1% and 0.4% of the land is currently not suitable for cattle, sheep, goats and camels, respectively. The study did not show areas which are classified as permanently not suitable even though there were factors in which permanently not suitable classes were observed. This is because; the final suitability is the cumulative effect of the weighted overlay factors. Among all the suitability factors considered in the lands study, landcover was the most significant in affecting the suitability of the rangeland for livestock production.

The Dire rangeland is marginally suitable for the three livestock species cattle, sheep and goats) while moderately suitable for camels and the moderate suitability was in agreement with the reports of Desalegn Gurmess (2006) and Fekadu Lemessa (2011) for camels species. The final objective of the study by Fikadu Lemessa (2011) in Yabello district, southern Ethiopia was to produce rangeland suitability map for livestock production but, in this study, the area is moderately suitable for all livestock species and there was no unsuitable rangeland area for livestock production in Yabello district using only biophysical factors while the current study showed that Dire rangeland is marginally suitable for cattle, sheep and goats while moderately suitable for camels as well as there is a rangeland areas, which is currently not suitable when considering both environmental and socio-economic factors. This indicates the significance of incorporating socio-economic indicators when undertaking suitability analyses.

The most important reducing factors in rangeland suitability were: (a) Landuse/landcover (rangeland dominated by bush encroachment), (b) distance from the water source, veterinary service center and market center). In general, no serious difficulty was observed in the rainfall but some areas the considerable soil and the slope resulted in a decrease or limitation in the graze suitability. Among all parameters studied, the landuse/landcover was determined as most significant factors in reducing the suitability of the rangeland for livestock production in the study area.

6.3. Landuse / landcover change between 1986 and 2011

A wealth of information was retrieved on land use/land cover changes with the help of interpretation of satellite images of 1986 and 2011. Interpretation of images of these periods indicated the existence of considerable dynamics in the land use/land cover systems of the study areas. In both images (1986 and 2011), eight landuse classes were identified but most of the landuses either increased or decreased in size at different change rates in 2011, as compared to 1986 (Figures 6.1).

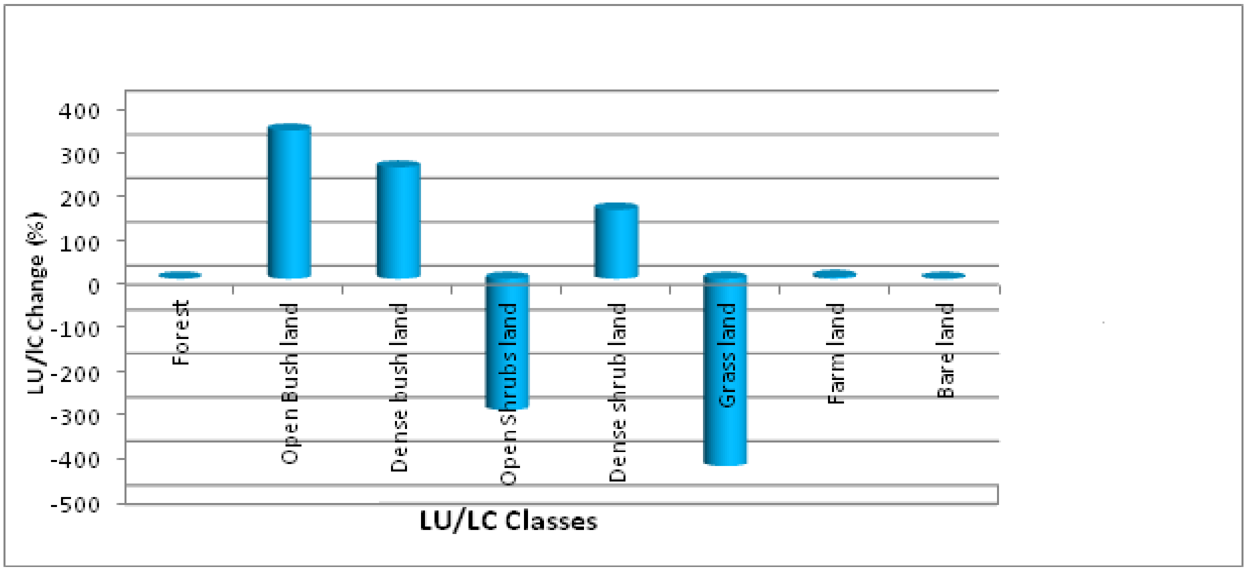

Figure 6.1. Landuse/landcover changes of Dire district in percent (1986-2011).

The rates of land use/land cover changes varied between 1986 and 2011, with grassland, open shrubsland and bareland areas exhibiting a decrease, while all other landuse/landcover classes increased. Accordingly, grasscover contained the largest landuse/cover pattern in 1986, but thereafter showed a significant decrease in the study area. Moreover, (Table 12 and Figures 20 & 25), indicates that about (28%) of the study area was covered by grassland before twenty five years but in 2011 it was reduced to18%. The decrease in grasscover could be associated with a steady increase in the other landuse/cover patterns such as bush and shrub cover land. As a result, an increase in bush and shrub cover has been reported elsewhere in response to heavy grazing in rangelands (Coppock, 1994; Smit, 2004). This will have a significant effect on ecology and socio-economic condition of the area and the consequences of the trends in land use/cover are far reaching.

Grasslands have been the main source of feed for livestock especially cattle in the area. The progressive reduction of grasscover may put serious constraints on animal feed and their productivity. Therefore, the relative increase in cultivated land could be a response to this problem in order to secure the required food demand of the society. This in turn could result in severe soil degradation, as has been shown in the expansion of barelands of the present study areas.

The area of open bush land, dense bush land and dense shrub land showed an increasing pattern over analysis period. Open bush land increased from 24% in 1986 32% in 2011 and dense bushland from 12 % to 17% and dense shrubland from 9% to 13%. In general, the overall increase in land covered by bush and dense shrubland might be attributed to a number of factors like overgrazing, drought, and ban on the use of fire (Ayana Angassa, 2007).

The major landuse/landcover changes within the Dire District were the results of the dynamic nature of bush encroachment, which is critically expanding and an issue of concern for the local communities (Figure 6.2). Bush encroachment has an adverse effect on the ecosystem and the environment. Herbaceous biomass production and bush encroachment are negatively correlated in the study area (Gemedo Dille *et al.,* 2006). The expansion of unpalatable woody species significantly reduced the rangeland size and availability of grasses. The consequence of the decrease in herbaceous biomass production might result in high risk of food insecurity in the area. In addition, the bush prohibits access of livestock to the underlying grasses and as the canopy closes the grasses and herbs disappear letting the ground susceptible to water erosion. This substantial encroachment of bush is mainly attributed to the ban fire, which was a traditional rangeland management system (Ayana Angassa, 2005; Gemedo Dalle *et al.,* 2006). Furthermore, Gemedo Dalle *et al.* (2006) recommended the re-introduction of fire as a rangeland management tool and selective clearing of encroaching woody plants could help reclaim degraded rangelands of Borena.

Figure6.2. Bush encroachment.

The current study has also revealed a slight increase in the spatial extent of farmland from 0.05% (2.11 km^2) in 1986 to 0.2% (6.6km^2) in 2011, in order to meet the increasing demands caused by human population growth. This has also been confirmed during the field work, i.e., previous grazing lands were converted to cultivation fields. For example, the Dubluk rangeland was once well known for its grazing potential, which is now converted to cultivation field (Fig. 6.3).

Figure 6.3. Conversion of grassland to farmland.

Areas under forest and bareland remain more or less stable and not showing remarkable change during the study period. Forest showed slight increase from 3.4km^2 to 4.2 km^2, while bareland areas decreased from (24.5km^2 to 23.7 km^2, which might be related to the increasing pattern of land covered bush and shrubs that hide the visibility of the land from the air.

The result of the present study is similar in the direction of change with Borghesio and Gainnetti (2005) in which the study undertaken on Bush crow (*Z. stresemanni)* in Yabello Sanctuary and its immediate surroundings, south to the town of Mega showed 8% increase in dense bush cover between 1986 and 2002. The result is also in agreement with the study reported by Sintayehu Mesele (2007) in Yabello district. According to this study, grassland cover declined by about 149 km^2 over 30 years, while that of bushland, bushed grasslands, and croplands (maize) increased.

5.4. Spatial distribution of livestock population

Noteworthy is that dots that are closer together have higher densities than dots that are farther apart, which have lower densities. Livestock density was calculated from the total livestock population in PA divided by the total area of the PA. Accordingly, the density is as high as 417.3 animals per kilometer square in Kebena PA, because it is mainly an area where people with a relatively better social status live and therefore can afford having relatively more livestock compared to other place. The lowest density was found in Denbela Bedeno PA, which had only 32 animals per kilometer square. The average livestock density of the district is 56.5 animal per kilometer square.

Large numbers of the cattle were distributed over moderately suitable areas. This condition also holds true for other livestock species as the large percent of the area was moderately and marginally suitable for the livestock species. But, the distribution map shows that a significant number of the animals are still distributed in those areas which are restricted from livestock production. But, it is not possible to show the exact percentage of the animals distributed over each suitability classes because the distribution map only shows spatial distribution of the livestock locality wise. To know the exact distribution of the animals over each suitability classes, it is necessary to know the spatial distribution of the herds within the localities.

CONCLUSION AND RECOMMENDATION

7.1. Conclusion

Assessment of rangelands is an activity that frequently challenges rangeland managers in the livestock industry, environmental protection and rangeland management. Rangeland suitability for livestock is a very important piece of information for livestock development and future planning. The results showed variations in land suitability for different livestock species in the study area.

In Dire district, of the total land area showed about 6.5% is highly suitable for different livestock species and this was mainly attributed to bush encroachment and poor access to water, veterinary and market services. Therefore, implementation of appropriate rangeland management plans in the district is essential. A wide range of the rangelands is marginally suitable (with major limitation) for cattle, sheep and goats and moderately suitable for camels. This reveals that the areas are endangered to be currently not suitable unless proper interventions are undertaken. About half of the sareas of the district is inaccessible to market and the major water sources deep well (*eelaa*) for small ruminants (sheep and goats). In the current study, it is evident that there is acute shortage of permanent water resource for livestock especially during the dry season.

The quantitative evidences of landcover dynamics presented were obtained from analyses of repeated satellite images coupled with the use of GIS application. Applications of these integrated approaches in the Dire rangelands showed the existence of appreciable land use cover dynamics. Dire rangelands had faced a significant decrease in grass land and open shrub land cover since 1986s; associated with a significant increase in all the other recognized land use/cover systems. This might have generally resulted in the deterioration of the ecosystem such as increasing the area prone to soil erosion and destruction of original grasses. On the other hand, it was not only coverage of grassland that decreased but also desirable vegetations species types might have been destroyed (e.g. increase in bush encroachment). This directly decreased the productivity and carrying capacity of the area and negatively affected the yield of grasses which in turn suppressed the productivity of livestock particularly sheep and cattle as they do not prefer bush grazing. As a result, local communities shifted to a change in landuse pattern (e.g. expansion of cultivated land and/or rearing of more drought resistance animals. These latter activities could further drive ecological disturbance to irreversible conditions that might result in high risk of food insecurity in the area unless proper interventions are made in time.

The spatial distribution of the livestock population depicts the fact that they are densely distributed in PAs having grassland and open bushland and accessible to water because of dense bushland and less access to water, which is not suitable for animal production.

7.2. Recommendations

- ✓ Creating awareness among the society concerning optimum use of natural resources, conservation systems, driving forces including population pressure and their respective benefits is vital for sustainable land resource management. Therefore, the local managers and responsible sectors in the district should give emphasis in the participation of the local communities in conservation activities and decision making.

- ✓ There were limitations in getting research generated suitability evaluation parameters and future effort should focus on improving the parameters and the methods of rating. Future study should incorporate biophysical factors like food biomass, temperature, and altitude and infrastructural parameters like arbiters and road access for the different livestock species must be studied and included in the suitability evaluation.

- ✓ Bush encroachment has been one of the problems responsible for decrease in the productivity of the rangeland. Fire is one of the most effective control mechanisms for bush encroachment, even though it has a devastating effect if not handled properly and that is why the government banned fire as mechanism for bush control. But under supervision of the government and experts, it should be considered as an option for the efforts being made to control bush encroachment.

- ✓ Dry season water supply is the critical limiting factor determining livestock production. As there are no perennial rivers or streams within the boundary of the study area, *eelaa*s (deep well) are the sole alternative sources of water for livestock drinking. However, the available *eelaas* are mostly inaccessible and insufficient for watering all the livestock. Therefore development efforts such as digging new *eelaas* and rehabilitating the old one's are necessary in order to solve the shortage of dry season livestock drinking water.

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APPENDICES

1. Factor weights calculated by AHP weight derivation module in IDRISI Andes for LUTs.

1.2. Environmental factors weights for Sheep.

Table 1. Environmental suitability classes of each factor with their respective area coverage for sheep

Factors	Land cover	Rainfall	Slope	Soil	**Total**	**Weight (%)**
Land cover	1				0.5495	54.95
Rainfall	1/3	1			0.2476	24.76
Slope	1/3	1	1		0.1293	12.93
Soil	1/5	1/3	1	1	0.0736	7.36
Total					***1***	***100***
Consistency Ratio					***0.07***	***7***

1.2. Environmental factors weights for Goats.

Table 2. Environmental suitability classes of each factor with their respective area coverage for Goat

Factors	Land cover	Rainfall	Slope	Soil	**Total**	**Weight (%)**
Land cover	1				0.5272	52.72
Rainfall	1/3	1			0.2409	24.09
Slope	1/3	1	1		0.1295	12.95
Soil	1/5	1/3	1	1	0.1024	10.24
Total					***1***	***100***
Consistency Ratio					***0.07***	***7***

1.3. Environmental factors weights for Camels.

Table 3. Environmental suitability classes of each factor with their respective area coverage for Camel

Factors	Land cover	Rainfall	Slope	Soil	**Total**	**Weight (%)**
Land cover	1				0.5255	52.55
Rainfall	1/3	1			0.2098	20.98
Slope	1/3	1	1		0.1579	15.79
Soil	15	1/3	1	1	0.1069	10.69
Total					***1***	***100***
Consistency Ratio					***0.04***	***4***

1.3. Socio-economic factors weights for Sheep and Goats.

Table 4. Socio-economic suitability classes of each factor with their respective area coverage for Sheep and Goats

Factors	Water access	Vet. service	market	**Total**	**Weight (%)**
Water access	1			0.4934	49.34
Vet. service	1/2	1		0.3108	31.08
market	1/3	1	1	0.1958	19.58
Total				***1***	***100***
Consistency Ratio				***0.05***	***5***

1.4. Socio-economic factors weights for Camels.

Table 5. Socio-economic suitability classes of each factor with their respective area coverage for Camels

Factors	Water access	Vet. service	market	**Total**	**Weight (%)**
Water access	1			0.4434	44.34
Vet. service	1	1		0.3874	38.74
market	1/5	1/3	1	0.1692	16.92
Total				***1***	***100***
Consistency Ratio				***0.02***	***2***

Table 6. Annual rainfall and mean monthly temperature data used for interpolation.

Metrological Station	**Easting (X)**	**Northing (N)**	**Annual Rainfall (mm)**	**Mean month. Temp.**
Mega	419482.88	458691.28	549.7	21.35
Moyale	497315.47	398435.94	534.35	23.06
Teltele	322352.25	552352.79	543	23.7
Yabelo	407347.88	537380.53	605.91	21.78
Arero	489950.87	518197.58	641.7	21.13

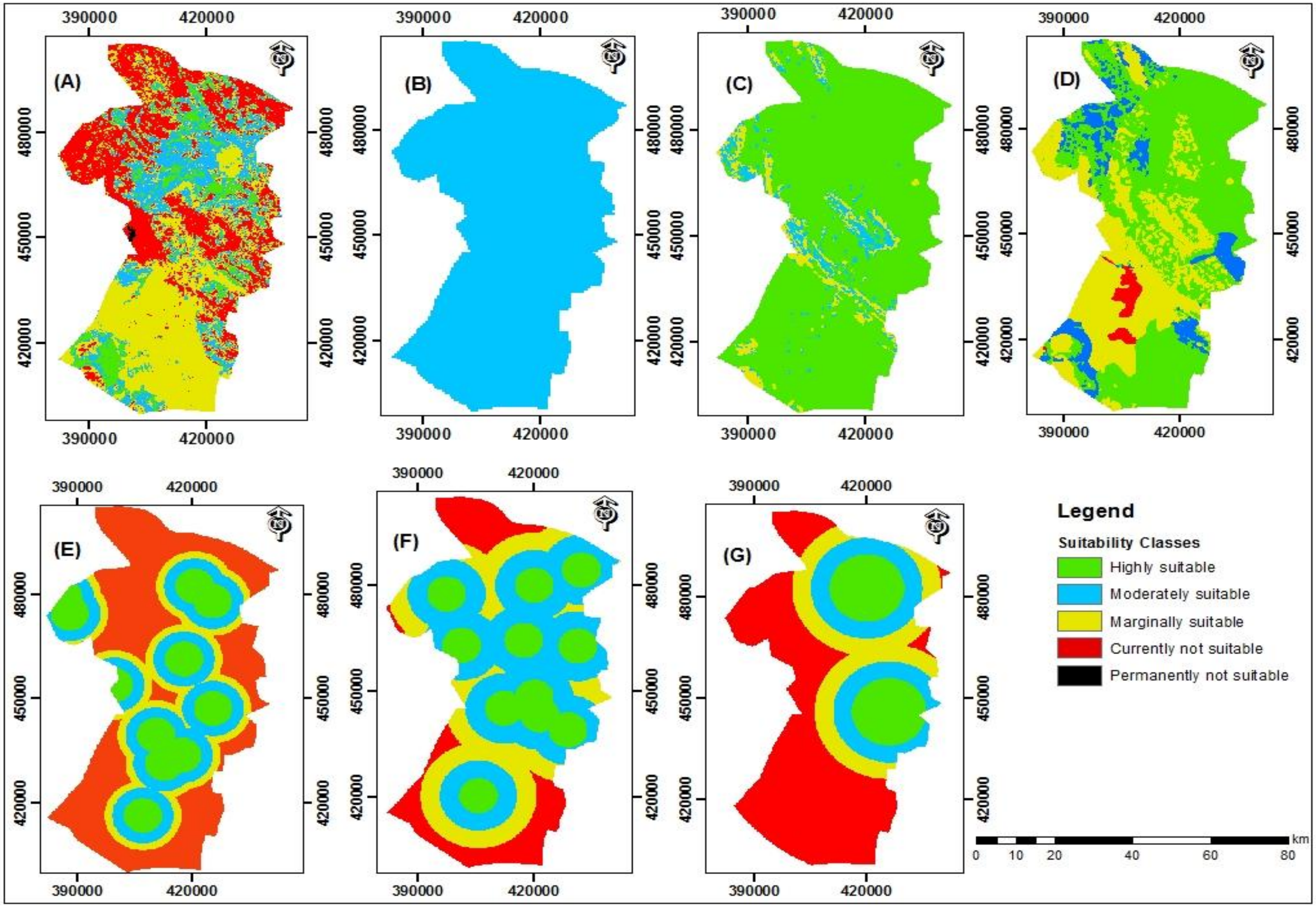

Figure .1. Standardized factors map for sheep suitability analyses (A. LU/LC, B. Rainfall, C. Slope, D. Soil (texture), and E. Water availability, F. Animal health service and G. Market Access)

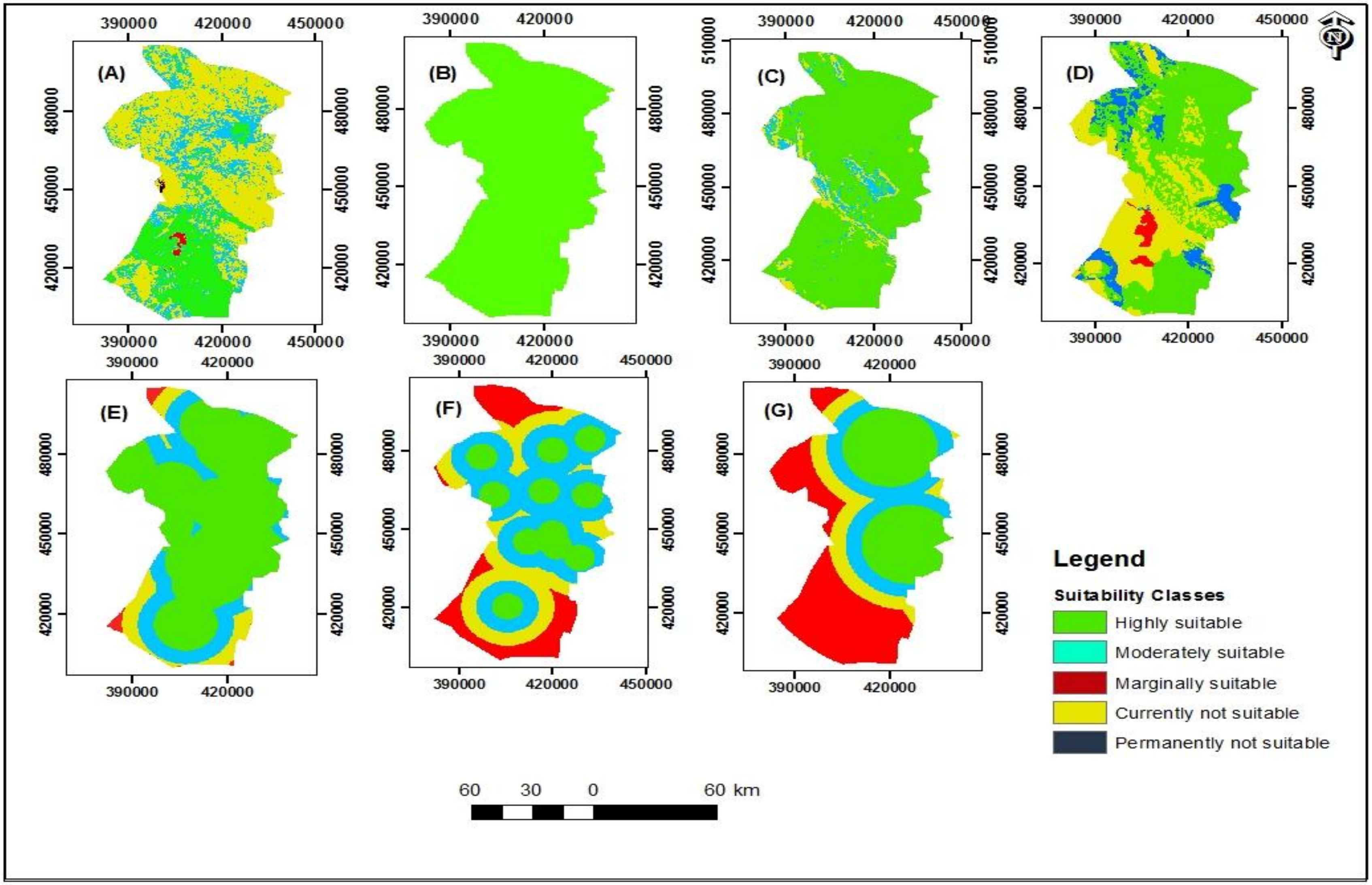

Figure 2. Standardized factors map for Goats suitability analysis (A. LU/LC, B. Rainfall, C. Slope, D. Soil (texture), and E. Water availability, F. Animal health service and G. Market Access)

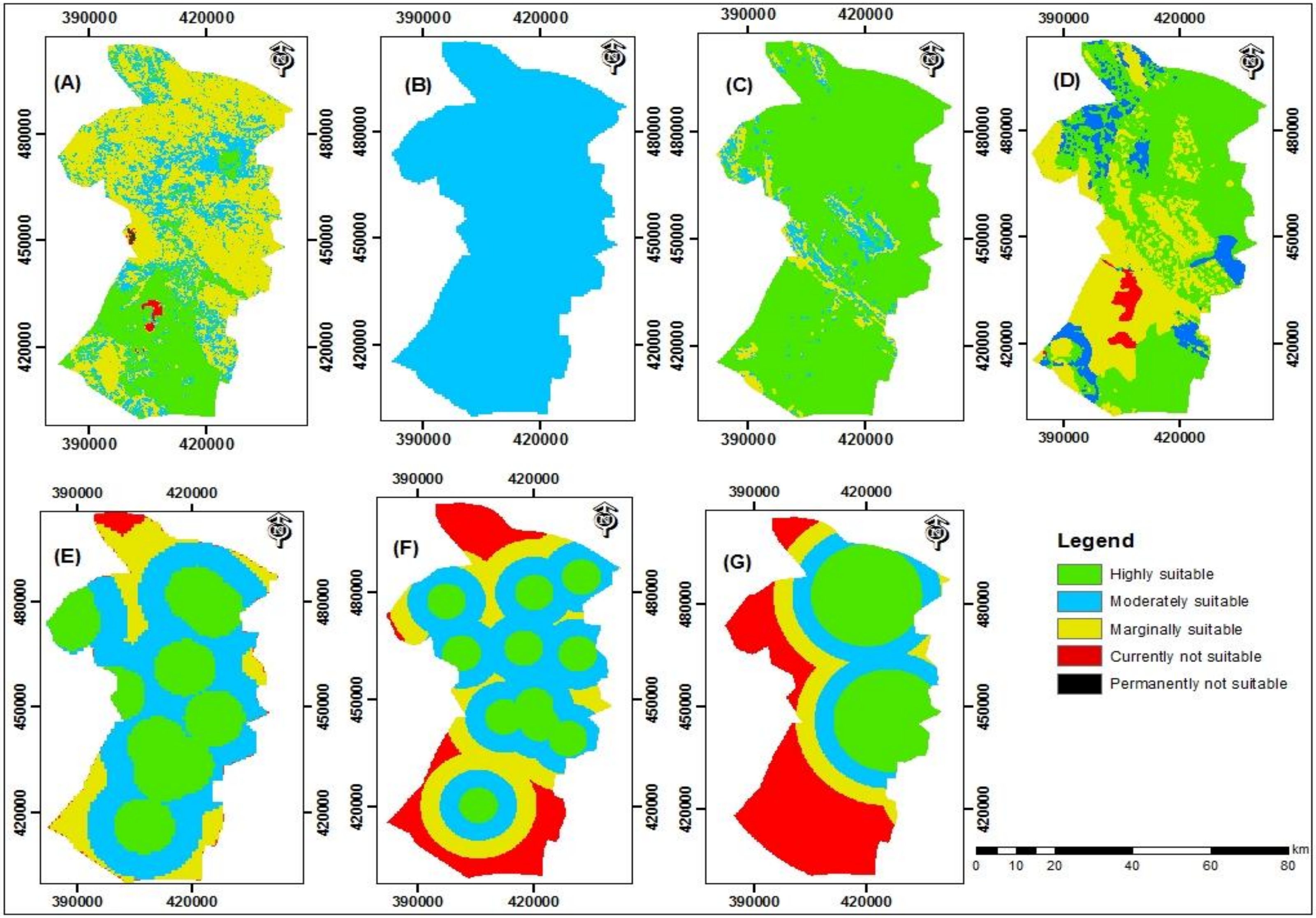

Figure 3. Standardized factors map for Camels suitability analysis (A. LU/LC, B. Rainfall, C. Slope, D. Soil (texture), and E. Water availability, F. Animal health service and G. Market Access

Table 7. GPS reading recorded for representative land use/land cover categories.

No	UTM Coordinate		
	Easting (X)	**Northing (N)**	**Land use/ land cover**
1	400876.71	449950.67	Forest
2	421624.13	452940.42	Farm land
3	422388.63	451909.71	Farm land
4	406661.69	425268.106	Bare land
5	408648.037	429534.313	Bare land
6	418955.19	420121.35	Shrub land
7	419159.97	419240.81	Grassland
8	421944.95	446203.23	dens bush land
9	416033.69	436005.29	Farm land
10	418559.29	414414.86	Grass land
11	407747.01	432687.89	Bare land
12	417439.83	427800.52	Open shrubs land
13	417685.57	428128.17	Grass land
14	417467.13	421384.15	Dens bush land
15	414845.98	455158.85	Open bush land
16	406163.39	432933.63	Bare land
17	416047.34	435937.03	Farm land
18	425228.23	470503.54	Open shrubs land
19	413371.58	466735.63	Grass land
20	411787.96	460564.99	Open bush land
21`	412552.47	461056.46	Dens bush land
22	400876.71	449950.67	Forest
23	421624.13	452940.42	Farm land
24	422388.63	451909.71	Farm land
25	406661.69	425268.11	Bare land
26	408648.04	429534.31	Bare land
27	418955.19	420121.35	Open shrub land
28	419159.97	419240.81	Grassland
29	421944.95	446203.23	dens bush land
30	416033.69	436005.29	Farm land
31	418559.29	414414.86	Grass land
32	407747.01	432687.89	Bare land
33	417439.83	427800.52	Open shrubs land
34	421590	453001.85	Farm land
35	422736.75	452892.64	Farm land
36	407337.458	429575.26	Bare land
37	406081.48	432851.71	Bare land
38	424866.453	484346.53	Dense shrub land
39	431637.77	437165.70	Dense shrub land
40	419624.13	445029.17	Dense shrub land
42	424429.59	482380.66	Dense shrub land

Figure 4. Some of the pictures taken during field visit which shows some the vegetation types of the area

A. Bush and shrub land

B. B. Clearing of bush encroachment in Dokole kebele

C. Shrub land

D. Borena Camel breed

E. Borena Cattle in grazing land

F. Pond with Borena cattle

G. Dubluk livestock market center