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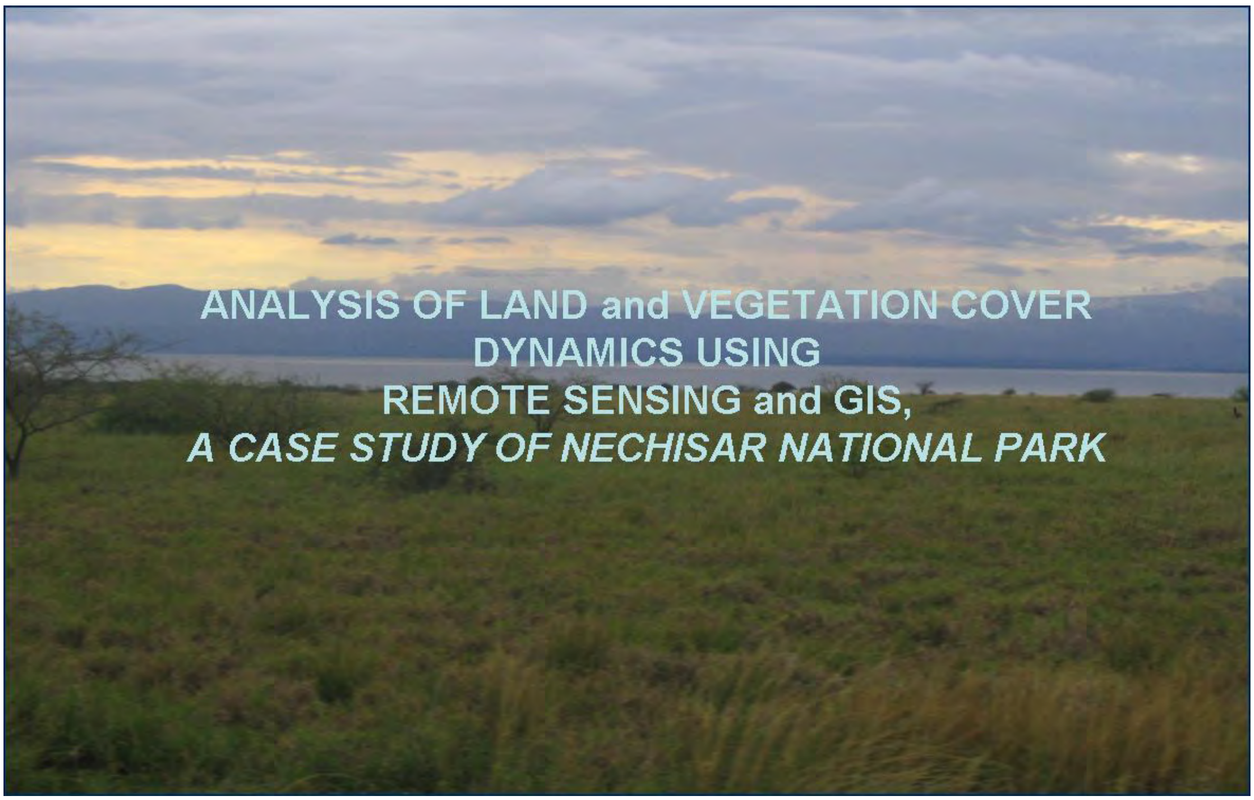

A Thesis submitted in partial fulfillment of the requirements for the Degree of Masters of Science in Remote sensing and GIS for the Earth sciences department

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ANALYSIS OF LAND AND VEGETATION COVER DYNAMICS USING REMOTE SENSING & GIS TECHINIQUES,*A CASE STUDY OF NECHISAR NATIONAL PARK*

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(ASAYE NIGUSSIE)

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List of Acronyms

APC	**African Parks Conservation**
AVHRR	**Advanced Very High Resolution Radiometer**
DEM	**Digital Elevation Model**
EOS	**Earth Observing System**
ETM+	**Enhanced Thematic Mapper**
EWNHS	**Ethiopian Wildlife and Natural History Society**
FAO	**Food and Agriculture Organisation**
GIRD	**Generation Integrated Rural Development () Consultants**
GIMMS	**Global Inventory Monitoring and Modeling Studies group**
GIS	**Geographical Information System**
GLCF	**Global Land Cover Facility**
ICBP	**International council for Bird conservation**
MAP	**Mean Annual Preceptaion**
MODIS	**Moderate Resolution Imaging Spectro radiometer**
MSS	**Multispectral Scanner**
MVC	**Maximum value composites**
NASA	**National Aeronautical and Space Administration**
NDVI	**Normalized Difference of Vegetation Index**
NIR	**Near Infra Red**
NOAA	**National Oceanic and Atmospheric Administration**
NSNP	**Nechisar National Park**
RVLB	**Rift Valley Lake Basin**
SESP	**SNV Ethiopia Southern Portfolio**
SNNPR	**Southern Nations, Nationalities and Peoples Region**
TM	**Thematic Mapper,**
UNDP	**United Nation Development Program**

Abstract

The research aims to analyze the trend of land and vegetation cover dynamics over the period from 1976, 1986 2000 and 2007 thus examine the conservation status of the area and generate up-to-date land cover map. Information is extracted from various Satellite images of multidated Landsat, ASTER and MODIS images. The Landsat images are the basic remote sensing data to generate the thematic maps which are further analyzed to show the cover dynamics in the park for 24years. All data's from the satellite images are processesed and analyzed using digital image processing techniques. Besides, different vector data are extracted from the images as well as other thematic maps. MODIS-NDVI images are analyzed for the different land cover classes and each vegetation cover seasonal response is compared for the year 2000 and 2005. The land cover classes identified in the study area from 1976, 1986, 2000 and 2007 are water body, riparian and ground water (GW) forest, wood land, dense bush land, bushy shrubbed grass land, open grass land, degraded grass land, cultivated land, swamp vegetation and bare land. Rate of land cover change and fragmentation of habitat were discussed for the different land cover classes. Rate of land cover change, fragmentation index and land cover conversion matrix clearly shows the dynamics of the different cover classes has happened for the past decades and generally the park conservation status is found to be poor. Bush encroachment in the study area is a major challenge to the park particularly for the grass land and overgrazing on the Nechisar plain has caused expansion of invasive plants erosion and land degradation. The community livelihood dependency both in the rural and urban setting is concluded and discussed as a challenge to the park from biodiversity conservation point of view.

*Key Words***:** *Land cover dynamics, National park, Vegetation cover, Remote sensing and GIS, Habitat fragmentation, degradation, biodiversity conservation***.**

1. Introduction

1.1 Back Ground and Justification

As in the case of many other developing countries, most of the population of Ethiopia live in rural areas and depends directly on the land for its livelihood. This rural population is currently growing rapidly, and consequently inducing high pressure on the resource base. A common concern addressed by many studies is the resource degradation brought about by the decrease in the area under natural vegetation and its conversion into other types of land use and land cover that are anthropogenic.

For centuries the Nechisar area was uninhabited. The park was gazetted in 1962, and the scant management provided sufficed until the last twenty years when Ethiopia's population exploded, propelling new communities to settle within Nechisar National Park (NSNP). The ensuing results of deforestation, grazing cattle, human habitation and over fishing in the park have caused severe stresses and degradation of park ecosystems, leaving the sustainability of Nechisar National Park's resources in question (Alison M. Jones, 2005).The natural resources in and around Nechisar National park are facing severe challenges due to gross over utilization in the past and present. The natural resources have not been adequately protected in the past (Denna, 2006).

The partnership agreement for the management of Nechisar National Park was signed on 14 February 2004 and the Government of the Southern Nations, Nationalities and Peoples Region (SNNPR) formally handed management responsibility for Nechisar over to African Parks (Ethiopia) on 1st February 2005. When African Parks assumed management for Nechisar, its environment was highly degraded. The Nechisar Plains and surrounding woodlands had been excessively encroached by invasive plant species and the small but rare groundwater forest had been subjected to unsustainable illegal harvesting of wood for use as fuel and construction material. In addition, over fishing in Lake Chamo was having a devastating effect on the wellbeing of aquatic life, including the Nile crocodile, wetland birds and fish which are an indispensable natural food base for these species (Report of African Parks foundation, 2005).

National Parks and Preserves are unique public lands or bodies of water within a country, set aside by the government to protect ecosystems, plant and animal species, scenic landscapes, geologic formations, or historical or archaeological sites. *National parks* are managed primarily for public recreation, providing exceptional locations where visitors can view wildlife and enjoy the outdoors. Generally, these protected public lands are off-limits to hunting, livestock grazing, logging, mining, and other activities that exploit natural resources. *National preserves*, sometimes called nature or wildlife reserves, often are located within or near national parks (ENCARTA encyclopedia, 2007).

Remote sensing and GIS application is a powerful tool for analysis of land and vegetation cover dynamics and mapping the vegetation distribution thus studying the spatial and temporal land cover variability. 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). Land cover mapping and analysis of multi dated satellite images of the study area is important for understanding of the cover dynamics for an effective and sustainable management of the natural resource of the area besides integrating the information extracted in the past and present could tell the major challenges and potentials of the area in both spatial and temporal context.

1.2 Problem statement

The study area, Nechisar National Park is degrading rapidly due to different natural processes and human activities; as a result there is a tremendous influence on the quality of the park, the lake, biodiversity and overall environment. The accelerated deterioration of the natural resources and their functions, therefore, calls for an urgent institutionalization of management plans, which can create harmony among resource users and ecological functions. Conservation of natural resource and ecosystem is very indispensable as it acts as a mask for environment and biodiversity.

In order to develop viable resource conservation and management plan in the area a great deal of effort has to go in understanding the causes and effects of the natural resource degradation through land cover change study at desired spatial and temporal variation. The problem is how to make this very applicable. Hence this research is aimed to create an important output for simplified ways of natural resource management by developing the different land cover changes and that helps to assess the conservation status of NSNP after studying the vegetation distribution and land cover dynamics of the area. Basically to alleviate all the problems associated with the natural resource loss of the area it has been found that first to know the actual causes, threats, rate and degrees of the loss. In this regard remote sensing and GIS have great role to assist to study land cover dynamics and develop management plans for the conservation and sustainable utilization of natural resources of the park.

1.3 Research objectives

- ***General Objective:***

The research aims to analyze the trend of land and vegetation cover dynamics over the period from 1976 to 2007, assessing the Nechisar National Park and examine the conservation status of the area and generate up-to-date land cover map for the year 2007,

- ***Specific Objectives:***

- To assess the trends of land and vegetation cover change in the study area for the period from 1976, 1986 and 2000,
- To generate up to date land cover map for the year 2007,
- To discuss the relationship between the trend of cover changes and the conservation status of the national park,
- To show the annual biomass growth response of the vegetation cover classes of Nechisar national park,

1.4 Limitations and future research gaps

This research has seen the spatial and temporal variability of the land cover around the Nechisar national park. The desired outcome of the research is to find out the rate of ecosystem loss and for the development of priorities through mapping the area that are disturbed highly for conservation and protection. Special interest will be placed on the spatial distribution and the rate and intensity of change of the vegetation cover. The bases of this study will be resulted from multidated satellite image classifications, field data collection and previous research results. The current park boundary of the NSNP which is still under negotiation between SNNPR regional government, Oromia regional government, APC (Ethiopia) and the community which are directly dependent on the park natural resource, thus the park boundary negotiation process is a sensitive issue to conduct community interview and mapping the park grazing and farming zones and villages in the park. The study also couldn't address mapping the cover distribution of invasive plants and the cover extent of some specific vegetation cover types rather it focuses on the general land/vegetation cover types and change analysis that are identified in the park.

2. Literature review

2.1 Concepts of Land Cover classifications

The common integrated approach adopted here defines land cover as *the observed (bio) physical cover on the earth's surface* (FAO, 2000), but in addition, it is emphasized that land cover must be considered a geographically explicit feature which other disciplines may use as a geographical reference (e.g., for land use, climatic and ecological studies).The definition of land cover is fundamental, because in many existing classifications and legends it is confused with land use. It is defined as: *Land cover is the observed (bio) physical cover on the earth's surface.*

When considering land cover in a strict sense it should be confined to describe vegetation and man-made features. Consequently, areas where the surface consists of bare rock or bare soil are describing *land* itself rather than land *cover*. Also, it is disputable whether water surfaces are real land cover. However, in practice, the scientific community usually describes those aspects under the term land cover.

Land is a basic source of mass and energy throughout in all terrestrial ecosystems, and land cover and land use represent the integrating elements of the resource base. Land cover, being the expression of human activities, changes with modifications in these activities. Therefore, land cover as a geographically explicit feature can form a reference basis for other disciplines.

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):

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

2.2 Remote Sensing and Land cover studies

Many studies such as those by Brandon & Bottomley(1998), Chen(2000), Diouf & Lambin (2001),Kuntz & Siegert(1999), Lambin(1994) Mendoza S. & Etter R(2002), Vance & Geoghegan(2002) have emphasized the importance of investigating land cover dynamics as a baseline requirement for sustainable management of natural resources. The knowledge of “where are the changes” and “what are the causes of the changes” is essential for the formulation of appropriate management strategies. The understanding of land cover change process and driving forces will help policy maker’s resource managers to decide where the action should be taken and what kind of intervention is needed. Understanding environmental or land-cover dynamics represents an important challenge in the study of the global environment, because many land-cover changes take place at fine scales of resolution, requiring Landsat-type of imagery for accurate measurement. Uses for such data range from biodiversity and habitat mapping for localized areas, to specifying parameters for large-scale numerical models simulating biogeochemical cycling, hydrological processes, and ecosystem functioning. These needs have been recognized in the International Geosphere Biosphere Programme, the World Climate Research Programme, and the International Satellite Land Surface Climatologic Project, among others (Becker *et al.*, 1988; IGBP, 1990; WMO, 1992). Responding to these needs, the Scientific Data Purchase Program of NASA’s Stennis Space Center has directed the production of global orthorectified and co-registered Landsat Multispectral Scanner (MSS), Thematic Mapper (TM), and Enhanced Thematic Mapper (ETM+) data for three periods: the late 1970s, 1990, and circa 2000, respectively (http://www.esa.ssc.nasa.gov/datapurchase) .

Different studies that were carried out using remote sensed data of different years, in parts of Ethiopia indicate that croplands have expanded at the expense of natural vegetation, including forest and shrub lands in the central highlands of Ethiopia (Selamyehun kidanu, 2004; Girmay Kassa, 2003; Belay Tegene, 2002; Gete Zeleke and Hurni, 2001; Solomon Abate, 1994). While Kibrom Tekele and Hedlund, (2000) reported increase in the size of open areas and settlements at the expense of shrub lands and forests. Dry land forests in Ethiopia are currently threatened by shifting cultivation, the spread of sedentary agriculture, increase in livestock, the increasing demands for fuel wood, charcoal and construction materials, and uncontrolled man-made fires. As a result the country is facing a situation of dramatic loss of forest resources, which easily result in the eradication of woody species and disturbance of an ecological set up. In some parts of Ethiopia the problem has gone beyond limits of reversal and the problem is still expanding at fast rate (Simon and Zerhun, 2006).

2.3. Image classification and out put preparation

Image classification is the process of creating thematic maps from satellite imagery. A thematic map is an informational representation of an image that shows the spatial distribution of a particular theme (Verbyla, 1995).The computerized interpretation of images from remote sensors is known as a quantitative analysis due to its ability to identify pixels based in the numerical properties. For quantitative analysis usually different procedures of classification are used (Richards,1993). Classification is a method that assigns categories to different pixel groups according with the spectral character. There are two main spectrally oriented classification procedures for land cover mapping: unsupervised and supervised classifications.

According to Diday(1994) unsupervised classification is computer-automated and it enables user to specify some parameters that the computer uses to uncover statistical patterns that are inherent in the data. These patterns are simply clusters of pixels with similar spectral characteristics. In some cases, it may be mere important to identify group of pixels with similar spectral characteristics than it is to sort pixels into recognizable categories. Lillesand and Kiefer(2000) describes In supervised classification the image analyst supervises the pixel categorization processes by specifying, to the computer algorithm, numerical descriptors of the various land cover types present in a scene. To do this, representative sample sites of known cover type, called training areas are used to create the parametric signatures of each class. Each pixel in the data set is then compared numerically to each category in the interpretation key and labeled with the name of the category. There are different algorithms under this classification type in which minimum distance, variance and covariance of the classes are considered during classification. Of these algorithms the best is maximum likelihood classifier. It quantitatively evaluates both the variance and covariance of the category spectral response patterns when classifying an unknown pixel.

It is hoped that, at the more generalized first and second levels, accuracy in interpretation can be attained that will make the **land** use and **land cover** data comparable in quality to those obtained in other ways. For **land** use and **land cover** data needed for planning and management purposes, the accuracy of interpretation at the generalized first and second levels is satisfactory when the interpreter makes the correct interpretation 85 to 90 percent of the time.

According to Anderson(1971) **Land** use and **land cover** classification system which can effectively employ orbital and high-altitude remote sensor data should meet the following criteria:

1. The minimum level of interpretation accuracy in the identification of **land** use and **land cover** categories from remote sensor data should be at least 85 percent.

2. The accuracy of interpretation for the several categories should be about equal.

3. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.

4. The classification system should be applicable over extensive areas.

5. The categorization should permit vegetation and other types of **land cover** to be used as surrogates for activity.

6. The classification system should be suitable for use with remote sensor data obtained at different times of the year.

7. Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible.

8. Aggregation of categories must be possible.

9. Comparison with future **land** use data should be possible.

10. Multiple uses of **land** should be recognized when possible.

2.4. Normalized Difference Vegetation Index (NDVI)

A vegetation index is a common spectral index that identifies the presence of chlorophyll. It is composed of reflectance in the red spectral region (0.62 to 0.7μm) and a portion of the near infrared spectral region (0.7 to 1.1μm). Chlorophyll has a relative low reflectance in the red part of the electromagnetic spectrum and a relative high reflectance in the near infrared part. Vegetation indices are empirical formulae designed to emphasize the spectral contrast between the red and near infrared regions of the electromagnetic spectrum. They attempt to measure biomass and vegetative health, the higher the vegetation index value, the higher the probability that the corresponding area on the ground has a dense coverage of healthy green vegetation (Gibson & Power, 2000). Spectral vegetation indices permit clear discrimination between bare soil surfaces, water bodies, and vegetation. Several vegetation indices, NDVI, DVI, PVI, SAVI, and others, have been developed in order to improve specific analyses. NDVI is one of the most widely used vegetation indices. Its strength is the vegetation cover, and it is tailored to give desirable characteristics for various parameters associated with vegetation growth, type and ecosystem environment. Its value ranges between –1 and +1 (Gibson & Power, 2000).

NDVI = Near infrared – Visible red/Visible red + Near infrared

NDVI is used in this study as one parameter in the identification of ground cover classes for preliminary verification during the unsupervised classification of the 2000 ETM+ image prior to field work. It is used as a color combination with the other bands and principal component outputs. Those areas with permanent vegetation throughout the year are easily identified. Since the time of image acquisition is on every 16 days of every month through the year and represents the vegetation situation for different season including the wet and dry.

The MODIS is the primary sensor for monitoring the terrestrial ecosystem for the NASA Earth Observing System (EOS) program (Justice et al. 2002) and has several advancements over AVHRR. The MODIS is more sensitive to changes in vegetation dynamics (Huete et al. 2002) and was found to be a more accurate and versatile instrument to monitor the global vegetation conditions than the AVHRR (Gitelson and Kaufman, 1998; Justice et al., 2002).The MODIS sensor acquires data in 36 spectral bands, in variable spatial resolution of 250-1000 meters, in narrow bandwidths and in 12-bits. The 36 MODIS bands are a compromise of atmospheric, land and ocean studies of which seven bands are considered optimal for land applications (Justice et al., 2002).

2.5. General Overview of National parks and Nechisar National park

ENCARTA Encyclopedia describes National Parks and reserves are unique public lands or bodies of water within a country, set aside by the government to protect ecosystems, plant and animal species, scenic landscapes, geologic formations, or historical or archaeological sites. *National parks* are managed primarily for public recreation, providing exceptional locations where visitors can view wildlife and enjoy the outdoors. Generally, these protected public lands are limited to hunting, livestock grazing, logging, mining, and other activities that exploit natural resources. *National preserves*, sometimes called nature or wildlife reserves, often are located within or near national parks. These lands are managed by national governments primarily for wildlife protection or scientific research instead of recreation, and provide “living laboratories” in which scientists observe plant and animal species in their natural habitat (ENCARTA Encyclopedia, 2007).

National parks are usually located in places which have been largely undeveloped, and often feature areas with exceptional native animals, plants and ecosystems (particularly endangered examples of such), biodiversity, or unusual geological features. Occasionally, national parks are declared in developed areas with the goal of returning the area to resemble its original state as closely as possible. Most national parks have a dual role as offering a refuge for wildlife and as serving as popular tourist areas. Managing the potential for conflict between these two roles can become problematic, particularly as tourists often generate revenue for the parks which, in turn, are spent on conservation projects. Parks also serve as reserves for substantial natural resources, such as timber, minerals and other valuable commodities. The balance of the demand for extraction of these resources, against the damage this might cause, is often a very important challenge in national park management. National parks have been subject to illegal logging and other exploitation, sometimes because of political corruption. This threatens the integrity of many valuable habitats (Wikipedia, 2007).

Melvin Bolton (1970) visited the Nechisar area as a consultant to EWCO in September 1969.In April 1970 as part of his mission to identify suitable areas for protection in the country and in his report and he classified and mapped the parks vegetation for the first time, and it seems that he did some collection especially of grasses.Kirubel Tesfaye(1985) was the first biologist of the park staff, from 1984 to 1985. Based on Bolton's report he remapped the park's vegetation in more detail and expanded on Bolton's classification of the vegetation, adding new species to the park and more detail to the descriptions.

According to the survey of ICBP(1992) the vegetation around the park was explored and Nechisar lies within one of the major floristic regions in Africa, the Somali-Masai regional center of endemism, an area of 1.9million km^2 covering most of east Africa between central Tanzania and northern Ethiopia and containing about 2,500 plant species .The vegetation in this region can be divided in to seven main types of which four occur in Nechisar.According to White(1983) the four habitat classes for the Nechisar park is discussed below.

1.Somalia-massai *Acacia commiphora* deciduous bushland and thicket: Bush land is the dominant vegetation of the park, covering most of the hills and greater gentle slopes with scattered shrub and low bushy tree set in grass land, denser impenetrable areas of bush land, termed 'thicket' (White,1983), are not so extensive, generally occurring on escarpments, steep rocky slopes and gullies through out the park, as well as on the marginal vegetation zone of lake Abaya, and as large expanse east of Hitu.

2. Somalia Masai edhapic grassland: Grassland covers the Nechisar plains, a flat or undulating area of about $270km^2$ at 1200m elevation extending from Degabule in the west and the Haro hills in the east and from Dache in the north down to the course of the dried up Mio river in the south the grass land also extend onto the hill slopes surrounding the plains (e.g. on to the south plateau) (White 1983).

3. Somali-masai riverine forest: Riverine forest occurs as narrow strips along the Kulfo and Seremele rivers and also as small area of spring fed "ground water forest" along the base of the scarp at the eastern edge of Arba Minch. From the east bank of the Kulfo river the hill rise steeply and almost all the forest lies to the west of the river (White 1983).

4. Herbaceous fresh water swamp and aquatic vegetation: The Kulfo river supports extensive swamps at its mouth in lake,dominated by *Thypha angustifolia*.Tall water side grasses and lush flood plains with *Sacchaarum spontaneum* occur along Sermele river.The margins of lakes Abaya and Chamo are mainly support a rich marginal vegetation of species such as *Thypha angustifolia,phargamites sp. and Juncus sp*; with tall waterside grasses such as *Loudetia phargmitoides* and bushes of *sesbania sesban var.nubica*.The hot springs drain very shallowly west from a point near the base of the Yaro hills producing a small marsh with reed bed and other marginal vegetation(White 1983).

2.6. Habitat Fragmentation and Landscape Pattern

According to a study conducted by The State of the Nation's Ecosystems (2006) Fragmentation of ecosystems into small patches can reduce habitat for wildlife species that require larger, connected patches. It can hinder the movement of some species and introduce predators, parasites, and competitors associated with different land uses. Fragmentation can also alter the frequency and extent of fire and affect the dispersal and regeneration of plants. Species that require large, unbroken expanses of habitat are often most sensitive to the effects of fragmentation. In some cases, the effects of fragmentation on sensitive species are a direct result of changes in the size and arrangement of suitable habitats across the landscape. In others, impacts are due mainly to more frequent interactions of species with humans, vehicles, or predators, or to other factors associated with an intruding land use. People also react to changing landscapes. Areas that were primarily forest, grasslands, or shrub lands but are now fragmented by other uses or bisected by roads provide a very different level of solitude and visual attraction. Likewise, the character of farm landscapes and communities changes radically when they are broken up by suburban development**.**

A number of packages for use with geographic information systems (GIS) permit the analysis and characterization of landscapes in terms of their patch composition, spatial relations and dynamics. Landscape ecological theory and GIS technology have generated a number of measures of the spatial distribution of habitat that express different aspects of its fragmentation in ways that relate to ecological processes. These have mostly been used in the evaluation of habitat and landscape processes at management unit scales. For example, Kramer (1997) used these analyses to describe landscape change as a result of management of two national parks in Costa Rica. She found that as forest cover increased, patch size increased and patch shapes became more compact for the shrinking pasture areas, but remained similar or became more complex over time for the expanding forest. Landscape diversity declined as the pasture areas shrank. In another example, Helmer (2000) used similar analyses to show that in the mountains of Costa Rica secondary forest is strongly associated with primary forest and occurs in smaller patches with more complex shapes.

As this example show, spatial analysis of landscapes and the metrics it produces has been the subject of much research and has been used widely for descriptive purposes. However, they represent a complex suite of ecological processes and effects that are beyond the detailed understanding of many decision-makers. Also, they often focus at scales (such as the 100 m edge effect postulated by Helmer(2000) that are beyond the resolution of currently available classified satellite data on land cover at regional and global scales. Furthermore, they have rarely been used to identify the likely relative value of different patches of habitat in the context of fragmentation, as a basis for monitoring changes in that condition or for making policy and management decisions.

3. Materials and Methods

3.1 Description of the study area

3.1.1 Location

Nechisar National Park is located in Africa's Great Rift Valley, 575km southwest of Addis Ababa, Ethiopia. Nechisar National Park's greatest asset is its diverse combination of ground water forest, Acacia woodland, open savanna, escarpment walls, hot springs and lake shores. The study area lies near the town of Arbaminch.

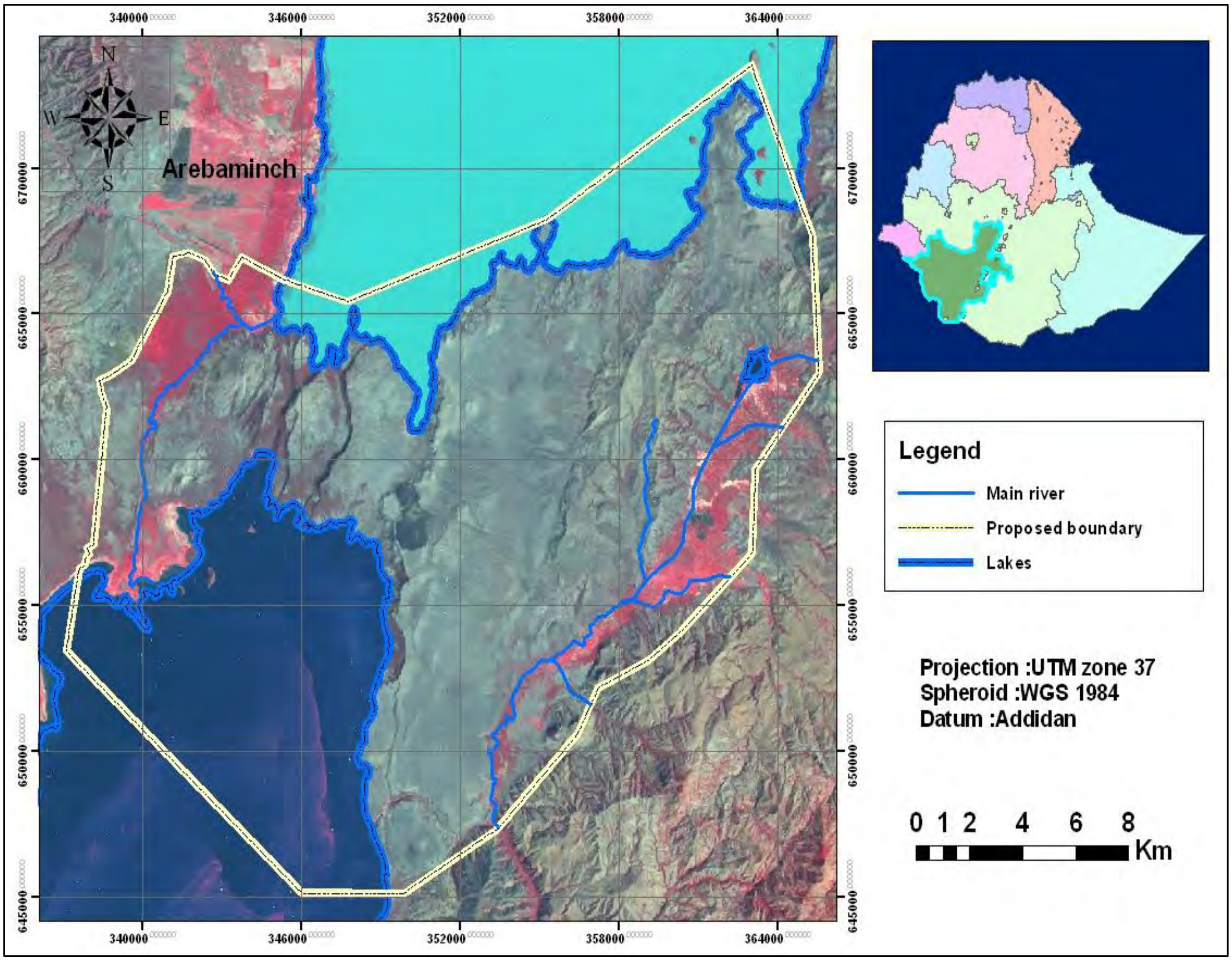


Figure.3.1 Location Map of the study area

3.1.2. Climate

According to Ethiopian climatic classification the Abaya Chamo basin is charactering hot semi-arid, warm temperate, tropical climate. Early studies made to identify the distribution of dryness ratio for the selected sites on the basin indicate the available water potential of the basin. Accordingly, Arbaminch, Bilate and Mirab Abaya (western Abaya) show radiation index greater than 2.0, whereas the Chencha highland has a radiation index of 1.1, the later is under the category of forest covered land.Average annual rainfall ranges from 664mm at Bilate to 1239 mm at Chencha with average maximum temperature 31.2^{0}C at Arbaminch and minimum in Chencha 13.9 ^{0}C(EPA, 2005).

The following climate diagram below (figure.3.4) is organized from the rainfall and temperature information collected from the Arbamench metrological station. It summarizes the general climate information for the rainy and the dry seasons. According to the diagram below when temperature exceeds the rainfall the area covered in this time is considered as dry season, in contrast when rainfall exceeded temperature there is a wet /rainy season.

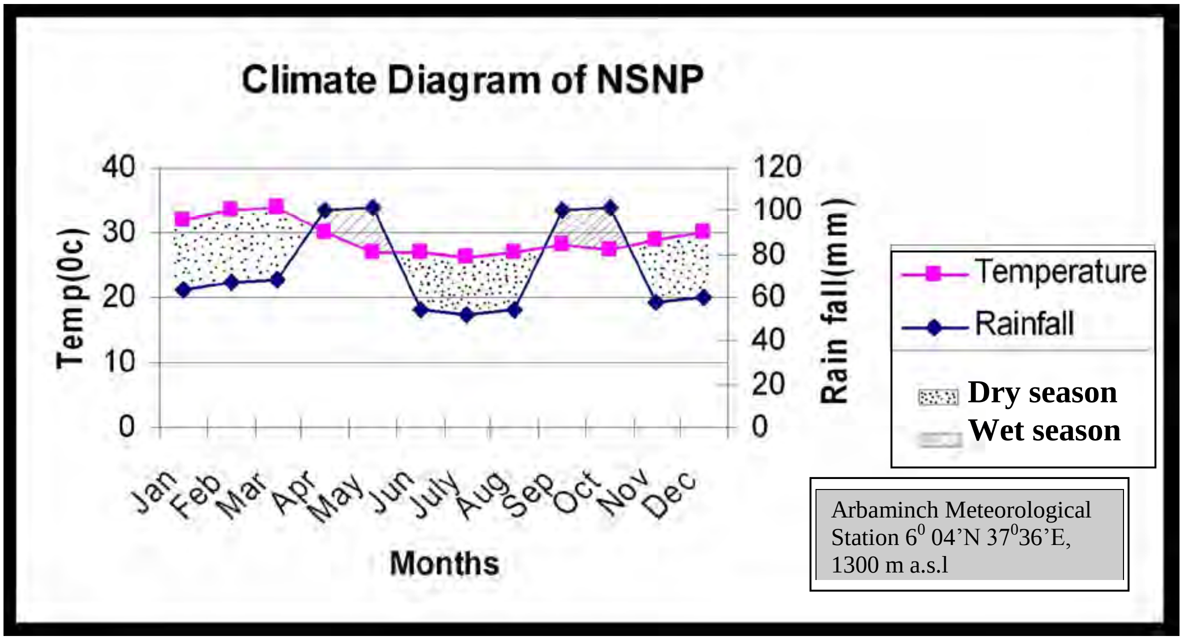


Figure.3.2 Climatic Diagram of Nechisar Park

3.1.3 Biological and Habitat diversity

Duckworth(1992) indicated that the park has five major habitats, from the eastern shores of the two rift valley lakes; there is an abrupt rise into the Nechisar plains that are the dominant feature of the park and the main source of food for grazing animals. These plains cover an area of 10,000 ha and are covered by the grass *Chrysopogon aucheri* that whitens during the dry season and grows on friable black soils. These larger, central plains support a population of zebra, Swayne's hartebeest, Grants gazelle and other plains game.To the east of the plains the country gradually changes to a zone of dry *Acacia* savannah and then to the thickly wooded valleys and foothills of the imposing Amaro Mountains that are the eastern wall of the Great Rift Valley. The eastern park boundary runs along the top of the first string of the foot hills. At the foot of Mount Tsebele there are hot springs that are regularly visited by local people for medicinal use.

African Parks Conservation (2006) reported that the third major habitat is the unusual evergreen groundwater forest in the western sector, which supports an exceptionally diverse range of plant species. This habitat is dominated by *Ficus* sycamorus and *Lecanodiscus fraxinifolius* species of trees that are up to 30m tall. This forest is said to be unique in Africa and its existence, as such, is closely associated with the series of freshwater springs, known as "Arba Minch", meaning "Forty Springs". Originating from the western edge of the forest, at the foot of the western escarpment, these springs provide the source of water supply to Arbaminch town, as well supporting the natural forest biodiversity. The fourth habitat is the narrow isthmus (less than 5km wide separating the two lakes), which is mostly old lava flows and is covered by dense thickets that in places are almost impenetrable. This is the main habitat in the park of Guenther's dikdik and is also excellent habitat for black-rhino. Lastly there is the fauna and flora associated with the wet lands and aquatic environments in and around Lakes Chamo and Abaya which make up the fifth major habitat. The Kulfo River flows through the north of Arba Minch and then cuts across the neck of the narrow isthmus of land and ends in a swamp on the shore of Lake Chamo. The lakes and lakeshore areas are an interesting component of the great biodiversity of the park.

i) Flora

EPA(2005) describes The vegetation along the steep gradient of the Arba Minch Chencha hillside is segregated into five community types as a reflection of the variation in altitude and the factors associated to it. The forest vegetation on the plain adjacent to the wetland is mainly composed of *Lepidotrichilia volkensii, Ficus sur, Acacia polyacantha, Maytenus senegalensis, Acacia seyal, Balanaites aegyptiaca, Acacia tortilis, Trichlia dregeana.*The vegetation on the base of the hill above the banana plantation and human settlement is composed mainly of *Acacia mellifera, Acacia tortilis, Rhus natalensis* and *Balanites aegypitica.* The vegetation on the steep hillside between 1300 and 1650m a.s.l is dominated by *Combretum molle, Euclia divinorum, Terminalia brownii* and *Dodonea angustifolia.* Above this altitudinal range is typical highland vegetation composed of *Myrisine Africana, Erythrina brucei, Arundinaria alpina* and *Pittosporum abyssinicum.* Inspection of the vegetation along the western escarpment suggests that the same pattern repeats all along the hillsides.

EWNHS (1996) studied the forest between the two lakes and by the Kulfo River is dominated by *Ficus syamorus which* reaches 30m height. Other large trees include *Garcinia livigstomea*, *Cordia africana*, *Diospyrus* spp., *Vepris dainellii*, *Teclea nobilis*, and *Trchinelia emetica*. There are a number of shrubs and scamblers but a few herbs on the forest floor. Species found near the edge of the forest include *Terminalia brownii*, *Kigelia pinnata* and *Tamarindus indica.*

EPA(2005) describes the freshwater swamps at the mouth of the Kulfo River and Lake Chamo are dominated by *Typha domingensis*, tall water grasses, e.g. *Saccharum spotaneum*, and the smaller leguminous tress *Sesbania sesban* and *Aeschynomene elaphroxylon*. The species of the vegetation in the wetlands and the adjacent woody and forest vegetation are listed in the annex section (Annex Tables 44 and 45). The wetland vegetation consists of mainly species, which can be categorized as wetland associated rather than obligate wetland plant species, which is an indication of the incursion of the wetlands by non-wetland species as result of the recession of the lakes and the drying up of the shores making the area vulnerable to invasion by other species and over grazing.

ii) Fauna

According to EPA(2005) Nechisar National Park is popular for its wilderness and the unique scenery being located on the hills and plains between the two majestic lakes of Abaya and Chamo. The high population crocodiles in the lakes and the Nile Perch are unique to the waters of Lake Abaya and Chamo. The Species diversity of mammals is very impressive. The mammal diversity is next to the Mago National park. The diversity of the mammalian density owes to its inaccessibility to people other than the pastoralists who are probably lived in harmony with the animals.

According to APC(2006) due to geographical isolation and wide variety of ecological environment, NSNP support a variety of wild animals (mammals, birds, reptiles, amphibians and fish).Large mammals currently present are the common Zebra, Swayne's hartebeest, Grant's gazelle, Greater kudu, Guenther's dikdik, Anubis baboon, Colobus monkey, and hippopotamus. Spotted hyaena, Mountain reedbuck, Black-backed jackal, Side-striped jackal, Golden jackal, Defassa waterbuck, Bushbuck, Klipspringer, Warthog and Bush pig are said to be still present and Lions are occasionally seen.Nechisar is particularly important as a sanctuary for Swayne's hartebeest (sometimes also referred to as the ***Qorkay***) that is endemic to the Horn of Africa but is now extinct in Djibouti and Somalia and only survives in three isolated populations in Ethiopia. The total population in Ethiopia probably does not exceed 250 animals. It is more endangered than the Ethiopian wolf. It is a beautiful animal, colored more like a tsessebe than a hartebeest and will be a special species for Nechisar to conserve. Special species of the bush lands and thickets are the Black-billed wood-hoopoe, Taita fiscal (shrike) and the Boran cisticola. The open plains support three species that are little known in Ethiopia, they are an isolated population of White-tailed lark, the endemic Nechisar nightjar (known from only one record of a broken wing found on the plains in 1990) and the rare Star-spotted nightjar. There are also a number of other special bird species in the park including Lammergeyer, Red-winged francolin, White-fronted black chat, African cuckoo hawk, Bat hawk, African swallow-tailed kite, Ovambo sparrowhawk, Finfoot, Scarce swift, Grey cuckoo shrike and Reichards'seed-eater.

Lake Chamo supports a high density of very large crocodiles (many individuals in excess of 5m in length) with a particular concentration of them at the beach known as the 'Crocodile Market', the largest hippo population in Ethiopia, and abundant fish including Nile perch. The bird life on the lakes and in the groundwater forest is very good with 343 species recorded. Nechisar is classified as one of the sixty-nine Important Bird Areas in Ethiopia. The particularly special migratory species are Lesser kestrel, Pallid harrier and Lesser flamingo on the lakes. Figure.3.5 shows the wildlife distribution in the park where African Parks conservation collects this data for monitoring the wildlife movement and their density in the park.

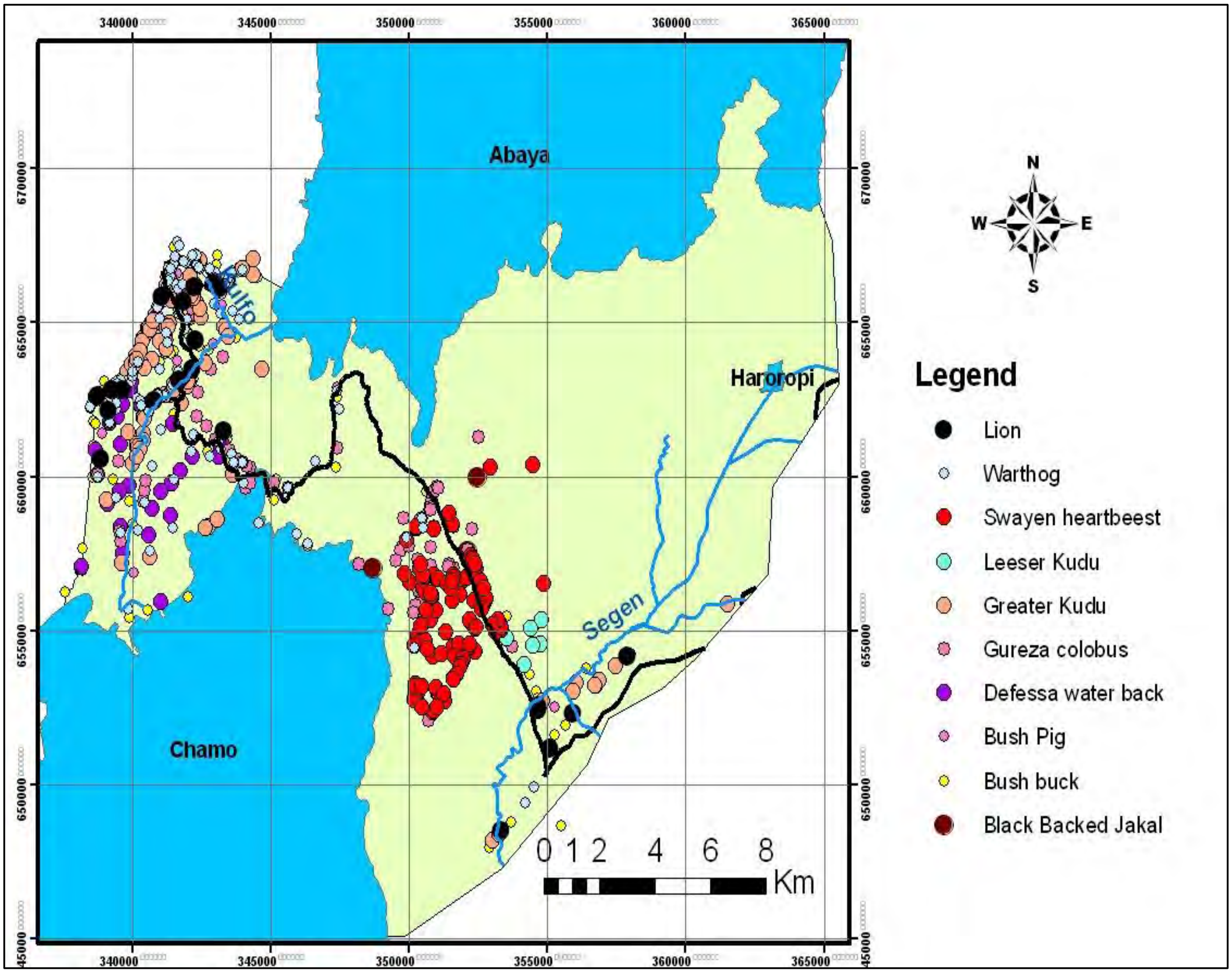


Figure.3.3 Wildlife distribution in the park: Nechisar-APF(2007)

3.1.4 Geology and Soil

EPA(2005) describes the Ethiopian Rift Valley is part of the great East African Rift Valley, which was formed as a result of Tertiary-Quaternary tectonic movements. The regression of the Mesozoic sea to the southeast and the occurrence of a major up lift, which is known as the *Arabo-Ethiopian* swell, preceded the formation of the rift. The Tertiary uplift and formation of the rift was followed by the extrusion of large masses of basaltic magma through fissures. As a result, in the Rift Valley lakes basins, including that of Lake Abaya and Lake Chamo, basalts, *ignimbrites*, *pyroclasts* and *lacustrine* sediments overlie the ancient basement rock. Other volcanic products such as ash flow, *tuffs*, *trachytic lava flows*, *alkaline* and *per alkaline silicics*, *rhyolites* and *pumicous* materials are found distributed through out the basin.Young volcanic and sedimentary rocks (Miocene to Recent) dominate the Rift Valley basin that lies within old (Precambrian) shield rocks. Quaternary basalt flows (recent basalts) are found near Arba Minch town and the hill separating he two lakes "*the Bridge of God*". The rift valley floor near Lakes Abaya and Chamo is filled with alluvial sediments.

Makin et.al(1975) describes soil types in the Rift Valley are closely related to soil parent materials: basalt, ignimbrite, lava, gneiss, volcanic ash and pumice, riverine and lacustrine alluvium. The soil of Nechisar plains and surrounding bush land is black cotton soil with high clay content. According to Bolton(1970) the rugged mountains parts of the park have brown calereous loam derived from volcanic rocks. The soil ranges from patchy dark clay alluvial soils along the river basin to dominating dry cotton soils with poor drainage.

3.1.5 Topography and Hydrology

According to a GPS site mark and checking the elevation values in DEM the study area has an altitude ranging between 1094m and 1383m above sea level (a.s.l) while the 90meter contour interval SRTM gives an elevation that ranges between 944m-3478m a.s.l. covering the Nechisar park and surrounding highlands as shown in the DEM hill shade values which is scaled in meter (figure.3.6). The Nechisar plains are bounded in the north by lake Abaya and in the south and southwest by lake Chamo. Lake Chamo receives runoff from river Kulfo originating from areas receiving rainfall following the climatic pattern of the southern parts of Ethiopia. This indicates that it receives runoff only once a year, unlike lake Abaya. Further more lake Abaya receives runoff from four river basins, while lake Chamo receives runoff from only two river basins. Lake Abaya receives 86.484mm^3 of discharge annually, while lake Chamo receives only 29.250 mm^3 of discharge. This partly explains why lake Chamo is more sensitive to climatic fluctuations than lake Abaya.

Kirubel(1985) describes the river Seremele that runs along the eastern most corner of the range is one of the permanent sources of water and it has both ecological as well as social influence concerning the settlement pattern in the study area. The seasonal river basin, flood plains and valley bottom are good providers of dry season grazing areas for domestic and wild herbivores. The Kulfo river flows through the north of Arbaminch and then cuts across the neck of the narrow isthmus of land and ends in a swamp on the shore of lake Chamo.The lakes and lakeshore areas are interesting component of the great biodiversity of the park.

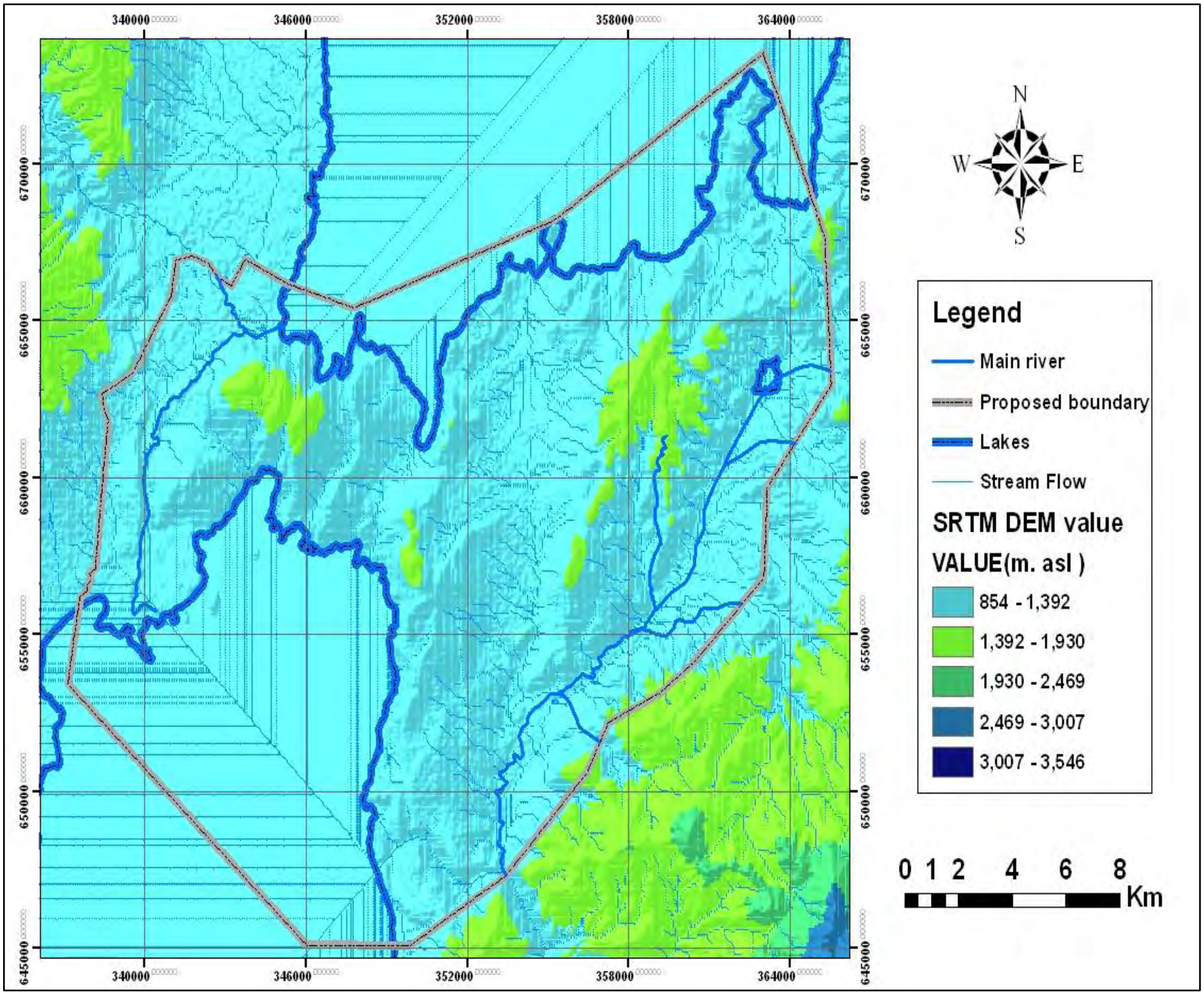


Figure.3.4 Topography and hydrology of the study area

3.1.6. Socioeconomic

According to SNV(2006) report Arbaminch Zuria Woreda covers an estimated area of 168,172 ha with estimated population of 232,000 with 50.8% male and 49.2% female proportion. Most of the area is mid-highland whereas 33% of the land is classified as low land and 14% as high land. The major crops growing in the area are maize, sorghum, teff, beans, bananas and mangos. The area is famous for its fish from the lakes and for the production of fruits such as banana,mango and highland fruits like apples and pears. The area is also on an important tourist route from Addis Ababa to Southern Ethiopia (Omo etc.). Since February 2005, African Parks (AP) has taken over the formal management of Nechisar National Park near the town of Arbaminch. The aim of African Parks is to rehabilitate and transform Nechisar into a model park for the benefit of Ethiopian people and communities around Arbaminch in particular. This requires local support and enthusiasm for conservation of Ethiopia's biodiversity. Moreover, people who used to depend on exploitation of natural resources from the park for their survival (i.e. firewood collectors, grass cutters, supposedly illegal fishermen), require alternative livelihood options. SNV Ethiopia Southern Portfolio(SESP) has been requested to assist African Parks in ensuring that local support through for example tourism activities and other viable income generating activities for rural people thus contributing to the park's sustainability.

According to EPA(2005) socioeconomic study the economic bases of the community in wereda adjacent to the national park are farming, fishing, and service (hotels and tour operators) and petty trade. In the case of Nechisar, the communities moving into the park came from two distinct ethnic groups, with different traditions of land use: the Kore people from the Amaro Mountains who cultivated land along the Sermele river floodplain and the Guji Oromo people who are nomadic pastoralists grazing approximately 4000 – 5000 head of stock inside the park. However, both these communities lived without schools, clinics and other essential services, and the Government is still in the process of relocating them to suitable areas near the Park where basic services can be provided.

3.2. Materials

For Remote Sensing and GIS works Software, program and other materials used:

- ArcGIS 9.2 and ERDAS Imagine 9.1,
- Garmin GPS-receiver,
- Digital camera,
- Topo map of the study area (1:50,000 scale),
- Landsat, ASTER and MODIS-NDVI Satellite images,
- SRTM(90m contour interval),
- Google earth Digital globe images,

Numerous researchers, including Lillesand et al. (1998), Lunetta and Balogh (1999), Oettera et al. (2000), Wolter et al. (1995), and Yuan et al. (2005) have demonstrated the value of multi temporal imagery for classification of land cover. Landsat imagery is available since 1972 from six satellites in the Landsat series. These satellites have been a major component of NASA's Earth observation program, with three primary sensors evolving over thirty years: MSS (Multi-spectral Scanner), TM (Thematic Mapper), and ETM+ (Enhanced Thematic Mapper Plus). Landsat supplies high resolution visible and infrared imagery, with thermal imagery and a panchromatic image also available from the ETM+ sensor. The collection of Landsat available through GLCF is designed to compliment overall project goals of distributing a global, multi-temporal, multi-spectral and multi-resolution range of imagery appropriate for land cover analysis.

The following Landsat images in table.3.1 were down loaded from the GLCF site that provides free multi-temporal, multi-spectral and multi-resolution range of imagery which is appropriate for land cover analysis of this study (www.landcover.org).

The general information of the other satellite images that were used for this study is organized in table 3.2.

Table.3.1 Landsat images downloaded for the study (www.landcover.org)

Landsat sensor Types	Path and Row	Date of Acquisition	Spatial Resolution (m)
Landsat-MSS	181_56	Jan.25,1976	57 * 57
Landsat-TM	169_56	Jan.28,1986	28.50 *28.50
Landsat-ETM+	169_56	Jan.27, 2000	28.50 *28.50
Panchromatic	169_56	Jan.27, 2000	14.25 * 14.25

Table.3.2 Satellite image general information used in the study

Type of Satellites	Platform	Sensor	1st launch	Bands	Spatial resolution	Revisit period
Earth Resource Satellites	Terra ASTER	VNIR		Band 1 (0.52 - 0.60) $w/m^2/sr/\mu m$ Band 2 (0.63 - 0.69) $w/m^2/sr/\mu m$ Band 3N (0.78 - 0.86) $w/m^2/sr/\mu m$ Band 3B (0.78 - 0.86) $w/m^2/sr/\mu m$	15 meters	16 days
Earth Resources Satellites	MODIS	Terra	March 2000	Band 1 620 – 670 nm Band 2 841 – 876 nm Band 3 459 – 479 nm Band 4 545 – 565 nm Band 5 1230 – 1250 nm Band 6 1628 – 1652 nm Band 7- 2105 – 2155 nm Band 8- Band 36	250meters	1 to 2 days
Earth Resources Satellites	SRTM	C-band and X-band	February 2000	C-band and X-band	30meters 90meters 1Kilometre	stopped

3.3. Methodology

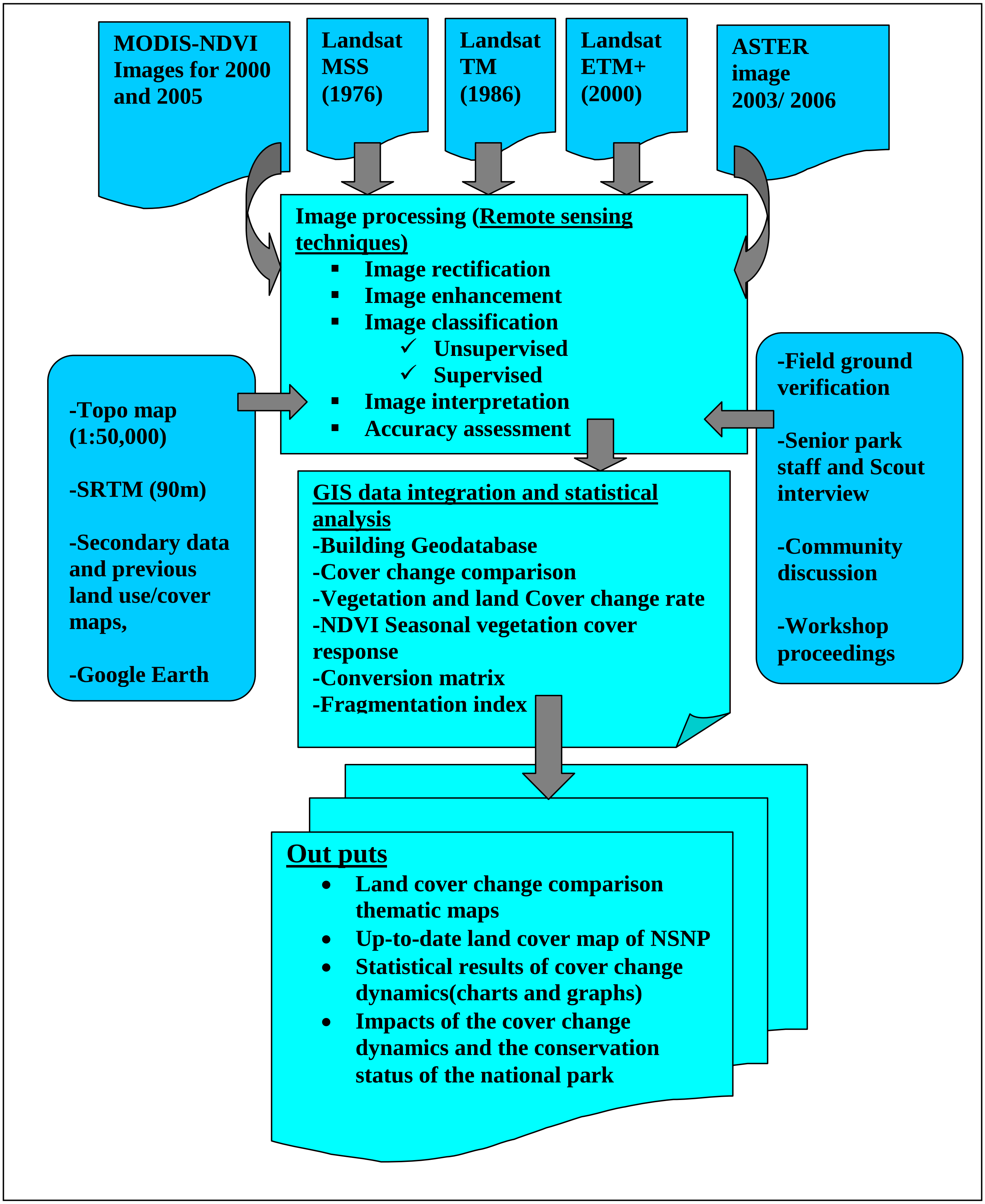
The three series of Landsat images for the years 1976, 1986, 2000 which are cloud-free and all taken at the same month as shown in Table.3.1. All images were ortho rectified to UTM zone 37N, WGS 1984. Image processing and GIS data analysis were carried out using remote sensing and GIS software including ERDAS Imagine version 9.1 and ArcGIS version 9.2 respectively. Image enhancement, Noise removal, radiometric correction and distriping were carried out for all Landsat images when necessary.

The Landsat images for the three series of years were used to study the major land cover dynamics for 24 years in order to show the conservation status of the national park. The MODIS Normalized Difference Vegetation Index (NDVI) data set is available on a 16 day basis for the two year period of 2000 and 2005. The product is derived from bands 1 and 2 of the Moderate-resolution Imaging Spectro-radiometer on board NASA's Terra satellite. A time-series of NDVI observations can be used to examine the dynamics of the growing season or monitor phenomena such as droughts.

ASTER image 2006, previous land cover results, Google earth image KML files, Field inventory are the basic source of information to generate up-to-date land cover map of the national park. During analysis of the ASTER images for accurate training area selection, information from various sources is integrated including the results from the past Landsat cover classification for 1976, 1986 and 2000.The MODIS-NDVI images are the important source of information to show the vegetation and land cover responses for a yearly period. The land cover classes are also generated from the MODIS images with a resolution of 250m.The response of land and vegetation cover has been compared for 2 years period including the year 2000 and 2005 and the profile for NDVI values are compared for selected land cover classes.

The research overall work flow is organized in the schematic diagram and all input data and images used for different analysis are presented in Figure.3.7 including the research processes and expected outputs.

Figure.3.5 Schematic diagram of the research work flow



3.3.1 Data collection

During the study various techniques were employed to collect basic data for the study. The basic data collection methods are listed below:

i) Preliminary field visit and general observation

A preliminary field survey has been conducted to get a general view on the physical condition of the area such as the major vegetation cover types; Land use and land cover types, landscape pattern and topography. During this stage of the process, detailed investigations were carried out into past and present land cover type condition and management practices. Information was gathered using different tools, such as taking Ground control points using GPS-receiver, interviewing park senior scouts, taking digital photographs, draw simple sketches with notes. The preliminary information helps to understand the existing situation of the park, the major vegetation and land cover types.

ii) Field inventory

To study the major land cover types and vegetation distribution intensive field work were conducted in all accessible park destination.Garmin GPS-receiver were used to mark the way points for various land cover types as referred from the unsupervised post classification. Senior scouts also provide the background of the different patches of land cover concerning resource utilization, community impact and also natural events such as fire. Concerning the vegetation types and distribution, general inventory were made for the whole site and physiognomy data collected for the woody type of vegetation such as height of trees and diameter at breast height(DBH) measures collected for representative sample plots to cross check the results with reviewed literatures and general information.

iii) Secondary data

Satellite images, Topo map and other resources in this study are treated as secondary data sources. All remote sensing land cover classes extracted from multidated satellite images have been cross checked with the information collected from reviewed literatures, Topo map and other published maps. For accurate land cover classification appropriate training sites are set to extract satellite image information according to classification criteria and based on the objective of the study

3.3.2 Data analysis

i) Training site selection for field work and pre field analysis

Prior to the field work unsupervised image classification were conducted to extract information from the Landsat images including 1976, 1986 and 2000 and to understand the general land cover classes of the study area. The post classification was conducted using remote sensing software; ERDAS imagine 9.1 and the land cover classes are visually cross checked from previous published maps. Since it’s difficult to rely on unsupervised classification to describe all the vegetation and land cover types thus interpreting satellite images should be complemented by field inventory. Based on the results from unsupervised classification sample training sites were selected for data collection during field work. Using Garmin GPS receiver all representative class way points are checked and collected from the national park.

ii) Satellite images spectral band selection

Landsat imagery is acquired in a very precise manner, to better emphasize particular land cover aspects. Some of the parameters of this precision involve a scene’s radiometry, providing distinct characteristics to components of the image scene. These measures help determine what the images are good for, from a science perspective. For example, Bands 1, 2 and 3 are used together to approximate how the real world appears. Bands 4, 5 or 7 from ETM+ are used in combination with 1, 2 or 3 to demonstrate vegetation conditions. It is sometimes necessary to convert the radiometric values from the initial at-sensor measures, to compensate for atmospheric interference. Basic information that were used for image interpretation and band combinations for Landsat images as referred from GLCF site is provided in the table below(Table.3.3).

Table.3.3 Landsat image Spectral Bands and their Application

Band	Band name	Application
0.45-0.56	Blue	-Soil and vegetation discrimination
0.52-0.66	Green	-Green vegetation mapping and cultural/urban features
0.63-0.69	Red	-Vegetated and non-vegetated mapping
0.76-0.90	NIR	-Delineation of water body -Soil moisture discrimination
1.55-1.75	MIR	-Vegetation moisture discrimination -Soil moisture discrimination
10.4-12.5	TIR	-Vegetation and soil moisture analysis -Thermal mapping
2.08-2.35	NIR	-Discrimination of minerals and rocks -Vegetation moisture analysis

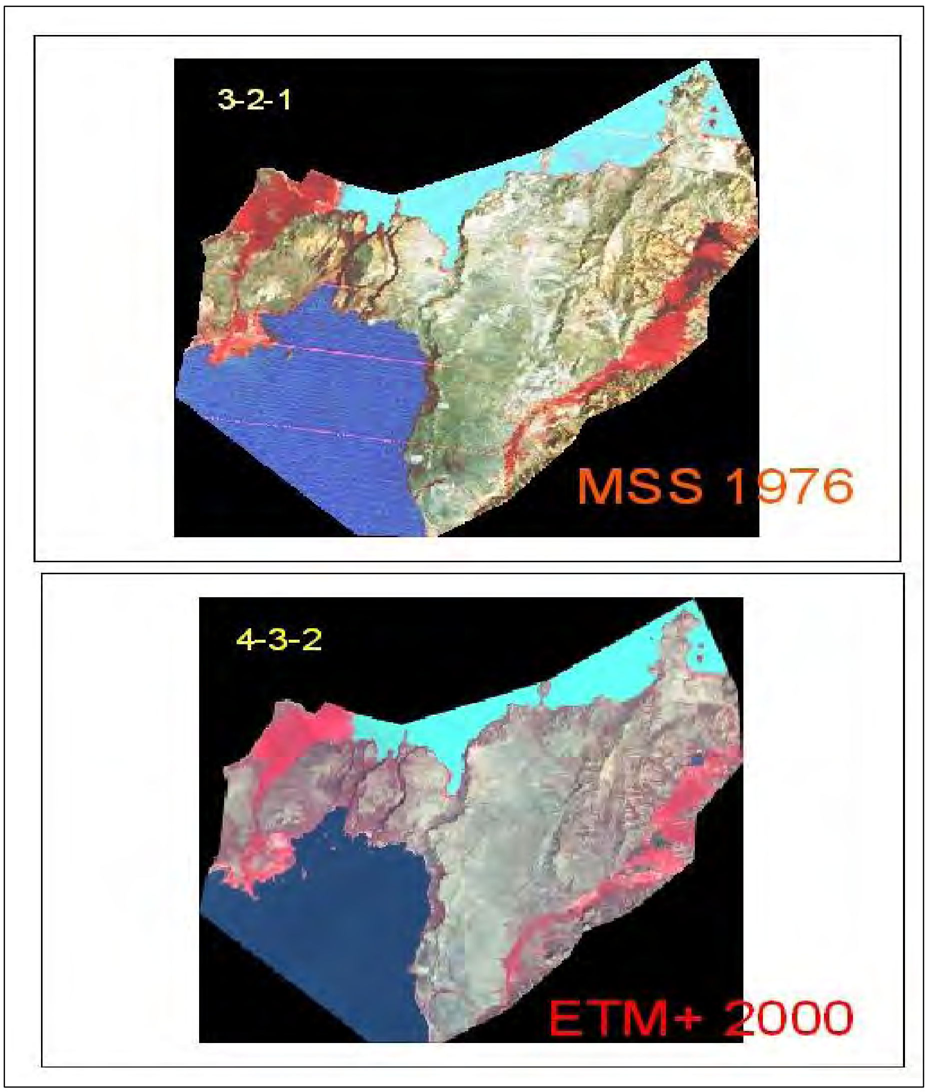


Figure.3.6. Landsat images used for land cover study

iii) True and False color composite image Preparation

In this research TCC and FCC were found to be more useful for the process of identifying the different land cover classes in the study area. The applications of bands for different feature identification were used according to the information provided in table 3.3. Different band combinations both TCC and FCC are used to select the training sites for supervised classification. According to the information extracted the spectral response for different features and land cover types is analyzed. The spectral profile graph below shows the response of each land cover for different spectral bands.

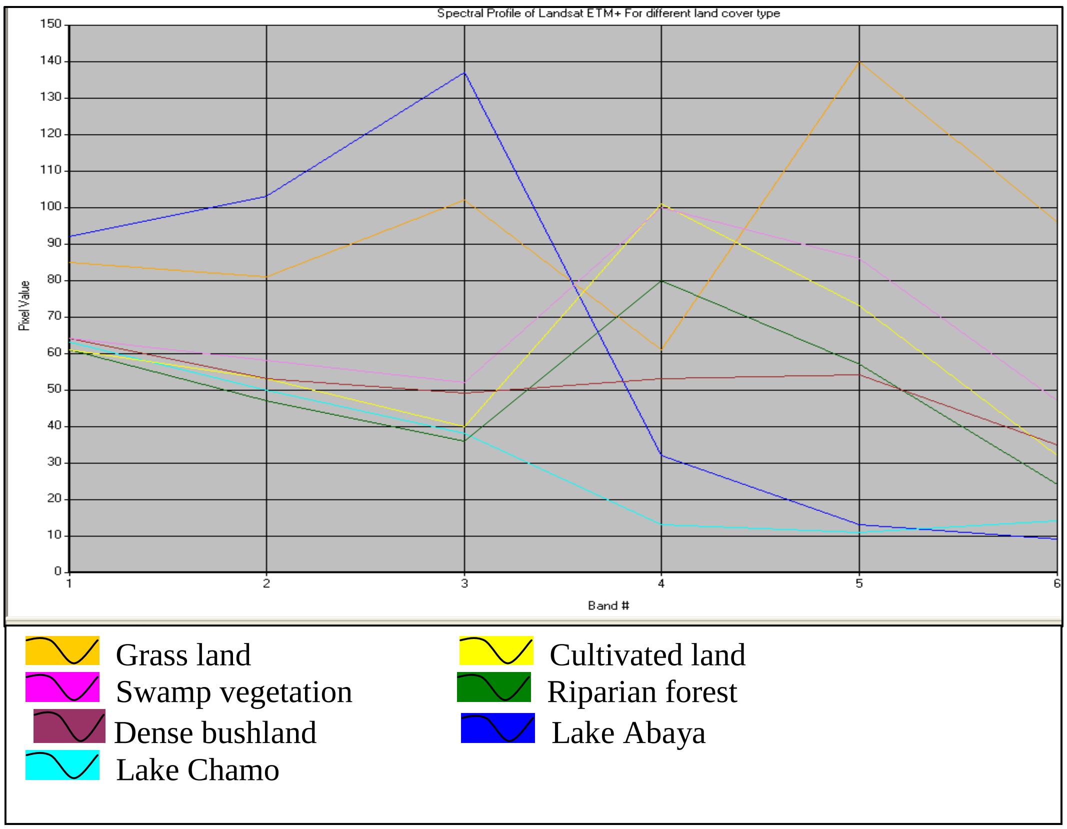


Figure.3.7 Spectral response of Landsat ETM+ for different cover classes

In order to enhance the images for visual interpretation of the different features FCC (False Color Composite) and TCC (True Color Composite) band combination gives various layers which are used to select training sites for major land cover class identification. The spectral value for all Landsat sensors is directly related to the land cover and scene of a given area in time. The figure below shows the Landsat image band response for different land cover classes (Figure

.3.9).For the analysis of various land cover types the different color composition of the band combinations were checked for better visual interpretation. In this case the one that allows identification of most of the categories of land cover classes were the color composite red 4, green 3 and blue 2 which is false color composite. A true and false color composite image helps to enhance the visualization and to prepare the image for further classification (Figure.3.10).

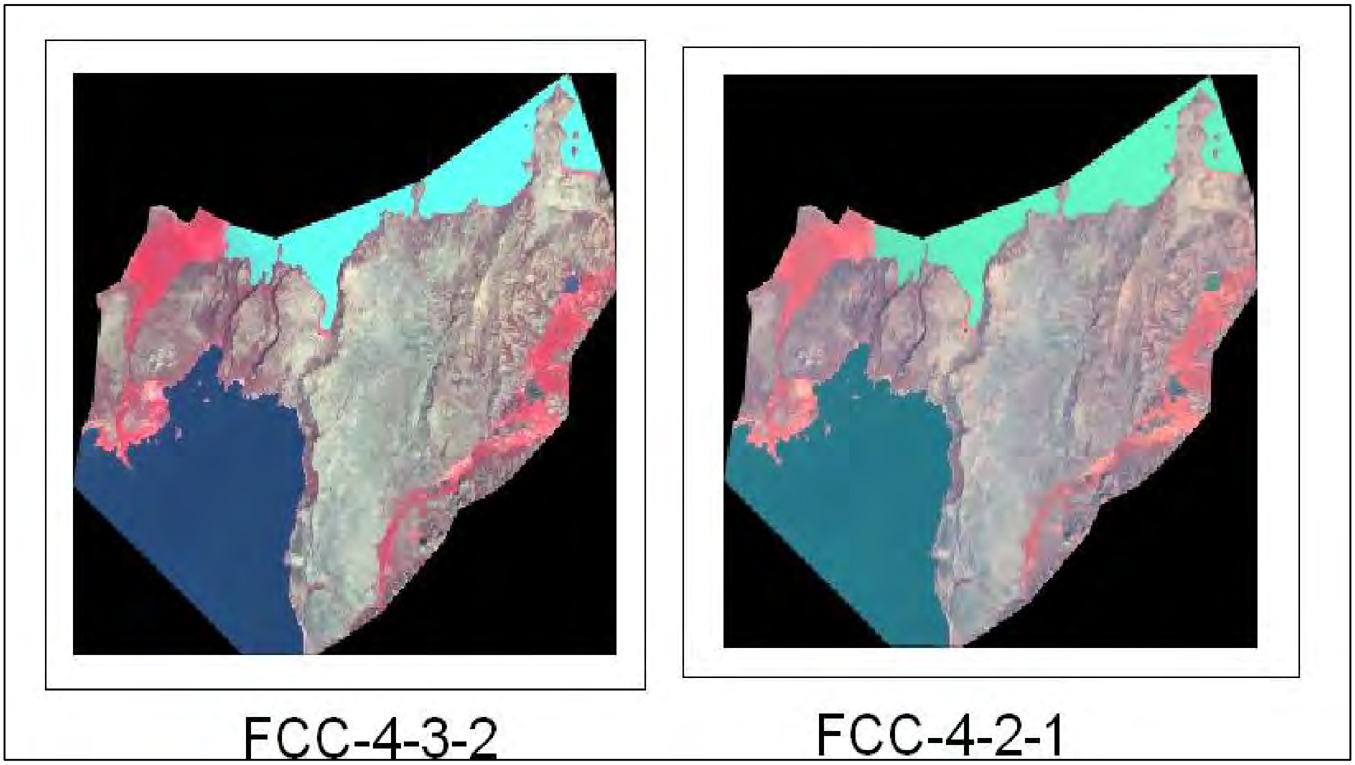


Figure.3.8. False color composite images of Landsat ETM+

Vegetation has a very high albedo in the NIR band since chlorophyll (the pigment in leaves that give plants their green color) reflects energy at this wavelength. Thus, in a 423 NIR composite image, vegetation is vividly depicted as varying shades of red. Since different types of vegetation have different levels of chlorophyll in their leaves, each type of plant has its own shade of red. This makes a 432 composite very useful in determining the extent of vegetation and for classifying different vegetation types as seen from space. Water, which absorbs nearly all of the NIR energy that reaches its surface, appears very dark, nearly black, in a 432 NIR composite images.

iv) Dynamics of Land cover structure

Land cover changes in the study area over 24-years of period were extracted from Landsat Multi temporal (Landsat MSS) Landsat Thematic mapper(TM) and Landsat Enhanced Thematic Mapper Plus (Landsat ETM+) images for 1976, 1986 and 2000 respectively. Land cover maps were generated from analysis of the geo-rectified satellite images, using a supervised maximum likelihood classification. Supervised Image classification was conducted for each of the satellite image using the ERDAS Imagine 9.1 software. In order to study the land cover structure changes in the study area land cover change rate, land cover conversion matrix and fragmentation index were analyzed.

▪ Land cover change rate

The land cover map for the three year series of images is analyzed based on land cover types area comparison and land cover changes using graphs and charts. The changes over 24 years were analyzed and rate of change for each land cover type is calculated. The rate of land cover change is calculated for the two periods from 1976-1986 and 1986-2000 using the following simple formula below.

Rate of land cover changes(ha/year) =(A-B)/C

Where A-Recent land cover area size
B- previous land cover area size
C-Number of years between A and B

▪ Land cover Conversion Matrix

The land cover conversion matrix used to analyze the source and destination of each cover type. The land cover conversion matrix analysis is conducted in ERDAS Imagine 9.1 and conversion comparison map prepared and each land cover change values are analyzed in excel sheet to clearly show the source and destination of cover types in table and graphs of cover change dynamics.

▪ Landscape Fragmentation index

Fragmentation of ecosystems into small patches can reduce habitat for wildlife species that require larger, connected patches. Landscape ecological theory and GIS technology have generated a number of measures of the spatial distribution of habitat that express different aspects of its fragmentation in ways that relate to ecological processes. These have mostly been used in the evaluation of habitat and landscape processes at management unit scales.

Fragmentation Index(Pa) = Ai/n

Where Ai = the total area of a given land cover type
n-the number of patches of each land cover

Fragmentation index is the mean area of the land cover/use type '**i**'. It is a measure of the degree to what extent a landscape is fragmented during the course of a change. The bigger Pa, the more fragmented is the land type i.e. disturbed land simply has fragmented Patches.

v) MODIS-NDVI images

Comparisons of cover classification using MODIS-NDVI images with resolution of 250m and it gives good result which puts a clear boundary for the vegetation cover types and other non vegetation cover classes. Spectral response of the NDVI images which gave the monthly NDVI response values in average throughout the year have been compared for the year 2000 and 2005 images to check seasonal responses.

vi) Accuracy Assessment and Current land cover mapping

Generally Nechisar national park has undergone a series of land cover changes for the past 31 years and this study includes the cover change analysis for 1976, 1986, 2000 and 2007. The land cover changes for the past 24years is analyzed using the Landsat multidated satellite images and the information from those thematic maps were used to interpret and generate the final land cover classes for up-to-date land cover mapping using the ASTER images.

To validate and crosscheck the result of the Landsat classification with known Ground truthing data Accuracy assessment is checked for the signature values of classified images calculating the error matrix in ERDAS Imagine 9.1 software. All land cover change analysis is conducted using the park boundary area which is proposed by APF- Ethiopia to be included as part of the National park. The exsisting park boundary covers small portion of the lakes particularly Chamo(Figure.3.11).The area distribution in the proposed boundary covers a large portion of Lake Chamo 82% which covers 7964.70ha, Lake Abaya covers 804.48ha, the remaining area covers part of the crocodile ranch forest, Arbamench town neborhood buffers including park main gate forest and Konso road ridge side open bushy field in total covers 526ha.

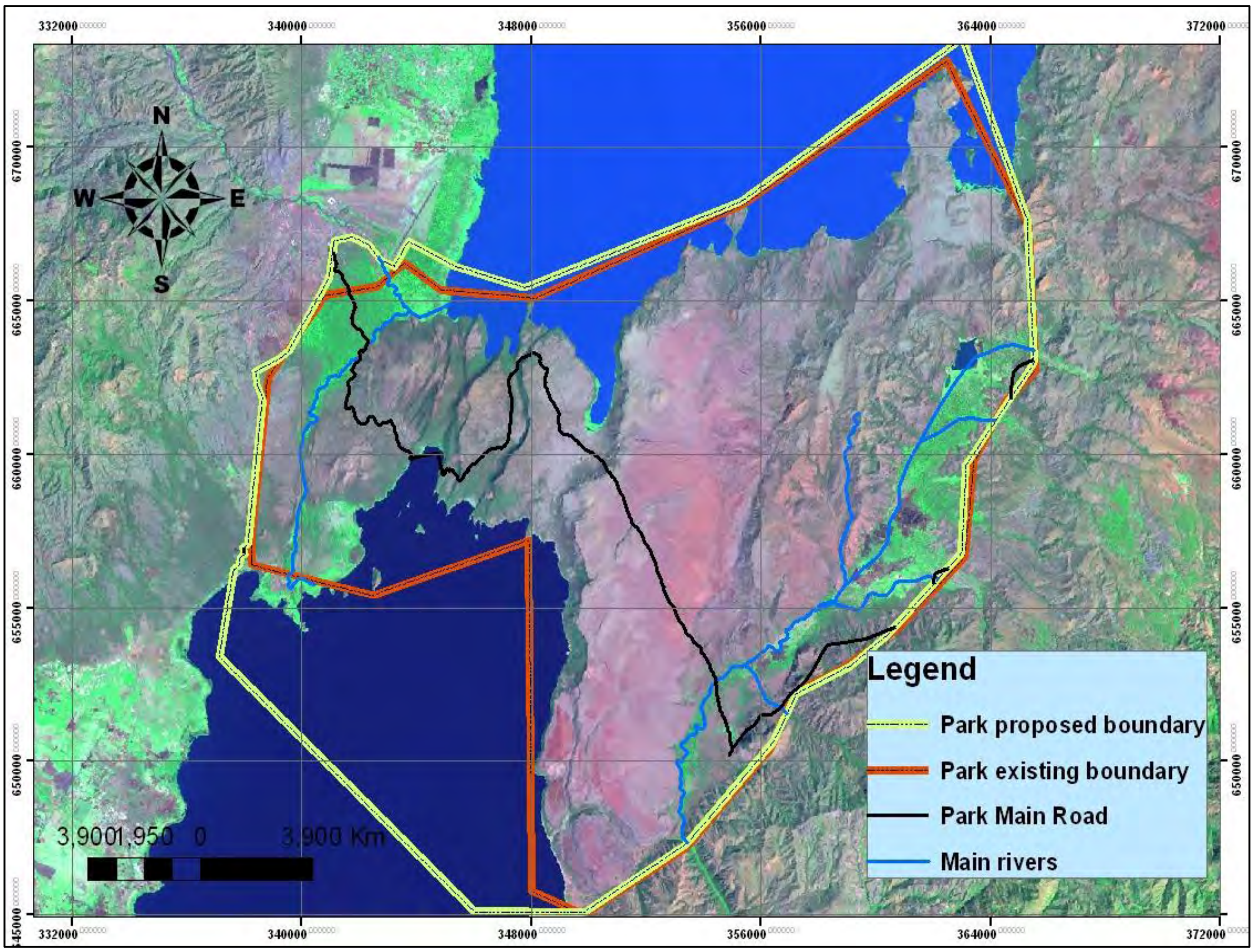


Figure.3.9 Existing and proposed park boundaries

4. Result and Discussion

4.1 Results

4.1.1. Land cover classification approach

The criteria's mentioned for **land use** and **land cover** classification in the literature section (Section 2-2) are used while conducting the land cover analysis from Landsat images in this study. Those criteria's mentioned in section 2-2 were applied primarily to set the **land cover** classes and to interpret the remote sensing data and also to check the accuracy of the classification. To understand the background information of the study area from the multidated Landsat images the major land cover classes of the study area are evaluated using the information extracted from various sources based on the important classification criteria.

According to Bolton(1970) the Nechisar national park vegetation type is described as savannah grassland with scattered *Acacia commiphora* trees and bush. He mapped the vegetation in to four major cover classes. This includes Grassland, Bush land, Riparian and Ground water forest and Thicket. Besides the vegetation classification he also mapped part of Chamo and Abaya as a water body of the park. Bolton classification provides important background information of the park situation for the 1970's and this are used to understand the park major land cover types starting from the 1970's and background information is extracted for the 1976 Landsat MSS-satellite image, which help as a baseline for the past and current land cover classification study .

Topo map of the study area which is published by the Ethiopian mapping authority in 1979 was a good source of Land cover information to guide for the previous years image classification. The Topo map gave detail description of features and cover types of the national park. Figure.4.1 shows the mosaic of the Topo map used for this study.

The other source of land cover information which guide Landsat classification is map of Rift Valley Lake Basin (RVLB) project which is published in 1992 by FAO/UNDP.This land use/land cover map is more detailed and have the major land cover classes of the study area such as lake Water body, Dense bush land, Open bush land, Bushed shrubbed grassland, Open grass land, Dense woodland, Riparian wood land and state farm.Fig.4.2 shows the cover classification according to RVLB(1992) project which is conducted by FAO/UNDP.

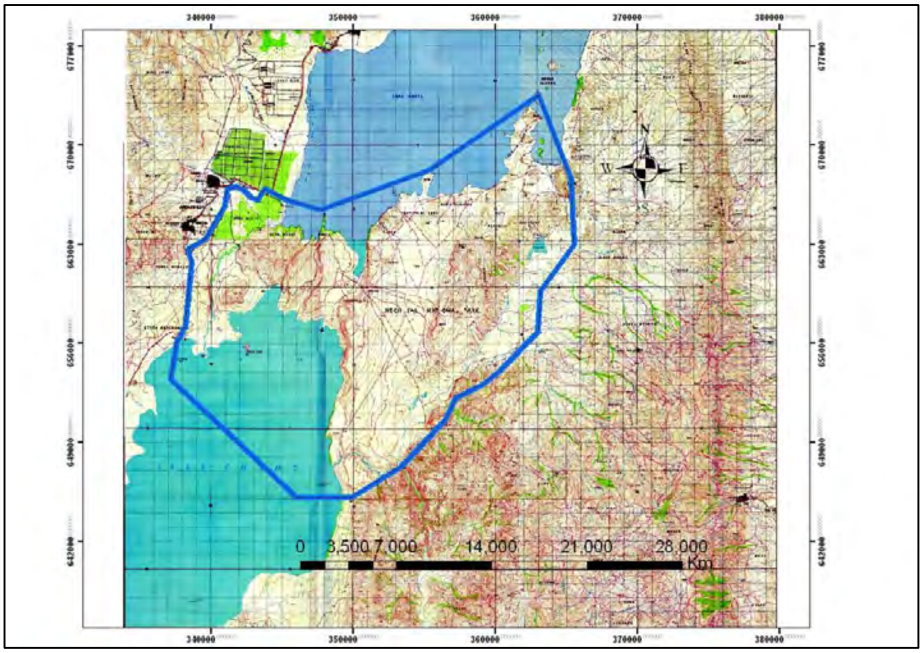


Figure.4.1 Topo map of the study area

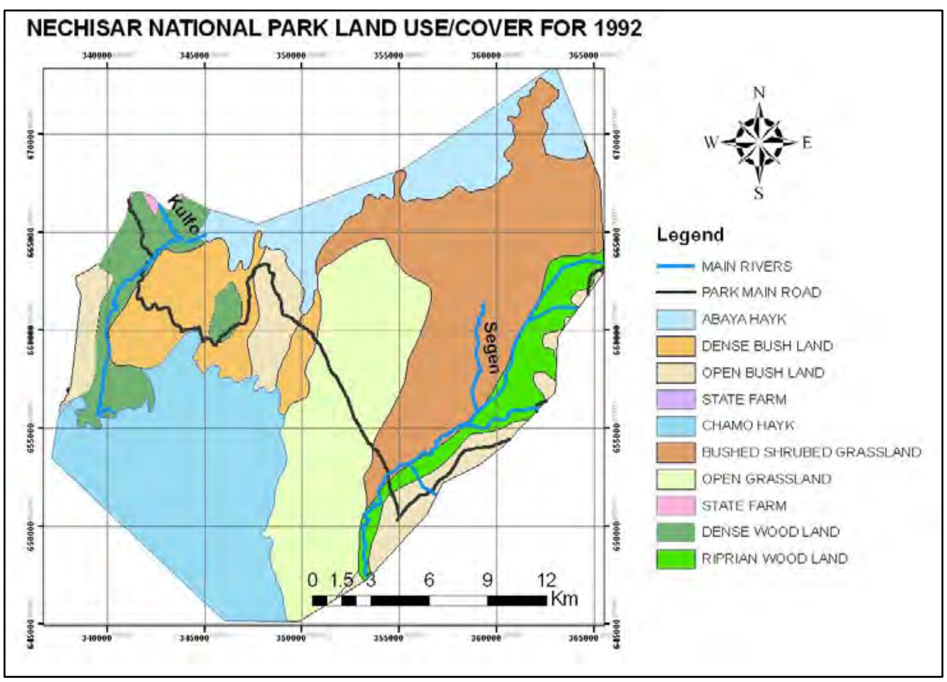


Figure.4.2 Land use/cover map according to RVLB project (FAO/UNDP, 1992)

The Major Land cover classes identified in the National park are discussed from field note information and reviewed literatures with supportive illustrative pictures which are selected from the site to represent each land cover class. According to the information extracted from various sources and results from field inventory the following major land cover classes are set to study the cover classes for 1976, 1986, 2000 and 2007:

1. Riparian and ground water forest
2. Acacia dominated Wood land
3. Dense bush land
4. Bushy shrubbed grass land
5. Open grass land
6. Swamp vegetation
7. Cultivated land
8. Water body
9. Bare land and erosion

The major vegetation and land cover classes are well defined in section 2 and here to give you a good impression of the study area and the above land cover classes each land cover description is discussed separately with illustration pictures that are taken from the site.

1. **Riparian and Ground water forest :** ICBP(1992) describes Riverine forest occurs as narrow strips along the Kulfo and Seremele rivers and also as a small area of spring-fed ground water forest along the base of the scarp at the eastern edge of the Arbamench town. From the eastern bank of the Kulfo river the hills rise steeply and almost all the forest lies to the west of the river. The evergreen groundwater forest in the western sector supports an exceptionally diverse range of species. According to field inventory this habitat is dominated by *Ficus sycamorus* and *Lecanodiscus fraxinifolius* species of trees that are up to 30m tall. APC(2006) reported this forest is said to be unique in Africa and its existence, as such, is closely associated with the series of freshwater springs, known as "Arba Minch", meaning "Forty Springs". Originating from the western edge of the forest,

at the foot of the western escarpment, these springs provide the source of water supply to Arbaminch town, as well supporting the natural forest biodiversity. The species composition of the Kulfo riverine forest and the ground water forest are so similar that they are treated together as referred from literatures and field inventory. The tallest forest occurs along the river banks and is dominated by in average 30m high *ficus sycamorus*,which species together with two other large trees *Garcinia livingstonea* and 'tendon tree' was confined to the river edge. Other common tall trees of the canopy include *Cordia Africana,Diospyros abyssinica,Vepris dainellii,Tecica nobilis and Trichilia emetica*,less widespread species are *Acacia poleacantha,Trema orentialis,and Celtis Africana.*Smaller sub canopy trees include *Mimusops kummel,vernonia* species *Cussonia holstil* and occasional *Eiclea schimpei and Tamarindus indica*(ICBP,1992).Large forest associated shrubs include *Carissa edulis(*scrambling*),Ricinus communis(on* open areas of river bank and an understorey bush Lianas and creepers include *Hippocraea aficana,Plumbago zeylanica,Pergularia daemia,Cissus rotundifolla.*Few herbs and grasses are present on the forest floor,most of which consists of bare expanses of leaf litter. Figure 4.3 shows part of the ground water forest canopy and Riparian vegetation.

Figure.4.3 Ground water forest and the Riparian vegetation

The Seremele river valley supports a riverine forest with fewer plant species compared to the Kulfo riverine forest /Ground water forest and with a more broken and uneven canopy, often less than 50m wide. At the camp the forest was very narrow, only 2 to 3 tree wide, perhaps the river here flowed in such a deep, narrow cutting and thus didn't provide such an extensive water table. Further to the north and upstream, however at least eight tributaries fed in to the river creating broader and quite swampy riverine forest, several hundered meters wide. It was characterized by large Ficus species and areas dominated by quite dense stands of *Acacia polecantha*,with an understorey of *Maerua aethiopica*,*Capparis tomentosa*,Grewia species,*Balanites aegyptiaca* and other bushes (ICBP,1992).

2. <u>Open Grass land</u>: According to APC(2005) report the Open grass land usually called as Nechisar plains that are the dominant feature of the park and the main source of food for grazing animals. These plain cover an area of 10,000ha and are covered by the grass *Chrysopogon aucheri* that whitens during the dry season and grows on friable black soils. The grasslands cover the Nechisar plains, a flat or undulating area of about 270sq.km at 1200m elevation, extending from Degabulle in the west to the Harre hills in the east and from Dachie in the north down to the course of the dried up Mio-river to the south. This grassland also extends onto the hill-slopes surrounding the plains (ICPB, 1992).Figure 4.4 represent the Open grassland Nechisar plain. The diagrams below is taken from field and selected to represent open grass land cover type (Figure 4.4).

Figure.4.4 Open grass land at Nechisar plain

3. <u>Bushy shrubbed grass land</u>: This habitat and land cover type includes the grass land with scattered trees, shrubs and bushes distributed evenly and cover a large area of the park**.** Most of the hills and gentler slopes of the Nechisar park are covered with a bush savanna which consists of scattered shrubs and low bushy trees commonly occurring are *Acacia melleferia,A.nubica,A.brevispica,,Combertum spp.Capparidaceous* forms such as *Cadaba adenotricha* and various small xerophytic shrubs.Sometimes there are taller scattered trees of *Acacia tortils,A.seyal,Combretum sp.,Balanites egyptica,D.cinerea* and occasionally *Acacia nilotica*(Bolton,1970).Figure .4.5 represents the cover class for bushy shrubbed grass land.

Figure.4.5 Bushy shrubbed grass land

4. <u>Wood land</u>: The woodland habitats which include mixed woodland, dominated by different species. This habitat mainly occurs in the south western parts of the park next to highland drainages the largest area cover is close to the Kulfo riparian forest and lake Chamo. This woodland habitat has an even distribution of trees, uniform canopy (*Acacia seyal*); almost with some under story of bushes or shrubs and typically with a well developed grass cover. Riparian woodland is also found along many of the drainages and tributaries to main rivers such as Seremele. This vegetation type has a clear understorey tall grass formation typically dominated by tall Acacia trees (*Acacia polychanta*).In the woodland *Acacia mellifera* and *A.nilotica* are the dominant plant species associated mostly with different herbaceous plants in the understorey.*Cenhrus ciliaris* and Digitaria species are localized to water logged areas under tree shades in the woodlands. In the mountains wood land where there is high stone cover and the land form is steep sloppy *Loudetia arundinacea and Loudetia flavida* are dominant grasses under the canopy of *combertum molle*,*Dichrostachys cinrea*,*Ozoroa insignis* and acacia species(Tamrat,2001).Figure 4.6 represents the land cover class of acacia wood land.

Figure.4.6 Acacia wood land

5. <u>Dense bush land</u>: This major habitat in the park is made up of a narrow isthmus of land, about 3.5-6km wide separating the two lakes. The isthmus is mostly composed of old lava flows and is covered by dense thickets that in places are almost impenetrable. These also occur on escarpments, steep rocky slopes and in gullies throughout the park as well as on the marginal vegetation of lakes Abaya and Chamo (Yisehak, 2006).During field inventory the common vegetation types includes *Acacia mellefera and Euphorbia inaequilatera* often dominant species in closed thicket together with *Acacia Senegal*,*A.brevispica*,*Rhus natalensis*,*Grewia spp*,*Balanites orbicularis*,*Capparis tomentosa and Savseveria spp*(APC, 2006).Look Figure 4.7 below.

Figure.4.7 Dense bush land

6. Swamp vegetation: The margins of lakes Abaya and Chamo are mainly shallow and support a rich marginal vegetation of species such as *Thypha angustifilia*,phrgmites sp. and Juncs sp. With tall water side grasses such as *Loudetia phargmitoides* and bushes of locally known as Shershento,*sesbania sesban var.nubica* and S.guzethia.The hot springs drains very shallowly west from a point near the base of the Yaro hills, producing a small marsh with a reed bed and other marginal vegetation. The Kulfo river supports extensive swamps at its mouth dominated by *Thypha angustifilia.*Tall waterside grasses and lush flood plains *with Saccharum spontaneum* occur along the Sermele river. According to field visit the small lake Haroropi surrounding is mainly covered by swamp vegetation including long grasses and a wood species locally known as Soke. figure.4.8 below shows the Soke and Shereshento at Chamo and Abaya lake shores .

Figure.4.8 Swamp vegetation at lake shores (Soke, Shreshento and swamp grasses)

7. Water body:

The lakes and lakeshore areas are an interesting component of the great biodiversity of the park ecosystem. Lake Chamo supports a high density of very large Nile crocodiles (many individuals in excess of 5m in length) with a particular concentration of them at the beach known as the 'Crocodile Market', the largest hippo population in Ethiopia, abundant fish including Nile perch and water related birds. The two water bodies (Abaya & Chamo Lakes) are important for lake tour (boating journey) and potential for fishing (APC, 2006). Many perennial and intermittent rivers drain into the two lakes. Lake Abaya receives high runoff all the year round except for two months. Lake Chamo receives Runoff mainly from river Kulfo originated from areas receiving rainfall following the climatic pattern of the southern parts of Ethiopia. This indicates that it receives runoff only once a year, unlike Lake Abaya. Further more Lake Abaya receives runoff from four river basins, while Lake Chamo receives runoff from only two river basins. Lake Abaya receives 86,484 mm^3 of discharge annually, while lake Chamo receives only 29,250mm^3 of discharge. This partly explains why Lake Chamo is more sensitive to climatic fluctuation than Lake Abaya (EPA, 2005). Figure.4.9 shows part of the beautiful lake Abaya and Chamo.

Figure.4.9 View of lake Abaya and Chamo

8. <u>Cultivated land:</u>

The Kore people from the Amaro Mountains who cultivated land along the Sermele River floodplain and the Guji Oromo people who nomadic pastoralists are grazing approximately 4000 – 5000 head of stock inside the park and rarely engage in farming activities. The farming activities following the Seremele flood plain was mainly run by the Kore community and after the resettlement program which is implemented by the government in negotiation with African parks conservation and the community is not active any more. But during field inventory there are encounters to investigate productive corn fields and also fruit tree and coffee farms along the Seremele valley.The other farming activity is located at Chamo letto which covers a large area and during field inventory the farmers mainly grown Corn, banana and sugar cane. The farming activity at chamo letto is still active and has a long history where the government plans the area for farming for the community that are resettled from other areas. The water for irrigation is directly diverted from the Kulfo river. Figure.4.10 shows the different crop types that are cultivated at the Seremele valley and Chmo leto areas.

Figure.4.10 Cultivated areas inside the park (Seremele valley and Chamo letto)

9. <u>Bare land, Bare bushed grass land and Erosion</u> :

The Bare land cover class represents areas that are covered by rock outcrop, bare soil, degraded land, rocky and rugged topography areas having thin vegetation cover. We can find this land cover scattered throughout the park. This land cover class exists mainly from human induced problems such as farming activities and cattle overgrazing, wild animal and cattle trampling. There are areas naturally bare such as lava flows, rock outcrops, land slides and eroded sloppy areas. This cover classes are hard to identify from images as they cover small non continuous patches and also scattered through out the park.

Figure.4.11 Bare land and erosion

4.1.2. Land cover classification

i. Unsupervised Classification and Field Verification

The unsupervised classification provides a "first look" statistical display of natural groupings of data based on spectral values in an image. Unsupervised classifications were performed on each of the scenes using image classification techniques. The resultant classifications were defined and then evaluated for accuracy. Evaluations included field verification of predicted vs. actual land cover for selected sample sites throughout all major land cover categories.

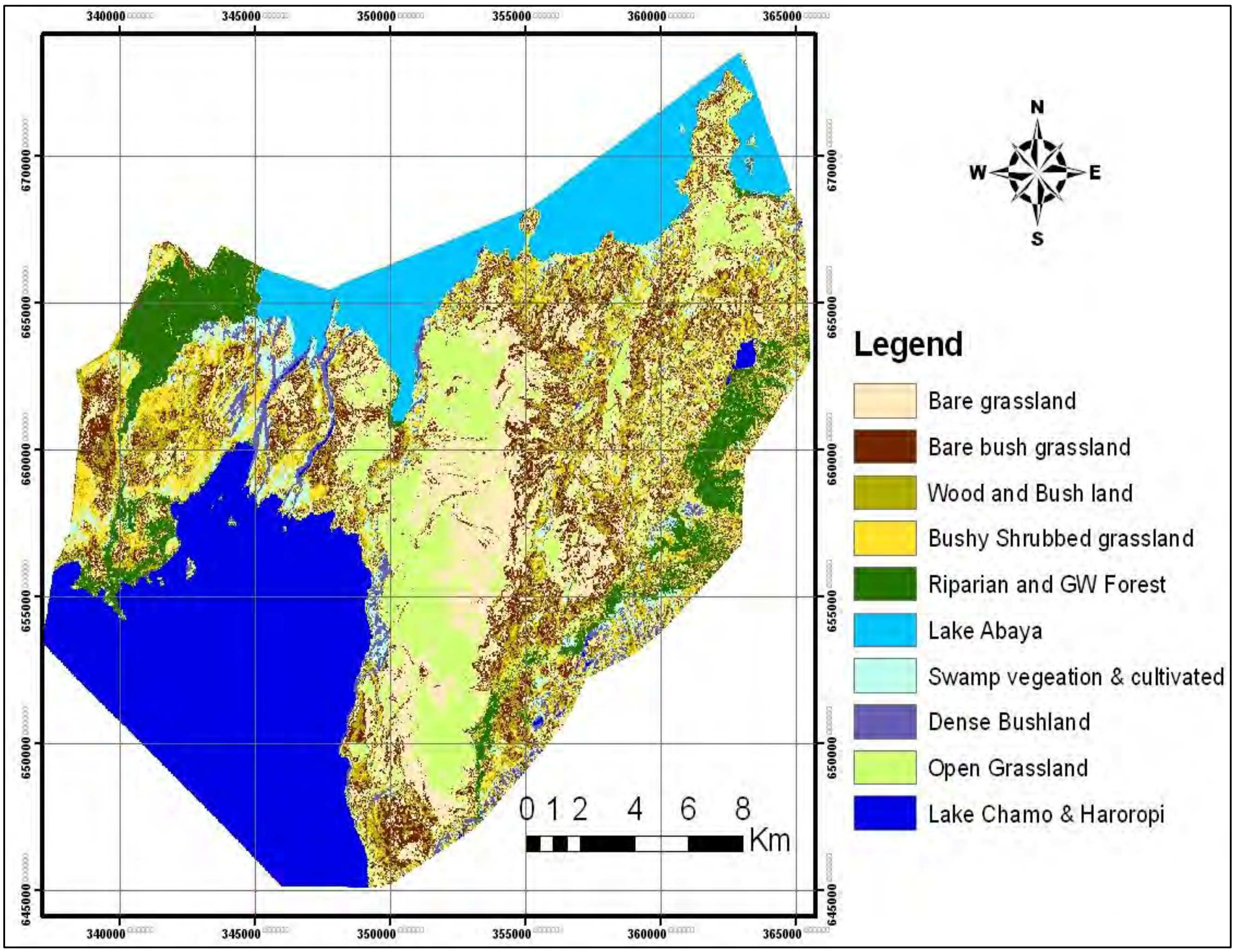


Figure.4.12 Unsupervised land cover classification of Nechisar for the year 2000

Global Positioning System (GPS) technology was used to establish locations of ground cover types for the purpose of "training" the computer to recognize the spectral characteristics of these particular land cover types. GIS point coverage was generated from the GPS points and field data were overlaid on the classified image and the results were evaluated visually. In addition to field verification, the classified map products were also distributed to senior staffs working in Nechisar Park and Feedback was generally good and the results were considered useful with a quantitative assessment of accuracy. Figure 4.12 below shows the resultant unsupervised classification of the whole scene for an accuracy assessment of the overall cover classes is calculated as 84 percent. The legends for this classification are assigned based on the ground verification and accuracy assessment result.

ii. Supervised Classification

Following evaluation of the unsupervised classifications, supervised classification was conducted for the whole Landsat images. Using the "intelligence" gained by linking GPS ground control points(GCP) sites with known coverage, a supervised classification was carried out. After the first supervised classification was completed, the major land cover classification result was visually checked and a field inventory was conducted to refine the supervised classification.

The final maps were again assessed for accuracy by field verification and evaluated both qualitatively and quantitatively. The results indicated that the supervised classification performed on the whole imagery was the most accurate and useful of the final products. The classification of the 1976 Landsat image was guided by Bolton (1970) general map information and the Topo map that is published in 1979 and generated from the aerial photographs which are taken in 1975 and 1976. This information is thoroughly discussed in section 4.1.1 as it's used to study the land cover description of the area for the past. The information extracted from these sources is used to set the land cover signatures and training areas for satellite image supervised classification.

The 1986 and 2000 Landsat image classification was guided by the spectral signatures applied in the classification of the 1976 image while the classification of both images was set based on ground truth data collected during fieldwork. A total of 350 ground control points were recorded in the study area using a Garmin Global Positioning System (GPS) and used for traning area selection, ground verification and accuracy assessment.

The ground control points were collected in two different times and divided into two ground truth GCP points. The first GCP was used to guide the training areas for the classification of the Landsat image for 1976, 1986 and 2000.The other GCP were used to validate the ASTER image 2007 land cover classification. To validate the classification of the satellite images ground truth data are used for accuracy assessment in the same way as the training areas used for the land cover classification and generate error marix. The accuracy assessment for each year land cover classification is calculated as an average accuracy of 78% for 1976 Landsat-MSS image,80% accurate for 1986 Landsat-TM image,72.22% accurate for 2000 landsat-ETM+ image and 95% accuracy for 2007 land cover mapping using ASTER image.

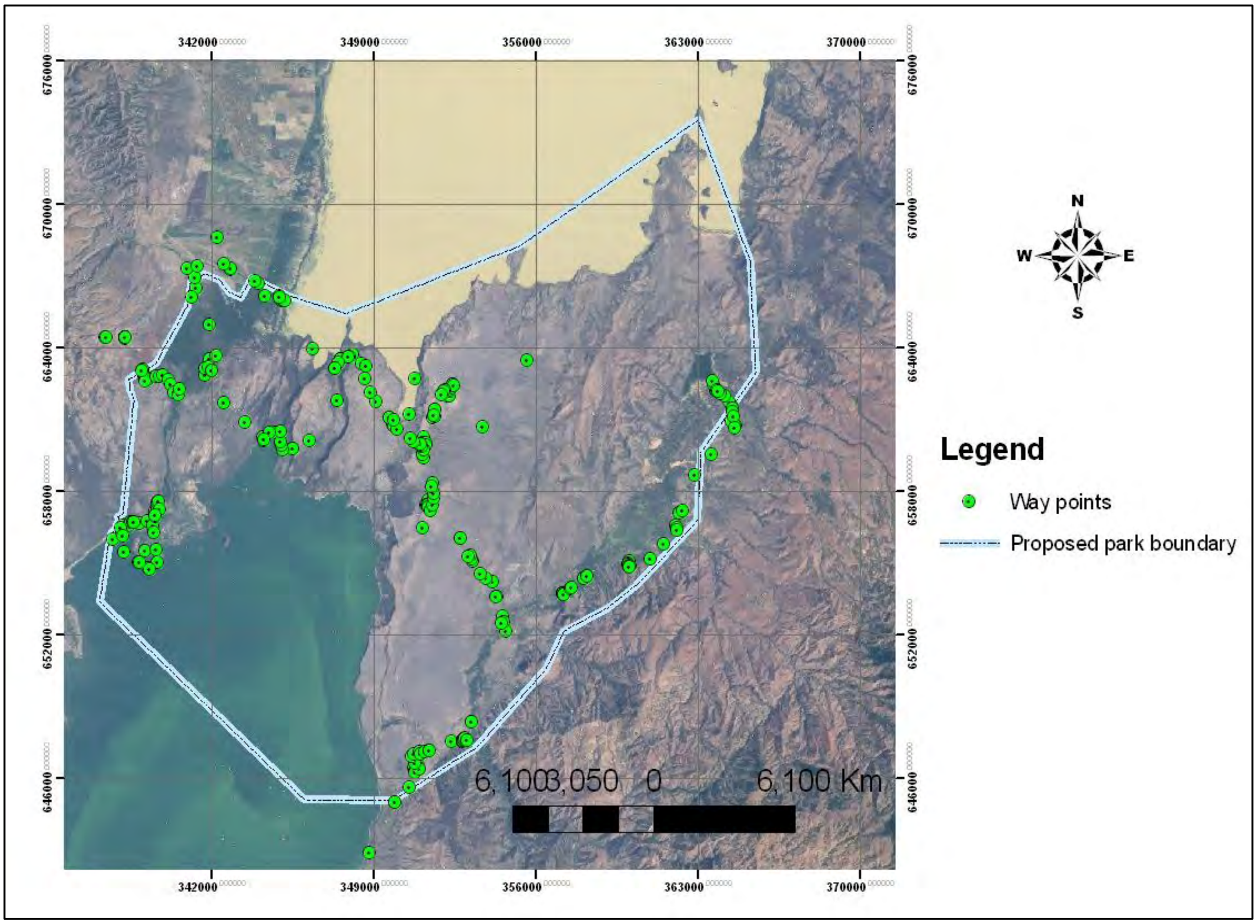


Figure.4.13 Ground truthing points collected during field inventory

To remove any noise the classified images are filtered using a majority statistical filtering of median window size of 3*3, 5*5 and 7*7 according to the occurrence of noise pixels. Subsequently, the new thematic land cover maps are vectorised and used for change detection analysis, showing land cover changes from 1976-1986 and 1986-2000; change matrices were calculated showing the transition in land cover classes and the information finally organized to generate up-to-date land cover map for 2007.

4.1.3. Land cover classification for 1976, 1986 and 2000

The land cover classification for this study uses the same classification legends which are logically accepted both in number of classes and cover types. For a clear comparison of the land cover dynamics for 1976, 1986 and 2000 during classification it’s usual to get some land cover types generalized when the cover classes are represented by fewer numbers of pixels. Land cover classes of bare land and cultivated are distributed fragmentally and usually have the same response although the training signatures is set separately for each. For instance there is a clear land cover mix-up particularly for the swamp vegetation, cultivated land and bare land. This is due to the spectral response for cultivated and bare land is usually overlapping when the cultivated land remains bare during non cropping season. The farming activity in the study area is dependent on water from the Kulfo and Seremele rivers for irrigation and the ground is usually water logged following the irrigation channels and the ground remains wetter thus it could confuse the same spectral response as the swampy cover classes.

Table.4.1 Land cover classification for 1976, 1986 and 2000

Land cover types	Area for 1976(ha)	1976 Area percentage	Area for 1986(ha)	1986 Area percentage	Area for 2000(ha)	2000 Area percentage
Riparian and GW forest	3091.1	6.38	3559.2	7.37	2707.96	5.60
Wood land	5354.35	11.06	1104.58	2.28	2910.78	6.02
Dense bush land	5116.53	10.56	2873.42	5.95	6726.57	13.93
Bushy shrubbed grass land	5226.02	10.79	12367.7	25.61	5787.85	11.98
Open grass land	11954.4	24.69	6328.4	13.10	6765.12	14.01
Bare bushed grassland	936.037	1.93	4881.3	10.11	5648.31	11.69
Cultivated land	280.389	0.57	721.197	1.49	2417.42	5.00
Swamp vegetation	1911.06	3.94	1892.22	3.911	595.298	1.23
Water body	14541.9	30.03	14553.1	30.14	14723.7	30.49
Total	48411.786	100	48281.117	100	48283.008	100

The major lands cover classes for 1976, 1986 and 2000 is quantitatively analyzed for the area covered by each land cover unit. Generally there is a continuous land cover change taken place for most land cover types in those 24 years and the results are given in table.4.1 above. The land cover classes for Nechisar national park as shown in table.4.1 helps to compare each value for the major changes takes place for the past 24 years. For a clear and informative comparison of the land cover change area value for the three years including 1976, 1986 and 2000 the summarized table above for the three thematic maps with each land cover class area value and percentage of area covered. The thematic maps and charts below are analyzed to give briefly the tabular information in (table.4.1) and show the land cover distribution for 1976, 1986 and 2000 of the Nechisar national park.

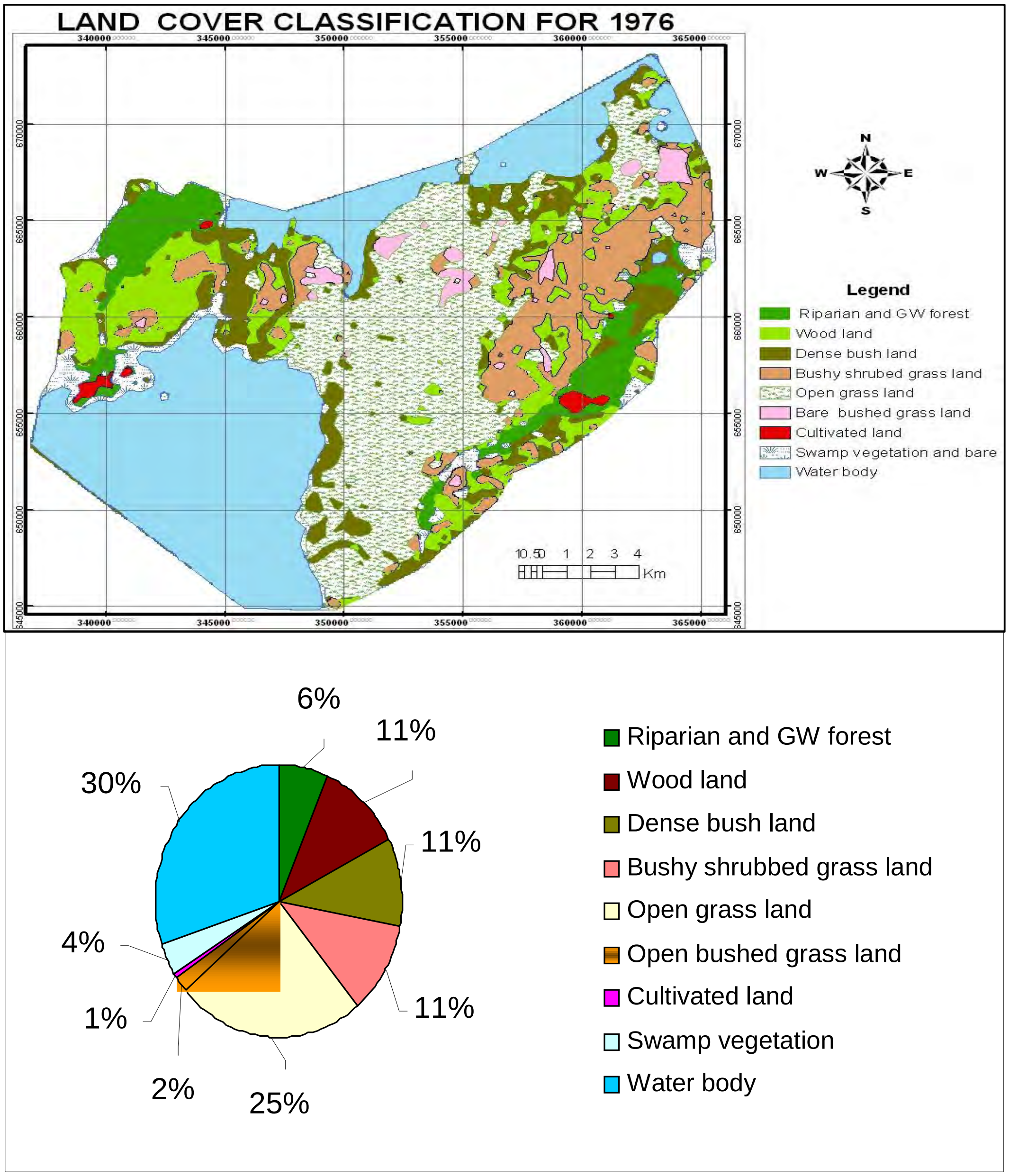


Figure.4.14 Land cover classes for 1976

The land Cover classes for 1976 is given as, water body which covers the lakes Abaya, Chamo and Haroropi that takes 14541.9ha of the total area, Open grass land covers 11954.4ha, Wood land covers 5354.35ha, Bushy shrubbed grass land covers 5226.02ha, Dense bush land covers 5116.53ha, The Riparian and ground water forest covers 3091.1ha, Swamp vegetation covers 1911.06ha, Bare bushed grass land covers 936.037ha and cultivated land covers 280.389ha. The figure and charts above shows the land cover distribution for 1976 in the Nechisar national park (Figure.4.14).

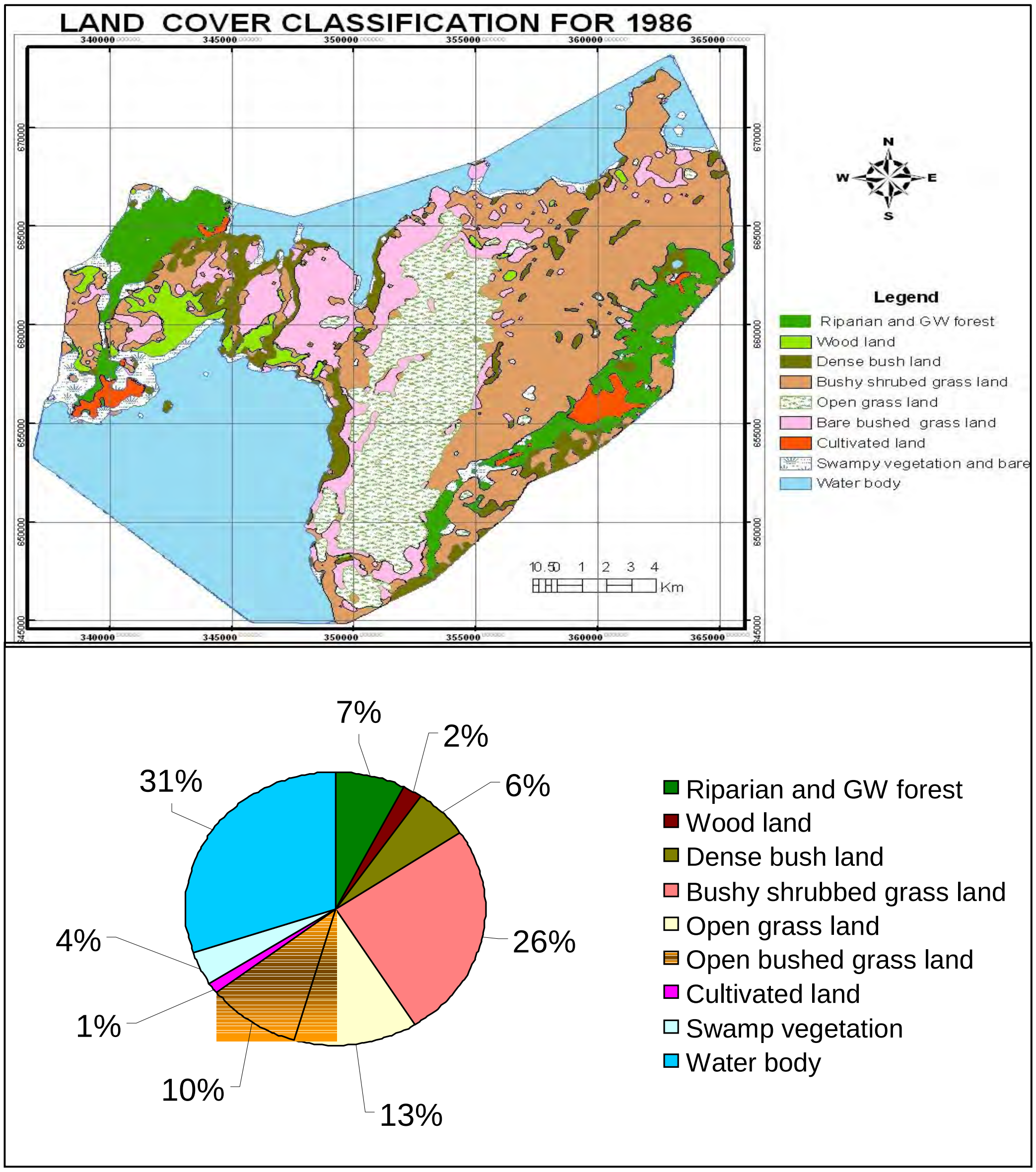


Figure.4.15 Land cover classes for 1986

The land cover classes for 1986 takes the highest share for water body covering 14553.1ha, Bushy Shrubbed grassland 12367.7ha, Open grass land covers 6328.4ha, Bare bushed grass land covers 4881.3ha, Riparian and ground water forest covers 3559.2ha, Dense bush land covers 2873.42ha, Swamp vegetation 1892.22ha, Wood land covers 1104.58ha, and Cultivated land covers 721.197ha. The figure and charts above shows the land cover distribution for 1986 for the Nechisar national park (Figure.4.15).

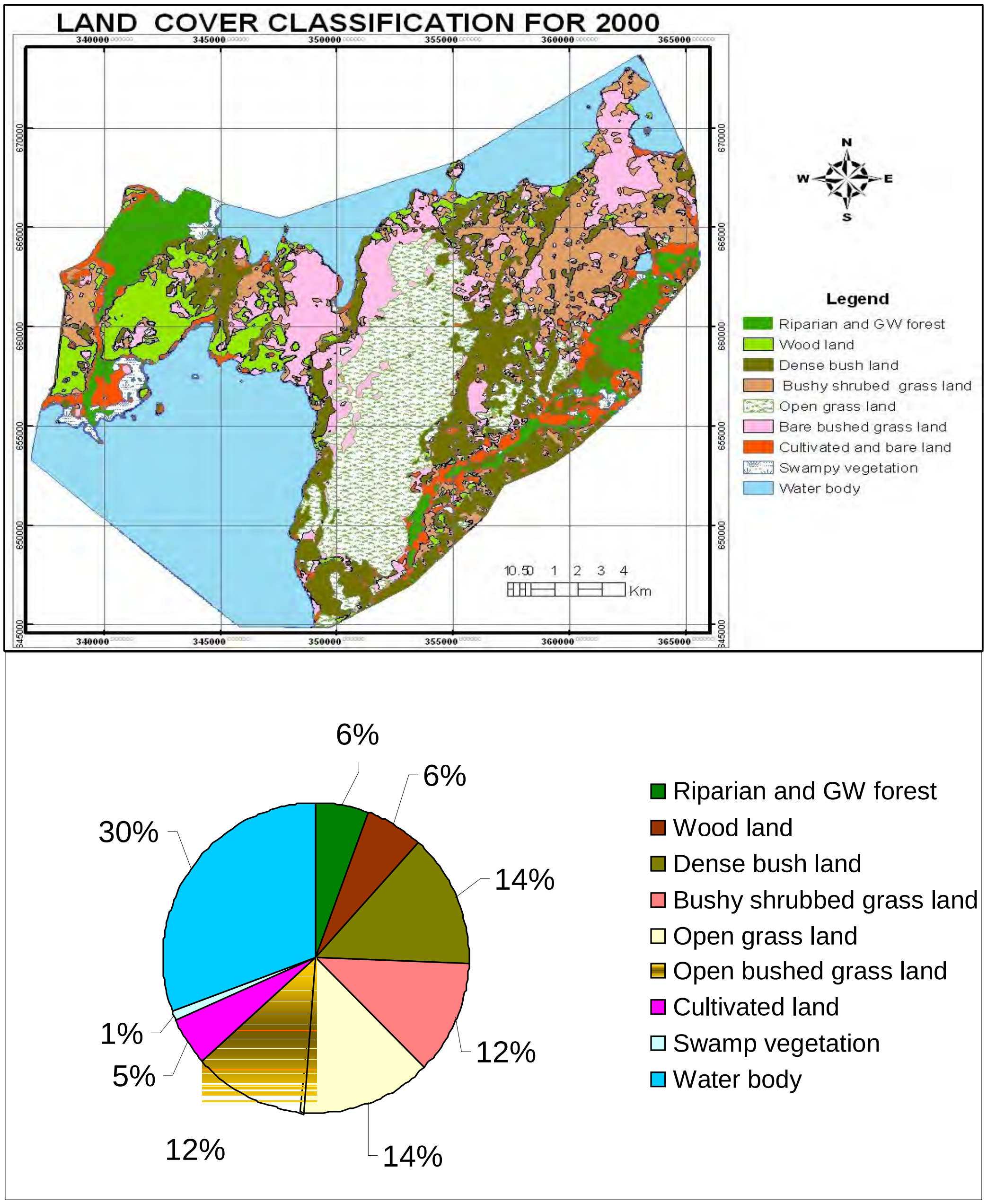


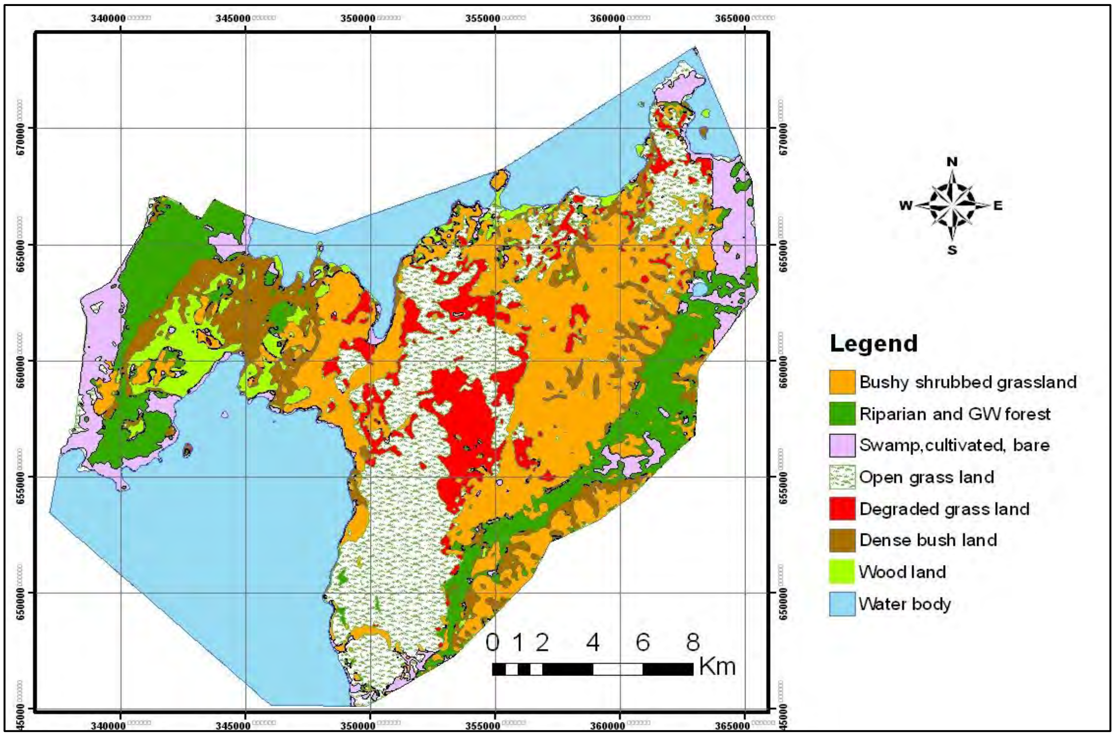
Figure.4.16 Land cover classes for 2000

The land cover classes for 2000 takes the highest value for water body as 14723.7ha,Open grass land covers 6765.12ha,Dense bush land covers 6726.57ha,Bushy Shrubbed grassland 5787.85ha,Bare bushed grass land covers 5648.31ha,Wood land covers 2910.78ha,Riparian and ground water forest covers 2707.96ha,Cultivated land covers 2417.42ha, and Swamp vegetation covers 595.298ha(Figure.4.16).

4.1.4 Land cover map for 2007

The year 2007 supervised land cover classification is conducted using ASTER image of 2006. Training site selection is properly set both in number and land cover class types. These Current land Cover map is finalized integrating information from various sources Such as the Back ground of the past Land cover classification results i.e. (Landsat 1976, 1986 and 2000), Optimum number of signature for ASTER 2006 satellite images, Ground truthing field inventory waypoint information, Google earth image KML files for feature comparison. The following thematic map (figure.4.17) below presents the distribution of the current land cover classes and area percentage occupied by each land cover class for 2007.

The area distribution of the land cover classes for 2007 as shown in Figure.4.17 Water body takes the highest area percentage i.e. 30% and covers 14531ha, Bushy shrubbed grass land covers 21% and 10124ha, the Open grass land covers 16% and 7610ha , the Riparian and ground water forest covers 10% and 4798ha, Dense bush land covers 7% and 3231ha,the degraded grass land covers 7% and 3549ha finally the cultivated, swampy and bare land together covers 5% and 2532ha of the total area while wood land covers the least percentage 4% and 1819ha of the whole area.



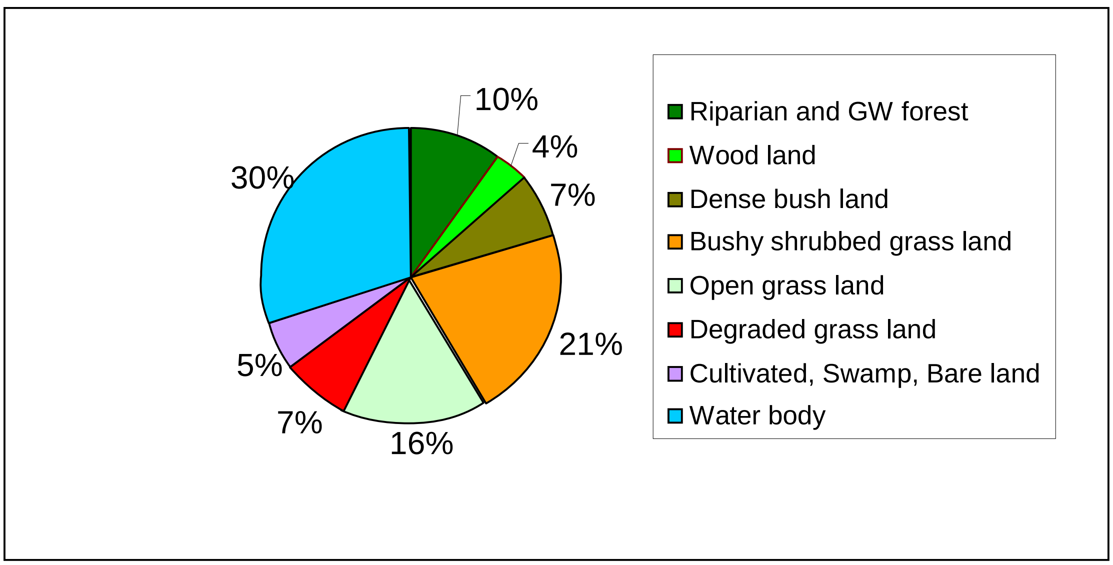


Figure.4.17 Nechisar National park Land cover map for 2007

4.1.5. MODIS-NDVI Classes and curves

This NDVI product is generated at 250m resolution from 16-day composites of MODIS data. Bands 1 through 7 contain the visible, NIR, and SWIR (Short Wave Infra-red) which are of greatest importance for monitoring vegetation dynamics.MODIS images unsupervised classification of the Nechisar national park is conducted to have a general comparison with the results of Landsat image cover classification. Though the resolution for the MODIS image is much coarser i.e.250m of spatial resolution as compared to Landsat images, most of the cover classes are appeared as a separate unit pixel representing one land cover type and some classes are generalized as a group and clustered together to represent a unit land cover. Thus the unsupervised MODIS image classification helps to extract information for land cover mapping of the study area. The following classified NDVI images for 2000 in Figure.4.18 below clearly shows the cover classes which are compared and has similar results with the Landsat 2000 image classification.

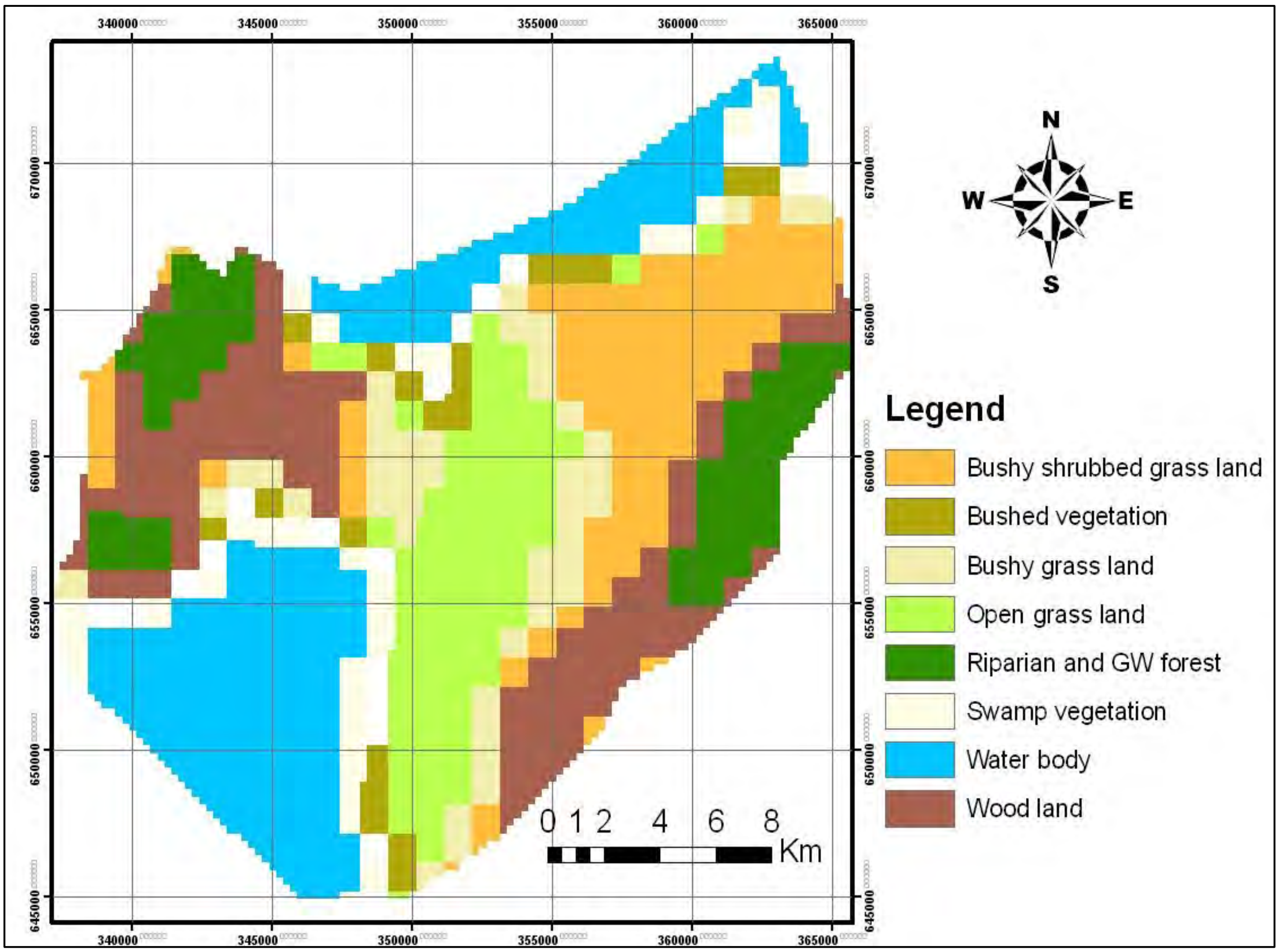


Figure.4.18 MODIS-NDVI image land cover classes

In this study the MODIS-NDVI images for year 2000 and 2005 were analyzed to check the major land cover classes in unsupervised classification, and also monitoring the response of the different land cover classes for different season and time. The land cover classification of the MODIS-NDVI image has generated interesting result that helped for comparing the results visually with the major land cover classes. The NDVI value response of the different cover types for the year 2000 and 2005 images clearly show highest value for forest cover as 0.78 and 0.73, and the 2nd value for Bushy shrubbed grass land and wood land, the 3rd NDVI value goes to Open grass land, swampy vegetation gets the fourth value and water body has a negative value of -0.096 as the Infera Red is all absorbed in the case of water body.

The spatial distribution of NDVI values for the different land cover class is more or less uniform for both 2000 and 2005 MODIS image.

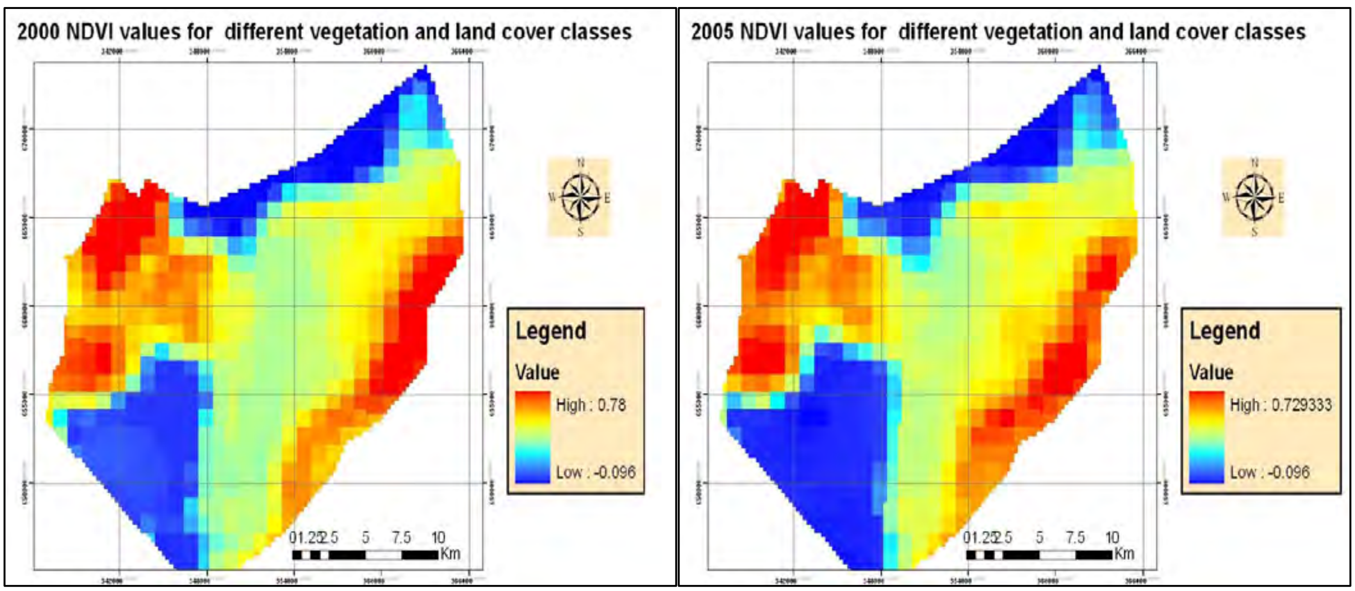


Figure.4.19 MODIS-NDVI land cover response values for 2000 and 2005

4.2. Discussion

4.2.1 Land Cover Dynamics and cover change structure

The cover dynamics for the past 24 years which are given in the above thematic land cover maps of section 4.1.3 and section 4.1.4 are discussed below with various statistical analyses and cover change comparison factors. Generally the land cover change from 1976 to 2000 has been discussed in two periods. The first period has 10 years of gap i.e. from 1976 to 1986 and the second period is from 1986 to 2000 that has 14 years of gap. The cover dynamics discusses the rate of land cover change from 1976 to 1986 and 1986 to 2000.Table 4.2 below clearly shows the land cover change rate for the past 24 periods.

Table.4.2 Rate of Land cover change

	Rate of land cover change(ha/year)	
Land cover class	**1976 to 1986**	**1986-2000**
Riparian and GW forest	46.8	-60.85
Wood land	-424.9	129
Dense bush land	-224.3	275
Bushy shrubbed grass land	714.1	-470
Open grass land	-562.6	31.2
Bare bushed grass land	394.5	54.78
Cultivated land	44	121
Swamp vegetation	-1.9	-92
Water body	1.12	12

Comparison of the land cover changes for the past 24 years clearly shows that the area covered by water is more or less stable and shows insignificant change than the other land cover classes. For the two periods the rate of change from 1976-1986 is 1.12ha/year that has a positive increase and for the second period from 1986 to 2000 is 12ha/year which gives a total cover increase of 168ha of land in 14years period. According to the field visit and the results of image classification the water body of the park covers part of Lake Abaya, Lake Chamo and the small swampy lake Haroropi which gives a total water body cover in the park. The continuous increment for the water body is a consequence of the rainfall increment which result a push to the lake shores.

There is a tremendous land cover change in the open grass land cover as compared for the two periods. It’s calculated from 1976 to 1986, a total loss of grassland 562.6ha/year is converted to other cover types and this has an area of 5626ha of land which is totally destroyed grassland over 10years.In the second period between 1986 and 2000 which has a 14years gap the total area which is changed to open grass land from other land cover types is 40.18 ha/year and 562.52ha of land is become part of the open grass land plain.

Considering the cover change in the dense bush land class, there has been a decrease in the first period i.e. from 1976-1986 and total shrinking of dense bush land by 224.3 ha/year, though in the second period from 1986 to 2000, in the contrary the dense bush land increased by 275 ha/year.

Bushy shrubbed grass land has increased highly for the first 10 years period at a rate of 714.1ha/year, and this cover increment decline in the second period from 1986-2000 by 470ha/year.

The Bare and Open bush grass land which is continuously increased for the past 24 years in both periods from 1976-1986 moves at a rate of 394 ha/year and from 1986 to 2000 increased by 54 ha/year. This is also a challenge for the grass land if the increment continues in the expense of other cover types particularly the open grass land.

The Riparian and Ground water forest has shown an increment in the first period for a consecutive 10 year at a rate of 46.8 ha/year and this land cover in the contrary declines for a consecutive 14years of period in the second period at a rate of 3.34ha/year and this shrinking shows a high pressure on the Riparian and GW forest vegetation cover considering the size of the forest.

The Wood land has shrunk highly for the first 10 years period by 424.9 ha /year while in the second period from 1986 to 2000 there is a wood land cover increment by 129 ha/year for the past 14years.

The swamp vegetation shows a continuous decline for the past 24 years with a rate calculated for the first period 1976-1986 1.9ha/year and in the second period for 1986-2000 there is a drastic loss of the swamp vegetation at a rate of 92 ha/year.

Finally there is a continuous expansion of cultivated land for the two periods at a rate of 1.12ha/year and 12ha/year from 1976 to 1986 and from 1986 to 2000 respectively. This is believed that the cultivated land expand with the expense of destroyed wet land. The following graph helps for comparison of the cover dynamism for 1976, 1986 and 2000(Figure.4.20).

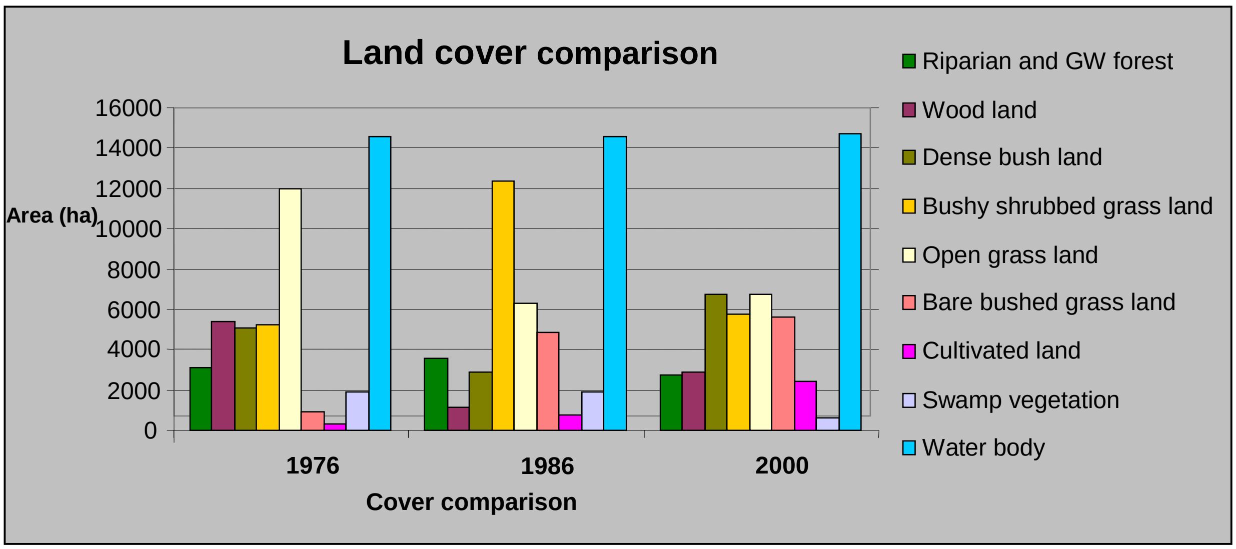


Figure.4.20 Spatial and temporal change comparisons of land cover classes

4.2.2. Land Cover Change Matrix

i. Change Matrix for 1976 and 1986

Land cover change comparison gives the general information of major changes of the land cover classes analyzed for the two periods. These cover comparison hide detail information such as which cover type goes to where. Thus, to clearly understand the major land cover change source and destination of cover classes Change conversion matrix for each period is analyzed.To discuss the result of the cover change matrix the following graph is important that clearly show and compare the spatial and temporal distribution of land cover types that undergone changes for the past 24 years including 1976, 1986 and 2000.The graph below shows the comparison of land cover changes for the three years and this helps to give a clear picture on the spatial cover that goes to other cover types as a result of several factors and this is discussed briefly using conversion matrix. The row of the table represents the initial stage as 1976 or 1986 and the column of the table represents the final stage of 1976 and 1986. The diagonal values of the table depict the unchanged values, which are found in both time images.

Table.4.3 Conversion matrix value for 1976 and 1986

Land cover Classes for 1976/1986	Riparian and GW forest	Wood land	Dense bush land	Bushy shrubbed grass land	Open grass land	Bare bushed grass land	Cultivated land	Swamp vegetation	Water body
Riparian and GW forest	0	401.04	0.2	242.64	0.36	0	284.04	0	0
Wood land	4.32	12.96	0.1	0	73.8	0.36	14.04	142	0
Dense bush land	0	2830.68	0.01	5588.64	118.08	31.32	3182.04	72	78.48
Bushy shrubbed grass land	230.4	5.76	0.1	0	0	30.96	1.08	0	0
Open grass land	0.36	631.44	0	94.32	61.56	82.44	418.48	38.16	34.2
Bare bushed grass land	0	369.36	2.13	85.32	591.84	191.16	3108.24	32.76	743.76
Cultivated land	392.76	12.6	0	0	65.52	2405.16	90.36	0.36	0
Swamp vegetation	0	0	67	0	0		0	0	0
Water body	88.92	63	0	8.64	177.48	351.72	202.68	43.92	38.16

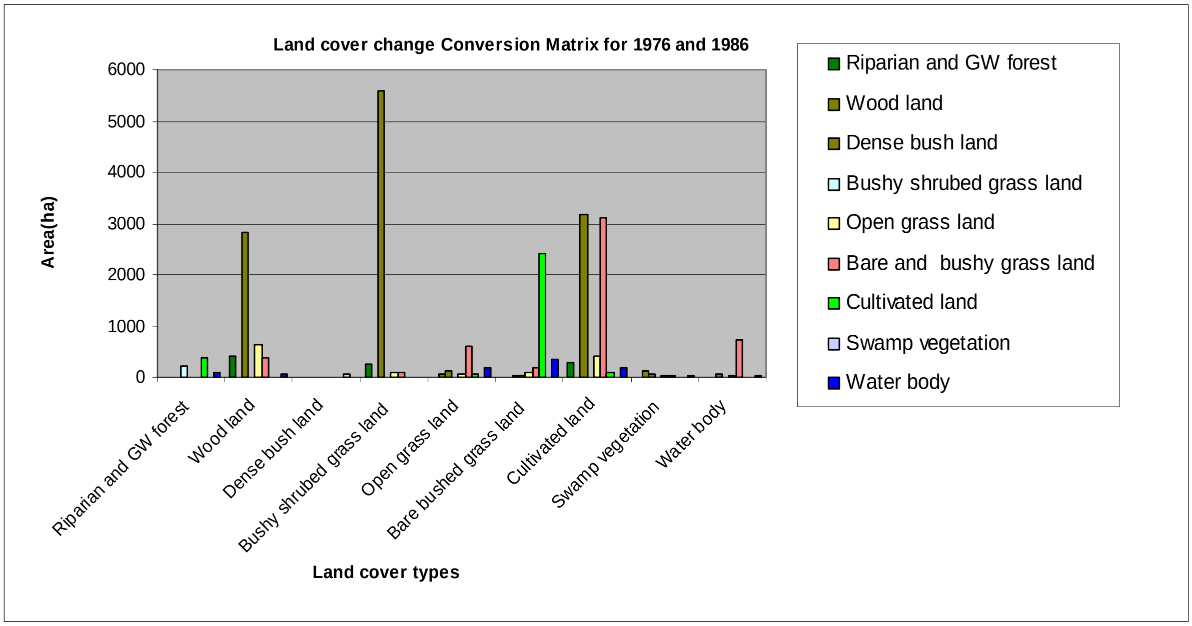


Figure.4.21 Land cover Conversion matrix value for 1976 and 1986

According to the results from the land cover conversion matrix the cover classes from 1976 to 1986 it's clearly shown in the above matrix table and graph the changes of most land cover classes goes to the final cover destination mostly to dense bush land, bare bushy grass land and Bushy shrubbed grass land. For instance the majority land cover types including wood land, Bushy shrubbed grass land and cultivated land converted to a single land cover type dominantly to dense bush land. Again if we see the open grass land, part of the wood land, water body and cultivated land are mainly converted to Bare and bushy grass land .The high pressure on the riparian forest clearly shown as most of the conversion of the forest is taken by cultivated land and Bushy shrubbed grassland. The conversion matrix values are given above in Figure.4.21 and Table 4.3.

2. Change Matrix for 1986 and 2000

Table.4.4 Land cover conversion matrix for 1986 and 2000

Land cover Classes for 1986/2000	Riparian and GW forest	Wood land	Dense bush land	Bushy shrubbed grass land	Open grass land	Bare bushed grass land	Cultivated land	Swamp vegetation	Water body
Riparian and GW forest	366.4	10	570.8	10	0.97	12.18	34.11	103.8	1
Wood land	11.7	5	47.5	0.5	0.97	2.59	71.6	105.1	0.5
Dense bush land	1843.15	3.12	158.7	0	6.9	5.6	81.8	323.5	0
Bushy shrubbed grass land	3095.3	0	656.2	3.33	10.2	848.85	2454.3	4195.5	1.30
Open grass land	440.7	1.1	36.47	2.0		5477.2	351.7	21.9	0
Bare bushed grass land	686.1	0	94.13	5.20	1.29	390.69	2598.3	764.4	0
Cultivated land	131.1	5.69	283.47	0		0.32	11.3	5.6	0.1
Swamp vegetation	93.3	0	555.17	0	30.21	2.27	41.9	220.1	0
Water body	31.8	1.0	15.5	10	34.19	3.16	2.4	40.9	17.20

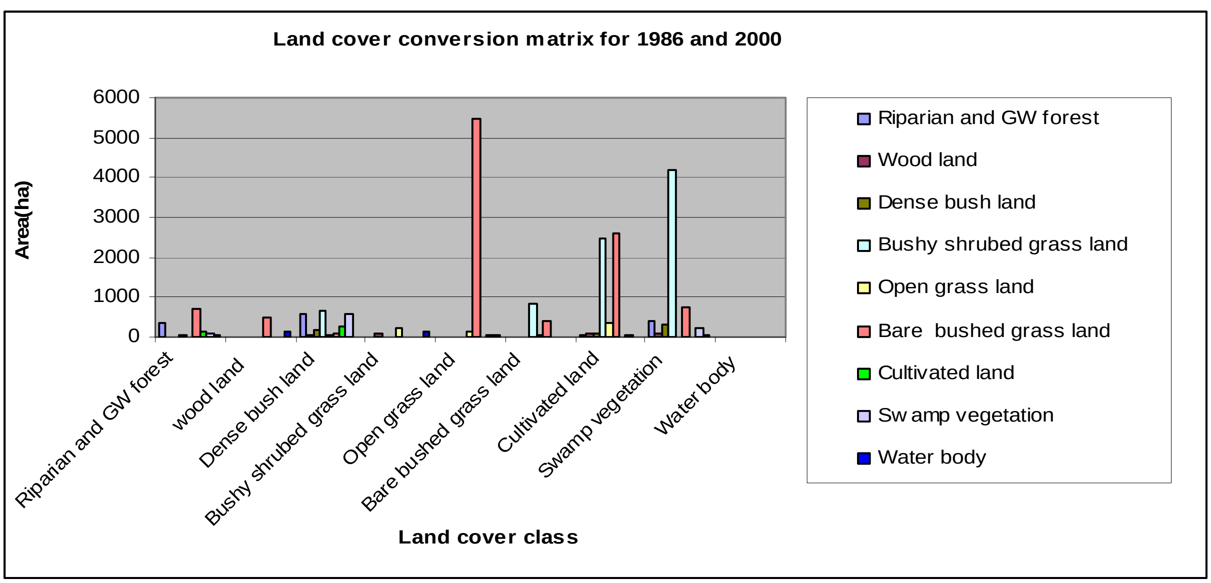


Figure.4.22 Land cover conversion matrix value for 1986 and 2000

The land cover conversion matrix from 1986 to 2000 in the second period gives similar results which is logical and shows the pressure on the natural resources of the national park for the past 14 years like the results from 1976 to 2000. The Riparian and Ground water foest has been exploiated and converted to cultivated,Bare bushed grass land and swamp vegetation.The wood land also converted to bare bushed grass land.The dense bush land shows conversion to various cover classes mainly to Bushy shrubed grass land and swamp vegetation.The open grass land which is converted to mainly bare bushed grass land have pressure from cattle grazing in the plain..The swamp vegetation also converted to bare bushed grass land and bushy shrubed grass land.The water body in the study area shows no conversion to other land cover classes (Figure 4.22 and Table 4.4).

4.2.3. Fragmentation index

Fragmentation index is used to analyze and compare how much the landscape for a given land cover type is fragmented through the land cover changes over time. When the Fragmentation index value increases or remains constant for each year it indicates the Landscape and habitat integration for a unit land cover type and check the health of the ecosystem. If we compare the fragmentation index value for the three land cover maps within 24 years including 1976, 1986 and 2000, except the Pa value for water body the rest of the land cover classes show a decrease in Pa value, means the number of patches for each cover class increases and this doesn't show good ecological and habitat stability. Species that require large, unbroken expanses such as grassland of the Nechisar plain habitat are often most sensitive to the effects of fragmentation. In some cases, the effects of fragmentation on sensitive species are a direct result of changes in the size and arrangement of suitable habitats across the landscape (Core national indicator, 2000). The table below shows the Pa value for fragmentation index for 1976, 1986 and 2000 land cover thematic maps. The Pa value clearly shows that highly fragmented land cover class is the open grass land for 2000. The riparian and Ground water forest is also highly fragmented for 2000 and also the bushy shrubbed grass land is highly fragmented in 2000 than 1986. There is an increasing pressure on the natural resources in the national park for the past 24 years as clearly indicated by the Pa values. Fragmentation of ecosystems into small patches can reduce habitat for wildlife species that require larger, connected patches. It can hinder the movement of some species and introduce predators, parasites, and competitors associated with different land uses. Fragmentation can also alter the frequency and extent of fire and affect the dispersal and regeneration of plants (Core national indicator, 2000).

Table.4.5 Fragmentation index values for 1976, 1986 and 2000

No	Land cover classes	Pa value for 1976	Pa value for 1986	Pa value for 2000
1	Riparian and GW forest	134	147	79
2	Wood land	55	35	22
3	Dense Bush land	34	34	33
4	Bushy shrubbed grass land	69	119	21
5	Open grass land	341	253	60
6	Bare bushed grass land	40	64	22
7	Cultivated and bare land	46	48	13
8	Swampy vegetation	23	24	18
9	Water body	3635	3637	3680

Recent evidence suggests that the impact of cultivation on vegetation, wildlife and soils in pastoral ecosystems is greater than that of livestock. Expansion of cultivation fragments rangeland landscapes when farmers convert rangeland into cropland (Hiernaux, 2000). Land degradation through crop cultivation has been documented (Niamir-Fuller, 1999), but the impact of livestock use and crop cultivation (or any other land uses) has rarely been compared. The Nechisar national park land cover classes of major habitats mainly the grassland plain, the Ripaian and ground water forest, indicates intolerable disturbance of Landscape as calculated for each cover class fragmentation index value and these needs quick response to preserve the national park core habitats such as the open grass land, riparian forest and swampy lakeshore vegetation.

4.2.4. MODIS land/vegetation cover Classes and NDVI Value comparison

The MODIS images that are taken every 16 days of the spectral response of NDVI values for a yearly base is taken every month and this images are stacked and helps to evaluate the seasonal responses of the land cover classes to see the vegetation situation. The comparison for the response of vegetation cover classes over a year and this helps to see environmental stresses and biomass cover increment. The NDVI value within a yearly period is given below for each month in a continuous profile for the year as compared for 2000 and 2005 images.

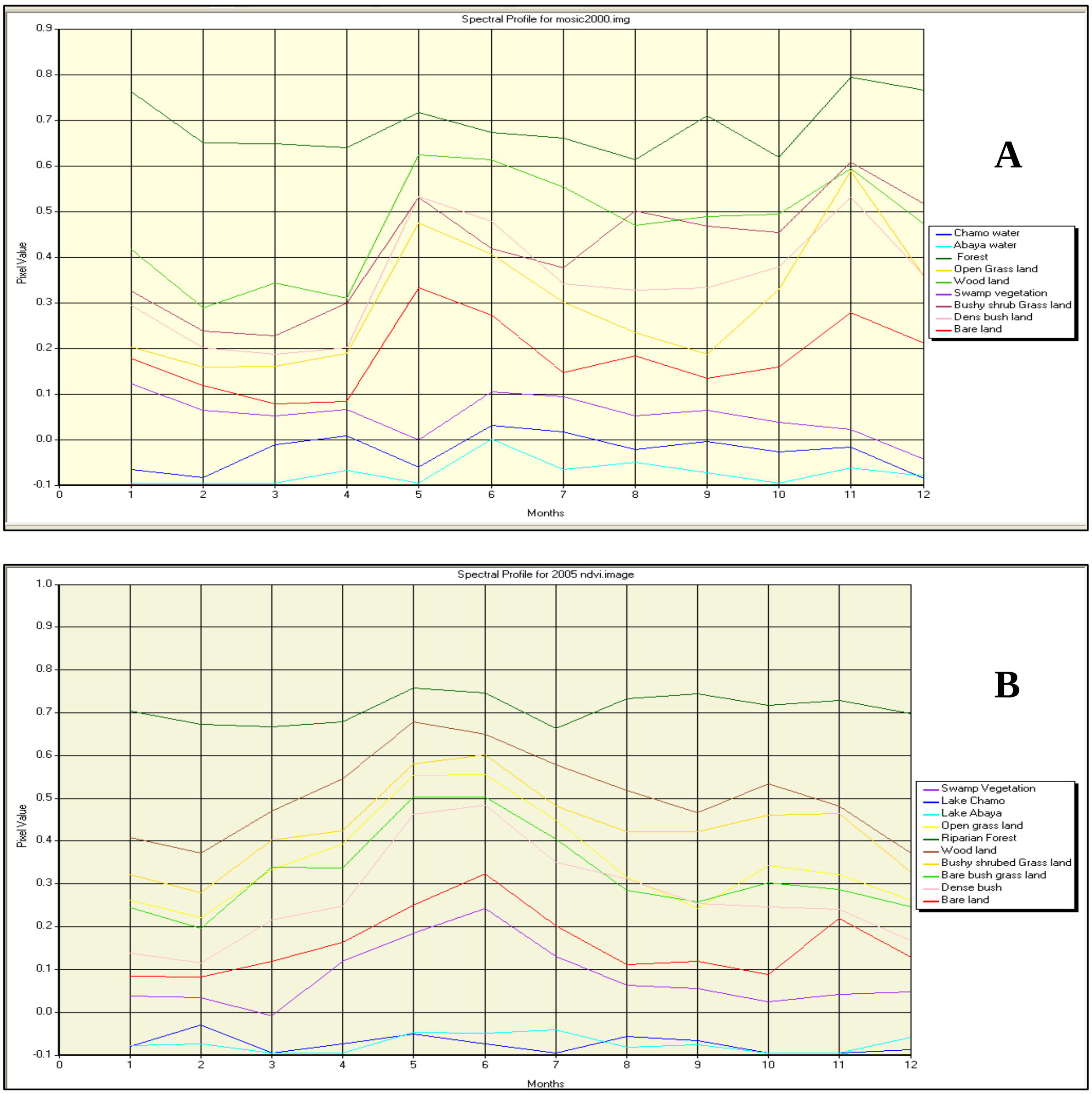


Figure.4.23 NDVI land cover response for 2000(A) and 2005(B)

The NDVI value is generally higher for the forest cover, Wood land, Grass land, and Bush land and lower for the swamp vegetation and negative for Water body. The seasonal fluctuation in climate i.e. perception controls the changes in the NDVI value while the biomass growth and greenness of the vegetation cover directly affected by precipitation for all vegetation cover classes. The profile of the NDVI values in both years 2000 and 2005 for the different land cover classes particularly the vegetation cover in the above graph clearly shows that the changes in land cover response vary seasonally due to climatic factors particularly perception. If we see the profile for April which is the 4th month and May the 5th month on the graph where the onset of rainy season of the study area and the vegetation cover increases thus the NDVI value in this months is higher and the profile shows a maximum record. Again if we compare the NDVI profile throughout the year for 2000 and 2005 we can see that the spectral response of vegetation profile increases on November 2000 than November 2005 and this is a good indicator of a decline in biomass cover growth. The NDVI value declines from the 5th month of the 2000 NDVI vegetation profile while it remains constant for the year 2005 profile. This could be due to the amount and the length of the rain in that rainy season for the year 2000 and 2005 vary for that particular period. The response of NDVI for 2000 and 2005 vary and this is an indicator of the probability of less Biomass growth in 2005 than 2000. This is also clearly shown on TRRM annual rainfall records, that the rainfall amount for November 2005 is much lower than the amount for November 2000(Figure.4.24). Tropical rainfall measuring mission (TRMM) will fill many gaps in our understanding of rainfall properties and their variation.TRMM, during its mission and broad sampling footprint between 35°N and 35°S, is providing some of the first detailed and comprehensive dataset on the four dimensional distribution of rainfall and latent heating over vastly under sampled oceanic and tropical continental regimes. The TRRM remote sensing data thus fill the gaps and provides the data for rainfall distribution of the Nechisar national park which has good results in comparison with the rainfall data from ground metrological station at Arbaminch station **(Figure.4.24).**

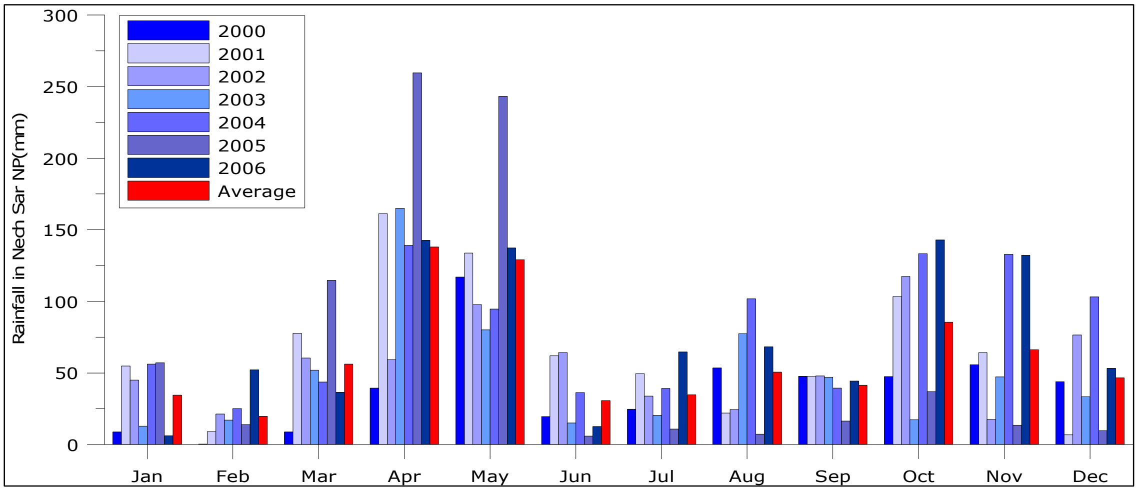


Figure.4.24 Rainfall of the Nechisar National Park based on TRMM

4.2.5 Land cover dynamics impacts and challenges on park Natural Resource

If we compare the land cover class area distribution for the past 31 years including 1976, 1986, 2000 and 2007 it's clearly shown that the dynamism in land cover is non uniform and uneven for most cover classes. Relative to other cover classes the water body that covers mainly lake Abaya and Chamo doesn't show significant spatial and temporal variation for the past 31years. The bar graph below (Figure.4.25) compares the land cover distribution for those years in the spatial and temporal cover dynamism of an area analyzed for all classes.

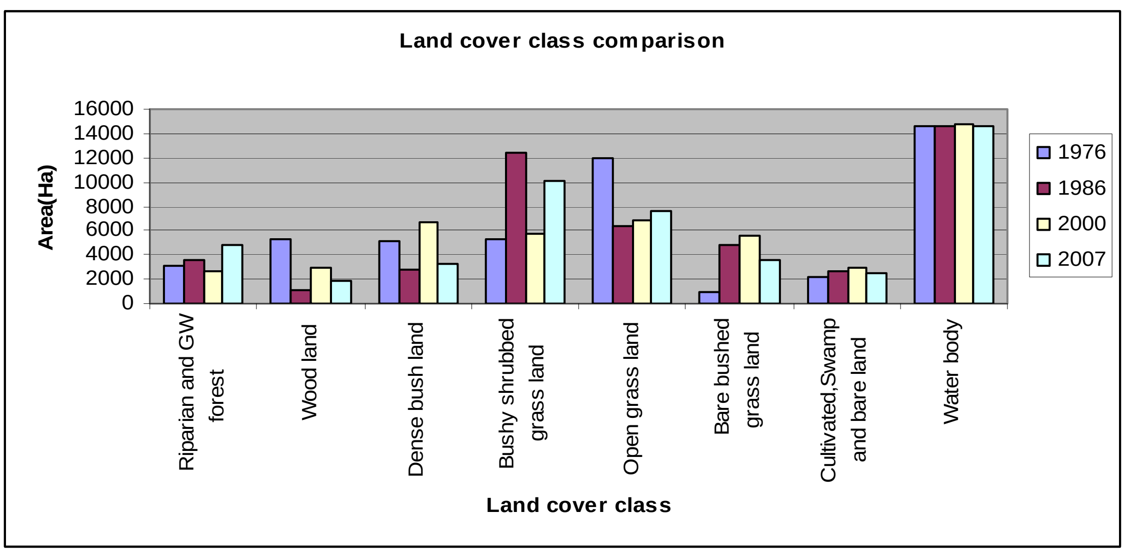


Figure.4.25 Comparison of land cover for 1976, 1986, 2000 and 2007

Generally the cover dynamics shown in the above bar graphs discussed as a major ecological challenge faced by the Nechisar National park due to anthropogenic and natural factors. For the sustainable management and survival of the biodiversity for generations the study tried to see critically the spatial and temporal variation for the core habitat in order to understand how to interact with the delicate nature as well how to respond and to react on the causes and effects of the management and utilization of the natural resource.

Even though, natural processes contribute to change in land cover, the major driving force is human induced land uses (Allen and Barnes, 1985). In order to understand the various implications of land cover change, understanding of land use change is essential. Different human driving forces mediated by the socio-economic setting and influenced by the existing environmental conditions, lead to an intended land use of an existing land cover through the manipulation of the biophysical conditions of the land (Turner et al., 1995)

As the case in many other developing countries, most of the population of Ethiopia lives in rural areas and depends directly on the land for its livelihood. This rural population is currently growing rapidly, and consequently inducing high pressure on the resource base. A common concern addressed by many studies is the resource degradation brought about by the decrease in the area under natural vegetation and its conversion into other types of land use and land cover that are anthropogenic. For up to date information and land cover area distribution of the park the current land cover map all the land cover values are calculated for each cover class are given in the following table.

Table.4.6 Land Cover Classes for 2007

Land cover classes for 2007	Land cover Area(ha)	Land cover percentage
Riparian and GW forest	4798	9.9
Wood land	1819	3.7
Dense bush land	3231	6.7
Bushy shrubbed grass land	10124	21.0
Open grass land	7610	15.7
Degraded grass land	3549	7.3
Cultivated land, Swamp and bare	2532	5.2
Water body	14531	30.1
Total	48194	100

As the population around Nechisar National Park and nearby Arbaminch increases, so do the Pressure on grazing cattle, fish and collect wood in the park. As Nechisar national Park is one of the few protected areas still viable in Ethiopia's Rift Valley, there is a heightened urgency to create an effective management plan (Alison, 2005).

The Master Plan in RVLB noted that despite early successes, political unrest during the early 1990s led to intense damages in a relatively short period of time, especially infrastructure and habitat destruction in the National Parks. The most serious damage was caused in the Abiyata-Shala National Park, but damages also occurred in the Nechisar National Park and the Senkelle Swayne's Hartebeest Sanctuary (HALCROW-GIRD, 2007).

Savannas are globally important ecosystems of great significance to human economies. In these biomes, which are characterized by the co-dominance of trees and grasses, woody cover is a chief determinant of ecosystem properties. The availability of resources (water, nutrients) and disturbance regimes (fire, herbivory) are thought to be important in regulating woody cover, but perceptions differ on which of these are the primary drivers of savanna structure. A study show, using data from 854 sites across Africa, that maximum woody cover in savannas receiving a mean annual precipitation (MAP) of less than ~650 mm is constrained by, and increases linearly with, MAP. These arid and semi-arid savannas may be considered 'stable' systems in which water constrains woody cover and permits grasses to coexist, while fire, herbivory and soil properties interact to reduce woody cover below the MAP-controlled upper bound. Above a MAP of ~650 mm, savannas are 'unstable' systems in which MAP is sufficient for woody canopy closure, and disturbances (fire, herbivory) are required for the coexistence of trees and grass. These results provide insights into the nature of African savannas and suggest that future changes in precipitation may considerably affect their distribution and dynamics (**Mahesh Sankaran etal, 2005)**.

Historically, fire played an important role in the ecology of the savannas of southern Ethiopia. Fire was used to control the expansion of bush cover and control ticks, to remove predator habitats, to improve pasture quality and to facilitate livestock movements. On a local level, the pastoralists regarded bush encroachment as a major threat to rangeland production. The shift towards bush encroachment changed the composition of the herbaceous layer in favor of annual grasses and unpalatable forbs (**Ayana Angassa, 2007)**.

The current status of the national park generally for the whole habitats is discussed in section-4 focusing on the land cover dynamics of the basic land cover types. In this study the conservation status of the national park particularly for the core habitats such as the open grassland and the ground water forest are well discussed below from different natural resource challenges and management point of view.

i. Ground water and Riparian forest

The Riparian and GW forest shows increment in 2007 than the past 31years with a total area covering 4798ha which is 10% percent of the total current coverage. This is due to after 2005 the park is taken under the management of African parks conservation thus the forest is managed and protected very well. The forest Guarding strategy implemented by APC Ethiopia has shown effective result and consequently, the price of wood tremendously increased. This is on top of wood supply shortage for lacking new tree planting and diminishing of the existing wood stands. These problems are aggravated due to lack of plantation and other fuel sources in the area that would play supportive roles (Arbaminch town fuel energy alternative sources workshop, 2007).

The Ground water forest is said to be unique in Africa and its existence, as such, is closely associated with the series of freshwater springs, known as "Arba Minch", meaning "Forty Springs". Originating from the western edge of the forest, at the foot of the western escarpment, these springs provide the source of water supply to Arbaminch town, as well supporting the natural forest biodiversity. The exploitation of the ground water for such projects unless wisely managed could result a disastrous for the unique and delicate ecology like the ground water forest. Forests in which dynamics are controlled by one or a few foundation species appear to be dominated by a small number of strong interactions and may be highly susceptible to alternating between stable states following even small perturbations (Ecol Environ, 2005). Regrettably, the lack of detailed knowledge of the natural history of most species in most forests, and the abandonment of courses and curricula in natural history (Dayton 2003), will leave us unaware of the collapse of the intricate webs of interactions and processes that are lost when foundation species disappear.

During the field inventory its checked that the stump remnant of important tree species have indication of the forest exploitation and this has been a disastrous activity which is encountered at the Ground water forest, the Kulfo and Seremele riparian forest that were exploited by both rural and Urban community livelihood interests for fuel wood and charcoaling, construction and lumber, bee hive and farmland expansion.

We are living in an era of unprecedented and rapid ecological change (Reid *et al*. 2005). Through habitat conversion, over-consumption of resources, and worldwide introductions of pests and pathogens, humans are causing species extinctions at a record rate: the sixth extinction crisis in the billion-year history of eukaryotic life on Earth (Eldridge 1998). The loss of a common or abundant foundation species (Dayton,1972), which by virtue of its structural or functional attributes creates and defines an entire ecological community or ecosystem, can have dramatic effects on our perception of the landscape and broad consequences for associated biota, ecosystem function, and stability. The situation in the forest is now improving through good management of the African parks and the park scouts also continuously patrol the park to protect the resource from external illegal exploitation. During field inventory the seed bank of the forest regenerate by itself and as a natural park there is no need for enrichment plantation although the natural regeneration and restoration should be managed for the ecological monitoring of invasive species and also control the loss of important ones.

Figure.4.26 Human induced and natural disastrous in the forest

Figure.4.27 Restoration of farm land at Seremele and farm expansion at Chamo letto

ii. The Open Grass land at Nechisar plain

The Nechisar plain is a unique feature of the park as well as being extremely beautiful in land of the grasses providing the natural habitat for the wild animals. The situation in the open grass land like the ground forest shows improvement in 2007 than the past years covering an area of 7610ha of open and healthy grass land and 3549ha is degraded grass land. In total the size of the open grass land covers 15.7 and 7.3 percent of the total park area and in total the Nechisar plain covers 23% of the total area 11,159ha including the healthy as well as the degraded Nechisar plain. The Plain is the major habitat of the park and grazing wild herbivores, for the hunting carnivore and for the birds. However the plain is also a major grazing site for thousands of Guji cattle's and these challenges the plain leading to increased soil erosion and the invasion of woody species and bush encroachment. The following Table shows the general information of the Guji cattle grazed at the Nechisar plain (APC, 2006).

Table.4.7 Guji villages, Population and cattle head count for 2000/2001

No	Guji Village	Total No of HH	No of Sample HH	Population	Total no of Cattle	Total No of Goat
1	Gandulo	40	20	304	1280	60
2	Awarche	24	12	108	600	43
3	Gode	44	22	321	1320	88
4	Watchole	42	21	315	1239	59
5	Mado	25	12	158	650	30
6	Datche	37	18	211	1065	89
7	Hare	10	5	46	310	35
8	Korde	28	14	177	616	103
	Total	250	124	1640	7080	507

The degradation of the grass land is very severe close to the villages where the highest house hold and cattle head count conducted that includes Gandulo,Gode,Watchole and Dache.

The degraded grassland as described in Section.4.1.4 and shown in figure.4.17 mainly lies on the area where the livestock population is very high as shown in Figure.4.27 below. The eastern central part of the Nechisar plain covers the area where the Guji cattle grazing.

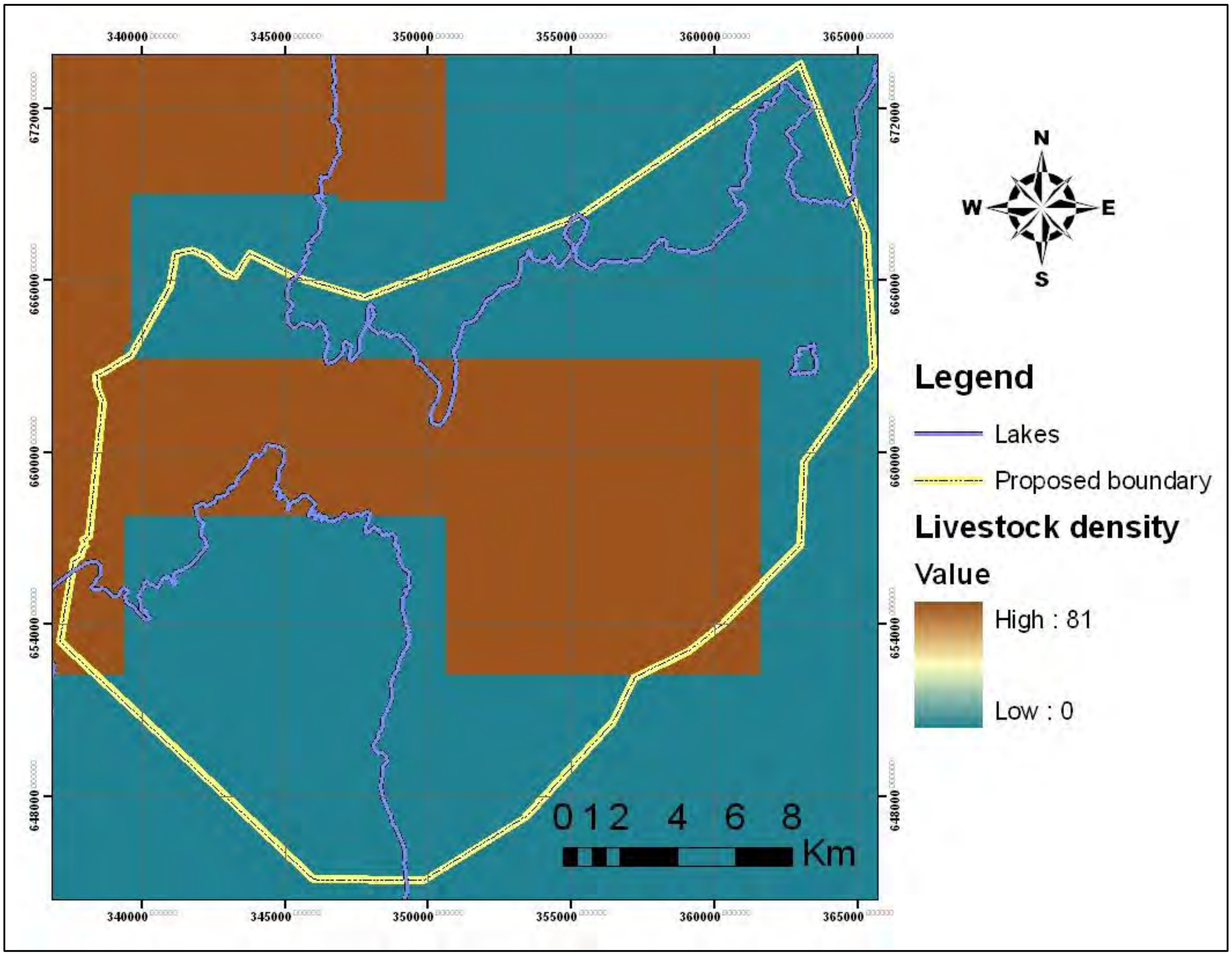


Figure.4.28 Livestock density around Nechisar park(PGIS project,2007)

Initially their were only few Guji Oromo tribe around the Nechisar plains(Bolton,1973) at present increasingly more human population is dependent on Nechisar plains for cultivation of crops and livestock grazing(Yisehak,2003).Human impact in the park including grazing of cattle's by nomadic Guji's and cultivation by the settled Kore and rampant poaching by Konso people(Kirubel,1985). In 1980,the previous military government evicted the local people who were living inside the park However they returned to the park area during the 1991 political change in the country(Yisehak,2003).This is believed to cause a widespread destruction both to the habitat and the wildlife in the area. After April 2005 African Parks gets the responsibility to manage the national park and encouraging measures are being taken to change the situation though the process is slow as it priorities the community participation for sustainable results.

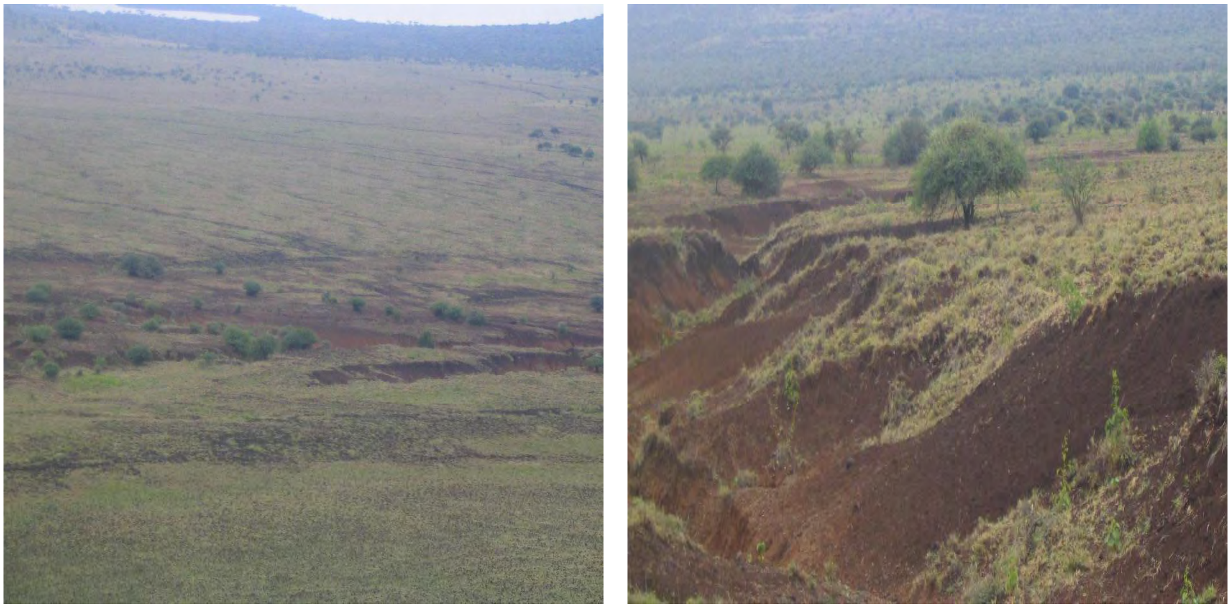


Figure.4.29 Degraded grass land at Dache/Northern part of the plain

Figure.4.30. Malvaceae family Invasive plant and Bush encroachment

Many parts of the Nechisar plain area is mainly savannah grass land with scattered *Acacia commiphora* trees and bushes(Bolton,1972).Currently there are scattered trees and bushes that are invading the open grassy plains. This change might be attributed to different factors Jacob(1999) showed that grazing, fire and rainfall regimes are factors that play an important role on plant species dynamics in Ethiopian savanna system.Tamiru (2001) shows in his study there is an indication that the abundance and distribution of some plant species such as *Themeda triandra* and *Cymbopogon* species is declining. Recently, these species are less frequent and localized in small patches in areas where there is no much grazing pressure. During field inventory most of the grass land is invaded specially the degraded grass land with a dominant invasive herb of *malvaceae* family identified in the Addis Abeba University herbarium center as *Abutilon bidentatum*, With characteristics, Erect or somewhat spreading shrub, Branches stellate pubescent, mixed with weak simple spreading hairs. This malvaceae plant family distributed in the open grass land invading mainly the degraded plain. As the park scouts reported that this herb starts to grow in the rainy season and lasts its stage of growth through out the year. Ewusie(1980) has shown that these species are more palatable and easily uprooted, and vulnerable for destruction. According to the park senior scouts report and personal community information the invasive herbs were not common before 2-3 decades. Bolton (1970) also reported that the grass species was abundant through out the park than herbs invasion before the past three decades.

Livestock can and do compete with several species of wildlife for forage in eastern Africa, but this may vary according to rainfall. Wildlife appear to avoid heavily grazed areas completely in arid northern Kenya (De Leeuw *et al.,* 2001), but mix more closely with livestock in semi -arid rangelands in southern Kenya (Waweru and Reid, unpub. data).Wildlife may cluster around settlements to have access to moderately grazed grasslands, where their access to energy and nutrients is very high. They may also graze close by for protection from predators. According to Yishak(2003) during the last thirty years, From the Nechisar plain 33.6% of suitable grassland for Burchell's zebra has been reduced. Yishak(2003) study also shows that the major components of habitat destruction at Nechisar plain includes bush encroachment, fire burning, cattle trampling, overgrazing and cachement floods. He also put the severity of those factors to degrade the Nechisar plains grass quality as 69.2% is recent bush encroachment, 21.2% is forest fire, and 9.5% is overgrazing and trampling. Although grazing effects can be difficult to disentangle from the effects of climate, those that have attempted to do so show that livestock grazing can drive grassland systems into bush land (Archer, Scimel and Holland, 1995). Heavy livestock grazing can convert grassland to bush land in eastern Africa, analogous to that observed in southern Africa (Ringrose *et al.,* 1990). Sometimes this conversion forms a mono specific stand of persistent woody species, which greatly reduces biodiversity (de Queiroz, 1993).

The African Parks foundation annual report shows that, in 2005 a total area of 17 hectares were cleared of invasive plant species (mainly *Dichrostachys cinerea, Acacia mellifera and Acacia oerfeta*) that had encroached a large area of the Nechisar Plain and surrounding woodland (APC report, 2005).

4.2.6 Biodiversity conservation and socioeconomic impacts

The creation of Nechisar was first proposed in 1967 when it still had a lot of game and no people. It was started in 1972 and well managed until 1991. Unfortunately, with the overthrow of the government in that year, there were invasions of people and livestock all over the protected areas in Ethiopia. In the case of Nechisar, the communities moving into the park came from two distinct ethnic groups, with different traditions of land use: the Kore people from the Amaro Mountains who cultivated land along the Seremele river floodplain and the Guji Oromo people who are nomadic pastoralists grazing approximately 4000 – 5000 head of stock inside the park (APC report, 2006).

Yet, Nechisar National Park is under threat from the exploitation of its natural resources by a livelihood dependent community directly to the natural resources from the park. Cattle grazing in the Nechisar plain, poaching of wildlife, illegal fishing and felling of timber from the groundwater forest, farming at Kulfo and Seremele valley encapsulate the main problems. Wild animal species such as: African elephant, Buffalo, Black rhinoceros, reticulated Giraffe, Lesser kudu, Gerenuk, Beisa oryx, cheetah, African wild dog and Grevy's zebra were present in large numbers in the past, but currently besides the decline in the number of most wilds, the important ones such as African elephant, Bufallo, Black rhinoceros, and Giraffe are extinct from the park. Similarly, if the rate of exploitation and direct natural resource dependency continues as it has been, the biodiversity is likely to collapse and die out within the next decade.

The Government claims to have allocated land outside of the Park to 1,800 of the Kore, a farming people, through their incorporation into its resettlement program. The Kore traditionally lived outside of the Park but cultivated within it. The approximately 5,500 Guji-Oromo, a semi-nomadic pastoral people, have been harassed and a number chased from the Park. They received no compensation for loss of property (Refugee international website, 2005).

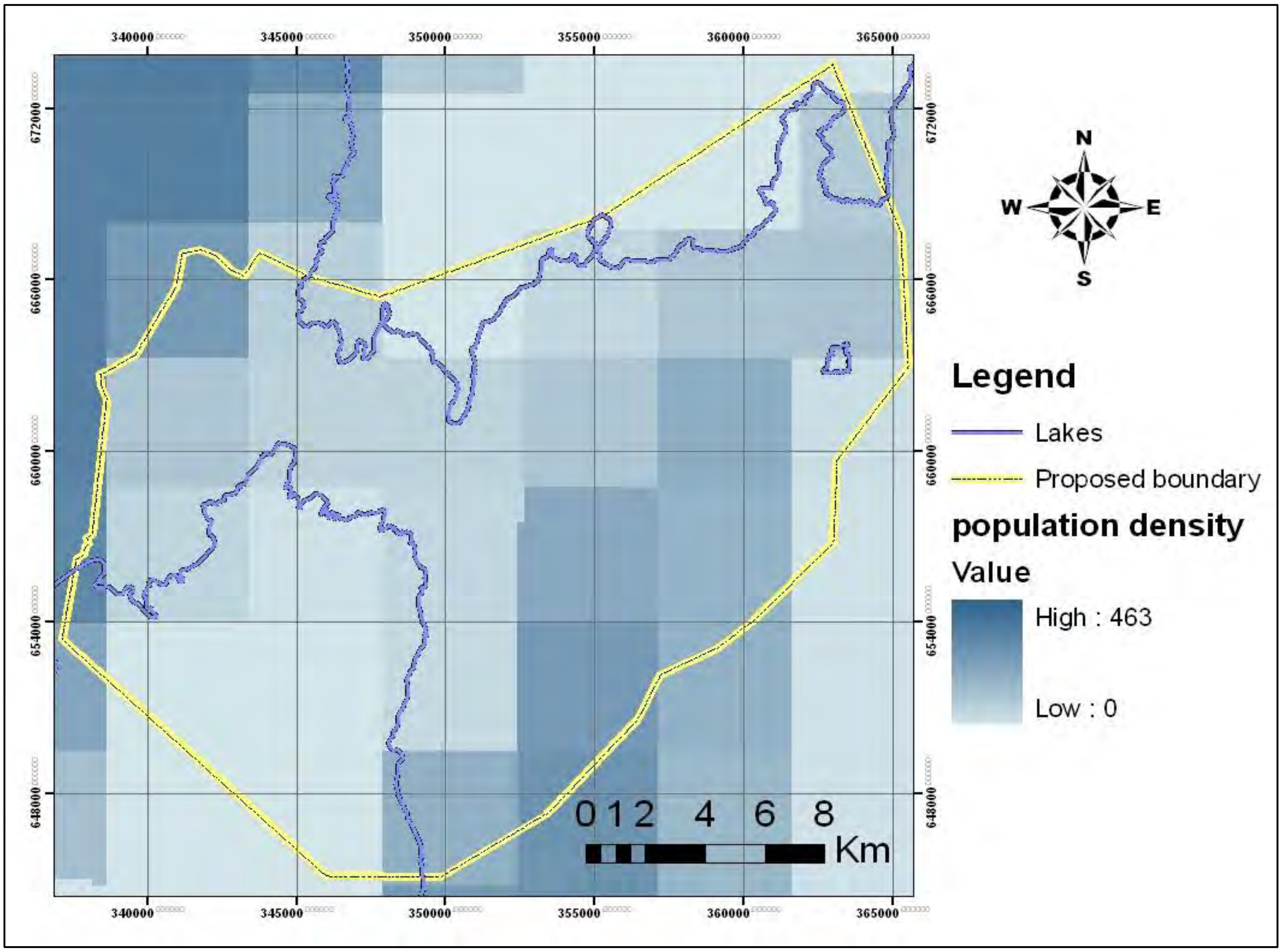


Figure.4.31 Population Density around the park (PGIS project, 2007)

As indicated in Figure.4.30 peoples are living inside the park boundary directly dependent on the natural resources of the national park especially the south eastern part which covers the grass land is excessively grazed by Guji Cattle's. The park boundary is also adjacent to the community living around Arbaminih town which lies to the North West side of the park. The Kulfo Riparian and Ground water forest is adjacent to the town and susceptible for exploitation.

However, except the Arebaminch town residents both the Kore and Guji communities lived without schools, clinics and other essential services, and the Government has been in the process of relocating them to suitable areas near the Park where basic services can be provided. During the field visit its checked that The Kore people have been resettled at Abulo and Alfecho about 15km south of the Park where a full suite of community services and infrastructure not previously available to this community has been provided. The planned relocation of the Guji Oromo community, has been planned and negotiated and is now also far advanced. The Guji have withdrawn their cattle from the Nechisar plains, which had become badly overgrazed and eroded, to the eastern edge of the Park and are in the process of moving further east where they have been allocated land (APC report, 2006).

The resettlement area including Abulo-Alfecho is set by the APC and the Kore community negotiation as a community conservation area; this helps for a sustainable biodiversity conservation and resource management at Nechisar park as well as neighborhood park areas.

Furthermore, referring to the resource depletion, there is also energy shortage and rapid deforestation in the area, the Administrators of Arbaminch Zuria (Arbaminch and surrounding woreda) and the Gamogofa Zone requested SESP (SNV Ethiopia Southern Portfolio) to identify sustainable income generating strategies for people and to promote alternative livelihoods projects for the Arbaminch population. Fire wood collecting is becoming an attractive job opportunity for many households. Though challenging and scarce, collecting and selling a bundle of firewood a day brings more income than working as laborer. That means, as fuel wood price increases, people involving in the sell earn more money; hence, more people tempted to collect wood for sale. Trees or woods are understood as money (APC-SNV Workshop proceedings, 2007).

Rehabilitation of grasslands usually involves use of enclosures and restricted access to allow the vegetation to recover and natural species to re-establish from the seed bank in the soil or from spread of plants by vegetative means. Grime (1979) recognized a variety of mechanisms of regeneration, with different types of regenerative strategies based on disturbance, vegetative cover and management, and proposed a model of vegetative succession and vegetation dynamics.

Vegetative expansion is associated with undisturbed habitats with few seedlings and relies on rhizomes and stolons of perennial grasses. Seasonal regeneration of gaps involves synchronous germination of seeds from abundant seeders. Regeneration from persistent seed banks and wind dispersed seeds is associated with spatially unpredictable disturbances. Woody species also have persistent seed and seedling banks but opportunities for recruitment are infrequent. Disturbances alter ecosystem processes and may alter the equilibrium balance of the system (Chapin, 2003). Disturbances are usually regenerated by species of the original community and return to the previous species composition within a few years (Belsky, 1986). Introduction of new species through colonization and recruitment following disturbances may result in system change, and plant traits may be important indicators to predict the consequences of global change (Chapin, 2003). Rehabilitation offers an opportunity to sequester carbon through forestation, grass and shrub establishment. This is particularly important because pastoral lands are so extensive and they sequester large amounts of carbon. Rangelands are only second to tropical forests in the amount of carbon they sequester, although most of this sequestration is unseen below ground in rangelands, in contrast to carbon above ground in rain forests (IPCC, 2000). Poor use of rangelands can cause up to a 50 percent loss in soil carbon, so the potential gains from rehabilitation are substantial (Cole *et al.,* 1989; IPCC, 2000; Reid *et al.,* 2003).

Seed supply to support reseeding is a major constraint in eastern Africa and most species have to be collected from the wild (Bogdan and Pratt, 1967), a situation that has changed little over the past 30 years. Most succession in pastoral areas is through natural means, such as wind dispersal, although some projects are collecting seeds from natural stands for revegetation purposes. A limited number of cultivars of Rhodes grass, setaria, coloured guinea grass (*Panicum coloratum*) and signal grass (*Urochloa decumbens*) are available in Kenya from the Kenya Seed Company. These are useful for pasture establishment but have limited use for reseeding rangelands, except for revegetation of the *Hyparrhenia* tall-grass region as described by Herlocker (1999) and other areas where these grasses are an important part of the natural ecosystem. These species can also be used for range improvement due to their high palatability and nutritive value, but establishment is often poor due to low rainfall and competition, as well as open grazing during the establishment phase (Bogdan and Pratt, 1967) Rehabilitation offers an opportunity to sequester carbon through forestation, grass and shrub establishment. This is particularly important because pastoral lands are so extensive and they sequester large amounts of carbon. Rangelands are only second to tropical forests in the amount of carbon they sequester, although most of this sequestration is unseen below ground in rangelands, in contrast to carbon above ground in rain forests (IPCC, 2000). Poor use of rangelands can cause up to a 50 percent loss in soil carbon, so the potential gains from rehabilitation are substantial (Cole *et al.,* 1989; IPCC, 2000; Reid *et al.,* 2003).

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Many previous attempts at rehabilitation have not been successful due to lack of consultation and involvement of local communities and their customs, and a perception that traditional systems need changes. Many technological interventions have been tested in the rangelands of southern Ethiopia but lack of development impact is linked to unrealistic expectations of development planners and poor appreciation of social values and production rationale of pastoralists (Coppock, 1994). Community participation in rehabilitation of degraded rangelands is an important step in promoting the success of current projects. A system in Samburu District in Kenya built on local knowledge and traditions to work in partnership with local people on local problems is having some success (Herlocker, 1999).

In Ethiopia the socioeconomic stand point of view, the government authority should justify nature preservation faced with ever increasing demand for pasture and agriculture land.

Decentralization of resource management from the central authority to local communities is considered as the first step forward for a successful community based conservation program. The key element of such program is that local communities participate in natural resource planning and wildlife management and that they gain economically from resource utilization. It also promotes the legal and sustainable use of the wildlife and other natural resources. In Ethiopia, recently the management of most of the country's protected areas are transferred to regional governments. The wildlife conservation policy of the region is therefore built around two basic principles. The first is protected areas must be economically productive and the second is the surrounding community must participate in management decisions and distribution of benefits. Thus the issue of conservation becomes more relevant to the local community around national parks (Grham, 1996).

Since February 2005, African Parks (AP) has taken over the formal management of Nechisar National Park near the town of Arbaminch. The aim of African Parks is to rehabilitate and transform Nechisar into a model park for the benefit of Ethiopian people and communities around Arbaminch in particular. This requires local support and enthusiasm for conservation of Ethiopia's biodiversity. Moreover, people who used to depend on exploitation of natural resources from the park for their survival (i.e. firewood collectors, grass land users, supposedly Illegal fishermen), require alternative livelihood options.

Arbaminch Zuria may be characterized as a typical subsistence economy with very limited source of income and investment from outside, the region certainly has an asset base which can serve as basis for alternative livelihood development. Moreover, sustainable investments in the natural environment would alter a number of negative trends in the region and improve the natural resource base on which numerous households depend. With the aim to build on the existing asset base and to break the negative trends at the same time, sustainable livelihood strategies were identified for the rural as well as urban settings and a number of concrete project proposals were formulated. The main purpose of these strategies and related projects is to provide economically viable opportunities to household's in the region so as to obtain a sustainable livelihood without (further) compromising the natural environment (SNV Ethiopia, 2006). There has been an effort to improve the situation in natural resource degradation and loss of biodiversity of NSNP.Thus to achieve a positive and sound result the community participation and the regional and federal government, other stake holders all hand in hand should assist African Parks in ensuring that local support through tourism activities and other viable income generating activities for rural and urban people thus contributing to the park’s sustainability to generations.

5. Conclusion and Recommendation

This study shows the land cover dynamics of the Nechisar Park for the past 31 years and discusses the factors on the major cover changes which is found to be human induced and also climatic i.e. precipitation fluctuation.

In the past three decades as the population around Nechisar National Park and nearby Arbaminch increases, so do the Pressure to the park natural resource such as grazing cattle at Nechisar plain, farming expansion with the expense of Seremele and Kulfo riparian vegetation, over fishing at lake Chamo and collect wood from the ground water forest. Nechisar National Park is under threat from the exploitation of its natural resources by a directly livelihood dependent community both rural and urban natural resource users from the park for decades. Though these activities are minimized from the effort of all actors playing pivotal role to change the situation, the past challenges in the park which this paper thoroughly discusses and find out could give a strong stand to change the situation and manage the park natural resource sustainable.

To reach the above conclusion the study fully utilized remote sensing and GIS tools, conduct field work and review different literatures.Sattelite images are the major source of raw data for this study including Landsat series images of MSS,TM and ETM+,ASTER images and the MODIS NDVI images. The research mainly focuses on the land cover dynamics of the national park for the past 31 years. The major component and analysis of the research comprises the following 1.Generate thematic Land cover maps for change comparison using Landsat images,
2. Analysis of land cover dynamics factors such as rate of land cover change, conversion matrix, Landscape Fragmentation index, 3. Generate up to date land cover map using ASTER image, 4.Analyse the impact of seasons on land and vegetation cover response using MODIS NDVI images, 5.Discuss the results from various point of view. All the research work is conducted using remote sensing and GIS techniques thus concludes the power of RS and GIS to conduct similar researches.

The results of the thematic maps for land cover classes of 1976, 1986, 2000 and 2007 shows dynamism for the different land cover classes except the changes for the water body is relatively insignificant . For instance the rate of change from 1976-1986 is 1.12ha/year for the water body that covers lake Abaya, Chamo and small swampy lake Haroropi. The land cover dynamics for the other land cover types such as the open grass land is found to be fragile and severely affected part of the park in the past decades. There is a tremendous land cover change in the open grass land cover as compared to other cover classes and it's calculated a total loss of grassland, 562.6ha/year to other cover types and a total area of 5626ha of land which is totally destroyed grassland over the 10years of 1976-1986. Bushy shrubbed grass land has increased highly for the first 10 years period from 1976-1986 at a rate of 714.1ha/year, and second period from 1986-2000 by 470ha/year. MODIS NDVI images are very important to see the response of the land cover over seasons on the situation of the park particularly biomass growth comparison for a yearly period and between a number of years. Generally this research ensures that the use of Remote sensing and GIS to study Land cover dynamics could facilitate for a proactive planning process that enhances the implementation of sustainable natural resource management for decision makers, park managers and other stakeholders.

The results from conversion matrix and fragmentation index are found to be very important to understand the conservation status of the national park for the past years.Bush encroachment has been mentioned as a challenge to the grass land by different authors and the expansion of this land cover type should be monitored for the health of the ecosystem. The grass land has to be cleared and burned of invasive plant species (mainly *Dichrostachys cinerea, Acacia mellifera and Acacia oerfeta*) that have encroached a large area of the Nechisar Plain and surrounding woodlands. Erosion and land degradation is also a major challenge to the grass land where the plain is excessively grazed by Guji cattles for the past decades. Although the natural resource of the park is open for the park livelihood dependent community for decades and the carrying capacity of the Nechisar plain seems to suffer from grazing cattle's beyond the limit and these impacts are clearly seen at field as a degraded plain with lots of erosion, gullies and bare land that only covered by invasive herbs and encroached bushes.

Habitat fragmentation is also a serious challenge in the park for the different land and vegetation cover classes as the broken patches of land cover results a fragmented landscape which is unhealthy for the park ecology. The other major habitats of the park including the Riparian and ground water forest, wood land, Swampy vegetation on this study are found to be highly exploited for decades and should get attention and properly managed and protected for biodiversity conservation. The Riparian and ground water forest, the wood land has been cleared and exploited by The Kore communities for farming activity and the Arebaminch town dwellers for fuel wood and construction which have caused forest degradation. There fore the dependency of the surrounding community to the natural resources of the park has to be a priority agenda and for successful and win-win solution there should be the participation of different actors who will have a key role to solve livelihood problems of the community and the well being of the national park for sustainable tourism and healthy ecosystem functioning.

The following recommendation are given for the overall management of the park

- The land cover dynamics study at Nechisar Park has given important results that show the conservation status of the park and this has to make stake holders aware of the severity of the situation such as bush encroachment, habitat fragmentation, land degradation and erosion thus there should be a quick start in planning to manage the national park with the full participation and integration of concerned all actors for a sustainable future.

- The Nechisar plain is severely affected by environmental and anthropogenic challenges thus needs priorities to completely stop overgrazing and plan appropriate bush encroachment controlling strategy.

- The ground water forest which is unique habitat for the country has to be protected from any exploitation and investment projects such as water bottling industries which are already proposed by investors and this should be discouraged unless detailed impact assessment is conducted.

- The situation in the park is improving once APF Plc. Ethiopia is taking the responsibility to manage the national park, thus Federal and regional government, the community and other partners should work together to realize the vision of APC plc to set the Nechisar national park a model to other treated parks in the country by rehabilitation and restoration of the area to the previous status both in flora and faunal diversity for the benefit of the country and the people through sustainable tourism.

- Currently the question of livelihood dependency of both urban and rural community in the natural resource of the park should be integrated with various projects which APC already engaged such as managing the resettlement Kore community and Guji areas as a community conservation areas and select scouts to protect the park and park nehborhood, the Arbamench town energy demand is can be solved by project such as fuel efficient stoves, alternative energy, and afforestation programs in selected sites and plant fast growing species.

- The current situation of the park is improving though African Parks Foundation (APF-Plc) already taken a decision to stop working for the management of Nechisar Park. Thus there should be a quick response for a wise decision before the remaining park resource is aggressively devastated while conflicts among the surrounding communities arise during transitional periods between APF Plc–Ethiopia, Regional Governments and the Federal Government. Thus awareness creation on the surrounding community for responsibility to manage and protect the park biodiversity is crucial for a peaceful and sustainable future.

- Finally I recommend for further researchers to study the impact of vegetation cover dynamics on the situation of endangered wild life such as *Swayenes heartbeets* and to conduct a scenario analysis on the relationships of natural resource degradation and wildlife extinction.

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ANNEX

Annex-1 Radiometric Characteristics of Landsat image series

Satellite	Spectral Resolution (µm)	Band	Spatial Resolution (meters)
Landsat 1-3	MSS Band 4: 0.50 - 0.60 Band 5: 0.60 – 0.70 79 Band 6: 0.70 – 0.80 Band 7: 0.80 – 1.10	 Green Red Near IR Near IR	 79 79 79 79
Landsat 4-5	MSS Band 4: 0.50 – 0.60 Band 5: 0.60 – 0.70 Band 6: 0.70 – 0.80 Band 7: 0.80 – 1.10	 Green Red Near IR Near IR	 82 82 82 82
	TM Band 1: 0.45 – 0.52 Band 2: 0.52 – 0.60 Band 3: 0.63 – 0.69 Band 4: 0.76 – 0.90 Band 5: 1.55 – 1.75 Band 6: 10.4 – 12.5 Band 7: 2.08 – 2.35	 Blue Green Red Near IR Mid IR Thermal Mid IR	 30 30 30 30 30 120 30
Landsat 7	ETM Band 1: 0.450 – 0.515 Band 2: 0.525 – 0.605 Band 3: 0.630 – 0.690 Band 4: 0.760 – 0.900 Band 5: 1.550 – 1.750 Band 6†: 10.40 – 12.5 Band 7: 2.080 – 2.35	 Blue Green Red Near IR Mid IR Thermal Mid IR	 30 30 30 30 30 60 30
	Band 8: 0.52 – 0.92	Pan	15

Annex-2 GPS Ground control and way points collected at Nechisar national park

TYPE	LAT	LONG	Y_PROJ	X_PROJ
road side-abuloalfacho- farming	5.80034447	37.63203889	641317.04580033	348540.15934623
road side-abuloalfacho- farming	5.72789163	37.61959394	633309.06655074	347142.61128020
Alfacho settlement	5.72785785	37.61957534	633305.33635718	347140.54225800
Alfacho settlement	5.69763129	37.61732806	629963.69965078	346883.61499428
Semele farming-banana,suger cane	5.91241077	37.71041983	653687.78079975	357248.40137518
WAYPOINT	5.91241093	37.71041966	653687.79853450	357248.38259472
Trees at sermele Acacia poleicanta,elephant grass	5.91272609	37.71010500	653722.72638965	357213.62596272
Trees at sermele Acacia poleicanta,elephant grass	5.91280648	37.71001959	653731.63700129	357204.19045171
Wood + Bush land and trees,Euphorbia trq,Acacia melefera/senegal/albida,Dobra glabra	5.91280790	37.71001766	653731.79450557	357203.97713686
Acacia polecanta and corn field	5.91837726	37.71838230	654345.45228738	358131.48279436
Wood +bush land-Acacia tortils/melefera,Dobera glabera	5.92328813	37.73638110	654883.87454850	360125.41389778
Open grass and acacia tortils-following the road farm plots	5.92293818	37.73631304	654845.19830250	360117.79080391
Small bush,grazed grass land,following the valey -farming	5.92574202	37.74431381	655153.20347048	361004.26734711
WAYPOINT	5.93168839	37.74939325	655809.41075749	361568.09677494
Tselke vilage and market	5.93768748	37.75456832	656471.42614459	362142.51464207
Tselke vilage and market	5.93772286	37.75455499	656475.34134725	362141.04770624
WAYPOINT	5.94351576	37.75596592	657115.49736410	362298.68804756
WAYPOINT	5.94335508	37.75558261	657097.82679181	362256.21318282
Scattered acacia -Bush grass land-we saw zebra grazing	5.94414524	37.75707945	657184.82036525	362422.11938155
River flood plain-cultivated -banana	5.96538347	37.76818413	659530.32134904	363656.71332219
WAYPOINT	5.97634130	37.77775208	660739.53614880	364718.58771913
WAYPOINT	5.97648723	37.77753398	660755.72480874	364694.48011494
River flood plain-cultivated -banana	5.96538347	37.76818413	659530.32134904	363656.71332219
WAYPOINT	5.97788885	37.77602591	660911.06877873	364527.88304734
Bushy grass land	5.98268146	37.77636504	661440.88941850	364566.60356195
Water stagnant-100m from this way point-thick acacia trees	5.98408928	37.77590102	661596.66217046	364515.58428366
View to HAROROPI	5.98866186	37.77173362	662103.26867148	364055.39360332
CORN FIELD	5.98992141	37.76992422	662242.98199574	363855.41082376
CORN FIELD	5.99209350	37.76884622	662483.41156994	363736.61857949
ELEPHANT GRASS + ACACIA POLICANTA	5.99321826	37.76855478	662607.84562445	363704.63637384
valley coverd with thick vegetation	5.85692558	37.67126360	647562.93222764	352898.61195902
MEO AND SERFMELE JUNCTION	5.85759999	37.67161447	647637.41040253	352937.63930862
ROAD TO abuloalfacho	5.76599434	37.62130477	637521.73276662	347342.24744175
CHAMO FISHERY CAMP SITE-AMARO CAMP-ACACIA TREES	5.76599367	37.62131500	637521.65594342	347343.38020785
invasive spp.point	5.84740114	37.65415295	646514.31245734	351001.46669636
invasive spp.point	5.84709546	37.65366579	646480.64205111	350947.44256915
invasive spp.point	5.84732948	37.65339212	646506.59059610	350917.20105250
invasive spp.point	5.84691818	37.65241236	646461.37236034	350808.60323522
invasive spp.point	5.84580716	37.65272979	646338.44076997	350843.45799150
invasive spp.point	5.84580146	37.65305065	646337.72541479	350878.98540722
acacia trees scattred and mixed	5.84488397	37.65258704	646236.39994767	350827.40671114
View point to litle nech sar,meo river	5.84628861	37.65425219	646391.27189886	351012.16114481
WAYPOINT	5.84835978	37.65276097	646620.68003027	350847.58679562
HOUSE,CATTLE BARN,TOMB	5.85085843	37.65146337	646897.30466381	350704.56661966

invasive spp.point	5.85200063	37.65223844	647023.39381016	350790.69255138
sermele side-forest	5.90204369	37.68716214	652547.51340329	354670.72015817
Acacia senegal dominant-rocky short grass	5.90151957	37.68633921	652489.77601463	354579.47060499
grass + scattred acacia	5.91151231	37.68441489	653595.18120725	354369.02521308
grass land-I see swaynes at distant	5.92692512	37.67425619	655302.06181083	353248.36058804
road side to burnt grass plain	5.92647585	37.67327861	655252.64427707	353140.01068115
acacia wood land	5.96909875	37.65446291	659970.56038168	351068.32328214
wooded grass land	5.97160066	37.65589018	660246.81588298	351227.00533707
Abaya side - rocky,short grass,scatreed acacia treess and others	5.97930682	37.65941796	661097.94843033	351619.62432127
overgrazed hill-gullies run at mountain foot and folowing the plain	5.99156678	37.66724238	662451.44611476	352489.10189578
overgrazed hill-gullies run at mountain foot and folowing the plain	5.99156678	37.66724238	662451.44611476	352489.10189578
Burntgrass close to road	5.96898434	37.65457976	659957.87823440	351081.22834746
small ridge foot-old rock made cattle barn	5.95446822	37.65936549	658351.51254795	351607.13411549
small ridge foot-old rock made cattle barn	5.95446822	37.65936549	658351.51254795	351607.13411549
small ridge foot-old rock made cattle barn	5.95446822	37.65936549	658351.51254795	351607.13411549
Wooded grass land	5.94394617	37.65856904	657188.28443546	351516.13661230
chamo side-closed bush	5.97000081	37.65178054	660071.02920894	350771.61356389
Abaya shore- swamp vegtation	5.97134108	37.65052451	660219.56642694	350632.92704592
open bush,bare red soil	5.98057291	37.65031287	661240.40845261	350612.00128346
open bush,bare red soil	5.97470096	37.64557256	660592.42268706	350085.63272984
open bush,bare red soil	5.97890683	37.64235534	661058.35446750	349730.61783674
Abaya shore- thick swamp vegtation	5.97908990	37.64252700	661078.55009337	349749.67130015
Abaya shore- thick swamp vegtation	5.97806135	37.64411478	660964.38703972	349925.16485083
open wod grass land	5.98874048	37.63516333	662147.66139390	348937.13099092
thick wod land	5.99397817	37.63278505	662727.46425858	348675.29177925
thick wod land	5.99397817	37.63278505	662727.46425858	348675.29177925
thick wod land	5.99397817	37.63278505	662727.46425858	348675.29177925
thick wod land-dense bush	5.99397817	37.63278505	662727.46425858	348675.29177925
WAYPOINT	5.99999537	37.62257514	663395.63533208	347546.70661886
dense bush-euphorbia triquali,acacia melefera	5.99772664	37.62109489	663145.18554159	347382.21042888
Open wood grass	5.99762446	37.62118483	663133.86208019	347392.13850275
WAYPOINT	5.98551035	37.62210382	661794.10522148	347490.50886848
WAYPOINT	5.97053382	37.61116493	660141.13869950	346275.34712620
steep slope	5.96734945	37.60477717	659790.81657796	345567.28209527
down to chamo dense bush	5.96737124	37.60466066	659793.25865486	345554.38956876
WAYPOINT	5.96922783	37.60000544	659999.85754227	345039.53910751
chamo swamp vegetation	5.97333128	37.59777451	660454.22340648	344793.71224155
boat harbour-chamo camp	5.97154761	37.59293295	660258.36200643	344257.21084017
Open bush and grass land	5.97040071	37.59359722	660131.35581223	344330.42697102
WAYPOINT	5.97726298	37.58612819	660892.27010166	343505.49166951
BIG ACACIA TRESS -WOOD LAND	5.98447326	37.57764537	661691.97247539	342568.44338066
WAYPOINT	5.99485869	37.57039745	662842.43456013	341769.04337998
BUSH AND WOODS	5.99702180	37.57264690	663080.97393802	342018.68984395
ROCKY,AVALANCHES,SHRUBS	6.00104562	37.57217014	663526.04919897	341967.06973569
ROCKY,AVALANCHES,SHRUBS	6.01401142	37.57186077	664959.84510159	341936.56243293
ROCKY,AVALANCHES,SHRUBS	5.99717276	37.54610988	663105.38561725	339080.96672128
ROCKY,AVALANCHES,SHRUBS	5.99465660	37.54631373	662827.09584085	339102.79641302
ROCKY,AVALANCHES,SHRUBS	5.99456121	37.54692343	662816.36903554	339170.26566467
ROCKY SLOPE FOOT-GOES TO THE PLAIN	5.99443967	37.54693869	662802.92501114	339171.91942959
ROCKY SLOPE FOOT-GOES TO	5.99443967	37.54693869	662802.92501114	339171.91942959

THE PLAIN				
WAYPOINT	5.99415586	37.54751603	662771.37283347	339235.75110019
STREAM	5.99339956	37.54787050	662687.63946239	339274.77155418
WAYPOINT	5.99307644	37.54779892	662651.93075793	339266.75265985
GRASSY PLAIN	5.99270462	37.54675688	662611.12140744	339151.28381303
GRASSY PLAIN-OLOD ROAD	5.99468417	37.55114850	662828.72828242	339638.04001118
BUSH	5.99441470	37.55269236	662798.47990401	339808.87490877
SHRUB	5.99474964	37.55371361	662835.21830933	339922.03036911
CLOSED BUSH-scatrred Acaciaa tortilis	5.99303680	37.55615350	662645.10644641	340191.64029318
gwf boundary acacia bush	5.99126461	37.55681567	662448.95068146	340264.43072345
close to kulfo	5.98980758	37.56053070	662286.75728742	340675.28315149
Eneramed camp-kulfo bridge turn	5.99738566	37.57051019	663121.82438571	341782.25258821
Kulfo bridge	5.99783703	37.57166857	663171.40085277	341910.61976106
Kulfo bridge	5.99652425	37.57302702	663025.84735049	342060.62741193
thick bush+ trees	5.99683807	37.57283977	663060.60224057	342039.98841636
abaya shore -swamp vegetation	6.02519992	37.59950085	666189.09608999	344999.48604103
abaya shore -swamp vegetation	6.02519992	37.59950085	666189.09608999	344999.48604103
compound of previous mango plantation	6.02519992	37.59950085	666189.09608999	344999.48604103
close to farm plots	6.03630309	37.56720965	667426.12289934	341428.15223379
Bush + acacia tress	5.93910553	37.54166069	656685.77480192	338571.42171640
Bush + acacia tress	5.93910553	37.54166069	656685.77480192	338571.42171640
chamo leto irrigation canal from kulfo	5.93915549	37.54232914	656691.10432738	338645.44501912
chamo leto irrigation canal from kulfo	5.93908014	37.54491596	656682.01890233	338931.82775530
corn field margin	5.93964919	37.54790302	656744.07435492	339262.71040915
corn field margin	5.94353185	37.55096720	657172.51739273	339603.08989391
thick bush+ trees	5.94360863	37.55189155	657180.73949648	339705.45210741
Foot of hill,irrigation diverted from kulfo	5.94467699	37.55165351	657298.94427064	339679.40669084
Compound of 40 springs	66.66199995	34.23959996	7401728.37813791	289723.17405419
WAYPOINT	5.93270285	37.53458066	655979.85207906	337785.66787538
Hill vegetation-bushy rocky ground	6.03693416	37.57752785	667492.91060887	342570.51709315

D E C L A R A T I O N

I here by declare that the dissertation entitled **"ANALYSIS OF LAND AND VEGETGATION COVER DYNAMICS USING REMOTE SENSING & GIS TECHINIQUES, *A CASE STUDY AT NECHISAR NATIONAL PARK*"** has been carried out by me under the supervision of Prof .Zerihun Woldu and Dr. K.S.R. Murthy, Department of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2007-2008 as a part of Master of Science programme in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa
Date: Feburary, 2008

(Asaye Nigussie)

C E R T I F I C A T E

This is certified that the dissertation entitled **"ANALYSIS OF LAND AND VEGETGATION COVER DYNAMICS USING REMOTE SENSING & GIS TECHINIQUES, *A CASE STUDY AT NECHISAR NATIONAL PARK*"** is original work carried out under the guidance and supervision of ***Prof.Zerihun Woldu and Dr. K.S.R. Murthy***. This is the actual work done by Asaye Nigussie for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University.

Prof.Zerihun Woldu and Dr. K.S.R. Murthy

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