



**ASSESSMENT OF LAND USE LAND
COVER DYNAMICS AT BALE MOUNTAINS
NATIONAL PARK USING GIS AND REMOTE SENSING**



**A THESIS
SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES**

**IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN GIS AND REMOTE SENSING**

BY

WALLELIGN ALEM DESTA

ADVISOR: Dr. K.S.R MURTHY

July, 2007



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**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
GIS AND REMOTE SENSING PROGRAM**

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DYNAMICS AT BALE MOUNTAINS NATIONAL PARK
USING GIS AND REMOTE SENSING**

BY

**WALLELIGN ALEM DESTA
GIS and Remote Sensing Program
Department of Earth Sciences**

Approval by Board of Examiners

Dr. Balemual Atnafu

Chairman, Department

Graduate Committee

Dr. K. S.R. Murthy

Advisor

Dr. Dagnachew Legesse

Examiner

Prof. Zerihun Woldu

Examiner

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Acronyms

ASTER	Advanced Space born Thermal Emission and Reflection Radiometer
BMNP	Bale Mountains National Park
DN	Digital Number
EMA	Ethiopian Map Authority
ETM	Enhanced Thematic Mapper
EWCP	Ethiopian Wild Life Conservation Program
FAO	Food and Agriculture Organization
GIS	Geographical Information System
GPS	Global Positioning System
HQ	Head Quarter
IR	Image Regression
ITC	Information Technology and Communication
LC	Land Cover
LU	Land Use
MAX	Maximum
MCE	Multi-Criteria Evaluation
MIN	Minimum
NFPA	National Forest Priority Area
MSS	Multi Spectral Scanner
NC	No Change
NDVI	Normalized Difference Vegetation Index
NIR	Near Infra Red
PIF	Pseudo-Invariant Feature
RCS	Radiometric control set
RGB	Red-Green-Blue
RRN	Relative Radiometric Normalization
UNDP	United Nation Development Program
UTM	Universal Transverse Mercator
WLC	Weighted Linear Combination

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Abstract

Effective management of natural resources, especially National Parks requires accurate and up-to-date information to guide park managers in making appropriate decision. The intension of this study is to provide such information using GIS and remote sensing technologies to guide policy development in managing protected areas in Bale Mountains National Park. By utilizing remote sensing technologies and implementing GIS mapping techniques, land use and land cover change of designated areas can be monitored and mapped for specific research and analysis. The present study was attempted to identify and quantify the major land use land cover changes over the past 33 years as well as to identify potential habitat for Mountain Nyala (one of wild life species) at BMNP. Three satellite imageries (Landsat MSS 1973, Landsat ETM+ 2000 and ASTER 2005) have been utilized for the change detection analysis. As a result, land use land cover map of 1973, 2000 and 2005 was generated. In this study post classification and image differencing methods of change detection were assessed and a suitable method among them was found to be the former one because of the merit that it provides to and from information and results in a base map that can be used for the subsequent year. More over, it identifies where and how much change has occurred. Eventually, Eight land cover classes were identified from supervised classification of both ASTER, 2005 and Landsat ETM+, 2000 images, namely, moist montane forest, dry ever green forest , wood land , alpine bush land , water body, , pasture and farm plot, barren land and mixed grass/cereals. Five factor layers (vegetation type, elevation, settlement, river and road) were employed for Nyala habitat suitability modeling, and four suitability classes (most suitable, suitable, moderately suitable and less suitable habitat) were identified after performing GIS overlay analysis. The majority of most suitable habitat lies around the northern part of the park and on the top of the harrena forest. Woodland vegetation type along with the elevation range between 2800-3200 m.a.s.l found to be the most suitable habitat for Mountain Nyala. In general, five major causes of land use/land cover changes were identified (haphazardly expanding of settlement, Exploitation of wood for fuel and construction materials, human induced fire, lack of legislation & law enforcement and uncontrolled grazing & increasing farming on higher elevation).

Key Words: Land cover/ land use, habitat, GIS, suitability, RS, BMNP

Chapter One

1 Introduction

Mankind's presence on the Earth and his modification of the landscape have had a profound effect upon the natural environment. These anthropogenic influences on shifting patterns of land use are a primary component of many current environmental concerns as land use and land cover change is gaining recognition as a key driver of environmental change (Riebsame, et. al., 1994). Changes in land use and land cover are pervasive, increasingly rapid, and can have adverse impacts and implications at local, regional and global scales.

During the past millennium, humans have taken an increasingly large role in the modification of the global environment. With increasing numbers and developing technologies, man has emerged as the major, most powerful, and universal instrument of environmental change in the biosphere today. Both globally and locally, land cover today is altered primarily by direct human use.

To better understand the impact of land use change on terrestrial ecosystems, the factors affecting land use must be more fully examined. Growing human populations exert increasing pressure on the landscape as demands multiply for resources such as food, water, shelter, and fuel. These socioeconomic factors often dictate how land is used regionally. Land use practices generally develop over a long period under different environmental, political, demographic, and social conditions. These conditions often vary yet have a direct impact on land use and land cover (Ojima, et. al., 1994). The interaction of nature and society and their implications on land use and land cover is a very complex phenomenon that encompasses a wide range of social and natural processes.

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental change. Since the late 1960's, the rapid development of the concept of vegetation mapping has lead to

increased studies of land use and land cover change worldwide. Providing an accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources has become an important priority.

As human being modify the landscape, resource agencies find it increasingly important to monitor and assess these alterations. Changes in land use affect vegetation this in turn would affect wildlife habitat, fire conditions, aesthetic and historical values and ambient air quality.

Viewing the Earth from space has become essential to comprehend the cumulative influence of human activities on its natural resource base. In a time of rapid, and often unrecorded, land use change, observations from space provide objective information of human utilization of the landscape.

Remote sensing and Geographic Information Systems (GIS) are providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of earth-system function, patterning, and change at local, regional, and global scales over time; such data also provide a vital link between intensive, localized ecological research and the regional, national, and international conservation and management of biological diversity (Wilkie and Finn, 1996).

By utilizing remote sensing technologies and implementing GIS mapping techniques, land use and land cover change of designated areas can be monitored and mapped for specific research and analysis.

1.1 Problem Statement

The Bale Mountains are the largest remaining alpine habitat on the African continent. They stand out for their many endemic animal and plant species and high biodiversity value. The proportion of endemic species in the Bale Mountain National Park is so high that with the loss of the Park's natural resources more species would become extinct than in any other area of comparable size worldwide.

Parts of the Bale Mountain National park are populated and are therefore under increasing population pressure and the encroachment of the natural habitats is one of

the most critical issues in wildlife conservation in the area. Park protection and maintenance are so far barely existent. The area is facing deforestation and habitat loss in recent years.

As human and cattle populations have demographically expanded, their demand for space and resources has increased. There are expansions of human habitations and agriculture at the expense of wilderness areas. The consequences of an ever-increasing pressure of human development are resulted in changes of land and vegetation cover in the area. or depletion, degradation and fragmentation of habitats, loss of corridors and an increased human–animal conflict .

The fact that activities such as grazing, cutting and fire have contributed to processes of land use land cover change in the area.

The need for land use and land cover change information has become a focus in current strategies for managing natural resources and monitoring environmental change.

The understanding of the environmental conditions and factors involved in the deterioration of the eco-systems found inside the park areas are fundamental for appropriate management. Chronic disturbances can lead to habitat loss and subsequent reduction of the number of wild life population.

Various studies clearly demonstrated the potential of integrating remote sensing, GIS and field information for landscape assessment.

The expanding geospatial technologies through remote sensing, geographic information system (GIS) and global positioning system (GPS) provide the capabilities to acquire, analyze and interpret land use land cover dynamics on various scales, time and cost effectively.

The scope of this study comprises the development and creation of BMNP land use and land cover maps for the years 1973, 2000 and 2005 as well as wild life suitability map for Mountain Nyala.

1.2 General Objective

Analyzing the trend of land use land cover dynamics in Bale Mountains National Park over the period 1973 to 2005, thus contributes to sustainable management of the resources in the area.

1.2.1 The specific objectives of this research

- ❖ to identify and quantify the major land use land cover changes in the study area during the stated period.
- ❖ to assess the underlining causes of land use land cover change.
- ❖ to identify potential habitat for Mountain Nyala which is endemic species to Ethiopia.

1.3 Materials and Method

1.3.1 Materials

- I. **Satellite images:** In this study multi temporal Landsat images were downloaded from global land cover facility website and the TERRA, ASTER image was obtained from BMNP. The images are summarized in (Table1.1).

Table 1.1: Input satellite images

Image	Sensor	Path-Row	Pixel size	Date of acquisition
Land sat 1	MSS	180-55	80x80m	01/21/73
Land sat 7	ETM+	168&167-55	30x30m	11/28/2000
ASTER	Terra		15x15m(VNIR) 30x30m(SWIR)	10/30/2005

II. Other data

Table 1.2: Ancillary data

Data	Data type	Data Source
Study area boundary	Shape file	BMNP
Settlement	Shape file	BMNP
Contour	Topographic map (1:50,000)	Purchased from EMA
Land use	Existing land use shape file	BMNP
Road	Shape file	BMNP
Ground Truth and Accuracy Assessment Points	Point data	Field

II. Software used

Table 1.3: Software used in the course of the study

Software	Application
ARCGIS 9.1	GIS; Image processing
ERDAS EMAGINE 8.7	Image processing
IDRSI 32	Weighting Factors
ENVI 4.2	Change detection
MS EXCEL	Chart, graphs
MS WORD	Word processing

1.3.2 Method

1.3.2.1 Land use/Land cover change at BMNP

Three satellite images were used in this study. Namely, Landsat MSS of year 1973, Landsat ETM+ of 2000 and ASTER image of year 2005. It was intended to incorporate 1986 Landsat image, but due to dominant cloud cover, the image was discarded.

The satellite images and other maps used in this study were projected to a common coordinate system (Universal Transverse Mercator (UTM), Zone 37 North, Datum: Adindan) and resampled to the same spatial resolution (28m x 28m).

Visual interpretation of satellite images was enhanced through the use of contrast stretching in ERDAS IMAGINE software. Two main steps were followed in land cover mapping. First, unsupervised image classification was carried out prior to field visit, in order to determine strata for ground truthing.

Supervised classification based on the Maximum Likelihood Classifier algorithm was used in the classification of the satellite images. This was based on training sets. The sample points collected during fieldwork were all used for validating classification results. A Focal Majority Filter in ArcGIS was used for smoothing the classification results. The accuracy of classification was carried out by means of a confusion matrix generated through overlaying of the classified maps and the test samples. The image classification accuracy was further assessed by calculating the Kappa coefficient ' k^{\wedge} '. The Kappa statistic is an estimate of measure of overall agreement between image data and the reference (ground truth) data. Its coefficient falls typically on a scale between 0 and 1, where the latter indicates complete agreement, and is often multiplied by 100 to give a percentage measure of classification accuracy. Kappa values are also characterized into 3 groupings: a value greater than 0.80 (80%) represents strong agreement, a value between 0.40 and 0.80 (40 to 80%) represents moderate agreement, and a value below 0.40 (40%) represents poor agreement (Congalton, 1996).

Final land use land cover maps of 1973, 2000 and 2003 were produced by combining supervised image classification techniques. Post-classification and spectral change detection approach was employed to obtain the difference change map.

1.3.2.2 Nyala habitat suitability

The process of identifying Mountain Nyala habitat suitability in BMNP is based on its life requisites was reviewed and evaluated up on assessing some literatures (Aggimarangcee 1992, Davis 1962, Diong 1973 , Grassman 1997, Harriossn 1962 , Lekagul etal 1997 , Sinchareon 1998 and Taylor 1963).

In addition, field investigation was conducted to examine the existing habitat of the defined wildlife species in relevant to its life requisites. The life requisites identified from the study consists of vegetation type, topography (elevation), water resource and buffer regions within/beyond specified distance from existing human settlement center and proximity to road. Vegetation layer was extracted from the classification out put of 2005 ASTER image, River and road themes were digitized from 1:50,000 topographic map. The slope gradient in the area was generated from SRTM using Global mapper soft ware. Each of the themes with its associated attribute data are digitally encoded in GIS data base. A geo database consisting of all factor layers was created in ArcGIS 9.1 soft ware then rasterized. Each layer was subjected to undergo reclassification process and weight influence was calculated through IDRSI 32 software. Eventually weighted overlay technique was performed to come up with Nyala habitat suitability map.

Schematic view of the model building process for Nyala habitat suitability map is illustrated in (Figure 1.2)

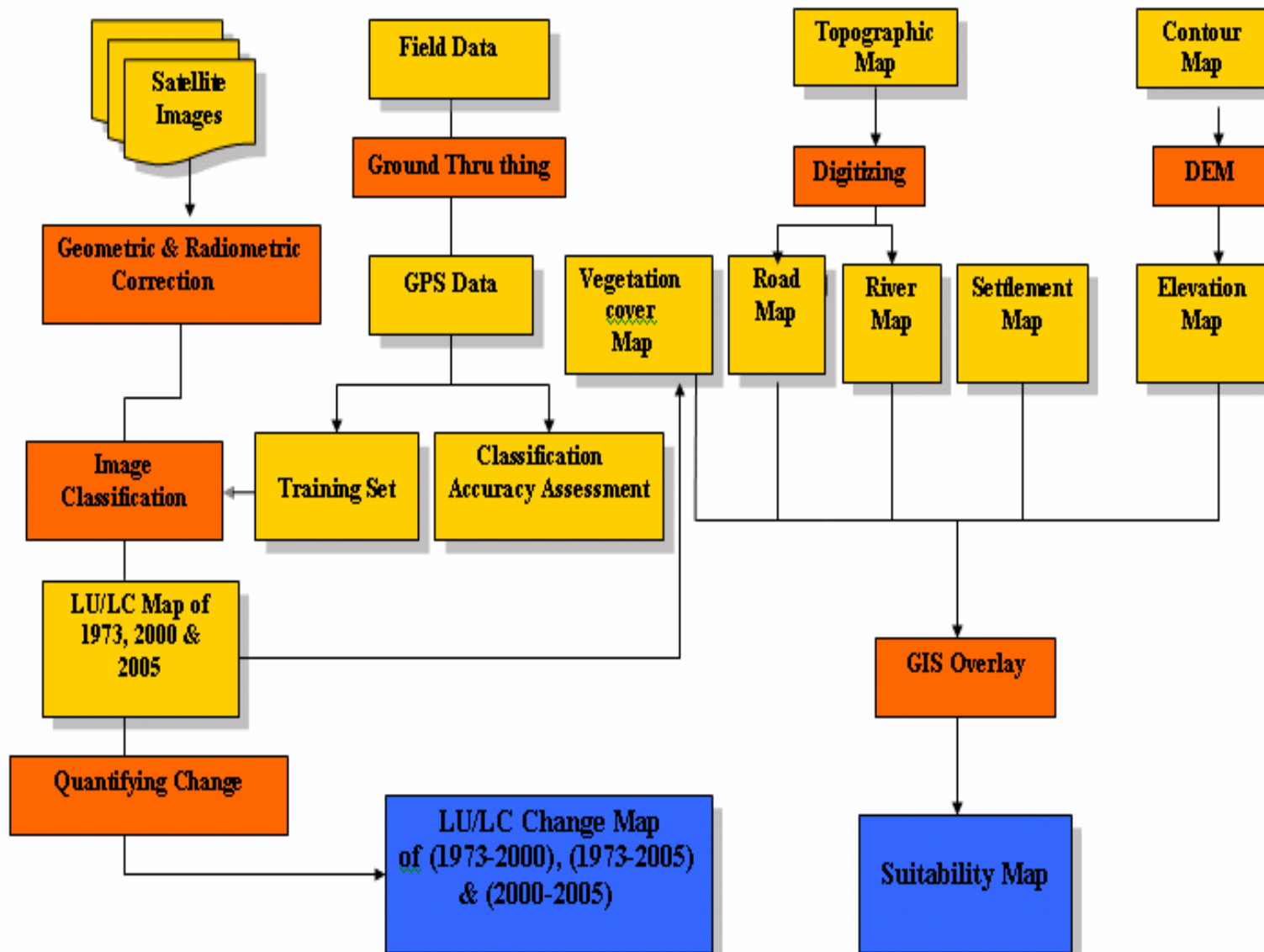


Fig 1.1: Flow chart showing the general methodology

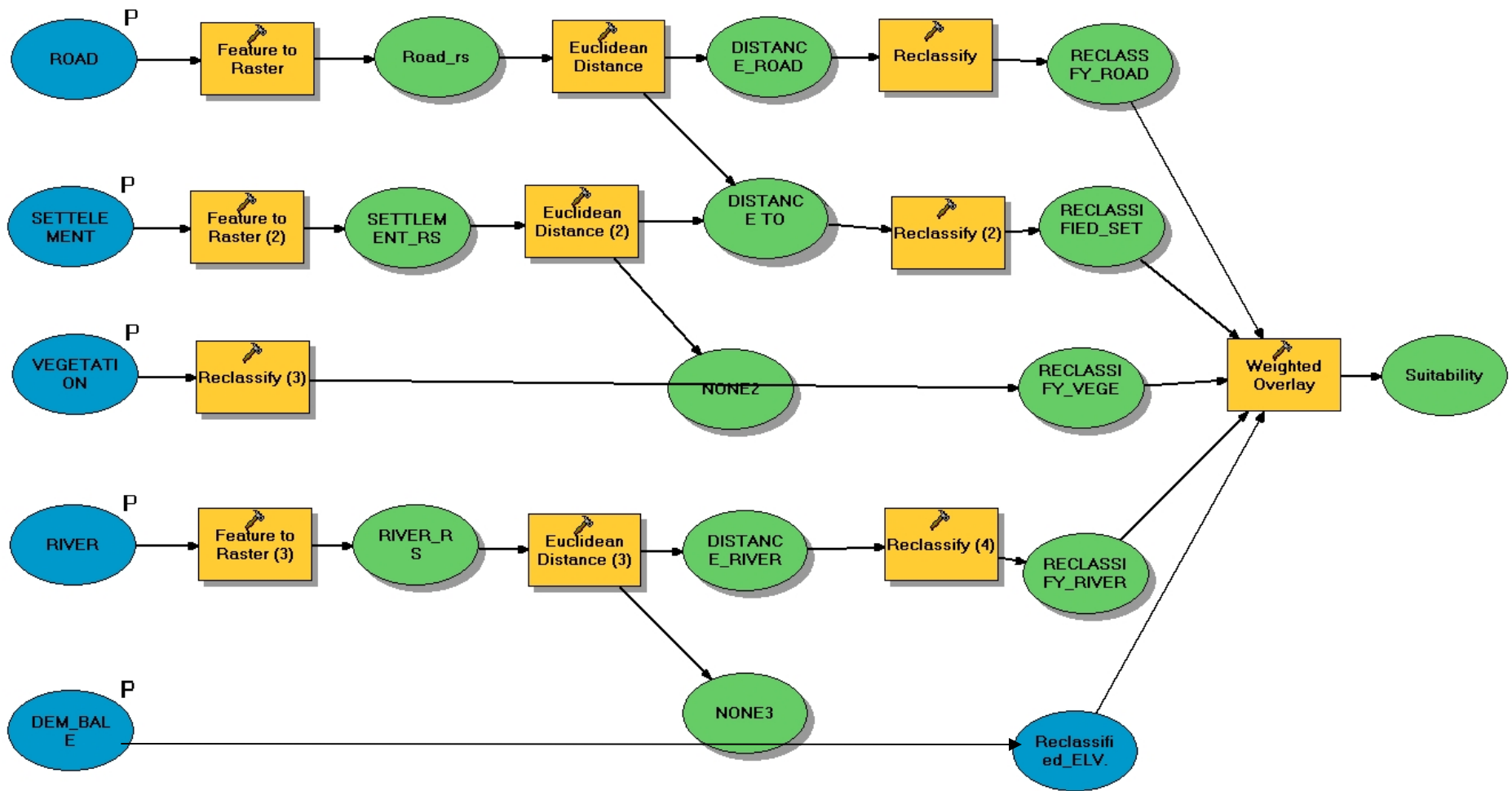


Fig 1.2: Schematic diagram of habitat suitability model building process

Chapter Two

2. Study Area Description

2.1 Location

Bale Mountains National Park is located at 6°30'-7°00'N and 39°30'-39°55'E, 400km south east of Addis Ababa in Oromia Regional National State in southeastern part of the country. It belongs to Bale-Arsi massif, which forms the western section of the southeastern highlands of Ethiopia. Geographical boundary of the park lies within five woreda of the Bale zone: Sinana-Dinsho in the North, Adaba in the west, Goba to the Northeast, and Mena-Angetu to the south and Haro to the East. National Forest Priority Areas (NFPA) and Controlled hunting area circumscribe the park. These include Aloshe-Batu in the East Mena-Angetu in the South, Harena-Kokosa and Adaba-Dodola in the west. The controlled hunting areas are: Hanto in the North, Besmena Odubulu and Abasheba Demero in the east. The NFPAs and the controlled hunting area adjacent to the park are meant to serve as buffer zone for protecting water catchments of the park, wildlife corridor and dispersal areas. The park possesses a total area of 2200km², but not the whole of the park area is under full control at present. It is only a portion of the northern part, which is relatively protected or managed.

Based on the landscapes and altitudinal differences, the park can be divided into three major parts (BMNP).

I. The northern Gesse area: the landscape varies from one mountain range to another in elevation. The broad flat valleys and high mountain ridges mainly lie between an altitude range of 3000 and 3500m a.s.l. In the southern ridge of Gesse, which is relatively dry is mainly covered with Juniperous procera, while the relatively wet northern ridge is largely occupied by Hagenia abyssinica and Hypericum revolutum. The flat valley of Gesse are dominated by species of the genera Artemisia, Helichrysum, Ferula, Kniphofia, etc. (BMNP).

II. Central Peaks and Sanete Plateau: the central part of the park lies between about 2800 (in the north) and 4377m.a.s.l. The northern escarpment of the Sanette plateau, which lies between 2800 and 3350m.a.s.l. is dominated by Juniperus followed by Hagenia-Hypericum stands between 3350-3500m. The area between 3550 and 4000m is covered by Erica scrub on ridges and Helichrysum moorland dotted with Lobelia. Much of the Sanette plateau lies over 4000m and there are several peaks ranging from 4050m at Worgona and Wasama to 4377m at Tulu Deemtu.(BMNP).

III. Southern part of the park-Harena Forest: the southern escarpment, which is covered by one of the most extensive natural forests remaining in Ethiopia, called “Harena forest”, roughly extends between 39°-40°E and 6°-7°N.The slope of the southern escarpment decreases rapidly in altitude from the tree line at 3200 to 2000m with in a distance of only 8 km.(BMNP).

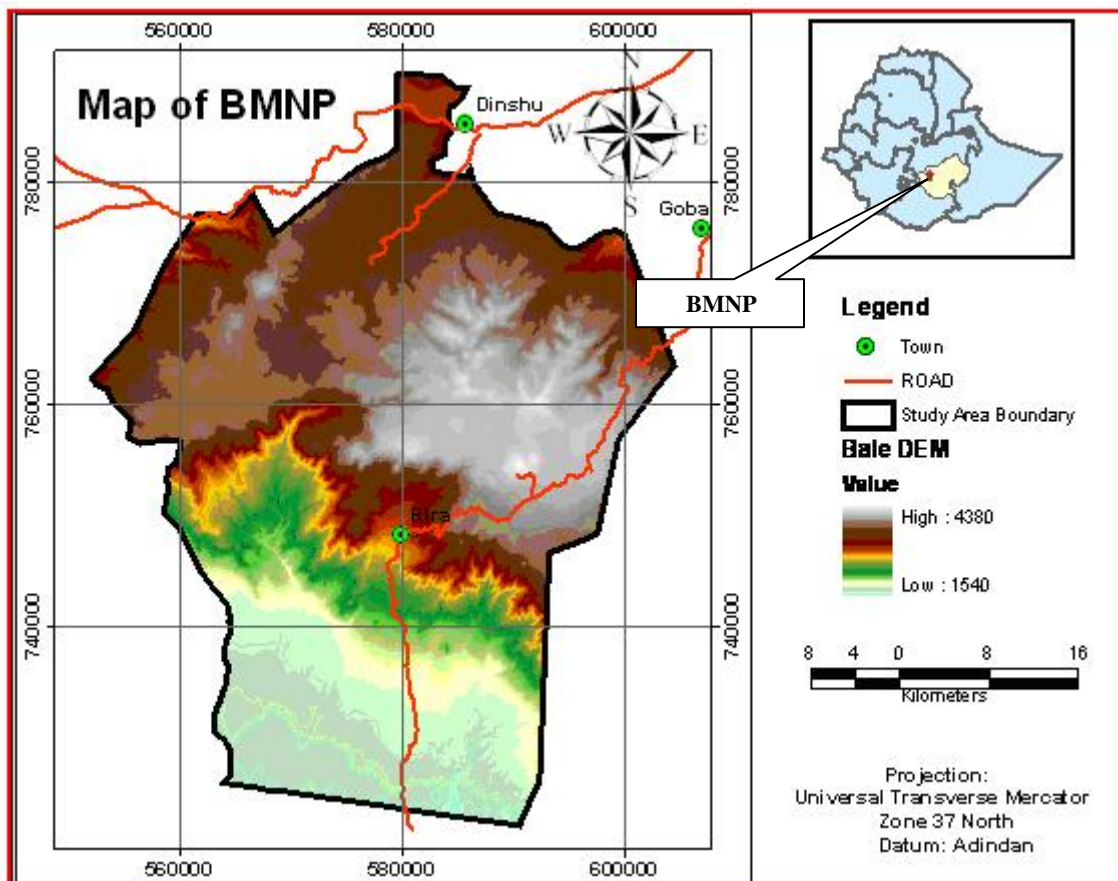


Fig 2.1: Location map of the study area

2.2 Physical environment

2.2.1 Geology

Geologically, the Bale massif consists of Tertiary (Oligocene) lavas, which covered the Mesozoic marine sediments by underlying the Precambrian rocks after the Eocene uplifting of Ethiopian highlands. During the Plio-pleistocene rifting phase, the Arsi-Bale massif was separated from the northwest Ethiopian mountains by the rift valley system, which also isolated the southwest Arabian part of land mass (Miehe & Miehe, 1994).

Hence Bale Mountains were formed from volcanic eruption lava in the Miocene and Oligocene geological periods early before the formation of the Great Rift Valley system, probably about 40-25 million years ago (Mohr, 1963). Since the crust of the Bale Mountains is of volcanic origin, are fairly fertile silty loams of reddish-brown to black colors.

There is an evidence of glaciations occurred in the Bale Mountains in the past, about 2000 years ago (Smeds, 1959; Mohr, 1963). It is believed that glaciations were in parallel with the glaciations of the Semien Mountains, and East African mountains such as Mt Kilimanjaro and Mt Ruwenzori (Mohr, 1963). Traces of former glaciers are common in the ericaceous and Afro alpine belt.

The present topography of Bale Mountains is a reflection of long term, probably over 20 million years of weathering processes that underwent due to heat and pressure that had been originated from the Oligocene lava outflows (BMNP).

2.2.2. Climate

As a result of the great altitudinal variation in Bale Mountains massifs, considerable variations of climatic conditions are recorded in the National Park.

Bale highlands belong to the east African Climatic domain, which is influenced by low-level easterly winds from the Indian Ocean causing small rains in January. The general rainfall patterns in the central Bale highlands are advective. The northern part some how conducive for plant growth, with ample amount of rainfall, and moderate temperature and relative humidity. The central plateau consists of extremely harsh climatic conditions-an erratic rainfall, usually wet and waterish air, icy and frostiness, frequent mist and some

times-random falls of hail. Additionally, due to macroclimate variations highlands and valleys create microclimatic conditions usually favored by plants and animals, particularly at the central plateau.

The Bale Mountains is characterized by having eight months rainy season (March to October) and followed by another four months dry season (November to February). Rainfall is well distributed through out the wet season, ranging from 1000 to 1400mm annually (Daniel Gamachu, 1977).

Temperature records from the Bale Mountains indicate that the wet seasons are comparatively warm and the dry seasons are extremely nocturnal cold and diurnal warm vis-à-vis. The lowest recorded temperature at highest plateau of Bale (Sanette) was -15°C and the maximum record was 26°C (Hillman, 1986). Similarly the lowest recorded temperature in Dinsho area was -6°C.

Relative humidity measured using thermo hygrograph ranged from 17% to 100% during the dry and wet periods respectively (Hillman, 1986).

2.2.3. Hydrology

The Bale Mountains are important water source like a tower that supports the life of millions of people and other organisms in the adjacent lowland areas. There are more than forty streams arise within the BMNP. These join to form four major rivers-the Wabe shebele, the Web (leading to the Genale and Juba Rivers), the Welmel and Dumal Rivers. In addition, the water for the numerous springs emerging in the lowlands originates from the Bale Mountains. These rivers and springs are the only sources of perennial water for the critical and lowlands of the east and southeast of Ethiopia, including the Ogaden and Somali areas. In these areas there is an extreme water deficit, particularly during the dry season (BMNP)

Table 2.1: Major Rivers and their tributaries in the BMNP

No	Major Rivers	Tributaries
1	Wabe shebele	Abasa, Arba, Baranda, Boko, Furuna, Gonedoh, Layleeso, And Solay, Wachekora, Mararo, Malka Segel
2	Web	Albabo, Dalcha, Danka, Dimbeba, Gareno, Gesse, Kebesha, Kaficho, Keyrensa, Lolla, Micha, Shaya, Shaya-Gugesha, Teynta, Tegona, Toroshoma, Wolla, Wasama, Web and Zetegn melka.
3	Dumal	Six un-named tributaries
4	Welmel	Geremba, Rira, Shawe, Shisha and Yadot.

2.3 Biological Diversity

2.3.1 Fauna

The BMNP support the world's highest density of endemic mammals together with a rich bird and lower vertebrate fauna. The great altitudinal variation and habitat diversity in the different part of the park creates conducive environment to harbor varieties of faunal resources. So far 78 mammal and 278 Bird species are recorded in the park.

The largest percentage of mammal distribution in the park is found in the northern woodlands of the park. As it is evidently found in the fossils, mineralized ivory and teeth in Shisha river during the 1984 expedition, the Hareenna forest is used to harbor big mammals such as Elephants (*Loxodonta africana*) and Buffalo (*Syncerus caffer*). The park preserves the last large and viable populations of two spectacular species, the Mountain Nyala (*Tragelaphus buxtoni*) and the Ethiopian Wolf (*Canis siemensis*). A number of less dramatic species of rodent, frog and others would probably also be doomed if the habitat in the Bale Mountains were to be irreparably degraded (BMNP).

Table 2.2: Faunal endemism of BMNP

Animals group	BMNP	Endemic Species	%	Ethiopia	Endemic	%	%Endemism Bale/Ethiopia
Mammals	78	11		260	22	8.5	
Birds	278	6		816	16	2	
Snakes	2	0	0	77	3	3.9	-
Frogs	8	7	87.5	55	20	36.4	35

2.3.2. Flora

The diversity of Bale Mountains in comparison to that of diversity of plants in the flora of Ethiopia and Eritrea have been studied and documented, from the published volumes and unpublished manuscripts. According to the National Herbarium reports the total number of species of vascular plants is about 6000. The total number of taxa for the Bale floristic region is estimated about 1650 species. Of these, about 1400 species occur between an altitude of 1500 and 4377m a.s.l.

There about 600 endemic taxa in the Flora of Ethiopia and Eritrea, of which 177 (29.5%) are also endemic to Bale floristic region (BMNP).

2.3.3. Vegetation

The Bale Mountains National Park and surrounding areas could be divided into southern and northern sides of Bale Mountains. The vegetation in the southern side falls within moist montane forest vegetation type while the northern side classified as Dry evergreen montane forest.

The BMNP and surrounding areas provide a complete altitudinal zonation of vegetation starting from the broadly deciduous woodland in the lower parts, extending through various types of moist montane forests to ericaceous woodland, and culminating at *Helichrysum* dominated moorland. The study of the National Herbarium generally categorized the vegetation of the southern part of the park into; (BMNP)

- ❖ *Ocotea-Olea-Podocarpus-Syzygium*
- ❖ *Syzygium-Polyscias-Allophylus-Erythrina*
- ❖ *Sheffleria-Hagenia-Erythrina-Galiniera*
- ❖ *Hagenia-Hypericum-Schefflera-Myrsine*
- ❖ *Erica arborea trees*
- ❖ *Erica arborea- E.trimera*
- ❖ *Helichrysum citrispinum- H.splendidum*

2.4 Land use in and around the BMNP

2.4.1 Agriculture

Agriculture is the major sector that supports the livelihood of households and communities in and around the Bale Mountains National Park. Agriculture in the Bale Mountains involves two major activities: Farming and Livestock husbandry. According to the findings of the socioeconomic survey of B&M Development Consultant, about 98% of the respondents indicated that agriculture, both crop production and livestock husbandry as the main occupation. Farming takes place up to altitude of 3500. Relatively the lower slopes use to produce barley and the upper slopes mainly used for vegetables like onion, potato and cabbage. The Northern and Northwestern localities of the park, including Rira grows Barley as the major crop. Areas like Angeso to the east of the Park grow Onion than any other crop. Even in the Northern areas currently Onion is becoming common agricultural practice. In a single market day at Dinsho town more than 10 lorries of Onion is taken off to big town like Shahemene and Addis Ababa, on top of this it is very easy to observe a bundle of onion on roadside between Dinsho and Geremba Dima kebele waiting for transportation. As of the observation made during settlement survey, the high demand and price of onion is the most important factor for the expansion of farming in the highlands of the Bale Mountains.

The common characteristics of the people living in and around BMNP do practice livestock husbandry although at different scale. The average number of each live stock type owned per household is relatively higher compared to many areas in the country (B&M Development Consultant survey). For the Bale people animals mean a source of income, transport, food, and fame. Hence cattle are found everywhere in the boundary of the park.

The Afroalpine plateau is the place where livestock husbandry takes place in a large scale. The western part of the plateau, Web valley, is being utilized by a number of livestock from the surrounding kebeles and some permanently resident livestock. Whereas the eastern part, Sanette, area serves for very few individuals having a large number of livestock per head. The density per type of livestock varies significantly from one locality to another. At the Sanette plateau Sheep and Goats are the most dominant while cattle are in the Web valley. As the survey made by the park experts indicated that there are, 119383 cattle, 9522 horses and donkeys, and 39404 Shoats with in the entire park boundary during the survey period. This figure varies with season; it increases during the dry season and when agricultural lands outside the park boundary are sown with crops (BMNP).

2.4.2 Settlement

There are about 66 different size settlements in the BMNP. The size and magnitude of their impact to the ecosystem varies significantly. The largest villages within the park include Gojera, Rira, WegeHarena, Ayida, Gama-taja, and Meskel-Haricho. Some of the villages affect movement of wild lives through blocking corridors like the Gojera village and others reduce the available habitat. Generally settlement is increasing with time in the park (BMNP).

2.4.3 Eco-tourism

Although the contribution of eco tourism to the local community is not clearly known there are some people who are engaged in eco tourism activities. Local communities are being benefited from tourism through guiding, horse rent, and being a porter. Basically the distribution of these benefits does not show a uniform distribution among the villages found in and around the park (BMNP).

2.4.4 Natural resources utilization

People in the park and nearby area do extract timber and non-timber forest products from the park. Construction wood, fuel wood, thatching grass, lianas, bamboo, medicinal plants, and softwoods for traditional beehives are some of the forest products that are usually

collected from the wild. The other most important resource utilization is the use of high altitude hora for cattle (BMNP).

2.4.5 Sport hunting

Currently there are two hunting concession area in the vicinity of the park. Hanto Controlled hunting area in the north and the Odubulu controlled hunting area in the eastern edge of the park. There is also another controlled hunting area being proposed in the southeastern end of the park. These controlled hunting areas actually produce a substantial amount of money to the regional economy; however, their contribution towards conservation of the adjacent park and development of the local community is insignificant. But the sustainability of these hunting areas is highly determined by the availability of viable population in the national parks and the support from the local people (BMNP).

2.4.6 Forestry Projects

The Mena-Angetu state forest project in the south and the Aloshe-Batu state forest project in the east buffer the national park. Their efficient management doubtlessly enforces the conservation of the park (BMNP).

2.4.7 Wildlife Conservation

The park it self can be considered as one type of land use being carried out in the area. Obviously the overall goal of having a national park is conservation of natural resources.

2.4.8 Water catchments conservation

The conservation of the Bale Mountains plays a great role in the protection of the watersheds that support millions of life in the southeastern part of the country and even to the Somali (BMNP).

2.4.9 Morrum extraction

For the purpose of road construction morrum is extracted from the Sanette plateau and Gesse area. The ecological impact of extraction is not yet supported with studies. However, its impact in reducing the scenic beauty of the area can be seen easily.

2.4.10 Public Roads

The road from Addis to Goba crosses the Gesse plain for about 15 km and the road from Goba to Mena goes all the way through the Sanette plateau and the Hareenna forest for about 100 km. Apart from the adverse impact through road kills and edge effect, public roads enhance human settlement and natural resource exploitation due to the fact that people do get easy access to sell products. In order to understand the magnitude of the impact from the public roads, demand for further studies and continuous monitoring (BMNP).

2.5 Research and Education

Bale Mountains National Park serves as a field laboratory for higher institutions of the country dealing with natural resource related field of studies. Addis Ababa University and the Debu University bring their students to the park to support theoretical principles taught in class through practical observation. A number of inland and foreign researchers do their thesis here in Bale Mountains. There fore the park is an important area for research and studies (BMNP).

2.5.1 Ritual areas

People do have different mechanism to satisfy their spiritual needs. In the Bale Mountains there are localities identified for spiritual purpose.

2.5.2 Hydroelectric power plant

Melkawakena hydroelectric power station, which generates power for the entire country's demand operates because of the streams flowing from the Bale Mountains. The mini hydroelectric power at Delo-mena also generates power from the Yadot River that flows from the Bale Mountains massifs (BMNP).

2.5.3 Social services

Social services such as Mosque, School and Health center are found in the national park.

2.6 Existing Infrastructures and Number of visitors

2.6.1 Infrastructures

Since the foundation of the park, the managing authority has passed through several endeavors to strengthen the park with necessary infrastructures. The main focus of construction was on residential buildings and subsidiary road net works. Basically during the time of establishment the park management used to use the buildings of the Belgian Sheep concessionaire as an office and residence. These buildings are still used for tourist accommodation and scouts residence. Mainly three important period of time could be recognized concerning buildings development of the park; the first was in 1978-79 where by a number of different standard residential buildings built by the government budget. The other contribution was from UNDP between 1995 and 1997, through parks rehabilitation program. Under this project a Park office and the rehabilitation of looted outposts and Ticket office were accomplished. The third significant construction work was done by DGIS_WWF. WWF has built two outposts and a ticket office at Rira and Angeso.

Road network within the park boundary was entirely done through the government Food for work program. More than 100 km of subsidiary road has been opened by human labor in 1984 up to 1988. These days large part of the road is out of use due to lack of

maintenance. Tentative maintenance is used to done through the government budget, however this maintenance covers very limited area particularly in the Northern part of the park only. Among the maintenance efforts made in the last decade, the one made through the UNDP fund which covered about 40 km road was the most significant. EWCP also try to keep the road goes to Web valley functioning most of the year time through continuous maintenance. Currently a total of 43.3 km road provide service. These include;

The Gesse area that covers 19km, from the HQ to the Web valley- 23km, within the HQ- 1.3km, there is also more than 30 km road that can be used with little maintenance (BMNP).

2.6.2 Visitors

The volume and recipient of tourism in the BMNP is far below its potential. The annual figure of tourists in some cases is lower than a monthly tourist volume of any one of the east African National Parks. As the tourist information from the park office indicates, the park received 2277 and 10896 local and foreign visitors respectively and generated 730,777 Birr in sixteen years.

This section describes the main issues that prevent BMNP from carrying out its conservation role effectively. These major issues are grouped under the following general topics:

Natural Resources

Cultural Resources

Interpretation and Public information

Visitors Use and Park Development

Park relationship with local people and neighboring

Park Operation and maintenance (BMNP).

Chapter Three

3. Literature review

3.1 Land cover, land use

According to FAO (2000): “Land cover is the observed biophysical cover on the earth’s surface”. The same document also defines land use as the arrangements, activities and inputs that people under-take on a certain land cover type. According to these definitions, land cover corresponds to the physical condition of the ground surface, e.g., forest, grassland, concrete pavement, while land use reflects human activities such as the use of the land like industrial zones, residential zones, agricultural fields.

The above definitions establish a direct link between land cover and the actions of people in their environment i.e. land use may lead to land cover change. Generally, land cover does not coincide with land use. A land use class is composed of several land covers. Remote sensing data can provide land cover information rather than land use information.

Land cover change can be divided into 2 forms as follows (FAO, 2000):

- 1) Conversion from one land cover category to another, e.g. from forest to grassland.
- 2) Modification within one category, e.g. from dense forest to open forest.

3.2 Land use change

Knowing the changes in land use/cover could be taken as a good indicator of ecosystem health that includes biodiversity. Therefore, mapping the land use/cover can be considered as benchmark for land use/cover change detection in the future and it could be a pillar for different land use planning. Hence, it becomes important to undertake studies of land use/cover changes to see the severity of the changes with time Belay (2002).

Land use/cover studies have been commonly carried out using aerial photographs and the recent aerial photographs that cover the study site are those taken in 1994. With the current, economy and technology, getting aerial photographs that covers large area with a better

resolution is becoming difficult. Thus, currently, more attention has been given to the use of satellite imagery. Although it depends on the type of image data and purpose of study, the applicability of space borne remote sensing is becoming important Sluiter (2005).

3.3 Studies done on land use land cover change

Several studies have been carried out in regard to land use land cover change globally, to mention few, research specialists such as Skole & Tucker (1993), Skole et al (1994), and Kummer & Turner (1994) perform extensive studies in an attempt to bring further attention to this situation by focusing on the social implications and the environmental degradation associated with tropical deforestation in the Amazon of South America and in Southeast Asia. Yet, with all the research, awareness, and attention of the world, this potentially devastating phenomenon continues. It is an unfortunate, but fact of life that land degradation occurs on numerous expanses and at varying scales around the globe.

Coming to Ethiopian situation, since GIS and Remote Sensing is relatively an infant technology, little researches are done. The intention of the present study is to fill such gap in relation to land use land cover change detection analysis.

3.4 Land cover mapping

Land cover mapping is one of the most important and typical applications of remote sensing data. Initially, the land cover classification system should be established, which is usually defined as levels and classes. The level and class should be designed in consideration of the purpose of use (national, regional or local), the spatial and spectral resolution of the remote sensing data, user's request and so on (Japan Association of Remote Sensing, 1996). According to Jensen (1996), there is a fundamental difference between information classes and spectral classes. Information classes are those defined by men while spectral classes are those inherent in the remote sensing data and must be identified and labelled by the analyst. The aim of digital classification is to translate spectral classes into information classes.

3.5 Digital Image Processing

In this study three types of digital image processing operations were used: image rectification and restoration (preprocessing), image enhancement and image classification. Preprocessing is aimed to correct distorted or degraded data to create a more faithful representation of the original scene. This typically involves the initial processing of raw image data to correct for geometric distortions, to calibrate the data radiometrically, and to eliminate noise present in the data. Image enhancement is a procedure applied to image data in order to more effectively display or record the data for subsequent visual interpretation. Normally, image enhancement involves techniques for increasing the visual distinction between features in a scene. For instance, Linear Stretch, which is one of the Contrast Stretching techniques, is the uniform expansion of limited image levels range to fill the range of display values (0-255). Subtle variations in input image data values would now be displayed in output tones that would be more readily distinguished by the interpreter. Light tone areas would appear lighter and dark areas would appear darker.

3.6 Image Classification

According to Jensen (1996) digital image classification is the process of assigning pixel to classes. Usually, each pixel is treated as an individual unit composed of values in several spectral bands. By comparing pixel to one another and to pixels of known identity, it is possible to assemble groups of similar pixels into classes that match to the informational categories of interest to users of remotely sensed data. Digital image classification is divided into supervised and unsupervised classification.

3.6.1. Unsupervised classification

Unsupervised classification uses statistical clustering techniques to combines pixels into groups (classes) according to the degree of similarity of their brightness value in each spectral band. The analyst then combines and relabels spectral classes into real land cover type as unambiguously as possible using maps and field based knowledge. The analyst

should understand the spectral characteristics of the terrain in the area of interest well enough to properly label certain clusters into a specific information class (land cover type). In this process many spectral classes can be assigned to a few land cover types (David & John, 1996; Jensen, 1996)

3.6.2. Supervised classification

Supervised classification is the process of using a known identity of specific sites (through a combination of fieldwork, analysis of aerial photography, maps, and personal experience) in the remotely sensed data, which represent homogenous examples of land cover types to classify the remainder of the image. These areas are commonly referred to as training sites (Jensen, 1996).

3.6.3. Maximum likelihood classifier

The maximum likelihood classifier is one of the most popular methods of classification in remote sensing. This classifier assigns a pixel with maximum likelihood into a corresponding class. The like-lihood L_k is defined as the posterior probability of a pixel belonging to class k (Japan Association of Remote Sensing, 1996).

3.7 Change detection methods

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multitemporal data sets (Singh, 1989). Many change detection methods have been developed and used for various applications. For example, there are post-classification comparison, image differencing, image ratioing, image regression, principal component analysis (Chen, 2000). However, they can be broadly divided into: post-classification, and spectral change detection approaches (Lunetta & Elvidge, 1999; Singh, 1989).

3.7.1. Post-classification approach

Post classification is among the most widely applied techniques for change detection purpose. Numerous studies have been carried out using post-classification approach.

In post classification change detection approach two images from different dates are classified and labelled. The area of change is then extracted through the direct comparison of the classification results (Lunetta & Elvidge, 1999).

Main advantages of post-classification include: detailed “from – to” information (Chen, 2000; Lunetta & Elvidge, 1999). It bypasses the difficulties associated with the analysis of images acquired at different times of year or sensor (Chen, 2000).

The main disadvantage of the post-classification approach is the dependency of the land cover change results on the individual classification accuracies (Chen, 2000). This approach can produce a large number of erroneous change indications since an error on either data gives a false indication of change (Singh, 1989). Therefore, it is imperative that the individual classification be as accurate as possible (Chen, 2000).

3.7.2. Spectral change detection approach

According to Chen (2000), a large number of techniques is in the spectral change identification category. Spectral change detection techniques rely on the principle that land cover changes result in persistent changes in spectral signature of the affected land surface. These techniques involve the transformation of the two original images into a new single band or multiband image, in which the area of spectral change is highlighted. Most of the spectral change detection techniques are based on some type of image differencing or image ratioing. Recent studies by Singh (1989) or Coppin and Bauer (1996), as cited in Petit et al. (2001) have identified image differencing as the most accurate change detection technique. This technique is performed by subtracting images from two dates pixel by pixel. Then threshold boundaries between change and no-change pixels are determined for the difference image to produce the change map (Singh, 1989).

Among spectral change detection methods, NDVI image differencing emerges as one of the most widely used. NDVI is a measure derived by dividing the difference between near-infrared and red reflectance measurements by their sum (Seller, 1989): $NDVI = (NIR - R) / (NIR + R)$. High positive values of NDVI correspond to dense vegetation cover that is actively growing, where negative values are usually associated with bare soil, snow, clouds or non-vegetated surfaces. Oindo in 2001 made a research in which examine the relationships between the species richness of vascular plants and different animal's communities. In his study he applied NDVI and its variability (standard deviation) were. A large number of comparative studies on different change detection methods including NDVI image differencing have been carried out (Fung & Siu, 2000; Hayes & Sader, 2001; Lunetta et al., 2002; Michener & Houhoulis, 1997; Petit C., Scudder T., & Lambin, 2001; Yuan & Elvidge, 1998). Except for the study by Yuan & Elvidge, (1998), which was carried out under the framework of North American Landscape Characterization project, most of the studies came to the common conclusion that NDVI image differencing method yields highest accuracy. Studies by Lyon et al. (1998), and Lunetta et al. (2002) reported that NDVI differencing was the best method for vegetation change detection in biologically complex ecosystem. Furthermore, Lyon et al. (1998) indicated that NDVI differencing was least affected by topographic factors.

In general, the advantage of spectral change detection techniques is that they are based on the detection of physical changes between image dates. This avoids the errors introduced in post-classification change detection where inaccuracies in the land cover classification are propagated into land cover change analysis. However, the greatest challenge to the successful application of these techniques is the discrimination of "change" and "no change" pixels. For spectral change detection, an accurate image coregistration is crucial.

3.8 Factors affecting comparability of images

The following are complicating factors which should be taken into account when performing change detection analysis (Yuan et al., 1999):

Spatial resolution and spectral bandpass between images acquired with two different sensors. Phenological variations in vegetation result in large changes in the reflectance

patterns of the land surface. Spectral differences in vegetation between wet and dry years can also be quite pronounced even if image dates are more closely matched.

Cloud cover, differences in the radiometric performance between sensors or changes in the performance of individual sensors over time Variations in solar irradiance, solar zenith angle, and solar azimuth (affects scene brightness, levels and location of shadows)

Scene to scene variation in atmospheric effects (scattering and absorption)

Spatial miss registration of images. This tends to reduce the accuracy of any digital change detection effort.

The listed above factors should be carefully considered during change detection analysis including the selection of images and method to ascertain whether the detected “difference” is “a real change”.

3.9 Accuracy Analysis

When the satellite images are classified, they intend to produce information that describe reality. This way, systems that allow us to verify to what extent the produced classification is compatible with what actually exists are fundamental and in practice a procedure inserted in the classification process itself should be taken into consideration.

The accuracy procedures involve the production of references or facts from the field that evaluate the produced classification. These references may be produced from maps, aerial photos or visits to the field with help from the GPS system and may be represented by points or areas (Stehman & Czaplewski, 1997). These references should necessarily be georeferenced, allowing them to be superposed to the produced classification and compared to the value of facts from the field and the value of the classified map. This comparison produces an error matrix that is the basis for the accuracy verification process (Gongalton, R.G., 1991).

The error matrix consists of rows and columns. The rows represent the classification values and the columns, facts from the field. The diagonal line of the error matrix represents the number of pixels that were correctly classified, as we can see in from the error matrix, three accuracy indices are usually produced: the overall, the producer and the user. The last two refer to each class individually. The overall accuracy index is produced by dividing all the pixels correctly classified by the total number of pixels in the matrix. The producer

accuracy index is produced by dividing the number of correctly classified pixels that belong to a class by the sum of the values of the column of this same class. The user accuracy index is produced by dividing the total number of correctly classified pixels that belong to a class by the sum of the values of the rows of this same class (Rosenfield and Fitzpatrick-Lins, 1986).

The producer and user indices allow the identification of relations among the classes, this way, in a six class context, for example, four of these classes may have balanced user and producer accuracy values while two classes may be very confused affecting the overall value of the accuracy. In this case, it is worth to start the classification process over again keeping the parameters that were used for other classes or merging them in one only class. Congalton (1991) suggests that, for classifications that have few classes, less than ten use from 50 to 60 reference points for the accuracy production. These points' proportion may be differentiated due to the volume of area occupied by a certain class.

This way, in a forestial landscape with one and only rocky outcrop, locating many points to identify this outcrop does not make much sense. The opposite can be said concerning the vegetation, that will need many points to check the effectiveness of the classification for its complete verification. Besides the accuracy indices shown above, there are other indices produced from the error matrix that involve more complex mathematical operations such as probabilities. One of these indices is called Kappa Statistic and it enables a generalization of information that allows us to compare classifications produced from different images. The Kappa Statistic was described in detail, Kalkhan (1994).

Most of the software that works with the classification of orbital images shows specific tools for the development of the accuracy process. The software that classify based on the pixel usually work with reference points and the software that work with objects work with areas as a reference.

3.10 Suitability Analysis

The proper utilization of land contributes a lot towards development of the economy of any country. This also helps in reclaiming and conserving the soil and other resources of a region through scientific approach to achieve its balanced development.

Land suitability analysis is the process of determining the fitness of a given tract of land for a defined use (Steiner, McSherry et al. 2000). In other words, it is the process to determine whether the land resource is suitable for some specific uses and to determine the suitability level. In order to determine the most desirable direction for future development, the suitability for various land uses should be carefully studied with the aim of directing growth to the most appropriate sites.

3.10.1 Multi-Criteria Evaluation (MCE)

In Decision theory, Multi-Criteria Evaluation is the process of applying a decision rule to a set of alternatives. A decision rule is a procedure by which criteria are combined to arrive at a particular evaluation, and by which evaluations are compared and acted upon. A decision is a choice between alternatives (such as alternative actions, land allocations, etc.). The basis for a decision is known as a criterion. Criteria may be of two types: factors and constraints. Factors are generally continuous in nature (such as the slope gradient or road proximity factors); they indicate the relative suitability of certain areas. Constraints, on the other hand, are always Boolean in character (such as the reserved lands constraint in the example above). They serve to exclude certain areas from consideration. Factors and constraints can be combined in the MCE module using one of three methods (Boolean intersection, Weighted Linear Combination and Ordered Weighted Average); each method is characterized by different levels of control over tradeoff between factors and the level of risk assumed in the combination procedure.

Trade off is the degree to which one factor can compensate for another; how they compensate is governed by a set of factor weights sometimes called tradeoff weights. Factor weights are given for each factor such that all factor weights, for a set of factors, sum to one; they indicate the relative importance of each factor to the objective under consideration. A factor with a high factor/tradeoff weight may compensate for low suitability in other factors that have lower factor/tradeoff weights.

In a Multi-Criteria Evaluation, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective. For example, a decision may need to be made about what areas are the most suitable for industrial

development. Criteria might include proximity to roads, slope gradient, exclusion of reserved lands, and so on. Through a Multi-Criteria Evaluation, these criteria images representing suitability may be combined to form a single suitability map from which the final choice will be made Eastman (2001).

The second method in MCE is a Weighted Linear Combination (WLC) where criteria may include both weighted factors and constraints. WLC starts by multiplying each factor by its factor/tradeoff weight and then adding the results; constraints are then applied by successive multiplication to "zero out" excluded areas. This procedure is characterized by full tradeoff between factors and average risk. Factor weights, not used at all in the case of Boolean intersection (no tradeoff), are very important in WLC because they determine how individual factors will tradeoff relative to each other. In this case, the higher the factor weight the more influence that factor has on the final suitability map. (Contrast this with method 3 below where the importance of factor weights is variable). Along with full tradeoff, this combination procedure is characterized by an average level of risk, as it is exactly midway between the minimization (AND operation) and maximization (OR operation) of areas to be considered suitable in the final result Eastman (2001).

3.11 Wild life habitat Modeling

Quantifying habitat quality is important for management of wildlife populations and conservation planning. Habitat suitability index (HSI) models have been used to evaluate wildlife habitat and the effects of management activities and development since the early 1980s (U.S. Fish and Wildlife Service 1980, 1981). These models are based on functional relationships between wildlife and habitat variables. Values of habitat variables (e.g., herbaceous canopy cover, tree canopy cover, tree height) are related to habitat quality on a suitability index (SI) scale from 0 = "not habitat" to 1 = "habitat of maximum suitability." Habitat suitability index scores, also on a 0–1 scale, are usually calculated using a mathematical formula representing hypothesized relationships among the individual SIs. Wildlife–habitat relationships may be supported by empirical data, expert opinion, or both (U.S. Fish and Wildlife Service 1980, 1981). Traditionally, HSI models are applied to a sample of locations within land cover types or dominant overstory vegetation types. Habitat quality in an area is typically summarized in terms of habitat units, which represent

the product of the mean HSI score in each vegetation type and the area of land in that vegetation type, summed across the study area. Now that geographic information system (GIS) software and high-speed computer hardware are widely available, their use among biologists is increasing. In addition to providing a new, powerful analytical tool, GIS technology allows land and wildlife managers to utilize novel sources of land cover, vegetation, and other habitat data, namely remote imagery from aerial photographs and satellite sensors and GIS databases of elevation, surface water, climate data, and ecological land types. Concurrent with GIS developments have been advances in our understanding of wildlife–habitat relationships, especially at landscape scales. Using GIS for HSI-type habitat evaluations has several advantages over traditional HSI modeling.

It is easier and faster to apply GIS-based habitat models to large geographic areas because time- and labor-intensive collection of field data is not necessary. Spatial structure and landscape patterns are often important aspects of habitat quality (Donovan et al. 1987, Rickers et al. 1995, Robinson et al. 1995) and are much easier to incorporate in GIS models. Furthermore, GIS based habitat models can be used to evaluate landscapes simulated by spatially explicit forest landscape models [e.g., LANDIS (He et al. 1996, 1999; Mladenoff and He 1999)], which are useful for comparing alternative land management scenarios over time (e.g., Marzluff et al. 2002, Shifley et al. 2000). The full use of GIS in habitat modeling, however, requires the revision of existing HSI models or the development of new ones. Whereas most existing HSI models are based on relatively small-scale habitat variables measured by biologists in the field, GIS-based HSI models have the capability to more readily focus on larger scale habitat variables that can be quantified without going a field.

Chapter Four

4 Analysis and Discussion

4.1 Introduction

The interpretation and analysis of remote sensing imagery involves the identification and measurement of various targets in images in order to extract information about the targets. In this study interpretation and classification was carried out in such away that first unsupervised classified color prints of year 2005 ASTER image had been prepared and taken to the field. In the field it was cross-referenced using Garmin GPS with ground features. In some cases different features appeared to be similar in reflectance. This could be best exemplified by bare land and farm plot land. Apparently this owes an impact on the classification accuracy. After fieldwork, supervised classification was carried out for the three images (ASTER, Landsat ETM+ and Landsat MSS) based on different false color composite of 5,4,1, 6,4,2 and 4,3,1 in the order of RGB respectively. Next, Change detection analysis was performed.

The change-detection analysis can be carried out by visual comparison of features identified in different years and detailed quantitative approaches (Wick ware and Howarth, 1981). Nonetheless; the complexities of natural characteristics of geographical territory cause difficulty to develop general method.

However, in the present study two methods of change detection were assessed and a suitable method among them was selected.

4.2 Change detection Analysis

4.2.1 Change detected by post classification

4.2.1.1 Land cover mapping

Six land cover classes were discriminated based on spectral characteristics of Landsat MSS, 1973 image. These include moist montane forest, dry ever green forest, wood land, alpine bush land, water body, and barren land. Water and shadow area showed an overlap in their spectral reflectance and posed some difficulties in the course of classification. The moist montane forest areas however, showed a good textural difference from alpine bushland forests.

Eight land cover classes were also identified from supervised classification of both ASTER, 2005 and Landsat ETM+, 2000 images. The description of identified land cover types is here under,

The moist montane forest

The moist montane forest is the dominant land cover type occurs in the southern escarpment of the park, which is covered by one of the most extensive natural forests remaining in Ethiopia, called “Harena forest”.

The vegetation consists of,

- *Ocotea-Olea-Podocarpus-Syzigium*
- *Syzigium-Polyscias-Allophylus-Erythrina*
- *Shefleria-Hagenia-Erythrina-Galiniera*
- *Hagenia-Hypericum-Schefflera-Myrsine*
- *Erica arborea trees*
- *Erica arborea- E.trimera*
- *Helichrysum citrispinum- H.splendidum*

Dry ever green forest

Dry ever green forest mainly occur on the tree line of harena forest escarpment which is about 3200m.a.s.l and north eastern part of the park or around the periphery of the park.

The types of dominant vegetation include *Hagenia abyssinica* and *Juniperous procera*.

Bare land

Bare land occurs around the central part of the park (for the 2000 and 2005 land use/land cover map) which is characterized by higher altitude.

Wood land

Wood land is dominantly occurring in the northern part of the park which is considered as the nyala species optimum habitat and the higher vegetation zone.

Alpine bush land

Alpine bush land is second to moist montane forest, the largest land cover type which can be found almost in all direction of the park.

Pasture and Farm plot

Pasture and Farm plot occur on the scattered pattern over the park.

Mixed Grass/ Cereals

Mixed Grass/ Cereals are mainly occur around the western part of the park beneath to pasture and scattered farm plot.

Water class

Water class refers to rivers and water bodies in the study area.

The out come of the three classified images are displayed in the following figures.

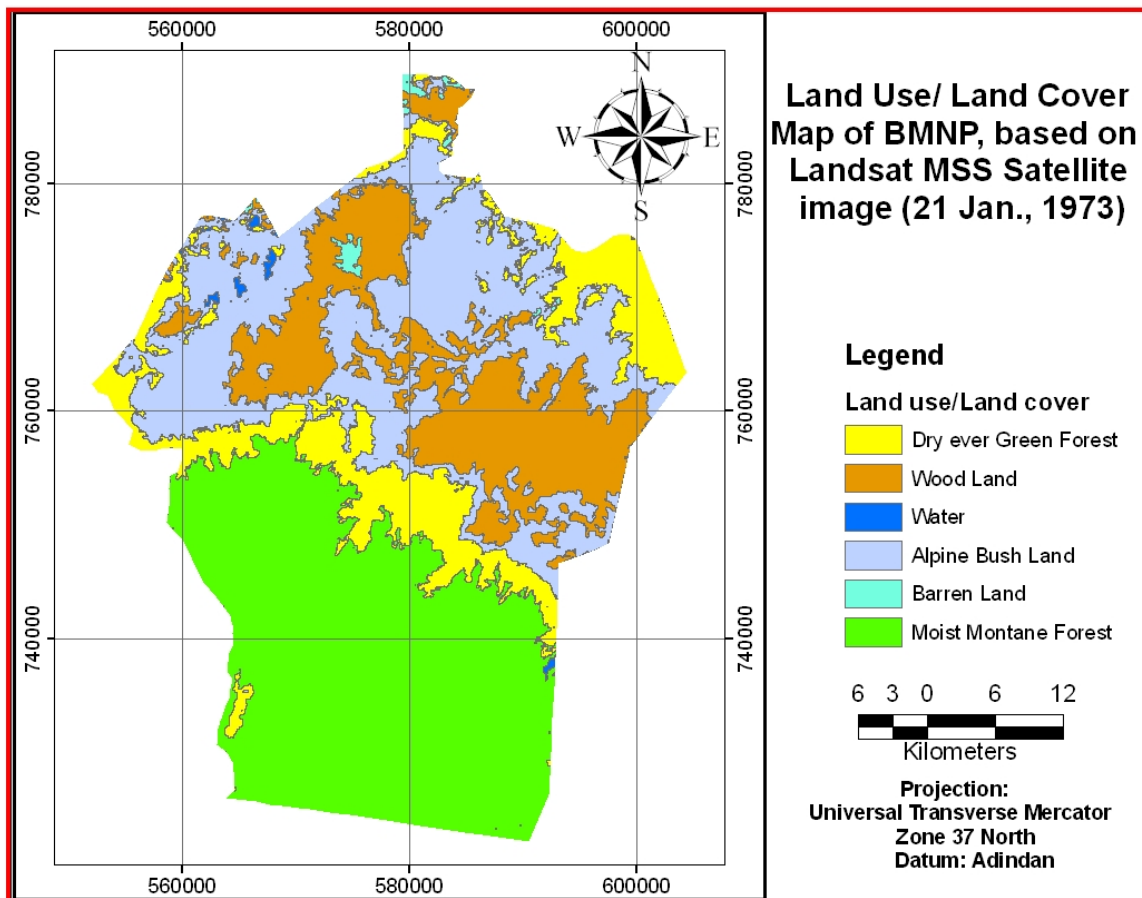


Fig 4.1: Land use Land cover map of 1973

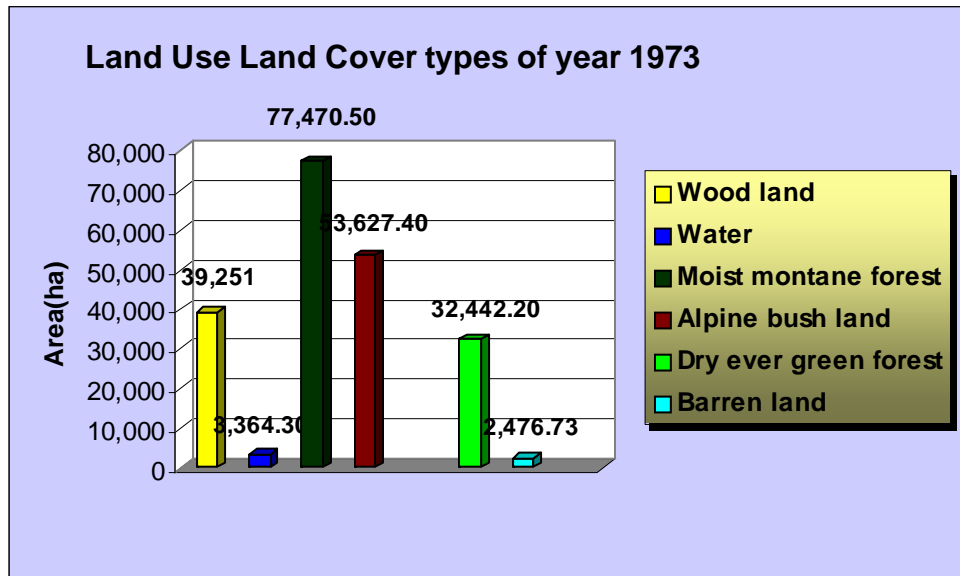


Fig 4.2: Graph depicting area coverage of each land use type of 1973

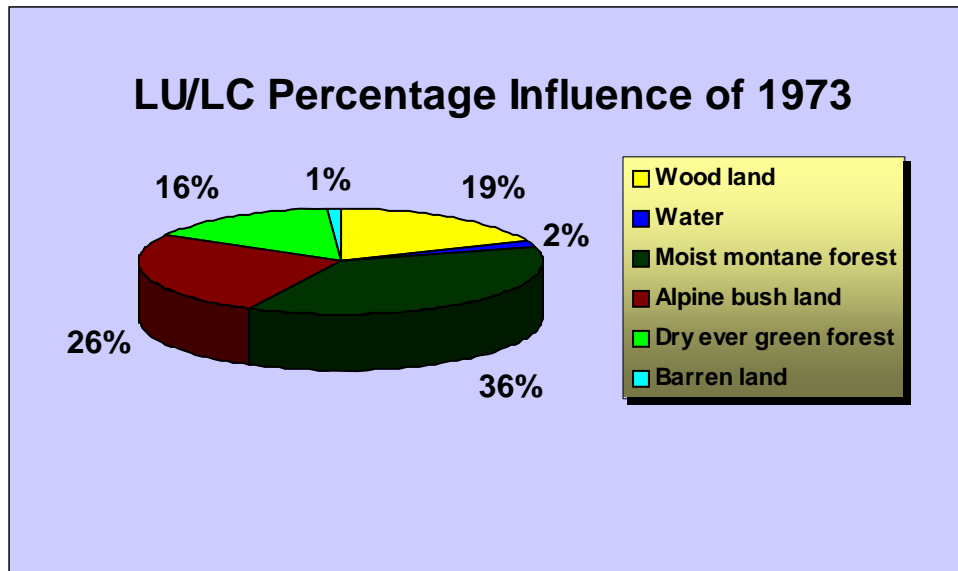


Fig 4.3: Chart showing the percentage of each class of 1973

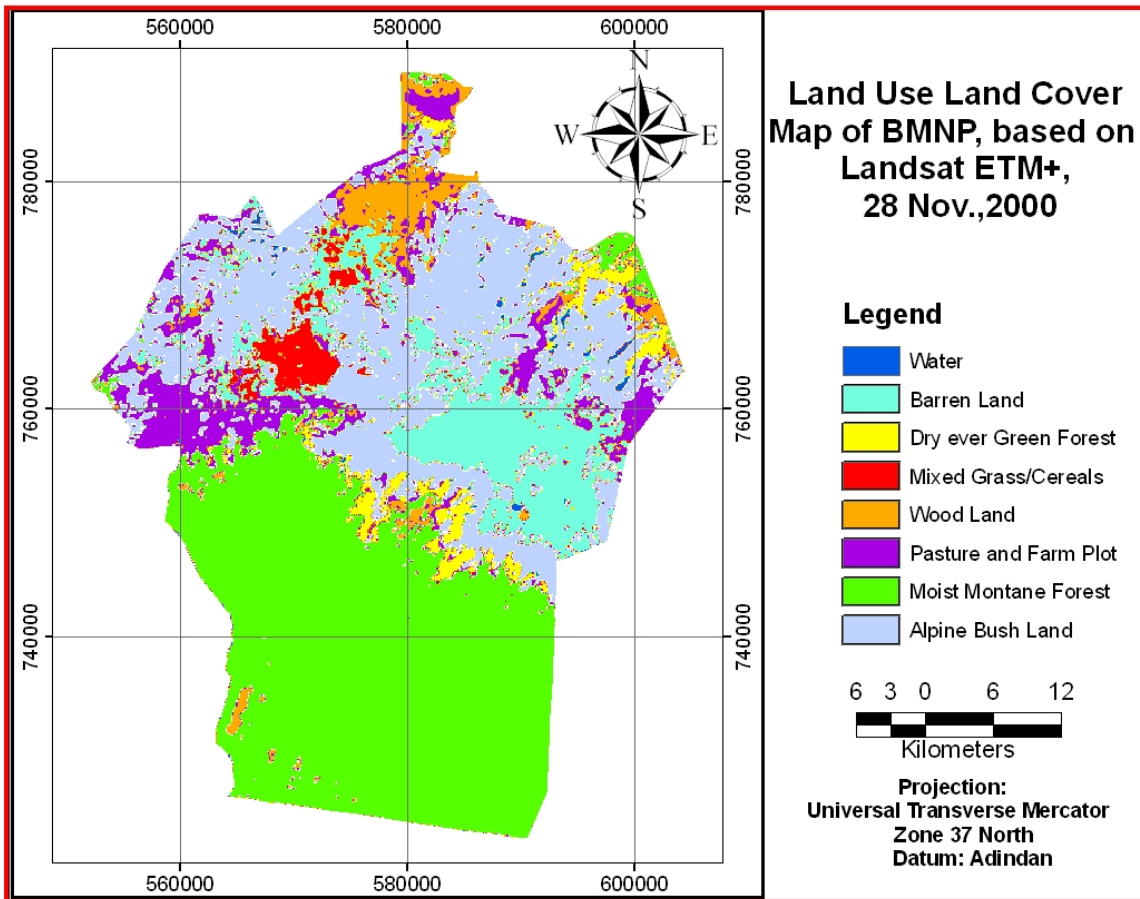


Fig 4.4: Land Use Land Cover Map of 2000

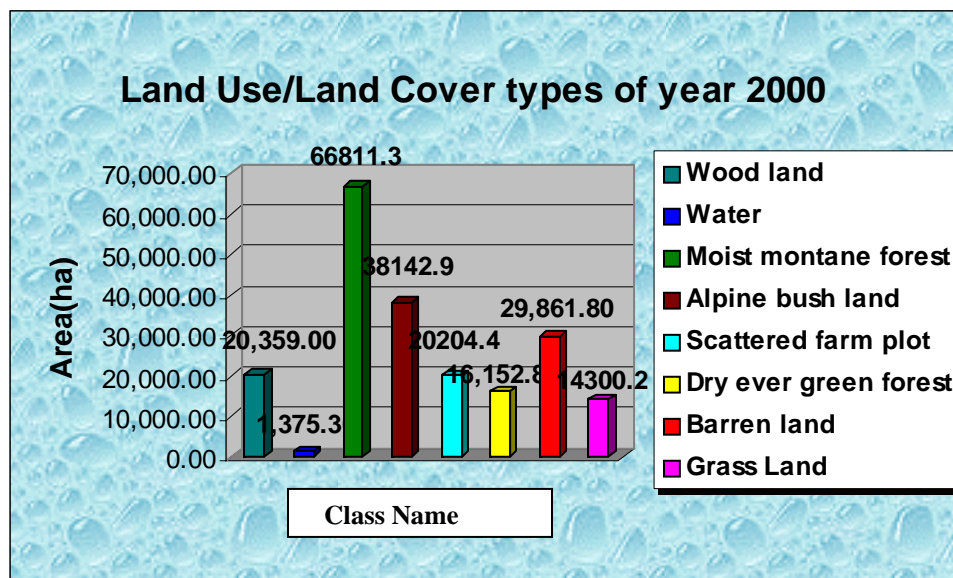


Fig 4.5: Graph depicting area coverage of each land use type of 2000

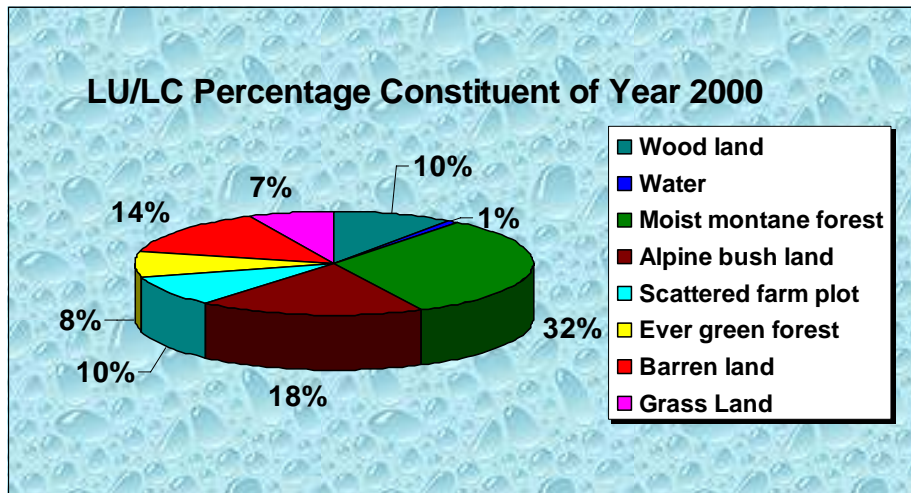


Fig 4.6: Chart showing the percentage of each class of 2000

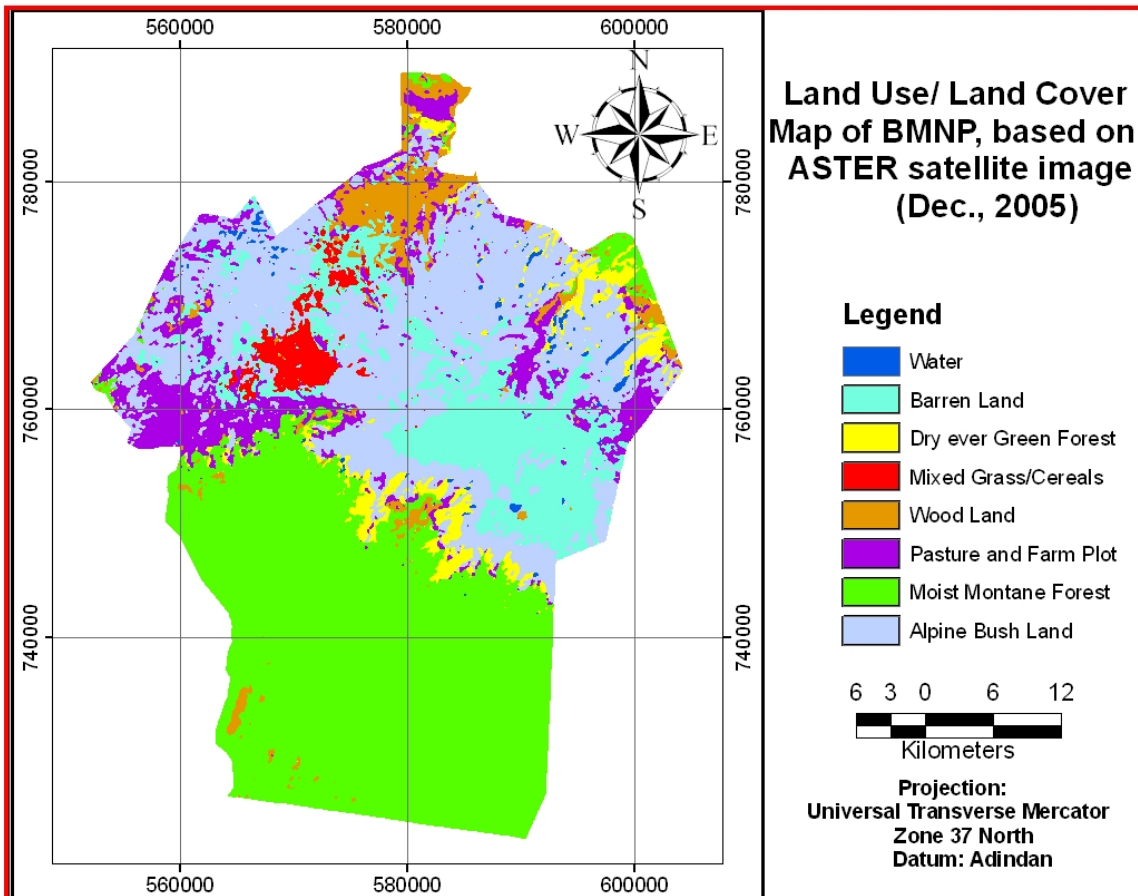


Fig 4.7: Land Use Land Cover Map of 2005

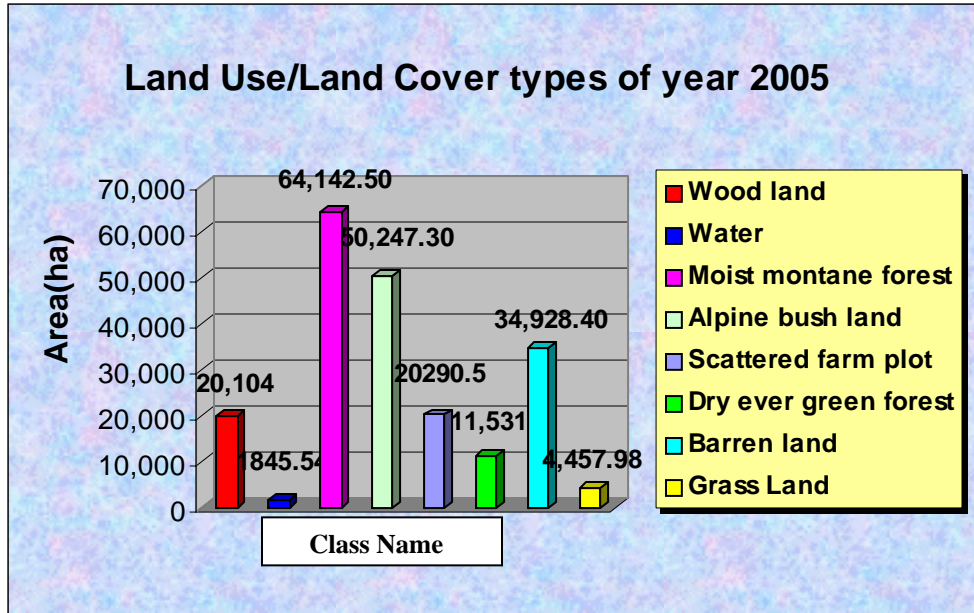


Fig 4.8: Graph depicting area coverage of each land use type of 2005

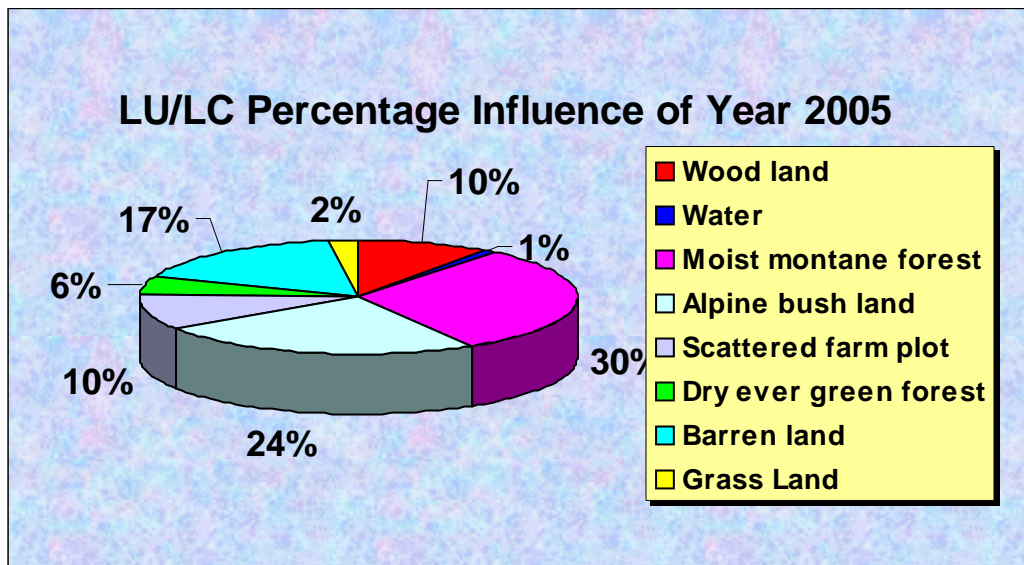


Fig 4.9: Chart showing the percentage of each class of 2005

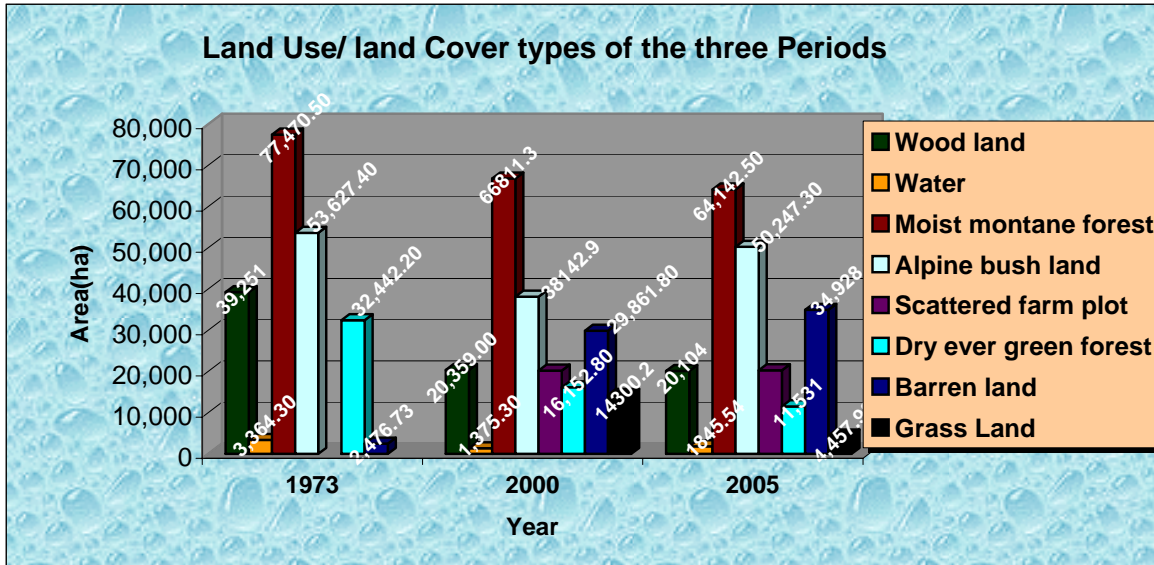


Fig 4.10: Land use land cover classes of the three periods

4.2.2 Spectral Change Detection

4.2.2.1 NDVI Image Comparisons

One of the most common vegetation indices is the normalized differencing vegetation index (NDVI). This technique was developed for identifying the health and vigor of vegetation and for estimating green biomass (Hayes and Sader 2001). The absolute value of the result will be between zero and one. The greater the amount of photosynthesizing vegetation present, the brighter the pixel will be (Jenson 1996). NDVI is calculated using the following equation:

$$NDVI = (NIR - RED) / (NIR + RED),$$

Where NIR = the near infrared band response for a given pixel,

RED = the red response

In this research the NDVI was used to get an over view of the vegetation biomass change over these periods for it indicates the amount of green vegetation, which is important for land cover identification. The NDVI is calculated by using the model maker in ERDAS IMAGINE software. The result obtained ranges between 1 and -1 as presented on (Fig: 4.11, 4.12 and 4.13) Then statistics of each of The NDVI images were calculated (in table 4.1)

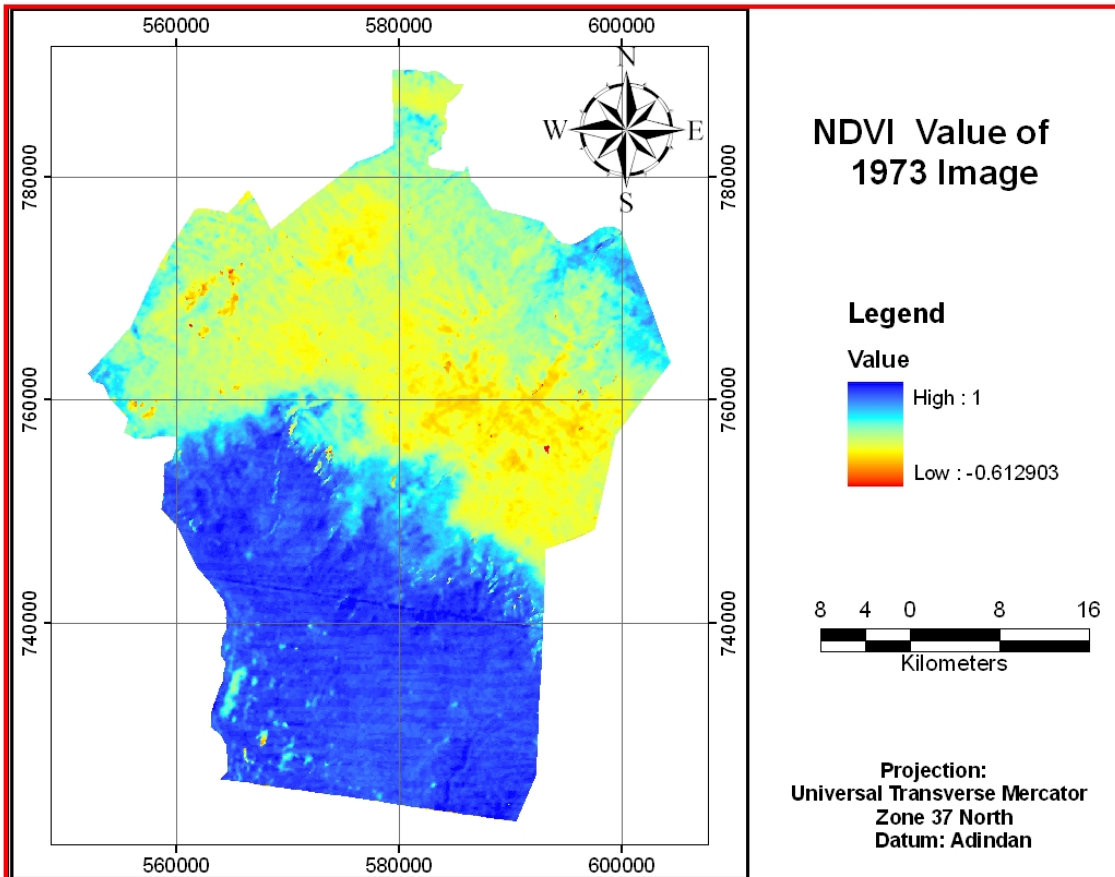


Fig 4.11: NDVI image of 1973

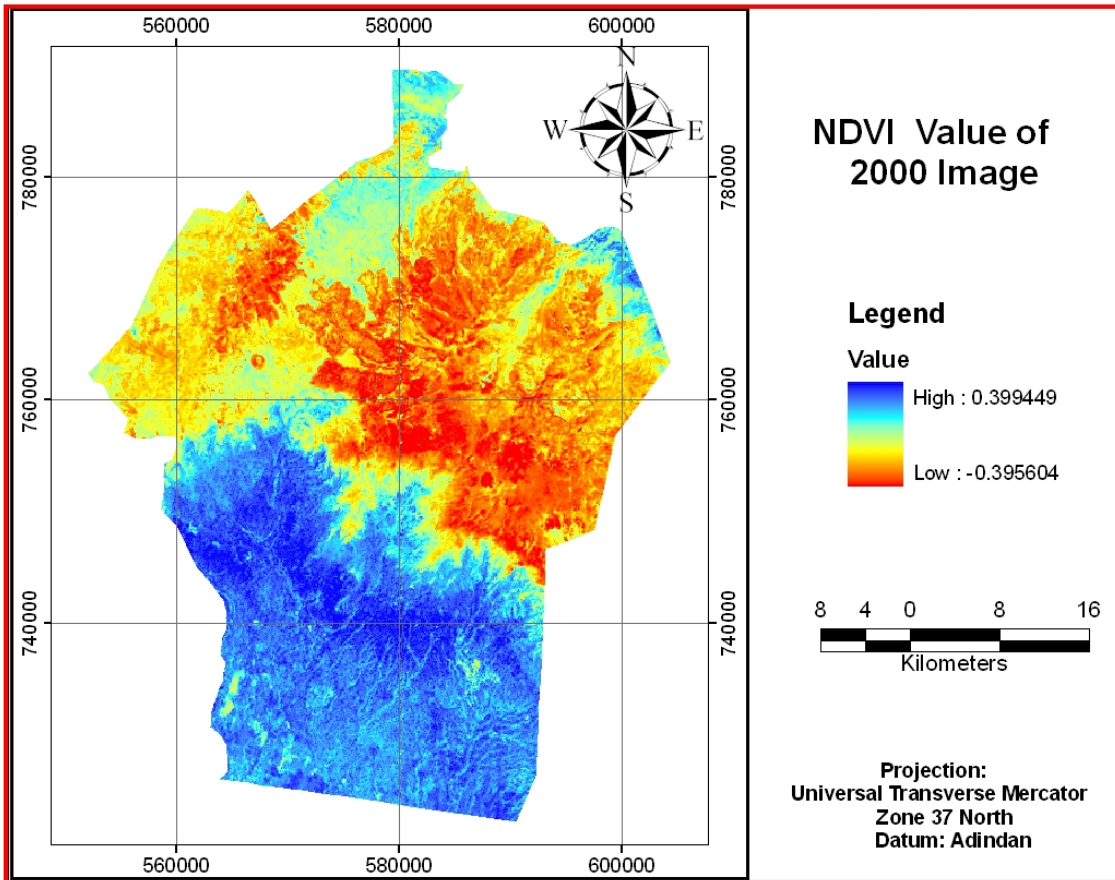


Fig 4.12: NDVI image of 2000

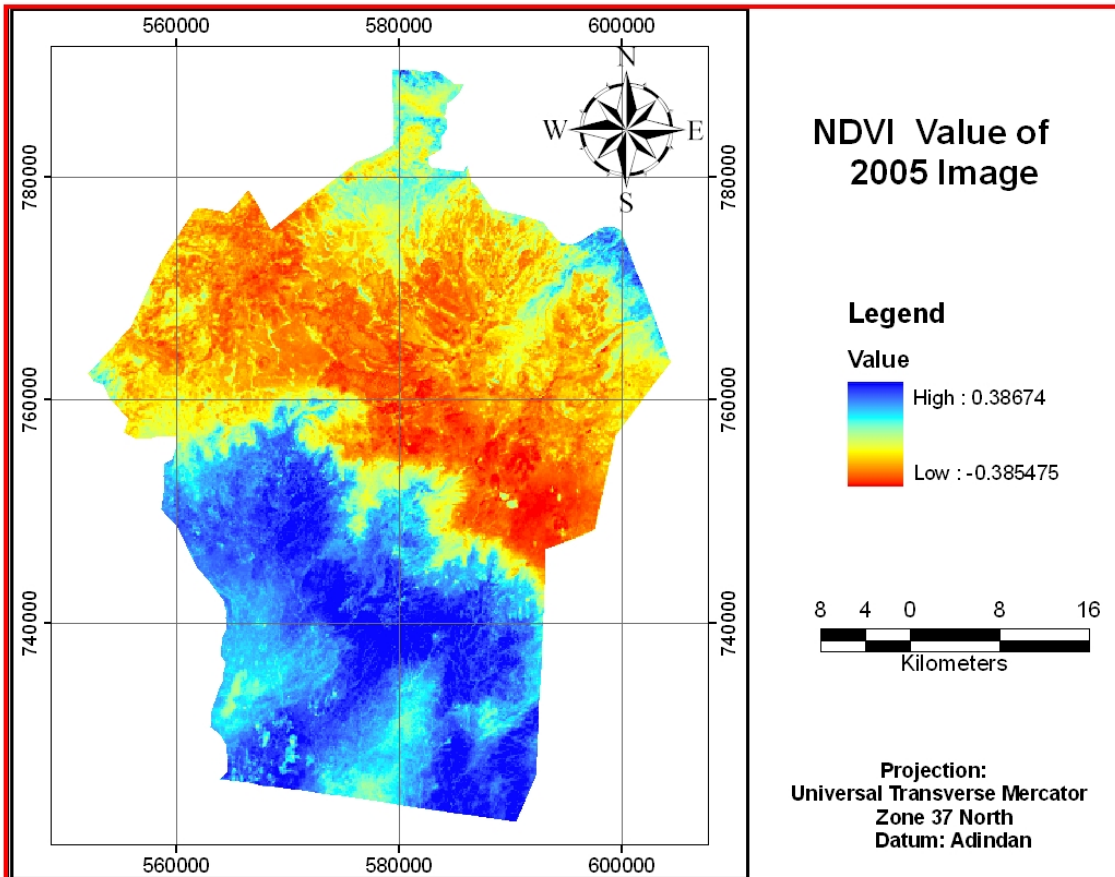


Fig 4.13: NDVI image of 2005

The NDVI was used for visual comparison and to aid classification.

The statistics and visual observation of the NDVI images over the subsequent periods show those decrements in vegetation biomass. As it can be visually compared the amount of green vegetation is falling. Taking the maximum value, it dramatically decreases from 0.99 in 1973 to 0.38 in 2005 this shows how vegetation biomass has degraded severely. The following table depicts NDVI statistics of the three periods (Table: 4.1)

Table 4.1: NDVI statistics of the three periods

NDVI statistics	Year		
	1973	2000	2005
Maximum	0.9937	0.396343	0.378649
Minimum	-0.612903	-0.395604	-0.377778
Mean	0.190398	0.000369481	0.000435722
Standard Dev.	0.466514	0.22996	0.219646

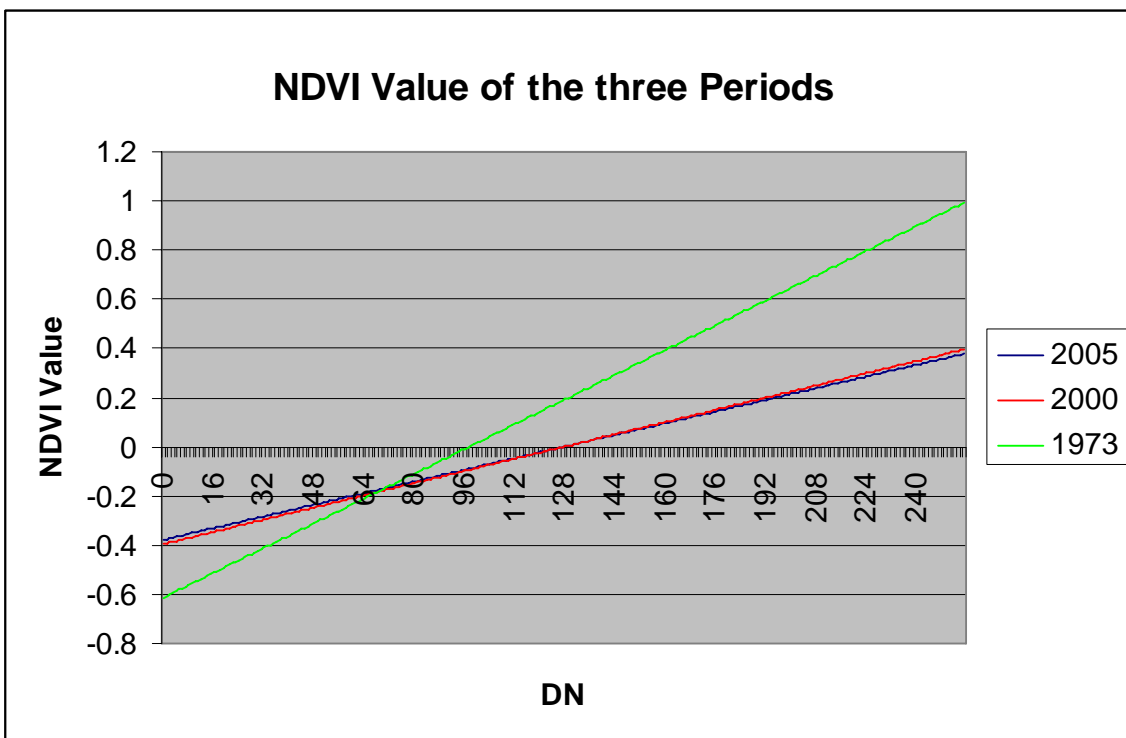


Fig 4.14: Comparison of NDVI values of the three years

4.3 Change detection method Comparisons

Post classification method avoids problems encountered, in image rationing and subtraction, and needs both images to be individually rectified and classified before they can be compared pixel by pixel (Jensen 1996). This method provides to and from

information and results in a base map that can be used for the subsequent year. It identifies where and how much change has occurred.

However, producing change map on the method under discussion requires more guarantees and the ultimate change classification is only as accurate as the product of multiplying the accuracies of each individual classification (Howarth and Wickware 1981). In this study, great attempts were done while performing classification of each images through incorporating better spatial resolution image (ASTER, 2005), ground truth data and other ancillary data such as pervious land use map.

The spectral change detection methods are useful for detailed quantitative results, however, one of the techniques of spectral change detection (image differencing) appear to be not reliable owing to the difficulty of atmospheric corrections. Yet atmospheric correction is necessary only to a lesser degree for post classification change detection where multiple images are classified independently and the maps are compared to identify changes (Foody et al., 1996). Thus, considering the above reasons, selection of post classification approach is found to be as suitable for the study area.

4.4 Land cover change detection qualification and quantification

4.4.1 Land cover change obtained from post classification change

detection

Land cover post classification change analysis for the sub periods (1973-2000, 1973-2005 and 2000-2005) revealed that some important land cover changes were consistent in all sub periods. Taking the 1973-2000 and 1973-2005 sub periods the results revealed that the extent of farm plot, bare land and grass land has increased at the expense of vegetation. This phenomenon can be clearly seen in the following graphs.

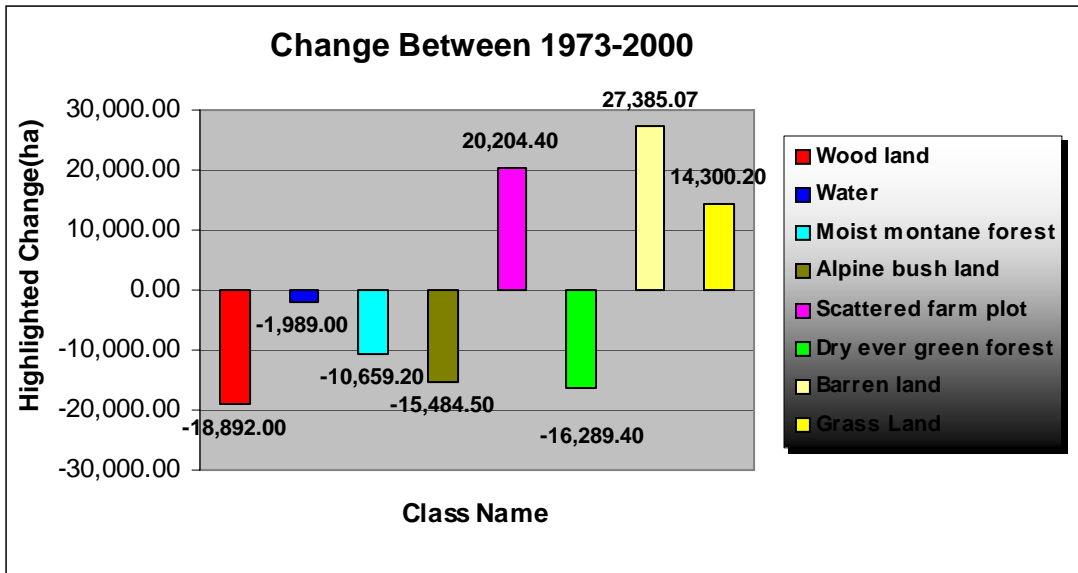


Fig 4.15: Change between 1973 and 2000

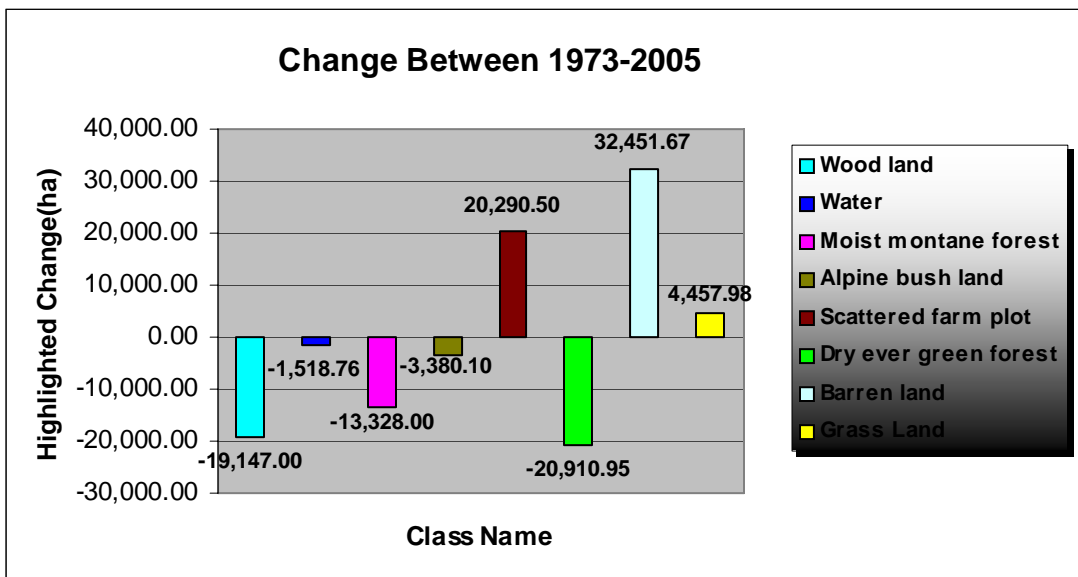


Fig 4.16: Change between 1973 and 2005

In the 2000-2005-sub period, it is apparent that the extent of alpine bush land has shown increment. This is due to the conversion of closed and dense forest to sparsely distributed and stunted vegetation. The graph shows the highlighted change in 6 years interval.

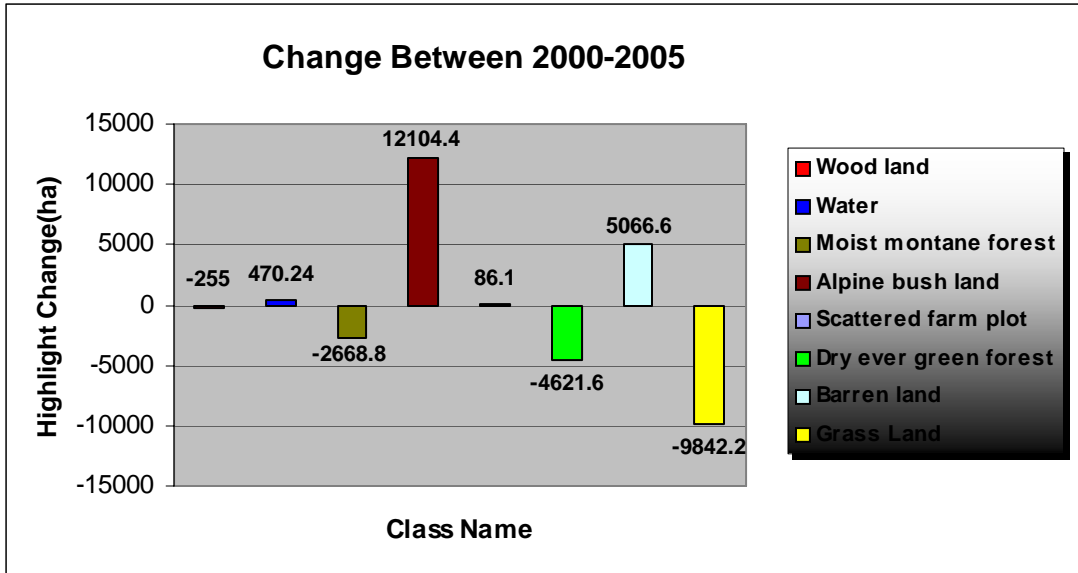


Fig 4.17: Change between 2000 and 2005

4.4.2 Land cover change map obtained from spectral change detection

4.4.2.1 NDVI differencing change Map

The following map reveals the difference in NDVI value between 1973 and 2005 images, however, NDVI image differencing can not provide detailed change information. It can only show the information of increase or decrease in NDVI value. The negative threshold indicates loss in NDVI and positive threshold indicates area of increase in NDVI.

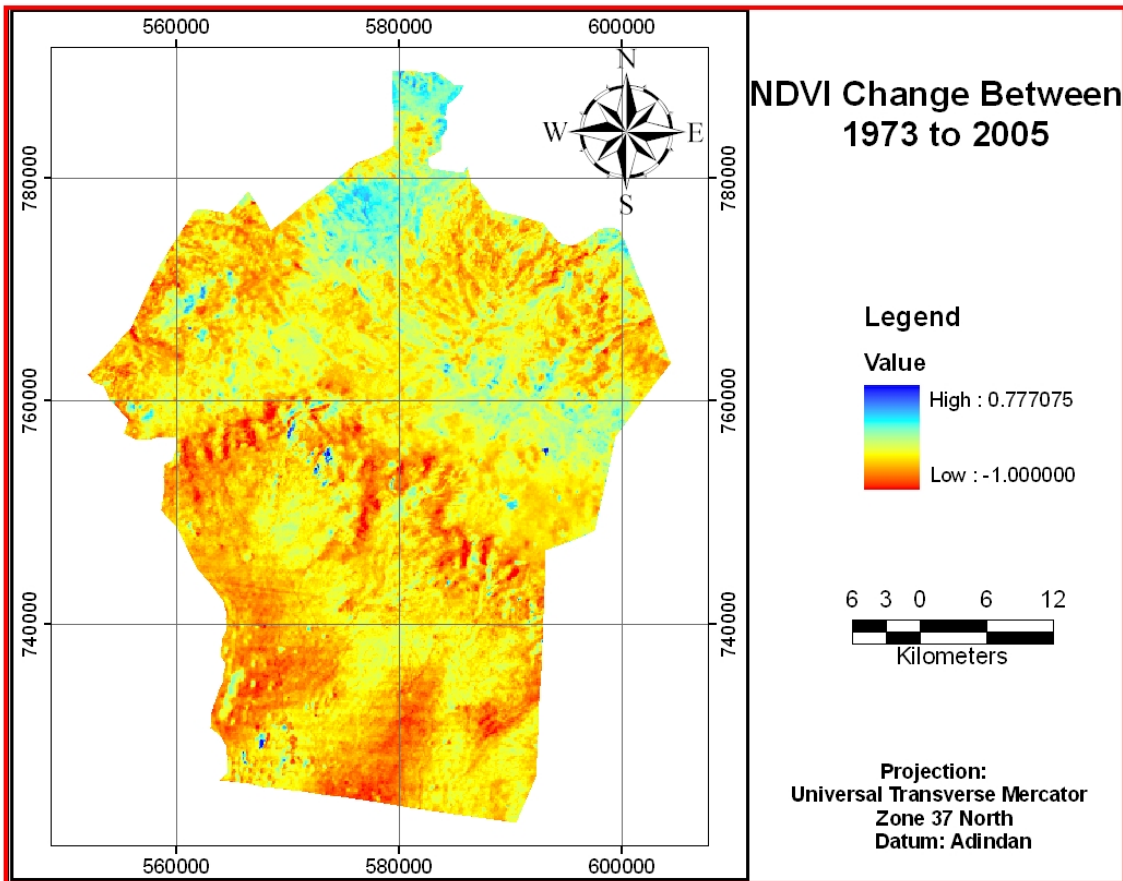


Fig 4.18: NDVI Change area between 1973 and 2005

4.4.2.2 Image differencing change Map

The following consecutive maps obtained through direct image differencing of the three periods.

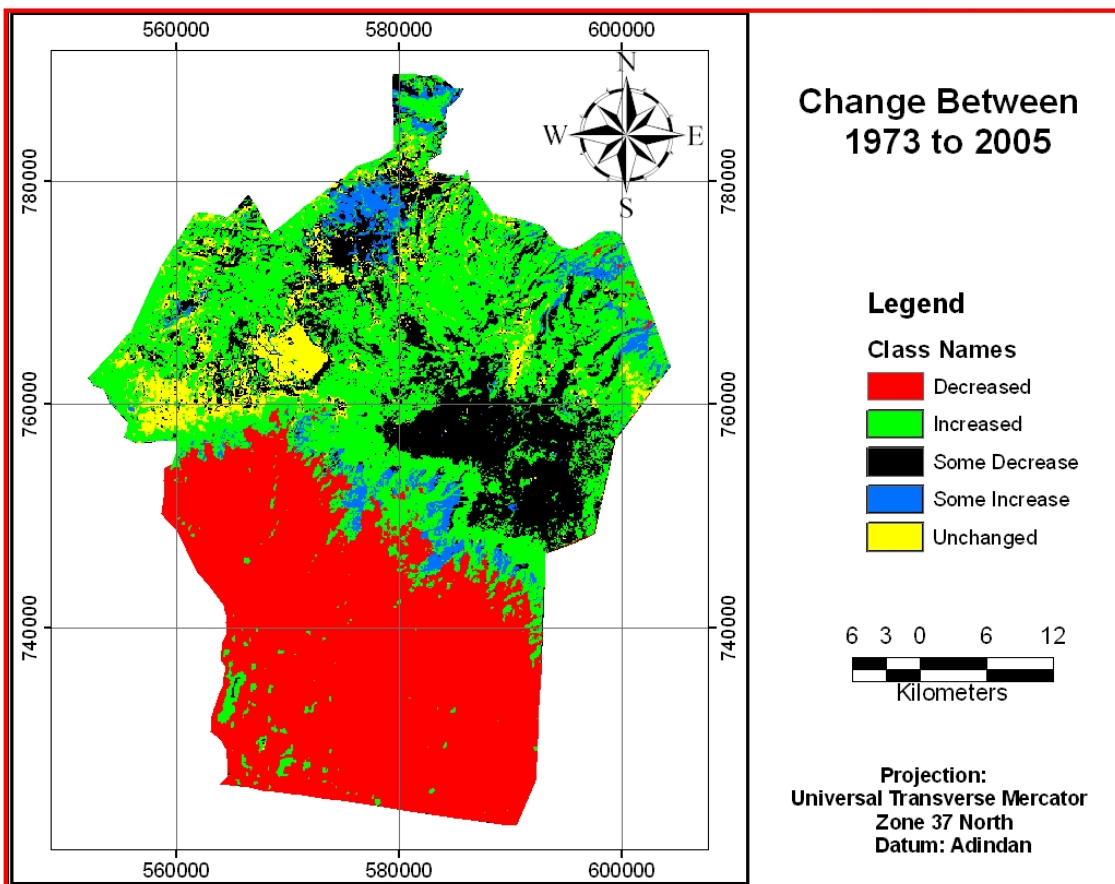


Fig 4.19: The highlighted change in the sub period 1973-2000

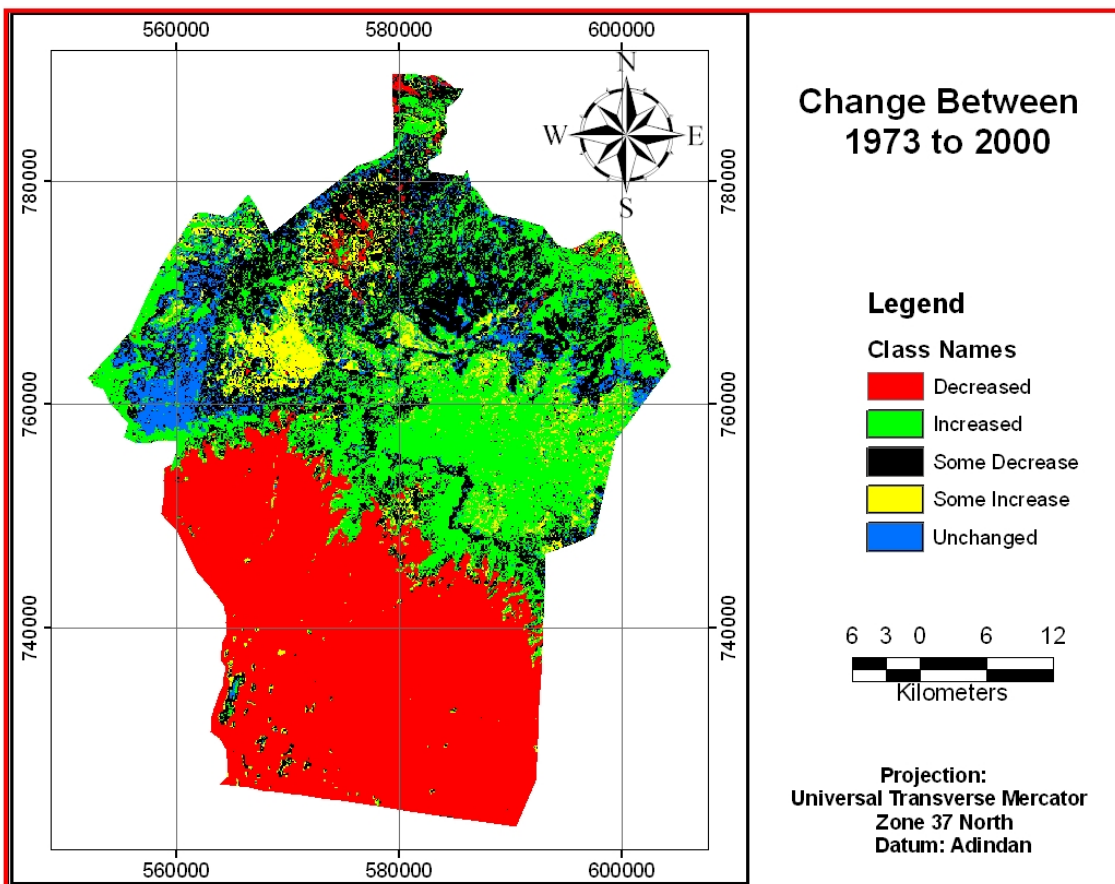


Fig 4.20: The highlighted change in the sub period 1973-2000

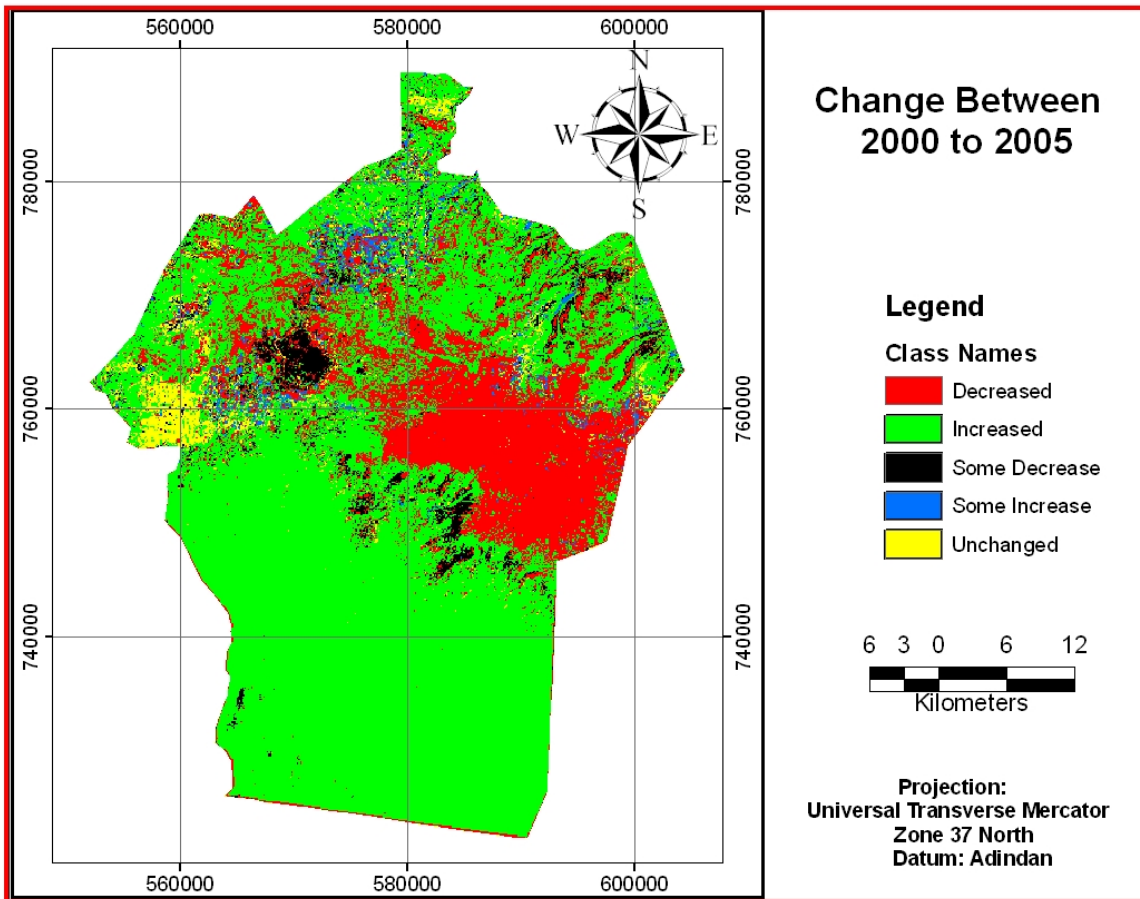


Fig 4.22: The highlighted change in the sub period 2000-2005

Highlighted Change	1973-2005 (ha)	1973-2000 (ha)	2000-2005 (ha)
Decreased	77879.6	78889.6	46772.7
Some decrease	37068.7	46167.6	9603.84
unchanged	15794.9	16158.1	15482.9
Some increase	9301.22	13321.5	5110.97
increased	71462.5	57128.5	13734.5

Table 4.2: The highlighted change in the three sub periods

4.5 Accuracy Assessment

To assess the classification accuracy, confusion matrix was used. Confusion matrix is strong in that it indicates the nature of the classification error ITC (2001) and used in many other research works Sluiter (2005); Nangendo (2005). Confusion matrix (table 4.3) was generated by crossing the two maps generated using the training sets and the independent data .

Table 4.3: Confusion matrix of 2005 land use classification of BMNP

Confusion/Error Matrix

Reference Data/Ground Truth Data

Classified Data	Unclassifi	Water	Bare Land	D.ever G	Mixed G	Wood L.	Pasture	Moist M.	Alpine B.	Row T.
Unclassified	0	0	0	0	0	0	0	0	0	0
Water B.	0	40	10	0	0	0	0	0	0	50
Bare Land	0	0	70	0	0	0	0	0	0	70
D.ever Green	0	5	0	32	0	0	0	0	0	37
Mixed Grass/Cer	0	0	0	0	0	0	0	0	0	0
Wood Land	0	0	0	0	0	48	0	22	4	74
Pasture and Farm P.	0	0	0	0	0	0	0	0	0	0
Moist Montane F	0	3	0	7	0	11	0	88	0	109
Alpine Bush Land	0	4	0	0	0	0	0	0	42	46
Column Total	0	52	80	39	0	59	0	110	46	386
Overall Classification Accuracy = 85.49%										
Overall Kappa Statistics = 0.806										
Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy		Users Accuracy				
Unclassified	0	0	0	---	---					
Water	52	50	40	76.92%		97.56%				
Bare Land	80	70	70	87.50%		100.00%				
D.ever Green	39	37	32	82.05%		86.49%				
Mixed Grass/cer	0	0	0	---	---					
Wood Land	59	74	48	81.36%		68.57%				
Pasture and Sca	0	0	0	---	---					
Moist Montane F	110	109	88	80.00%		80.73%				
Alpine Bush Land	46	46	42	91.30%		91.30%				
Totals	386	386	330							

4.6 Rate of land use land cover changes

The rate of change was calculated for each land use land cover using the following formula:

$$\text{Rate of change (ha/year)} = (A-B)/C$$

Where A = Recent area of land use/ cover in ha.

B = Previous area of land use/ cover in ha.

C = interval between A and B in years

The result is presented in table 4.4 and fig 4.23

Table 4.4: Land use/land cover class and change rate (1973-2005)

Class	Years			Rate Of Change (ha/year)		
	1973	2000	2005	1973-2000	1973-2005	2000-2005
Moist montane forest	77,470.50	66811.3	64,142.50	-394.785	-416.5	-533.76
Alpine bush land	53,627.40	38142.9	50,247.30	-573.5	-105.628	2420.88
Dry ever green forest	32,442.20	16,152.80	11,531	-603.311	-653.467	-924.32
Wood land	39,251	20,359.00	20,104	-699.704	-598.344	-51
Pasture and farm plot		20204.4	20290.5	748.3111	634.0781	17.22
Mixed grass/ cereals		14300.2	4,457.98	529.637	139.3119	1968.44
Barren land	2,476.73	29,861.80	34,928.40	1014.262	1014.115	1013.32
Water	3,364.30	1,375.30	1845.54	-73.6667	-47.4613	94.048

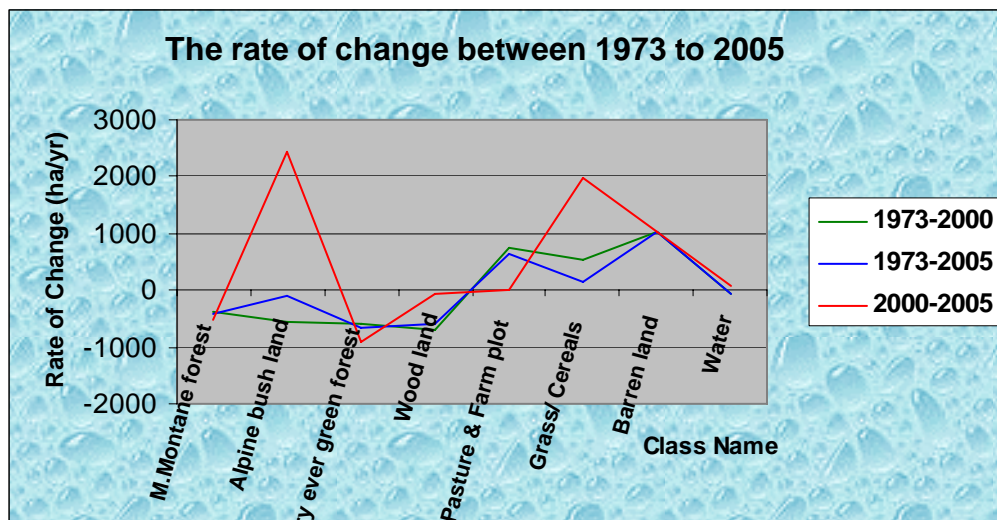


Fig 4.23: Rate of change between 1973-2005

4.7 Nyala habitat suitability analysis

4.7.1 Introduction

The mountain Nyala is the magnificent antelope restricted a small part of the southeast Ethiopia. The species has only been recorded in a series of volcanic mountain range that lie parallel to the southeast wall of the Great Rift Valley.

The species is known to occur in six locations. These sites are the Bale Mountains, the Arssi mountains, Munnessa, Arba Gugu, Din din and Kunni Muktar. The largest area of habitat lies in bale mountain national park, about 75% of the nyala habitat.

Their habitat extends from 2000_3400m. Variation in slope, aspect and rainfall produce considerable variability across the range of nyala. However in most places the forest are ever green with a canopy from 20-40m, Podocarpus gracilor, Croton macrostachyus and Warburgia ugandensis are common. Above 2700 Hagenia abyssinica is often dominant in drier area and Hypericum revolutum may extend above the Hagenia to 3200m.

The limit of the giant heath zone (Erica and Philippia) is variable with some heather occurring as low as 2400m on dry slope, however it is the dominant vegetation from 2800-3400m. The plants can vary from small trees up to 10m in lower protected sites to 2-3 thickets above the tree line. Much of the remaining habitat is in the heath zone. This ecosystem is susceptible to both human and natural fire.

Between 3600-3800m, the heath zone gives away to alpine moorland. These are dominated by annual grass with small ever green shrubs in the genus Helichrysum common in the drier area.

A small area of montane grassland at 3000m by Dinsho in the bale mountain has provided an important habitat. Grasses in the genera Bromus, Festuca and Poa cover a small opening in the surrounding montane forests

The mountains which the Nyala inhabit intercept rain both from the Atlantic (March_June) and from the Indian Ocean (June_ October). Rainfall above 2500m usually exceeds 1000mm annually. There are numerous perennial streams through the mountain. There is a steep rainfall gradient with elevation.

Mountain nyala requires two kind of habitat, cover in which to conceal theme selves and foraging grounds. in the bale mountains the species uses almost any tall vegetation for covering including Juniperous , Hagenia and Hypericum forest, and specially tall stand of gaint heath. The have also been recorded feeding in most of the habitat available in the bale mountain including, grass land, heath lands, moorlands and wood lands. The also make incursion in to farm land. They have not seen in two to areas. One is the short grassland at 3600m of the Web valley. This area is very exposed and heavily grazed. The other area is the forest that covers the southern ranges of the slope called Hareenna forest. This is the largest track of high altitude forest left in Ethiopia and includes large clearings as well as closed canopy forest. Apart from the first record of Nyala in bale by Hodson (1927) who may have seen them at the top of the hareenna forest, there is no evidence that they exploited this area. Most of the tragelaphine antelope to which the Nyala belongs are forest dwellers and there is no large browthing species in the hareenna. The reason for their absence is not clear but it is possible that the forest has always been setteled at a density to exclude Nyala.

Leslie Brown (and many of the hunters report s) considered the sronghod of the mountain Nyala to be in the heathlands, and the great majority of his sighting were in the heather . once the bale mountain national park was established and some protection was provided the nyala congregated on the grassland and woodlands around gaysay at about 3000m. dta from other part of the species range , show that the species can flourish in forest and wood areas. Hillman (1986) considered the grassland and woodlands as the species optimum habitat and the higher vegetation zone, the heath and moorlands, were refugees from human disturbance. However, the population of Mountain Nyala decline from time to time, owing to habitat degradation. The following graph shows their population trends over four periods.

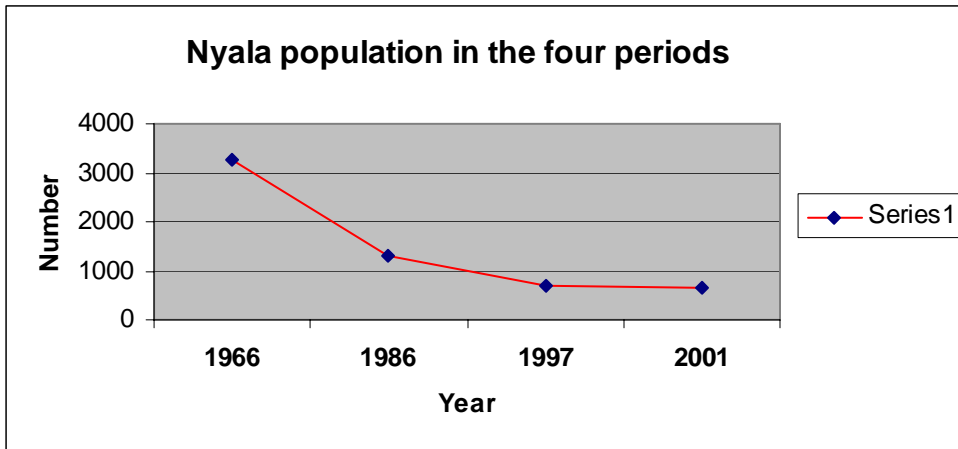


Fig 4.24: Population survey of Mountain Nyala in Bale Mountains
 Note: The census taken at Gaysay and Central Mountains areas.

(Source: James Malcolm & Paul H. Evangelista, 2005)

Year	1966	1986	1997	2001
Number	3250	1320	690	665

Photo:Female Mountain Nylals (Source: BMNP)



Photo: Male Mountain Nyala (Source: BMNP)

4.8 Factor development

The factors have been developed based on literature review. Accordingly five factors were considered for Nyala habitat suitability analysis. Those are, vegetation type, topographic factor (elevation), distance from settlement, proximity to road and proximity to river.

1) **Vegetation factor:** this is one life requirement of Mountain Nyala. Mountain nyala requires two kind of habitat, cover in which to conceal themselves and foraging grounds. In the bale mountains the species uses almost any tall vegetation for covering including Juniperous, Hagenia and Hypericum forest, and specially tall stand of gaint heath. They have also been recorded feeding in most of the habitat available in the bale mountain including, grass land, heath lands, moorlands and wood lands.

2) **Elevation:** it is one of important topographic factor which need to be considered. In general, suitable elevation extends from 2400 to 3500 m.a.s.l

3) **Distance from settlement:** many wild life species including Nyala need safe area with no human disturbance/interference. Thus, potential habitat for Nyala should preferably be some distance away from human settlement. Accordingly areas which are found away from the settlement have given relatively higher weight/value.

4) **Proximity to road:** accessibility is one of important infrastructure consideration with regard to tourism development. In order to have good access for the tourist to visit/admire this endemic creature, suitable habitat for Nyala preferably be situated near to all weather road or access road. However, 500m buffer distances was masked from the analysis for safety purpose.

5) **Proximity to river:** it is another important life requirement for the survival of the species including Nyala. Obviously, suitable habitat for the species should be located near to river.

4.9 Data Analysis

4.9.1 Reclassification

It is the process of replacing input cell values with new output cell values. The most common reasons are, to replace values based on new information, to group

certain values together and to classify values to a common scale.

The values of derived datasets representing vegetation type, elevation, distance to settlement, distance to road and river have all been

reclassified to a common measurement scale, giving each range a discrete,

integer value 1 to 10 . Higher values have been given to attributes with

in each dataset that are more suitable for locating the Nyala habitat.

Table 4.5: Weighted suitability analysis (Nyala habitat analysis)

Factors	Weight	Sub-factors	Ranking
Elevation (meter)	0.4233	2042-2376	6
		2376-2710	8
		2710-3044	9
		3044-3378	10
		3378-3712	7
Vegetation type	0.2934	Dry ever green forest	10
		Wood land	9
		Alpine bush land	8
		Grass land	7
		Water	6
Distance from Settlement	0.1574	0-1297	1
		1297-2594	2
		.	.
		.	.
		11676-12974	10
Proximity to River	0.0817	0-216	10
		216-433	9
		.	.
		.	.
		1950-2167	1
Proximity to Road	0.0442	0-2150	10
		2150-4300	9
		.	.
		.	.
		19353-21504	1

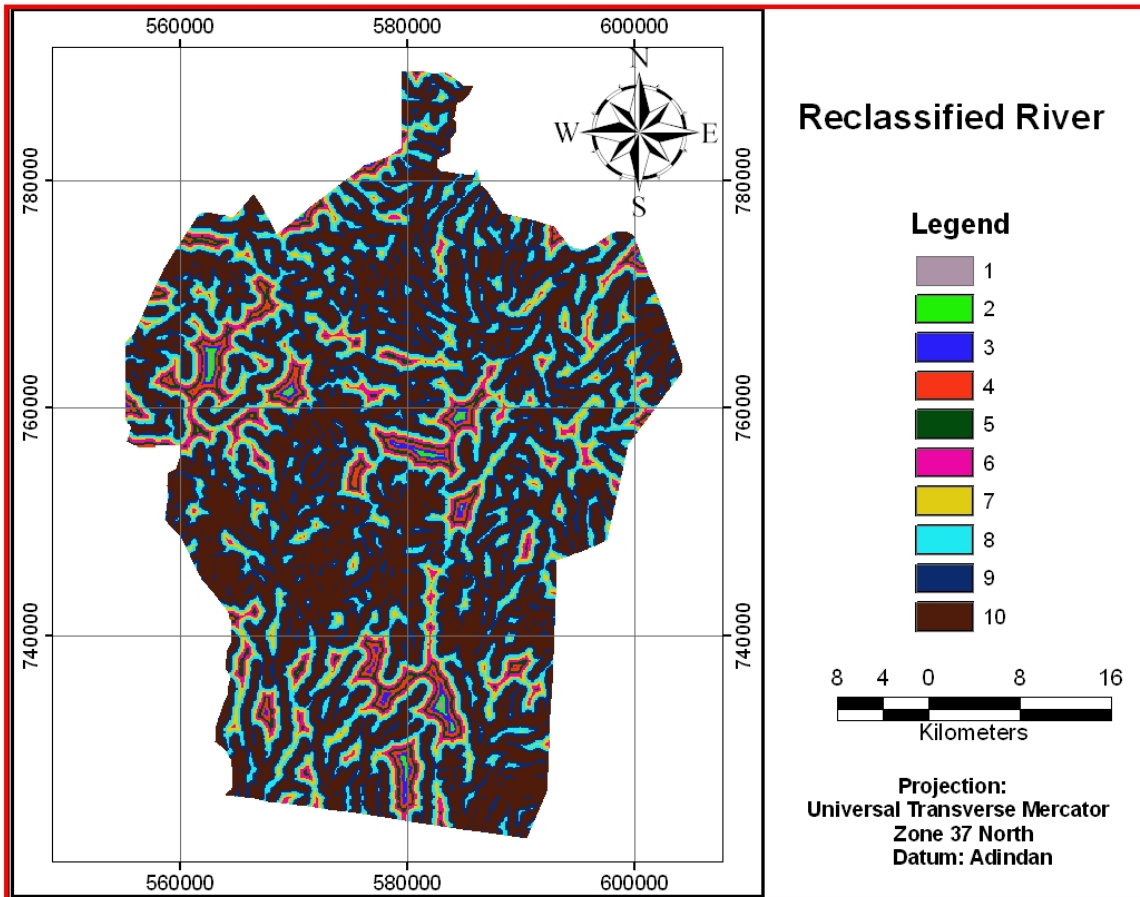


Fig 4.25: Reclassified River layer

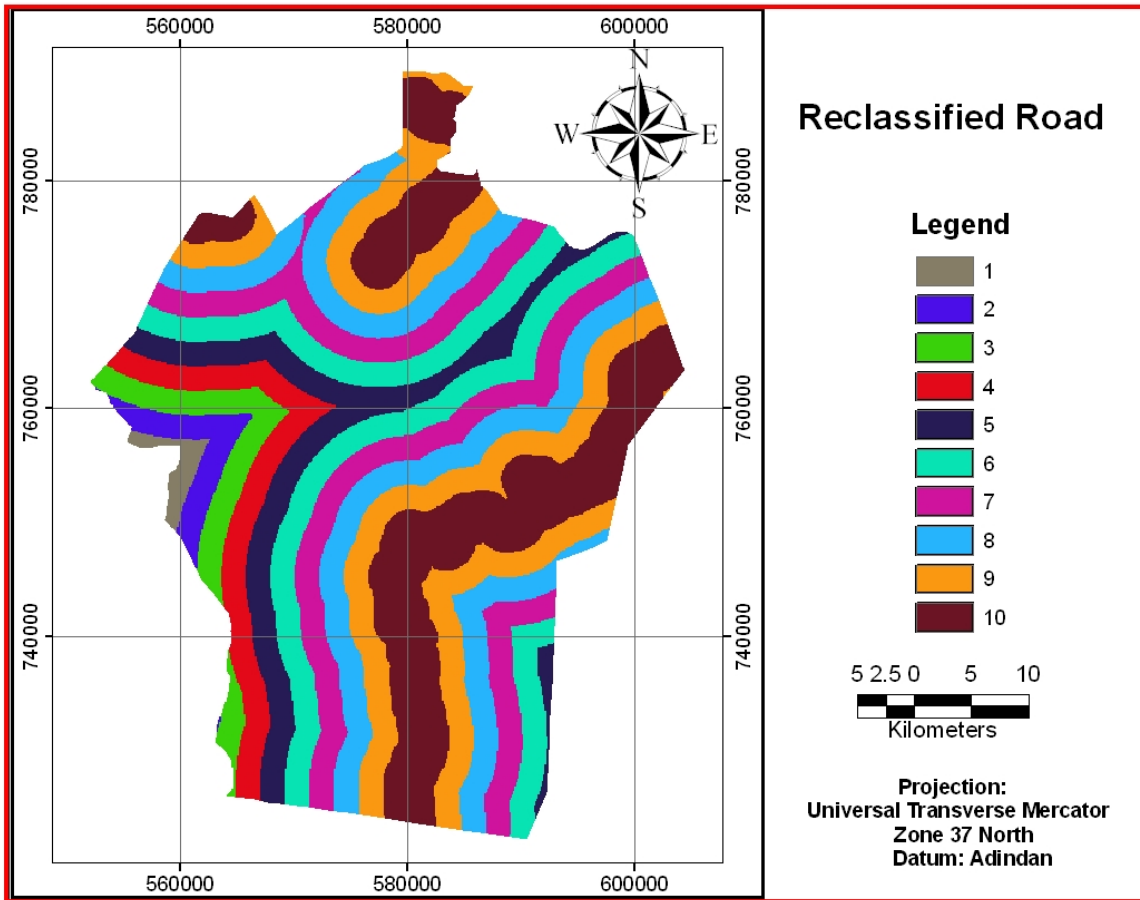


Fig 4.26: Reclassified Distance to Road layer

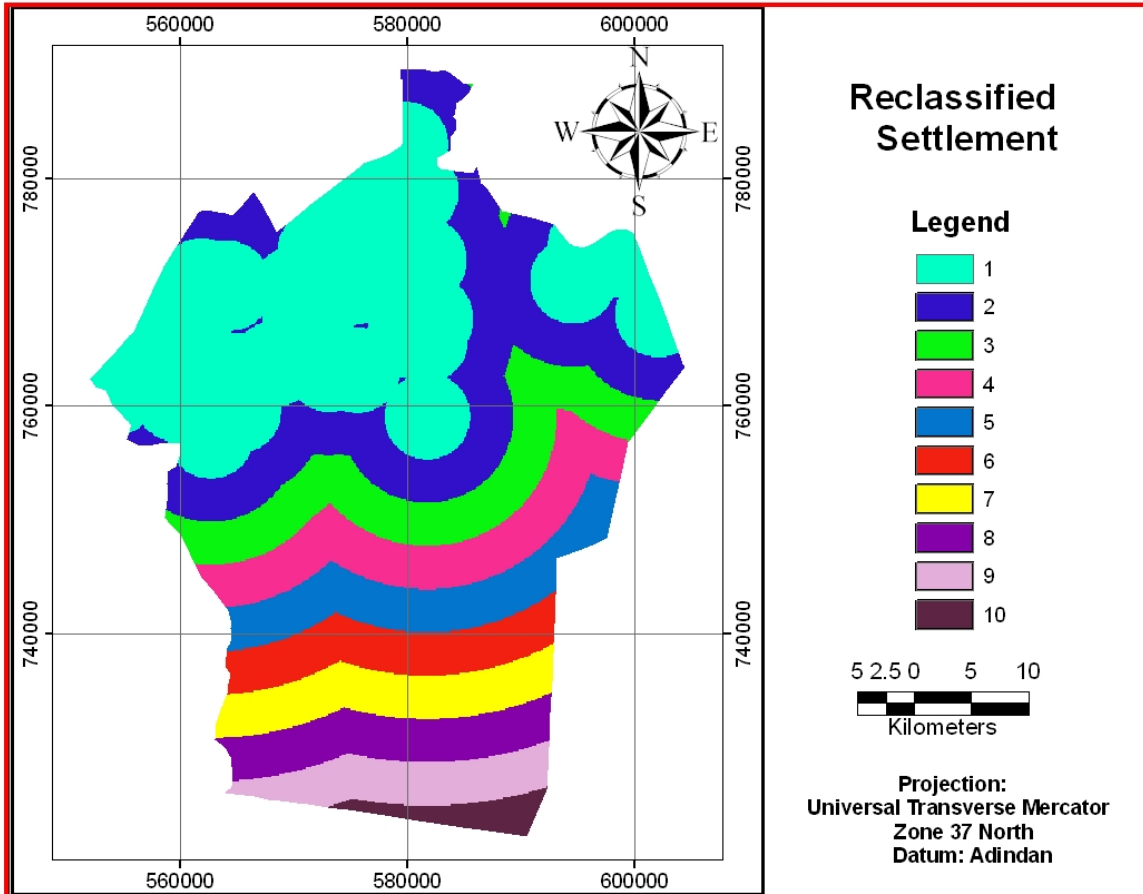


Fig 4.27: Reclassified distance to Settlement layer

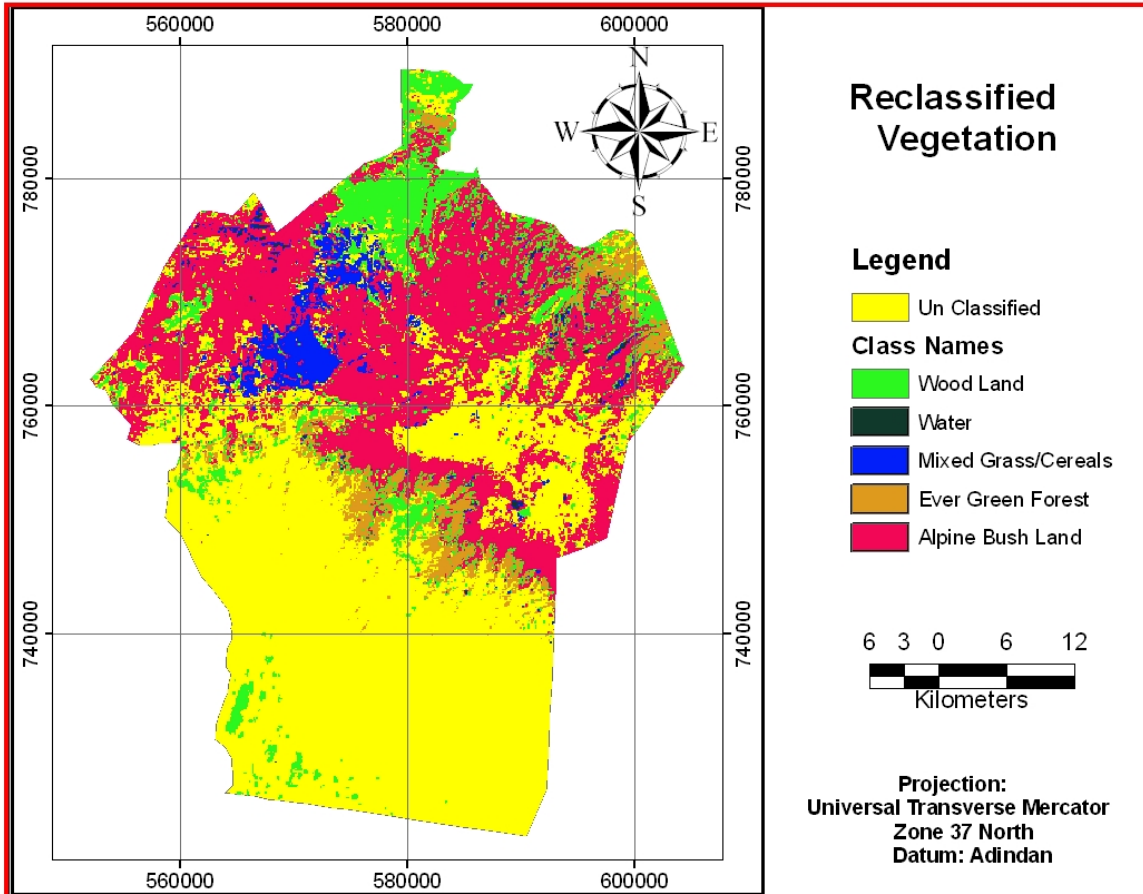


Fig 4.28: Reclassified Vegetation layer

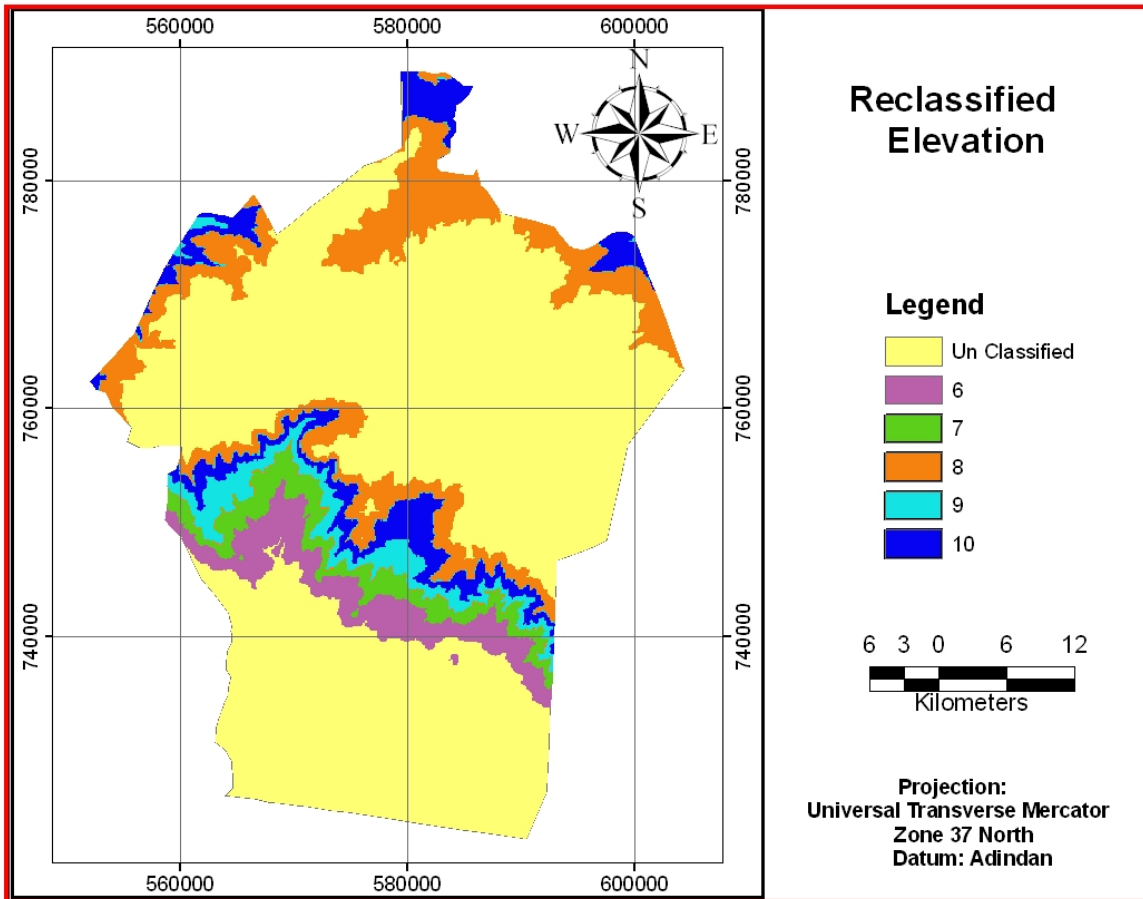
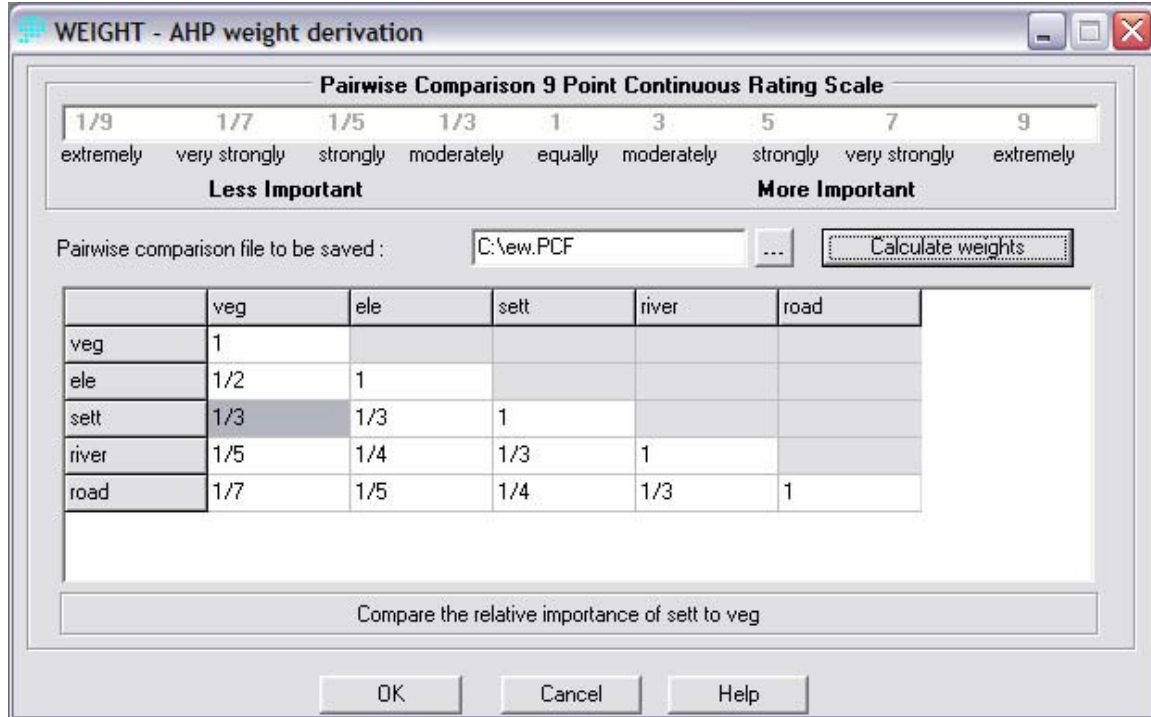


Fig 4.29: Reclassified Elevation layer

4.9.2 Weighing and combing the datasets

The reclassified raster layers were prioritized according to their importance. Pair wise Comparison of the six parameters carried out to develop the following pair wise comparison matrix.

Table 4.6: Pair wise comparison matrix and weights of importance for the evaluation criteria



To produce the best set of weights, the principal eigenvector of the above pair wise comparison matrix was computed in IDRSI 32 software by a special module named Weight.

Factor	Weight
Vegetation Type	0.4765
Elevation	0.2600
Distance from Settlement	0.1427
Proximity to River	0.0783
Proximity to Road	0.0425

Consistency Ratio (CR) is **0.04**, which is Acceptable

Table 4.7: Factors with their percentage influence

Using raster calculator in the special analyst extension and a model, the reclassified raster layers have been multiplied by their percentage influence. After summed and evaluated, the suitability map was generated.

$$\begin{aligned}
 & \text{Reclassified Vegetation type} * 0.4765 + [\text{Reclassified Elevation}] * 0.2600 \\
 & + [\text{Reclassified Settlement}] * 0.1427 + [\text{Reclassified River}] * 0.0783 \\
 & + [\text{Reclassified Road}] * 0.0425 = \text{Suitability Model (Suitable Area)}
 \end{aligned}$$

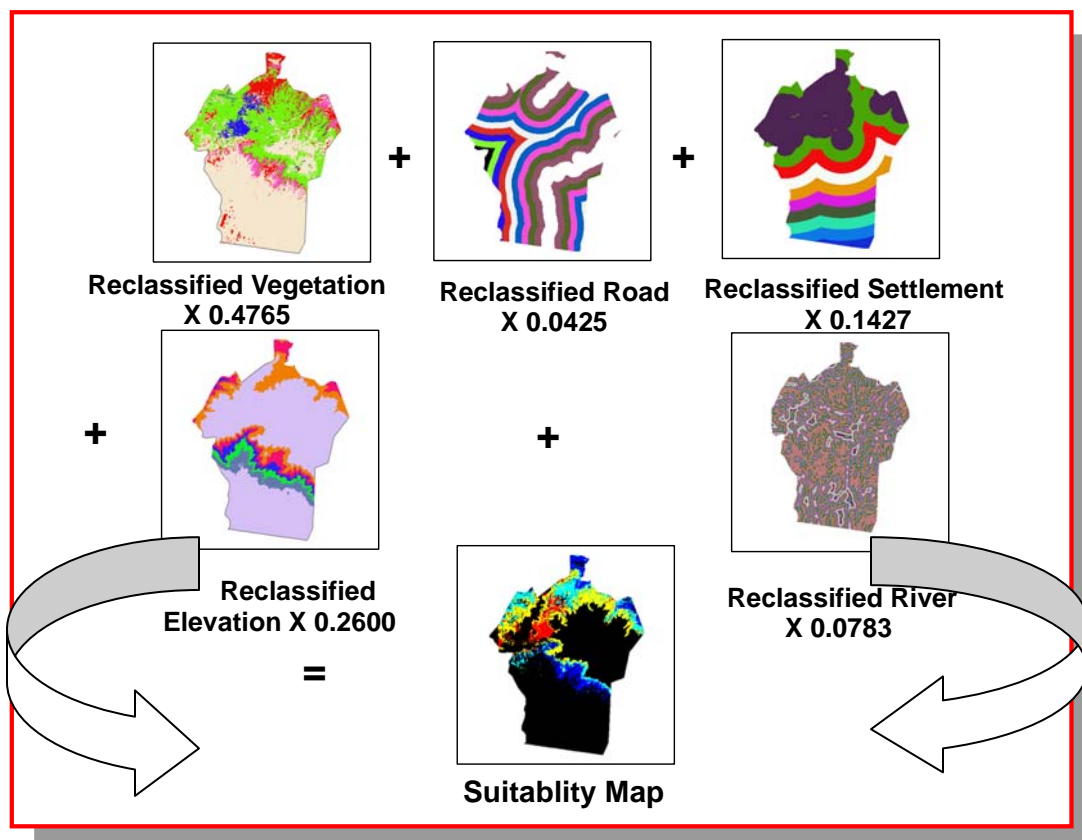


Fig 4.30: Combing different layers

Based on the GIS overlay analysis, four suitability classes has been identified. These classes are most suitable, suitable, moderately suitable and less suitable. The majority of suitable habitat lies around the northern part of the park and in the peak of the so-called harrena forest. Wood land vegetation type along with elevation range between 2800-3200 m.a.s.l found to be the most suitable habitat for Mountain Nyala.

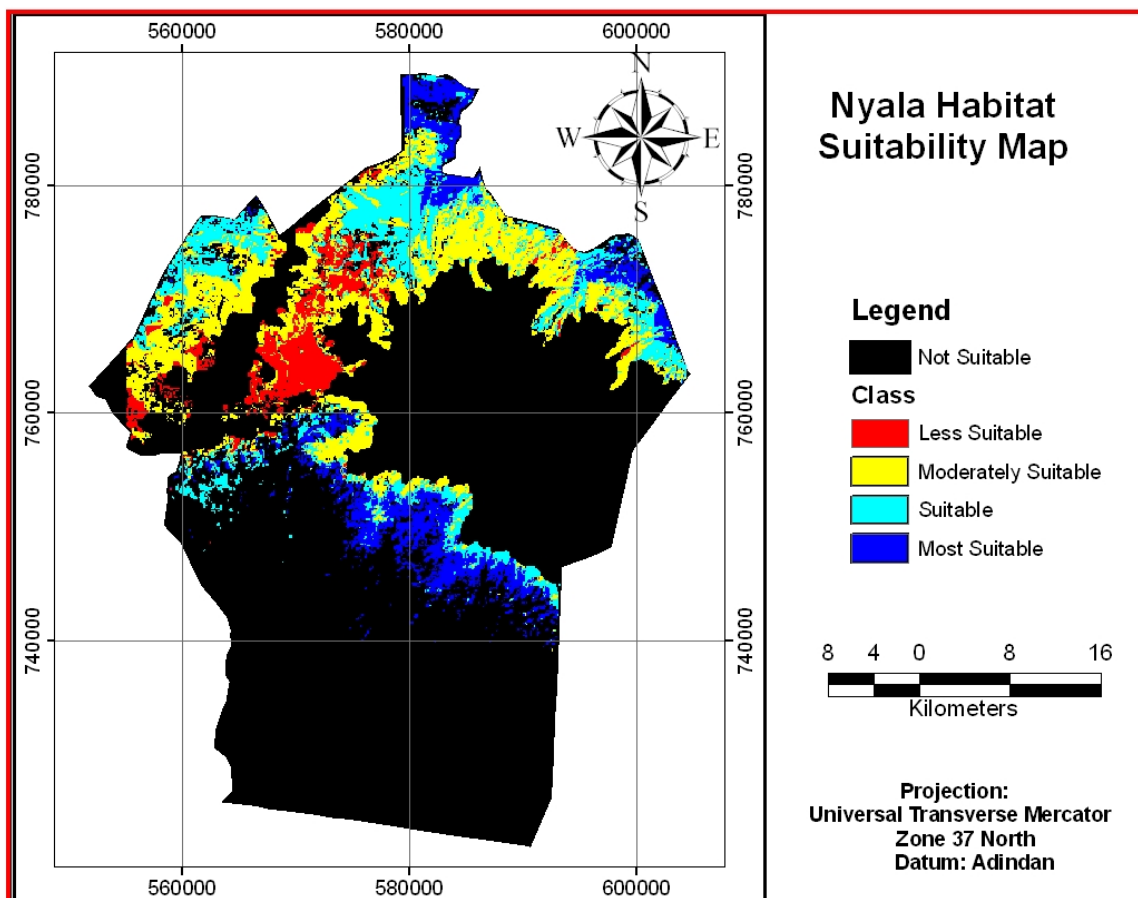


Fig 4.31: Map showing the Nyala Habitat Suitability

Table 4.8: Area of suitability classes

Class Name	Area (ha)
Most Suitable	7641.5
Suitable	14681.8
Moderately Suitable	18635.1
Less Suitable	6558.4

4.10 The major causes identified for the land use land cover change in the area.

Causes of change are identified using ancillary information and fieldwork

I. Haphazardly expanding of settlement

Settlement is increasing in the national park since its establishment. However the rate of expansion raised abruptly in the last ten to fifteen years time following the change over of the Government in 1991. There is a significant amount of settlement in the mountains and the forest today. According to Hillman (1986) permanent settlement was mainly concerns three main areas- the upper web valley, the western boundary and the Harena escarpment areas. At then, in around 1986, permanent settlements in the park were estimated to account for about 2500 people living in the park. To date there are about 71 permanent and temporary settlements within the park boundary. The largest villages within the park include Gojera, Rira, WegeHarena, Ayida, Gama-taja, and Meskel-Haricho. Currently the total number of people living in these settlements has raised fifteen fold and has reached 41530(park office settlement survey, 2004). Table-5 summarizes the administrative kebeles, number of villages, permanent and temporary houses, and human population in different part of the park.

Table 4.9: Administrative Kebeles, Villages, Number of houses and population size in different part of the park.

Description	Northern BMNP	Sanette Plateau	Web Valley	North eastern Part of the Park	West of the Web valley	Harena Forest			Total
						Rira	Western Edge	Hawo	
No of Administrative Kebeles	4	3	5	7	5	1	1	1	27
No of villages	5	8	21	12	19	1	2	3	71
No of permanent Houses	506	135	712	1432	170	295	495	1292	4531
No of temporary Houses	-	10	122	26	70	20	-	51	299
House hold size	405	66	402	984	182	230	600+	660	3529
Total Family size	2835	345	3151	7980	871	1694	7695+	13430	38001
Human Population	3240	411	3553	8964	1053	1924	8295	14090	41530

The impacts from these villages vary according to the fragility of the area they occupy, the size of the village and the land use activity involved to sustain the community livelihood. Settlements on the Sanette plateau and Web valley are mainly used for livestock husbandry. Grazing pattern and carrying capacity in these areas is not determined based on appropriate scientific study, although the former somehow is regulated by tradition. Villages in the forest and at the edge of park boundary utilize the area for both farming and livestock. However, the most prominent activity of these areas is farming. The ever-increasing settlement in the web valley and on Sanette plateau adversely affect the endemic and endangered Ethiopian Wolf (*Canis seimensis*) and its prey by reducing available habitat and disturbing their movement pattern. Similarly, settlements in the north, northwestern and northeastern part of the park significantly affect the survival of the endemic Mt.Nyala (*Traglaphus buxtoni*). Expansion of these settlements critically reduces the habitat available for this precious endemic mammal. Some villages impose more adverse impact by blocking corridors like Gojera village, which blocks the corridor

between the headquarters and the main part of the park at Gesse and Web valley. Blocking these corridors through time causes habitat fragmentation.

Settlement in the National Park exacerbated due to the fact that there is no regulation or control of the development of these settlements and associated human activity. The development of these villages do affect the environment through increasing and uncontrolled demands on the vegetation (Juniperus, Hypericum, Heather and Lobelia) for building material and fuel wood, and recurrent burning of the heather areas. Tracking and resultant erosion of the fragile soils is evident near settlement and water sources, and in Narrow Mountain passes. These ascertain the truth that settlement causes habitat degradation. On top of these settlement substantially alter and reduce the natural scenic beauty of an area, hence results in a negative trend of tourism development.

II. Uncontrolled Grazing and Increasing Farming On Higher Elevation.

The population and density of livestock in the park is extremely greater than the wild ungulates. Looking at the number of livestock one may think that the park is not for wild live conservation rather it is a ranch for domestic animals. The census made in 2004 by the park staff revealed that there are more than 168,327 livestock in the entire park boundary. Actually this figure increases following seasons. It increases from September to February, because during this period of time large area outside the park covered by crops and therefore shortage of grazing land occurs. The only common land used to overcome the shortage of grazing land is to use the highlands of the park. The distribution of these livestock varies with specific area in the park. The highest density is in the Western edge of the park in the Harena forest, Web valley and the Northeastern part of the park, where 95967, 20542 and 20704 livestock observed respectively during the survey carried out by the park staff. On the Sanette plateau and areas west of the Web valley, and Hawo 5622, 5434 and 15294 livestock were counted respectively during the survey time. Cattle are the most dominant livestock followed by Sheep and Goat. The distribution of livestock in the different part of the park is indicated in (table 4.10)

Table 4.10: Number and type of Livestock in the National Park

Type of livestock	Sanette Plateau	Web Valley	North eastern Part of the Park	West of the Web valley	Harena Forest			Total Population
					Rira	Western Edge	Hawo	
Cattle	2053	7750	10684	2514	2205	83340	10837	11,9383
Sheep and Goat	3393	11954	7100	2727	1577	9806	2847	39,404
Transport animal	176	1000	2758	193	964	2821	1610	9,522
Total	5622	20704	20542	5434	4764	95967	15294	168,327

The vegetation type, Human populations occupy the area and Special natural features such as Hora are some of the factors contributed to the variation of population distribution. Web valley, which carries the largest number of livestock, is a flat land dominated by palatable grass species. In addition Web valley is surrounded by a number of village to the West and North that use the area regularly. People who settled permanently in the Web valley are significantly larger. The Harena Forest possesses the highest density of human population that contributed to the presence of large number of livestock. In the Northeastern part in addition to large number of human population there are a number of mineral springs that pull a great number of cattle to the area.

Farming is another type of land use that is increasing in alarming rate in the National Park. Particularly the northern, northeastern, northwestern and southern Harena Forest is highly influenced by farming. Main crop production and amount of yield varies from one locality to another. The study carried out by the B&M Development Consultant reveals that, the northern part of the park and the Rira village in the Harena forest largely produce Barley and to some extent horse bean and peas. The yield of these crops relatively higher in the northern edge of the park than the forest part because the weather pattern and the altitude favor the production of the crops. Hawo area mainly produces maize. The land hold by household and land allocated for the production of crops vary from one locality to another. People in the northern part of the park possess larger land comparing to people living in the forest. The mean holding size per household size is largest for Hora soba and Gojera with about 2.35 ha and 2.18 ha respectively.

In a general speaking both uncontrolled over grazing by domestic livestock and expansion of farming have a severe adverse impact on the environment. The most important effects are:

Reducing the cover of vegetation:

The loss of vegetation cover increases run-off, thereby making the streams and rivers into pronounced seasonal rivers with floods during the wet season and an absence of flow during the dry season. The pronounced seasonality of the rivers that results from overgrazing, loss of vegetation cover and erosion leads to the problems in low lands as during the wet season, the rivers flood which leaves little flow during the dry season. The natural vegetation in the mountains retains and releases the water slowly, thus providing an inherent flow regulation system. Put simply, the removal of vegetation removes the control of water flow. Erosion also commonly results from loss of vegetation cover.

Increasing the cover and abundance of “grazing weeds”:

These are plants that are poisonous or unpalatable to herbivores that flourish at the expense of the palatable plants. The expansion of *Solanum*, *Kniphofia* and *Lobelia* in the foothill of Bale Mountains are the best evidence.

With reducing food supplies, productivity of domestic livestock drops and competition between livestock and wildlife species increases:

For example, there will be competition between the Afroalpine rodents and the domestic livestock, which, in turn, will lead to a decrease in the prey availability for the Ethiopian Wolf. Studies have indicated that Mountain Nyala usually avoids area used by domestic animals, which in turn reduces habitat to the wild animals.

The regeneration of woodlands is prevented as domestic livestock feed on and remove all young trees:

Agriculture alters the landscape with an irreversible loss of biodiversity. This has a significant adverse impact on biodiversity conservation and tourism development in the park.

Inappropriate tilling of land leads to erosion:

This, in turn, leads to increased seasonality of the rivers as described above.

Agriculture enhances conflict between park management and local community:

As farmlands became closer to the place where wild animals living apparently the frequency of the crop field being raided by the wild animals increases, which ultimately create bad relationships between the park and the community.

III. Exploitation of wood for fuel and construction materials.

The percentage of population dependent on forest products is significantly high since it is used as income source in addition to various domestic uses including fuel wood and construction. The present rate of exploitation cannot be sustained. The use of wood products as energy source is a major threat to forest resources compared to other uses of forest products. As of the projection of fuel wood consumption of Bale zone indicates there will be about 38% growth in fuel wood and charcoal demand while that of fuel wood alone will be about 37.2% between 2003 and 2013(B&M Development Consultant). The outcome of this exploitation is a loss of vegetation cover and erosion both of which lead to run-off and marked seasonality in water flow.

-The local communities prefer indigenous trees and shrubs (including *Hagenia abyssinica* and *Juniperous procera*) for fuel and construction material. The study by B&M Development consultant has found out that there are about 45 different tree species are reported to be used for animal feed, 43 tree species for fire wood, 39 and 38 tree species for shelter and honey production respectively. The exploitation of these species is uncontrolled and the forest and woodlands of the Bale Mountains are threatened.

_ All livestock in Bale are regularly led to natural mineral springs (hora). They stay for a period of about a month or more. Most of the hora are at very high elevations in parts of the mountains that would ideally be kept as a sanctuary area for Ethiopian wolves. Trampling and grazing obviously remove the fragile vegetation cover to that is not easily recoverable.

-The local communities often burn the Erica moorlands. They do this for two reasons: first, to clear the scrubby heathers to allow their livestock access to the herbaceous layer, and second, to burn off the foliage to allow collection of the wood for fuel and construction. This, in turn, has great adverse impact on stream seasonality and loss of biodiversity as discussed above

IV. Human induced fire

In the study area, fire can be taken as the main cause of vegetation degradation.

Fire occurs mainly on the dry season, which happen at different times of the year (beginning, middle and end of the dry season). By influencing plants, soil and animals fire induced several changes in ecosystem process: energy flow and biogeochemistry

Fire affects animal in two major ways: the direct effect during the burning and the indirect effects that result from changes in the animal environment. Owing to the lack of systematic studies on fire in the past, there are no statistical data on fire, which are amenable to analysis of causes, risk and extent of damage. However, general information has accumulated over many years as a result of causal observation and experience that can be used to deduce the major causes of fire.

The fire incidents that are known to have occurred between 1990 and 2000 have been started by people. Human set fire deliberately for various reasons. According to the preliminary result of informal survey, factors that are believed to have caused the fire in Bale zone in 2000 include:

- Immigration into and the subsequent settlement of people inside forests;
- Expansion of coffee plantation associated with emerging markets in the surrounding areas;
- Burning of woody plants to regenerate new grass for their livestock;
- Care less use of fire during fumigation of beehives to harvest honey;
- Commercial utilization of timber that has raised issue of equity with the local people;
- Un extinguished cigarettes left behind by people passing through the forest;
- Fire started to scare wild animals that eat crops, or attack domestic animals or people; and
- Unfavorable policy and institutional matter

The largest impact from the fires occurred in 2000, a year which had very high fire. In Bale and Borena Zones over 150,000 ha of forest were destroyed which include natural forest and natural coffee stands, wild and domestic animals, traditional beehives, harvested coffee and maize, local houses and traditional grain storage facilities.

V. Legislation and Law Enforcement

There are two main problems faced by the Bale Mountains National Park management regarding legislation and law enforcement- lack of explicit wildlife management enabling legislations and undefined or unknown park boundary.

a) Undefined Park boundary

Local communities have never been consulted and/or involved in the establishment of a national park at the Bale Mountains. Thus, there is no body from the community that would witness the location of the park boundary at the time of establishment. Further more, several actions have been taken to extend the park boundary, particularly in the Dergue regime. Hillman (1986) shows that the park boundary has been revised at least three times including the extension proposed by him. Basically, all the changes made to the park boundary is felt only by the people living near the headquarters, others who are at a considerable distance are not really aware what is going on, or even whether they are inside or outside of the park boundary.

Currently there are confusions and controversies about the boundaries of BMNP and surrounding areas. Many people are unclear about the exact location of the park boundary. Though the park management attempts to assert a boundary in the northern area of the park close to the head quarter, in the rest of the area there is little, if any control. Even in the northern parts and despite some patrolling by park staff, the communities dispute the boundary; suggest that they are still uncertain as to its exact location; and/or knowingly ignore the boundary and continue to for example, graze cattle inside it. This has created a problem to set the equilibrium between the conservation and utilization of the natural resources in the park.

b) Legislation

There is no enforcing wildlife policy and legislations that define the ownership or the use of the wildlife and other resources to promote management of the resource base both within and outside the BMNP. The present legislations make no provisions over the control of

different human induced activities in the park. BMNP at present has no legal bases for its existence, but informally is respected as National Park. As a result increasing human population and escalating pressure ultimately lead to destruction of the site and the wildlife with the other resources.

The only available legislation is the “Forest and Wildlife Conservation and Development Proclamation No. 192/1980”, and the only policy made “the wildlife Management Policy of 1979” which is currently incomplete and outdated. Accordingly there is a need of formulation of policies and legislations at national and regional levels.

Chapter Five

5 Conclusion and Recommendation

5.1 Conclusion

The basis of this research comprises the multitemporal classification of Landsat satellite imageries to detect, delineate, and map land cover change between 1973 to 2005. This time periods were chosen based on the availability of satellite imageries for classification and change detection.

Based on the analysis of the input data, in general about eight land use land cover classes were identified. These include moist montane forest, dry ever green forest, wood land, alpine bush land, water body, pasture and scattered farm plot, mixed grass/cereals and barren land.

In this study, immense attempts were done while performing classification of each images through incorporating better spatial resolution image (ASTER, 2005), ground truth data and other ancillary data such as pervious land use map.

Land cover post classification change analysis for the sub periods (1973-2000, 1973-2005 and 2000-2005) revealed that some important land cover changes were consistent in all sub periods. Taking the 1973-2000 and 1973-2005 sub periods the results revealed that the extent of farm plot, bare land and grass land has increased at the expense of vegetation.

Post classification out performed than NDVI differencing change detecting approach in that it can give more detailed information. In addition, it provides also the general picture of land cover class's boundaries. Therefore, post classification comparison is proved to be the best method for the study area.

If one only needs a general idea of vegetation change (just loss or gain in NDVI), NDVI image differencing is better for visual comparisons.

About five major causes or deriving forces are identified for land use land cover change (haphazardly expanding of settlement, uncontrolled grazing and increasing farming on higher elevation, exploitation of wood for fuel and construction materials, human induced fire and lack of legislation and law enforcement). Generally, they are attributed to population pressure which is prevailing in the area and the result has shown that the rate of land cover change has increased from time to time.

The change has negative implication on wild life species in particular and biodiversity values & the surrounding ecosystem in general.

With regard to habitat suitability modeling, for many wildlife species including Nyala, it is possible to evaluate habitat with identification of life requisite and vegetation cover. According to the present Nyala habitat suitability modeling, potential habitats have been identified through GIS analysis of five factors. Woodland vegetation type along with the elevation range between 2800-3200 m.a.s.l found to be the most suitable habitat for Mountain Nyala. Application of the habitat models in this specific area demonstrated that it satisfactorily predict habitat suitability. In light of this, it can be conclude that, Geographic Information Systems (GIS) along with remote sensing technology could provide new opportunities to model and evaluate wildlife habitat suitability.

In general, the result from this study appears practically useful for natural resources management in Bale Mountains National Park. Especially with the availability of low cost and timely satellite images as well as recent advances in GIS and remote sensing technology, the use of remotely sensed data for natural resource management becomes more feasible and efficient.

5.2 Recommendation

- ✚ The management and rehabilitation of natural resources needs sufficient data collection and detail analysis to identify the factors and propose appropriate methodologies that enable decision makers to make appropriate decision. In this regard, having updated Land use and land cover information is crucial. For that matter, application of remote sensing and GIS was found helpful in quantifying past and present condition so that appropriate planning could be made for the future. It is therefore hoped that future development activities will exploit these resources more.
- ✚ Creating awareness among the society concerning optimum use of natural resources, conservation systems and their benefits by policy makers and NGOs could play significant role in rehabilitation of the environment. In addition, since most important factor for the land cover change in the in Ethiopia in particular in the study area is the increase in population, continuing the current efforts of introducing family planning to make the people aware of consequences of population pressure should be carried out intensively.
- ✚ A strong legal and regulatory framework for the park should be established.
- ✚ Controlling agricultural expansion through appropriate legislation.
- ✚ Core areas should be identified and protected with special management emphasis.
- ✚ Settlement in the park should be reduced to tolerable size and distribution.
- ✚ This study has touched single wild life habitat suitability modeling; further studies could be conducted in depth for other wild life species.

References

- Aggimarangsee ,N. 1992. survey for semi-Tame colonies of Macaques in Thailand . Nat. Hist. Bull. Siam soc.40:103-166.
- Bannari, A., D. Morin, F. Bonn, and Huete, A.R. 1995. A review of vegetation indices. Remote Sensing Reviews. (13) 95-120.
- Chen, X. (2000). Using remote sensing and GIS to analyse land cover change and its impacts on the regional sustainable development. International Journal of Remote Sensing, 23(1), 107-114.
- David, S. W., & John, T. F. (1996). Remote sensing imagery for natural resources monitoring – A guide for first time users. New York: Columbia University Press.
- Davis D.D. 1962. Mammals of the Lowland Raim Forest of North Borneo. Bull .Nat. Mus. St. Sing. 31:1-129
- Doing, C.H. 1973. studies of the Malayan Wild Pig in Perak and Johore. Malay.Nat .Jour . 26(2): 120-151.
- Donovan, M.L.; Rabe, D.L.; Olson, C.E., Jr. 1987.Use of geographic information systems to develop habitat suitability models. Wildlife Society Bulletin. 15(4): 574–579.
- Foody, G. M., Palubinska, G., Lucas, R. M, Curran, P. J., and Honzak, M. (1996), Identifying terrestrial carbon sinks: clas sification of successional stages in Regenerating tropical forest from Landsat TM data. Remote Sens. Environ.55:205-16.
- Grassman jr., L.I.1997. Ecology and Behavior of Four Sympatric Carnivore species (Mammalia : carnivora) in Kaeng krachan National park, Thailand. MS. Thesis. Graduate School, Kasetsart University.

- Groten, S.M.E., W. Immerzeel and L.van Leeuwen. 1999. Monitoring of crops, rangelands and food security at national level. ITC-FAO, Rome.Hall, F. G., Strebel, D. E., Nickeson, J. E., & Goetz, S. J. (1991). Radiometric rectification: toward a common radiometric response among multi-data, multi-sensor images. Remote Sensing of Environment
- Harrison , J.L. 1962. the distribution of feeding Habit among Animals in Tropical Rain Forest. Jour. Anim. Eco .31:53-64
- FAO. (2000). Land Cover Classification System (LCCS): Classification Concepts and User Manual. Retrieved 1-July-2003, from the World Wide Web: http://www.fao.org/DOCREP/003/X0596E/X0596e00.htm#P-1_0
- Fung, T., & Siu, W. (2000). Environmental quality and its changes, an analysis using NDVI. International Journal of Remote Sensing, 21(5), 1011 - 1024.
- Hayes, D. J., & Sader, S. A. (2001). Comparison of change-detection techniques for monitoring tropical forest clearing and vegetation regrowth in a time series. Photogrammetric Engineering and Remote Sensing, 67(9), 1067-1075
- Hayes, Daniel J. and Steven A. Sader. 2001. Comparison of Change-Detection Techniques for Monitoring Tropical Forest Clearing and Vegetation Regrowth in a Time Series. Photogrammetric Engineering & Remote Sensing. 67 (9): 1067-1075.
- He, H.S.; Mladenoff, D.J.; Boeder, J. 1996. LANDIS: a spatially explicit model of forest landscape change. LANDIS 2.0 User's Guide. Madison, WI: Department of Forest Ecology and Management, University of Wisconsin. 43 p.
- Hillman,J.C. 1986. Conservation in Bale Mountain National Park, Ethiopia, Oryx 20:89-94.
- Hodson, A. W. 1927. Seven years in Southern Abyssinia. T.Fisher Unwin Ltd.London.

- Howarth, Philip J. and Gregory M. Wickware. 1981. Procedures for change detection using Landsat digital data. *Int. J. Remote Sensing*, 2(3): 277-291.
- ILWIS. (1997). The integrated land and water information system (Version 2.1). Enschede: ITC.
- Japan Association of Remote Sensing. (1996). Text book on Remote Sensing and GIS. Retrieved 20 -12, 2003, from the World Wide Web:<http://www.profc.udec.cl/~gabriel/tutoriales/rsnote/contents.htm>
- Jenson, John R. 1996. *Introductory Digital Image Processing: a remote sensing perspective*, Second Edition. Prentice Hall. New Jersey. 318.
- Lambin, E. F. (1994). *Modelling deforestation processes - A Review: Tropical Ecosystem Environment Observation by Satellites (TREES) - Research Report No. 1*. Institute for Remote Sensing Application. Joint Research Center, Commission of the European Communities.
- Lekagul , B and McNeely. 1977. *mammals of Thailand*. Kurusapha Ladprao Press. Bangkok.
- Lillesand, M. Thomas and W. Ralph Kiefer. 2000. *Remote Sensing and image Interpretation*: 4th ed. John Wiley & Sons, Inc. 750 pp.
- Lyon, J. G., Yuan, D., Lunetta, R. S., & Elvidge, C. D. (1998). A change detection experiment using vegetation indices. *Photogrammetric Engineering and Remote Sensing*, 64(2), 143-150
- Mather, P.M. 1999. *Computer processing of remotely-sensed images: an introduction*. John Wiley and Sons, Inc.
- Jensen, J. R. (1996). *Introductory digital image processing*. New Jersey: Trentice Hall.

- Mladenoff, D.J.; He, H.S. 1999. Design and behavior of LANDIS, an object-oriented model of forest landscape disturbance and succession. In: Mladenoff, D.J.; Baker, W.L., eds. *Advances in spatial modeling of forest landscape change: approaches and applications*. Cambridge, UK: Cambridge University Press: 125–162.
- Nangendo, G. 2005. *Changing forest-woodland-savanna mosaics in Uganda: With implication for conservation*. Wageningen, Wageningen University, 2005. ITC Dissertation 123, 139pp. ISBN: 90-8504-200-3.
- Ojima, D.S., et. al. 1994. The Global Impact of Land-use Change. *Bioscience*. Vol. 44. p. 300.
- Pilon, P. G., Howarth, P. J., & Bullock, R. A. (1988). Enhanced classification approach to change de-tection in semi-arid environment. *Photogrammetric Engineering Remote Sensing of Environ-ment*, (54) 1709–1716.
- Robinson, S.K.; Thompson, F.R., III; Donovan, T.M.; Whitehead, D.R.; Faaborg, J. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science*. 267(5206): 1987–1990.
- Rossiter, D. G. (2001). *Assessing the thematic accuracy of area-class soil maps*. Enschede.
- Riebsame, W.E., Meyer, W.B., and Turner, B.L. II. 1994. Modeling Land-use and Cover as Part of Global Environmental Change. *Climate Change*. Vol. 28. p. 45. 35, 11 - 27.
- Rucker, R.A.; Kennedy, M.L.; Heidt, G.A.; Harvey, M.J. 1989. Population density, movements, and habitat use of bobcats in Arkansas. *Southwestern Naturalist*. 34(1): 101–108.
- Shifley, S.R.; Thompson, F.R., III; Larsen, D.R.; Dijak, W.D. 2000. Modeling forest landscape change in the Missouri Ozarks under alternative management practices. *Computers and Electronics in Agriculture*. 27(1): 7–24.

- Sluiter, R. 2005. Mediterranean land cover change: Modeling and monitoring natural vegetation using GIS and remote sensing. PhD Thesis, Universiteit Utrecht, the Netherlands. 145pp
- Simchareon , S. 1998. Home Range of and Habitat Uses by Male Asiatic Jackal, *canis aureus* at Khao Nang wildlife Research Centre, Thailand. Wildlife Research Division, Royal Forest Department, Bangkok.
- Singh, A. (1989). Digital change detection techniques using remotely sensed data. Intl. Journal of Remote Sensing, 10(6), 989–1003.
- Wickware, G. M. and Howarth P. J. (1981). Change Detection in the Peace-Athabasca Delta Using Digital LandsatData. Remote Sensing of Environment, 11:9-25
- Wilkie, D.S., and Finn, J.T. 1996. Remote Sensing Imagery for Natural Resources

Annex

Annex 1 : Buildings in the BMNP

S.No	Type of the building & size	Quantity	Purpose	Location	Remark
1	Hollow blocks- 6.5x15	1	Residence	Head Quarters	Currently serve as the Park's office
2	Hollow blocks- 8x10	1	Residence	HQ	Warden's house
3	Hollow blocks- 6x22.5	1	Office	“	Under construction
4	Hollow blocks- 6.5x15	1	Residence	Web camp	
5	Hollow blocks- 4x10	1	Ticket office	Gesse	
6	Hollow blocks- 12x6	2	Residence	Gesse	
7	Hollow blocks- 2.5x6.5	2	Kitchen	Gesse	
8	Hollow blocks-4x4	1	Toilet	HQ	
9	Hollow blocks-	2	Residence	Angeso	Built by WWF
10	Hollow blocks-	1	Ticket office	Angeso	“
11	Hollow blocks-	2	Residence	Rira	”
12	Hollow blocks- 6.5x9	1	Kitchen	HQ	
13	Stone block	1	Lodge	HQ	
14	Mud wall- 6x8	2	Residence	HQ	
15	Mud wall with Sand- 6x12	1	Residence	HQ	Experts residence
16	Corrugated Iron sheet wall-Different size	22	Kitchen, store, toilet, residence,		Maintenance is required
17	Mud wall- 3x7	1	Kitchen	HQ	
18	Mud wall- 8x12	5	Residence	Web	All need maintenance

Annex 2: Number of visitors and income in the BMNP

No	Year (Ethiopian Calendar)	Ethiopian	Foreign	Total	Revenue In Birr
1	1981	71	579	650	3790
2	1982	134	699	833	6647
3	1983	60	208	638	3373
4	1984	78	25	103	717
5	1985	136	539	673	21672
6	1986	109	505	614	37301
7	1987	207	623	830	49726
8	1988	47	464	511	31659
9	1989	130	806	936	57891
10	1990	164	880	1044	67428
11	1991	203	751	954	58919
12	1992	207	797	1004	62807
13	1993	151	801	952	56910
14	1994	171	892	1063	78964
15	1995	230	1289	1519	108764
16	1996	179	1038	1217	84209
	Total	2277	10896	13541	730777

Annex 3

Photo: Nyalas while feeding around Dinsho (the park head quarter)



Annex 4

Photo: one of the magnificent landscape of BMNP

