Faculty of Science

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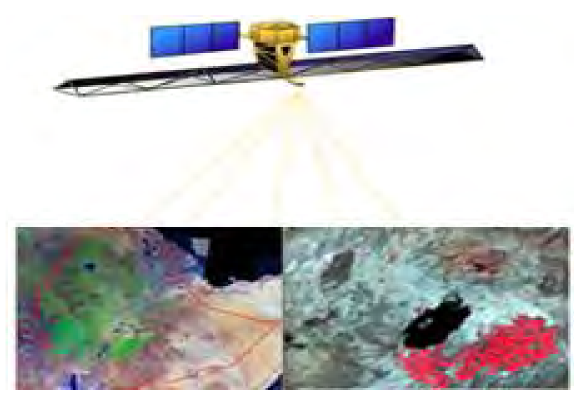
Land Use /Land Cover Dynamics in *Prosopis juliflora* invaded area of Metehara and the Surrounding Districts Using Remote Sensing & GIS Techniques



By: Ashenafi Burka

A Thesis Submitted for Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science in Remote Sensing and Geographic Information System (GIS)

Advisor:
Dr. Dagnachew Legesse

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LIST OF ABBREVIATION

ASE: Average Standard Error

ASLNP: Abijata Shala Lakes National Park

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer

EIAR: Ethiopian Institute of Agricultural Research

ETM+: Enhanced Thematic Mapper Plus

FAO: Food and Agricultural Organization

FCC: False color Composite

GIS: Geographical Information System

GPS: Global Positioning System

ISODATA: Iterative Self-Organizing Data Analysis Technique

IAS: Invasive Alien Species

LUCC: Land Use and Cover Change

LULC: Land use and Land Cover

ML: Maximum Likelihood

MSS: Multi Spectral Scanner

OK: Ordinary Kriging

RMSE: Root Mean Squared prediction Error

RMSSE: Root Mean Square Standard Error

RS: Remote Sensing

TCC: True Color Composite

TM: Thematic Mapper

VNIR: Visible and Near Infra Red

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ABSTRACT

Land use and land cover changes are derived by natural process and anthropogenic interference in ecosystem. Appropriate management of natural resources requires quick and up-to-date information for effective decision making. The aim of this study is to generate such kind of information using RS and GIS technology to support the land use planning and strategy formulation of the newly emerging problem of the study area. The present study has been attempted to identify and quantify the main land use and land cover change that occurred for the last three decades. Besides, in this study assessment of the spatial distribution of Prosospis juliflora tree species using geostatistical analysis has been conducted. Three satellite imageries of Landsat MSS 1973, Landsat TM 1986 and ASTER 2002 were utilized for detection of Land use/land cover change. Prior to change detection analysis, land use/land cover map of 1973, 1986 and 2002 was generated. Eight land use/land cover classes have been identified from the three independent image classification processes. Subsequently, post classification change detection method was applied to quantify the land use/land cover change and to provide information about the source and destination of the change. The change detection analysis revealed the existence of significant land use/land cover change in the study area. The findings of change detection analysis indicates the continuous spatial increment of cultivated land, bare land and water body (Lake Beseka) at the expense of grass land and open shrub land. The rate of expansion of Lake Beseka and cultivation land was 109.9 ha and 63.8 ha per year from 1973 to 2002, respectively. On the other hand, the rate of decrease in spatial extent of open shrub land and grass land was 182.4 ha and 38.5 ha per year from 1973 to 2002, respectively. Using geostatitical analysis it has been possible to map the current invasion of the nuisance plant P.juliflora overcoming the problem of getting high spatial and spectral resolution satellite image. From the geostatistical analysis, the highest and the lowest density of the species has been observed at the southern and north western part of the study area, respectively. In addition, there has been a trend in decrease of P.juliflora density from south to north western and north eastern part of the study area. The infestation of P.juliflora has been observed in areas of relatively better moisture and lower altitude of the study area. Furthermore, socio-economic survey was conducted to assess the social and environmental impact of P.juliflora and the results of the survey disclosed that 91% of the respondent said that the species has a negative impact on other plants. In addition, 76% of the respondent from high infestation area and 90% from medium infestation area believed that P.juliflora has been threatening the livestock production by encroaching the grazing land. In general, significant land use/land cover change in the form of conversion and modification has been occurred in Metehara and its surrounding area. The outcome of land use/land cover change, geostatistical and socio-economic survey analysis can serve local and regional planners as a primary source of information for better management of natural resources in the study area.

Key words: RS & GIS, LULC Change, Conversion and Modification, Geostatistics, Invasion, *Prosopis juliflora.*

1. INTRODUCTION

1.1. Background of the Study

The earth has been in a state of continuous change since a long time ago. The adaptation of landscape by the action of man either to create better living condition or to cope with the demand of resource required to fulfill man's subsistence have taken place since the down of mankind. These activities of human being create an impact on the environment causing change by disturbing the equilibrium condition of nature. The impacts associated with, though significant at the beginning, have transformed the face of the earth for good or bad as no other living species ever done. The environmental change observed could be categorized into modification and total conversion.

Being a less developed society, the observed changes of the land is swifter in Africa than in other continents. Environmental degradation is the most prevalent phenomenon in Ethiopia since agriculture was begun. High population pressure, decline of land holding size, low production, loss of soil fertility, and increasing demand for fuel energy and construction are some of the expected challenges to Ethiopia for the coming years.
Modification of the environment has impact on the ecology and foster pressure on the living condition of human being. Land use and rapid alteration of land cover have great implications for the very existence of human as dependents of natural biophysical systems for survival (Kwabena, 2007). As stated also on Belay (2002) a change in land cover can negatively affect the potential use of an area and may ultimately lead to degradation and loss of productivity.

It is natural, patterns and trends of the land use and land cover have under gone through changes since the element of land use and land cover is not static. Land use and land cover changes cause by natural and human activities. Land use change, caused by human activities accelerates the rate of deforestation, soil erosion and loss of biodiversity. And land use and land cover change have a great influence in global warming, loss of biodiversity, and impact on human life (Anwar, 2002).

In addition to anthropogenic effect, natural phenomenon also changes the environment. Invasion of native plant communities by other unwanted species are one means of modification of the environment. Invasive species are a form of biological pollution (Greg *et al.*, 2004).

Now a day, alien species (also called non-indigenous species) invasion is one of the challenges that Ethiopia faces.

Since majority of the people depend on land and land resources, rural poverty has become common and natural resources are alarmingly dwindled and degraded from time to time. This problem is also aggravated by invasive species, through the invasion of agricultural, grazing and protected lands. The environmental Policy of Ethiopia (EPE) and the Biodiversity Strategy and Action Plan (NBSAP) have identified invasive species as posing a major threat to biodiversity and economic well-being of the country.

Land use and land cover change in the form of conversion is one of the real problems of the study area. Moreover, at present, invasion of IAS is the pressing problem of Metehara and its environs. This study may be considered as the stepping stone to generate information about the current situation of problem mentioned above.

Hence, the result of this study may have the following contribution:

- The study of pattern in land use and land cover is one of the indicators of the status of resources utilization and management of land that provides basis for conservation planners to plan for the sustainable use of land.
- The study may give general information about the natural resource base of the area which used as base line information for researcher, governmental and non governmental organization.
- The finding of the study would give suggestion to strategy and decision makers, some possible ways of combating environmental problem at local and regional level.

The thesis is organized into six chapters. The first chapter introduces the background information, statements of the problems and objectives and of the study. Chapter two deals with the theoretical framework and literature review which focus on the issues related to this study. Chapter three describes about the general situation and resource condition of the study area. Chapter four shows the methodologies used to collect data and different analysis techniques. Chapter five describes the findings of the study and what it means. The last part of the thesis, conclusion and recommendation synthesizes the summary of the findings and suggestions to be considered.

1.2. Statement of the Problem

The Ethiopian Rift valley region constitutes a large part of the dry land ecosystem, and Metehara & its surrounding is part of the Central Rift Valley of Ethiopia. Increased population pressures due to immigration and natural high growth rates coupled with reduction of the available land for large scale irrigation has put pressure on the natural resource of the locality. Movement of pastoralists to utilize resource over a wide range is restricted and consequently overgrazing has caused rangeland degradation and low productivity, and poor quality of livestock.

Prosopis juliflora is one of the invasive species, which is found dominantly on the arid part of Ethiopia like Afar, some parts of Oromia, Dire Dawa and Amahara regions. This species has high capacity to invade the new areas within a short period, which causes modification of the environment. Because of expansionist invasiveness, grazing land around Metehara area has been decreasing, grass and other local indigenous species have been suppressed by the species. In Ethiopia, the aggressive invasion of (*P.juliflora*) in pastoral areas is displacing native tree species, forming impermeable thickets and reduced grazing potential and agricultural lands. Moreover, protected areas like the Awash National Park are threatened (Esther *et al.*, 2005).

It was begun to be planted some years before, but it has been spread like a weed. *P. juliflora* was intentionally introduced as an agroforestry species in the Awash basin. Because of its high expansion, it is highly competing for space with grazing, agricultural lands and protected areas. In Awash basin of Ethiopia, the species is aggressively invading pastoral areas in the middle and upper Awash valley, and it is one of the three top priority invasive species in Ethiopia and has been declared as a noxious weed (Esther *et al.*, 2005).

The invasive species is also changing the biodiversity of the area. Therefore, the species negatively affects the natural ecosystems by out-competing native flora and fauna for the resource and growing space. The impacts of invasive alien species are immense, insidious, and usually irreversible and they may be as damaging to native species and ecosystems on a global scale as the loss and degradation of habitats (IUCN/SSC/ISSG, 2000). Since there is no well organized controlling systems for the species its negative impact threatened and endangered native species found in the area (Esther *et al.*, 2005). Beside anthropogenic activities, modification of the environment and land cover change is aggravated due to the invasive *P.juliflora* expansion.

Land use and land cover change play an important role in environmental change. The change constitutes loss of biodiversity, land degradation, climatic change, etc. Moreover, pastoralists whose main livelihood depends on livestock view *P.juliflora* negatively because it invades valuable pastures. Hence, to reduce its environmental, social and ecological impact and to utilize it as a resource in a sustainable manner, having up-to-date information on land use/ land cover change, rate of land use/land cover change, spatial distribution and environmental impact of the species are indispensable. Actual and reliable information on land use and land cover is needed both for agriculture , environmental applications and management of resources (Clevers *et al*., 2004; Yuksel *et al*., 2008; Tadesse *et al*., 2001) and land use and land cover change has become a central component in strategies for managing natural resources and monitoring environmental change (Ayodeji, 2006). Up-to-date information about the dynamics in land use/land cover condition of the environment is the basis for knowing the status of the environment since a certain land use and land cover change may affect the biophysical environment and the livelihood of the community. In order to improve the economic condition of the area without further deteriorating the bio environment, every bit of the available land has to be used in the most rational way and this requires the present and the past land use/ land cover data of the area (Nagmani *et al*., 2003) and of this reason concern about land use/land cover change emerged in research agenda with the realization that changes significantly affect central aspect of earth system functioning (Lambin *et al*., 2003). As indicated by Etter *et al.* (2005) from a planning perspective, it is important to have a spatially explicit understanding of existing and predicted land cover changes, and knowledge of their underlying drivers.

Moreover, information on the actual and potential distribution of invader (*P.juliflora*) is crucial for decision making for its proper management. Managers require accurate and timely spatial information to assist with locating and controlling small infestation before become too large to eradicate effectively and to monitor the effectiveness of their management strategies and biological conservation (Law, 2006; Yang, 2004).

Land resource and environmental decision makers require quantitative information on the spatial distribution of land use types and their conditions as well as temporal changes. Undoubtedly the Remote Sensing and GIS technology has enabled ecologist and natural resource managers to acquire timely data and observe periodical change (Bedru, 2006). Remotely sensed satellite data in conjunction with available other data sources have been used to find such land uses. Having acquired geographical data in digital form, it becomes possible to display and analyze the data in ways that are often much quicker and more effective than was possible using manual techniques (Jones, 1997).

With creating a geodatabase for the study area, it is possible to analyze and interpret the resource condition with GIS and remote sensing. The GIS environment permits the synthesis, analysis, and communication of virtually unlimited sources and types of biophysical and socioeconomic data as long as they can geographically referenced (Lillesand *et al.*, 1994). Hence, GIS is an invaluable decision-making and a powerful tool of analysis (CTA, 1998). Furthermore, geostatistics has emerged as an important tool for characterizing spatial or temporal phenomena. Spatial analysis techniques, including geostatistics and GIS-based approaches, are increasingly being used to estimate the ecological phenomenon based on the field survey data. In light of this discussion, the major points addressed in this study were about the major LULC changes existed, what forces drive the changes and the status of spatial distribution of *Prosopis juliflora* in the study area. Accordingly, this study was formulated with the following objectives.

1.3. Objectives of the Study

1.3.1. General objective:

The overall objective of this study was detection of land use/land cover change and assessment of the spatial distribution of *P.juliflora* for decision support system for sustainable natural resources management.

1.3.2. Specific objectives:

- To under take land use/cover change analysis to quantify the rate of change of the study area.
- To map the current land use/land cover of the study area.
- To assess and map the current spatial distribution of *P.juliflora* using representative samples.
- To evaluate social and environmental impact of *P.juliflora* on the study area.

2. LITERATURE REVIEW

2.1. Theoretical Framework

2.1.1. RS & GIS for Land Use/Land Cover

The remote nature of remote sensing technology allow us to make observations, take measurements (i.e. measuring the reflected and/or emitted electro magnetic energy from the earth's features), and produce images of phenomena that are beyond the limits of our own senses and capabilities. 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).

Satellite remote sensing provides a large amount of data at different spatial, spectral, and temporal resolutions by using the appropriate combination of bands to bring out the natural and man-made features that are most pertinent to a certain project for detecting changes. The data obtained from satellites imagery used for a wide array of change related application areas such as vegetation and ecosystem dynamics, hazard monitoring, hydrology, land use and land cover change, and so on. Satellite image data enable direct observation of the land surface at repetitive intervals and therefore allow mapping of the extent and monitoring and assessment. Remote sensing at various scales plays a major role in spatio-temporal earth surface monitoring (Neteler *et al.*, 2004).

Remote sensing can detect features unseen on the surface, map them accurately, and offer interpretations based on their form, distribution, and context. The techniques are particularly suited for providing reliable, up-to-date and comprehensive data on land use/land cover. As noted by Bedru (2006) the Landsat images that were made available soon after its launch disclosed the shocking reality of Amazonian deforestation and the so-called 'fish-bone' pattern that was detected by remote sensors revealed the role of new roads in facilitating deforestation. The same author state that detection of deforestation on the Amazon forest from satellite images paved the road for wide acceptance of the remote sensing for natural resource conservation. The synoptic and repetitive coverage of land resource satellites made possible the availability of time series imagery for land use/land cover change detection analysis. Satellite imagery has been well utilized in the natural science communities for measuring qualitative and quantitative terrestrial land-cover changes (Coppin *et al.*, 1994: Cited by Seto *et al.*, (2002)).

The most useful characteristic of Remote Sensing in land use and land cover change detection is the multi spectral and temporal resolution of the data. That is, images are obtained in different portions of the electromagnetic spectrum and the same area is imaged with a specified periodic time interval. The advantage of using remote sensing in land use/land cover is that information from the same area could be easily obtained at different times, and this is important in change detection applications. Further more, remote sensing can provide the required data in short time with a reasonable accuracy (Billah *et al.*, 2004) and has an important contribution to make in documenting the actual change in land use/land cover on regional and global scales from the mid-1970s (Lambin *et al.*, 2003).

Geographic Information Systems (GIS) is a technology, which enables the analysis of data related to entities that have geographic distribution.

Georeferenced data, land use/land cover, crop type, or soils, can be incorporated in a GIS to produce map layers or "coverages". A map layer, generally composed of only one type of data, and thus considered to have a "theme". Many of these themes that have a similar spatial extent can be combined to form a full GIS database. As a result, the GIS serve as a tool for analyzing interactions among and within the various spatially referenced data themes.

Development of Remote Sensing and Geographic Information System (GIS) technologies have lead to the advancement of mapping and interpretation techniques as a means of understanding and effectively managing the natural resource in a sustainable manner. Analysis mechanisms of land use pattern changes play an important role not only forecasting changes but also formulating local development strategies. At present, remote Sensing in combination with GIS have given rise to the advent of more precise and geographically referenced data on land use and land cover, which in turn have created opportunities for improved assessments and analysis issues related with the land use/land cover dynamics (Codjoe, 2007).

2.1.2. Land use/Land cover

Many individuals use land use and land cover terms interchangeably, although they are different. Land cover refers to the physical characteristics of the earth’s surface, captured in the distribution of vegetation, water, desert, ice and other physical features of the land, including those created solely by human activities such as mine exposures and settlement (Billah *et al.*, 2004). And the same author defines land use as the intended employment and management of strategy placed on land cover type by human agents or land managers.

The demand for land use and land cover data can increase as we seek to assess and manage areas of important concern for environmental control such as highly fragile eco-system, wildlife habitat, and areas such as agricultural development sites. Land cover is perhaps the most important characteristic of the land surface, from both an environmental and a societal perspective. Most ecosystem processes strongly depend on the land cover which in turn influence land cover attributes. Similarly, land use is strongly conditioned by land cover. One of the prime prerequisites for better use of land is information on existing land use patterns and changes in land use through time (Anderson *et al.*, 1976). Advanced satellite images classification represents an accurate and cost-effective alternative to the classical techniques of land cover mapping. Since land cover varies in time and space, mapping approaches have been used to obtain information on land cover distribution and spatial variation in the past. Satellite data with synoptic view, repetitive coverage and multispectral viewing etc has brought drastic changes in the land use/ land cover mapping and monitoring (Chaudhary *et al.*, 2008)

Continuous monitoring of land uses in Remote Sensing has provided land use planning an effective way to prepare land use maps and detect changes frequently. Remotely sensed data can be converted into land map using systematic process in a shorter time as compared to the time consumed in manual land surveys. Use of Remotely sensed images and GIS has proved to be very effective technique for land use mapping when time constraint and data coordination are taken into considerations. According to Giri *et al.* (2005) the particular interest on land use / land cover mapping is to better understand and manage emerging environmental problems arising from local to global scale. Land use and land cover mapping is the primary activity which has to be conducted prior to change detection analysis.

2.1.3. Digital Image Processing

Digital image processing is the most important task in remote sensing and GIS analysis. It is conducted to extract valuable information from the raw data mostly satellite imagery. All remotely sensed data have to undergo a certain degree of preprocessing before analysis and interpretation to extract useful set of information. This technique, which is partly science and partly art, is called image processing (Lillesand *et al*, 2004).

Prior to analysis, a number of pre-processing steps have to be performed to the satellite data in order to make the pixel brightness values comparable between dates (Clark, 2004).For instance, accurate coregistration is imperative if images of different years are compared. Digital image processing is performed with a computer facility and it incorporates various techniques. Some of these techniques involve modifying an image in order to improve contrast between features in a well defined spectral range or to improve resolution and detail from a set of raw image data.

Raw satellite data often contain a vast amount of information that is not readily apparent to the analyst. Therefore, image enhancement techniques are used to highlight features of interest and expose subtle differences in the spectral signature of the components of the target. For instance histogram equalization is one of the most well-known methods for contrast enhancement (Starck *et al.*, 2003).After the necessary preprocessing is applied on the raw data, the analysis like the land use and land cover classification and change detection could be carried out.

2.1.3.1. Satellite Image Classification

Classification is a process by which a set of items is grouped into classes based on common characteristics. Classification of satellite image data is based on placing pixels with similar values into groups and identifying the common characteristics of the items represented by these pixels. Kokaljl *et al.* (2007) described the main purpose of satellite imagery classification is the recognition of objects on the earth's surface and their presentation in the form of thematic maps.

Classification is one of the digital image processing that is very useful when multispectral imagery of the same geographical region is compared. Classification algorithms can be used that derive a value for each pixel in the image from its brightness values in each image. The analyst that is classifying an image must distinguish between spectral classes and information classes. Spectral classes are groups of pixels that have nearly uniform spectral characteristics. Information classes are the various themes or groups the analyst is attempting to identify in an image. Information classes may include classes such as deciduous and coniferous forests, various agricultural crop types, etc. Each object has unique and different characteristics of reflection or emission in different environment as a result an object can be identified using reflected /emitted electromagnetic radiation from that object (Billah *et al.*, 2004)

One band classification is usually very difficult to classify since more than one surface type will exhibit the same digital number. As a result, two or more bands are used for classification, and their combined digital numbers are used to identify the spectral signatures of the spectral classes present in the image. Consequently, remotely sensed datasets provide useful thematic information and extracting thematic information from the data is obtained through image classification. There exist a variety of techniques for extracting thematic information from an image. Unsupervised and supervised image classifications are the most frequently applied classification techniques in remote sensing.

In unsupervised classification, the pixels in an image are examined by the computer and classified into spectral classes. The grouping is based solely on the numerical information in the data and the spectral classes are later matched by the analyst to information classes. In order to create an unsupervised classification the analyst typically determines the number of spectral classes to identify and a computer algorithm will find pixels with similar spectral properties and group them accordingly. Clustering algorithms like ISODATA are used to determine the statistical groupings in the data for the accomplishment of the unsupervised classification.

A supervised classification is performed when some prior or acquired knowledge of the classes in a scene is used to identify representative samples of different cover types. This prior knowledge is used to select homogenous areas within the image that posses the thematic information to be extracted. The first step in the supervised classification is to identify representative areas to develop a numerical description of the spectral attribute for each land cover type of interest (Yuksel *et al.*, 2008).These areas are commonly referred to as training sites and must be selected for every image class that is to be identified. The determination of training sites is based on the analyst's knowledge of the geographical region and the surface cover types present in the image. After all training sites have been selected and the classifier algorithm examines the spectral characteristics of the training sites to determine statistical parameters related to each class. Next all the pixels, including the training sites, are spectrally evaluated and assigned to a class based on the highest likelihood of being a member of that class. The final product is a classification in which all pixels within the image have been assigned to one of the predefined classes. According to Lillsand *et al.* (2004) maximum likelihood classifier is the widely used algorithm in supervised classification which is based on the estimation of probability distributions for the land cover types in the training data.

Classification accuracy assessment is the next task to be carried out so as to evaluate the likeness of classified thematic information with reality. Land cover accuracy is commonly defined as the degree to which the derived classification agrees with reality, and the accuracy of the map in a larger part determines the usefulness of the map (ERDAS, 2002; Behera *et al.*, 2000: Cited in Ge (2007)). An accuracy assessment requires performing direct comparisons between the final classification and information derived from independent ground-truthing (Douglas *et al.,* 2001).And ground truth data are determinant in defining and/or identifying the surface features embedded in the satellite imagery (Kazadi, 2003).
The classification system must allow for the inclusion of all parts of the area under study and should also provide a unit of reference for each land use and land cover type. The error matrix and associated statistics are useful tools in classification accuracy assessment (Congalton, 1991: Cited on Hammond *et al.* (1996)).

2.1.3.2 Change Detection

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. Land use/cover studies using remote sensing data have been received immense attention worldwide due to their importance in global change analysis (Cihlar, 2000; cited in Dewan *et al.* (2004)) and both human-induced and natural land cover changes can influence the global change because of its interaction with terrestrial ecosystem (Houghton, 1994: Cited in Dewan *et al.* (2004)), biodiversity (Sala *et al.*, 2000: Cited in Dewan *et al.* (2004)) and landscape ecology (Reid *et al.*, 2000: Cited in Dewan *et al.* (2004)).

According to Billah *et al.* (2004) land use and land cover change can grouped into two broad categories: conversion and modification. Conversion refers the complete replacement of one cover type by another, whereas modification involves more subtle changes that affect the character of the land cover without changing its overall classification (Coppin, 2004).With various reasons one land cover could be changed to other land uses/cover types (i.e. forested land into agricultural land) and a shift in intent and/or management results a land use/land cover changes. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989; Rymasheuskaya, 2007; Mas, 1998). And, Change detection is an important process in monitoring and managing natural resources development because it provides quantitative analysis of the spatial distribution of the variable under study.

With change detection it is possible to quantify the rate of change and understand the source and destination of land use and land cover changes occurred on a particular place. Understanding the land use and land cover change that have occurred on a particular place help us to infer information about the status of the environment.

Vagen (2006) and Bergen *et al*. (2002) stated that there are a number of methods that are available for temporal land use change detection; and, post-classification comparison, temporal image differencing and rationing, change vector analysis and spectral mixture analysis are some of them to be mentioned. According to Fan (2007) the post-classification change detection method was found to be the most suitable for detecting land use/land cover change. In the post-classification technique, two images from different dates are independently classified and accurate classification is crucial to insure precise change detection results. Post-classification comparison can provide a complete matrix of change directions (Lu et al., 2003).

2.1.4. Geostatistical Analysis

Geostatistics is a branch of applied statistics specialized in analysis and interpretation of geographically referenced data (Webster *et al.*, 2001). There is spatial variability on the surface of the earth and this spatial variability refers to variation of a target variable among observations in space. The appropriate statistical methods for the analysis of the spatial variability of regionalized data are those of geostatistics. Geostatistics is an analytical tool for statistical analysis of sampled field data (Hengl, 2007) and its goal is to model and estimate patterns in the spatial variability of regionalized data.

According to Webster *et al.* (2001) and Isaaks *et al.* (1989) a geostatistical analysis can be broken down into four phases: exploratory data analysis, modeling of the spatial autocorrelation (characteristics of the spatial continuity), estimating at unsampled locations across a surface (surface maps) and evaluation of the reliability of the estimates.

Geostatistics originates from the mining and petroleum industries, first developed 40 years ago by Georges Matheron and name in the honour of Danie Krige (Clark, 1978). Compared to the classic approaches which examine the statistical distribution of sample data, geostatistics incorporates both the statistical distribution of sample data and the spatial correlation between the sample data. Because of this difference, many earth science problems are more effectively addressed using geostatistical methods. Predictive geostatistical models and maps provide valuable information for researchers and resource managers (Kalkhan, 2007).The model variogram is the pre request for estimation of the variable under study.

The primary method of extracting information of the spatial correlation is through the variogram. It expresses the variability of pairs of spatially indexed observations as a function of their separation vector. The study of spatial data where the spatial correlation is modeled can investigated through the variogram calculation. The variogram can be calculated using the following equation (Isaacs *et al*., 1989):

$$\gamma * (h) = 1/ 2\ N(h) \sum_{i=1}^{Z(h)} [Z(x_i) - Z(x_i + h)]^2$$

Where:

N (h) is the total number of pairs of variable counts which are separated by a distance h,

Z (xi) represents the observed values of the regionalized variable (presence or absence of the variable under study).

The graph of **γ (h)** versus the corresponding values of **h**, called a **Semivariogram**, is a function of the distance **h**, and, therefore, it depends on distance magnitude and direction.

Semivariogram is described by the parameters of **range, sill**, and **nugget**, which are needed to interpolate data with a Kriging method (*Main et al.*, 2004).For properties that are spatially dependent, the increment **[Z (xi) – Z (xi+h)]** is expected to increase with distance, up to some distance beyond which it stabilizes at a **sill** value, and is numerically almost equal to the variance of the data. This distance is called the **range** and represents the radius of a circle within which the observations are correlated.

The semivariance value at the intercept to the $\gamma^*(h)$ axis is called **nugget effect**, and represents the variability at distances smaller than the minimum sampling distance.

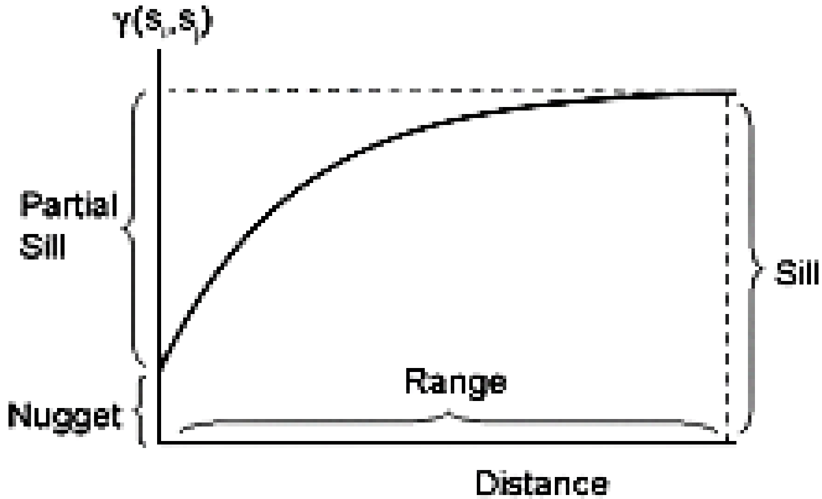


Figure 1: A theoretical feature of Semivariogram depicting range, sill, and nugget, where (s_i, s_i) is the location coordinate of location i (ESRI, 2004).

In spatial variation modeling, there is developing a model for correlation structure. And the proposed model used to predict responses at unsampled locations. After modeling the spatial structure, it is necessary to interpolate between the sampled points to produce precise map of the variable under study. The goal of variograme modeling is to determine the best fit for a model that pass through the points in the Semivariogram (ESRI, 2005).

Krigring is for interpolation (what measured value tells us about the properties at un-sampled location). It is a geostatistical interpolation technique which uses a linear weighted-averaging method and the weights depend on the model of spatial correlation.

Kriging is considered the best predictor of non-sampled locations, because mean residual error is minimized by its calculation (Main *et al.*, 2004). It maintains two distinct advantages over other interpolation techniques such as e.g. inverse distance weighting. First, standard interpolation techniques do not include any information about the spatial correlation structure. Secondly, kriging allows a prediction variability estimate to assess the prediction accuracy.

2.2. LULC Change at Global Perspective

Land use and land cover changes occur at all scales, and changes at local scales can have cumulative impacts at broader scales. Consequently, land use and land cover changes are not just of concern at local and regional levels (i.e., because of impacts on land management practices, sustainability, and social processes), but globally as well.

It has been stated by many authors that land use and land cover changes are driven by natural processes (climate change, wild fire, etc), direct effect of human activity (deforestation, road construction, etc) and indirect activity of human activity. According to Turner II and Meyer's (1994) land cover transformation did not stop, but rather accelerated and diversified with the onset of industrial revolution, the globalization of the world economy and the expansion of population and technological capacity. And Lambin *et al.* (2003) summarizes the global land cover change and the area of cropland has increased from an estimated 300-400 million ha in 1700 to 1500-1800 million ha in 1990. The area under pasture increased from 500 million ha in 1700 to 3100 million ha in 1990. These increases led to the clearing of forests and the transformation of natural grasslands, steppes, and savannas. The same author noted that forest area decreased from 5000-6200 million ha in 1700 to 4300-5300 million ha in 1990. The area under steppes, savannas, and grasslands declined from around 3200 million ha in 1700 to 1800- 2700 million ha in 1990.

Furthermore, the world total of cultivated land was estimated to have increased by 446% between 1700 and 1980 (Turner *et al.*, 1992: Cited by Muluneh (2003)). Estimate of cultivated land of the world land range from 14.5 to 15 million kilometers area. The land devoted to agricultural use has been increasing in almost all countries of the Third World since 1950s. The 770 million hectares of agricultural land in the 1980s was expected to grow by 11% by the beginning of the millennium and about half of this growth was expected to occur in Latin America and a third in sub-Saharan Africa (Bilsborrow *et al.*, 1992: Cited by Muluneh (2003)). On the contrary, because of the expansion of settlement and forest, cultivated land in Europe decreased by about 3.5% in the period between 1973 and 1988 (Meyer *et al.*, 1992: Cited by Muluneh (2003)).

2.3. LULC Change at National Perspective

The highland of Ethiopia is divided by the Rift Valley, which runs from the Danakil depression to the southern part of the country in a south-southwestern direction. The undulating nature of topography coupled with high population pressure on the highland facilitates the degradation of environment. The reputation of Ethiopia as one of the earliest crop domestication countries indicates that ecosystem modification has probably been an age-old phenomenon (Tewolde-Berhan (2006): Cited by Bedru (2006)).

Due to extensive land use practice and high population pressure, the land is severely degraded and eroded for a long time. The population density, settlement pattern, economic status, climate, physiographic and other factors are not similar throughout the country; accordingly, the land use and land cover change, rate and extent might not be the similar.

2.3.1. LULC Change in the Highland of Ethiopia

Majority of the population of Ethiopia settled in the Ethiopian highlands, which triggers the land use and land cover change. Belay (2002) indicated both kinds of land use/land cover change (modification and conversion) had been observed on Derkolli catchments of Amhara region. The same author described that, between 1957 and 1986 the area under shrub land decline by 58%, while those shrub grass land registered a net gain 29.82 and 190.98%, respectively. According to Belay (2002) the main driving force for this change was group of interacting variables that are responsible for the change despite the generally expected overgrazing by livestock and subsequent bush encroachment. And the first of these is the extensive use of the woody vegetation for charcoal production and firewood.

On the other part of the highland, it is indicated by Muluneh (2003) following the increase in population pressure, eucalyptus wood lots, cultivated area and wasteland expanded by about 170% , 53% and 25% respectively, while grazing areas and shrub lands , respectively, decreased by about 34% and 15% in about four decades on the Gurage highland. While about 51% of the land involved land use transformation, the remaining 49% showed no change on the Gurage highland. The same author found out that population growth, land scarcity, increasing need for cash, development of motorable road transportation, rural-out migration and emergence of rural towns and market places were identified as the driving forces landscape change.

2.3.2. LULC Change in the Lowland of Ethiopia

Recorded anthropogenic interference in ecosystems through land use change in Ethiopia does not date back farther than four or five decades (Hailu 2000; FDRE 1998: Cited on Bedru (2006)). The land cover change in the Rift valley of Ethiopia mainly caused due to the deforestation of the Acacia woodland and agricultural land expansion. Dry land forests in Ethiopia are currently threatened by shifting cultivation, the spread of sedentary agriculture, increase in livestock, the increasing demands for fuel wood, charcoal and construction materials, and uncontrolled man-made fires (*Simon et al.*, 2006) and Ethiopian rift valley is found to be one of victims of these problems.

According to Bedru (2006) from 1973 to 2000, agriculture alone was the driving force for 83.4% and 70.1% of the natural vegetation loss in ASLNP and in Zeway- Awassa Basin, respectively. The same author disclosed that, from the 45 households interviewed in the ASLNP, a staggering 43 of them responded that their agricultural plot has been expanded significantly in the past 10-20 years. However, the drive to expand has been largely set off by the need to fulfill household food demand. Only 13.3% of the farmers expanded their agriculture to produce cereals for commercial purpose.

3. DESCRIPTION OF THE STUDY AREA

3.1. Location

The study area is located in the axial part of the Main Ethiopian Rift valley in Fentale Woreda, east Shoa zone of Oromiya regional state at 195 km east of Addis Ababa. It covers an area of about 393.5 km^2, and geographically located within 8^{0}45′ to 9^{0}00′ north of latitude and 39^{0}45′ to 40^{0}00′ east of longitude. The study area has a border with Amhara Regional State to the north, Afar Regional State to east and north east, West Harerge to the south and Arsi zones and Boset Woreda to the west. Metehara town is the capital of the study area and there is also a newly expanding town called Addis Ketema at the southern direction of the main high way on Metehara. The main high way from Addis Ababa to Assab and the railway line connecting Ethiopia to Djibouti crosses the study area at the northern tip of Beseka Lake. One of the main exploitable and important rivers of Ethiopia, Awash, found at the south western part of the study area. This river is the major source of water for the local pastoralists and state farms found in the study area.

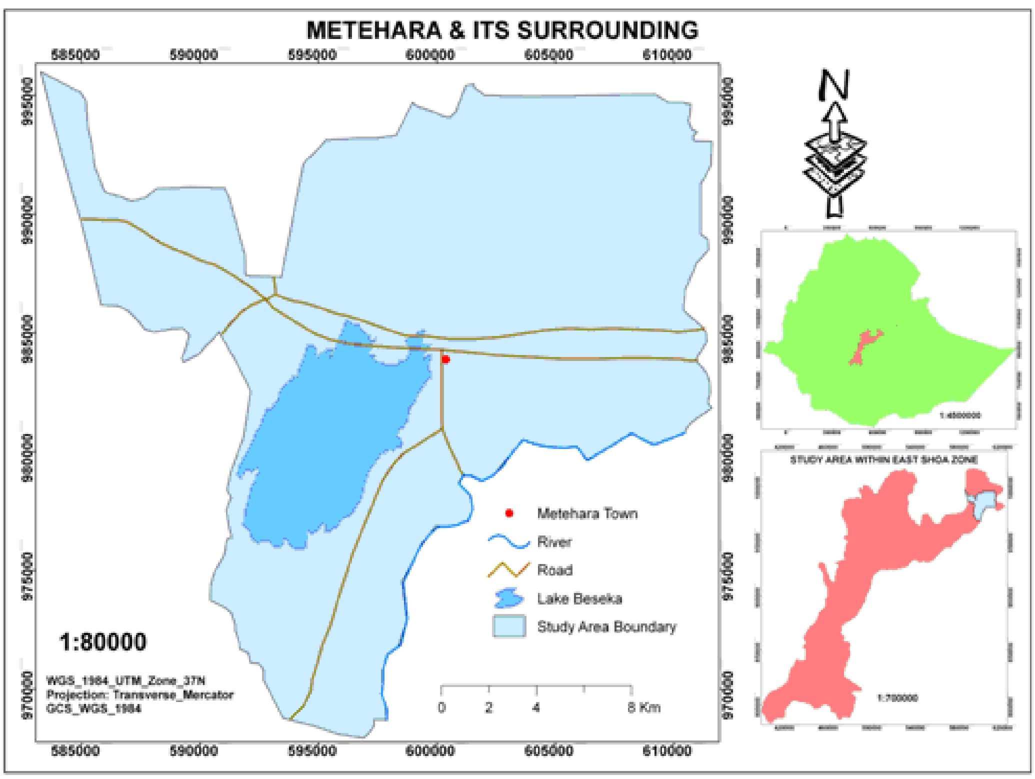


Figure 2: Location of study area.

3.2. Climate

Metehara and its surrounding area are totally within tropical (Kolla) agro-climatic zone. The mean maximum and minimum temperature as an average of 20 years are 33.36^0C and 17.83 ^{0}C respectively, with the highest mean maximum and the highest mean minimum temperature occur in June which is the hottest month for the study area. The rainfall regime in the study area is weakly bi-modal, characterized by high degree of erratic nature and variability both in amount and distribution. The main rainy season (locally known as Gannaa) occurs July to September which is relatively reliable, and the short rainy season (locally known as Afrasa) occurs March to April which is usually unreliable. The mean annual rainfall of the area, according to the Metehara Sugar Factor Research Center's 20 years data (1988-2007) is 541.95 mm.

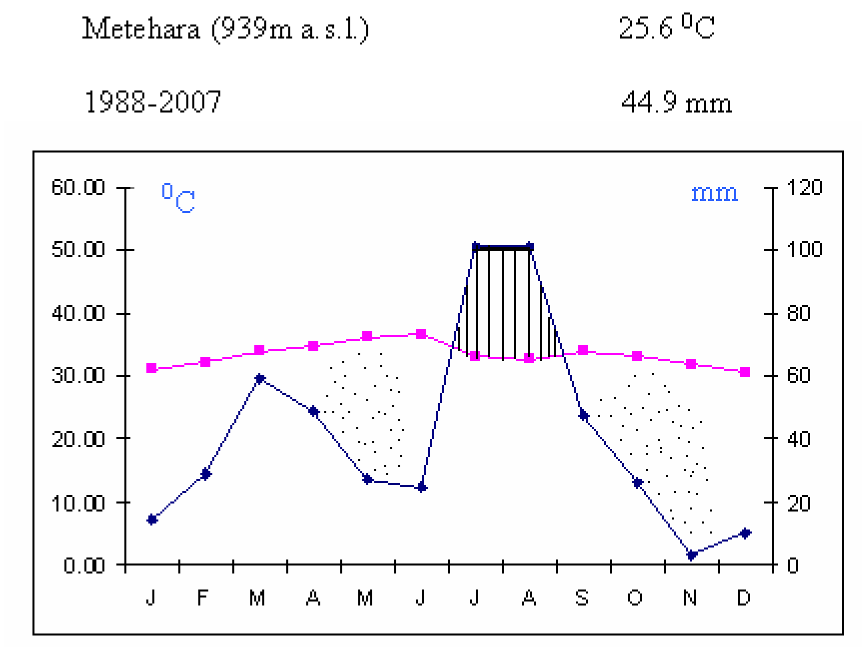


Figure 3: Climate Diagram for Metehara & its surrounding, (Drawn after Walter, 1985) (Source of Climate data: Metehara Sugar Factory Research Center)

3.3. Physiography

The major landform of the area consists of flat to undulating plains, hilly plain, volcanic cones, high gradient Mountain etc. Of these major landforms, flat plain to undulating topography occupy the major parts of the study area. The high gradient mountain occurs in the northern part of the study area including the Fentale Mountain. The altitude of the study area ranges from 930m to 1890 m above mean sea level.

3.4. Soil

The soil types in the study area are classified in to three types known as volcanic materials, ancient alluvial and colluvial soils and recent alluvial soils.

Volcanic materials include Regosols and Andosols; soils whose parent materials are derived from basalt gravel of colluvial origin, and those which are as a result of the eruptive nature of the parent rocks respectively. These types of soil are found at the base of Fentale Mountain and Metehara area.

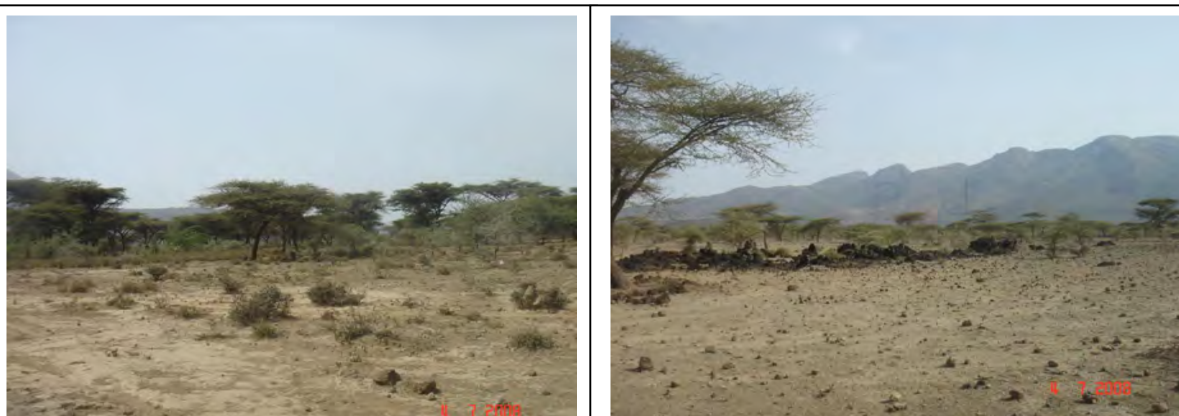
Under recent alluvial soil there is fluvosols which developed from recent alluvial deposits. This soil is found along the banks of Awash river and in irrigated farm lands.

3.5. Land Use and Land Cover

The land use and land cover of the area consists of different components. These include:

3.5.1 Semi-Natural vegetation

According to the Fentale Woreda agricultural office estimation, Forests and shrubs accounted for 28.8% of the district, while degraded land and others covers 55.4%. The vegetation mainly found around Fentale mountain and other hillside.



Field photo 1: The Acacia wood land below the foothill of Fentale Mountain (Photo by Author; July, 2008).

3.5.2 The open Grass land

The open grass land covers the areas located in Sabober and Arole plains, the gently slopping areas at the foothill of the Fentale Mountain and areas bordering Metehara Sugar Plantation.

3.5.3. Shrub land/Grass land

In this cover class, the proportion of grass to shrub differs considerably among different places in the locality. Shrubs predominant on the rock ridge and the major species that could be mentioned are *Acacia mellifera*, *Acacia Senegal* and *Acacia tortillas*.

3.5.4. Riverine Vegetation

The most dominant riverine vegetation consists of *Acacia nilotica* whose pods and leaves are palatable to livestock. This land cover found on alluvial soils mainly along the Awash river. *Acacia nilotica*, *Acacia seyal* and *Acacia tortillas* are the most common tree species growing along the margin of Awash river.

3.5.5. Water

Awash river is the important river that flow along the borderlines of the study area at the south eastern direction. Beseka is a recently formed lake that expands in area from time to time. According to Tenalem (2007) Lake Beseka is has recently been growing as a result of increase in the net groundwater flux in to the lake. Table 1 below depicts temporal changes of the size of Lake Beseka.

Table 1: Temporal size increment of Lake Beseka

Period of Recoding	Elevation (m.a.s.l)	Area (Km^2)	Width (Km)	Length (Km)	Depth (M)
1957/1964	940.82	3	1.09	8	0.58
Jan., 1972	942.77	11	1.86	21.5	1.38
Apr., 1978	946.96	29.5	2.84	36.4	3.45
Dec., 1998	950.701	39.97	3.5	44.4	5.8

Source: (Tenalem, 2007)

Field photo 2: Partial view of the Expanding Beseka Lake. (Photo by the Author; July, 2008).

3.5.6. Cultivated land

Even though majority of the local communities are pastoralists and agro-pastoralis, there are some cultivated lands by individual farmers. Maize is the dominant cereal crop grown both from rain fed and irrigation agriculture. Metehara Sugar Factory and other private investors occupy the major cultivated land which covers wide area.

3.6 Socio-Economic Features

3.6.1. Economic Base

The most dominant economic activities for the local community in the study area are livestock production. They depend on a diversified composition of livestock which includes cattle, sheep, goat and camels. The major source of feed for their livestock is open grazing and browsing on the range land based on seasonal movement between dry and wet season grazing area. Metehara town is commonly used as local market for livestock where the trade is carried out between the highlander and the local people.

An irrigated land use system was introduced to the area in the late 1950s by state and private investors. Currently, the Awash River Basin is the most developed part of the commercial irrigated agriculture of the country. The valley divided into three basins: the Upper Awash, the Middle Wash and the Lower Awash basins and the study area located in the Upper Awash Basin. In the upper Awash Basin vast amount of irrigable land is in use and part of it is found in the study area.

3.6.2. Population and Social structure

The study area is predominantly occupied by Karrayu and Ittu pastoral communities. Both groups belong to the Oromo ethnic group and speak common language “Oromiffa”. Afar, Argoba, Arsi and Tulema Oromo from Wolenchiti area are communities bordering the study area and interacting with the pastoralists. The town people are coming from different parts of the country and forms different ethnic groups.

The total population of the study area was 58902. The people in Metehara, Addis Ketema town and the worker in Metehara Sugar factory constitute significant part of the population. Out of the total population 24.4% live in urban and the remaining 75.6% were rural dweller. Female were 12.1% of the urban and 87.9% of the rural population.

3.7. Status of *Prosopis juliflora*

Prosopis juliflora (Sw.) DC (Fabaceae - Mimosoideae) is native to semi-arid areas of the West Indies, Mexico, Central America and northern South America (Noor *et al.*, 1995).It is drought resistant plants growing on even on the rocky area. *P. juliflora* is an evergreen tree with a large crown and an open canopy, growing to a height of 5-10 m. The root system includes a deep taproot. It is mainly found in the arid and semi-arid regions of the world (Mohamed, 1997).

P.juliflora is one of the alien species currently invaliding wide area in arid and semi arid part of the country mainly Afar region and the neighboring Metehara district. Alien species are organisms that colonize area outside their normal range with or without human interference (Huvered, 1993) and whose introduction and spread cause socio-cultural, economic or environmental harm or harm to human health(FAO, 2008). With various reasons, this species invasion is increasing from year to year around Metehara causing social and environmental problem and urgent assessment and measurement is a pre request for the proper management of the species. Currently, the road sides, grazing lands, water ways and settlement areas are highly invaded with *Prosopis juliflora* and by most pastoralists it is considered as a “devil” tree because of its expansion on grazing land.

Field photo 3: *Prosopis juliflora* infestation (A) on grass land around Addis Ketema town, and (B) on degraded grass land at Golan kebele of the study area. (Photo by the Author; September, 2008).

Field photo 4: (A) *Prosopis juliflora* stand in Metehra Sugar Factory near sugar cane plantation, and (B) *P.juliflora* infestation on barren land around Metehara town. (Photo by the Author; September, 2008.

4. MATERIALS AND METHODS

4.1. Data and Materials Used

Different kinds of data have been collected to conduct this study. The collected data were from different sources. The data from primary sources include satellite imagery, field data, and information from local experts and member of the surrounding community.

The secondary data such as topographic map, climate, census and socio-economic data were used to carry out this study.

GPS (Garmin12), digital camera, compass and tape meter were some of the material used to collect the field data. The following table depicts the satellite image and software used.

Table 2: Satellite image and software used.

A. Satellite Imagery				
Sensors	**Path**	**Row**	**Spatial Resolution**	**Date of Acquisition**
MSS	180	054	57mx57m	30 January, 1973
TM	168	054	28.5mx28.5m	21 January, 1986
ASTER	-	-	15mx15m	2002
B. Software				
ArcGIS 9.1				
ERDAS 9.1				
ENVI 3.4				
MS Application				

4.2. Data Collection

4.2.1. Field work

Prior to the field work, the necessary satellite imagery such as MSS 1973, TM 1986, and ASTER 2002 were collected. In addition to this literature review which clarify the theoretical background of land use /land cover change was conducted to become more familiar about the different aspect of the study. On the raw data of satellite imagery some analysis like unsupervised classification was carried out to get some valuable information about the different land cover classes. Field reconnaissance survey was carried out in the initial stage, while intensive field data gathering were conducted during the middle stages of the study. During the field work, different data were collected. Ground control points (GCPs) have been collected using GPS for LULC classification and accuracy assessment.

4.2.1.1 Sampling method for *P.juliflora* mapping

Before commencing the data collection process for geostatistical analysis, reconnaissance survey was conducted to become familiar about the *Prosopis juliflora* cover of the study area. Based on the information from the survey, the study kebeles was selected using non-probability sampling technique.

The assessment of *P.juliflora* was conducted on few kebeles from the study area due to resource limitation. Moreover, the selection of these kebeles was determined taken in to consideration the infestation coverage of the species.

The samples of data have been collected by using systematic and grid sampling techniques. Systematic sampling was found to be efficient as it is the most common way of field data collection method in geostatistics. Hence, in this study systematic sampling using transects was applied. In systematic and grid sampling, samples are taken at regular spaced (2 Km.) intervals over space. Systematic and grid sampling has been used for mapping the spatial distribution of *P.juliflora.* At each grid points, $400m^2$ area rectangular sample plots are selected for collecting biophysical data.

According to Mersha (2003) there is no fixed rule for the plot size to be used; in general it should be large enough to accommodate vegetation variation within a locality and relative to vegetation size to be surveyed. Large plots are required for larger trees and open stands while small plots are needed for dense thickets and small trees (to capture sufficient information). The size of sample plots should ordinarily be large to include 20 to 30 measurable trees and small enough so as not to require excessive measurement time (Spurr, 1952: Cited by Mersha, 2003)). The samples was located at the intersection of the grids and accessed through navigation of GPS.

At the center of each sample plots, longitude and latitude, number of *P.juliflora* tree species, elevation, and other relevant data have been collected with the help of local experts from Fentale Woreda Agricultural and Rural Development office. *P. juliflora* was recorded by counting each plant head within every plot ($400m^2$) from 42 sample plots.

4.2.1. 2. Socio-economic Survey

To assess the social and environmental impact of *P. juliflora*, socio-economic survey was conducted on the selected kebeles.

The assessment was done by interviewing 40 individuals (30 individuals from high infestation Kebeles and 10 individuals from medium infestation kebeles). During the assessment, an attempt was made to include individuals from different occupation, sex and age. During the survey emphasis was given to get the perception of pastoralist and agro-pastoralist about the invasion of *Prosopis juliflora*.

After data collection, all data which was collected from the field (primary and secondary data) were organized so as to make further analysis easier. Different data analyses have been conducted on the raw data to extract valuable information about the study area. The different data analysis techniques incorporated in this study have been treated in the following methodology section.

4.3. Methodology

Different stages of digital image processing techniques were followed in order to attain the objectives of this study. Multi temporal satellite images of the area were imported to the image processing software. Figure 4 shows the general procedure of data analysis.

4.3.1. Image processing

The topographic map of the study area was scanned to support georeferencing of the satellite image. Mosaicing was performed on different sections of scanned topographic map prior to georeferncing of the topographic map. Map to image registration was applied on image in order to prepare them for an accurate land cover classification.

The simple image pre-processing was carried out including georeferncing, resampling, and image enhancement before initiation of the analysis. Enhancement techniques were applied on satellite image in order to increase visual distinctions between features and increase the amount of information that can be visually interpreted from the data. Landsat MSS 1973, TM 1986 and ASTER 2002 imagery were enhanced using enhancement techniques to improve interpretability of image.

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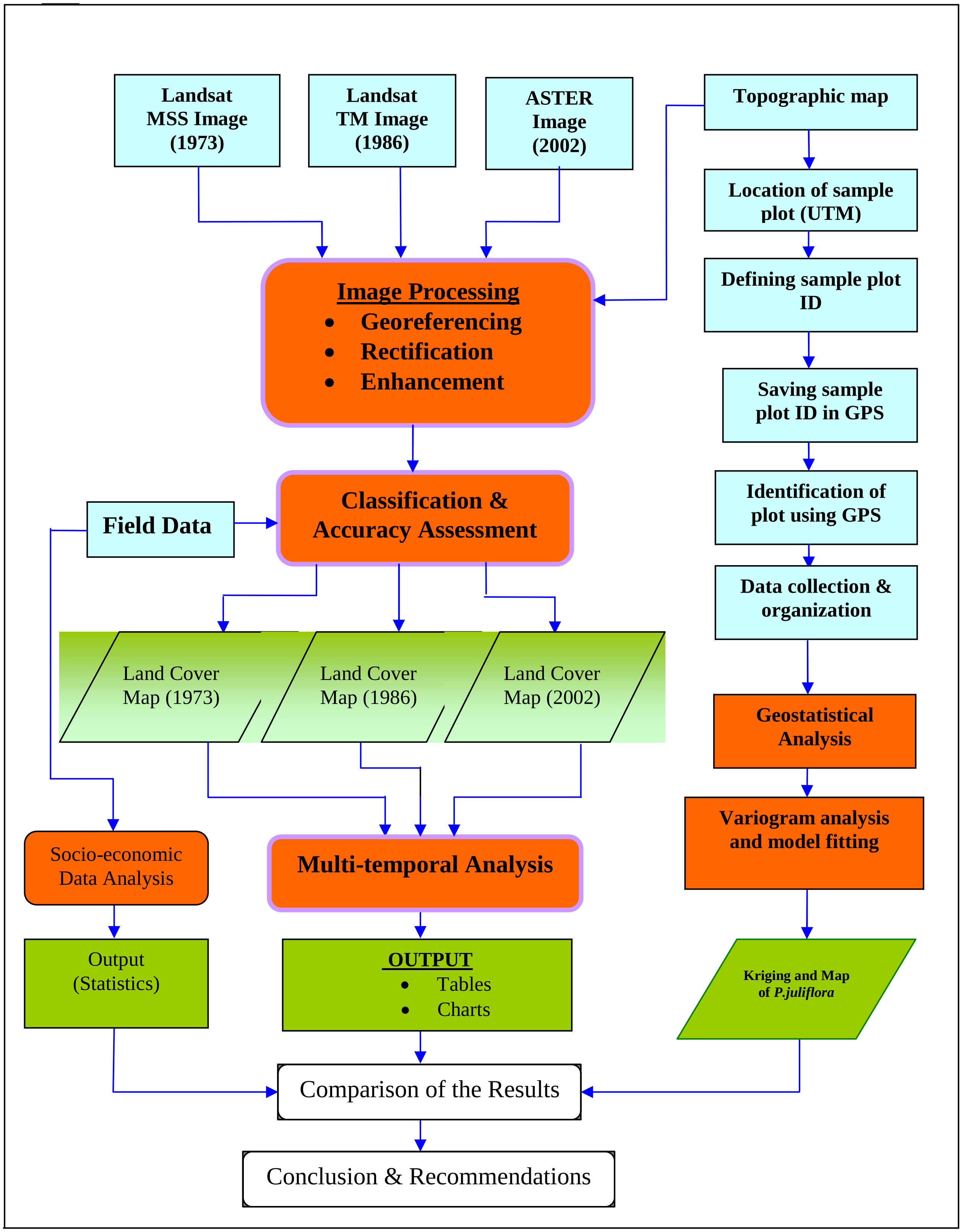

Figure 4: Flow chart depicting Land use/cover mapping, change detection & Geostatistical analysis.

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For accurate image classification, band selection also crucial since one feature which is not discriminated apparently may be clearly differentiated on another band. For this purposes FCC and TCC were utilized. The MSS 1973 image has four bands with a spatial resolution of 57m and 4:2:1 band combination has been used to map the land use and land cover map. The Landsat 1986 image has seven bands with a spatial resolution of 28.5m and 4:7:1 has been used for LULC mapping. The ASTER 2002 image used for this study has only three bands with a spatial resolution of 15m and for this reason color composite(3:2:1 band combination) has been used the LULC classes mapping.

The following consecutive figures show the different raw satellite imagery color composite used in different band combination for LULC classification (Figure 5, 6, and 7).

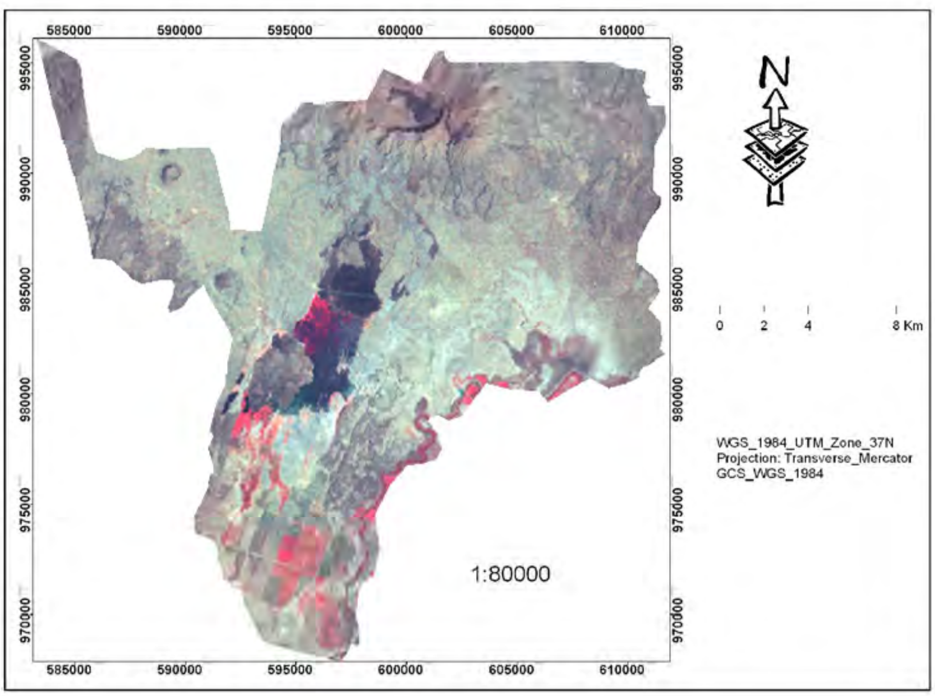

Figure 5: False Color Composite (4:2:1) map of Landsat MSS image (source: 1973 Landsat MSS image).

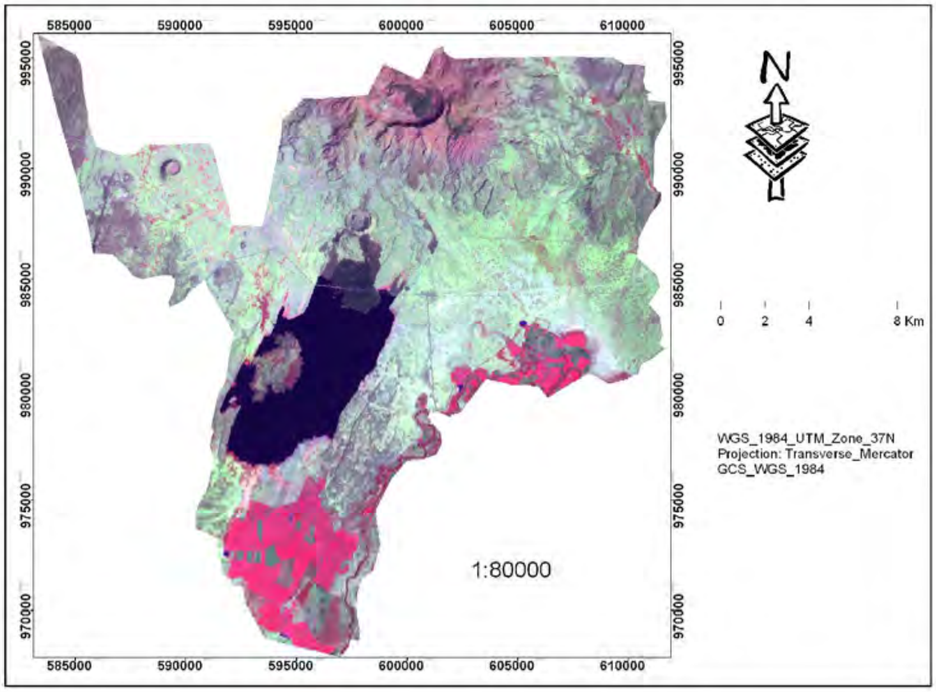

Figure 6: False Color Composite (4:7:1) map of Landsat TM image (source: 1986 TM image).

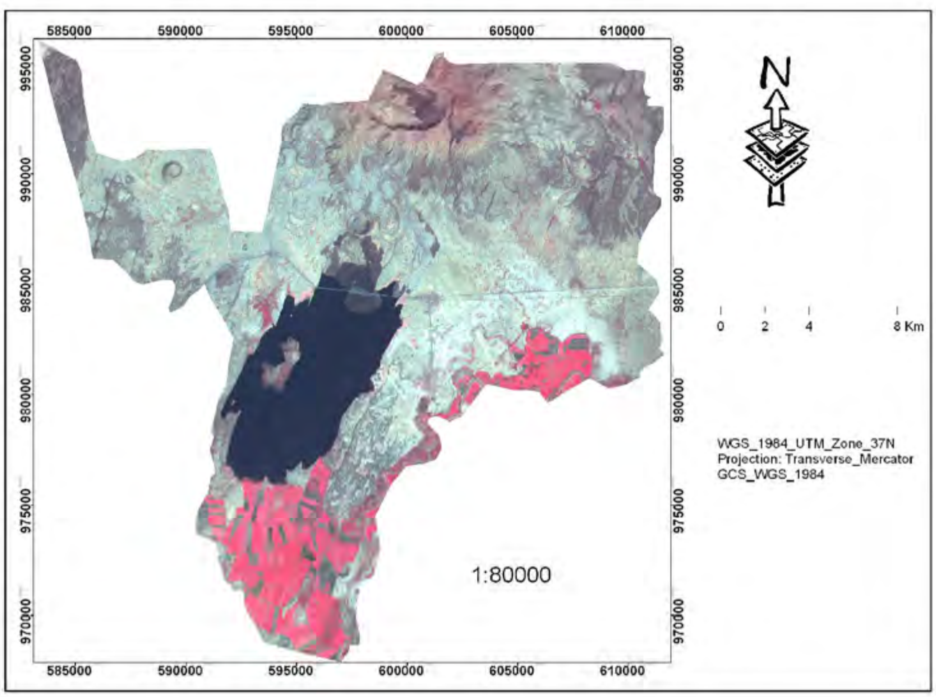

Figure 7: True Color Composite (3:2:1) map of ASTER image (source: 2002 ASTER image).

The aim of the image classification process is converting image data to thematic data. Unsupervised classification with ISODATA classification algorithm was applied to classify the Landsat images of the study area. ISODATA clustering method classifies pixels iteratively, redefines the criteria for each class, and classifies again, so that the spectral distance pattern in the data gradually emerges. This is useful for generating a basic set of classes, and subsequently supervised classification was applied to further definition of classes. Eight land use/cover types were identified in this study, including: dense shrub land, cultivated land, bare land, open shrub land/settlement, wood land, water body, grass land and fallow land/others.

Training areas for each land use and land cover were selected from the information generated by ground-truthing based on the class desired. On-screen digitizing of samples from the display of enhanced image composites was implemented to generate eight signature files. Each signature class is used with a decision rule to assign pixels in the image file. Signature evaluation was done to determine the spectral property of individual training sample class and its separability over the other. The statistics contained in the signature files helps in determining whether the classes are good in terms of separability in the multi-dimensional attribute space. Different signature separability assessment tools like histogram and spectral reflectance profile analysis were utilized. Supervised image classification using Maximum Likelihood classification was carried out on the three episodic satellite images based on these training sites.

The results of image classification should be evaluated using accuracy assessment. In this study, accuracy assessment of classification has been calculated using an error matrix. For accuracy assessment, pixels were randomly selected from the ground truth coverage. The overall accuracy and a Kappa analysis were used to perform a classification accuracy assessment based on error matrix analysis. For the 2002 dated image, overall classification accuracy for the eight classes was established as 85% and the Kappa coefficient was computed 0.765. Likewise for the 1986 dated TM image the classification resulted with 80% total accuracy with a kappa coefficient of 0.731. Since the MSS image was another input of the land use and land cover dynamics, the accuracy assessment also conducted to evaluate the image classification of MSS image.

As mentioned above, Landsat MSS 1973, Landsat TM 1986, and ASTER 2002 imagery constitutes the base data layers from which the land cover maps of the area on different period of time generated. In this study, post-classification method, the most widely used change detection method was used using the results of image classification.

Land use conversion matrix has been used to study the land use/land cover source and destination in the course of change .Conversion matrix for the years 1973 to 1986 and 1986 to 2002 have been produced to investigate the sources and destinations of the land use/land cover changes during these periods. Furthermore, quantification of the rate of change has been applied to generate information about the land use/land cover dynamics of the study area.

The rate of change of each land use and land cover can be calculated using the following formula:

Rate of change (ha/year) = X-Y/Z

Where: X = Recent area of land use/land cover

Y = Previous area of land use/land cover

Z = Year interval between X and Y

4.3.2. Geostatistical Analysis

4.3.2.1. Exploring the Data

The biophysical data obtained from the field were tested prior to analysis in order to check its normality for geostatistical analysis. This was done by investigating the statistical properties of the dataset. The investigation of the dataset was done by examining the data distribution and understanding the spatial autocorrelation. The investigation of the dataset was conducted since the interpolation methods that are used to generate surface map give best results if the data is normally distributed or if there is a bell-shaped curve (ESRI, 2005). The normality of the data was checked with histogram distribution and Norma QQ plot of geostatistical extension in ArcGIS 9.1 software.

Table 3: Descriptive statistics for number of trees per sample and density (number of trees/ha).

No	Parameter	Tree per sample(400m^2)	Density(1ha)
1	Mean	35.976	898.81
2	Median	34.00	850.00
3	Maximum	82	2025
4	Minimum	0	0
5	Standard Deviation	20.591	513.42
6	Total no of individuals	42	42

The mean and median are some how closer in sample tree than density of tree which indicates the normality of the data (ESRI, 2005).

4.3.2.2. Variogram Modeling

In geostatistical analysis it is better to determine a good lag size for grouping semivariogram value for better results. Accordingly, the experimental variogram which is the variogram computed from the sample data (Webster *et al.,* 2001) was assessed at different lag sizes (cut-off) before fitting the model. The appropriate lag spacing for the experimental variogram was determined by generating and visually inspecting several experimental variograms. The variogram were calculated with different lag spacing by observing which variogram best revealed the spatially dependent correlation of the data(Isaaks *et al*, 1989) and also with visual observation(Webster *et al.*, 2001). The variogram modeling was carried out to determine the best fit for a model that pass through the points in the semivariogram. The model fitting was done for the empirical variogram values. Experimental (empirical) variogram is computed from sample data and fitted by one of a limited number of variogram model which serve to provide data for computing interpolation weights (Burrough *et al*, 2000).

Spherical model was used for predicting *Prosopis juliflora* density in this study. This model (shown on figure 1) rises from the nugget value almost linearly and reaches an absolute sill value at distance of range (Webster *et al.*, 2001). And the spherical model is described to be the best model for vegetation parameters prediction (Wallace *et al.*, 2000).

The best fit variogram for number of trees per sample was found to be at 1500 lag size. Hence, the experimental variogram was fitted with spherical model.

The parameters of the variogram, the nugget, sill and range and the spherical variogram model are presented in table 4 and figure 8, respectively.

Table 4: Model parameters for different environmental factors.

Types of Environmental Factors	Types of Model	Nugget Effect	Sill
Trees per Sample	Spherical	156.05	403.3
Density	Spherical	96516	2511980
Elevation	Spherical	10.528	33.417

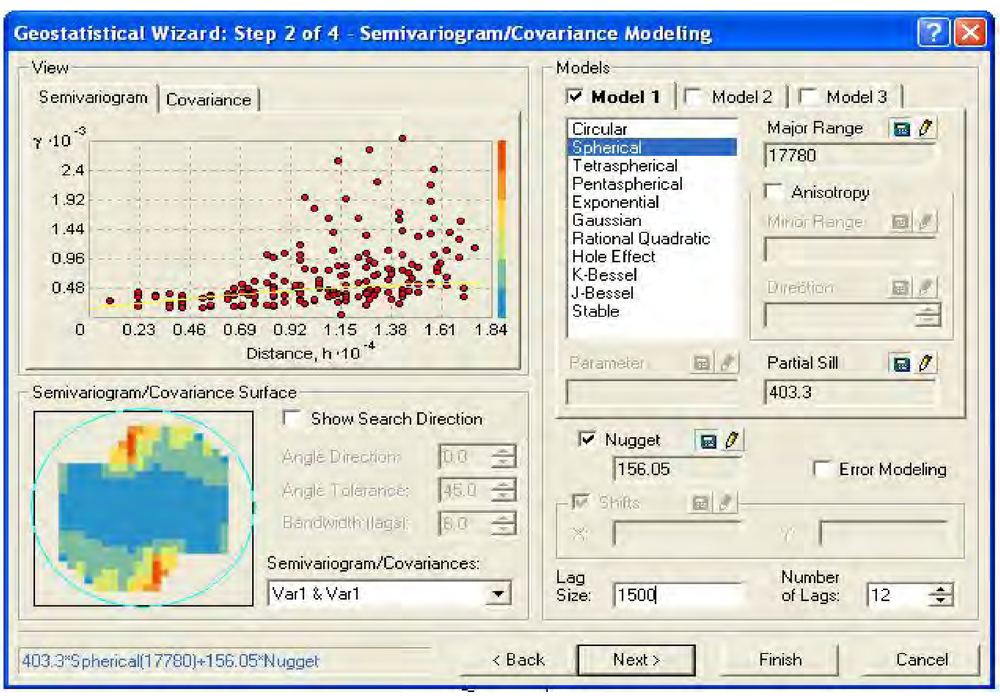

Figure 8: Experimental variogram model (indicated by yellow line (ESRI, 2001) for spatial distribution of P.juliflora map (source: Semivariogram/Covariance modeling interface of Geostatistical Analyst Extension in ArcGIS 9.1).

4.3.2.3. Kriging and Mapping (Densification)

The principle behind in kriging is to estimate the value of a random variable at one or more unsampled points from more or less sparse sample data. Since there have been different kinds of kriging, two kriging methods were selected and assessed for *Prosopis juliflora* distribution prediction. These methods include: Simple Kriging (SK) and Ordinary Kriging (OK).

These kriging methods were tested for their best performance. The comparison of the kriging accuracy prediction data of all 42 plots was used. The variogram and its best fit model were analyzed on geostatistical extension of ArcGIS 9.1. It was found that at 1500 lag size the variogram has the best fit. Spherical model was found with nugget = 156.05, sill= 403.3 and range = 17780 for OK and in a similar way, with 1500 lag size, the nugget = 177.75, sill = 236.13 and range = 7564.4 was for SK.

Table 5: Descriptive statistics for comparison of two kriging methods in spatial distribution prediction of P.juliflora.

Parameters	Kriging methods	
	OK	SK
Minimum error	0.0030897	0.14245
Maximum error	52.784	46.178
Mean error	0.4146	0.7907
Mean standard error	0.01393	0.03603
RMSE	16.24	15.93
Average Standard error	15.73	17.19
Root mean square-standard error	1.015	0.9179

In comparison of these two kriging methods, the one with less bias is considered to be the best method. For this purpose, the prediction error and the standard prediction error value were used. The prediction error is estimated value minus observed values and the standard prediction error is prediction errors divided by their prediction standard error (Isaaks and Srivastava, 1989).In this *Prosopis juliflora* spatial distribution prediction, the minimum error of prediction for OK was found to be lower than SK and the maximum prediction is greater in OK than SK (Table 5).Both OK and SK have very low mean stem density prediction and mean standard stem density prediction error. The mean error as well as mean standardized errors of OK are very low as compared to SK.

The second criteria for comparison were the validity of the prediction standard errors. This means how well the variability of *P.juliflora* spatial distribution was represented by kriging methods. The validation of prediction errors of these two kriging methods was done by comparing the average standard error and the root mean squared prediction error. If the ASE is close to RMSE the kriging method was considered to be more correctly representing the variability in prediction (ESRI, 2004). OK methods has very close ASE and RMSE values than SK (Table 5).The difference between ASE and RMSE in OK is 0.51 and that of SK is 1.26.

The third comparison criterion was root-mean-squared standardized error (RMSSE). This was obtained by dividing each prediction error by its estimated prediction standard errors. The closer the values of RMSSE to unity, the more correct the kriging method in estimating the variability (ESRI, 2004). For this criterion both methods were found to have almost the same value, which is close to 1(Table 5).

Ultimately, taken into consideration the criterion mentioned above, OK was found to be the best method and the actual prediction mapping of *P.juliflora* was done using this method. The non-outlined OK prediction map of *P. juliflora* has been shown on figure 9.

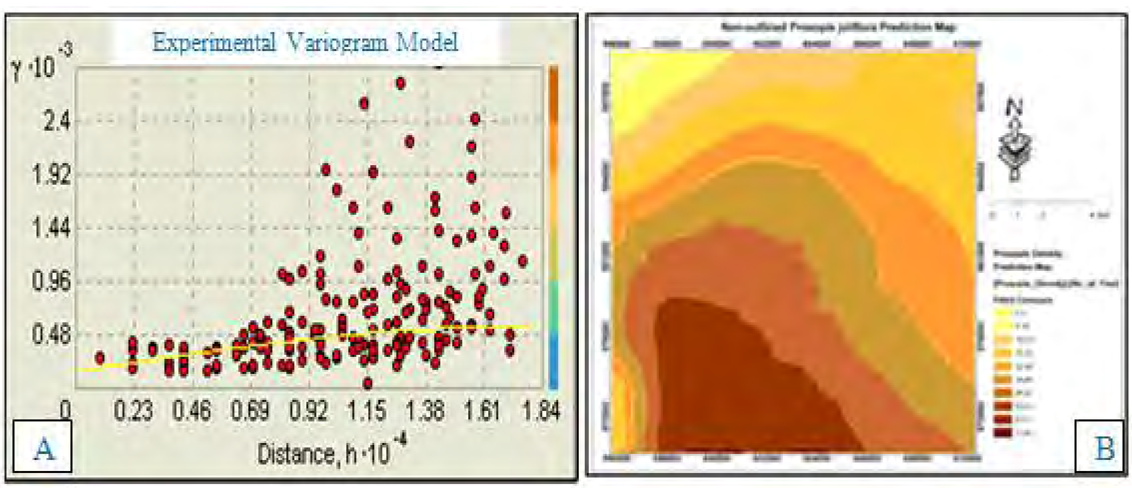

Figure 9: A) Experimental Variogram model for density prediction of *P.juliflora*, and B) Non-outlined prediction map generated using experimental variogram model.

The assessment of the *P.juliflora* was conducted on the selected Kebeles based on the infestation coverage of the species. Hence, the map from geostatistical analysis produced on the spatial extent of surveyed area which includes Algee, Golan, Metehara and part of Kobo, Dhaka Hedu and Dire Sadden Kebeles in stead of the whole study area. The surveyed area for geostatistical analysis is indicated with blue line on Figure 10A below.

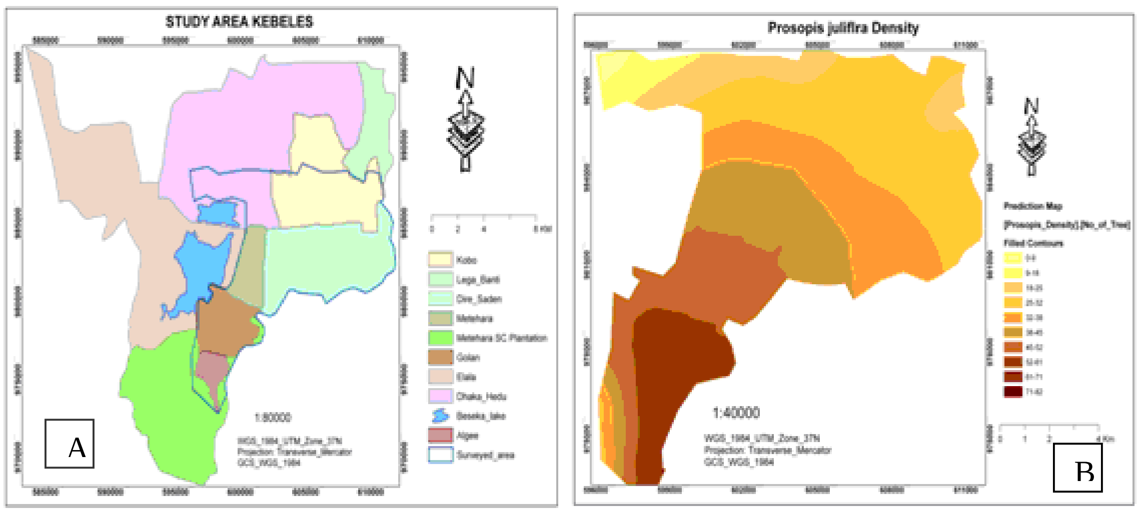

Figure 10: A) Map of study area Kebeles with boundary of surveyed area for *P.juliflora* assessment, and B) The *P.juliflora* outlined prediction map produced using experimental variogram (Figure 14A)

5. RESULT AND DISCUSION

5.1. Land Use /Land Cover of the study Area

From the independent image classification of the three episodic satellite imagery (1973 MSS, 1986 TM, and 2002 ASTER), eight different land uses and land cover classes(wood land, water body, open shrub land/settlement, grass land, dense shrub land, cultivated land, bare land and fallow/others) identified. The 1973 image classification results the water body (Lake Beseka) covered 3 % of the study area. The classification result also shows that 22% of the area was covered by grass land which was mainly found at southern and south western sides of Lake Beseka. During this time, 17% of the area covered with wood land located in the northern part of the study area which is higher in altitude (Figure 11 & 12).

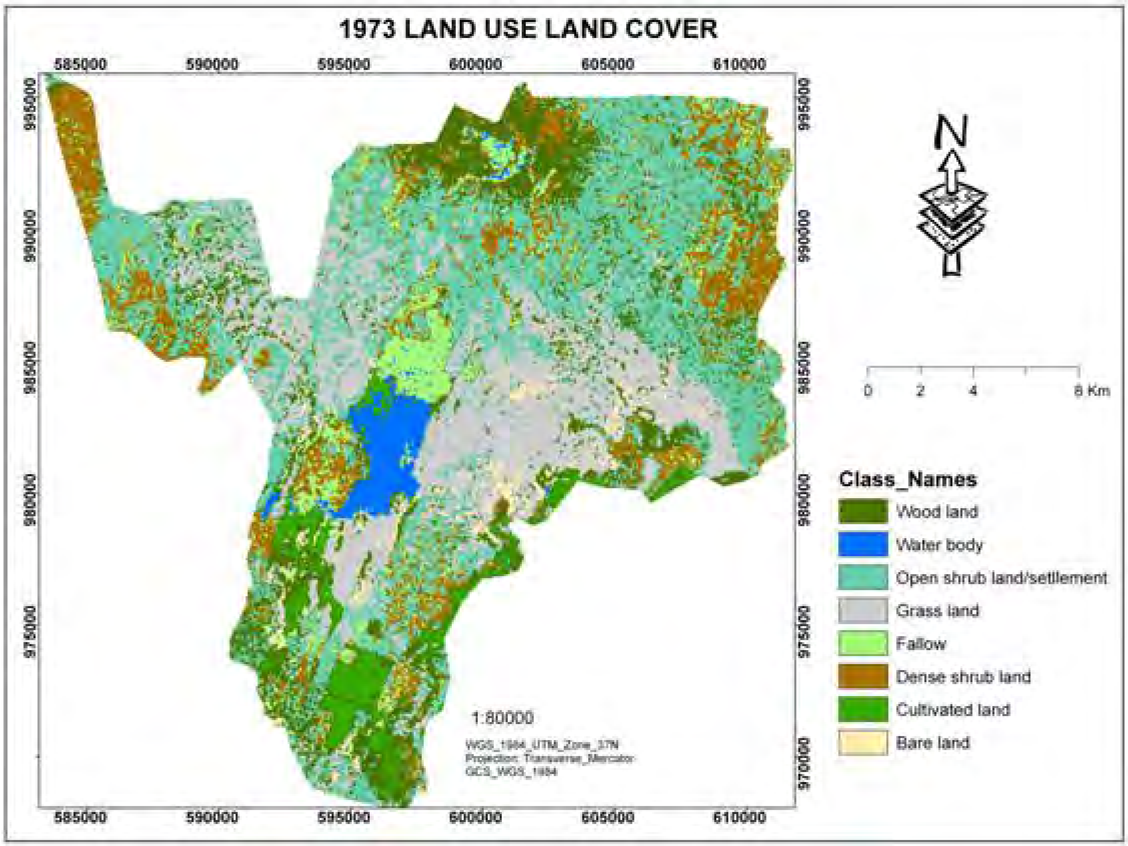

Figure 11: Land use/Land cover map of the study area in 1973 9 source: 1973 Landsat MSS image classification)

On the south and south eastern part of the study area intensive agricultural activities has been practiced and this land use (cultivated land) covers 4% in 1973. Dense shrub land, open shrub land/settlement and bare land covered 13%, 31% and 2% of the study area, respectively.

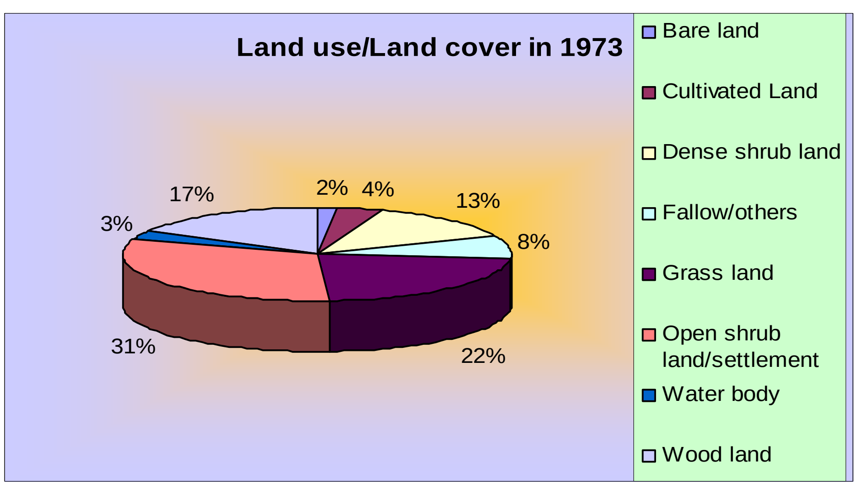

Figure 12: Percentage of Land use/Land cover classes in 1973.

From 1986 image classification the water body (Beseka Lake) covered 9% of the study area showing increment of size. The grass land covered with 16% of the study area and 15% was covered with woodland. Whereas agricultural land(cultivated), dense shrub land, open shrub land/settlement and bare land covered with 7%,14%,13% and 14% of the study area, respectively. In 1986 image classification, there has been some land cover increment compared to 1973 image classification. For instance, the bare land increased in size in the case of 1986 land cover map (Figure 13 & 14).

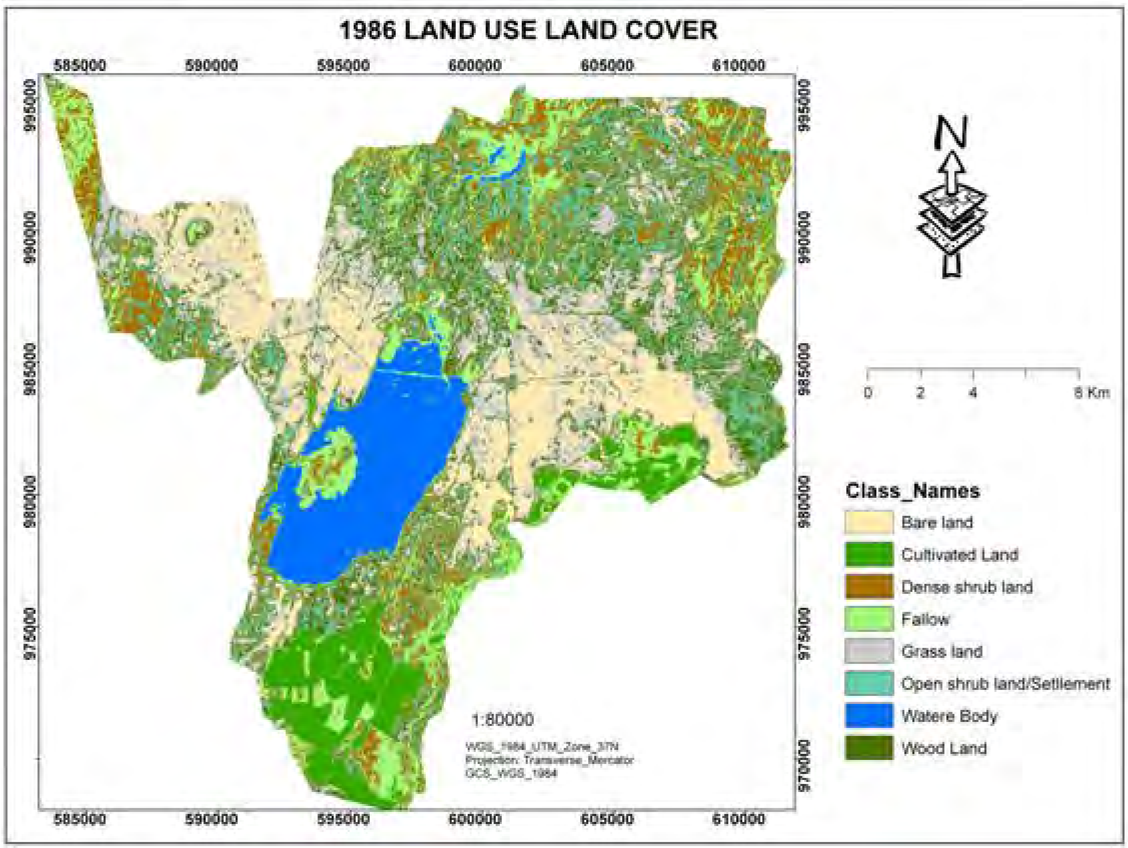

Figure 13: Land use/Land cover map of the study area in 1986 (source: 1986 Landsat TM image classification).

The land use and land cover types and its percentage of 1986 image classification has been indicated on figure 14.

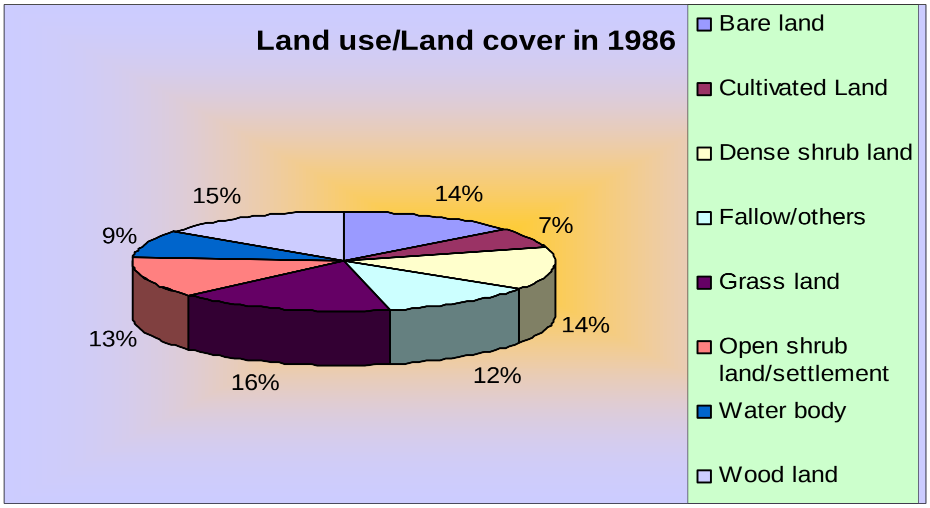

Figure 14: Percentage of Land use/Land cover in 1986.

The 2002 analysis result indicated that water body (Beseka Lake) size increased and expanded to 11%, which was 9% in 1986. The grass land cover of the study area also increased, in the year 2002, as compared to the 1986 image classification result. The wood land covered with 10% of the study area. Whereas agricultural land (cultivated land), dense shrub land, open shrub land/settlement and bare land covered with 8%,12%,18% and 10% of the study area, respectively (Figure 16 & 17).

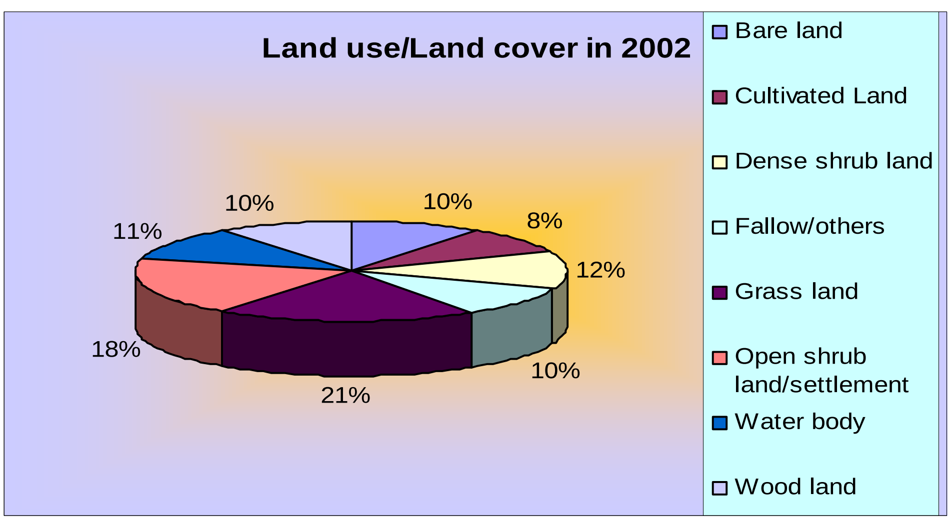

Figure 15: Percentage of Land use/Land cover in 2002.

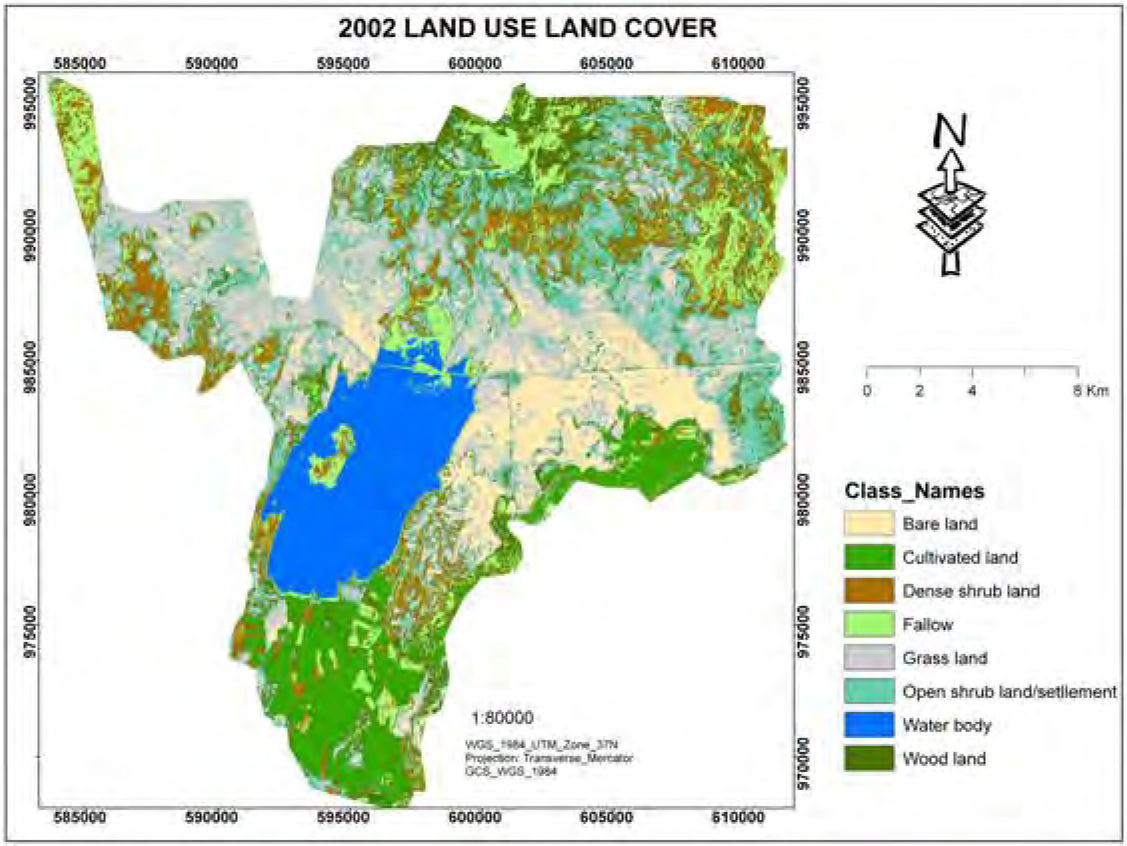

Figure 16: Land use/Land cover map of the study area in 2002. (Source: 2002 ASTER image classification).

5.2. Land Use/Land Cover Change Detection

The satellite image classification of the three periods (1973, 1986 and 2002) result indicated significant land use and land cover change of the study area. The 1973-1986 sub period change detection analysis shows increment in spatial extent of water body, cultivated land and bare land. On the contrary, open shrub land, grass land and wood lands area coverage decreased in 1986 as compared to the year 1973 image classification result (Table 6). Intensive commercial agricultural activities have been practiced by Metehara Sugar Factory in the study area. And, the expansion of sugar cane plantation is one of the factors for differences in LULC area between the year 1973 and 1986.

Table 6: LULC Change of the study area between 1973 and 1986.

LULC Class Types	1973 Area(ha)	1986 Area(ha)	Change between 1973 and 1986
Bare land	701.1	5439.3	4738.2
Cultivated Land	1498.4	2826.4	1328.0
Dense shrub land	5080.8	5472.6	391.8
Fallow/others	3197.9	4854.9	1654.0
Grass land	8858.7	6633.9	-2224.8
Open shrub land/settl.	12573.3	5152.3	-7421.0
Water body	1098.8	3600.5	2501.7
Wood land	6655.9	5992.5	-663.4

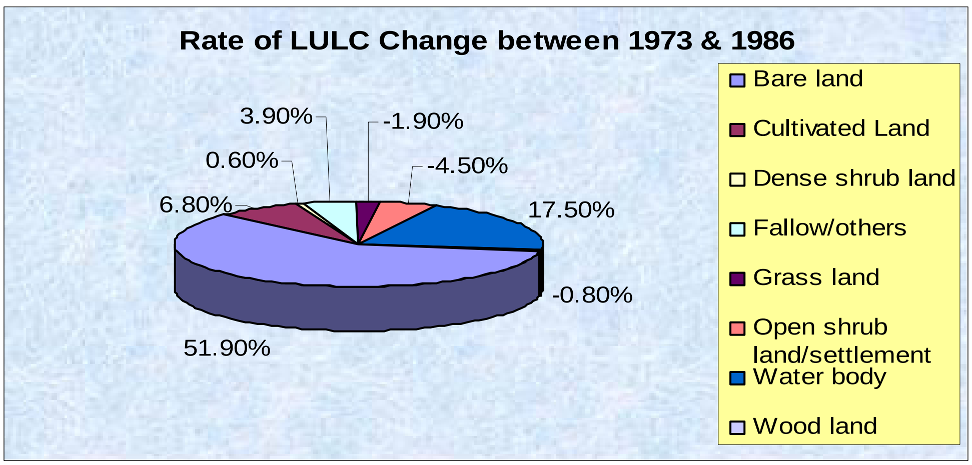

Figure 17: Percentage influence of Rate of LULC change between 1973 and 1986.

The 1986-2002 sub period change detection analysis shows the increment in spatial extent of water body, cultivated land, open shrub land and grass land whereas the bare land ,dense shrub land, and wood land show diminished in area coverage (Table 7). In this period, the water body shows increment in size and the reason behind for the expansion of the lake is increase in the net groundwater flux into the lake (Tenalem, 2007). The expansion of cultivate land was because of the profit oriented Metehara Sugar Factory engagement in expanding sugar cane plantation. Similarly, percentage cover of open shrub land of the study area increased. This result may be associated with the expansion of alien invasive species (*P.juliflora*). Personal observation also indicated that the species has been expanding on extensive part in the study area.

Table 7: LULC change of the study area between 1986 and 2002.

LULC Class Types	1986 Area(ha)	2002 Area(ha)	Change between 1986 & 2002
Bare land	5439.3	3994.1	-1445.2
Cultivated land	2826.4	3347.9	521.5
Dense shrub land	5472.6	4852	-620.6
Fallow/others	4854.9	3835.9	-1019
Grass land	6633.9	7743.1	1109.2
Open shrub land/settl.	5152.3	7282.8	2130.5
Water Body	3600.5	4287.8	687.3
Wood land	5992.5	4051.8	-1940.7

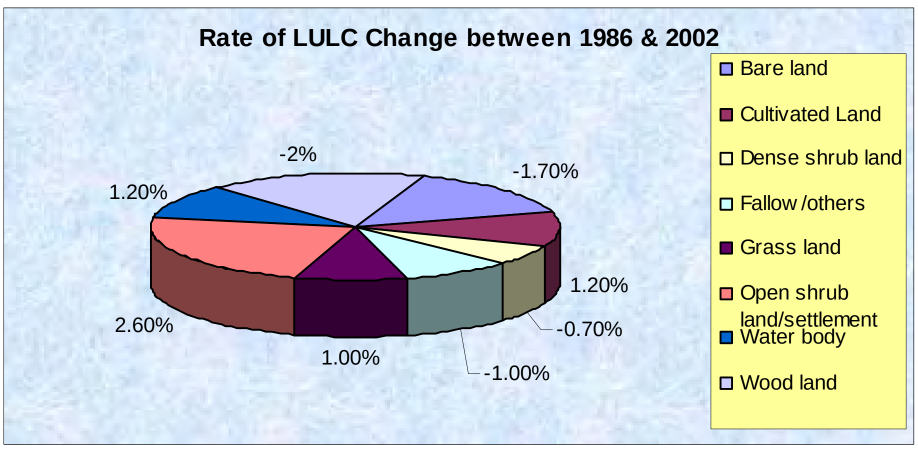

Figure 18: Percentage influence of Rate of LULC change between 1986 and 2002.

Table 8: LULC Change of the study area between 1973 and 2002.

LULC Class Types	1973Area(ha)	2002 Area(ha)	Change between 1973 & 2002
Bare land	701.1	3994.1	3293.0
Cultivated Land	1498.4	3347.9	1849.5
Dense shrub land	5080.8	4852.6	-228.2
Fallow/others	3197.9	3835.9	638.0
Grass land	8858.7	7743.1	-1115.6
Open shrub land/settl.	12573.3	7282.8	-5290.5
Water body	1098.8	4287.8	3189.0
Wood land	6655.9	4051.8	-2604.1

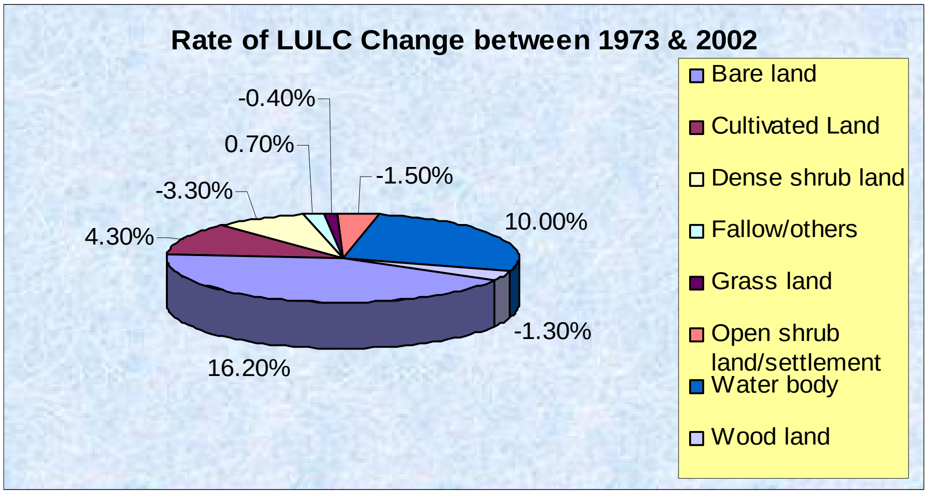

Figure 19: Percentage influence of Rate of LULC change between 1973 and 2002.

The results of the change detection analysis (Table 6, 7 & 8) of the study area indicated series of land use and land cover change for the last three decades. One of the most conspicuous changes was increment in water body size (Lake Beseka). From 1973 to 2002 the water body of the study area has been extending 109.9 ha per year, reaching a total area 4287.8 ha in 2002(Table 9). The change detection analysis revealed the continuous size increment of Lake Beseka which results 10.6Km^2 in 1973, 32.0 Km^2 in 1986 and 43.9 Km^2 in 2002. Tenalem (2007) research result is some how in line with the finding of this study. His research result revealed a continuous size increment of the lake (Table 1). Similarly, the area of cultivated land showed an increment. It showed an annual increment of 63.8 ha from 1973 to 2002. The rate of increment on cultivated land expected to be higher than 63.8 ha per year since during the image classification the fallow land was considered in different land use classes due to the signature difference with that of cultivated land. On the other land, open shrub land and grass land indicated an annual diminishing rate of 182.4 ha and 38.5 ha between the year of 1973 to 2002, respectively. Like wise, wood land shows continuous decrease in spatial extent on the three different periods (1973, 1986 and 2002). The expansion of Beseka Lake and cultivated land was resulted at the expense of grass land and open shrub land in the area.

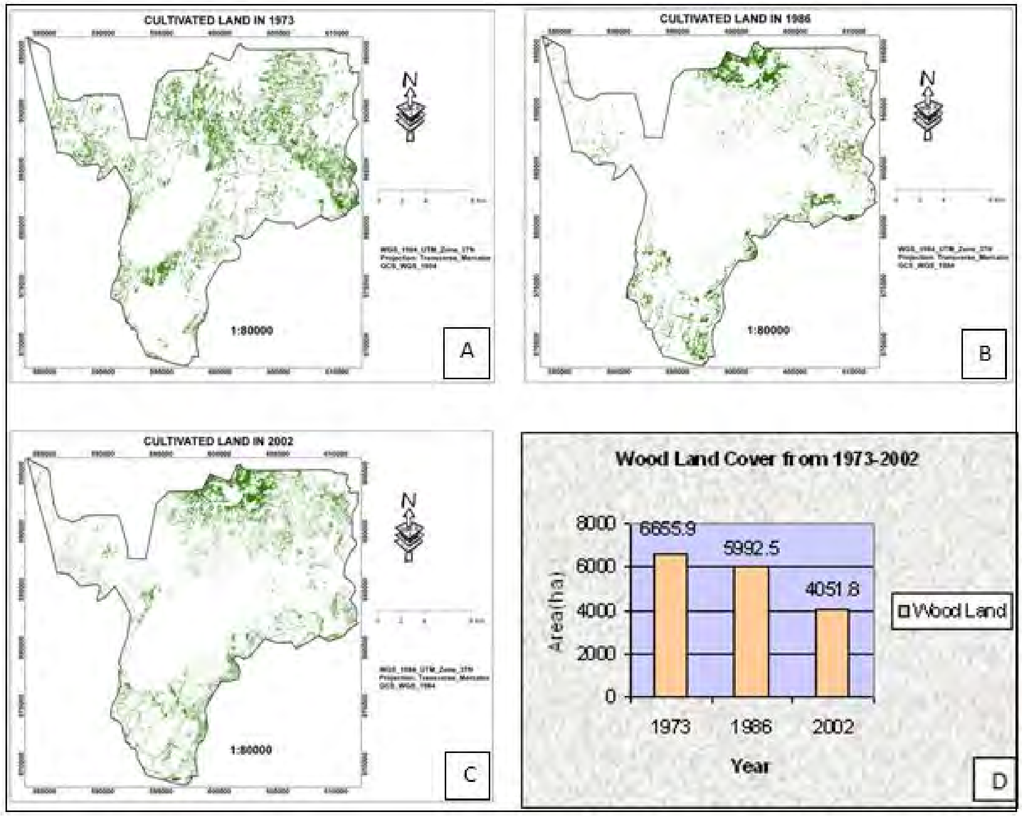

Figure 20: Wood land covers A) 1973, B) 1986, C) 2002 and D) Chart depicting area coverage.

In addition, the human and livestock population growth and the increasing demand of resource utilization can be mentioned as one of the driving forces for grass land and open shrub land cover degradation.

The trend of cover change in grass land and open shrub land cover is indicated on figure 22 and 23 below. The 1973-1986 sub-period Land use/cover change detection analysis indicates the decrease of open shrub land. To the contrary, the 1986-2002 sub-period change detection analysis shows the increment of open shrub land. And the increment of open shrub land probably related with the alarming rate expansion of *P.juliflora*. But, the grass land and open shrub shows an overall decrease of the coverage from 1973 to 2002.On the other hand, the cultivated land and water body (Lake Beseka) show a continuous increasing trend of coverage from 1973 to 2002.

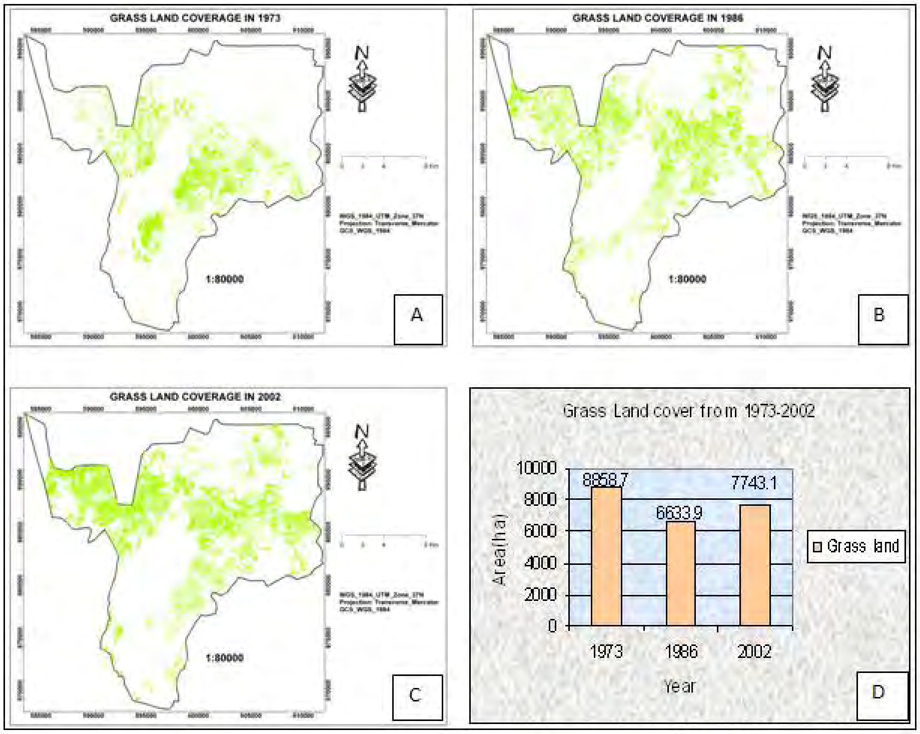

Figure 21: Grass land covers in A) 1973, B) 1986, C) 2002 and D) Chart depicting area coverage.

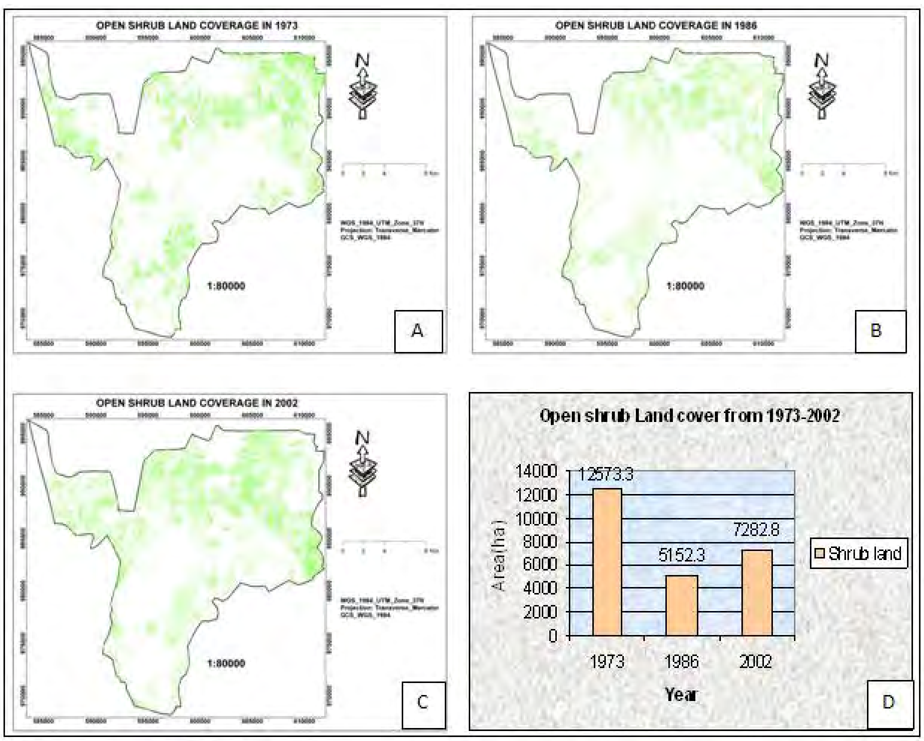

Figure 22: Open shrub land A) 1973, B) 1986, C) 2002 and D) Chart depicting area coverage.

The rate of land use and land cover change among the different years indicated on the following table:

Table 9: Rate of change between 1973-1986, 1973-2002 and 1986-2002.

LULC Class	LULC Area in different years			Average Rate of change (ha/year)		
	1973	1986	2002	1973-1986	1986-2002	1973-2002
Bare land	701.1	5439.3	3994.1	364.5	- 90.3	113.5
Cultivated Land	1498.4	2826.4	3347.9	102.2	32.6	63.8
Dense shrub land	5080.8	5472.6	4852.6	30.1	- 38.8	- 168.2
Fallow/others	3197.9	4854.9	3835.9	127.2	- 63.7	22.0
Grass land	8858.7	6633.9	7743.1	-171.1	69.3	- 38.5
Open shrub land	12573.3	5152.3	7282.8	-570.8	133.2	- 182.4
Water body	1098.8	3600.5	4287.8	192.4	42.9	109.9
Wood land	6655.9	5992.5	4051.8	-51.0	- 121.3	- 89.8

The land use conversion matrix in table 10 and 11 indicates the dynamics of land use and land cover change of the study area between 1973-1986 and 1986-2002, respectively. The column shows the land use/cover class in 1973 and the row shows that the land use/cover in 1986 in case of table 10. In the same way in table 11, column indicates land use/cover class in 1986 and the row indicates the land use/cover in 2002.

Table 10: Land use/cover conversion matrix of the study area between the years of 1973-1986.

Class Name	Water Body	Cultivated Land	Fallow/ others	Dense Shrub L	Open shrub L.	Wood Land	Grass Land	Bare Land
Water Body	**1033**	377	619	125	139	461	760	88
Cultivate land	1	**542**	248	333	650	815	203	29
Fallow/others	59	385	**1098**	1698	535	932	126	18
Dense shrub L.	2	77	652	**1855**	1631	1048	175	23
Open shrub L.	2	40	290	726	**2688**	1026	345	31
Woodland	0	24	137	225	3169	**841**	1028	57
Grass land	1	19	66	51	2769	836	**2782**	100
Bare Land	0	40	74	3	910	648	3407	**355**

The land use conversion matrix in1973-1986 indicates the existence of land use/cover dynamics in the study area. Accordingly, table 10 shows that 2782 ha of land that was covered with grass remained unchanged in 1986. And, 3407 ha of land was converted to bare land and 760 ha to that of water body. Like wise, 2688 ha of land that was covered with open shrub land in 1973 remained unchanged in the year 1986. The result shows that 650 ha of land changed to cultivated land and the remaining large proportion of the area changed to grass land, wood land and dense shrub land (Table 10).

The result of land use conversion matrix indicated that considerable amount of grass and fallow lands were changed to water body from 1973 to 1986. In addition to that the cultivated land had got much of the land area coverage from open shrub land to be increased in terms of spatial extent in 1986.

Similarly, the land use/cover conversion matrix for 1986 to 2002 land use/cover dynamics shown in table 11.

Table 11: Land use/cover conversion matrix of the study area between the years 1986-2002.

Class Name	Water Body	Fallow/ others	Dense shrub L.	Wood Land	Cultivated Land	Open shrub L.	Grass Land	Bare Land
Water Body	**3371**	363	97	145	24	96	108	84
Fallow/others	191	**1581**	1065	154	396	330	75	36
Dense shrub L.	71	873	**1624**	642	186	1119	306	90
Wood land	11	655	973	**642**	310	944	338	172
Cultivated L.	1	835	295	147	**1784**	154	71	53
Open shrub L.	8	401	979	1890	88	**1624**	1612	692
Grass land	2	113	345	1495	26	728	**2934**	2098
Bare land	0	18	69	362	11	142	1178	**2206**

5.3. Causes and Effect of Land Use/Cover Change

The land use and land cover change has been triggered by different causative factors which may lead to an irreversible environmental problems and natural resources degradation. On one way or another, the change in land use and land cover is the reflection of socio-economic condition of the surrounding community. The human activities and natural processes are the responsible factors for LULC change in the study area.

One of the most observable land use changes is expansion of cultivated land. Even though there has been increment of individual farm land from time to time, the major expansion of agricultural land has been commenced by the Metehara Sugar Factory and private investors. The other land cover change was spatial extent increment of Beseka Lake, which is triggered by natural process. Expansion of the lake creates a trouble on the transportation line of Addis Ababa-Djibouti road. The continuous rise of water level and its spatial expansion forced the concerned body to be engaged on the timely rehabilitation of the rail way line. Moreover, its expansion decreased the grass cover of the area, which in turn affects the surrounding pastoralists mostly at the southern and south-eastern side of the lake. As a result pressure on natural resource is increasing because of the ever increasing human and livestock population of the area.

In addition, the expansion of cultivated land in Metehara has been taken considerable amount of grass land and consequently the surrounding local community forced to move at the northern part of the study area in search of grass for their cattle. The migration of the community to other part of the area create great concentration of human and cattle population on a limited area and ultimately leads to degradation of the grass and shrub land with in a short period of time.

The limited availability of grazing land coupled with increasing livestock number have caused overgrazing and rangeland degradation which indirectly indicates the existence of series pressure on the natural resource.

This situation in turn results poor quantity/quality of livestock which is the main livelihood activity of the local community. As a result, most of the pastoralists have been currently engaged themselves in different economic activities like farming, charcoal making and fuel wood sales. The engagement of the local people in charcoal and fuel wood sale activities accelerates the land use and land cover change and degradation of natural resources in the study area.

5.4. Assessment in Spatial Distribution of *Prosopis juliflora*

Even though *P.juliflora* was introduced recently in the study area, it covers considerable amount of land in a short period of time. It has been invaded the roadsides, bare land, grass land and settlement area. The highest density of the species has been recorded in the field at Algee (82 trees/400m$^{2)}$ which is the southern part of the study area.

Field assessment has indicated that high infestation of the species was observed on the south part of the study area (Algee and Golan Kebeles). The medium infestation of the species observed at Metehara and Addis Ketema town. The lower density was at the north western (Dhaka Hedu Kebele) and north eastern (Kobo Kebele) part of the study area.

On northern part of the study area which is relatively higher in altitude, there has been low infestation of the species. There is also a trend of decreasing in *P. juliflora* density from south to north western and north eastern part of the study area (Figure 24).

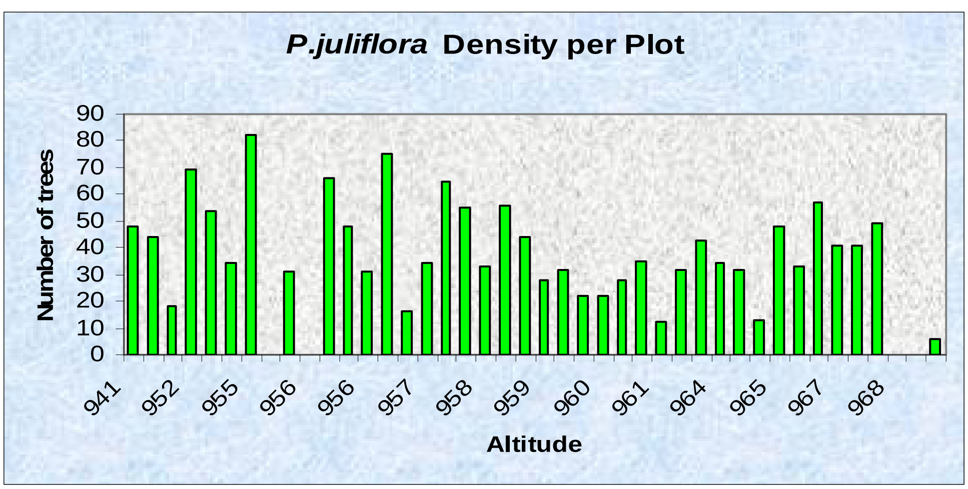

Figure 23: P.juliflora density per 400m^2 area plot size.

Generally, the invasion of *P.juliflora* has been observed on areas of low altitude and relatively better moisture area (around Lake Beseka and Awash River).

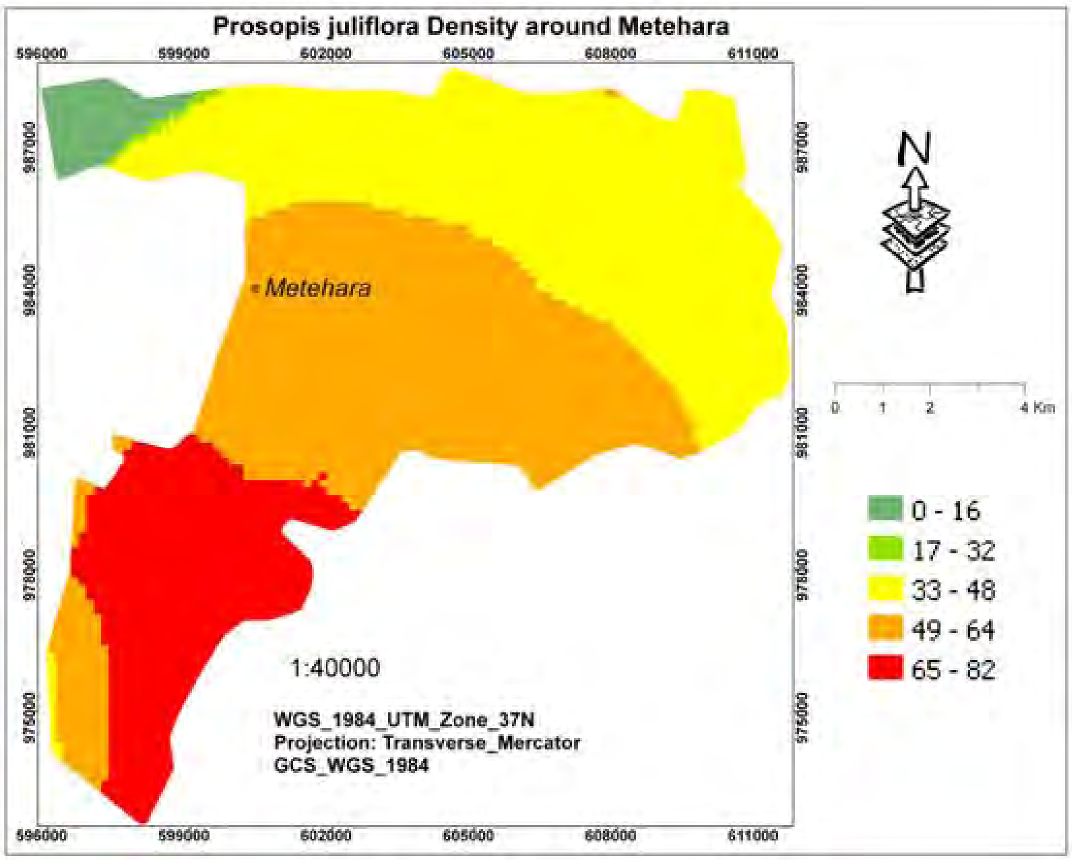

Figure 24: The current density of *P.juliflora* in Metehara and its surrounding area. (Prepared from field data geostatistical analysis).

5.5. Socio-economic and environmental Impacts of *P. juliflora*

P.juliflora has been observed expanding along roadsides, bare lands, gardens, waterways, grasslands and settlement area. The perception of individuals varied when the species was introduced into the area. Some of the people said that it was observed in the area between 10 to15 years ago, while the majority of the dwellers responded that it was introduced to the locality recently. Socio-economic survey results indicated that about 91% of the total respondents are aware of the impacts of *P. juliflora.*

The survey results also indicated that 60% of the respondents believe as cow dung is one of the facilitators of the species to invade the locality.

According to the respondent explanation, the cattle especially the camel (feaces of the camel) from the neighboring region, Afar area, was suspected on the introduction of *P. juliflora* into their locality.

And 33% of the respondent believed that wind as the means of introduction while 7% said that planting of seedling was the other means of introduction.

Table 12: The Expected means of introduction of *Prosopis juliflora* in Metehara and its surrounding.

Means of Introduction	High Infestation Area (N=30)		Medium Infestation Area(N=10)		Overall sample (N=40)	
	n	%	n	%	n	%
Cattle	19	63	5	50	24	60
Wind	10	33	3	30	13	33
Nursery	1	4	2	20	3	7

N= total respondent, n= number of individuals.

Regarding about the dissemination status of the species, majority of the respondent said that *P.juliflora* was disseminated by cattle. The cattle feed on the pods (which is palatable and testy) and the seeds were distributing all over the places through their dung. About 73% the respondent of high infestation area (Algee and Golan kebeles) and 70% from medium infestation area (Metehara kebele) believe that cattle dung was the main disseminating factor for the invasion of *P.juliflora* (Table 13).

Table 13: Agents facilitating dissemination of *P.juliflora* in Metehara and its surrounding.

Disseminating Agents	High Infestation Area (N=30)		Medium Infestation Area (N=30)		Overall Sample (N=40)	
	n	%	n	%	n	%
Cattle Dung	22	73	7	70	29	73
Flood	1	3	-	-	1	2
Wind	7	24	3	30	10	25

N= total population, n= number of individuals.

The result of awareness level studies on both high and medium infestations area on the impact of the species indicated that the entire respondent agreed on the highly invasiveness of the species (Table 14).

Table 14: Individuals' perception on the invasiveness of *P.juliflora* in Metehara and its surrounding.

Invasiveness	High Infestation Area (N=30)		Medium Infestation Area (N=10)		Overall Sample (N=40)	
	n	%	n	%	n	%
Very high	30	100	10	100	40	100
High	-	-	-	-	-	-
Medium	-	-	-	-	-	-
Low	-	-	-	-	-	-

N= total population, n= number of individuals.

The respondents identified also it has an impact on the flora and fauna of the area. The socio-economic survey result showed that 91% of the respondents believe that *P.juliflora* has a negative impact on plants, through loss of plant diversity and competition of nutrients in the soil. Grass and other indigenous trees/shrubs species were highly threatened by it.

The disappearance and diminishing of the grass and other shrubs are the disappointing phenomena on the area since most of the local communities are heavily dependent on it for their livestock. This finding is in line with EIAR (2007) study results. The study result showed that 94% of the respondent in the high infestation area and 97% of the medium infestation area believe that considerable number of plants species had disappeared from the area because of *P.juliflora*, in Amibara district. Even if most of the dwellers in the study area do not engaged in crop production, 51% of the respondent from high infestation area and 70% from medium infestation area said the species has a negative impact on crop production, through competition of agricultural land, wastage of time for clearing and labor cost increment.

The study results also indicated that *P. juliflora* has significant impact on livestock production in different ways. According to the perception of the respondents, 76% from high infestation and 90% from medium infestation areas agreed on the species has negative impact on livestock production by invading the grass land and threatening fodder shrub species. Moreover, 24% from high infestation and 10% from medium infestation area associate its impact on animal health (Table 15). Almost all of the respondents said that its thorns affect human and animal health. These results also in line with the EIAR (2007) study of Amibara district, Afar region.

It indicated that all samples in high and medium infestation categories stated that *P. juliflora* encroaches grazing land and all individuals in high infestation category and 94% in medium infestation categories believed that *P.juliflora* threatens animal health.

Table 15: Effect of *P.juliflora* on livestock production in Metehara and its surrounding.

Effect of Prosopis on Livestock production	High Infestation Area (N=30)		Medium Infestation Area(N=10)		Overall Sample (N=40)	
	n	%	n	%	n	%
Encroaching grazing land	21	76	9	90	32	80
Threaten animal health	9	24	1	10	8	20

N= total population, n= number of individuals

In addition, an attempt was conducted to assess the merits of *P. juliflora* on the area. The result indicates that 30% from high infestation and 90% from medium infestation area pointed out its different purposes. Some of the benefits are mentioned as a source of fuel wood and shed. Moreover some people mentioned that it ameliorate the local microclimatic condition of the area. Some respondent also explained it controls soil erosion on degrade area. In order to plan the best management option, local people interest on the existence of *P.juliflora* might have a contribution.

Regarding the control measures, 80% from higher infestation and 60% of the respondent from medium infestation area agree the species has to be eradicated from the area by any means. The rest of the interviewed people believe it is important and has to exist (Table

16). The assessment result shows that majority of the local people develop a negative attitude towards *P.juliflora* in view of the fact that they are highly dependent on livestock production for their livelihood

Table 16: Attitude of individuals' on *Prosopis juliflora* in Metehara and its surrounding.

Attitudes of Individuals	High Infestation Area (N=30)		Medium Infestation Area(N=10)		Overall Sample (N=40)	
	n	%	n	%	n	%
It should be eradicated	24	80	6	60	30	75
It should be exist	6	20	4	40	10	25

N= total population, n= number of individuals

In addition, individuals from governmental and non-governmental organization said that *P.juliflora* is a nuisance plant which prohibits the growth of other indigenous plant in its underneath. And most of the respondent added that there will be a devastating and irreversible environmental change due to *P.juliflora* expansion unless appropriate mitigation measures are formulated. On the contrary, some individuals particularly town dwellers who engaged in activity like charcoal making and trading acknowledge its benefits for different purposes.

In the end, LULC change detection analysis indicates the change in the form of conversion. From change detection analysis, it has been observed the expansion of water body and cultivated land at the expense of grass and shrub land. The geoststistical analysis also indicates the current spatial distribution of *P.juliflora*. From the analysis high density of the species is found at the southern part of the study area which is the place where most pastoralists settled because of water availability. Moreover, the socio-economic survey analysis supports the geostatistical analysis by investigating the perception of the community towards *P.juliflora*. The socio-economic survey analysis revealed the existence of change in some attributes of the environment.

The invasion of the species results the disappearance of grass and some useful shrubs form the locality. The invasion of *P.juliflora* has its own contribution for modification of the environment in the study area. Hence, LULC change detection, geostatistical and socio-economic survey analysis show the existence of land use and land cover change in the form of conversion and modification.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The results of this study revealed the existence of significant land use and land cover change for the last 29 years. Especially the expansion of sugar cane plantation by Metehara Sugar Factory and Beseka Lake curtailed grazing space and affect pastoral movement. The restriction of the mobility in pastoral community leads to the relative over population on a limited fragile environment which in turn caused reduction of livestock production. This situation forced the local communities to engage themselves in firewood and charcoal sale since livestock production is insufficient to support their lives. Consequently, due to the ever increasing population and the increasing demand for resource create great pressure on the natural resources and as a result degradation of vegetation cover existed. The land use/land cover change detection analysis disclosed the change in land use/land cover in the form of conversion. Thus, the findings of the land use and land cover analysis have a paramount importance for the management of natural resource by using as an input for land use plan at local level. Formulating a land use plan using these results will facilitate an optimum resource allocation and implementing of mitigation measures for each local development activity.

Using geostatistical analysis it has been possible to locate (map) the spatial extent of *P.juliflora* and generate valuable information about the spatial distribution of the species. From the assessment of the two selected kriging methods (SK and OK), OK was found to be the best method for *P.juliflora* spatial distribution mapping. Based on geostatitical analysis results, high density of *P.juliflora* observed relatively around better moisture and low altitude of the study area. Besides, from the out put of geostatistical analysis, it is possible to identify which parts of the study area has been occupied with high infestation of the species. For instance, the inavasion of *Prosopis juliflora* is severe at the southern part (Algee and Golan kebeles) of the study area. Relatively, medium infestation of the species has been observed around Metehara town and the lower invasion at north and north western part of the study area. Hence, the finding from geostatistical analysis can be used as one of the input for decision making in controlling the very high infestation of this invasive alien species.

Furthermore, the socio-economic survey indicates the communities' perception towards *P.juliflora.* Currently, the weed (Prosopis *juliflora*) is growing on grazing land, road side, gardens, to some extents on farm lands and in towns and villages.

The invasion is increasing from year to year in alarming rate and likely to continue to expand its territory unless something has been done.

It was observed that the impact of *P.juliflora* decreased the abundance of grass and shrubs which is useful for livestock production. Due to this reason the local people develop a negative attitude towards *P.juliflora*. From the relative density observed and socio-economic survey conducted, it is possible to conclude that the *P.juliflora* has been facilitating the land use and land cover change in the form of modification of the environment. Hence, the land use and land cover change which occurred in the study area manifested in the form of conversion and modification.

In general, remote sensing is very helpful in land use and land cover classification, also RS and GIS play a pivotal role in providing information regarding the spatial distribution of various land use and land cover over the years.

Change detection analysis aid to generate up-to-date information about every bit of the land and facilitates wise utilization of the natural resources in a sustainable manner. GIS is also provide technical support in planning and decision making using maps and other related statistical data. Therefore, the use of RS and GIS coupled with geostatistical analysis used for the planning of appropriate resource utilization and strategy formulation which is crucial in management of natural resources in the study area. Natural resource managers and decision makers should stick themselves in use of the information generated from RS and GIS analysis, as a decision support for better design of natural resource management.

6.2. Recommendations

The findings of this study on land use/land cover change detection indicate mainly the expansion of cultivated land and the water body (Beseka Lake) at the expense of grass land and open shrub land. At present, the local community particularly the pastoralists are facing a severe problem due to the expansion of the commercial irrigated land and Beseka lake. With increasing population and reduced access to resource as a result of the external intervention, the natural resources are exploited at faster rate which leads to irreversible degradation of the environment. Furthermore, this problem is triggered by the invasion of the aggressive alien species, *P.juliflora*, for the last few years.

There has been no much effort done by all responsible organization including the local community to control the expansion of *P.juliflora*. Therefore, an integrated effort should be made to understand and resolve the prevailing problem requiring strategy, institutional and technical intervention. Having said this, the following suggestions are forwarded:

- Matching the land with appropriate land use/land cover and resource allotment is very important for sustainable land use management. The land cover dynamics is vital as it is the most important base line data in resource allocation and therefore should be used as one of the main inputs in land use planning.
- The expansion of large-scale commercial farms in the area should be limited even though it generates foreign currency and losses incurred by the local pastoralists due to the expansion of the farms should be recognized.
- Currently, the Awash Basin Authority is developing large scale irrigation scheme to support the local community for agricultural activities which provide water for eleven Kebeles including the study area. Hence, agroforestry and dry land fodder trees species should be introduced and forestation programme should be encouraged.
- The rapid expansion and rise of Beseka Lake has a negative impact on a railway line although the road has been elevated frequently. The expansion of the lake is likely to continue its expansion in the future and may flood the southern part of the lake like Addis Ketema town and Metehara Sugar Factory's sugar cane

plantation in the future. Some studies indicate that the nature of the water is saline and alkaline. Thus, the responsible body should devise to utilize the lake water for extraction of useful industrial chemicals like Abidijata Soda Ash Factory to control the water fluctuation.

- Remote sensing satellite imagery are widely applicable for land use and land cover classification and land use/land cover is the most valuable input for land use planning and other development activity. Hence, remote sensing and GIS should be utilized for natural resource management to acquaint the managers and decision makers themselves with up-to-date information.
- Even though the growing of *P.juliflora* is improving the microclimate of the surrounding area, the encroachment of this plant should get special attention. This is because of that once the plant has been established itself, it is costly and labor intensive to manage it.
- *P.juliflora* has some merits like other kinds of Acacia species. It is useful plant in minimizing desertification and provides fuel wood if properly handled and controlled. Therefore to benefit from it, there should be a possibility to develop and control it on a barren and unproductive land. And to utilize it as a useful natural resource, the responsible body particularly the local agricultural office should delineate closure area for its development.
- There should be large scale awareness creation campaign to inform the community how to utilize *P.juliflora* and motivate community participation to control its expansion of the plant for sustainable management.

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APPENDICES

Appendix 1: Data table used for Geostatistics analysis.

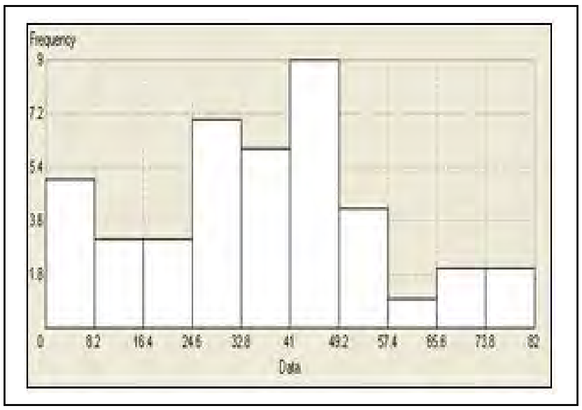
Plot Id	Kebele	Longitude	Latitude	Altitude	No of Tress	Density
AL01	Algee	597881	974100	955	82	2025
AL02	Algee	597997	976262	957	75	1875
AL03	Algee	595988	976082	956	0	0
AL04	Algee	596079	974100	955	0	0
AL05	Algee	595971	973198	952	69	1725
AL06	Algee	598692	975992	956	66	1650
GO07	Golan	596619	977995	958	65	1625
GO08	Golan	598061	977973	958	55	1375
GO09	Golan	600044	977975	959	56	1400
GO10	Golan	600043	979957	963	43	1075
GO11	Golan	598061	979952	966	57	1425
GO12	Golan	596709	979957	968	49	1225
MT13	Metehara	600134	984103	967	41	1025
MT14	Metehara	600044	982120	965	48	1200
MT15	Metehara	601666	980318	956	48	1200
MT16	Metehara	601936	982300	959	44	1100
MT17	Metehara	601756	984103	967	41	1025
MT18	Metehara	604009	984193	947	44	1100
DS19	Dire	604097	981840	941	48	1200
DS20	Dire	605902	983742	960	32	800
DS21	Dire	605811	983202	964	34	850
DS22	Dire	608064	983923	961	35	875
DS23	Dire	608155	982120	954	34	850
DS24	Dire	609884	986087	962	32	800
DS25	Dire	609957	982300	958	33	825
DS26	Dire	609884	986087	957	16	400
DS27	Dire	609940	987985	960	22	550
DS28	Dire	610090	980785	955	31	775
KO29	Kobo	602117	986085	957	34	850
KO30	Kobo	604099	986085	959	28	700
KO31	Kobo	606082	986085	956	31	775
KO32	Kobo	608185	986085	947	18	450
KO33	Kobo	607974	988068	952	54	1350
KO34	Kobo	606082	988068	960	22	550
KO35	Kobo	604009	987978	961	12	300
KO36	Kobo	602117	987978	960	28	700
DH37	Dhaka	600134	986085	964	32	800
DH38	Dhaka	598061	986176	965	33	825
DH39	Dhaka	595988	986176	969	0	0
DH40	Dhaka	595988	988068	968	0	0
DH41	Dhaka	598061	987888	970	6	150
DH42	Dhaka	599954	988068	964	13	325

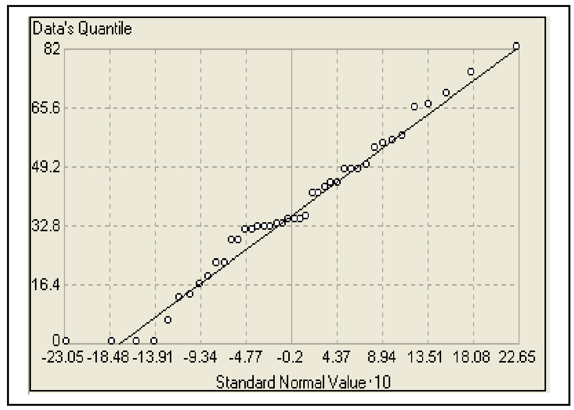
Appendix 2: Comparison of measured and predicted value for OK and SK.

Sample plot	Easting	Northing	Ordinary kriging(OK)					Simple kriging(SK)				
			Measured	Predicted	St.error	Error	Stdd.error	Measured	Predicted	St.error	error	Stdd,err
1	595988	976082	0	50.01	16.01	50.01	3.12	0	46.18	17.49	46.18	2.64
2	595988	986176	0	21.05	16.74	21.05	1.26	0	23.47	18.14	23.47	1.29
3	595988	988068	0	12.06	17.27	12.06	0.7	0	18.24	18.18	18.24	1
4	596079	974100	0	52.78	16.56	52.78	3.19	0	45.59	17.75	45.59	2.57
5	596619	977975	65	42.44	15.54	-22.6	-1.45	65	41.03	17.01	-24	-1.41
6	596709	979957	49	45.98	16.1	-3.02	-0.19	49	48.35	17.65	-0.65	-0.04
7	597881	974100	82	47.89	15.44	-34.1	-2.21	82	46.99	16.72	-35	-2.09
8	597971	973198	69	50.24	16.5	-18.8	-1.14	69	49.55	17.49	-19.5	-1.11
9	597997	976262	75	52.2	14.91	-22.8	-1.53	75	52.14	16.31	-22.9	-1.4
10	598061	977973	55	55.61	15.06	0.61	0.04	55	56.02	16.54	1.02	0.06
11	598061	979952	57	49.59	15.4	-7.41	-0.48	57	49.84	16.94	-7.16	-0.42
12	598061	986176	33	18.16	15.56	-14.8	-0.95	33	17.81	17.2	-15.2	-0.88
13	598061	987888	6	15.53	15.78	9.53	0.6	6	19.17	17.26	13.17	0.76
14	598692	975992	66	59.81	15.25	-6.19	-0.41	66	60.17	16.68	-5.83	-0.35
15	599954	988068	13	20.22	15.9	7.22	0.45	13	24.3	17.46	11.3	0.65
16	600044	977975	56	56.52	15.87	0.52	0.03	56	52.17	17.53	-3.83	-0.22
17	600044	979957	43	52.51	15.36	9.51	0.62	43	51.49	16.9	8.49	0.5
18	600044	982120	48	44.72	15.52	-3.28	-0.21	48	44.37	17.18	-3.63	-0.21
19	600134	984103	41	37.17	15.44	-3.83	-0.25	41	38.78	17.07	-2.22	-0.13
20	600134	986085	32	27.92	15.31	-4.08	-0.27	32	28.95	16.89	-3.05	-0.18
21	601666	980318	48	47.62	15.78	-0.38	-0.02	48	43.89	17.4	-4.11	-0.24
22	601756	984103	41	39.43	15.2	-1.57	-0.1	41	40.74	16.75	-0.26	-0.02
23	601936	982300	44	44.46	15.31	0.46	0.03	44	44.14	16.86	0.14	0.01
24	602117	986085	34	30.48	15.24	-3.52	-0.23	34	30.84	16.82	-3.16	-0.19
25	602117	987978	28	21.67	15.8	-6.33	-0.4	28	23.47	17.37	-4.53	-0.26
26	604009	984193	44	35.39	15.26	-8.61	-0.56	44	35.55	16.85	-8.45	-0.5
27	604009	987978	12	28.05	15.78	16.05	1.02	12	30.45	17.33	18.45	1.06
28	604097	981840	48	40.5	15.94	-7.5	-0.47	48	39.82	17.68	-8.18	-0.46
29	604099	986085	28	30.78	15.24	2.78	0.18	28	30.22	16.82	2.22	0.13
30	605811	983202	34	36.34	15	2.34	0.16	34	36.64	16.41	2.64	0.16
31	605902	983742	32	34.69	14.89	2.69	0.18	32	35.37	16.3	3.37	0.21
32	606082	986085	31	29	15.31	-2	-0.13	31	28.67	16.92	-2.33	-0.14
33	606082	988068	22	29.67	15.85	7.67	0.48	22	31.34	17.41	9.34	0.54
34	607974	988068	54	21.32	15.9	-32.7	-2.06	54	23.53	17.38	-30.5	-1.75
35	608064	983923	35	29.9	15.25	-5.1	-0.33	35	29.79	16.84	-5.21	-0.31
36	608155	982120	34	34	15.69	0	0	34	34.4	17.27	0.4	0.02
37	608185	986085	18	30.71	15.29	12.71	0.83	18	31.09	16.86	13.09	0.78
38	609941	986088	16	29.33	15.84	13.33	0.84	16	29.96	17.33	13.96	0.81
39	609941	987985	22	30.17	16.97	8.17	0.48	22	33.55	18.04	11.55	0.64

Sample plot	Easting	Northing	Ordinary kriging(OK)					Simple kriging(SK)				
			Measured	Predicted	St.error	Error	Stdd.error	Measured	Predicted	St.error	error	Stdd,err
40	609957	982300	33	30.66	15.75	-2.34	-0.15	33	32.08	17.09	-0.92	-0.05
41	610034	980729	31	33.96	17.51	2.96	0.17	31	35.45	18.26	4.45	0.24
42	610047	984013	32	27.87	15.78	-4.13	-0.26	32	28.59	17.31	-3.41	-0.2

Appendix 3: The approximate normal distribution of *Prosopis juliflora* stems count (Histogram and Normal QQplot analysis). (Source: Histogram & Normal QQplot analysis interface in Geostatistical Analyst Extension of ArcGIS 9.1).





Appendix 4: Photo showing field Data collection for *P.juliflora* count in area of 400m^2 rectangular plot laid within 2 Km distance.

Appendix 5: Questionnaire for *Prosopis juliflora* social and environmental impact assessment.

Detection of Land Use /Land Cover Dynamics and Assessment in Spatial Distribution of *Prosopis juliflora:* a case study in Metehara

Questionnaire for data collection to assess perceptions of local people on the distribution and socio-economic impacts of Prosopis juliflora

Survey area:
Region ------------------ Zone------------------ Woreda---------------------
PA/Kebele------------------------------------
Date of Interview----------------------------
Name of Interviewer------------------------
Name of Head of household____________________ Age _____ Sex______

1. For how long did you live in this area?

2. Are you familiar with Prosopis juliflora? a) Yes b) No

3. What is the local name of Prosopis juliflora?

4. Since when Prosopis juliflora appears in this area?

5. What is the means of introduction of Prosopis juliflora in your locality?

6. Where did Prosopis seen on the first time?
a) Grazing land b) Irrigated land c) Road side d) others

7. What are the factors that facilitate the dissemination of Prosopis juliflora?
a) Cattle b) flood c) wind d) others

8. How do you see the infestation rate of Prosopis juliflora in your locality?
a) Very high b) high c) medium d) low

9. Does the infestation of Prosopis juliflora have effect on plants and animals?
a) Yes b) No. If yes go to question 10 & 11

10. What plant species disappear from your locality? Mention:

11. What animal species disappear from your locality? Mention:

12. Is there any new species of plants and animals which appear after the invasion of this species?

13. Does Prosopis juliflora has impact on crop production? Is it positive or negative impact? Mention the impacts:

14. Does Prosopis juliflora has impact on livestock production?
a) Encroaching grazing land b) threatens animal health c) foster malaria d) others

15. Do you believe that Prosopis has impact on human health? If there, how it affect human health?

16. In your opinion what are the most endangered tree species due to the invasion of Prosopis? Mention:

17. Which land cover is highly threatened by invasion of Prosopis juliflora?
a) Grass land b) bare land c) agricultural land d) others

18. What change have you observed in the grazing lands in terms of species composition and cover since the last 10 years?
a. Natural grass has increased
b. Natural grass has decreased
c. Prosopis has increased
d. Prosopis has decreased
e. Others (please, specify) ____

19. The invasion of Prosopis in your village and in your farm land
a. Affect the quality of crop and animal outputs
b. Affect the quantity of crop and animal outputs
c. Affect the income level and welfare of the society
e. Hamper the movement of the people and cattle
f. Others (please, specify)

20. Do you think that Prosopis has uses in your locality?
a) Yes b) No

21. If yes, what are its benefits? a) Increase soil fertility b) Serve as a shed c) Used as fodder for animal d) Control soil erosion e) Others

22. Comparing the advantages and disadvantages of Prosopis, what is your interest on Prosopis? a) Should be eradicate b) should be exist

23. Has the invasion of Prosopis juliflora negatively affected your cattle productivity?
a) Yes b) No

24. If yes, what are some of these negative impacts?
a. Cattle productivity declines
b. Quality of cattle product declines
c. Declines the income level of the family
d. Take too much labour and time of the family
e. It affects the taste of their products
f. Others (please, specify).__________________

25. Is there any trial of controlling mechanisms in your locality?
a) Yes b) No

26. Is there any organization who gave you orientation about Prosopis juliflora?

a) Yes b) No

27. Do you think that Prosopis juliflora is changing the environment in this area?
a) Yes b) No c) may be in the future

28. What do you suggest to control the invasion of Prosopis juliflora in your locality?

Thank you, for your cooperation !

DECLARATION

I here by declare that the thesis entitled" Land Use/Land Cover Dynamics in *Prosopis juliflora* Invaded area of Metehara and the Surrounding Districts" has been carried out by me under the guidance of Dr. Dagnachew Legesse during the year 2006-2008 as part of Master of Science programme in the Remote Sensing and Geographical Information System. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma and all sources of material used for this thesis have been dully acknowledged.

Ashenafi Burka
January, 2009

This thesis has been submitted for examination with my approval as a University advisor.
Dr. Dagnachew Legesse
