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REMOTE SENSING AND GIS BASED SUITABILITY ANALYSIS FOR LIVESTOCK PRODUCTION IN YABELLO DISTRICT, SOUTHERN ETHIOPIA


BY

DESSALEGN GURMESSA DESSO

AAU

JUNE, 2009

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Declaration

I, the undersigned declare that this thesis is my original work and has not been presented for a degree in any other university and that all sources of material used for this thesis have been dully acknowledged.

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Table of contents

Contents Page

List of Tables

List of Figures

Acronyms

AOI= Area of Interest

ASALs= Arid and Semi-Arid Lands

DEM= Digital Elevation Model

EMA= Ethiopian Mapping Agency

IIED= International Institute for Environment and Development

NMSA= National Meteorological Services Agency

ENVI= Environment for Visualizing Images

ERDAS= Earth Resource Data Analysis

ETM+= Enhanced Thematic Mapper Plus

FLDP= Fourth Livestock Development Project

FAO = Food and Agriculture Organization of the United Nations

GCPs= Ground Control Points

GCS= Geographic Coordinate system

GDP= Gross Domestic Product

GIS= Geographic Information System

GLOVIS= Global Visualization Viewer of the United States Geological Survey

GPS= Global Positioning System

ILRI= International Livestock Research Institute

LSA= Land Suitability Analysis

LU/LC= Land Use/Land Cover

MCA= Multiple Criteria Analysis

MCDM= Multiple Criteria Decision Making

MCE= Multiple Criteria Evaluation

MIR= Mid Infra Red

NASA= National Aeronautics and Space Administration
NDVI= Normalized Difference Vegetation Index

NIR = Near-Infrared

RMS=Root Mean Square

SERP= Southeast Rangelands Project

SORDU= Southern Rangelands Development Unit

SPOT= Systeme Probatoire d'Observation de la terre

SRTM= Shutle Radar Topographic mission

TLDP= Third Livestock Development Project

TM= Thematic Mapper

USGS= United States Geological Survey

UTM=Universal Transverse Mercator
WGS= World Geodetic System

WOA= Weighted Overlay Analysis

Abstract

Land suitability analysis is the evaluation and grouping of specific areas of land in terms of their suitability or capability for a defined use. To get the maximum benefit out of the land, proper use of it for specific purposes is inevitable. Yabello district, which is situated in arid and semi-arid lands, experiences low and erratic rainfall and high temperature that hinder any significant crop production. However, rapid population growth of the study area has resulted in increasing demand for arable land leading to reduced amount of land for natural grazing and forage production. Thus, the above conflicting and challenging issues could lead to fast depletion of land resources. Therefore, locating appropriate areas for livestock production using spatial models of Geographic Information systems (GIS) and Remote Sensing would be indispensable input to improve livestock productivity which enhances resilience of the environment. This study intended to analyze and map suitable land areas for livestock production in Yabello district using GIS and Remote Sensing techniques. Besides, it aimed at identifying land cover change in the study area for the last 23 years and to what extent and direction the change occur. The study made use of Landsat 1986 and 2003 Remote Sensing Satellite Image analysis to determine the extent and pattern of rangeland change, and Multi Criteria Evaluation in a GIS environment to come up with the final suitability map. The study used weighted overlay technique of MCE in a GIS platform to arrive at the final land suitability for livestock species. The current analysis showed that, 31.6%, 31.5%, 18.2% and 26.9% of the total study area is most suitable for the production of cattle, sheep, goats and camels, respectively. Furthermore, it should be noted that the larger portion of the study area (39.2% and 38.2%) fell under the suitability class called marginally suitable for cattle and sheep, respectively. This could be attributed to the encroachment of the rangelands by the woody plant species which needs due treatment (e.g. rangeland rehabilitation or bush clearing) so as to reverse the scenario. In addition, the study revealed that more than half of the study area is permanently inaccessible to the major *eelaas*. In the current study, it is evident that there is acute shortage of *eelaas* for watering livestock especially during the dry season.

Keywords: Yabello district, Suitability analysis, GIS and Remote Sensing techniques, Multi-criteria Evaluation, *eelaas*

1. Introduction

1.1. General Background

Ethiopia exhibits remarkable diversity of topography and various livelihood strategies. The central highland massif, where altitude rise above 4000 meters in places, is surrounded by an apron of semi-arid lowlands, where altitudes are often not much above sea level (Hogg, 1997). Economically, the country is dominated by smallholder farmers and herders. Altogether the agricultural sector accounts for 85% of total employment, about 45% of GDP and 75% of exports. Livestock production accounts for about 30 percent of the output value of agricultural sector.

The overwhelming majority of the populations of the country are rural. Most of these live in the highlands. These high concentrations of population on little over 40 percent of the land mass of the country (Ezra 1990; cited in Hogg 1997) reflect the close relationship between physiography, climate, economy and population distribution. The average population density in the highlands is more than eight times that of the lowlands. On the other hand, lowlands house low population densities due to various socio-economic and health problems. They are also beset with problems of poorly developed infrastructure and communications and highly variable and uncertain rainfall patterns. Exceptions are pockets along the main rivers such as the Awash, Omo and Shebelle, which are suitable for irrigation development (Hogg, 1997) and extensive livestock herding.

Pastoralists are living scattered throughout the country. In fact, the majority of Ethiopian pastoralists are made up of Somali, Borana and Afar pastoralists living in the Southeast, South and Northeast rangelands, respectively. There are smaller groups of pastoralists and agro-pastoralists such as Hamar, Arbore, and Dassanetch who are living in the extreme south-western part of the country. Other groups such as Nuer, who are semi-pastoralists, have stretched along the Baro River in the West and the Karayu live near the Awash National Park at the center of the country.

In Ethiopia, there has never been any national livestock census to date and estimates are fluctuating from time to time. Livestock herds and flocks are generally estimated at 42 million cattle, 15 million sheep, 14 million goats, 448 thousand camels, 2 million horses, 4 million asses, 4 million mules and 43 million poultry (CACC, 2003). If correct, this represents by far the largest concentration of domestic herds in any one African country. Of the total, it is estimated that the pastoral nomadic sector keeps 40 percent of the cattle, 75 percent of the goats, 25 percent of the sheep, 20 percent of the equines and 100 percent of the camels (CACC, 2003).

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

In view of the multitudes of uses of livestock in enhancing national food security strategies and its remarkable share of rural agricultural GDP, focused researches on suitability of the current rangelands are vital to disentangle and understand the intricacies of rangeland management, water and livestock production in pastoral areas of Ethiopia. The Borana people have accumulated huge traditional experiences in pastoralism and are still actively exercising this way of life. Therefore, the current study has used GIS and Remote sensing environments to model suitability of the rangelands of Yabello for livestock production.

1.2. Problem Statement and Justification

Land resource is limited in nature and its use is not only determined by the user but also by land capability to sustain agricultural production. Land capability is governed by the different land attributes such as the types of soil, underlying geology, topography, hydrology, and etc. These attributes limit the extents of land available for various purposes. Hence, in order to get the optimum benefit out of the land, proper utilization of its resources is inevitable. As a result, a land use plan which incorporates different land characteristics has a paramount importance. Geographic Information System (GIS) and Remote Sensing offer a convenient and powerful platform to integrate spatially complex and different land attributes for performing land suitability analyses and allocations.

Land suitability analysis is the evaluation and grouping of specific areas of land in terms of their suitability or capability for a defined use. It involves the application of criteria to the landscape to assess where land is most and least suitable for a particular purpose. The suitability of a given piece of land is its natural ability or the biological productivity of land to support a specific purpose. Analyzing suitability is mainly based on the land qualities such as erosion resistance, water availability, and flood hazard (FAO, 1976). Thus, the common way of determination of land quality from land characteristics is mainly by assessing and grouping the land types in orders and classes according to their value (Atesmachew Bizuwork et al., 2005).

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 and 2006) leading to reduced amount of land for natural grazing and forage production. 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 systems (GIS) would be indispensable input to improve livestock productivity (Alemayehu Abebe, 2006). Land suitability is the ability of a given type of land to support a defined use. 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.

1.3. Objectives

1.3.1. General Objective

The main objective of this study is to analyze and map suitable land areas for livestock production in Yabello district using GIS and Remote Sensing techniques.

1.3.2. Specific Objectives

- To create a buffer zone from the available water resources (wells) for livestock drinking and then produce water accessibility maps.
- To identify land cover change in the study area for the last 23 years and to what extent and direction the change occur.
- To produce feed availability maps of the study area.
- To provide a Geodatabase on the Yabello rangeland and livestock resource to ensure an efficient and sustainable rangeland production system.
- To produce a dot density map of livestock population which is a basic function of the GIS software where the population count is represented as 1 dot per X number of livestock.

1.4. Research Questions

- What are the major factors and constraints for land suitability for livestock production in Yabello district?
- What are the magnitude and the rate of land cover change that have occurred in the study area between 1986 and 2003?
- How much percent of the total study area fell under the accessibility class which is permanently not accessible to the major wells/*eelaas* of the district?
- How much area of the district is currently not suitable for cattle and sheep production? Why?

2. Literature Review

2.1 An Overview of Rangeland Development in Ethiopia

Rangeland has been defined as a land where the potential natural vegetation is predominantly grasses, grass-like plants, forbs, or shrubs (Lillesand et al., 2004). Rangelands provide forage for domestic and wild animals. They also represent areas potentially supporting land uses as varied as intensive agriculture, recreation, and housing.

The Ethiopian lowlands, where extensive rangelands are available, occur below 1500m elevation (Coppock, 1994). The lowland, pastoral areas of Ethiopia account for approximately 60% of the total landmass but between 12-15% of the national population (USAID, SC/USA and SOS Sahel Ethiopia, 2007). Climate in the lowlands includes arid (64%), semi-arid (21%) and sub-humid (15%) zones largely defined by four rainfall and temperature regimes. Coppock (1994) stressed the variation among these zones in terms of the number of plant growing days per year, forage production, common plant associations, livestock and human carrying capacities and incidence of livestock disease.

Ethiopia has about 74 million people and over 124 million head of livestock (CSA, 2007; CACC/EASE, 2003). The lowlands are home to 12% of the human population (or about 9 million people) and 26% of the livestock (or 32 million livestock head). Land use by lowlanders is dominated by various forms of pastoralism and agro-pastoralism. Livestock depend upon rangelands consisting of native vegetation and the values of crop residues as livestock feed has increased over time owing to annual rainfall decreases.

The highlands of Ethiopia, which occur well above 1500m elevation, have a higher abundance of livestock than the lowlands. However, the lowlands play a crucial role in the national livestock economy (Coppock, 1994; Halderman, 2004 and Hesse and MacGregor, 2006). Livestock production is an important component of the national economy. It is to be noted that livestock production comprised 33% of the gross value of annual agricultural output and 15% of the gross domestic product in the mid-1980s (Coppock, 1993). Besides supporting rural and urban lowland livelihoods through providing livestock products (e.g., milk and meat), employment and investment opportunities (Alemayehu Mengistu, 2006), lowland breeds of cattle and sheep made up over 80 % of legal exports of live animals (Coppock, 1993).

Some development projects had targeted development of lowland livestock production systems in the 1950s. However, large-scale development efforts did not occur regularly until after1965 (Coppock, 1994). These projects were generally intended to foster greater integration among lowland and highland production systems. The Third Livestock Development Project (TLDP) has been the dominant force in the development of the pastoral livestock sector since 1975. The TLDP has improved local and regional infrastructure (roads, markets, water) and support services such as veterinary and facilitation of inter-regional trade. Coppock (1994) reported that the TLDP has made distinguished contributions, particularly in terms of infrastructure. As one of the three sub-projects of TLDP, the Southern Rangelands Development Unit (SORDU) has been most successful in implementing programs in the Borana pastoral system.

Later development initiatives have included the pilot project of SORDU. These are the Fourth Livestock Development Project (FLDP) which was initiated in 1988 and the Southeast Rangelands Project (SERP) in the Ogaden which was formed in 1990. These projects were designed to incorporate participatory approaches to enhance pastoral development in addition to provision of infrastructure and support services.

2.2. Impact of Bush Encroachment on the rangelands

Bush encroachment is defined as "the invasion and/or thickening of aggressive undesired woody species resulting in an imbalance of the grass: bush ratio, a decrease in biodiversity, and a decrease in carrying capacity," causing severe economic losses for Borana people (Melesse Maryo, 2003). An increase in woody plant abundance is normally accompanied by decreases in herbaceous production and undesirable shifts in production (Archer & Bassham, 1988; cited in Solomon Tefera et al., 2007). This in turn, poses a threat to livestock management. The phenomennon of bush encroachment in this area is viewed as the process of desertification, climate change and altered traditional rangeland management systems (Sileshi Nemomissa,2006; Melesse Maryo2003). The main woody plants species causing the encroachment problems are, among others, *Acacia drepanolobium* (whistling thorn), *Acacia mellifera, Acacia seyal* and *Tarchonathus camphoratus*.

The causes of bush encroachment have been illustrated in the framework of models such as Walter's Two-layer model and The State-and-Transition model. The former maintains the notion of the cascade of events, i.e., overutilization of the grass layer leads to infiltration of water and nutrients to subsoil and hence reduces competitive ability of grasses. This process, instead, favours colonization of grassland areas (or rangelands) by woody plant species. The second model recognizes the dynamic nature of Rangeland ecosystems, i.e., they are event-driven where climate variability (mainly rainfall) is more important for native vegetation growth and composition (feed availability) than intensity of grazing. Therefore, bush encroachment is not a permanent phenomenon and can be reversed through robust rangeland management or environmental conditions.

Ecological changes and rapid increases in woody population densities in many rangelands of the world have made it increasingly difficult for pastoralists to plan effective resource management and utilization strategies (Ayana Angassa, 2005). Ecological changes are manifested by a progressive growth of bush encroachment, which leads to herbaceous vegetation loss in dry savannas and is a driving force for a decline in range conditions (Smith, 1988; Scholes and Walker, 1993; cited in Ayana Angassa, 2005).

In the rangelands of Borana, bush encroachment is considered a threat to the pastoral economy. Gemedo Dalle et al (2006) reported that encroachment of woody plants has been among the major threats to the livelihoods of the Borana pastoralists and their ecosystem. Earlier evidences from the 1980s indicated that 40% (estimated at 90,000 km^2) of the Borana rangelands were affected by bush encroachment (Coppock, 1994), while Gemedo Dalle (2004) estimated a 52% increase in bush cover following the official ban of traditional rangeland management systems such as fire.

Borana pastoralists in Southern Ethiopia have a well established traditional system of range and water management (Gemedo Dalle et al., 2006). They use their indigenous knowledge to categorize landscapes not only in terms of seasons of use, but also in terms of grazing capacity (Oba & Kotile, 2001). However, less application of the indigenous range and water management strategies of Borana pastoralists might have contributed to woody plants encroachment (Gemedo Dalle et al., 2006).

Increase in encroachment of woody plant and herbaceous biomass production are negatively correlated (Scholes & Archer, 1997; Oba & Kotile, 2001). Scholes & Archer (1997); Oba et al. (2000) further pointed out that there is a strong, negative correlation between tree density or cover and grass cover and biomass. Encroachment of woody plants jeopardizes grassland biodiversity and threatens the sustainability of pastoral subsistence and commercial livestock grazing (Richter et al., 2001 and Archer, 2003; cited in Gamado Dalle et al., 2006). Hence, bush encroachment has an adverse influence on grass biomass production and decrease potential grazing capacity.

This concurs with the findings of Gemedo Dalle et al. (2006) which reported that herbaceous biomass in the Borana lowlands was negatively correlated with woody plants density and cover. It follows that the decrease in herbaceous biomass production directly affects livestock production. Noteworthy is that the livelihoods of Borana pastoralists are directly linked to livestock production.

2.3. Remote Sensing Applications for Rangeland Change Detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multitemporal data sets. One of the major applications of remotely sensed data obtained from Earth-orbiting satellites is change detection because of repetitive coverage at short intervals and consistent image quality. Change detection is useful in such diverse applications as land use change analysis, seasonal changes in pasture production, assessment of deforestation, study of changes in vegetation phenology and other environmental changes.

Remote sensing techniques have assisted mapping and monitoring rangeland change (Warren and Hutchinson, 1984; Smith et al., 1990; Franklin and Turner, 1992; cited in Yool et al., 1997). Changes observed in remotely sensed data can complement ecological assessments of restorable rangelands. Both restoration and long-term management efforts require location and monitoring of the spatial patterns of change. Besides, regional maps of rangeland vegetation change provide range managers with information for setting long term grazing practices.

Management of grasslands subject to replacement by woody species requires an understanding of the scale and pattern of change and how to detect and express them. In this regard, repeated satellite images play a major role in setting up inventories of grassland resources because they give a visual assessment of land cover changes over a period of time. In addition, they provide quantitative information on the trade-offs between different land cover categories. Furthermore, empirical evidence of land cover changes delivered by repeated satellite images can greatly contribute to planning more appropriate management of available resources, especially in developing countries (Kebrom & Hedlund, 2000) where other kinds of background data are often lacking.

2.3.1. The SPOT vegetation satellite and feed availability

The SPOT vegetation satellite is designed primarily for vegetation monitoring. The vegetation sensor uses linear-array technology to provide a very wide angle image swath 2,250 km wide with a spatial resolution at nadir (i.e. the point of the celestial sphere that is directly opposite the zenith and vertically downward from the observer) of approximately 1Km and global coverage on a daily basis. It makes use of four spectral bands, namely, the blue, red, near infra red (NIR) and mid infra red (MIR). Applications of the vegetation satellite data set range from regional forecasting of crop yield to monitoring forest cover and observing long term environmental change (Lillesand et al., 2004).

The NDVI is an index that provides standardized methods of comparing vegetation greenness between satellite images. It is computed from the equation:

$$\text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}}$$

Where NDVI is Normalized Difference Vegetation Index

NIR is the reflectance value of the SPOT image at Near Infra Red wavelength (0.79- 0.89µm)

R is the reflectance value of the image at Red wavelength of the electromagnetic spectrum (0.61-0.68µm)

The index generally yield high values for Vegetated areas because of their relatively high NIR reflectance and low visible (R) reflectance. In contrast clouds, water and snow have larger visible reflectance than NIR reflectance. Thus, these features yield negative index values.

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

Land Suitability Analysis (LSA), conceptualized as Multiple Criteria Decision Making (MCDM) problem, implies the assignment of values to alternatives that are evaluated along multiple decisions or criteria (Pereira et al., 1993). In this regard, for LSA in a raster environment, each grid cell in the database is taken as an alternative to be evaluated for its quality or appropriateness for specific purposes. Therefore, land suitability is a biological productivity of an area for a given set of uses.

Livestock production suitability analysis involves integration of information from various streams of science. There are many criteria that are detrimental to land suitability analyses for livestock production. The suitability analysis evaluates many alternative 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 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 for suitable outcomes (FAO, 1985).

Land capability (also considered as land suitability) is primarily the potential biological productivity of land (FAO, 1985). Productivity of land can be determined by environmental components such as climate, local topography (roughens, steepness, 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 weight value ranging from 5 (unsuitable) to 1 (most suitable) are given. The weighted value of each factors were reclassified for each land use. Each parameter is given a value based on its suitability for each land use type. The weighted value of each land characteristic 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.

Table 1: Suitability Classes (FAO, 1993).

Order	Class	Description
Suitable(S)	S1 (Highly Suitable)	Land without significant limitations. Include the best 20-30% of suitable land as S1. This land is not perfect but is the best that can be hoped for
	S2 (Moderately Suitable)	Land that is clearly suitable but which has limitations that either reduce productivity or increase the inputs needed to sustain productivity compared with those needed on 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 currently acceptable cost
	N2 (Permanently not Suitable)	Land with limitations to sustained use that cannot be overcome

2.5. GIS based land suitability Analysis

GIS is a computer based system that offers a convenient & powerful platform for performing suitability evaluation. Site suitability assessment is inherently a multi-criteria problem. That is, land suitability analysis is an evaluation/decision problem involving several factors. Spatial Multi-Criteria Decision Making (MCDM) which refers to the application of Multi-Criteria Analysis (MCA) deal with these spatial decision problems. Chakhar and Mousseau (2008) defined spatial decision problem as those problems in which the decision implies the selection among several potential alternatives that are associated with some specific locations in space. Spatial decision problems typically involve a large set of feasible alternatives and multiple, conflicting and incommensurate evaluation criteria (Malczewski, 2006). The alternatives are often evaluated by a number of individuals (decision-makers, managers, stakeholders, interest groups) which 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 (Malczewski, 2006).

GIS and MCDA can benefit from each other (Laaribi et al., 1996; Malczewski, 1999; Thill, 1999 and 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 problem solving environment. On the other hand, MCDA provides a rich collection of techniques and procedures for structuring decision problems, and designing, evaluating, and prioritizing alternative decisions (Malczewski, 2006).

Above all, an important advantage in using GIS to perform a spatial MCDM study is the ease with which one can develop valuation criteria based on neighborhood analysis operations (Malczewski, 1996; Pereira et al., 1993). The integration of multi-criteria methods of suitability assessments in to a GIS system offers both the spatial capabilities of GIS and the analytical power of formal MCDM tools. Furthermore, integrating Multi-Criteria Evaluation (MCE) with GIS for spatial decision-making purposes is a mainstay application of GIS technology (Carver, 1991). This will in turn create the opportunity for the increased use of GIS based technology as the basis of decision support system.

It is important to note, however, that GIS and MCE techniques are merely tools which provide a means to an end. Without knowledge and expertise of the operator and decision-maker, and without appropriate data, such tools will be useless (Carver, 1991). Nevertheless, GIS-MCE applications appear to represent potentially fruitful areas for further research and development.

2.6. Tragedy of the Commons

According to the tragedy of the commons theory, "every pastoralist has access to the grazing lands, while nobody takes care of it. It was believed that pastoralists would like to maximize their livestock numbers at the expense of communally owned grazing lands, thereby causing environmental impact on the rangelands". Hence, the theory of the "tragedy of the commons" describes the ill effects associated with private ownership of livestock on communal grazing land (Hardin, 1968; cited in Ayana Angassa, 2007). The essence of this theory is that common property will suffer loss and degradation as a result of abuse and overexploitation of resources by individual livestock owners. The individual usually tends to maximize his livestock. As a result, the more the livestock holders benefit from maintaining a great number of herds, the more the communal land will be overstocked and overgrazed.

Pastoralists in Eastern Africa and elsewhere in the world have always lived in resource poor and inhospitable environments. They have managed to exist on marginal lands down through the centuries with their unique survival abilities and potentials (Ayalew Gebre, 2001). Therefore, through a process of self adaption to harsh conditions, pastoral communities continue to utilize in their own way, whatever fringes of resource base they find available.

Contrary to the above theory, the ethos (philosophy) of common property resource management and communal ownership is deep rooted among the Borana Oromo. Land, the ultimate provider and source of livelihoods, is the property of the whole society, and is collectively owned, defended and managed. The depth of the concept of common property is discernible from everyday language. Words such as "we" and "our" feature predominantly in Borana conversations, expressing the philosophy of collective resource ownership.

According to Boku's findings (2000), Borana pastoral land tenure provides further corroboration of the weakness of the so-called 'tragedy of the commons'. However, today pasture management is under increasing pressure from competing land use systems, ambiguity in land tenure, ecological change (due to changes in management systems), increasing sedentarisation, and shrinking area of pasture due to regional border changes.

3. Description of the study area

3.1. Location

The study area, Yabello district, is located in Borana Zone of Oromia Regional State encompassing a total area of 5556.7 square kilometers (Fig.1). It is located between latitude $4^0 30'55.81''$ and $5^0 24'36.39''$N and longitude $37^0 44'14.70''$ and $38^0 36'05.35''$E. Yabello town, the capital of the District, is located at about 570Km South of Addis Ababa on the Addis Ababa-Moyale highway. The study area shares boundary with four Districts of Borana Zone, i.e. Dugda Dawa in the North, Arero in the East, Dire in the South and Taltale in West.

3.2. Topography and drainage systems

Physiographically, the study area is characterized mainly by lowlands and hills. Altitudinally, it lies between 1350 and 1800 m.a.s.l. Obida highland and El-waya lowland are the major features in the district. There are no known rivers and streams in the district, except traditional wells and ponds. Unfortunately, there is no perennial river that crosses the boundary of the study area (Bassi, 1997).

3.3. Climate

The area has an arid to semi-arid climate with bimodal rains of spring and autumn seasons. The main rainy season (59% of the annual precipitation) is expected between March and May and the short growth season during October and November. The two intervening dry seasons are June to August and December to February when forage resources become scarce (Coppock, 1993).

The data obtained from National Meteorological Services Agency (NMSA), which was recorded at Yabello, Surupha and Dhedhertu stations, indicates the mean annual temperature of 18.9^{o}c, 20.03^{o}c, and 20.14^{o}c respectively. The mean annual rainfall at the above stations is 605mm, 711mm, and 684mm respectively. During the period 1980-2004 the mean annual rain fall for the nearest stations was 478mm year^{-1}. Besides, the area is characterized by droughts, occurring every five to ten years (Coppock, 1994).

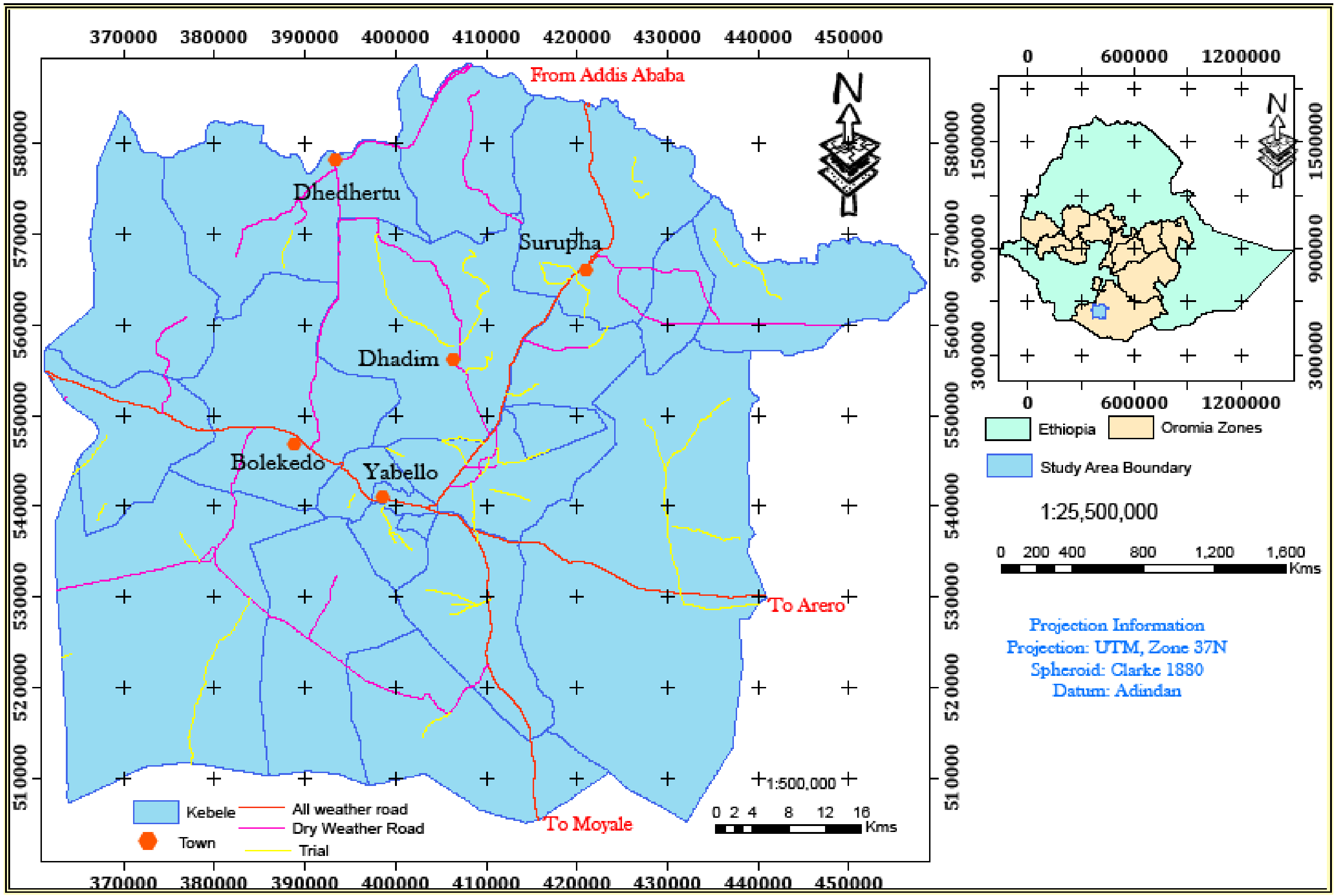

Fig. 1. Location Map of the Study area.

3.4. Traditional land use and herd movement

Traditionally, the land use system of the study area was based on extensive livestock production (Coppock, 1994) and the mobility between the *warraa*- and *foraa*-herds management systems. The *foraa*-herds include dry cows, bulls, immature males, oxen and heifers; while the *warraa*-herds consist of lactating cows and calves (Coppock, 1994; Hogg, 1997; Bassi, 1997).

The grazing lands are allocated between the wet and dry season grazing (fig.2). The wet season grazing is exploited using the rain water, while during the dry season the mobile and milk herds returned to the rangelands of the wells (Oba & Kotile, 2001). Hence, traditional land use involves seasonal movement of stock across landscapes between the dry and wet seasons. This reflects the long-term history of land use by the mobile *(loon foraa*) and the home herds (*loon warraa*). During the dry season, the dry and highly mobile animals were sent to the *foraa*, while lactating cows were moved back to the home herds and vice versa (Gemedo-Dalle, et al., 2006). For instance, Prior to 1970s, the open grasslands of Dida-Hara were grazed during the wet season with the mobile *foraa* herds and rested during the dry season when surface water was exhausted (Ayana Angassa & Oba, 2007) (fig. 2).

The Dida-Hara population settled in semi-permanent settlements (*olla teeso*) following the development of semi-permanent water ponds in the 1980s that changed traditional patterns of land use (Ayana Angassa & Oba, 2007). The period coincided with the official banning of the use of fire to control bush encroachment and increased heavy grazing pressure around settlements (Fig. 2). These changes in land use created a scarcity of forage near settlements. The response of the community in individual settlements was to enclose large areas (150–200 ha) (Ayana Angassa & Oba, 2007) that were protected from livestock grazing during the wet season (WS) and grazed during the dry season (DS) (Fig. 2c).

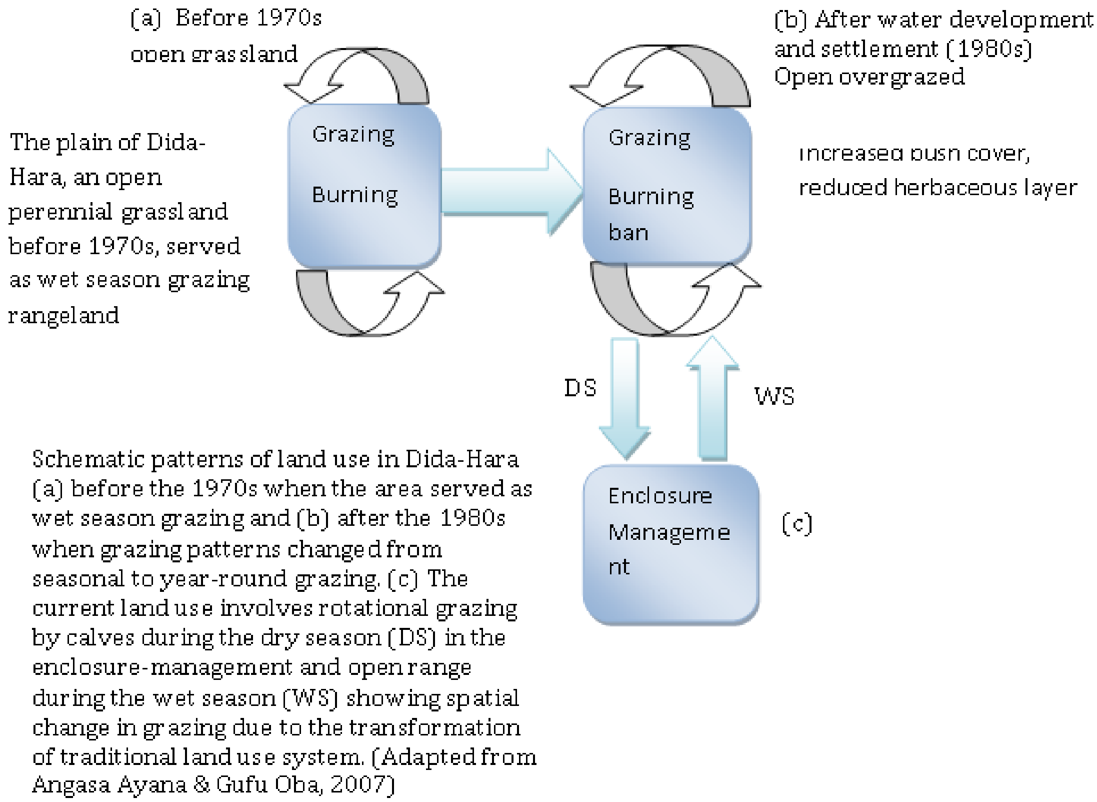

Fig. 2. Schematic patterns of land use in Dida-Hara (a) before the 1970s, (b) after the 1980s and (c) the current land use.

Cossins and Upton (1987) characterized the Borana rangelands of Southern Ethiopia as one of the most sustainable systems of traditional pastoral lands in East Africa. In this regard, Hogg (1990); related the past success to the traditional system of range management, where the decision-making process on resource management at local levels rests with the *Ardaa* (small neighborhood units) or *madda* (water sources). Furthermore, access to rich and diverse rangelands comprising of sub-humid, semi-arid and arid ecosystems also accounted for past successes (Coppock, 1994).

3.5. Soil

The major soil types in the study area are Chromic Cambisols, Chromic Luvisols, Eutric Cambisols, Eutric Fluvisols, Lithosols and Pellic Vertisols. Bottomlands of the study area are dominated by vertisols (Coppock,1994). Further, the survey conducted by Gemedo Dalle (2004), in general, indicated that Dida Hara soils of Yabello district were lighter, containing the highest proportion of sand. According to FAO soil classification, chromic cambisols and chromic luvisols are the two dominant soil types collectively covering 61.9 per cent of the district's total area. The remaining soil types altogether account for 38.1 per cent of the total area of Yabello District. The figure bellow (fig.3) illustrates the major soil types of the study area.

3.6. Livestock husbandry

Pastoralism is the dominant economic activity in the area. Borana family unit, known as a *warra*, is inconceivable without the herd of animals (Helland, 1997). Furthermore, the data obtained from Borana Zone Agriculture Bureau elucidate that the majority of the pastoral associations (PAs) are pure pastoralists. For pastoralists of the study area cattle are the most important livestock species. Owing to this cattle outnumber other livestock species. Ancillary livestock include small ruminants, camels, equines and poultry. General aspects of livestock husbandry of the area are similar to elsewhere in semi-arid Africa (Coppock, 1994). One unusual feature, however, is a high degree of water restriction for livestock during the dry seasons such that animals may be watered only once every three to four days after long distance travel of up to two or more days in some cases (personal communication with pastoralist elders).

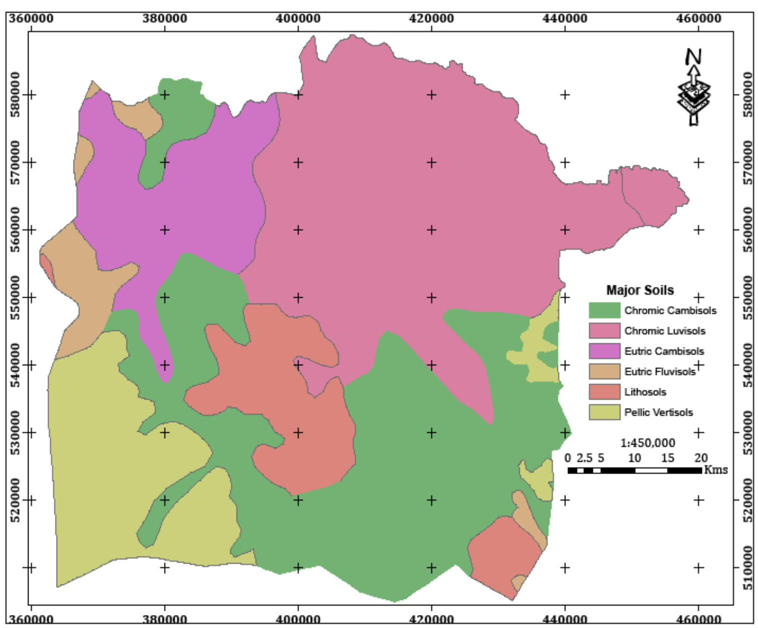

Fig. 3. Major Soil Types of the Study Area

4. Materials and methods

4.1. Materials

The following softwares were used in this study. These are ArcGIS 9.2, ERDAS IMAGINE 9.1, ENVI 4.3, IDRISI Andes 15.0, Global Mapper, 3DEM, Microsoft Word and Microsoft Excel (Table 2). In addition, topographic maps of scale 1:50000, time series satellite imageries and diverse ancillary data have been used in order to identify historical and recent land use/ land cover of the study area.

Table 2: Details of materials and softwares used in the current study

S/N	Type	Description	Source
1	Maps	Topographic Maps (1:50000)	EMA
		Digital soil map	FAO
		District and Kebele Shapefiles	CSA
2	Softwares	ArcGIS 9.2, ERDAS 9.1, ENVI 4.3, IDRIS Andes 15.0, Global Mapper, 3DEM, MS Excel, MS Word	AAU,GIS Lab.
3	Instruments	GPS (GARMIN), Digital Camera	

4.2. Methodology

4.2.1. Data Collection

The success of any GIS application depends on the quality of the geographic data used (Lo and Yeung, 2002). Collecting high-quality geographic data for input to GIS, therefore, marks a critical stage. Data collection is one of the most time-consuming and expensive, yet important for GIS-based studies. GIS can contain a wide variety of geographic data types originating from many diverse sources (Longley et al., 2005). For the present study, both primary and secondary raster and vector data were used. Indeed, time series satellite imageries and diverse ancillary data have been collated in order to identify historical and recent land use /land cover.

4.2.1.1. Topographical Maps

Topographic maps of the scale 1:50000 of the study area were purchased from the Ethiopian Mapping Agency (EMA). These maps were originally prepared from an aerial photo series acquired from 1986 and1987. Thus they are to some extent comparable to the January 1986TM data sets obtained from the ILRI. In addition to historical land use and land cover information obtained from the local community, these maps proved to give an important insight into the historical situation in terms of land cover in better details than the historical imagery.

4.2.1.2. Satellite imagery

The most popular form of primary raster data source is remotely sensed imagery (Lo and Yeung, 2002). Hence, to make the multitemporal analysis for the study area, two mosaic images from the satellite landsat (path-row: 168-56 and 168-57) of 1986 and 2003 were used. All were acquired in the month of January during the dry season, the first image (1986) with the Thematic Mapper sensor (TM) and the latter (2003) with the Enhanced Thematic Mapper Plus sensor (ETM+).

- Landsat TM and ETM+

Mosaic of Landsat TM imagery, path-row 168-56 and 168-57, taken in January 1986 by TM sensor aboard Landsat 5 was used as the oldest available dataset for the study area. On the other hand, the imagery taken in January 2003 for path-row 168-56 and 168-57 by ETM+ sensor assumes a recent data in the absence of up-to-date cloud free and useable imagery. The Landsat TM imagery was obtained from ILRI whereas the ETM+ image data was acquired from online archive of the USGS GLOVIS.

The TM and ETM+ sensors are advanced, multispectral scanning devices designed to achieve higher image resolution, sharper spectral separation, improved geometric fidelity and greater radiometric accuracy and resolution than the MSS sensor (Lillesand et al., 2004). Landsat-7, which carries onboard the Enhanced Thematic Mapper Plus (ETM+) instrument, was launched on April 15, 1999 as part of the global research program of NASA's Earth Science Enterprise. The sensor has six spectral bands in the visible, near-infrared, and shortwave infrared regions of the electromagnetic spectrum (at 28.5m spatial resolution), two thermal infrared band (60m and 120m spatial resolution products), and one panchromatic band (at 15m spatial resolution).

The SPOT NDVI

The SPOT NDVI data set was acquired from International Livestock Research Institute (ILRI). From this dataset the availability of feed during both dry and wet months were derived. The images were taken for two months of each year, i.e., January (dry season) and April (wet season). The total span of the images is 9 years. Before the analyses of the images, their Geographic Coordinate System (GCS) was transformed. Following transformation of GCS every ten days NDVI dataset of the selected months for the whole Ethiopia was subset to Yabello District boundary area of interest (AOI). Furthermore, the NDVI value was rescaled to the range between -1.0 and +1.0 and the mean of each month NDVI image was executed using ERDAS IMAGINE model maker. Finally, NDVI map for months of January and April for nine years (2000-2008) was prepared in ArcGIS platform to generate tri-monthly mean NDVI maps of wet and dry seasons of the study area from 2000-2008. Further elaboration of the above procedure is given in the flowchart below (Fig. 4).

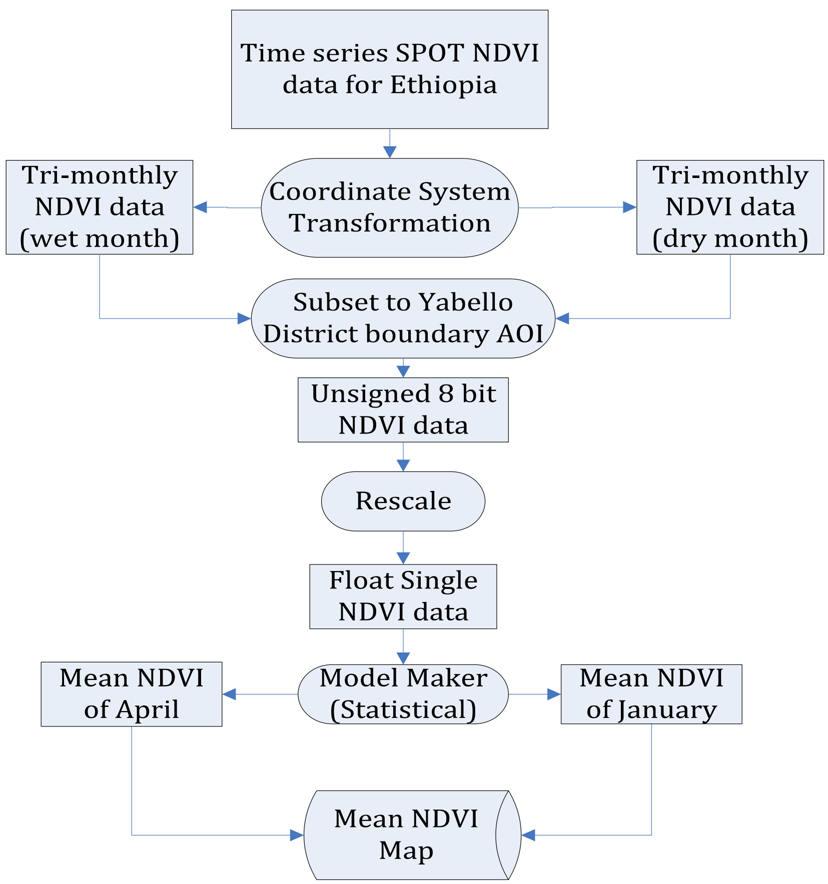

Fig. 4. Flowchart for the derivation of mean NDVI map.

- Digital Elevation Models (DEM)

DEM data was acquired by the Shuttle Radar Topography Mission (SRTM) aboard the Space Shuttle Endeavour, launched in February 2000. Most of the SRTM data has some missing data points where no data was recorded by the mission due to some problems. These anomalies must have been overcome by correcting/patching the missing data using 3DEM software. Afterwards, slope data and subsequent derivations like elevation and aspect were calculated from the Digital Elevation Model (DEM).

Table 3: Summary of satellite images used in the study

Image Types	Path/Row	Acquisition Date	Spatial Resolution (m)
Landsat TM	168/56 & 168/57	January,1986	28.50x28.50
Landsat ETM+	168/56 &168/57	January, 2003	28.50x28.50
SPOT NDVI		January& April, 2000-2008	1000
SRTM Data		February, 2000	90

4.2.1.3. Field surveying

Field surveying is one of the most important constituent of primary data. To this end, field investigations either to collect training data for digital classification or for ground verification is part and parcel of applied remote sensing. It is obvious that accurate ground or reference data must be collected in order to adequately assess the accuracy of the remotely sensed classification. In this study, the first step was stratification of the study area according to a presumed land cover classes to avoid biased data collections.

Accordingly, the study area was stratified in to seven major land use/ land cover (LU/LC) classes after reviewing different literatures on the study area (Coppock, 1993 and 1994; Ayana Angassa and Baars, 2000; Oba et al., 2000; Oba and Kotile, 2001; Ayana Angassa, 2005; Gemedo Dalle, 2006; Ayana Angassa and Oba, 2007, Solomon Tefera et al., 2007), discussion with Yabello district agricultural experts and field observations.

These LU/LC classes, which are taken as the first step to get the result, are grassland, bushland, woodland, farmland, forest, bareland and built up areas.

Digital signature of each land cover class is a function of its spectral property. In remote sensing studies of land resources, a representative ground data is a prerequisite to associate the reflectance property to the object (Bedru Sherefa, 2006). 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. Consequently, representative ground data of the above classes were collected using GARMIN GPS II Plus. While collecting GPS data for the presumed LU/LC classes, information on the status of each land cover before 6 and 23 years were asked and recorded to assist digital image classification. To this end, local community elders have been involved in this process. Furthermore, a methodology flowchart is given in Fig. 5.

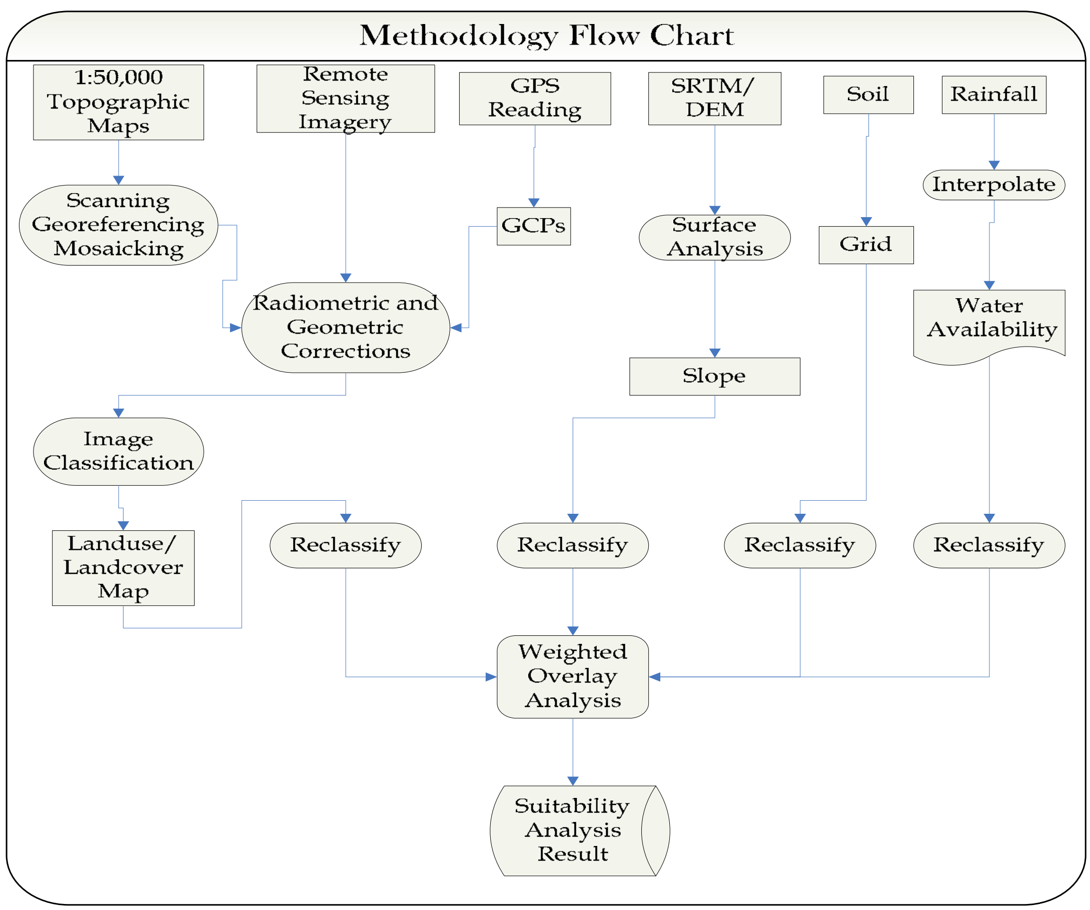

Fig. 5. Methodology flowchart.

5. Spatial data processing and analysis

5.1. Satellite image processing

5.1.1. Image pre-processing

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

- Radiometric correction

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 data acquisition. Furthermore, it may be desirable to convert and/or calibrate the data to known (absolute) radiation or reflectance units in order to facilitate comparison between data.

- Geometric correction

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

The geometric registration process involves identifying the image coordinates (i.e. row, Column) of several clearly discernible points called ground control points (or GCPs), in the distorted image and matching them to their true positions in ground Coordinates (e.g. latitude, longitude). The true ground coordinates are typically measured from a map, either in paper or digital format. This is image-to-map registration. Once several well-distributed GCP pairs have been identified, the coordinate information is processed by the computer to determine the proper transformation equations to apply to the original (row and column) image coordinates to map them into their new ground coordinates.

The Landsat images obtained for this study had already been orthorectified by the image supplier. However, the model used for orthorectification is too broad (global) to be in the state of usable precision. Therefore, they must be rectified (georeferenced) by associating the center of the pixel to a point on the earth surface in one of the map projection systems in order to use these images for mapping or other purposes. Orthorectified images are difficult but not impossible to georeference them again, since the pixel position has already been moved formerly.

From the 1:50,000 scale topographic map and using GPS, sufficient number of GCPs were collected. Consequently, the exact position of these points was located on the image and geocoding (georeferencing) was performed using polynomial geometric model. Indeed, to remove the geometric distortions in ETM+ imagery, ETM+ image of the study area was geocoded (georeferenced) to a UTM coordinate system with a pixel size of 28.5 meters using a first order transformation and nearest neighborhood resampling. A root-mean- square error of approximately 1.5 pixels was achieved for the fit between ETM+ image of the study area and the 1:50,000 scale topographic maps using 15 ground control points (GCPs) gathered from the topographic maps and collected from field using GARMIN GPS II Plus during the field survey. The other image (TM) was then coregistered to the ETM+ image using 20 image to image control points. All RMS errors were less than 0.5 pixels for the fit between images. The environment of ERDAS 9.1 system was used for this task.

5.1.2. Image classification

Image classification serves a specific goal, i.e., converting image data in to thematic data. The resulting classified image is comprised of a mosaic of pixels, each of which belong to a particular theme, and is essentially a thematic map of the original image. In the application context, one is reasonably interested in thematic characteristics of an area rather than in the reflection values. 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* multispectral bands result in a single band raster file. As far as classification of images is concerned, there are two common classification types (Lillesand et al., 2004). Accordingly, the current study used both of the classification types, i.e., the unsupervised classification before field visit and the supervised classification after field survey.

- Unsupervised classification

Unsupervised classification algorithms compare pixel spectral signatures to the signatures of computer-determined clusters and assign each pixel to 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 et al., 2004). Classified land cover maps then require knowledge of the area in order to label each cluster with its equivalent in real world. Accordingly, unsupervised classification of land cover of the study area was performed prior to field visit.

- 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 priori 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 the field visit (cf. appendix 2.2). These points were used to sample representative signatures for the various land cover types identified during the field visit. Following this, supervised land use/land cover classification has been carried out using ENVI 4.3 software from time series satellite images.

5.1.3. Assessment of classification accuracy

Land cover maps derived from remote sensing imagery always contain some sort of errors due to several factors which range from classification technique to method of satellite data capture. Therefore, owing to the complexity of digital classification, the reliability of the results need robust and thorough 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 the accuracy of each category is evidently described.

Most assessments were conducted using the same data set as was used to train the classifier. These training and testing on the same data set result in overestimates of classification accuracy (Congalton, 1991). The present study, however, used a total of 1098 randomly selected pixels for the 2003 land use/land cover map, which were checked with reference data (ground data) in the field to assess the accuracy of the classification.

The current study revealed an overall accuracy of 80.8% and a Kappa index of agreement of 0.7707 (Table 4). The Kappa coefficient of 0.7707 implies that the classification process is avoiding 77% of the errors that a completely random classification generates. Individual class accuracies ranged from 63.30% to 93.57% for producer's accuracy and 70.44% to 98.85% for user's accuracy. However, user's accuracy for woodland showed a value less than 75%. With regard to producer's accuracy four classes such as bareland, bushland, grassland and woodland were over 80% while three classes (built up area, farmland and forest) exhibited a value below 75%.

It is to be noted that producer's accuracy is calculated as the total number of correct pixels in a category divided by the total number of pixels of that category as derived from the reference data (i.e. the column total). This accuracy measure indicates the probability of a reference pixel being correctly classified. On the other hand, if the total number of correct pixels in a category is divided by the total number of pixels that were classified in that category, it is said to be user's accuracy or reliability.

Table 4 : An error matrix for classification accuracy assessment of the 2003 image.

		Reference data									
		BL	BUA	B	FL	F	GL	WL	RT	OE (%)	UA (%)
Classified data	BL	131	9	0	2	0	16	1	159	6.34	82.39
	BUA	1	71	12	0	0	0	10	94	29.00	75.53
	B	4	13	196	3	2	16	16	250	15.52	78.40
	FL	0	1	0	69	0	0	0	70	36.70	98.57
	F	0	0	0	0	86	0	1	87	28.93	98.85
	GL	4	3	0	35	2	191	0	235	15.11	81.28
	WL	0	3	24	0	31	2	143	203	16.37	70.44
	CT	140	100	232	109	121	225	171	1098		
	CE (%)	17.61	24.47	21.60	1.43	1.15	18.72	29.56			
	PA (%)	93.57	71	84.48	63.30	71.07	84.89	83.63			

Note:

1. Land cover categories: BL= Bare land, BUA= Built up area, B= Bushland, FL= Farmland, F= Forest, GL= Grassland and WL= Woodland .
2. Accuracies: Overall Accuracy=887/1098=80.8%, Kappa Coefficient= 0.7707
   UA= User's Accuracy, PA= Producer's Accuracy
3. Errors: OE= Omission Error, CE=Commission Error
4. Totals: RT= Row total, CT= Column Total
5. The columns of table 4 represent the reference data while the rows indicate the classification generated from the remotely sensed data.
6. = pixels along the major diagonal of the error matrix (correctly classified pixels).

User's accuracy is indicative of the probability that a pixel classified on the map/image actually represents that category on the ground (Congalton, 1991). For instance, comparing user's and producer's accuracies for grassland category reveals that, although the producer of the classification/map can claim that 84.8% of the time an area that was grassland was identified as such, a user of this map will find that only 81.2% of the time will an area he visits that the map says is grassland will actually be grassland.

5.2. Land suitability analysis

As discussed in chapter two (suitability analysis and multi-criteria decision making section), GIS is an important aid for spatial decision making (Carver, 1991; Pereira and Duckesstien, 1993). Developments in GIS have led to significant improvements in its capability for decision making processes in land allocation and environmental management (Jiang and Eastman, 2000). Multi-Criteria Evaluation (MCE) is one of the most important procedures for GIS-based decision making processes (Jankowski, 1995; Malczewski, 2000). Hence, in order to locate optimally suitable geographic areas for a specific land-Use, criteria development is crucial.

5.2.1. Factors of suitability for livestock production

Suitability Modeling/analysis is a methodology or a set of analytical procedures that simulate real world conditions within a GIS using their spatial relationships of geographic features to locate optimally suitable geographic areas for a specific land use. In order to locate optimally suitable geographic areas for a specific land-Use, criteria development is crucial. Criteria are of two types, i.e., constraints and factors. Constraints are Boolean criteria that constrain (i.e., limit) the analysis to a particular geographic regions. In contrast, factors are criteria that define some degree of suitability for all geographic regions (Eastman, 2006).

The current study illustrates the use of multi-criteria evaluation (MCE) methods in the context of land use suitability analysis for identifying the suitable areas for livestock production. It focuses on the application of the GIS-WOA method. To this end, the set of evaluation criteria for the current objective was identified from field survey, literature review and consulting decision makers. They include topography/slope, land cover types, moisture availability/rainfall, and soil type. Each criterion map displays land suitability measured on an ordinal scale, that is, parcels of land were assigned values of high, medium or low suitability depending on land attributes. On the contrary, the study constrains or restricts built up areas and forest areas from the analysis. These two land cover classes were classed as restricted during the analysis to sustain the natural environment. By doing so, deforestation of forest cover will be prevented. Alienating livestock production area from settlement areas is also environmentally friendly.

The criteria maps are the input data to the GIS-WOA based decision making procedure. Given these maps, the next step is to combine the maps so that one can identify the suitable sites for livestock production. The combination procedure follows the conventional scheme for GIS-based MCDA (Malckzewiski, 1999). 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 (cf. criteria standardization/ reclassification-section 5.2.3). Second, derivation of the weights of relative criterion importance using the pairwise comparison method (cf. assigning criterion weights-section 5.2.4). The criterion weights are automatically calculated once the pairwise comparison matrix is entered in the IDRISI-AHP weight derivation module. Third, the criterion weights and the standardized criterion maps were combined/ aggregated by means of the WOA operations.

- Rainfall

Availability of feed and water is one of the most important determining factors for land use decision for livestock development. More importantly, water availability for feed growth is one of the single most important factors that determine suitability for livestock production. In other words, feed source is abundant in areas of high rainfall. To this end, the mean monthly average rainfall of 13 stations (4 within the study area and 9 from the adjoining districts) for 20 years was collected from National Meteorological Services Agency (NMSA), Ethiopia. Subsequently, a surface was interpolated from the points data in a GIS platform using Geostatistical Analyst's ordinary kriging technique (Fig. 6).

- Soil

Davidson (1980) defined soil as a natural body consisting of layers or horizons of mineral and /or organic constituents of variable thickness, which differ from the parent material in their morphological, physical, chemical and mineralogical properties and their biological characteristics. Soil is crucial for rating landscape-livestock suitability. The major soil types in the study area include chromic cambisols, chromic luvisols, eutric cambisols, eutric fluvisols, lithosols and pellic vertisols. Cambisols combine soils with at least an incipient subsurface soil formation. Medium and fine-textured materials derived from a wide range of rocks constitute parent material of cambisols.

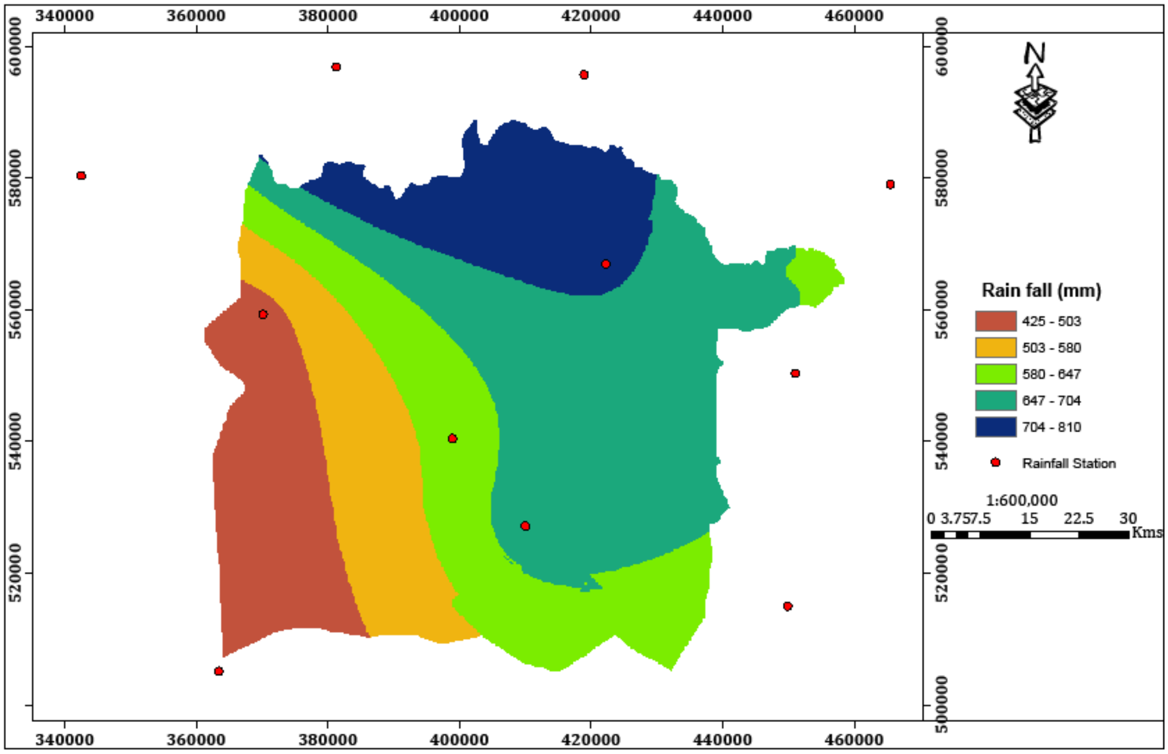

Fig. 6. Twenty Year Average Rainfall of Yabello District.

They are characterized by slight or moderate weathering of parent material and by absence of appreciable quantities of illuviated clay, organic matter, Al and/or Fe compounds (FAO, 2006).

The major soil types in the study area include chromic cambisols, chromic luvisols, eutric cambisols, eutric fluvisols, lithosols and pellic vertisols. Cambisols combine soils with at least an incipient subsurface soil formation. Medium and fine-textured materials derived from a wide range of rocks constitute parent material of cambisols. They are characterized by slight or moderate weathering of parent material and by absence of appreciable quantities of illuviated clay, organic matter, Al and/or Fe compounds (FAO, 2006). Cambisols are particularly well represented in temperate and boreal regions. They also occur in dry regions but are less common in the humid tropics and subtropics where weathering and soil formation proceed at much faster rates than in temperate, boreal and dry regions (FAO, 2006).

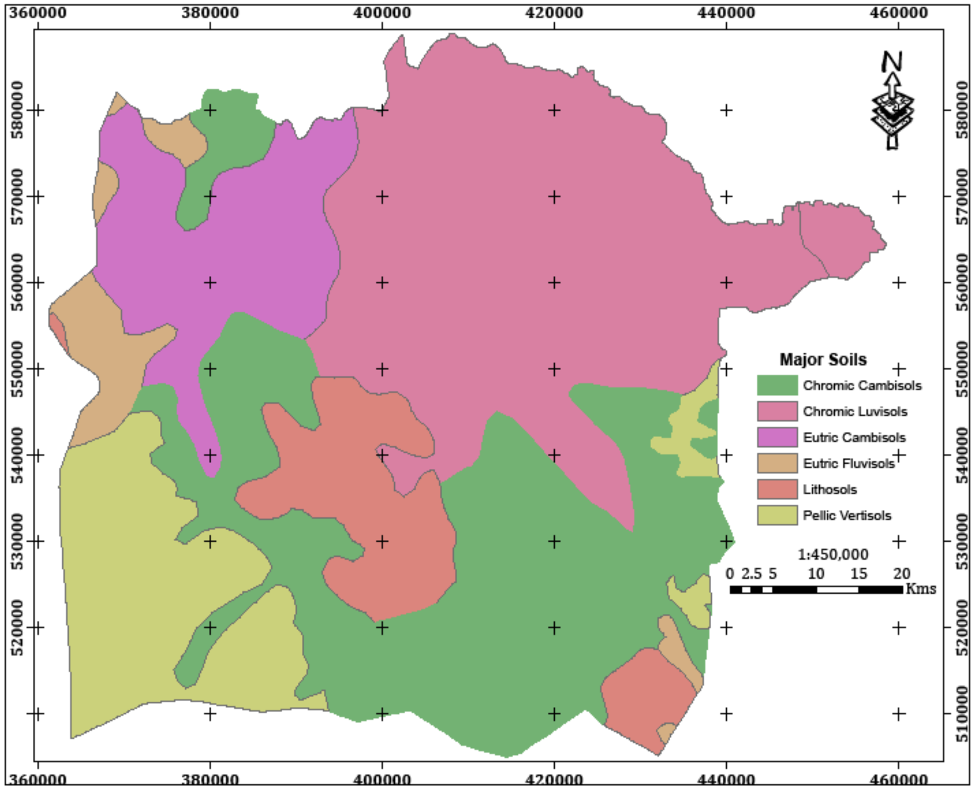

Fig. 7. Major Soil Types of Yabello District

Cambisols generally make good agricultural land and are used intensively. More acid Cambisols, although less fertile, are used for mixed arable farming and as grazing and forest land.

Luvisols are soils that have higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes. They are most common in flat or gently sloping land and the parent material constitute a wide variety of unconsolidated materials including glacial till, and aeolian, alluvial and colluvial deposits. Most Luvisols are fertile soils and suitable for a wide range of agricultural uses. Luvisols with a high silt content are susceptible to structure deterioration where tilled when wet or with heavy machinery (FAO, 2006).

Fluvisols accommodate genetically young, azonal soils in alluvial deposites. They are found typically on level topography that is flooded periodically by surface water or rising ground water. Fluvisols are cultivated for dry land crops and used for grazing in the dry season.

Vertisols are the other major soil type in the area. These are churning, heavy clay soils with a high proportion of swelling clays. These soil types predominate depressions and level to undulating areas, mainly in tropical, subtropical, semi-arid to sub-humid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland.

These soils have considerable agricultural potential, but adapted management is a precondition for sustained production. The agricultural uses of Vertisols range from very extensive grazing trough smallholder post-rainy season crop production to small-scale and large-scale irrigated agriculture. Large areas of Vertisols in the semi-arid tropics are still unused or are used only for extensive grazing, wood chopping, charcoal burning and the like (FAO, 2006).

Slope

Slope has a great influence on livestock production. The flatter the slope, the higher is the suitability of the area for livestock production. On the contrary, slope steepness will reduce the suitability of the area and the amount of forage. Slope of the study area was derived from the digital elevation model (DEM) which in turn was clipped from SRTM of NASSA satellite 90 m resolution of Ethiopia by using a masking layer of the Yabello district boundary (Fig. 8).

Land use/ land cover

Land use/land cover map is useful for resource assessment, land use planning, land evaluation, and land use/ land cover change detection. For the present study, LU/LC is one of the major factors that are considered for livestock suitability analysis. It was developed from the January 2003 satellite image (Fig. 9).

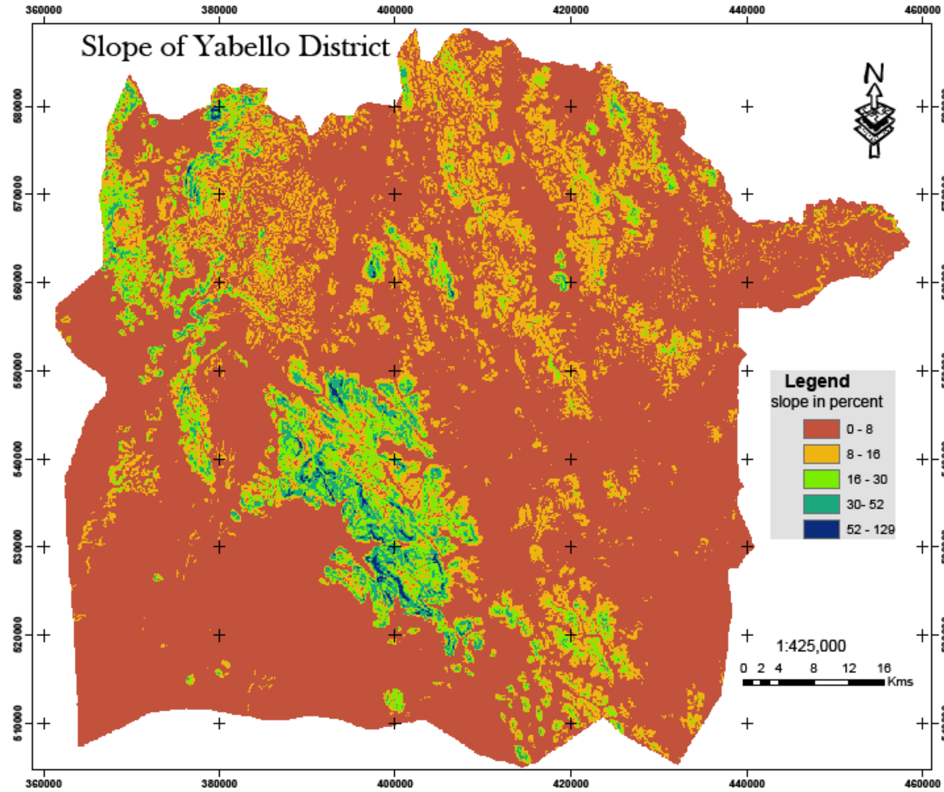

Fig. 8. Slope Map of Yabello District

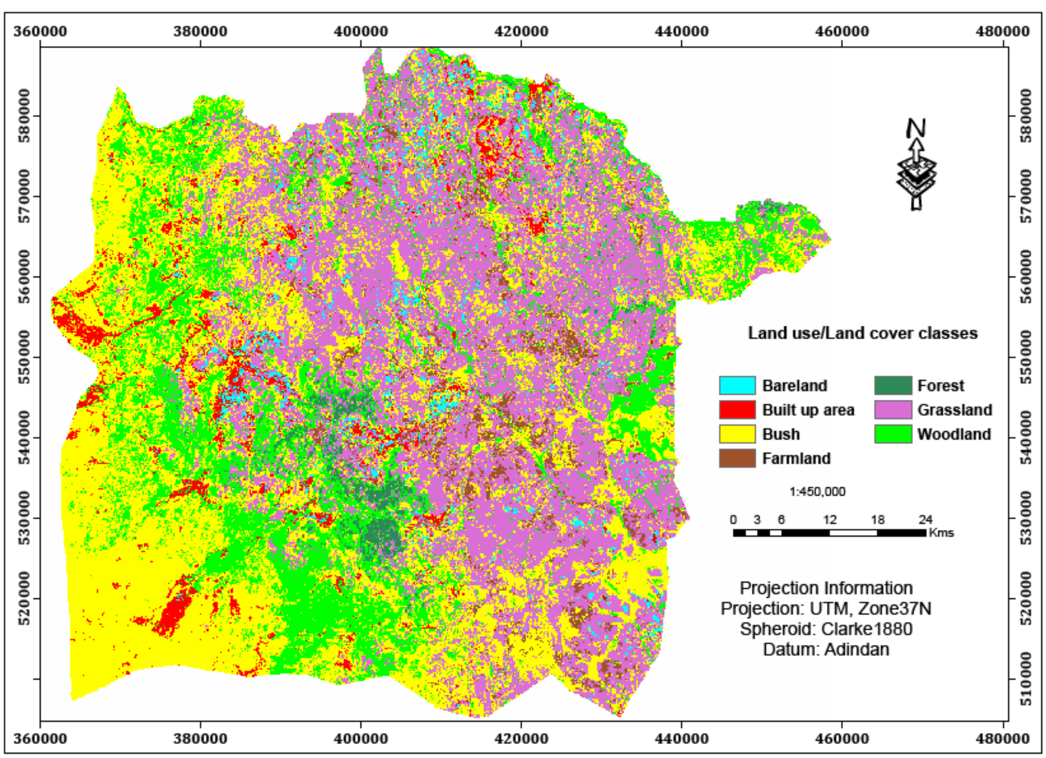

Fig. 9. Land use/ Land cover Map of Yabello District extracted from 2003 satellite image.

5.2.2. Factor/criteria ratings

Livestock production needs suitable land use land cover, slope, sufficient moisture availability, and fertile soil for feed growth. These are the most important requirements common for all livestock. Thus, as a first step, compilations of the livestock production requirements that will be considered in the evaluation were made. In the present study, requirements for land use land cover, slope, rainfall/moisture availability, and soil were assessed for the selected livestock species according to the environment of the study area. Then, the second stage is to decide on the factor ratings for each livestock species. 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 (S1), Moderately suitable (S2), Marginally suitable (S3), Currently not suitable (N1), and Permanently not suitable (N2) (FAO, 1985; 1993).

In establishing the factor rating table (table 5) reference were made to: national manuals, guidelines, research station publications, and relevant literature. In addition, Pastoralist elders and local agriculturalists experience and opinion were considered in arriving at a factor rating of a given land use that can be used in the matching processes.

5.2.3. Criteria reclassification

The livestock suitability analysis evaluation criteria discussed above are typically noncommensurate (i.e. not measured using compatible units). To make them comparable a standardization of each factor is required (Malczewki, 1996). There are a number of approaches that can be used to make the attribute map layers comparable. The present study used the module named Reclass (in ArcGIS environment) for standardization/reclassification of the factors.

- Reclassifying slope

Reclassification involves assigning higher or lower values to more suitable locations, or cell values. In this study, the suitable slope values are those that represent conducive grazing, and travel. Thus, it is reclassified in to five suitability classes in accordance with the FAO (1993) suitability class. Since the range of the new reclassified value is 1-5, the value of 1 takes the most suitable slope values where as 5 takes the least suitable steepness.

Reclassifying soil

The major soil types are converted to raster format and then reclassified based on their suitability rate. In the new reclassified evaluation scale of 1 to 5, 1 represents the highest suitability and 5 the lowest suitability.

Reclassified rainfall

Once again the rainfall surface was reclassified in to common scale with the assumption that the higher the rainfall amount the more suitable the area will be. Like other suitability factors, the rainfall map is reclassified in to five suitability classes ranging from 1 to 5 where 1 indicates the most suitable and 5 the least suitable areas.

Reclassified Land use /Land cover

Finally, the raster data format of land use/land cover was reclassified in to a common scale in order of their suitability. Thus, from the reclassified version, 1 stands for the most suitable whereas 5 for the least suitable.

The forthcoming figure (fig.10) demonstrates the reclassified factors map for cattle as a sample. (Refer appendix 1 for the remaining reclassified factor maps)

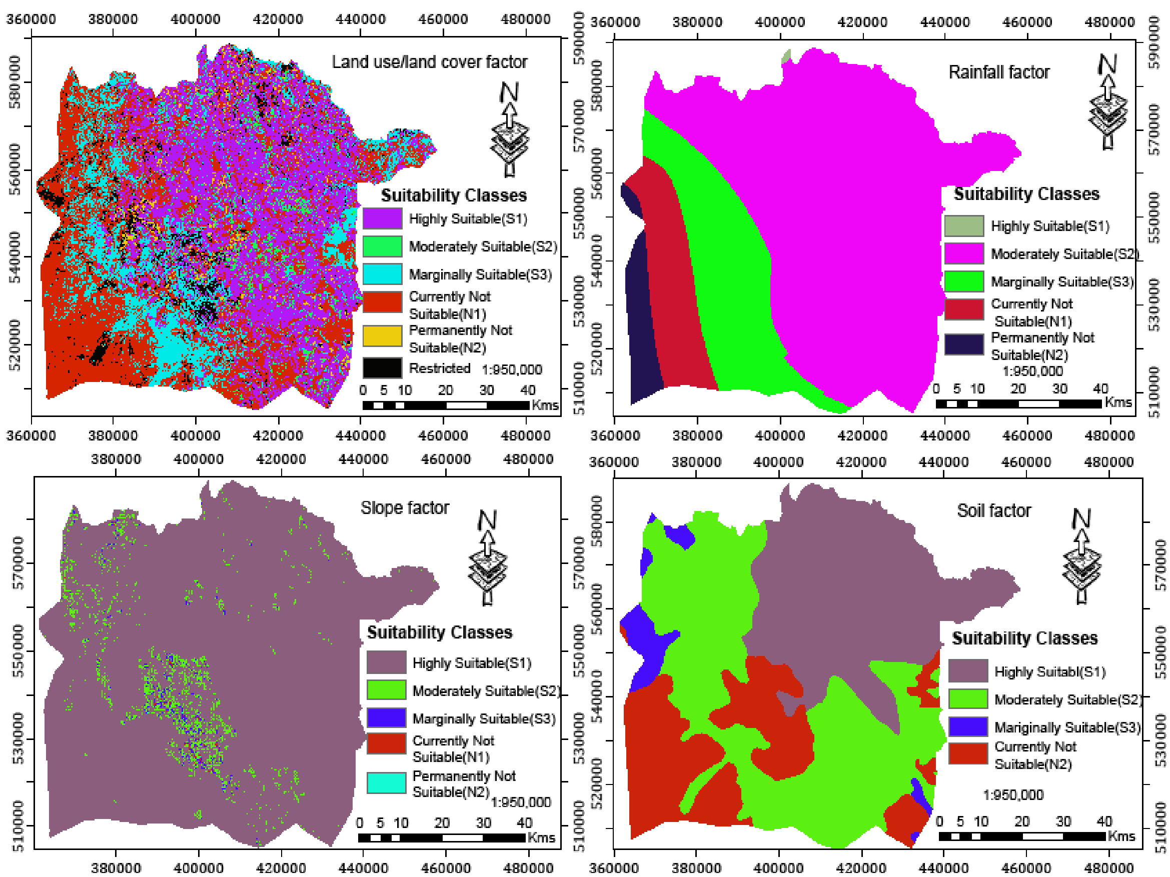

Fig. 10. Reclassified factors map for cattle production.

Table 5: Rating of factors/criteria for livestock production.

Livestock species	Factor/Criterion	Range of suitability				
		Highly Suitable(S1)	Moderately Suitable(S2)	Marginally Suitable(S3)	Currently Not Suitable(N1)	Permanently Not Suitable(N2)
Cattle	Slope (%)	0-16	16-30	30-40	40-50	>50
	Rainfall (mm)	800-1600	600-800	500-600	450-500	<450
	Soil	luvisols	cambisols	fluvisols	vertisols and lithosols	
	Land use/ Land cover	grassland	farmland	woodland	bushland and bareland	
Sheep	Slope (%)	0-16	16-30	30-40	40-50	>50
	Rainfall (mm)	800-1600	600-800	500-600	400-500	<400
	Soil	luvisols	cambisols	fluvisols	vertisols and lithosols	
	Land use/ Land cover	grassland	farmland	woodland	bushland and bareland	
Goats	Slope (%)	0-16	16-35	35-50	50-60	>60
	Rainfall (mm)	800-1600	600-800	500-600	400-500	<400
	Soil	luvisols	cambisols	fluvisols	vertisols and lithosols	
	Land use/ Land cover	bushland	woodland	grassland	farmland and bareland	
Camels	Slope (%)	0-8	8-16	16-30	30-40	>40
	Rainfall (mm)	800-1600	600-800	500-600	300-500	<300
	Soil	luvisols	cambisols	fluvisols	vertisols and lithosols	
	Land use/ Land cover	bushland	woodland	grassland	farmland and bareland	

5.2.4. Assigning criterion weights

Spatial decision problems typically involve criteria of different importance to the decision maker's (Malczewski, 2000). Consequently, information about the relative importance of the criteria is required. The derivation of weights is a central step in provoking/eliciting the decision maker's preferences. In the procedure for MCE, weights can be derived by taking the principal eigenvector of a square reciprocal matrix of pairwise comparisons between the criteria (Malczewski, 2003; Eastman, 2006).

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 a pairwise comparison matrix, factors are compared two at a time in terms of their importance relative to the stated objective. For instance, the rating of land use/land cover relative to slope gradient is 5, where as the rating of slope gradient relative to land use/ land cover will be 1/5(Fig. 11).

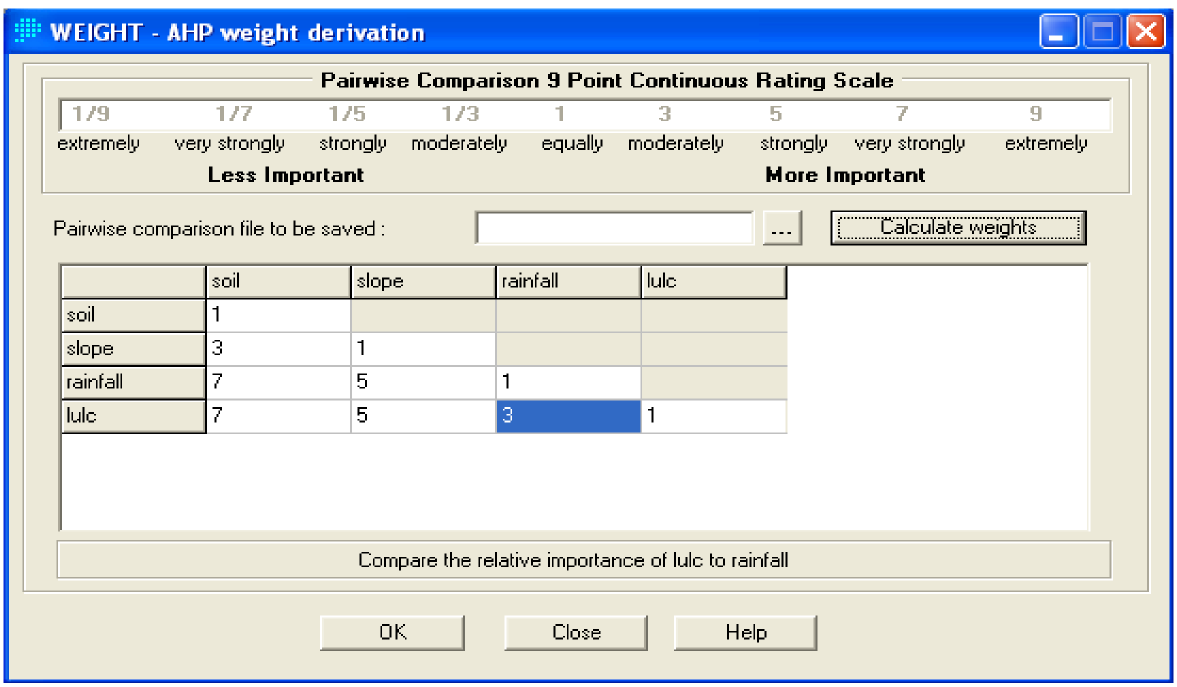

Fig. 11. A pairwise comparison matrix for assessing a comparative importance of the four factors for livestock suitability assessment.

After all possible combinations of two factors are compared, the module calculates a set of weights. In developing the weights, an individual or group compares every possible pairing and enters the ratings into a pairwise comparison matrix (Eastman, 2006). To this end, after debate and careful analysis of the set of evaluation criteria with decision makers, experts and local community, all the pairwise comparisons for the set of the four criteria was made. Finally, the criterion weights are automatically calculated once the pairwise comparison matrix is entered.

Table 6: Weights derived by calculating the principal eigenvector of the pairwise comparison matrix

Factor/Criteria	Weight	Percentage weight
Soil	0.0479	4.79
Slope	0.0975	9.75
Rainfall	0.3109	31.09
Land use /Land use	0.5437	54.37
Total	1.0000	100

5.2.5. Aggregating the criterion weights and the reclassified criterion maps

GIS can be used not only for automatically producing maps, but it is unique in its capacity for integration and spatial analysis of multisource datasets (Malczewski, 2003). These data are manipulated and analyzed to obtain information useful for a particular application such as land-use suitability analysis. In the context of GIS, three decision rules i.e. Boolean overlay, weighted overlay and ordered weighted averaging are common for MCE (Jiang and Eastman, 2000; Malczewski, 2000; Malczewski, 2003). The present study, however, adopts only the weighted overlay technique for deriving composite suitability maps.

6. Results and discussion

6.1. Suitability Analysis Results for livestock Species

The weighted overlay analysis result showed four classes of lands. These are

- highly suitable
- moderate suitability
- marginal suitability and
- currently not suitable for the selected livestock groups (cattle, sheep, goats and camels).

Although areas with a high cover of woody bushes are currently not suitable for cattle and sheep, they are highly suitable for goats and camels since the latter are browsers (Fig. 25). Generally, cattle and sheep prefer bush free areas to graze. In some places of the study area, for example, Haro Wayu PA, bush encroachment is a serious factor deteriming development of livestock production sector of the study area (Fig. 12).

Fig. 12. Different encroachers of tree species: *Acacia mellifera* (Vahl.) Benth. (Sigirso), *Acacia mellifera* (Saphansa), *Commiphora africana* (Hamessa), Cordia gharaf (Madhera) and *Acacia senegal* (Hidhadho)

The areal coverage of each suitability class for each livestock species under the present study was calculated after converting the raster output of the weighted overlay to a polygon feature and dissolving the result in a GIS platform. Table 7 shows these findings. Table 7 also reveals that 31.6%, 31.5%, 18.2% and 26.9% of the study area are classified as most suitable for cattle, sheep, goats and camels production, respectively. In addition, 12.8%, 12.9%, 65.8% and 55.4% were found to be moderately suitable while 39.2%, 38.2%, 10.2% and 11.9% is least suitable land for the same group of livestock. Noteworthy is that 10.6%, 11.6%, 0.2% and 0.2 % of the study area is currently not suitable for the same livestock groups in the same order. The result of the study showed that no part of the study area was recorded to be permanently unsuitable for the production of any of the livestock species considered in this study.

Table 7: Suitability classes versus area for livestock species.

Livestock species	Suitability class	Area (ha)	Percent of total area
Cattle	Highly suitable	176078.18	31.69
	Moderately suitable	71516.47	12.87
	Marginally suitable	218299.00	39.29
	Currently Not suitable	59413.90	10.69
Sheep	Highly suitable	175521.00	31.59
	Moderately suitable	72125.45	12.98
	Marginally suitable	212691.00	38.28
	Currently Not suitable	64970.10	11.69
Goats	Highly suitable	101245.00	18.22
	Moderately suitable	365768.00	65.83
	Marginally suitable	57202.50	10.29
	Currently Not suitable	1092.06	0.20
Camels	Highly suitable	149665.00	26.93
	Moderately suitable	308120.90	55.45
	Marginally suitable	66199.50	11.91
	Currently Not suitable	1322.14	0.24
Restricted Area		30359.10	5.46
Total Area		555666.70	100.00

Details of the suitability analyses were presented from Fig. 13, Fig. 14, Fig. 15 and Fig. 16 for cattle, sheep, goats and camels, respectively.

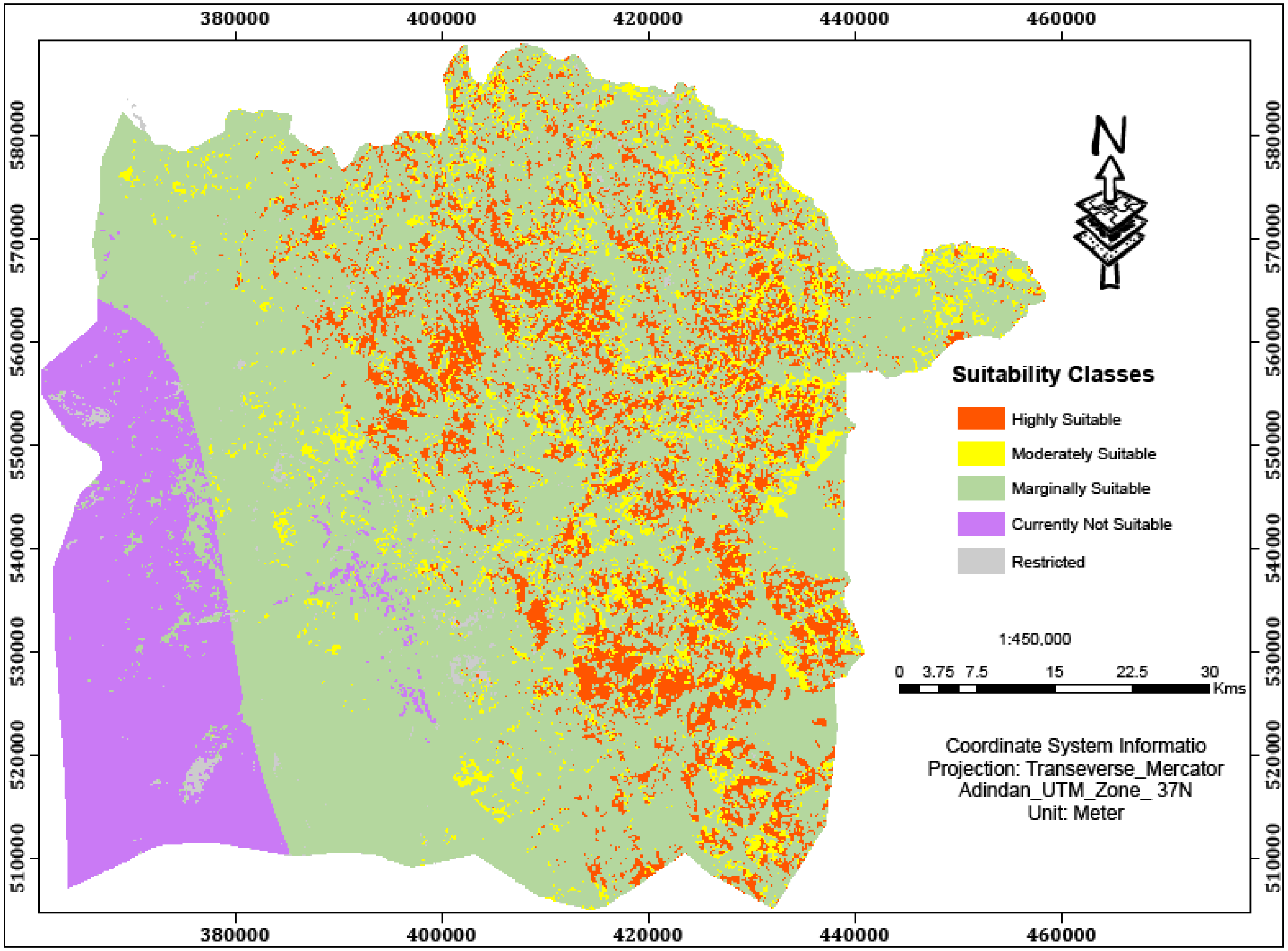

Fig.13. Suitability analysis result along with suitability classes for cattle production.

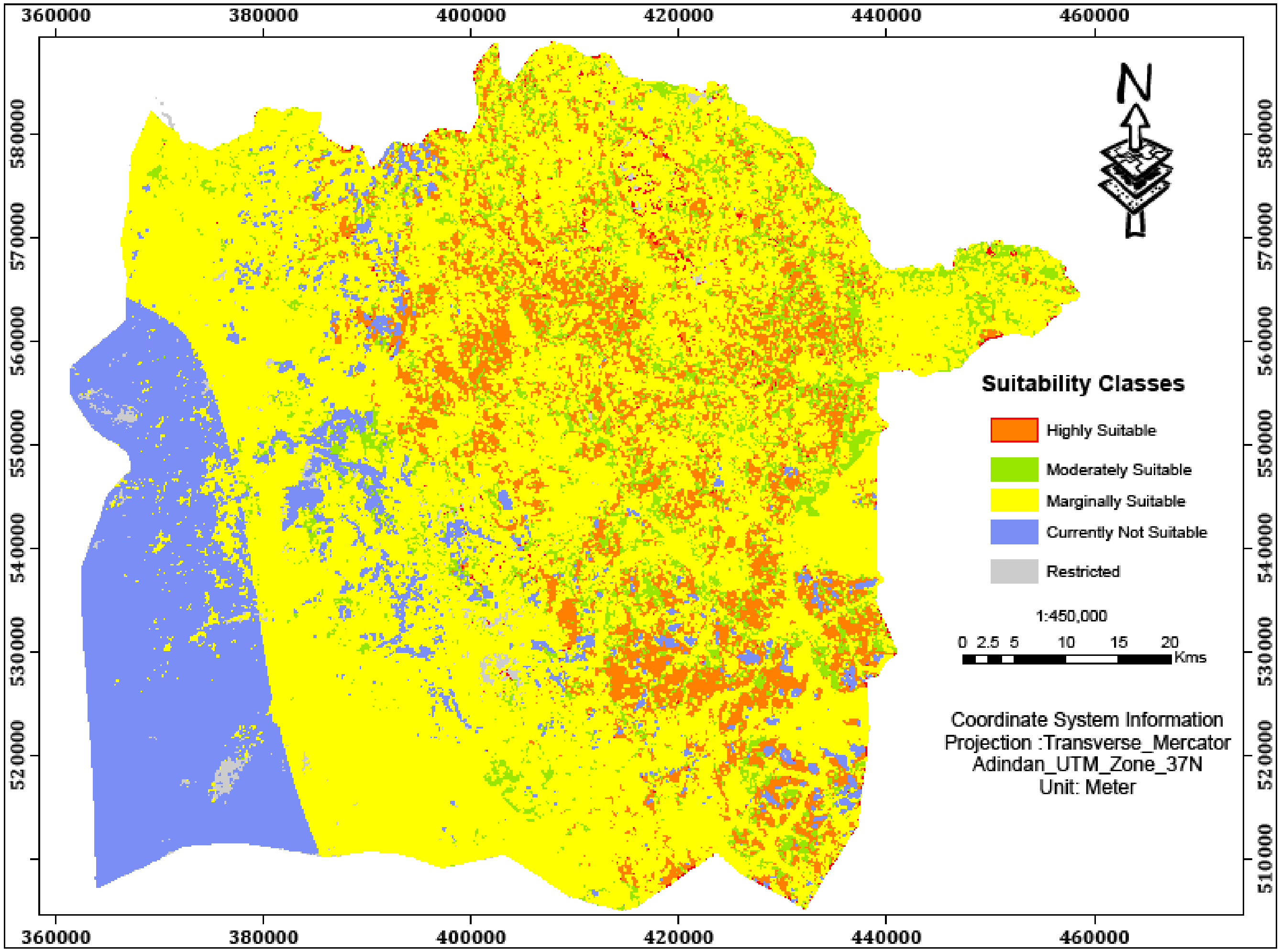

Fig. 14. Suitability analysis result along with suitability classes for sheep production.

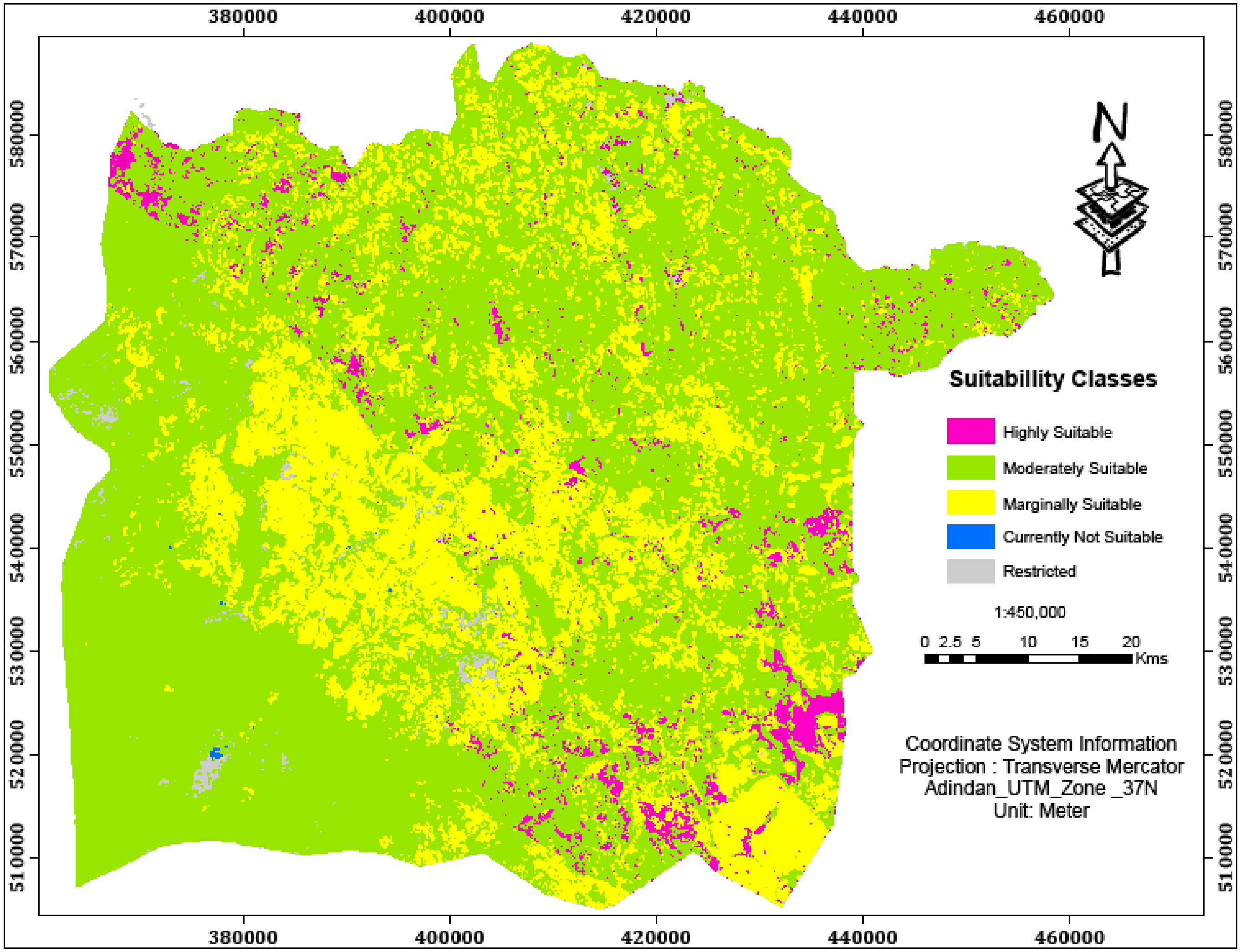

Fig. 15. Suitability analysis result along with suitability classes for goats production.

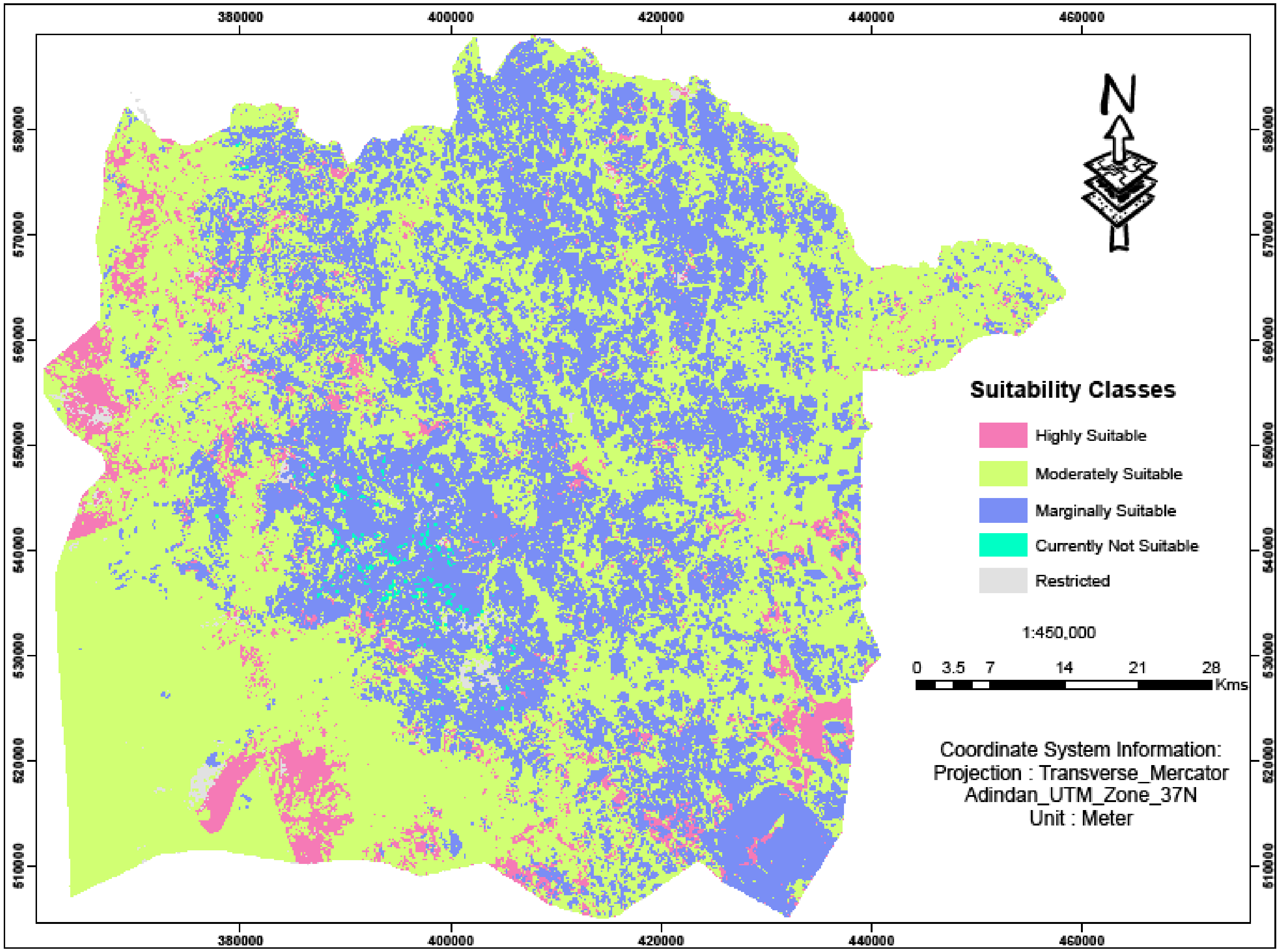

Fig.16. Suitability analysis result along with suitability classes for camels production.

6.2. Water resources (wells) for livestock drinking

The availability of water is a crucial issue for livestock production. Hence, the knowledge of the spatial locations of water sources of the study area is very useful for sustainability and further management of this sector of agricultural production. Point data of the locations of the prominent wells (hereafter called *eelaas)* available in the study area were collected using GPS during the field survey. Seven major *eelaas* were recorded in the study area (Fig. 17). They are Dhariito, Digalticha, Gambuura, Adee Galchat, Areri, Haro Bake, and Chichale Yatu. These *eelaas* are the backbone of livestock production by the pastoralists of the study area during the dry season. It is to be noted that there are no perennial rivers, streams and lakes in the study area.

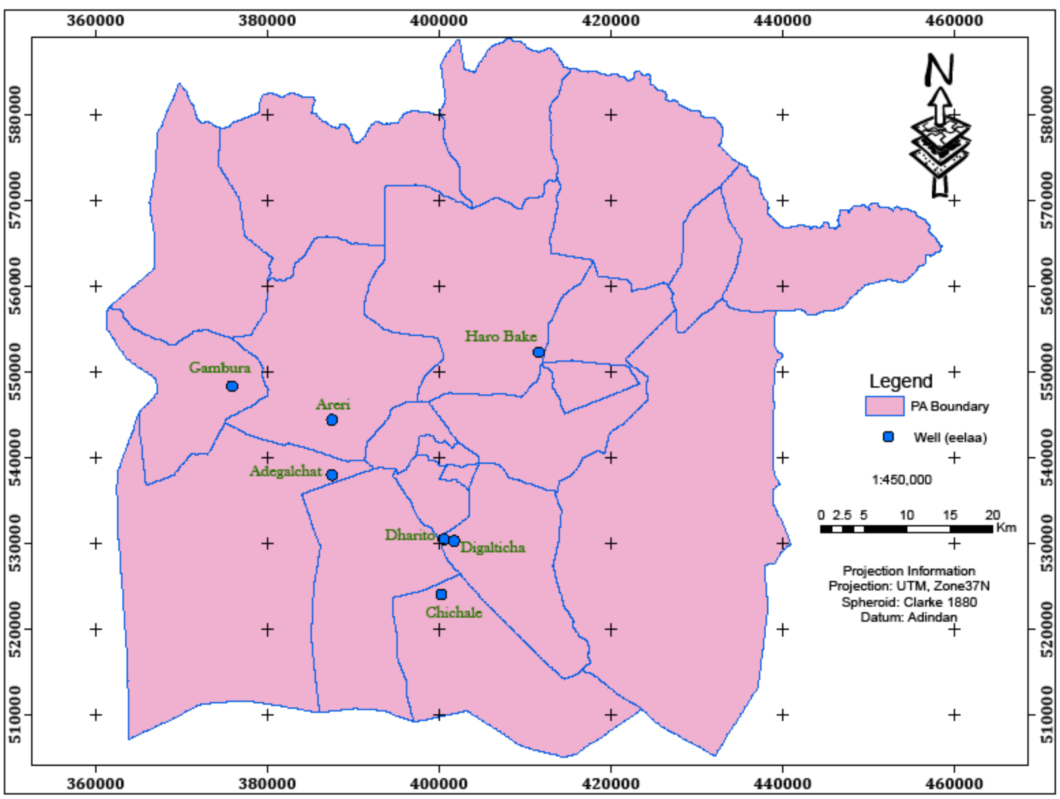

Fig. 17. Spatial distribution of major *eelaas* of the study area

It is evident that the above *eelaas* are insufficient and in most cases inaccessible for most parts of the study area because of topographical situations. To overcome this problem, the pastoralists use these scarce resources in a rotation where the livestock of a particular group drink water once in three days. Noteworthy is that these permanent *eelaas* are used even for pastoralists from the adjacent Districts such as Arero who travel for 30 km to 40 Km to find water for their livestock during the dry season.

Hence, livestock drinking water accessibility mapping is of paramount importance to elucidate the above scenario (Fig. 18). The proximity analyses of *eelaas* have resulted in five accessibility classes (Alemayehu Abebe, 2006).

1. Most accessible: distance ranging up to 0.5 km from *eelaas*
2. moderately accessible: distance up to 1 km from *eelaas*
3. Least accessible: distance in a radius of 5km from the *eelaas*
4. Currently inaccessible: distance within a radius of 8 km from the *eelaas*
5. Permanently inaccessible: distance of 12km from the *eelaas*

The above five accessibility classes were elucidated on the map by performing multiple buffering of proximity tool in a GIS platform. It is important to note that prior to the field survey, a GPS was adjusted to record data in UTM (Universal Transverse Mercator) Cartesian coordinates (Clarke 1880, zone37N) for analysis with other features. As a result, the GPS readings of the *eelaas* recorded during the field survey were not transformed.

It is to be noted that the major available *eelaas* of the study area are unevenly distributed and limited in number for watering livestock of the whole study area especially during the dry season (Fig. 18). Owning to this, only 183778.2 ha (33.1%) of the total study area is covered by a buffer distance of 12km from the seven major *eelaas*. The remaining 371888.4 ha (66.9%) of the district falls in the accessibility class that is considered as permanently inaccessible due to distance limitation.

However, pastoralists of the study area in particular and of the Borana zone in general take their livestock to a watering point even traveling a long distance, i.e., more than the specified distance limitation. Whereas 98887.8 ha (17.8%) of Yabello District is under the category of currently inaccessible class, only small portions, i.e., 549.6 ha (0.1%) 2113.5ha (0.4%) and 44363 ha (8.0%) of the District's total area (about 555,667 ha) are categorized as most, moderately and least accessible classes, respectively.

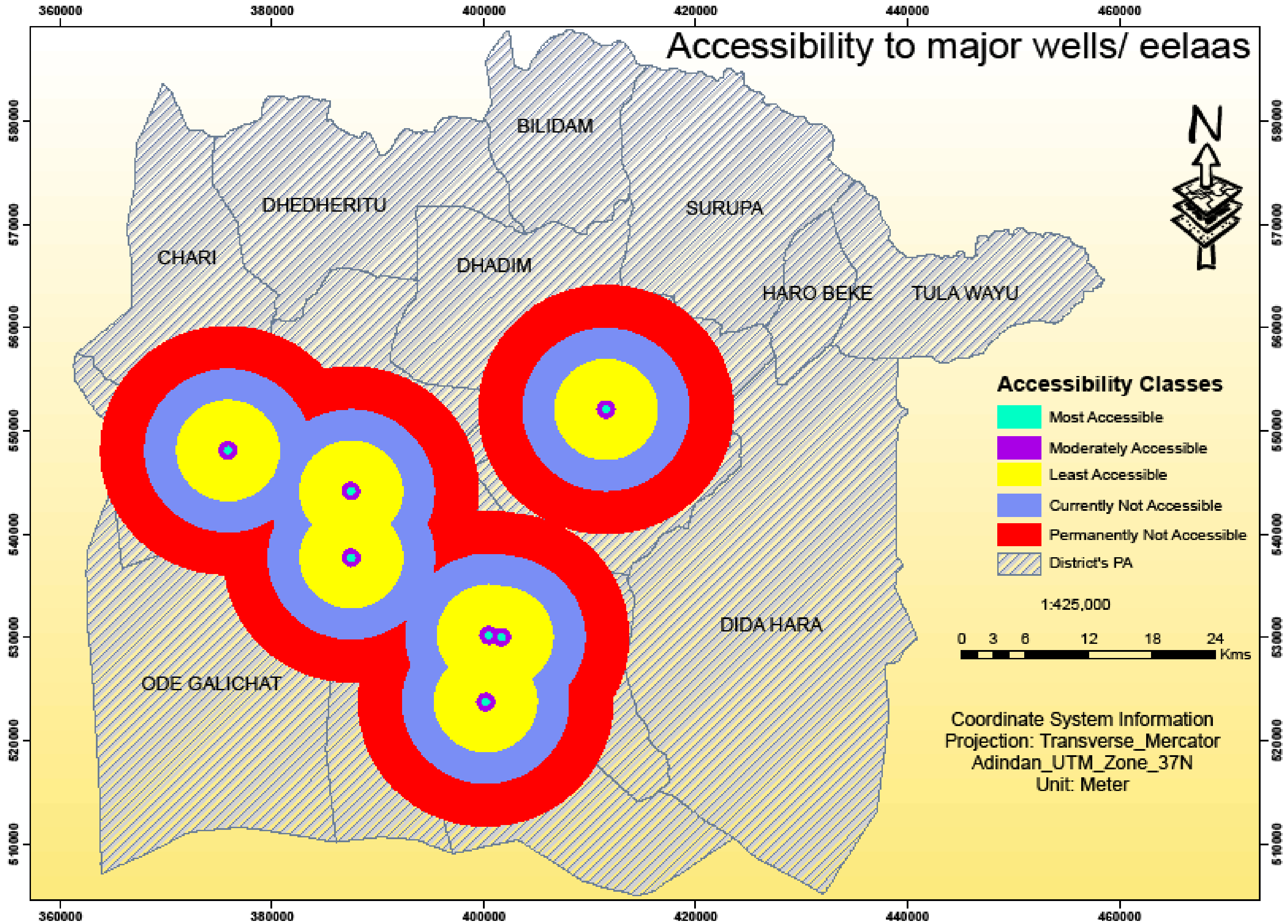

Fig. 18. Accessibility of *eelaas* at 0.5km, 1km, 5km, 8km, and 12km buffer distances.

6.3. Livestock Feed Availability

The availability of feed is one of the crucial factors for livestock production. Data on the availability of feed during both dry and wet months were derived from the Normalized Difference Vegetation Index (NDVI) of time series data of French SPOT Vegetation satellite. The SPOT vegetation satellite is designed primarily for vegetation monitoring.

6.3.1. Wet season feed availability

The current study showed that there is a remarkable variation of the availability of green materials (Fig. 19). For example, low NDVI values predominate the 2000 mean NDVI map of the month of April. This generally reveals the scarcity of vegetated areas which in turn implies lack of adequate feed for livestock grazing even during the wet season.

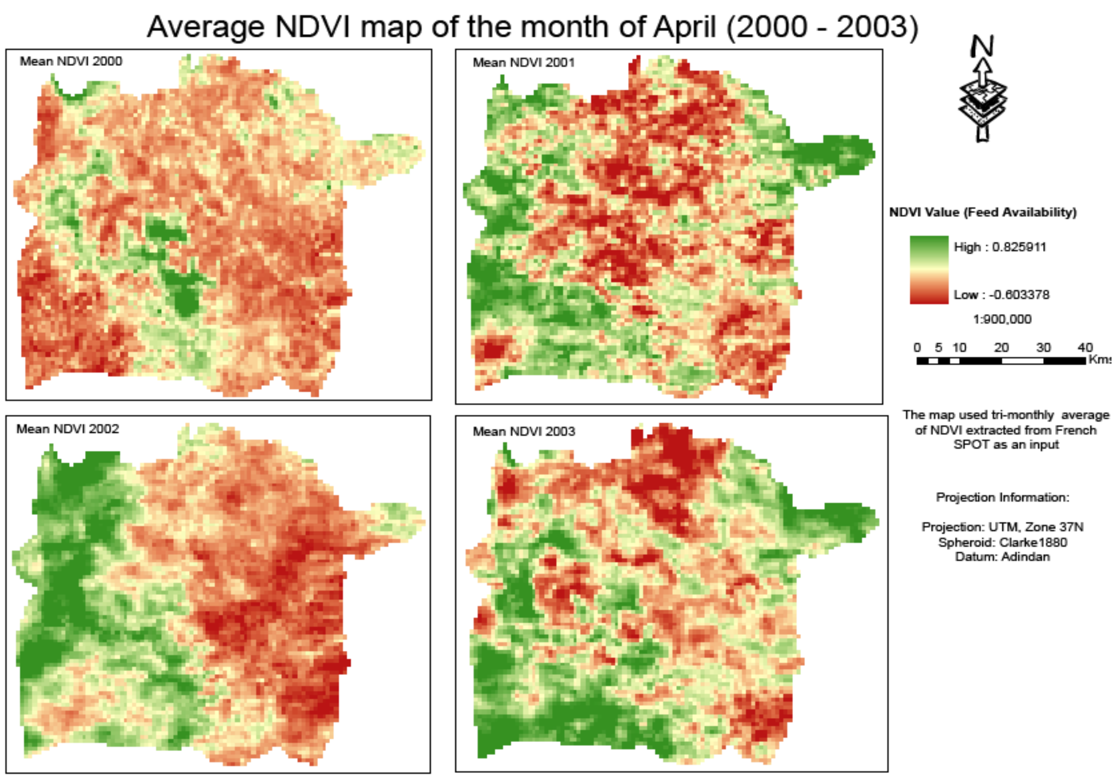

Fig. 19. Mean NDVI map for wet seasons- April 2000-2003 (SPOT Satellite)

Furthermore, Fig. 20 demonstrates another series of mean NDVI map for the wet season (2004-2007). Here, the NDVI values follow similar pattern with those of Fig. 19.

The mean NDVI map for the month of April for all the consecutive years (2000-2007) generally depicts the availability of green material (vegetation cover) which in turn implies adequate feed source. However, this does not mean that all the green materials are palatable by all livestock species of the study area. For example, the following tree species, *Commiphora africana* (Hammeessa), *Acacia drepanolobium* (Fulleessa), *Acacia seyal* (Waaccuu), *Acacia sp* (Bokosa) *Acacia mellifera* (Vahl.) Benth. (Sigirso), *Acacia mellifera* (Saphansa), *Endostemen tereticaulis* (Urgo) and *Acacia Senegal* (Hidhadho) were reported unpalatable by cattle (Solomon Tefera et al., 2007). On the other hand, some tree species such as *Cordia gharaf* (Madheera) and *Acacia brevispica* Harms. (Hammarreessaa) are palatable by selected livestock species (goats and camels). Therefore, it should be noted that the NDVI is a generalized indication of the presence of plant cover but cannot be a direct show for the details of feed availability in terms of their palatability for different livestock species.

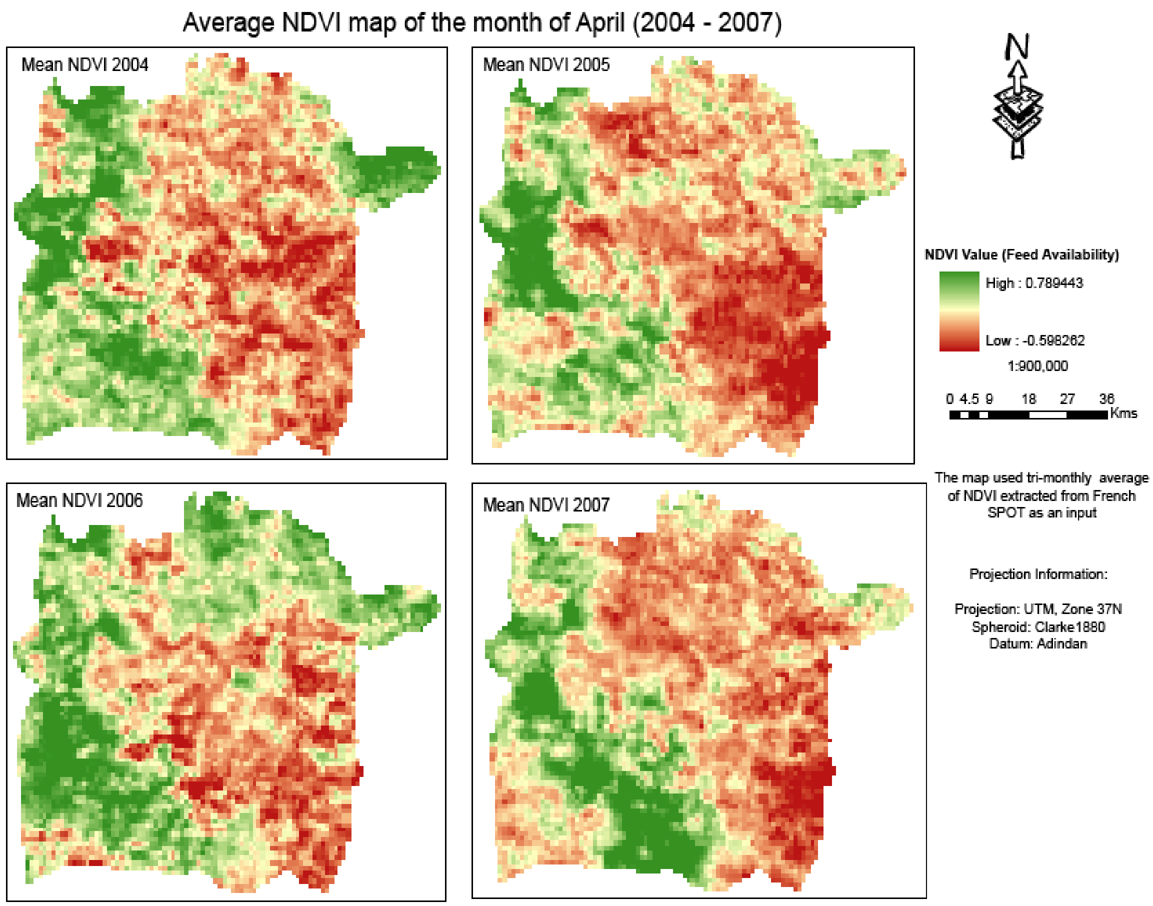

Fig. 20. Mean NDVI map for wet seasons- April 2004-2007 (SPOT Satellite)

6.3.2. Dry season feed availability

Both Fig. 21 and Fig. 22 depict the mean NDVI map of the study area for the dry month (January) from 2000-2007. The scrutiny of each map reveals the general scarcity of vegetated areas which corroborates the observed paucity of livestock feed during the dry season. For example, the mean NDVI map for January of 2002 (Fig. 21) was almost without vegetation cover except the small patch of Dharito forest partly surrounding Yabello town.

The traditional adaptive strategy of the pastoralists of the study area with regard to the paucity of feed especially during dry season is the mobility between warra-and foraa-herds management system (cf. chapter 3 under *traditional land use and herd movement section*). Pastoralists of the study area designate rangeland for wet and dry season grazing.

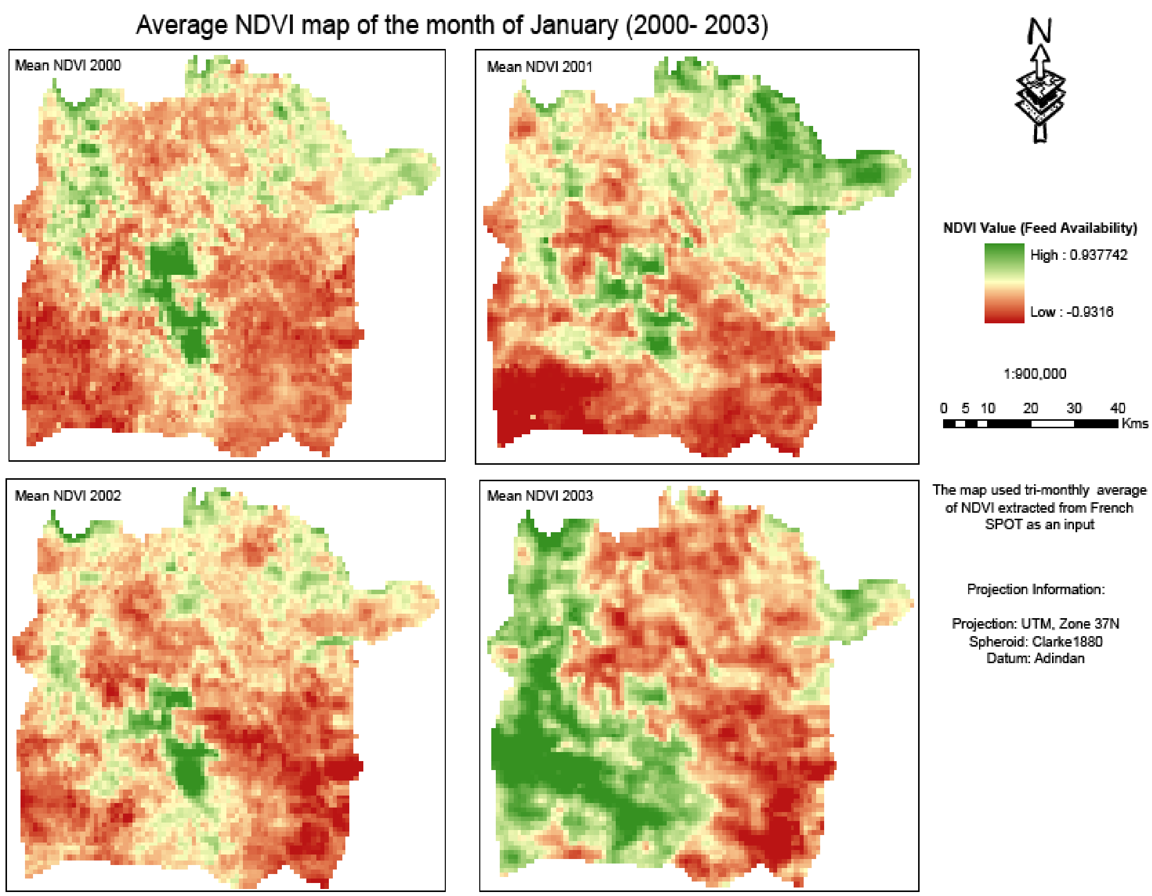

Fig. 21. Mean NDVI map for dry season- January 2000-2003.

During the dry season, the dry and highly mobile animals were sent to the *foraa*, while lactating cows were moved back to the home herds and vice versa (Ayana Angassa & Oba, 2007; Gemedo-Dalle et al., 2006; Oba & Kotile, 2001).

The wet season grazing is exploited using the rain water. But during the dry season, those livestock which produce milk are moved to graze around the permanent *eelaas*. It is to be noted that these pastoralists have developed a long-history of sustainable resource uses and management where the livestock are dived into two, i.e., the mobile *(loon foraa*) and the home herds (*loon warraa*).

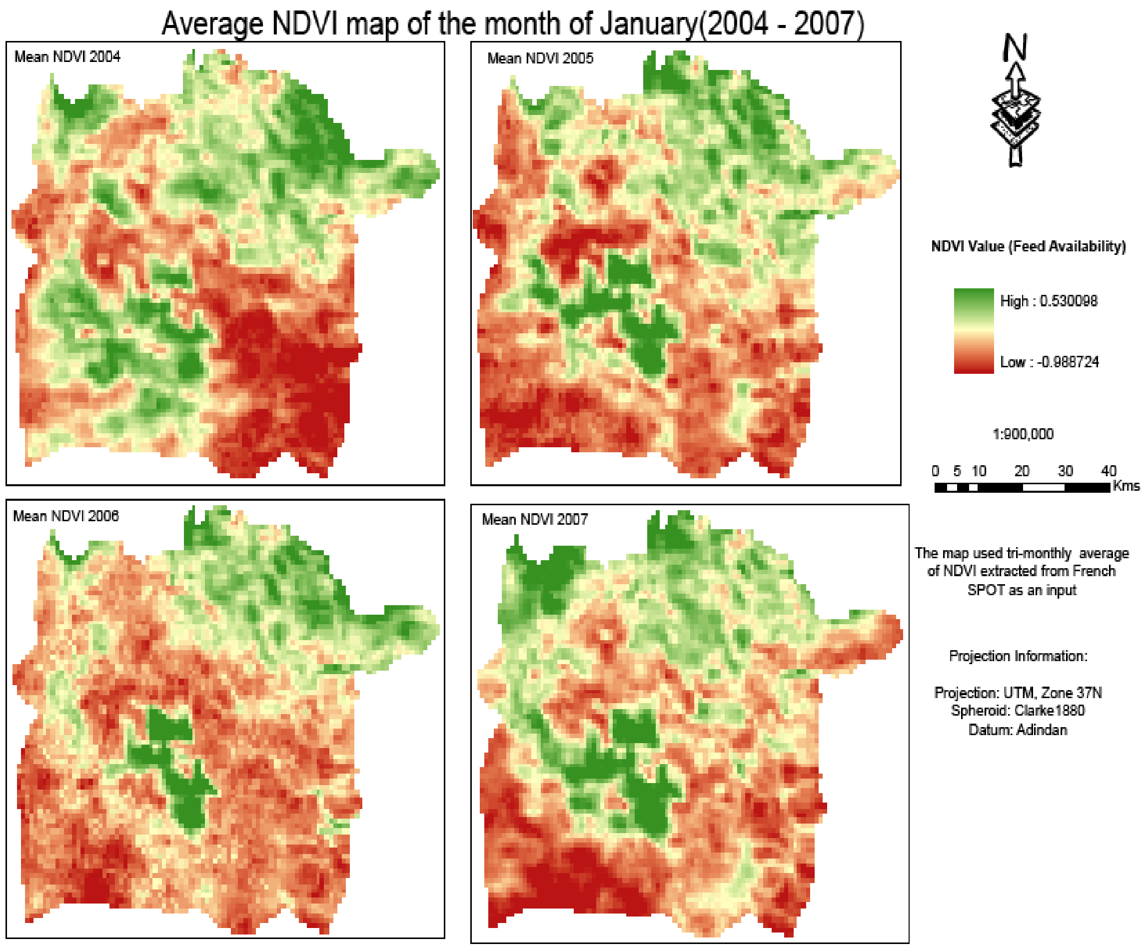

Fig. 22. Mean NDVI map for dry season- January 2004-2007

6.4. Spatial distribution of livestock population

The recent available (2008) population number of four livestock groups (cattle, camels, goats and sheep) of the study area was obtained from Borana Zone Agriculture Office.

The current distribution of livestock of all the PAs of the study area is depicted in Fig. 23. Noteworthy is that dots that are closer together have higher densities than dots that are farther apart which have lower densities.

It is to be noted that Dida Hara PA has the largest number of total livestock species in the study area. That is, a total of 61253 livestock (14.6%) of the study area are herded in this PA (Table 8). The second largest livestock population concentration was found in Dida Yabello PA where there are a total of 50715 (12.1%) livestock. On the contrary, sparse distribution of the livestock species was noticed in Obida PA. Such a relatively high number of livestock population at Dida Yabello PA could be attributed to the presence of Dida Xuyura government ranch that contributed a significant number of livestock. This ranch was established with the objective of conserving Borana cattle breed (Fig. 24).

Noteworthy is also that Haro Bake PA has the largest number of camels than any PAs in the study area. But camels account only for 5.2% of the total compared to other livestock species of the District. As a rule, the Borana pastoralists did not keep camel. However, it has been found that conversion of the grasslands to bushland has exerted a significant pressure on the livelihoods to the Borana people. They have now started to keep camel as an alternative livelihood strategy in the view of the changing environment (Fig. 25).
With regard to goats and sheep population distribution of the study area, Dida Hara PA ranked first. This could be attributed to (1) suitable topography for goats and sheep production and (2) this PA is currently playing a role model for rehabilitation of rangelands and hence, a lot of effort and resource from various Nongovernmental Organizations are being invested.

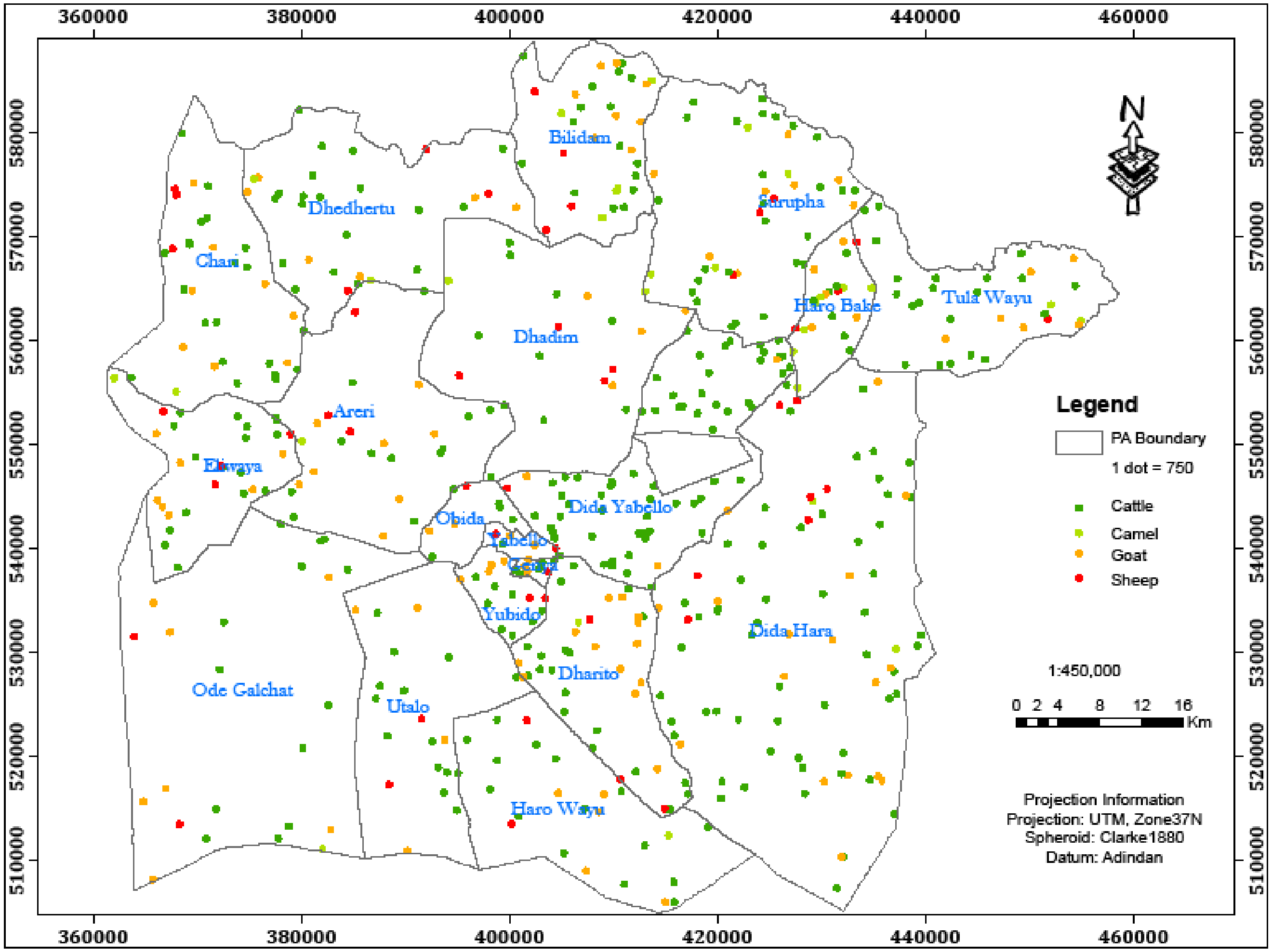

Fig. 23. Livestock density of Yabello District for the year 2008 (Borana Zone Agriculture Office).

Table 8: Livestock population of PAs of Yabello District (Borana Zone Agriculture Office).

No.	PAs	Livestock Species									
		Cattle		Camels		Goats		Sheep		Total	
		Number	%	**Number**	%	**Number**	%	**Number**	%	**Number**	%
1	Areri	10976	4.1	490	2.2	6360	7.0	2300	6.0	20126	4.8
2	Bildam	11812	4.4	4100	18.7	5630	6.2	2630	6.9	24172	5.8
3	Chari	15110	5.6	401	1.8	5980	6.6	2700	7.1	24191	5.8
4	Dhedhertu	14496	5.4	1600	7.3	4504	4.9	2200	5.7	22800	5.4
5	Dhadim	7060	2.6	880	4.0	3202	3.5	2800	7.3	13942	3.3
6	Dharito	15011	5.6	590	2.7	9534	10.5	2100	5.5	27235	6.5
7	Dida Yabello	46212	17.2	312	1.4	3301	3.6	890	2.3	50715	12.1
8	Dida Hara	42280	15.6	1433	6.5	12340	13.5	5200	13.6	61253	14.6
9	Eliwaya	11694	4.4	380	1.7	5460	6.0	2800	7.3	20334	4.7
10	Genya	4108	1.5	34	0.2	2008	2.2	830	2.2	6980	1.7
11	Haro Wayu	11660	4.3	480	2.2	3830	4.2	1710	4.5	17680	4.2
12	Haro Bake	10976	4.2	5500	25.1	3600	3.9	1860	4.9	21936	5.2
13	Obida	3797	1.4	15	0.1	1865	2.0	600	1.6	6277	1.5
14	Ode Galchat	11812	4.5	580	2.6	5243	5.7	1873	4.9	19508	4.6
15	Utalo	15110	5.6	75	0.4	3100	3.4	1300	3.4	19585	4.7
16	Surupha	14496	5.4	3500	16.0	5980	6.6	2400	6.2	26376	6.3
17	Tula Wayu	15436	5.8	1500	6.7	4506	4.9	1520	4.0	22962	5.5
18	Yabello	500	0.2	0	0	1790	2.0	1370	3.5	3660	0.9
19	Yubida	5836	2.2	42	0.2	2981	3.3	1200	3.1	10059	2.4
	Total	268382	100	21912	100	91214	100	38283	100	419791	100

Fig. 24. Borana cattle breed in Dida Xuyura ranch.

Fig. 25. Goat and camels browsing bush.

6.5. Land use / land cover change between 1986 and 2003

A post-classification comparison change detection technique (in ENVI platform) revealed different trends in land use/land cover changes over the period from 1986-2003. Accordingly, the major land use/ land cover changes were dominated by changes from grassland to bush and woodland to bush (Table 9). On quantitative terms, 1154.6Km^2 of grassland and 651.0Km^2 of woodland were converted to bushland (Table 9 and Fig. 26).

From Table 10 and Fig. 26, grassland and woodland areas were the dominant land use/land cover classes of the study area during 1986. Moreover, Table 10 elucidates that nearly half of the study area was covered by grasses before twenty three years. Whereas grassland and woodland occupied 48.8% and 24.9%, respectively, forest, farmland, built up area, bareland and bushland areas occupied only 26.1% of the study area in 1986. But significant spatial expansion in bushland and the rapid decrease in grassland were observed in the 2003 land use/landcover map (Fig. 26). The area of bushland increased to 45.1% while grassland and woodland areas were shrinked substantially to 26.0% and 12.9%, respectively. This substantial encroachment of bush is mainly attributed to the ban fire, which was a traditional rangeland management system (Angassa Ayana, 2005; Gemedo Dalle et al., 2006). Furthermore, Gemedo Dalle et al (2006) recommended that re-introduction of fire as a rangeland management tool and selective clearing of encroaching woody plants could help reclaim degraded rangeland of Borena.

Table 9: Land use/ Land cover change of Yabello District for the period 1986-2003.

		Initial State(1986)								
Final State(2003)		BL	BUA	B	FL	F	GL	WL	RTC	CTC
	BL	33.34	10.13	7.75	1.05	0.01	96.77	12.03	161.08	161.25
	BUA	15.26	25.54	33.93	2.15	0.08	182.99	70.81	330.76	328.89
	B	62.47	183.51	411.97	31.21	4.62	1154.68	651.03	2499.49	2517.69
	FL	4.30	5.66	24.58	20.29	0.16	161.93	23.45	240.37	237.75
	F	0.57	6.00	13.80	0.19	30.36	24.82	66.69	142.43	144.67
	GL	110.11	42.22	115.23	30.86	2.18	910.80	254.60	1466	1446.63
	WL	5.29	44.19	157.74	2.28	12.60	185.36	309.08	716.54	719.79
	CTR	231.34	317.25	765	88.03	50.01	2717.35	1387.69		
	CCR	198	291.71	353.03	67.74	19.65	1506.55	1078.61		
	ID	-70.09	11.64	1752.80	149.72	94.66	-1289.7	-667.91		

Note: Land cover categories: BL= Bare land, BUA= Built up area, B= Bushland, FL=Farmland, F= Forest, GL= Grassland and WL= Woodland

=Area of land cover remained unchanged over twenty three years

CTR= Class total row: indicates the total area of each initial state class.

CCR =Class changes row: indicates the total area of initial state classes that changed category.

ID= Image difference: is the difference in the total area of equivalently classed pixels in the two images.

RTC= Row total column: is a class-by-class summation of all final state areas that fell into the selected initial state classes.

CTC= Class total column: indicates the total area of each final state class.

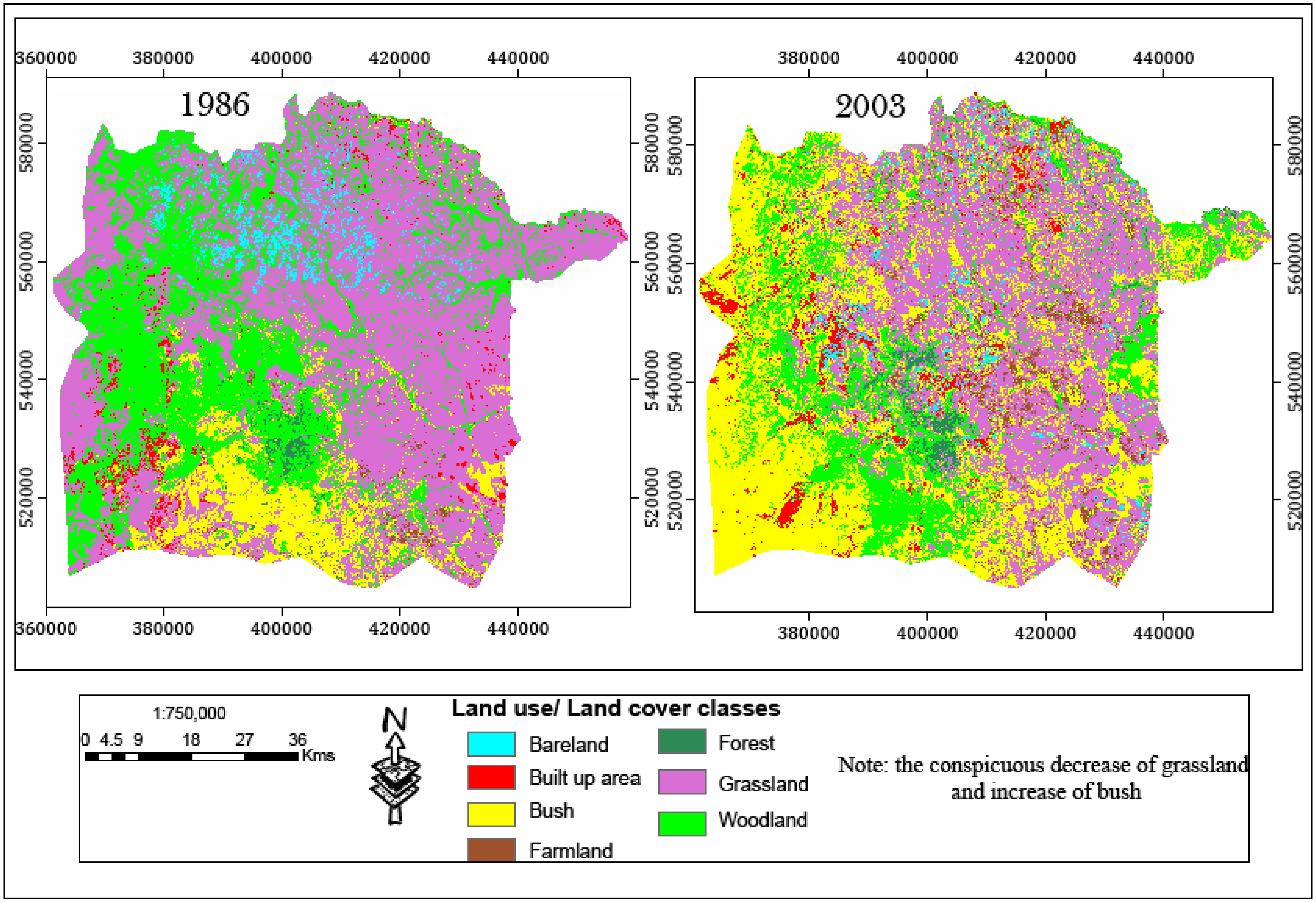

Fig. 26. Land use/land cover maps of the study area (1986 and 2003).

Table 10: Land use/ land cover changes in Yabello district as extracted from time series of landsat images (1986 and 2003).

Land use/land cover (Lu/LC)	1986		2003		Percentage change in LU/LC
	Area(km^2)	%	Area(Km^2)	%	
Bare land	231.35	4.15	161.25	2.90	-1.25
BUA	317.29	5.70	328.89	5.91	0.21
Bush	765.37	13.75	2507.69	45.13	31.38
Farm L	88.16	1.57	247.75	4.46	2.89
Forest	50.01	1.00	144.67	2.60	1.6
Grassland	2716.65	48.88	1446.63	26.03	-22.85
Woodland	1387.84	24.95	719.79	12.97	-11.98
Total	5556.67	100	5556.67	100	

The current study has also revealed a slight increase (4.44%) in the spatial extent of farmland. This has also been confirmed during the field work, i.e., previous grazing lands were converted to cultivation fields. For example, Dharito rangeland was once well known grazing area, which is now cultivation field (Fig. 27).

Fig. 27. A photograph taken as an evidence for the conversion of grassland to farmland.

General patterns of land use/land cover identified in the two images were largely dominated by grassland, bushland and woodland areas (Fig. 28).

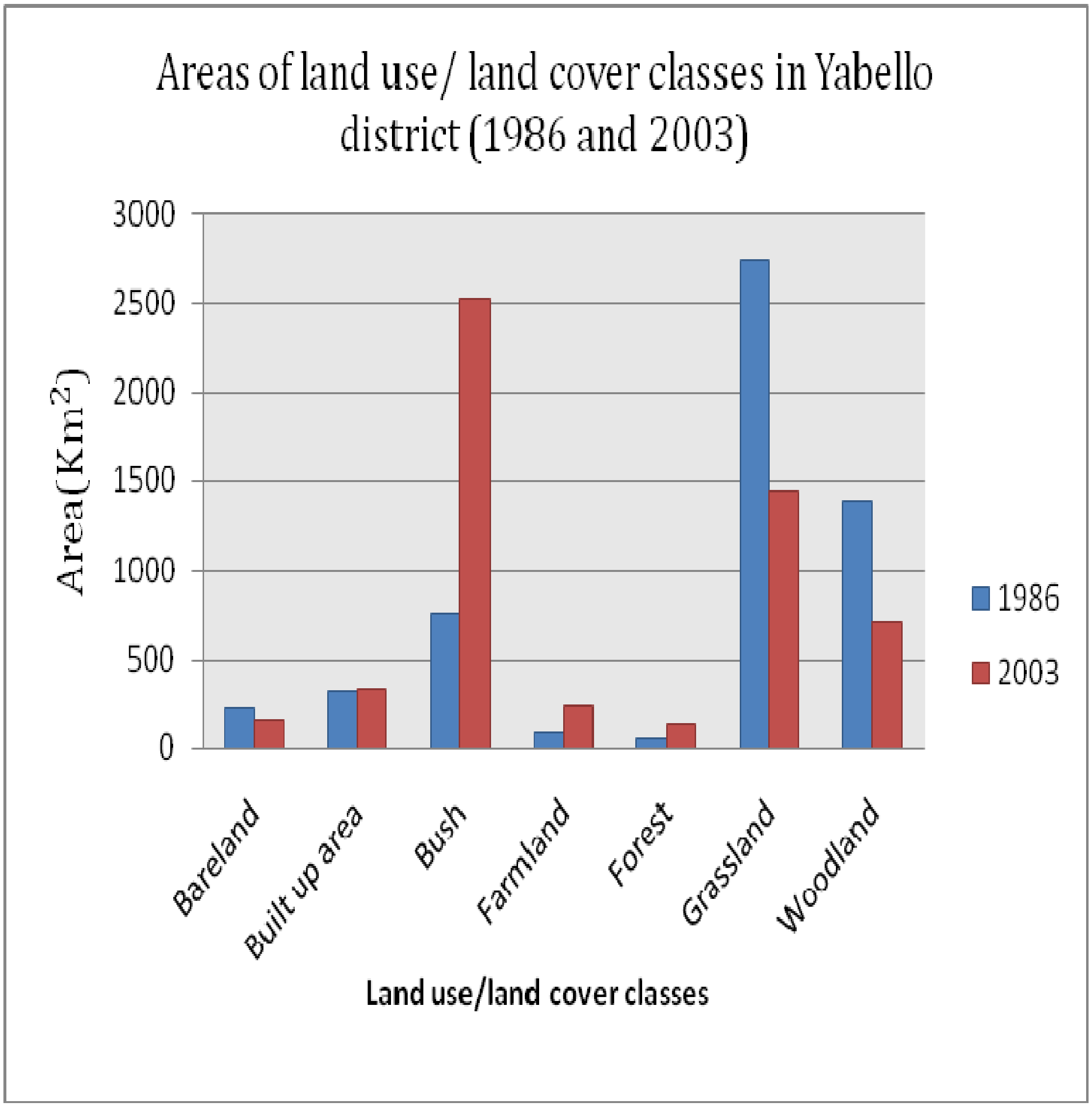

Fig. 28. Summary of areas of land use/ land cover classes in Yabello district (1986 & 2003)

Furthermore, the rates of land use/land cover changes varied between 1986 and 2003, with grassland, woodland and bareland areas exhibiting a decrease, while all other land use/land cover classes increased (Table 10 and Fig. 29). Major land use/ land cover changes within the Yabello District were the result of the dynamic nature of bush encroachment, which is critically expanding and an issue of concern for the local communities.

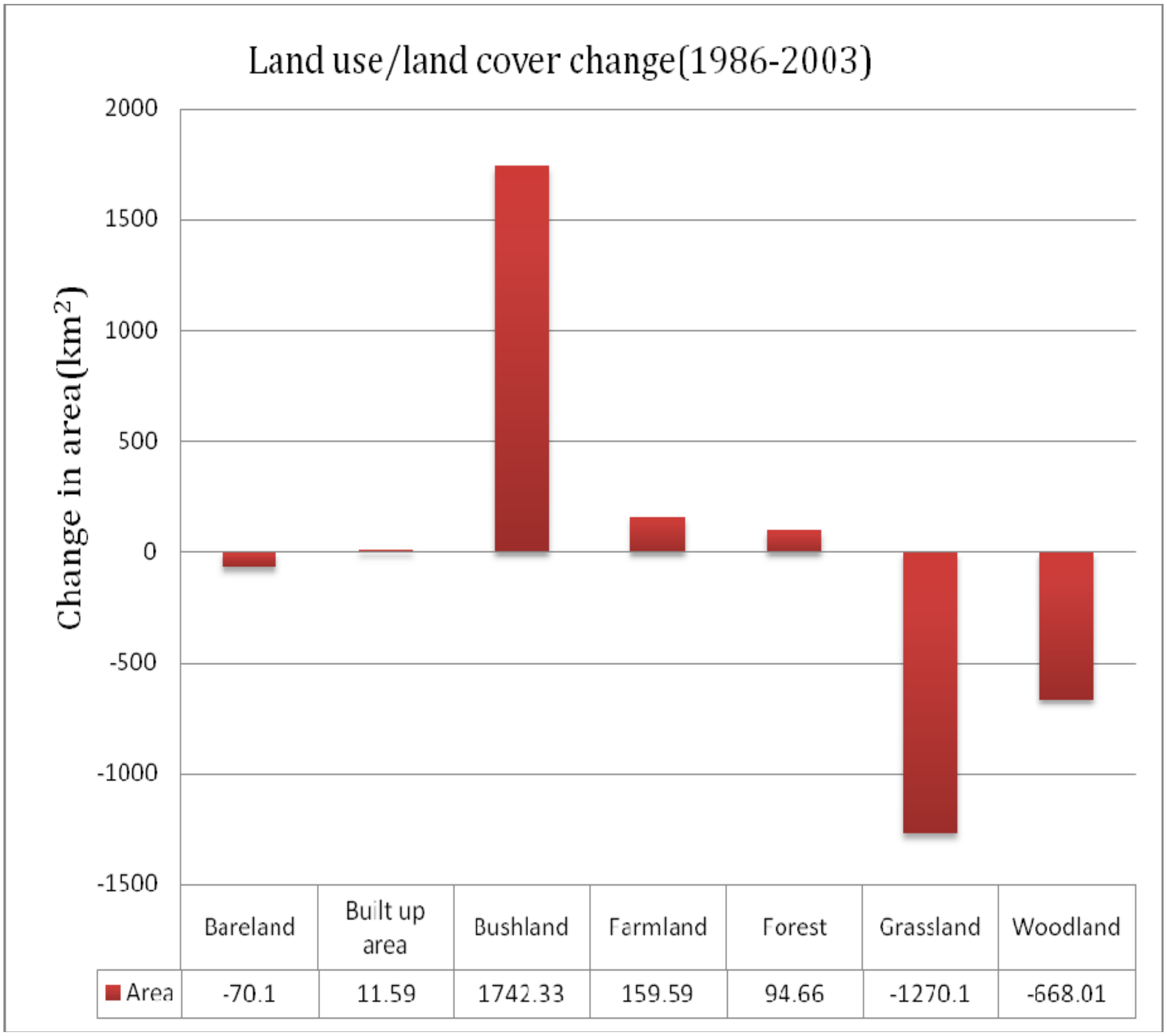

Fig. 29. Rates of land use/land cover changes of Yabello District between 1986 and 2003

7. Conclusion and Recommendations

7.1. Conclusion

The main aim of this study was to identify the suitable land parcels for livestock production in the Yabello District. Integrating MCE with GIS for spatial decision making process is a worthwhile technique. The study used weighted overlay technique of MCE in a GIS platform to arrive at the final land suitability for livestock species. As per the suitability analysis result, 31.6%, 31.5%, 18.2% and 26.9% of the total study area is most suitable for the production of cattle, sheep, goats and camels, respectively. Furthermore, with regard to the output of the suitability analysis, it should be noted that the larger portion of the study area (39.2% and 38.2%) fell under the suitability class called marginally suitable for cattle and sheep, respectively. Clearly, this is a corroboration for the advancement of bush which needs due treatment (e.g. rangeland rehabilitation or bush clearing) so as to reverse the above scenario.

Land cover mapping and documentation may not provide the ultimate explanation for all problems related to land cover changes and cannot be an end in itself. Nevertheless, it serves as a stepping stone for understanding trends and possible causes of land cover changes. As per the change detection result, in between 1986 and 2003, there had been substantial grassland and woodland losses owing to the advancement of sever bush encroachment as influenced by official ban of fire as a tool for rangeland management. The impact of bush expansion on the overall rangeland condition is definitely adverse. That is bush encroachment negatively affected the yield of grasses which in turn suppressed the productivity of livestock particularly sheep and cattle as they do not prefer bush grazing. In a nutshell, the general trend observed by the present study is a decrease in grassland, woodland and bareland and a matching increase in the remaining land use land cover classes.

Of equal significance is the accessibility of existing *eelaas* to livestock drinking. The study discloses that more than half of the study area is permanently inaccessible to the major *eelaas*. Evidently, this elucidates the acute shortage of *eelaas* for livestock watering especially during the dry season. Nevertheless, the indigenous water management systems of the pastoralists of the study area to some extent lessen the seriousness of the situation.

In addition, the study has shown that the spatial distribution of the livestock population under the present study was visualized using dot density map. As regards the population number of each livestock species cattle by far outnumber all the rest. Perhaps, this is a confirmation for the value and respect the Boran have for cattle than any other livestock species.
Furthermore, the availability of feed is one of the crucial factors for livestock production. To this effect, the output of the mean NDVI map reveals the paucity of livestock feed particularly during the dry season. Like water management system, here also, the adaptive strategy devised by pastoralists of the study area for the shortage of feed is the mobility between *warra*-and *foraa*- herds management system.

7.2. Recommendations

As bush expansion controlling mechanism, many local and international organizations are currently mobilizing the local community of the study area against rangeland rehabilitation through bush cleaning. However, it is impractical to successfully overcome the situation through bush clearing. Therefore, the government should allow the systematic return of the use of fire for controlling invasive woody plants, which the pastoralists used to.

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, as demonstrated in the study, the available *eelaas* of the study area are mostly inaccessible and insufficient for watering livestock species. Therefore, development efforts (such as digging new *eelaas* and rehabilitating the old one's) should be in place to ameliorate this acute paucity of dry season livestock drinking water. To this end, the indigenous knowledge of the pastoral community is very crucial. From long experience and customarily they know potential areas for excavating new *eelaas*. Culturally the pastoralists believe that "there is water where there is Oda tree".

Finally, as there cannot be any development without inter-ethnic peace, solutions have to be found to the recurrent inter-ethnic conflict over access to local resources.

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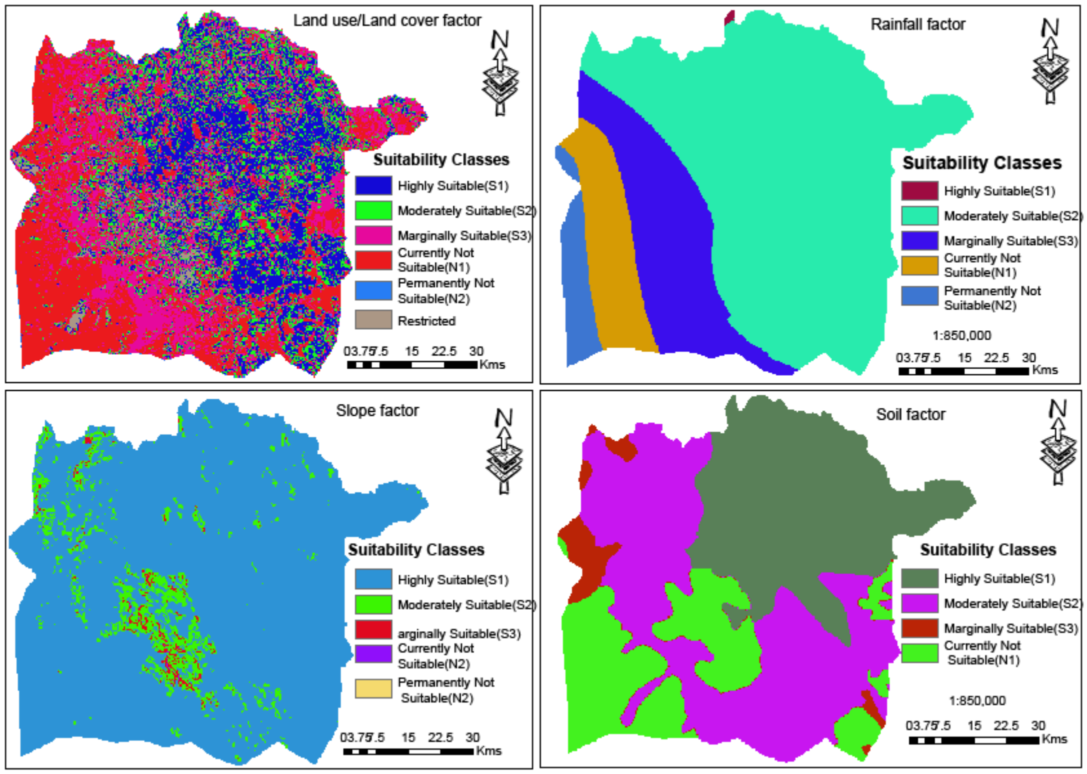
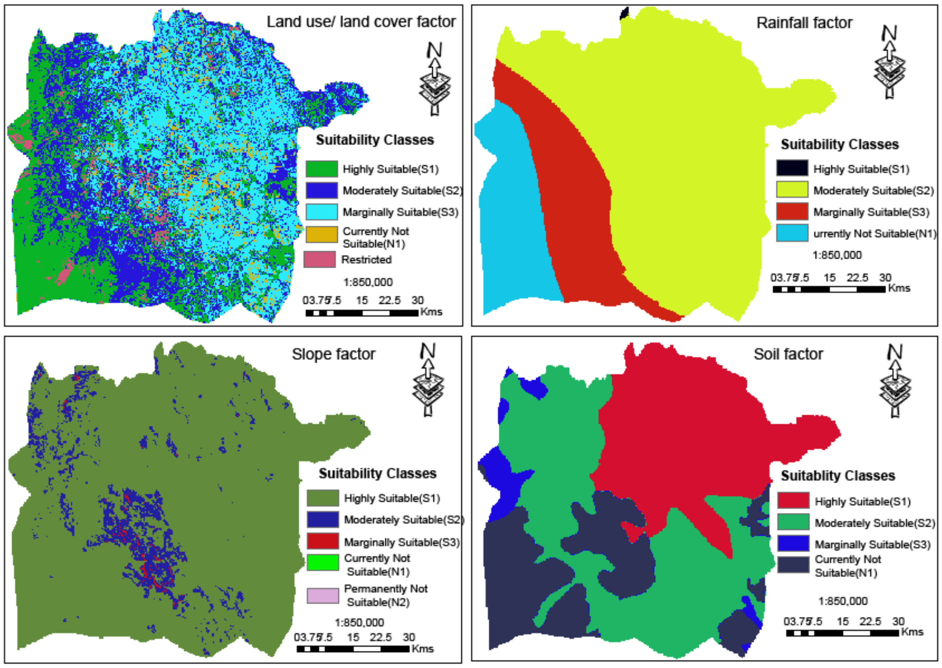
Appendixes

Appendix 1 Reclassified factor maps for different livestock groups.

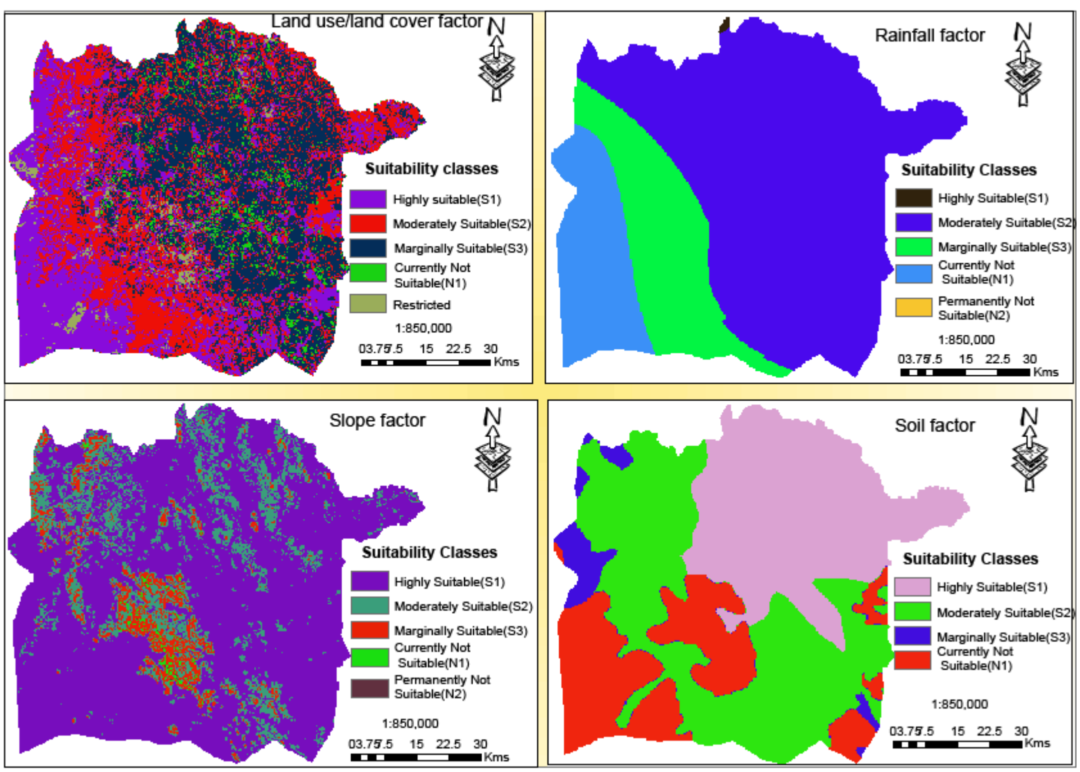
1.1. Reclassified factors map for sheep production



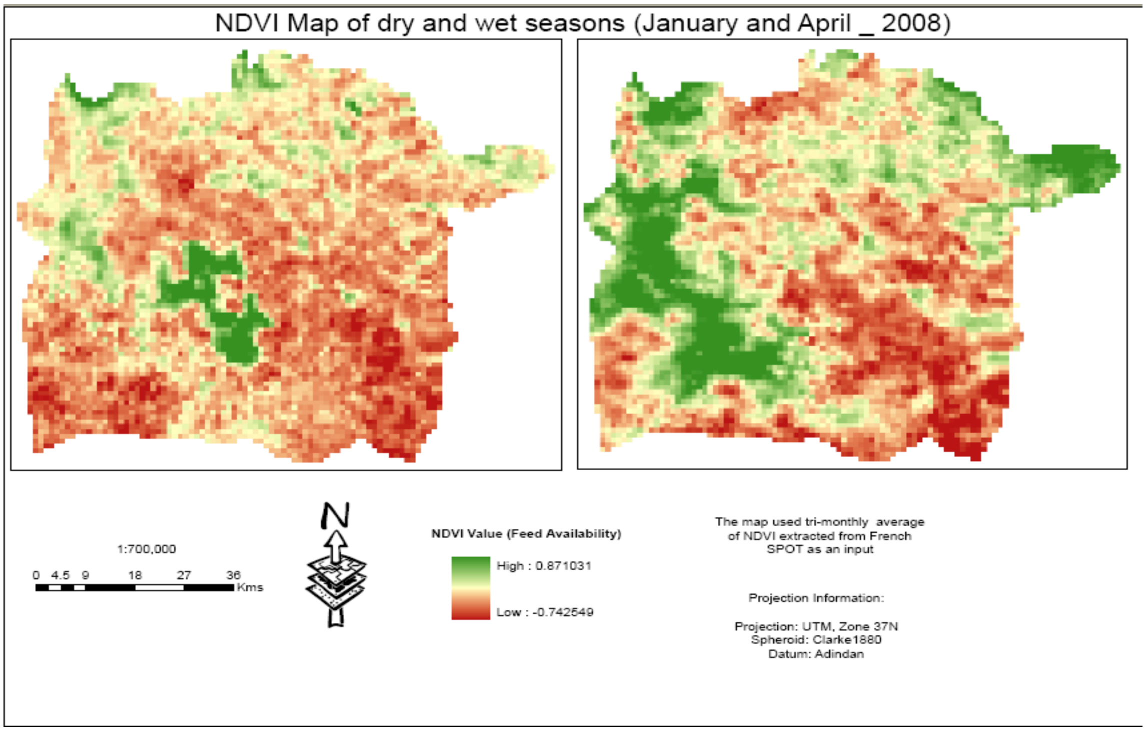
1.2. Reclassified factors map for goats production



1.3. Reclassified factors map for camels production



Appendix 2 Mean NDVI map of Yabello District for January (left) and April (right) of the year 2008; dry and wet months respectively.



Appendix 3 GPS Readings recorded during the field data collection

3.1. GPS Readings recorded for the seven major *eelaas*

Way point	UTM Coordinate		Name of *eelaa*	Date recorded
	Easting(X)	Nonthing(Y)		
31	401772	530264	Dhariitoo	08/04/2009
34	400560	530450	Dhigalticha	08/04/2009
44	375915	548315	Gamburaa	09/04/2009
65	411636	552285	Haroo Bake	12/04/2009
70	387569	537944	Adegalchat	13/04/2009
75	387553	544397	Areri	13/04/2009
85	400271	523996	Chichale Yatu	15/04/2009

3.2 GPS readings recorded for representative land use/ land cover categories

Way point	UTM Coordinate		Land use/land cover category	Way point	UTM Coordinate		Land use/ land cover category
	Easting(X)	Northing(Y)			Easting(X)	Northing(Y)	
27	404430	530784	Forest	66	411824	552796	woodland
29	403334	530605	Forest	72	386271	538547	woodland
35	402742	532224	Forest	77	387281	544637	woodland
36	402689	532297	Forest	69	385322	543656	Bushland
2	425458	521711	Grassland	74	386570	538623	Bushland
3	425073	521452	Grassland	42	376157	548404	Bushland
4	425827	522522	Grassland	84	402057	517808	Bushland
92	411930	548966	Grassland	79	398737	538691	Farmland
93	412629	550149	Grassland	80	398762	538328	Farmland
95	413104	549686	Grassland	81	399251	537504	Farmland
97	413200	549162	Grassland	82	399560	537518	Farmland
98	413041	548845	Grassland	89	397759	540687	Farmland
99	412791	548643	Grassland	90	398281	541060	Farmland
100	412474	548070	Grassland				