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Rangeland suitability analysis for livestock production using GIS and Remote sensing: The case of Yabello Woreda, Southern Ethiopia.

By
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Table of Contents

List of tables

List of figures

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
DM	Dry Matter
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resource Data Analysis
ETM^+	Enhanced Thematic Mapper Plus
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
LQ	Land Quality
LSA	Land Suitability Analysis
LUR	Land Utilization Requirement
LUT	Land Utilization Type
MCDA	Multi-criteria Decision Analysis
MCE	Multi-Criteria Evaluation
MOA	Ministry of Agriculture
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
UET	Ultimate Environmental Threshold
UN-EUE	United Nations Emergencies Unit for Ethiopia
UN-OCHA	United Nations-Office for the Coordination of Humanitarian Affairs

Abstract

Livestock production is essential for household food security in pastoralist areas since they uses their products directly to exchange with other household commodities. Yabello Woreda is one of the pastoral Woredas found in southern part of Ethiopia. For many centuries, these rangelands were productive. However, high population growth which resulted in increasing demand for arable land, increasing land use conflicts, land degradation and bush encroachment in the study area led to reduced amount of land for natural grazing and forage production.

Improper land use results in land degradation and decline in agricultural productivity. Hence, in order to get maximum benefit out of land, proper utilization of its resources is inevitable. Therefore, land suitability analysis is needed in order to make proper land use planning. Geographic Information System and Remote Sensing offer a convenient and powerful platform to integrate spatially complex and different land attributes for performing land suitability analysis and land allocations. This study is intended to analyze and map suitable areas for livestock in Yabello Woreda using Geographic information system and Remote Sensing techniques. For this study, seven suitability factors; Altitude, feed biomass, rainfall, land use/land cover, soil, temperature and slope were considered. To arrive at final suitability result for each livestock, weighted overlay technique of Multi-criteria evaluation in a Geographical information system platform was used. For the case of land allocation for livestock species, a vector (union) module was used. Livestock density was visualized using dot density map. The result of the suitability analysis showed that, 13%, 11%, *3%and 7% of study area was highly suitable for cattle, sheep, goat and camel respectively. In addition, 78%, 52%, 79% and 75% of the land was classified as moderately suitable for cattle, sheep, goat and camel respectively. While, 4%, 32%, 13% and 12% was marginally suitable for cattle, sheep, goat and camel respectively. There is no parcel of land classified as currently not suitable nor permanently not suitable. In the case of land allocation, 22 % and 77% were allocated as highly suitable and moderately suitable respectively for a single species or a combination of them. Thus, the study shows that the greater portions of Yabello Rangelands have moderate suitability for livestock production.*

Keywords: GIS and Remote Sensing techniques, Yabello Woreda, Suitability analysis, Multi-criteria evaluation, Livestock

1. Introduction

1.1. General Background

Livestock play multiple functions in the Ethiopian economy and its people by providing food, input for crop production, soil fertility management, raw material for industry, cash income, saving, fuel, social functions and employment. Therefore, livestock can serve as a vehicle for improving food security, better livelihood and sustainable land management and contribute significantly to agricultural and rural development. Ethiopia has the largest livestock population and the highest draft animal population in the continent, yet productivity is generally lower than in comparable African countries and national and per capita production of livestock and livestock products, export earnings from livestock and per capita consumption of food from livestock origin have declined since 1974 (Helderman, 2004). It is often argued that increasing population pressure has led to deforestation and conversion of pastureland into cropland, leading to overstocking and overgrazing and degradation of remaining pastures.

Pastoralism is the mainstay of most people living in the dry lands of Ethiopia. About 61-65 percent of the total area of the country is estimated to be occupied by pastoral areas (Biruk, 2007). These areas are home to 12-13 percent of the total population (MOA, 2000).

The Borana plateau is one of the best remaining pastoral areas in Africa (Gemedo *et al*., 2005; Leykune Abune, 1991). It occupies an area of about 95 thousand km^2 in southern Ethiopia (Kamara *et al.,* 2002). The livelihood of the dominant ethnic, the Borena, mainly depend on extensive livestock production predominantly cattle and small number of small ruminants, camels and donkeys.

The Borana are semi-sedentary pastoralists who specialize in cattle-keeping, though they may also keep camels and small stock. Recently, increasing numbers 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. The area is environmentally heterogeneous: large areas are covered by annual or perennial grasses, suitable for cattle grazing; bushes and trees proliferate in other areas, particularly species of acacia. These bushes are suitable for the browsing of camels and small stock.

For many centuries, the Borana pastoralists were able to manage their rangeland based on their own experience and traditional knowledge. Their management system involves the interaction between plants, grazing animals, abiotic components and the anthropogenic factors. Since the past three decades, however, the area has faced many problems. Reports indicate that the threats are getting more as time goes (UN-EUE, 1996; UN-OCHA, 2008). These threats range from anthropogenic pressures on the environment to catastrophic natural occurrences.

Borana pastoralists and agro-pastoralists in southern Ethiopia have a well established traditional system 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 and Kotile, 2001). Less application of the indigenous range and water management strategies of Borana pastoralists might have contributed to woody plants encroachment. 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 land use units and/or sites across different districts in the Borana lowlands (Gemedo, 2006).

In Ethiopia, agricultural land suitability analysis is very important since agriculture accounts on the average for about 46.3% of the GDP, 83.9% of the exports and 80% of the labor force (MOA, 2000). Livestock production accounts for about 30 percent of the output value of agricultural sector. The same source indicated that 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, Ethiopian agriculture has remained underdeveloped because of drought, a poor economic base, and low level of technologies on agricultural application (MOA, 2000).

Geographic Information System, geo-spatial mapping and remote sensing technologies are central to achieving a successful transition from traditional environmental and resource management practices to sustainable development because of their integrative quality (linking social, economic and environmental data) and their place-based quality (addressing relationship among places at local, national, regional and global levels) (World Bank, 2006).

In Ethiopia, current land use practices is not based on suitability analysis; therefore, there is an urgent need to use land in the most rational and possible way. In this sense, GIS and remote sensing technologies offer a dynamic tool for multidimensional purpose of land use. This study applied multi-criteria evaluation (MCE) integrating with GIS to delineate the suitable areas for livestock production (cattle, sheep, goat and camel) using the relevant variables of altitude, biomass, soil, temperature, rainfall, land use/land cover and slope through the MCE technique within a GIS context to improve livestock production and allocate land to the most suitable use type.

Evaluation of land suitability which has great physical and chemical land qualities is very needed to contribute to the world's food production in general and the country, Ethiopia in particular to improve food security.

1.2. Problem Statement and Justification

Land is the overwhelmingly most important, valuable and scarce capital asset in agricultural production, on which the majority of the population depends (Helland, 2006). Accordingly, inappropriate land use leads to inefficient exploitation of natural resources, 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 (Rossiter, 1996). 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.

The Borana rangeland, which covers about 95 000 km^2 area (Coppock, 1994) was considered until the early 1980s as one of the few remaining productive pastoral system (Cossins and Upton, 1987) 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). 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), changes in land use, suppression of fire that resulted in the proliferation of bush encroachment and a general decline in forage production (Oba *et al*., 2000 as cited by Ayana Angassa, 2007).

Yabello district, which is situated in the arid and semi-arid lands (ASALs), experiences low and erratic rainfall and high temperature that hinder any significant crop production (Hogg, 1997; Gemedo Dalle et al., 2006; Ayana Angassa, 2007 and Solomon Tefera *et al.*, 2007). However, high population growth has resulted in increasing demand for arable land in the study area (Alemayehu Mengistu, 1998, 2006) leading to reduced amount of land for natural grazing and forage production. Increasing land use conflicts, land degradation and bush encroachment are also the problems responsible in addition to high population growth. Thus, the above conflicting issues could lead to fast depletion of land resources. According to Atsemachew Bizuwork *et al*. (2005), conversion of grazing lands and forestland to cultivation is a common practice and a great threat to livestock production and natural resources. Therefore, proper usage of the land for specific purposes could alleviate the problem. Locating suitable areas for livestock production using spatial models of Geographic Information system (GIS) would be indispensable input to improve livestock productivity (Alemayehu Abebe, 2006; Dassalegn Gurmessa, 2009). 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.

A few researches were conducted on the application of GIS and remote sensing for livestock suitability analysis. Alemayehu Abebe (2006) and Desalegn Gurmessa (2009) are few to be mentioned. In their research, they considered slope, rainfall, land use/land cover and soil as a factor for suitability analysis. Other than the factors they used, temperature, altitude and feed availability are also important factors which influence livestock production. In this study, in addition to the above mentioned factors, temperature and feed biomass were used as factors for the evaluation of the rangeland for livestock production.

1.3. Objectives

1.3.1. General Objective

The main objective of this study is to evaluate the suitability of the rangelands for livestock production using spatial multi-criteria evaluation in Yabello Woreda.

1.3.2. Specific Objectives

- To provide a Geodatabase on the Yabello rangeland and livestock resource to ensure an efficient and sustainable rangeland production system.
- To produce thematic maps of land suitability for some livestock species.
- To produce appropriate land allocation maps for sustainable land use and management.
- To produce dot density map of the livestock population.

2. Literature review

2.1. Livestock Production and Rangeland Development in Ethiopia

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 capacities and incidence of important livestock diseases (Coppock, 1994).

Ethiopia today has about 80 million people and over 104.505 million head of livestock. Among are 49.3 million cattle, 25.02 million sheep, 21.88 million goats and 760,000 camels (CSA, 2009). The lowlands are home to 12% of the human population and 26% of the livestock. Land use 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 annual rainfall increases.

Although the 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 programmes. The lowlands are thus an important source 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.

2.1.1. Past and recent rangeland development efforts.

Although some development 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 centres 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 a 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, and 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 470km of stock routes, 10 staging points and 10 grazing areas, 11 primary and 3 terminal markets, 159 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 had been able to utilise 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. The 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, the 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 development 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 have been 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 woredas 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.

2.1.2. 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).

2.1.3. 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 (Gemedo *et al.*, 2006; BLPDP, 2004).

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, abiotic 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 near years, by external influences and interventions as well as internal factors (Ahmad 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 and neglecting it, 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 conducive 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 (*Z. 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).

2.2. GIS and Remote Sensing

Geographic information system are a special class of information systems that keep track not only of events, activities, and things, but also of where these events, activities, and things happen or exist, almost everything that happen somewhere. Knowing where something happens can be critically important (Paul et al, 2004) and according to Arnoff (1989), it is a computer based system that provides four sets of capabilities to geo-referenced data: data input, data management (storage and retrieval), manipulation and analysis, and finally data output.

Similarly, (Burrough, 1986) defined GIS as a set of tools for collecting, storing, retrieving, at will, transforming and displaying spatial data from the real world for a particular set of purposes. Like any information system, a GIS is an organized accumulation of data and procedures that help people make decisions about what to do with things (John et al., 2003).

Remote sensing provides the information about the various spatial criteria/factors under consideration. According to Lillisand *et al.* (2004), remote sensing is a technique used to derive information about physical, chemical and biological properties of objects without direct physical contact. Remote sensing techniques are more effective and useful for understanding and studying those areas in the out-of-the way mountains and remote deserts (LO and Young, 2005). Hence it offers an efficient and effective means of collecting the information required in order to map land suitability.

2.2.1. GIS and its applications

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 land uses according to specify requirements, preferences, or predictors of some activity (Malczewski, 2004). The GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habitant 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, and regional planning (Malczewski, 2004).

Furthermore, a Geographic Information System 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. In the light of the fact that almost 80% of the data has geographical reference as its denominator, it becomes imperative to underline the importance of a system which can represent the data geographically (Alemayehu Abebe, 2006).

2.2.2. Role of Remote Sensing and GIS in Rangeland Management

Satellite remote sensing was introduced as an important tool in understanding and monitoring various components of rangeland function and health (Tueller, 1991 as cited in Palmer and

Fortescue, 2003). 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 from its 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 units (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 assist 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. GIS has diverse application in rangeland management. These include selection of suitable site for establishing new livestock water points, access road construction, disease infestation mapping, animal migration mapping, habitat suitability analysis, habitat modeling and the likes (Bettiner and Wing, 2004). The application of remote sensing and GIS is not limited to this level. They are also utilized in complex models used to assess range degradation, net primary production, below and above ground carbon sequestration (Bettiner and Wing, 2004).

2.3. Land suitability analysis

Land suitability is the fitness of a given type of land for a defined use (FAO, 1976). Similarly, Ignas (2004) defined it as a part of land use planning methodology and defines possible options for the future land use and helps to describe these interactions (policies, institutions and information management). Broadly defined, land-use suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specific requirements, preferences, or predictors of some activities as cited in (Malczewski , 2003) and also 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.

The way people use land is based on the available skills, knowledge, culture and experiences. The land use attitude changes when the income of land changes through, example improved technology (Ignas, 2004). Land suitability assessment is similar to choosing an appropriate location, except that the goal is not to isolate the best alternatives, but to map a suitability index for the entire study area. Senes and Toccolini (1998) combine Ultimate Environmental Threshold (UET) method with map overlays to evaluate land suitability for development. Hall *et al*. (1992) cited in Malczewski (2006) also used map overlays to define homogeneous zones, but then they apply classification techniques to assess the agricultural land suitability level of each zone. Combining GIS and MCDA is also a powerful approach to land suitability assessments. GIS enable computation if the criteria while a MCDA can be used to group them into a suitability index (Florent *et al*, 2001).

The 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 1: Suitability classes (FAO, 1993)

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

2.4. Spatial Multi-Criteria Decision Making

An important advantage in using a GIS to perform a spatial MCDM study is the ease with which one can develop valuation criteria based on neighborhood analysis operations. The quality of a site for a specific use often lies not only on the values of environmental variables at the site, but also on its vicinity (Pereira *et al*., 1993).

Spatial decision problems typically involve a large set of feasible alternatives, multiple conflicting and incommensurate evaluation criteria. The alternatives are often evaluated by a number of individuals (decision-makers, managers, stakeholders, interest groups). The individuals are typically characterized by unique preferences with respect to the relative importance of criteria on the basis of which the alternatives are evaluated. Accordingly, many spatial decision problems give rise to the GIS-based multi-criteria decision analysis (GIS-

MCDA). These two distinctive areas of research, GIS and MCDA, can benefit from each other (Laaribi *et al*. 1996; Malczewski 1999; Thill 1999, Chakhar and Martel 2003;cited in Malczewski, 2006). On the one hand, GIS techniques and procedures have an important role to play in analyzing decision problems. Indeed, GIS is often recognized ‘as a decision support system involving the integration of spatially referenced data in a problem solving environment’ (Cowen 1988). On the other hand, MCDA provides rich collection of techniques and procedures for structuring decision problems, designing, evaluating and prioritizing alternative decisions. At the most rudimentary level, GIS-MCDA can be thought of as a process that transforms and combines geographical data and value judgments (the decision-maker’s preferences) to obtain information for decision making. It is in the context of the synergetic capabilities of GIS and MCDA that one can see the benefit for advancing theoretical and applied research on GIS-MCDA (Malczewski, 2006).

The general objective of MCDM is to assist the decision-maker in selecting the best alternative from the number of feasible choice-alternatives under the presence of multiple choice criteria and diverse criterion priorities. The problem of multi-criterion (multi-objective) choice in decision making is the paramount challenge faced by individuals, public, and private corporations. The challenge of multi-criterion choice can be attributed to many spatial decision making problems involving search and location/allocation of resources. These problems, often analyzed in GIS, include location kite selection for: service facilities, recreational activities, retail outlets, hazardous waste disposal sites, and critical areas for specific resource management and control practices (Jankowski, 1995).

2.5. Land suitability analysis and Spatial Multi-criteria Decision Making

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 land use 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 land suitability mainly based on the land quality. Land quality is a complex attribute of land that has a direct effect on land use (FAO, 1993). These attributes are availability of water and nutrients, rooting conditions and erosion hazards. Most land qualities are determined by interaction of several land characteristics, which are measurable attributes of the land. For example, the quality of availability of water is 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, for example, 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 suitable outcomes (FAO, 1985).

3. Materials and Methods

3.1. Description of the Study Area

3.1.1. Location and Topography

The Borana rangeland is found in Oromia Regional State, southern Ethiopia. It covers about 95,000 km^2 which is estimated to be 7.6% of the national area (Figure 1). The Borana zone has 10 Woredas of which six are classified as lowland rangelands. Yabello Woreda lies between 505074-588452 meters N and 361267-459116 meters E covering about 5534 km^2. Yabello town, the capital of the Woreda is 570kms far from Addis Ababa. Most of the lowlands of Ethiopia are characterized by plain topography. According to the Woreda Pastoralist Development Office, about 5% of the district is covered by mountainous topography. Except these few mountains with peak elevation of 2200 m.a.s.l., the landscape is gently undulating across an elevation of 1450-1600 m.a.s.l., which falls within the Rift Valley System of East Africa (Leykun Abune, 1991; Coppock, 1994).

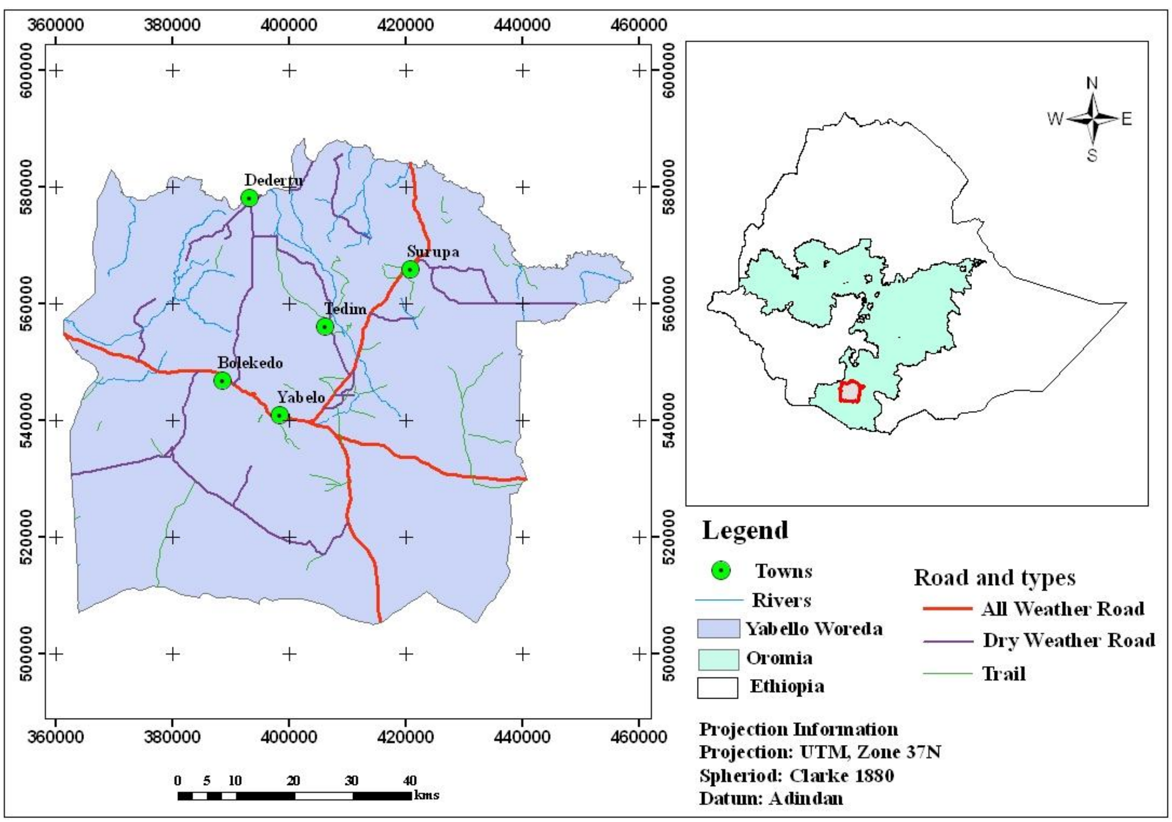

Figure 1: Location map of the Study Area.

3.1.2. Climate

Climatic condition in the lowlands of Ethiopia is largely a result of altitude. Based on the climatic map of Ethiopia, the climate of the study area falls with hot and semi arid "Upper Kolla" zone (National Meteorological Services Agency, 1989 as cited in Leykun Abune, 1991). The climate of the area is influenced by the relief of high mountain ranges of Bale in the northern and equatorial winds from the south.

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). Seasons in the study area are classified by the local people in to four sets according to climatic variation and the uses of the range.

The overall average temperature ranges from an annual mean minimum of 13.3^{o}C to annual mean maximum of 25.1^{o}C (Sintayehu Mesele, 2007). The area has an absolute monthly minimum temperature of 12.1^{o}C and an absolute monthly maximum temperature of 26.9^{o}C. Figure 2 shows ten years (1997-2007) average mean monthly temperature of Yabello Woreda.

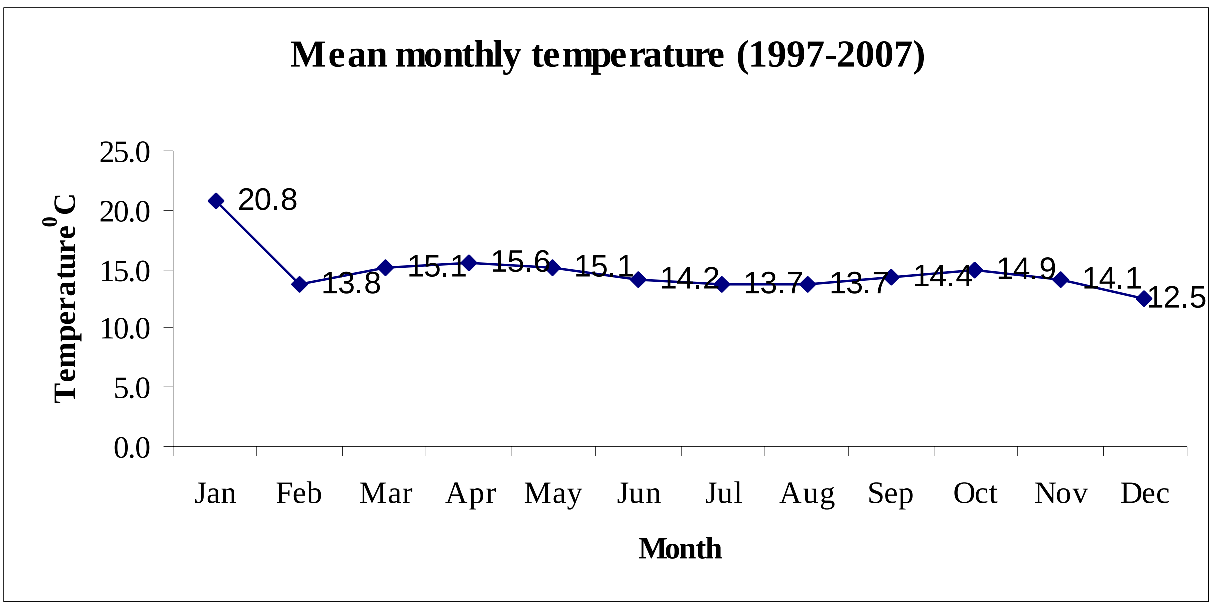

Figure 2: Mean monthly temperature

A prominent feature of the Borana ecosystem is the erratic and variable nature of the rainfall, with most areas receiving between 238 mm and 896 mm annually, with a high coefficient of variability ranging from 18% to69% (Ayana Angassa and Oba, 2007). Thus Figure 3 shows ten year annual rainfall of Yabello Woreda. Droughts are common every five years (Oba, 1998). 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 a mobile herd management system. Pastoralism is the primary mode of life (Ayana Angassa, 2007) though agropastoralism is recently emerging as mode of life in some peri-urban areas.

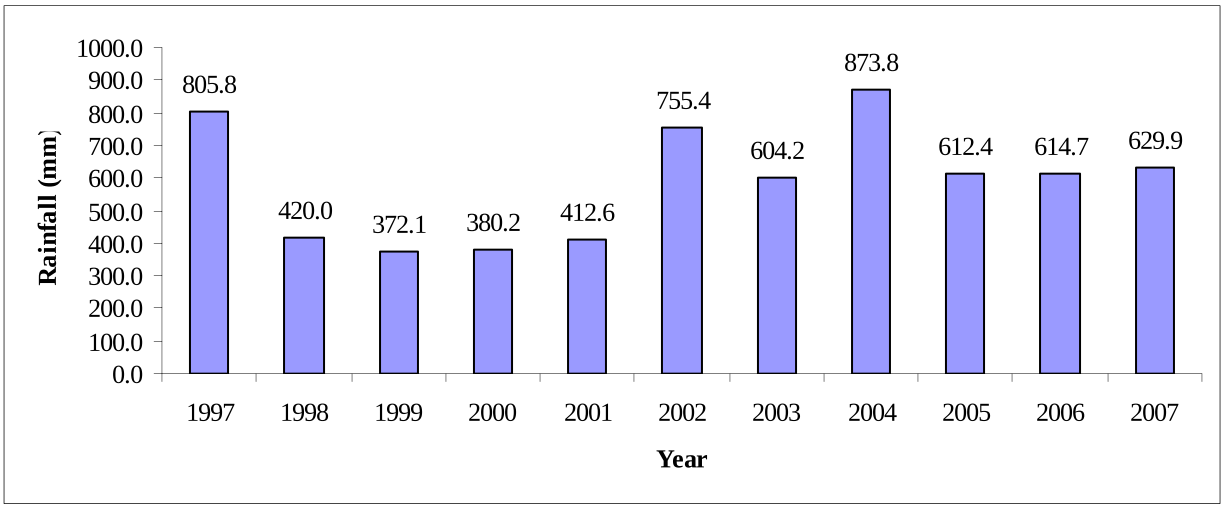

Figure 3: Annual Rainfall of Yabello Woreda (1997-2007)

3.1.3. Soil and Geology

The geology of the whole system is basement complex and soils developed on Precambrian basement complex rock formations (Coppock, 1994). According to Ayana Angassa (2000), soils of the study sites are shallow red sandy loam in the uplands and vertisols in the bottomlands. The area is notable for its red soils, which have little organic matter. The rangeland soils of Yabello are regarded as having low fertility probably due to the inherent fertility of the parent material (Getachew *et al.*, 2007).

3.1.4. 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 Yabello district. Most of the central mountain vegetation was 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 (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, 2006).

3.1.5. 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 Yabello Woreda in particular are characterized by a general scarcity of surface water and perennial rivers. The main water sources for human and livestock consumption in the Woreda are deep wells (Eellas) and hand-dug ponds (Haros). There are nine major wells in the district. Ponds are found in greater concentration than wells. Harobeke is the largest pond found in the Woreda which is the main water source for livestock during dry seasons. The pond is also utilized by pastoralists in neighboring Woredas when there is sever water scarcity.

3.1.6. Socio-economy

3.1.6.1. Human Population and Settlement Pattern

The dominant ethnic group of the study area is Borana Oromo amalgamated with a few Guji Oromo, Amhara, Somali, Geri and Konso. The production and livelihood system is based on traditional Gada system, an approximately 550 year’s democratic, economic and socio-political 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 life revolves 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). According to the Woreda Pastoralist Development Office, the total population of the Woreda in 2007 was 116,436 of which 98,688 reside in rural areas and 17,748 live in urban area.

3.1.6.2. 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 adapting adverse environmental condition under arid and semi-arid environmental conditions, which is developed through time and selection. Cattle take the largest number being 204370. Goat, sheep and camel were 98781, 39073and 23852, respectively, in 2009 (Yabello Woreda Pastoral Development office).

3.1.6.3. Farming System

It is known that agriculture is the basis of 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). According to Yabello Woreda Pastoralist Development Office, out of 23 PAs in the district, 7 are identified as agro-pastoralists and the rest of them are classified as pastoralists. In some of the pastoralist PAs, there are small tracts of lands which are tilled only to satisfy household grain requirement. Cultivated land is estimated to cover 11971 ha, which is 2.02% of the Woreda. Agro-pastoralism is a newly emerging phenomenon in Borana rangelands. Agro-pastoralism 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 of lands as opportunistic farmers (Sora Adi, 2007). According to Sintayehu Mesele (2004), the observed trends of increasing cropland areas in Borana rangelands could be attributed to a substantial proportion of the grassland were lost in response to environmental change and the recurrent drought forced the pastoralist to till their land in greater extent than before to cope up with the conditions.

3.2. Materials

The following softwares were used in this study. These are ArcGIS 9.2, ERDAS IMAGINE 9.2, IDRISI Andes 15.0 Global Mapper, 3DEM, Microsoft Word and Microsoft Excel. In addition, topographic maps of scale 1:50000 time series satellite imageries and diverse ancillary data were used in order to identify historical and recent land use/land cover of the study area.

3.3. Methods

3.3.1. 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 (Longley *et al.*, 2005). For this study, both primary and secondary raster and vector data was used. Topographic maps of the scale 1:50000 of the study area were purchased from the Ethiopian Mapping Agency (EMA).

3.3.1.1. 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 for the study area, two mosaic image from the satellite Landsat (path-row: 168-56 and 168-57) 2005 was used. All were acquired in the month of January during the dry season, with the Enhanced Thematic Mapper Plus sensor (ETM+).

3.3.1.1.1. Digital Elevation Models (DEM)

DEM data was acquired by the Shuttle Radar Topography Mission (SRTM) abroad the space Shuttle Endeavour, launched in February 2000. Slope data and subsequent derivations like elevation were calculated from the Digital Elevation Model (DEM).

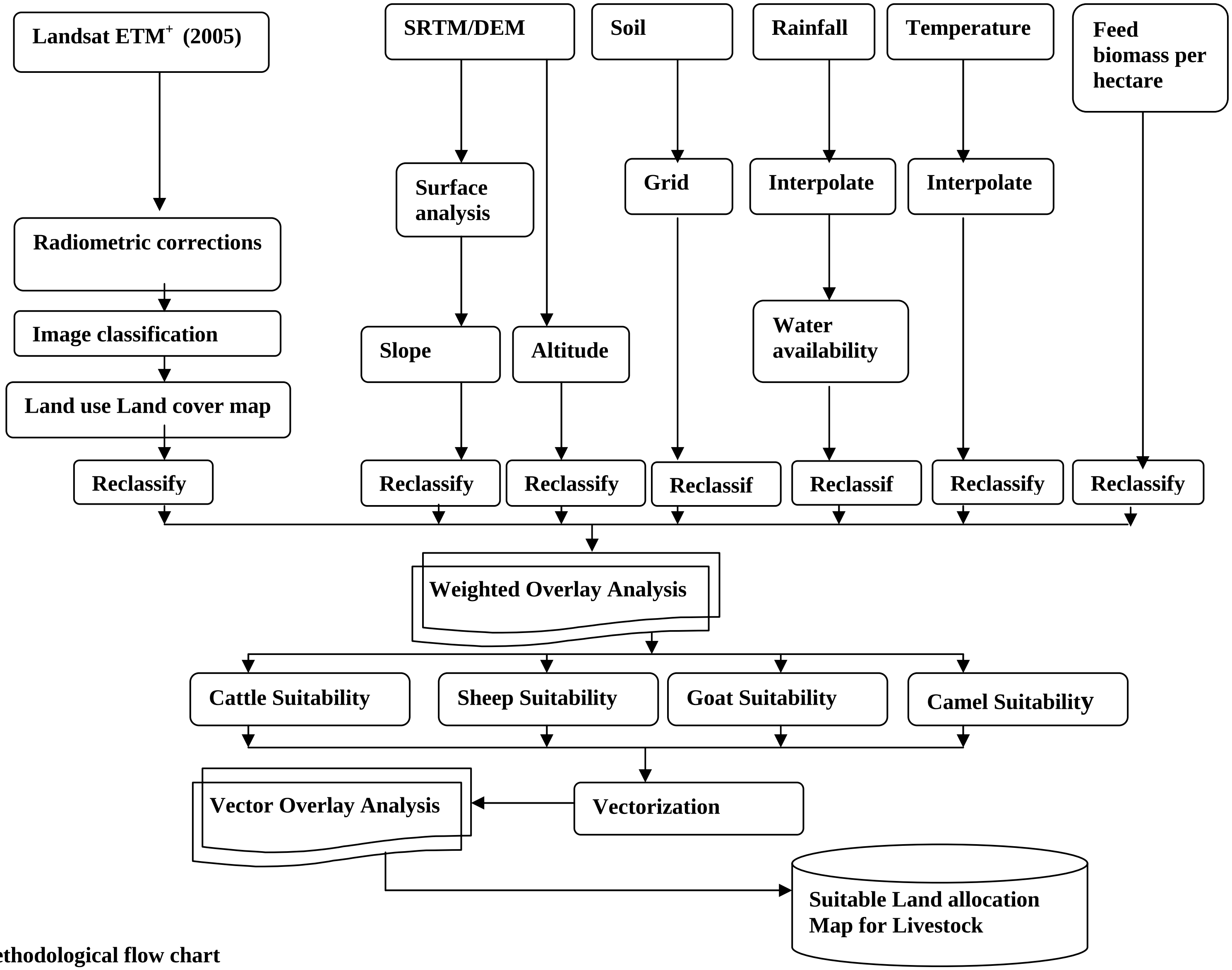

Figure 4: Methodological flow chart

3.3.1.2. Field Surveying

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, land use/land cover 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 land-use/land-covers of the study area were collected in December 2010. The collection procedure included defining the dominant land-use/land-cover 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 were identified as forest, bushland, grassland, cultivated land, urban or built-up, water and shrubland. Secondary data were collected from Yabello Woreda 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. The 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) (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 and canopy cover not exceeding 2%. Savannah type of grassland is included in this category (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 irrigatedlands are not significant and thus were not included in this category.

Built up areas refers to areas occupied by urban or peri-urban settlement. Yabello town is the largest urban settlement found in Yabello Woreda.

Water body refers to a land occupied by water permanently throughout the year. There is only one perennial water body called Harobeke in the area.

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 dense or open depending on the canopy cover of the vegetation (Zemenu Mintesnot, 2009).

3.4 Image Processing

3.4.1. Satellite image processing

Cloud free Landsat ETM^+ imageries (path 168; row 56 and 57) that were acquired on January 2005 were analyzed to classify the land use/ land cover of the study area. The mosaics of the two scenes (row 56 and 57) covering the whole extent of the study area was prepared. Landsat ETM^+ data have 8 bands. The additional band on the ETM^+ is a panchromatic band with 15m spatial resolution and thermal band. The thermal band and panchromatic band were not utilized in the analysis.

3.4.1.1. Image pre-processing

Pre-processing operations some times referred to as image restoration and rectification, area intended to correct for sensor and platform specific radiometric and geometric distortions of data (Lillesand *et al*., 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 *et al*., 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. Landsat ETM^+ has stripes caused by malfunction of the part of the sensor. Therefore, it was important to fill the missing data from the same scene of the previous years; before or 2002. Accordingly, the missing data was filled from the same seen of the year 2002.

3.4.1.2. Image classification

Image classification serves a specific goal, i.e., converting image data into thematic data. The resulting classified image is composed of a mosaic of pixels, each of which belong to a particular theme, and is essentially a thematic map of the original image. Thematic characteristics such as land use/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 *et al*., 2004). Accordingly, I used both types of classification systems in this study, i.e., the unsupervised classification before field visit and the supervised classification after field survey.

A. Unsupervised classification

Unsupervised classification algorithms compare pixel spectral signatures to the signature of computer determined clusters and assign each pixel to the one of these clusters. Knowledge of the materials contained within the scene is not needed beforehand as the computer assesses the inherent variability and determines cluster identification (Lillesand e*t al*., 2004). Classified land cover maps require knowledge of the area in order to label each cluster with its equivalent real world. Accordingly, unsupervised classification of the study area was performed prior to field visit.

B. Supervised classification

Supervised classification can be used to cluster pixels in a data set into classes corresponding to user defined training classes. This classification type requires selecting training areas for use as the basis for classification. The most common supervised classification techniques are the Maximum Likelihood Classifier for parametric input data and Parallelpiped classifier for non-parametric data (Lillesand *et al*., 2004). Supervised classifications require a prior knowledge of the scene area in order to provide the computer with unique training classes. Regions containing a material of interest within a scene are delineated graphically and stored for use in the supervised classification algorithm. It is the job of the user to define the original pixels that contain similar spectral classes representing certain land cover class.

Accordingly, 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 land cover types identified during field visit. Following this, supervised land use/land cover classification has been carried out using ERDAS IMAGINE software.

3.4.1.3. Accuracy assessment

Land cover maps derived from remote sensing imagery always contain some sort of errors due to several factors which range from classification technique to a method of satellite data capture. Therefore, owing the complexity of digital classification, the reliability of the results need robust and through assessments. 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 *et al*., 2004). It is a very effective way to represent accuracy because each category is evidently described.

Most assessment were conducted using the same data set was used to train the classifier. These trainings and testing on the same data set result in overestimate of classification accuracy (Congalton, 1991). Error matrix for each land use/land cover is shown in table 2.

Table 2: An error matrix for classification accuracy

	Reference Data													
		WB	DSL	OGL	OSL	FR	CL	DBL	OBGL	OSGL	BUA	OBL	RT	UA
Classified Data	WB	1	0	0	0	0	0	0	0	0	0	0	1.0	100.0
	DSL	0	35	0	0	2	0	0	1	2	0	1	41.0	85.4
	OGL	0	0	26	0	0	2	0	3	2	0	0	33.0	78.8
	OSL	0	1	1	51	0	0	0	1	3	0	0	57.0	89.5
	FR	0	0	0	0	11	0	1	0	0	0	0	12.0	91.7
	CL	0	0	0	0	0	2	0	0	0	0	0	2.0	100.0
	DBL	0	0	0	0	0	0	8	0	0	0	0	8.0	100.0
	OBGL	0	0	0	0	0	0	1	56	1	0	0	58.0	96.6
	OSGL	0	0	0	0	0	0	0	1	35	0	0	36.0	97.2
	BUA	0	0	0	1	0	0	0	3	1	3	0	8.0	37.5
	OBL	0	0	0	0	0	0	0	0	0	0	1	1.0	100.0
	CT	1	36	27	52	13	4	10	65	44	3	2	257.0	
	PA	100.0	97.2	96.3	98.1	84.6	50.0	80.0	86.2	79.5	100.0	50.0	100.0	

Over all Accuracy=229/257=89.1%

UA=User's Accuracy

PA=Producer's Accuracy   Kappa Coefficient =0.8687

3.4.2. Land Suitability Analysis

3.4.2.1. Factors of Suitability for Livestock production

Land suitability analysis is governed by several factors ranging from bio-physical factors to socio-economic factors. In this study, six bio-physical land parameters were considered. These are soil, topography (slope), climate (temperature and rainfall) and land use/land cover. The assessment of these parameters provides the information about the limitations of the land for agricultural development. The concept of limitation is derived from the quality of the land. 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. On the other hand the study constrains or restricts built up areas, water body and forest areas from the analysis. 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 and vector overlay analysis.

A. Soil

All forage plants used a source of livestock feed are rooted in the soil and it is from the soil that the plants draw the water essential for their growth. Furthermore, the soils are very important to different animal species as a source of natural mineral and sleeping ground (Chiisaa) in the Borana rangelands. 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 and the animal as well. For this study, soil mapping unit of Yabello Woreda 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 is indicated in Figure 5 and include Calcaric Fluvisol, Calcic Solonetz, Chromic Cambisol, Chromic Luvisol, Epileptic Leptosol, Epileptic Leptosol & Rock, Eutric Cambisol, Eutric Fluvisol, Eutric Vertisol, Haplic Calcisol, Leptosols, Pellic Vertisol and Rhodic Nitisol (OWWDSE, 2009).

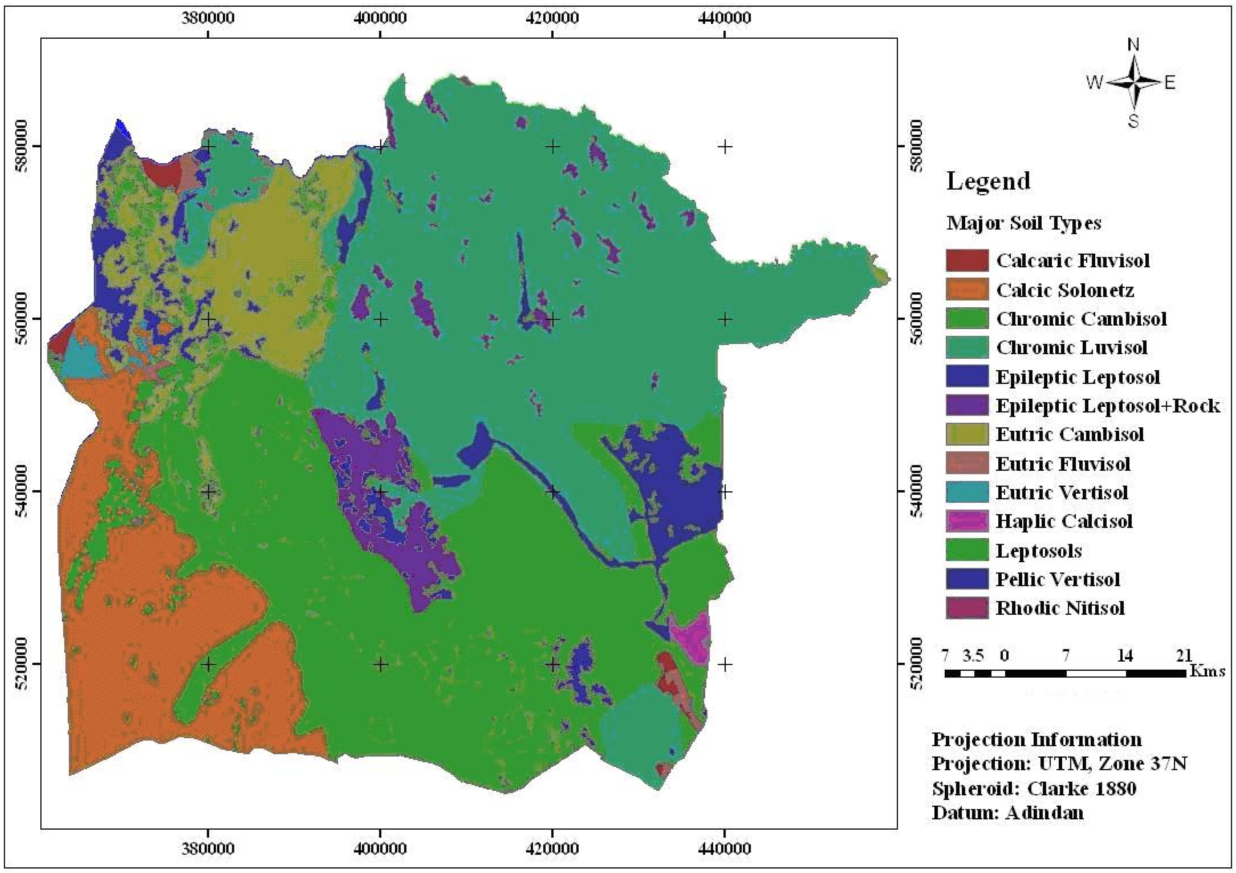

Figure 5: Soil map (OWWDSE, 2009)

B. Temperature regime

Temperature causes stress to animals in hot, warm and very cool climates. Heat to the body comes mainly from outside and from the metabolism within the body metabolic heat. It costs energy to get rid of excess heat and to maintain the body temperature. When body temperature is high appetite is lost, resulting in a negative energy balance and sometimes with heart collapses. If the climate is hot but not dry it is easier to keep high-producing animals than it is in a hot and humid climate. High surrounding temperature decreases feed intake more with Bos taurus or high-grade Bos taurus cattle than Bos indicus (Abule Ebro, 2009).

Water intake varies with type of animals and production level. It is quite evident that high-producing dairy cows need more water than the low-producing indigenous stock. Constant availability of water is thus a must in dairy production with grade cattle. A term often found in textbooks is "the comfort zone ", that means the environment in which livestock thrive best. The optimum temperature is from 13-18^{0}C. A high day temperature can be compensated by a cool night. "The comfort zone" for temperate cattle is 4-5^{0}C lower than for tropical. Temperature creates real problem when the mean monthly temperature exceeds 24^{0}C for 5 months or more. There are very few places in Ethiopia where this is the case (Abule, 2009). In general, the mean annual temperature in the Borana rangeland varies from 15°C to 24°C and shows little variation across the seasons (Coppock, 1994). However, the mean maximum temperature is 27.74°C and the mean minimum temperature is 16.45°C.

Six (Yabello, Hageremariam, Mega, Moyale, Teltele and Arero) stations as shown on Figure 6, were taken into consideration for temperature and rainfall. Temperature and rainfall data of these stations for 20 years was collected from NMSA of Ethiopia. The surface interpolation was carried out in the GIS environment using Spatial Analyst’s Inverse Distance Weighted (IDW) technique. Figure 7 shows the temperature map of the study area.

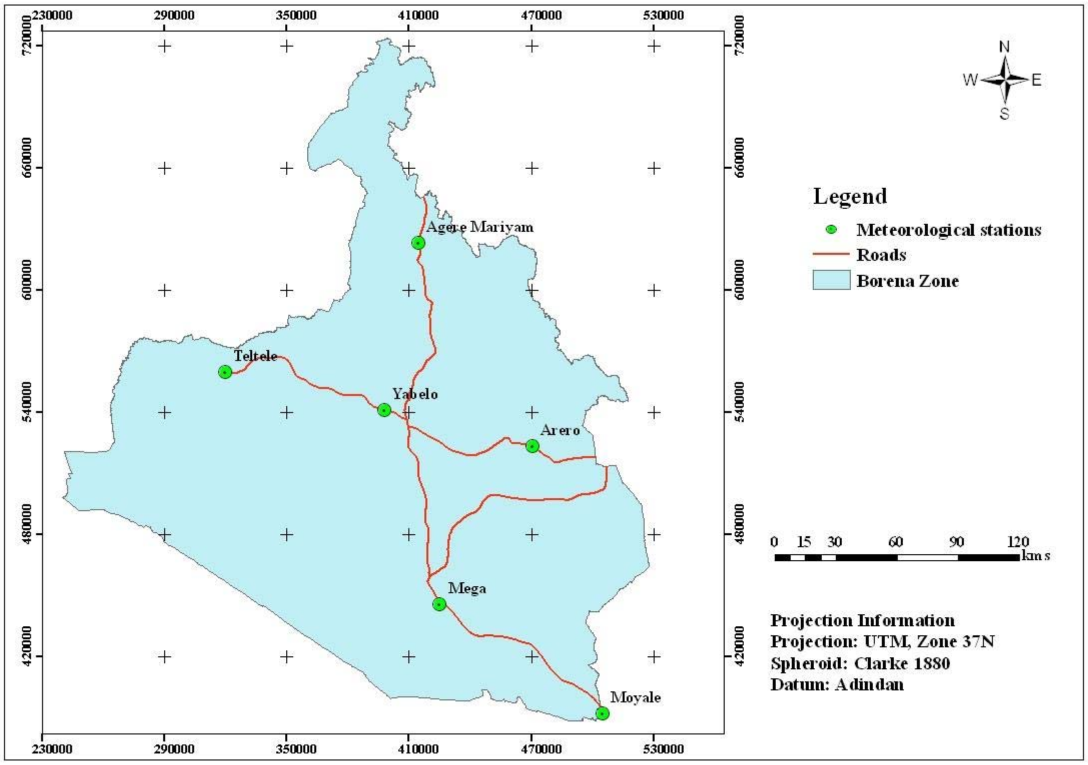

Figure 6: Distribution of the meteorological stations

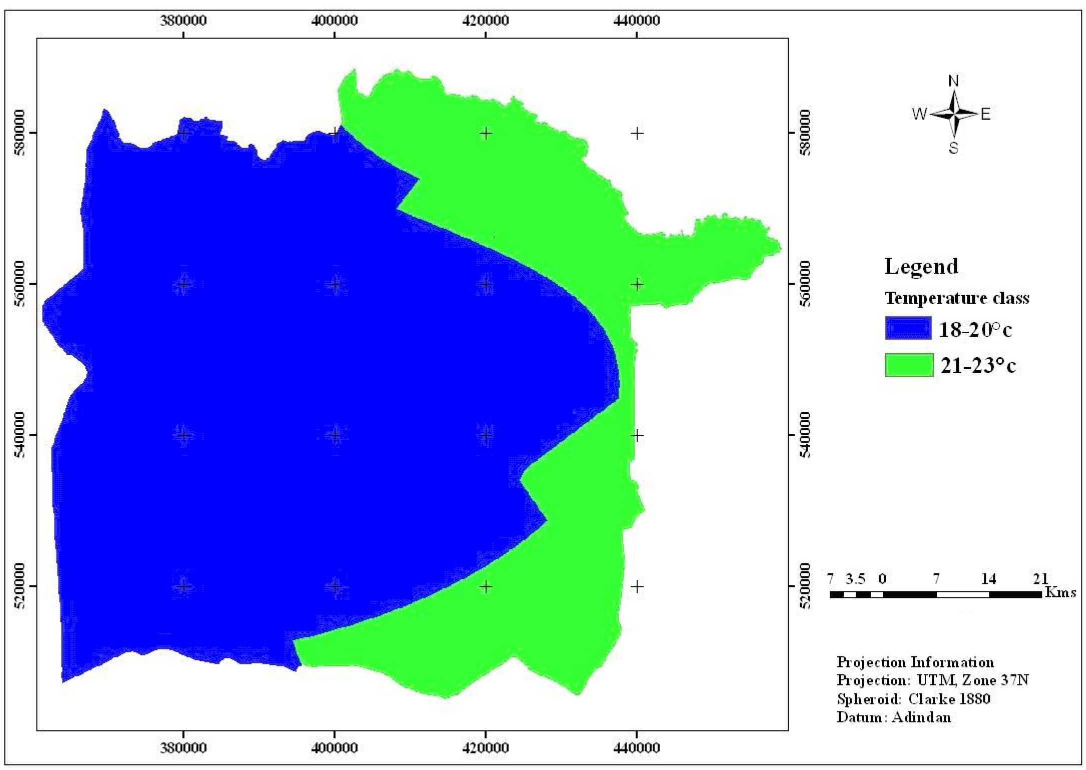

Figure 7: Mean monthly temperature map (NMSA, 2010)

C. Moisture availability (amount of rainfall)

Rainfall is important to the agronomist and stockman, as it controls the plant growing seasons and affects the availability of drinking water. Moisture in the Borana rangeland is one of the major factors dictating livestock production of the area (Abule Ebro, 2009). According to Ayana Angassa (2007), the mean annual precipitation for the Borana rangelands of Southern Ethiopia over 21 years of period (1983-2000) was approximately 500 mm (± 163) ranging from 238 to 896 mm. thus, Figure 8 shows ten years mean annual rainfall of Yabello Woreda. Generally, below average rainfall occurred in 11 out of the 21 years. During the major droughts of 1983-1984, 1992-1993, and 1999-2000 the mean annual rainfall declined by about 14, 35, 18, 17, 52, and 43%, respectively.

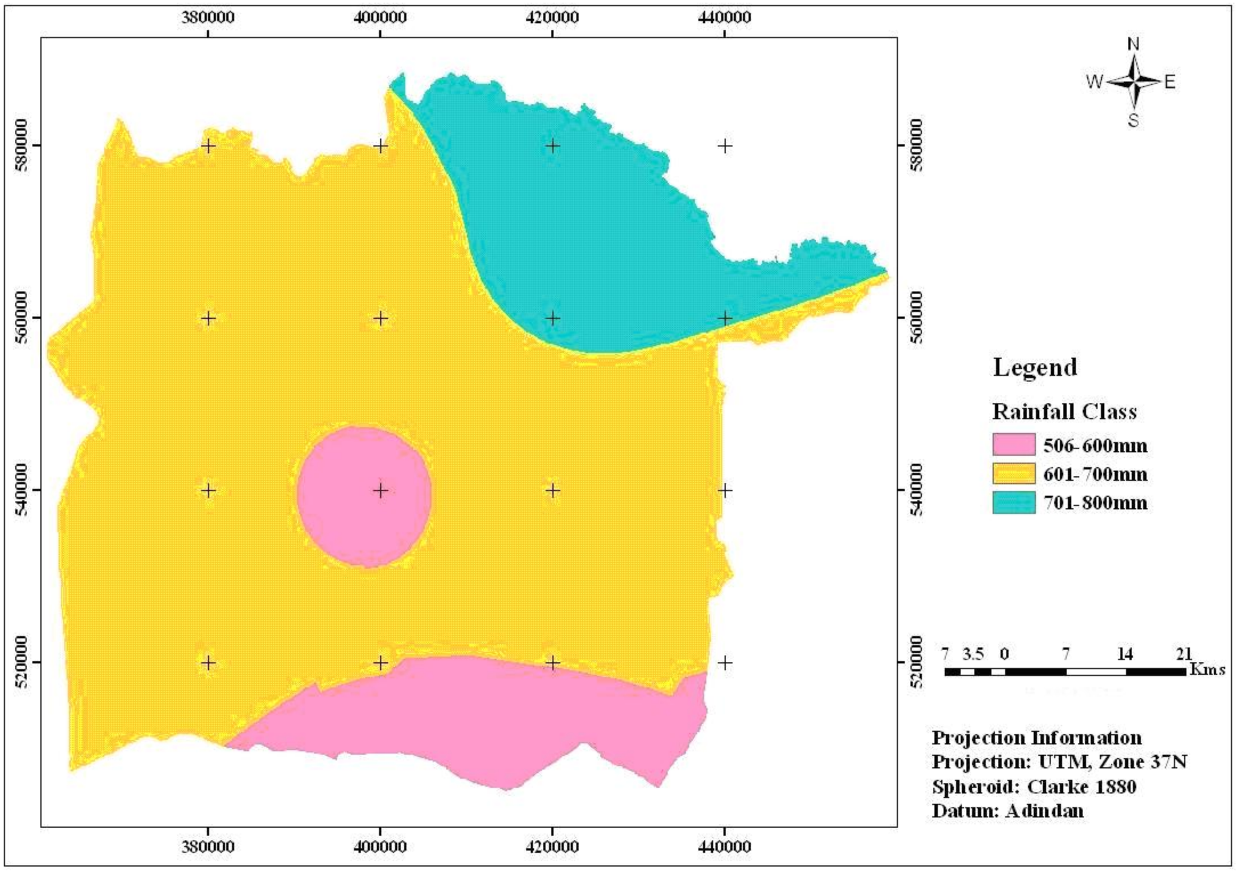

Figure 8: Mean annual rainfall map (NMSA, 2010)

D. Land use/Land cover

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 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). The Borana plateau is dominated by savannah type of vegetation containing a mixture of perennial herbaceous and woody plants (Coppock, 1994). These savannah communities are varying from grassland to bush encroached areas. The variation in woody and herbaceous materials as well as marked shifts in composition that occurred in response to grazing, browsing, burning and droughts or various combinations of these. According to Haugen (1992), the vegetation of the area can be classified into four types: (i) evergreen and semi-green bush land and tickets; (ii) rangeland dominated by Acacia and commiphora trees; (iv) rangeland dominated by Acacia and allied genera; and (iv) dwarf shrub grassland or shrub grassland. The dominant herbaceous plants were perennial grasses. According to the current land use/land cover analysis there are 11 land use/land cover (table 4) in Yabello Woreda. Figure 9 shows Land use land cover type of the Woreda and their spatial distribution.

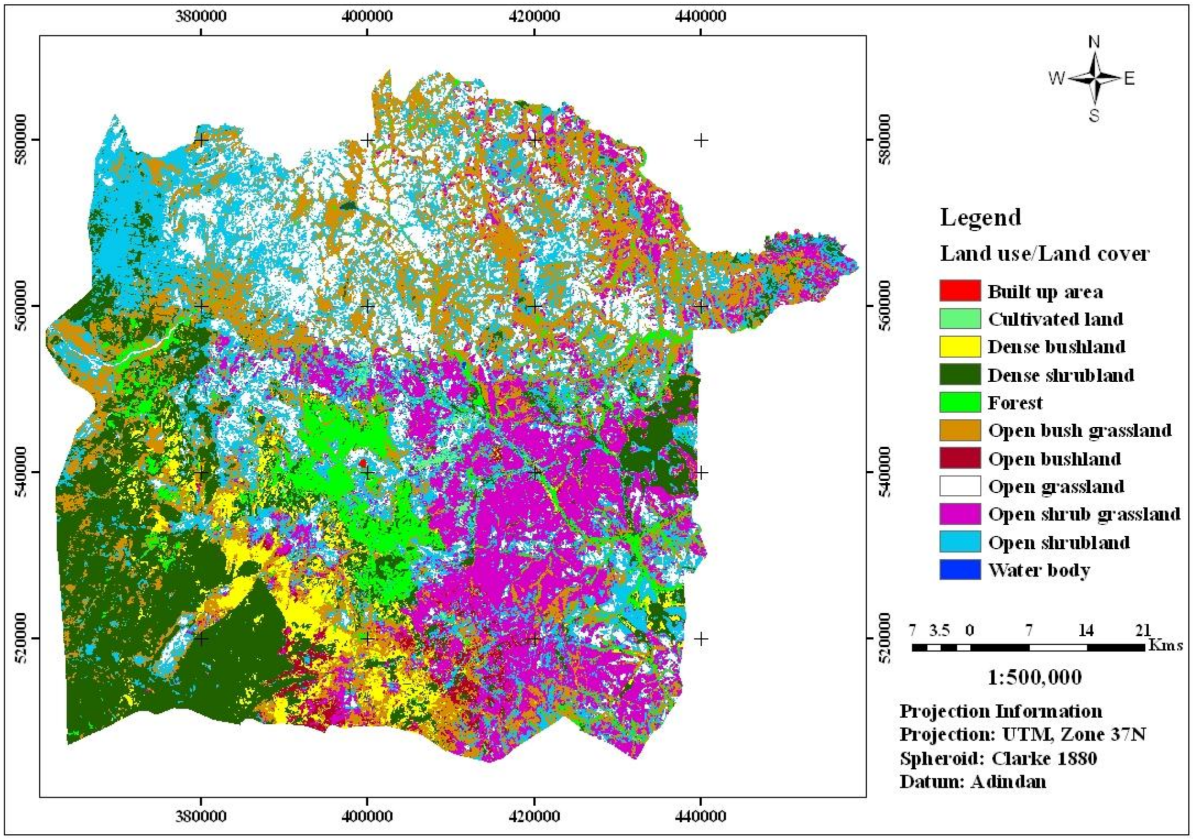

Figure 9: Land use/land cover map

Table 3: Land use/land cover

Land use/land cover	Herbage biomass*	Browse biomass*	Area (km^2)	Area (%)
Water body	0	0	0.62	0.01
Dense shrubland	0.3	2.2	956.31	17.25
Open grassland	2.3	0.5	730.47	13.18
Open shrubland	0.8	1.5	1208.21	21.79
Forest	0.5	1	295.37	5.33
Cultivated land	0.9	0.3	39.95	0.72
Dense bushland	0.4	2	209.94	3.79
Open bush grassland	1.4	1.5	1135.23	20.47
Open shrub grassland	1.4	1.5	865.94	15.62
Built up area	0	0	26.29	0.48
Open bushland	0.5	1.5	75.81	1.37
Total			5534	100

***Herbage and browse biomass coefficient taken from PADS (2004)**

E. Altitude

Altitude has a marked influence on the kind, nature and productivity of rangeland and it creates ecologically diverse vegetation (Herlocker, 1999) and hence affects livestock production. Moreover, altitude is identified as the most important environmental variable that contributed significantly to the differences in spatial distribution of both herbaceous and woody plant species which influences the quantity and quality of feed for grazers like cattle and sheep and browsers like camel and goats (Ayana Angassa, 1999). Figure 10 shows altitude map of the study area. According to the figure, most of the area falls in an altitude range of 1000-2000 m.a.s.l.

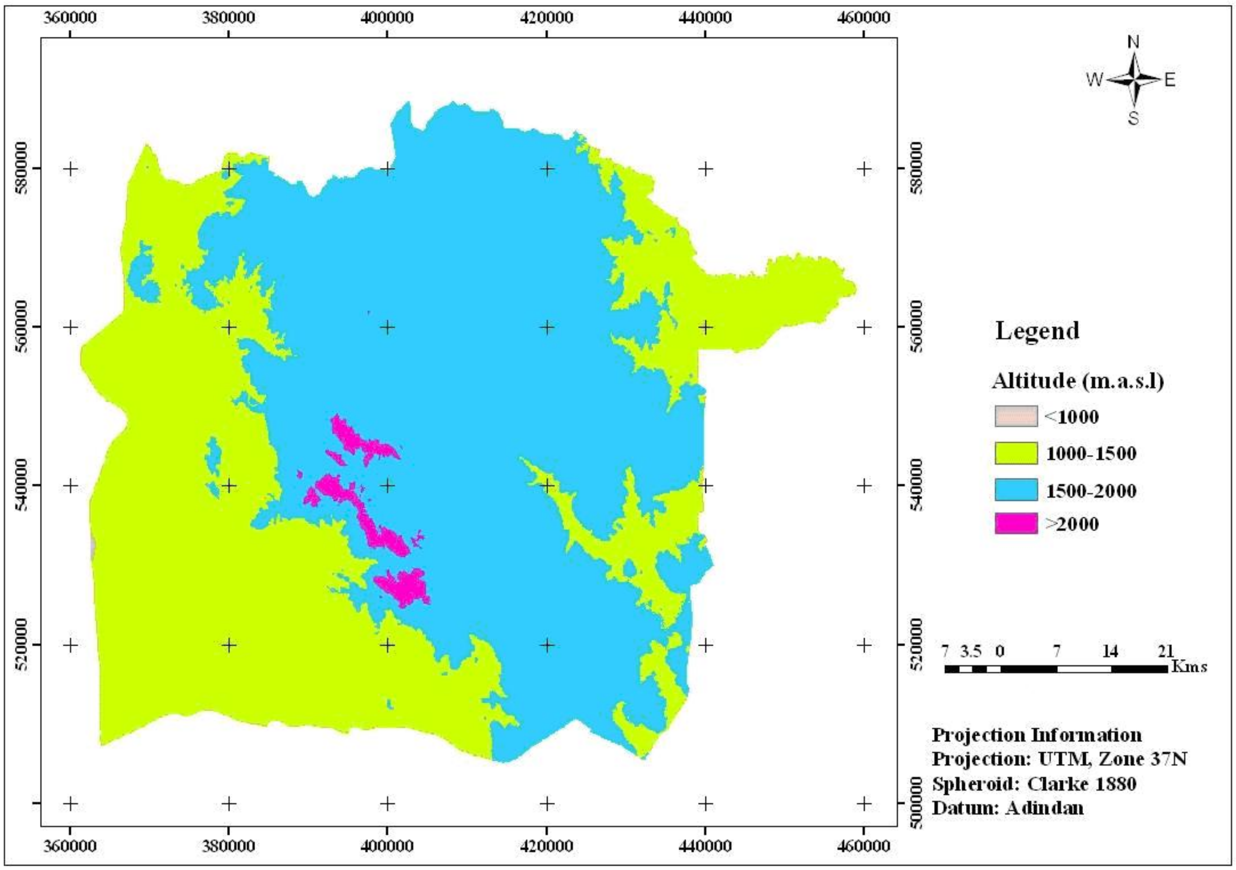

Figure 10: Altitude map

F. 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 camel 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. Figure 11 shows the slope map of the study area.

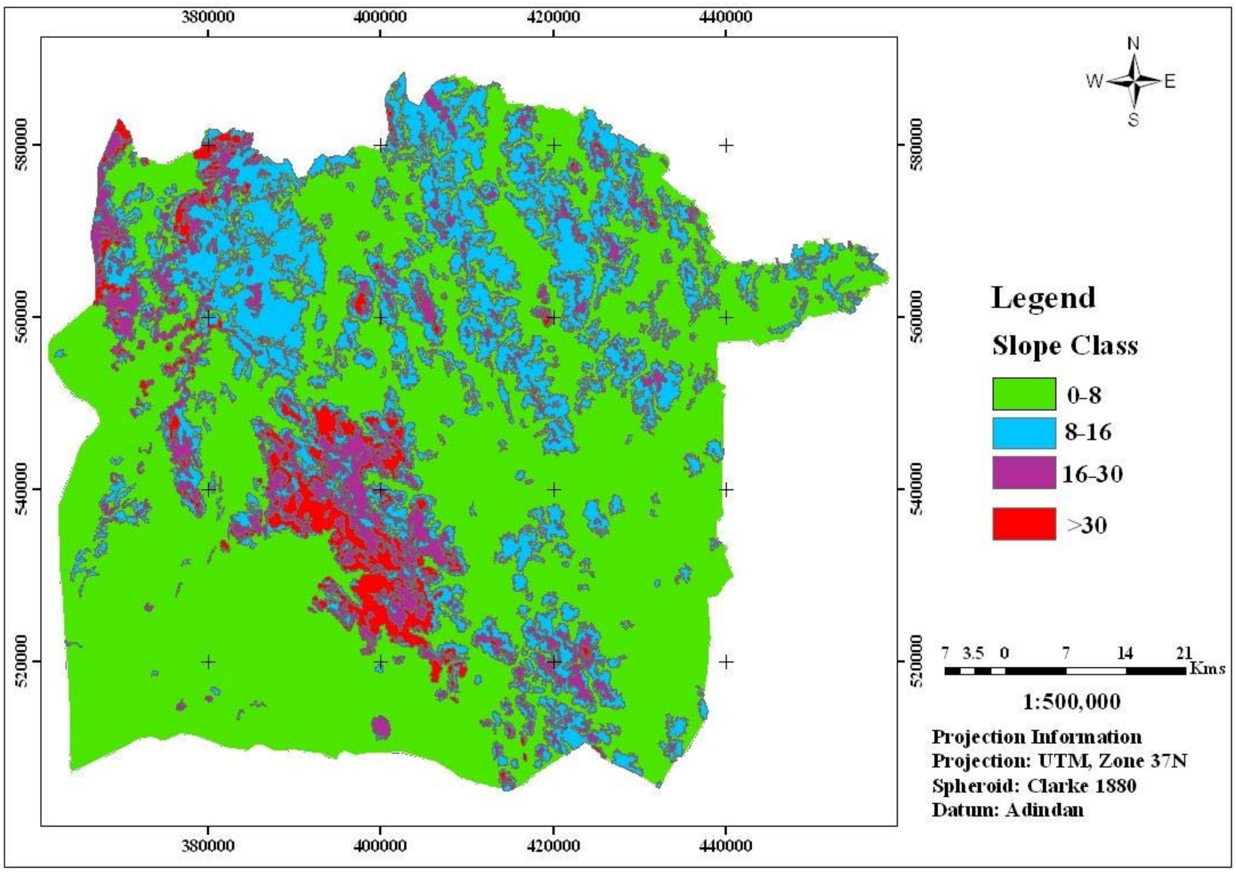

Figure 11: Slope map

G. Feed availability

The first and most important thing to be assessed for livestock suitability analysis is availability of feed and water. Feed can be obtained from grazing land for cattle and sheep, and from browsing on bushes and shrubs for goat and camel. Another source of feed for livestock production is crop residue and concentrates. The quantity of crop residue depends on the amount of land used for cultivation of crops. In the case of Yabello Woreda, the amount of feed from residue is small. As far as concentrates concerned, it is expensive and not available in the area. Therefore, grazing and browsing is the main source for livestock feed in the area.

3.4.2.2. Livestock requirement

Animals have specific environmental (bio-physical) requirement under which they grow and reproduce successfully. These specific biophysical conditions are referred as optimal environmental conditions. It is assumed that, these optimal conditions have no adverse effect on the growth and production of animals. In other word, this range of biophysical condition is called highly suitable. The selection of animal environmental requirement is usually referred as land use requirements (LURs) of land utilization types (LUTs). The selection of land use requirements is based on four criteria; 1) Importance of the use; 2) Existence of critical value in the study area; 3) practicality of obtaining the information; 4) availability of the knowledge with which to evaluate the corresponding land quality (LQs). Accordingly, 7 major animal requirements were selected. These are, 1. Rainfall, 2) temperature, 3) slope, 4) soil, 5) land use/land cover, 6) altitude, 7) herbage or browse biomass per hectare of the cover types. Table 4 shows environmental requirement of these livestock.

Table 4: Environmental requirement of Borana cattle, sheep, goat and camels (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)
Cattle	Soil	Scc,VReu,VRpe	CMcr,LVcr,CMeu,NTtro	FLca,LPel,FLeu,CLha,Lp		
	Temperature (^{0}C)	T4 (13-19)	T3 (19-23)	T2 (23-27.5)	T1 (>27.5)	
	Rainfall	>800	500-800	300-500	<300	
	Slope	0-8	8-16	16-30	>30	
	Land use land cover	OGL	OBGL, OSGL	OSL, CL, OBL	DSL, DBL	WB,FR,BA
	Altitude	1000-1700	700-1000, >1700	500-700	<500	
	Feed availability (ton/ha)	1.8-2.3	1.2-1.8	0.6-1.2	<0.6	
Sheep	Soil	FLca,CLha	CMcr,LVcr,CMeu,NTro	SNcc,LPel,FLeu,VReu,Lp,VRel		
	Temperature (^{0}C)	T4 (13-19)	T3 (19-23)	T2 (23-27.5)	T1 (>27.5)	
	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
	Altitude	1000-1700	700-1000, >1700	500-700	<500	
	Feed availability (ton/ha)	1.8-2.3	1.2-1.8	0.6-1.2	<0.6	
Goat	Soil	FLca,CLha	CMcr,LVcr,CMeu,NTro	SNcc,LPel,FLeu,VReu,Lp,VRel		
	Temperature (^{0}C)	T4 (13-19)	T3 (19-23)	T2 (23-27.5)	T1 (>27.5)	
	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
	Altitude	800-1500	500-800, >1500	300-500	<300	
	Feed availability (ton/ha)	1.8-2.3	1.2-1.8	0.6-1.2	<0.6	

Camel	Soil	FLca,LPel,FLeu,CLha,LP	CM			
	Temperature (^{0}C)	20-27	27-35	16-20, >35	<16	
	Rainfall	450-700	350-450	200-350	<200, >700	
	Slope	0-8	8-16	16-25	>25	
	Land use land cover	OSL	OBGL	OGL, CL, OSGL	DSL, DBL	WB,FR,BA
	Altitude	500-1000	300-500, 1000-1500	250-300, 1500-1800	<250, >1800	
	Feed availability (ton/ha)	1.8-2.3	1.2-1.8	0.6-1.2	<0.6	

Note:

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

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

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
FLca Calcaric Fluvisol

3.4.2.3. Factor/Criteria rating

Land suitability for livestock production needs the consideration of different factors including; bio-physical (environmental), infrastructural and social conditions of the area under consideration. Factor ratings are sets of values which indicate how well each factor/criterion is satisfied by particular conditions of the corresponding land quality. Factor ratings are usually made in terms of five classes: highly suitable, moderately suitable, marginally suitable, currently not suitable and permanently not suitable (FAO, 1985; 1993). In this study, only bio-physical parameters of the area were used as a factor for suitability analysis. Accordingly soil was analyzed for its textural classes since it is one of the most important parameter used to evaluate the suitability of the rangelands for different livestock as a source of feed, sleeping ground, ease of trekking and livestock disease prevalence. Rainfall and temperature are climatic factors which highly determine the productivity and survival of animals. Amount of rainfall determines the availability of drinking water. Temperature also affects animal's metabolic condition which directly influences the productivity level. Land use land cover is an indicator for the availability of feed. Slope determines how easily the animals graze or browse on the available forages and efficiency of their utilization. Thus, all livestock types prefer plain topography over steep or rugged topography since the latter one is more difficult for the mobility of the animals and easily fragile.

3.4.2.4. Criteria Standardization

For data standardization in GIS-based land suitability evaluation often arises as a consequence of the need to integrate into the evaluation process data measured not only in different units but also in different scales of measurement, such are measured on as nominal, ordinal, interval and ratio scales (Pereira and Duckstein, 1993). Because criteria are measured on different scales, it is necessary that factors be standardized before combination, and that they are transformed, if necessary, so that all factor maps are positively correlated with suitability. There are a number of approaches that can be used to make the attribute map layers comparable. Linear scale transformation is the most frequently used GIS-based approach for criteria standardization (Malczewski, 2003). However, the module named reclass of ArcGIS environment was used to standardize the factors used in present study. Thus, each factor will have an equivalent measurement basis before any weights are applied. Accordingly, all the factors used for this study are reclassified into five classes (S1, S2, S3, N1 and N2) with the range of values 1 to 5, where the values of 1 takes the most suitable and 5 takes the least suitable for all factors considered. However, there are some factors that will not fulfill the whole range due to the animals' requirement. Figure 12 indicates the standardized factor maps for cattle suitability.

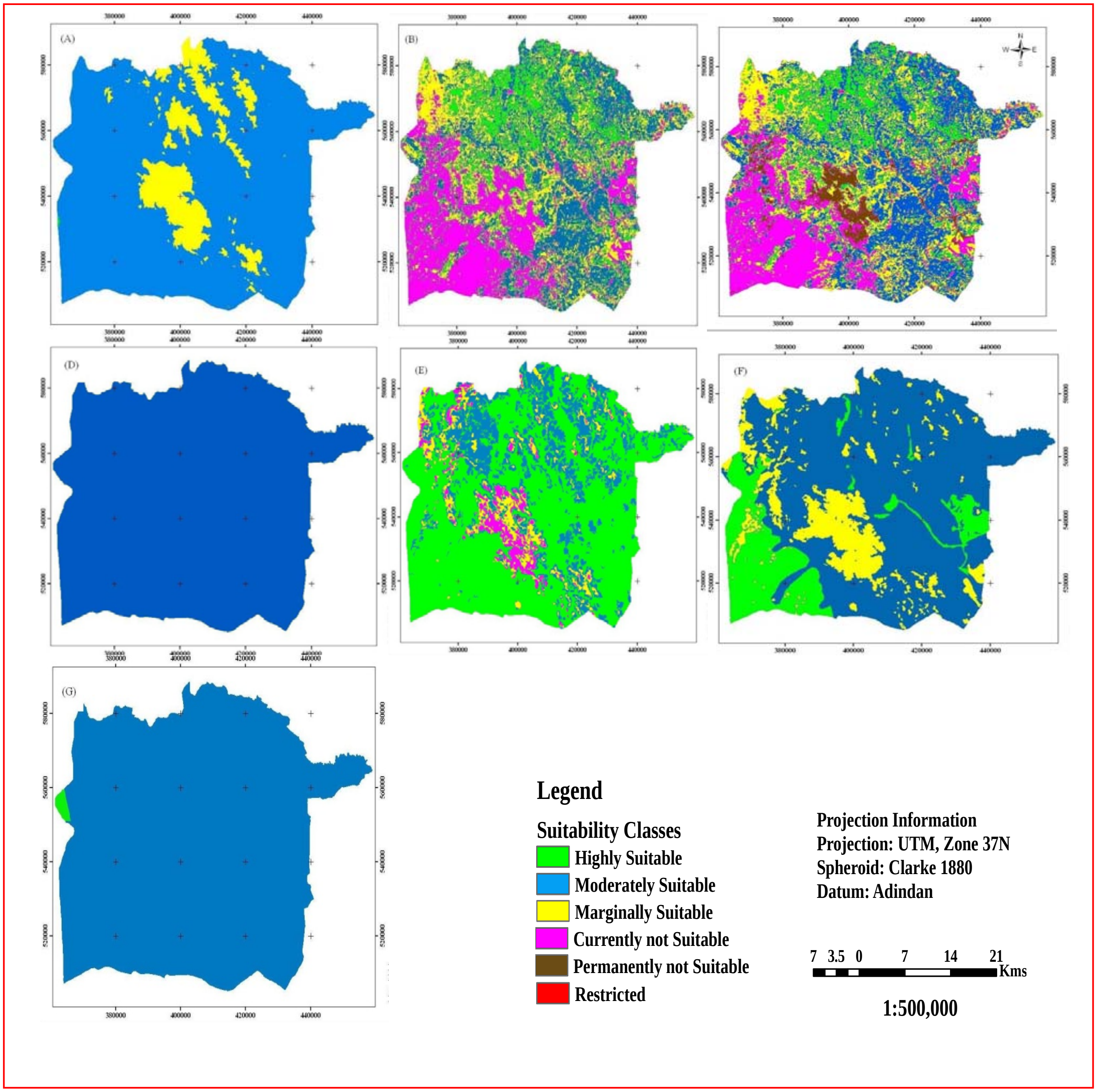

Figure 12: Standardized factor maps for cattle suitability analysis (A. Altitude, B. Herbage biomass, C. Land use/land cover, D. Rainfall, E. Slope, F. Soil (texture), and G. Temperature)

3.4.2.5. 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 5). 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 pairing and enters the rating into a pairwise comparison matrix or ratio matrix (Eastman, 2006). Since 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 have been arisen during the pairwise comparison process. Themodule allows repeated adjustments to the pairwise comparisons and reports the new weights and consistency ratio for each iteration. Figure13 reveals the analytical hierarchy process (AHP) weight derivation interface to derive the weights for the factors for livestock production. Table 5 shows both factor weights as well as consistency ratio calculated for the factors for livestock production in IDRISI Andes AHP weight derivation module for all livestock species.

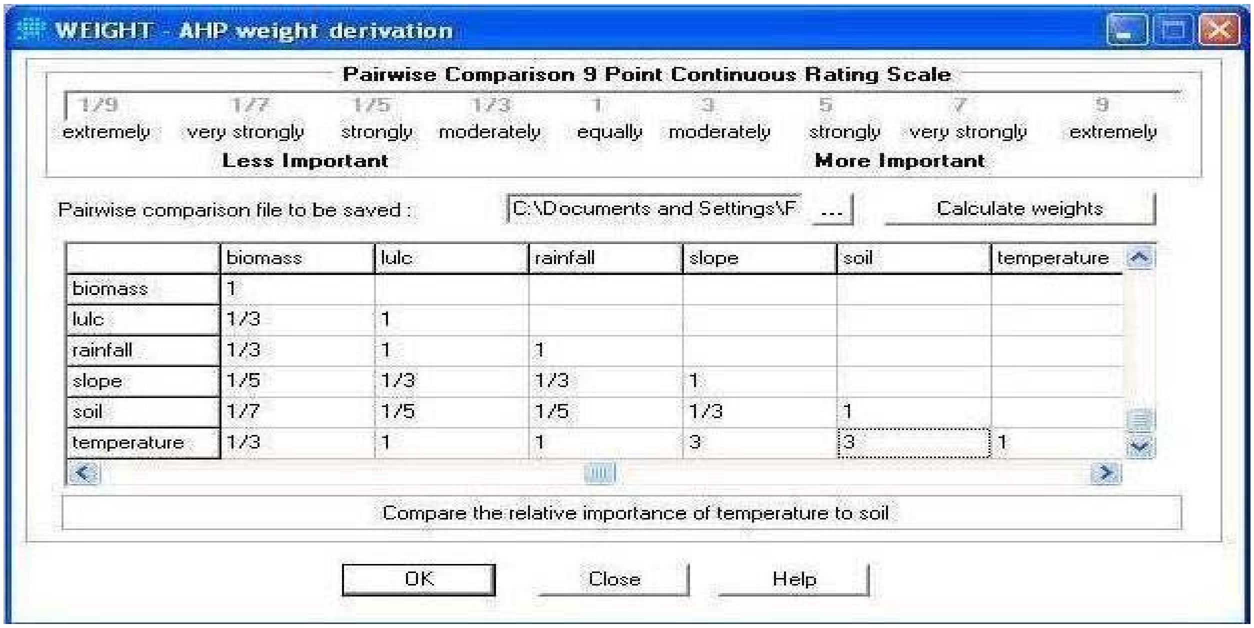

Figure 13: AHP weight derivation method for factors considered for cattle

Table 5: Criterion weights derived by AHP for cattle, sheep, goat and camel

	Cattle		**Sheep**		**Goat**		**Camel**	
Factors	**Weights**	**Weights (%)**	**Weights**	**Weight (%)**	**Weights**	**Weight (%)**	**Weights**	**Weight (%)**
Altitude	0.0284	2.84	0.0300	3	0.0284	2.84	0.0281	2.81
Biomass	0.3523	35.23	0.3709	37.09	0.3523	35.23	0.3387	33.87
Lulc	0.1713	17.13	0.1644	16.44	0.1713	17.13	0.1729	17.29
Rainfall	0.1713	17.13	0.1644	16.44	0.1713	17.13	0.1729	17.29
Slope	0.1007	10.07	0.0731	7.31	0.1007	10.07	0.1119	11.19
Soil	0.0444	4.44	0.0451	4.51	0.0444	4.44	0.0445	4.45
Temperature	0.1318	13.18	0.1521	15.21	0.1318	13.18	0.1309	13.09
Total	1.0000	100	1.0000	100	1.0000	100	1	100
CR	0.04	4	0.04	4	0.04	4	0.06	6

Note: CR= Consistency Ratio

4. Results and Discussion

4.1. Land Suitability Analysis Result

Land suitability analysis was done by weighted overlay of the factors that govern livestock production. Those factors were discussed in chapter 3. The suitability analysis result shows three classes of land suitability. These are, highly suitable, moderately suitable and marginally suitable. However, there is no land that is classified as currently not suitable and permanently not suitable for the four livestock species considered in this study even though there are all suitability classes for some of the factors when analysed individually. The area coverage of each suitability classes for each factor is shown in table 6.

The area coverage of each suitability class for each livestock was calculated after converting the raster output of the weighted overlay to a polygon feature in a GIS platform. The output of the analysis was shown in table 7. Thus, the results portray that areas with high biomass (>1.8 ton/ha), flat to gentle slope, open grassland, T4, mean annual rainfall greater than 800mm are identified as highly suitable areas for cattle and sheep production (Figure 14 and Figure 15 respectively). This is because, as far as feed is concerned, it has high quality and good amount of grass biomass which is preferable by cattle and sheep. Slope is the other factor which makes this portion of land most suitable. Because, animals can easily graze on flat and gentle slope and they can utilize most of the available feed with out much loss of energy. Rainfall and temperature is also in comfort zone of these animal requirements. Soil and altitude are also animals' preference. But in cases where soil and altitude is less suitable, the area is still fall under most suitable area as far as the other aforementioned suitability factors fulfilled. This is because; the weighted of these factors over weighs that of altitude and soil. But, this does not mean that altitude and soil have not influenced the suitability analysis, but their effect is masked by the other factors which have more weight. Compared to the other group of suitability classes, this group of land is very small even though most part of the area is flat, temperature and rainfall is in comfort zone. This is resulted from the fact that the area is being encroached by bush which decreases the amount of palatable forage production like grass species which are most preferred by grazing animal species, cattle and sheep. In addition, bush reduces the ease with which animals move from place to place in search of feed. Thus, 12.67% (701.26 km^2) and 10.63% (588.56 km^2) is highly suitable for cattle and sheep respectively. The amount of land which fall under high suitability class for browser species (goat and camels) is small compared to the total area as well as that of the grazers, 2.38% (131.66km^2) and 6.97% (385.88km^2) for goat and camel (Figure 16 and Figure 17 respectively). This is because the area, as far as camel is concerned, most part of the area for the major limiting factors like biomass, temperature and land use/land cover are fall under , marginal suitability or moderate suitability. This effect is not only observed in the case of browsers but also observed the case of grazers but the effect is slightly greater in the case of browsers.

Areas having herbage biomass 1.2-1.8 ton per/ha, slope 8-16,T3, land use/land cover OBGL, OSGL, and rainfall of 700-100 and >1700 are found to be moderately suitable for cattle. The above conditions also hold true for sheep suitability except slope class 16-30 have moderate suitability for sheep. This is because; sheep can manage themselves better than larger animals because of their smaller body weight. In utilization of slope, smaller animals like sheep and goat are more tolerant to steeper slope than cattle and camels. Concerning biomass, land use/land cover and temperature camels and goat have more or less the same preference except slight differences.

Considerable amount of the area fall under marginal suitability class for the four livestock species. Accordingly, 4.24% (234.53km^2), 31.59% (1748.51km^2), 13.47% (745.42km^2) and 12.47% (689.83km^2) of the land is marginally suitable for cattle, sheep, goat and camels.

The study does not show areas which is classified as currently not suitable and permanently suitable even though there are factors in which currently not suitable and permanently not suitable classes were observed. This is because; the final suitability is the cumulative effect of the weighted overlay factors.

Table 6: Suitability classes of each factors with their respective area coverage

Species	Suitability	Factors						
		Altitude (km^2)	Biomass (km^2)	LULC (km^2)	RF (km^2)	Slope (km^2)	Soil (km^2)	Temp (km^2)
Cattle	Highly Suitable	1.4	713.0	713.0		3725.2	915.7	23.9
	Moderately suitable	4842.8	2054.4	2054.4	5543.5	1203.1	3850.3	5519.6
	Marginally suitable	699.7	1239.0	1313.6		383.5	776.1	
	Currently not suitable		1536.7	1164.8		232.1		
	Permanently not suitable			297.3				
Sheep	Highly Suitable	1.4	713.0	713.0		3725.3	46.2	23.9
	Moderately suitable	4842.8	2054.4	2054.4	5543.5	1203.2	3850.3	5519.6
	Marginally suitable	699.7	1239.0	1313.6		383.2	1645.7	
	Currently not suitable		1536.7	1164.8		232.2		
	Permanently not suitable			297.3				
Goat	Highly Suitable	2345.0	1164.8	1200.2	4806.3	5096.6	776.1	23.8
	Moderately suitable	3198.9	3329.2	870.9	737.2	372.8	3850.3	5519.6
	Marginally suitable		296.0	3174.6		60.9	915.7	
	Currently not suitable		753.1			13.0		
	Permanently not suitable			297.3				
Camel	Highly Suitable	1.4	1164.8	2458.3	4844.1	3825.9	3850.3	1572.7
	Moderately suitable	2343.6	3329.2			1211.3	46.2	
	Marginally suitable	2947.6	296.0	1622.7	699.4	107.7	1645.7	3970.8
	Currently not suitable	251.3	753.1	1164.8		399.0		
	Permanently not suitable			297.3				

Table 7: Land Suitability Classes for Livestock with their respective area coverage

Livestock Species	Suitability Class	Area (km^2)	Percentage (%)
Cattle	Highly Suitable	701	13
	Moderately Suitable	4304	78
	Marginally Suitable	235	4
Sheep	Highly Suitable	589	11
	Moderately Suitable	2902	52
	Marginally Suitable	1749	32
Goat	Highly Suitable	132	2
	Moderately Suitable	4367	79
	Marginally Suitable	745	13
Camel	Highly Suitable	386	7
	Moderately Suitable	4170	75
	Marginally Suitable	690	12
Restricted Area		295	5
Total Area		5534	100

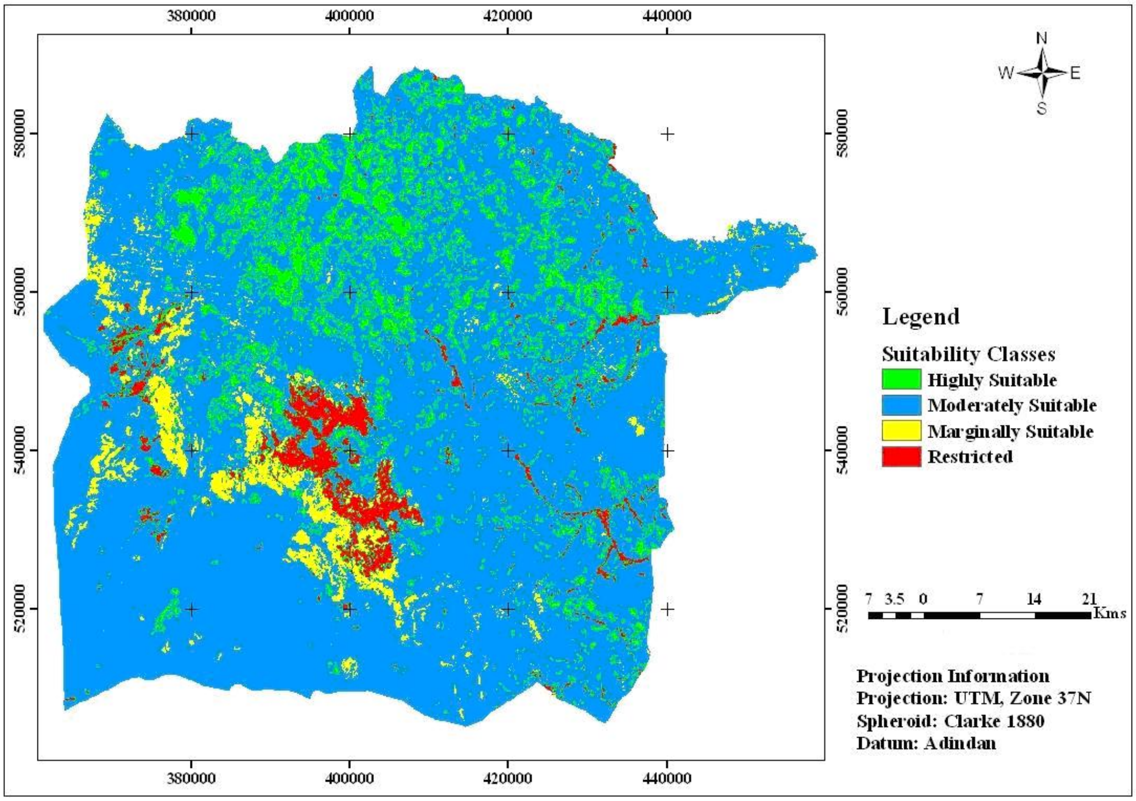

Figure 14: Land suitability classes for cattle in Yabello Woreda

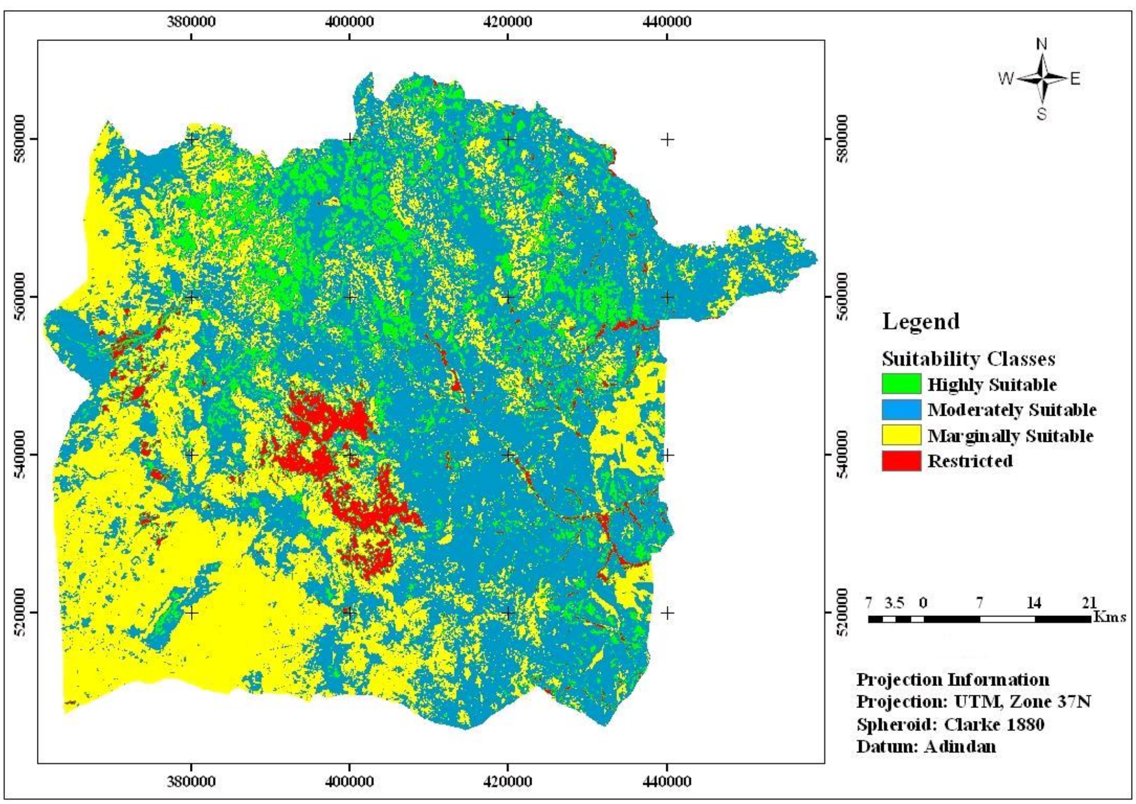

Figure 15: Land suitability classes for sheep in Yabello Woreda

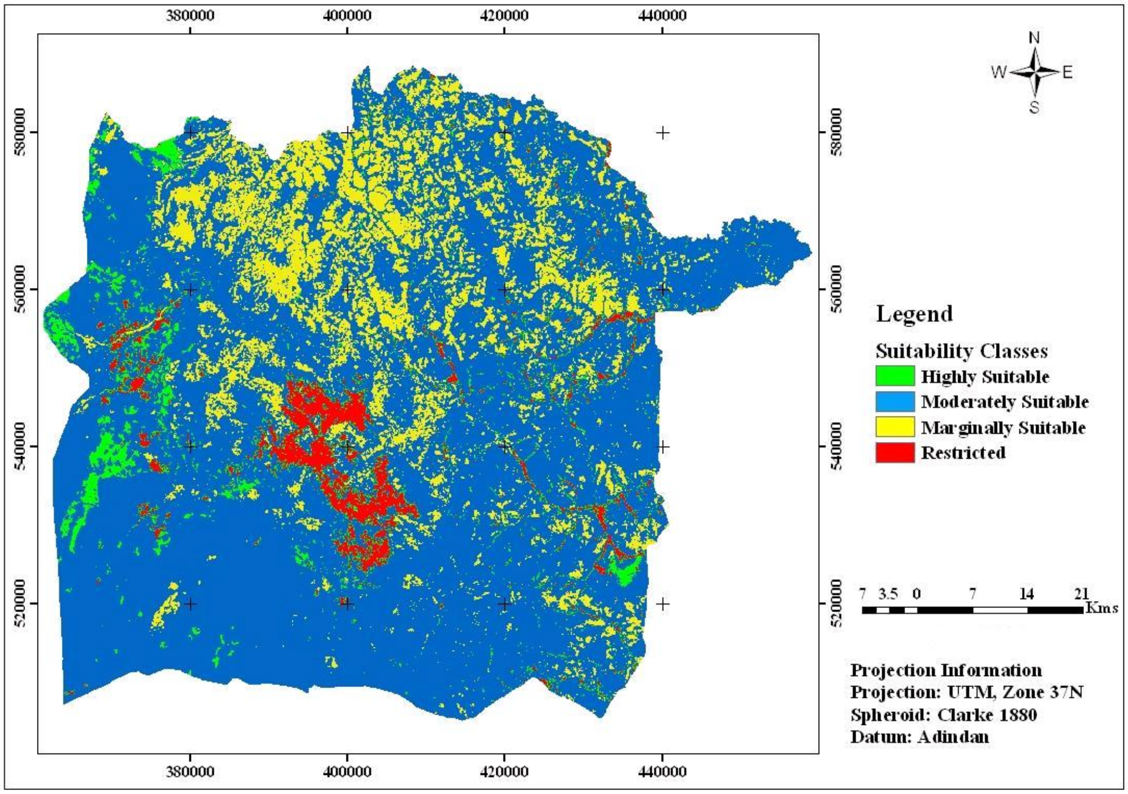

Figure 16: Land suitability classes for goat in Yabello Woreda

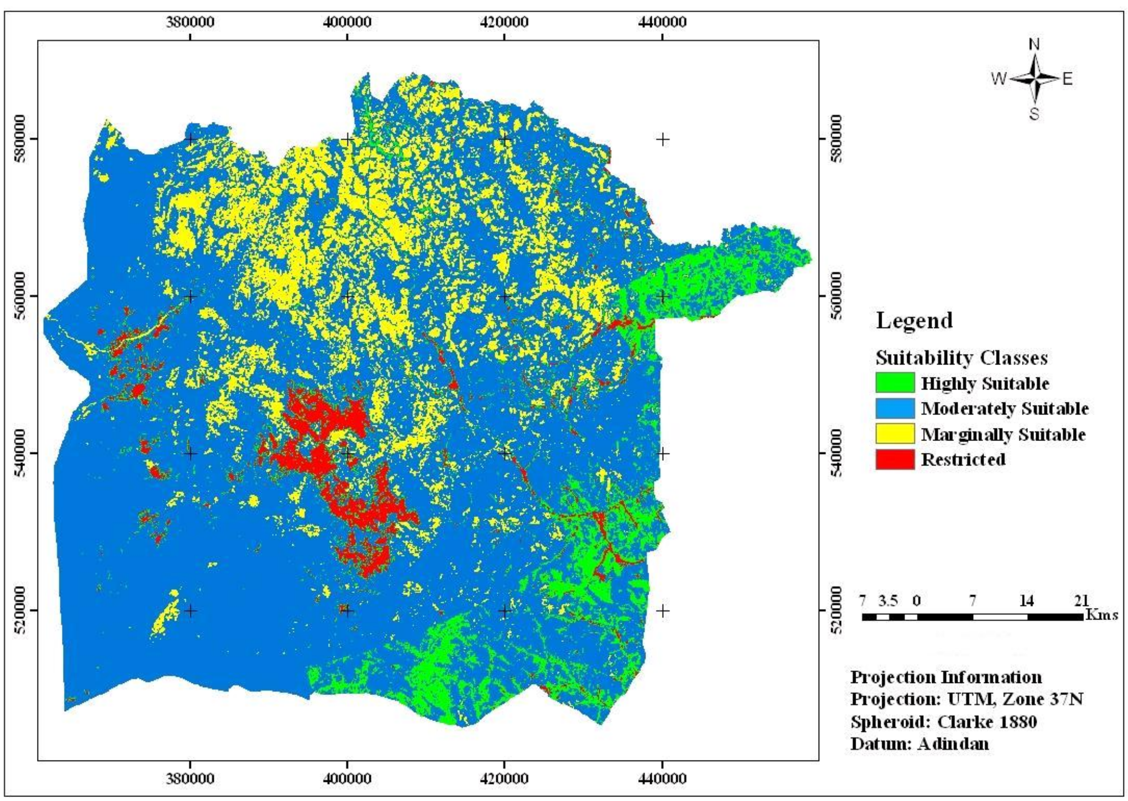

Figure 17: Land suitability classes for camel in Yabello Woreda

4.2. Land Allocation

The land suitability result obtained from Specific LUTs only indicates the different suitability classes for that LUT in the study area. When different LUTs are involved in the evaluation, it seems good to indicate the appropriate parcel of land best suitable for the LUTs and which LUTs compete for the same parcel of land at its best suitability class. Overall land suitability analysis result indicates the overall suitability of the land for each LUTs compete for the parcel of land at the same level of suitability class. Overall land suitability analysis is an indicative of appropriate land allocation. Hence, the overall land suitability analysis is performed for the LUTs considered in the study area.

Overall land suitability analysis is done after converting the raster data to a vector data format for all LUTs (Figure 18). Table 8 shows the result of appropriate land allocation for the LUTs along with their best suitability classes. The result demonstrates the condition where a plot of land is suitable for more than one livestock species at the same level of suitability class. According to the result, there is an instance in which a single parcel of land which is 3% of the total land is highly suitable for cattle, goat and camel at the same time. There is also a condition in which a single parcel is suitable for two livestock species. For example, 10% of a single parcel of land of the total area is highly suitable for cattle and sheep. In spite of the competition of one or more LUTs for a single parcel of land, there are parcels of land in which only single Livestock species is highly suited. Thus, 7%, 2%, 2% and 0.2% of the land is highly suited for camel, cattle, goat and sheep respectively. Likewise, such kinds of situation are also observed in parcels of land which allocated as moderately suitable. Thus, 42% of the area is moderately suitable for all the livestock species considered. 25% is allocated for cattle, goat and camel as moderately suitable. 4% is allocated as moderately suitable for goat and camel.

In this land allocation process, only 0.5% of the area is allocated as marginal suitability. This is because, if a parcel of land is not have a good suitability for one species, it may have a good suitability class for the other species. About 5% of the area, which is urban and forest land is not allocated for any of the livestock species considered. Rather these areas are restricted from evaluation and allocation.

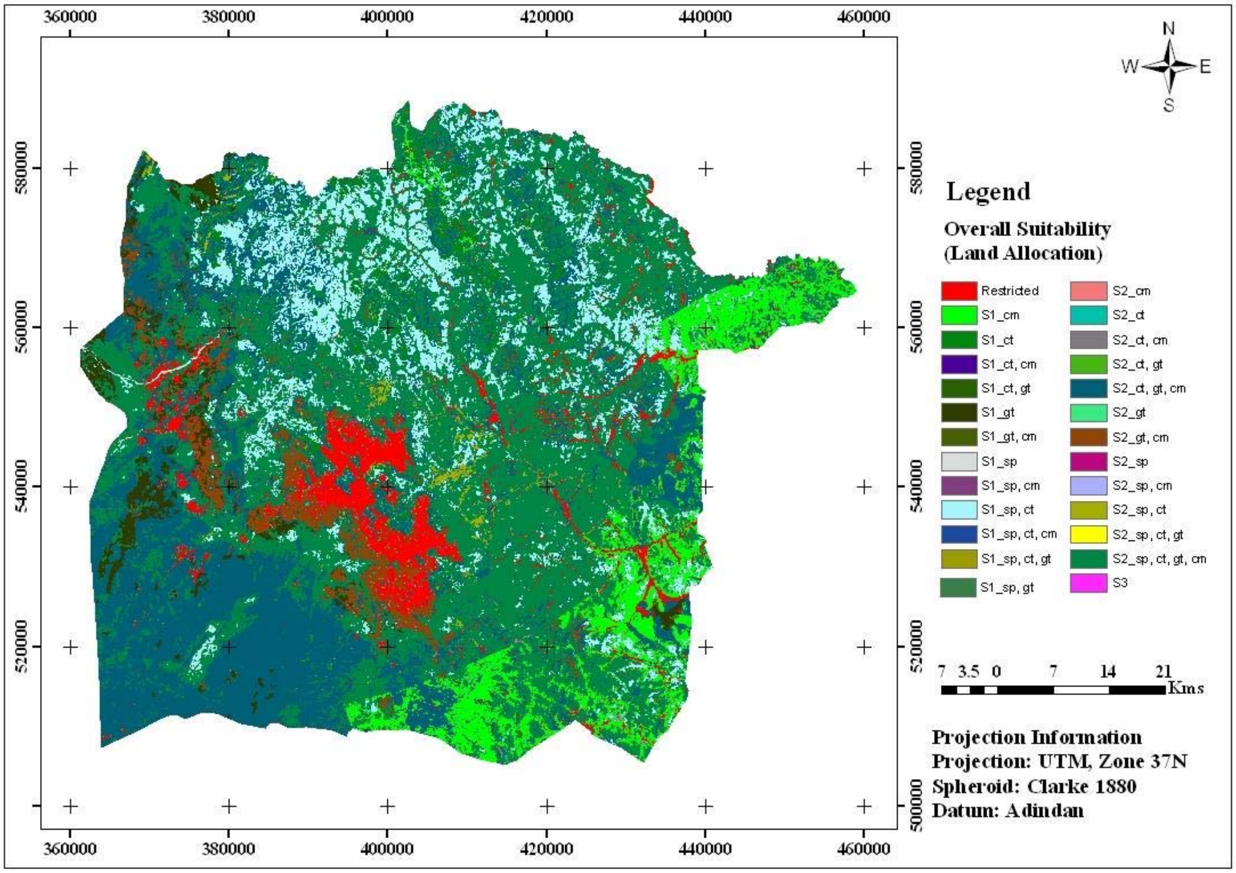

Figure 18: Appropriate land allocation map with their respective degree of suitability.
(Note: S1=Highly Suitable, S2=Moderately Suitable, S3=Marginally Suitable, ct= Cattle, sp=Sheep, gt=Goat, cm=camel)

Table 8: Suitable land allocation for cattle, sheep, goat and camel with their area coverage.

Overall Suitability Analysis					
Code	Area (km^2)	Area (%)	Code	Area (km^2)	Area (%)
S1_cm	381.4	6.8827	S2_ct	20.1	0.362411
S1_ct	121.0	2.1829	S2_ct, cm	5.0	0.09061
S1_ct, cm	0.2	0.0040	S2_ct, gt	2.7	0.049108
S1_ct, gt	0.1	0.0026	S2_ct, gt, cm	1382.6	24.95018
S1_gt	130.1	2.3480	S2_gt	5.9	0.105631
S1_gt, cm	1.1	0.0206	S2_gt, cm	207.0	3.735113
S1_sp	8.4	0.1512	S2_sp	1.1	0.020733
S1_sp, cm	0.2	0.0042	S2_sp, cm	0.1	0.002371
S1_sp, ct	576.8	10.4089	S2_sp, ct	67.2	1.213227
S1_sp, ct, cm	2.9	0.0521	S2_sp, ct, gt	0.2	0.003741
S1_sp, ct, gt	0.2	0.0044	S2_sp, ct, gt, cm	2319.3	41.98007
S1_sp, gt	0.0	0.0003	S3	29.5	0.532476
S2_cm	4.4	0.0789	Restricted	266.7	4.813657
Total				**5534**	**100**

(Note: S1=Highly Suitable, S2=Moderately Suitable, S3=Marginally Suitable, ct= Cattle, sp=Sheep, gt=Goat, cm=camel)

4.3. Spatial distribution of livestock population

The recent 2010 total livestock population (cattle, sheep, goat and camel) of the 18 PA's of Yabello Woreda was collected from Yabello Woreda pastoral development office (Table 9). According to the data obtained almost all kinds of the livestock species were found in all PA's except variations in number and density among them.

The highest population of animals is found in Tsadim PA, which is 37,792 (10%), the second highest population is found in Did Hara PA which is 32,666 (9%) where as the smallest number is found in Abida PA 6,277 (2%) and Genya PA 6,980 (2%). As far as the distribution of each species is concerned, the highest number of cattle is found in Tsadim 20,169 followed by Surupa 19, 650. The highest number of sheep is found in Eliweya and Chari, 2,800 and 2,700 respectively. The highest number of goat is found in Did hara and Tsadim, 12,340 and 10,073 respectively. Compared to the other livestock species, the number of camels population is small in the Woreda. The variation in the number of camels is very high among some PAs. For example the number is as high as 5500 in Harobeke and only 15 in Abida. The spatial distribution of livestock populations is shown in Figure 19.

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 920 animal per kilometre square in Genya PA, where as the lowest density is found in Ede gelchet PA which is only 25 animal per kilometre square when compared with the other PAs. The average livestock density of the Woreda is 66 animal per kilometre square.

By combining livestock suitability map of each livestock species with spatial distribution map for each livestock species, it is possible to indicate in which suitability class most of the livestock species are distributed. Accordingly, an attempt was made to visualize the spatial distribution of each livestock species over the suitability classes. Thus, large number of the cattle was distributed over moderately suitable areas. This condition also holds true for other livestock species since the large percent of the area was moderately 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 with in the localities.

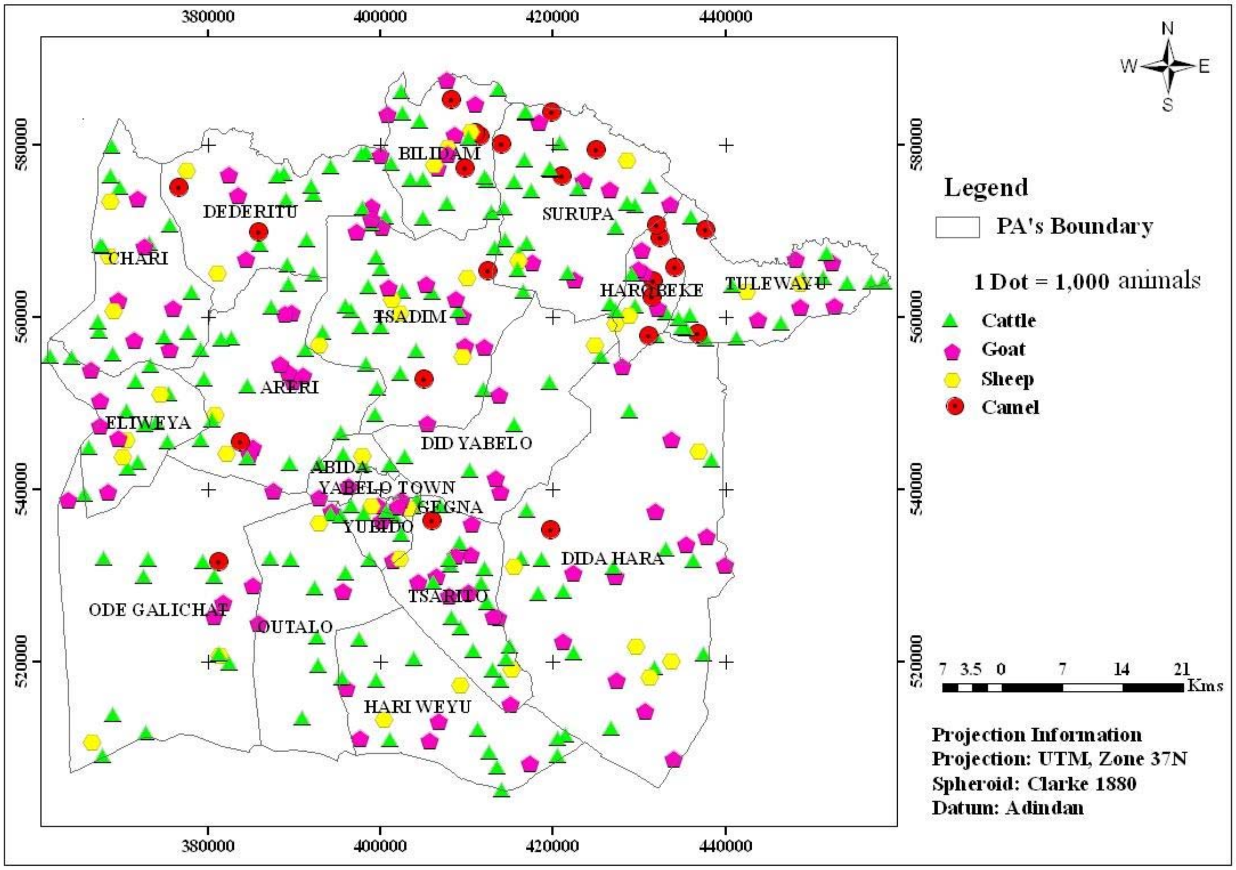

Figure 19: Livestock distribution map

Table 9: Livestock population of the study area

No	Kebele/Locality	Livestock population							
		Cattle	Goat	Sheep	Camel	Total	Percent	Area	Density
1	YABELO TOWN							16	
2	CHARI	15110	5980	2700	401	24191	6.6	293	83
3	DEDERITU	14496	4504	2200	1600	22800	6.2	334	68
4	BILIDAM	11821	5630	2630	4100	24181	6.6	209	115
5	SURUPA	19650	5980	2400	3500	31530	8.6	382	82
6	TULEWAYU	15436	4506	1520	1500	22962	6.3	236	97
7	HAROBEKE	4953	3600	1860	5500	15913	4.4	83	192
8	DID HARA	13693	12340	5200	1433	32666	8.9	985	33
9	DID YABELO	4622	3301	890	312	9125	2.5	295	27
10	TSADIM	20169	10073	5120	2430	37792	10.3	437	86
11	ARERI	13259	7846	2140	880	24125	6.6	372	65
12	ELIWEYA	11694	5460	2800	380	20334	5.6	186	109
13	ODE GALICHAT	9595	5243	1873	580	17291	4.7	703	025
14	OUTALO	9460	3100	1300	75	13935	3.8	329	042
15	ABIDA	3797	1865	600	15	6277	1.7	49	129
16	YUBIDO	5836	2981	1200	42	10059	2.8	49	207
17	GEGNA	4108	2008	830	34	6980	1.9	8	920
18	TSARITO	15011	9534	2100	590	27235	7.4	221	123
19	HARI WEYU	11660	4830	1710	480	18680	5.1	314	59
	Total	**204370**	**98781**	**39073**	**23852**	**366076**	**100**	**5534**	**66**

Yabello Woreda Pastoral Development Office (2010)

5. Conclusion and Recommendation

5.1. Conclusion

This study was intended to analyze suitability of Yabello rangeland for livestock production integrating GIS and Remote Sensing techniques with MCE. Among several factors governing land suitability for livestock production, seven factors (Altitude, biomass, land use/land cover, rainfall, slope, soil and temperature) which have more influence on livestock productivity were considered. Since the influence of these factors is not equal, weight was given during overlay analysis.

For all the livestock species considered, highest percentage of the land is to moderately suitable for livestock production. For instance, 78%, 52%, 79% and 75% of the land gone to moderate suitability class for cattle, sheep, goat and camels respectively. This indicates that the majority of the area is moderately suitable for livestock production even though there are some areas under which high suitability and marginal suitability classes are possible.

Land allocation technique demonstrates that it is possible for a parcel of land to suit for two or more LUTs at the same time with the same suitability level. Thus, 22% of the area was allocated to high suitability class. Where as 73% was allocated for moderate suitability class. Out of 73%, 41% of the area was still moderately suitable for all the livestock species considered. This is an indication that the area is still productive for cattle, sheep, goat and camels even though Yabello rangelands have problems like drought, bush encroachments and expansion of cultivation.

The spatial distribution of the livestock population depicts the fact that they are densely distributed in PAs having opengrassland open bush grass land and open shrub grassland like Yubido, Tsarito, Surupa, Harobeke, Bilidam and Eliweya. Where as are livestock population distribution is spase in PAs like Ode Gelechet because of dense shrub land and dense bush land which is not suitable for animal production.

Generally, analysis made by GIS and Remote Sensing showed that Yabello rangeland has moderate suitability class for the four livestock species considered in the evaluation. Thus, integrating GIS and Remote Sensing it is possible to monitor the capacity and conditions of rangelands.

5.2. Recommendations

- There were limitations in getting research generated suitability evaluation parameters and future effort should focus on improving the parameters and the methods of rating. Parameters like palatability of the different vegetation components for the different livestock species must be studied and included in the suitability evaluation. Furthermore, which soil parameter influences the suitability for the different livestock species must be investigated. It is also important to refine the parameters by undertaking a detailed study with regard to livestock diseases, market situations and others.

- 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 encroachments.

- In this study, only bio-physical factors (altitude, biomass, land use/land cover, rainfall temperature, slope and soil) were considered for the analysis. Future study should incorporate socio economic (income, preference) and infrastructural factors like availability of veterinary services and livestock markets.

- 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, eelaas 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 shortage of dry season livestock drinking water.

- There is a dire need for the formulation of a land use policy in a participatory way with the community. Policy makers and planners should integrate environmental concerns into the Borana economic planning and social development through participatory processes.

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Appendices

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

1.1. Factor weights for Cattle.

Factors	Altitude	Biomass	Lulc	Rainfall	Slope	Soil	Temperature	Weights	Weight (%)
Altitude	1							0.0284	2.84
Biomass	7	1						0.3523	35.23
Lulc	5	1/3	1					0.1713	17.13
Rainfall	5	1/3	1	1				0.1713	17.13
Slope	5	1/3	1/3	1/3	1			0.1007	10.07
Soil	3	1/7	1/5	1/5	1/3	1		0.0444	4.44
Temperature	5	1/3	1	1	1	3	1	0.1318	13.18
Total								1.0000	100
CR								0.04	4

1.2. Factor weights for Sheep

Factors	Altitude	Biomass	Lulc	Rainfall	Slope	Soil	Temperature	Weights	Weight (%)
Altitude	1							0.0300	3
Biomass	7	1						0.3709	37.09
Lulc	5	1/3	1					0.1644	16.44
Rainfall	5	1/3	1	1				0.1644	16.44
Slope	3	1/5	1/3	1/3	1			0.0731	7.31
Soil	3	1/7	1/5	1/5	1/3	1		0.0451	4.51
Temperature	5	1/3	1	1	3	1	1	0.1521	15.21
Total								1.0000	100
CR								0.04	4

1.3. Factor weights for Goat

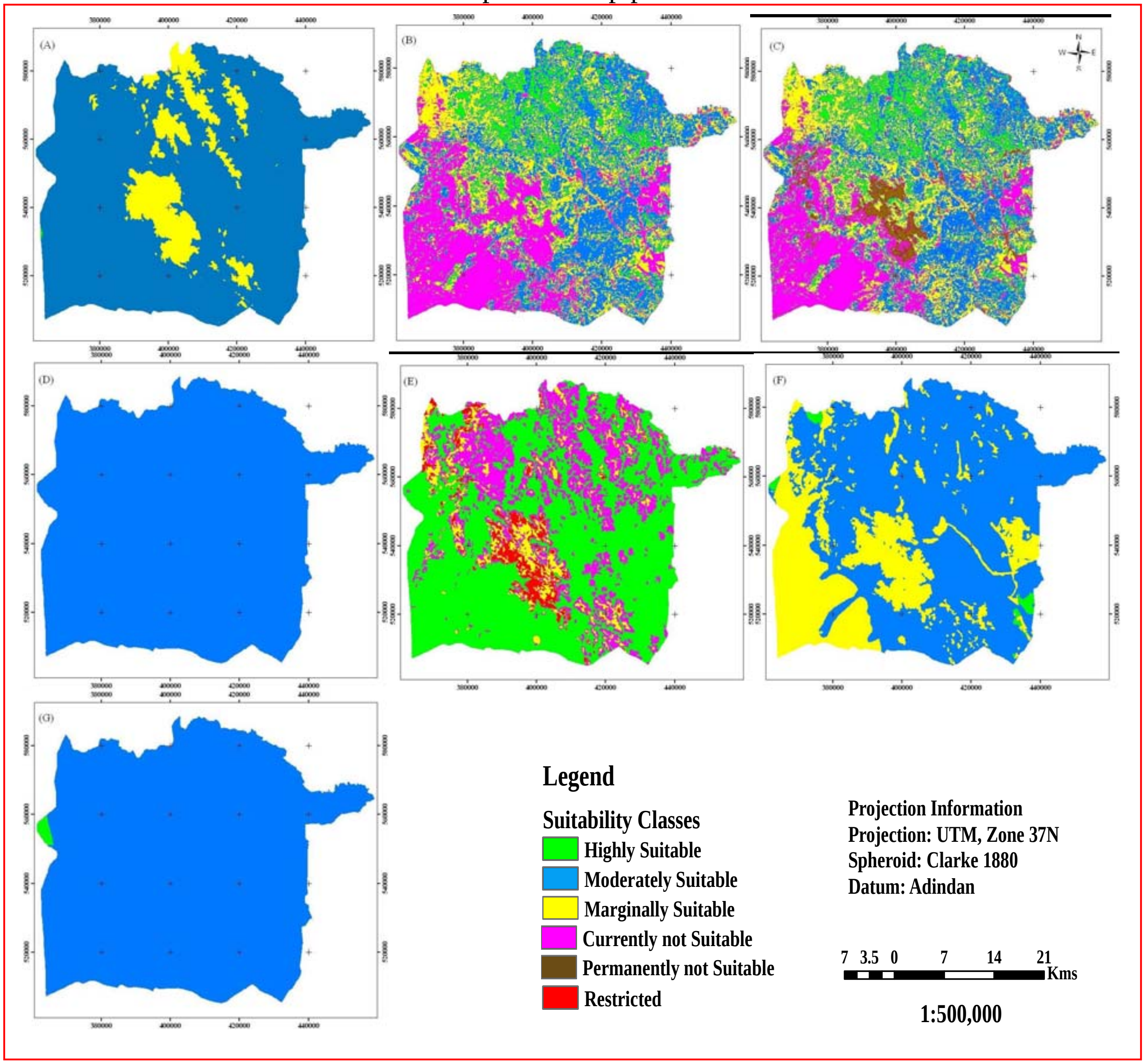
Factors	Altitude	Biomass	Lulc	Rainfall	Slope	Soil	Temperature	Weights	Weight (%)
Altitude	1							0.0284	2.84
Biomass	7	1						0.3523	35.23
Lulc	5	1/3	1					0.1713	17.13
Rainfall	5	1/3	1	1				0.1713	17.13
Slope	5	1/3	1/3	1/3	1			0.1007	10.07
Soil	3	1/7	1/5	1/5	1/3	1		0.0444	4.44
Temperature	5	1/3	1	1	1	3	1	0.1318	13.18
Total								1.0000	100
CB								0.04	4

1.4. Factor weights for Camel

Factors	Altitude	Biomass	Lulc	Rainfall	Slope	Soil	Temperature	Weights	Weight (%)
Altitude	1							0.0281	2.81
Biomass	7	1						0.3387	33.87
Lulc	5	1/3	1					0.1729	17.29
Rainfall	5	1/3	1	1				0.1729	17.29
Slope	5	1/3	1/3	1/3	1			0.1119	11.19
Soil	3	1/5	1/5	1/5	1/5	1		0.0445	4.45
Temperature	5	1/3	1	1	1	3	1	0.1309	13.09
Total								1	100
CR								0.06	6

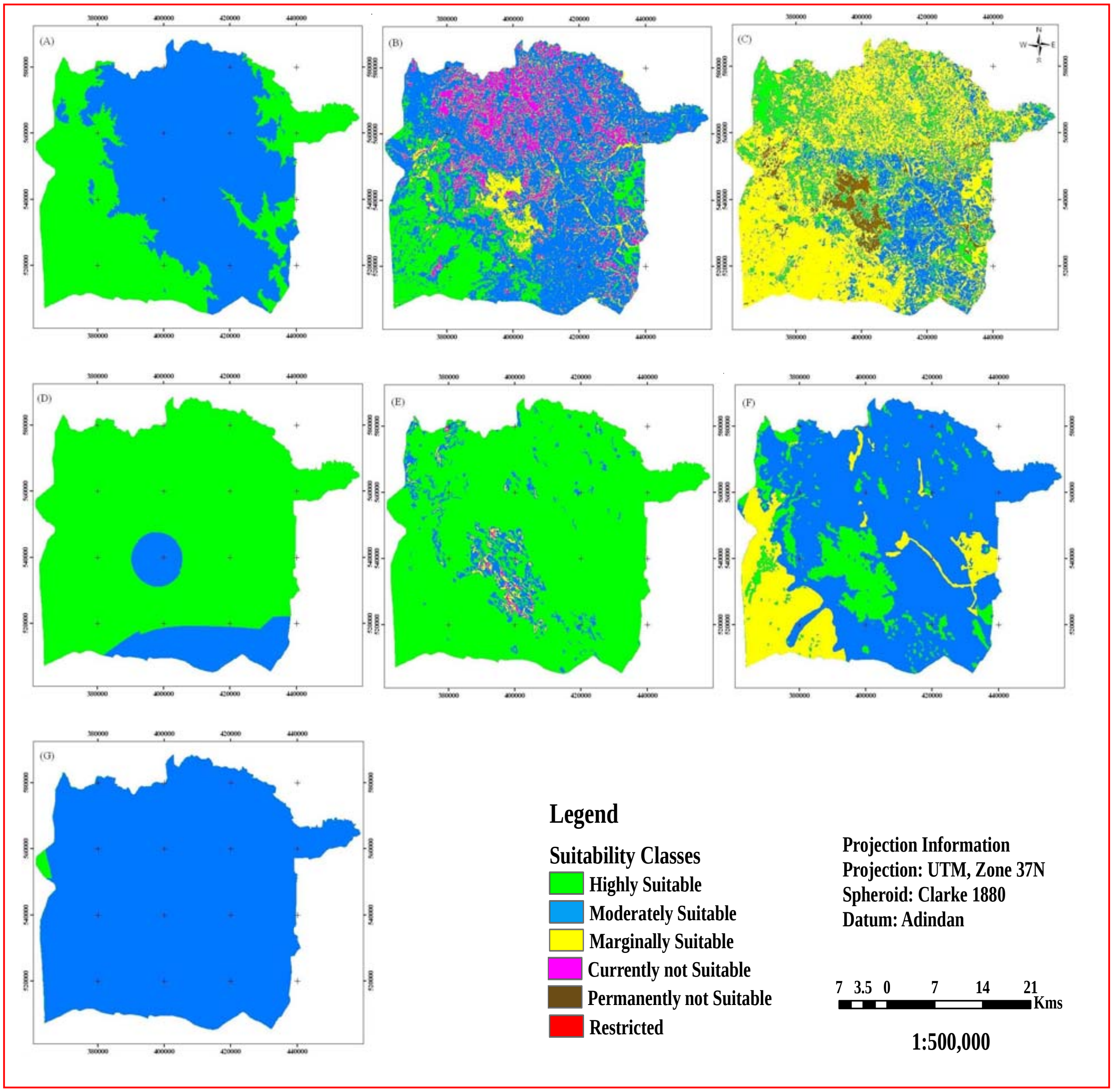
2. Standardized/Reclassified factor maps for the selected LUTs

2. 1. Standardized/Reclassified factor maps for sheep production



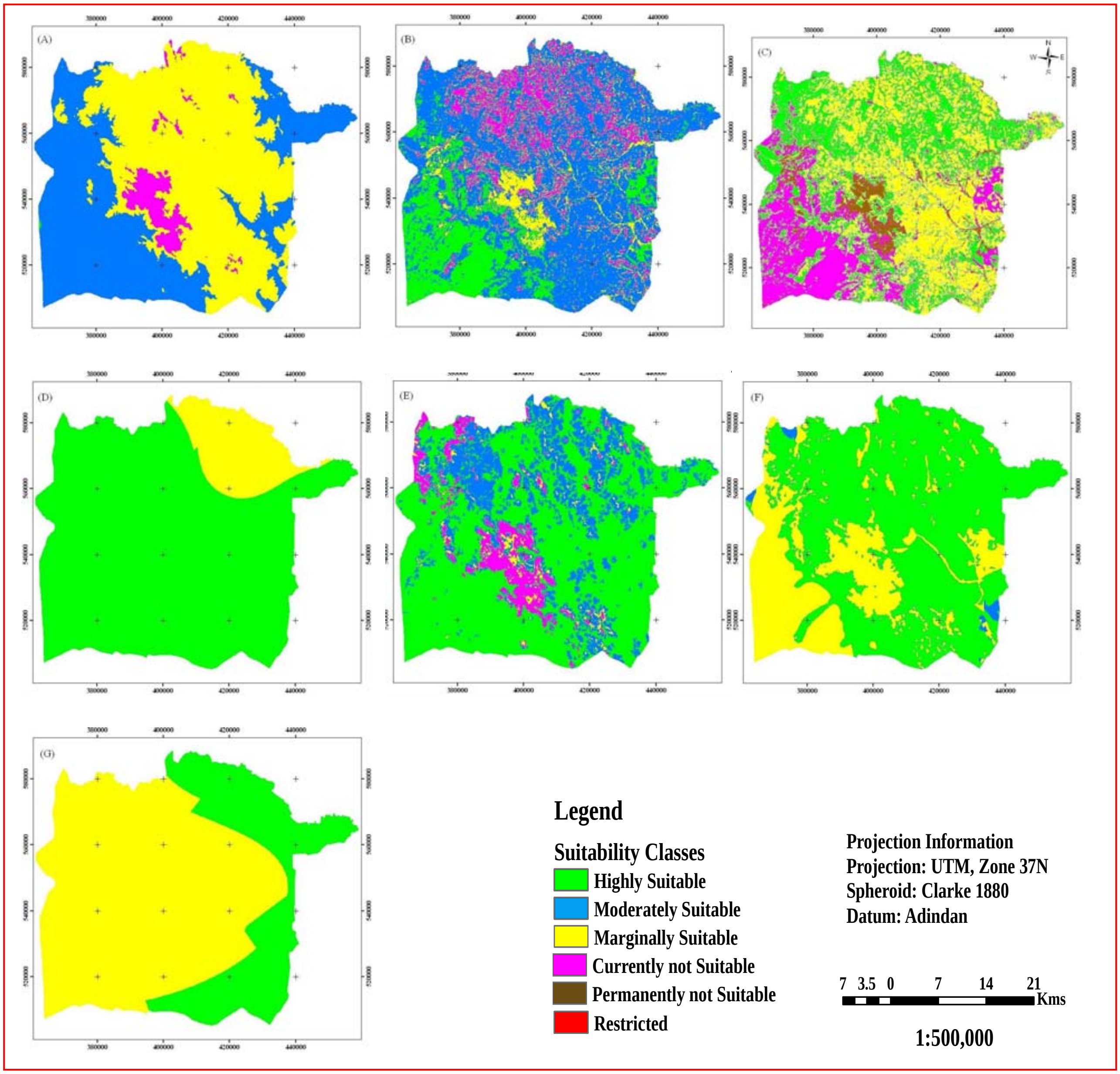
Standardized factor maps for Sheep suitability analysis (A. Altitude, B. Herbage biomass, C. Land use/land cover, D. Rainfall, E. Slope, F. Soil, and G. Temperature)

2.2. Standardized/Reclassified factor maps for goat production



Standardized factor maps for goat suitability analysis (A. Altitude, B. Herbage biomass, C. Land use/land cover, D. Rainfall, E. Slope, F. Soil, and G. Temperature)

2. 3. Standardized/Reclassified factor maps for camel production



Standardized factor maps for camel suitability analysis (A. Altitude, B. Herbage biomass, C. Land use/land cover, D. Rainfall, E. Slope, F. Soil, and G. Temperature)

3. GPS reading recorded for representative land use/land cover categories.

Way points	UTM Coordinate		Land use/land cover
	Easting (X)	Northing (Y)	
157	408072	538096	Cultivated land
159	408905	536931	Open bush shrub land
163	410636	532204	Open bush shrub land
164	410798	530435	Cultivated land
165	411093	527219	Open bush grass land
166	411100	527128	Open bush land
169	410803	521784	Dense bush land
170	410823	521690	Dense bush shrub land
171	410981	520502	Dense bush shrub land
178	405095	517608	Dense bush shrub land
179	403199	518671	Dense bush shrub land
180	399615	518093	Dense shrub land
181	398066	517587	Dense shrub land
183	396898	516837	Dense shrub land
184	395188	515803	Dense shrub land
185	393524	515254	Dense shrub land
186	390262	514747	Open shrub grass land
187	388668	514582	Dense shrub land
188	385285	514615	Open shrub land
189	381371	514054	Open shrub grass land
190	378702	512981	Open shrub grass land
191	375061	512158	Dense shrub land
192	373892	511842	Open shrub grass land
193	371528	511218	Dense shrub land
194	368970	510867	Cultivated land
195	366435	510543	Dense shrub land
196	399120	540886	Dense shrub land
201	406729	539181	Cultivated land
202	408483	537615	Cultivated land
178	405095	517608	Dense bush shrub land
179	403199	518671	Dense bush shrub land
180	399615	518093	Dense shrub land
181	398066	517587	Dense shrub land
183	396898	516837	Dense shrub land
184	395188	515803	Dense shrub land
185	393524	515254	Dense shrub land
204	409858	537199	Open bush land
205	412897	536165	Open bush land
206	412936	536162	Open bush land
207	413992	536095	Open bush shrub land

208	417119	535744	Settlement
209	417174	535710	Open bush shrub land
210	418711	534288	Dense bush land
211	419090	534145	Settlement
213	420673	533940	Cultivated land
214	421529	533889	Open bush grass land
215	424519	532533	Dense bush land
217	430988	530546	Settlement
218	431044	530538	Open bush land
219	432105	530381	Dense bush shrub land
220	432765	530291	Dense bush shrub land
221	434780	530019	Settlement
223	435085	529999	Open bush grass land
224	440314	530165	Open shrub land
225	438392	530195	Open bush grass land

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

A. Borana Cattle in grassland

B. Dense bush land observed from distant

C. Open shrubland

D. Rural settlement