ADDIS ABABA UNIVERSTY

SCHOOL OF GRADUATE STUDIES

FACULTY OF NATURAL SCIENCE

DEPARTMENT OF EARTH SCIENSES

ASSESSMENTS OF FOREST COVER CHANGE USING REMOTE SENSING AND GIS TECHNIQUES: CASE STUDY IN ADABA-DODOLA FOREST PRIORITY AREA, ETHIOPIA

By

Meseret Mideksa

Addis Ababa
June, 2009

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University, in Partial Fulfilment of the Requirements for the Degree of Master of Science in Remote Sensing and Geographic Information System

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Declaration

I here by declare that the thesis entitled "**Assessments of Forest Cover Using Remote Sensing and GIS Technique: Case of Adaba-Dodola Forest Priority Area"** has been carried out by me under the supervision of Dr. Dagnachew Legesse Department of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2009 as part of a Master of Sciences Programme in Remote Sensing and GIS (Earth Sciences). I further declare that this thesis is my original work and has not been submitted to any other University or Institution for the award of any degree or diploma and that all sources of material used for the thesis have been dully acknowledged.

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Acronyms and Abbreviations

DEM	Digital Elevation Model
EMA	Ethiopian Mapping Agency
ETM	Enhanced Thematic Mapper
EMS	Electromagnetic Spectrum
FAO	Food and Agriculture Organization of the United Nations
FCC	False Colour Composite
FODWA	Forest Dwellers Association
GCP	Ground Control Point
GIS	Geographic Information System
GPS	Global Positioning System
IFMP	Integrated Forest Management Project
MCE	Multi-Criteria Evaluation
MoA	Ministry of Agriculture
NDVI	Normalised Difference Vegetation Index
NIR	Near Infra Red
PA	Peasant Association
SNNPR	Southern Nations, Nationalities and People's Region
SRTM	Shuttle Radar Topography Mission
TCC	True Colour Composite
TM	Thematic Mapper
UNEP	United Nations Environmental Programme
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WAJIB	Waldaa Jiraatota Bosonaa or FODWA
WLA	Weighted Linear Combination
WGS	World Geodetic System

Abstract

The aim of this study was to detect the magnitude and rate of forest cover change over the last 20 years (between 1986 and 2005) and generate human disturbance risk map based on land-use/land cover of the area using Remote sensing and GIS techniques in Adaba-Dodola Forest Priority Area that covers the total area of around 87,432 ha. NDVI image differencing and post-classification comparison change detection methods were employed. The major land-use/land cover types in the study area have been identified as: dense forest, open forest, grassland, farmlands and settlement. The study made use of Landsat images of the year 1986, 2000 and 2005 to know land-use/land cover change and the forest cover changes and rate of deforestation during the different periods and the type of land cover to which the forest is changed to. In addition Multi Criteria Evaluation in a GIS environment was used to come up with the final human disturbance risk map. The result of change detection analysis revealed that the area had remarkable land-use/land cover changes in general and forest cover change in particular. Specifically, the forest cover land declined from 57,389ha in 1986 to 50,472 ha in 2000 and dropped to 45,809 ha in the year 2005 in the study area. A significant forest cover reduction by 0.57% has been realized in the year 2005 when compared with the 1986 forest cover condition with a deforestation rate of 494 ha per annum. The problem of forest cover change is directly linked with the activity of man such as population pressure, and the socio-economic factors like expansion of agricultural activities, demand of fuel wood and construction materials, as well as using such resources for income. In order to holdback the problem of forest cover change and its impact, corrective measures was suggested.

Key words: Adaba-Dodola, Deforestation, Forest Cover, Remote Sensing and GIS

1. Introduction

1.1 General Background

Resources that are abundant once may change to other forms or be degraded or even depleted. Natural resources such as wildlife and forests were abundant on the earth and there were no concern about wise use of such moments . As human population continue growing rapidly, resources are becoming scares. Obviously, these resources are changed or exhausted unless wisely used. In order to mitigate the scarcity or complete loss, mankind has started to become concerned about conserving natural resources, of which one is forest resource (IFMP, 2000).

Forest is one of the most essential kinds of resources that human beings and other animals depend on. It regulates environmental and ecological changes in which soil, water climate and rainfall are in good existence in sustainable condition. Apart from its intrinsic value for many indigenous and other forest-dependent people, forests are their livelihood. Forests provide them with edible and medicinal plants, bush meat, fruits, honey, shelter, firewood and many other goods, as well as with cultural and spiritual values. Whether it is private or public property, forest is the nationally and globally mutual treasure. The value of forest resources to the world's human population is becoming increasingly evident.

Despite this, forest have been subjected to over exploitation due to human population has been growing and other factors; The forest has been either modified or converted. If modified, once dense stands of closed forests have been replaced by more open stands of secondary species that yet further changed into savanna of open grasslands and the whole process frequently being a prerequisite to clearing for agricultural activities (Williams, 1990).

The presence of forest in Ethiopia is relevant at several levels. Socially and economically speaking, forests are a traditional resource for local communities as a source for fuel wood and construction wood. In addition it is used for commercialisation of non-timber product in some local market. Moreover, they represent pasture for domestic grazers. Ecologically, forests are essential for the whole Ethiopian ecosystem, because they prevent the loss of fertile soil top layers. Damages are already visible in deforested part where the poor soil considerably reduce agricultural performance and hinder reforestation possibility for the future.

However, human interference, mainly for subsistence and economic reasons, is the most important reason for fast depletion and serious degradation of natural forest in Ethiopia. The conventional, futile and unsuccessful protection and guarding of state forests by employed guards is quite unsuccessful but, attempts to improve the situation are made by empowering and shifting the responsibility to the community level.

With regard to this, the annual loss of natural forest resources, by biotic and abiotic agents, in Oromia Regional State reaches up to 100,000 ha (Dechasa, 2001). In its neighbouring Southern Nations, Nationalities and People's Region (SNNPR), it is estimated that about the same area of forest is lost annually for the same reason.

Adaba-Dodola forest priority area is one of the remnant high forests in Ethiopia. The area is situated on the northern slopes of the Bale Mountains rising up to 3,800 m.a.s.l. It is bordered by treeless and vast agricultural plain at an altitude of 2,400 m.a.s.l and represents one of the few remaining examples of afromontane coniferous forest in Ethiopia. The areas largely consists of natural but degraded forest with about 5% plantation area of mainly *Cupressus lusitanica* and *Eucalyptus globulus*. The vegetation of the natural forest is dominated by *Hagenia abyssinica*, *Podocarpus falcatus*, *Juniperus procera* and *Erica heather*. However, for the last several decades the forestland cover in Adaba-Dodola priority area has been changed from natural forest to mixed forest, grassland and other land cover.

Information derived from remote sensing particularly in the form of land-use/land covers mappings and forestland changes and rate of deforestation is essential to detect changes, predict as well as monitor the results and useful for rational planning activities (Hellden, 1987). To address this issue technology has developed during the last 35 years that the possibilities are virtually unlimited in different areas of applications which can be addressed through earth observation satellite data and decisions support tools such as Geographic Information System (GIS).

Therefore, in this research study emphasis was given to assess the forest cover change and rate of deforestation in Adaba-Dodola forest priority area and mapping the cover change and human disturbance risk by using the integrated techniques of Remote sensing and GIS technology.

1.2. Statement of the problem

Ethiopia is a country well endowed with diversified natural resources. These resources endowments are its soil, diverse climate, extensive water resources, wild animals, rich livestock population as well as big reservoir of vegetation. However, what continuous to be highly visible and increasing concern is the ever accelerating rate of resource change and /or degradation.

Deforestation and land degradation in Ethiopia, however, are impairing the capacity of forests and the land to contribute to food security and to provide other benefits such as fuel wood and fodder. Ethiopians are facing rapid forest cover change and deforestation. Population increases have resulted in extensive forest clearing for agricultural use, overgrazing, and exploitation of existing forests for fuel wood, fodder, and construction materials. Forest areas have been reduced from 40 percent a century ago to an estimated less than 3 percent today. The current rate of deforestation is estimated at 160,000 to 200,000 hectares (ha) per year (IFMP, 2000).

In the case of Oromia region, forests were also exposed to extensive human pressure. The situation of forest cover change and rate of deforestation could be more sever in Oromiya than the other regions as of demographic factors. The deforestation rate of the region estimated to be about 3.1 percent (IFMP, 2000).

Even though, Adaba-Dodola forest priority area is one of the remnant high forests in the country, the forests are highly degraded because of unregulated extraction. The standing volume consists mainly of poor quality and over-sized trees. Almost all medium sized intermediate trees have already been extracted, as they are easy to fell with the locally available tools and known techniques.

More over, settlement in the Adaba-Dodola forest is illegal; over 200,000 people inhabit the area. The boundaries between the village administrations extend into the forest area although they are not established officially and not clearly defined. The number of livestock that seasonally graze inside the forest area can be estimated at 480,000. These patterns coupled with the high demand for forest resources have resulted in annual reduction of the forest cover by 3 percent or 1,600 ha. This was made known for the area by comparing satellite images of 1993 and 1997 (Tsegaye, 1999).

Rapid population growth, agricultural expansion due to land pressure, absence of community involvement and unstable institutional arrangement have resulted in unregulated access and the core problems for managing the forest. In the past, the forest administration has generated income from the forest through commercial logging and charcoal production. The forest is particularly important for the local communities, namely as pasture and source of wood for various purposes. Small scale commercialisation of forest produce by the local people in local markets is a routine activity. Some 200,000 people depend on earning their living from the forest of Adaba-Dodola. This use pattern has resulted in Adaba-Dodola high natural forest priority area being changed. So the forest cover change is a very serious problem in Adaba-Dodola forest area.

The critical issue stated in this study would be the nature of Ethiopia's forest cover change and rate of deforestation in general and Adaba-Dodola forest priority area in particular. It has become increasingly important to assess the status of forest resource cover change and rate of deforestation by means of Remote Sensing and GIS techniques, to suggest conservation measurer to protect and use the valuable forest resources on a sustainable manner.

1.3. Objectives

1.3.1 General objective

To assess forest cover change and analysis of the rate of deforestation in Adaba-Dodola forest priority area over the period of 1986 to 2005, thus contributing to sustainable management of the forest resource in the area

1.3.2. Specific objectives

- To asses the aerial and temporal extent, and the pattern of forest cover change during the stated period
- To quantify rate of deforestation
- To produce disturbance risk map
- To identify driving forces and impact of forest cover change in the study area.
- Recommending appropriate solutions for sustainable forest management

1.4. Research questions

- What was the area of natural forest land cover during the different period?
- What are the major causes and consequences of forest cover change?
- What are the factors responsible in determining the forest land cover change in Adaba - Dodola Area?
- What are the solutions for sustainable forest management in the study area?

2. Review of Literature

2.1. Forest cover and deforestation

Forest is one of the great inherited resources of the earth. It includes natural forests and forest plantations. The term is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha (FAO, 2000). (WBISPP, 1992) also defines forest as "a relatively continuous cover of trees, which are ever green or semi-deciduous only being leafless for a short period, and then not simultaneously for all species". Forests are determined both by the presence of trees and the absence of other predominant land-uses. The trees should be able to reach a minimum height of 5 m. Young stands that have not yet reached, but are expected to reach, a crown density of 10 percent and tree height of 5 m are included under forest, as are temporarily unstocked areas (FAO, 2000).

Some define deforestation as the area that no longer remains in primary forest (Pichon, et al., 2001). Others use strict sense of land-use conversion and define deforestation as the complete clearing of tree formations and their replacement by non-forest land-use (Thwin, 2003; Jempa, 1995). Forest degradation is a temporary or permanent deterioration in the density or structure of vegetation cover or its species composition. This encompasses the effect of selective logging, which causes change in canopy cover. It is also useful in accounting for the effects of short-rotation shifting cultivation, in which secondary forest (forest fallow) grow on abandoned plots but never reaches the same biomass or overall quality as mature forest as it is cleared again for cropping after a few years. The difference in the definition not only affects the measurement of the forest resources but also of annual deforestation.

In the context of this study, deforestation is equivalent to high forest cover change to non-forest land-use. Therefore, deforestation is defined as land-use change from high forest to other non-forest land-use, mainly agriculture, whereby the primary forest is altered structurally and in species composition and no more resemble the character of high forest.

2. 2. Global overview of forest cover change

Based on Earth observing satellite image 1990, there were some 1150 million ha of tropical rain forest with the area of the humid tropics deforested annually estimated at 5.8 million ha. A further 2.3 million ha of humid forest is apparently degraded annually through fragmentation, logging and/or fires. In the sub-humid and dry tropics, annual deforestation of tropical moist deciduous and tropical dry forests comes to 2.2 and 0.7million ha, respectively. Southeast Asia is the region where forests are under the highest pressure with an annual change rate of 0.8 to 0.9%. The annual area deforested in Latin America is large, but the relative rate (0.4 to 0.5%) is lower, owing to the vast area of the Amazonian forests. The humid forests of Africa are being converted at a similar rate to those of Latin America 0.4 to 0.5% per year (Mayaux et al., 2005)

2.3. Trend of forest covers change in Ethiopia

The forest cover of Ethiopia estimates made from 1940s to early 1960s ranged between 2.6 million ha and 12.2 million ha (Table 1). Apparently, estimates given by different authors show variation and this has been attributed to the differences in defining the forest by the authors (Melaku, 1992). The general truth, however, is that the forest cover has been diminishing through time.

Table 1: Forest cover estimates by different authors

Author	Year	Area (10^6) ha	Proportion from total land mass
Russ	1944	05.5	04.1
Logan	1946	02.6	02.1
Swain	1952	12.2	10.0
Mooney	1953	02.4	02.0
Verende	1957	03.8	03.1
Heske	1960	10.0	08.1
FAO	1961	03.0	02.5
Von Breitenbach	1962	03.0	02.5

(Source: Melaku Bekele ,1992)

More recent work on forest monitoring of Ethiopia (Reusing, 1998) clearly indicated the high rate of forests clearing in the country during the last three decades. The study was conducted using the Geographic Information System (GIS), and analysis from the satellite images of 1973-1976 showed that the forest cover in the country was 4.75% , while it declined to 3.93 % between 1986 and 1990 (Reusing, 1998). Accordingly, deforestation between 1973 and 1990 was around 24,543 Km^2 (2.14%) of the country. Reusing, (1998) has also showed the change detected in the natural forest cover between 1973 and 1990 in Ethiopia (Table 2).

Table 2: The detected forest cover change in Ethiopia between 1973 and 1990

Forest Classes	**Area (Km^2)**	**Proportion (%)**
Change not detectable*	15,227	1.33
Closed high forest/no change	02,192	0.19
Closed high forest to slightly disturbed high forest	02,335	0.20
Closed high forest to heavily disturbed high forest	16,828	1.47
Closed high forest to no forest	08,888	0.78
Slightly disturbed high forest/No change	01,642	0.14
Slightly disturbed high forest to heavily disturbed high forest	04,537	0.40
Slightly disturbed high forest to no high forest	07,979	0.70
Heavily disturbed high forest/no change	02,295	0.20
Heavily disturbed high forest to no high forest	07,676	0.67
Total	**69,599**	**6.08**

* High forests not classified by FAO/UNDP (1978); (Source: Reusing, 1998)

2.4. The causes and impact of deforestation

2.4.1. The causes of deforestation

The causes for deforestation accompanied by the loss of biodiversity can be explained on two different levels: the local level and the global one. The local level includes destruction of forests caused by local inhabitants. The rural poor living around forests heavily depend on biodiversity to satisfy their basic needs such as food, water, housing and social services. The economic dependency of the people on the forest which offers firewood and area that can be converted to agricultural land is one of the main reasons for deforestation. The global level of deforestation is formed by the worldwide demand for natural resources (e.g. timber, soil, gas, oil). In this context mining and industrial digging cause high damage to forests. Another aspect which has a negative impact on the ecological value of forests is conventional tourism. According to the United Nations, "waste treatment and disposal are often major, long-term environmental problems in the tourism industry" of concerned countries (UNEP, 2007).

Extensive conversion of forest land for agriculture started with the beginning of agricultural activity in the highlands of Ethiopia around 5000 years BP (Anonymous, 1997). The early development of agriculture in this area is attributed to the favourable climatic and ecological conditions, sufficient rainfall, moderate temperature and well-developed soils (Hurni, 1993). As the human population increased, the demand for arable land was inevitable and, gradually, agricultural activity started to dominate vast areas from gentle slope to the steeper slopes of the high mountains. The conversion of land to agriculture had also extended into the flat swampy plains of the plateau. Hence, through several millennia, vast areas of forest land were converted to agricultural lands. Moreover, through the influence of humans, most of the high forests in the country, particularly the dry evergreen montane forests and highland grassland as well as most of the moist evergreen montane forests, had been changed to farmlands and grasslands (Hurni, 1993).

In his findings, (Bekure, 1996) stated that the increasing demand for croplands, grazing land, construction poles and fuel wood including charcoal production are the main reason for the forest cover change in Ethiopia. In addition, forests are cleared to acquire constructional materials, to provide source of energy, to make space for grazing, farming, and building and layout infrastructure networks and to supplement raw materials such as an input for agricultural production and livestock grazing (Mesfin, 1991).

2.4.2. Impact of deforestation

The loss of forests and biodiversity has manifold negative consequences. Particularly due to the unique significance of forests for CO_2 conversion and storage, deforestation of forests entails an intensification of the greenhouse effect which contributes to global warming. But biodiversity loss also disrupts natural functions of an ecosystem which makes it more vulnerable to shocks and disturbance and less able to supply humans with its diverse services.

As a result of deforestation unimaginable problems would arise. The most and direct effect of deforestation is land degradation and desertification. According to Gaffar et al. (1998) ,34 percent of the land of Africa is now under the threat of desertification and more than 80 percent of Africa's dry lands are moderately or severely decertified. A 1984 survey of desertification trends estimated that as much as 742 million hectares in Africa 26 of total land area and more than 85 percent of the dry land area was undergoing moderate to sever desertification. A total of 108 million people lived in the affected zones in 1983 with 61 million people in areas undergoing sever desertification. This process has been accelerated the poor management of semiarid zones, population pressures, and adverse human impact and sever widespread poverty condition. To make matters worse, prolonged and extended drought has become a recurrent phenomenon with devastating impact on lives, agriculture and land; sediments in many Africa rivers are increasing roughly one and a half times as fast as population in their catchment areas; the utilization of marginal land and soil erosion and degradation (Gaffar et al,. 1998).

Moreover, according to population report, the adverse consequences of deforestation are erosion, siltation, and flooding in river basins, changes in microclimate, and loss of habitat (Population and Development, 1983).

In the case of Ethiopia, the most challenging situation for the country as a whole, particularly, highland areas are land degradation or loss of land fertility due to soil erosion as a result of deforestation. Most of the economic activity directly or indirectly depends on agriculture. The productivity of land that satisfies the demand for food and necessary produce for industry and export is depending on the fertility of land. Land degradation and the occurrence of drought are the two major challenges to the country production and productivity. According to Teferi, (1999) the major cause of land degradation in Ethiopia is soil erosion, which nearly one billion tones per year in the country's highlands. This is primarily due to human activities, particularly overgrazing, over-cultivation and deforestation.

The direct impact of the forest destruction in Ethiopia was the creation of a wide gap between supply and demand for fuel wood, construction materials, timber and other forest products and further disappearance of the flora and fauna of the country. Indirectly, this has brought about a change in climate and the soil is exposed to desiccation and erosion, has to reduce land productivity (Berhanu, 1993).

2.5. Remote Sensing and GIS

2.5.1. Remote Sensing

Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand and Kiefer, 2000). The focus of remote sensing in scope of this study is the measurement of emitted or reflected electromagnetic radiation, or spectral characteristics, from a target object by a multispectral satellite sensor. Remote sensing satellite images are immensely used in natural resources monitoring and management, study the time to time changes due to its repetitive coverage especially in forest resources estimation and monitoring.

2.5.2. Geographic Information System (GIS)

Different authors defined GIS from different perspectives. Borrough and Mc Donnel (1986) define "GIS is a Powerful tool for collecting, storing, retrieving, as well, transforming and displaying spatial data from the real world for a particular set of purpose".On the other hand, ESCAP (1996) define "GIS is a specific information system applied to geographic data and is mainly referred to as a system of hardware, soft ware and procedures designed to support the capture, management, manipulation, analysis, modelling and display of spatially-referenced data for solving complex planning and management problems".

Most of the definitions given to GIS are relay on the computer based. This is because; it is a computer technology that realized the digital data. By now, GIS is popular as a result of the rapid access to data, flexibility, easy update opportunity and other features that enable to analyze different databases. In addition, the popularity of GIS has become more pronounced as a result of parallel development with satellite technology and computer science (Burrough and Mc Donnel, 1986).

GIS is an information system that is designed to work with data referenced to spatial or geographic coordinates. GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operation for working with data. The functions of GIS include data entry, data display, data management, information retrieval and analysis. The applications of GIS include mapping locations, quantities and densities, finding distances and mapping and monitoring change.

2.6. Application of Remote Sensing and GIS to monitor forest cover change

Remote Sensing is a powerful technique for surveying, mapping and monitoring earth resources. This technology combined with GIS which outshine in storage, manipulation and analysis for Geographic information and Socio-economic data to provide a wider application. 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. The potential of remote sensing and GIS in the field of forestry become established over many years through the use of aerial photos and satellite image interpretations in forest cover change detection analysis, for the generation of cover map and inventory analysis.

Remote sensing brings together a multitude of tools to better analyze the scope and rate of deforestation. Multitemporal data provides for change detection analyses. Images of earlier years are compared to recent scenes, to tangibly measure the differences in the sizes and extents of forest cover change. Data from a variety of sources are used to provide complementary information. Satellite image data can be used to efficiently monitor the status of existing clearcuts or emergence of new ones, and even assess regeneration condition. In countries where cutting is controlled and regulated, remote sensing serves as a monitoring tool to ensure companies are following cut guidelines and specifications.

2.7. Change detection methods

Change detection involves the use of multi-temporal datasets to discriminate areas of land cover change between dates of imaging, (Lillesand and Kiefer, 2000). In addition (Singh, 1989) indicate that change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multi-temporal data sets. Singh (1989) also note that change detection is useful in such diverse applications as land use change analysis, monitoring of shifting cultivation, assessment of deforestation, seasonal changes in pasture production, damage assessment, disaster monitoring, day/night analysis of thermal characteristics as well as other environmental changes. All digital change detections are affected by spatial, spectral, temporal, and thematic constraints. The type of method implemented can profoundly affect the qualitative and quantitative estimates of the disturbance (Chen, 2000).

Digital change detection is a difficult task to perform. An interpreter analyzing large-scale aerial photography will almost always produce more accurate results with a higher degree of precision (Edwards, 1990). Nevertheless, visual change detection is difficult to replicate because different interpreters produce different results. Furthermore, visual detection acquires large data acquisition costs. Apart from offering consistent and repeatable procedures, digital methods can also more efficiently incorporate features from the infrared and microwave parts of the electromagnetic spectrum.

Many change detection methods have been developed and used for various applications. For example, there are post-classification comparison, image differencing, image ratioing, image regression and principal component analysis (Chen, 2000). However, they can be broadly divided into: post classification, and spectral change detection approaches (Singh, 1989).

2.7.1. Post-classification approach

Post classification is among the most widely applied techniques for change detection purpose. Numerous studies have been carried out using post-classification approach. In post classification change detection approach two images from different dates are classified and labelled. The area of change is then extracted through the direct comparison of the classification results (Lunetta Elvidge, 1999).

Main advantages of post-classification include: detailed “from – to” information (Chen, 2000). It bypasses the difficulties associated with the analysis of images acquired at different times of year or sensor (Chen, 2000). The main disadvantage of the post-classification approach is the dependency of the land cover change results on the individual classification accuracies (Chen, 2000). This approach can produce a large number of erroneous change indications as an error on either data gives a false indication of change (Singh, 1989). Therefore, it is imperative that the individual classification be as accurate as possible (Chen, 2000).

2.7.2. Spectral change detection approach

According to Chen (2000), a large number of techniques are in the spectral change identification category. Spectral change detection techniques rely on the principle that land cover changes result in persistent changes in spectral signature of the affected land surface. These techniques involve the transformation of the two original images into a new single band or multi-band image, in which the area of spectral change is highlighted. Most of the spectral change detection techniques are based on some type of image differencing or image ratioing. Studies by Singh (1989) have identified image differencing as the most accurate change detection technique. This technique is performed by subtracting images from two dates pixel by pixel. Then threshold boundaries between change and no-change pixels are determined for the difference image to produce the change map.

Among spectral change detection methods, vegetation indices are among other methods that have been reliable in monitoring vegetation change. One of the most widely used indices for vegetation monitoring is the Normalised Difference Vegetation Index (NDVI), because vegetation differential absorbs visible incident solar radiant and reflects much of the infrared (NIR), data on vegetation biophysical characteristics can be derived from visible and NIR and mid-infrared portions of the electromagnetic spectrum (EMS). The NDVI approach is based on the fact that healthy vegetation has low reflectance in the visible portion of the EMS due to chlorophyll and other pigment absorption and has high reflectance in the NIR because of the internal reflectance by the mesophyll spongy tissue of green leaf (Lunetta and Elvidge, 1999). NDVI can be calculated as a ratio of Red and the NIR bands of a sensor system.

NDVI values range from -1 to +1, because of high reflectance in the NIR portion of the EMS, healthy vegetation is represented by high NDVI values between 0.1 and 1. Conversely, non-vegetated surfaces such as water bodies yield negative values of NDVI because of the electromagnetic absorption quality of water. Bare soil areas represent NDVI values which are closest to 0 due to high reflectance in both the visible and NIR portions of the EMS. NDVI is related to the absorption of photosythetically active radiation and basically measures the photosynthetic capability of leaves, which is related to vegetative canopy resistance and water vapour transfer (Lillesand and Kiefer, 2000).

A large number of comparative studies on different change detection methods including NDVI image differencing have been carried out. Most of the studies have concluded that NDVI image differencing method yields highest accuracy.

In general, the advantage of spectral change detection techniques is that they are based on the detection of physical changes between image dates. This avoids the errors introduced in post-classification change detection where inaccuracies in the land cover classification are propagated into land cover change analysis. However, the greatest challenge to the successful application of these techniques is the discrimination of "change" and "no change" pixels. For spectral change detection, an accurate image co-registration is crucial. This study reviews the art of digital change detection by both post classification and NDVI image differencing approach on forest cover change, with emphasis on Adaba-Dodola forest priority area.

2.8. Multi-Criteria Evaluation (MCE)

A decision is a choice between alternatives the alternatives may represent different courses of action, different hypotheses about the character of a feature, different classifications, and so on. The procedure by which criteria are selected and combined to arrive at a particular evaluation and by which evaluations are compared and acted upon is known as a decision rule. A decision rule might be as simple as a threshold applied to a single criterion (such as, all regions with slopes less than 35% will be zoned as suitable for development) or it may be as complex as one involving the comparison of several multi- criteria evaluations.

A standard is some basis for a decision that can be measured and evaluated. Criteria can be of two kinds: factors and constraints and can pertain either to attributes of the individual or to an entire decision set. To meet a specific objective, it is frequently the case that several criteria will need to be evaluated. Such a procedure is called Multi-Criteria Evaluation (Eastman, 2001).

Multi Criteria Evaluation (MCE) is most commonly achieved by one of two procedures. The first involves Boolean overlay where by all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operators such as intersection (AND) and union (OR). The second is known as Weighted Linear Combination (WLC) where in continuous criteria factors are standardized to a common numeric range, and then combined by means of a weighted average. The result is a continuous mapping of risk that may then be masked by one or more Boolean constraints to accommodate qualitative criteria and finally threshold to yield a final decision.

While these two procedures are well established in GIS, they frequently lead to different results, as they make very differently about how criteria should be evaluated. In the case of Boolean evaluation, a very extreme form of decision making is used. With WLC, criteria are permitted to trade off their qualities. A very poor quality can be compensated for by having a number of very favourable qualities. This operator represents neither an AND nor an OR-it lies some where in between these extremes. It is neither risk averse not risk taking. In general, the primary issue in Multi Criteria Evaluation is concerned with how to combine the information form several criteria to form a single index of evaluation.

3. Materials and Methods

3.1. Study Area Description

3.1.1 Location

The Adaba-Dodola forest priority area is located in the northern slopes of the Bale Mountains and 320 km southeast of Addis Ababa. It is one of the 38 forest priority areas in Oromia, and serves as a buffer zone for the Bale Mountains National Park. The study site is situated between latitude 6^0 45' and 7^0 02' N and longitude 39^0 02' and 39^0 33' E. It covers some 874.32 square kilometres of mountain slopes. Its forest remnants cover part of the northern slopes of the Bale Mountains in the two districts of Adaba and Dodola in West Arsi Zone (former Bale Zone). About 30 villages (so-called Peasant Associations) are more or less close to the forest priority area. Because of IFMP, a technical cooperation project of the governments of Ethiopia and Germany, is operating ten PA in Adaba-Dodola Forest Priority Area this study only includes ten PA theses are; Aluma Shafa, Kechama, Keta Berenda, Bura Adela, Berisa, Deneba, Geneta Hara, Bucharaya, Ejersa and Besete Bubisa, of which three of the Peasant Association territories cover about one quarter of the area, still considered being forest. These are Berisa, Bura-Adele and Deneba peasant association (Asfaw, 1999).

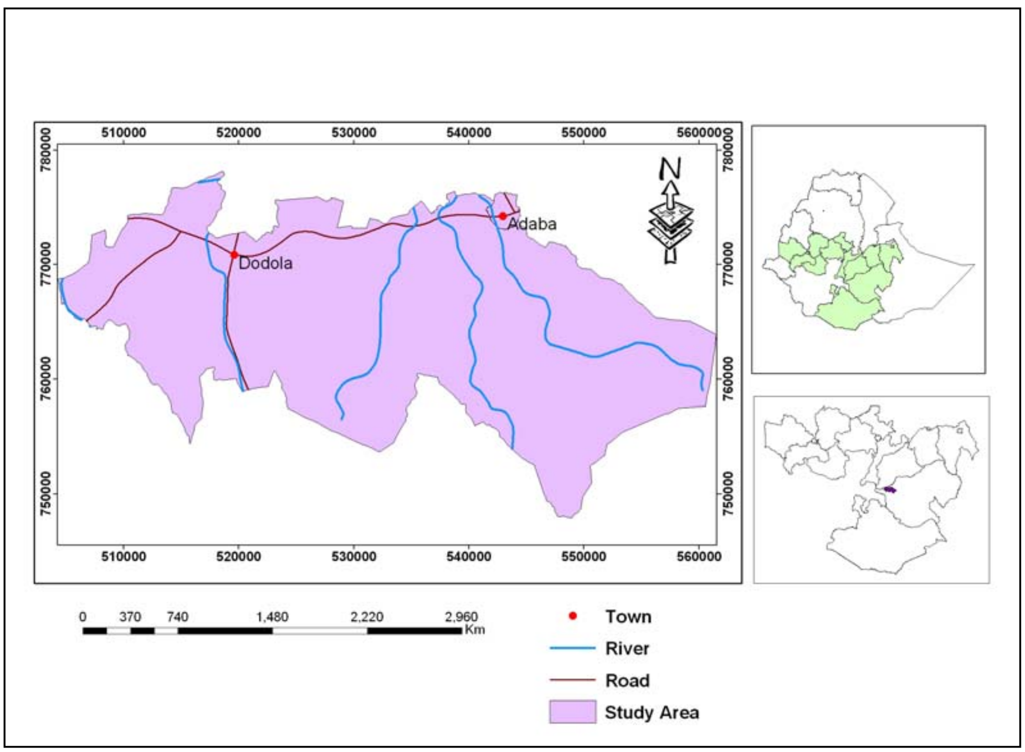

Figure 1: Location map of the study area

3.1.2. Climate

The rainfall depends on the prevailing winds, which are governed by the seasonal fluctuation of the inter tropical convergence zone, but modified by local relief. Rainfall of the study area is bimodal, with the main rainy season occurring between July and September. The dry season lasts from November to February, followed by the short rainy season during the months of March and April. From the weather records of 1994-2004, the average rainfall of the study area is 733 mm (Ameha, 2004). The temperature ranges from 7-24^{0}C.

3.1.3. Topography and Soils

The topographic landscapes of the study site are rugged, made up of mountain chains and divided into two categories (Asrat et *al., 1997)* the northern part with an average elevation of 2,400 m .a.s.l. is devoid of tree vegetation and intensively cultivated with barley and wheat, whereas the southern half is mountainous with a maximum elevation of 3,800 m .a.s.l. Part of the landscape is covered by degraded forests. Most of the slightly disturbed forest patches are located in inaccessible areas such as valley bottoms, and along river banks and ridges. The whole area is a source of important perennial rivers, which flow northwards to the River Wabe Shebele and to the Genale-Dawa drainage basin to the south.

The soil is volcanic in origin, mainly from alkali basalt and tugs and generally of well structured silt or clay-loam of more than one-meter depth on the gentle slopes, in the valleys and depressions. It is generally shallow on slopes and on top of hills whereby rocky outcrops are regularly observed. The colour is reddish brown, well drained and of medium texture. If forest cover is removed, erosion can be expected (Girma, 2005).

3.1. 4. Vegetation

FRIIS (1992) classified the vegetation as undifferentiated afro-montane forests, which are also called mixed upland evergreen forests, upland dry evergreen forests and coniferous and mixed forests. They are either dominated by *Juniperus* and *Podocarpus* or predominantly *Podocarpus* forests, both with an element of broadleaf species. The forest formation changes along the altitudinal gradient.

The forest formation reveals the strong dominance of conifers up to 2,850 m a.s.l. where *Juniperus excelsa* rules over all other species, followed by *Podocarpus falcatus*. At the middle altitude between 2,850-3,000 m.a.s.l., *Juniperus excelsa* is still dominant in association with other broadleaf hardwood species. *Podocarpus falcatus* no longer occurs at this altitude as a canopy species although some trees may appear in the under storey. At the lower and middle altitudes *Mytenus species* and *Rapanea melanphloeos* are the most frequent under storey species (Tegaye, 1999). At the upper zone between 3,000-3,400 m.a.s.l., *Hagenia abyssinica, Hypericum lanceolatum* and *Erica arborea* dominate the forest formation, sometimes mixed with *Juniperus excelsa*. *Erica arborea* occurs as a shrub at its uppermost distribution range.

Before the establishment of community-based forest management the forests were seriously affected by the uncontrolled use for wood extraction and grazing. According to the report produced by the 'Woody Biomass Inventory and Strategic Planning Project' (WBISPP), 10 % of the forest area is situated on a slope in excess of 30 %.

3.1.5. Socio-economic Condition

The total population of the two district Adaba and Dodola was 333, 466 in the year 2008. The main source of livelihood for the majority of the people is farming. The crops grown mostly are wheat, barley and teff during and after the rainy season. The crop rotation is shifted every year (WAJIB, 2008). Farming is not only done for subsistence but also to create income. Till the end of the dry season, the farmers also do livestock herding in the Mountain Savannah, which is an important contribution to their livelihoods the importance of livestock grows with rising altitude. In some areas there are *enset* plantations (edible plant) around homesteads (IFMP, 2000). It is observed that the livelihood of the majority of the WAJIB members is dependant on mixed farm, which constitutes farming outside the forest area and animal husbandry. Besides, the use of forest resources is of high importance as the people in the research area live near or inside the forest.

3.2. Data and Material

Satellite imageries and ancillary data have been collected in order to identify historical and recent land-use/land cover. The image data used for this study were Landsat TM 1986, ETM+

2000 and ETM+ 2005 and Topographic maps at the scale of 1:50,000, were purchased from the Ethiopian Mapping Agency (EMA). Digital elevation model (DEM) of the study area, with 90 meter resolution and horizontal and vertical absolute precision of 20m and 16m respectively from the Shuttle Radar Topography Mission (SRTM) of NASA, is obtained from GIS lab, AAU. This data were used to observe the relationship between topography, mainly altitude and slop for forest cover change by using 3DEM and ArcGIS 9.2 software.

Satellite Images

Landsat TM

Landsat TM satellite data have spatial resolution of 28.5 meters and includes two middle-infrared and one thermal channel. These high-resolution scanners have seven spectral bands and cover a 185-by-185km area. For the study area, a single scene path/row 168/55, taken in January 1986 by TM sensor on board was used (Table 3).

Landsat ETM+

Landsat-7, which carries onboard the Enhanced Thematic Mapper plus (ETM+) instrument, was launched on April 15, 1999 as part of the global research program of NASA's Earth Science Enterprise. The sensor has six spectral bands in the visible, near-infrared, and shortwave infrared regions of the electromagnetic spectrum (at 28.5m spatial resolution), one thermal infrared band (60m and 120m spatial resolution products), and one panchromatic band (at 15m spatial resolution). For this study a single scene path/row 168/55) was used that had been acquired by this sensor in February 2000 the same path and raw was also used for 2005 image (Table 3).

Table 3: Summery of data source and material

I. Satellite Image Data			
Image Type	Path and Row	Date of Acquisition	Resolution (meter)
Landsat-TM	168/55	01/21/1986	28.5 X 28.5
Landsat-ETM+	168/55	02/05/2000	28.5 X 28.5
Landsat-ETM+	168/55	12/03/2005	28.5X 28.5
II. Materials			

Type	Description	Source	
Instruments	GPS	rent	
Software	ArcGIS 9.2, ERDAS 9.1, 3DEM IDRISI Andes and ENVI 3.4	GIS lab	
III. Topographic Maps			
Scale	Woreda	T. Sheet No.	Source
1:50,000	Adaba Asasa Dodola Herero	0739C4 0739C3 0639A1 0639A2	Ethiopian Mapping Authority/EMA

3.3. Methods

The procedure followed in this study was presented using the flow chart (Figure 2). It shows the steps followed beginning from the acquisition and classification of multitemporal satellite image of the study area to the extraction of the required information both secondary and primary data to answer the research questions.

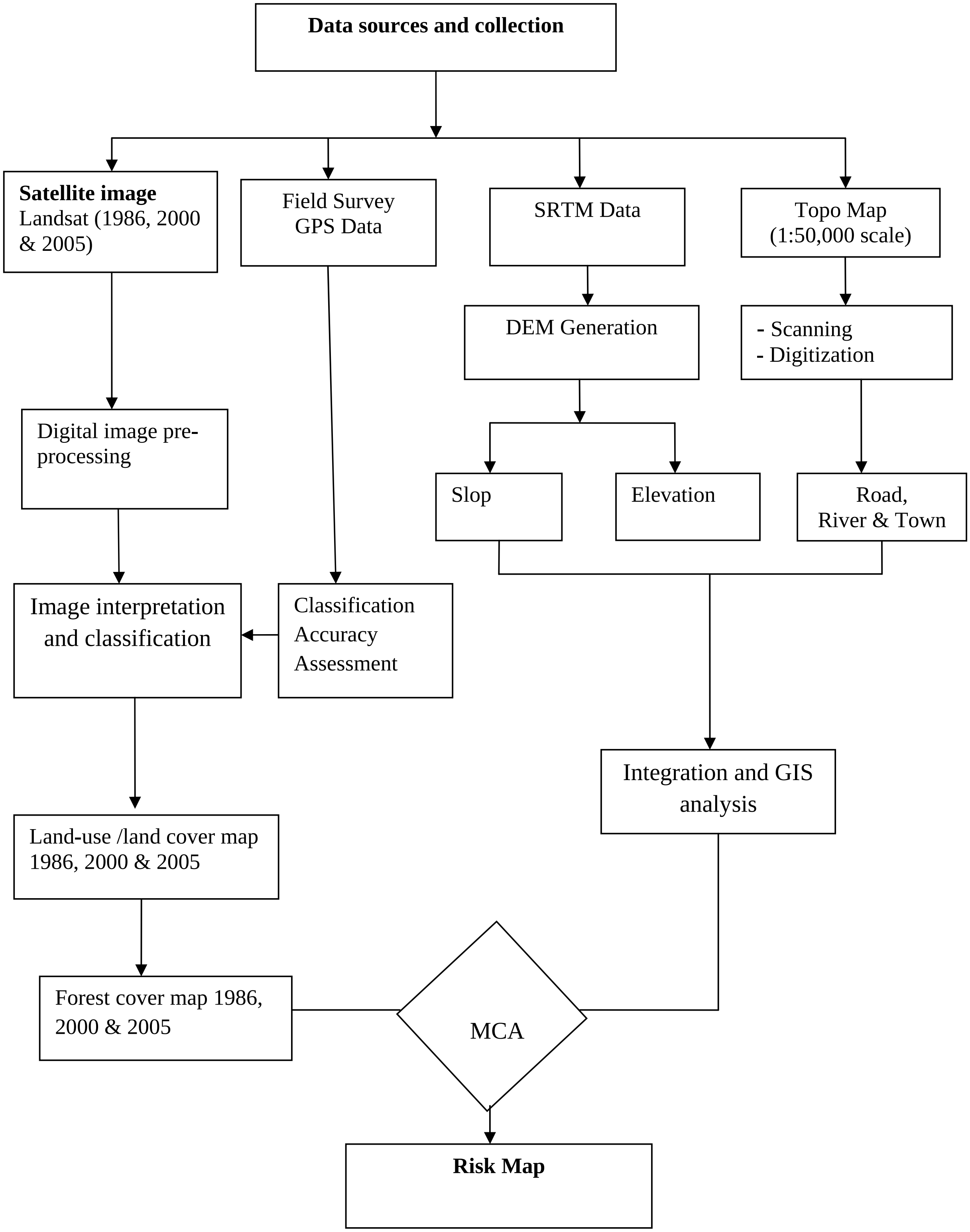

Figure 2: Flow chart

3.4. Pre-field work

3.4.1. Image/data pre-processing

For this study multi-temporal image, topographic maps and STRM data were used. The 1:50,000 topographic maps of the study area were scanned, georeferenced and projected to UTM coordinate system, map zone 37N of WGS-84 spheroid and datum. The satellite images and the SRTM data were originally ortho-rectified and therefore did not require geo-referencing. Road and river layers were digitized from the georeferenced topographic maps.

3.4.2. Band selection

Band selections were made in order to obtain the most important information from remotely sensed data through the analyses of reflectance properties of objects or features. Spectral reflectance curve of the different vegetation types of the area and the histogram behaviour of the bands were used for the purpose of image processing of Landsat satellite images the ERDAS IMAGIN 9.1 software was used.

Reflectance of healthy vegetation is better observed at 0.52 - 0.60 µm range (Green, Band 2 of TM and ETM+). At 0.63 - 0.69 µm range (Red, Band 3 of TM and ETM+) chlorophyll absorbs a considerable portion of the incoming energy (Jacquemoud etal., 2001). Hence ,this band is important for identification of healthy green vegetation. The near infrared spectrum ranges from 0.76 to 0.90 µm in Landsat TM and ETM+ images (known as Band 4) as opposed to the previous range, reflectance from green plants sharply increases in this range. Several indices, which attempt to quantify vegetation attributes, primarily use these two ranges due to this contrasting reflectance behaviour of plants at these spectral ranges. At the far mid-infrared (1.55 - 1.75 µm Band 5 in TM and ETM+), the moisture content of plants is detected. This property is especially important in agricultural crop observation studies because some signs of plant stress, which cannot be seen by naked eye, are readily distinguished. Features those look similar in visible ranges like clouds, snow and ice are also clearly identified. At the spectral coverage gap between Band 3 and Band 4 (0.69-0.75 µm), very important chlorophyll dependant plant activities could be identified. In other words band 3 and 4 were useful in the discrimination and classification of vegetation types; bands 5 and 7 are sensitive to the content of moisture in vegetation and bands 4, 5, and 7 are also useful for the delineation of water bodies (Lillesand and Kiefer, 2000). So, band 1, 2, 3, 4, 5 and 7 of the TM and ETM+ images were used for this study and stacked together and subset to area of interest by using ERDAS IMAGINE 9.1 software.

3.4.3 Image enhancement and interpretation

Satellite image contains a detailed record of features on the ground at the time of data acquisition. In relation to this Lillesand (2000) suggested that image interpreters should have good power of observations coupled with imagination and it is important that the interpreters have a careful understanding of the phenomenon being studied as well as knowledge of the geographic region under study. To do so, digital image enhancement and interpretation techniques were used in this study.

To increase the visual interpretability of the satellite images and the amount of information that can be visually interpreted from the data both True Colour Composite (TCC) and False Colour Composite (FCC) were produced. Digital image enhancement techniques were to be done such as contrast stretching, band ratios and NDVI analysis. The TCC and FCC composites of the 2005 ETM+ images subset to the study area boundary were provided in Figure 3 and 4 respectively for evidence.

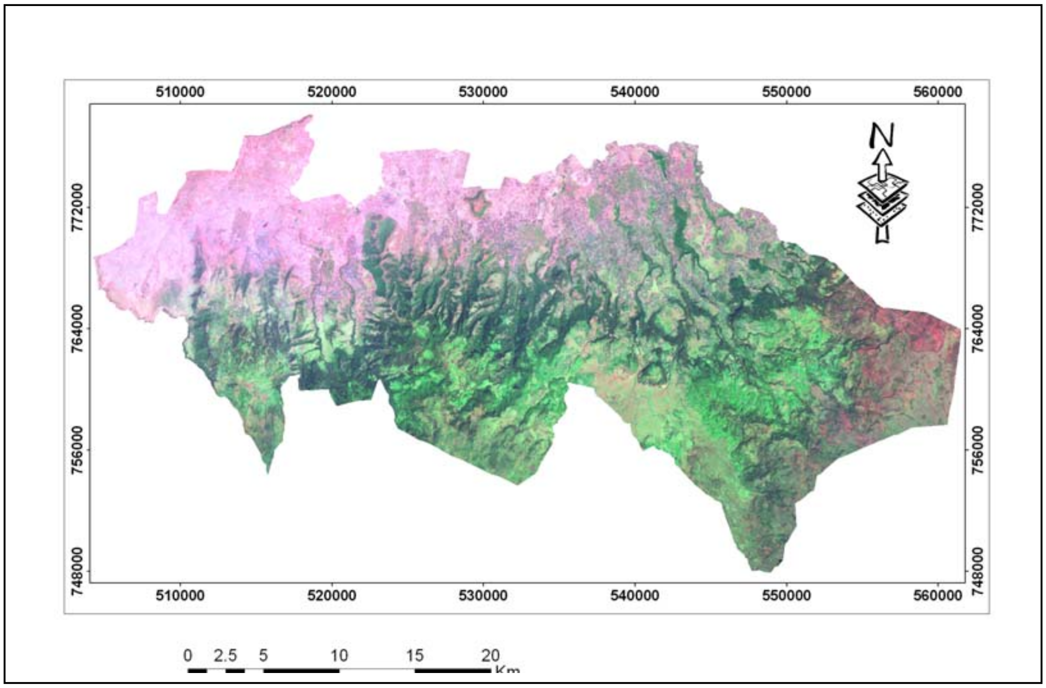

Figure 3: True Colour Composite of 2005 image

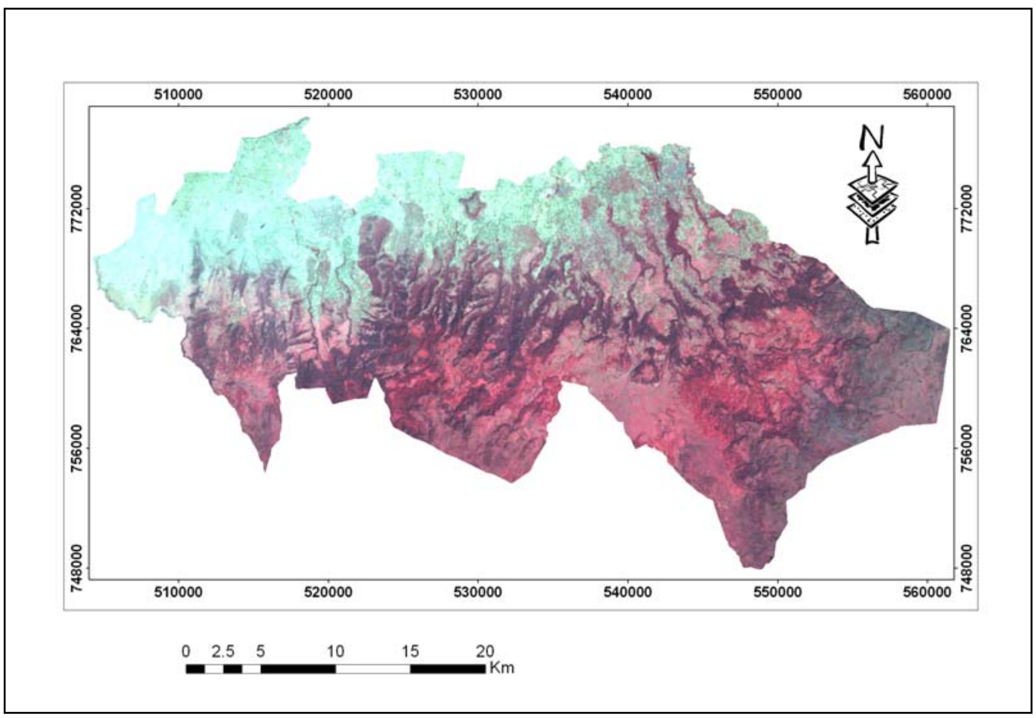

Figure 4: False Colour composite images of 2005

3.5. Data collection

During the present study, both spatial and temporal data were gathered, both from primary and secondary sources. Primary data were generated from the analysis of satellite image, field visits, and interview with concerned bodies. Secondary data were obtained from published and unpublished materials including books, journals, research articles and census reports.

3.5.1. Satellite images and spatial data

The major primary data required for the study has been extracted from satellite images. Land-use/ land cover types at various times have been extracted from Landsat TM (1986), ETM+ (2000) and ETM+ (2005) images. Altitude and slope have been generated from Shuttle Radar Topography Mission (SRTM) 90m resolution data; river and various road category networks were also generated from 1: 50,000 scale topographic maps through manual digitizing and towns' layer was obtained from Ethio-GIS from GIS lab, AAU.

3.5.2. Ground truth/field visit

Apart from the satellite image of remote sensing data, field visits were the second major data collection mechanisms.

3.5.2.1. Preliminary field visit

Preliminary field visit was carried out to get an overall overview of the study area, to identify the various land-use/ land cover types, identify various forest cover type and to collect GPS readings of the various features and land-use/land-cover types. These data were used for designing of final image classification and testing sample site, which was used for land-cover map validation of the subsequent supervised classification.

3.5.2.2. Second field work stage

The second field visit was taken to verify the various land-use/land-cover types identified through satellite image manipulation and to consult the local community, district agricultural and rural development office experts and Adaba Dodola forest enterprise experts in order to identify the factors behind the forest cover change and GPS readings of important forest cover boundary of the study area. These data were used for designing of final image classification and testing sample site, which was used for land cover map validation. At each sampling site more than 13 reference points were randomly taken during May 2-8/ 2009 using Garmin76 GPS receiver for ground truth verifications. In addition to these data, photographs were taken at each site and essential information were generated, which helped to support the identification of patterns, trends, causes and impacts of forest cover change.

3.5.3. Secondary data

Secondary data collections were made from various sources. Background information of the study areas were obtained from previous research works in the study area. Digital copy maps of kebele boundaries, land use map and soil maps other published and unpublished documents journals and books were used to describe the study area.

3.6. Post field phase

Based on the final training sample site, which were generated during field work stage, all the available images were classified in to five land-use/cover types by applying supervised classification method and maximum likelihood algorithm with the support of ERDAS Imagine 9.1 software. In relation to this, the year 2005 land-use/land cover classification result was evaluated by employing accuracy assessment technique using ERDAS IMAGIN software to investigate how the result reflects the reality on the ground.

Likewise, the years 1986, 2000 and 2005 forest cover maps were also extracted independently from each land use land cover maps. In addition, on the bases of the years 1986, 2000 and 2005 multi-temporal Landsat image data forest cover change detection analysis were carried out using NDVI and Postclassification change detection comparison methods by using ENVI 3.4 software.

Based on 2005 forest cover condition Multi Criteria Evaluation (MCE) analysis was carried out to produce human disturbance risk map. GIS software such as IDRISI Andes and ArcGIS 9.2 using raster calculator in Spatial Analyst tools were used.

3.6.1. Data Analysis

3.6.1.1. Image classification

Image classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to those criteria.

There are two primary types of classification algorithm applied to remotely sensed data. These are unsupervised and supervised. Unsupervised classification algorithms such as ISODATA (Iterative Self-Organizing Data Analysis) cluster data according to several user-defined statistical parameters in an iterative fashion until either some percentage of pixels remain unchanged or a maximum number of iterations have been performed. This method of classification is most useful when no previous knowledge or ground truth data of an area is available. However, the classes determined by the algorithm still require land cover identification by an experienced analyst, which has a disadvantage in using this method. An unsupervised classification approach was adopted for this study for pre field visit purpose.

3.6.1.2. Unsupervised Image Classification

Using unsupervised image classification methods, land-use/ land cover types were identified. In this study the forest cover types played a much more important role than other types of land-use/land cover found in the study area. Based on the characteristics of Landsat satellite image of the year 2005 the number of land cover types were determined to run unsupervised classification,which aided the preliminary field visit. In the year 2005 the major land-use /land cover types were classified as, dense forest, open forest, grassland, farmland and settlement. With the support of ERDAS Imagine 9.1 Software the map, of unsupervised landsat 2005 image classification was produced (Figure 5).

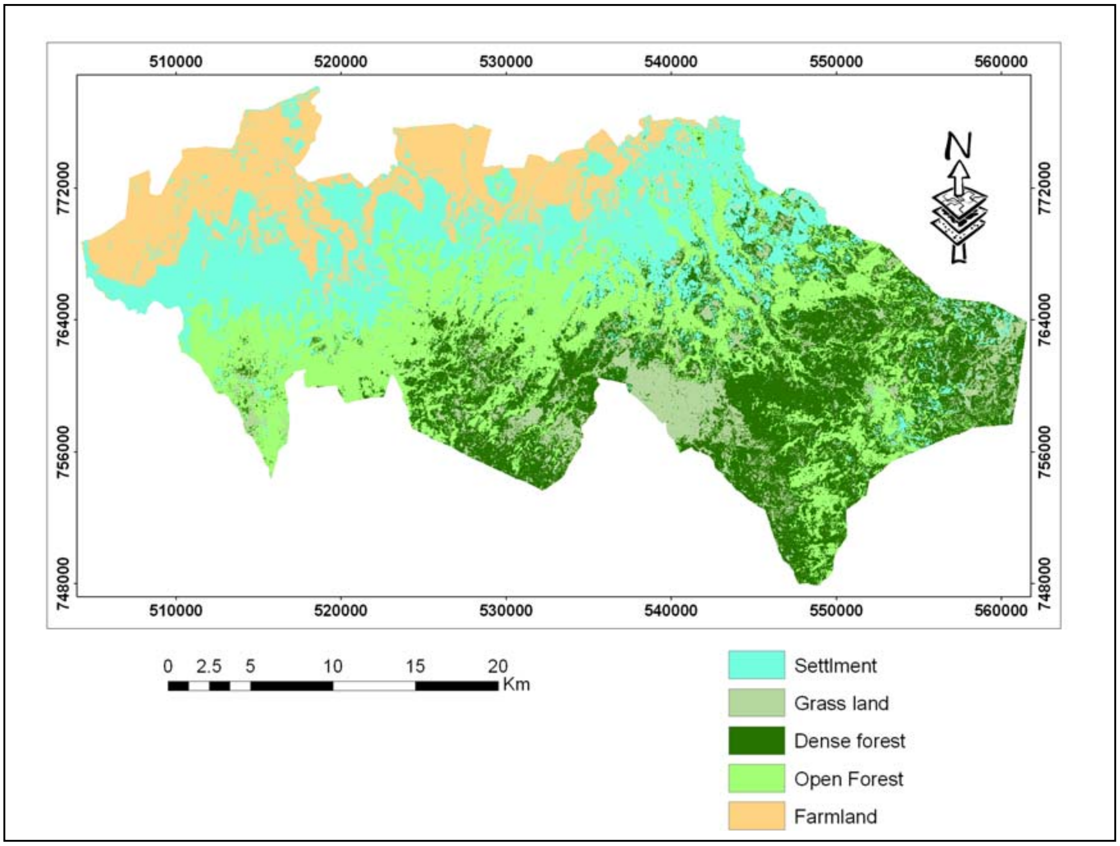

Figure 5: Unsupervised image classification

3.6.1.3. Supervised Classification

During the preliminary field visit the various land cover classes were taken by systematic sampling using GARMIN 76 GPS devise. These samples were used to representative signatures for the various land cover types identified. The ETM+ 2005 satellite images were classified using the Maximum Likelihood supervised classification using the sample training signature prepared from the GCPs collected for the ETM+ 2005 image. For Landsat TM 1986 and ETM+ 2000 images, visual observation of the FCC Landsat image, TCC Landsat image and the spectral information of the known land cover categories observed from unsupervised classified Landsat ETM+ image (Figure 5) and from visual observation of the supervised classified ETM+ 2005 image were used. From supervised classified Landsat ETM+ 2005 image, five classes were identified as dense forest, open forest, grassland, farmland and settlements.

Description of land covers classes

As there are some differences between the land classes in the historical land-cover maps of 1986, 2000 and land-cover classes, which can be discriminated from the satellite image, recoding was needed to create a common classification for change detection purposes. This section describes the land classes, which are only used for land-cover mapping from satellite images.

Dense forest: This class represents the evergreen forest and montane forests. The general tree height was from 18 – 40 m, and the crown coverage is over 60% (IFMP, 1999).

Open forest: This class corresponds to forest, which was disturbed by human activities. It is composed predominantly of regeneration forest from the past disturbance such as, logging. The general height in this class range 2m to 25m tall. The crown coverage was generally below 60 % (IFMP, 1999).

Grassland: This land cover includes areas of shrubs, short tress, bushes, pasture lands, grazing areas dominantly covered with grasses.

Farmland: This area cover includes agricultural crops

Settlement: are those areas composed of intensive use with much of the land by rural villages, towns and roads.

3.6.2. Classification Accuracy Assessment

Land cover maps derived from remote sensing always contain some sort of errors due to several factors which range from classification technique to method of satellite data capture. In order to wisely use the land cover maps which are derived from remote sensing and the accompanying land resource statistics, the errors must be quantitatively explained in terms of classification accuracy. Whether the output meets expected accuracy or not is usually determined by the users themselves depending on the type of application the map product will be used latter. Accuracy levels that are acceptable for certain task may be unacceptable for others.

The common means of expressing classification accuracy is the preparation of classification error matrixes. An error matrix (confusion matrix) is a square array of numbers organized in rows and columns which express the number of sample units assigned to a particular category relative to the actual category as indicated by reference data. These tables produce many statistical measures of thematic accuracy including overall classification accuracy, percentage and the kappa coefficient, an index that estimates the influence of chance (Congalton etal. 1999).

Error of omission is the percentage of pixels that should have been put into a given class but were not. Error of commission indicates pixels that were placed in a given class when they actually belong to another. These values are based on a sample of error checking pixels of known land cover that are compared to classifications on the map. Errors of commission and omission can also be expressed in terms of user's accuracy and producer's accuracy. User's accuracy represents the probability that a given pixel will appear on the ground as it is classed, while producer's accuracy represents the percentage of a given class that is correctly identified on the map. One of the problems with the confusion matrix and the kappa coefficient is that it does not provide a spatial distribution of the errors (Foody, 2002).

The quality and sufficiency of reference data are important if reliable accuracy assessment is required. A reference data that is not verified thoroughly should not be expected to set accuracy standard. Insufficient number of verified data also affects the quality of the assessment (Congalton etal., 1999).

In this study, an error matrix was generated based on the year 2005 land use/land cover classification and area of interest data (Table 4). The accuracy is essentially a measure of how many ground truth pixels were classified correctly.

The kappa value is a measure of the agreement between classification and reference data with the agreement due to chance removed. None of the kappa values in any of the images were very high. Landis and Koch (1977) ranked the kappa values, ranging from -1 to 1, into 3 groups: 1) those greater than 0.80 represented strong agreement between the classification and reference data; 2) those between 0.40 and 0.80 represented moderate agreement; and 3) those less than 0.40 represented poor agreement. The low kappa also was a product of classifying the imagery into just 2 classes. If there had been more classes, the kappa values probably would have been higher.

The Kappa coefficient lies typically on a scale between 0 and 1, where the latter indicates complete agreement, and is often multiplied by 100 to give a percentage measure of classification accuracy. This implies that the Kappa value of 0.8146 represents a probable 81% better accuracy than if the classification resulted from a random assignment. The result obtained in this study fits to the view of Anderson (1971) who stated the minimum level of accuracy in the identification of land use/land cover categories from remote sensor data should be at least 85 %. The classification accuracy of the study meets this requirement.

The highest user accuracy from the vegetation classes were for dense forest land followed by Farm land. The settlement showed relatively lower users accuracy (77.78%). The reason was the spectral signature of settlement was mixing largely with grass land (Table 4). Open forest was having a user accuracy of 87.50 %. In general, the overall accuracy of 86% was achieved with a Kappa coefficient of 82% (Table 4)

Table 4: Confusion matrix for landsat image of 2005

Class Name	Farmland	Grassland	Open Forest	Dense Forest	Settlement
Farmland	85.95	3.15	0.04	0.13	9.54
Grassland	4.8	84.58	6.91	0.33	4.27
Open Forest	4.3	6.73	81.93	2.84	9.5
Dense Forest	0.28	0.06	1.54	94.64	0
Settlement	4.64	4.5	6.61	0	82.74
Prod. Accu	85.29	84.62	84.85	89.47	87.50
User. Accu	87.88	78.57	87.50	89.47	77.78
Over all classification accuracy		**85.98%**			
Kappa coefficient		**82%**			

3.6.3. Change Detection Procedures

In order to detect and assess the changes of land-use/land cover as well as forest cover ecosystem over times the years 1986, 2000 and 2005 multi-temporal Landsat data were acquired. To carry out change detection, NDVI and post-classification change detection comparison methods were employed in this study.

3.6.3.1. NDVI Comparison

As indicated earlier, spectral band ratio is one of the most common mathematical operations applied to multi-spectral data. Ratio images were calculated as the divisions of digital number values in one spectral band by the corresponding pixel value in another band. Based on the reflectance pattern of vegetation, different models of vegetation indices were developed to explain the healthiness, vegetation cover and biomass condition of vegetations. Various mathematical combinations of the Landsat channel 3(Red band) and channel 4(NIR band) data were found to be sensitive indicators of the presence and condition of green vegetation. Among these, NDVI is the most common used index for forest vegetation biomass monitoring .The absolute value of NDVI for vegetation change analysis is between 0 and 1. The NDVI empirical analysis is computed using equation (1).

$$NDVI = \frac{NIR\ (band4) - R\ (band\ 3)}{NIR\ (band4) + R\ (band\ 3)} \quad \text{……………}\textit{Equation (1)}$$

Where, NIR=Image of Near-Infra Red,

R= Image of Red

As to vegetation conditions, NDVI values vary from 0 to +1. Healthy vegetation yields have high positive NDVI values because of their relatively high reflectance in NIR and low in visible wavelength. After conducting NDVI analysis, the mean and standard deviations values were summarized using ERDAS IMAGINE 9.1 software to evaluate the trends of vegetation cover change condition of the area.

3.6.3.2. Post Classification

To examine the land –use/land cover change and forest cover change detection and the rate of its changes, post classification comparison change detection method was employed. This kind of change detection method identifies where and how much change has occurred. In this study, three dates of satellite imagery was used to determine the change by generating quantitative information on spatial and temporal distribution. Four aspects of forest cover change detection characteristics such as, detecting the changes that have occurred, identifying the nature of the change, measuring the temporal and areal extent of the change, and assessing the spatial pattern of the change were investigated.

Additionally, change detection matrix had been generated to investigate the trends and patterns of land-use/land cover change detection in general and forest cover change detection in particular. The rate of forest cover change also computed using equation (2).

$$r = \frac{Q_2 - Q_1}{t} \quad \text{------------------------------} \textit{Equation (2)}$$

Where, *r= Rate of Change*
Q_2= Recent year forest cover in ha
Q_1= Initial Year forest cover in ha and
t= Interval year between Initial year and Recent year

From land-use/ cover maps of the year 1986, 2000 and 2005, three dates polygons representing the forest areas were extracted. This was done by converting the classified forest areas raster data in to vector. The various data layers to be used in the subsequent analysis extracted using these polygons and discussed in the result section.

3.6.3.3. Disturbance Risk Map Analysis

In order to examine forest cover change and generate human disturbance risk map of the study area the year 2005 forest cover map, which iwas extracted from other land-use/land cover map, was considered to be the base line for this analysis. This map was generated from the land-use/ land cover map of the year 2005 satellite image classification. Forest disturbance is understood that the forest resources can be influenced or degraded by human activities. In reality, forest resources are degraded not only by human activities but also due to other natural factors.

However, in this research human activities were taken in to consideration because the unplanned actions such as illegal logging, exploitation of forest resources for fuel wood and charcoal production as well as expansion of agricultural lands along the margin and inside the forest cover areas were the main contributing factors that caused forest disturbance.

3.6.3.4. Multi Criteria Analysis

To produce human disturbance risk map, MCE analysis was used. MCE is a concept, an approach and a method to help decision makers to describe, evaluate, sort, rank and select or reject on the basis of evaluation based on several criteria (Sharifi, 2001). GIS software (Idrisi Andes and ArcGIS 9.1) were used to facilitate this process. Hence, the primary issue of MCE is concerned with how to combine the information from several criteria to form a single index of evaluation.

The first step to run MCE is deciding, analyzing and generating proximity to forest cover area data stets or factor maps which were factors for forest disturbance. Accessibility to forest resource was used as how easily the local people can go to or penetrating the forest areas to extract different types of forest products for the purpose of household consumption and income generation as well as expansion of agricultural lands along the borders of the forest areas. The selected datasets were town proximity, road proximity, the slope, elevation and river proximity. The masking layers for analysis were done based on the forest cover map of the year 2005.

4. Results

4.1 Land-use/land cover map

Land use/land cover unit of the study area were categorized in to five types; these are: Dense forest, open forest, grassland, farmland and settlement. The forest in the study area has been divided in to dense forest and open forest based on variation in tone and NDVI values, and field verification. The intension was to separately identify the natural dense undisturbed forest with disturbed by human forest. The three dates of land use/land cover classification map of the study area is presented in the figure 6, 7 and 8.

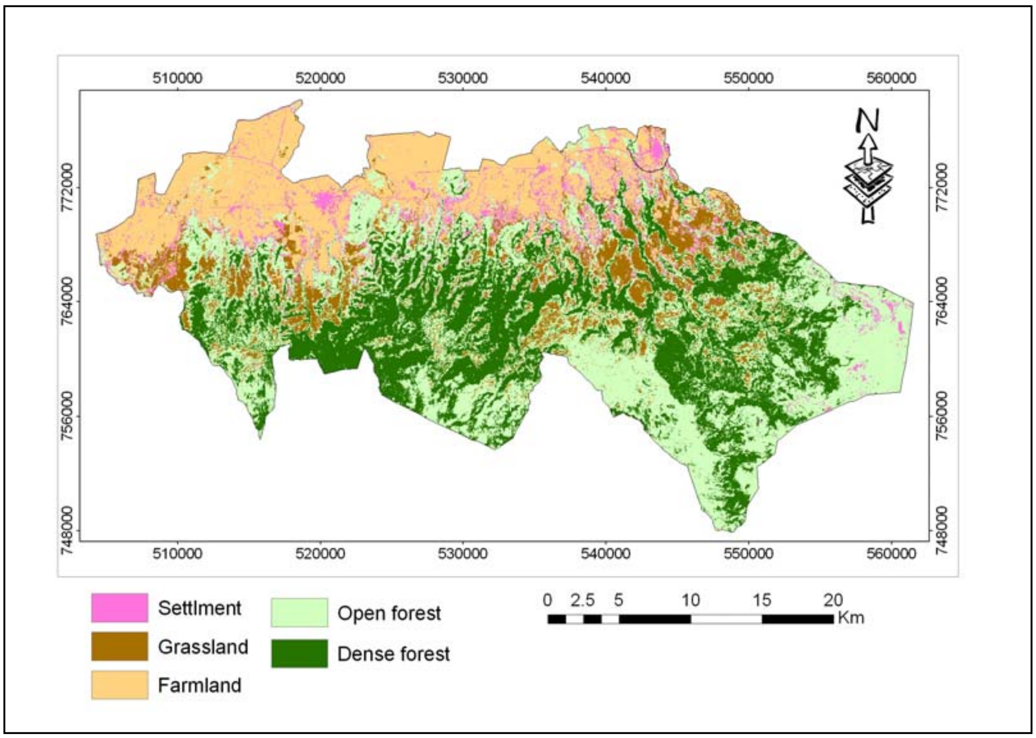

Figure 6: land-use/ land-cover map of 1986

From the 1986 land use and land cover map interpretation, the areal coverage of open forest was accounted for 37% from the total study area. The dense forest land and grass lands were occupied about 28% and 19%, respectively.

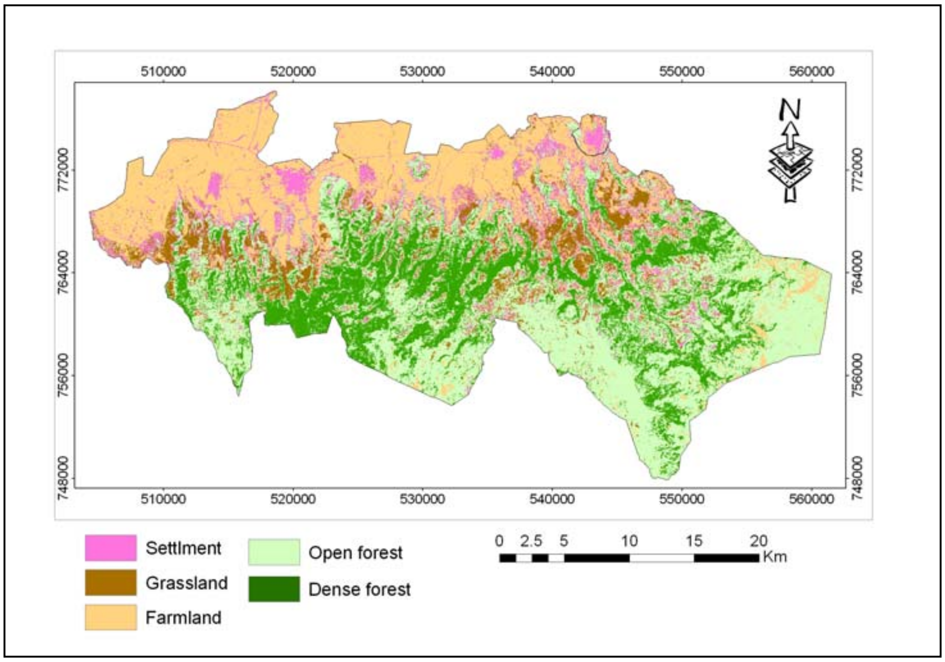

Figure 7: land-use /land-cover map of 2000

From the total land coverage, farmland were accounted for about 22,314ha (26%) in the year 2000. Dense forest and open forest take the share of 18,293 ha (21%) and 32,178 ha (36%) respectively. The remaining area was covered with settlement and grassland 14, 646 ha (17%).

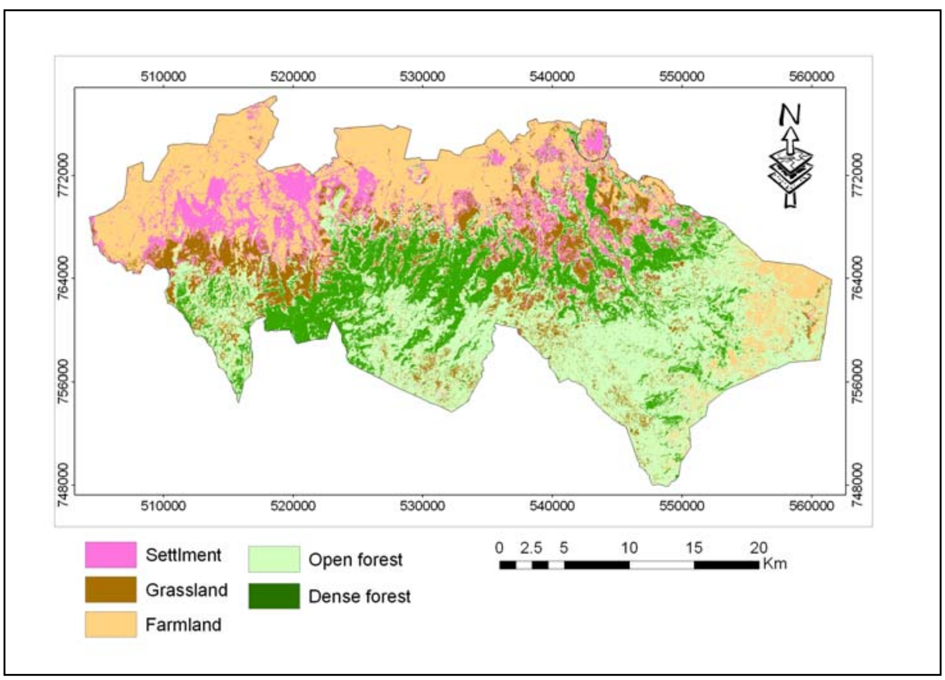

Figure 8: land-use /land-cover map of 2005

In 2005 the open forest areal coverage units was about 31564.9ha or 36.09% of the total area and dense forest accounts about 16%. Land category under grassland, farmland and settlement accounted around 11%, 27 and 10 %, respectively.

The results of land-use/ land cover map (Figure 9 & Table 7) show that the area of dense forest and open forest declined in both periods. The rate was greater in the open forest than dense forest. Grassland class shows a sharp decrease in the first period and an increase in the second period due to shift of both forest types to grassland. Farmland and settlement show general trend of increase in both periods. This is just the general impression of land cover dynamics based on comparison of individual land cover maps.

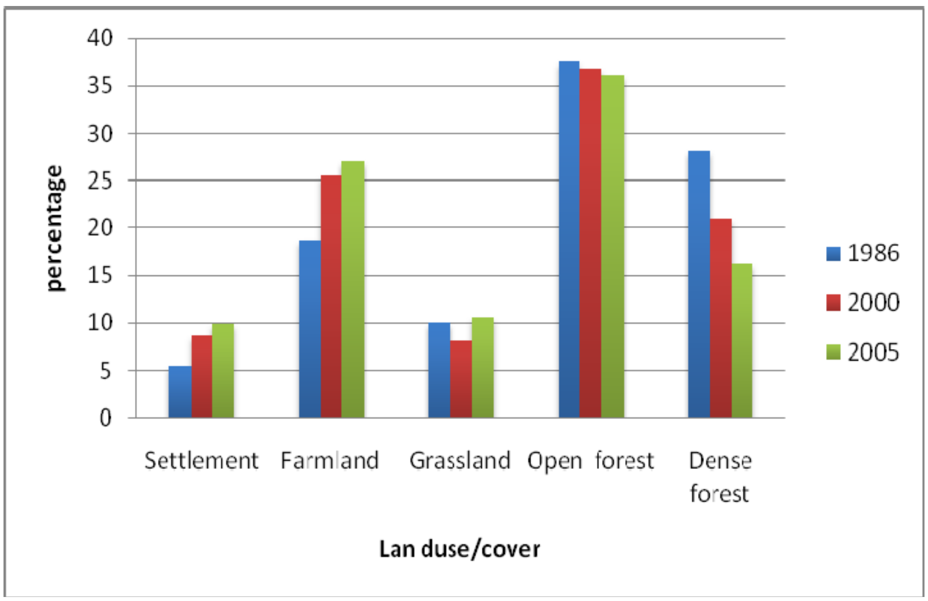

Figure 9: Summery of land use/Land cover extents by percent at different years

Table 5: Summary statistics of land-use/land cover units; 1986, 2000 and 2005

Class Name	Year					
	1986		2000		2005	
	area/ha	%	area/ha	%	area/ha	%
Settlement	4850.84	5.55	7560.42	8.65	8674.02	9.92
Farmland	16448.96	18.81	22313.97	25.52	23674.50	27.07
Grassland	8743.71	10.00	7085.99	8.10	9299.34	10.63
Open forest	32780.38	37.49	32178.26	36.80	31564.89	36.09
Dense forest	24608.25	28.15	18293.49	20.92	14244.21	16.29
Total	**87432.13**	**100.00**	**87432.13**	**100.00**	**87432.13**	**100.00**

4.2 Detection of land cover changes by different methods

4.2.1. Change between 1986 and 2000

The major cover changes observed during this period had been the reduction in the area of both forest categories, dense and open forest by 6,315 and 602 ha respectively, and grasslands by 1, 658 ha and a considerable increase in the overall areas of farmland land and settlements by 5, 865 and 2,710 ha respectively. As indicated in Table 6, the reduced forest and grassland had been changed to farmland and Settlements. Though the overall change on grasslands had been negative, there had also been forest conversion to grasslands (Table 6) in this period. Therefore, the removal of forest land to expand cultivation and cutting of trees for different purposed had been the most important scenario worthy of considering in this particular period.

In this period, expansion of farmlands and intense deforestation were directly linked to population growth within that period. Rise in human population in this period had in turn been the result to get additional land for cultivation and settlement through forest clearance. On the other hand, the forest had been the source of wood for construction and other domestic uses like fuel.

Table 6: Land-use /land cover change matrix between 1986 and 2000

	Area (ha)	Initial state (1986)					
		Settlement	Grassland	Farmland	Open forest	Dense forest	Class Total
Finial state (2000)	Settlement	1477	1195	1738	2899	252	7560
	Grassland	362	3942	371	2348	62	7086
	Farmland	2311	2124	14136	3474	268	22314
	Open forest	680	1469	204	21991	7834	32178
	Dense forest	20	13	0	2068	16192	18293
	Class Total	4851	8744	16449	32780	24608	0
	Class Changes	3374	4801	2313	10789	8417	0
	Image Difference	2710	-1658	5865	-602	-6315	0

*Note: The numbers in the class total **row** indicate initial state where as the class total **column** indicates the final state. The diagonals indicate areas remained unchanged.*

4.2.2. Change between 2000 and 2005

This period shows revers of the trend of the previous period. The area covered by grassland was increased while the area covered by dense forest and open forest cover types reduced. The major change observed in this period were decrease in the overall area of open forest from 32, 178 ha in 2000 to 31,505 ha (by 674 ha) in 2005 and an increase in the areas of the grassland from 7, 086 ha in 2000 to 9,297 (by 2, 211 ha) and, increase farm lands and settlements (Table 7). During this period, in most parts of the highlands of Ethiopia, forest lands are continuously cleared to expand crop cultivation.

Table 7: Land- use/land cover change matrix between 2000 and 2005

	Area/ha	**Initial state (2000)**					
		Open forest	Farmland	Grassland	Settlement	Dense forest	Class Total
Final state (2005)	Open Forest	21408	1171	1423	1399	6062	31505
	Farmland	3374	16935	796	1842	680	23652
	Grassland	3328	817	3857	1177	111	9297
	Settlement	1317	3262	966	3052	69	8668
	Dense forest	2691	34	37	76	11353	142
	Class Total	32178	22314	7086	7560	18293	0
	Class Changes	1077	5379	3229	4508	6940	0
	Image Difference	-674	1338	2211	1108	-4093	0

4.2.3. Change between 1986 and 2005

While considering the whole range of time under consideration, the reduction in the area covered by both forest type (closed forest and open forest) were remarkable, despite the grassland expansion observed in the second time period due to high shift of open forest land to grassland. Image differencing of the two extreme times, 1986 and 2005 indicated that dense forest cover reduced from 24, 608 to 14,191 ha (12, 352 ha) and open forest cover reduced from 32,780 to 31, 505 ha (1276 ha). This extent of land was transformed in to farmland as a function of population growth; Part of the original farmland was also transformed in to grassland owing to deforestation during the second time period (Table 8).

Table 8: Land-use/land cover change matrix between 1986 and 2005

	Area/ha	Initial state (1986)					
		Open forest	Farmland	Grassland	Settlement	Dense forest	Class Total
Final state (20005)	Open Forest	18172	113	1845	385	10950	31505
	Farmland	5653	13049	1714	2342	869	23652
	Grassland	4363	352	3778	438	360	9297
	Settlement	2692	2853	1329	1642	150	8668
	Dense forest	1831	8	67	30	12255	14191
	Class Total	32780	16449	8744	4851	24608	0
	Class Changes	14609	3400	4966	3209	12353	0
	Image Difference	-1276	7203	553	3817	-10408	0

Note: The numbers in the class total ***row*** *indicate initial state where as the class total* ***column*** *indicates the final state. The diagonals indicate areas remained unchanged.*

4.2. 4. Detected changes by post classification

Land cover change analysis by post classification method revealed nine types of changes in the two periods (Table 9). However, not all of the changes were taken into consideration given the focus on forest cover land for this study. Changes from farmland to settlement and vice versa were not taken into consideration since they were not important given the focus on forest cover land for this study. Nine changes, which were analysed, were regrouped in to two land-cover change categories namely, deforestation and natural forest regrowth (Table 9 and 10).

Table 9: Land covers changes detected by post-classification methods

No	**Land cover change 1986 - 2000**	**Land cover change 1986 -2000**	**Regrouping**
1	From dens forest to open forest	From dens forest to open forest	Deforestation
2	From dense forest to grass land	From dense forest to grass land	
3	From dense forest to farmland and settlement	From dense forest to farmland and settlement	
4	From open forest to grass land	From open forest to grass land	
5	From open forest to farmland and settlement	From open forest to farmland and settlement	
6	From open forest to dens forest	From open forest to dens forest	Natural forest regrowth
7	From grass land to open forest	From grass land to open forest	
8	From farmland to Settlement	From farmland to Settlement	Not considered
9	From Settlement to farm land	From Settlement to farm land	

Table 10: Changes detected by post-classification method

Changes	Period 1986_2000 (ha)	Period 2000_2005 (ha)
Deforestation	11,308	9,390
Natural forest regrowth	3,570	4,261
Total	14,878	13,651

4.2.2. Changes detected by NDVI differencing

NDVI image differencing cannot provide detailed change information. It can only give the information of increase or decrease in NDVI value. The negative threshold indicates loss in NDVI and positive threshold indicates area of increased NDVI. As indicated in Table 11 there was change of land cover in general in the three date of image. To this effect the standard value decreased in certain amount, showing that there were changes or decrease of green vegetation.

Table 11: Statistics for NDVI analysis

Type	Year		
	1986	2000	2005
Minimum	-0.14783	-0.33333	-0.62963
Maximum	0.67832	0.73134	0.53846
Mean	0.119	0.098	-0.029
Median	-0.0026048	-0.0006219	-0.0045183
Mode	-0.0026048	-0.0006219	-0.0045183
Standard Deviation	0.164	0.123	0.103

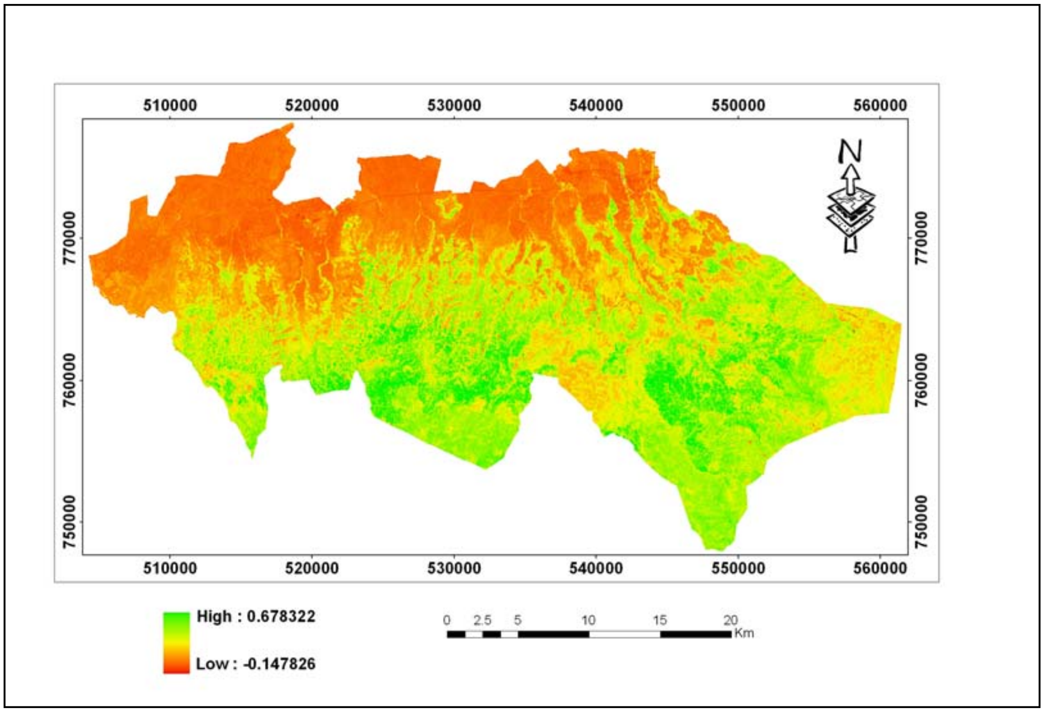

Figure 10: NDVI Map of 1986

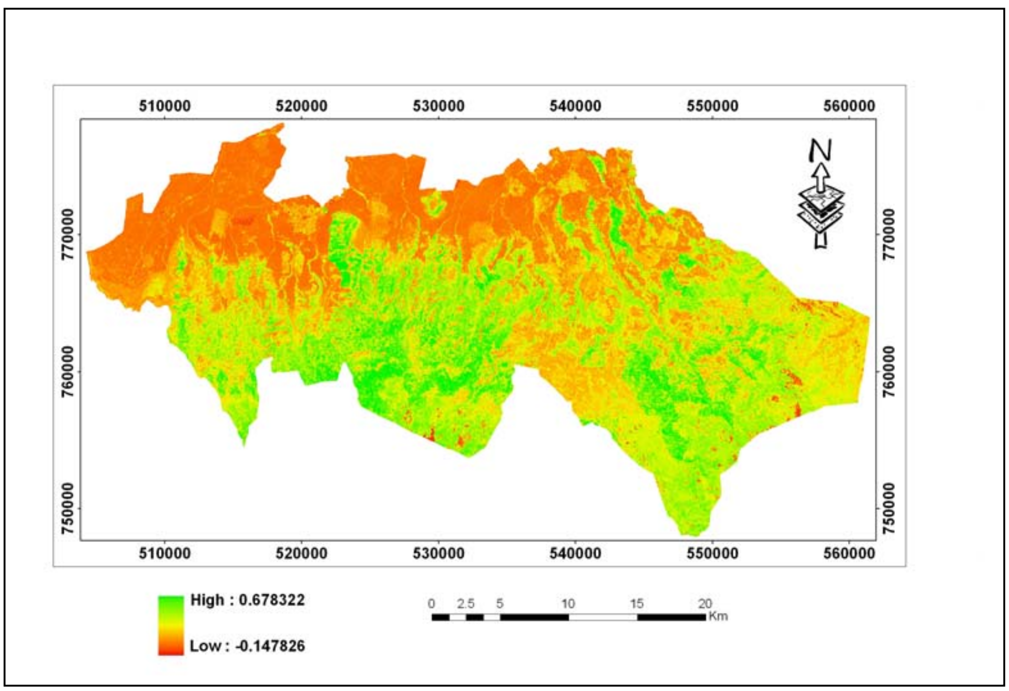

Figure 11: NDVI Map of 2000

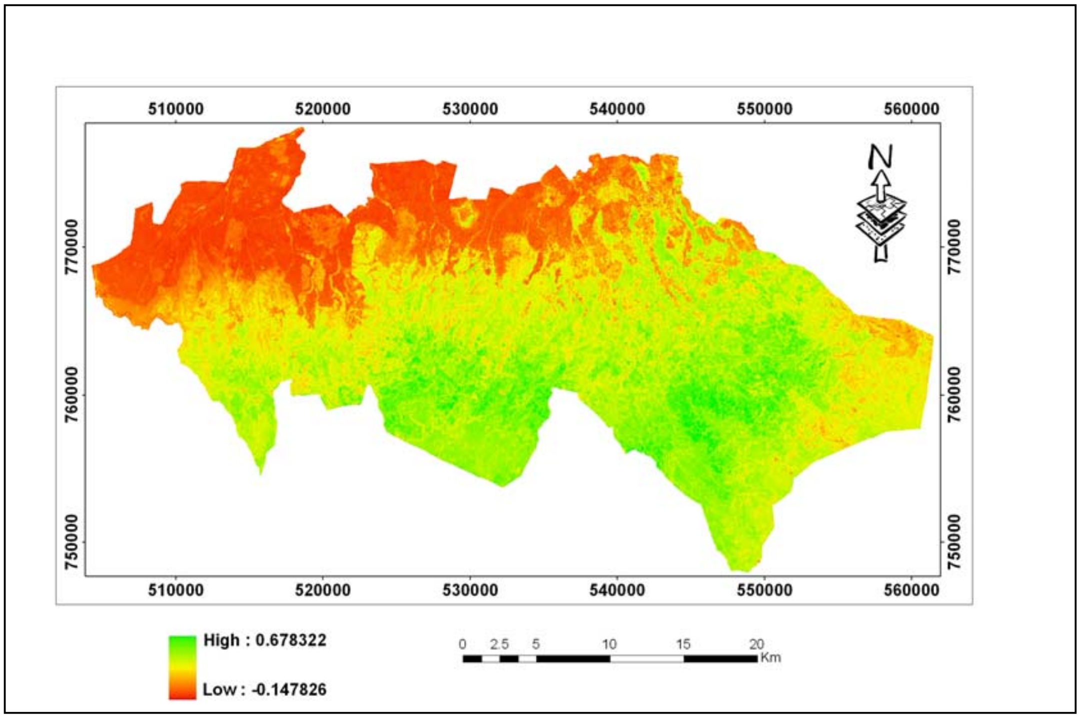

Figure 12: NDVI Map of 2005

4.3. Forest cover analysis

In order to determine areas of the forest to be subjected to different change extract the area covered with both forest type (dense forest and open forest) therefore requires the extraction of polygons representing the forest areas. On the other hand, reducing the data extent would speed up the subsequent process (for risk map). Accordingly, polygons representing the forest areas have been extracted. This was done by converting the classified forest areas raster data in to vector. The various data layers to be used in the subsequent analysis was therefore be extracted using these polygons. Figures (13, 14 and 15) show extracted forest in different time period.

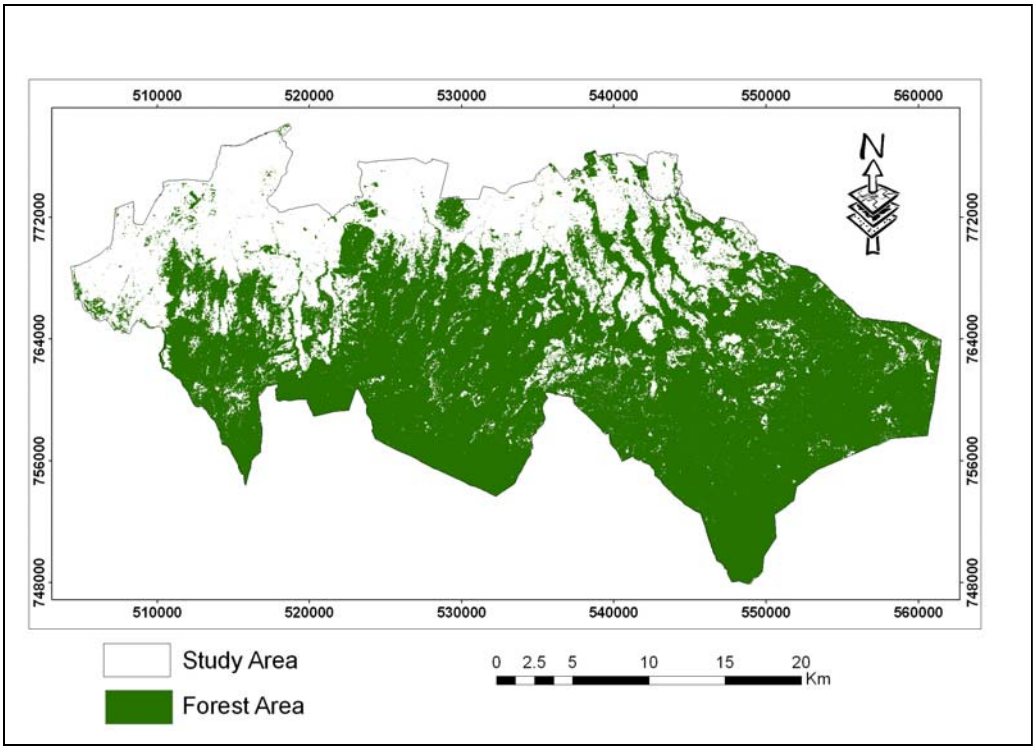

Figure 13: Forest Cover map of 1986

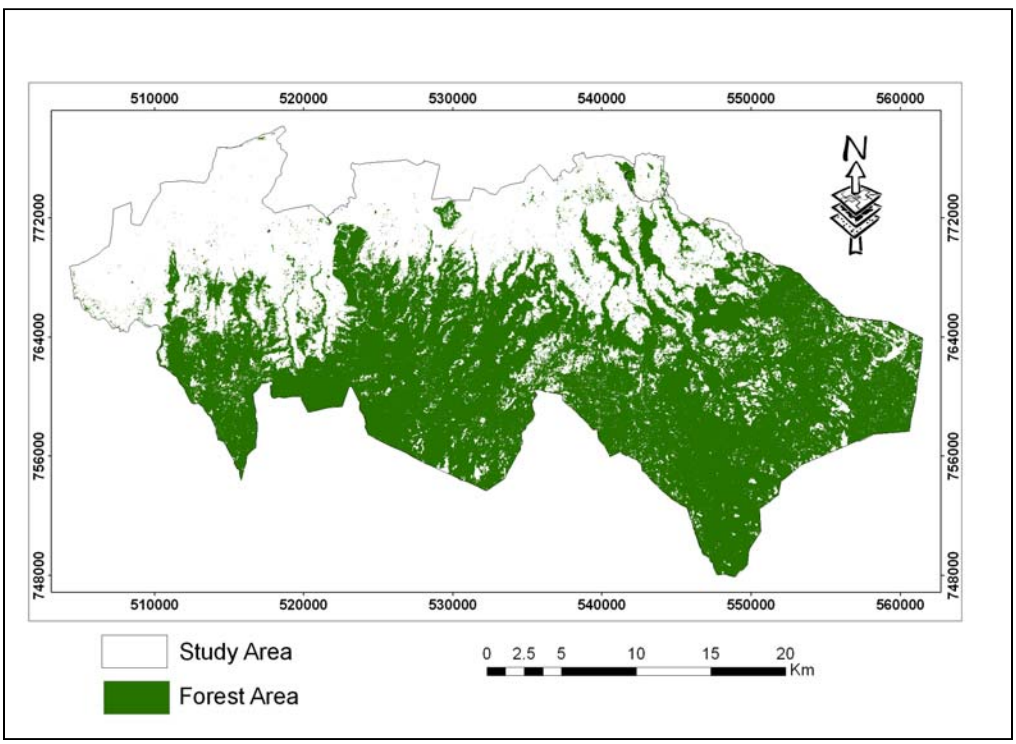

Figure 14: Forest Cover map of 2000

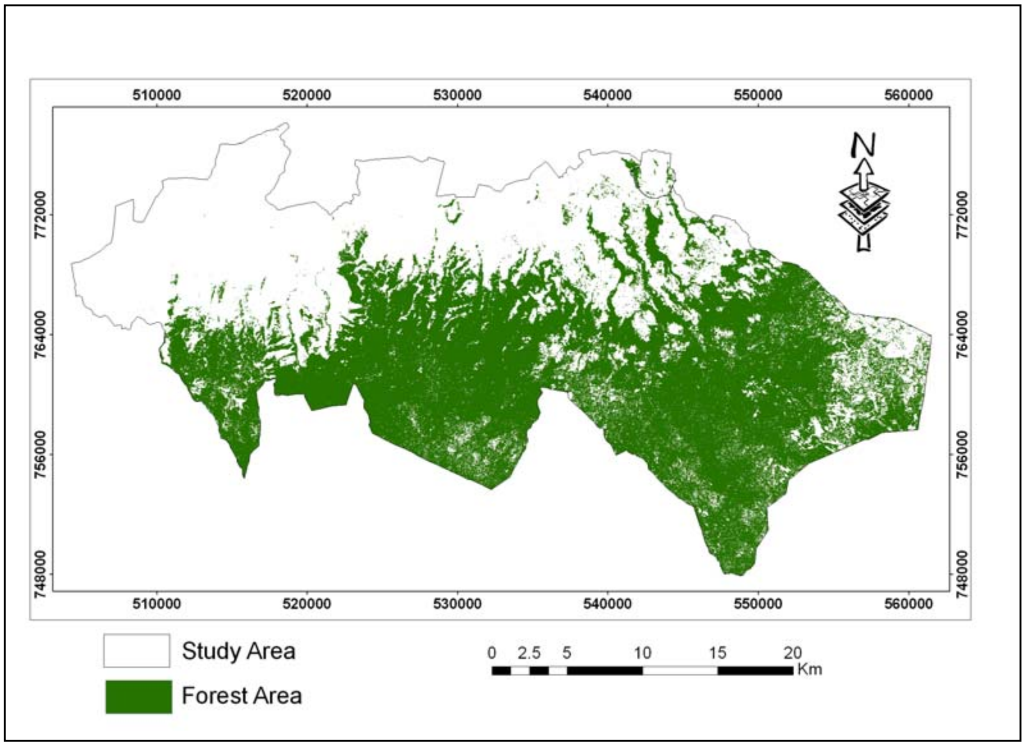

Figure 15: Forest Cover map of 2005

4.4. Distribution and rate of forest cover change

The distribution of forest cover change has been done to makes it possible to visualize and analyze the spatial pattern of change, which would help to identify the various factors assumed to cause forest loss and determine their relative importance for the successive disturbance risk analysis and management strategy formulation. Second is that it highlights the seriousness of the forest cover change dynamics which strengthens the need for protected forest cover establishment by using remote sensing and GIS techniques with the integration of field survey. In this study, three Landsat satellite images were used to visualize the distribution and rate of forest cover change with in time series. During the analysis stage, digital image interpretation of forest cover area for each year was performed and total area of the forest cover and its percentage from each date were computed and summarized in the following tales.

Table 12: Temporal distribution of Adaba-Dodola forest covers

Year	Forest area (ha)	Forest cover (%)
1986	57,389	65.64
2000	50,472	57.72
2005	45,809	52.38

About 57,389 ha of the area were covered with forest resource in the year 1986 and the cover was accounted for 50,472 ha and 36,683ha in the year 2000 and 2005 respectively (Table 12). The percentage share (relative to the total of study area) for each year forest cover value and with its trend (Figure 16) indicate that in the year 1986, 65.65 % of the study area was covered with forest resources, while it was only 57.72 % in 2000 and this was farther declined to 52.38 % in the year 2005.

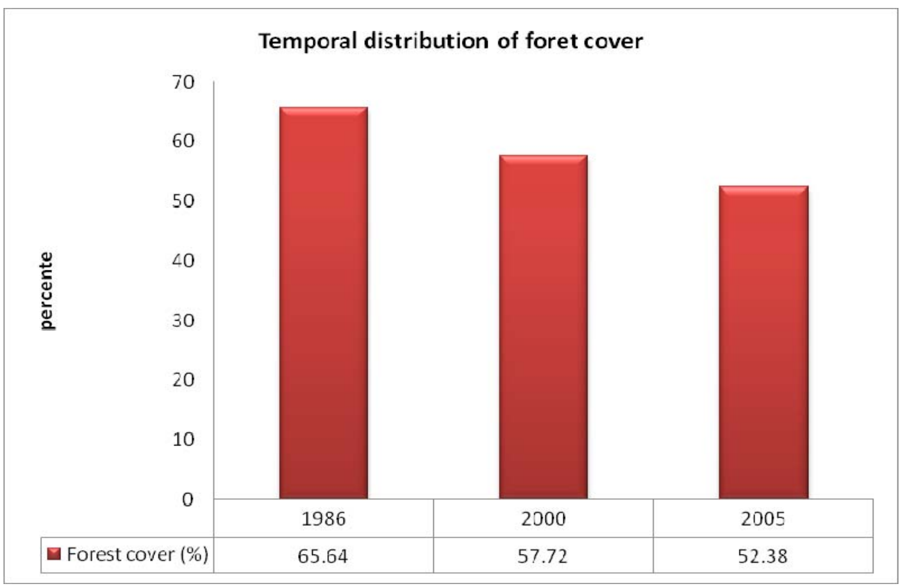

Figure 16: Temporal distribution of forest cover

Table 13: Rates of forest cover change

Interval (Year)	Rate of forest loss	
	hectare per year	% per year
1986-2000	609.47	0.70
2000-2005	333.06	0.38
1986-2005	494.07	0.57

The calculated result (Table 13) shows that the average rate of forest covers loss from year 1986 to 2000 was 609.47 ha per year and from year 2000 to 2005 it was 333.06 ha per year. Besides, considering the annual rate of forest cover loss from the entire period (1986 to 2005) the result is 494.07 ha per year.

4.5. Forest disturbance risk mapping

One of the objectives of this study was to produce human disturbance risk map of forest cover area, in order to classify the forest area in to various conservation zone. It was vital to determine which part of the forest was at risk of human disturbance. To arrive at this disturbance risk map, various factors that are likely to cause forest disturbance should be examined. Then an indicator that high deforestation was related with road network and major settlement centres or towns (Dereje, 2007).

4.5.1 Forest layer analysis

A masking layer serves to limit the alternatives under consideration. Masking layer identifies those cells within the analysis extent that was considered when running analysis tool. In this case, after converting the vector forest cover shape in to raster file form and standardizing it, the year 2005 forest cover map was used as analysis masking layer. Areas excluded from consideration are outside the forest cover areas and those opened for consideration are inside the forest area. Figure 17 show the forest cover area of 2005.

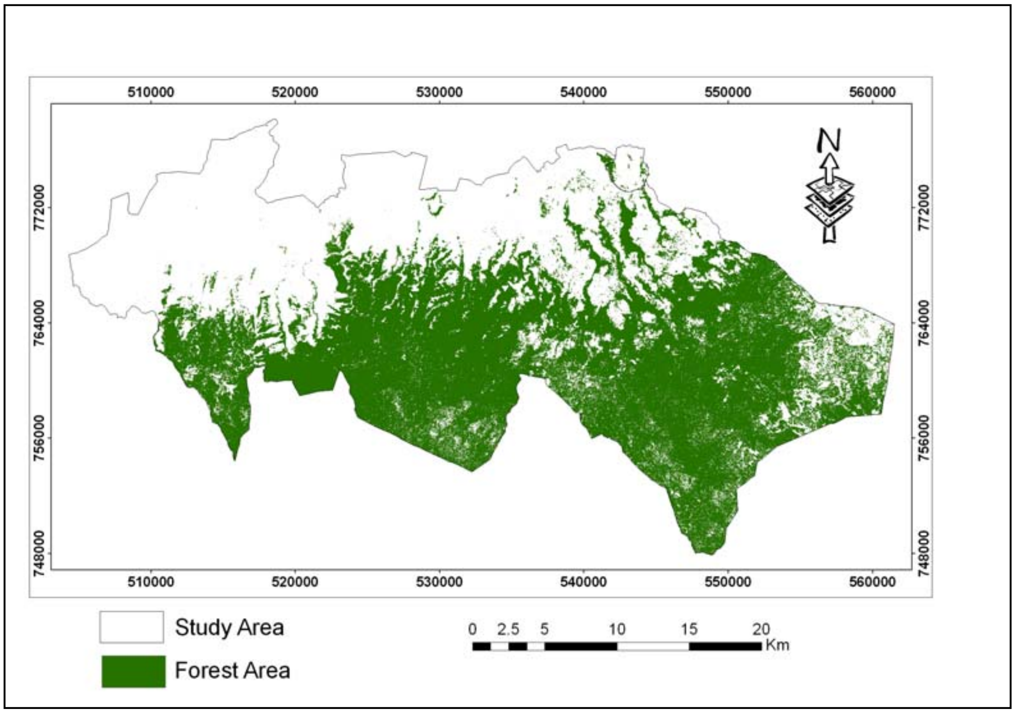

Figure 17: Masked forest cover of 2005

4.5.1. Setting criteria dataset preparation

To produce the risk of forest disturbance through the analysis of spatial forest cover change pattern in the current study, five factors were identified to be evaluated. These are: altitude, proximity to river, proximity to the major road, slope, and proximity to town. All these factors were rasterized and reclassified to evaluate the level of disturbance in the area. Finally MCE using ArcGIS 9.2 and IDRISI Andes software were applied to develop disturbance risk map which was helpful to develop conservation of forest land. Below each reclassified maps of considered factors were presented.

4.5.1.1. Altitude

Altitude is one of the major environmental variables that determine the convenience of a certain area for various uses including human settlement. Agricultural practices are highly governed by altitude. In the current study area, clear deforestation had a strong correlation with altitude.

Within the context of the current remnant forest under consideration, destruction of the forest ecosystem for the purpose of crop cultivation and settlement medium altitudes part of the study area was more important. Hence, medium altitude was convenient for crop production, and settlements were more prone to disturbance than the higher altitude within the current context of the study area. Therefore, higher disturbance value was assigned to the medium altitudes, followed by the higher ones.

After settling and standardizing altitude dataset, it was reclassified using forest cover raster dataset as analysis masking layer and prepared as input factor map for MCE. From the output reclassified altitude dataset map (Figure 18), the forest cover areas shaded with red colour were more prone to disturbance than forest cover areas shaded with green colours.

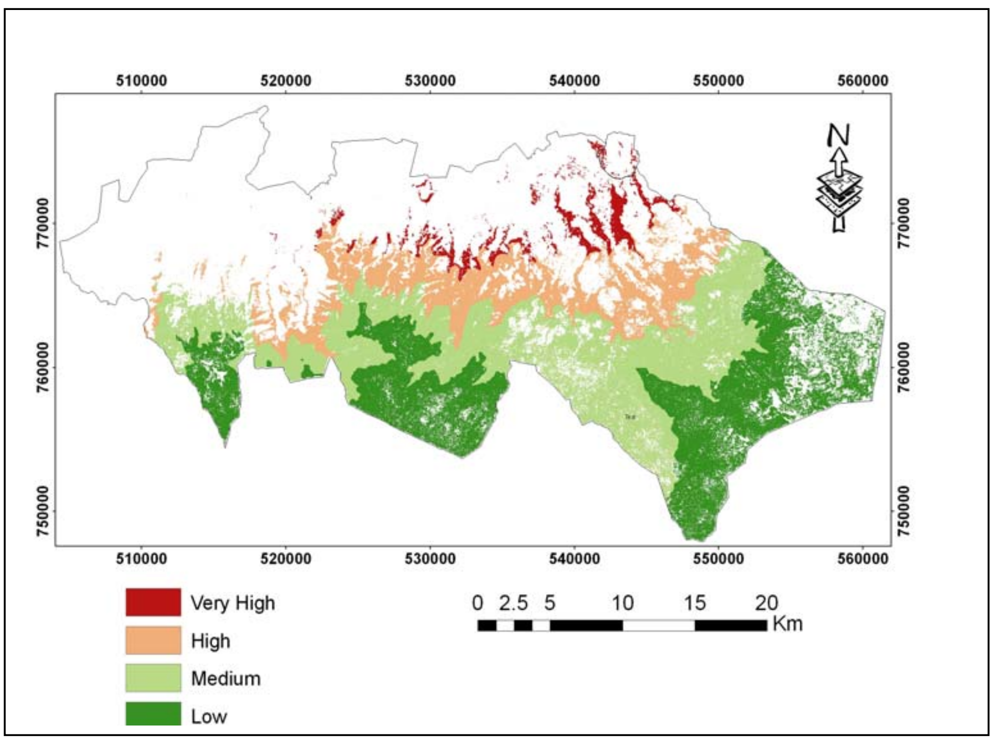

Figure 18: Altitude Factor Dataset

4.5.1.2. Proximity to River

It was essential to characterize the forest cover condition of the area and its future disturbance in relation to river proximity. Then, river distance raster dataset was derived. The river raster data layer was reclassified to analyze and determine the degree of forest disturbance in relation with river proximity. From the reclassified river proximity (Figure 19) dataset forest cover areas having low distance value from river location have less susceptible to disturbance than those located to high distance. Because, areas near the major rivers were steep and rugged and hence less workable and therefore less preferred by people. On the other hand, farmers have pointed out that areas in the near vicinity of the major rivers in the study area are more prone to both human and livestock diseases and therefore less convenient for settlement. Therefore areas near the major rivers were less prone to human disturbance and gave less rank.

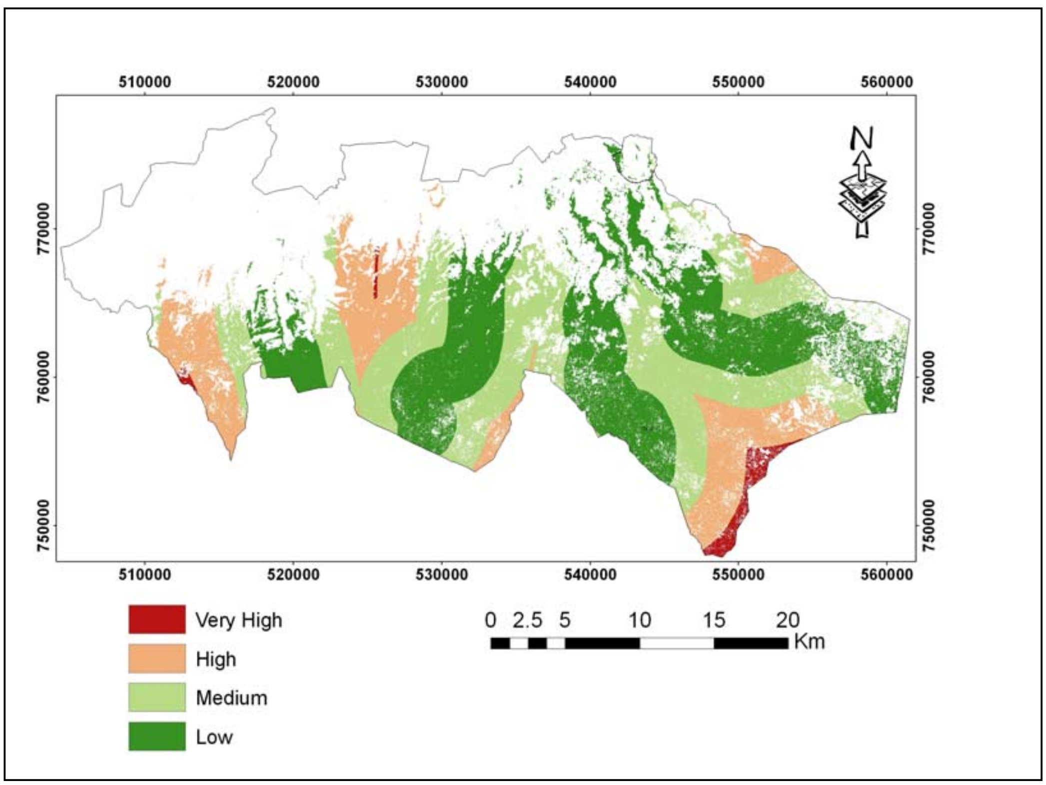

Figure 19: River Proximity Factor Dataset

4.5.1.3. Proximity to Road

Proximity to roads was another factor considered in the disturbance risk map. Apart from the impact they have during their construction, roads provided access for human to the natural forest. However, their influence on disturbance depends on how intensively they were being used by human. In the study area, the major road types were identified. As it was more intensively used, asphalt roads contribute larger influence to forest disturbance by human.

The road raster data layer was reclassified to analyze and determine the disturbance of forest cover in relation with road proximity. From the reclassified asphalt road proximity dataset (Figure 20), forest cover areas having low distance value from road network location was highly contribute for forest disturbance than those located far away from road networks.

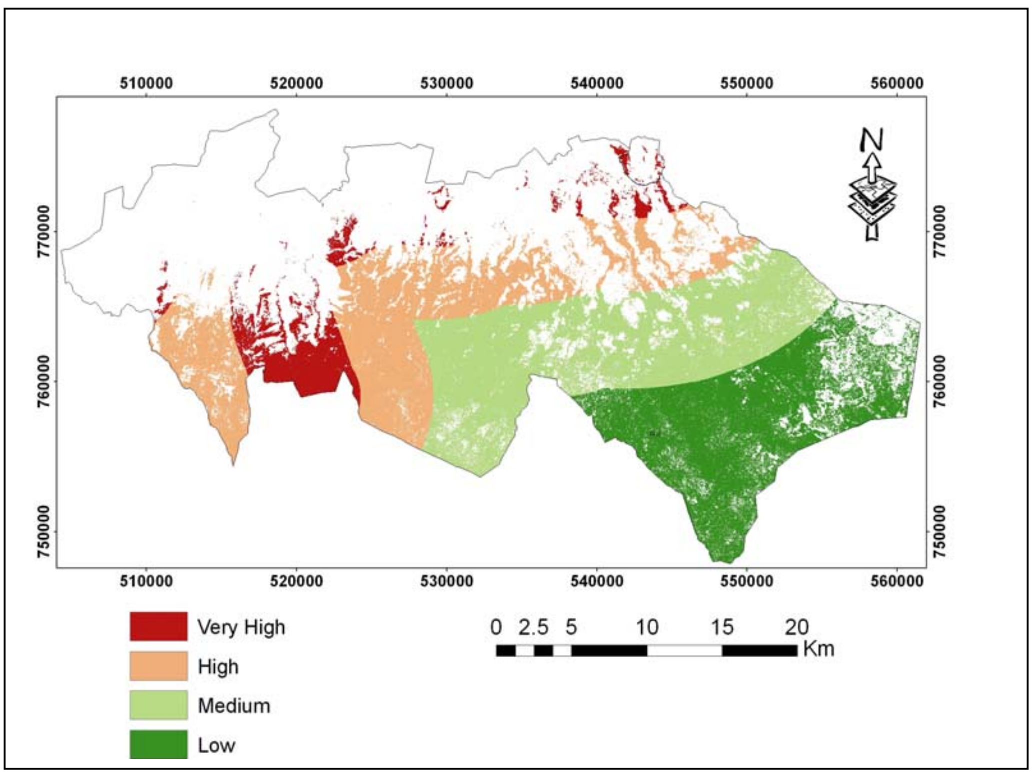

Figure 20: Road Proximity Factor Dataset

4.5.1.4. Slope

The slope nature of the area was considered to be one of the factors for forest disturbance. Generally, forest disturbance was decreases away from relatively gentle slope gradient to steep slope. Gentler slopes were preferred to steep ones by human for various agricultural uses because steep slopes were prone to erosion as compared to the gentler slopes. Based on this fact, steeper slopes were given lower values in terms of their influence on forest disturbance.

The out put slope dataset of high values shaded with green colour on the map represents steep slope areas and red colour shading areas depicts those areas having relatively gentle gradient. From the output reclassified slope dataset map (Figure 21), the forest cover areas shaded with red colour were more prone to forest disturbance than areas shaded with green colour.

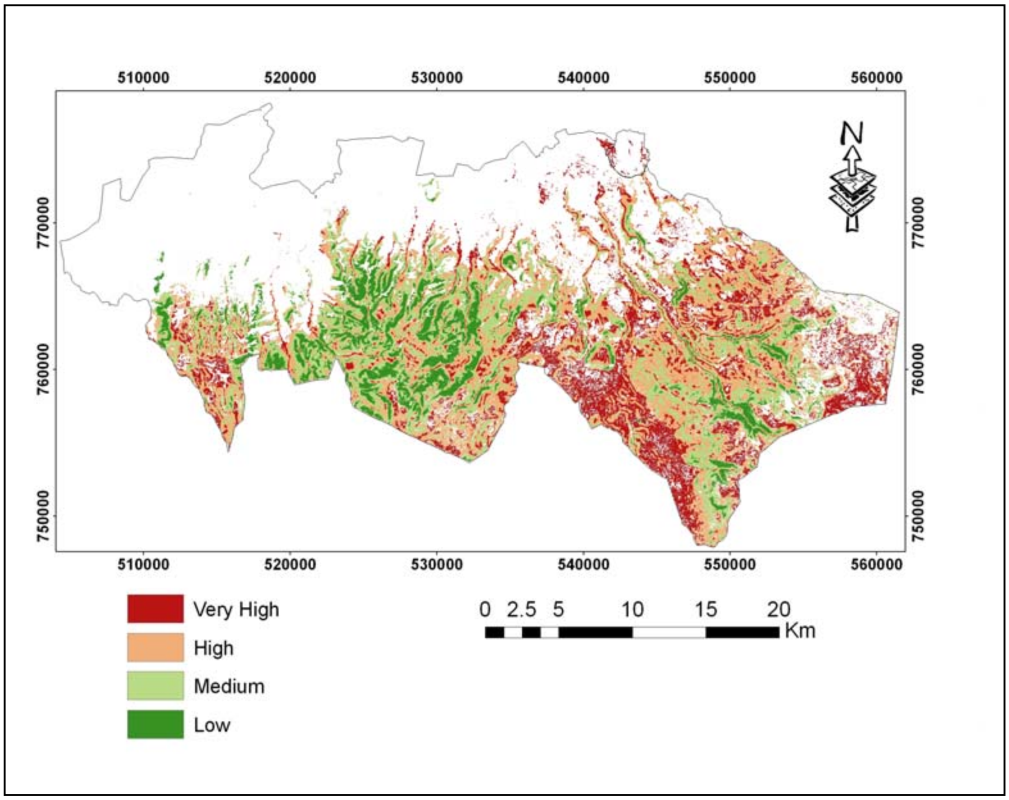

Figure 21: Slope Factor Dataset

4.5.1.5. Proximity to Town

Similar to the above factor maps, proximity to town dataset also rasterized and standardized in order to reclassify and to distinguish the future forest disturbance problem in the study area. Around the major settlement centres like towns, crop lands were expanding at the expense of natural forest. For this reason, proximity to towns has been considered as one of the major factor in the forest disturbance analysis. The reclassified town proximity raster map with respect to forest cover was presented in (Figure 22). The forest cover land shaded with red colour is highly prone to disturbance than the forest cover found far away from town location.

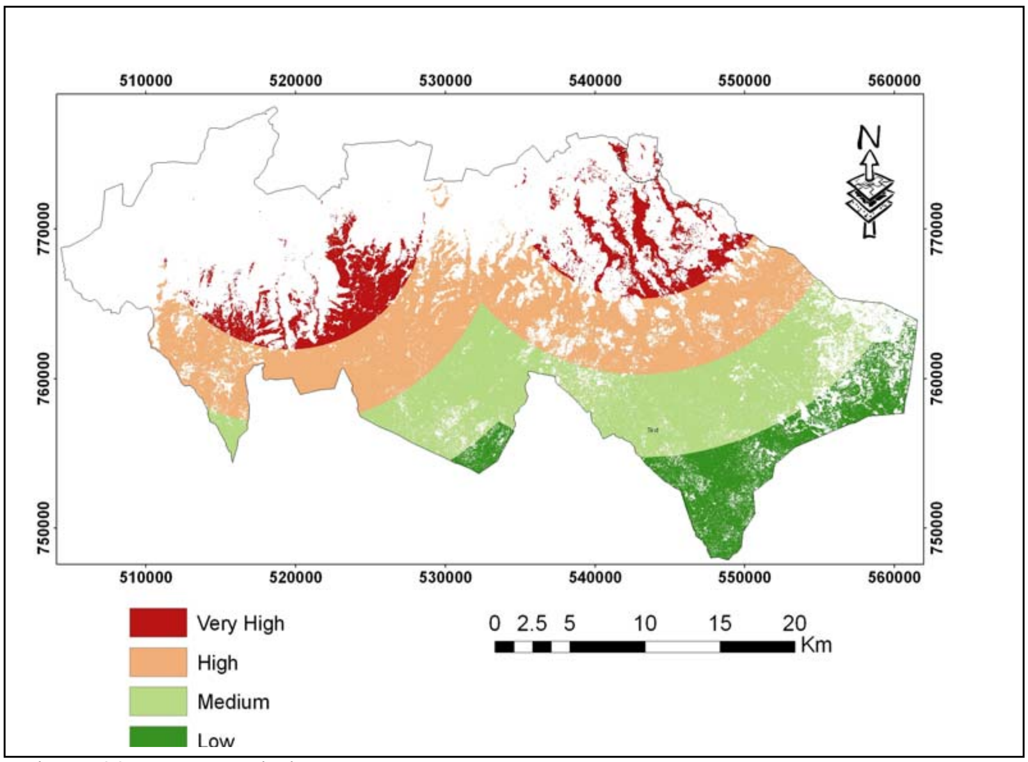

Figure 22: Town Proximity Factor Dataset

4.5.1 Weighting overlay analysis

Assigning weights for each datasets and combining together based on their weight is the subsequent procedure for conducting MCE in the present study. Weighting is used to express the relative importance of each factor relative to other factor. The larger the weight the more important is the factor in overall usefulness. The various comparisons indicated that highest weight was for the slope dataset followed by the proximity to town, altitude, road proximity and proximity to river value dataset (Table 14).

Table 14: Overlay criteria

No	Dataset	Range	Rank	Scale	Weight
1	Altitude (m.a.s.l.)	2400-2700	Very high	4	0.1472
		2700-3000	High	3	
		3000-3300	Medium	2	
		>3300	Low	1	
2	Proximity to river (km)	0-1.9	Low	1	0.0814
		1.9- 4	Medium	2	
		4-6.6	High	3	
		>6.6	Very high	4	
3	Proximity to road (km)	>14.6	Low	1	0.1162
		8.2-14.6	Medium	2	
		3.4-8.2	High	3	
		0-3.4	Very high	4	
4	Slope (degree)	>18	Low	1	0.3427
		11-18	Medium	2	
		5-11	High	3	
		0-5	Very high	4	
5	Proximity to town	>19.6	Low	1	0.3126
		14-19.6	Medium	2	
		8.9-14	High	3	
		0-8.9	Very high	4	

In order to produce the forest disturbance risk map of the area, the above raster layers along with their weighted values was developed in to equation (3) and then fed in to the spatial analyst raster calculator of the ArcGIS 9.2 software.

Disturbance Risk = *Altitude** 0.1472+*Distance from river** 0.0814+ *Proximity to Road** 0.1162 + *Slope** 0.3427+ *Proximity to Towns* 0.3126 ……………… (3)*

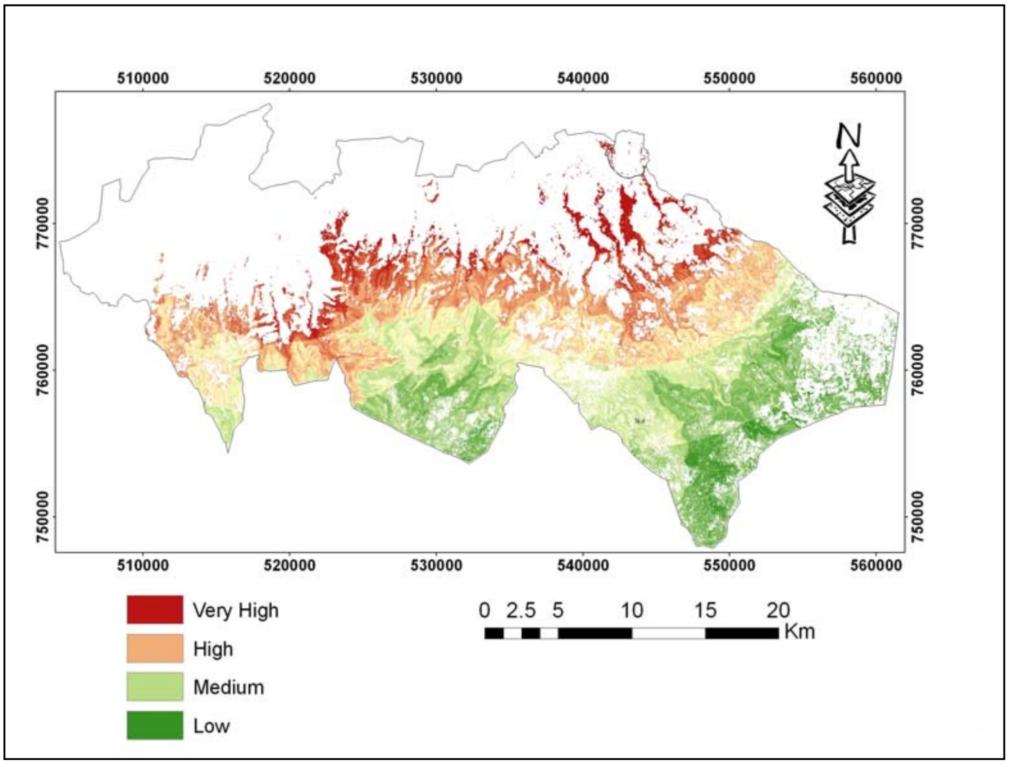

Figure 23: Forest disturbance map

According to the equation (3) (Figure 23) forest disturbance risk map was obtained. It shows the proneness of the forest to disturbance. The green areas indicate parts of the forest that are less prone to disturbance while the red areas indicate parts that are most prone and therefore at high risk of disturbance.

Table 15: Areal coverage of forest disturbance risk

Disturbance level	Area ha	Percentage
Low	8,978	20
Moderate	22,068	48
High	14,768	32
Total	**45,809**	**100**

Based on the total forest cover area of the year 2005, about 8,978 ha of forest cover was categorized under low risk of disturbance. On the other hand, 22,068 ha and 14,768 ha forest cover lands are considered to be moderately and highly disturbance to forest degradation respectively.

5. Discussion

5.1. The causes for forest cover change

Human beings have attempted to domesticate tropical ecosystems and landscapes in order to channel a large number of primary productions toward their own consumption. This was started from subtle way by enriching forest close to living garden with useful plant species or clearing small patches of forest with hand made tools and fire. But as human population and their technological capabilities increased and market for agricultural products developed, the impact of agriculture on tropical ecosystems and landscapes became more dramatic (Schroth etal. , 2004). The forest cover change and its driven factors studied in Adaba -Dodola forest priority area also reaffirm this phenomenon.

In the study area change of forest cover was triggered by various factors, of which man are responsible. For the purpose of clarity in the present study, the factors have been grouped into population pressure and its resultant effects such as the prevalence of various types of agricultural activities, fire wood and charcoal production, cutting trees to satisfy the demand of constructional materials, settlement expansion and income generation. Each of the factors has been discussed in the following sub-sections.

5.1.1. Population pressure

The total population of both districts Adaba and Dodola was increased from 284,284 in the year 1986 to 333, 466 in the year 2005. Population growth is the major factor, which affected forest resources in the study area. The forces behind the forest cover change problems were partly population pressure as well as increased demand of various types of forest products such as fuel wood, building poles and making furniture as well as to obtain adequate agricultural lands. Based on the interviewing local people and field observation data, due to the alarming increase for the demand of forest products, both the natural as well as plantation forests which were grown in the study area were seriously depleted, but the rate of forest cover change was lower in the year 2005-2000 than the rate in the year 2000-1986. Because, from the year 2000 there was establishment of integrated forest management project in the area in local language WAJIB (Waldaa Jiraatoota Bosona) approach which mean forest dweller association.

5.1.2. Agriculture land expansion

The agro-ecological conditions of the study area and the surrounding districts are convenient for agriculture. It has also been noted that agriculture is the major livelihood of the area. Due to this, crop production and livestock rearing is the basic elements of the subsistence production system and the products obtained used as supplementary food sources for peasants who are inhabited in the area. Most of the farmers in the area and surroundings rear livestock and want to maintain larger numbers. According to the information gathered from local people, the larger number of cattle population in a given family is both a source of wealth and status.

There was an increase of farmland from 16448.96 ha in the year 1986 to 23674.50 ha in the year 2005. This indicates that an increased farmlands at the expense of other land-use/land cover spectrally open forest and dense forestland. For instance between the year 1986 and the year 2005, about 6,522 ha of both forest types is changed into agricultural land. Therefore, the presence of peasant association with their various types of agricultural activities (both crop production and livestock rearing) inside and along the margin of the study area expansion of farmland was considered to be the major factor for forest cover change.

5.1.3. Fire wood and charcoal production

In the rural areas, fire wood (collected from the near by forest areas) and cow dung are the two most important sources of energy. According to the information from local people, fire wood was commercialized as its demand has increased particularly in those areas which are devoid of trees and in the urban place of the study. Besides, the area is the core supplier of charcoal and fire wood to nearby towns. Some amount of charcoal is even transported all the way to the near by urban areas.

For instance, Aklilu (2002), indicate that the average per capita consumption rates of fuel wood in Bale area are 0.51 m^3. Based on this figure, the annual demand of fuelwood in the study area is 102,000m^3. More over, the respondents in the local community identified fire wood and charcoal productions are major causes of forest cover change. Hence, the increasing demand of forest products, in the form of firewood and charcoal with in and outside the study area was the cause of deforestation.

5.1.4. Wood for construction and timber

The demand of forest products for the construction of house and fence and timber has been causing forest cover change in the study. From the information of local people it was evident that cutting trees for the demand of constructional material is considered as the causes of deforestation in the area.

In the forest blocks east of Dodola, namely Ferekessa and Sokota, immense deforestation was recorded. Due to the spatial closeness to the nearby villages, one can assume that this happened for additional use of the forest by the inhabitants of Dodola town. The area south-west of Dodola town is affected by a decrease of forest cover and moreover displays a larger share of areas identified as grassland and of increasing grassland, which is a consequence of deforestation. The three most affected forest blocks, where forest is converted to grassland, are: Wa’ee negelle, Nageyo-xixio and Agado golba and are also located closely to a settlement, Kechema. In these two areas, the demand for forest products like wood for construction and timber may be higher due to the nearby located settlements and therefore cause a higher deforestation.

Figure 24: Poles of Trees from the near by forest area and ready to sell for construction
(Photo: Author, 2009)

5.1.5. Income generation

However, huge proportions of the study area dwellers are engaged in different activities. Selling of wood and wood products are traditional way of working activityof village people Referring to this, agricultural officers and forestry experts argue that these groups of people illegally cut down the trees from the forest area so as to supply a large quantity of forest products for urban dwellers and they sell it in small markets. In relation to this, data obtained from field observation indicated that large amount of loads of leave, tree branches and poles were carried by a number of people from different direction of forest areas towards Adaba and Dodola towns; for the purpose of income generation this leads to forest cover change (Figure 24 & 25).

Figure 25: wood from the near by forest area and ready to sell for fire wood

(Photo: Author, 2009)

5.1.6. Settlement expansions

Between the year 1986 and 2005, about 2,779 ha of forest cover was converted in to settlement land-use units. Hence, settlement expansion is considered to be one cause of forest cover changes in the study area.

5.2. Impact of forest cover change

People are depending on forests, especially for their socio-economic, environmental and aesthetic value. These precious resources have a variety of products and services. They provide raw materials for housing and they are traditional sources of fuel wood. Besides, they are the best biological conservation structure for the soil resources. Despite of all these importance, this resource is miss-treated and deforested unwisely. The increasing demands for fuel wood, constructional timber, and cultivated as well as grazing land to support the growing population aggravate the rate of forest cover change.

Likewise, the major environmental problems in the study area, which are resulted from forest cover change such as increased land degradation, soil erosion, as well as deteriorating of bio-diversity, are discussed here under in the following paragraphs.

5.2.1. Land degradation

The term land degradation is a process, which resulted in a radical change in the complete character of the land due to the loss of plant nutrients and organic matter, the break down of soil structure and destruction of vegetation cover (Blaikie and Brookfield, 1987). Land degradation is the decrease in biological productivity of land use resulted from unsustainable land-uses such as over cultivation, deforestation, overgrazing, poor management and poor cultivation. It is a process, which results in an absolute change of the complete characteristics of the land due to the loss of minerals and disappearance of the organic matter .One can argue that unrestricted removal of vegetation cover from the land is the most important factor encouraging land degradation.

Land degradation accelerates soil erosion, which is defined as the removal of loose surface materials and nutrient content by different agents mainly water and wind. It is largely assisted in many cases by human activities and grazing animals especially in the removal of vegetations. Due to high population concentration, land degradation in the form of soil erosion is common particularly in the northern and central high lands of Ethiopia (Hurni, 1993).

From the above stated statements, land degradation is manifested most seriously in central and northern high lands of Ethiopia with soil erosion. Likewise, the mountainous region of the study area reflects this reality if not typical example of excessively degraded. The relief feature of Adaba Dodola is rugged with wide range of altitudinal variation ranges from 2400 m. a. s. l to 3800 m.a.s.l. This rugged nature of topography coupled with removal of vegetations and high amount of summer rainfall results in greater soil erosion.

Figure 26: Land degradation near to Deneba village

(Photo: Author, 2009)

5.2.2. Declining Biodiversity

As it has been stated previously, the geographical setting of the study has a diverse and conducive ecological condition due to its wide range of altitude and relatively high amount of rainfall. As a result of this, the area was originally the land of many indigenous tree species such as *Juniperus excelas, Podocarpus falcatus, Hagenia abyssinica, Hypericum lanceolatum Erica arborea* and other valuable tree species to name but a few. However, one of the known indigenous tree species, for instance, *Hagenia abyssinica*, is over exploited by selective cutting.

This clearly shows that the exploitation of indigenous forests through selective tree cutting greatly affects the biological diversity of the area. In addition, according to the interview made with elders various types of wild animals which used to inhabit the locality has now disappeared due to de-vegetation of the area.

Generally, the growing human population created and still creates pressure on these remaining forests. On the one hand people come from the nearby settlements, but on the other hand from the villages Dodola and Deneba to make use of the forest. The degradation of the forest leads to erosion of soil and less retention of rain in the rainy season. These impacts of deforestation can be regarded all over Ethiopia. In fact, the degradation of forest has manifold reasons. The population increases with a high rate and people heavily depend on forest products. Wood from the forest is used for construction, as fuel wood for heating and cooking and even to earn money from selling it. This collocation of problems is still worsened by missing income opportunities in this area Additionally, the limited amount of farming and grazing land as well as unproductive soils make the people degrade the forest to create more arable land for the satisfaction of the population’s needs. Whereas the forest decreases, farming and grazing land increase.

6. Conclusions and recommendations

6.1 Conclusions

The present study area is composed of five major land use/land cover types; dense forest, open forest, grasslands, farmlands and settlement. The quantitative evidences of land cover dynamics presented were delivered by repeated satellite images coupled by GIS analyses.

From the analyzed results, the magnitude of land-use/ land-cover in general and forest cover change in particular was observed between the year 1986 and 2005 in the study area. Particularly, expansion of farmland and decline of both dense forest land and open forest land were observed. In relation to this, currently, the over all condition of the forest cover land of the study area is strongly disturbed. Besides, the areal extent of forest cover is reduced from time to time. The findings indicated that from the total area of the forest land (both dense and open forest) about 57, 389 ha of land were covered with forest in 1986. But, this figure declined to 45,809 ha in the year 2005. More over, for the annual rate of forest cover change between 1986 and 2005, the computed result indicated that about 494.09 ha of forest land is changed in to other land use land cover. Yet the rate of forest cover change between 2000 and 2005 show declining as compared with the first period due to the practice of WAJIB approach project.

The spatial forest cover change pattern indicated that the major complete forest clearance occurred on the relatively higher altitudes (2300-2750masl) of the study area which are more convenient for both human settlement and crop cultivation. On the other hand, the disturbance of the natural forest for the purpose of income generation, fuel wood, charcoal production and agricultural land expansion mainly occurred in the medium to low altitude parts of the study area. This implies that forest resource management strategies at higher altitudes where crop production is more important should differ from that of the mid to lower altitudes.

In addition to this, forest cover risk map was generated based on the year 2005 forest cover map. The computed quantitative data revealed that from the total forest cover condition of the year 2005 about 8,978 ha of forest cover land is categorized under low risk to human disturbance. On the other hand, 22,068 ha and 14,768 ha of forest cover lands are considered to be moderately and highly susceptible human disturbance respectively.

Finally, both quantifiable and non-quantifiable socio-economic data were identified as major causes of forest cover change in the study area. This resource has been changed due to population growth (with other variables) such as demand for forest products for construction, fire wood and charcoal production, income generation and expansion of various types of agricultural activities and builtup areas along the margin and even in side the forest areas. This circumstances lead to further depletion of forest resources in the study area. As a result, the problem of forest degradation as well as deforestation with other related factors has aggravated land degradation with soil erosion in the area. Hence, this type of data was very useful for the concerned bodies in protecting the remaining forest resources from distraction.

6.2. Recommendations

From the whole study, it had been recognized that the forest cover land of Adaba-Dodola Area has declined though, the rate was different in different period. To protect the forest resources from further depletion and to use these precious resources in a sustainable basis, the following feasible suggestions are forwarded based on the findings and the conclusions drawn.

- In order to raise the carrying capacity of the study area, new agricultural inputs and techniques should be adopted, which are to be supplemented by modern agriculture extension services such as the use of fertilizers and selection of proper crop varieties. Furthermore, uncontrolled overgrazing would lead to different types of ecological problems such as devegetation and soil erosion. Thus, an intensive livestock production system has to be initiated

- Wood cutting for household energy consumption was identified as one of the causes that accelerated forest degradation. Hence, in order to save energy, improved stove that is appropriate to the rural areas has to be introduced. Besides, most of the towns of Adaba and Dodola dwellers depend on fire wood for energy consumption. This encourages those groups of people who are engaged in the activity of illegal tree cutting and harvesting to further exploitation of the existing forest resources found in the study area. Therefore, the urban population should be encouraged to use alternative energy source and fuel efficient stores.

- To overcome the problem of soil erosion, feasible soil and water conservation methods should be studied and implemented in the study area. Further more, to conserve and increase the biodiversity of the study area planting various types of indigenous vegetation and plantation tree species should be carried out with a workable afforestaion and reforestation program.

- Population growth is identified as a problem in the study area. Thus, to prevent the population pressure and its impact on the forest resources and there by improve the living conditions of the inhabitants, family planning awareness creation campaigns with adequate health services should be introduced.

- To protect the forest resources from further destruction, to realize the impact of deforestation as well as how to use this precious resource with a sustainable manner, awareness creation campaigns among the farmers dwelling along the margin and inside the forest areas should be develop.

- More research should be carried out on forest cover change and forest degradation mapping using remote sensing and GIS techniques. The potential is huge. It might be able to achieve better result than that of visual interpretation. This kind of research will benefit the forest cover change detection efficiently as well as in order to provide sound information to take appropriate measures to combat the problem of forest cover change.

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