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LAND COVER DYNAMICS IN SAVANNA ECOSYSTEM OF BORENA ETHIOPIA

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LAND COVER DYNAMICS IN SAVANNA ECOSYSTEM OF BORENA ETHIOPIA

Thesis
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DECLARATION

I declare that this thesis is my genuine work and that all sources of materials used for this thesis have been duly acknowledged. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

Teshome Abate Beza

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Land cover dynamics in savanna ecosystem of Borena Ethiopia

ABSTRACT

A study was conducted to examine land use and land cover change dynamic and spatial pattern of landscape structure in arid and semi-arid rangeland of Borena, Ethiopia. Three multi-temporal satellite (TM, and ETM+) images of 1987, 1995 and 2003 were used. Supervised maximum likelihood classification at pixel level and post-classification comparison of images was used. The landscape structures were calculated using Fragstats3.3 soft ware. Over the past 16 years, the arid and semi-arid savanna ecosystem of the Borena experienced land use and land cover change. Result indicated that about 39.04% of the total landscape remains unchanged and about 51.8% of total landscape was covered by bush land and woodland together. During 1987 to 2003 bush land, cultivation and urbanization had increased by 17%, 72.49% and 79.75% whereas woodland (11.68%) grassland (7.73%) and shrubby grassland (86.14%) were reduced. Spatial metrics analysis showed that during 1987 to 2003 the Borena landscape went through important change. The resulting landscape has become more fragmented and indicated by the proliferation of large number of patch, increasing of patch density, decreasing of largest patch index; more diversity and heterogeneity with tend to more unevenly distribution of patch and irregular shape patch within landscape. In overall, the present tendency of bush and woodland cover in the landscape may lead to more bush encroachment and grassland shrinkage if no proper measurement has taken. The continued land use cover change, coupled with a drier and climatic variability and considering human induced factor in the area, it is likely that the landscape change tendency will be continued which greatly affects people’s livelihood and put the pastoral production system under increasing threat

KEYWORDS

Land use change

Landscape structure

Spatial metrics

Vegetation cover

Borena pastoralist

Ethiopia

ACRONYMS

ETM+	Enhanced Thematic Mapper plus
FAO	World Food and Agriculture Organization
GIS	Geographical Information System
GLCF	Global Land Cover Facility
GPS	Global Positioning System
IHDP	International Human Dimensions Programme
IGBP	International Geosphere-Biosphere Programme
ILRI	International Livestock Research Institute
LPI	Largest Patch Index
LUCC	Land Use and Land Cover Change
MSS	Multispectral Scanner
NMA	National Metrological Agency
NDVI	Normalized Difference Vegetation Index
SHDI	Shannon's Diversity Index
SHEI	Shannon's Evenness Index
TM	Enhanced Thematic Mapper
USGS	United States Soil and Geological Survey

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1. INTRODUCTION

1.1 Study background

Land use and land cover change (LUCC) information constitutes key environmental information for many scientific, resource management, policy related issue, as well as for a range of human activities. As a result, LUCC have become a major focus for the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP) at different scale. Since the 1970s, concerns about changes in LUCC have emerged in the research on global environmental change (Lambin *et al.,* 2003) due to LUCC change are closely linked to the sustainability of socio-economic development and livelihood of people (Lambin *et al.*, 1997).There is complex and dynamic LUCC change at various scales, which have global environmental implication. Thus due to the dynamic nature of LUCC change the scope of problem still remains an area of active study and debate. Hence, detailed and continuous study at different scale is needed (Fuller and Chowdhury, 2006). Adequate and accurate information in LUCC cover change is a key to many diverse applications for instance, information on LUCC change is required to understand and manage the environment at variety of spatial and temporal scales. It is essential for monitoring global change and for sustainable management of natural resource. It is also input data for a range of environmental models and policy-driven need (Rosenqvist *et al.,* 2003).

Land use and land cover change are result of prevailing interacting natural and anthropogenic process by human activities such as population growth, deforestation, expansion of crop cultivation and land degradation. The human use of land contributes to significant modification of hydrology, climate, biogeochemical, biodiversity and ecological balance (Liverman and Cuesta 2008). Hence, there is a need to understand LUCC change, dynamic and its effect on the overall ecosystem (Lambin *et al*, 2003) as well as understanding local pattern and process is essential. However, our understanding of where, when and why land cover change take place in tropical region is highly hampered by lack of quantitative information (Lambin, 1997) for instance information relating to land cover change in many arid savanna ecosystem of Ethiopia is scanty. Thus, assessing of LUCC change dynamic, driving force and its impact behind LUCC change is essential. To these end timely and accurate change detection of Earth's surface features is extremely important for understanding relationship and interaction between human and natural phenomena in order to promote better decision making (Lu *et al.,* 2004).

Recently, a substantial amount of data from the Earth’s surface is collected using Geospatial technologies such as Global Position System (GPS), Geographical Information System (GIS) and Remote Sensing. Remote Sensing and GIS provide an excellent source of data over large geographical area from which updated LUCC information and change can be extracted, analyzed and predicated efficiently. Many studies have demonstrated remote sensing using satellite image detect and monitor LUCC change in savanna ecosystem (Duadze, 2004; Bedru, 2006). Research proves that remote sensing can be considered a useful tool for studying arid and semi-arid ecosystem.

1.2 Statement of problem

Rangelands in Ethiopia are located below an elevation of 1 500 masl. They cover about 61-65% of the total area of the country and are characterized by arid and semi-arid agro-ecologies, experiencing a relatively harsh climate with low, unreliable and erratic rainfall. The rangelands are home to 12-15% of the human population and 26% of the total livestock population and provide habitat for many wildlife species. Pastoralism and agro-pastoralism are the dominant type of land use system in these areas. Livestock in the rangeland play a significant role in the national economy. However, many of these rangelands at present are degrading owing to natural and human-induced factors (Abule *et al.,* 2005).

The Borana rangeland which is located in Southern Ethiopia, comprise important cultural landscape until a few decades ago, the area was considered as one of the finest savanna grazing land in East Africa and had good ecological potential for livestock production (Hogg, 1997). However, many studies (Coppock 1994; Gemedo Dale, 2004; Homann, 2004; Solomon *et al*., 2006; Angassa and Oba, 2008) reported recently the condition of Borena rangeland has been degraded and transformed due to climate and human induced factors including land degradation, expansion of bush cover, expansion of cultivation of crop, frequent and recurrent drought, ban on use of fire, human population pressure and weakening of traditional indigenous management system. Such pastoral land use transformation are affecting the sustainable use of savanna landscape as well as pastoral production system (Angassa and Oba, 2008).These pastoral land use transformation has occurred at different degree of magnitude and temporal scale. Several studies have reported land cover change in Borana rangeland currently has accelerating and causing wide range environmental problem (e.g. rangeland degradation and bush encroachment).Proper understanding of land use transformation scenario and quantifying the extent and rate of change is critically important owing to the changing patterns of land cover reflect changing environment, economic and social conditions of the area.

So far in Borena rangelands some research and development work has been conducted in various field of research for instance in rangeland ecology and management, socio-economic condition of pastoral communities and cultural studies (Coppock 1994; Gemedo Dale, 2004; Homann, 2004; Ayana, 2007). However, studies related to LUCC change using satellite image is scanty in savanna landscape of Ethiopia in general and in Borena rangeland in particular, only Getachew *et al*., (2010) studied land use cover change using of aerial photograph (1968 and 1987) and Landsat image of 2002.Thus, for sustainable landscape management, proper understanding and having accurate and up-to-date information on land cover change dynamic and magnitude of change in spatial-temporal scale is essential. In this view extent and trend of spatio-temporal quantitative information of LUCC change using GIS and remote sensing is lacking in the study area. Therefore, this study was focus on land use and land cover change of savanna landscape covering period of 1980' 1990', and 2000'. These periods are selected because of dramatic change, which have been observed in range development and consequently change in traditional land use and vegetation shift in southern Ethiopia over the last 4-5 decade.

1.3 Aim and objectives

The overall objective of the study was to analysis LUCC change pattern using multi-temporal Landsat imageries in three different time series (1987, 1995 and 2003). Furthermore, it has designed to studies landscape structure in different temporal and spatial scale.

Specific objectives:

- To map and determine the extent and rate of LUCC change using post and pre classification approaches
- To analyze spatial pattern and landscape structural change using selected spatial metrics.
- To generate some baseline information for future research and development activities

1.4 Research hypothesis and question

Hypothesis

We hypothesized that whether significant variation in LUCC dynamic and landscape structure change has observed in the rangeland of Borena in given spatio-temporal scale.

Research question

In order to meet the hypothesis and objectives, the study set the following research questions

- Is there any land use/land cover change in the study area?
- What was the spatial extent of the land cover change and where was the highest magnitude of change?

- Is there any landscape structural change in the study area?
- Is remote sensing a suitable tool for detection of LUCC change in the arid and semi arid environment?
- Is NDVI a suitable tool for detection of vegetation change in the arid and semi arid environment?

1.5 Thesis structure

The thesis has organized into six main chapter outlined and presented in Figure1. The first chapter deals with the introduction and statement of the problem, objectives, hypothesis and research question. The second chapter covers review of related literature which include definition and concept of LUCC change, remote sensing and LUCC change, different change detection technique, image classification method, landscape metrics and LUCC change in Ethiopia. The third chapter described about the study area and type and nature of data set used. In this chapter location, climate, topography, vegetation and the main land use practice was discussed. Chapter four emphasizing mainly on research methodologies which include image pre-processing, classification, accuracy assessment, change detection and spatial metrics analysis procedure. Chapter five deals on result and discussion. Finally, chapter six covers conclusion and recommendation and limitation of the study.

1.6 Tools used in the study

Different software program such as ERDAS IMAGINE 9.2 and IDRISI ANDES was used in this study to process, classify, quantify, and analyze LUCC change. For the preliminary data processing and extracting the study area, ArcGIS 9.3 was used. In order to determine the spatial pattern analysis, Fragstats 3.3 public domain soft ware was used.

1.7 Significance of the study

Land use and land cover change studies are important tool for land manager and decision makers in formulating appropriate land use policy as well as locating development program for sustainable use of savanna ecosystem in southern Ethiopia. The result of this study would provide information relevant to contribute in the rangeland management plan. It is also expected to:

- Provide information on the status and dynamic of LUCC change of area and also provide information the use of remote sensing from satellite imagery for analysis of landscape, sustainable management and conservation
- Provide a base line information for future research and development intervention

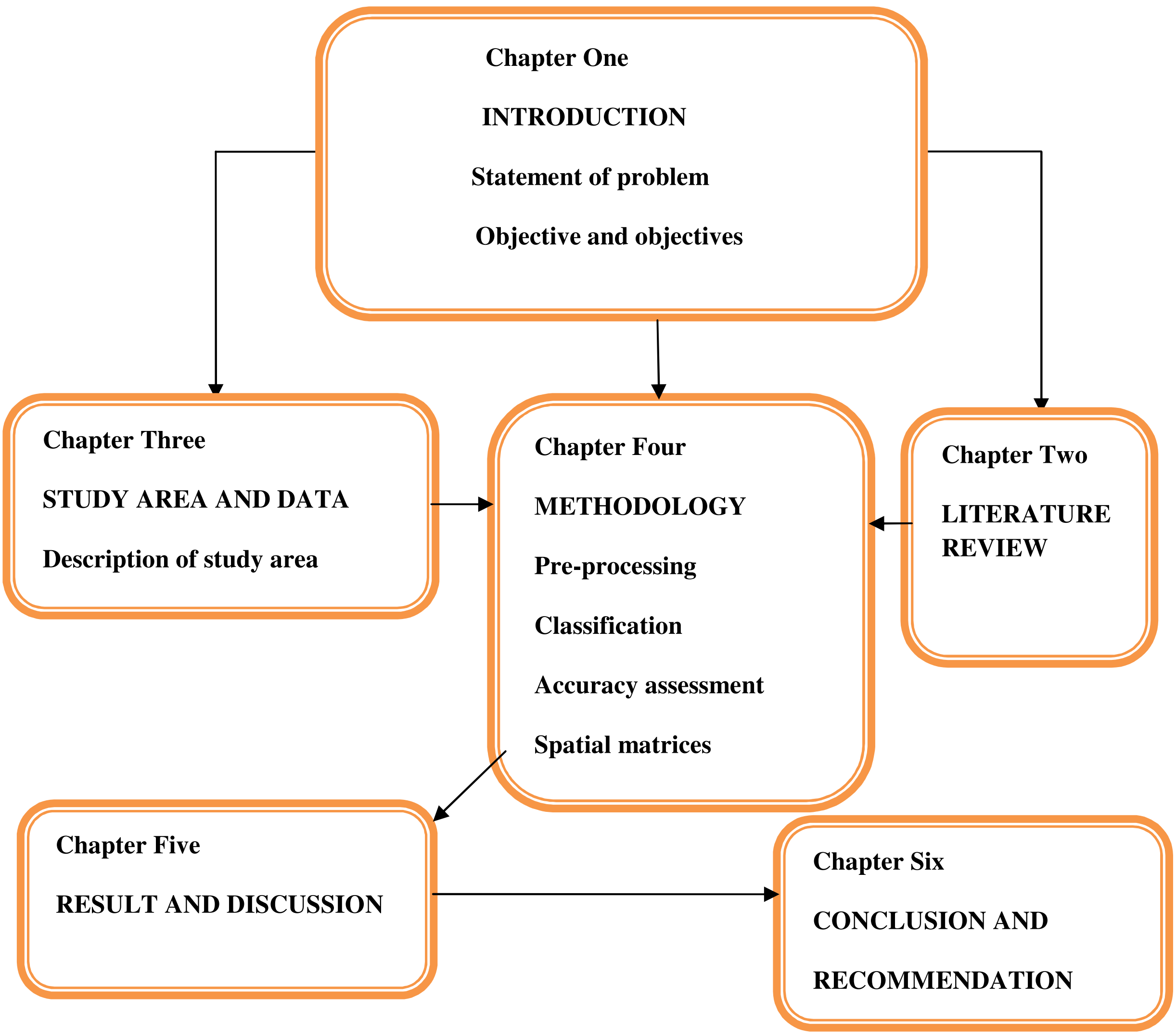


Figure 1 The flow diagram of thesis outline

2 LITERATURE REVIEW

This chapter highlight literature review related to LUCC change done so far at various scale and the review mainly focus on the definition and concept of LUCC change, remote sensing and LUCC change, change detection techniques, image classification method, landscape metrics and LUCC change and LUCC change in Ethiopia. These topics have reviewed under the following sub-topic.

2.1 Definition and concept of land use and land cover change

Land use and land cover change is a general term for the human modification of Earth's terrestrial surface. Though humans have been modifying land to obtain food and other essential for thousands of years, current rate, extent and intensities of LUCC change are far greater than ever in history, driving unprecedented change in ecosystem and environmental process at local, regional and global scale. These changes encompass the greatest environmental concern of human population today including climate change, biodiversity loss and the pollution of water, soil and air. Monitoring and mediating the negative consequence of LLCC change has therefore become a major priority of researcher and policymaker around the world. (http://www.eoearth.org/article/Land-use_and_land-cover_change[1]).

Before discussing about LUCC change, it is important to define the term. In order to appreciate the definition and concept of land use and land cover, it may be necessary to, first of all, define the term "land". Land is a complex and dynamic combination of factors: geology, topography, hydrology, soils, microclimates, and communities of plant and animal that are continually interacting under the influence of climate and people activities (FAO, 1998) it is the basic natural resource, which provide space, energy and nutrients that are essential for all biochemical metabolisms occurring in any organism. Land plays a key role in major biogeochemical cycle both within ecosystem and globally (FAO, 1998). Generally, land can be considered in two domains: (1) land in its natural condition and (2) land

[1] http://www.eoearth.org/article/Land-use_and_land-cover_change.

that has been modified by human being to suit a particular use or range of use. The natural capability of land to meet a certain anthropogenic activity in a broad sense is referred to as land quality, and this is traditionally interpreted in terms of land resource, which determines land use. Historically, land has been exploited in different ways, from a simple watching of landscape and primitive collection of herbs to artificially generated industrial areas (Stolbovoi, 2002). In these ways, humans are adapting to land capacity or rebuilding land to fit their demand. Many authors or groups have defined “land use” and “land cover. Land cover it refers to the physical and biological cover of the earth's surface including artificial surfaces, agricultural areas, forests, (semi-)natural areas, wetlands, water bodies. Whereas, land use is a more complicated term, natural scientists define land use change is the conversion of land use due to human intervention for various purpose, such as for agriculture, settlement, transportation, commercial, recreation, mining and fishery (Turner et al., 1993). While social scientists and land managers define land use more broadly to include the social and economic purpose and context for and within which lands are managed (or left unmanaged), (e.g. as subsistence versus commercial agriculture ,rented vs. owned, or private vs. public land (http://www.eoearth.org/article/Land-use_and_land-cover_change).Thus land use encompasses a wide range of natural and socio-economic aspects and their interrelations (Stolbovoi, 2002).

Land use and land cover change may be also grouped into two broad categories as conversion and modification. Conversion refers to change from one cover or use type to another, For instance, the conversion of forest to pasture is an important land use and land cover conversion in the tropic. The abandonment of a piece of land that has been permanently cultivated over a period in the past to regenerate to forest is a land use and land cover conversion while modification involve maintenance of the broad cover or use type in the face of change in its attribute. Thus, a forest may be retained while significant alterations take place in its structure or function (e.g., involving biomass, productivity, or phenology). Land use change is the proximate cause of land cover change. Many studies (e.g. Reid *et al*., 2000) indicted that LUCC change dynamic is a result of complex interaction between several biophysical and socio-economic factors which may occur at various temporal and spatial scale. The driving force to this change could be environmental, economic, land policy and development program, technological, demographic, and or other factors.

2.2 Remote sensing and land use and land cover change studies

Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with object, area, or phenomenon under investigation (Lillesand and Kiefer, 1994). The modern usage of the term remote sensing has more to do with the technical ways of collecting airborne and space borne information. Earth observation from airborne platforms has a one hundred and fifty years old history although the majority of the innovation and development has taken place in the past thirty years. The first Earth observation using a balloon in the 1860s is regarded as an important benchmark in the history of remote sensing. Since then platforms have evolved to space stations, sensors have evolved from cameras to sophisticated scanning device and the user base has grown from specialized cartographers to all rounded disciplines. It was the launch of the first civilian remote sensing satellite in the late July 1972 that paved the way for the modern remote sensing applications in many fields including natural resources management (Lillesand et al. 2004). For the past couple of decade the application of remote sensing not only revolutionized the way data has been collected but also significantly improved the quality and accessibility of important spatial information for natural resources management as well as LUCC change studies.

Nowadays, a number of new satellite sensors have been designed and launched more specifically for observing land cover change. These satellite sensors provide improved data in terms of spatial, spectral, radiometric and temporal resolution thus making it increasingly possible to map, evaluate and monitor land use and land cover over wide area (FAO, 1998). There are many satellites sensors in the space providing remote sensing data, which have different properties and imaging capabilities, scan the surface of the earth repeatedly, with frequencies that vary with the satellite type. The major ones whose data are most commonly used for the study of the Earth's resources including Landsat the Multispectral Scanner (MSS, 79m resolution), Landsat Thematic Mapper (TM, 30m resolution) and Landsat Enhance Thematic Mapper (TM, 30m resolution) has medium resolution sensors which are suitable for the study of land use and land cover, and have been used to derive detailed land use classification of many part of the world including the tropics (Purevdor *et al.,* 1998). Major change to the surface of the earth such as desertification, deforestation, and other natural and anthropogenic events can be detected, examined, measured and analyzed using Landsat data. The information obtainable from historical as well as current Landsat data plays key roles in the study of surface change through time (ERDAS, 1999).

Remote sensing integrated with GIS has been recognized as powerful and effective tool in extract useful thematic information pertaining to the environment, mapping and monitoring LUCC dynamic. Land use and land cover information is important for many planning, management and decision making activities concerned with the surface at various spatial-temporal scale (Lambin, 1997), because it constitutes a key environmental information for resource management and policy driven issue. This information is play important role for a wide range of themes and issues that are fundamental to the study of global environmental change. For instance, change in LUCC contributes to change in biogeochemical cycles, alter hydrological cycles, and influence ecological balances and complexity. For example, large-scale deforestation increase the atmospheric carbon level (IPCC, 2001). Through these environmental impacts at local, regional and global level. Land use and land cover change, driven by human activity and biophysical factors; have the potential to significantly affect food security, natural resource, biodiversity and the sustainability of the agricultural. For sustainable management of savanna ecosystem like Borena of Ethiopia LUCC map of the existing natural resources are important for estimation and mapping of condition of vegetation cover, distribution of different plant species, their ecosystem, landscape, bioclimatic condition (Joshi *et al*., 2003) which is important for local communities and monitoring of arid and semi-arid environment.

2.3 Change detection techniques

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Thus, change detection is an important process in monitoring and managing natural resource and understanding the nature of change in the use of land resources. Change detection determines change of a particular object between two or more time periods to produce a quantitative spatial analysis in an area of interest (Macleod and Congalton, 1998). The four aspects of change detection which are important when monitoring natural resources and land use cover are detecting the change that have occurred, identifying the nature of the change, measuring the area extent of the change and assessing the spatial pattern of the change (Singh, 1989; Macleod and Congation,1998). However, the accuracy of change detection depend on many factors, including, precise geometric registration between multi-temporal images, calibration or normalization between multi-temporal images, availability of quality ground reference data, the complexity of landscape and environment of the study area, using appropriate change detection algorithms and others. Thus, identifying a suitable change detection technique has significance contribution to produce good change detection result. The temporal, spatial, spectral and radiometric resolutions of remotely sensed data have also a significant impact on the success of remote sensing change detection. In general, when selecting remote sensing data for change detection applications, it is important to use the same sensor, same radiometric and spatial resolution data with anniversary or very near anniversary acquisition dates in order to eliminate the effects of external sources such as sun angle, seasonal and phonological differences.

So far different techniques have been developed to detect land cover change (Singh, 1989). Nevertheless, there is no single standard method applied for all change detection case. Despite there are several change detection methods some studies for instance (Lu, 2004) in the review suggested that image differencing, principle component analysis (PCA) and post-classification are the most widely used technique. Change detection can broadly divided into two namely pre-classification spectral change detection or post-classification methods (Singh 1989). Post classification change detection, two multi-temporal images are classified separately and labeled with proper attributes. The area of change is then extracted through then direct comparison after obtaining the classification result. With the post-classification procedure basic issues are the accuracies of the component classification and more subtle issues associated with the sensors and data preprocessing method (Lu and Weng 2007). In pre classification spectral change detection where changes occur in the amount or concentration of some attribute that can be continuously measured (Coppin and Bauer, 1994). In spectral change detection, image of two dates are transformed into a new single-band or multi-band image, which contains the spectral changes. The resultant image must be further processed to assign the changes to specific land cover types. Since these methods are based on pixel-wise or scene-wise operations, they are sensitive to image preprocessing such as registration and co-registration accuracy. Discrimination of change and no-change pixels is of the greatest importance in successful performance of these methods. A common method for discrimination is use of statistical threshold. In this method a careful decision is required to place threshold boundaries to separate the area of change from no-change (Singh, 1989).

There are several pre classification techniques such as image differencing, image rationing, image regression, change vector analysis and vegetation index differencing are some of the common. Image differencing one of the most common pre-classification methods used in change detection algorithm. It involves subtracting one date of imagery from a second date that has been precisely registered to the first. According to recent research, image differencing emerges to perform generally better than other method of pre-classification change detection (Singh, 1989). The other per-classification method is vegetation index differencing, in vegetation studies the ratio (known as vegetation indices) is used to enhance the spectral differences between strong reflectance of vegetation in the near-infrared part of spectrum and chlorophyll-absorption band (red part) of the spectrum (Singh, 1989). Typical vegetation indices include: Ratio Vegetation Index, Normalized

Vegetation Index, and Transformed Vegetation Index. In this study Normalized Vegetation Index is used to observe the general greenest of the study area.

2.4 Satellite image classification methods

Satellite image classification is the process of assigning classes to the pixels in images. It is a complex and time consuming process, and the result of classification may be influenced by various factors such as nature of input images, classification method, scale of the study area, and post classification processing. In general, image classification method can be grouped as supervised and unsupervised, or parametric and nonparametric, or hard and soft (fuzzy) classification, or per-pixel, sub pixel, and per field (Lu and Weng 2007). Among all classification method some of them will be discussed. Pixel-based classification, in this method, each pixel is classified based on the spatial arrangement of edge features in its local neighborhoods (Im *et al.* 2008). Image classification at pixel level could be supervised or unsupervised; parametric and hard classifiers. In a supervised classification method the image analyst has responsible for the supervises the pixel categorization process by specifying to the algorithm, class definitions, or signatures of the various land use and land cover types present in a scene to train the algorithm (Lillesand and Kiefer, 1994). Maximum likelihood of supervised classifier is the most commonly used method.

Unsupervised classification is a method of clustering of pixels having similar spectral characteristics (ERDAS, 1999). In unsupervised method, input from analyst is very limited in an i.e. specifying number of clusters and labeling the classes. The unsupervised classification technique is usually used when little is known about the data before classification (ERDAS, 1999). Most classification methods are based on per-pixel information, however, a pixel-based method is associated with the mixed-pixel problem. The other method of image classification is object-based; this approach considers group of pixels and the geometric properties of image objects. It segments the pixel imageries into homogenous objects based on neighboring pixels' spectral and spatial properties, a classification is then implemented based on objects, instead of individual pixels (Lu and Weng, 2007).The eCognition method is so far the most commonly used object-oriented classification (Lu, 2004). The other classification approach is advanced classification approaches. In recent year various advanced image classification approaches have been widely developed and applied such as artificial neural networks, expert systems, fuzzy-set theory, decision tree classifier, etc. (Lu and Weng, 2007)

2.5 Landscape metrics and land use and land cover change studies

Knowing the landscape structure, the nature and magnitude of its change, and how it affects landscape processes are essential in the sound management of land and their resource. Particular, important for resource manager because its need spatial and temporal information to make decision about landscape patch size, the dispersal or aggregation of activities, edge densities, and connectivity in the landscape (McGarigal, *et al.,* 2002). Landscape is defined as a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout (Forman and Godron, 1986). It is composed typically of various types of landscape elements (patches). Patches represent relatively discrete area (spatial) of relatively homogeneous environmental condition. Landscape metrics is one of imperative method for understanding the structure, function and dynamic of landscape. The ability to quantify landscape structure is fundamental to the study of landscape function and change (McGarigal and Marks, 1994).

Landscape structure could be described by its composition and configuration. Landscape composition refers to features associated with the variety and abundance of patch type within the landscape, but without considering the spatial character, placement, or location of patches within the landscape (McGarigal and Marks, 1994). Composition metrics measure landscape characteristics such as patch proportion, richness, evenness or dominance and diversity. Composition metrics require a classification of the landscape into different classes. On the other hand, landscape configuration relates to patch geometry and spatial distribution of patches. It could be measured using statistics based on shape, nearest neighbour, contagion, and interspersion, dispersion. In many field of research including land use and land cover change, landscape metrics are used to quantify the spatial heterogeneity at different level (patch, class and landscape). Metrics at patch level measure and characterize the spatial character and context of patch, parameter including the size and shape of each individual patch. Whereas class metrics measure, the characteristic of a particular class (e.g. the number of patch for each class, the percentage of the landscape occupied by that class etc). Metrics at the landscape level measure for over all patch type or classes over the entire landscape. Landscape metrics can be used as indicators for watershed integrity, landscape stability, resilience, biotic integrity and diversity (McGarigal, *et al.,* 2002). In Europe, the Joint Research Centre of the European community has suggested metrics based approaches utilizing remotely sensed image used to develop biodiversity indicators at the landscape level (JRC, 1999).Many literatures indicated that so far varieties of landscape metrics have been developed. However, the most commonly used metrics include area, patch density, patch size and variability, edge, shape, nearest-neighbour, and diversity metrics (McGarigal and Marks,1994). In this study different metrics to characterize the savanna landscape composition and spatial configuration at different spatial and temporal was used

2.6 Land use and land cover change in Ethiopia

In Ethiopia studies relating to LUCC change using remote sensing tool are scarce and so far only a few studies have documented on LUCC change in time and space. Most of the studies were based on aerial photography, satellite imageries, and socio-economic questioner studies. Several studies in the country indicate intensity of land use has changed over time. Since agriculture is the major economy of country where 85% of the population depends on farming and more than 85% of the total export income of the country comes from the agricultural sector (Khairo *et al.,* 2005). Many studies have indicated an expansion, intensification of agricultural land, and settlement have expanded at the expense of natural vegetation, including forest, shrubby grassland and grassland in north part of Ethiopia (Gete and Hurni 2001; Belay, 2002; Hadgu, 2008), in central highland (Girmay 2003; Amsalu *et al.,* 2007), rift valley area (Rembold *et al.,* 2000) are the major change observed over the last 4-5 decade. Shibru *et al.* (2003) reported the effect of LUCC in causing major gullies and quantified the rate expansion and their effect on the livelihood of people in eastern and central highland of Ethiopia. Similarly many studies reported there was depletion of natural vegetation and reduction of habitat structure over the past 4-5 decade. For example FAO, 2001 estimate the annual rate of deforestation in Ethiopia in the range of 36,600 to 40,000 hectare.

Like other part of Ethiopia, there is no much extensive studies relating to land cover change in arid and semi arid ecosystem of Ethiopia using remote sensing tool and of a few of these have been carried out in the arid and semi arid savanna ecosystem. Such studies include the work of Bedru (2006), Efrem (2009), Aynekulu, *et al.,* (2009), Kebede (2009) and Direse *et al*, (2010). In these studies they used aerial photography, Landsat MSS, TM and ETM+ images and ASTER imageries from early 1970's to 2007's to analyses LUCC change, habitat assessment, vegetation change and biodiversity assessment in arid and semi arid region of Ethiopia. The studies indicated that there were more active LUCC change and the intensity of land use has change over time for example Diress *et al*. (2010) in his studies clearly indicated that arid and semi-arid rangeland in Northern Afar region of Ethiopia experienced substantial and increasing rate of land use and cover change during 35 years from 1972 to 2007. There have been persistent changes both spatially and temporally, resulting in 47% of the total area experiencing transitional change among the land cover type. The same author further reported that a rapid reduction in woodland cover (97%) and grassland cover (88%) took place between 1972 and 2007. Bush land cover increased more than threefold, while the size of cultivated land increased more than eightfold. Bare land increased moderately, whereas bushy grassland and scrubland remained stable. Similarly, Bedru (2006) reported in the arid and semi arid middle rift valley of Ethiopia, from 1973 to 2006, the area of cropland doubled at the expense of woodland and wooded-grassland in both of the study sites and deforestation and forest degradation took place from 1973–1986; woodland cover declined from 40% to 9%

in one of the his study sites, while the other lost all of its original 54% woodland cover.

In overall most researchers pointed out that, population pressure, expansion of crop land, deforestation, recurrent drought, government policies, land degradation, macroeconomic activities and natural factors were the major LUCC driving force in Ethiopia particularly in arid and semi-arid environment. The alarming nature of these changes is reflected in a decrease in biodiversity, the livelihood food insecurity of local communities up to food aid, poverty and environmental degradation at local level. These problems were particularly worse in the arid and semi rangeland of Ethiopia due to high climatic variability and anthropogenic disturbance of environment. Thus, studies of the magnitude, rate, pattern, cause and socioeconomic implication of land cover dynamic at the local level like pastoral area of Borena is extremely essential for designing of effective pastoral land management strategies and polices.

3 DESCRIPTIONS OF STUDY AREA AND DATA

3.1 Description of study area

The study was conducted in Borana rangeland, Southern Oromiya, Yabelo. The Borana rangelands are located in the southern part of the Ethiopian lowland and it covers a total land of 95,000km².Yabelo district is found in central Borana rangeland of south Ethiopia (Coppock, 1994) and the district is situated 570 km south of Addis Ababa (capital town of Ethiopia) and it covers an area of about 5523km².The district is borders Hagere Mariam in North, Arerro in East, Dire in south and Teltele district in West respectively. The areas are predominantly occupied by pastoral people, whose livelihood is mainly dependent on extensive livestock production; mainly keep cattle (232,949) along with goat (99,681), sheep (39,043) and camel (22,972). The Booran are the dominant pastoralist ethic group, this group had well established and organized indigenous system on water technology, grazing land management for example, Borana pastoralist classify their grazing land both spatially and temporally. Furthermore they had a highly organized and durable social organization of the gada system.

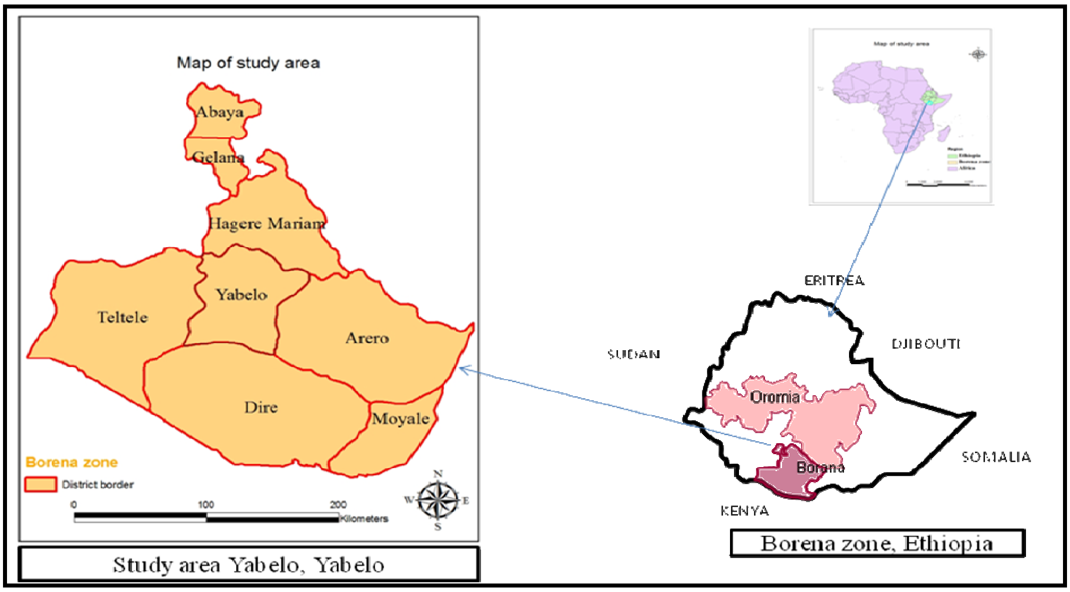


Figure 2 Map of study area, Yabelo

3.2 Climate and land use

The climate of the area is categorized under arid and semi arid agro ecology. Rainfall data obtained from National Metrological Agency (NMA) (1980 to 2004) indicated that in Yabelo mean monthly rainfall ranged from 9.17mm to142.1mm (Figure 3 and Table1). The average annual rainfalls varied and mean annual rainfall (526.75mm). Rainfall is bimodal with 60% of the annual rainfall occurring between March and May (main rainy-season) followed by a minor peak between September and November (small rainy-season). Mean annual temperature of the area varied from 19°C to 24°C. However, the mean maximum and minimum temperature is 27.74°c and 16.45°c, respectively (Figure 4 and Table 1). A drought is common in the area and has occurring frequently some of the drought occurred years in the study area were 1975/1976, 1979/1980, 1984/1985, 1987/1988, 1991/1992, 1995/1996, 1999/2000 (Sabine *et al.*, 2005). Out of the total land area, 10% is arable, 60%rangelands, 10% forest, and the remaining 20% is considered degraded or otherwise unusable.

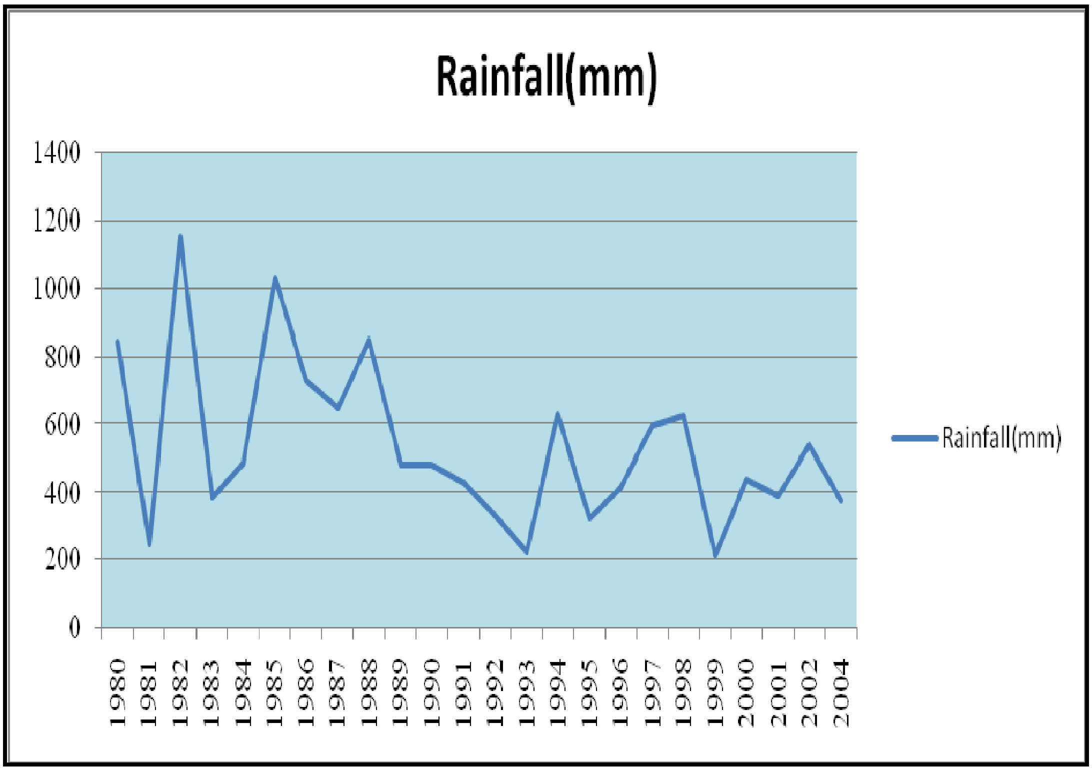


Figure 3 Mean annual rainfall (mm) of Yabelo district from 1980 to 2004, Borana rangelands, Ethiopia [sources*:* National Metrological Agency (NMA)]

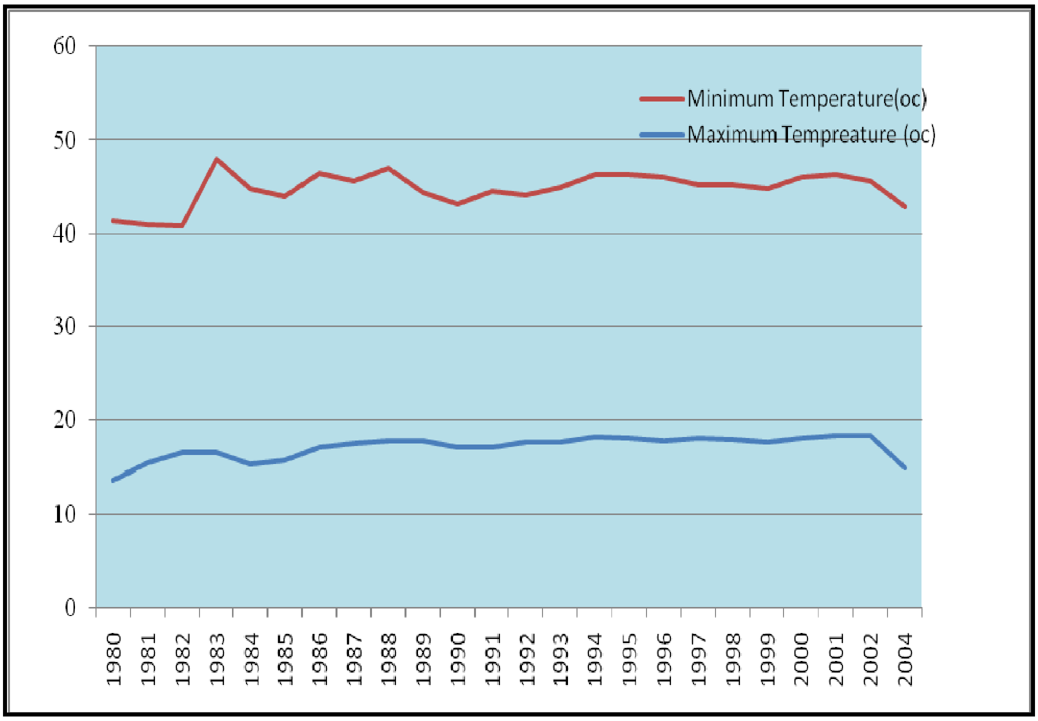


Figure 4 Mean annual minimum and maximum Temperature of Yabelo district from 1980 to 2004, Borana rangelands, Ethiopia (sources: NMA*)*

Table 1 Mean monthly rainfall in mm (1980-2004) and the coefficient of variation, maximum and minimum temperature in Yabelo, Ethiopia

Month	J	F	M	A	MA	J	JUL	AU	SEP	O	N	D
RF	12.91	21.19	43.79	148.09	86.77	17.40	18.24	9.43	13.87	58.15	74.80	33.96
Max Tep	31.41	32.05	31.14	27.82	26.31	24.83	24.48	25.65	26.29	26.41	27.37	29.02
MinTep	19.06	17.81	18.48	17.57	16.97	16.19	15.69	15.44	16.19	16.93	17.57	16.30
RF CV	176	98	97.95	79.53	99.51	124.1	325.5	88.11	141.7	83.65	78.01	108.9

CV= Coefficient of Variation; J= January; F2=February; M= March; A= April; MA= May; J= June; JUL= July; AU=August; SEP= September; O= October; N= November= December= ;(Sources: NMA), RF=Rainfall, MaxTep=Maximum temperature, Min Tep=Minimum Temperature, RF CV= Coefficient of variation for rainfall

3.3 Topography and vegetation

The topography is consists of isolated mountains, valleys and depression, and an altitude range of 1000 to 1,700 m.a.s.l. The Borana plateau is dominated by savanna type of vegetation containing a mixture of perennial herbaceous and woody plant (Coppock, 1994).These savanna communities are varying from grassland to bush encroached area. The variation in woody and herbaceous materials as well as marked shifts in composition that occurred in response to grazing, browsing, burning and droughts or various combination of these. According to Haugen (1992) woodland of Yabelo rangelands are characterized by species from the genera *Combretum* and *Terminalia*, whereas the bush land and thicket, which cover major parts of the Borana lowlands, are dominated by *Acacia* and *Commiphora* species. Besides, species of the genera *Boscia, Maerua, Lannea, Balanites, Boswellia* and *Aloe* are common in the study area. The dominant herbaceous plants were perennial grasses. The Borana rangeland is a water-limited environment with the major source of water for both human and livestock were wells and ponds**.** The soils of the study area are predominated with sandy-loam textural classes**.** The black clay soil (Vertisols) cover nearly 30% of the area and other types of silty soil occupied the balance. The valley and bottomlands are occupied by cracking and volcanic light colored soils having slight drainage impedance, relatively high fertility and high water holding capacity (Coppock, 1994).

3.4 Data type

The main data sets used in the study were three different time series of satellite data. These include the Landsat Thematic Mapper (TM) of 1987, 1995 and Landsat Enhanced Thematic Mapper plus (ETM+) of 2003.These images were obtained from USGS, free of cost through the Global Land Cover Facility (GLCF) archive (http://www.landcover.org). A summary of acquired imagery is presented in Table2

Table 2 Description of Landsat image data used in the study

Reference year	Sensor	Resolution	WRS path/raw	Date of acquisition
1987	Landsat TM	30m	168/057	Feb,09,1987
1987	Landsat TM	30m	168/056	Feb,09,1987
1995	Landsat TM	30m	168/057	Jan,30,1995
1995	Landsat TM	30m	168/056	Jan,30,1995
2003	Landsat ETM+	30m	168/057	Jan,12,2003
2003	Landsat ETM+	30m	168/057	Jan,12,2003

For change detection analysis, it is important to acquire imagery of anniversary dates and similar season to minimize variation in reflectance of a feature caused by season and sun-angle differences (Coppin *et al.* 2004). Even though selection of appropriate imagery is an important component for successful LUCC change analysis, data selection was primarily determined by availability of imagery covering the study area. The TM and ETM^+ imagery used in this study were cloud free and acquired for month of January to February which is dry season image.

Unlike the MSS sensor of Landsat, the TM and ETM+ sensors used were advanced, multispectral scanning devices designed to achieve higher image resolution, sharper spectral separation, and greater radiometric accuracy and resolution. The wavelength of the TM and ETM+ sensor ranges from the visible, through the mid-IR, into the thermal-IR portion of the electromagnetic spectrum. It has a radiometric resolution of 8 bits; these sensors have a spatial resolution of 28.5 meter for all the bands except band 6 which has a spatial resolution of 120 m in TM and 60m for ETM+. The ETM+ has an additional panchromatic band with 15 meter spatial resolution. The satellites orbit of TM and ETM+ sensor an altitude of 705km and provide 16-day repletion, covering 185km swath. The application of the spectral bands of Landsat TM and ETM was shortly summarized in Table 3.

Table 3 Image spectral bands of Landsat TM and ETM and their importance

Wave length of band (µm)	Band name	Spatial Resolution m	Application
0.45-0.56	Blue	30m	-Soil and vegetation discrimination and -Bathymetry and coastal mapping -Cultural/ urban features
0.52-0.66	Green	30m	-Green vegetation mapping and cultural/urban features
0.63-0.69	Red	30m	-Vegetated and non vegetated mapping -Cultural/urban features
0.76-0.90	NIR	30m	Delineation of water body, soil moisture discrimination
1.55-1.75	MIR	30m	Vegetation moisture discrimination -Soil moisture discrimination and differentiation of snow and ice
10.4-12.5	TIR	120m(60m ETM+)	Vegetation and soil moisture analysis -Thermal mapping
2.08-2.35	MIR	30m	-Discrimination of minerals and rocks -Vegetation moisture analysis

Source: ERDAS, 1999

3.4.1 Reference data

It is necessary to use different reference data sets to develop training samples, classification and accuracy assessment. It is true that ancillary data such as high resolution imageries and existing map of the study area was essential for classifying and assessing the accuracy of the classification. In relation to this study, land use map of study area, road network, district boundary, protected area map, Google earth map and other meteorological data were used as ancillary data for classification, accuracy assessment and LUCC change analysis. The land use map, road network were acquired from International Livestock Research Institute (ILRI) (http://64.95.130.4/gis/search.asp[2]) and Biomass Inventory Planning Project. Furthermore, topographic map at the scale of 1:50000 which cover the entire study area was obtained from the Ethiopian Mapping Agency. In addition, over 442 GPS point ground truth data were gathered from study area and used as accuracy assessment.

[2] http://64.95.130.4/gis/search.asp

4 METHODOLOGY

Imageries and ancillary data were processed to determine the LUCC change, pre- and post-classification method was used to detect change in land use and land cover class. The flow chart of the procedure for image pre processing, enhancement, classification, accuracy assessment, and spatial metrics analysis was depicted in Figure 5. Data from remotely sensed image obtained from different sources are not usually ready to use directly, because of satellite data obtained from various sensors undergo some degree of geometric and radiometric distortion due to earth rotation, platform instability, atmospheric effect, etc. Thus need to a series of preprocessing steps to remove errors associated with acquisition of multi-temporal data and to correct the error during scanning, transmission and recording of the data. The preprocessing steps used are geometric correction, image registration (georeferencing); mosaicking, and subsetting unnecessary features, edge maching (ERDAS, 1999).

Image registration and Geometric correction; Image registration is the process of transforming the different set of data into one coordinate system. All the Landsat TM and ETM+ images had been already orthorectified by the image supplier to Universal Transverse Mercator (UTM) projection on the WGS84 datum, UTM Zone 37. For further analysis image to image registration were done using IDRIS ANDES and edge matching also done taking 1987 image as reference image using AUTOSYNC tools of Erdias imagine soft ware.

Mosaicking and Subsetting; Since a single image was not covering the spatial extent of entire study area, more than one satellite image was needed to cover the entire study area and mosaicking two images was necessary, thus two scenes of dry season images of the year 1987, 1995 and 2003 were mosaiced on a band by band basis using mosaicing tool. However, the resulting mosaic image was much larger than the study area. Thus, it was necessary to reduced the size of the image and include only the area of interest. Image subsetting helps to cut out the unnecessary data from the file and increase the data-processing speed. The vector file defining the boundary of the study area was used to mask the image and cut the area of interest from all satellite imagery

Image Enhancement; Image enhancement deals with the procedures of making a raw image more interpretable for a particular application. There are a number of method can be used to undertake enhancement of image. In this study, simple contrast, haze reduction, linear stretching, and histogram matching were used.

Radiometric correction; Radiometric correction can be achieved through many methods such as detailed correction of atmospheric effect, calibration to surface reflectance, and bulk correction of atmospheric effect (dark object subtraction). Detailed correction of atmospheric effect requires detailed atmospheric information such as humidity and temperature at time of image acquisition, which is not easily available. Calibration to surface reflectance requires a spectral library of the darkest and brightest object in the image. Unfortunately no spectral library and no field spectrometer data have been available. In this study, radiometric correction such as linear stretching, haze reduction, histogram matching was done.

Spatial resembling: Since the images have different spatial resolution, it is difficult to carry out change detection analysis. Therefore to have the same resolution in all periods of image, spatial resembling was done using nearest neighbor algorism of spatial resembling tool and the spatial resolution of all images become 30m by 30m which is important to perform change detection

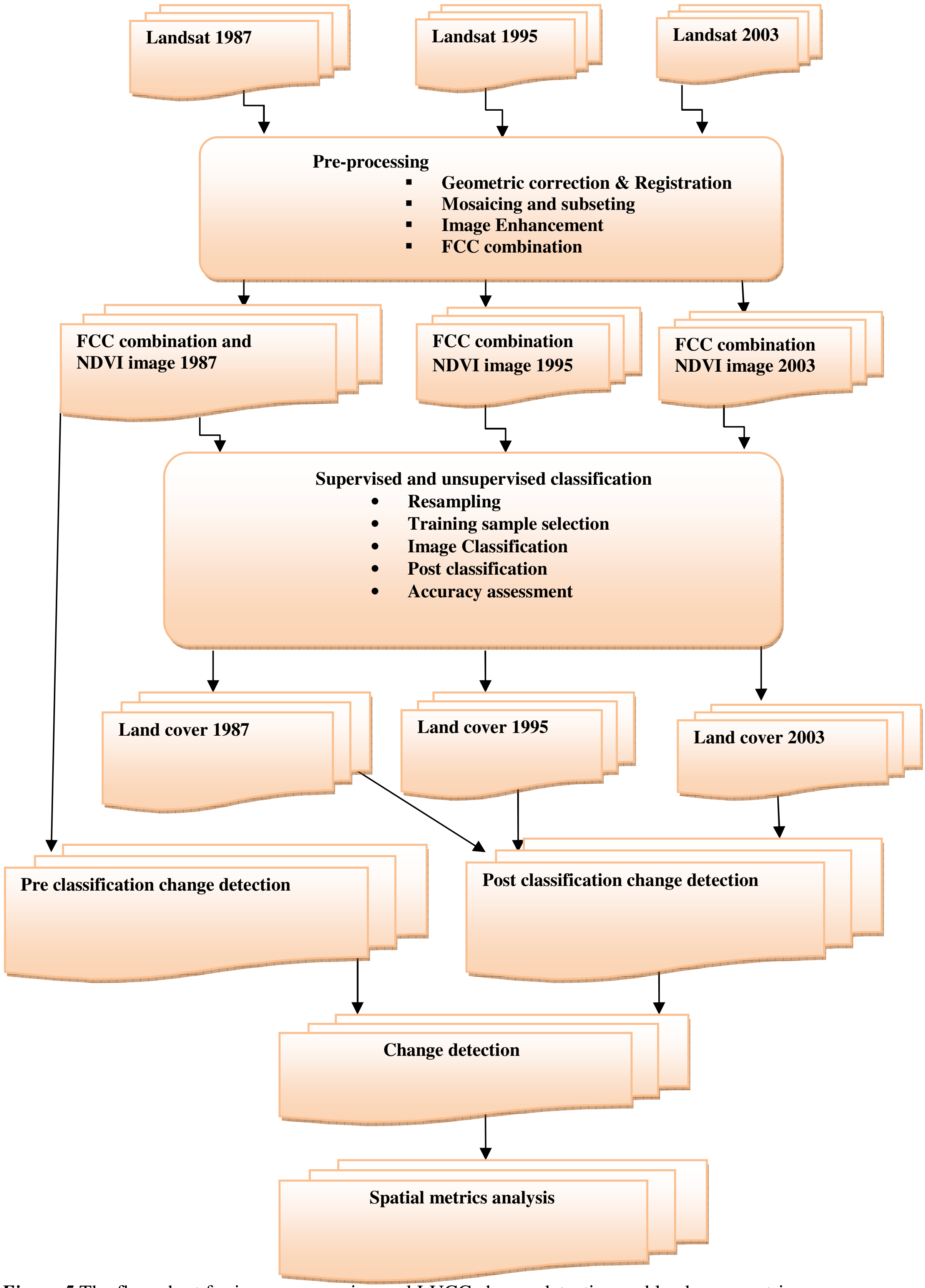
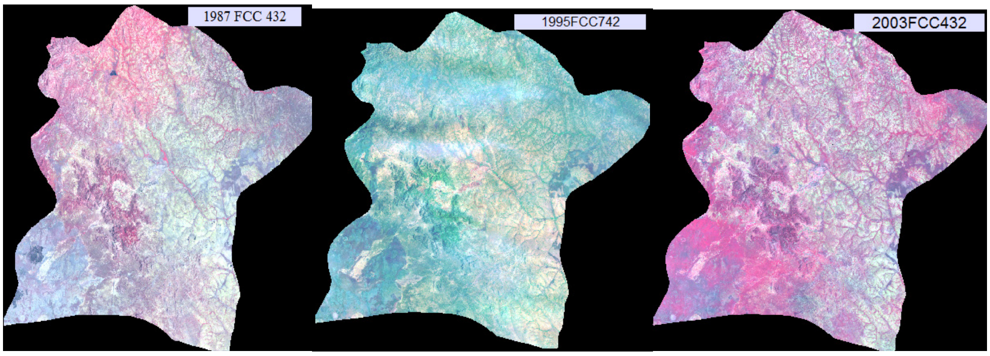


Figure 5 The flow chart for image processing and LUCC change detection and landscape metrics Analysis

Band Selection for FCC (false color composite): After tested different band combination, RGB 4, 3 and 2 was selected for 1987 TM and 2003 ETM^{+} and RGB 7, 4 and 2 was used for TM 1995. It has been found that standard RGB 4, 3 and 2 band combinations provide very useful information for land use mapping. Similarly, a false color composite of RGB 7, 4 and 2 is particularly suitable for provide useful information for arid and desert region (Figure 6)



1987FCC432 1995FCC742 2003FCC432

Figure 6 RGB composite Landsat images used for classification

Normalized Difference Vegetation Index: Normalized Difference Vegetation Index (NDVI) is a data transformation which reduces data dimensionality. NDVI is the most widely used of all vegetation indices because it requires data from only the red and near-infrared portion of the electromagnetic spectrum, and it can be applied to virtually all remotely sense multi-spectral data types. In this study NDVI was computed to quantify the general vegetation condition such as relative greenness and change detection (ERDAS, 1999). The NDVI is defined as reflectance in the near-infrared (NIR) range minus reflectance in the visible red (R) spectrum portion divided by their sum. It is expressed mathematically as follows

$$NDVI= (NIR - R)/ (NIR+ R)$$

The NDVI computed from the equation above for all the images. In the resulting image, vegetated areas will generally have high values for the NDVI index because of their relatively high reflectance in NIR and low reflectance in the visible wavelengths. On the contrary, water and bare soil will have higher reflectance in visible wavelength than in the NIR, thus these features yield negative and near-zero values (ERDAS, 1999). NDVI is not always suitable especially in semi-arid area where the vegetation cover is very sparse and soil background in reflectance value is very high (mixed pixels).Vegetation indices are likely to underestimate live biomass in desert, they are insensitive to nonphotosynthetic vegetation and are sensitive to soil color (Okin and Roberts, 2004).

Land class nomenclature: The land cover classes used in this study was adopted from the classification scheme used by the Ministry of Agriculture of Ethiopia and based on classification criteria for East African rangeland (Pratt and Gwynne, 1977) and based on the previous studies made in the similar study area (Diress *et al,* 2010, Getachew *et al*., 2010). For the sake of simplicity, land class nomenclature was modified into seven classes and summarized in Table 4.

Table 4 Land use and land cover class nomenclature used in the study area

Land use/land cover	Description
Wood land	Land with woody species cover >20% (height ranges 5–20m), areas with trees mixed with bushes and shrubs, with little use especially for cattle. Those sites where woody cover is fully mature and herbaceous plants have been almost eliminated.
Bush land	Land with >20% bush or shrub cover (<5m in height)
Shrubby grassland	The shrubed grasslands are former grassland sites where shrubs and bush have increased in density to be co-dominant with herbaceous plants in terms of cover
Grassland	Grassland with <20% bush or shrub cover, Grass and herb cover with scattered trees and shrubs, areas with permanent grass cover used for livestock grazing including communal and protected areas. They tend also to be open areas with good visibility on flat areas and hill slopes Another descriptive term would be mixed savanna.
Cultivated land	This unit includes cropping area
Bare land	Areas with no vegetation, which occur in rangelands including gullies and exposed rocks.
Settlement	Urban and rural settlements in the study area.

Image Classification

After the necessary image preprocessing, classification was computed. The classification of image was done using both unsupervised and supervised classification. Initially, unsupervised classification was used to get insight about the overall class and to identify the training site. The result of unsupervised classification was used as a guide for the selection of training site for supervised classification and it also gives preliminary information on the potential spectral clusters to be assigned to thematic classes. Finally, image was classified at pixel level using supervised classification of maximum likelihood classifier approaches. Seven land cover classes were identified, namely wood land, bush land, grassland, shrubby grassland, bare land, cultivation and settlement.

Post-classification enhancement: Post-classification enhancement such as filtering of the final classification result using different filter techniques to reduce the heterogeneity of the classified image is essential. However, filtering was not carried out in this study because it tended to generalize the classification to the extent that some mapping units, e.g., cultivation area and settlements totally disappeared. Duadaze (2004) and Su (2000) made a similar observation. Finally, maps were prepared using the ARC GIS 9.3 version. A post and pre classification comparison method was used for detecting of land use and land cover change where Landsat image for each year was classified and labeled independently and then comparison were made for the generated LUCC maps of 1987–1995, 1995–2003 and 1987-2003 the area of change also determined and compared.

Accuracy assessment

Land cover maps derived from classification of images usually contain some sort of errors due to several factors that range from classification technique to method of satellite data capture. Hence, evaluation of classification result is an important process in the classification procedure. In this study 230,132 and 80 GPS ground truth data were used to evaluate 2003, 1995 and 1987 classification map. Moreover, Google earth as well as Google map was used. Accuracy was assessed by using Kappa statistics of error matrix (Congalton and Green, 1999). An error matrix is a square assortment of numbers defined in rows and columns that represent the number of sample units assigned to a particular category relative to the actual category as confirmed on the ground. The rows in the matrix represent the remote sensing derived land use map, while the columns represent the reference data that was collected from field work. The Kappa statics of accuracy including overall classification accuracy, percentage of omission and commission error and kappa coefficient (Congalton and Green, 1999). Error of omission is the percentage of pixels that should have been put into a given class but were not. Error of commission indicates pixels that were placed in a given class when they actually belong to another. These values are based on a sample of error checking pixels of known land cover that are compared to classification on the map. Error of commission and omission can be expressed in terms of user's accuracy and producer's accuracy. User's accuracy represents the probability that a given pixel will appear on the ground as it is classed, while producer's accuracy represents the percentage of a given class that is correctly identified on the map. On the other hand, Kappa coefficient is a measure of the interpreter agreement. The Kappa statistics incorporates the off-diagonal elements of the error metrics (i.e., classification errors) and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance(Foody, 2002).

Spatial pattern analysis

Landscape change is a fundamental component of landscape dynamic (Forman and Godron1986).The arid and semi arid savanna ecosystem of Borena rangeland have been under landscape change over period of time as a consequence, the livelihood of pastoral people have changed significantly in recent decade (Desta and Coppock, 2004). Quantifying landscape structure is a prerequisite to the study of landscape function and change. In relation to these, the spatial and temporal dynamic of landscape structure of study area was determined using spatial metrics. Spatial metrics are algorithms used to quantify spatial characteristics of landscape or classes of patches (McGarigal *et al.,* 2002). It is developed in the late 1980s based on information theory and fractal geometry (Herold *et al.,* 2003). A number of spatial metrics such as class area(CA), Number of patches(NP),Patch Density(PD), Largest Patch Index (LPI), Percentage of landscape(PLAND), Euclidian Mean

Nearest Neighbor Distance(EMN_NN), Mean Patch Fractal Dimension (FRAC_AM), Patch Richness(PR), Shannon's Diversity Index (SHDI), Shannon's Evenness Index(SHEI) which have already been used in different studies (Herold *et al.,* 2003) were adopted and used (Table 5). These metrics describe the composition and configuration of landscape pattern and also used to measure, the landscape fragmentation, dominancy, and diversity. The metrics were computed for each land cover map of 1987, 1995 and 2003 at the class and landscape level. Even though many of the class and landscape indices represent the same fundamental information, class indices represent the spatial distribution and pattern within a landscape of a single patch type; landscape indices represent the spatial pattern of the entire landscape mosaic, considering all patch types simultaneously. All these metrics were calculated using the FRAGSTAT software3.3 public domain software (McGarigal *et al*., 2002).

Table 5 Class and landscape metrics adopted and used in this study

Metrics	Description
Class Area (CA\TA)	CA is a measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch type.
Patch density (PD)	Equals the number of patches of a specific land cover class divided by total landscape area
Number of Patch (NP)	The number of patches of the corresponding patch type (class) Simple measure of the extent of subdivision or fragmentation of the patch type
Largest Patch Index (LPI)	LPI the percentage of total landscape area comprised by the largest patch
Euclidian Mean Nearest Neighbor Distance (ENN_MN)	MNN equals the distance(m) mean value over all patches to the nearest neighboring patch, based on shortest edge to edge distances from cell center to cell center
Percentage of landscape (Pland)	Quantifies the proportional abundance of each patch type in the landscape. Like total class area, it is a measure of landscape composition important in many ecological applications.
Landscape shape index (LSI)	Provides a simple measure of class aggregation or clumsiness LSI = 1 when the landscape consists of a single square or maximally compact (i.e., almost square) patch of the corresponding type;
Shannon's diversity index (SHID)	SHID quantifies the diversity of the landscape based on two components: the number of different patch types and the proportional area distribution among patch types
Patch richness(PR)	PR equals the number of different patch types present within the landscape boundary. Patch richness is perhaps the simplest measure of landscape composition, but note that it does not reflect the relative abundances of patch type
Shannon's evenness index (SHDI)	SHDI is expressed such that an even distribution of area among patch types results in maximum evenness. As such, evenness is the complement of dominance. SHDI = 0 when the landscape contains only 1 patch (i.e., no diversity)

Source: McGarigal, *et al.,* 2002

5 RESULT AND DISCUSSION

5.1 Result

This chapter presents the result of LUCC change from classification of Landsat images and mainly focuses on result of classification accuracy assessment, analysis of the nature, extent and rate of land cover change, land use and cover change detection and spatial pattern of land cover dynamic.

5.1.1 Classification accuracy assessment

Accuracy assessment is very important to measure the reliability of classification. Accuracy assessment requires determination of classes based on reference data which have been gathered by collecting ground truth derived from field work or the analysis of large scale maps or the visual interpretation of imagery. The reference classes are compared with the result of classification and the ratio of correctly versus wrongly classified pixels are calculated for each class. In this study 80, 132 and 230 GPS of ground truth data which collected during field work were used as reference for 1987, 1995, and 2003, respectively. Furthermore, Google earth and Google map image was used as supplementary reference information. Based on these reference data and the classified maps accuracy for land use and cover classification of was performed by constructing confusion matrices (Table 6, 7 and 8). The resulting Landsat land cover map of the three periods of 1987, 1995 and 2003 had an overall classification accuracy of 81.82%, 84.55% and 81.30% respectively (Table 6, 7 and 8).The Kappa coefficient usually lies on a scale between 0 and 1, where one indicate complete agreement, and is often multiplied by 100 to give a percentage measure of classification accuracy, Kappa values has usually classified into 3 groups: a value greater than 0.80 represents strong agreement, a value between 0.40 and 0.80 represents moderate agreement, where as a value below 0.40 represents poor agreement (Rahman, *et al.,* 2006). Based on this, all the LU/LC classification of this study lies on the kappa coefficient that shows strong agreement. This was reasonably good overall accuracy and accepted for the subsequent analysis and change detection. User's accuracy of individual classes ranged from 71.43 to 90% for 1987 classified map whereas 76.92% to 88% for 1995 and 42.86% to 95% for 2003. Producer's accuracy ranged from 75% to 83.33% (1987), 50% to 96% (1995), and 54.29% to 92.86 % (2003). Overall kappa statistics also computed for each classified map to measure the accuracy of the results, thus 76.71%, 81.46% and 77.84% was quantified for 1987, 1995 and 2003, respectively. The spectral overlapping and similarity of some surface feature was one source of misclassification. Classes like woodland and bush land showed closer and overlapping spectral in some place. Similarly, grassland, bush land and shruby grass land also showed overlapping spectral response. Furthermore, bare land, settlement and cultivation also showed similar spectral closer in some area and difficult to discriminate. This might be related to heterogeneous and diversified vegetation cover and land use pattern of the study area. In the study area vegetation is found in mixed form and diversified type (Annex Figure 1). Under this circumstance the chance of spectral overlap and misclassification is high. Since the study area is arid and semi-arid pastoral area where pastoral production often practiced. In an arid, highly variable and unpredictable environment, movement and migration in search of feed and water has been a key strategy for pastoralists. Mobility is part of production system in the study area and the direction and pattern of movement of pastoralist in study area is seasonal but depending on mainly on the available of water and pasture. The time and frequently of mobility has occurred during dry season mainly from December to March. Thus, it is important to recall our image; all the images were taken during the dry season (January and February) when most of the natural vegetation and cultivated crops in the landscape has undergone dry (Annex figure 1).Hence, during dry period there could be high chance of land feature to be spectral similar and this might contribute for misclassification of image.

Table 6 Landsat TM classification accuracy for 1987

LC	WL	BL	GR	SGL	BL	CU	SET	UA%
WL	17	2	1	-	-	-	-	85.00
BL	1	9	-	-	-	-	-	90.00
GR	3	-	25	2	-	2	-	83.33
SGR	-	-	1	6	1	-	-	75.00
BL	-	-	3		10	-	1	71.43
CU	-	-	-	-		6	-	75.00
SET	-	-	-	-	1	-	5	83.33
RT	21	11	30	8	12	8	6	
PA (%)	80.95	81.82	83.33	75.00	83.33	75.00	83.33	
Kappa	0.80	0.89	0.75	0.73	0.66	0.73	0.82	

Overall classification accuracy = 81.82%
Overall Kappa Statistics = 0.7671

WL: Woodland; BL: Bush land, GR: Grassland: SGR: Shrub grassland, BL: Bare land, CU: Cultivation: ST: Settlement, RF: Reference total, UA: User accuracy, PA: Producer accuracy

Table 7 Landsat TM classification accuracy for 1995

LC	WL	BL	GR	SGL	BL	CU	SE	CT	UA
WL	17	2	1	-	-	-	1	21	81.00
BL	2	20	-	-	-	-	2	24	83.33
GR	-	3	27	-	1	-	2	33	81.82
SGR	-	1	-	8	-	-	1	10	80.00
BL	-	1	-		13	-	1	15	86.67
CU	-	2	-	1	-	10	-	13	76.92
SET	-	-	-	-	-	1	7	8	88.00
RT	19	29	28	9	14	11	14	110	
PA (%)	89.47	68.97	96.43	88.8	92.86	91.0	50.0		
Kappa	0.79	0.89	0.76	0.78	0.84	0.75	0.81		

Overall Classification Accuracy =84.55%
Overall Kappa Statistics = 0.8146%

WL: Woodland; BL: Bush land, GR: Grassland: SGR: Shrub grassland, BL: Bare land, CU: Cultivation: SE: Settlement, RF: Reference total, UA: User accuracy, PA: Producer accuracy, CT: Classification total

Table 8 Landsat TM classification accuracy for 2003

LC	WL	BL	GR	SGL	BL	CU	SET	CT	UA
WL	35	5	0	1	0	0	5	41	85.37
BL	6	38	2	0	0	1	0	47	80.85
GR	1	2	42	0	1	0	0	46	91.30
SGR	0	0	1	9	3	1	7	21	42.86
BL	0	0	0	0	18	0	8	26	69.23
CU	0	1	0	0	0	26	1	28	92.86
SET	0	0	0	1	0	0	19	20	95.00
RT	42	46	45	11	23	28	35	230	
PA %	83.33	82.6	62.61	81.82	78.3	92.86	54.29		
Kappa	0.82	0.76	0.89	0.40	0.66	0.91	0.94		

Overall Classification Accuracy = 81.30%
Overall Kappa Statistics = 77.84%

WL: Woodland; BL: Bush land, GR: Grassland: SGR: Shrub grassland, BL: Bare land, CU: Cultivation: SE: Settlement, RF: Reference total, UA: User accuracy, PA: Producer accuracy, CT: Classification total

5.1.2 Land use and land cover classification 1987-2003

Land use and cover classification map result for 1987, 1995 and 2003 satellite image for Yabelo district is presented in Table 9 and Figure 7, 8, 9 and 10. The study area was classified into seven different land use class, thus include woodland, bush land, grassland, shrubby grassland, bare land, cultivation and settlement area. Of the classified land use and cover map in 1987 grassland was the dominate land use and cover type which account about 40.02% (2172km^2) which was followed by woodland 22.29%(1209.48km^2) and bush land 22.06%(1197.12 km^2). A substantial proportion of land was also covered by shrubby grassland 13.14% (713.06 km^2) (Table 9). Bare land 2.03 %(110.14 km^2), cultivation 0.31% (16.58 km^2) and settlement 0.15% (7.86 km^2) were covered small proportion of the study area. In 1995 TM satellite image grassland also the dominate land use type which account about 35.48 %(1925.24 km^2) and followed by woodland which estimated about 27.26% (1478.93 km^2), whereas small proportion of land were covered by bare land, cultivation and settlement (Table 9). In 2003 Landsat ETM+ image showed that although grassland was the dominate land cover class, it had showed progressive reduction from 40.03 %(1987) to 35.48 %(2003) and followed by bush land 26.61% which showed rapid increment in the study area. Shrubby grassland cover about 6.98% of the area which indicated doubled fold reduction in cover from 13.14% to 6.99%. Although cultivation and settlement had covered small proportion of the study area, it had showed rapid increment. On the other hands, bare lands were showed little change (Table 9).

Table 9 Area statistics and percentage of the land use/cover units in 1987-2003

Land Cover	1987	Cover %	1995	Cover %	2003	Cover %
Wood land	1209.48	22.29	1478.93	27.255	1369.46	25.24
Bush land	1197.12	22.06	1161.19	21.40	1443.98	26.61
Grassland	2172.06	40.03	1925.24	35.48	1994.39	36.75
Shrubby grassland	713.06	13.14	705.31	12.99	379.03	6.99
Bare land	110.14	2.03	109.08	2.01	108.18	1.99
Cultivation	16.58	0.31	28.10	0.52	59.29	1.09
Settlement	7.86	0.15	18.68	0.35	71.96	1.33
Total	5426.30	100.00	5426.52	100.00	5426.30	100.000

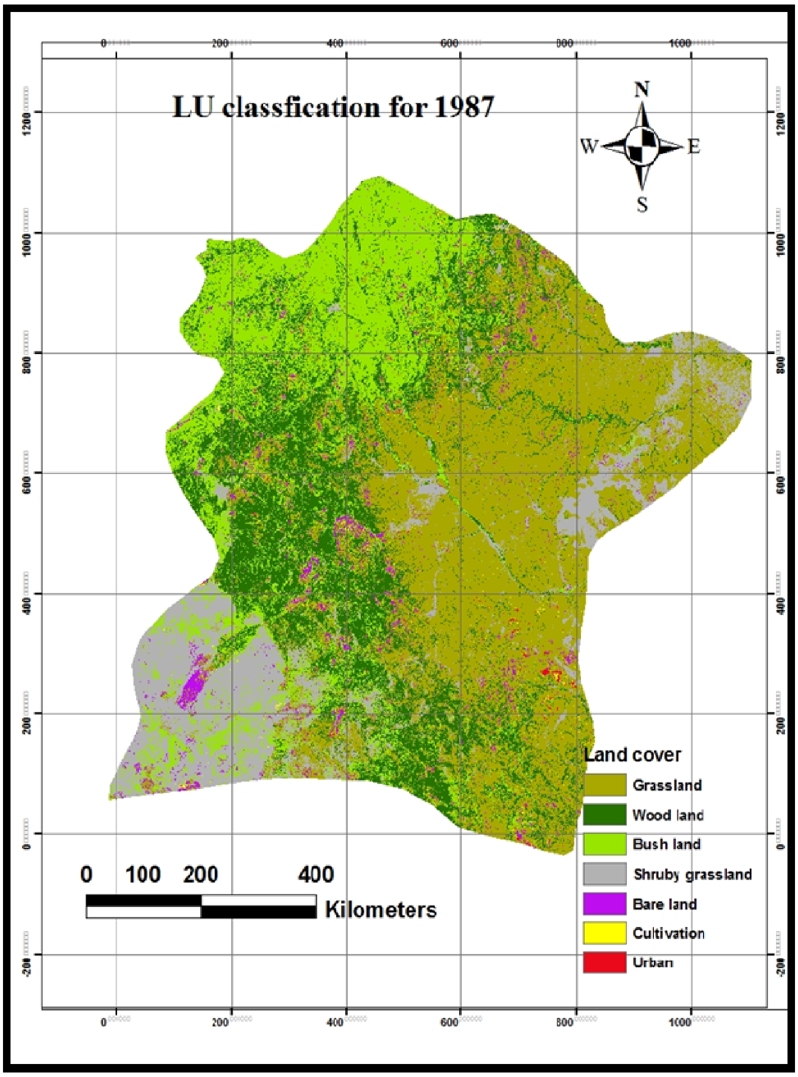


Figure 7 Land use land cover classification map for 1987

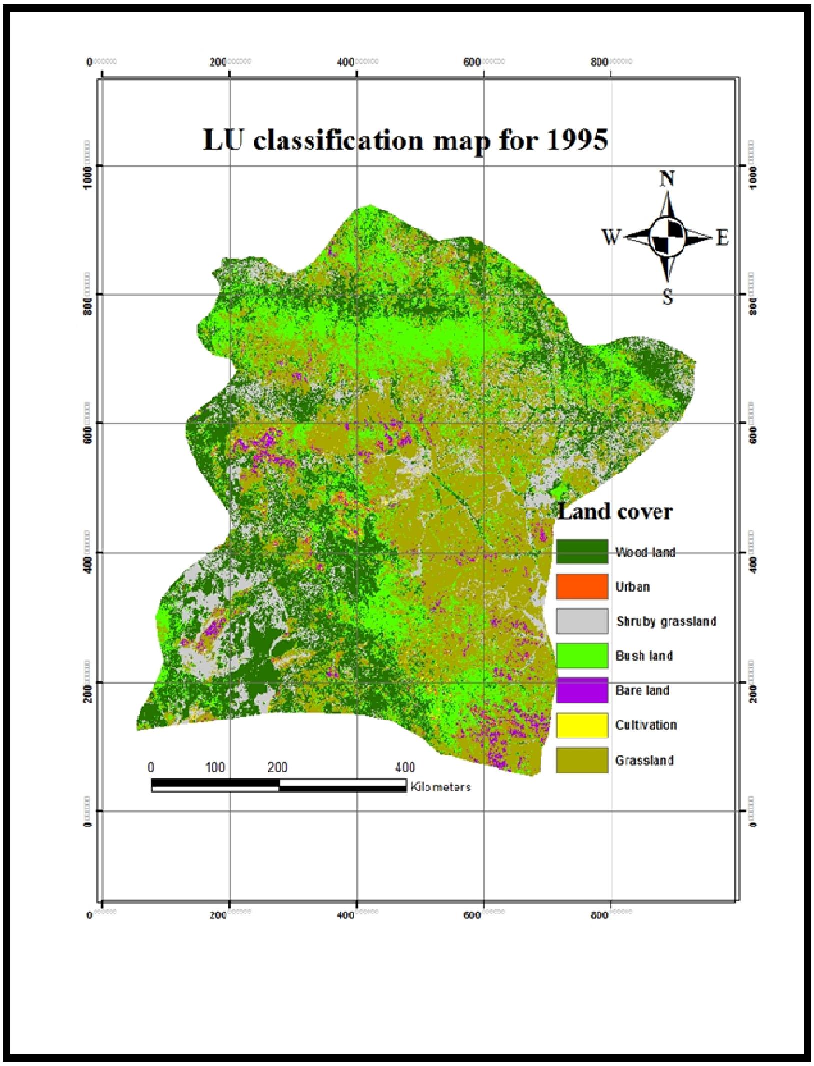


Figure 8. Land use land cover classification map for 1995

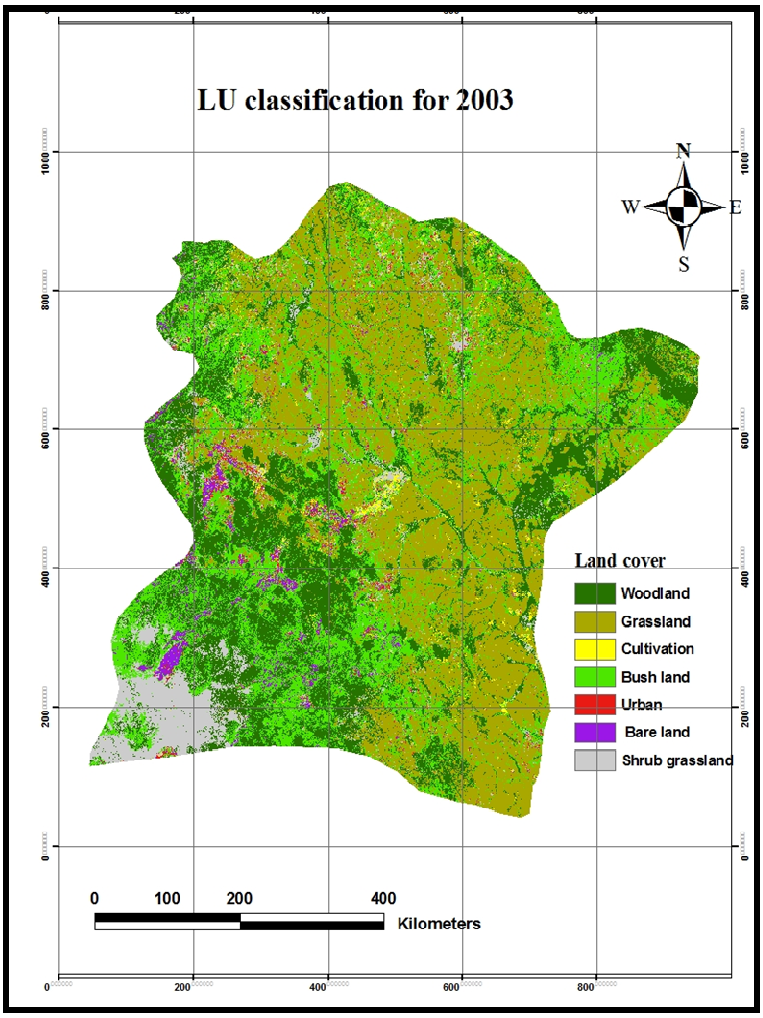


Figure 9 Land use land cover classification map for 2003

In order to determine the magnitude, extent and rate of change of land use and land cover change dynamic in the study area, the following variables were calculated and used. These variables include Total Area (TA), Changed Area (CA), Change Extent (CE) and Annual Rate of change (CR). The variable was calculated as follows

CA=TA (t2)-TA (t1)

CE= 100x [CA/TA (t1)]

CR=CE/ (t2-t1)

Where t1 and t2 are the beginning and ending time of the land cover studies conducted and the result was presented in Table 10.

Result indicated a rapid expansion of woodland cover was recorded between 1987 and 1995 (22.28%) (Table 10), but then declined between 1995 and 2003(5.24%). In overall, during 1987 to 2003, woodland had reduced by 11.68%. Similarly, the proportion of bush land had moderately reduced by 3%, in the earlier period (1987–1995) than significantly increased to 24.84% in second period of studies (1995-2003). In general, over the years from 1987-2003 bush lands were increased by17.49% in the landscape. Grassland had showed rapid reduction (11.36%) in the first period than moderate increased during second period (4.81%). In overall, over the past 16-years rapid reduction of grassland (7.73%) cover in the savanna landscape was take place (Table 10). Unlike bush land, shrubby grassland showed significant reduction in the study period both in the first (1.09%) and second period of time (45.19%). In general, over 86.14% of reduction of shrubby grassland had been identified between 1987 and 2003. Bare land had showed little change over the past year from 1987 to 2003 and the change was consistence and less than 1%. Although cultivated area covered a small proportion of the landscape, rapid increment was observed over the past 16 years (72.49%) and dramatic increment had recorded in the second period of study (111.92%) than earlier time (69.52%). This suggesting that the Borana pastoralist have probably gradually shifted from a heavier dependence on livestock keeping to crop cultivation in some location.

Although settlement had small proportion of cover in the district significant increment (79.8%) over the past 16 years had observed. In both phase of study time remarkable growth of settlement had observed morethan100% times. The higher growth of urbazation was observed between 1995-2003 (249.34%) than1987 to1995 (137%) (Table 10). Over the past 16 years, both in the first and second period, cultivation (4.53) and settlement (4.98) had indicated highest positive trend of annual rate of change. On the other hand, shrubby grassland showed highest annual rate of change (-5.38) but in negative trend (Table 10).Of all land use and cover bare land had showed the lowest annual rate of change (-0.05) (Table 10). Over the study period from 1987 to 2003 grassland, woodland and, bush land changed annually with the rate of 0.48 (negative trend), 0.73 (negative) and 1.09 (positive trend) (Table 10).

Table 10 Overall amount, extent and rate of land cover change (1987-2003)

Land Cover	1987-1995			1995-2003			1987-2003		
	CA km^2	CE %	CR %	CA km^2	CE %	CR %	CA km^2	CE %	CR %
WL	269.44	22.28	2.78	-77.50	-5.24	-0.65	-159.97	-11.68	-0.73
BL	-35.93	-3.00	-0.38	288.43	24.84	3.10	252.50	17.49	1.09
GR	-246.83	-11.36	-1.42	92.64	4.81	0.60	-154.19	-7.73	-0.48
SGR	-7.75	-1.09	-0.14	-318.76	-45.19	-5.65	-326.51	-86.14	-5.38
BL	-1.06	-0.96	-0.12	0.26	0.24	0.03	-0.80	-0.74	-0.05
CU	11.52	69.52	8.69	31.45	111.92	13.99	42.97	72.49	4.53
SET	10.82	137.62	17.20	28.46	249.34	31.17	57.39	79.75	4.98

CA=Changed Area; CE=Changed Extent; CR=Annual rate of changed; WL: Woodland; BL: Bush land, GR: Grassland: SGR: Shrub grassland, BL: Bare land, CU: Cultivation: ST: Settlement

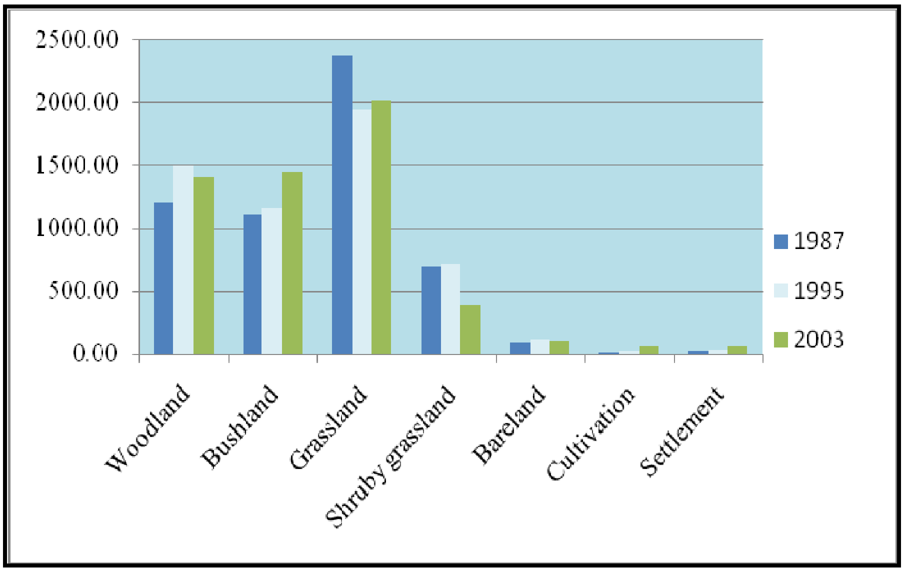


Figure 10 Nature of relative land cover changes 1987 to 2003

5.1.3 Change detection analysis

The LUCC change dynamic in Yabello, Ethiopia have detected and quantified by analyzing the classified multi-temporal satellite images of 1987, 1995 and 2003. A post classification comparison change detection algorithm was employed to determine change in land cover in time intervals, 1987-1995, 1995-2003 and 1987-2003. This is the most common method to change detection. The post classification approach provides detailed "from-to"change information and the kind of landscape transitions that have occurred. In relation to this, change detection matrix of 'from-to' change was derived to show land cover class transition over the past 16-year. In relation to the transition matrix, net change, persistence and net change to persistence ratio (Braimoh, 2006; Pontius *et al,* 2004) were computed to show the resistance and vulnerability of a given land use and cover type using IDRIS ANDES Land Change Modeler. Furthermore, change detection using NDVI approaches was done to observe the trend of the vegetation greenness in the study area. The Table 11, 12 and 13 presented below is the change detection matrix that depicts what is changed to what. The column of the table represents the initial stage and the row represents the final stage. In this regard, image differencing was applied likewise from initial to final image. The diagonal values of the table shows the unchanged values, which are found in both times image. Unlike the diagonal values the class change tells the total changed image areas of each LUCC of the initial stages. Whereas the class total value of the column indicates the initial stage image total area of each LUCC classes where as the row total represents the final stage area of LUCC classes. The net change is the total net change of the two time images. The negative image change indicates a certain land use and land cover is in a state of decrement while the positive value indicates increment.

Land use change detection and net contribution by each land use class for 1987-2003 is presented in Table 11 and Figure 11 (right side of graph refers to gain whereas left side is loss for given land cover).Result indicated that between 1987 and 2003, the net change (i.e. Net change = gain-loss) woodland, bush land, cultivation and settlement had increased by 159.97, 246 km^2, 42.71 km^2 and 64.10 km^2 whereas grassland, shrubby grassland, bare land were changed to other land cover type (Table 11).The highest net increase was observed in shrubby grassland land cover (334.03). On the other hand, the lowest net change was identified in bare land (1.95) (Table 11).Woodland in the landscape was primarily converted to bush land (0.46%) and grassland (0.51%) (Figure 11 and Annex Table 4). On the other hand, woodland mainly converted from shrubby grassland (2.94%) (Figure 11). Bush land mainly increased at the expanse of grassland (1.79%) and shrubby grassland (0.79%). On the other hand, substantial amount of bush land was converted to cultivation (0.13) and settlement (0.23%) land type (Figure 11). Result also indicated that grassland (1.79%) had primarily converted to bush land and considerable amount of area was converted from woodland (0.51%). On the other hand, considerable proportion was gain from transformation of woodland (0.51%) (Figure11).Shrubby grassland mainly gained from grassland (0.17%). On the other hand extensive proportion of area was converted to woodland (2.94%) and bush land (0.79) (Figure 11 and Annex Table 4).

Table 11 Land-use/cover transition matrix showing major change in the landscape (km2), Yabelo, Ethiopia, 1987-2003

From initial state (1987)	To final state (2003)							
	WL	BL	GR	SGL	BL	CU	SET	Total 2003
WL	**389.23**	311.72	342.15	304.79	19.93	1.32	0.29	1369.46
BL	354.26	**366.81**	524.89	167.09	28.42	1.88	0.61	1443.98
GR	388.61	361.29	**1163.89**	39.63	22.59	5.69	1.69	1994.39
SGR	35.71	94.71	55.41	**178.35**	13.35	1.30	0.19	379.03
BL	21.13	27.42	30.19	13.36	**14.58**	1.00	0.49	108.18
CU	4.59	13.75	27.15	7.26	5.75	**4.46**	0.32	59.29
SET	15.93	21.43	25.37	2.56	5.49	0.91	**4.27**	71.96
Total 1987	1209.49	1197.12	2172.07	713.06	110.14	16.58	7.86	**2118.6(39%)**
Gain	980.21	1077.17	827.51	200.68	93.59	58.82	71.7	
Loss	820.24	830.31	1005.18	534.71	95.55	16.11	7.59	
Net change	159.97	246.86	-177.67	-334.03	-1.95	42.71	64.1	
Persistence	389.23	366.82	1166.88	178.35	14.59	0.46	2.27	
Np	0.40	0.67	-0.15	-1.87	-0.13	9.6	15	

WL: Woodland; BL: Bush land, GR: Grassland: SGR: Shrub grassland, BL: Bare land, CU: Cultivation: ST: Settlement. Np refers to net change to persistence ratio (i.e., net change/diagonals of each class, in ratio).The shaded figure is the sum of diagonals and represents the overall persistence (i.e., the landscape that did not change). Net change = gain−loss.

Although bare land converted to cultivation and settlement, at the same time comparable size of area had gained from grassland (0.08) (Figure 11). Analysis of result also showed that cultivation was entirely increased at the expanse of all land use except settlement (Fig 11). Of all vegetation component (woodland, bush land, grassland and shrubby grassland); wood land (0.40) was the most persistent cover type which was followed by grasslands (0.15) whereas cultivation (9.6) and settlement (15) was the lowest persistence (Table 11). 'Persistence' is indicated in Table 11 as the bolded diagonal elements for each land use and cover class (i.e. Bolded diagonal elements represent proportions of each land use and cover class that were static (persisted), the landscape that did not change between 1987 and 2003. When persistence is closer to zero indicating that they had a higher tendency to persist rather than decline or increase. The net change to persistence ratio (i.e., net change/diagonals of each class) important to indicate dominant trends in the changing landscape was large for settlement (15) (Table 11).Grassland and bare land was showed negative trend whereas woodland, bush land, cultivated land and settlement was positive indicating the most dominant trends in the changing landscape (trend). The net change-to persistence ratio is closer to zero for the grassland land use and cover classes, indicating that they had a higher tendency to persist rather than decline or increase. Overall, 39.04% (i.e., sum of diagonal elements) of the total landscape remains unchanged (Table 11), whereas the balance was vulnerable to change.

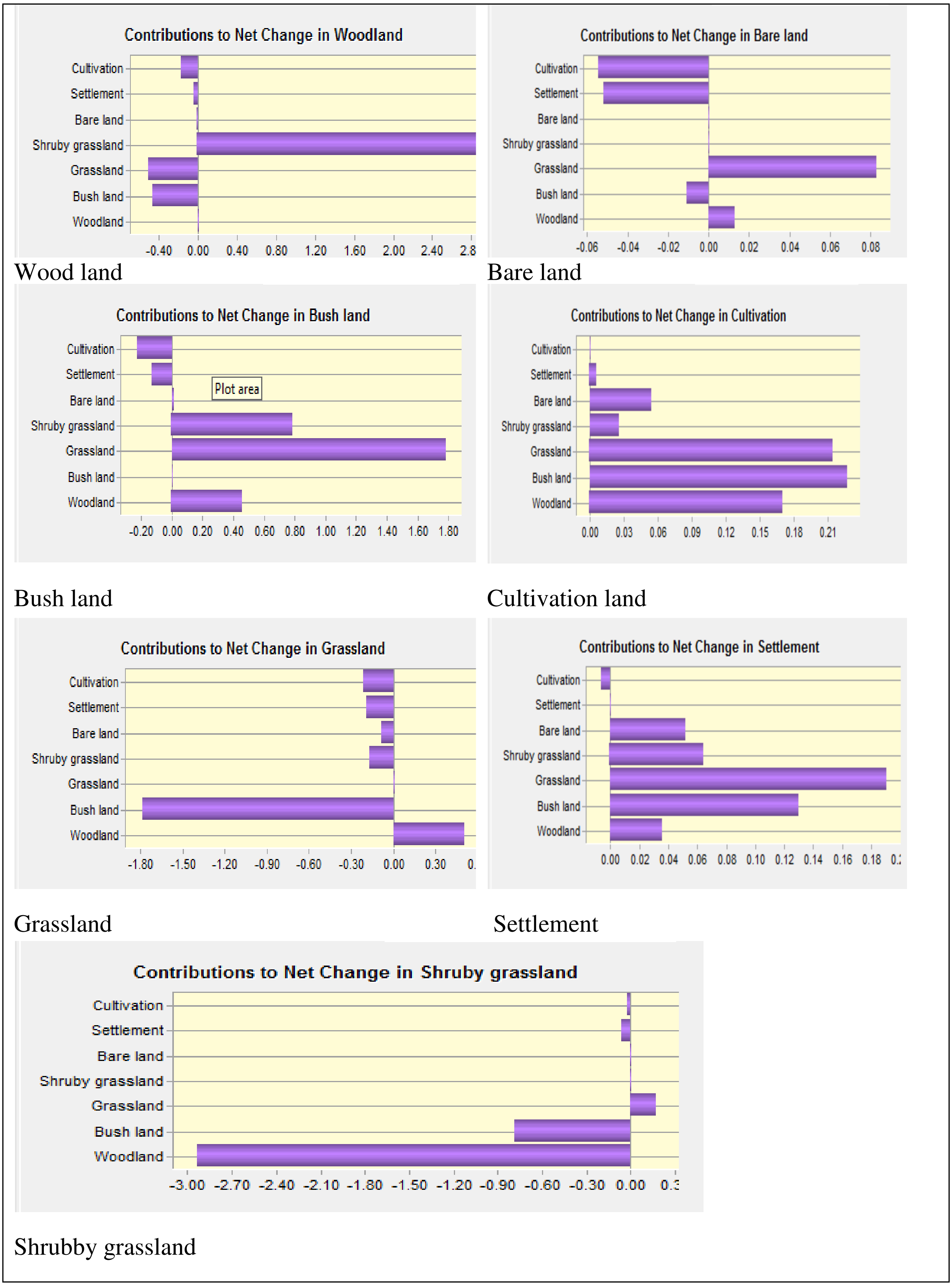


Figure 11.Contribution in net land use change experienced in each land use type (% area), 1987-2003.

Table 12 Land-use/cover transition matrix showing major changes in the landscape (Km^2), Yabelo, Ethiopia, 1987-1995

From initial state (1987)	To final state (1995)							
	WL	BL	GR	SGL	BL	CU	SET	Total 1995
WL	**458.43**	397.09	303.28	304.89	12.01	2.63	1.10	1478.93
BL	297.69	**366.12**	384.67	76.35	27.30	2.07	0.48	1161.19
GR	326.49	295.50	**1175.47**	71.16	44.46	4.43	1.73	1925.24
SGR	104.34	116.51	218.19	**254.06**	11.67	0.47	0.08	705.31
BL	11.78	13.64	67.34	2.21	**10.10**	2.10	1.91	109.08
CU	5.32	3.43	14.40	1.09	2.77	**4.60**	0.40	18.68
SET	4.20	3.46	6.40	2.66	1.65	0.23	**3.08**	28.10
Total 1987	1209.48	1197.12	2172.06	713.06	110.14	16.58	7.86	**2272.04** (41.87)
Gain	1020.50	789.07	749.77	451.25	98.98	27.41	18.60	
Loss	749.81	829.63	994.28	458.36	99.87	15.93	7.70	
Net change	270.69	-40.56	- 244.51	-7.10	-0.90	11.48	10.91	
Persistence	458.43	366.12	1175.47	254.06	10.10	4.60	2.08	
NP	0.59	-0.11	-0.21	-0.03	-0.09	2.49	3.54	

WL: Woodland; BL: Bush land, GR: Grassland: SGR: Shrub grassland, BL: Bare land, CU: Cultivation: ST: Settlement. Np refers to net change to persistence ratio

Land use change detection and net contribution by each land use class for 1987-1995 is presented in Table 12 and Figure 12. Analysis indicated that grassland, bush land, shruby grassland, bare land had decreased by 244.51, 40.56, 7.10 and 0.90 km^2, respectively. On the other hand, woodland, settlement and cultivations were increased by 270.69, 11.48 and 10.91 km^2 area respectively Table 12. The highest net change was observed in woodland (270.69 km2) and grassland type (244.51 km2) while the lowest was observed in bare land (0.90) (Table 12). Between 1987 to 1995 woodland was converted to all land use type (Figure 12). Bush land (1.08%) had increased at expense of woodland. Similarly, shrub grassland (1.60%), cultivation (0.08%) and settlement (0.02%) predominantly increased at the expanse of grassland (Figure 12 and Annex Table 4).The net change-to persistence ratio of woodland, cultivation and settlement showed positive trend. On the other hand, bush land, grassland, shrub grassland, bare land were showed negative trend in the changing landscape. In general, 41.87% of the total landscape remains unchanged (Table 12).

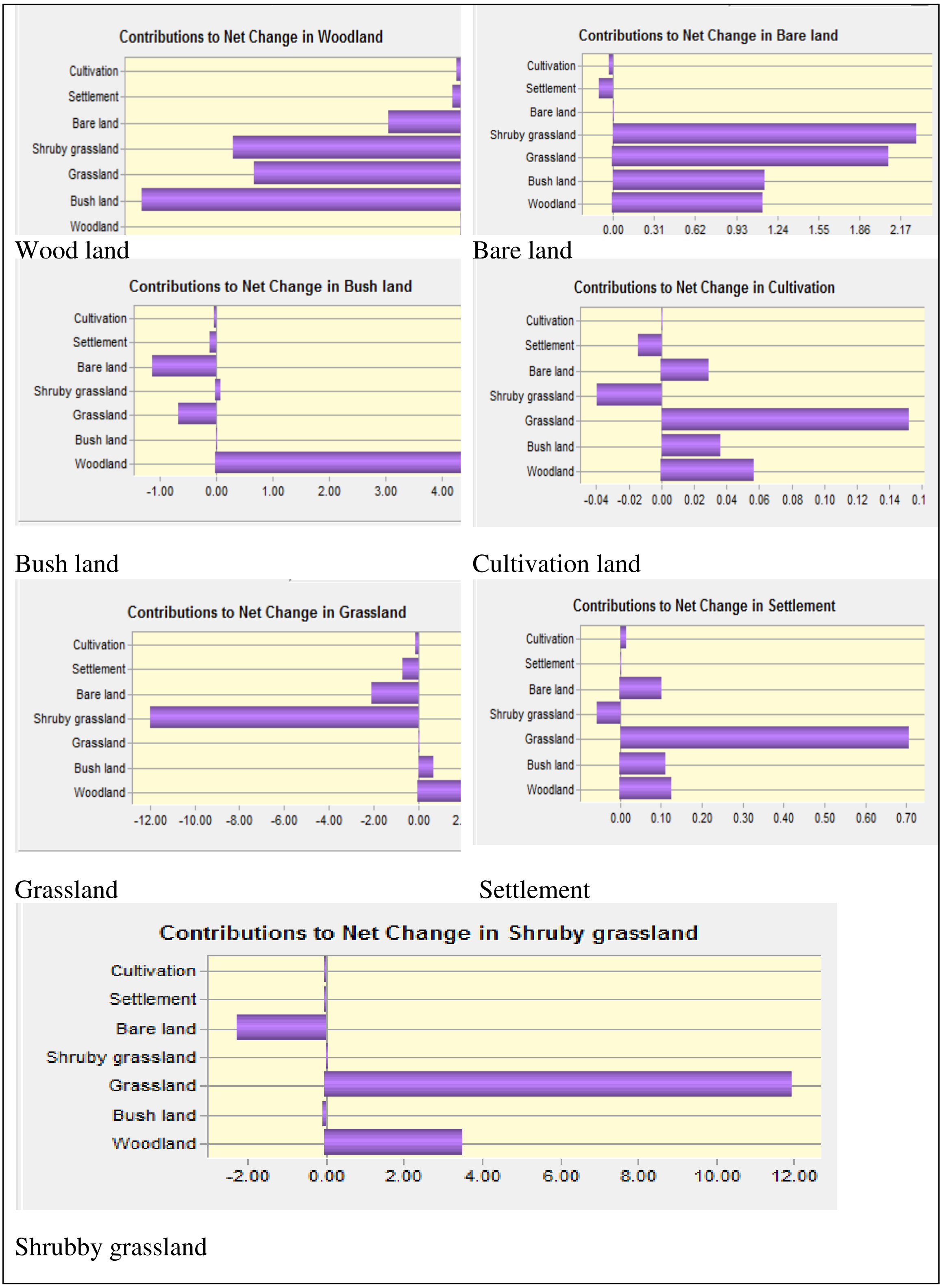


Figure 12 Contribution in net land use change experienced in each land use type (% area), 1987-1995

Land use change detection and net contribution by each land use class for 1995-2003 is presented in Table 13 and Figure 13. Based on the analysis, woodland, shrubby grassland and bare land had continuously decreased by 110.82, 326.65 and 0.94 km^2, respectively. On the other hand, grassland, bush land, settlement and cultivations were increased by 287.30, 66.62, 31.25 and 53.24 km^2 areas, respectively. The highest net change was observed in shrubby grassland while the lowest was identified in bare land (0.94) (Table 13). Between 1995 to 2003 woodland in the landscape converted to all land use type (Figure 12).This indicating that there was human activities on woodland. Result also indicated that bush land was mainly converted to woodland. From Figure 13 grassland mainly increase at expense of shrub grassland. Similar, cultivation mainly increases at the expanse of shrubby grassland while settlement was mainly converted from grassland (Figure 12 and Annex Table 4). The net change-to persistence ratio of bush land, grassland, cultivation and settlement was showed positive trend. On the other hand, woodland, shrubby grassland, and bare land had negative trend in the changing landscape. Overall, 42.42% of the total landscape remains unchanged (Table 13).

Table 13 Land-use/cover transition matrix showing major changes in the landscape (km^2), Yabelo, Ethiopia, 1995-2003

From initial state (1995)	To final state (2003)							
	WL	BL	GR	SGL	BL	CU	SET	To final state (2003)
WL	**679.79**	236.14	164.10	283.019	3.10	1.039	0.92	1369.46
BL	374.67	**396.98**	461.63	191.478	8.85	4.149	4.73	1443.98
GR	258.91	405.69	**1108.82**	120.45	69.82	7.91	3.28	1994.39
SGR	139.83	66.838	69.59	**91.83**	5.53	2.35	2.10	379.03
BL	17.86	18.167	46.00	6.86	**13.37**	3.35	2.03	108.18
CU	6.28	18.503	35.62	1.72	6.00	**6.84**	1.12	59.29
SET	1.59	12.875	30.48	9.96	2.40	0.04	**5.42**	71.96
Total	1478.93	1161.19	1925.24	705.31	109.08	28.10	18.68	**2303(42.42)**
Gain	688.32	1045.50	874.04	286.83	94.76	70.51	58.43	
Loss	799.14	758.20	807.42	613.48	95.71	17.26	27.18	
Net change	-110.82	287.30	66.62	-326.65	-0.94	53.24	31.25	
Persistence	679.79	396.98	1108.82	91.83	13.37	6.84	5.42	
NP	-0.16	0.72	0.06	-0.26	-0.07	7.78	3.45	

WL: Woodland; BL: Bush land, GR: Grassland: SGR: Shrub grassland, BL: Bare land, CU: Cultivation: ST: Settlement. Np refers to net change to persistence ratio

Figure 13 Contribution in net land use change experienced in each land use type (% area), 1995-2003

5.1.4 Change detection using NDVI

To observe general green vegetation change in Borena rangeland, change detection based on NDVI image differencing approach was computed. Image differencing could be the most widely applied change-detection method (Singh 1989). Image differencing involve subtracting pixel by pixel the first date of NDVI imagery from a second date that have been precisely registered to the same coordinate system and produces an image showing the change between the two dates (Singh 1989). The change image has positive and negative values in area where reflectance change occur and zero or near zero in area where no change between two dates. Image statistics were then used to define the level of change intensity. Pixel values greater than one a standard deviation from both sides of the mean served as an interval to classify changed and unchanged area (Grey *et al.,* 1998). The standard deviation levels were then assigned different colors. By applying the individual colors and brightness levels, quantifiable changes may be visualized for each tail of the image histogram (Grey *et al.,* 1998). However, this method will not help to determine the 'from-to' change of land-cover types. The NDVI of 1987, 1995 and 2003 satellite image is presented in Figure 14 and 15.In this study, there was no consistency among the three images in pattern of area increased and decreased. However, result indicated that about 9.94. 21.12 And 29.87% of the landscape were classified as good green vegetation cover in 1987, 1995, and 2003, respectively (Figure 14). Large proportion of the landscape in 1987, 1995, and 2003 were classified as poor green vegetation cover. On the other hand, relatively small proportion of area was classified as no green vegetation cover (Figure 14).

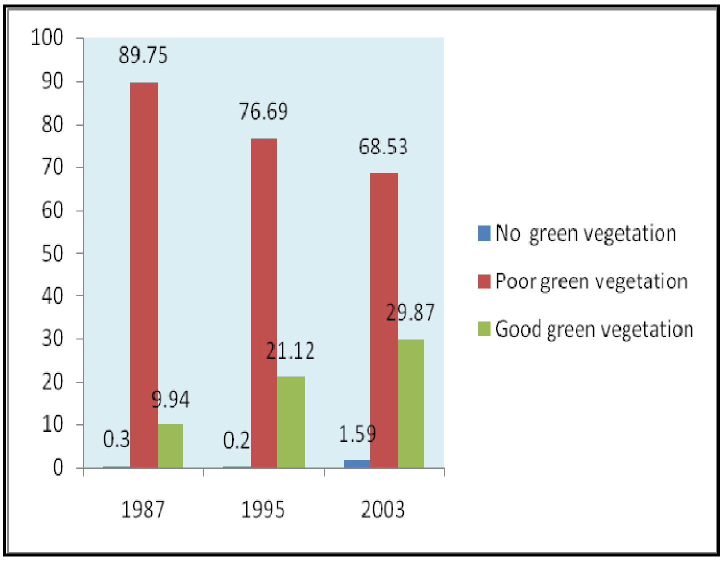


Figure 14 Areas of green vegetation cover calculated using NDVI

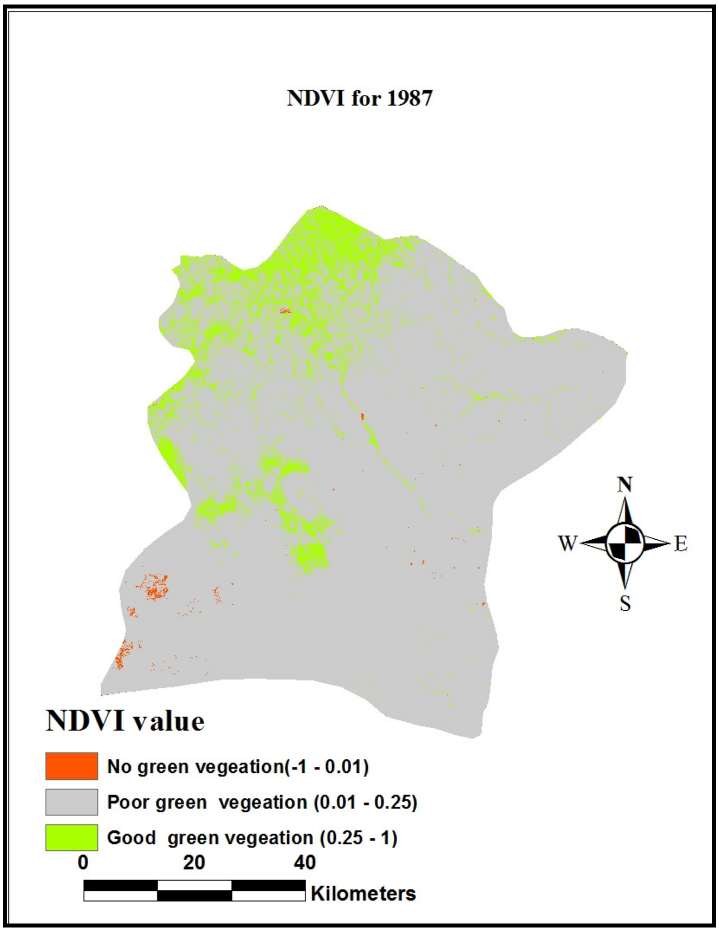


Figure 15 NDVI of 1987

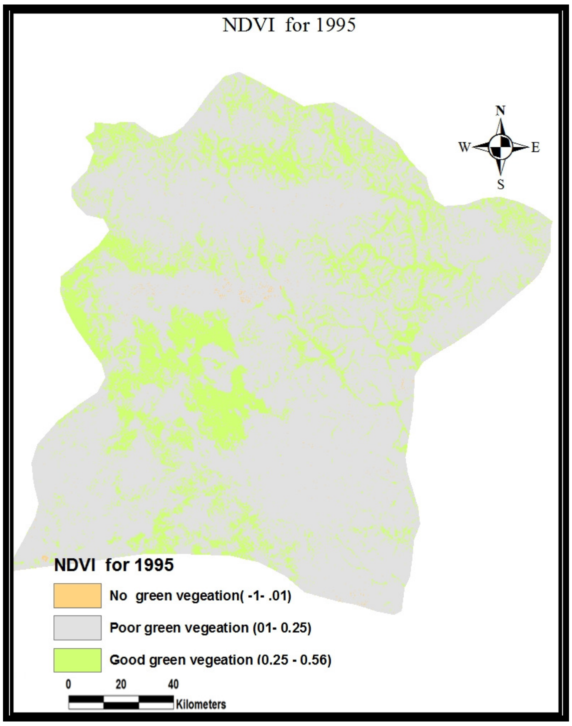


Figure 16 NDVI of 1995

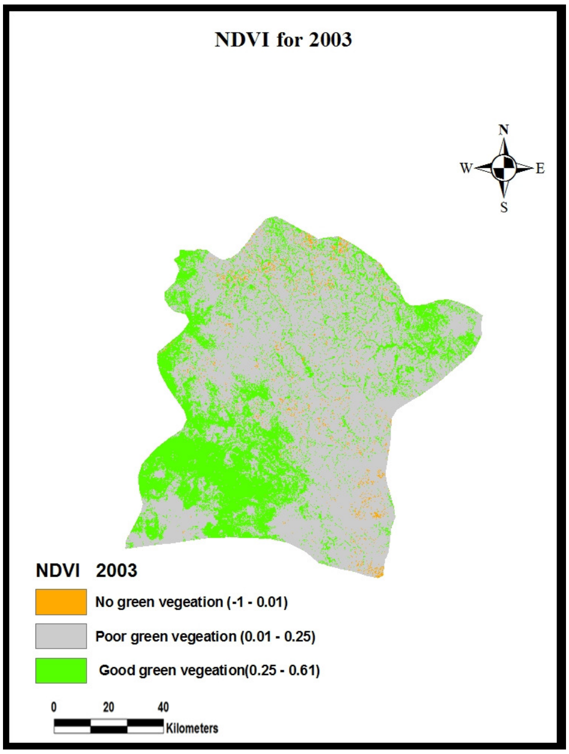
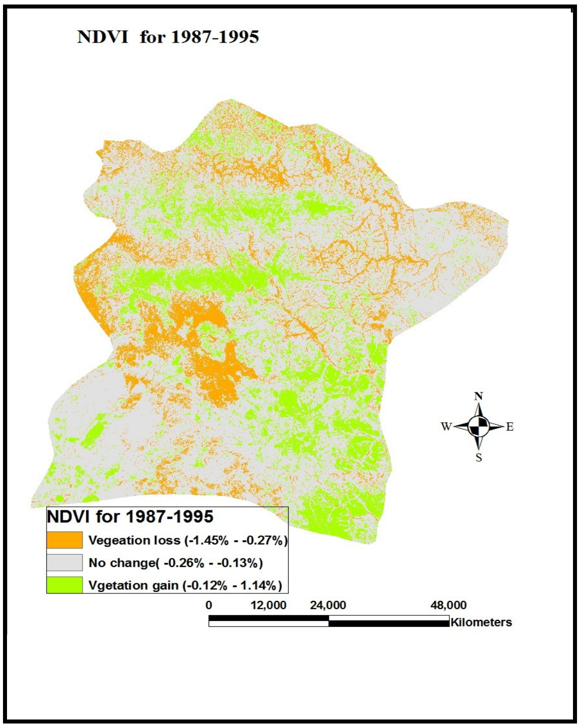


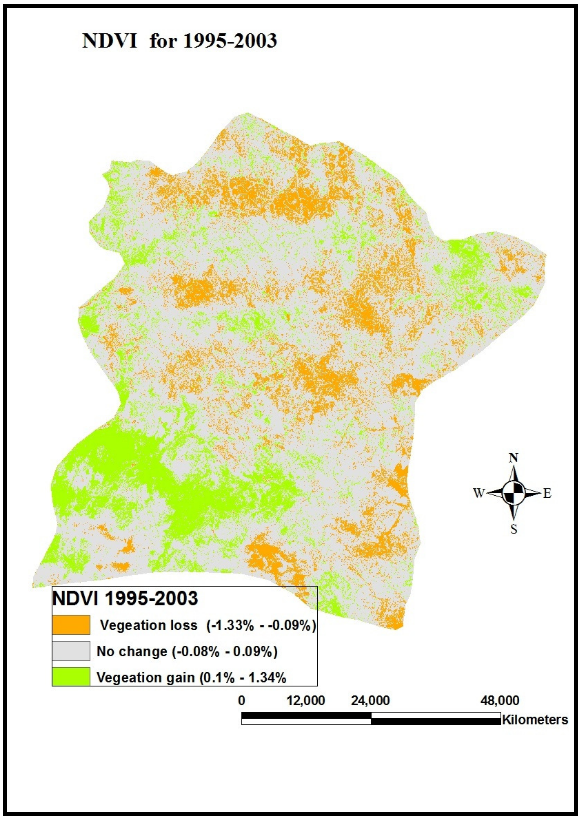
Figure 17 NDVI of 2003

The change detection using NDVI differencing of image resulting from subtraction of NDVI 1987 from NDVI 1995, 1995-2003, 1987-2003 was categorized into negative, no change, and positive change using one standard deviation threshold level from the respective mean (Figure 15 and Table 14). Between 1987 and 1995 (15.23%) of green vegetation cover was lost while 16.01% of the landscape was showed positive change. On the other hand, large proportion of study area was indicated no change (68.86%). Similarly, between 1995 and 2003 extensive proportion of the landscape showed no change (95.38) where as relatively small proportion of area was identified as negative and positive change (Table 14). Over the past 16 years, considerable proportion of the study area (81.11%) showed no change in green vegetation cover where as substantial (17.60%) proportion of the area indicated as positive change while relatively small proportion of the area showed negative change. Since all the images were taken during the dry season when most of the natural vegetation in the landscape has undergone senescence, the low proportion of green vegetation cover could be associated with dried season of the landscape, recurrent drought that experienced in the area as well as inter annual rainfall variation could influence the vegetation cover. Rainfall has detrimental and overriding effect in vegetation change in arid and semi arid environment. In general, there was change in green vegetation cover over the years from 1987 to 2003.

Table 14 Area of vegetation (%) change calculated by difference of NDVI

Categories	**1987-1995** %	**1995-2003** %	**1987-2003** %
Negative change	15.23	1.83	1.8
No change	68.86	95.38	81.11
Positive change	16.01	2.79	17.60


NDVI for 1987-1995
N
W
E
S
NDVI for 1987-1995
Vegeation loss (-1.45% - -0.27%)
No change(-0.26% - -0.13%)
Vgetation gain (-0.12% - 1.14%)
0
12,000
24,000
48,000
Kilometers


NDVI for 1995-2003
N
W
E
S
NDVI 1995-2003
Vegeation loss (-1.33% - -0.09%)
No change (-0.08% - 0.09%)
Vegeation gain (0.1% - 1.34%
0
12,000
24,000
48,000
Kilometers

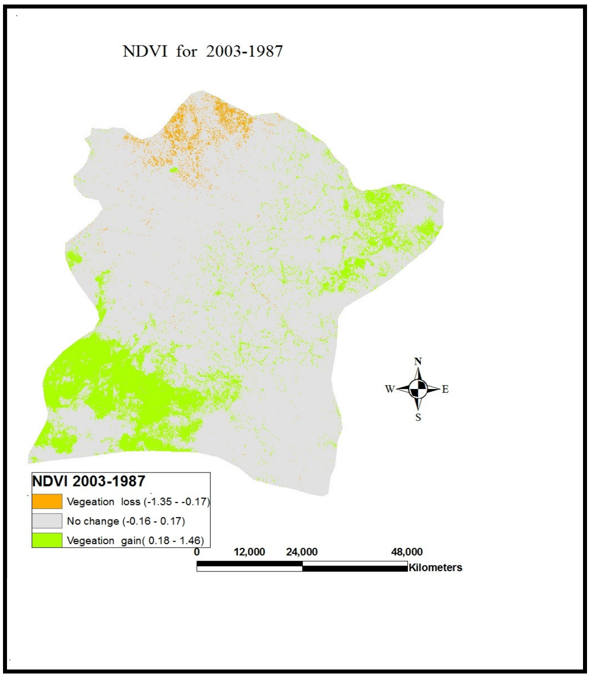


Figure 18 Change detection based on NDVI from 1987-2003

5.1.5 Spatial patterns of land use and land cover dynamics

The result of spatial metrics at landscape level is presented in Table 15. Landscape metrics considering major land use classes indicated that landscape of Borena rangeland undergone relevant modifications over the past 16 years. Number of patch is considered as representing landscape configuration and provides a simple measure of the extent of subdivision or fragmentation of the patch type (McGarigal, *et al.,* 2002). In this studies, the number of patch had substantially increased over the years, indicating the breaking up of landscape area into smaller parcels from 265102 (1987) to 316725 patch (2003) (Table 15) and the increase of patch number lead to increased Patch Density (PD). Patch density is a good reflection of the extent to which the landscape is fragmented and therefore fundamental for the assessment of landscape structure (McGarigal *et al.,* 2002); PD was increased from 28.93 in 1987 to 34.57(2003).This suggesting that extensive land transformation has occurred due to land use changes in study area. This is further supported by the largest patch index. For example, the largest patch index, which represents the percentage of the landscape occupied by the largest patch of all the land classes, was reduced by half from 40.02% (1987) to 21% (2003). Diversity was measured using Shannon's Diversity Index (SHDI) indicated over the past 16 years, SHDI was 1.52which implies the landscape was more heterogeneous and maintained heterogeneity over the years. SHDI increases as the number of different patch types (classes) increases and/or the proportional distribution of the area among patch types become more equitable. During study period, 1987-2003, the patch richness which indicates the number of different patch types in the landscape and Shannon Evenness Index (SHEI) (0.74) were the same (Table 15).When SHEI approaching to one the distribution of area among patch types is perfectly even. In our study, SHEI indicting that the patch within the landscape tends to distribute more unevenly. Regarding to patch indices, Landscape Shape Index (LSI) which is a simple measure of class aggregation showed that patch in 1987(196.14) was less aggregated and fragmented. On the other hand, disaggregation and more fragmentation of patch were increased in 2003 (264.11). The another shape index parameter was average fractal dimension (FRAC-MN); FRAC-MN usually describes the complexity and the fragmentation of patch, it approaches one for shapes with very simple perimeters such as circles or squares; it approaches two for shapes with highly convoluted, plane-filling perimeters (McGarigal, *et al.,* 2002). Our result showed that value greater than one, indicating that the average patch shape in all landscape is non-square and irregular in shape which indicating that an increase in shape complexity. From Table 15 the FRAC-MN value for the three images showed no difference. The average nearest-neighbor distance (ENN_MN) measure the average edge-to-edge distance from a patch to the nearest neighboring patch of the same type. These values indicate inter-patch proximity and isolation due to fragmentation. Result showed that ENN_MN value decreased from 1987 (93.48m) to 1995 (87.48m) than slightly increased after 1995(91.78m) (Table 15). However, during study period from 1987 to 2003 slight reduction from 93.48m (1987) to 91.78m (2003) was measured this suggesting that reduction of the distance between the neighboring patch of similar land use was the result of creation of several new patch within close proximity as the result of fragmentation processes. This was supported by number of patch, patch density and largest patch index value of the years.

Table 15 The calculated landscape metrics at the landscape level

Parameters	1987	1995	2003
Class Area CA (ha)	542630.1	542630.07	542630.07
Number of Patch (NP)	265102	307226	316725
Patch Density (PD) (no./ 100 ha)	28.94	33.54	34.57
Largest Patch Index LPI (%)	40.02	35.52	21.77
Patch Richness (PR)	7	7	7
Shannon's Diversity Index (SHDI)	1.51	1.53	1.53
Shannon's Evenness Index (SHEI)	0.73	0.74	0.74
Landscape shape Index LSI (m)	196.14	238.41	246,11
Mean Patch Fractal Dimension (FRAC-MN)	1.03	1.04	1.03
Mean Shape Index (SHEP_MN)	1.17	1.18	1.20
Mean Nearest Neighbor Distance (m)	93.48	87.48	91.78

CA: Class Area, NP: Number of patches, PD: Patch Density, LPI: Largest Patch Index PR: Patch Richness: LSI: Landscape shape Index, SHDI: Shannon's Diversity Index, SHEI Shannon's Evenness Index, FRAC_AM: Mean Patch Fractal Dimension, SHEP_MN:

The result of spatial metrics at class level is depicted in Table 16. Class area (CA) is a measure of landscape composition. Grassland was the dominate land use type in the landscape during study period; however decreased from 217206.45ha, (1987) to 199439.91 (2003). Similarly, shrub grassland had decreased from (1987) to (2003) (Table 16). On the other hand, woodland, bush land, cultivation and settlement increased from 1987 to 2003 (Table 16). Bare land showed no variation over the past 16 years. This result was further supported by the percentage of landscape (PLAND) which quantifies the proportional abundance of each patch type in the landscape (Table 16). Grassland cover was reduced from 40.03 %(1987) to 36.75 %(2003). Similarly, shrubby grassland reduced from 13.14 %(1987) to 6.99% (2003). On other hand, woodland, bush land, cultivation and settlement increased from 1987 to 2003 (Table 16). This variation was due to land use change occurred in the study area. Result also indicated number of patch increased over the years from 1987 to 2003 in bush land, shrub grassland, cultivation and settlement land use class. On the other hand, number of patch was decreased in woodland, grassland and bare land. Highest number of patch was observed in bush land ranging from 72071 (1987) to 98990 (1995) this is due to continuous conversion of grassland and woodland to bush land whereas, the lowest patch number was observed in cultivated land type (Table 16). The increasing patch number over the years from 1987 to 2003 indicates that there was a significant increase in land use types. This implies that from 1987 to 2003, there was an increase in human activities within the landscape and result in transformation and fragemation of lands. Patch density is simply indicating the number of patches per unit and measures of fragmentation. Highest patch density was calculated for bush land range from 7.87(1987) to 10.0(2003) (Table 16) whereas the lowest was observed for cultivation land cover ranging from 0.73(1987) to 3.20 (2003). In general, over the past 16 years, patch density was increased in bush land, shruby grassland, cultivation and settlement land class; this implies that there was fragmentation and land transformation. On the other hand, slight reduction of PD was observed in grassland after 1995.

The Largest Patch Index (LPI) is also one of the measures of fragmentation and dominance index in the landscape. Result showed that LPI was reduced over the years for woodland, bush land, grassland, and shruby grassland class type. The Grassland had highest LPI but reduced over years, this suggesting that grassland was the dominant land cover type and more fragermented. In general, LPI indicating that vegetation component of landscape (woodland, bush land, grassland and shrubby grassland) has undergoes transformation and fragmentation. On the other hand settlement and cultivation showed compacted nature over years (Table 16). Edge Densities (ED) indicating the amount of edge relative to the landscape area and usually are considered as representing landscape configuration and measuring fragmentation. From Table 16, the increase of patch density often leads to increased edge density (ED); because of it's create new edge segments in the patch. The ED index rapidly increased in grassland and cultivation over the years from 1987 to 2003. ED often increased when land use fragmentation occurred due to land use change.

Table 16 The calculated landscape metrics at the class level

Parameters	Year	WL	BL	GR	SGL	BL	CU	SET
CA ha	1987	120948.48	119711.88	217206.45	71305.83	11013.66	786.06	1657.71
	1995	147892.95	115518.60	192523.95	70531.11	10907.73	2801.43	1867.86
	2003	136945.71	144398.07	199439.91	37903.14	10818.27	5928.66	7196.31
PLAND (%)	1987	22.29	22.06	40.03	13.14	2.03	0.14	0.41
	1995	27.28	21.31	35.52	13.01	2.01	0.52	0.34
	2003	25.24	26.61	36.75	6.99	1.99	1.09	1.33
NP(No)	1987	70459.00	72071.00	53832.00	35656.00	24309.00	2127.00	6648.00
	1995	53313.00	98990.00	52766.00	64240.00	14722.00	12963.00	10232.00
	2003	64864.00	92256.00	37654.00	58335.00	21626.00	12523.00	29467.00
PD (No./100ha)	1987	7.69	7.87	5.88	3.89	2.65	0.23	0.73
	1995	5.82	10.81	5.76	7.01	1.61	1.42	1.12
	2003	7.08	10.07	4.11	6.36	2.36	1.36	3.20
LPI (%)	1987	5.25	8.03	18.71	4.05	0.10	0.01	0.01
	1995	7.46	3.44	7.80	1.02	0.06	0.01	0.00
	2003	2.14	4.10	10.13	1.89	2.36	1.37	0.01
ED (m/ha)	1987	52.43	42.96	51.09	20.92	7.95	0.62	1.60
	1995	50.40	57.70	54.84	34.88	6.93	3.01	2.11
	2003	49.379	71.52	44.76	7.56	7.76	4.52	7.56
LSI (No)	1987	345.21	284.36	250.99	179.37	173.30	50.23	89.55
	1995	300.10	388.77	286.15	300.74	151.72	130.05	111.37
	2003	305.49	430.97	229.5	222.20	170.67	134.49	203.81
ENN_MN(m)	1987	81.5	85.16	81.20	106.73	124.9	183.16	222.53
	1995	82.25	78.63	78.88	87.03	113.84	128.67	149.69
	2003	83.49	67.01	83.49	100.19	116.89	136.73	114.99
FRAC_MN	1987	1.04	1.04	1.04	1.03	1.03	1.03	1.02
	1995	1.03	1.03	1.03	1.02	1.01	1.4	1.21
	2003	1.04	1.04	1.037	1.03	1.03	1.03	1.03
SHAPE_MN	1987	1.21	1.19	1.20	1.16	1.15	1.12	1.10
	1995	1.20	1.22	1.24	1.10	1.08	1.20	1.22
	2003	1.22	1.25	1.22	1.14	1.17	1.19	1.13

CA: Class Area, PLAND: Percentage of Landscape, NP: Number of Patches, PD: Patch Density, LPI: Largest Patch Index, ED: Edge Density, Landscape Shape Index. WL: Woodland; BL: Bush land, GR: Grassland: SGR: Shrub grassland, BL: Bare land, CU: Cultivation: ST: Settlement

Landscape Shape Index (LSI) from Table 16 indicated that class aggregation increased over the years from 1987 to 2003 for bush land, cultivation and settlement land class while wood land and grassland showed reduction. The average nearest-neighbor distance (ENN_MN) value also decreased over the years from 1987 to 2003 for settlement, cultivation, bare land and bush land and shrub grass land (Table 16). This value indicates that decreasing of inter-patch proximity or isolation due to fragmentation. The 2003 patches are becoming less isolated for settlement, cultivation, bare land and bush land patch as compared to 1987 land cover (Table 16). This is due to rapid expansion of settlement and cultivation in the study area has created several patches within close proximity by fragmenting the land into new patch, this process reducing the distance between the neighboring patch of similar land uses. Furthermore a decrease of ENN_MN for settlement and agriculture over the study period suggesting that in 1987 the urbanization process was confined mostly in the rural areas of the existing settlement area. The mean shape index (SHAPE_MN) showed that all class had greater than 1, indicating that the average patch shapes in all landscapes were non-square and irregular, this implies that an increase in shape complexity. Furthermore, difference in mean patch fractal (FRAC_MN) value of the three images was negligible and showed no difference Table 16.

5.2. Discussion

The study clearly showed the arid and semi-arid rangeland of Borena experienced substantial and increasing rate of land use and cover change over the years (e.g. 1987 and 1995, 1995 and 2003 and 1987 and 2003).There has been persistent change both spatially and temporally, resulting in 39.04% of the total landscape remains unchanged and 61% of the total areas experiencing transitional change among the land cover type. Like any other arid and semi-arid savanna ecosystem similar types of land cover type have identified. The major challenge of change detection in land cover is identifying the cause of change (Singh 1989). However, the reasons and the causes of land use and land cover change over the past 16 years were discussed below. The change in land use and cover and vegetation cover change observed during study period could be most of the vegetation type suffered from short term direct and indirect drought effect. In the study area between 1987 and 2003 drought had occurred frequently for instance in 1988-1989, 1991-1992, 1995-1996, 1999-2000 (Delta and Coppock 2002; Sabina *et al.,* 2005). This could have influence on vegetation dynamic in turn aggravate land use and cover change of the study area. Furthermore, variation in amount and distribution of inter annual rainfall in the study area over the past 16 years could have influence in vegetation change particularly by reducing herbaceous layer and favor for bush and wood vegetation cover, the long term 25 years (1980-2004) rainfall data of study area showed that amount of intra and inter annual rainfall was highly fluctuate (Figure 4 and Annex Table 1) and the amount of rainfall received in 1995 (323.6mm per year) and 2003 (377.1mm) was smaller than 1987 (649mm) this could contributed for variation of vegetation cover and land use and cover change. Studies conducted on the same study area by Desta and Coppock (2002) who studied relationship of long term rainfall variability (1980to1997) to cattle population dynamic indicated that average cattle holdings of pastoralists dropped from 92 to58 head/household between 1980 and 1997, respectively. The same authors further reported droughts in 1983–1985 and 1991–1993 resulted in the deaths of 37 to42% of all cattle. Similarly Ayana and Oba (2007) reported the total cattle holdings over a 21-year period (1980 to 2003) decline with of 54%, from 94 animals in 1983 to 51 animals in 2003. Both studies clearly indicated that inter annual rainfall have influence on livestock population at local level. This suggesting that inter annual rainfall has strong influence on pastoral land use and vegetation change. In a arid and semi arid environment, vegetation dynamics should be primarily driven by factors such as moisture variability rather than herbivore (Ellis and Swift 1988).

As in other area of East Africa (Reid *et al.,* 2004), anthropogenic factor such as human disturbance has been one of the key driving forces behind the land-use/cover change in South Ethiopia, Borena, Yabelo. Human disturbance such as population pressure, use of fire, heavy grazing pressure and poorly designed developmental intervention has been some of them. The population of Borana including the study area was about 300,000 in the 1980s and has reportedly increased to over 500,000 in recent years (Sintayehu *et al.,* 2006) and in the region human population growth rate was 2.2% per annum (CSA 1996) this could contributed for the expansion of cultivation, settlements and aggravate pressure on natural resource. Lack use of fire and heavy grazing pressure (Ayana and Oba, 2008) on savanna landscape of the study area were another driving factor for the increase in wood and bush vegetation cover over the years. The Borena pastoralist traditional used fire as rangeland management tool, before the Ethiopian government banned it. The pastoralist's repeatedly have been unable to use fire to control bush since the mid of 1970s. The official ban of fire has contributed to the progressive increase of bush and wood plants cover (Oba *et al.,* 2000, Gemedo Dale, 2004 and Ayana and Oba, 2008).

Development interventions were widely practiced in the study area. However, many report indicated that (Angassa and Fikadu, 2003) constructing of watering point (pond) , it was noted that the water points in the Yabalo project area attracted settlements and resulted in severe overgrazing and conversion of grassland to woodland (Taffesse, 2001). In general, the pastoralists were grateful to government and development projects for these ponds. However, in some places ponds were constructed without consulting the pastoralists and at the end contributed to rangeland deterioration. Coppock (1994) and Oba and Kotile (2001) also reported that water development caused pressure on land use resulting in environmental changes leading to land degradation. Furthermore the establishment of ranch in the area as one of the major factor that caused rangeland shrinkage and resulting in overgrazing. In the study area, over 10,010ha of grazing land were allocated to ranches (Oba and Kotile, 2001). Mobility and opportunistic resource utilization are key issues for the sustainable resource use in semi-arid ecosystem. But the ranches introduced to the Borana area reduced the grazing land and also contributed to restricting of the free movement of livestock in the area. Angassa and Fekadu (2003) also reported that traditional grazing practices in the Borana lowlands were becoming highly marginalized due to ranching, allocation of communal grazing areas to private investors, cultivation and privately reserved pasture areas.

In study area bush land and woodland is mainly composed of *Acacia, Gerewia* and *Comiphora,* species and showed an increasing pattern between 1987 and 2003. Like many rangelands in East Africa and other part of Ethiopia, the increase in bush land cover in the study area was not unexpected. The present bush and wood cover of the study area was in agreement with the reports of earlier studies made by Getachew *et al.* (2010) using Landsat 2002, Coppock, (1994) who indicated that the woody cover in the Borana rangeland has increased nearly about 40%. Similarly, studies made by Gemedo Dale (2004) on the same environment indicated percent cover of woody plants increased from 40% reported in the early 1990s to 52% which was agreement with present study sum of both bush land and woodland cover was 52.85%. Another studies made by Sintayehu *et al*.,(2006) on the same study area using Landsta TM who reported that between 1986 and 2002 the bush land increased by 15% which is similar with the present study (17%). Several studies report that (e.g.Ayana and Oba 2008, Solomon *et al*, 2006, Homann, 2004, Gemedo Dale, 2004; Coppock, 1994) indicated that drought, absence of fire and overgrazing are some of the major factors that cause conversion of grasslands to wood and bush land.

Grassland was the dominate land use and cover over the years from 1987 to 2003, the decrease in grass cover during study period could be due to the increase of bush land, expansion of cultivation and settlement. The result was in agreement with Sintayhu *et al.,* (2006) and Getachew *et al.,* (2010) using Landsat TM images who reported that grassland continuously reduced and Getachew *et al.,* (2010) further reported that the grass cover has declined by 8% which was similar with present study 7.73% and the present result of grass cover change between 1987-2003 was in contrast with report made by Sintayehu *et al.,* (2006) who reported that the change was 77%. Many investigators (e.g.Coppck 1994; Gemedo Dale, 2004; Homann, 2004; Solomon *et al.,* 2006; Angassa and Oba, 2008) reported grassland cover has reduced and degraded in the study area. Bush encroachment, frequent drought, lack of fire, high livestock and human populations, privatization of formerly open-access grazing sites (kalo),weakening of traditional resource management strategies and establishment of ranch in pastoral grazing lands were perceived as the major factors and driving forces of declining grassland The Borana pastoral system, traditionally based on extensive cattle production for survival and income generation, and grassland has been major source of feed for livestock and this region is one of the important area of cattle production in Ethiopia.The progressive reduction of grass cover and land use shifts caused by different drivers directly affect livestock production, on which the livelihood of Borana pastoralists depend. This may result in high risk of food insecurity in the region.

During study period bare land showed a very little variation between 1987 and 2003, but a declining pattern. The causes for bare ground could be complex and related with climate, landscape, geology, vegetation cover and pattern of land use (Oba *et al.,* 2000).The declining of bare ground in study area might be associated to the increasing pattern of land covered by bush land and woodland that hide the visibility of the land from the air. Study conducted in the same environment by Getachew *et al.,* (2010) indicated that bare ground cover was declining.

The small cover of settlement as compared with other land type in study area during the past 16 years could be due to most of settlement areas (town/villages) were built from woody materials of the native vegetation such as trees, shrub and grasses, thus it was difficult to separate them settlement from their surroundings land cover features such as bare land, shruby grassland (Annex Figure1). Furthermore, pastoral area settlement is scattered and too small in size to be detected by the Landsat TM, this may underestimate the percentage. Beside these most often in pastoral mode of life, it was difficult to detect and quantify the settlement area because pastoralists have not been totally settled. On the other hand, the increase of settlement cover over the past 16 years could be related with the increase of population growth. Similarly, the low percentage of cultivated area could be associated with recent adoption of cultivation in the study area; Furthermore, in area where crop cultivation is practiced, individual farming plot of field is too small. Since most of communities cultivating less than one hectare such small fields are scattered nature in distribution and spectrally also heterogeneous to be detected by Landsat TM and identified as cultivated land. Surveys conducted during the 1980s in area similar to the current study estimated that the pastoral households involved in cultivation and the average cultivated plot size per household were 45% and 0.29 ha, respectively (Coppock, 1984). During 1990, 37% of the Borana pastoralists were involved in crop cultivation in similar areas (Alemayehu, 1998). Study made by Ayana and Oba (2008) in similar environment reported that 80% of crop field age has less than 20 years this in general implies that the low proportion of cultivated land in study area was not unexpected. Although cultivation has small proportion, dramatic increment was observed over the years from 1987 to 2003 (79%) in study area. Many investigators indicated that cultivation has undertaken mainly in bottomland because it was the most fertile with the highest soil water status. These bottomlands were traditionally used as calf grazing reserves and the loss of these areas has contributed to increased vulnerability of livestock farming during drought years. Some published evidence suggest that cultivation is increased the result of several factors such as recurrent drought and major death losses of milking cow due to starvation create significant periods of food insecurity for pastoralists, Secondly, due to the gradual change in livelihood, the Borana have probably become agro-pastoralists in some areas and plan to grow maize as a routine part of their production system. The other reason was increased access to cultivation facilities via government and non government institution. However, the main driver was the agricultural land use policy, promoted by the Department of Agriculture which was encouraging the semi-privatization of grazing lands which reported by Ayana (2007).

The different landscape metrics, such as area, patch density, largest patch index; patch shape, diversity index, and nearest-neighbor distance reveal that the structure of the savannah landscape of the study has undergone important change. This change of landscape might be directly and indirectly associated to human and natural induce factors such as land use and cover change, rangeland degradation (Gemedo Dale, 2004), the prevailing recurrent drought and extreme climatic variability, promotion of crop cultivation and ranching, human population growth, bush encroachment, ban on the use of fire and weakening of traditional pastoralist's management system. During study period from 1987 to 2003 the Borena savanna landscape became fragmented. The concept of landscape fragmentation (in the narrower sense refers to the breaking up of habitat or land type into smaller parcels), there are other spatial processes in land transformation that need to be mapped: perforation, dissection, shrinkage and attrition (*e.g.* Forman, 1986). A vegetation patch may have shrunk and became perforated, but did not become fragmented.Yet, the impact of shrinkage and perforation on the landscape processes could be more important.

In the study area, that there are many grassland vegetation patches that decreased in size, disappeared, or became perforated. For instance, construction of watering points (pond) in the dry season grazing area, establishment of ranches, promotion of cultivation all this subdivided some vegetation patch into sections. The resulting landscape has become more fragmented: this fragmentation is characterized by the proliferation of large number of patches, increase patch density, decreasing of largest patch index, heterogeneity and inequitable of distributed of patch and irregular shape of patch. In overall, both at the class and landscape level, metrics quantify landscape structure which affect ecological processes of the landscape independently and interactive. In this study, part of the metrics were used, it is then suggested more could be analyzed further to get more comprehensive implication of changes of landscape structure in relation with land use and cover change dynamic.

Limitation of the study

This study attempted to overcome and minimize the effects of many limitations. These limitations include lack of multi-temporal Landsat satellite image from the same season that would have allowed comparison of images and perform change analysis. Furthermore, lack of satellite images that cover the entire study area particularly the 1970', 1980' 1990' and 2000.

The Landsat imageries that used in the study were highly affected by climatic fluctuation of the study area particularly the Landsat of 1995 which influenced its spectral reliability. Furthermore, nature of the study area highly heterogeneous and makes difficult to identify some feature because of the spectral overlap and similarities. Scarcity of ancillary data such as historical spatial data related to land use/land cover maps, and aerial photography that help for study.

6. CONCLUSION AND RECOMMENDATION

This study clearly indicated that remote sensing in integration with GIS is important tool for classification, mapping, change detection and landscape spatial pattern analysis for understanding of arid and semi arid savanna ecosystem. The analysis provide valuable insight into the extent and nature of change that has taken place in the arid environment from 1987 to 2003 and generated some baseline information for further development program and research work. Furthermore, the change detection analysis useful for the monitoring of land use/ land cover change over time and space.

Over the past 16 years there was change in land use and land cover in arid and semi-arid ecosystem of Borena, Yabelo. Analysis indicated that between 1987-2003, about 39.04% of the total landscapes remain unchanged. Result showed that both bush land and wood land together cover about 51.8% of total landscape. Result further indicated that bush land, cultivation and settlement cover had increased by 17%, 72.49% and 79.75%, whereas shrubby grassland (86.14%), woodland (11.68%) and grassland (7.73%) were reduced between 1987 and 2003. Result also showed that bush land has mainly increased at the expanse of grassland and shrubby grassland. Result of spatial pattern analysis indicated during 1987-2003, the Borena savanna landscape went through important change and remarkable variation in terms of proportion of the landscape structure was quantified due to change in land use and land cover dynamic. The resulting landscape has become more fragmented, this is characterized by the proliferation of large number of patch, increasing of patch density, decreasing of largest patch index, more diversity of patch and heterogeneity with uneven distribution of patch in the landscape and irregular shape of patch. The general trend observed in the study area implies a loss of grassland cover and an increase in bush land cover, settlement and cultivated area. The present tendency may lead to more bush encroachment and grassland shrinkage if no measurement has been taken. The continued land use cover change, coupled with a drier climate, greatly affects pastoral people's livelihood and puts the pastoral production system under increasing threat. Considering the human induced and climatic variability of study area it is likely that the landscape change tendency will be continued in the study area. In overall, both at the class and landscape level, metrics quantify landscape structure which affect ecological processes of the landscape independently and interactive. In this study, part of the metrics were used, it is then suggested more could be analyzed further to get more comprehensive implication of changes of landscape structure in relation with land use and cover change dynamic. In the future study need to be continued by including more time series data, investigating driving forces behind LUCC change modeling and predicating. Furthermore, studies that integrating remote sensing approaches with pastoral land use and their environment would be essential for properly understanding and generating of spatio-temporal information of savannah ecosystem.

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Annexes Table 1 Mean monthly rainfall of Yabello district from 1980 to 2004, Borana rangelands, Ethiopia

Year	Months												
	J	F	M	A	MA	J	JUL	AU	SEP	O	N	D	Mean
1980	0	3.5	38.2	453.5	0	0.9	0	43.5	15	19.3	95.4	171.5	840.8
1981	0	18.33	140	0	3.87	12.5	0	13	13	14.102	15.978	17.854	248.63
1982	0	0	22.8	184.35	340.2	25.5	289.3	31.83	45	58.17	71.33	84.501	1152.99
1983	0	8.43	4.4	153.3	118.7	48	9.5	8.4	4.5	9.5	20.8	0	385.53
1984	0	0.5	16.6	54.2	113.9	9.8	16	0	11.5	99.4	162.2	0	484.1
1985	22.9	47.4	186.3	206	246.2	52.8	2.6	12	8.5	182.5	**35**.1	24.53	1026.83
1986	0	4.5	33.5	327.4	67	19.7	29.7	0	0	92	126.9	26.9	727.6
1987	17.3	53	39.5	109.6	292.1	4	1.4	29.2	8.9	15.7	71.2	7.4	649.3
1988	0	19.3	86.4	405.8	11.9	56.6	0	13.6	90.5	73	61.4	27.1	845.6
1989	30	29.1	60.8	187.9	50.6	20.9	3.6	3.4	4.3	35.7	-	54.9	481.2
1990	4.6	70.8	33.1	129.5	79.5	0	1	0	0.3	88.5	45.3	26.8	479.4
1991	16	27	34.8	67.9	160.1	1	24	0	0	33.5	45.4	16.8	426.5
1992	0	40.2	16.9	0	43.7	0	1.5	12.4	50	72	80.1	16.6	333.4
1993	2.26	39.15	3.9	63.7	11.6	18.9	0.6	0	1.7	50.2	13.2	16	221.21
1994	0	0	26.6	96.9	84.6	17.7	10.2	0.2	8.2	158.8	198.6	25.5	627.3
1995	0	18	67.5	70.6	30.8	0.7	12.9		3.6	59.2	31.5	28.8	323.6
1996	0.7	27	82	102.4	130	6.8	11.6	0.3	7.4	19.7	27	0	414.9
1997	0	0	24.7	228.7	6.1	14.4	8	2.4	10	7.4	254	39.5	595.2
1998	129	68.1	8.4	130.8	129.8	47.7	11.1	15.8	0.9	12.4	38.4	29.9	622.3
1999	0.5	0	44.2	41.8	11.1	25.2	3.1	8.5	1.1	9.9	47.3	20.5	213.2
2000	23	0	0	48.5	105	2.5	10.2	11.6	16.9	81.8	71.6	64.8	435.9
2001	2	34.1	51.7	139.3	19.4	9.5	5.8	14.5	8	24.2	65.3	14.6	388.4
2002	19.2	0	35.6	148.3	54.4	16.4	0.1	1.4	24.8	111.3	34.9	90.9	537.3
2003	17	4.9	10.2	87.8	43.8	13.1	0.8	13	0	4	158.7	23.8	377.1
2004	38.3	16.5	26.7	263.9	15	10.5	3.1	0.7	12.6	121.4	98.4	19.9	52.25
CV	176	98	97.95	79.53	99.51	124.08	325.46	88.11	141.69	83.65	78.01	108.85	

CV= Coefficient of Variation; J= *January; F2=February; M= March; 4= April; MA= May; J= June; JUL= July; AU=August; SEP= September; O= October; N= November= December*

Annexes Table 2 Mean monthly maximum Temperature of Yabello district from 1980 to 2004, Bomana rangelands, Ethiopia

	Months												
Year	J	F	M	A	MA	J	JUL	AU	SEP	O	N	D	Mean
1980	31.2	30.3	31.5	29.3	29.2	27.4	26.8	24.3	24.56	26.8	27.3	24.41	**27.76**
1981	31.5	30.6	32.2	25.7	25.1	25.1	25.1	24.9	22.4	21.43	20.46	20.29	**25.6**
1982	31.8	32.9	32.9	22.1	21	22.8	23.4	25.5	20.24	16.06	27.3	16.17	**24.35**
1983	32.1	33.87	39.1	34.2	28.5	29.3	30.3	30	30.4	30.3	30.2	30.1	**31.5**
1984	33.4	34.1	33.9	31.5	28	26.1	25.3	26.2	26.7	28.9	29.6	31.3	**29.58**
1985	31.9	32.5	30.3	27.8	26.4	24.9	26.2	26.2	26.7	28.2	29.2	29.6	**28.325**
1986	33.2	35.3	34	29.6	28.1	27	25.1	26.9	27.5	27.8	27.8	29.6	**29.325**
1987	31.5	32.1	31.4	27.4	26	23.8	24.9	25.7	27.5	27.6	29	31.1	**28.17**
1988	31.4	32.7	33.07	29.43	36.82	25	26.36	27.82	26.2	27.1	26.8	28.5	**29.27**
1989	30.4	30.7	30.7	26.9	25.5	23.8	22.4	23.9	27	26.4	26.7	26.5	**26.74**
1990	29.7	29.5	27.2	26.2	24.7	24.2	23.1	24.6	26.3	26	26	26.2	**26.14**
1991	30.1	31.7	30.8	28.4	25.5	24.5	22.6	26	26.2	27.6	27.6	27.7	**27.39**
1992	32.1	31.63	27.6	27	25.5	23.1	23.7	24.8	26.1	26.5	26.06	25.27	**26.61**
1993	33.03	32.13	27.65	27.75	25.8	23	22.6	23.2	26	27.7	29.7	30	**27.38**
1994	31.7	32.8	31.5	27.2	25.8	22.91	23.18	24.14	25.66	27.77	29.73	34.73	**28.09**
1995	32.4	31.7	28.8	26.6	25.8	27.1	25.1	24.02	26.3	26.4	26.6	39.46	**28.36**
1996	31.1	32.1	28.4	26.2	25.95	23.7	23.4	25.1	26.2	26.5	27.7	44.19	**28.38**
1997	31.5	32.7	31.2	26.2	24.8	25.2	24.8	25.7	27.2	24.4	25.4	26.9	**27.17**
1998	27.1	29.2	29.7	27.8	25.4	24.2	22.7	31.2	26.4	27.7	27.8	28.7	**27.35**
1999	31.1	31.67	29.2	27.5	25.5	25.1	23.1	25.3	26.7	25.1	26.7	28.7	**27.14**
2000	31.3	32.8	31.1	29.3	26.1	24.5	23.7	25.1	27	27	28.4	30	**28.03**
2001	31.9	31.6	31.3	29.3	26.1	24.5	23.7	25.1	27	27	28.4	30	**27.99**
2002	32.23	31.67	31	26.9	24.9	23.8	24.9	25	26.9	25.9	27.3	27.8	**27.35**
2003	30.8	33	32	28.6	25.7	24.6	24.8	25	27	28.8	26.7	28.8	**27.98**
2004	30.9	31.9	32	26.7	25.7	25.2	24.7	25.6	27	25.4	25.7	29.4	**27.52**

CV= Coefficient of Variation; J= January; F2=February; M= March; A= April; MA= May; J= June; JUL= July; AU=August; SEP= September; O= October; N= November= December

Annexes Table 3 Mean monthly minimum Temperature of Yabello district from 1980 to 2004, Borana rangelands, Ethiopia

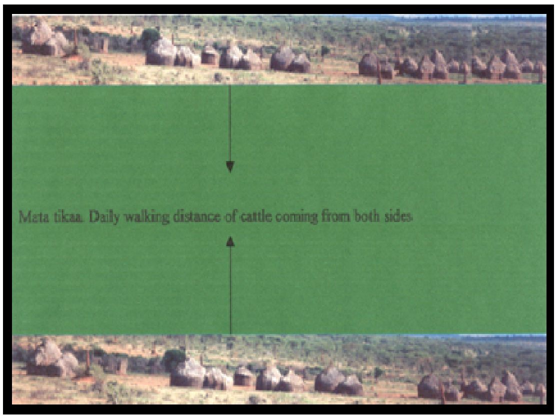
Year	Months												
	J	F	M	A	M	J	Jul	Au	Sep	O	N	D	Mean
1980	9.7	9.4	9.1	8.7	9	15.6	17.1	16.2	16.9	16.2	17.7	17.7	13.61
1981	16.7	9.4	16.7	15.7	15.8	16	16	15.8	15.73	15.66	15.59	15.52	15.38
1982	23.7	16.9	14.9	15.9	19.6	15.5	14.9	15.4	15.17	15.12	15.07	15.02	16.43
1983	30.7	19.4	19.5	17.1	14.2	14.7	14.6	14.6	15.2	14.7	15	7.5	16.43
1984	16.4	16.6	17.9	17.6	16.6	15.7	15.1	15.2	15.9	15.7	13.69	6.16	15.21
1985	17	17.2	17	18.2	17.8	16.4	16.1	16.1	16.2	16.2	16.2	3.05	15.62
1986	16.3	17.2	17.1	16.9	17.1	16.6	15.8	15.6	15.6	17.1	18.9	20.8	17.08
1987	23.4	17.6	20.3	19.1	18.3	16.9	14.6	12.5	13.7	16.9	18.7	17.6	17.47
1988	25.3	17.73	21.43	18.97	18.23	17.13	14	11.13	15.9	17.7	17.7	17.5	17.73
1989	18.2	19.2	19.3	18.1	17.8	15.9	15.6	17.2	16.6	15.8	20.20	18	17.66
1990	18.2	18.7	18.3	18.2	17	15.6	15.7	15.9	16.5	16.6	16.8	16.6	17.00
1991	18.2	19.4	19.6	18.4	15.5	16.2	15.2	15.1	15.8	16.4	17.7	17.2	17.06
1992	19	19.3	18.00	17.1	17	16.8	16.1	15.7	16.5	17.7	19.31	17.8	17.53
1993	19.26	19.4	18.33	16.8	17.2	16.5	16.2	15.6	16.1	17.6	19.711	18.4	17.59
1994	18.5	19.4	19.7	18.7	17.9	16.8	16.83	15.96	16.43	18.43	20.11	19	18.15
1995	18.2	20.2	19.3	19	18.3	16	16.6	16.26	17.1	18.1	17.9	18.6	17.96
1996	14.3	20.1	19.1	18.8	18.9	17.1	16	15.9	16.9	17.7	18.3	19.2	17.69
1997	19.3	18.7	20.1	18.2	17.7	17.3	16.4	16.6	17.5	17.9	18.1	17.9	17.98
1998	18.3	19.1	19.3	19.5	18.5	17	16	16.4	16.7	17.4	17.4	18	17.81
1999	18.6	18.9	19.4	18.6	16.9	16.4	16.9	16.6	16.8	17.4	17.4	17.8	17.64
2000	18	19.6	19.9	19.3	18	16.7	16.3	16.4	16.4	18	18.5	19.1	18.02
2001	20	19.4	20	18.8	18.5	16.9	16.3	16.3	17.4	18.5	18.4	18.7	18.27
2002	19.7	20.2	20.4	18.6	17.1	16.5	16.52	16.52	16.88	19	18.47	19.11	18.25
2004	20.4	14.4	18.8	15.5	14.3	12.4	11.7	11.7	14.6	14.5	14.8	14.9	14.83
CV	**20.67**	**16.45**	**13.26**	**12.58**	**12.67**	**6.31**	**7.41**	**9.97**	**5.51**	**7.27**	**9.91**	**26.98**	

CV= Coefficient of Variation; J= *January; F2=February; M= March; A= April; MA= May; J= June; JUL= July; AU=August; SEP= September; O= October; N= November= December*

Annexes Table 4 Contribution to net land use change by each land cover (%) of area (1987-2003)

Land cover	Wood land	Bush land	Grass Land	Shruby grassland	Bare land	Cultiva tion	Settle ments
	1987-2003						
Woodland	0.00	-0.46	-0.51	2.94	-0.01	-0.04	-0.17
Bush land	0.46	0.00	1.79	0.79	0.01	-0.13	-0.23
Grassland	0.51	-1.79	0.00	-0.17	-0.08	-0.19	-0.21
Shruby grassland	-2.94	-0.79	0.17	0.00	0.00	-0.07	-0.03
Bare land	0.01	-0.01	0.08	0.00	0.00	-0.05	-0.05
Cultivation	0.04	0.13	0.19	0.07	0.05	0.00	-0.01
Settlement	0.17	0.23	0.21	0.03	0.00	0.05	0.00
	1987-1995						
Woodland		1.08	-0.25	2.19	0.00	-0.02	-0.04
Bush land	-1.08	0.00	0.97	-0.44	0.15	-0.01	-0.03
Grassland	0.25	-0.97	0.00	-1.60	-0.25	-0.08	-0.02
Shruby grassland	-2.19	0.44	1.60	0.00	0.10	0.00	-0.03
Bare land	0.00	-0.15	0.25	-0.10	0.00	0.01	0.00
Cultivation	0.02	0.01	0.08	0.01	0.01	0.00	0.00
Settlement	0.04	0.03	0.02	0.03	0.00	0.00	0.00
	1995-2003						
Woodland		-11.99	-4.92	20.30	-13.53	-1.97	-28.68
Bush land	9.37	0.00	2.91	17.67	-8.54	-31.15	-73.76
Grassland	6.41	-4.84	0.00	7.21	21.83	-59.15	-162.45
Shruby grassland	-9.68	-10.79	-2.64	0.00	-1.22	-27.16	5.24
Bare land	1.00	0.81	-1.24	0.19	0.00	3.39	-18.64
Cultivation	0.04	0.76	0.86	1.08	-0.87	0.00	-6.75
Settlement	0.36	1.19	1.58	-0.14	3.19	4.50	

Annexes Figure 1 Land use class of study area during dry season

	
Bush land	Grassland
	
Bare land	Settlement
	
Wood land	Cultivation land

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