



**Addis Ababa University
School of Graduate Studies,
Department of Earth Science**

**FOREST COVER CHANGE AND SUSCEPTIBILITY TO
FOREST DEGRADATION USING REMOTE SENSING
AND GIS TECHNIQUES: A CASE OF DENDI DISTRICT,
WEST CENTRAL ETHIOPIA**



**Berhan Gessesse
March, 2007**

**Forest Cover Change and Susceptibility to Forest Degradation
Using Remote sensing and GIS Techniques: A Case of Dendi
District, West Central Ethiopia**

*A Thesis Submitted to the School of Graduate Studies Of Addis Ababa
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Master of Science in Geographic Information System and Remote Sensing*

By:

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March, 2007

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Dedicated to the Memory of My Dear:

Father

&

Mother

Who Were Big Sources of Inspiration Throughout in my Academic career!

I really miss you and I wish you were still here to help me!

Declaration

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

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List of Acronyms

a.m.s.l:	above mean sea level
CWS:	Common Wealth secretariat
CNRASD:	Consultants on Natural Resources Assessment and Sustainable Development
CSA:	Central Statistics Authority
DEM:	Digital Elevation Model
ERDAS:	Earth Resource Data Analysis System
ENVI:	Environment for Visualizing Image
ETM+:	Enhanced Thematic Mapper+
ESCAP:	Economic and Social Commission for Asia and the Pacific
FWCDA:	Forestry and Wild life Conservation and Development Authority
G.C:	Gregorian calendar
GIS:	Geographic Information System
GPS:	Global Position System
FAO:	Food and Agricultural Organization
ha:	hectare
Km:	Kilometer
LC/LU:	Land Cover/ Land use
MCE:	Multi Criteria Evaluation
MOA:	Ministry of Agriculture
M:	Meter
mm:	millimeter
MSS:	Multi Spectral Scanner
OFDWSZ:	Office of Finance and Economic Development for West Showa Zone
RGB:	Red-Green-Blue
SIDA:	Swedish International Development Agency
NGO:	Non Governmental Organizations
NDVI:	Normalized Differencing Vegetation Index
PCA:	Principal Component Analysis
WBE:	World Book of Encyclopedia
WGFRI:	Wondo Gent Forestry Institute
WGS:	World Geodetic System
WRI:	World Resource Institute
sq. km:	square kilometer
UN:	United Nation
UTM:	Universal Transfer Mercator
TIN:	Triangulated Irregular Network
TM:	Thematic Mapper

Abstract

At present, an excessive and destructive exploitation of forest resources is a threat that exists at Dendi District. The principal aims of this study is to detect the magnitude and rate of forest cover change over the last 27 years (between 1973 and 2000) and generate susceptibility to forest degradation map using Remote sensing and GIS techniques in Dendi District. NDVI image differencing and post-classification comparison Change detection methods were employed.

The result of change detection analysis revealed that the area has shown a remarkable land cover/land use changes in general and forest cover Change in particular. Specifically, the forest cover land declined from 26,363 ha in 1973 to 25,020.4 ha in 1984 and dropped to 7,629.38 ha in the year 2000 in the District. A significant forest cover reduction by about 71.06% has been realized in the study area in the year 2000 when compared with the 1973 forest cover condition with a deforestation rate of 693.84 ha per annum. More over, with respect to slope and elevation, the amount of forest cover change process is so significant along with areas having a gradient of less than 25⁰ and elevation values of bellow 2,550 m.

In addition to this, susceptibility to forest degradation was done by considering factors such as town Proximity, road Proximity, cultivated land proximity, slope gradient and elevation value. In the mean time, three level of susceptibility to forest degradation compartment map was generated with the support of GIS technology. Based on the forest cover areas of the year 2000 (7,629.38 ha) of Dendi District, about 1,543.52 ha, 4,402.4 ha and 1,683.46 ha of forest cover land are categorized under low, moderately, and highly susceptible to degradation respectively.

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 constructional materials as well as using this resource as income generating menses were identified as causes for forest cover change at the study area. Besides, due to the problem of forest cover change; land degradation in the form of soil erosion, runoff and flooding, as well as declining of biodiversity seems to have reached a critical stage due to the problem of forest cover change. In order to hold back the problem of forest cover change and its impact, corrective measures had been suggested which can be implemented both in the short term and long term phase.

1. Introduction

1.1 Background

There are few landscapes remaining on the Earth's surface that have not been significantly altered or are not being altered by humans to some extent. Mankind's presence on the Earth and his modification of the landscape has had a profound effect upon the natural environment. Changes in land use and land cover are increasingly rapid, and can have adverse impacts and implications at local, regional and global scales (Brandon, 1998).

Regarding this, the modern world has been facing for massive changes in its lands in the past few centuries. Forests, wetlands, grasslands and deserts have altered profoundly in area and in composition. Besides, the vicinity of human settlement, agricultural lands, and the scale of timbering, mining, quarrying and other land use activities have grown enormously (Richards,1990). In relation to forest resource cover change and its impacts Williams (1990) confirmed that the most important factor that altered the face of the earth in many parts of the world is the clearing of forests. The forest has been subject to a sustained and steady attack by human beings through out the centuries (Richards 1990).

Besides, deforestation has recently become a major concern for many countries in the world, due to increase population which demands shelter, food, firewood and infrastructure, which in turn put pressure on forest resources either directly or indirectly. Hence, it is one of the most pressing land use problems. Forest cover change is occurring around the world on a scale never known before. More than 30% of the world's forest is believed to have been deforested (Misana, 1999). Most of the damage is believed to have taken place during the last 45 years. By the early 1990s, almost 40% of the earth's forest resources had been converted into cropland and permanent pasture (WRI et al, 1996).

Moreover, as the world population has grown, 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 grass lands and the whole process frequently being a prerequisite to clearing for agricultural

activities (Williams, 1990).

In Ethiopia, the available information on forest cover including their changing pattern is very limited. Regarding this Reusing (1998) documented that there is no adequate information on the location, extent of the remaining forest cover of the country and the rate at which this resource is depleted. However, there were some efforts made to provide information on forest cover of the country. Accordingly, FAO (1981) using Landsat imagery analysis has suggested that the vast areas of the Ethiopian high lands were covered with forests at the beginning of the 19thc. These forests are among the forests of the world known for its high biodiversity value (Breitenbach, 1962). Due to massive exploitation, the forest resource of the country has confined as small remnants on the high lands particularly, almost all located at unreachable areas (Azene, 1993).

Closely associated with this, for the last several decades the forest cover land in Dendi District has been under dwindling. For instance, previous study made by CNRASD (1999) noted that the Chilimo-Gaji natural forest reserve (found in the District) has been under serious destruction and therefore has reduced in productivity as well as extent. But, there is no document that indicates the necessary information in quantitative terms like the spatial distribution, extent and patterns forest cover changes.

It is known, information regarding to natural resources of the environment and on the changes they undergo is essential to detect changes, predict as well as monitor the results and 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 (here after abbreviated to GIS) (ESCAP, 1996).

Remotely sensed data sources can be used to detect forest cover change with the integration of GIS and relevant information obtained from locally. Hellden (1987) conclude that whenever environmental data are needed for retrospective analysis the historical remotely sensed data is often the only available solution. This is because useful satellite data (Landsat MSS) is available from 1972 onwards. Besides, it is possible to

analyze the spatial distribution of land cover changes using GIS. In this regard, Aronoff (1989) indicated that GIS has gained a considerable importance and application in the context of computer analysis of remotely sensed data for resource management. From the above statements one can recap that remote sensing provides the primary sources of spatial data, while GIS act upon a computational environment for analysis to extract the required information.

Therefore, in the present study emphasis was given to detect the forest cover change and the rate of its depletion in Dendi District along with the future susceptibility to forest degradation mapping using the integrated techniques of Remote sensing and GIS technology.

1.2 Problem Statement and Justification

Ethiopia is a country well endowed with diversified natural resources. Regarding this, Ermias (1994:1) noted that Ethiopia's outstanding natural resources endowments are its soil, diverse climate, extensive water resources, wild animals, rich livestock population as well as big reservoir of vegetation. However, what continues to be highly visible and increasing concern is the ever accelerating rate of resource degradation. The country has faced quite a number of environmental problems such as severe deforestation, land degradation, soil erosion, expanding desertification, recurrent drought, as well as decline of biodiversity are to name but a few. The most critical problem stated in this study would be the nature of Ethiopia's forest depletion in general and the problem of forest cover change at Dendi District in particular.

“Deforestation is a serious problem in many parts of tropical world (Burton 1994:288).” Being a tropical country, among the various natural resources in Ethiopia, forest resource is perhaps the one most affected by human activities. Whatever the extent of the land surface that might have been covered by forests, today most of the forest resources (mainly the indigenous forests) in Ethiopia have disappeared. Research findings revealed that almost all the forests in Ethiopia have been deforested in the last 40 years and only less than 3% of the entire country is now covered with trees, prompting fears of a threatening environmental disaster if the problem is going to get worse.

Further more, in 1984 the SIDA Forestry Team in Ethiopia Wrote: *"Due to the speed of exploitation, illegal cutting and burning, the forests are diminishing rapidly. If the present misuse is allowed to continue, natural forests of any importance will have been destroyed within a short period of time (SIDA, 1984)."* As a result of this, today only a few scattered and relatively small areas of forest remain, largely confined to inaccessible steep hill slopes, escarpments and mountains far from road net works (Markos and Dilnessaw, 1998), particularly in the Southwest and South-Central parts of Ethiopia.

Like in many other parts of the country, the problem of forest cover change is a very serious environmental problem at Dendi District and extensive areas of forest cover lands including shrub lands have been deforested. A decade's ago, the district was covered with rich natural indigenous Vegetations. But, the ruthless pressure put on forests by human induced activities is threatening the existence of these forest cover lands. Much more damages have been caused legally or illegally on the forest resources. The depletion of the forest resources was due to mainly poverty driven use of forest products for household use purpose and income generation. According to CNARSD (1999) due to forest proximity to towns like Ginchi (capital of Dendi District), Ambo (capital of West Showa Zone) and Addis Ababa city the number of people using the various forest products has been very high.

The rate and extent of forest cover change in the district is not determined till date. However, from available records and field visits, it is evident that forest cover change is very widespread and is continuing at an alarming rate. The process involves the shrinking of forest lands through selective cutting of tree species to complete clearance of forest cover land into other land cover and land use systems. Based on the views of agricultural officers, extensive forest cover land areas have been converted into cultivated land. In a nutshell, the forest resources have been deteriorated due to uncontrolled cutting and clearing for the expansion of cultivation and grazing lands, income generation as well as constructional material and fuel wood supply for the people who are living in and around the study area.

Hence, it has become increasingly important to assess and monitor the status of forest resource exhaustion in the study area, so that a coherent conservation measures should be suggested and implemented immediately to protect and use the valuable forest resources in a sustainable manner.

1.3 Research Objectives

General objective

Based on the above problem statement, the main purpose of this study is to provide a modest contribution to the much needed but very scarce level of information about the magnitude of forest cover change at Dendi District using 'land sat image' over a period of 27years between 1973 and 2000 G.C. as well as generating susceptibility to forest degradation map of the district.

Specific Objectives

- to assess the areal extent, rate and the pattern of forest cover change status in Dendi District using Remote sensing and GIS techniques;
- to generate the year 1973,1984 and 2000 forest cover map of Dendi District,
- to analyze the relationship between forest Cover change and Landscape attributes such as slope and elevation using the integration of Remote sensing and GIS techniques.
- to generate susceptibility to forest degradation map of the District based on 2000 forest cover condition,
- to identify the major causes and impact of forest cover change in the study area;
- to suggest remedial measures in order to holdback the problem of forest degradation as well as deforestation.

1.4 Research Questions

In order to address the stated problem and objectives, the study attempted to answer the following questions:

1. What is the areal extent and rate of forest cover change in Dendi district?

2. What are the major causes and impacts of forest cover change in the study area?
3. What are the factors responsible in determining susceptibility to forest degradations in Dendi district?
4. How can factors involved are used as spatial data for determining susceptibility to forest degradations in the study area ?and finally
5. Where are zones of different susceptibility to forest degradation in Dendi district?

1.5 Usefulness of the Present Study

At present, one of the challenges facing in Ethiopia has been the alarming rate of deforestation being experienced in many parts of the country. Yet the rates and extent of the problem are still debatable due to limitations of reliable data and the processes involved are not clearly understood. This study is considered to be an important step towards the bridging of this information gap at district level. Specifically, the result of the study is expected to have the following contributions:-

- May provide an insight towards an understanding of the dynamics of forest cover change process in Dendi District for agricultural officers, forestry experts, other concerned government bodies, NGOs and local dwellers so as to have appropriate interventions on the issue.
- Provide achievable solutions for those who are responsible and interested for taking measures to mitigate the problem and
- Generate first hand information on the problem of forest cover change in the study area for those who are interested to conduct further research on the issue.

1.6 General Research Approach

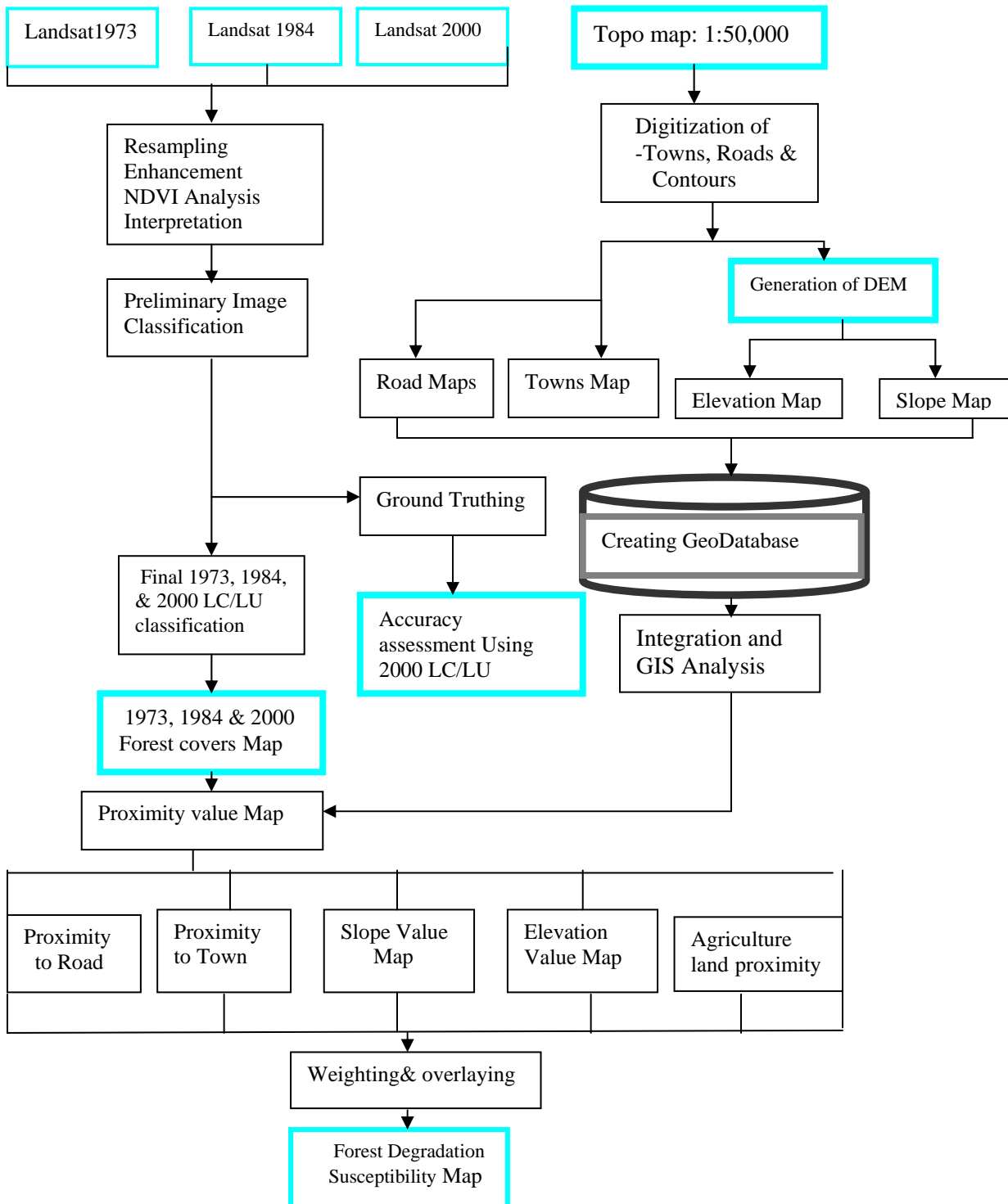


Fig. 1: Flow Chart of Research Methodology

1.7 Limitation of the Study

Due to the lack of ‘Kebele’ boundary map and lack of reliable quantitative demographic data such as total population, its growth rate and population density at ‘kebele’ level, the demographic characteristics of the District had not been considered as a factor or input data sets to analyze susceptibility to forest degradation problem. In addition, owing to the longer time elapsed for the interpretation and analysis of the remotely sensed as well as mapping of GIS data, it was found to be difficult to carry out detailed socio-economic survey.

1.8 Organization of the Thesis

The thesis is organized in six chapters. The first chapter is an introduction part, which comprises background of the study, problem statement and justification, objectives of the study, basic research questions, significance of the study, general research approach and limitation of the study. After this brief introductory chapter, chapter two provides a literature review with an over view of related studies conducted in other parts of the world simultaneously with previous works in Ethiopian context. Background of the study area as well as the various data sets, materials and methodology which are manipulated in this research is presented in chapter three. The results obtained with the various methods are out lined in chapter four. First, the contribution of Landsat image with other ancillary data and the results from various digital images processing as well as forest cover change detection and mapping outputs are documented. Secondly, the potential of GIS techniques for susceptibility to forest degradation mapping and its result is presented. Chapter five describes the major causes and impact of forest cover change in the study area. Finally, the major findings and the conclusions drawn together with recommendations are presented in chapter six.

2. Review of Literatures

2.1 Forest, Its Use and Cover Change

Forest is one of the great inherited resources of the earth. As a result, today people depend on the forest resources more than ever, mainly for their economic, environmental and enjoyment value. Forests supply many products. Wood from forest trees provides lumber, play wood and also used in making furniture and various hand tools World Book Encyclopedia (WBE, 1994). Based on the economic value of the forest Zemedie and Kedir (1997) stated that wood obtained from the forests serve as the chief source of fuel for cooking and heating. In this regard WBE (1994) argued that various manufacturing processes change wood into great number of different products. For instance, paper is one of the most valuable products made from wood.

Regarding forests environmental value, Zemedie and Kedir (1997) noted that forest plants renew the atmosphere. As forest plant and other green plants make their own food, they give off oxygen. If green plants did not continuously renew the oxygen supply, almost all life would be soon stopping. In contrast, if carbon dioxide increases in the atmosphere it could severely altered the earth's climate. Forests also provide a home of various wild animals, birds, insects and plants that can live nowhere else (WBE, 1994). In addition to this, millions upon millions of living things that can be seen only under a microscope also live in side the forest (Encyclopedia Britannica, 1992).

In spit of all these advantages, forest cover lands all over the world in general and in Ethiopia in particular, have been modified and converted in to other land use or land cover system. Forest cover change is a way in which the level of diversity and the density of individual species that make up dense vegetation structure are altered as a result of both natural and human factors (WBE, 1994). Accordingly Davidson (1988), Ermias (1994), CWS(1991) and WGFRI (1979) observes that, forest cover change involves the complete destruction of forest cover through clearing for agriculture, cattle ranching, small holder farming practice and large scale commodity crop production whether planned or spontaneous and their replacement by non-forest land use. Moreover,

Lanly (1982) conclude that forest cover change is defined as the transformation of forested land either into a shifting cultivation cycle or in to permanently cleared land. *Therefore, in this thesis forest cover change has one directional meaning and it is used to describe the modifications or complete transformation of forest cover to non-forest land use/land cover systems.*

2.2 Extent and Trends of Forest Cover Change: A Global Perspective

Nowadays, many people are aware of our changing the natural environment and an increasing pressure of mankind on its easily fragile nature. In light of this, human activities have become recognized as major forces in shaping the physical and manmade environment. Accordingly, Williams (1994) asserted that the action of human beings rather than natural forces is the sources of most contemporary change in the states and flows of this dynamic world.

Regarding to Turner II and Meyer's (1994) view, land cover transformation did not stop, but rather accelerated and diversified with the onset of industrial revolution, the globalization of the world economy and the expansion of population and technological capacity. Plant and animal species become thinned; grass lands plowed or grazed; croplands and cities expanded; wet lands drained and forests cleared for millennia, yet never so rapidly world wide as at present.

Although the magnitude of deforestation in the tropics, particularly in developing countries varies substantially, available data suggest that deforestation is a real trend. Large forests have been transformed for farm and settlement developments. This shows that people have assumed that rich vegetation is a sign of the fertile soils that lie under the forest, and this has lead to rapid forest clearance for agriculture as well as timber supply.

Forest tree cutting in many parts of the world become ruthless after man's development of metal tools to enable him to fell trees quickly and as a result the world has lost much of the original forest cover (Zemedie and Kedir, 1997). In addition, William (1990) shows that felling trees for the combined objectives of obtaining wood for construction, shelter

and tool making; of providing fuel to keep warm; cook food; and smelt metals; and above all, of creating land for growing food has culminated in one of the main processes where by human kind has modified the worlds surface cover of forest resources.

According to the study by Bunnett (1973) argument, vast number of forest trees is felled annually. Some of these come from natural forests, both tropical and temperate, and the remaining come from coniferous forests, which have been planted by man. Moreover, since 1850, as a result of unprecedented demographic change, demand for forests have substantially increased resulting in to deforestation of both temperate and tropical forest regions (Markos and Dilnessaw, 1998).

Most of the decline in the temperate forest has come from the clearing in Europe and Eastern America with intensive small scale peasant farming followed by commercial farming activity (Williams, 1990 and Howard, 1991). CWS (1991) further outlined that in the middle latitude deforestation started even before the industrial revolution more than 200 years ago. Mean while, in the 1800s and 1900s, large areas of temperate forests have been eliminated because of logging activities and industrial timber (WBE, 1994)

According to WBE (1994) the severe deforestation occurs in low latitude areas, primarily as a result of the clearing of land for agricultural activity and raw materials for timber industry. Besides, Howard's (1991) finding verified that in the tropical region many types of forest cover are now rapidly declining because of mismanagement and the slash-and-burn practices of the increase human population. Until the late 1940s, tropical rain forest covered about 16 million sq. km of the earth's land. But, in the late 1980s, this figure decreased to wards about 10 million sq. km. In the mean time, literatures indicated that as many as 20 million ha of tropical rain forest are destroyed each year and most of this destruction is occurred in Latin America, Africa and South East Asia. In relation to this, Burton (1994) has stated that in the year between 1981and1995; 2,016,000 ha, 3,676,000 ha and 5,611,000 ha both closed and open forests were destroyed in tropical Asia, Africa and Latin America respectively. In addition, 150 million ha of tropical forest and 76 million ha of tropical wood land, existing in 1980, were deforested by the year 2000 (Howard, 1991). Matthews (1983) estimated that the pre-agricultural closed forest once

covered $46.28 \times 10^6 \text{ km}^2$ of the globe, and wood land some $15.23 \times 10^6 \text{ km}^2$ being reduced to $39.27 \times 10^6 \text{ km}^2$ and $13.10 \times 10^6 \text{ km}^2$ respectively by the end of 20th century.

Besides, using Remote sensing techniques the UN carried out the first worldwide study on tropical deforestation during the early 1980s and measured the rates of deforestation in more than 60 countries. The study indicated that the area covered by tropical forest was declined at the rate of 0.62 percent per-annum (about 11 million ha of land each year (Markos and Dilnessaw, 1998).

After comparing the experiences of other parts of the world CWS (1991) arrived at some useful conclusion about the nature of forest cover change in Africa. In the continent forest cover change is different from Europe, as it's primarily due to expansion of agricultural areas, the practice of shifting cultivation, uncontrolled grazing of livestock and the exploitation of forest products especially for fuel wood. Moreover, Africa is the most severely deforested continent. With the world's fastest population growth rate, the continent has also experienced high rates of deforestation. It is estimated that between 1930 and 1970 alone, about 25% to 30% of the African rainforest was destroyed. By 1970s the forest resources of the continent had shrunk to 60% of its original size. Recent estimates show that 5 million ha were being deforested annually (Burgess, 1993); while a decrease in forest and woodland cover of 3.1% has been recorded over a ten-year period from 1981/82 to 1991-92 (WRI et al, 1996).

2.3 Trends of Forest Cover Change on the Highlands of Ethiopia

The Ethiopian high plateaus were almost completely covered with more or less dense forest in ancient times (FWCDA, 1982). But forest cover change is by no means a unique modern phenomenon for Ethiopia. It has there from time immemorial to meet the growing demand for cultivable land, grazing land, settlement, fuel wood, commercial wood and building materials (Breitenbach, 1962). The presence of massive exploitation of forests in Ethiopia has been witnessed by different scholars. The problem of forest cover change in the medieval period of Ethiopia, particularly, in the vicinity of settlements, royal and other military camps was recorded by different historians and

missionaries. In this regard, Pankhrust has cited an important description given by one of the known Portuguese's Jesuit missionary, Manoel de' Almida, who put his early 17th century experiences:

“There was no much wood land in the country, which he adds, not well stocked with trees. This shortage, he declared, was not the soils fault but the inhabitants, for every day, the latter cut down trees for their household uses and for fuel, but non of them, he complains, has either the energy or the will replant a single one (Pankhrust, 1992:276).”

Although, estimates of forest resources of Ethiopia vary widely from one source to the other, different literatures indicated that for 35% to 40% of Ethiopia's land area was covered with heavy forests on the basis of the potential climatic climax during the beginning of 20th century. But, one fact all research findings indicated that Ethiopia's forests and woodland resources have continued to decline. The natural forest cover of Ethiopia at the beginning of 20th century was first estimated in the 1960s by Breitenbach (1962) as 41.2 million ha or 37% of the total land of the country. These forest areas was reduced over the years and the trend of reduction has been shown in table: 1

Table 1: Annual Average Destruction of Forest in Ethiopia from 1955 to 1979

Year	Area Annually Destroyed(in ha)
1955-67	697,000
1967-76	293,000
1976-79	205,000

Source: FWEDA (1982)

Table1 indicated that from 1955 to 1979 the total destroyed forest area is estimated to be 13,000,000 ha along with an average annual destruction of 500,000 ha. Meanwhile, in the early 1950's forests were reduced to 16% of the total land area while by the early 1980s the forest land of the country declined to 3.6% and by the year 1989 reduced to 2.7%. This is based on the work of (WGFRI, 1979; FAO, 1984; Davidson, 1988; Gedion, 1995 and Desta, 2001).

Based on the recent satellite imagery analysis, the work's of Waber (1999) indicated that about 2.35% of the area of the country is covered with forests and this forest resources

can be seen only in some parts of the country. It includes localized areas in the western and south western parts of Ethiopia, which is found far away from human settlements such as along stream banks, near the tops of steep hills and in most valleys, safe from fire as well as human disturbance.

The estimated rate of forest cover change in Ethiopia by the late 1980 was 100,000 ha in a year or about 1 ha for every five minutes (Davidson, 1988). Later on, some findings indicated that the rate of deforestation in Ethiopia varies between 150,000 ha and 200,000 ha per annum and this situation threaten to eliminate the remaining both natural and plantation forests within a short period of time (SIDA, 1984; Gedion, 1995; Demel, 2000 and Desta, 2001).

2.3.1 Causes of Forest Cover Change in Ethiopia

The causes of deforestation are complex. Markos and Delenessaw (1998) confirmed that the rapid rate at which the population increased over the decades is the major factor contributing to the accelerated rate of deforestation in Ethiopia. The immediate causes are the need for farming and grazing land, the demand for fuel wood and construction materials, repeated fire out breaks, and movement of political center (Davidson, 1988; Demel, 2000 and Desta, 2001).

Now a day's much more damages have been done on the forest resources of Ethiopia. With their axes a group of people can destroy dense forests so as to get fresh farm and grazing lands (Zemedie and Kedir, 1997). Kassahun (1999) indicated that the problem of deforestation is very common for the rural people to clear vegetation cover for cultivable land expansion and procuring essential forest products such as constructional materials and fuel wood. In his findings Bekure (1996) stated that the increasing demand for croplands, grazing land, constructional poles and fuel wood including charcoal Production are the main reason for the uncovering of the lands of Ethiopia. In addition, forests are cleared to acquire constructional materials, to provide source of energy, to make space for grazing, farming, building and layout infrastructures networks and to supplement raw materials such as an input for agricultural production and livestock grazing (Mesfin, 1990).

The use of forests for traditional sources of energy is one of the major causes of deforestation in Ethiopia. Fuel wood accounts for the bulk of the wood used in the country and it is the fundamental domestic energy sources for people who are living both urban and rural parts of Ethiopia (SIDA, 1984). Current official estimation of commercial wood operations asserted that about 90% (21.6 million m³) of the 24 million m³ wood extracted annually is used for fire wood (20 million m³) and charcoal (1.6 million m³). The remaining 10% is used as construction, poles and other industrial requirements (Davidson, 1988). This shows that, the use of forests for the source of energy is contributed for the rapid rate of forest cover change in the country.

Although, various factors involved in the destruction of forests in Ethiopia, those initiated by humans using fire to remove forest resources is the most sever. Fire has been responsible for forest cover change mainly in northern Ethiopia. In addition, forest fires contribute to the destruction of hundred hectares of forestlands annually. Peasants living in or on the borders of the forest often burns in order to get rid of wild animals (e.g. birds and monkeys which destroy a large part of the agricultural crops) and to expand agricultural lands (FWCDA, 1982).

By analyzing the records available in the MOA, Demel (2000) provides some facts about the occurrence, extent and risk of fire in Ethiopia during in the early 1980s and between 1990 and 2000. In 1984, about 209,913 ha areas of both plantations and natural forest were burnt, the largest impact being on natural forest about 209,913 ha. In the mean time, in the years between 1990 and 2000, about 155,960ha areas of forest were burnt. Only in the year 2000, over 150,000 ha forest resources were destroyed. From this explanation, fire is one of the major contributing factors for forest cover change in Ethiopia.

In addition, the shifting of political center from place to place in the past was important determinant factor for the problem of deforestation in Ethiopia. Historical source's indicated that the movement of political center from Axum in the North via Gondar to Addis Ababa was related to the royal camp's need of wood for fuel and building material. In relation to this Harvith's (1968) findings indicated that before Addis Ababa become a permanent capital of Ethiopia there were other many capital towns. As a result the kings

and rulers with their followers move from place to place in order to hear complaints from the people and to check some rebellions tribes. Thus, the location of their capitals changes three to four times during a year. These frequent changes of residence were not only due to the above mentioned political and social reasons but also resource exhaustion, mainly forest resources.

On top of this, the introduction of sawmill industry and their uncontrolled activity is to a large extent responsible for the massive destruction of forest resources and large areas were selectively exploited without reforestations (FWCDA, 1982).

To sum up, rapid population growth along with the need for farming and grazing land, movement of political capital in the country for a long period of time, the need of fuel wood and building materials, forest fire and the introduction of sawmill industry are the major contributing factors for the transformation of forest cover land into other land use and land cover systems in the country.

2.3.2 Impact of Forest Cover Change in Ethiopia

The decline of forest cover in many developing countries creates several wood famines. Hartshorne (1988) argued that in many areas of Asia and Africa peasants scavenging for wood possess a major effort. Where wood cannot be found, dried cattle dung serves as a substitute fuel. Besides, the immediate human suffering from lack of wood, the depletion of forest resources is associated with increased erosion, siltation, and flooding, climatic change and declining of biodiversity.

Being a developing country, the same is true for the impact of forest cover change in Ethiopia. Regarding this, some of the major identified impact of this senseless destruction of forest resources beyond its regenerative capacity in Ethiopia is land degradation, soil erosion mainly by water, frequently happening drought, declining of biodiversity, shortage of fuel wood and constructional materials and unbelievable high cost of fire wood products (FWCDA, 1982 and Davidson, 1988).

2.4 The Need of Remote sensing and GIS

2.4.1 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, 2000:1)” Within the frame work of this study, the focus of Remote sensing 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.

As noted by Mather (1987) a multispectral sensor acquires multiple images of the same target object at different wavelengths (bands). Hence, multiple band images can be used to identify different features as each band measures unique spectral characteristics about the target. A spectral band is a data set collected by the sensor with information from discrete portions of the electromagnetic spectrum which ranging from cosmic waves to radio waves.

In relation to this, spectral reflectance characteristics of common earth surface features are located within the visible and near to mid-infrared range. The reflectance of different features on the earth surface varies with the wave length of the interacting radiation. The reflectance of vegetation, soil and water, which are the three major features on the earth surface, shows different spectral reflectance characteristics. The spectral reflectance curve of the vegetation is of immense use to study the forest resources and there condition in an area.

Although, at the very beginning Remote sensing technology was only for military use, recently it has been in the use for civilian applications such as agriculture, archaeology, forestry, geography, geology, planning, and mapping, decision making and similar resource and inventory analysis(Hellden,1987). Furthermore, Larsson and Stromquist (1991) reported that Remote sensing could be applied within the following fields:

hydrology, land use/land cover change detection, vegetation monitoring, soil erosion, land degradation and research in environmental monitoring.

During the past several decades' new and unique possibilities have been created to collect environmental data on a monitoring basis. According to Hellden (1987) data can be collected on an individual grid cell basis with a complete ground coverage of any region of interest, be it a continent or a small development project area by applying an adequate level of Remote sensing technology, ranging from the use of Aerial photography to earth resource and metrological satellites data . Whenever data are needed for time series environmental change detection analysis the use of remotely sensed data is often available and efficient solution from 1972 onwards.

2.4.2 Geographic Information System

The development of GIS could be viewed differently by different scholars based on the perception of what GIS is. Because of lack of a single universally accepted definition provided for GIS, different authors defined it from different perspectives.

Borough and Mc Donnel (1986): *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.*

Hellden (1987): *GIS is a multipurpose computer based information system for retrieval, administration, processing, integrated analysis and graphic, cartographic and statistical presentation and combination of data which can be defined in time and space.*

ESCAP (1996): *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, modeling and display of spatially-referenced data for solving complex planning and management problems.*

Aronoff (1989): *GIS is a computer-based system that is used to store and manipulate geographical information.*

Lovett (2000): *GIS is part of the modern revolution in knowledge management as well as it is a system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the earth.*

Whichever definition is given, most of the definitions relay on the computer based GIS. This is because; it is a computer technology that realized the 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).

More specifically, Aronoff (1989) has well-documented that GIS technology is important to day because it offers an important means of understanding and dealing with some of the most pressing environmental problems of our time: Problems like tropical forest cover change/deforestation, the feature of global climate, the need for ecologically sensitive development of global natural resources and rapid urbanization. In addition, GIS technology helps us to organize the data about such problems and understand their spatial associations and provides a powerful means for analyzing and synthesizing information about them. According to Hellden (1987) GIS technology continues to be used for making forest cover and socio economic mapping as well as the modeling capabilities of the GIS have been being used for analyzing natural resources issues. Lovett (2000) also concluded that by combining GIS and Database Management System technology make it is easier to crate and maintain compressive information about natural resources. Hence, GIS technology can be used to mimic the behavior certain aspects of the real world. It is being used to model the present, and predict the future. In addition to this, this technology is thoroughly used in forest resources monitoring, forest degradation studies and susceptibility mapping.

2.4.3 Integration of Remote sensing and GIS

Remote sensing and GIS are inherently linked technologies- technologies that in many ways share common historical roots. Star et al. (1997) noted that, the problem of this planet require data/information in a timely fashion at scales from local to global level.

But, data on important attributes such as population distribution and dynamics, topography, land use/ land cover and its changes, water resources and air quality are inadequate, or in some areas they simply do not exist. Remote sensing is the only practical means to acquire much of the data needed to address the wide variety of challenges we face across scales.

After the launch of landsat-1 in 1972, a tremendous progress has been made in a relatively short time in developing effective methods for processing and analyzing such data (Hoffer, 1994). Moreover, in the last decades it had been observed that rapid advances and significant increase in the operational use of remotely sensed data. To be effectively analyzed and employed, remotely sensed data must be combined with other data or information. The most effective way to realize this situation is within the context of geographic information system (Star et al, 1997).

According to Hoffer's (1994) view much of this increased use of remotely sensed data will be due to the continued integration of Remote sensing, GIS and GPS technologies. Remotely sensed data is used to provide input to new GIS database, to update existing database, and assessing and monitoring land use/land cover changes in various types. Not only does Remote sensing provide input data to GIS database, but also GIS data often can be very helpful in the analysis of remotely sensed data and enabling significant improvements in the classification accuracies. So, for GIS to be most effective, it needs to contain accurate and up-to-date data. The best way to update a number of GIS data is through the analysis of remotely sensed information.

To sum up, the combining of GIS with expert systems, the use of GPS technology to enhance data capture for GIS and the use of Remote sensing especially image processing, provides more rapid updating of GIS databases and as a result of this the two technologies are inherently linked.

2.4.4 Applications 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.

Several scientific researches indicated that remote sensing and GIS are used in various fields like, watershed management, flooding, road network analysis, urban and rural development, mining, hydrology, irrigation, hydropower, monitoring of forest resources and so on. Especially, 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. Larsson and Stromquist (1991) described that the interpretation of Landsat imagery was found to be the most convenient rapid appraisal technique for assessing and estimating dynamic environmental changes and trends. Image interpretation and analysis will provide accurate information on forest cover, forest type, forest condition and biomass and land potential for afforestation program.

The application of satellite remote sensing in forest cover change detection has developed rapidly in association with the digital image analysis of earth resource satellite data. With rapid changes in land cover occurring over large areas, Remote sensing technology is an essential tool especially in monitoring tropical forest conditions. The remote and inaccessible nature of many tropical forest regions limits the feasibility of ground based inventory and monitoring methods for extensive land areas. Initiatives to monitor land cover and land use change are increasingly dependent on information derived from remotely sensed data. An array of techniques is available to detect forest cover changes from multi-temporal Remote sensing data (Daniel and Steven, 2000).

Further more, Howard's (1991) argument revealed that satellite remote sensing can be used to provide quick information about forest cover land and for monitoring of forest cover change over a long period of time at the continental and regional level. The assessment of forest cover change into other land cover and land use systems on country basis using Landsat data has contributed to the world wide appreciation of the problem of

the diminishing forest cover land. In this regard, Howard (1991) had been quoted several examples to indicate the usefulness of Remote sensing techniques to apply on forest cover change:

- I. A study in Gambia using land sat MSS imagery taken in 1973 and in 1978 indicated a loss of forest cover exceeding 20 %.
- II. A study of Central Sumatra using satellite imagery revealed that the agricultural lands, resulting from the loss of high forest cover, increased by 45% or 300,000 ha.
- III. In eastern Thailand satellite Remote sensing analysis shows that an annual rate of deforestation by administrative province of 1.2 % to 12.5% between 1972-1976,
- IV. In Brazil landsat data of 1973 and 1976 were compared digitally and the results indicated that about 115,000 ha of forest had been exploited within three years.

Hence, from this analysis we can generalize that satellite Remote sensing data were very useful in deriving quantitative data on forest cover change and presenting the results in an understandable form. Besides, digital image analysis applied to forest cover monitoring has the advantage of being fast and able to handle large quantity of data and, is increasingly being used.

2.5 Change Detection Methods

According to Lillesand and Kiefer (2000) change detection involves the use of multi-temporal datasets to discriminate areas of land cover change between dates of imaging. In addition Jonsen et al (1997) indicated that change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. For example, information about change in the landscape provides valuable data on the processes at work and the information may be obtained from remotely sensed data and/or by visiting the specific sites on the ground. Therefore, the goal of change detection is to determine those areas on digital images that depict change features of interest (e.g. forest cover change) between two or more image dates.

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 (Brandon, 1998). The basic premise in using satellite data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing flexibility in manipulating digital data and increasing computing power.

A wide variety of digital change detection techniques have been developed over the last two decades. Regarding this Jensen et al (1997), Brandon (1998) and Lillesand and Kiefer (2000) all provide an excellent and comprehensive summary of methods and techniques of digital change detection. Based on the above scientific literatures there are two major methods to detect the changes in the case of using satellite image data: 1) pre-classification interpretation and 2) post-classification comparison. In the first one, a Normalized Difference Vegetation Index (NDVI) change detection method is employed.

On the contrary, one way of discriminating change between two dates of imaging is to employ post-classification comparison change detection algorithm. According to Jensen et al (1997) post-classification comparison is the commonly used method of quantitative Change detection analysis. This approach requires a complete classification of the individual dates of remotely sensed data. In this method two dates of imagery are independently classified and registered. Then after classification algorithms can be employed to determine those pixels with a change in classification between dates. Moreover, statistics and change maps can be compiled to express the specific nature of the changes between the dates of imagery.

3. Data source, Material and Methodology

3.1 Background of the Study Area

3.1.1 Dendi District–A Geographical Setting

The study area, Dendi District is located in West Shewa Zone of Oromiya Regional State. Geographically, the district lies within the coordinates of 8^o43'N-9^o17' North latitude and 37^o47'E-38^o20' East longitude. It is found at a distance of 90 km west of Addis Ababa City. The district covers about a total area of 1,296.12 km².

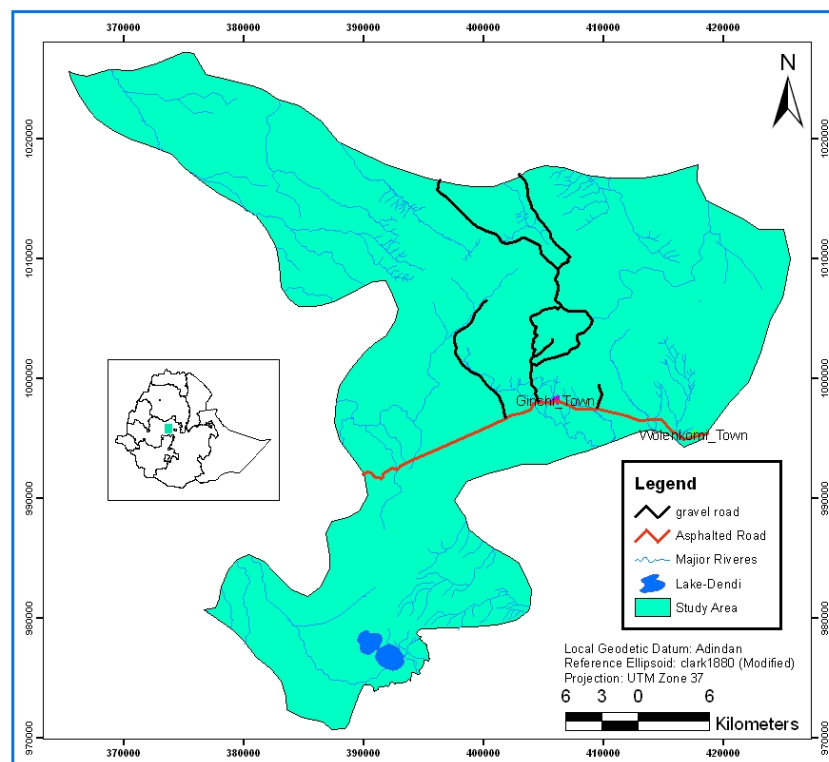


Fig. 2: Location Map of Dendi District

3.1.2 Relief and Drainage

The Physiographic region of the District is characterized by one major escarpment running from east to west direction. The steepness of the escarpment varies from place to place being generally steeper at the central part of the district. Both on the top and bottom, the escarpment merges with flat lands largely used for farming. The altitudinal range of the district is between 1440 to 3260m a.m.s.l. Besides, the relief feature of the area is characterized by rugged topography, which provides a variety of hills having an

interesting view. Moreover, the central part of the study area (on which the existing dense natural forest is located) is the main watershed between the Blue Nile (Abay) basin in the north and Awash basin in the south. As a result, the terrain is intersected by rivers and streams flowing south and northward directions. Several streams and rivers originated from the southern central part of the district and run from north to south ward direction and finally ended up in the upper Awash basin. On the contrary, some rivers also commenced from the northern central part of the district and drain towards north and northwest direction and finally merging with Blue-Nile basin. The drainage pattern in the study area is dendritic in nature with medium drainage density. Furthermore, Lake Dendi is one of the high land lake in Ethiopia found in the district and has a good potential for tourist attraction (Plate 1).



Plate 1: The View of Lake Dendi in the Study Area. Foreground is the Dendi hill which was covered by dense forest and shrub land in previous time. Now, most of it converted in to agricultural land (white patch) (Photo by Berhan, December, 2006G .C)

3.1.3. Climate

Being Ethiopia is a low latitude country; the climatic condition of the study area is tropical in nature. In relation to this altitude is the determinant factor that affects the climate of the local region. According to OFDWSZ (2004) the study area is divided in to three traditional Agro-climatic Zones namely: Dega (10%), Woina-Dega (60%) and Kolla (30%).

There is one meteorological station in the district which records temperature and rain fall. Based on the station, the annual average temperature of the study area is 17.5⁰c. The mean maximum and minimum temperature of the district is 23.8⁰c and 9.3⁰c respectively. In addition, the area has an average annual precipitation of 1,225mm and has two rainy seasons i.e. the small rainy occur from March to May and the big rainy from June to September, with the highest intensity of rainfall in July and August.

3.1.4 Soil

CNRASD (1999) Cited from Tamrat (1993) indicated that the majority of the soil of the study area range from sandy to sandy-loams and clay-loams. Generally, the soils are reddish brown and shallow at higher altitudes, while at lower sites they tend to become dark, gray and deep. The soils in the surrounding low plains are Vertisols black soils with characteristics of high clay content.

3.1.5 Vegetation and Wildlife

Dendi District is covered with ever green forests with various types of vegetation such as higher trees, riverian trees, small trees, shrubs and ground cover grasses (Plate 2). The entire high lands of the district are believed to have been covered once with dense forest resources. Currently, the Chilimo-Gaji protected forest area is found in the Dendi District. The forest, which is found in and around Chilimo-Gaji area, is one of the few remnant dry Afro-mountain forests on isolated part of the central plateau of the district. The major tree species in the canopy are Junipers procera, Podocarpus falcatus, Purns afiricana, Olea-europaea, Cuspidata, Hagenia abssinica, Ficusspp, Erythrinaburcei, Crotonma crostachyus and Eucalyptus globules. Besides, the study area is a land of small indigenous flowering grasses, herbs as well as bushes such as Carissa edulis and Rosa abyssinica.

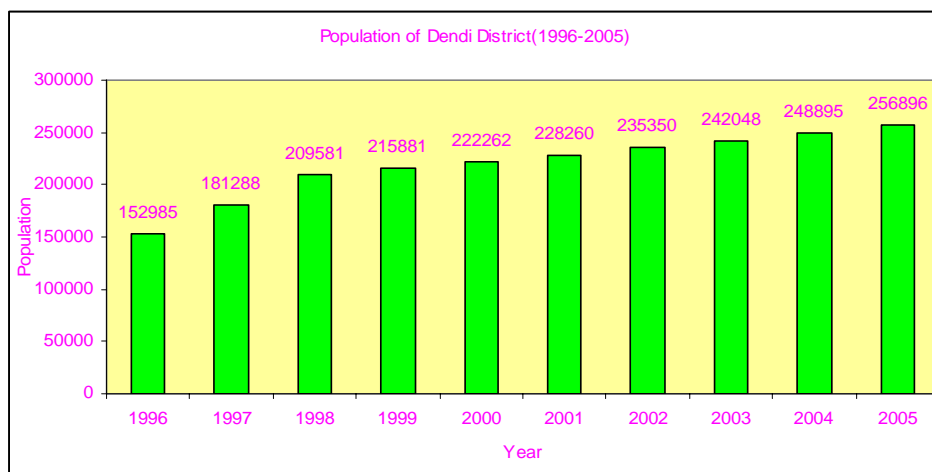
Even though, there is no reserved areas for wildlife conservation like parks and game reserves still some wild life are found in the district. According to local dwellers, among the major types of wild animals found in the district are Menelik's bushbuck, Vervet monkey, Colubus Monkey, Anbasu Baboon, Warthog, Spotted hyena, Jackal, Hunting dog and Leopard.



Plate 2: Forest Trees which Dominates in side Chilimo-Gaji Forest Area of at Dendi District (Photo by Berhan, December, 2006G .C)

3.1.6 Population

Based on the 2005 CSA population projection, the total population of Dendi District is estimated to be 256,896(Fig.3). The high population growth is attributed to the favorable climatic conditions for both crops and livestock production, which attract a lot of people from outside the district. Along the Addis Ababa-Ambo road the district is inhabited by urban dwellers and densely populated areas have been observed particularly in and around the towns of Ginchi and Welenkomi.



*Fig. 3: Population Growth Trends of Dendi District from 1996 to 2005 G.C
Source: CSA, Annual Abstracts from 1996-2005(G.C)*

3.1.7 Socio-Economic Conditions

Presently, agriculture is the back bone of the local community's economy and about 89.6% of the district population is engaged in the activity of agriculture (OFDWSZ. 2004). Since agro-climatic zone of the district is conducive for crop production, various types of crops such as barely, wheat, teff, maize, sorghum, beans, chickpeas etc. are the major crops grown in the district. Furthermore, cattle breeding is very common in the area.

In addition, forest exploitation and sale of forest resources is also one of the major household income sources of the forest surrounding community. Forest products such as constructional materials, fuel wood and charcoal are supplied to Welenkomi, Ginchi and Ambo town and even to the city of Addis Ababa from the existing forest resources in the district.

3.2 Data Source and Material

In the present study, to understand the dynamics of forest cover change, both spatial and temporal data are gathered. These data were collected from both primary and secondary data sources.

Primary data were generated from the analysis of satellite image, field observation, and the response of agricultural officers, foresters and elders in the district using interview.

On the other hand, secondary data were obtained from the study area topographic maps. Besides, the published materials including books, journals, research articles and census reports were reviewed. Table 2: shows data sources and study materials that are used in this study.

Table 2: List of Data source and Material

I. Satellite Image Data					
	Sensor	Path	Row	Spatial Resolution	Date of Acquisitions
Landsat 1	MSS	188	54	57 X57 meter	31,January 1973
Landsat 5	TM	169	54	28 X 28 meter	22,November,1984
Landsat 7	ETM+	169	54	30X30 meter	26,November,2000
II. GIS Data					
<ul style="list-style-type: none"> ➤ Topographic maps of the year 1978 G.C having the scale of 1:50,000 were used for the digitization of roads, contours and towns as well as field survey. ➤ The Ethio- GIS data was used to generate District boundary 					
III. Other Ancillary Data					
Climatic data from Ginchi Agricultural weather station and population data using different census and abstract reports from CSA were extracted.					
IV, Software Used					
<ul style="list-style-type: none"> ➤ ERDAS Imagine 8.6: used for Resampling, and Image analyses. ➤ ENVI4.2 used for Visual Interpretation and Image analyses. ➤ ArcView3.3 and ArcGIS9.1: used for GIS analysis and mapping. ➤ IDRISI32 Release 2: used for GIS analysis. ➤ Other soft-ware used in this research includes Microsoft Internet, word, Excel and power point. ➤ During field work Global Positioning System (GPS) receiver, Digital Camera and compass were used to collect field data. 					

3.3 Research Methods

This part of the paper describes the activities involved when conducting the present research in time sequence, namely: Pre-field work stage, field work stage and post-field work stage.

3.3.1 Pre-field Work Stage

To begin with, literature study is an important part of this research. It is not only enlarges author's knowledge in various relevant fields, but also directly determines the data acquisition and processing techniques in order to handle the proposed research. The literature study is mainly focused on the description of forest cover change and the role of GIS and Remote sensing techniques to assess forest cover change. Besides, special attention was given with the works of change detection methods mainly NDVI analysis and Post Classification Comparison Change detection techniques.

After acquiring satellite image of the years 1973, 1984 and 2000, preliminary image analysis was performed to extract meaningful information from remote sensing data. So an attempt is made to use the remotely sensed data with the support of ERDAS Imagine8.6 and ENVI4.2 software at different level of pre-processing methods so as to generate essential information. The conventionally accepted methods of image processing techniques used in this particular study are image re-sampling, image interpretation and enhancement and preliminary classifications. In addition to this, after collecting and scanning the topographic map of the study area having the scale of 1:50,000, road network, town shape, and contours were digitized using ArcView3.3 and ArcGIS9.1 software. Moreover, other ancillary data such as population and metrological data were gathered and analyzed. Finally, geo-database was created and all spatial data was stored within a geo-database environment to facilitate further analysis.

3.3.2 Field Work Stage

Field observation sheet (Appendix II) is designed for storing all information observed during field survey, i.e., land cover and land use types as well as illegal human activities on forest resource. These data has been used for designing for final image classification and testing sample site, which was used for land cover map validation. In the mean time, for ground truth and data verifications field visit was carried out. At each sampling site more than eight reference points were taken using Garmin72 GPS receiver (Appendix III) for ground truth verifications. At every reference point, a surrounding area of about 1 to 2 km was viewed and data such as co-ordinates (longitude and latitude) and the current human activity evidences on each land use/land cover were documented. In addition to these data, photographs were taken at each site and essential information was generated, which helped to support the identification of patterns, trends, causes and impacts of forest cover change.

3.3.3 Post Field Work

Based on the final training sample site, which were generated during field work stage; all the available images were classified in to 8 land cover/use types by applying supervised classification method and maximum likelihood algorithm with the support of ERDAS

Imagine8.6 software. In relation to this, the year 2000 land cover and land use classification result was evaluated by employing accuracy assessment technique using ENVI4.2 software to investigate how the result reflects the reality on the ground. Moreover, the years 1973, 1984 and 2000 forest cover map also independently generated from each land use land cover maps.

Furthermore, on the bases of the years 1973,1984 and 2000 multi-temporal Landsat data forest cover change detection analysis were carried out using NDVI and Post-classification change detection comparison methods.

Besides, to analyze the forest cover change processes in relation with landscape attributes, the three dates of forest cover land of the study area was cross-tabulated with slope and elevation layer using cross-tab module with the support of ‘Spatial Analyst Extension’ of ArcView3.3 software.

To analyze susceptibility to forest degradation based on 2000 forest cover condition, Multi Criteria Evaluation (MCE) analysis was carried out. GIS software such as Idrisi32 and ArcGIS9.1 (Spatial Analyst), a model named MCE had been used to facilitate this process. A model builder (Fig.6) which is designed to run MCE analysis was developed in order to generate susceptibility to forest degradation map.

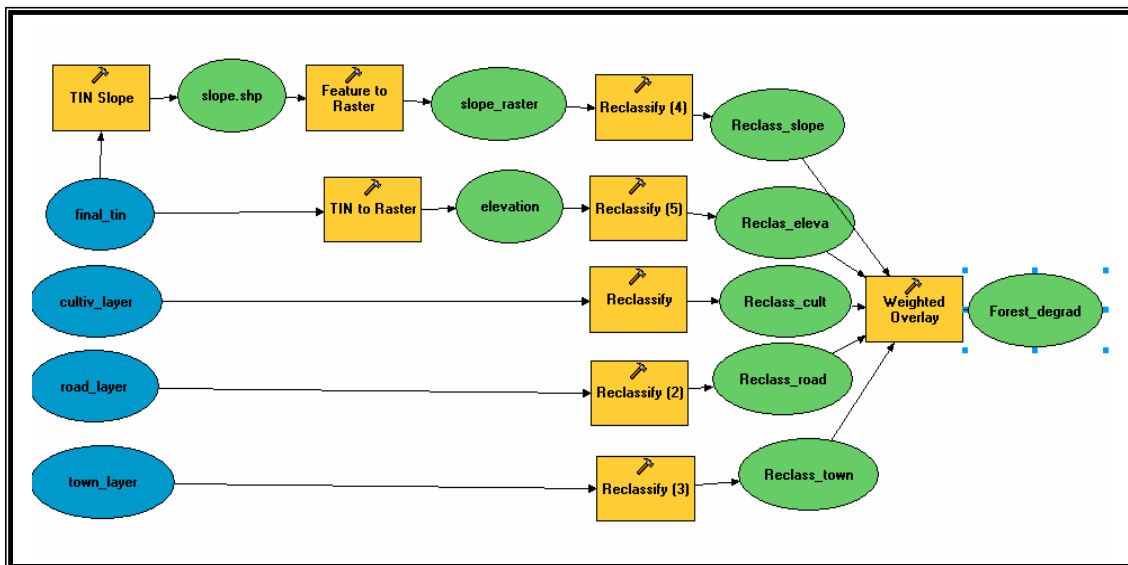


Fig. 4: Model Builder Dialogue Box for Forest Susceptibility to Degradation Mapping

4. Data Analysis, Result and Discussion

4.1 Data Analysis

4.1.1 Image Pre-processing

Performing image analysis is an inevitable task to extract meaningful information from remotely sensed data. So, an effort is made to use the remotely sensed data with different level of image pre-processing methods. The methods of image processing techniques used in the current study are:

i. Image Re-sampling

Procurement of best and available different dates of satellite image data is the initial stage for image processing and analysis in this study. In the mean time, multi-temporal Landsat images (it is already geo-referenced) were down loaded from 'Global Land Cover Facility website' and used (table: 2). Landsat satellite images of the year 1973, 1984 and 2000 having a map projection of UTM zone37 and datum WGS84 were re-sampled to UTM zone37, spheroid Clark 1880 (modified) and local datum Adindan using ERDASImagine8.6 software in order to well-suited the image with other map layers.

The 1973 image has four bands with a spatial resolution of 57m. This image was used detailed land use land cover classification using 7-5-4 false color band combination of RGB (Red, Green and Blue) order (Fig.5).

Besides, Landsat image of the year 1984, has seven bands with a spatial resolution of 28 meter was used for land use/land cover classification using 4-7-2 false color band combinations in RGB order (Fig.6).

Furthermore, the 2000 satellite image of Landsat-7 ETM+ is used for most of the analysis and mapping activities in the present study since it is the recent available satellite image. This image was already geo-referenced and its quality was found to be very good during field work. From this image, 6 bands: band 1, 2, 3, 4, 5 and 7 in visible, near infrared and farinfrared electromagnetic spectrum having spatial resolution of 30m was used. Besides, this image was used for land use/land cover classification using 4-7-2 false color band combinations in RGB order (Fig.7).

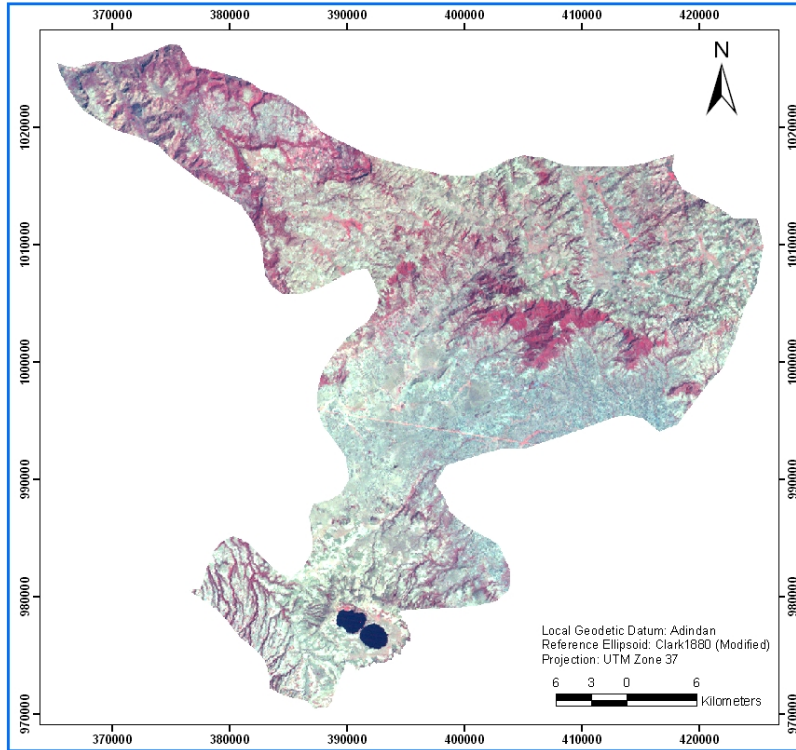


Fig. 5: False Color Composite Map of Landsat MSS Image, 1973
Source: 1973 Landsat MSS Image

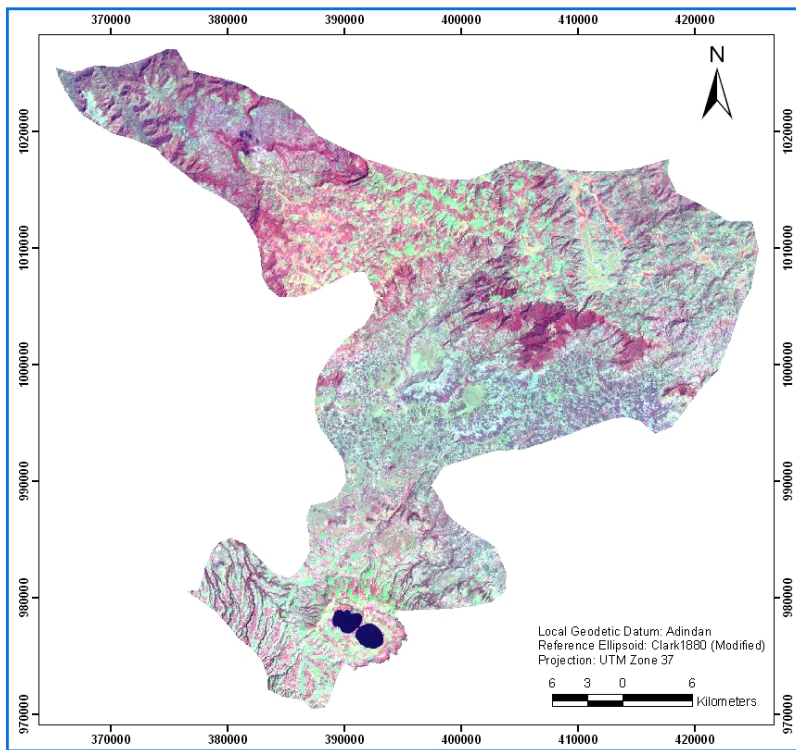


Fig. 6: False Color Composite Map of Landsat TM Image, 1984
Source: 1984 Landsat TM Image

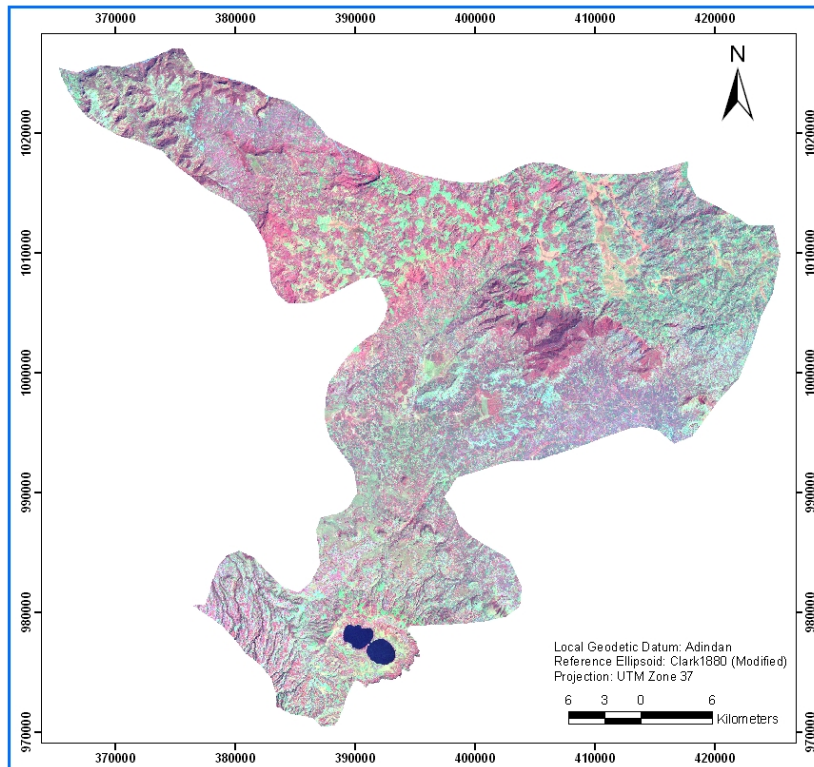


Fig. 7: False Color Composite Map of Landsat ETM+ Image, 2000
Source: 2000 Landsat ETM+ Image

ii. 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 and Kiefer, 2000) suggested that image interpreters should have good power of observations coupled with imagination and it is important that the interpreters have a thorough 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.

In addition to this, to increase the visual distinction between features in a scene, the amount of information that can be visually interpreted from the data and to extract important summarized statistical data, digital image enhancement techniques such as band ratios and NDVI analysis were employed.

ii. Preliminary Classification

The principle of image classification is that a pixel is assigned to a class based on its

feature by comparing it to predefined clusters in the feature space. In this study, both unsupervised and supervised image classifications were important steps for digital image processing and to develop training samples. In addition to this, maximum likelihood image classification algorithm was utilized.

Using the application of image classification methods, land cover and land use types are identified in order to perform forest cover change detection and to determine forest degradation susceptibility analysis. Therefore, in this study the forest cover types play a much more important role than other types of land cover/land use found in the district. Based on the characteristics of Landsat satellite image of the year 1973, 1984 and 2000, the District's major land cover and land use types were classified as follows with the support of ERDAS Imagine 8.6 Software:

1. Water body: lands completely covered with water.
2. Forest Cover: It represents both natural and fragmented plantation forest areas that are stocked with trees capable of producing timber or other wood products.
3. Built-up area: are those areas composed of intensive use with much of the land by rural villages ,towns and roads.
4. Cropland: are lands covered with agricultural crops.
5. Fallow land: Are farmlands that has been but then left with out crops being implanted on it, in order to allow essential chemical elements to increase in it.
6. Grazing land: are those lands where small grasses are the predominant natural vegetation. It also includes land with scattered or patches of trees and it is used for grazing and browsing.
7. Marshy/Grass cover: those areas where the water table is at near or above the land surface for a significant part of most of the years and covered with grass lands, which is used for grazing purpose.
8. Shrub land: land supporting an assemblage of small trees and shrubs.

Later on, the printout of draft land cover/use map which is generated based on the above

land cover/ land use type using unsupervised classification method was used during field work preparation and field survey.

4.1.2 Field Data Processing and Analysis

The sample ground control points (see appendix III) were stored in to the computer GIS spatial database and analyzed. Based on the final image classification samples which were prepared during field work stage; all the available images were classified in to 8 land cover/use types by applying supervised classification method and maximum likelihood algorithm. The first step in the supervised classification is to identify training samples which were selected based on the homogeneity of the image spectral characteristics in order to cover the full range and finally to be assigned the same land cover type. Mean while, the land cover / land use maps in general and the forest cover map of Dendi District in particular were generated from the years 1973, 1984 and 2000 satellite image. Finally, on the bases of the processed image value, NDVI and post classification change detection analysis is employed.

4.1.2.1 Evaluating Classification

After classification is performed, evaluating the classification result is the next task for testing the accuracy of the classification since it gives evidence of how the results reflect the reality on the ground. Congalton (1991) as cited by LeIca Geosystems (2002) stated that *“a classification is not complete until it has been assessed .Then and only then can decisions be made based on that information has any validity.”* In this research the accuracy assessment of the classification result was made on the basis of the year 2000 land cover /land use image classification using ENVI4.2 software. Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of the classification process. Usually the assumed–true data are derived from randomly selected ground truth data. *Accuracy assessment* evaluation includes an error matrix with percentage which is a report of the overall proportion of correctly classified pixels in the data. Finally, *Kappa* was calculated for the different areas that were classified. Kappa is a measure which expresses to what degree the pixels in the interpreted map differ from a class category taken by chance.

4.1.2.2 Forest Cover Change Detection Procedures

In order to detect and assess the changes of forest ecosystem over times the years 1973, 1984 and 2000 multi-temporal Landsat data were acquired. To perform change detection monitoring, NDVI and Post-classification Change Detection comparison methods were employed.

I. NDVI Image Comparison and Change Detection Analysis

As clearly indicated earlier, spectral band ratio is one of the most common mathematical operations applied to multi-spectral data. Ratio images are 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 are 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 have been 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.

$$NDVI = \frac{NIR(Band4) - R(band3)}{NIR(Band4) + R(Band3)} \dots\dots\dots \text{Equation 1}$$

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. Later on, after conducting NDVI analysis, the mean and standard deviations values are summarized using ERDASImagine8.6 software to evaluate the trends of vegetation cover change condition of the district.

II. Post Classification Change Detection Analysis

To examine the 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 and provides where and how much change has occurred. In this forest cover change detection study, three dates of satellite imagery is used to determine the change by generating quantitative information on spatial and temporal distribution. In the mean time, four aspects of forest cover change detection characteristics such as, detecting the changes that have occurred, identifying the nature of the change, measuring the areal extent of the change, and assessing the spatial pattern of the change are investigated. More over, change detection matrix had been generated to investigate the trends and patterns of land cover/land use change detection in general and forest cover change detection in particular. Besides, various types of summary statistics were documented. In the mean time, the rate of forest cover change also computed using equation 2:

$$r = \frac{Q2 - Q1}{t} \dots\dots\dots \text{Equation2}$$

Where, r = Rate of Change

$Q2$ = Recent year forest cover in ha

$Q1$ = Initial Year forest cover in ha and

t = Interval year between Initial year and Recent year

To do so, careful digital image interpretation analysis of the forest cover land change was employed. In the mean time, from land cover and land use maps of the year 1973, 1984 and 2000 three dates of forest cover maps of the study area were generated. Later on, the raster data converted in to Arccoverage vector layer using ERDAS Imagine8.6 Software and the ERDAS Arccoverage vector layers were converted into shape files using ArcView3.3 software then after forest cover maps of Dendi District were generated.

4.1.3 Susceptibility to Forest Degradation Analysis

In order to monitor forest degradation and generate susceptibility to forest degradation map at Dendi district, the year 2000 forest cover map was considered to be the base line for this analysis. This map is generated from the land cover/ land use map of the year 2000 satellite image classification, which is the only available recent satellite image data source for this study. Susceptibility to forest degradation 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 too. 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 are the main contributing factors that cause forest degradation in Dendi district.

To carry out susceptibility to forest degradation mapping, 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 systems provide the basic tools for evaluating such a model. Especially in Idrisi32 and ArcGIS9.1 (Spatial Analyst Extension tool) soft ware, a model named MCE has been 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 procedures which were designed to run MCE analysis in the present study are:

I. Preparing Input Datasets/Factor Maps

The first step to run MCE is deciding, analyzing and generating proximity to forest cover area data sets or factor maps which are responsible for forest degradation. Accessibility to forest resource is 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 house hold consumption and income generation as well as expansion of agricultural lands along the borders of the forest areas. The selected datasets are town proximity, road proximity, the

slope and elevation physiographic nature of the district and cultivated land proximity. In addition, the year 2000 forest cover map of the study area was also used as ‘Analysis Masking Layer.’ The first four factors which are roads, towns, slope and elevation, were generated through digitization from 1:50,000 topographic maps of the study area. The factor map of agricultural land and the ‘Analysis Masking Layer’ of forest cover map were derived from the year 2000 Land cover/use map of the study area. The rationale to select these criteria as a dataset is stated under here:

To begin with, slope is considered to be one of the contributing factors that aggravate the susceptibility to forest resource degradation in Dendi District. The underlying assumption is that; if the existing forest resource is found in relatively gentle slope gradient, there is a possibility of easily degradation to this resource. This argument is also strongly supported by the district’s agricultural officers, foresters and even by local dwellers. According to their views, if the physiographic region of the area lies with relatively gentle slope gradient, there is a positive correlation for the expansion of agricultural and grazing land as well as rural settlement at the expense of forest cover; shrub land and grass cover areas. On the contrary, they said “*Steep slope areas are the natural forest cover keepers.*” This means that when forests are found in steep slope gradient, this area is not convenient for any activities. As a result, forests may sustain for a long period of time with out disruption. And that is why slope is considered as one factor for future susceptibility to forest degradation.

Secondly, the expansion of agricultural land is the major triggering factor for the depletion of forest resources in Ethiopia. When the forest area is encroached by agricultural lands and rural settlements; there is a probability of these resources to be degraded as well as deforested in order to secure sufficient cultivated and grazing lands. As indicated in the change detection result part, the encroachments of cultivated lands at the expense of forest cover units is the major factor for the conversion of forest cover land in the study area. Due to this, proximity to cultivated land is considered to be one of the decisive factors for future susceptibility to forest resource degradation.

In recent times, urbanization is the most vital development phenomenon all over the globe and side by side it creates a great pressure on various types of environmental

recourses. In the light of this, along urban and industrial areas the problem of forest cover change is very critical. According to Williams (1994), for instance, the closed forests within 100 km of nine Indian cities have been reduced from 9,662.5 ha to 7,227.8 ha between 1972 and 1982. Like wise, as indicated in the literature review part, urban growth is one of the factors for the destruction of forest resources in Ethiopia. This is because most urban dwellers are dependent on forest resources found in and around the urban areas in order to secure the demand of constructional material as well as fuel wood supply. In addition to this, most people (especially women and jobless youths) are used the forest resources found the near by urban areas as income generation means for them. That is why characterizing the forest cover areas using urban proximity as a factor for susceptibility to forest degradation resources in Dendi District.

Besides, road network proximity to forest cover land areas is considered to be one of the factors aggravating for susceptibility to forest degradation. For example, WB (1987) indicated that the forest resources which is found in and around Addis Ababa city along with major road proximities such as Wolmera's Forest (between Ambo and Gojjam Ber Roads), Almegena's Forest (between Debrezite and Jimma Rods),Akaki's Forest (between Debrezite and Jimma Roads),Sendafa's Forest (between Debrezite and Debre Berhan Roads and Entoto/Sululta's (between Debre Berhan and Gojjam Ber Roads) having a total forest area 19208.8ha had drastically decreased by more than 50% since 1980's.

In this forest susceptibility degradation model, both the graveled as well as asphalted roads radiating across all over the district (Fig.2) were considered to be the input criterion which contributes for the problem of forest degradation in the study area. The principal assumption is when the proximity of the forest cover area to the road networks facilitates the movement of various types of forest products from the source to market centers and enables large number of people to generate in come from forest products. As a result, if the location of the present forest cover areas is near to road networks, the forest resources are easily vulnerable for degradation.

Finally, the elevation range of the district lies between 1440m and 3260m a.m.s.l.

According to (OFEDWSZ, 2004) about 60% of the district area is found in the “Woina Dega’ (between 1500 and 2500m a.m.s.l) traditional agro-climatic zone. Most of the rural population of the district is agglomerated in this agro-ecological zone due to its suitability for the practice of different types of agricultural activity. As a result, the presence of high population concentration and the expansion of agricultural activity within the stated altitude range create a great pressure on the forest resources. Mainly, the forest cover land with low elevation is given higher value in terms of forest resource accessibility because local people can easily access the forest areas found in this particular region.

II. Deriving and Standardizing Raster Datasets (Factor Maps)

Standardization of different datasets to the same scale before overlaying and combining them is the next important procedure for susceptibility to forest degradation mapping using MCE analysis. Meanwhile, all the vector data layers are converted into raster data with ArcGIS9.1 software using Spatial Analyst extension module. Then, all the datasets are organized with the same data analysis extent and cell size of 30 meter resolution to perform different GIS analysis.

Accordingly, the factors or datasets are categorized into two systematic groupings. The first ones are proximity factors (proximity to road, town & agricultural land) which are derived by distance spatial analyst tool and further reclassified into a common scale using Natural break (Jenks) classification scheme and masked by using the year 2000 forest cover raster layer. Masking is used to perform analysis on cells in a particular area. Hence, forest cover raster layer had been prepared as an ‘Analysis Masking Layer’ that identifies those cells within the analysis extent that will be considered when running the analysis tool to generate susceptibility to forest degradation map. During reclassification stage, the masking layer (forest cover) is overlaid on the input raster data sets (such as slope, elevation, proximity to roads, towns and agricultural land); only cells covered by the masking layer will be processed. All other cells were assigned the No Data value in the result after running the analysis tool.

The second groups of topographical factors (slope and elevation maps) are generated from the study area contours. Besides, after converting the contour to 3D shape and

Triangulated Irregular Network (TIN) feature by using 3DAnalyst Extension of ArcGIS9.1 software, TIN feature is used to derive slope and elevation datasets. Consequently, these datasets are rasterized and reclassified by Natural break (Jenks) classification scheme and masked by using the year 2000 forest cover raster layer with the support of Spatial Analyst extension tool.

Finally, in order to run MCE and to combine the datasets using weighted overlay and combination techniques, all the factor maps are prepared using a common scale within the range 1 to 5 by giving higher value to attributes for each dataset that are more influential for the susceptibility to forest resource degradation.

III. Weighting of the Factors

Basically, the level of susceptibility to forest degradation is affected by all of the selected factors above. However, their influence is different with each other. That is why quantifying the importance level (weight) of the selected factors are an important task before running MCE. Accordingly, after analyzing the influence of each factor with forest resource degradation based on literature review, the view of professionals and local dwellers, the weights of all the factors involved were ranked and calculated by using Pair Wise Comparison methods with the support of Idrisi32 Release 2 software.

***N. B: A Natural Break (Jenks)** is one of the Standard classification schemes in which Classes are categorized based on natural groupings inherent in the data. Arc Map identifies break points by picking the class breaks that best group similar values and maximize the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big jumps in the data values” (ESRI Arc GIS Desktop Help)”*

***Mask:** Sometimes you only want to perform analysis on cells in a particular area. The mask layer identifies those cells within the analysis extent that will be considered when running a tool. If the mask was overlaid on the input raster you want to use for analysis, only cells covered by the mask will be processed. All other cells will be assigned the No Data value in the result after running a tool. ” (ESRI Arc GIS Desktop Help)*

IV. Running MCE

For the assessment of susceptibility to forest degradation in Dendi District, the selected five factor maps were evaluated by employing a procedure called MCE, under the principle of weighted overlay and combination analysis with the help of ArcGIS9.1 software. Weighted Overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. After the weights were established, the module MCE was used to overlay the factors. Finally, the weighted overlay combination result is derived using equation 3.

$$\text{Weighted over Lay and Combination Result} = ((\text{factor 1} * \text{weight 1}) + (\text{factor 2} * \text{weight 2}) + (\text{factor 3} * \text{weight 3}) + (\text{factor 4} * \text{weight 4}) + (\text{factor 5} * \text{weight 5}) \dots\dots\dots \text{Equation 4}$$

In order to use datasets as a spatial data for determining susceptibility to forest degradation, these factors need to be mapped. To do so, GIS technology plays a vital role from the beginning for the mapping factors to the end by combining those factors in order to come up with the final result of the present research that is mapping of susceptibility to forest degradation.

4.2 Result and Discussion

This part of the paper describes the results obtained through data processing and analysis methods and it encompass two major parts. In the first part, the nature of forest cover change detection and the magnitude of its change are documented using NDVI analysis and post classification comparison change detection techniques. In the second part, an attempt has been made to present the prospects of forest degradation condition using MCE techniques by considering different proximity factors which have a contribution for forest degradation as well as deforestation process.

4.2.1 Accuracy Assessment of the Year 2000 Image Classification

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. An error matrix was generated based on the year 2000 land cover and land use classification and ground truth data. The accuracy is essentially a measure of how many ground truth pixels were classified correctly.

Table 3: Confusion matrix of the year 2000 Land cover /Land Use Supervised Classification

Class	Water Body	Forest	Shrub land	Built up area	Crop cover	Fallow land	Grass cover	Marshy/ Grass	Total
Water Body	88.12	0.00	0.00	00.00	0.00	0.00	0.00	0.00	13.00
Forest	10.4	90.00	0.00	0.00	0.00	0.00	0.00	0.00	14.83
Shrub land	0.00	0.13	92.13	4.95	3.80	0.00	1.83	0.00	16.33
Built up area	0.00	0.00	1.12	84.65	0.00	0.59	0.00	0.00	14.42
Crop cover	1.49	8.67	5.62	9.41	91.14	1.18	10.05	16.67	8.42
Fallow land	0.00	0.00	1.12	0.00	5.06	92.90	0.00	0.00	6.83
Grass cover	0.00	0.00	0.00	0.00	0.00	1.78	88.13	0.00	12.58
Marshy/Grass	0.00	0.00	0.00	0.50	0.00	3.55	0.00	83.33	13.58
Total	100.00	100.00	100.00	0.00	100.00	100.00	100.00	100.00	100.00

Class	Prod. Acc.(Percent)	User Acc (Percent)
Water Bodies	88.12	100.00
Forest Cover	90.00	86.54
Shrub Land	92.13	81.19
Built-up Area	84.65	98.84
Crop Cover	91.14	47.68
Fallow Land	92.90	96.32
Grass cover	88.13	98.47
Marshy/ Grass	83.33	91.46

Overall Accuracy = (1063/1200) 88.5833%
 Kappa Coefficient = 0.8612

An overall accuracy of 88.58% was achieved with a Kappa coefficient of 0.8612. 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 0.8612 represents a probable 86% better accuracy than if the classification resulted from a random assignment.

4.2.2 NDVI Image Comparison and Change Detection Result

As clearly indicated earlier, NDVI analysis was employed to get an over view of the vegetation biomass change based on 1984(fig.8) and 2000(fig.9) satellite image. But, the 1973 satellite image data was not considered in NDVI analysis due to the near infrared band (Band3) is seriously has an effect on striping problem and unable to resolve this defect during image processing stage, with out this band it is impossible to carry out NDVI analysis.

The NDVI value is calculated using ‘equation, 1’ with the support of ERDAS Imagine 8.6 soft-ware. Then, the mean and standard deviation result is obtained within the ranges of 0 and 1 and following the statistical values of each of the images were presented in table 4.

Table 4: NDVI Analysis Statistics

	Year	
Type	1984	2000
Minimum	-0.64706	-0.91304
Maximum	0.73822	0.73684
Mean	0.097	0.062
Median	-0.0031207	-0.0043174
Mode	-0.0031207	-0.0043174
Standard Deviation	0.145	0.122

Source: Satellite Image Interpretations

As indicated in table 4, the standard deviation of the 1984 image is 0.145 which is a greater value comparing with the value of the 2000 NDVI image has a value of 0.122.

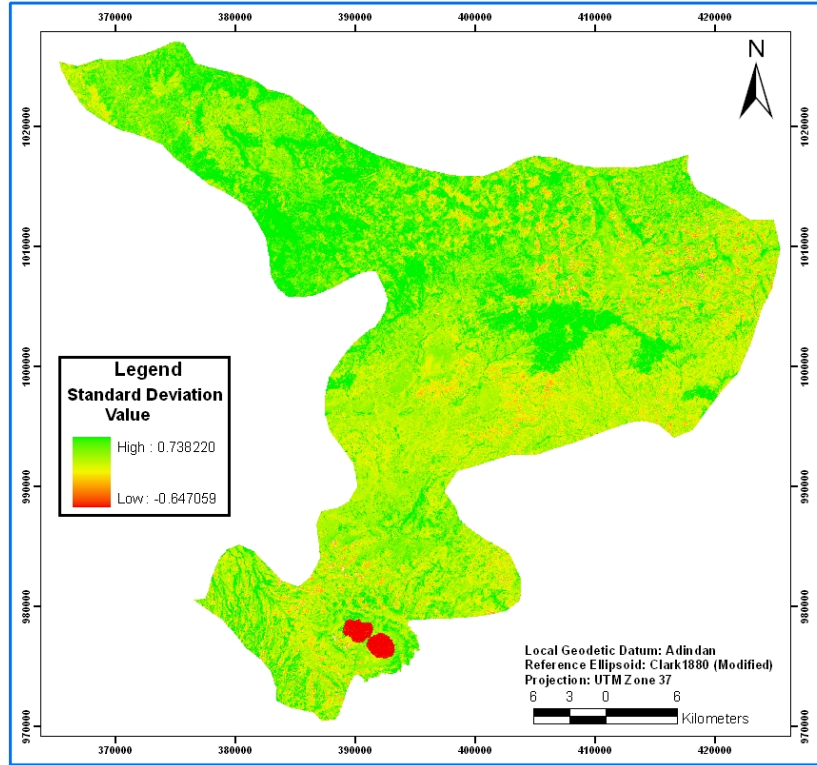


Fig. 8: NDVI Map of Dendi District, 1984
Source: 1984 Image Interpretation

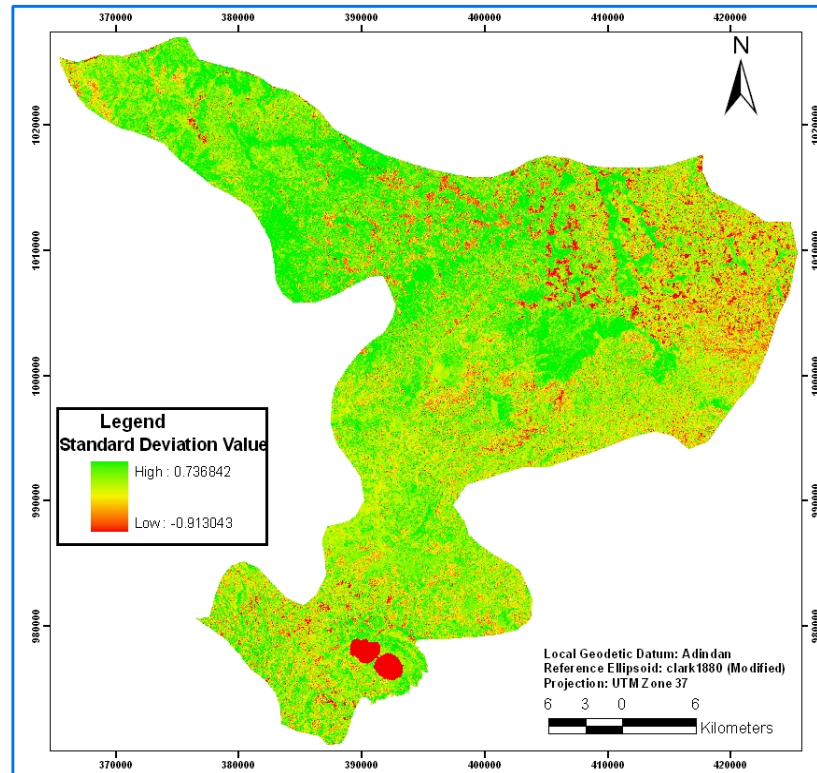


Fig. 9: NDVI Map of Dendi District, 2000
Source: 2000 Image Interpretation

4.2.3 Post Classification Change Detection

Post classification comparison change detection scheme is employed to discriminate forest cover changes between 1973, 1984 and 2000 dates of imaging. In addition, the forest cover change in the form of maps and statistics had been compiled to investigate the specific nature and magnitude of the forest cover changes between the stated dates of imageries in the study area.

4.2.3.1 Land cover and Land Use Units at Dendi District

The distribution of land cover/land use units of the study area are categorized in to eight classes .These are water bodies, forest cover, shrub land, built-up areas, crop cover, fallow land, grass cover, and marshy with grass land areas. The three dates of land cover/land use classification map of the study area is presented from figure10 to 12. In addition, the statistics of land use /land cover change in general and forest cover change in particular were computed and summarized to detect the nature of the changes based on the years 1973, 1984 and 2000 dates of imageries. The areal extent of each land cover land use types with respective percentage is presented in table 5.

Table 5: Summary Statistics of Land cover/ Land Use units of Dendi District; 1973, 1984 and 2000.

Cover Classes	Years					
	1973		1984		2000	
	Area (in ha)	%	Area(in ha)	%	Area(in ha)	%
Water Bodies	706.658	0.54	709.299	0.55	716.28	0.55
Forest	26363	20.33	25020.4	19.3	7629.38	5.89
Shrub Land	40330.1	31.1	33690	26	12665.1	9.77
Built-Up Area	4015.44	3.1	6291.27	4.85	8020.7	6.19
Crop Cover	11092.7	8.56	42297.2	32.63	76731.9	59.2
Fallow Land	24876	19.18	9164.97	7.07	12217.3	9.43
Grassland	13476.17	10.44	3092.61	2.39	2854.52	2.2
Marshy/Grassland	8752.23	6.75	9346.03	7.21	8776.51	6.77
Total	129612.3	100	129612.3	100	129612.3	100

Source: Computed from Satellite Image Interpretation

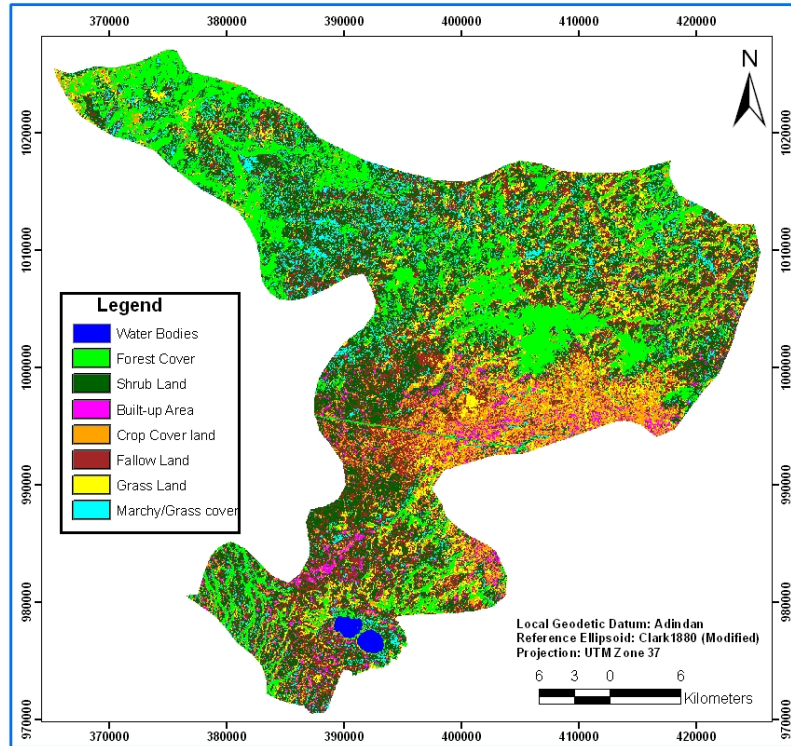


Fig.10: Land cover/ Land use Map of Dendi District, 1973
Source: 1973 Satellite Image Interpretation

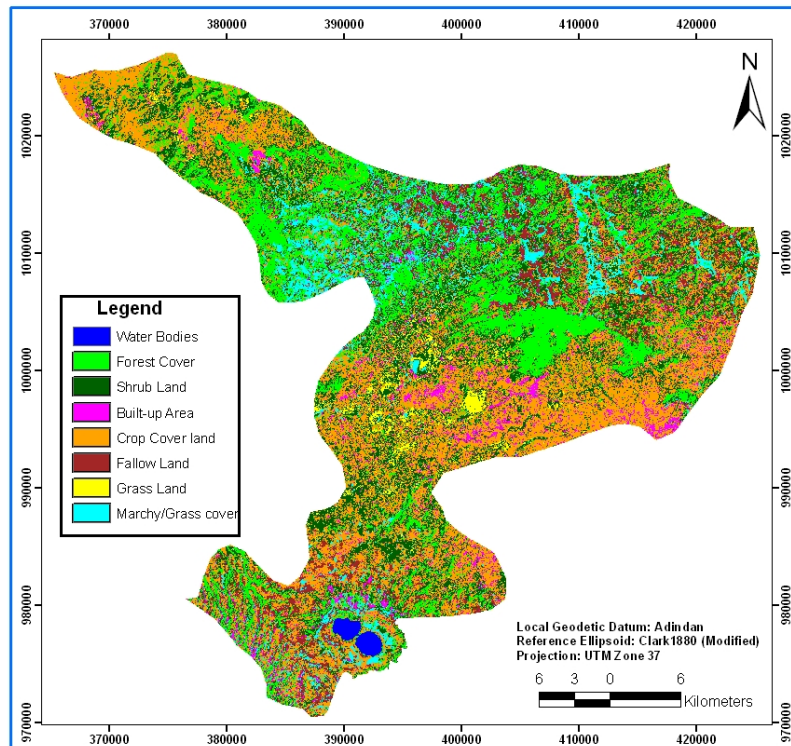


Fig. 11: Land cover/ Land use Map of Dendi District, 1984
Source: 1984 Satellite Image Interpretation

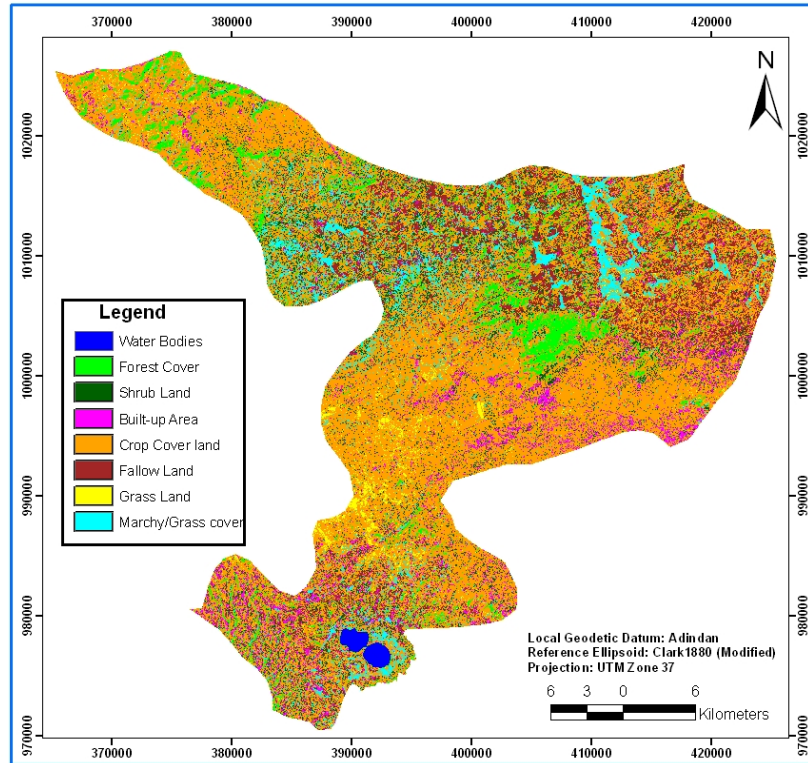


Fig. 12: Land cover/ Land use Map of Dendi District, 2000
Source: 2000 Satellite Image Interpretation

From the 1973 land cover and land use map interpretation and classification, the areal coverage of water bodies are accounted for 0.54% from the total study area. The cover land of forest and shrub lands were occupied about 20.33% and 31.1% respectively. Besides, cultivated land (together with crop cover 8.56% and fallow land 19.18%) was accounted for about 27.74% from the total coverage of the study area. More over, land cover and land use units of built up areas, grass lands and marshy/grass cover were occupied about 3.1%, 19.18 % and 10.44% in the same order.

In 1984 the forest areal coverage units was about 19.3% of the total area. Land category under cultivation and shrub land were accounted for 39.7% and 26% respectively. Other cover types such as grass lands, built up areas, water bodies and marshy/grass lands covered a lesser percentage (about 15%) of the study area (table 5).

From the total land coverage, cultivated land (both crop cover and fallow land) were accounted for about 68.45% in the year 2000. Forest and shrub lands take the share of 5.89% and 9.77% respectively. The remaining area was covered with different land cover

and land use units of water bodies, built up areas, grass lands and marshy/grass land areas, accounted for 0.55%, 6.19%, 2.2% and 6.77 % in the same order.

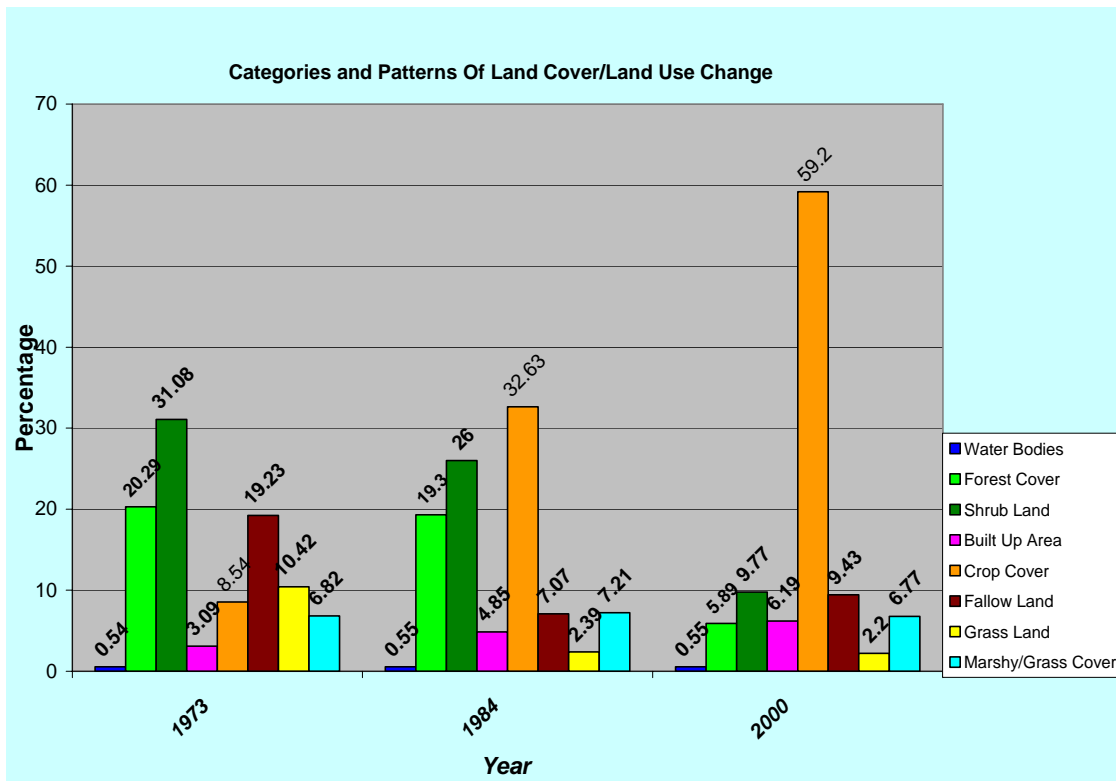


Fig. 13: Patterns of land Cover /land use units of Dendi District, 1973, 1984 and 2000
Source: computed from Table 5

More over, to have a clear understanding about the cover change and its pattern's in the study area, the land cover and land use change matrix had been generated based on the 1973, 1984 and 2000 satellite image interpretations and presented with table 6 and 7. These tables are showing an areal distribution of land cover and land use units and also provides information about what proportion of each cover and use types changed in to other cover units in the forthcoming time reflection. To analyze and extract information from these land cover/land use change matrix, the following points should be taken in to considerations:

- I. the land covers /use value is presented in square kilometer.
- II. Each column values gives the cover and use type in the previous years and
- III. Each row values indicate the cover and use types for the recent years.

Finally, in the change matrix the value above and bellow the diagonal lines represent

change in land cover/use .On the contrary, as the value along the diagonal line represent where no change has occurred.

Table 6: Matrix of Land Cover/Land Use Changes Between 1973 and 1984 at Dendi District

		Land Cover/Land Use Units of 1973								
		Water Bodies	Forest Cover	Shrub Land	Built-up Area	Crop Cover land	Fallow Land	Grass Land	Marshy/grass	Class Total
Land Cover/ Land Use of 1984	Water Bodies	6.45	0.35	0.07	0.02	0.06	0.03	0.04	0.03	7.04
	Forest Cover	0.42	132.3	62.22	1.22	4.68	17.88	14.3	16.7	249.82
	Shrub Land	0.07	54.6	120.56	5.47	20.33	70.19	39.86	25.31	336.6
	Built-up Area	0	5.77	17.19	6	10.76	13.2	7.38	2.56	62.95
	Crop Cover	0.1	57.61	123.73	23.11	64.26	85.91	47.71	20.61	423.36
	Fallow Land	0.01	5.89	26.21	2.37	5.95	32.43	14.53	4.4	91.86
	Grass Cover	0	1.23	10.01	0.42	2.83	9.83	4.75	1.66	30.74
	Marshy	0.01	4.92	42.41	1.39	1.74	19.46	6.78	17	93.75
	Class Total	7.07	263.63	403.7	40.15	110.93	249.76	135.74	88.52	1296.12

Source: 1973 and 1984 land cover/ Land Use Classification Maps

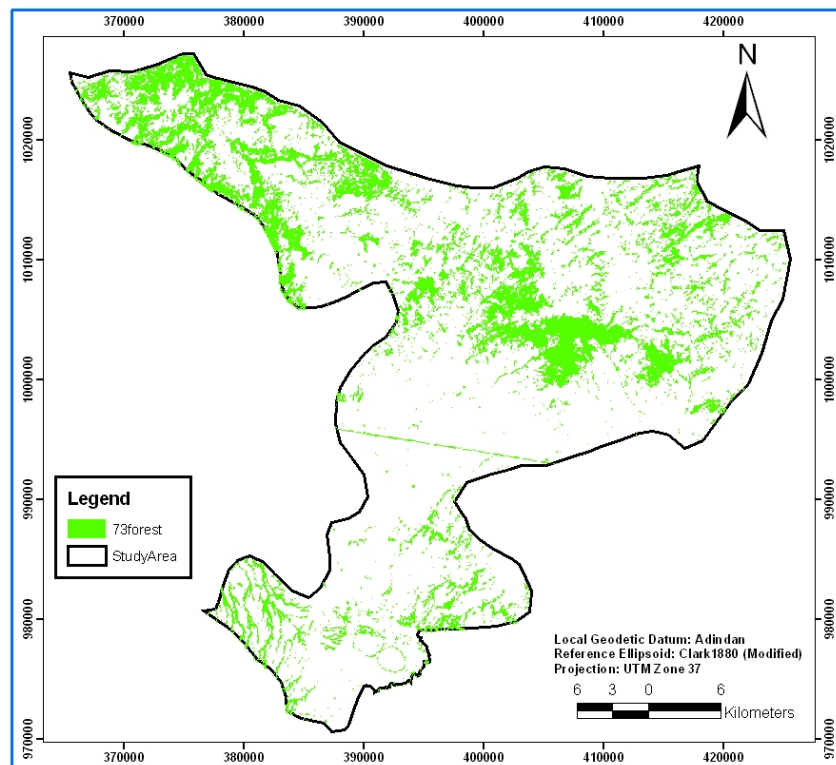
Table 7: Matrix of Land Cover/Land Use Changes Between 1984 and 2000 at Dendi District

		Land Cover/Land Use Unites of 1984								
		Water Bodies	Forest Cover	Shrub Land	Built -up Area	Crop cover	Fallow Land	Grass Cover	Marshy/ Grass	Class Total
Land cover/Land use of 2000	Water Bodies	6.99	0.17	0	0	0.01	0	0	0	7.16
	Forest Cover	0.11	57.96	5.06	0.61	12.01	0.2	0.1	0.25	76.29
	Shrub Land	0	26.36	34.14	6.21	39.45	8.44	1.51	10.54	126.65
	Builtup Area	0	3.55	11.06	14.99	34.02	11.73	0.71	4.15	80.21
	Crop Cover	0	135.32	227.15	31.36	290.07	28.35	21.14	33.93	767.32
	Fallow Land	0	6.43	25.98	8.2	29.22	38.94	1.13	12.27	122.17
	Grass cover	0	1.12	14.62	0.38	6.1	0.68	4.4	1.25	28.55
	Marshy/ Grass	0	19.3	18.89	1.17	12.09	3.31	1.94	31.08	87.77
	Class Total	7.09	250.2	336.9	62.91	422.97	91.65	30.93	93.46	1296.12

Source: 1984 and 2000 land cover/ Land Use Classification Map

4. 2.3.2 Areal Extent and Rate of Forest Cover Change

Assessment of forest cover change was done using remote sensing and GIS techniques with the integration of field survey. In this study, three Landsat satellite images (see table 2) were used to monitor the areal extent and rate of forest cover change with in time sequence. During the analysis stage, digital image interpretation of forest cover area for each year was performed and total area of the forest cover in terms of ha and its percentage from each date of satellite interpretations were computed and summarized. Figures from 14 to 16 and table 8 revealed that the pattern of forest cover changes between 1973 and 2000.



*Fig. 14: Forest Cover Map of Dendi District, 1973
Source: Derived from 1973 Land Cover /land use Map*

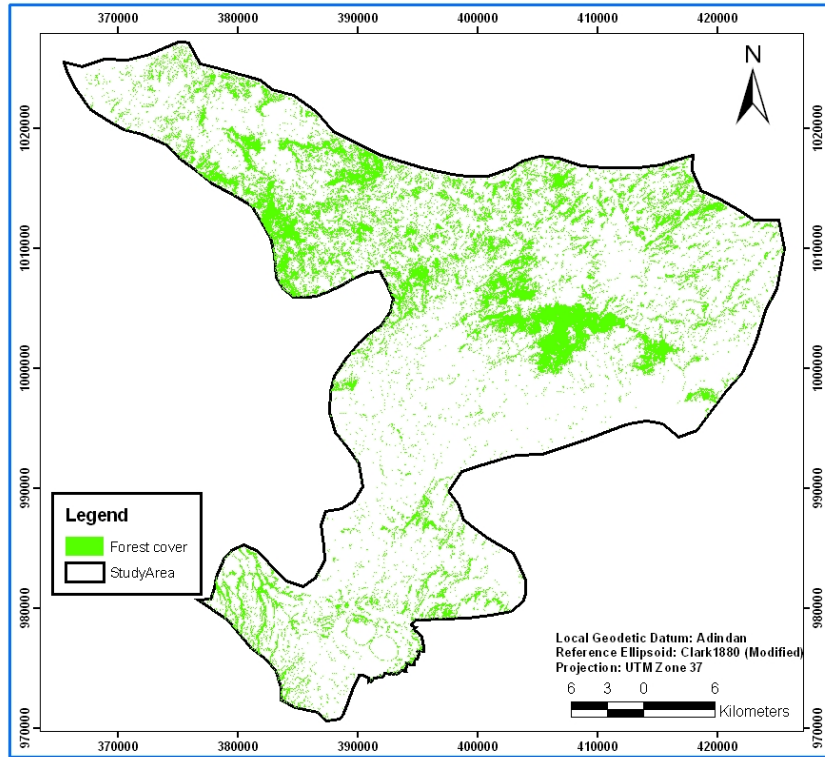


Fig. 15: Forest Cover Map of Dendi District, 1984
Source: Derived from 1984 land Cover/ land use Map

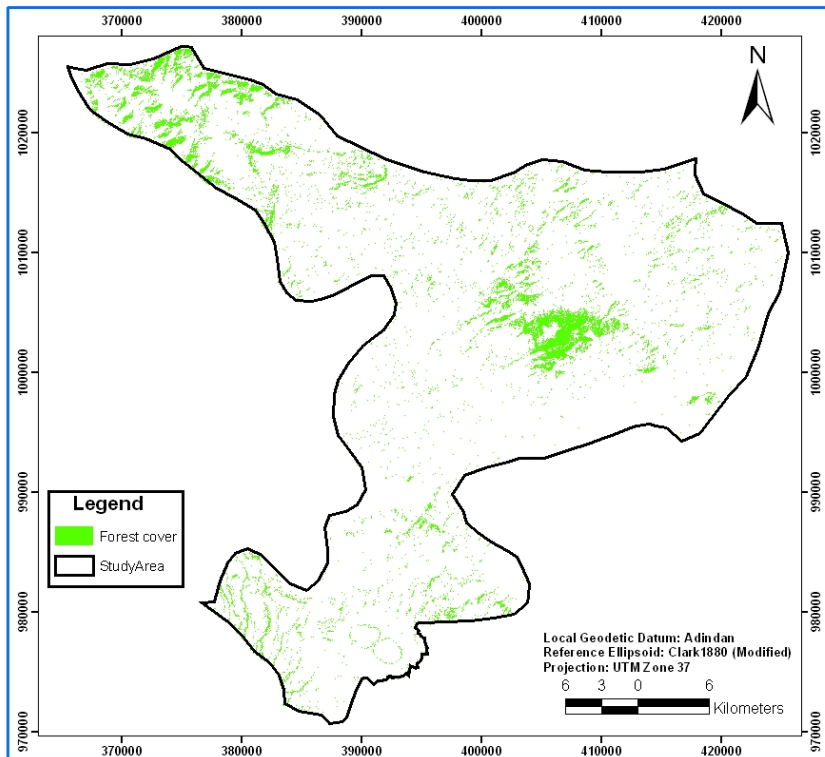


Fig. 16: Forest Cover Map of Dendi District, 2000
Source: Derived from 2000 land Cover/ land use Map

Table 8: Total Forest Covers Land Area of Dendi District; 1973, 1984 and 2000.

Year	Forest Cover unit from the total area (in ha)	Forest Cover In %
1973	26363	20.33
1984	25020.4	19.3
2000	7629.38	5.89

Source: Computed from table 5

From this result, about 26,363 ha of the district were covered with forest resource in the year 1973. Meanwhile, the forest cover land of the district was accounted for 25,020.4 ha and 7,629.38 ha in the year 1984 and 2000 respectively. The percentage share of each year forest cover value and with its diminishing trend is presented in fig.17.

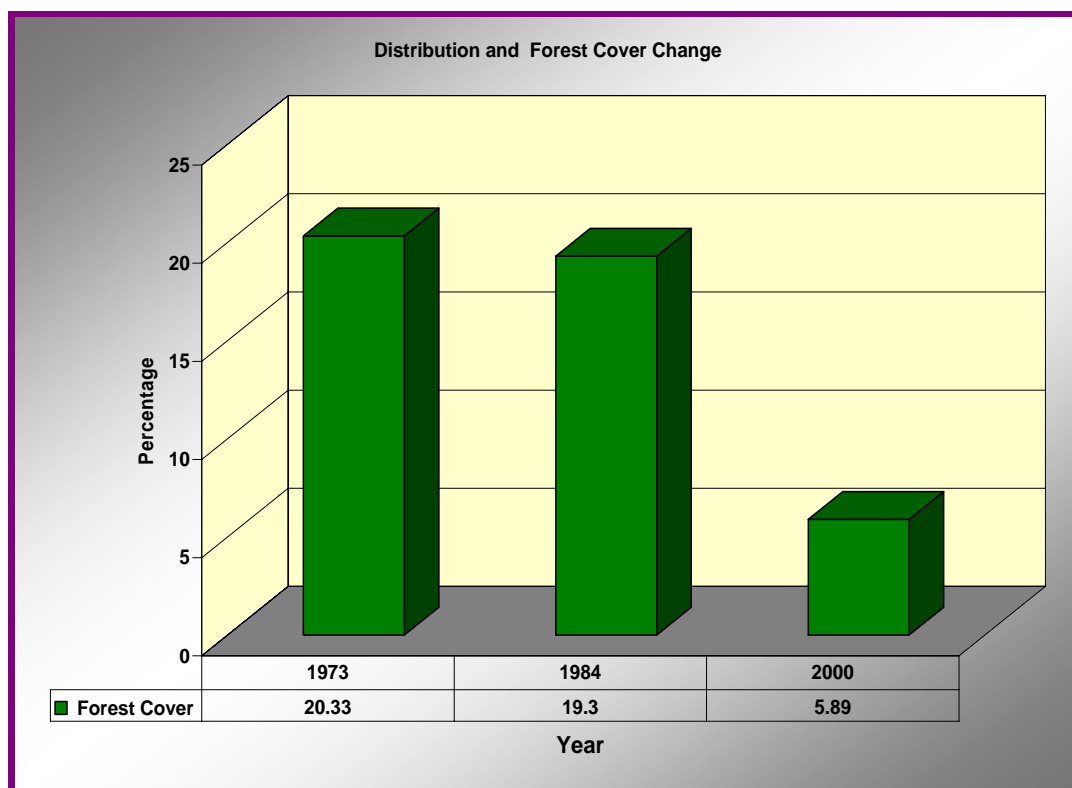


Fig. 17: Distribution of Forest Cover with percentage value in Dendi District; 1973, 1984 & 2000
Source: Computed from Table 8

In the year 1973, 20.29 % of the district was covered with forest resources while from the total area of the district about 19.3 % was covered with forest resources in 1984. In the

mean time, this figure turned down in to 5.89% in the year 2000. Based on this data, the rate of forest cover change also computed and its results presented in table 9.

Table 9: Trends and Rates of Forest cover change In Dendi District

Cover Classes	Years			Rate of Change		
	1973	1984	2000	1973-1984	1984-2000	1973-2000
Forest Cover & Loss in ha	26363	25020.4	7629.38	-122.05	-1086.94	-693.84

Source: Computed From Table 8

The computed result (table 9) shows that the average rate of forest cover change from year 1984 to 1973 is -122.06 ha per year (25020.4 ha –26363 ha / 11 years) and from year 1984 to 2000, it was -1086.94 ha annually (7629.38 -25020.4 ha/ 16 years). Besides, considering the annual rate of forest cover change between 1973 and 2000, the computed result is -693.84 ha per year (7629.38-26363/27).

4.2.3.3 Patterns of Forest Cover Change

The pattern of change from forest cover to other land cover land use units between in the year 1973 and 2000 is presented in table 10. The result indicates the areal distribution of forest cover lands and also gives information about what proportion of forest cover land changed in to other land cover and land use units in the indicated time period.

Table 10: Patterns of Forest Cover Change in to Other Land Cover/ Use Unites

Forest Cover Change	B/N 1973 & 1984		B/N 1984 & 2000	
	Area(in ha)	Percentage	Area(in ha)	percentage
Forest to Water	35	0.27	17	0.09
Forest to shrub	5460	41.88	2636	13.71
Forest to Built up	577	4.43	355	1.85
Forest to Crop cover	5761	44.19	13532	70.39
Forest to Fallow Land	589	4.52	643	3.34
Forest to Grass land	123	0.94	112	0.58
Forest to Marshy/grass	492	3.77	1930	10.04
Total change	13037	100	19225	100

Source: Computed from Change Matrix Table 6 and 7

Based on the computed results (table 10), 13,037 ha of forest cover land are converted into other land cover and land use units between 1973 and 1984. Specifically, about

48.9% of the forest cover is changed into cultivated land (crop cover and fallow land) followed by forest cover to shrub lands (41.9%). The remaining 3.77%, 4.43%, 0.94% and 0.27% of the forest cover land is converted into Marshy/grass cover, built up-area, grass land and water respectively.

From the 1984 and 2000 forest cover conversion summary out put, 19,225 ha of forest cover land is changed in to other land cover units. The conversion of forest land to cultivated land takes the lion share, about 73.73%. The remaining 26.27% of the forest land is converted into other land cover/use units such as to water bodies, built up areas, shrub lands, grass lands and marshy with grass cover(see table10).

4.2.3.4 Forest Cover Change with Respect to Slope and Elevation

Forest cover change processes in relation to landscape attributes have a certain importance to characterize the forest cover land of the area in relation with the various slope and elevation classes. It is also fascinating to see the distribution of forest cover land of the area and to investigate its changes along with slope as well as elevation classes.

Table 11: Areal Coverage of Forest Cover Units by Slope Class at Dendi District; in 1973, 1984 & 2000

Slope In Degree	1973 Forest cover(in ha)	%	1984 Forest Cover (in ha)	%	2000 Forest cover (in ha)	%
< 3	3067.71	11.64	2754.43	11.01	425.34	5.58
3-8.	66.6	0.25	39.05	0.16	0.63	0.01
8-13	1946.62	7.38	1525.2	6.1	4.95	0.06
13-18	1360.36	5.16	1281.88	5.12	94.95	1.25
18-25	7135.5	27.07	7103.36	28.39	1014.21	13.29
25-33	10065.93	38.18	9656.81	38.6	3836.71	50.29
33-56	2672.63	10.14	2613.11	10.44	2220.5	29.1
>56	48.41	0.18	46.56	0.19	32.09	0.42
Total	26363	100	25020.4	1000	7629.38	100

Source: Computed From the 1973, 1984 & 2000 Forest Cover Maps and slope Class Map

The spatial distribution of forest cover across slope class is different between the years. When the slope gradient increases, the areal coverage of forest cover of the three dates of interpretation also increases (table: 11). In 1973, from the total forest cover land (26,363 ha) about 51.5% was found to be in the slope gradient less than 25⁰. Besides, roughly the

same amount of forest cover (50.1%) also found in the year 1984 with slope value less than 25°. On the contrary, based on the year 2000 interpretation, from the total forest cover of the district (7,629.38 ha) only 20.19% of the study area is covered with forest resources having the gradient of less than 25° and the remaining 79.81% of the forest cover was found in areas having slope gradient greater than 25°. In addition to this, the years 1973, 1984 and 2000 forests cover land of the district also analyzed along with the district's elevation range.

Table 12: Areal coverage of Forest Cover Units by Elevation Class at Dendi District; in 1973, 1984 and 2000

Elevation (in M)	1973		1984		2000	
	Area (in ha)	%	Area (in ha)	%	Area (in ha)	%
1440-1687	1355.92	5.14	693.08	2.77	17.67	0.23
1687-1888	3520.18	13.35	1391.9	5.56	503.21	6.6
1888-2114	794.07	3.01	424.35	1.7	109.17	1.43
2114-2349	1717.29	6.51	1324.62	5.25	318.96	4.18
2349-2550	4277.79	16.23	3968.01	15.86	677.43	8.89
2550-2761	6170.95	23.41	6240.33	24.94	3023.56	39.63
2761-2929	5667.42	21.5	6818.58	27.32	2024.94	26.54
2929-3260	2859.49	10.85	4159.57	16.6	953.78	12.5
Total	26363	100	25020.44	100	7628.38	100

Source: Computed From the 1973, 1984 & 2000 Forest Cover Maps and Elevation Map

The distribution of forest cover land unit along with elevation variation is investigated in the present study. In the year 1973, from the total forest cover area of 26,363 ha, about 44.24% was found below the elevation 2,550m and the remaining 55.76% was found above 2,550m. Furthermore, in 1984 from 25,020.44 ha of forest cover land, 31.14% and 68.86% was found with elevation less than 2,550m and above 2,550m respectively. Moreover, from the remaining 7,628.38 ha of forest cover found in the district in the year 2000, about 21.33% found below 2,550m. The remaining 78.67% is found above the reference elevation boundary line.

In summary, two different techniques namely NDVI change detection analysis and post classification comparison change detection methods are used for forest cover change detection assessment. To begin with, the visual comparison analysis of the two NDVI maps (Fig.8 and 9) shows that there is a dwindling of vegetation biomass coverage in the

study area from in 1984 to 2000. This argument is supported by the standard deviation value of NDVI analysis which indicates 0.145 in 1984 and 0.122 in 2000(table 4).

In addition to this, post classification comparison change detection method is employed to investigate forest cover change. Based on this method, there is a good understanding about the state of land cover/land use units in general and forest cover land in particular at Dendi District. In the year 1973, the vegetation cover of the area was higher than that of non-vegetated areas such as crop fields; water bodies, grass lands and built-up areas. Roughly, vegetation cover of forest lands and shrub lands covered 51.43% of the total area of the district. But starting from the year 1973 to 2000 the proportion of vegetation cover mainly forest cover land was kept on declining. The main reason for the decline is considered to be the conversion of forest cover land to cultivated fields. In this change quantified result, the rate at which the forest cover was highly depleted. This is because in one way or the other way, this cover class had been the important source of change, to the other land cover and land use types. Besides, the annual rate of forest cover change between 1973 and 2000 is -693.84 ha per year. This result strongly confirmed that there is an increasing trend of the rate of forest cover depletion in the study area.

More over, with respect to slope and elevation, the amount of forest cover change process is so significant along with areas having a gradient of less than 25° and elevation values of below 2,550 m. Thus, this output indicated that forest cover found relatively in gentle slope terrain and areas having an elevation of less than 2,550m, is being easily converted in to other land cover / land use units. This condition is also observed during field visit (Plate1) and it can be argued that currently the forest cover land of the district is marginalized in to inaccessible steep slope areas, Church compounds and isolated hills. Hence, the problem of forest cover change as well as destruction of forest resource is a decisive problem in Dendi district.

4.3 Susceptibility to Forest Degradation

4.3.1 Driving and Standardizing Datasets

Susceptibility to forest degradation mapping of the study area is one of the major objectives of this study. So that, the result of this section is developed for answering

research question 5: *Where are areas of different susceptibility to forest degradation at Dendi district?* As indicated previously to analyze forest degradation susceptibility problem, MCE with the techniques of weighted overlay and combination procedure was performed. Then, the derived raster data sets and reclassified raster maps are:

4.3.1.1 Analysis Masking Layer

A masking layer serves to limit the alternatives under consideration. Masking layer identifies those cells within the analysis extent that will be 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 2000 forest cover map is 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.

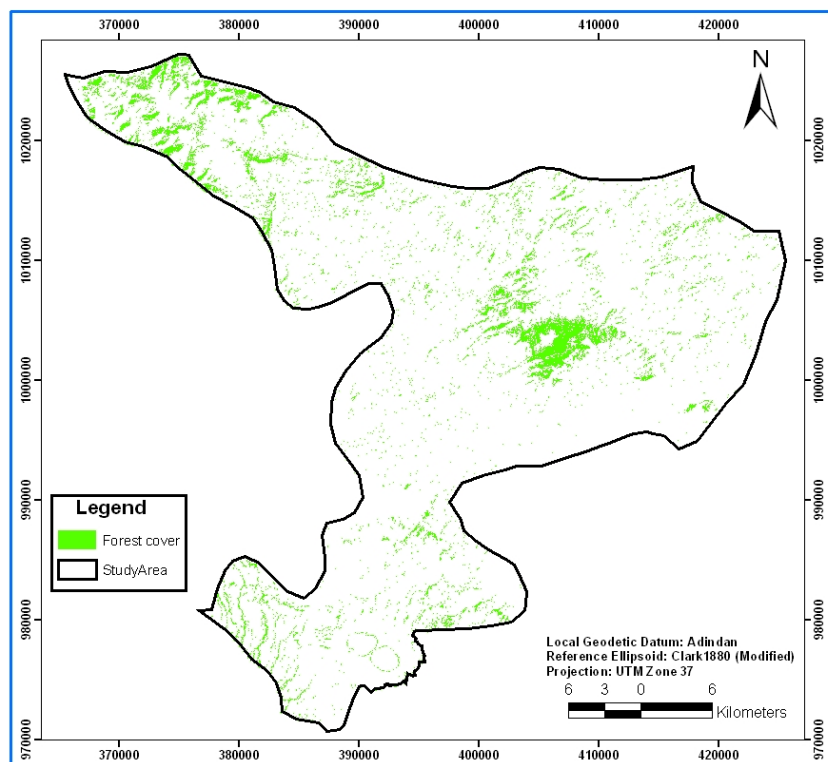


Fig. 18: Forest Cover Raster Data layer, 2000 Condition
Source: Derived from 2000 Land Cover/Land Use Map

4.3.1.2 Slope Value Dataset

The slope nature of the area is considered to be one of the factors affecting the susceptibility to forest resource degradation. Generally, forest degradation decreases

away from relatively gentle slope gradient to steep slope. The out put slope dataset of high values (24° - 82°), shaded with red color on the map represents steep slope areas. On the contrary, the blue color shading areas depicts those areas having relatively gentle gradient, less than 3° (fig.19) In the mean time, after settling and standardizing slope dataset, it is reclassified using forest cover raster dataset as analysis masking layer and prepared as input factor map for MCE. From the output reclassified slope dataset map (fig.20), the forest cover areas shaded with red color (located in gentle slope areas) are more susceptible to forest degradation than forest cover areas shaded with blue colors.

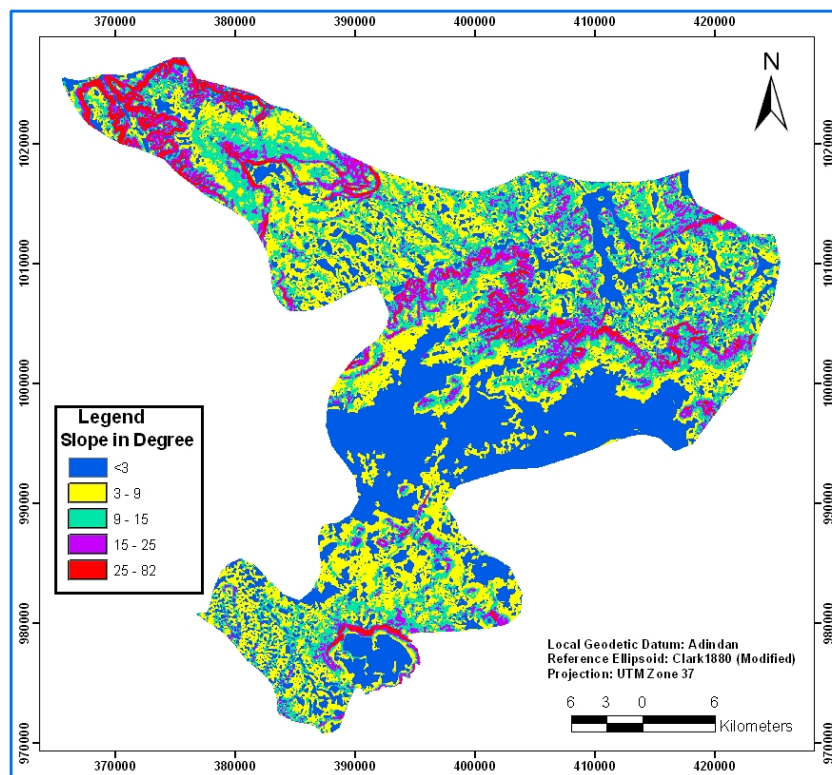


Fig. 19: Slope Factor as Raster Dataset

4.3.1.3 Cultivated Land Proximity Dataset

The crop cover and fallow land categories map were generated independently from the year 2000 land cover/ land use map and finally merged together to consider as independent dataset for susceptibility to forest resource degradation analysis (fig.21). Then this data is standardized and reclassified to run MCE.

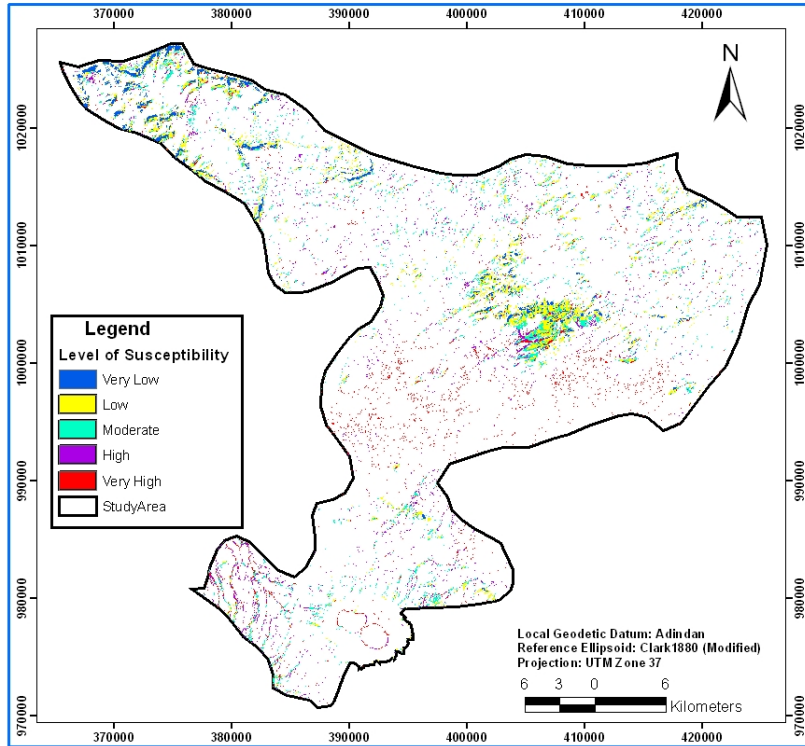


Fig. 20: Reclassified Slope Factor Using Forest Cover as Analysis Masking Layer

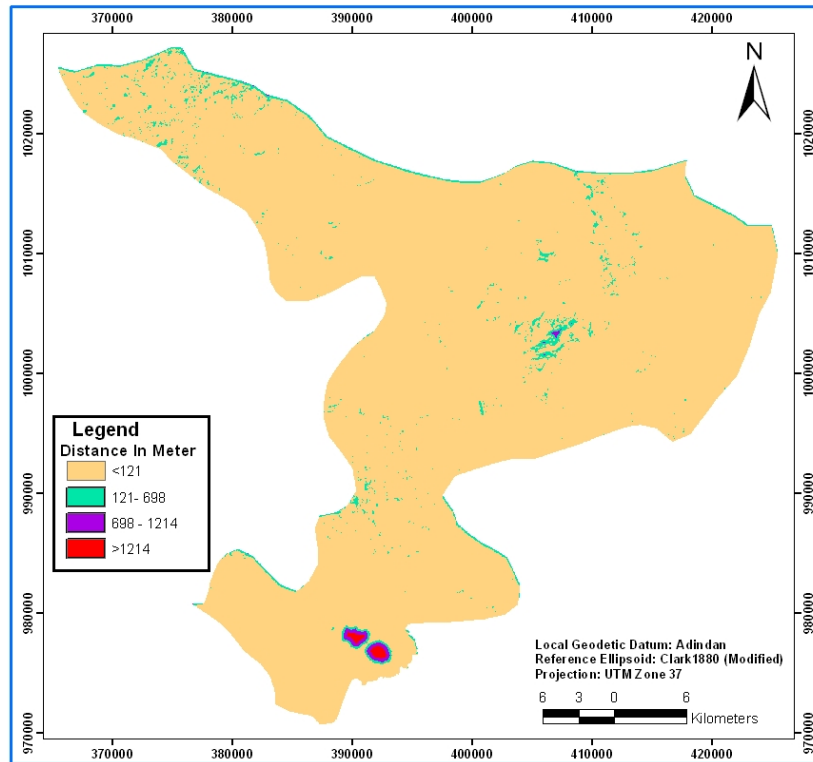


Fig. 21: Cultivated land Proximity Factor as Raster Dataset

Later on, the cultivated land raster data layer is reclassified using forest raster dataset as analysis masking layer and straight line distance is calculated to characterize susceptibility to forest degradation (fig.22).

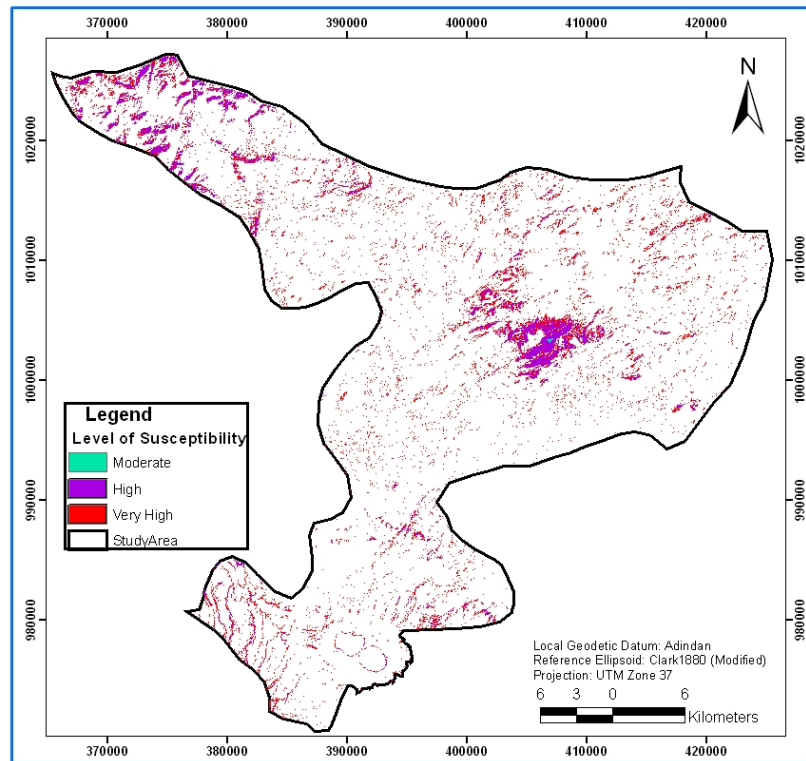


Fig. 22: Reclassified cultivated land Factor using Forest Cover as Analysis Masking Layer

From the reclassified cultivated land, forest cover areas found along the margin of cultivated land is highly susceptible to degradation. On the contrary, forest areas far away from cultivated land; relatively have low degree of susceptibility value.

4.3.1.4 Town Proximity Dataset

Like slope and cultivated land factor maps, proximity to town dataset also rasterized and standardized (fig.23) in order to reclassify and to characterize the future susceptibility to forest degradation problem in the study area. The reclassified town proximity raster map using forest cover as analysis masking layer is presented in fig.24 and from this reclassified town proximity dataset, the forest cover land shaded with red color is highly susceptible to degradation than the forest cover found far away from town location.

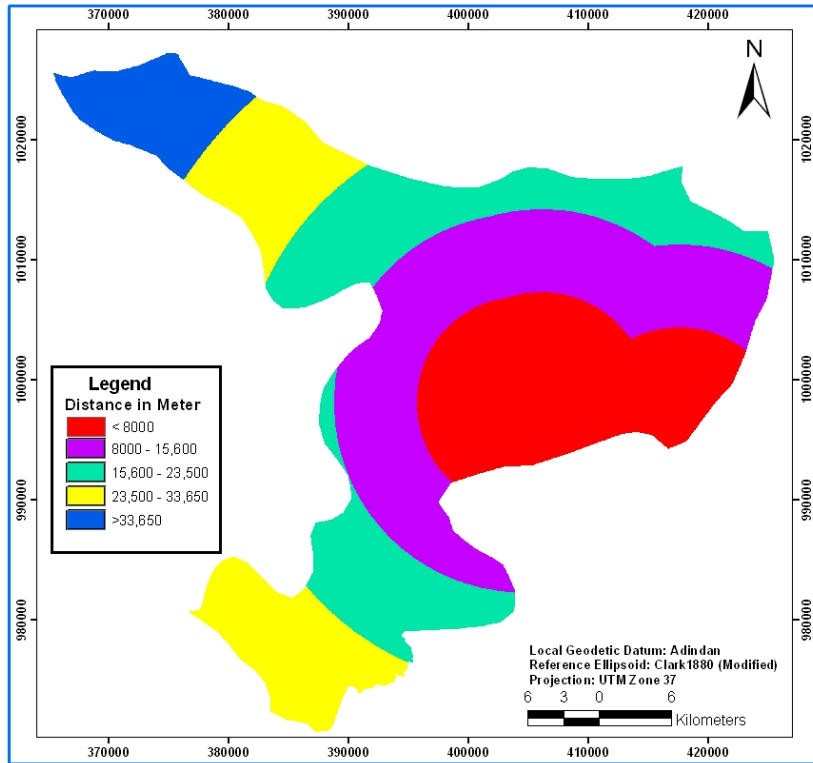


Fig. 23: Town proximity Factor as Raster Dataset

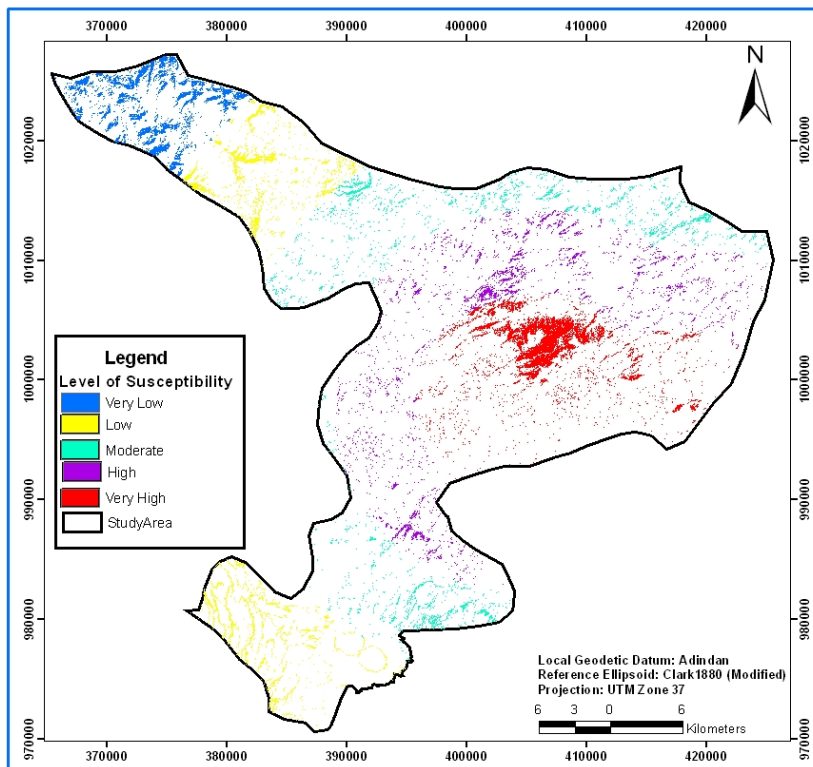


Fig. 24: Reclassified Town proximity Factor using Forest Cover as Analysis Masking Layer

4.3.1.5 Road Proximity Dataset

It is essential to characterize the forest cover condition of the district and its future susceptibility in relation to road proximity. Then, road distance raster dataset is derived (fig.25). Consequently, the road raster data layer is reclassified to analyze and determine the degree of susceptibility to forest degradation in relation with road proximity. From the reclassified road proximity dataset (fig.26), forest cover areas having low distance value (shaded with red color) from road network location are highly susceptible to degradation than those located far away from road networks.

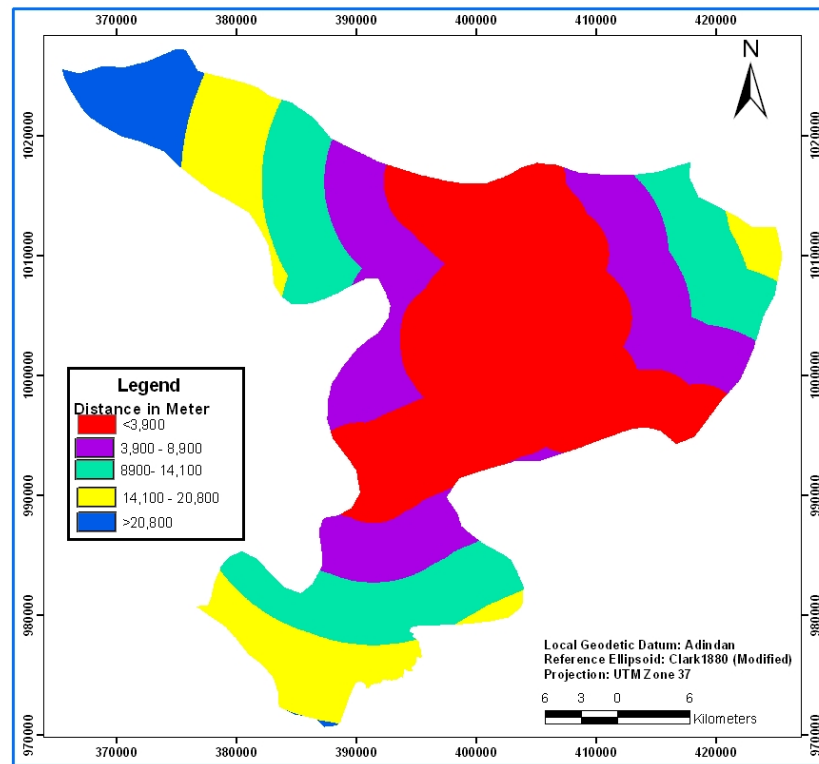


Fig. 25: Road Proximity Factor as Raster Dataset

4.3.1.6 Elevation Value Dataset

The elevation criterion dataset is rasterized and standardized to evaluate the degree of susceptibility to forest cover change using this dataset (fig.27). Later on, the rasterized dataset is reclassified (fig.28) by using forest cover raster data layer as analysis masking layer to correlate the existing forest cover with the future forest susceptibility to degradation. Then, from the reclassified elevation dataset, the forest cover areas found at relatively lower elevation (shaded with red color) is highly susceptible than those forest cover areas found at higher altitude.

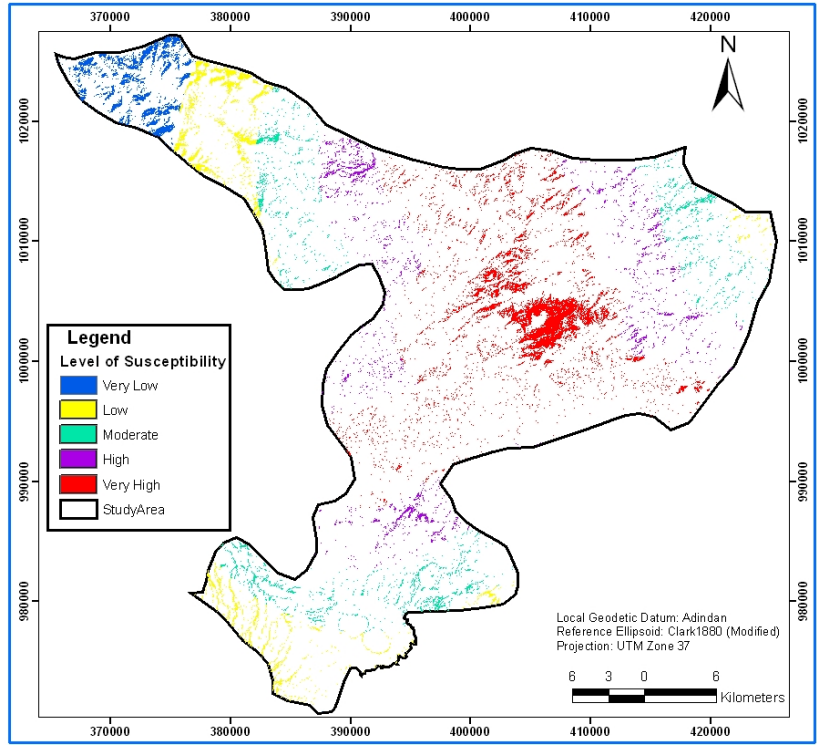


Fig. 26: Reclassified Road proximity Factor Using Forest Cover as Analysis Masking Layer

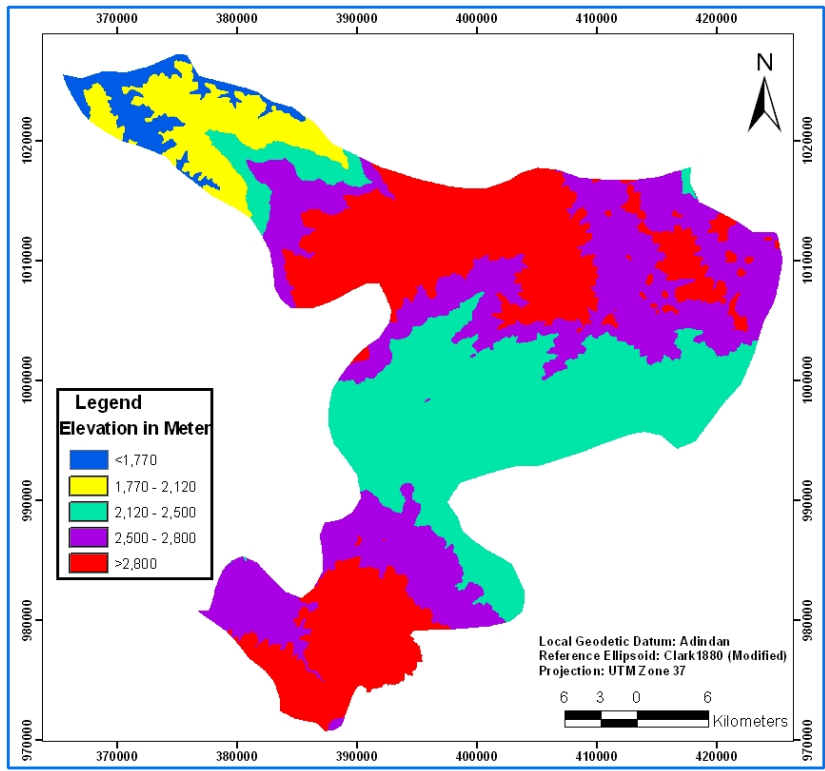


Fig. 27: Elevation Value Factor as Raster Dataset

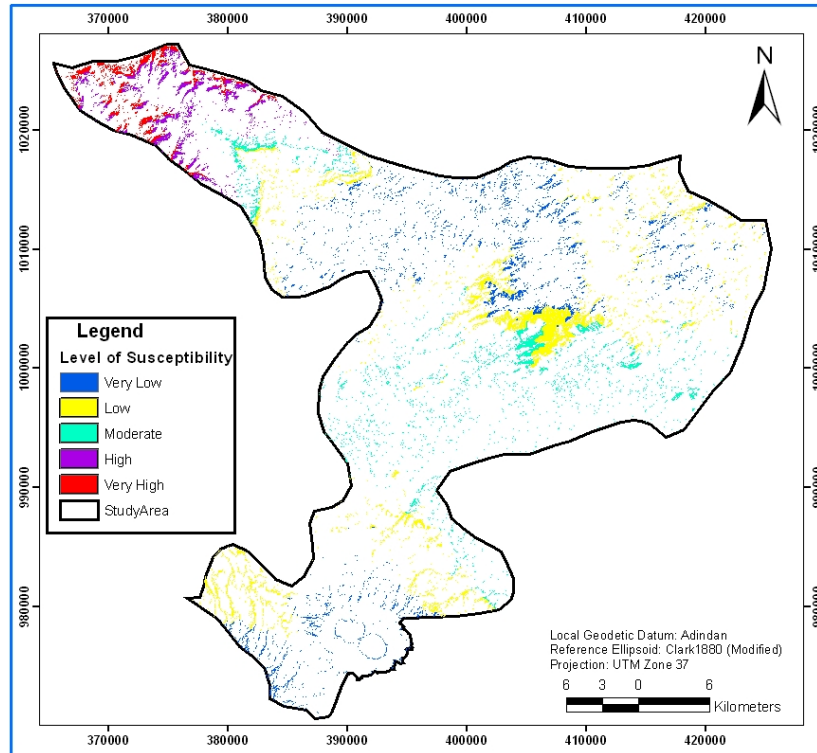


Fig. 28: Reclassified Elevation Value Factor using Forest Cover as Analysis Masking Layer

To sum up, after reclassified the five factor maps, the areal coverage summary statistics (in ha) and its percentage share based on the five level of susceptibility to forest degradation was derived (see appendix IV).

4.3.2 Weight of Factor Maps

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 is for the slope dataset followed by the cultivated land proximity, town proximity, and road proximity and elevation value dataset.

The final combined result gives susceptibility to forest degradation maps of the study area. Based on the Pairewise Comparison method, the Eigen vector ratio matrix of the weight is calculated for all layers (Fig.31). The consistency ratio was also calculated (Fig.32) that shows if the given pair-wise weights are accepted.

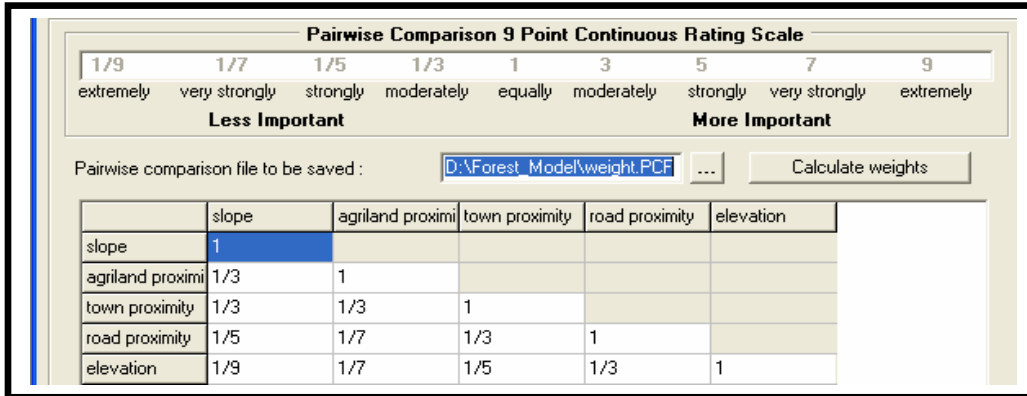


Fig. 29: Weight of Factors that Aggravates Forest Degradation Process in Dendi District

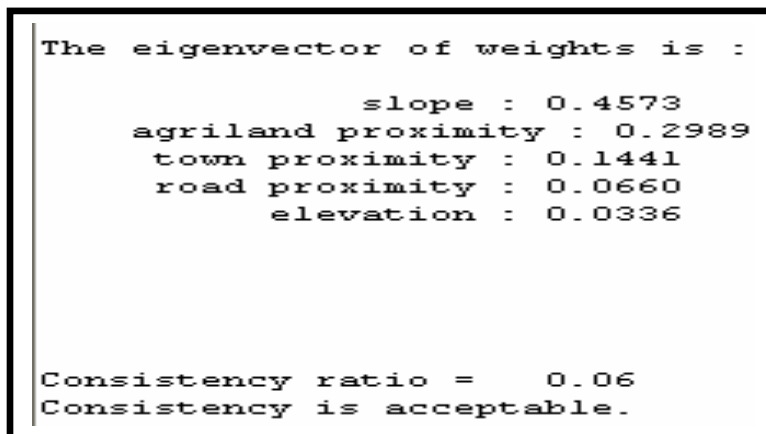


Fig.30: Eigenvector Ratio Matrix That Gives Weight for Each Factor

4.3.3 Multi-Criteria Evaluation

After the input raster datasets are reclassified to a common measurement scale using the Reclassify tool a scale, of 1 to 5 (1 being least susceptible and 5 being highly susceptible) and an evaluation scale of 1 to 5 by 1 entered for the evaluation scale in the Weighted Overlay dialog box, MCE analysis is employed.

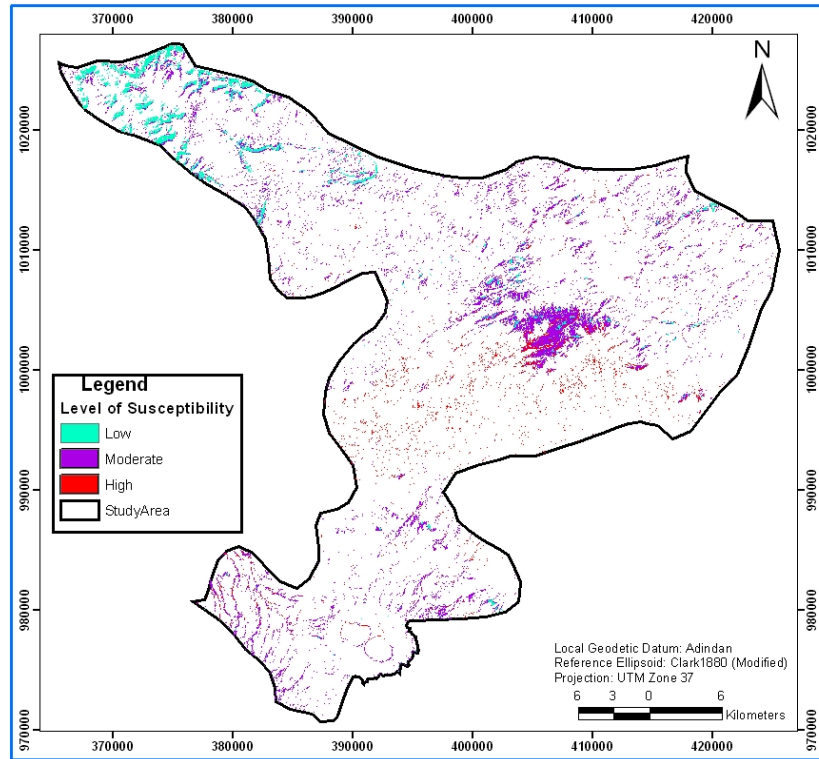


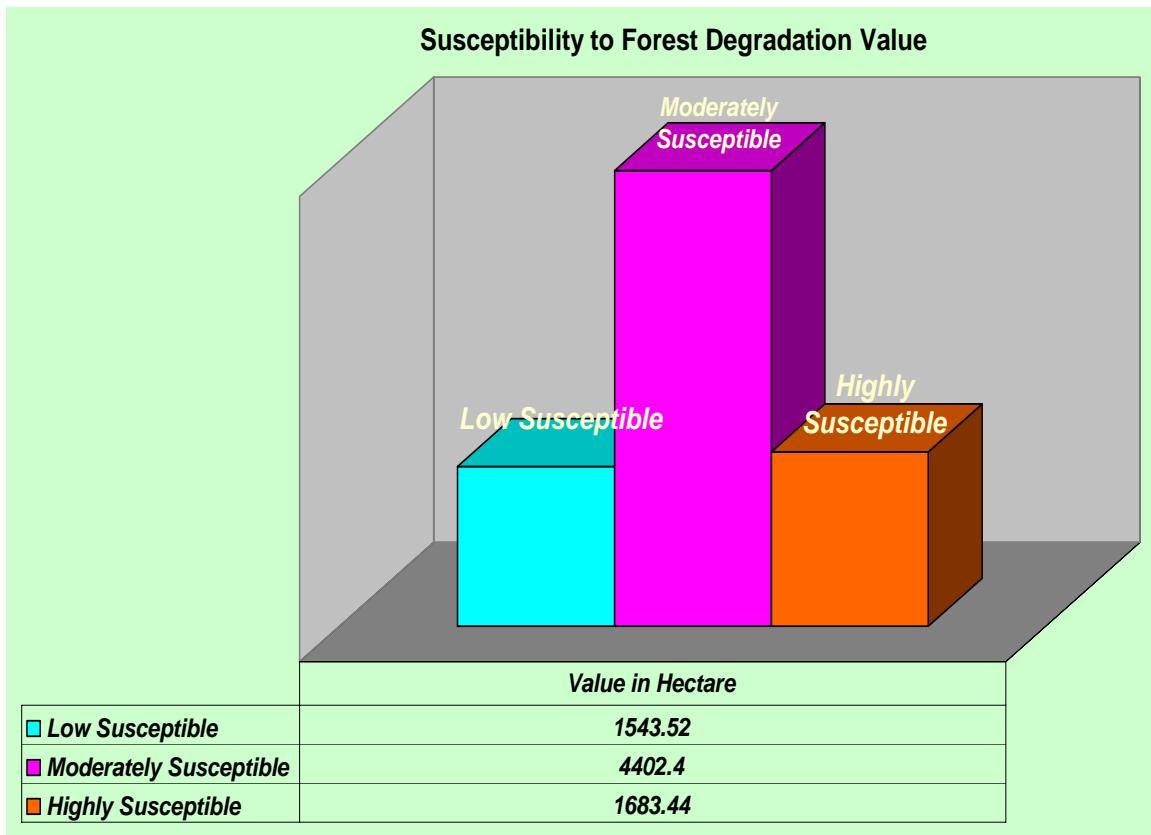
Fig. 31: Map of Forest Compartments with Different level of Susceptibility to Forest Degradation

After over laying and combining the entire reclassified maps (slope value map, Proximity to cultivated map, Proximity to town map, proximity to road map and elevation value map), the weighted over lay analysis techniques was processed and forest compartment with three level of susceptibility to forest degradation map was generated. The three categories are highly susceptible (shaded with red color), moderately susceptible (shaded with Purple color) and low susceptible (shaded with cyan color).The areal coverage value of the three level susceptibility to forest degradation categories are presented in table 13 and figure32.

Table13: Areal coverage of the three level of susceptibility to forest Degradation, In Dendi District

Level of Susceptibility	Area (in ha)	Percentage
Low	1543.52	20.23
Moderate	4402.4	57.7
High	1683.44	22.07
Total	7629.36	100

Source: Computed from Figure 31 Map



Figuer32: Hectareage Distribution of Susceptibility to Forest Degradation Value in Dendi District.

Source: Computed from Table 13

To sum up, based on the total forest cover areas of the year 2000 (7,629.38 ha) of Dendi District about 1,543.52 ha of forest cover land is categorized under low susceptible to degradation. On the other hand, 4,402 .4 ha and 1,683.44 forest cover lands are considered to be moderately and highly susceptible to forest degradation respectively.

5. Causes and Impact of Forest Cover Change

5.1 Causes of Forest Cover Change

Forest cover change is triggered by various factors that undermine the forest cover potential and its productivity and leading to irreversible deterioration. Besides, forest cover change is the direct reflection of the dynamics of socio-economic development. Regarding this, Burton, (1994:288) states that the complex nature of human activities has had a tremendous impact on modern forests and large forest areas have been cleared for various reasons since agriculture began about 11,000 years ago. Like wise, several factors stimulated by the activity of man are responsible for massive conversion of forest cover land into other land cover and land use units in Dandi District. For the purpose of clarity in the present study, the factors have been grouped into population growth and its resultant effects such as the prevalence of various types of agricultural activities, fire wood and charcoal production, cutting trees to fulfill the demand of constructional materials, settlement expansion and income generation (table 14).

I. Population Growth

As it has been explained in chapter three, Dendi District is attracting a lot of people because of its favorable climatic condition. The population is almost enlarged from 152,985 (1996) to 256,896 (2005). Population growth is the major factor which affects forest resources in the study area. The forces behind in the forest cover change problem are partly population pressure as well as increased demand of various types of forest product such as fuel wood, building poles and making furniture as well as to obtain adequate agricultural lands. Based on the view of informants and field observation data, due to the alarming increase of the demand of forest products, both the natural as well as plantation forests which are grown in the district have been seriously depleted.

Table 14: Views of Respondents Regarding on Reasons for the Decline of Forest Cover

Change in Dendi district

Perceptions	Agricultural officers		FWCs		Household Heads		Total	
	No.	%	NO.	%	NO.	%	No.	%
Expansion of Agricultural Lands	4	50	1	8.3	17	56.67	22	44
Fire wood and Charcoal production	2	25	4	33.3	8	26.67	14	28
Demand of Constructional materials	-	-	1	8.3	3	10	4	8
settlement Expansion	2	25	-	-	-	-	2	4
Income Generation	-	-	6	50	2	6.66	8	16
Total	8	100	12	100	30	100	50	100

Source: 2006/7 Field Data

Discussion with (Agricultural officers, Female Wood Carriers (FWCs) and Household Heads) summary report , revealed that the leading causes of forest cover change in Dendi District is expansion of agricultural activities and followed by fire wood and charcoal production, demands of constructional materials, settlement expansion and income generation.

II, Agriculture Land Expansion

“In the developing world, increasing population size has two-fold impact on the forest resources. On the edges, sedentary cultivators are nibbling away in order to create more land to grow food, while in the forest itself the expanding numbers of shifting cultivators are forced to shorten rotations, leading to permanent change (Williams 1994:11)”. This argument confirmed that man’s habitual abuse of the precious forest resource knowingly or unknowingly for immediate economic use (mainly to secure ample cultivated lands) by ignoring the facts of their ecological as well as environmental values is the major causes of forest cover change. This is manifested over exploitation of forest resources through the process of deforestation.

As discussed in the previous sections, the agro-ecological conditions of the district are convenient for agriculture. It has also been noted that agriculture is the major livelihood of the study area population. 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 district. Most of the farmers in the district rear livestock and want to maintain larger numbers with little care for their quality. According to the informants, the larger number of cattle population in a given family is both a source of wealth and status. Indeed, this mental attitude is not limited to the study area and is prevalent through out Ethiopia. In this regard, Ermias (1994:1) rightly put it as *“Ethiopia has a very large number of livestock resources. She ranks first in Africa and 10th in the world, but the quality of the live stock is very poor”*.

Table 5 indicated that there is an increasing of cultivated land from 35,968.7 ha in 1973 to 88,949.2 ha in the year 2000. The implication of increased cultivated land interms of areal coverage means other land cover/land use units have been converted into cultivated lands. For instance, between 1973 and 2000, about 20,525 ha forest cover land is drastically changed into agricultural lands (both crop cover and fallow land) (fig.10). In addition to this, according to the views of respondents (44%), the expansion of various types of agricultural activities is the major sources of forest cover change in the study area. Therefore, the presence of peasants with their various types of agricultural activities (both crop production and livestock rearing) inside and along the margin of the district’s forest cover land is considered to be the major factor for forest cover change in the study area.

III. Fire wood and Charcoal Production

As indicated in the literature review part, as much as 93% of Ethiopian energy supply comes from biomass, with one-thirds of all the energy being derived from wood and charcoal. In this regarded, the Ethiopian Forestry Action Program (1994) estimated that in 1990/91 Ethiopia consumed about 15 million tons of energy, of which 95% was wood, dung, crop residue and charcoal. More specifically, the majority of the people in Dendi District are also depending on fuel wood as a source of energy (plate3).



Plate 3: Loges of Trees which have been Felled for Fire wood Production from the near by Chilimo – Gaji Forest Reserve area and Ready for selling along Ginchi_Jeldue Road, in Dendi District (photo by Berhan, December, 2006)

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 informants over the recent years fire wood is commercialized as its demand has increased particularly in those areas which are devoid of trees and in the urban areas of the district. Besides, the district is the core supplier of charcoal and fire wood to both Ginchi and Welenkomi town (found in the District) and some amount of charcoal is even transported all the way to the near by urban areas mainly to Ambo town as well as Addis Ababa city by illegal charcoal makers. More over, 28% of the respondents identified fire wood and charcoal productions are one of the major causes of forest cover change. Hence, the increasing demand of forest products, in the form of fire wood and charcoal with in and outside the district has been causes of deforestation in Dendi district.

IV. Cutting Trees for Constructional Materials

The demand of forest products for the construction of house and fence has been aggravated the destruction of forest in Dendi District .From the respondent s' point of view about (8%, table14); it was evident that cutting trees to fulfill the demand of constructional material is considered to be the causes of deforestation in the district. Field observation data also indicated that woody biomass (plate 4) was found to be the single most important house construction material in the district.



Plate4: Poles of Trees which have been Felled from the near by Forest Areas and ready to sell for the purpose of House as well as Fence Construction, in Ginchi Town (Photo by Berhan, December, 2006)

V. Income Generation

According to, the view of agricultural officers most of the population of the district are poor and exposed for lack of adequate access to basic needs (such as food, clothing and shelter). However, huge proportions of Dendi districts dwellers are engaged in different activities to supplement their living condition. Selling of wood and wood products are traditional way of working activity for the poorest people such as jobless youths and women fuel wood carriers who are living in the district as well as inside the forest area. 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 are carried by a number of people from different direction of forest areas towards Ginchi and Welenkomi towns.

V. Settlement Expansions

In addition, between the year 1973 and 2000 about 932 ha of forest cover land was converted in to built-up land use units (see table 10). Hence, settlement expansion is considered to be one cause of forest cover changes in the district.

5.2 Impact of Forest Cover Change

Currently people depend on forests more than ever, 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 with no shadows of doubt. Likewise the major environmental problems in the study area, which are resulted from forest cover change such as increased land degradation, soil erosion, run-off and flooding as well as deteriorating of bio-diversity, are discussed here under in the following paragraphs.

I. Land Degradation with Soil Erosion

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 (Markos and Delnessaw, 1998). 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 (Markos and Delnessaw 1994).

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 Dendi District reflects this reality if not typical example of excessively degraded. As it has been stated in the previous chapter, the relief feature of Dendi District is rugged with wide range of altitudinal variation (ranges from 1440 to 3260m). This rugged nature of topography coupled with removal of vegetations and high amount of summer rain fall (see appendix IV) results in greater soil erosion.





Plate 5: Erosion Features (A and B), which leads the Continuation of Intense Land Degradation, near Boda Village, South of Ginchi Town in the study area. (Photo by Berhan, December, 2006)

II. Run-off and Flooding

Forests help to conserve and enrich the environment in several ways. For example, forest soils absorb large amount of rainfall, thus, it prevents the rapid runoff that can cause erosion and flooding .Besides, rain is filtered as it passes through the soil and become ground water flows and provides a clean source of water for streams, lakes and wells (WBE,1994:391).However, according to the view of agricultural officers of Dendi District, the study area due to topographic features and the problem of forest destruction, this vital roles of forests is strongly disrupted and runoff and flooding is intense during rainy season.

To begin with, the steepness of slope is the major topographic features that influence the nature of runoff. As it has been explained in chapter three, the physiographic nature of Dendi District area is predominated by high land and undulating landscape. This has a great effect on the nature of runoff and flooding. Therefore, in the wet season especially in June, July, August and September, this rugged topography of the study area facilitates the degree of runoff. Furthermore, the degree of runoff is intense in the study area due to removal of vegetation cover. As a result, flashfloods during the rainy season are common, thus destroying the up stream landscape and silting the down stream areas. This situation is directly or indirectly the result of forest cover change.

III. Declining Bio- Diversity

As it has been stated previously, the geographical setting of Dendi District has a diverse and conducive ecological condition due to its wide range of altitude and relatively high amount of rain fall. As a result of this, the district was originally the land of many indigenous tree species such as Juniperus procora, Olia africana, Acacia abyssinica, Acacia nugri, Hagenia abyssinica and other valuable tree species to name but a few. However, one of the known indigenous tree species, for instance, Hagenia abyssinica (Plate 6), is over exploited due to selective cutting and currently confined only in few inaccessible areas such as church yards and at the hilly lands of Chilimo-Gaji Forest reserve areas.



Plate6: Hagenia abyssinica an Endangered Indigenous Tree species, Found in Chilimo- Gaji Forest Reserve Areas of Dendi District (Photo by Berhan, December, 2006)

This clearly shows that the exploitation of indigenous forests through selective tree cutting greatly affects the biological diversity of Dendi District. In Addition, according to the interview made with elders various types of wild animals who used to inhabit the locality has now disappeared due to devegetaion of the area. Generally, the major consequence of forest cover change in the study area is land degradation with associated variables such as soil erosion, rapid runoff and deteriorating of biodiversity.

6. Conclusion and Recommendation

6.1 Conclusion

Forest cover change in the form of degradation as well as deforestation is a major environmental problem manifested at Dendi District. The case study as presented in the current research is a vivid example of how rapidly the forests are disappearing in the District. Now a days, the situation at Dendi shows that extensive areas of forestland have been completely deforested while some areas of the forest cover land has been considerably degraded. Many of the forestland areas have been converted into cultivated land or grassland with a few scattered trees and shrubs. Areas which were covered by dense forest lands in the early 1970s are now completely devoid of trees.

From the analyzed results, the magnitude of land use and land cover in general and forest cover change in particular was drastically changed between 1973 and 2000 at Dendi District. Particularly, expansion of cultivated land and decline of both forest cover as well as shrub land were observed. In relation to this, currently, the over all condition of the forest cover land of Dendi District is strongly disturbed. Besides, the areal extent of forest cover land is reduced from time to time. As empirical findings indicated that from the total area of the district about 26,363 ha of land was covered with forest in 1973. But, this figure is declined to 7,629.38 ha in the year 2000. On top of this, considering the annual rate of forest cover change between 1973 and 2000, the computed result indicated that about 693.84 ha of forest land is changed in to other land use land cover annually. In addition to this, large portion of forest cover change process is observed along with areas having a gradient of less than 25⁰ and elevation values of bellow 2,550m in the stated time period.

In the mean time, forest cover compartment with three levels of susceptibility to forest degradation was generated based on the year 2000 forest cover map. The computed quantitative data revealed that from the total forest cover condition of the year 2000 (7,629.38 ha) about 1,543.52 ha of forest cover land is categorized under low susceptible to degradation. On the other hand, 4,402.4 ha and 1,683.44 ha of forest cover lands are considered to be moderately and highly susceptible to degradation respectively.

Finally, both quantifiable and non-quantifiable socio-economic data were identified as major causes of forest cover change in Dendi District. This resource has been utilized in unsustainable manner due to population growth (with other variables) such as demand of forest products for construction, fire wood and Charcoal production, income generation and expansion of various types of agricultural activities and built up areas along the margin and even in side the forest areas. This circumstances leads 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 and deterioration of biodiversity in Dendi District. Hence, this type of data is very useful for the concerned bodies in protecting the remaining forest resources from distraction.

6.2 Recommendation

In closing, from the whole study it had been recognized that the forest cover land of Dendi District has been declined. Therefore, 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.

1. In order to raise the carrying capacity of the study area, new agricultural inputs and techniques should be adopted, which have 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 and attempts should also be studied and made to balance the size of domestic animals with the available feed as well as grazing grounds. Hence, this situation leads to protect further destruction of the remaining forest resources.
2. Wood cutting for house hold energy consumption was identified as one of the causes that accelerated devegetaion. Hence, inorder to save energy, improved stove that is appropriate to the rural areas has to be introduced. Besides, most of the towns of Ginchi and Welenkomi dwellers depend on purchased fire wood for its 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 sources.

3. To overcome the problem of soil erosion, runoff and flooding, 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 afforestation and reforestation program. Besides, the practice of agro-forestry should be strongly introduced at the District.
4. Population growth is identified as a problem at 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, strong family planning awareness creation campaigns with adequate health services should be introduced for the study area.
5. 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 especially for the farmers who are dwelling along the margin and inside the forest areas should be an indispensable phenomenon.
6. Jobless youths and Women Fuel Wood Carriers who are engaged in illegal tree cutting and harvesting activities should be educated about the economic and ecological value of the forests as well as the consequences of deforestation. Besides, organizing them in to a legally recognized group that operates small-scale economic enterprise will enable to attain self-sufficiency.
7. Besides, more research should be done on forest cover change and susceptibility to 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 for sure will benefit the forest cover change detections efficiently as well as in order to provide soundable information to take appropriate measures to

combat the problem of forest cover change. In relation to this, today the technology of Remote sensing and GIS techniques are progressing both increased data acquisitions and processing capabilities. The training of man power with the use of Remote sensing techniques, GIS and major application areas should be given a due consideration.

8. Above all, there is a need for designing of policies and strategies to protect the destruction of forest resources. This requires well-organized institutions to take responsibility for the conservation of forest resources at a District level. In addition to this, massive and concentrated effort should be exerted by the government officials of Dendi District and all citizens who are inhabited in the study area in order to conserve and manage the remaining forest resources in a sustainable basis.

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Appendices

Appendix I: Interview questions and chick lists for Group Discussion to investigate the trends of forest cover change in Dendi District

1. What are the major uses of forests in the area?
2. How do you relate the impact of population growth on forest resources of the area?
3. Do you think that, deforestation is the major problem in your locality?
4. How is today's coverage of the forest when compared to the conditions before 1973?
 - A. Declined (thinned) B. Increased C. No change
5. According to your knowledge is severe and rapid forest cover change observed today?
6. If the answer for question number '7' is yes, what were/ are the major causes of deforestation? (Put in order)
 - A. Cultivated land expansion _____
 - B. Cutting trees for fire wood _____
 - C. For charcoal production _____
 - D. for additional grazing lands _____
 - E. Cutting of trees for house and fens construction-----
 - f. Wild fire _____
 - G. Cutting trees to get rid of wild animals.____
 - H. Income generation _____
7. What is your major source of income? (For HHH only)
 - A. Sale of cash crops B, Sale of wood and charcoal C, Other _____
8. If you are stopped to go and cut the trees what type compensation you want?
 - i. Monthly salary ii. Permanent Work
9. What types of fuel do you use for house hold needs (List of them in order).

Description	Before 1973	Bin 1973 to 1991	From 1991 to present
1. Forest trees			
2. crop residue			
3. cow Dung			
4. charcoal			
5. kerosene			

10. Historical matrix

Land use/cover types	Before 1973	B/n 1973 – 1984	From 1984 to present
1. Water body			
2. Natural Forest			
3. Plantation forest			
4. Built Up and Settlement			
5. Shrub Land			
6. Cultivated Land			
7. swampy area			
8. Grass land			

Question to be asked, in relations with developing the historical matrix are:-

- 10.1. What are the important events in each period?
- 10.2. What are the most common reasons of changes in land cover and land use?
- 10.3. Which cover types have been changes to other type's very commonly?
- 11. How do you evaluate the susceptibility of the current forest resource degradation in relation to the following factors?

Factors	Degree of susceptibility					
	Extremely sever	V. Sever	sever	Moderate	Low	v. low
Near to road networks						
Near to towns						
Encircled by cultivated lands						
Gentle slope						
Steep Slope						
Low elevation						
High elevation						
High pop. concentration						
Low pop. concentration						

12. Rank the major accessibility factors which play a major role for the susceptibility to forest degradation in level of ordering (for agricultural officers only)?

- A. Slope Value_____
- B. Elevation value_____
- C. Rod proximity _____
- D. Town proximity_____
- E. Cultivated land Proximity_____

13. On the basis of your knowledge, what are the impacts of deforestation/Forest cover change on the Area? (Put in order).

14. Are there species of "trees" and wild animals endangered for extinction due to forest cover change from the local region? Please mention if any?

15. What do you think about the possible solution to alleviate the current problem deforestation and to use forest resources in a sustainable manner?

Appendix II: Field Observation Sheet

Date	Way-Points	X Coordinate	Y Coordinate	Photo No.	Land Use/cover/ type	Human Activities Evident

Appendix III: Image Interpretation and Classification Ground Control Points

Ground control points which were Generated During Filled survey For Ground Truthing			
Way points	x	y	Land use/cover
166	406237	100331	Forest
167	406211	1003253	Forest
172	405239	1001734	Forest
173	405806	1002008	Forest
175	406304	1001920	Forest
176	406612	1002251	Forest
177	406625	1002133	Forest
171	404128	1001318	Forest
178	405087	1001518	Forest
195	404066	1000516	Forest
194	405343	1001595	Forest
201	393353	976516	Water
202	393251	976066	Water
203	393070	975862	Water
181	393270	974257	Water
157	407241	1010476	Built up Area
162	417534	997964	Built up Area
169	405325	997964	Built up Area
204	392027	992332	Built up Area
205	392322	992398	Built up Area
206	400713	997915	Built up Area
174	405808	1001987	Built up Area
180	399772	979877	Built up Area
191	406010	998027	Built up Area
220	404397	999242	Shrub land
221	404545	999185	Shrub land
222	404208	999446	Shrub land
223	406670	999562	Shrub land
224	406383	999393	Shrub land
225	418579	997766	Shrub land
226	418822	997451	Shrub land
189	400507	980479	Shrub land
193	406516	999350	Shrub land
197	404419	999126	Shrub land
159	405984	1007153	Fallow Land
182	395577	976952	Fallow Land
184	395730	977131	Fallow Land

207	405506	1008166	Fallow Land
208	407364	1010377	Fallow Land
209	427291	1006064	Fallow Land
210	406927	1005554	Fallow Land
211	406927	1005930	Fallow Land
153	406698	1007908	Fallow Land
150	406203	1008074	Fallow Land
151	406429	1007999	Crop Cover
158	406057	1007446	Crop Cover
161	415380	995466	Crop Cover
164	405673	1003318	Crop Cover
212	403704	997029	Crop Cover
213	401810	996880	Crop Cover
214	401235	996551	Crop Cover
215	398165	994980	Crop Cover
213	401810	996880	Crop Cover
185	397854	978730	Crop Cover
199	400132	995744	Crop Cover
200	399422	995429	Crop Cover
156	406524	1010043	Bare Land
160	409084	1005154	Bare Land
183	395673	977233	Bare Land
187	398975	978486	Bare Land
152	406906	1007749	Marshy/Grass Area
216	407616	1005908	Marshy/Grass Area
217	407519	1009721	Marshy/Grass Area
218	405774	1009721	Marshy/Grass Area
219	406727	1011597	Marshy/Grass Area
155	406382	1009814	Marshy/Grass Area
154	406290	1009717	Grass Land
161	413614	996685	Grass Land
168	406130	1003239	Grass Land
170	404897	1002432	Grass Land
186	39885	978500	Grass Land
196	404066	1000516	Grass Land
198	400907	996889	Grass Land
227	401180	996466	Grass Land
228	400977	996705	Grass Land
229	401079	996902	Grass Land
230	400718	997183	Grass Land

Appendix IV: Result of Classification of Compartments with Different Level of Susceptibility to Forest Degradation

	Very High		High		Moderate		Low		Very Low		Total	
	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
Slope	1466.17	19.23	2161.87	28.34	2058.52	26.98	1013.13	13.28	929.88	12.17	7629.57	100
Culti_Land	5412.65	70.95	2208.25	28.94	8.42	0.11	—	—	—	—	7629.32	100
Town	2519.32	30.02	1238.11	16.23	1200.43	15.73	1087.51	14.25	1584.01	20.76	7629.38	100
Road	3189.8	41.81	1017.07	13.33	1047.26	13.73	1060.39	13.9	1314.72	17.23	7629.24	100
Elevation	927.37	12.15	1118.11	14.65	1079.9	14.15	2743.43	35.56	1760.76	23.08	7629.57	100

Appendix V: Monthly Rain Fall (in MM) Distribution of Ginchi Town from 1974 to 2005

Year	Jan.	Feb	Mar	Apri.	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974	28.3	11.9	132.8	23.1	112.9	119.3	181.6	173.4	216.4	8.1	0.0	0.0
1975	0.0	8.7	27.8	41.6	85.3	158.1	289.7	142.7	296.6	18.2	0.0	0.0
1976	30.8	38.4	39.5	75.7	103.3	197.7	222.4	254.9	96.7	13.1	145.0	8.1
1977	116.6	58.3	87.8	21.3	46.5	116.5	303.3	281.8	123.1	243.7	40.0	0.0
1978	0.0	39.1	87.8	47.9	67.4	155.1	244.9	270.4	197.5	45.5	0.0	13.7
1979	52.2	77.6	129.7	46.9	155.4	108.3	248.3	191.1	106.3	24.7	0.0	9.5
1980	32.1	42.5	65.3	114.3	131.9	87.8	224.5	212.3	164.7	42.6	0.0	0.0
1981	0.0	5.5	159.4	140.9	59.4	50.5	325.4	236.9	156.4	24.4	0.0	3.0
1982	47.0	62.6	59.9	40.6	84.9	39.5	181.0	251.2	68.0	78.5	68.2	0.0
1983	36.1	41.3	79.1	192.5	229.8	116.1	315.1	190.6	211.6	49.5	3.7	31.5
1984	14.1	0.0	21.6	7.0	121.5	189.3	185.0	126.7	95.1	3.8	15.5	13.3
1985	5.1	0.0	26.6	116.3	162.3	54.1	298.0	300.1	164.4	7.3	5.7	4.7
1986	0.0	98.4	103.0	92.2	141.7	270.2	276.0	236.6	159.1	67.7	0.0	0.0
1987	16.0	50.8	219.9	91.1	259.3	106.6	242.4	142.4	129.7	26.6	0.0	5.9
1988	35.9	108.2	51.1	74.8	21.6	135.2	274.8	375.9	287.4	49.8	0.0	0.0
1989	12.6	118.7	151.1	126.1	14.5	134.1	334.7	253.8	157.0	86.5	10.2	85.6
1990	0.0	184.2	101.8	65.6	69.9	126.1	111.9	279.9	141.2	22.1	10.9	5.0
1991	11.8	39.7	27.8	9.0	54.5	163.6	147.8	260.5	130.6	0.0	0.0	4.2
1992	21.1	112.9	55.9	60.7	70.7	127.5	243.8	180.4	93.1	54.5	15.3	0.0
1993	22.8	87.8	33.0	157.0	153.5	137.5	208.9	374.5	246.6	23.4	0.0	0.0
1994	0.0	0.0	98.3	77.5	91.9	138.6	216.8	361.1	167.0	12.3	12.0	0.0
1995	0.0	30.2	14.9	280.7	84.1	61.8	171.6	209.7	106.8	0.0	0.0	27.1
1996	24.9	2.9	116.8	90.6	108.5	151.5	254.7		190.9	19.7	1.2	0.0
1997	63.4	0.0	0.0	131.3	47.1	118.2	199.6	188.2	101.7	100.0	74.9	2.8
1998	71.5	18.8	99.4	24.7	79.8	174.2	236.7	267.0	182.8	66.6	0.0	0.0
1999	16.3	0.0	26.5	163.4	66.1	150.3	226.4	196.0	96.4	178.7	4.2	0.0
2000	0.0	0.0	8.3	129.4	85.2	159.4	141.6	236.2	185.9	43.7	37.0	
2001	3.5	47.3	118.4	33.8	112.4	270.7	238.0	151.0	96.5	31.3	2.5	0.0
2002	112.7	76.5	88.7	40.5	38.2	157.2	209.4	160.1	79.9	0.0	0.0	61.4
2003	12.8	55.2	72.3	43.9	58.4	142.8	219.4	149.1	81.4	45.2	12.4	24.8
2004	29.0	35.4	62.1	54.5	45.0	132.1	198.4	189.4	101.2	23.4	21.8	32.4
2005	30.5	21.4	86.1	85.6	59.2	151.4	224.7	211.1	94.2	57.1	19.4	19.4

Source: Ginchi Metrological Stations

