Addis Ababa University

School of Graduate Studies,

Department of Earth Sciences.

FOREST COVER CHANGE DETECTION AND FIRE RISK SUSCEPTIBILITY MAPPING USING GIS AND REMOTE SENSING: CASE OF GOBA WOREDA.

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University, in Partial fulfillment of the Requirements for the Degree of Master of Science in Remote Sensing and Geographical Information System(GIS)

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ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF EARTH SCIENCE

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DECLARATION

I hereby declare that the dissertation entitled "FOREST COVER CHANGE DETECTION AND FIRE RISK SUSCEPTIBILITY MAPPING USING GIS AND REMOTE SENSING: CASE OF GOBA WOREDA." has been carried out by me under the supervision of Dr. K. V. Suryabhagavan, Department of Earth Sciences and, Dr. Sileshi Nemomissa, Addis Ababa University, Addis Ababa during the year 2007-2008 as a part of Master of Science programme in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa

Date: July 16, 2008

(Genanaw Alemu)

C E R T I F I C A T E

This is certified that the dissertation entitled "FOREST COVER CHANGE DETECTION AND FIRE RISK SUSCEPTIBILITY MAPPING USING GIS AND REMOTE SENSING: CASE OF GOBA WOREDA" is a bonafied work carried out by under my guidance and supervision. This is the actual work done by Genanaw Alemu for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

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List of acronyms

ASTER	Advanced Space born Thermal Emission and Reflection Radiometer
m.a.s.l.	Meter above the sea level
AOI	Area of Interest
CBD	Secretariat of the Convention on Biological Diversity
CESP	Center for Ecosystem Science and Policy
CIFOR	Center for international Forestry Research
CRISP	Center for Ecosystem Science and Policy
CSA.	Central Statistical Agency
DEM	Digital Elevation Model
DMSP	Defense Meteorological Satellite Program
EFAP	Ethiopian forest action Program
ENVI	Environment for visualizing Images
EPA	Environmental Protection Authority
ERDAS	Earth Resource Data Analysis System
ETM	Enhanced Thematic Mapper
FAO	Food and Agricultural Organization
GIS	Geographical Information system
GPS	Global Positioning System
ha	Hectare
IAWF	International Journal of Wild land Fire
IRS	Indian Remote sensing
ISODATA	Iterative Self-Organizing Data Analysis Technique
ITTO	International Tropical Timber Organization
m	Meter
MCE	Multi Criteria Evaluation
MNRCDEP	Ministry of Natural Resources Conservation and Development and Environmental Protection
MODIS	Moderate Resolution Imaging Spectrometer.

MSS	Multi Spectral Scanner
NASA	National Aeronautics and Space Administration
NIR	Near Infrared
NMA	National Metrology Agency
OLS	Optical Linescan System sensor
ROI	Region of Interest
SPOT	Satellite Pour l'Observation de la terra
SRTM,	Shuttle Radar Topography Mission
TM	Thematic Mapper
UTM	Universal Transverse Mercator
VI	Vegetation Index
WGS	World Geodetic System

Abstract

Goba woreda, despite its economical, hydrological, and biological importance both nationally and globally, the forest of the area is under serious threat owing to deforestation and forest fire. As a consequence, the forest cover of the area has been deteriorating and endemic tree species are under sever anthropogenic impacts. The aim of the present study is to determine the extent and the rate of deforestation as well as pattern of forest cover change over the past twenty seven years (1973 -2000). Besides, it also attempts to map forest fire risk susceptibility of the forest of the area using GIS and remote sensing techniques. Landsat MSS 1973 and Landsat ETM^+ *2000 satellite imageries have been used to determine extent & rate of deforestation and pattern of change. Both spectral (NDVI) and post classification change detection techniques have been used to determine the forest cover change of the woreda. The forests of the area which consists of Erica bush land, moist montane forest, dry ever green forest and plantation. Among the forest classes, moist montane forest and dry ever green forests are experiencing intensive human pressure. In 1973,* 62.7*% (101086 ha) of the woreda was covered by forest where as the coverage dropped to 56.2 % (90603 ha) in 2000. The coverage decreased by 10.4 % within this period and it has amounted to 388.3 ha (0.2 % of the total area) deforested per year. Intensification of agricultural activities in the forest territories takes the lion share for the cause of deforestation. Seven factors such as NDVI value, vegetation type, aspect, slope, elevation and distance from settlement and roads have been taken in to consideration to examine the susceptibility of the forest to fire. The forest fire susceptibility result revealed that* 35 %, 25 %, 21 % and 18 % of the forest of the woreda are categorized under the moderate, high, low and very high susceptibility level respectively. *Searching fresh pasture land is the underlying cause forest fire.*

Key words: Deforestation, forest fire risk susceptibility, GIS, Remote sensing.

1. INTRODUCTION

1.1. Back ground

Rapid population growth of the world has exerted pressure on the earth's natural resources in general and forest in particular. According to FAO (2007) report, the global forest coverage decreased by annual rate of 0.22 % and 0.18 % between the period of 1990-2000 and 2000-2005 respectively. Hence it is clear that the global forest has been decreasing from time to time as the expense of earth's environment. Ethiopia is one of the countries in which its forest resources are highly depleted due to massive removal by its growing population even though it endowed with wide variations in climate, topography and soils. The country is one of the few countries in Africa where virtually all major types of natural vegetation are represented, ranging from thorny bushes to tropical forests and to mountain grasslands.

Some sources indicate that about 35 - 40 percent of the country's land area was covered with high forests at the turn of the 19-century.In the early 1990's, only about 2.7 % of the land mass was covered by closed forests. Annual rate of deforestation in Ethiopia is estimated between 150,000-200,000 ha (EFAP, 1994). This rate is not static instead it has increased tremendously over periods of time. According to the FAO (2005) ,the annual rate of deforestation in Ethiopia has increased from1% during the period 1990-2000 to 1.1% between 2000-2003.The Bale mountains of Ethiopia are an example which face a serious challenge of deforestation and recurrent forest fire .

According to the Environmental Protection Authority (EPA, 1997) of Ethiopia some two million hectares of land in the country has now become irreversibly barren as a result of the extensive deforestation. As a consequence, various forest products are no longer easily available. Their price has escalated. As a consequence the rural population becomes directly subjected to the problem as they depend primarily on forest resources for construction materials, farm implements, energy and fodder needs. More than 85% of the populations of Ethiopia live in rural areas, and more than 90% of the energy requirement of the country comes from fuel wood (EFAP 1994).

Rapid population growth, extensive forest clearing for agriculture, over grazing, movement of political centers and exploitation of forest for fuel wood without replanting reduced the forest area of the country to 16 percent by 1950s and 3.1 percent by 1982 FAO (2005).

1.2. Statement of the Problem

Goba woreda, despite its economical, hydrological, and biological importance both nationally and globally, the area is under serious threat due to unsustainable use of the natural resources. The forest cover of the area has been deteriorating and endemic tree species are under anthropogenic impacts. This situation poses a great challenge on the function of the ecosystem and the livelihoods of the people who depend up on it for their existence.

The majority of rural people of the woreda live in forest or near the forest boundary. Their livelihood depends on the forest for fuel-wood, fodder, and timber and generates income from forest to maintain their daily needs. Besides to this, they use intentional fire as a tool of clearing forest to execute their temporal demand of grazing and. As a result, the natural environment as well as ecological balance of the area is under a serious of threat due to the Persistent disturbance of the forest resources by the local community.

Identification of potential fire risk zones plays a paramount role for devising proper forest planning and management strategies to curve the problem. Forest fire needs urgent Protective measures by developing early warning strategies to minimize the potential risk before the fire results in a massive economical and environmental destruction. Therefore, discovering and forecasting forest fire as early possible is an urgent requirement for forest management to assure its sustainability. To this end, the capability of remote sensing and GIS is important to identify susceptible areas and to develop forest fire risk zonation map based on appropriate parameters such as fuel type, fuel condition, slope, aspect, elevation and distance from roads and settlement.

Besides to this, an integrated approach of remote sensing and GIS techniques are also important to detect forest coverage of an area. Information on the extent and rate of deforestation should be first considered before the devising and implementing forest management strategies. Hence, remote sensing and GIS tools play a significant role to obtain such kind of information and to make sensible decision regarding resource management in general and forest in particular.

However, in most African countries in general and Ethiopia in particular these effective planning tools– GIS and remote sensing have not been effectively used for cover change detection and generation of forest fire risk zone map.

Thus, the purpose of this paper is to demonstrate the capability of remote sensing and GIS application for potential forest fire areas identification and to detect forest cover change in Goba woreda over the last twenty seven years between 1973 and 2000.

1.3. Objectives

1.3.1. General Objectives

The general objective of this study is to examine the extent, rate and pattern of forest cover change over the twenty seven years (1973 -2000) and to generate forest fire risk susceptibility map of Goba woreda to aid decision for forest planning and management purposes of the area.

1.3.2. Specific Objectives

- To produce land use / land cover and forest cover map of the study area
- To determine the extent rate and pattern of forest cover change over the last twenty seven years.
- To identify and analyze the main cause of forest cover change of the study area
- To assess the main causes of forest fire.
- To develop forest fire susceptibility map using remote sensing and GIS techniques.

2. LITRATURER REVIEW

2.1. Extent and Trends of Forest Cover Change: A Global Perspective

Some people use deforestation and forest degradation interchangeably to refer forest decline. However, conceptually they are quite different. Deforestation is the complete removal of tree and cover or substantial reduction of canopy cover (below 30 %) over large area while by forest degradation we mean loss of the main attributes of forests such as capacity to produce timber ,fire wood ,non-wood products and environmental services,(Gessesse& Christiansson,2007).Hence ,in this paper, forest decline involves both deforestation and forest degradation .

Most countries mange forests for multiple uses, and increasing attention is being paid to the conservation of soil, water, biological diversity and other environmental values. Even though, forest has multiple significances, it has been facing continuing decline in coverage and total biomass. As a consequence it becomes a matter of serious global concern.

History has shown that human beings have most often considered the forest as a space that must be cleared in order to develop activities other than forestry (particularly farming), and used, eventually beyond its capacity to regenerate itself, as a wood and forage resource. Human beings have exerted an immense pressure on the global forest resource in order to satisfy their interest at the expense of its vegetation biomass. In this regard Foster ,(1992) stated that human activities are responsible for a permanent loss of forest cover, or at least for leaving long lasting legacies in altered forest structure and composition, even under condition s of subsequent reforestation. Hence, human activities are the major determinant factor for global forest degradation and coverage loss.

Forest degradation and deforestation trend has been increasing from time to time as global population grows even if positive trend has been recorded in some developed countries. According to FAO (2007) report, the global forest coverage decreased by annual rate of 0.22 % and 0.18 % between the period of 1990-2000 and 2000-2005 respectively. Similarly, net global change in forest area in the period 2000–2005 is estimated at -7.3 million hectares per year (an area about the size of Panama or Sierra Leone or equivalent to a loss of 200km2 of forest per day), down from -8.9 million hectares per year in the period 1990–2000. In 1990 about

4,077,291,000 ha of the earth's surface was covered with forest. However, after a gap of 15 years total forest area in 2005 was estimated to be 3,952,025,000 ha (just under 4 billion ha) or 30 percent of total land area. This figure suggests that the world lost 3 % of its total area, an average decrease of some 0.2 % per year between the specified periods.

The total net loss for countries with a negative change in forest area was 13.1 million hectares per year for 1990–2000 and 12.9 million hectares per year for 2000–2005. This would indicate that annual deforestation rates were at least at this level. Since, the net change rate takes into account afforestation efforts and natural expansion of forests, the rate of deforestation might be higher still, (ITTO, 2006). Similarly, FAO(2007) reported that the global deforestation rate was estimated that at 13 million ha per year during the period 1990-2005, with few sign of a significant decrease over time due to afforestation and natural expansion of forest in some countries and regions.

Globally the extent of deforestation is not uniform as the respective management strategies vary from region to region. For instance, the estimated forest area for Africa in 1990 was 699 million hectares (accounting for about 16 percent of global forest area) but in 2005 it decreased to 635 million hectares (16.1 % of the global forest area). Thus, the continent lost more than 9 % forest area within 15 years period from 1990 to 2005. Between these periods net annual forest loss in the continent was about 4 million hectares, this accounts almost 55 percent of the global reduction in forest area. In a typical year, Africa accounts for more than half of the global forest area damaged by wild fire. Almost 90 percent of the wood removals in Africa are used for fuel, compared with less than 40 percent in the world at large. The annual rate of forest loss of the continent is still high even though it shows decline scenario, it was 0.64 % and 0.62 % between the periods of 1900 –2000 and 2005 respectively (FAO, 2007).

Similarly, Latin America and the Caribbean join Africa as the two regions that are losing their forest at the highest rates. The annual net rate of loss between 2000 and 2005 (0.51 %) was higher than that of the 1990s (0.46 %). Within this period South America suffered from the largest net loss of forests; it lost about 4.3 million hectares per year – followed by Africa, which lost 4.0 million hectares annually (FAO, 2007).

According to the report of FAO (2007) six countries took the share of the ten top countries of the world with the largest annual net loss in forest area between 2000-2005. In this period, Sudan took the largest share of annual net loss of forest area (about 589 000 ha) among African countries followed by Zambia and Tanzania with a net loss of 44500 ha and 412000 ha respectively. In similar period, however, no African counties exist in the list of the world ten top countries with largest annual net gain in forest area.

On the contrary the net forest area of Asia and the pacific region increased between 2000 and 2005, reversing the down ward trend of the preceding decades. However, the increase was limited to East Asia, where a large investment in forest plantations in china was enough to offset high rate of deforestation in other areas. Asia suffered from a net loss of some 0.14 % (800 000 ha) per year in the 1990s. However, in between 2000 and 2005 the forest area of the continent increased by 0.18 % (1million ha) per year, primarily as a result of large-scale afforestation recorded by China (FAO, 2007).

Likewise, Europe has achieved sustainable forest management as a result its forest area is increasing in most countries, and the positive trends exceed the negative. The forest area of Europe increased annually by 0.09 percent (77000 ha) with in a gap of ten years between 1990 and 2000. Between the period of 2000 –2005, the forest areas of Europe continued to expand annually by 0.07% (661 000 ha) although at a slower rate than in the 1990s (FAO, 2005).

Exceptionally, in North America region (accounts 17 % of the world forest area) the annual rate of change was not significant from 1990 to 2000; relatively it was stable. However, the forest cover decreased by 0.01 % (101000 ha) per year in between 2000 and 2005 (FAO, 2007).

2.2. Forest Cover of Ethiopia Past and Present

Regardless the variability of estimates of Ethiopia's forest base, it is clear that the forest resources of the country have been declining at alarming rate both in size (deforestation) and quality (degradation). It has subjected to extensive depletion due to massive removal by its fast growing population.

In 1885, the forest cover of Ethiopia estimated 44 percent of the total area of the country and had diminished to just 40 percent in 1900, (James, 1997). Some sources are also indicate that about

35 – 40 percent of the country's land area was covered with high forests at the turn of the 19-century, over the last 3,000 years there has been progressive deforestation, which has accelerated tremendously during the last century (Britenbach, 1961). Similarly,(MNRCDEP 1994,) pointed out that high forests, either coniferous or broad-leafed, were the climax vegetation of 35 – 40 percent of Ethiopia before human settlement took place. With the inclusion of savanna woodlands some 66 percent of the country was covered with forest or woodlands at that time.

Rapid population growth (3 % per year) , extensive forest clearing for agriculture, over grazing, movement of political centers and exploitation of forest for fuel wood without replanting reduced the forest area of the country to 16 percent by 1950s(James,1997, MNRCDEP 1994). 3.1 percent by 1982 (UNEP, 1983) and only 2.7 percent in 1989. Study made on the basis of information from LANDSAT imagery (1979) revealed that only 2.8 percent of the land surface was under forest and woodland (MOA, 2000). In the early 1990's, only about 2.7 % of the land mass was covered by closed forests (EFAP 1994). In 1994, it was estimated that such forests covered less than 2.7 percent of the country (MNRCDEP 1994).

However, Reusing, (1998), found that within 17 years (1973-1990) high-forest cover decreased from 54,410 to 45,055 km² or from 4.75 to 3.93% of the land area. Similarly, Earth trends (2003) estimated that in 2000 Ethiopia had 43,440,000 km² of natural forest area (about 4% of its total land area), which is higher than the previous years' estimates. Compared to other East African countries Ethiopia's deforestation rate is about average. Regardless of the inconsistency of forest cover estimates, each estimate shows the declining trend of the country's forest cover from year to year.

The annual rate of deforestation in Ethiopia is estimated between 150,000-200,000 ha (EFAP, 1994, MNRCDEP 1994). This rate is not static; instead it has increased tremendously over periods of time. According to the FAO (2005), the annual rate of deforestation in Ethiopia has increased from1% during the period 1990-2000 to 1.1% between the years 2000-2005.The recent deforestation rate of Ethiopia estimated about 141000ha per year, (FAO 2007). Even though deforestation continues in various parts of the country at alarming rate, efforts are not sufficient enough to reverse and coup up the problem.

2.3. Causes and Consequence of Deforestation in Ethiopia

Forest decline in Ethiopia is highlighted by several authors,(Gessesse,Demel,Reusing).Regardless of the disagreement exists about the cause and consequences of deforestation, the need for more space for cultivation is mentioned as the major and underlining factor of the problem. As the result of the growing demand of agricultural land, more trees being increasingly removed, (Gessesse, & Christianson, 2007).EFAP (1994) claims that the population increase plays a major role.

Similarly, Demel (2000) stated that the major reasons for deforestation are the clearing of forests and woodlands for cultivating crops and the cutting of trees and shrubs for various purposes, notably for fuel wood, charcoal, construction materials, etc.

However, others linked the underlying causes of deforestation with the vicious cycle of mutually reinforcing factors, namely poverty, population growth, poor economic growth, and the state of the environment (MNRCDEP 1994).

With population increasing faster than the economy, the per capita income declined. These factors adversely affected natural resources, particularly forests and woodlands. Deforestation is one of the major factors contributing to land degradation by exposing the soil to various agents of erosion. With high-intensity rainstorms and extensive steep slopes, Ethiopia is highly susceptible to soil erosion, especially in the highlands. The organic content of soils is often low due to the widespread use of dung and crop residues for energy (Demel, 2000).

Land degradation in turn greatly affects agricultural productivity and production. In 1990 alone, for instance, reduced soil depth caused by erosion resulted in a grain production loss of 57,000 (at 3.5 mm soil loss) to 128,000 tons (at 8 mm soil depth). It has been estimated that the grain production lost due to land degradation in 1990 would have been sufficient to feed more than four million people. The availability of land suitable for agriculture is shrinking, while at the same time the amount of land required to feed the growing population is steadily increasing (Demel, 2000).

Hence, deforestation results in environmental degradation in the form of land and water resources degradation as well as loss of biodiversity (Demel, 2000).

2.4. Causes and Consequence of Forest Fire; Global and Ethiopia Perspective

Forest fire is any nonstructural fire, other than prescribed fire, that occurs in the wild land and encompasses previous terms such as “prescribed natural fire” and “wildfire”). Hence, a forest fire is defined as any fire in forest land which is not being used as a tool in forest protection or management in accordance with an authorized plan.

Fire has been a source of natural and important disturbance in much forest for thousands of years but in others it can cause devastation, (CBD, 2001). Hence, forest and wild land fires have been taking place historically, shaping landscape structure, pattern and ultimately the species composition of ecosystems, (Roy, 1996). It is important to remember that fire is a vital and natural part of some forest ecosystems, and that humans have used fire for thousands of years as a land management tool. Some ecosystems, such as the Mediterranean shrub lands and many pine forests, are fire dependent, and their continued existence depends on the periodic occurrence of fires. In some forests, fire is deliberately used as a management tool (prescribed burning) to maintain ecosystems, allow regeneration and clear debris, (CBD,2001).The ecological role of fire is to influence several factors such as plant community development, soil nutrient availability and biological diversity(Roy,1996).

Therefore, forest and wild land fire are considered vital natural processes initiating natural exercises of vegetation succession. However, uncontrolled and misuse of fire can cause tremendous adverse impacts on the environment and the human society. As a result, changes in the man-fire dynamic and an increase in El Niño frequency, fires are now a major threat to many forests and their biodiversity therein (CBD, 2001, Roy, 1996).

2.4.1. Causes of Forest Fire

The causes of forest fire can be classified in three main categories. These are: i) Natural, ii) Intentional due to man iii) accidental due to man. Naturally, forest fire occurs mainly due to lightning or sometimes due to rolling stone and rubbing of dry tress with each other by strong wind. Although some forest fires occur naturally, a combination of human activity, fuel availability, and climate accounts for the majority of fires. That is the contribution of natural fires is insignificant in comparison to number of fires started by humans (CBD, 2001, Bartlett 1955, 1957, 1961, Goldammer, 1988). Lightning is an important source of natural fires which have influenced savanna-type vegetation in pre-settlement periods.

The vast majority of wild fires are intentional for timber harvesting, land conversion, slash – and-burn agriculture, and socio-economic conflicts over question of property and land use rights. In recent years extended droughts (prolonged dry weather), together with rapidly expanding exploitation of tropical forest and the demand for conversion of forest to other land uses, have resulted in significant increase in wild fire size, frequency and related environmental impacts. (Roy, 1996.CBD, 2001).Accidentally fire occurs in a forest due to carless throwing of match –sticks and burning ends of cigarettes etc.

Forest fire statistics at the global level indicates that the largest numbers of fire occurrence of the world are caused by human. According to FOA, at least 80 percent of forest fires of the world are caused by people – and in some regions up to 99 percent. Agricultural needs and land clearing are the most common causes of fire, followed by arson. Lightning is the major non human cause of wildfires (FAO, 2007).

Similarly, the majority of forest fire of Ethiopia is induced by human intentional action to execute their temporal needs. In connection to this MOA (2000) stated that Fires started by people account for 100 percent of the total fires. Of the human-caused fires, 20 percent are classified as arson and negligence and carelessness cause 80 percent. However, there is no research conducted on fire causes. These observations are based on personal experience in the field for the last 20 years.

2.4.2. Consequence of Forest Fire; Global and Ethiopia Perspective

Globally, no reliable, consistent and comprehensive statistics about the annual distribution and extent of forest fires exist,(CBD,2001).That is there is insufficient information to conclude whether the total area burned or number of forest fires is increasing. Although statistical data on fire loss are weak, estimate indicates that about 350 million hectares of the world forest suffer wild land fires each year. This is equivalent to about 9 percent of total forest area, but the term “wild land” includes non-forest areas such as savannah, brush and open range. The actual damage to forests is less than 5 percent per year (FAO, 2006 d).

The magnitude of forest fires is not uniform; instead it is vary from region to region and year to year. For instance, Fire damage to forests in the Europe region (excluding the Russian Federation) constitutes less than 10 percent of the area reported for insect pests, diseases and

other disturbances. Compared with other regions of the world, non-fire disturbances are relatively well reported in Europe, with information received on over 90 percent of the forest area (FAO, 2007).
A study conducted in Africa indicates that the continent accounted for 64 percent of the global area burned by wildland fires in 2000, when 230 million hectares were burned, accounting for 7.7 percent of the total land area of the continent. A follow-up study in 2004 revealed similar results (FAO, 2007).

As reported to the 2005 FAO Regional Conference for Africa (FAO, 2006c), two areas of particularly high fire frequency stands out: one is northern Angola and the southern Democratic Republic of the Congo, and the other southern Sudan and the Central African Republic. Even though there is no reliable recorded data that permits analysis for extent of damage, in Ethiopia forest fire have resulted in considerable economical and biological loss. There were forest fires in early 1984 that affected a considerable forest area in the country. As a consequence of this fire , estimated about 308198 ha forest damaged (MOA, 2000).

There were no major wildfire reports for the 1990s in Ethiopia .A major wildfire episode affected the afro-montane forests in 2000, mainly in Oromia Regional State. The total forest area affected by fire was 95 000 ha. Forest fires hit Ethiopia in March 2000, the first big fires since 1984. The threatened, afro-montane forests and moist tropical forests were badly damaged with as much as 53,000 ha of Bale National Park destroyed (Goldammer, 2000).

In the history of the country, the major forest fire incidence has been recorded in the year 2000. In this period more than 120 significant forest fire incidences reported from the various corner of the country. The second largest recorded forest fire incidences reported in the 1993 when 20 prevalence were reported .Surprisingly no major fire incidences were recorded in the year 2002,(MOA,2004).Having in mind the extent of forest fire impact on the physical change of the global forest cover, causes and impacts of forest fire discussed in the following sections.

2.4.2.1. The major impacts Fires on biological diversity and forest ecosystem functioning

Forest fires controlled or uncontrolled have profound impacts on the physical environment including: land cover, land use, biodiversity, and climate change and forest ecosystem. They also have enormous implication on human health and on the socio-economic system of affected countries. Burning of forest in South East Asia for instance resulted in 4 billion dollar economical damage and estimated 20 million people of the region are in danger of respiratory problem (Roy, 1996).

Fire is also results in biomass burning which in turn causes climatic change. Researchers have founded the contribution of biomass burning to the global budgets of many radioactively and chemically active gases such as carbon dioxide, carbon monoxide, methane, nitric oxide, tropospheric ozone, methyl chloride and elemental carbon particulate.,(Roy,1996). Thus, large-scale uncontrolled fires, at a global scale, they can influence the chemical composition of the atmosphere,(CBD,2001).Biomass burning is recognized as a significant global source of emission contributing as much as 40% of gross Carbon dioxide and 30% of troposphere ozone, At the regional and local scale, forest fires change biomass stocks, alter the hydrological cycle with knock-on effects for marine systems such as coral reefs, reduce visibility to near zero, impact plant and animal species functioning and detrimentally impact the health and livelihoods of the human population (Goh 1999; Schwela 1999). Smoke from fires can significantly reduce photosynthetic activity (Davies and Unam, 1999).

Apart from the effect on forest vegetation, fire can have a significant impact on forest vertebrates and invertebrates. In forests where fire is a natural part of the system, species are adapted to a natural fire regime and can benefit from the aftermath of a fire. However, in forests where fire is not a natural disturbance or where man suppresses the natural fire regime the impact on species can be negative. The direct effect of fire on forest fauna is death. Indirect effects of fires are far reaching and longer term and include stress, loss of habitat, territories, shelter and food Fires can also cause the displacement of territorial birds and mammals, which may upset the local, balance and ultimately result in the loss of wildlife, since displaced individuals have nowhere to go. Loss of food trees reduces the carrying capacity of the forest, causing overall decline in species that rely on fruits for food, this is especially true in tropical forests.

Hence, forest fires cause loss of human life and personal property, economic upsets, and disturbances in regional and global atmospheric composition and chemistry, and climate.

2.5. Forest Fire Characteristics

Even though the major factor for forest fire is human, there are major factors which accelerate the burning capacity of fire once it is ignited by human. In simplified models, the behavior of wildland fire depends on three elements: fuel, weather, and topography. Each element has several characteristic parameters, which create a complex set of different combinations for wildland fire behavior. In other words, the devastating capacity of forest fire directly or indirectly influenced by the weather and fuel condition as well as the type of the topography of an area (Wirawan,2000).

The fuel may be characterized by the following parameters: biomass condition (living or dead); biomass quantity; moisture content; and vertical and horizontal structure (continuity). To burn, the fuel needs favorable atmospheric conditions, which can be described in terms of weather. The weather's impact on wildland fire behavior can be characterized by the following parameters: wind velocity, wind direction, relative humidity, precipitation, and temperature. A fire's propagation also depends on topographic factors such as aspect (steepness, orientation and position) of the terrain; elevation; and general shape of the terrain (for example, ridge, canyon, flat terrain), (Wirawan, 2000).

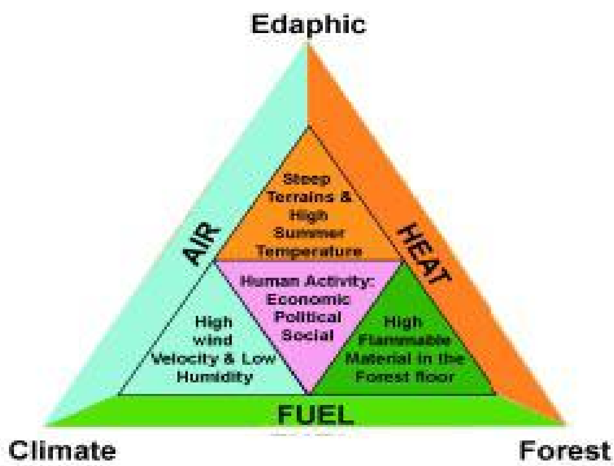
In this regard, Roy stated that a combination of edaphic, climatic and human activities account for the majority of wild land fires. High terrain steepness along with high summer temperature supplemented with high wind velocity and the availability of high flammable material in the forest floor accounts for the major damage and wide wild spread of the forest fire (Roy, 1996).

Vegetation conditions or moisture contents have a major effect on fire behavior owing to its influence on ignition and fuel combustion. Obviously, higher fuel moisture contents require a greater heat supply to dry the fuel before the combustion starts, and likewise slow down the fuel consumption rate contrast, lower moisture contents yield greater fire intensity, spread rate and facility ignition (Fiorucci, Francesco, 2007).

Besides to above factors, the level of forest fire risk is also depends up the amount of biomass of the fire area. In turn the amount of biomass is determined by the amount of rain fall in a particular year. Figure 2 below clearly depicts the relation between edaphic, climate and fuel .

Thus, being other things constant good rainy season produce better amount of biomass. More amount of biomass produce more fuel for dry season. A comparison of the extent of burning there in 1992, when southern part of Africa experienced a severe drought, and in 2000, following a season of above-average rainfall, showed much earlier and more extensive burning in 2000.This link between rainfall and biomass production means that regional, seasonal climate forecasts can be used to anticipate the likely vegetation biomass conditions in the coming season and to assess the level of fire risk (FAO, 2007).

Whether it is human induced or natural forest fire, it is highly depend up on seasons for its occurrence and severity. Thus, various regions of the world have different normal and peak fire seasons.



Source: (Roy, 1996).

Figure 1 :Triangle of forest fire

A study conducted in India shows that in the plains of northern and central India, most of the forest fires occur between February and June. In the hills of northern India fire season starts later and most of the fires are reported between April and June. In the southern part of the country, fire season extends from January to May. In the Himalayan region, fires are common in May and June (Roy, 1996).

While in Ethiopia peak forest fire frequently occurs every year, just before the short rainy season starts, very large areas of lowland woodland and grassland formations are affected by fires, particularly in the drier parts of the country. Fire is mainly used to clear land for cultivation, and the timing is synchronized with the dry season before the onset of rains in March-April. Fire is used at least once a year in January and February so that the land is ready for planting in April. Honey collection takes place in April/May and October/November. Fire is used in the lowland areas, where livestock raising is an important part of the economy, to control tsetse fly or ticks, or to induce sprouting of fresh grazing or browsing vegetation and grasses. Fire is also used to smoke bees out of the hives in the process of harvesting honey. In Ethiopia, accumulation of fuel load and flammability attain peak values in January and February of each year. There is usually one incidence of fire in Ethiopia, which is mainly in January, February and March before the onset of the rainy season (MOA, 2000).

2.6. The Role of Remote Sensing and GIS for Forest Fire and Cover Analysis

2.6.1. Potential Forest Fire Identification

Remote sensing data can be used to provide forest related information to governments and civil society in a timely and cost-effective way. The use of satellite data to map forests has become an increasingly common way to pinpoint deforestation, active fires and logging in protected areas. (CIFOR, 2004). Active forest fire is one of the major threats of the global forest resource which needs immediate response before it results in major loss. However, before the advent of remote sensing technology, identification of active forest fire and potential sites were a challenging task for most foresters.

Currently, however, this situation is not a problem due the advancement of remote sensing technology which provides high resolution imageries. These satellite imageries offer information not only active forest fire sites but also the scares of burnt forest as well as the extent of fire damage. The most frequently used data source for forest fire information is NOAA/AVHRR data. Alternative data sources are MODIS, ATESR-2; the VEGETATION onboard SPOT 4 (Ahern, Goldammer, and Justice, 2001, Roy, 1996).

Measurement of vegetation stress is one of the most frequent uses of remote sensing in forest fire management. Fuels, climatological data; terrain; vegetation type /density and moisture level (live and dead); historic fire regime; digital elevation models (DEMs) distance from road .vicinity to settlement etc are important factors should be considered to identify potential forest fire sites within forest area. . Fuels mapping is really a modeling exercise using the inputs listed above. One process to map fuels looks at departures of current vegetation / forest types from potential vegetation types. Additional information is needed for determining structural risk associated with biomass, fuel composition and fuel moisture status. This requires high-spatial resolution data (imagery) to provide estimations of vegetation structure and biomass (Ahern, Goldammer, and C. Justice, 2001, CRISP, SISV, AARS, 2001).

Hence, fuel condition or character is one of the major factors to be considered to identify potential forest fire sites within the forest .Fuel represents the organic matter available for fire ignition and combustion. Fuel condition information for forest fire study can be acquired by analyzing imageries from remote sensing data. Traditionally, fuel type is collected directly from the field with an intensive and accuracy measurement (Pickford, 1995). In case of forest fire hazard model it is required information of fuel type on large areas, and remote sensing has succeeded to overcome this task (Chuvieco and Congalton, 1988). Fuel represents the organic matter available for fire ignition and combustion. Hence, traditionally, fuel type so vital can be derived from land use /land cover map of supervised classification of Landsat TM, and from the NDVI image (Burgan Klaver R.W. and Klaver J.M., 2000).

Besides to this, fire potential depends on the amount of dead and live vegetation and moisture contents in each. The amount of dead and live vegetation is estimated from a high quality land cover map derived from (ideally) a high resolution sensor, such as the IRS, Landsat TM or SPOT multispectral scanner or from lower resolution sensor such as NOAA-AVHRR or NASA Moderate Resolution Imaging Spectrometer (MODIS), (P.S .Roy, 1996).

Once, the necessary information related fuel combustion properties are identified using remote sensing techniques, the next task needs to integrate it with other factors such as terrain condition and human factors to model forest fire,(IAWF,2001). GIS takes advantage of its capability to combine different source of information (e.g. Fuel type, dried vegetation index, elevation, gradient, aspect and buffer road) for modeling or mapping potential forest fire risks. (CRISP, SISV, AARS, 2001). GIS plays a major role to model potential forest fire based on the existing relationship between forest fire and factors which directly or indirectly related to it. Hence, fire risk zonation model can done using GIS t o obtain the combined effect of fuel type, elevation, aspect, and distance or accessibility. Weighting is assigned to each variable as per their respective impact on forest fire hazard (Roy, 1996,) Various approaches were used by different researcher to model forest fire risk susceptibility considering various variables which have impose their respective impact to forest fire. Each researcher attempted to model using GIS techniques based on the assumption that in forest fire hazard the availability of fuel type is a key factor on fire spreading. A fuel type provides a burning resource or plays as source of ignition based on its combustion properties (Mulyanto, 2001, Chuvieco, and Congoltan, 1988).

Accordingly, Mulyanto (2001) developed six forest fire risk hazard models at different conditions. In summary the GIS models applied for forest hazard as follow:

Model 1. All the variables have the same weight.

FT + EL + GR + AS + BR ………………………………………………………… (1)

Model 2. Fuel type derived from land use/cover has a weight twice higher than the other variables

20 FT + 10 EL + 10 GR + 10 AS + 10 BR ……………………………………………..(2)

Model 3. Fuel type derived from land use/cover has a weight higher followed by gradient

30 FT + 20 EL + 10 GR + 10 AS + 10 BR……………………………………………... (3)

Model 4. A model derived from Dried Vegetation Index and all the variable have the same weight

DVI + EL + GR + AS + BR . ……………………………………………………….(4)

Model 5. A model derived from DVI has a weight twice higher than the other variables

20 DVI + 10 EL + 10 GR + 10 AS + 10 BR…………………………………….…..(5)

Model 6. A model derived from DVI has a weight higher followed by gradient

30 DVI + 20 EL + 10 GR + 10 AS + 10 BR………………….……………………… (6)

Where FT, DVI, EL, GR, AS, and BR represent fuel type, dried vegetation index, elevation, gradient, aspect and buffer road respectively.

Similarly, Roy (1996) Spatial modeling has been done to obtain the combined effect of fuel type index, elevation index, slope index, aspect index and the distance/accessibility index. Weighting over lay have been assigned as per the importance of particular variable contributing in fire environment. In this case the highest weightage has been given to fuel type index because fuel contributes to the maximum extent because of inflammability factor. The second highest weightage has been given to aspect because sun facing aspects receives direct sun rays and makes the fuel warmer and dry.

CFRISK = FUI * 4 + ASI * 3 + SLI * 2 + ACI + ELI1

Where FUI, ASI, SLI, ACI and ELI are the fuel type index, aspect index, slope index, accessibility index and elevation index. Finally, the obtained map was reclassified to obtain final fire risk zone map which depicts the degree of susceptibility with in the forest environment.

However, (Chuvieco, and Congoltan, 1988) developed another approach to deal with forest fire hazard susceptibility. In this approach frequency ratio model used to produce forest fire susceptibility map .Using this model, the spatial relationships between hot spots –occurrence location and each factors contributing hot spots were derived. The frequency is calculated from analysis of the relation between the observed hot spots and the attributing factors .Therefore, the frequency ratios of each factor factor's type were calculated from their relationship with hot spot events. Hence, to calculate the forest fire susceptibility index (FFSI), each factor's frequency ratio values were summed to the the training areas .The hotspot susceptibility value represents the relative susceptible to forest fire occurrence .So the greater the value , the lower the susceptible to forest fire occurrence .FFSI=Fr1 +Fr2 +Fr3 …………….Frn . Where Fr :Rating of each factor's type .

2.6.2. Active Forest Fire Identification

To detect active forest fire, satellite borne sensors operate within the visible, thermal, and mid-infrared bands. Active forest fires can be detected by either sensing their thermal or mid-infrared signature during the day or night, or by detecting the light emitted from the forest fires at night. The sensors must also have frequent over flights with data available in near real time.

Thus, monitoring of forest fire is highly dependable on the temporal resolution of the sensor, (Burgan, Klaver R.W. and Klaver J.M., 2000, Roy, 1996). Satellite systems that have been evaluated for fire detection include AVHRR (NOAA-AVHRR) which has a thermal sensor and makes daily over flights, the Defense Meteorological Satellite Program (DMSP) Optical Linescan System (OLS) sensor (DMSP-OLS) , which makes daily overflights and routinely collects visible images during its nighttime pass, and the NOAA Geostationary Operational Environmental

Satellite (GOES) sensor (NOAA-GOES), which provides visible and thermal images every 15 minutes over the United States and every 30 minutes elsewhere. Therefore AVHRR has been used most extensively for detecting and monitoring wildfires (Roy, 1996).

All of the sensors currently used were not designed with wildfire detection as an objective. They are instruments with alternative missions that have been creatively used to detect wildfires (with varying degrees of success). MODIS is the only instrument that has as one of its mission objectives, the detection of wildfires with a working prototype of a global fire detection system (Burgan, Klaver R.W. and Klaver J.M., 2000).

2.6.3 Post-fire assessment

The most important post-crisis activity in forest fire management is the assessment of the burned area and protection of critical resources. Regarding this, remote sensing has already proven its usefulness for assessment of forest fire damage. With space-borne remote sensing, the forest fire damage or the extent of burned area is determined by the single-date or multi-temporal analysis of the images .Once fires are extinguished, a combination of low resolution images (AVHRR) and higher-resolution images (SPOT, Landsat and Radar) can be used to assess the extent and impact of the fire. Radar has proved effective in monitoring and assessing the extent and severity of fire scars in the boreal forest (Roy 1996).

On national and international scales, NOAA/AVHRR data have been most commonly used for burned area mapping. MODIS data, which has a similar swath width to AVHRR with sixteen times the resolution and superior geolocation accuracy, is quickly assuming this role.
The VEGETATION instrument onboard SPOT4 is a new alternative source of data, (Chuvieco E. and Martin M.P., 1994).At regional scales within national boundaries, high-resolution data from Landsat Thematic Mapper and SPOT/HRVIR are used to determine the extent of forest fire damage. Space-borne radar data (mainly from ERS/SAR) has been used experimentally, but is not in operational use, probably because of the intrinsic complexity in computer processing of SAR images and unacceptable spatial resolution (Chuvieco E. and Martin M.P., 1994).

2.6.4. Forest Cover Change Detection

According to Lillisand and Kiefer (2000) change detection whether it is forest or not involves the use of multi temporal data set to discriminate areas of land cover change between dates of imaging .Similarly, Singh, (1989) defined change detection as the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multitemporal data sets .Hence, change detection methods use some function of the spectral values from two different images acquired at two different times. There are various approaches of change detection which employed for various applications. These include post classification comparison, classification of multitemporal data sets, principal component analysis, temporal image differencing and temporal image ratio, (Lillesand and Kiefer, 2000). Among the various approaches of change detection techniques, post classification comparison change detection is the most straight foreword method. It involves the over lay of two or more classified images. Change areas are simply those areas which are not classified the same at different times (Singh, 1989).

3. MATERIAL AND METHODS

3.1. Description of the Study Area

3.1.1. Location

Goba woreda is found in southeast part of Ethiopia, Bale Zone, in Oromia Regional State, about 445 km far away from the Addis Ababa. It shares boundary with Sinanana Dinsho woreda in the north and north east, Berberie Woreda in south east, Menana Harena woreda in south and Adaba woreda in the west. It extends from 39^0 36 '51" to 40^{0} 12 ' 07" east longitude and 6^{0} 25' 16'' to 7^{0} 04' 65'' north latitude and covers a total area of 161348 hectare. Location map of the study area is shown in figure 2 bellow.

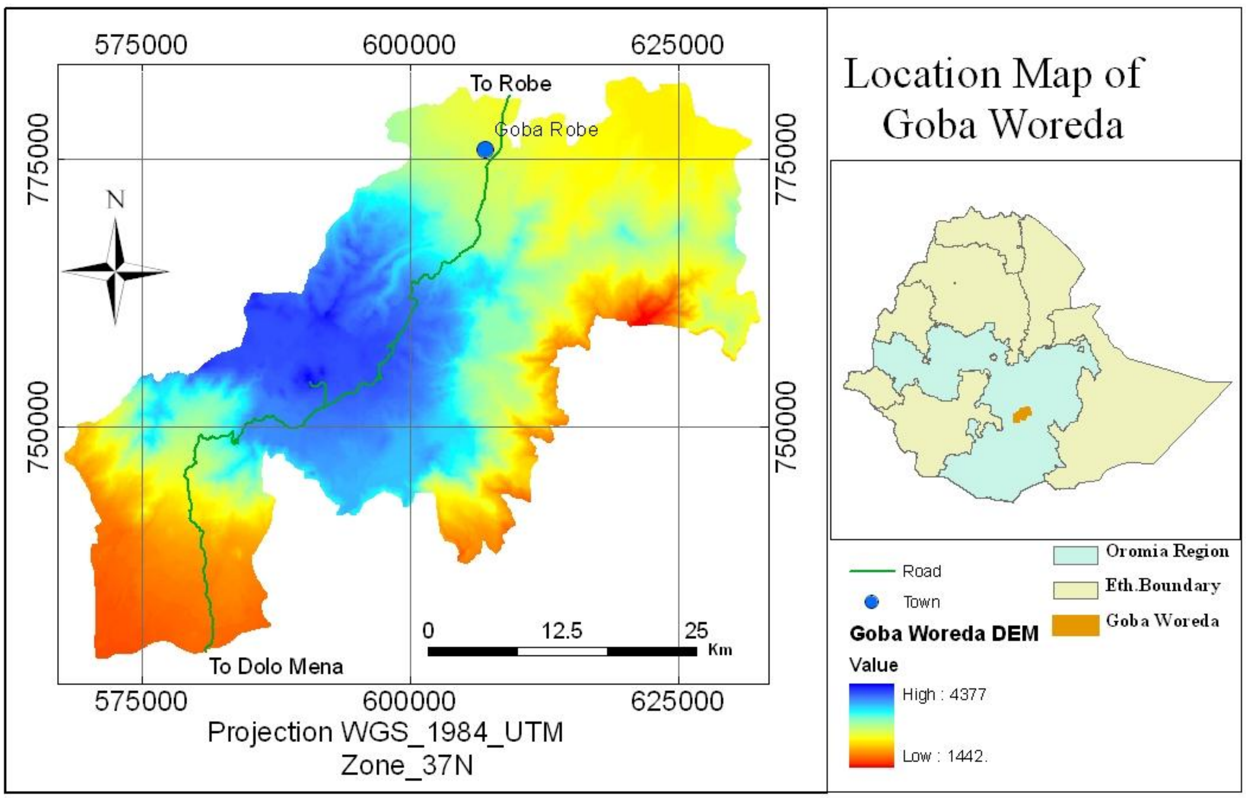


Figure 2: Map showing the Study Area

3.1.2. Climate

The climatic condition of Goba woreda largely governed by altitude and causes climatic zone ranges from Kolla, to Afro alpine (wurch). The climate of Goba woreda is dominated by woina dega and dega climate. Besides to this, due to high altitude of the Sanate plateau, the central part of this woreda consists of extremely harsh climatic conditions such as an erratic rainfall, usually wet and waterish air, icy and frostiness, frequent mist and hail. The annual rain fall of the woreda varies from 650 mm to 1300 mm. As indicated in figure 3 bellow woreda characterized by having eight months rainy season (March to October) and followed by another four months dry season (November to February. The area experiences driest month during February and wettest month during August. The woreda is also influenced by the easterly winds from Indian Ocean and causing small rain fall during January.

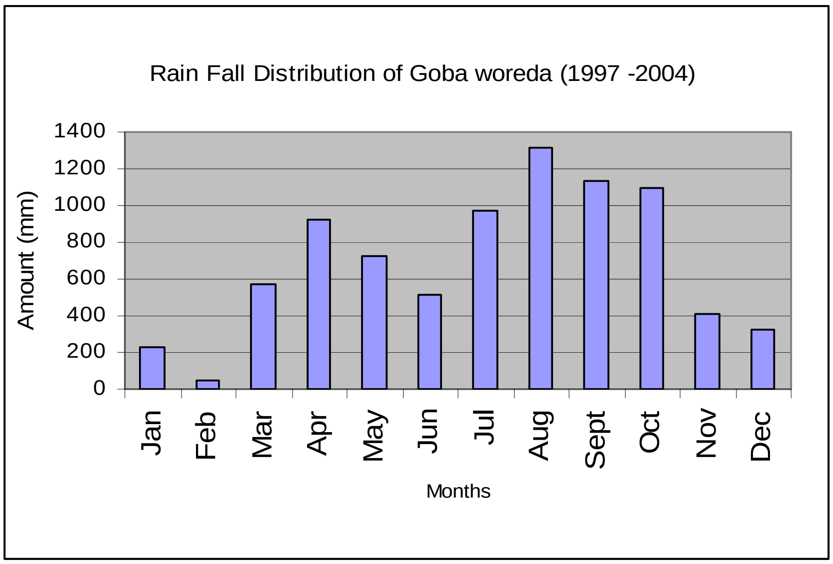


Figure 3 : ***Average Rain Fall Distribution of Goba Woreda (1997-2004).***

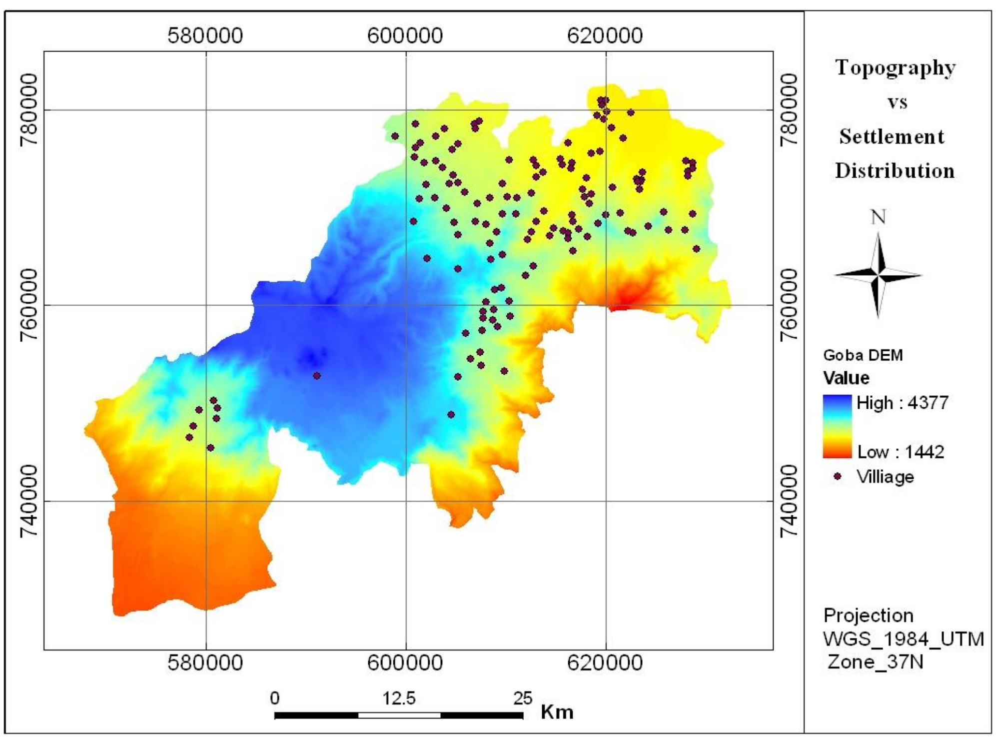
As far as temperature condition is concerned, wet seasons are comparatively warm and the dry seasons are extremely nocturnal cold and diurnal warm.

3.1.3. Topography

The study area under investigation largely lies within Bale Mountains and characterized by very rugged topography. The altitudinal variation of the area ranges from 1442 m a.s.l to 4377 m a.s.l. Mount Batu, the second highest mountain in the country with an elevation of 4377 m a. s. l. is one of the most prominent feature of the study area .Besides to this, Sanate plateau, which is one of the most extensive plateau of the country is also found in this area. The central part of the woreda is dominated by very elevated high land and very rugged terrain in which Sanate plateau, mount Batu and Tulu Dimtu are part of it. Vertical distribution of vegetation is clearly reflected in the area due to the significant altitudinal difference. As one moves up, moist montane forest, dry ever green forest, Erica vegetation (called Satoo by local people), and Alpine vegetation are clearly distinguishable based on their respective altitude.

3.1.4. Population

According to the 1994 census report, the total population size of Goba woreda was 59028,(CSA,1994). Due to the rugged nature and very high elevation, settlement is not evenly distributed in the woreda. Settlement and agricultural activities are not common or non existence in the central part particularly around Sanate plateau. Hence, settlement and agricultural activities are common in the northern part around Goba town. Figure 4 bellow shows the distribution of population in the Goba woreda.

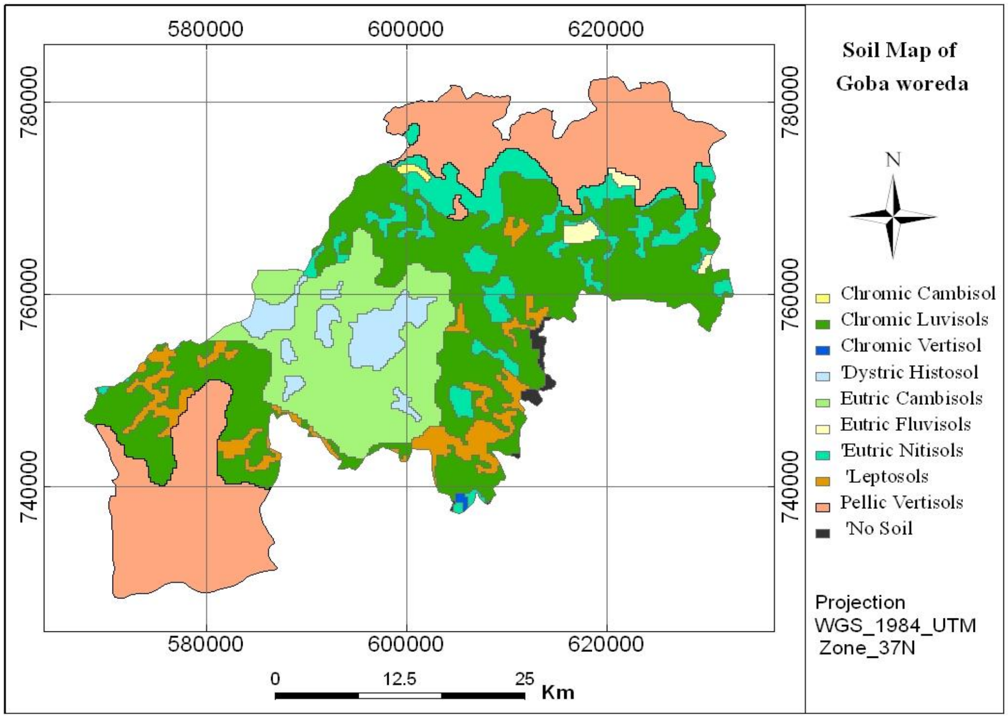


Source: Computed from SRTM Data

Figure 4: Map showing population distribution of Goba woreda

3.1.5. Soil

Goba consists of nine different soil types. Chromic luvisols, chromic Cambisols and pellic vertisol are the dominant typed soil types which the most part of the woreda**.**



Source :Shapefile obtained from Farm Africa .

Figure 5: Map ***showing Soil Distribution of Goba Woreda***

3.2. Methods and Materials used

To execute the intended objectives, both primary and secondary data were collected from various sources. Primary data generated from multi- temporal satellite image, GPS data from field collection, interviews and observation. Besides to this, secondary data such as SRTM, statistical report, metrological data, journals, and published books will be assessed.

The multi-temporal Landsat satellite imageries were analyzed and processed using ERDAS Imagine 8.6 and ENVI 4.3 softwares to quantify the extent and rate of deforestation as well as to obtain information regarding the pattern of deforestation in the study area. Besides to this, land Use / land cover map for the years 1973 and 2000 have also been generated using these softwares.

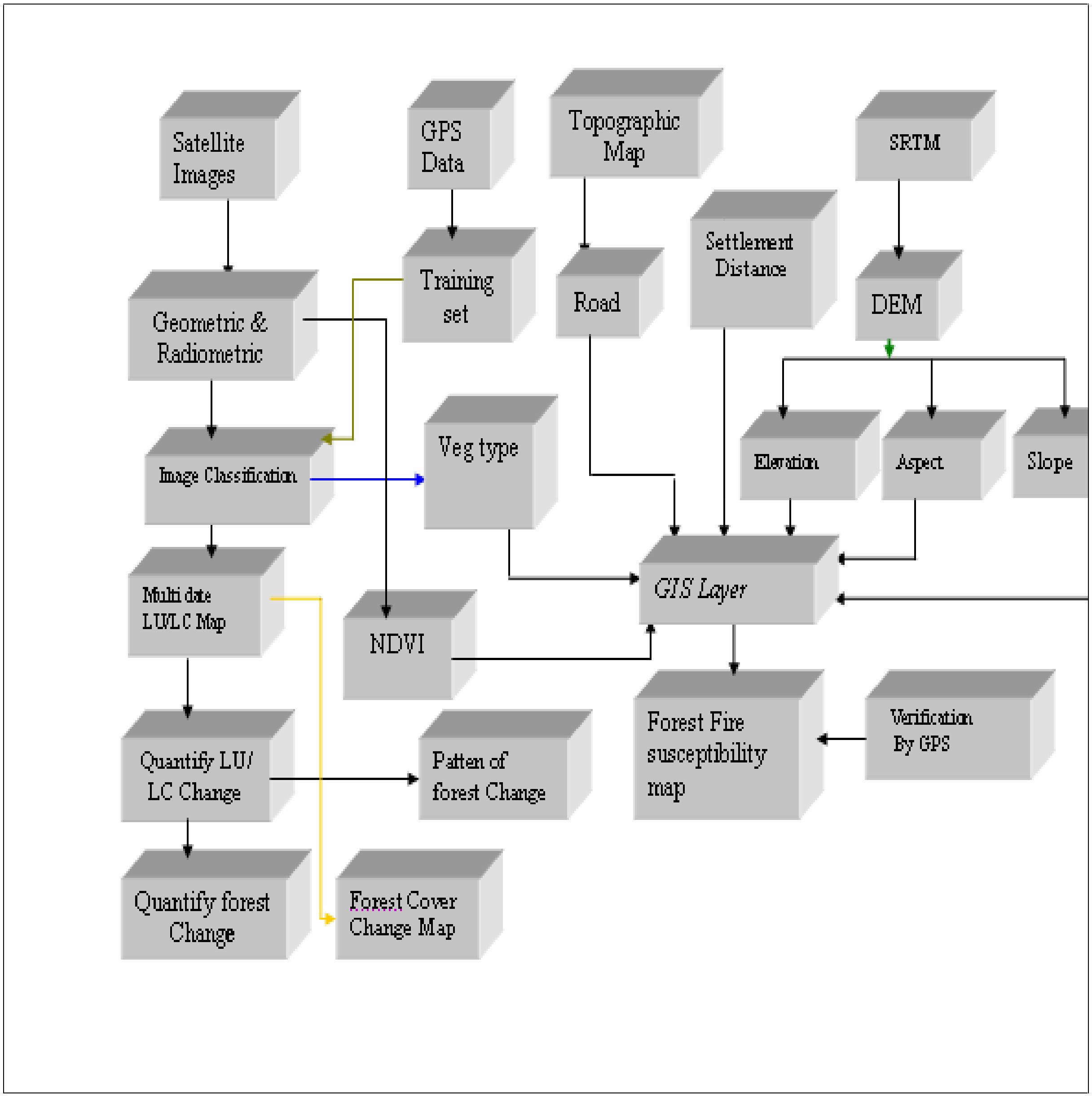


Figure 6*: Schematic Representation of Methodology*

For the analysis of forest fire susceptibility, various data sets have been generated using the integrated application ERDAS 8.6, ENVI 4.3 and ArcGIS 9.1. Vegetation condition map (NDVI map) has been generated from the Landsat ETM $^{+}$ 2000 image. Other data sets such as fuel type data set extracted from classified 2000 satellite imagery (Landsat-7ETM) while slope and aspect have been generated from SRTM data. The remaining data sets such as road (all types) and settlement obtained from CSA. In this regard, one hundred thirty three villages (localities) GPS point data have been used to identify susceptible part of the forest to fire with respect settlement distance. Each of these data sets collected in to a common geo-database. Then all of the datasets converted in to raster format and reclassified in the same scale and cell size to facilitate raster calculation. Finally, each of these factors is weighted according to their respective potential to influence forest fire. At the end, a map shows potential forest fire risk zone has been generated and the generated map verified by the ground truth collected by GPS from the previous fire spot. The methodology as well as the satellite imageries and data used in this study are summarized in figure 6 above and Tables 1 and 2 bellow.

Table 1: ***Satellite image descriptions***

S/N	Image Type	Resolution (m)	Sensor	Path	Row	Date of Acquisition
1	Landsat 1	80	MSS	180	55	01/21/73
2	Landsat 7	30	ETM+	168	55	11/28/2000

Table 2: ***Secondary Data Description***

Data	Type	Source
Settlement Data	Shapefile	CSA
Road	Shapefile	CSA
Metrology	Monthly Report	NMA
Study Area Boundary	Shapefile	Ethio-gis
Soil Data	Shapefile	Farm Africa

3.2.1. Data Analysis

3.2.1.1. Image Processing

Image processing is an important step that should be done before using the raw digital satellite image directly for the intended purpose. It involves operations that are normally required prior to the main data analysis and extraction of information. These include image rectification and restoration, image enhancement, image classification data merging GIS integration, (Lillisand, 2004).Hence, the theme of image processing resides on boosting up the reliability and accuracy of information that obtained from the satellite imageries via correcting distorted or degraded data. In other words, the core concept behind digital image processing is creating a more faithful representation of the original image and there by acquiring reliable information of the area under investigation. Selecting appropriate satellite imagery is the first task prior to any image processing. In this regarded, Landsat imageries of 1973(MSS) and 2000(ETM +) used for this study. Then, for each respective imageries digital image processing operations such as image enhancement (spatial and spectral) and image classification (unsupervised and supervised) have been done using ENVI 4.3 and ERDAS 8.6 image processing softwares.

3.2.1.1.1. Image Enhancement

Image enhancement is the process of making an image more interpretable for making a particular application .It makes important features of raw, remotely sensed data more interpretable to human eye and often used instead of classification techniques for features extraction and deriving useful information from images, LeIca Geosystems(2002). Among the various types of enhancement techniques, radiometric enhancement (for haze and noise reduction) and spectral enhancement such as natural color, tasseled cap transformation and vegetation indices part normalize vegetation index (NDVI) have been applied to each respective satellite imageries.

3.2.1.1.2. Image Classification

Image classification is the process of sorting pixels in to a finite number of individual class ,or categories of data, based on their data file values .Hence, if the a pixel satisfies a certain set of criteria , then the pixel is assigned to the class that corresponds to that criteria. Extracting different types of information of the target under investigation is largely possible classification to the raw digital satellite imageries. In this regard, both unsupervised and supervised classifications techniques have been employed phase by phase. At the first phase, unsupervised classification has been applied at pre-field stage to get general over view of the study area in relation to land use and land cover types .Then after supervised classification has made based on training areas that collected from field. Finally, post classification techniques such as confusion matrix and kappa statistics have been used to assess the accuracy of the classified image. Statistical data are also computed using ENVI 4.3 software to determine pattern of change of cover types between the 1973 and 2000.The brief description of each task regarding image classification is described bellow as follow.

3.2.1.1.2.1. Unsupervised classification

Unsupervised classification is a technique of image classification which clusters pixels in a data set based on statistics only, without any user-defined training classes .In this regard Jensen (1996) as cited by Bedru (2006),the algorithms compare pixel spectral signatures to the signatures of computer-determined clusters and assign each pixel to one of these clusters. Knowledge of the features contained within the scene is not needed beforehand as the computer assesses the inherent variability and determines cluster identification. In the present study, a color print map which consists of ten classes had been prepared using ISODATA of unsupervised classification.

The *Iterative Self-Organizing Data Analysis Technique* (ISODATA) is by far the most used method, (Bedru, 2006).It calculates class means evenly distributed in the data space then iteratively clusters the remaining pixels using minimum distance techniques. Each iteration recalculates means and reclassifies pixels with respect to the new means. Iterative class splitting, merging, and deleting is done based on input threshold parameters. All pixels are classified to the nearest class unless a standard deviation or distance threshold is specified, in which case some pixels may be unclassified if they do not meet the selected criteria. This process continues until the number of pixels in each class changes by less than the selected pixel change threshold or the maximum number of iterations is reached (Tou and Gonzalez, 1974).

Unsupervised classification is not sufficient by itself to determine precisely the areas land use and land cover type because of its classification draw backs. In this regard, Bedru (2006) stated that unsupervised classification has several shortcomings. The most serious one is that some of the clusters may be meaningless as they represent a mix of different land covers. It is also common that a single land cover class is split into more than one spectral cluster. Therefore, unsupervised classification requires considerable knowledge in order to assign proper land cover class to each of the clusters. Sometimes it is impossible to do so without post classification ground survey.

Employing supervised classification is a mandatory task to resolves the draw backs of unsupervised classification. Hence, in the current study, each classes of cover types has been cross referenced at the field using the ground truths collected from the field using GPS receiver and supervised classification applied to each satellite imageries by selecting representative training areas to resolve the drawback of unsupervised classification .

3.2.1.1.2.2. Supervised Classification

Supervised classification is also another classification technique which clusters pixels in a data set into classes corresponding to user-defined training classes. Training classes are groups of pixels (ROIs or AOI) or individual spectra. This technique includes Parallelepiped, Minimum Distance, Mahalanobis Distance, Maximum Likelihood, Spectral Angle Mapper (SAM), and Binary Encoding to classify the image in to user defined classes.

In this study maximum likelihood techniques has been applied to Landsat of the year 1973, and 2000 using ENVI 4.3 software to determine land use and land cover dynamics in general and forest cover in particular as well as to process forest fire susceptibility analysis .

Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless a probability threshold selected, all pixels are classified .Each pixel is assigned to the class that has the highest probability.

Supervised classification is usually appropriate when we want to identify relatively few classes, or when we have selected training sites that can be varied with ground truth data a s well as when we can identify distinct, homogeneous regions that represent each class. In this study, GPS ground truth sample data have been collected from the field for each respective land cover and land use types to select training areas. Based on the collected GPS ground truth data and field observation, the study area under investigation has been classified in to ten major categories, though there is no one ideal classification of land use and land cover, and it is unlikely that one could ever be developed.

There are different perspectives in the classification process, and the process itself tends to be subjective, even when an objective numerical approach is used. There is, in fact, no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use and land cover patterns change in keeping with demands for natural resources. Each classification is made to suit the needs of the user, and few users will be satisfied with an inventory that does not meet most of their needs (USGS, 1976).

Accordingly, in this study, to make suit for the analysis of forest fire risk susceptibility, the forest coverage of the area further classified in to moist montane forest, dry ever green forest, plantation forest and alpine bush land (Erica bush land). Besides to this, agricultural land and settlement areas are categorized in the same class though ideally the two classes lie in to different categories due to intermixing pattern settlements with agricultural land in the study area .In general, land use and land cover maps have been generated from the processed Landsat imageries of the years of 1973,and 2000 for the area under investigation and summarized as follow.

Moist Montane forest: It the part of "Harena forest", the most extensive forest natural remaining of Ethiopia, which consists of various types of vegetation and covers the lower altitude of the southern part of the Goba district along the Goba –Dello Mena main road. It extends from 1450 to 3200 m .a.s.l.

Dry Ever green forest (Dry afro-montane forest): It consists of Hagenia *abyssinica* and Juniperous procera.

Erica Vegetation (Ericaceous vegetation): Vegetation types which covers escarpment of the mountains immediately bellow "Sanetti plateau", one the most high elevated plateau of Ethiopia .This vegetation locally called "Satoo".

Alpine vegetation (Afro-alpine vegetation): It consist of short flowery plants intermixed with short grass and the largest part of Sanetti plateau

Plantation forest: It represents forest planted by human.

Water body: Consists small ponds and rivers

Bare land: It is land of limited ability to support vegetation.

Agricultural land and Settlement: Agricultural land defined as land used primarily for production of food and other crops. While built up primarily involves areas inhabited by settlement.

Finally, post classification and spectral change detection techniques applied to determine the land use / land cover change cover dynamics of the area in general and forest in particular. In addition to this, the accuracy of the classification examined based on the Landsat 2000 image using confusion matrix and kappa statistics.

3.2.1.2. Computing Change Detection

3.2.1.2.1. Forest Cover change Detection

Change Detection Analysis encompasses a broad range of methods used to identify, describe, and quantify differences between images of the same scene at different times or under different conditions. Essentially, it involves the ability to quantify temporal effects using multitemporal data sets (Singh, 1989). In this regard, satellite imageries have a paramount role to record the state of an object at different times. In this research both post classification and spectral change detection procedures have been employed to examine the forest degradation and deforestation condition of Goba between 1973 and 2000.Besides to this, confusion matrix has been generated based on the classified Landsat images of 1973and 2000 to determine the trends and pattern of land use and land cover in general and forest cover in particular.

3.2.1.2.2. Post Classification Change Detection

In post classification each two periods of images are classified and labeled. The area of change is then extracted through direct comparison of the statistics computed from each respective classified imagery and each classified image has been compared based on the derived statistics. However, post classification approach is highly dependent up on the land cover change results on the individual classification accuracies. As a consequence, this approach can produce a large number of erroneous change indications since an error on either data gives a false indication of change (Singh, 1989). However, the draw backs of post classification approach can be resolved by employing spectral change detection techniques.

3.2.1.2.3. Spectral Change Detection

As opposed to post classification, spectral change detection techniques are based on the detection of physical changes between image dates. This resolves the errors introduced in post-classification change detection where inaccuracies in the land cover classification are propagated into land cover change analysis. However, it is hardly possible to identify change and no change pixels. This technique applies for change detection based on the assumption that land cover change results in spectral change in spectral signature of the affected areas.

There are different types spectral change detection techniques which are used for the analysis of vegetation condition at different time or condition. Among spectral change detection methods, NDVI image differencing emerges as one of the most widely used .It is one of the oldest, most well known, and most frequently used vegetation indices (VIs). .The combination of its normalized difference formulation and use of the highest absorption and reflectance regions of chlorophyll make it robust over a wide range of conditions. It can, however, saturate in dense vegetation conditions when LAI becomes high. NDVI is defined by the following equation:

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

Where: NDVI =Normalize Difference Vegetation Index

NIR =Image in near infrared band.

R = image in red band

The value of this index ranges from –1 to 1. The common range for green vegetation is 0.2 to 0.8. Ideally healthy vegetation yields value approaching to 0.8 while vegetation under high stress provides value approaches to 0.Thus forest exhibiting low stress conditions is usually made up of healthy vegetation where as a forest under high stress condition shows signs of dry or dying plant material.Hence, healthy vegetation provides high reflectance in NIR band and low reflectance in visible red band. As a consequence, healthy vegetation results in very high positive value as opposed to vegetation under high stress. While water bodies and moist soil yield very negative values approaches to negative one. Thus, its value indicates the amount of green vegetation present in the pixel; higher NDVI values indicate more green vegetation.

To examine and compare the trends of vegetation condition of the study area under investigation, NDVI values have been computed from respective images. Finally, the vegetation condition between 1973 and 2000 has been compared based on the derived NDVI values which computed from the respective images.

3.2.1.3. Forest Fire Risk Susceptibility Analysis

In order to determine the susceptibility of the study area's forest to fire, forest map of was generated from the 2000landsat ETM^+ image. Though forest fire in the area under investigation is human induced, other factors have been considered to identify susceptible areas based on these fire influential factors .To carry out forest fire risk susceptibility mapping, seven factors have been developed based on their respective potential to influence or aggravate forest fire. These are fuel condition (NDVI value), Vegetation type, elevation, aspect, slope and distance from settlement and road.

Each of these factors was analyzed in the following order of importance: Vegetation condition (moisture content evaluate by NDVI value), vegetation type, slope &aspect, distance from settlements and roads. Thus, each class has different weights. How these factors influence forest fire are briefly described and summarized in section 5.4.

3.2.1.3.1. Weighting of Dataset and Running of MCE

Prior to performing MCE to determine forest fire risk susceptibility, each data sets have been converted in to raster format and reclassified in to a common scale using ArcGIS spatial analyst, giving each range a discrete, integer value 1 to 4. In addition,each reclassified data set masked by using the year 2000 forest cover raster layer to execute the intended analysis on cells in a particular area of interest ; forest area in this paper context.Therefore, areas out of forest excluded from computation or considered as no risk as far as forest fire is concerned .Where highest values assigned to data set which pose more influence in triggering forest fire and vice versa., To resolve personal biased in assigning weight for each data, Pair wise comparison matrix has been computed using IDRSI 32 software. Finally, each factor has been multiplied by their respective weights obtained from the paire wise comparison and factors and the final output of forest fire risk susceptibility map is obtained.The equation used in GIS to determine forest fire risk places is shown in equation 1 below.

$$FFRZ = VC * w + VT * w + S * w + A * w + DS * w + DR * w + E * w. \quad ...Equation\ 1$$

Where: *FFRZ = Forest fire risk zone*

VC = Vegetation condition evaluated by NDVI value

VT = vegetation type

S= slope

A= aspect

DS =settlement distance

RD = road distance

E = Elevation.

W =Weight

4. RESULTS AND DISCUSSIONS

This part of the paper explains the results extracted from the raw satellite imageries and other ancillary data through data processing methods. The whole of this section is broadly classified in to two sections. The first section focuses on describing the land use and land cover dynamics of Goba woreda between the year 1973 and 2000 in general and patterns and rate of forest change in particular between these periods. While the second section, particularly emphasizes on identification of potential forest fire areas using MCE techniques considering forest fire relation with fire triggering factors such as slope, aspect , elevation, fuel condition or type , distance from settlement and roads .

4.1. Post Classification Change Detection

4.1.1. Land use/Land cover Result of 1973

Based on the results extracted from the 1973Landsat image, the land use /land cover of Goba woreda is classified in to seven major classes. These are moist montane forest, dry ever green forest, alpine bush land (Erica –locally called "satoo"), alpine vegetation, water body, bare land and agricultural land. As indicated in Table 3 bellow, in 1973, the largest part of the woreda was covered by dry ever green forest, followed by moist montane forest and agricultural land which accounted 35%, 19.9 % and 16.2% of the total area of the woreda respectively and the least part of the woreda was covered by water accounted 0.5 percent.

Table 3: Land use /land cover summary of Goba woreda of 1973

Cover types	Coverage	
	ha	**%**
Erica	*12550*	7.8
Alpine Veg.	*25315*	15.7
Water Body	*826*	0.5
Agriculture &Settlement.	*26084*	16.2
Bare land	*8037*	5.0
Dry Ever green forest	*56454*	35.0
Moist Montane forest	*32082*	19.9
Total	161348	100

Source: computed from the classified Landsat 1973 image.

As indicated in Table 3, the forest which consists of alpine bush land (Erica), dry ever green and moist montane forest took the lion share coverage (62.7 percent) in this specified year and the remaining 37.3 percent of the woreda covered by the other types of cover classes. These figures imply that the woreda had immense forest coverage in the country during this period and it was one the symbolic example in the country where natural forest relatively was undisturbed by the local community. Figure 7 and 8 bellow depict the coverage and distribution each respective land use / land cover of Goba woreda in 1973.

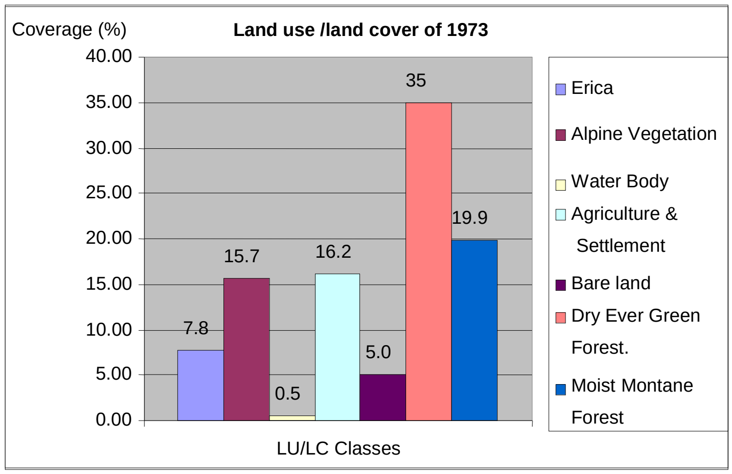
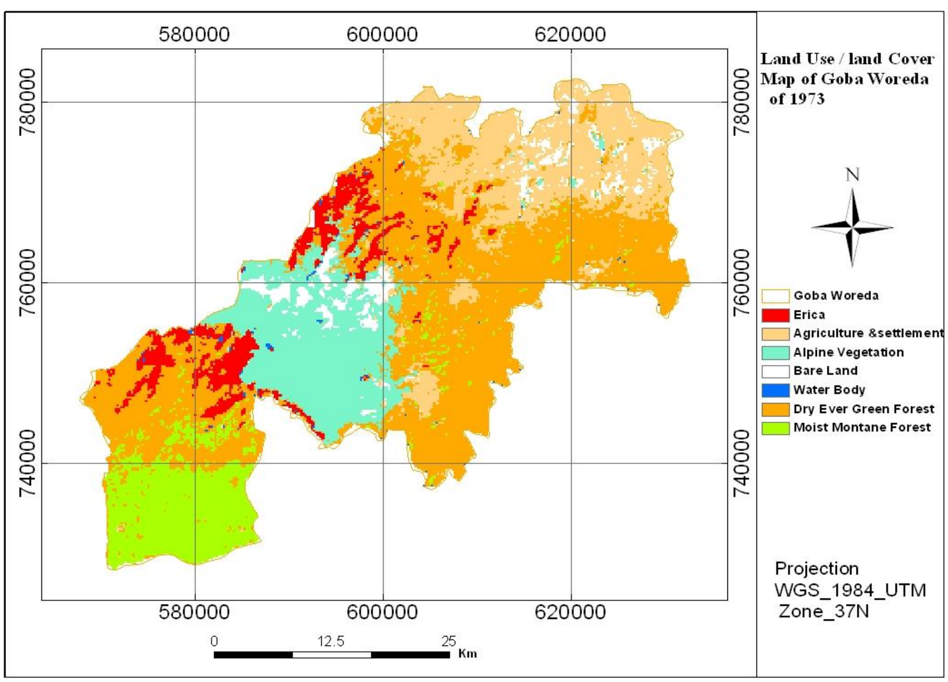


Figure 7: Graph **depicting area coverage (ha) of each land use type of 1973**



Source:Computed from the 1973 Landsat image.

Figure 8***: Map showing land use/land cover of Goba woreda of 1973***

4.1.2. Land use/Land cover of 2000

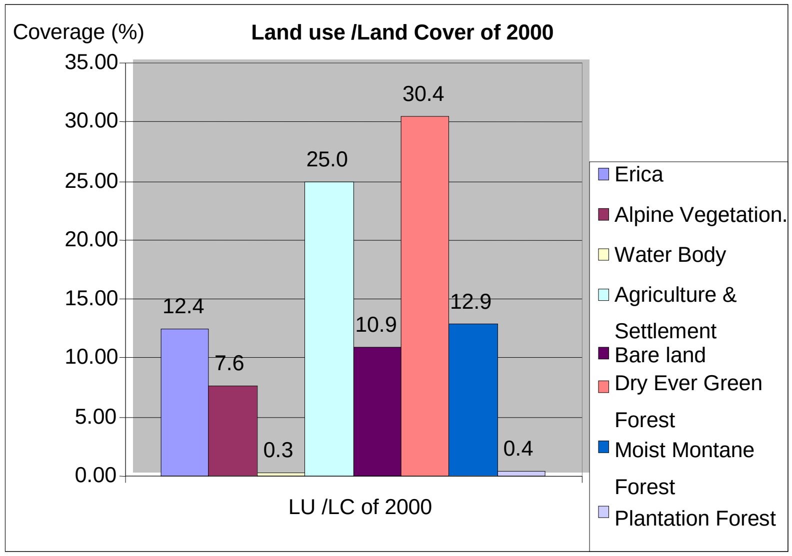
Based the on the results obtained from the processed Landsat 2000 image , the land use /land cover of Goba woreda classified in to eight major classes and depicted in Figure 9 and 10 bellow. These are moist montane forest, dry ever green forest, alpine bush land alpine vegetation, water body, bare land , plantation forest and agricultural land .Among these classes , dry ever forest , agricultural land and moist montane forest took the lion share of coverage as compared the remaining cover classes. As it indicated in Table 4 and figures 9 bellow, 30.4 %, 25 % and 12.4 % of the woreda was covered by these classes respectively during the year 2000. In similar year, the least coverage share took by water body and plantation forest which accounted 0.3 % and 0.4 % of the total area.

The forest which consists of alpine bush land (Erica), dry ever green, moist montane and plantation forest covered half of total area (56.2 %) of the woreda and the remaining 43.9 percent of the woreda was covered by the other types of cover classes.

Table 4: Land use /land cover summary of Goba woreda of 2000

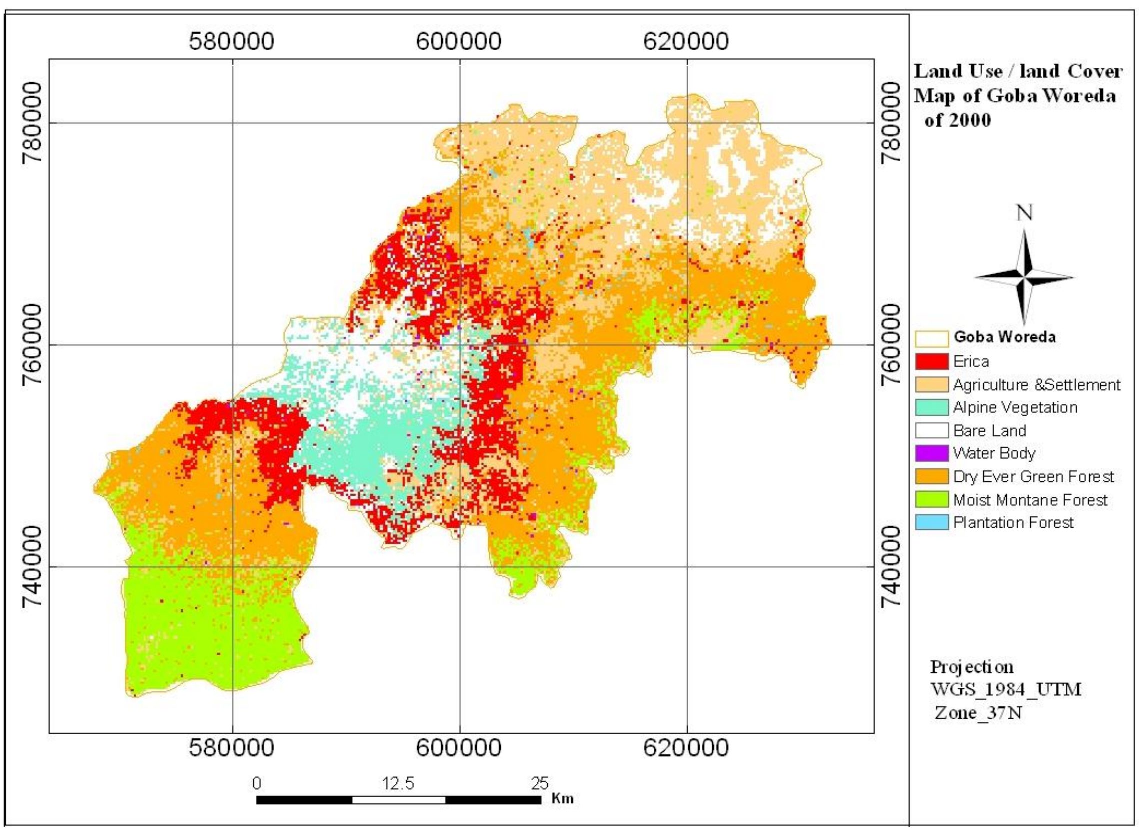
Cover types	Coverage	
	ha	**%**
Erica	20009	12.4
Alpine Vegetation	12265	7.6
Water Body	530	0.3
Agriculture &Settlement	40342	25.0
Bare land	17608	10.9
Dry ever green forest	49081	30.4
Moist Montane forest	20797	12.9
plantation forest	716	0.4
Total	161348	100.00

Source: computed from the classified Landsat 2000 image.



Source: *computed from the classified Landsat 2000 image*

Figure 9: **Graph depicting area coverage (in ha) of each land use type of 2000.**



Source:Computed from the 2000 Landsat ETM+ image**.**

Figure 10***: Map showing land use/land cover of Goba woreda of the year 2000.***

4.1.3 Accuracy Assessment

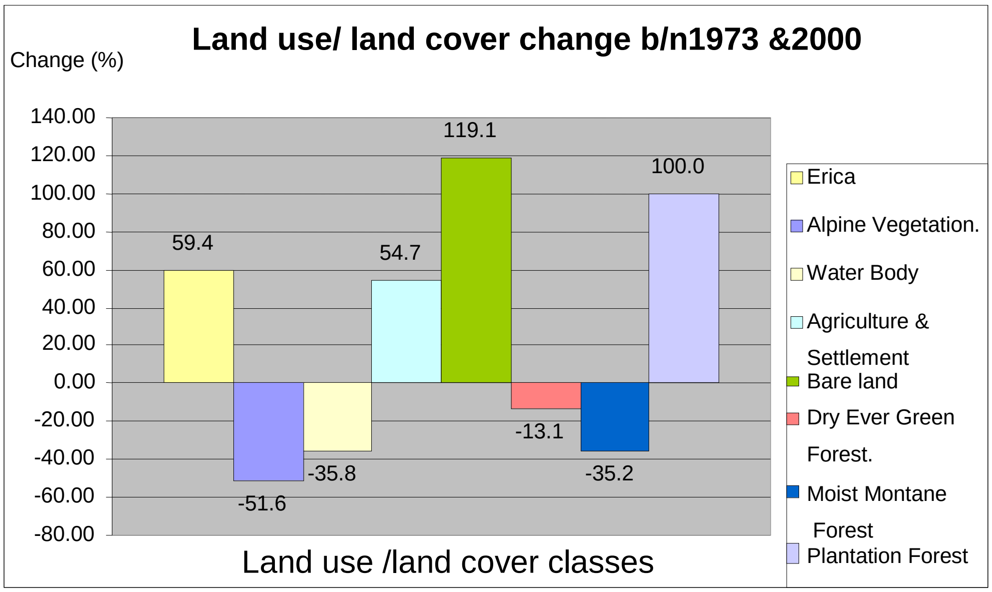
It is a general term for comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of the classification process .usually; the assumed true data are derived from ground truth data, (LeIca Geosystems, 2002).

Thus, it is essential to assess thoroughly the accuracy of the classification before utilizing the classified satellite imageries for intended purpose. In this paper confusion matrix has been made to determine the number of ground truth pixels that are classified correctly during the classification process based on the 2000 classified Landsat ETM^+ satellite image and ground truths collected by GPS during field work .Thus, the use of confusion matrix is aimed at showing the accuracy of a classification result by comparing a classification result with ground truth information. The computed confusion matrix revealed 86.4 % and 0.81over all accuracy and kappa coefficient respectively.

The kappa value normally ranges from 0 and 1. If kappa value equals to 1 indicates complete agreement and the inverse is true if the value equals to 0. In the process of satellite image classification, the minimum level of accuracy should not be less than 80%. In accordance with this concept, the computed result of kappa statistics and over all accuracy satisfies this requirement. Thus, it is possible to perform further analysis based on the classified image to execute the intended purpose.

4.1.4. Comparison land cover /land use dynamics between 1973 and 2000

Land use / land cover changes are inevitable in an area as far as there is time gap; however the degree change depends up on the length of time and the magnitude of human interaction of the area. Comparing a given land use class with the same or other classes based on a known time reference will provide information on the state of the cover types during different periods. Hence, the result obtained from the comparison will aid planners on the process of devising strategies targeted sustainable use of the resource of an area. Here, land use /land cover comparison has been made based on 1973 and 2000 as time reference to describe the intended comparison. The results obtained from classified Landsat imageries of the years 1973 and 2000 have been used to examine land use /land cover dynamics of the study area under investigation. As indicated in Table 5 and figure 11, significant land use /land cover dynamics have been observed in the woreda between the specified periods. Some cover types such as Erica (alpine bush land), agricultural land bare land and plantation forest shows positive trend between 1973 and 2000. Within a gap of twenty seven years these cover types have shown an increment by 59.4 %, 54.7 %, 119.1 % and 100 % respectively. On the contrary, alpine vegetation ,water body dry ever green forest and moist montane forest have indicated a negative trend and decreased by 51.6%,35.8 % 13.1 % and 35.2 % respectively between 1973 and 2000. (See figure 11 bellow).



Source: *computed from the classified Landsat 1973& 2000 image.*

Figure 11: Graph showing land use /land cover change between 1973 and 2000

The forest, which consists of erica, moist montane forest, dry ever green forest and plantation forest together , decreased by -10483 ha (10.4 %)with a gap of twenty seven years between 1973 and 2000. The down ward trend of the forest coverage is mainly attributed to increasing population who clear forest for intensification of agricultural and grazing land as well for other purpose at the expense of the forest cover.

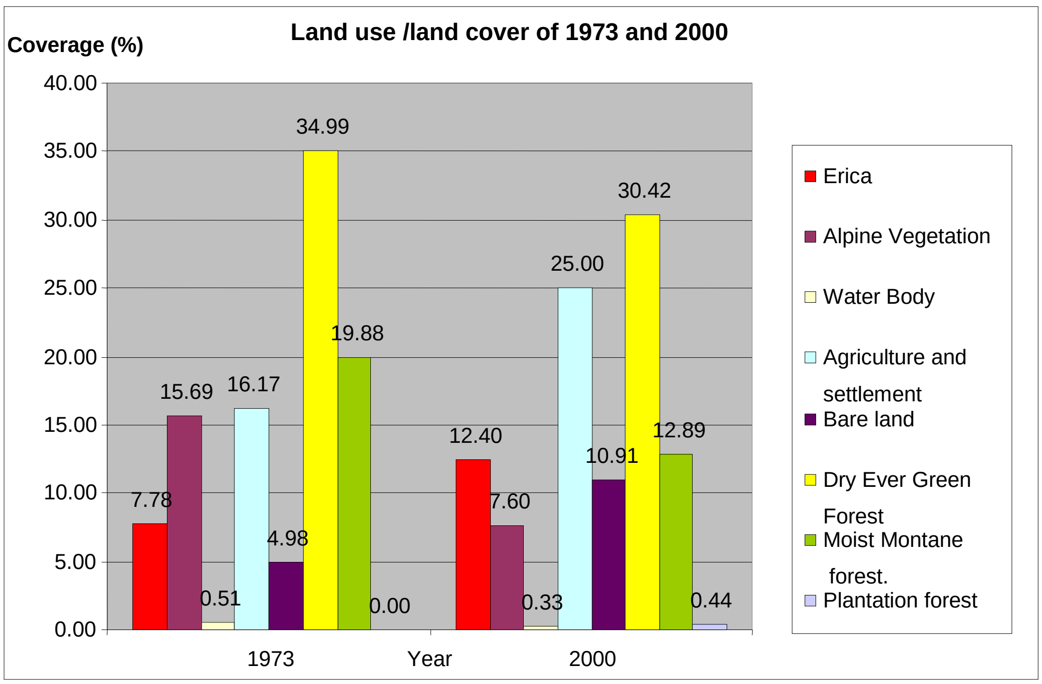
Table 5*: **Summary Statistics of Land cover/ Land Use units of Goba woreda***

between 1973 and 2000

Cover types	Year				Trends of change between 1973 &2000	
	1973 Coverage		2000 Coverage			
	ha	**%**	**ha**	**%**	**(ha)**	**(%)**
Erica	*12550*	7.8	20009	12.40	7459	59.4
Alpine Veg.	*25315*	15.7	12265	7.60	- 13050	-51.6
Water Body	*826*	0.5	530	0.3	-296	-35.8
Agriculture & Settlement.	*26084*	16.2	40342	25.0	14258	54.7
Bare land	*8037*		17608	10.9	9571	119.1
Dry Ever green Forest	*56454*	34.99	49081	30.4	-7373	-13.1
Moist Montane Forest	*32082*	19.9	20797	12.9	- 11285	-35.2
plantation forest	0	0.00	716	0.4	716	100.0
Total	161348	95.0	161348	100.00		

Source: computed from the classified Landsat 1973 and 2000 imageries.

Among the forest classes, moist montane forest and dry ever green forest are the main victim of deforestation in the area. As indicated in Table 5 and figure 11, the coverage of Erica bush land increased by 59.4 percent between 1973 and 2000. This positive trend of alpine bush land (Erica) is related to the frequent forest fire of the area which facilitates the regeneration of fire resistant vegetation at the expense of the main forest. Erica vegetation is one of the most important sources of pasture for the livestock of the local community. This vegetation serves as a pasture only at the stage before maturity. Hence, the community uses fire as a tool of clearing the matured Erica vegetation to get fresh pasture source. This results in a serious damage on the nearby main forest area (dry ever green and moist montane forest) where regeneration of the forest is hardly possible and this permits regeneration and succession of fire resistant vegetations among which Erica is dominant. Even though Erica is the most victim to forest fire, its spatial extent has increase profoundly because its capability to regenerate rapidly. Hence, after burning the Erica covers not only its previous area but also covers other burned areas which previously covered by other forest types. As indicated in Table 7 bellow, 20009 ha land of Goba woreda is shifted to Erica vegetation from other cover types between 1973 and 2000. Among this 3161ha (15.8 %), 6467ha (32.3 %), and 2973 ha (14.9 %) were from Moist Montane forest, Dry ever Green Forest and Alpine Vegetation respectively.



Source: Computed from Table 5 above

Figure 12*: Graph showing land use/ land cover of Goba woreda of the year 1973 and 2000.*

4.1.5. Extent and Rate of Forest Cover Change of Goba Woreda between 1973 and 2000

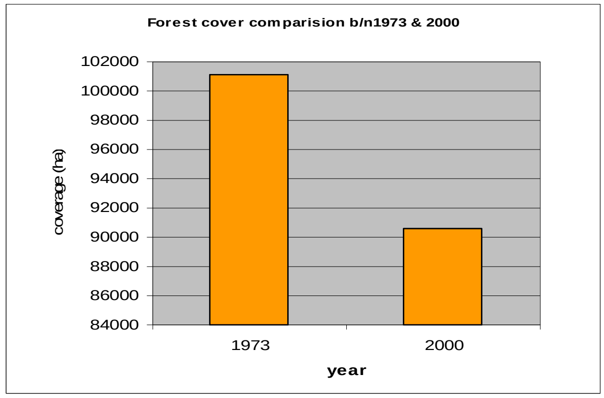
Forest coverage change is predictable in the area where inhabited and surrounded by human settlement. In this regard, statistical data have been computed by employing digital image processing techniques on Landsat 1973 and 2000 satellite imageries to determine the extents as well as the forest change of the study area under investigation and the computational results are summarized in Table 6 bellow.

Table 6: ***Summary of total forest area and rate change between 1973 and 2000***

Forest types	Year				Cover Change b/n1973 &2000	Rate/year	Rate /Total Area per Year
	1973		2000				
	Coverage		Coverage				
	ha	**%**	**ha**	**% of Total area**	**(ha)**	(ha)	**%**
Erica	12550	7.8	20009	12.4	7459	276.3	0.2
Dry Ever green forest	*56454*	35	49081	30.4	-7373	-273.1	-0.2
Moist Montane forest	*32082*	19.9	20797	12. 9	-11285	-418.0	-0.3
plantation forest	0	0.0	716	0.4	716	26.5	0.02
Total Forest Area	101086	62.7	90603	56.2	-10483	-388.3	-0.2

Source: computed from the classified Landsat 1973 and 2000 imageries

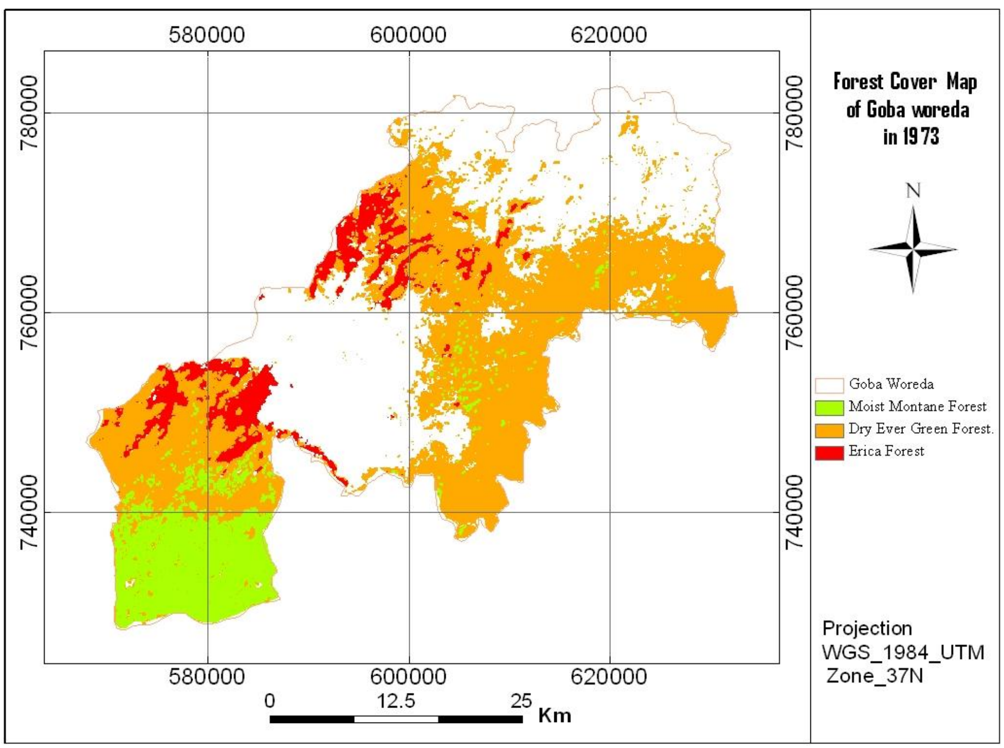
As depicts in Table 6, in 1973, 101086 ha (62.7%) area of the woreda was covered by forest and after a gap of twenty seven years in 2000, the coverage decreased to 90603 ha (56.2). This figure implies that the forest coverage decreased by 10483 ha (10.4%) within these years and further it implies 388.26 ha (0.2 % of the total area) forest deforested per year. This rate is relatively is small as compared to the overall the country's rate deforestation which equals to 150,000-200,000 ha. The dominance of rugged topography is one of the reasons attributed to the small rate of deforestation in the area. It is obvious that farming and settlement are hardly possible in areas where is dominated by rugged topography like Goba woreda. In relation to this Berhan (2007) stated that" Steep slope areas are the natural forest cover Keeper." .The current pattern of forest distribution and settlement location of the area by itself an evident for this argument. Currently, the majority of agricultural activities and settlement are almost found in the northern part of the woreda where rugged terrain is relatively small (*See Figure 4. above: Map showing Settlement distribution and topography).*



Source: Computed from Table 5.6 above.

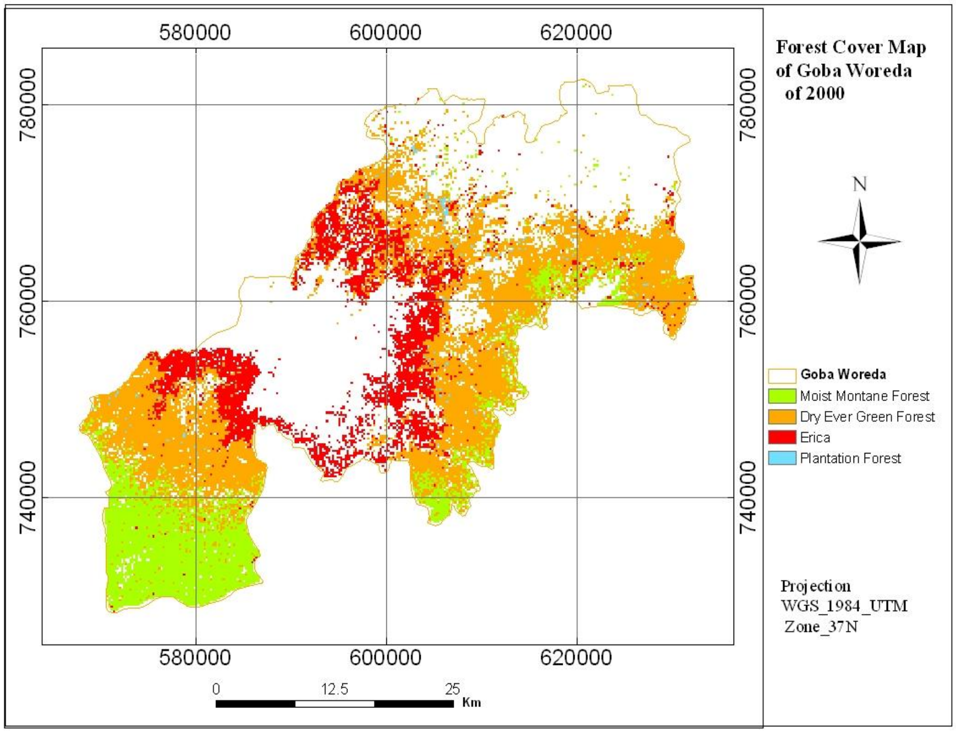
Figure 13*: Graph showing forest coverage of the year 1973 and 2000*

The forest cover map of the area the year 1973 and 2000 generated from land use land cover map. The land use land cover map was converted in to vector format to clip specifically the forest from the others cover classes. Figure 14 and 15 below shows the forest distribution of Goba woreda in 1973 and 2000 respectively.



Source: Computed from the 1973 Landsat image.

Figure 14*:* *Forest Cover Map of Goba Woreda in 1973*



Source: Computed from the 2000 Landsat ETM^{+} image

Figure 15: *Forest* ***Cover Map of Goba woreda in 2000***

4.1.6. Land use /land cover Pattern of change

It is clear that some land use /land cover classes change in to other classes as far as there is a cover change an area. That is an area previously covered by a given land use cover type may not be completely covered with the same land use after a gap of years. Hence, some portion of the area will be covered by other types of land use types. Determining the land use pattern change is so vital to devise proper strategies to curve problems that aroused by the change. In this study land use and land cover change matrix have been generated based on the classified Landsat 1973 and 2000 imageries and the result is presented in Tables 7, 8 and 9 bellow .The matrix arranged in such a way that the initial state classes (1973 land use /land cover classes) represented in the columns and the final state classes (2000 land use /land cover classes) stated in the rows. In other words, the row total gives the total amount of land covered by a particular land use /land cover type during the initial year (1973 in this context) and the row total represents the total amount land covered by a given land use /land use type during final year (2000). In this matrix table, values stated in the diagonal represents the amount of land remains unchanged and values above the diagonal indicate the amount of land that is changed in to other classes. Generally, this matrix provides the distribution of land use /land cover classes in each respective year as well as the amount or the proportion of cover types changed in to other classes. Therefore, it is easy to identify not only where changes occurred but also the class into which the cover types changed.

Table 7: Land use /Land cover change matrix between 1973 and 2000.

Initial period(1973) (ha)

Final Period (2000) (ha)

Cover types	Erica	Alpine Vegetation	Water body	Agriculture & Settlement	Bare land	Dry Ever Green Forest	Moist Montane Forest	Class Total
Erica	**6027**	2973	270	1058	53	6467	3161	20009
Alpine Vegetation	206	**10781**	30	194	403	427	224	12265
Water Body	112	120	**29**	16	30	166	57	530
Agriculture &settlement	826	3299	94	**18573**	3302	11298	2950	40342
Bare land	533	7664	99	3920	**4007**	1030	355	17608
Dry ever green forest	4719	463	271	1783	165	**31498**	10182	49081
Moist Montane forest	58	13	31	471	71	5127	**15026**	20797
plantation forest	69	2	2	69	6	441	127	716
Class Total	***12550***	***25315***	***826***	***26084***	***8037***	***56454***	***32082***	
Class Changes	6661	14800	920	7964	4246	26685	17253	
Image Difference	7445	-13308	-414	14070	9396	-8844	-11288	

Source: Computed from the classified Landsat image of 1973 and 2000**.**

Table 8: **Land use /Land cover change matrix between 1973 and 2000**

Land use /land cover types during initial period (1973) in ha							
Land use /land cover types during initial period (2000) in ha	*Cover Types*	*Forest*	*Alpine Vegetation*	*Water Body*	*Agriculture & settlement*	*Bare land*	*Class Total*
	Forest	**82902**	3451	574	3381	295	90603
	Alpine Vegetation	857	**10781**	30	194	403	12265
	Water Body	335	120	**29**	16	30	530
	Agriculture &settlement	15074	3299	94	**18573**	3302	40342
	Bare land	1918	7664	99	3920	**4007**	17608
	Class Total	**101086**	**25315**	**826**	**26084**	**8037**	
	Class Changes	18184	14534	797	7511	4030	
	Image Difference	-10483	-13050	-296	14258	13578	

Source: Computed from the classified Landsat image of 1973 and 2000.

Table 9: ***Patterns of Forest Covers Change***

Change from	**Area (ha)**	**Percentage**
Forest to Alpine Vegetation	857	**0.9**
Forest to water body	335	0.3
Forest to Agriculture &Settlement.	15074	14.9
Forest to Bare land	1918	1.9
Total forest change	18184	18
Remain unchanged	82902	82.

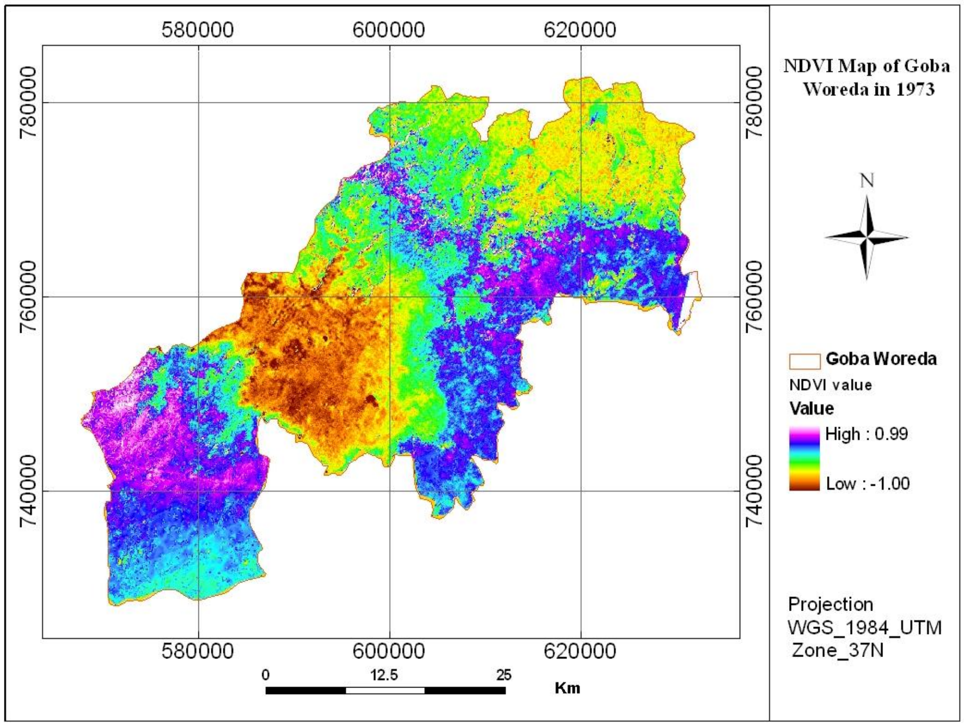
Source: Computed from the Table 8

As indicated in Tables 8 and 9 above, the 1973 forest cover changed in to other land use /land cover types between 11973 and 2000. Between these periods, the largest proportion of the forest changed in to agricultural land and bare land. More precisely about 14.9 %, 1.9 %, 0.9 % and 0.3 % of the 1973 forest cover changed in to agricultural land, bare land alpine vegetation and water body respectively. These figures imply that about 18 percent of the 1973 forest cover changed in to other land use/land cover types within the gap of twenty seven years. The remaining 82.2 % (82902 ha) of the forest remain unchanged. The proportion of forest cover that changed in to other classes is relatively low as compare to the proportion of the forest remained unchanged .This may be attributed to dominance of rugged topography of forest area where practicing agricultural and related activities is hardly possible. In other words, 82 % of the forest area may not remain unchanged if the area favors agricultural activities and human settlement. The majority part of the Goba woreda is the part of Bale Mountains National Park; being it is the part of the park, the forest within the woreda has been protected from the local community to practice freely agricultural and related activities. Hence, conservation also plays a vital role for the slow rate coverage change besides to topography factor.

4.2. Spectral Change Detection

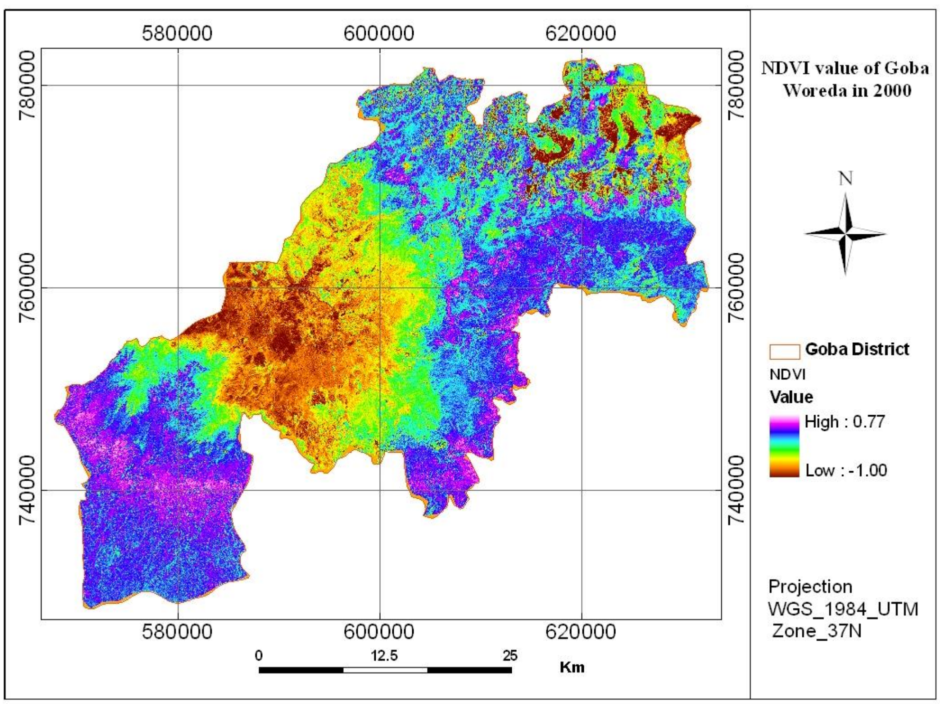
4.2.1. NDVI Result

Based on the landsat1973 and 2000 satellite imageries, NDVI values have been computed for each respective year to get an over view of the vegetation biomass in the study area between these periods and the results are presented in Table 10. Thus by comparing these values it is possible to determine whether the vegetation biomass of the area increased or not. The NDVI value of the study area reveals the change of the vegetation biomass between the period of 1973 and 2000. As it indicated in 10, the minimum and maximum NDVI values ranges from – 1.00 to 0.99 and -1 to 0.77 for the period of 1973 and 2000 respectively. Figure 16 .a and 17 also show the NDVI condition of the study area in1973 and 2000 in the same order. Even though NDVI index constrain to provide data regarding the actual amount of vegetation biomass, the above values indicate degradation of the vegetation biomass of the area under investigation. In 1973 the maximum NDVI value was 0.99 while after a gap of twenty seven year in 2000 the value reduced to 0.77 and it decreased by 22 percent. This implies that the vegetation biomass of the area is decreasing from time to time. In the same manner, the mean NDVI values also reveal similar result.



Source: Computed from the 1973 Landsat image.

Figure 16: ***Map Depicting Normalize Difference Vegetation Index of Goba woreda in 1973***



Source: Computed from the 2000 Landsat ETM^+ image

Figure 17*:* ***Map Depicting Normalize Difference Vegetation Index of Goba woreda in 2000***

Table 10: NDVI value between 1973 and 2000.

Year	NDVI Value			
	Min	Max	Mean	Stddev
1973	-1	0.99	0.00	0.58
2000	-1	0.77	-0.12	0.51

Source: computed from Landsat 1973 and 2000 image

4.3. Cause of Forest Cover Change of Goba woreda

As indicated in Table 9 above, the forest coverage of Goba woreda has been decreased from 101086 ha in 1973 to 90603 ha in 2000. Within a gap of twenty seven years, the forest coverage of the area decreased by 10483 ha. To identify the underlying cause of forest cover change of the area, it is essential to examine land use/land cover pattern of the study area under investigation. Table 5.7 C, clearly shows the forest pattern change of Goba woreda between 1973 and 2000. Between these periods the largest proportion (18 %) of the forest has changed in to into various cover types including agriculture. During these periods, 15074 ha (15 percent) forest changed in to agriculture (Table 9). This figure by itself reveals intensification of agricultural land is the underlying cause of deforestation in the woreda. . Hence, the need for more space for cultivation is the major and underling factor of the problem. As the result of the growing demand of agricultural land, more trees being increasingly removed.

4.4. Forest Fire Risk Susceptibility Analysis of Goba Woreda

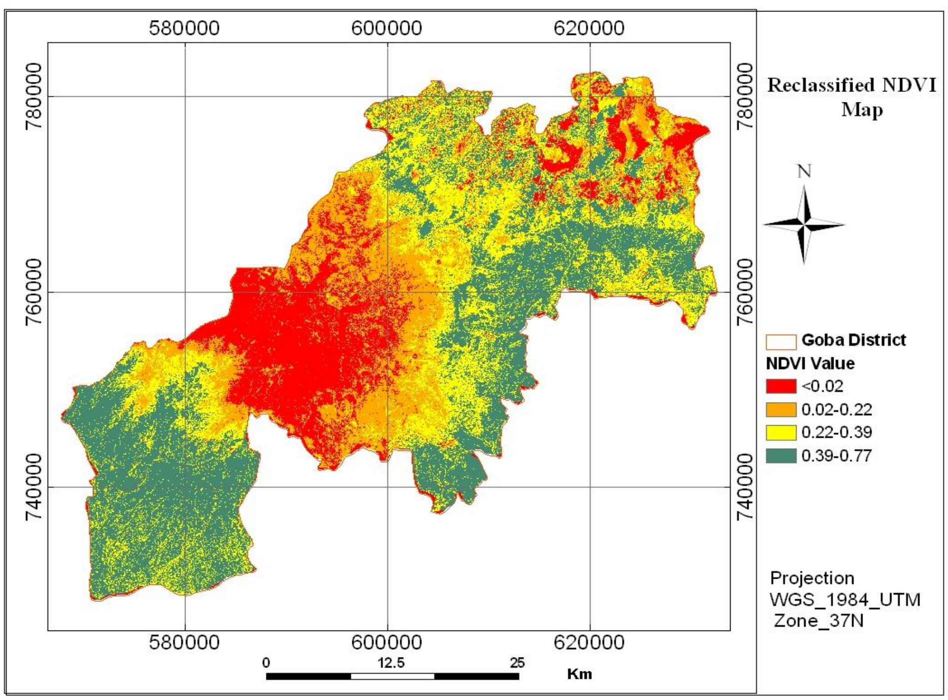
4.4.1. Dataset and masking layer preparation

Preparation of data set for forest fire influencing factors is a prerequisite to identify potential forest fire areas in the study area under investigation. As a consequence, various thematic layers representing, vegetation condition (NDVI value), vegetation type, slope, aspect, Elevation, road and village distance have been prepared in raster format. The respective potential of each of these factors in relation to forest fire has been described briefly in the following section.

4.4.1.1. Vegetation Condition

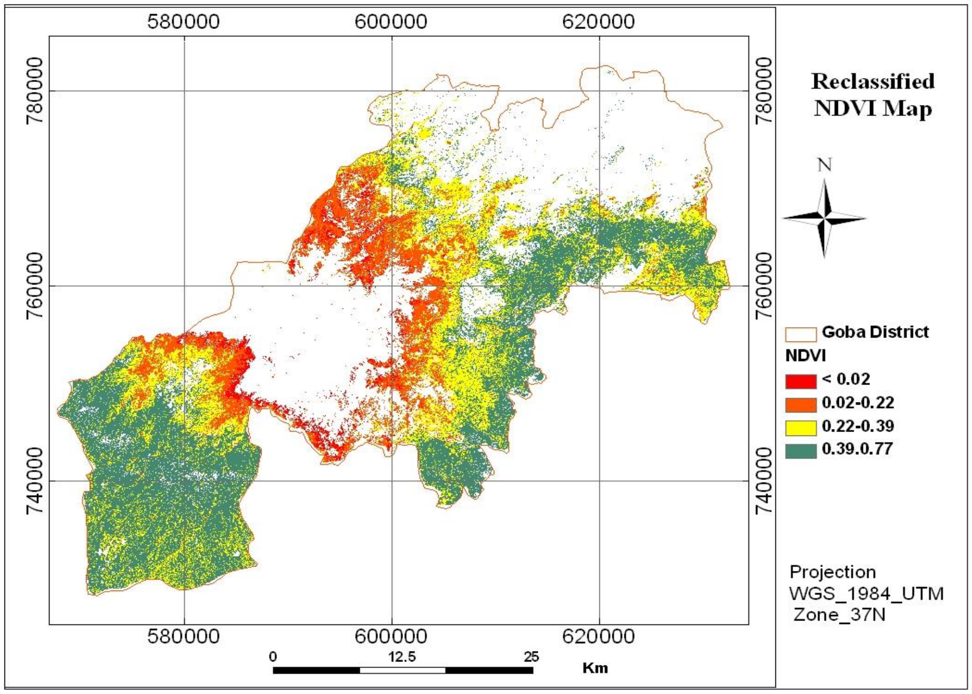
The vegetation condition was classified according to the moisture content that has an influence on breaking out forest fire. For example, the vegetation condition that is very dry is the most flammable whereas the fresh type is non flammable. Forest with low level of green vegetation is found in high dry areas and exhibit low level of NDVI value and as a result usually vulnerable to fire as opposed to forest of high level of green vegetation. In this study, NDVI result of the 2000 Landsat satellite image has been used to obtain information regarding the greenness level of the forest at the time of acquisition. This image was acquired during one of the dry month of the area. As stated above in chapter one, date of acquisition of the image used in this study was on Dec.28, 2000. Hence, the value obtained from NDVI analysis truly represent the actual greenness (moisture)condition of the respective forest type .This means , higher NDVI value represents the higher level of green vegetation and vice versa . In other way, this refers to low level of NDVI value indicate low level of moisture content and dominance of dry vegetation.

Therefore, low level of green vegetation is found in high dry area and these area are usually vulnerable to fire .Based on this concept, NDVI map of the study area has been prepared from the 2000 Landsat ETM$^+$ image and reclassified in to four classes to suit it for analysis and represented in figure 18 .The reclassified NDVI map is masked by the forest layer obtained from the 2000 land use /land cover map and depicted in figure *19 bellow.*



Source: Computed from the 2000 Landsat ETM$^+$ image.

Figure 18*: Map showing NDVI value of the Goba woreda of the year 2000*.



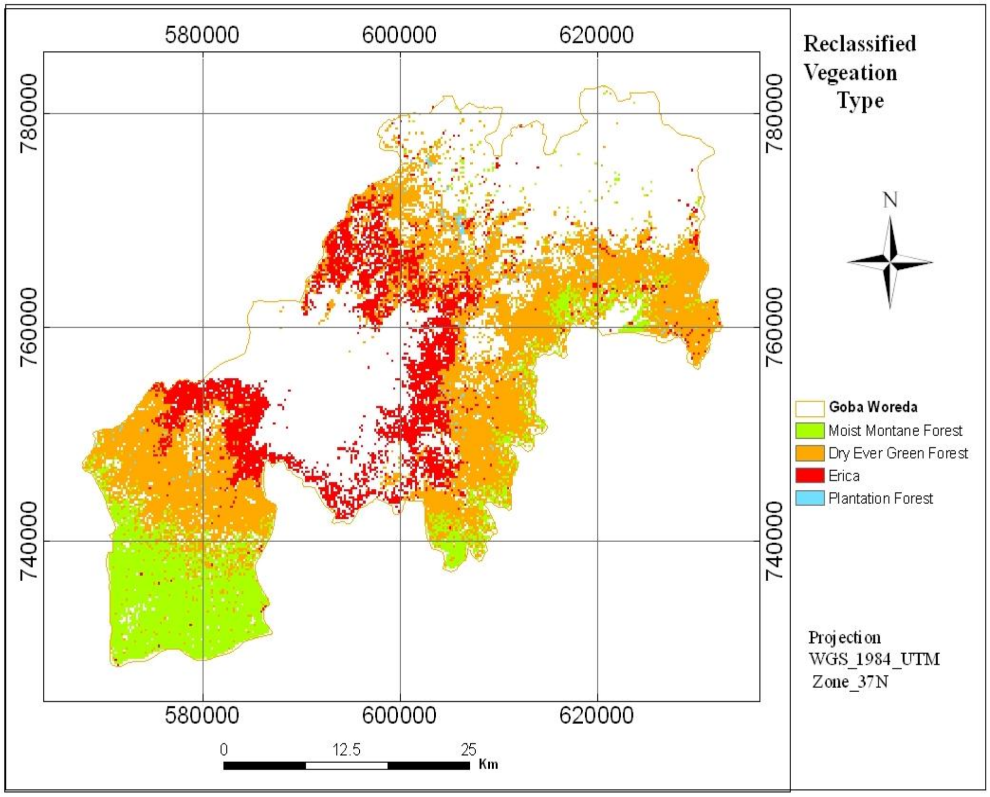
Source: Computed from the 2000 Landsat ETM^{+} image.

Figure 19*: Map showing NDVI value of the forest*

Some part particularly at southern part around "Harena forest'' Moist montane forest attain high amount and the part of Erica zone at upper part reveals low amount of NDVI. Based on these parameters, all parts of or types of the forest are not equally susceptible to forest fire.

4.4.1.2. Vegetation Type

Vegetation type is also classified in accordance to their respective flammable property. In this regard, Erica (locally called satoo) is most flammable as opposed to other types .while dry ever forest is the second highest flammable and followed by moist montane and plantation forest. Water bodies areas, alpine vegetation, agricultural and barren lands are excluded from consideration in fire risk susceptibility analysis. Therefore, these zones have no weights in determination of fire rating class. To perform the analysis only on the forest area, the forest cover map of the study area generated from the land use / land cover map of the year 2000. Then land use land cover map was converted in vector format to clip specifically the forest from the other classes and the result has shown in figure 20 bellow.

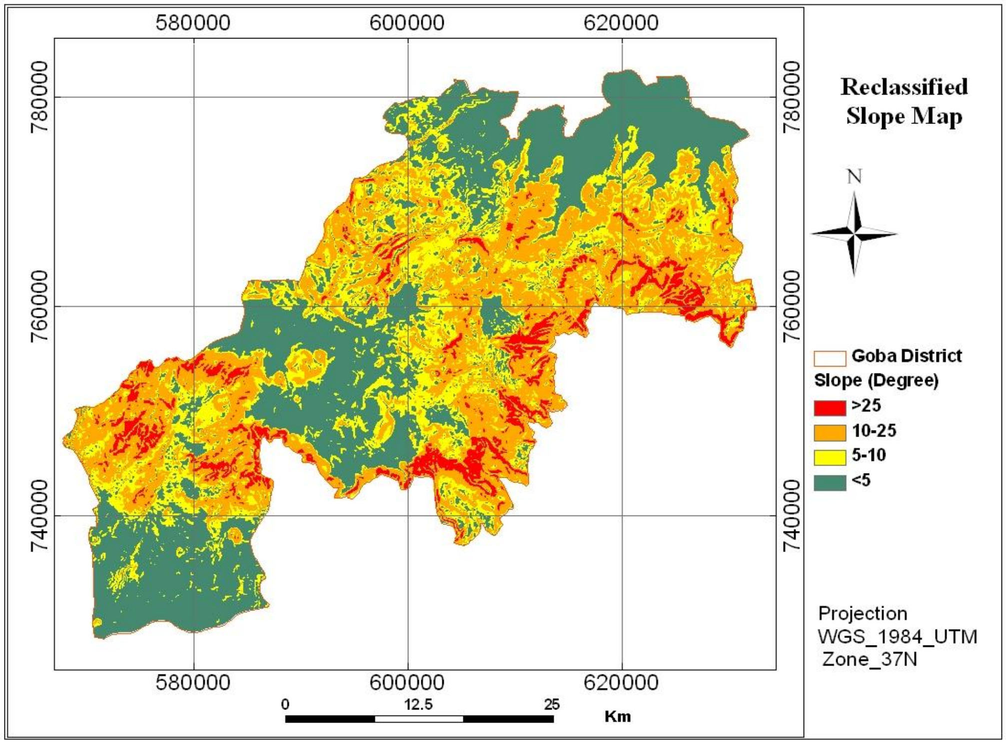


Source: Computed from the 2000 Landsat ETM+ image

Figure 20: Map depicting the vegetation type of Goba woreda

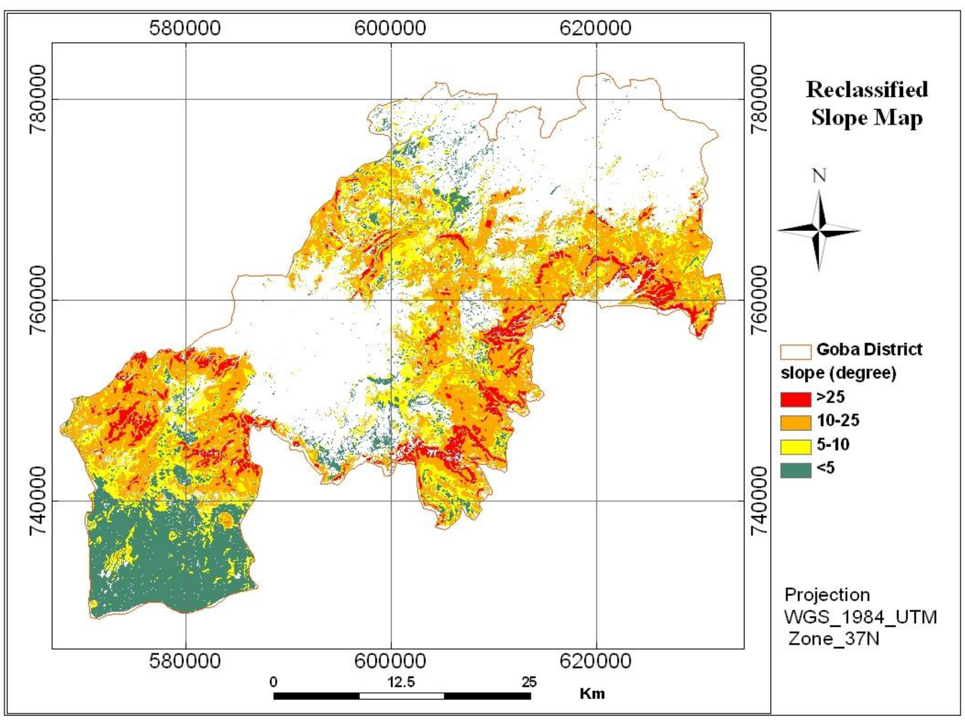
4.4.1.3. Slope

Slope is one of the elements of the physical environment and broadly defined as the steepness or the inclination of the land surface of an area. Slope influences forest fire as it determines the speed of fire with in the forest. Fire travels most rapidly up-slopes and least rapidly down-slopes. Steep slope increases the rate of fire spread because of more efficient convective preheating and ignition. Slope classes were created according to this rule. Hence, forests at steep become more susceptible to forest fire as opposed to forest lying at gentle slope. Figure 21 shows reclassified map of Goba woreda and the slope of the forest area generated by masking of this map using the forest cove map of the year 2000. Figure 22 shows forest cover map of the area reclassified based their respective slope.



Source: Computed from SRTM data

Figure 21: ***.Map showing distribution of slope***

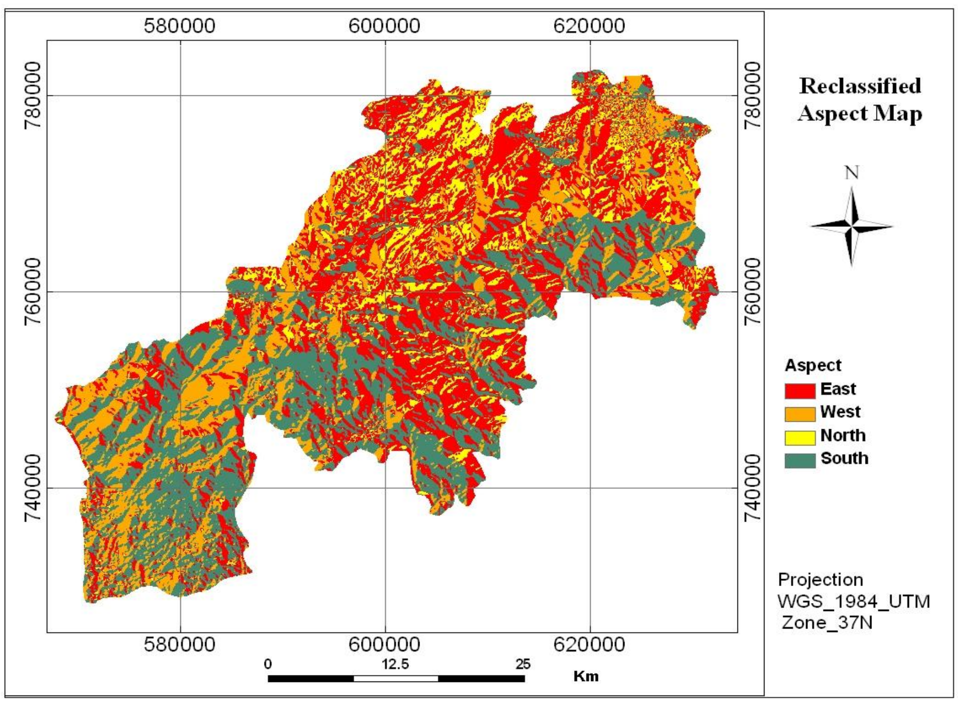


Source: Computed from figure 21.

Figure 22: Map depicting the slope of the forest area

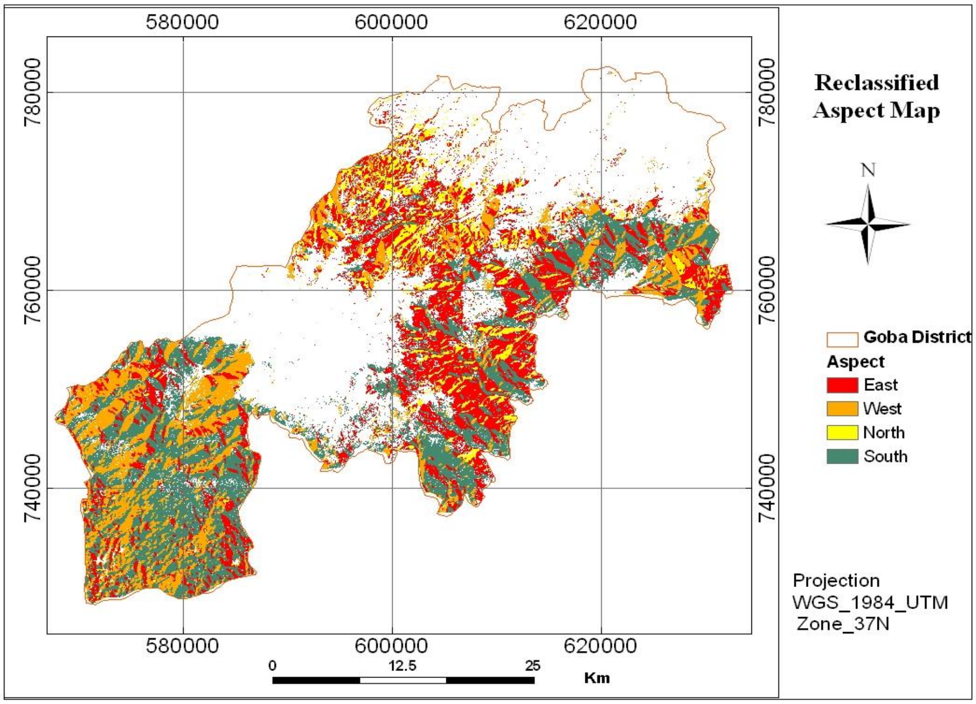
4.4.1.4. Aspect

Aspect is also other factor considered in this study and its potential to influence forest fire equally weighted with slope. Figure 23 bellow depicts the aspect of the of the area . It has been classified in to four major classes such as east (45^0 to 136^0), south (136^0 to 225^0) west (225^0 to 315^0) and north (315^0 to 45^0). The aspect of the forest area is generated by masking the aspect map by the forest map and presented in figure 24 bellow. Since gradient facing to the east and west receives more heat more ultraviolet during the day, as a consequence east and west aspects are drier compared to aspect facing to north and south. According to this concept .both east and west are weighted equally. Similarly, gradient facing to the north and south would not have potential difference with respect to forest fire as a consequence both factors have been weighted equally.



Source: Computed from the SRTM data.

Figure 23: Map depicting Aspect of the study area



Source: Computed from the SRTM data

Figure 24: **Map depicting Aspect of the forest area**

4.4.1.5. Distance from Settlement

Distances from settlements were evaluated as the fifth highest weight. To examine settlement proximity from forest areas, the location of each locality within the woreda has been considered in this analysis. Accordingly, one hundred thirty three villages (localities) GPS point data have been used to identify susceptible part of the forest to fire with to respect settlement distance .Hence, Proximity analysis is performed on village locations by creating buffers according to the specifications. Finally, the created buffer is converted in to raster and reclassified in to a common scale. The fire risk factor decreases farther from these places. It means that a forest zone close to these places were evaluated a higher rating. Figure 25 bellow shows distance from the centre each locality that exists within the woreda. To perform the analysis specifically on the forest area, the settlement proximity ma p clipped by the forest map and the result has shown in figure 26.

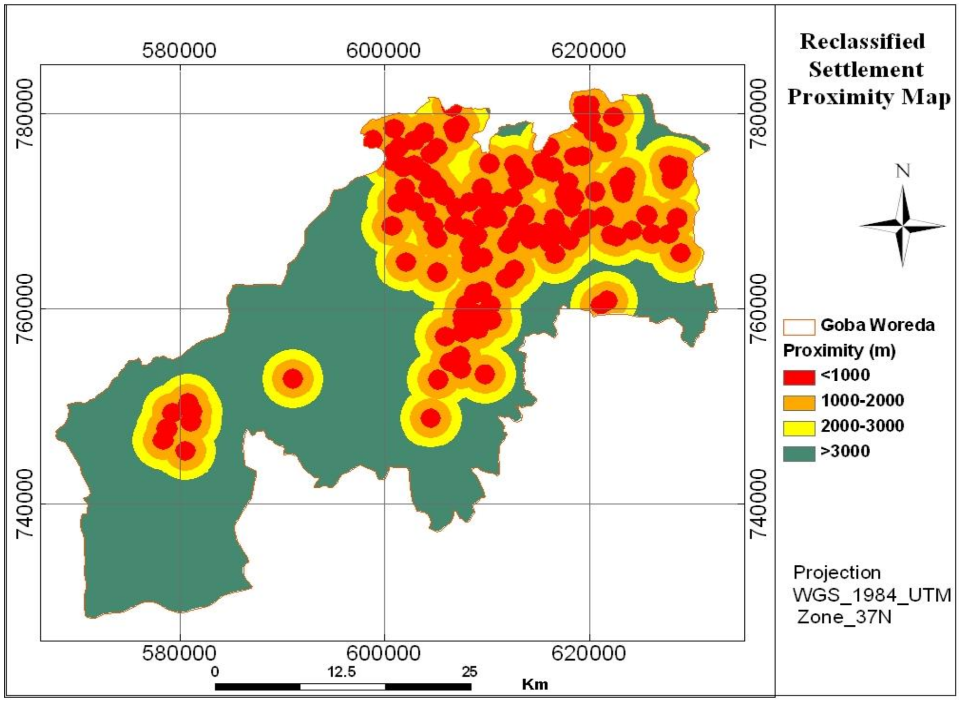


Figure 25: **Map showing settlement proximity**

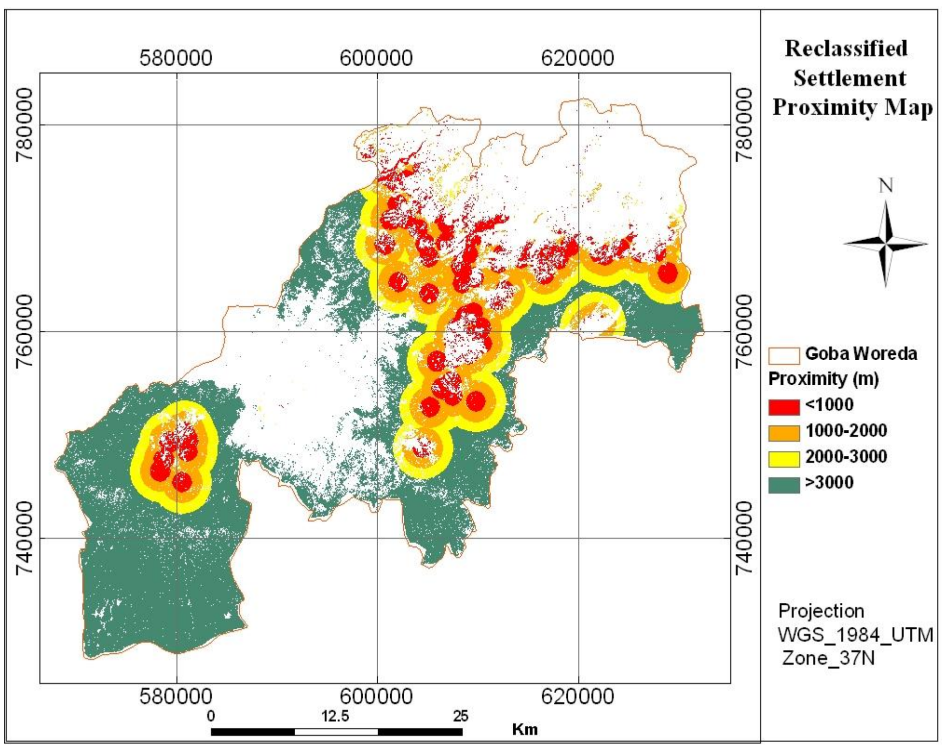


Figure 26: Map showing forest proximity to settlement

4.4.1.6. Road Proximity

Distance from road was also considered in this analysis and evaluated as the six highest weight based on its influence on forest fire. To examine road proximity from forest areas, all types of road ranging from all weather roads to trails in the woreda have been considered in this analysis Hence, Proximity analysis is performed on road network by creating buffers according to the specifications . *Figure 27* bellow indicates roads classified based the distance from the center. Finally, the created buffer is converted in to raster and masked by forest map to show the proximity of the forest to settlements, (*Figure 28*).The fire risk factor decreases farther from these places. It means that a forest zone close to roads were evaluated a higher rating.

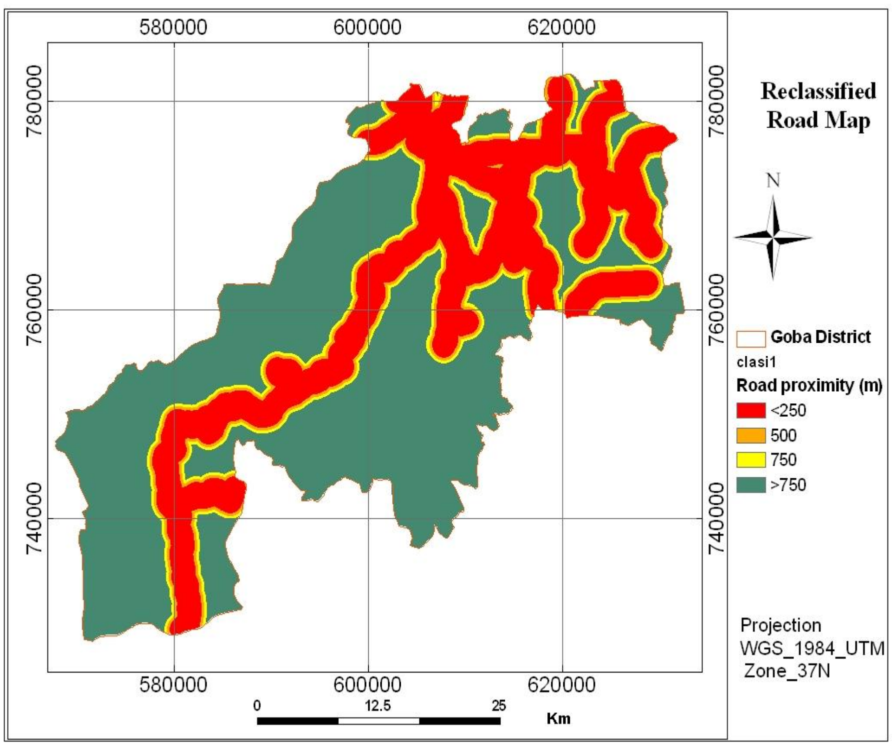


Figure 27: Map showing Road proximity

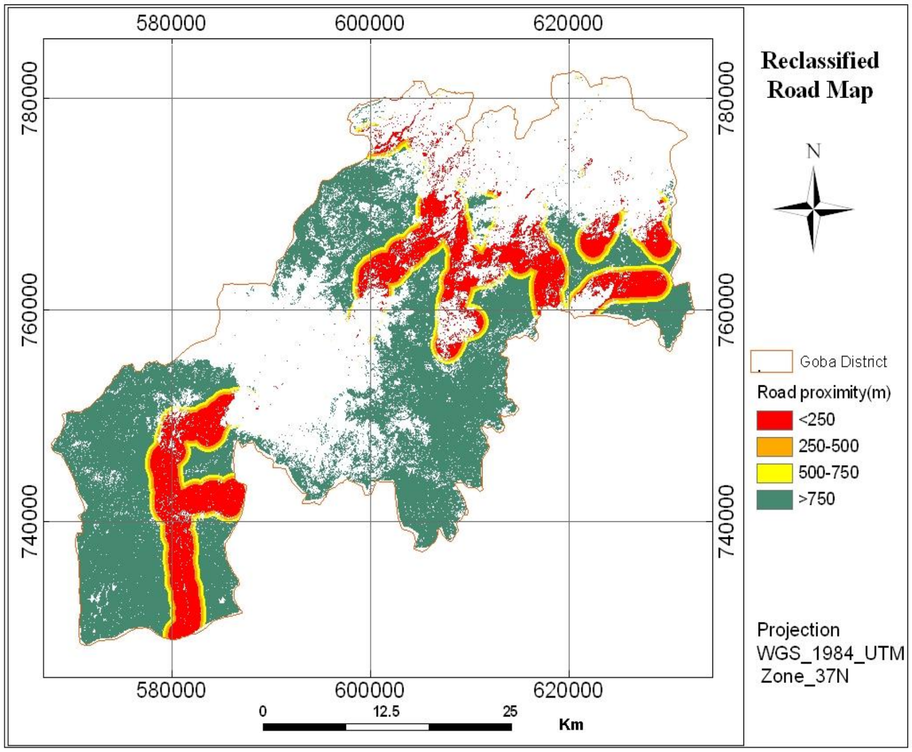
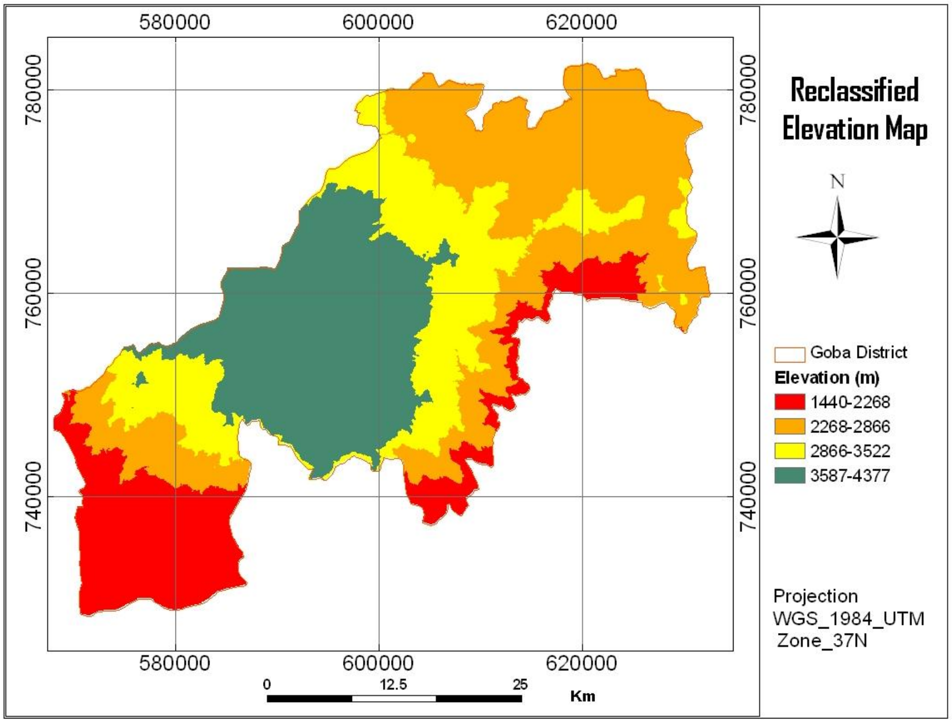


Figure 28: **Map showing forest proximity road net work.**

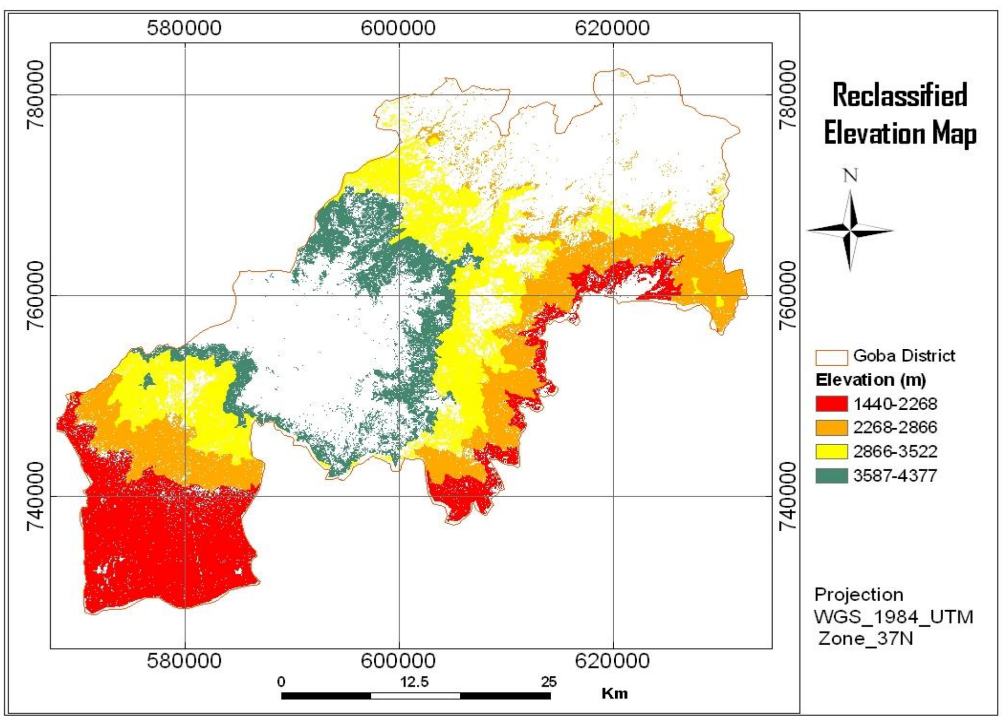
4.4.1.7. Elevation

Elevation is one of the governing factors of climate of an area. It controls the rain fall and temperature amount that prevails over a particular part of the earth surface. The vegetation types that grow over an area can be controlled by the altitude. The vertical zonation of vegetation in the study area with respect to altitude variation is an evident for how elevation determines vegetation type. Altitude determines not only vegetation type but also the moisture content of the forest. Being other things constant, forest lying at lower altitude generally is dominated by higher temperature and may have high amount dry fuel during dry seasons and the inverse is true for forests lying at higher altitude. In regard of this study, elevation is considered and evaluated as the seventh highest weight to trigger forest fire. As indicated in figure 29, the altitudinal variation of Goba woreda varies from 1440m a.s.l to 4377m.a s.l and figure 30 shows forest cover map of Goba classified according to respective elevation. Relatively, forest lying at lower altitude is more susceptible to forest fire as compared to the one found at higher elevation.



Source: Computed from the SRTM data

Figure 29*:* ***Reclassified elevation map of Goba Woreda***



Source: Computed from the SRTM data

Figure 30: ***Reclassified forest elevation map of Goba Woreda***

4.4.2. Weighting of Dataset and Running of MCE

It is natural that all the prepared dataset would not have equal potential to influence or aggravate forest fire. One factor may trigger more severely forest fire as compared to the remaining factors. Hence, weighting of each dataset is an important task to identify forest fire susceptible areas. In this regard, weight has been assigned for each reclassified dataset and weighted based on their relative potential to pose influence on forest fire. As indicated in Table 11, weight to each factor has been assigned based on Pair wise comparison matrix techniques IDRSI 4.3 software to resolve personal bias and the result is presented in Table12.Finally; each factor has been multiplied by their respective weights obtained from the paire wise comparison. Table 13, bellow shows a summary of factors and sub factors with respective weights that have been used to generate forest fire risk susceptibility map of the area under investigation.

Table 11: Paire Weise comparison matrix

Pairwise Comparison 9 Point Continuous Rating Scale

1/9	1/7	1/5	1/3	1	3	5	7	9
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely

Less Important — More Important

Pairwise comparison file to be saved : D:\B\output\tmp024.PCF ... Calculate weights

	D:\B\NDVI.rst	D:\B\Veg..rst	D:\B\Slope.rst	D:\B\Aspect.rs	D:\B\Settle..rst	D:\B\Road.rst
D:\B\NDVI.rst	1					
D:\B\Veg..rst	1/3	1				
D:\B\Slope.rst	1/5	1/3	1			
D:\B\Aspect.rs	1/5	1/3	1	1		
D:\B\Settle..rst	1/7	1/5	1/3	1/3	1	
D:\B\Road.rst	1/7	1/7	1/5	1/5	1/3	1

Table 12: Eigen vector of weights

Datasets	eigenvector of weights
NDVI	0.4157
Veg. Type	0.2377
Slope.	0.1171
Aspect.	0.1171
Settle. :	0.0590
Road. :	0.0336
Elevation	0.0198

Consistency ratio = 0.07

Consistency is acceptable.

Table 13: Summary of index value for forest fire risk

Datasets	Eigen vector weights	Subclasses	Rank with in the same dataset	Risk Class
NDVI value	0.4157	< 0.02	1	Very High
		0.02-0.22	2	High
		0.22-0.39	3	Moderate
		0.39-0.77	4	low
Veg.Type	0.2377	Erica	1	Very High
		Dry Ever Green forest	2	High
		Moist Montane Forest	3	Moderate
		Plantation forest	4	low
Slope (Degree)	0.1171	>25	1	Very High
		10-25	2	High
		5-10	3	Moderate
		< 5	4	low
Aspect.	0.1171	East	1	Very High
		west	1	Very high
		North	2	Moderate
		South	2	Moderate
Settle Distance (m).	0.0590	< 1000	1	Very high
		1000-2000	2	High
		2000-3000	3	Moderate
		>3000	4	low
Road. Distance (m)	0.0336	<250	1	Very high
		250-500	2	High
		500-750	3	Moderate
		>750	4	low
Elevation (m)	0.0198	1400-2268	1	Very high
		2268-2866	2	High
		2866-3522	3	Moderate
		3522-4377	4	low

As indicated in equation 2 below, datasets masked by the forest layer have been multiplied by their respective weight to generate forest fire risk susceptibility map of Goba woreda.

$$\boldsymbol{FFRZ} = VC * 0.4157 + VT * 0.2377 + S * 0.1171 + A * 0.1171 + DS * 0.0590 + RD * 0.0336 + E * 0.0198. \quad \ldots$$

Equation 2

Where: FFRZ = Forest fire risk zone

VC = Vegetation condition evaluated by NDVI value

VT = vegetation type

S= slope

A= aspect

RD = road distance

DS =settlement distance

E = Elevation.

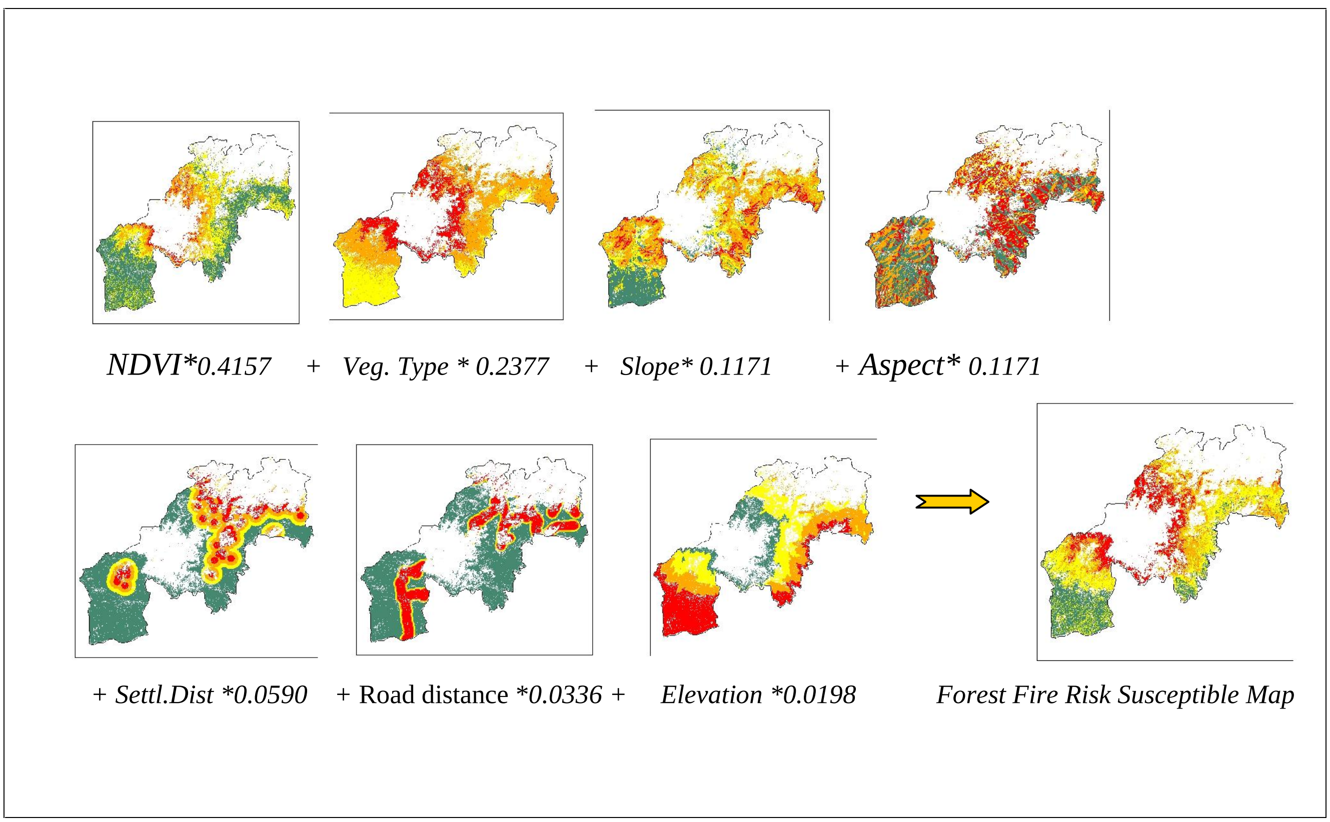


Figure 31: Forest Fire Risk Susceptibility Mapping Procedure.

As it indicated in the above figure 31, the entire datasets have been multiplied by their relative weight to determine the final forest fire risk susceptible map of the area under investigation. Accordingly four classes of forest fire risk susceptibility zone have been obtained based on the factors considered in the analysis.

After integration of the above Layers such as forest moisture condition (evaluated by NDVI value) , vegetation type , Slope, Aspect, Elevation , Road and Settlement buffers through GIS overlay technique a final integrated map was obtained and presented in figure 32 .

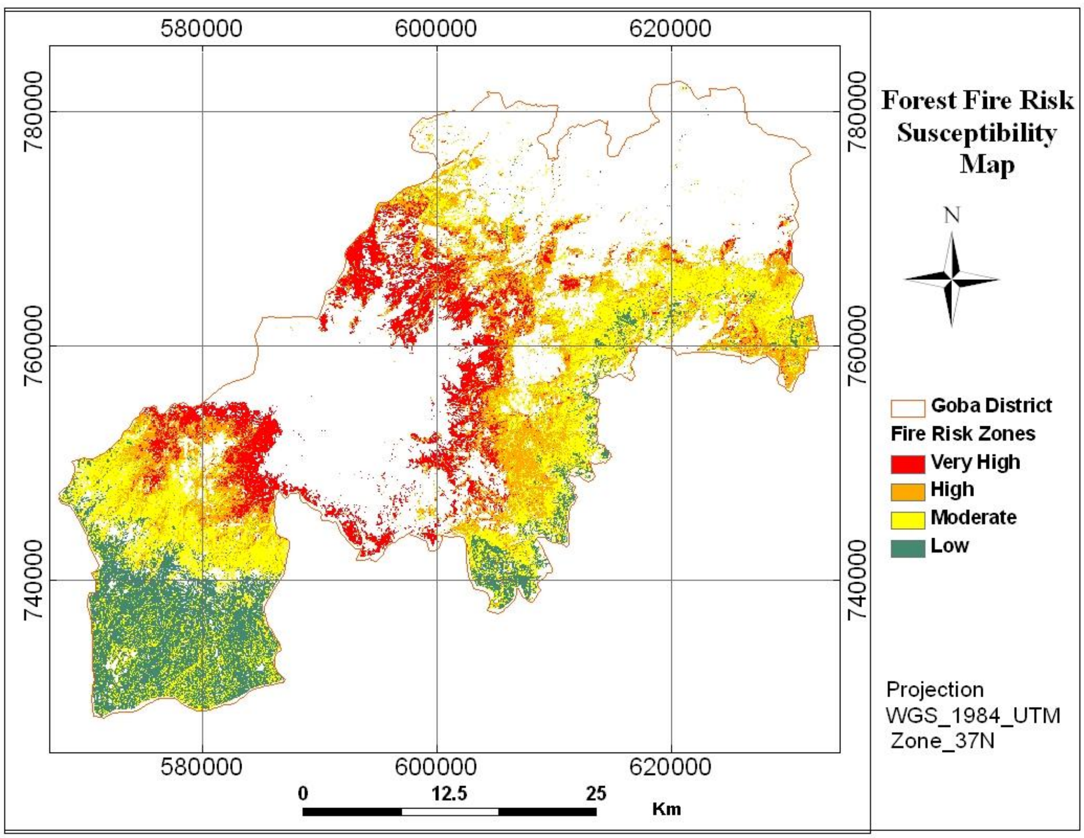


Figure 32***: Map showing Forest Fire Risk Susceptibility of Goba Woreda***

The result reveals that the whole forest of the area is categorized in to four zones of susceptible levels. These are very high susceptible, high susceptible, moderately susceptible and low susceptible. This study reveals that very high susceptible category areas are those in high slopes with Erica vegetarian where NDVI value is low and dominated by eastern and western phasing slope. High susceptible categories are generally falling in some part of Erica vegetation and Dry ever forest on higher slope and altitude where NDVI values are high and moderate. Moderately susceptible areas are largely dominated by dry ever green forest. While a Low risk areas are falling under moist montane forest at lower altitude and where NDVI value is lowest among the existing forest types of the area. Areas out of forest are not considered in the whole course of forest fire analysis since without fuel source (forest) threat of forest fire risk is hardly possible. In this study non risk areas have been identified prior any factor development at the time of forest masking layer preparation. Excluding cover types such as agriculture, water body, bare land and alpine vegetation by forest masking layer by itself imply that these areas are out of the treat forest fire risk. The final results obtained of Fire risk zonation areas are checked by the ground truth. Finally, comparison has made between the previous fire spots location and the generated forest fire risk susceptible map overlying GPS point data collected from the previous fire spots to validate the generated fire risk susceptibility map. As it depicts in figure 33 the previous fire spots totally lie on very high and high zones on the forest fire susceptible map.

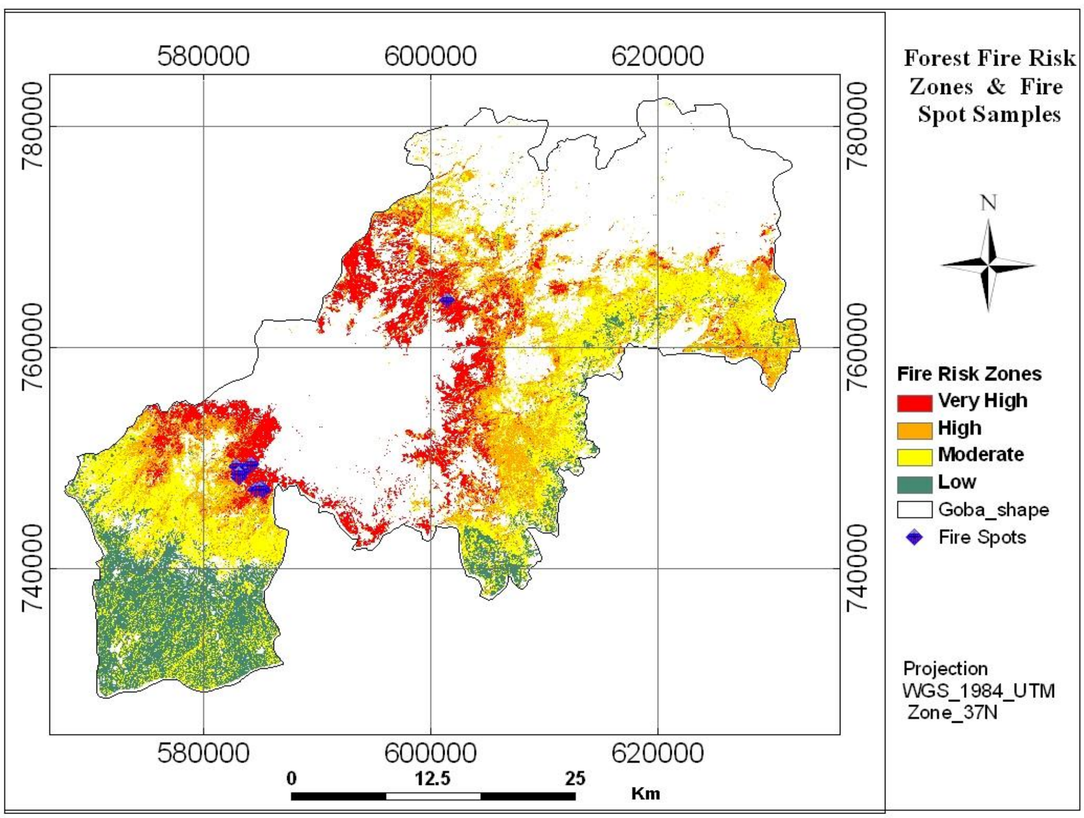


Figure 33: ***Map depicting fire spot sample points and forest fire risk Susceptibility Zones.***

The study further reveals that the majority of the forest (35%) of the woreda lies in the category moderately susceptible as far as forest fire is concerned .While the least proportion of the forest is categorized under the very high susceptible class. As indicated in Table 14 and *figure 34* bellow , 35 % and 25 % of the total forest coverage of the woreda are categorized under the moderate and high susceptibility level respectively .The remaining 21 % and 18 % are classified under low and very high level in the same order .

Table 14: Areal coverage of forest fire susceptibility levels

Susceptibility level	Area (ha)	% Share
Very High	16758.33	18
High	23083.16	25
Moderate	31824.05	35
Low	18937.46	21

Source: Generated from forest fire susceptibility map of figure 5.14

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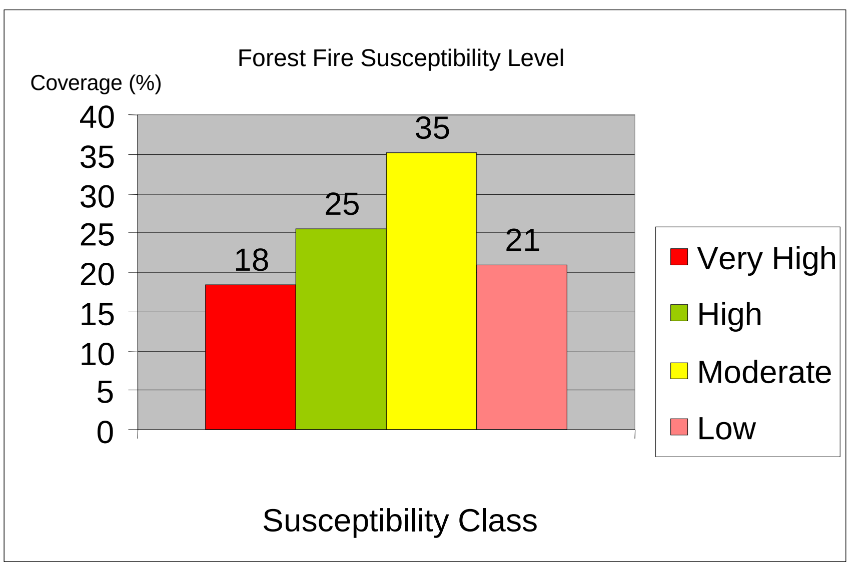

Source: Generated from forest fire susceptibility map of figure 5.14

Figure 34: Graph showing Fire susceptibility level of Goba woreda forest

4.4.3. Causes of Forest of Goba Woreda

There were no major wildfire reports for the 1990s in Ethiopia .A major wildfire episode affected the afro-montane forests in 2000, mainly in Oromia Regional State. The total forest area affected by fire was 95 000 ha. Forest fires hit Ethiopia in March 2000, the first big fires since 1984. The threatened, afro-montane forests and moist tropical forests were badly damaged with as much as 53,000 ha of Bale National Park destroyed, (Goldammer, 2000).

The majority of forest fire of Ethiopia is induced by human intentional action to execute their temporal needs at the expense of the forest resource. The fire incidents have also occurred in the study area between 1990 & 2000 and recently 2008.

All these fire incident of the area have been induced by the local community. Some of the fire incidents of the area are non intentional caused by the carelessness of the people in using fire with in the forest area. Fire caused by such kind condition is generally grouped as non intentional fire. Un extinguished cigarettes left behind by people passing through the forest, Care less use of fire during smoking of beehives and fire ignited from villages with in forest are some of the examples of non intentional cause of forest fire the woreda.

However, the major cause of forest fire of Goba woreda is intentional. The local community use fire as a tool burning woody vegetation particularly Erica to generate fresh pasture for their livestock Erica vegetation is one the most important source of pasture for the livestock of the local community. This vegetation serves as a pasture only at the stage before maturity .Hence, the community uses fire as a tool of clearing the matured Erica vegetation (which is strong if it is matured) to substitute it by fresh one that can be easily grazed by their livestock.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The forest of Goba woreda has been deteriorating due to anthropogenic impacts. Currently, the forest is subjected to a considerable degradation and deforestation as well as recurrent fire which is ignited deliberately by the local people to get more fresh pasture land for their live stocks. The local community burns the Erica bush land before the main rainy season to generate fresh pasture and the whole forest adjacent to Erica zone including "Harena Forest", always lies under forest fire treat particularly during the dry months specifically one month before the main rainy season.

The results obtained from classified Landsat imageries of the years 1973 and 2000 have been used to examine land use /land cover dynamics of the study area under investigation. Significant land use /land cover dynamics have been observed in the woreda between the specified periods. Some cover types such as Erica (alpine bush land), plantation forest, and agricultural and bare land shows positive trend between these periods.

The forest which consists of Erica bush land, moist montane forest, dry ever green forest and plantation forest together. Among the forest classes, moist montane forest and dry ever green forest are the main victim of deforestation.

The rate of deforestation of the Woreda is relatively small as compared to the county's rate of deforestation. The dominance of rugged topography is one of the reasons attributed to the relative small rate of deforestation in the area. Being the forest of the woreda is part of BMNP, conservation also plays a vital role for the relative slow rate coverage change besides to topography factor.

As far as the forest pattern is concerned, the largest proportion of the forest changed in to agricultural land and bare land. The remaining forest changed into alpine vegetation and water body respectively. The computed result indicate that about 18 percent of the forest cover changed in to other land use/land cover types including agriculture within the gap of twenty seven years. The remaining of the forest remains unchanged. Intensification of agricultural land is the underlying cause of deforestation in the woreda. On top of this, fire is also another factor which poses its own ring of influence and results in forest degradation in the woreda though there are no statistical figures that help to describe the amount of devastation of previous fire incidence in the area.

To examine fire risk of the forest fire, susceptibility analysis has been conducted. Influencing factors like vegetation condition and type, topography (aspect & slope), elevation, proximity to village and road etc., have been considered in identification of fire susceptible areas within the forest of the woreda.

Accordingly, four classes of forest fire susceptibility levels have been identified. These are very high susceptible, high susceptible, moderately susceptible and low susceptible. Based on the vegetation type, Erica vegetation is identified as the most fire risk susceptible as compared to other vegetation types of the area. Even though Erica is the most susceptible to forest fire, its spatial extent has increased profoundly between 1973 and 2000 because its capability to regenerate rapidly as opposed to other vegetation types. Hence, after burning the Erica covers not only its previous area but also it covers other burned areas which previously covered by other forest types. The major cause of forest fire of Goba woreda is intentional. The local community use fire as a tool burning woody vegetation particularly Erica to regenerate fresh pasture for their livestock

5.2. Recommendations

The following feasible suggestations are forwarded to overcome the existing problems so as to assure the sustainability of the forest resource of the area.

- Intensification of agricultural land in forest area is the underlying cause of degradation and deforestation in the woreda .To reduce the communities' pressure on the forest in searching of new farm lands, intensive agricultural system should be introduced and intensified to increase productivity of an area. Besides to this, family planning strategies should be strengthened throughout every corner in the area to minimize the stress of population on the forest in the long run.
- It is had better to protect further settlement and intensification in to park boundary and forest area. On top of this, the existing settlements within the core forest area should be relocated to sites before they intensify further settlement and related agricultural activities.
- To assure the sustainability of the forest resource as a whole there should be strong legal frame work which protects non legal human intervention in the forest environment.
- Fire protection measures must be taken and should form an integral part of forest management.
- Remote sensing and GIS integrated approach have an immense potential in identifying fire risk susceptibility level within the forest area. Hence, it is advisable to conduct Remote Sensing and GIS based further studies to model forest fire risk susceptibility so as to determine the susceptibility levels each forest compartment and to take protection measure as per the risk category.
- Fire watching towers & strong patrolling mechanisms should be implemented in the forest area to take immediate action before the fire causes severe destruction.
- In order to minimize the risk of fire destruction it had better to implement early warning system and act accordingly.
- It is advisable to initiate and introduce intensive live stock production to reduce number of livestock population and thereby to minimize the possibility of burning of the forest in searching of new pasture land

References

Ahern, F.J. G. Goldammer, and C. Justice (eds.) 2001. Global and regional vegetation fire monitoring from space: Planning a coordinated international effort. SPB Academic Publishing by, The Hague, the Netherlands, 302p

Bartlett, H.H. 1955, 1957, 1961. Fire in relation to primitive agriculture and grazing in the tropics: annotated bibliography, Vol. 1-3. Mimeo. Publ. Univ. Michigan Bot. Gardens,Ann Arbor, USA.

Bedru Sherefa Muzein.2006.Remote Sensing & GIS for Land Cover/ Land Use Change Detection and Analysis in the Semi-Natural Ecosystems and Agriculture Landscapes of the Central Ethiopian Rift Valley. Submitted for fulfillment of Doctor of Natural Science**.** Technische Universidad Dresden

Berhan Gessesse .2007. Forest cover change and susceptibility to Forest degradation using remote sensing and GIS. Unpublished. Accessed on April 24, 2008 from http:// 10.4.10.30.dspace.

Burgan R.E., Klaver R.W. and Klaver J.M., 2000. Fuel models and fire potential from satellite and surface observations, International Journal of Wildland Fire

CBD (Secretariat of the Convention on Biological Diversity .2001. Impacts of human-caused fires on biodiversity and ecosystem functioning, and their causes in tropical, temperate and boreal forest biomes. Montreal, SCBD, 42p. (CBD Technical Series no. 5)

Chuvieco, E. and R G. Congoltan, 1988. Mapping and Inventory of Forest Fire from Digital Processing of TM Data.GeocartoInternational, 4, pp. 41-53

Chuvieco E. and Martin M.P., 1994. Global Fire Mapping and Fire Danger Estimation Using AVHRR Images, Photogrammetric Engineering and Remote Sensing, vol. 60, 5, pp. 563-570.

CIFOR.2004. Center for international Forestry Research (CIFOR) (Remote sensing and forest governance in Indonesia: Increasing transparency and accountability).Work shop organized by Center for Ecosystem Science and Policy (CESP), University of Miami, Bogor, Indonesia.

Davies, S. J. and L. Unam .1999. Smoke-haze from the1997 Indonesian forest fires: effects on pollution levels,local climate, atmospheric CO2 concentrations, and tree photosynthesis. Forest Ecology and Management 124:137-144

Demel Teketay.2000."Vegetation and Forest Fire Management in Ethiopia."Proceedings Round Table conference on Integrated Fire Management in Ethiopia, on September 19 and 20, 2000. Published by MOA, Addis Ababa.

EarthTrends .2003.Ethiopiandeforestation.http://en.wikipedia.org/wiki/Ethiopian_deforestation

EFAP (Ethiopian forest action Program).1994. Ethiopian Forest action Program Vol.1 and 2 Ministry of Natural resources Development and Environmental Protection, Addis Ababa, Ethiopia.

EPA (Environmental Protection Authority).1997 conservation Strategy of Ethiopia.Addis Ababa.

FAO. 2005. State of the World's Forests .Rome, Italy, Retrieved, 21st,April, 2008 from www.fao.org.

FAO. 2006d. Fire management – global assessment 2006. FRA 2005 thematic study. FAO Forestry Paper

.FAO.2007. State of the World's Forests , Rome,Italy. Retrieve,21st,April, 2008 from www.fao.org. Rome.

Foster, D.R .1992. Land use history (1730–1990) and vegetation dynamics in central New England, USA. Journal of Ecology 80, 753–72.

Gessesse Dessie [1,2] and Carl Christiansson,[1] .2007 .Forest decline and Its causesin South Central rift Valley Of Ethiopia :Human impact Over a Hundred year Perspectives. *[1]Department of Physical Geography and quaternary Geology ,Stockholm university ,Sweden and *2wondo Genet College of forestry and Natural resources ,Hawassa University ,Ethiopia . Accessed on 15/04/2008 from http://www.capacity.undp.org/activeweb/uploads/users/gessesse/CVGD.doc

Goh, K.T., D.H. Schwela, J.G. Goldammer, and O. Simpson.1999. Health Guidelines for Vegetation Fire Events. Background Papers. Published on behalf of UNEP, WHO, and WMO. Institute of Environmental Epidemiology, Ministry of the Environment, Singapore. Namic Printers, Singapore, 498 pp.

Goldammer, J.G. (2000). Ethiopian Fire Special. The Ethiopia Fire Emergency between February and April 2000. International Forest Fire News No.22 .

Goldammer, J.G. 1988. Rural land use and fires in the tropics. Agroforestry Systems, pp : 235-253.

ITTO (International Tropical Timber Organization). 2006. Status of tropical forest management. Yokohama, Japan. Retrieve, 21st, April, 2008 from www.fao.org.

IAWF (International Journal of Wild land Fire) .2001, Scientific Journal of IAWF, Volume 10, Published by CSIRO Publishing, Canada.

James C. McCann. 1997 .The Plow and the Forest: Narratives of Deforestation in Ethiopia, 1840-1992 Environmental History, Vol. 2, No. 2, (), pp. 138-159 .Published by: Forest History Society and American Society for Environmental History Stable. Accessed on : 05/04/2008 11:39 from http://www.jstor.org/stable/3985505

LeIca Geosystems .2002. **ERDAS Field Guide TM**. Sixth Edition.Atlanta,Georgia **.**

Lillesand, T.M. and Kiefer, R.W. 2000. Remote sensing and Image Interpretation. John Wiley and Sons, Inc. New york

MNRCDEP (Ministry of Natural Resources Conservation and Development and Environmental Protection). 1994. Ethiopian Forestry Action Program. Addis Ababa.

MOA. 2000. Proceedings of the Ethiopian Round Table Workshop on Forest Fire Management .Addis Ababa. http://www.fire.uni-freiburg.de/iffn/country/et/et_3.htm Accessed date April 05,2008

MOA, (Ministry of Agriculture & Rural Development). 2004.

Mulyanto Darmawan. 2001. Forest Fire Hazard Model Using Remote Sensing and Geographic Information Systems: Toward understanding of Land and Forest Degradation in Lowland areas of East Kalimantan, Indonesia, Paper presented at the 22nd Asian Conference on Remote Sensing, 5 - 9 November 2001, Singapore.

Paolo Fiorucci , Francesco Gaetani .2007. Nation-wide forest fire risk assessment. Performance analysis and validation of two different dynamic fire weather systems in Italy.

Pickford, S.G., 1995. Fuel Type and Wildfire Hazard in the Bukit Suharto Project Area, East Kalimantan, Indonesia. IFFM,Document No. 4, 41p.

Paolo Fiorucci , Francesco Gaetani . 2007. Nation-wide forest fire risk assessment. Performance analysis and validation of two different dynamic fire weather systems in Italy.

P.S. Roy .1996. Satellite Remote Sensing and GIS Applications in Agricultural Meteorology pp. 361-400, National Remote Sensing Agency, Hyderabad, India.

Reusing, M. 1998. Monitoring of Natural High Forests in Ethiopia. Government of Ethiopia in cooperation with GTZ, Addis Ababa.

Singh, A. 1989. Digital change detection techniques using remotely sensed data. Intl.Journal of Remote Sensing, 10(6), 989–1003.

USGS .1976 .A Land Use And Land Cover Classification System For Use With Remote Sensor Data. Geological Survey Professional Paper 964. A revision of the land use classification system as presented in U.S. Geological Survey Circular 671.United States Government Printing Office, Washington

Wirawan, N., 2000. Factors Promoting the spread of Fire .Accessed on April 21, 2008.from http: // www.unu.edu/unpress/unupbooks/ 80815e/80815Eoq.html.