JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL ENGINEERING CHAIR

ANALYSIS OF FOREST COVER CHANGE DETECTION IN RELATION TO CLIMATE CHANGE BY USING GIS AND REMOTE SENSING TECHNIQUE : CASE OF KAFFA ZONE SOUTH WESTERN ETHIOPIA

By: Kinde Teshome

A Thesis submitted to Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering, Environmental Engineering chair in Partial fulfilment of the requirements for the Degree of Master of Science in Environmental Engineering.

March, 2020

Jimma, Ethiopia

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Main advisor: Dr. DEJENE BEYENE (PhD.)

Co advisor: Mr. SEIFU KEBEDE (MSc.)

March, 2020

Jimma, Ethiopia

DECLARATION

This Thesis is my original work and has not been presented for the award of any degree in any other university.

I have identified all materials in this Thesis which are not my own work through appropriate referencing and acknowledgement.

Done By:

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	Signature	Date

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Examined By

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(External Examiner)	Signature	Date
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(Internal Examiner)	Signature	Date

ABSTRACT

The consumption of forest and forest products has been shown to be higher than the incremental yield (forest gain) of forests leading to deforestation and forest degradation in the country. A forest loss of 50% within the last 37 years has been reported for south western Ethiopia. The main focus of this study was the applicability of Geographic information systems to detect forest cover change in relation of climate trends during last 32 years (1986-2018) in Kaffa zone south western Ethiopia. Satellite images from USGS Landsat TM (1986, 1990), ETM+ (2010, 2016) and OLI 8 (2018) were used for forest cover change detection. Beside of these rainfall and temperature data were analysed to correlate the NDVI value with annual climate data. A supervised classification was made using maximum likelihood method in ERDAS imagine V 9.2 software. In order to examine the areal extent and rate of forest cover change post classification change comparison method were done using ArcGIS V 10.4.1. The major land use land cover types in the study area have been classified as settlement, farmland, wetland and forest. The statistical results show that the pattern of forest area was decreased from 10020.33 Ha to 9143.19 Ha between the year of 1986 and 2010. As well as it was reduced in to 8851.23 Ha in 2018 in the study area respectively and net change were 846.45 Ha and 322.2Ha in interval of the 1986-2010 and 2010-2018. In general, the result indicates that the overall vegetation is not in stable condition. In 1986 minimum value and maximum value of 0.06 and 0.64 respectively declined to 2010 (minimum 0 and maximum value 0.77) When we compared to 2010 and 2016 image NDVI value the minimum and maximum value ranges from 0 to 0.77 declined to minimum and maximum value of -0.08 to 0.12 at 2016. The linear regression shows as there was continues fluctuation of rainfall and minimum temperature and increase of maximum temperature. These also indicates if the two parameter was fluctuates each other there was negative effect on the NDVI value; but the rainfall and temperature exceeds at the same time the NDVI does not decreased and there is no vegetation that were unhealthy. The information generated from these study area is expected to be of immense help in formulating policies and programmes required for sustainability of forest land and climate variability.

***Keywords**: climate change, forest cover, Geographic information system, land use land cover.*

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First of all, I would like to thank the Almighty God who made all things possible. I am deeply grateful to my advisors Dr. Dejene Beyene and Mr. Seifu kebede (MSc) for their ideas, constructive comments and sharing their experience in shaping my study by spending their valuable time with me. My sincere thanks and appreciations go to Jima University, Jimma Institute of Technology, Environmental Engineering chair, Ethiopian road authority and Ethiopian Metrological agency for their invaluable cooperation in providing me the necessary intellectual and material resources.

Lastly not least I would like to express my deepest gratitude to my family and special thanks to my elder brother and best friends for their friendship and cooperation during my stay in the university.

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ACRONYMS

ADF	Africa Development Forum
BR	Biosphere Reserve
EWNHS	Ethiopian Wildlife and Natural History Society
ETM+	Enhanced Thematic Mapper Plus
ERDAS	Earth Resource Data Analysis System
FAO	Food and Agriculture Organization
FRA	Forest and Resources Assessment
FDRE	Federal Democratic Republic of Ethiopia
GIS	Geographic Information System
GPS	Global Positioning System
Ha	Hectare
IBC	Institute of Biodiversity Conservation
IPCC	International Panel on Climate Change
KBR	Kaffa Biosphere Reserve
LULC	Land Use and Land Cover
LULCC	Land Use And Land Cover Change
MaB	Man and Biosphere
Masl	Meters Above Sea Level
MSS	Multi Spectral Satellite Image
NABU	Nature and Biodiversity Conservation Union
NDVI	Normalized Difference Vegetation Index
NFPA	National Forest Priority Area
NGO	Non-Governmental Organization
NIR	Near Infrared Rays
NTFP	Non-Timber Forest Product

PFM	Participatory Forest Management
SNNPRS	South Nations Nationalities People Regional State
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Conventions on Climate Change
USGS	United States of Geological Survey
WBISPP	Woody Biomass Inventory and Strategic Planning Program
WGS	World Geodetic System

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Forests are one of the natural resources that covered 30 % or 4 billion hectares of the Earth's land surface which provide valuable ecosystem services and goods, serve as a habitat for a wide range of flora and fauna and hold a significant standing stock of global carbon (UNFCC, 2011). According to FAO (2010) the total area of natural forests in 1990 was 15.1 million ha and was reduced within 20 years to 12.3 million ha. Accordingly, Ethiopia has lost 140,000 ha natural forest annually (Feleke, 2002).

Changes in land cover and the way people use the land has become recognized over the last 15 years as important global environmental changes in their own right (Turner, 2002). In Africa the annual loss of about 3.4 million hectares making it the second largest net forest loser in the world (ADF, 2012).

According to Genanaw (2008), Ethiopia is one of the countries in which its forest resources are highly depleted due to massive removal by its growing population. Thus, the country has lost much of these forest resources. These high-forests have declined from 40% of land cover to approximately 3.6% in 2013 and the remaining high forests are found in the southwest of the country; more than 60% of the original forest has been lost over the last 30 years, between 1970 and 2000 (Maereg *et al.*, 2013).

Global mean temperature has increased by 0.85˚C over the period of 1880 to 2012 and this increase in temperature is likely due to anthropogenic activities that have increased the concentrations of greenhouse gases to unprecedented levels (IPCC, 2013).

FAO (2010), report indicates that world's forests store more than 650 billion tonnes of carbon, 44% in the biomass, 11% in dead wood and litter, and 45% in the soil. For the world as a whole, carbon stocks in forest biomass decreased by an estimated 0.5 Gt annually during the period 2005 – 2010. This was mainly because of a reduction in the global forest area and occurred despite an increase in growing stock per hectare in some regions.

Various initiatives have been undertaken to conserve the unique forest resources of Kaffa zone. Through the Man and Biosphere Programme of UNESCO, the Kaffa Biosphere Reserve was intiated in June 2010. The BR concept is based on three interrelated zones, each with different conservation functions First, a Core Zone is totally protected from all uses. The Buffer Zone is reserved for ecologically-sound land use concepts. Finally, the Transition Zone combines different interests towards the aim of using resources sustainably (UNESCO, 2011).

The Buffer Zone which includes a number of National Forest Priority Areas such as Bonga NFPA covers a total area of 161,427 ha. The Transition Zone constituting the man-made (cultural) environments where consumptive land uses are practiced, with specific reference to deforestation and land-clearing for crop cultivation, and where the highest settlement densities occur. It includes a variety of land uses predominantly in ownership of the state covers a total area of 337, 885 ha.

Based on SNNPR, department of Kaffa zone finance and economic development report of 2013, the total population of the Kaffa zone was about 1,041,754. From this Gimbo woreda 108,571, Decha woreda 188, 685 and the zone capital Bonga town accounts 27,634. The population density of the zone is about 98 persons per square kilometre but Bonga town accounts 2017 persons per square kilometre.

Remote Sensing and Geographic Information System are now providing new tools for advanced ecosystem management. Nowadays, data from satellites are very applicable and useful for forest cover change detection studies. Monitoring of forest cover change is one of the main applications of remote sensing based change detection (Abyot *et al*., 2014).

The pertaining clues or initiating factor for this study was vast clearance of forest resource in past years for consumption of different domestic purpose without considering Indigenous and environmentally feasible nature protection of local community especially the Manjo tribe and lack of reliable data which indicate spatial extent forest cover in the study area. An attempt has been made to map the status of forest cover changes of the study area between in the year of 1986 to 2018.

1.2 Statement of the problem

The consumption of forest and forest products has been shown to be higher than the incremental yield of forests leading to deforestation and forest degradation in the country (Asefa, and Bork, 2014).

A forest loss of 50% within the last 37 years has been reported for South-western Ethiopia (Tadesse *et al*., 2014). Agriculture expansion is the main proximate driver of deforestation in the BR, while fuel wood consumption is the main direct cause of forest degradation (Dresen, 2011).

Few studies have been conducted in the study area focusing on mapping of land use land cover change, agriculture, production and marketing of cash crops. Studies related to climate change have not been conducted in Kaffa Zone so far. The current study has come up with application of GIS and remote sensing tools for the assessment of forest cover change detection and its correlation with climate change, which provides update and relevant information in decision making for concerned bodies to manage natural resource basis.

The estimated annual deforestation rate in Kaffa Zone is about 22.500 ha (Stellmacher, 2005). The severity of this issue even created an international concern and global well known non-governmental organization even to be a part of mitigation and rescuing for endangered species. That is why one of the keen observer and environmental analyst in international level NGO, NABU selected the study area as one of their project area for the last eight years. Their aims are to preserve habitat and species biodiversity, forestry and water management and enhancing the profile of nature conservation within society.

Geographic information system and remote sensing hold much prospect for analysing the urban and pre-urban environment with a higher degree of effectiveness and clarity (Appiah *et al*., 2015; Olokeogun *et al*., 2014; Weng, 2001;Asiyanbola, 2014; Rimal, 2011). In spite of the potentials of the strengths of the application of this tool, within the context of the Kaffa Biosphere Reserve, the literature has remained sparse on the integration of the application of the geo information tools with its implications of forest cover change detection.

In general, even if mankind spent thousands years to perfect inside there have been a lot of miss out in his environment. The following sever issues were the problems which state the concept of this research.

- ✓ High rate of daily and seasonal deforestation which was used for natural resource utilization and local energy demand satisfaction without eco charcoal production mechanism.
- ✓ Forest cover change has significant and cumulative impact on regional and global climate changes, since environmental problems have no boundaries and they are interrelated
- ✓ The problem of climate condition variability of the study area was increasing especially there was seasonal pattern change on rainfall and temperature.
- ✓ There is well-known science manifestation and virtual expression of theoretical and practical implementation of optimized multifarious forest which is unique and forms of iconic figures for the culture and ethnicity of the society.

1.3 Research Hypothesis

The recently residence of the study area forest is still lack of optimized implementation of natural resource development and monitoring of green Eco system approach and perm culture eco forestry conservation.

1.4 Objective of the study

1.4.1 General objective

The general objective of this study was to detect forest cover change and its implication to climate change using ArcGIS 10.4.1, ERDAS Imagine 9.2 software and pivot table in excel.

1.4.2 Specific Objectives

1. To map the forest cover change over a period of 32 years
2. To analyse the pattern of rainfall and temperature changes in the three decades.
3. To correlate forest cover change with climate change

1.5 Research questions

1. How the forest cover has been changed over the last three decades?

2. How the patterns of rainfall and temperature changes look like in the study area?

3. How does forest cover change correlates with climate change in the study area?

1.6 Scope of the study

This study was delineated to analyse forest cover change and its implication to climate change by integrating GIS and remote sensing data in Kaffa Zone for about 32 years for the duration of 1886 to 2018 alone.

1.7 Significance of the study

This study has been focused in possible modifications that can be applied to the current harvesting method of forests to make it more ecologically sustainable. The analytical result synthesises and interpretation of land use and land cover has been generated important areal map, which could be a bench mark for ecosystem conservation and sustainable utilization to create a consensus attitude and generative special and temporal data for the natural resource protection agencies.

Creating a link and chain of collaboration with agricultural research agencies and industry link programs by impounding existence of relevant basic issue based data and giving full rights to use it as the essence of existed or on-going researches which was conducted in this area. The study can used as primary data for the background pilot study on the sight area which could serve as the regionalization and policy adaptation of eco-friendly adopted forest project. With perspective of these it help as the alpha trial on this field of expertise so that locally established NGO's that have been working on the ecosystem and the governmental agencies that have collaborating to resolve the issues like Global warming and environmental pollution mitigation, combat deforestation and sustainable natural resource utilization.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

A forest is a complex ecosystem which is mostly composed of trees, shrubs and is usually a closed canopy and the home of a large variety of life forms such as plants, mammals, birds, insects and reptiles (Amritkar, 2009). FAO (2001) defines a forest as land with a tree canopy cover of more than 10 % and an area of more than 0.5 hectare; the trees should be able to reach a minimum height of 5 meter at maturity in situ.

Human activities have a role in the modification of physical or man-made environment, so making suitable or harshen is in its hands Workaferahu, (2015). According to (Melillo *et al*., 1985) between 1950 and 1983, reported that forest and woodland areas declined by about 38% in Central American and 24% in Africa.

A recent forest resource assessment (FAO, 2010) estimated the World forest covers 30% of the total land area. This is approximately 4 billion hectares corresponding to 0.62 hectares per capita. This is unevenly distributed with 62 countries of combined population of approximately 2 billion having less than 0.1 ha per capital (FAO, 2010).

According to the study by Mayaux *et al*. (2005) based on Earth observing satellite image of 1990, there were 115 million ha of tropical rain forest with the area of the humid tropics deforested annually estimated at 5.8 million ha.

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). The aim of change detection is to discover temporal differences of the same objects at different time.

2.2 Land use and land cover change

According to Sherbinin (2002), land use is the term that is used to describe human uses of land, or immediate actions modifying or converting land cover land use and land cover changes have a wide range of impacts on environmental and landscape attributes including the quality of water, land and air resources, ecosystem processes and functions (Rimal, 2011).

2.2.1 Factors influencing land-use and land cover change

According to Turner. and Mayer (1994) distinguish the macro level societal factors further according to the role they play in the process of change in to human driving force, human mitigating forces and proximate sources of change. Human mitigating forces are forces which may become driving forces of land-use change to cope with the adverse effects of past land use change. Table 2.1 presents listing of large scale proximate sources of change suggested by Turner and Mayer (1994).

Table 2-1: Proximate sources of land-cover change (Turner and Mayer, 1994)

Process of land –cover conversion		
Harvesting	Replacement	External inputs
Hunting/fishing	Clearing/firing	Plant or animal introductions
Gathering	Plowing/tilling	Supplementary livestock feed
Fuel wood cutting (industrial and domestic)	Hydrological control (irrigation, drainage)	Supplementary water
Timber cutting	Terracing	Fertilizer/trace/elements
Grazing	Planting/vegetation change	Energy/machinery
Slash-and-burn cultivation	Pasture improvement	Herbicides/pesticides
Mining/quarrying /drilling	Construction paving, earth shaping	

2.3 Causes of forest cover change, Deforestation

The finding of Kathleen, and John, (2011) illustrates that the absence of clear institutional authority and communication between concerned agencies further retarded transparency in forest management and leads to unwise use of forest resource in Ethiopia.

According to Tigabu (2016) indicated that in higher population growth, low agricultural productivity, the poor economic performance of the country, shifting agriculture activities, livestock production and fuel wood consumption are the main causes of deforestation.

The rural poor population living around forest area highly dependent on biodiversity to satisfy their basic needs such as food, water, housing and social services. This economic dependency of the people on the forest is the main reasons for deforestation Workaferahu, (2015).

According to Elijah, (2007) the three main causes of deforestation in the world are; agriculture (including huge investment), infrastructure expansion and wood extraction. He asserted that the action of human beings rather than natural forces is the sources of most contemporary change for this dynamic world.

Population growth is another major cause for deforestation and obstacle for the achievement of sustainable development. Population growth without considering environment by itself have great impact on sustainable development, so sustainable development must be environmentally friendly (FAO, 2010).

2.4 History of forest cover and changes in Ethiopia

In 2005, the forest cover had further declined and was estimated to cover 13.0 million ha of the country. In other words, Ethiopia lost over 2 million ha of the forests, with an annual average loss of 140, 000 ha between 1990 and 2005. In 2009, the area is estimated at 12.3 million ha, 11.9 % of the total land area. Of this, the remaining closed natural high forests are 4.12 million ha or 3.37% of Ethiopia's land (FAO, 2010).

This indicates that the coverage of forest resource was declined at an alarming rate. The remaining forest area of the country unevenly distributed that 95 percent of the total forest area occur in Oromia, Southern Nations and Nationalities Regional State and Gambella regions (WBISPP, 2004).

Ethiopia owns diverse vegetation resources, from tropical rain and cloud forests in the southwest and on the mountains to the desert scrubs in the east and north east and parkland agroforestry on the central plateau (Demel *et al.*, 2010).

Now a day much more damages have been done to the forest resources of Ethiopia. With their axes a group of people can destroy dense forests so as to get fresh farm and grazing lands (Zemedie and Kedir, 1997). In his findings (Bekure, 1996)stated that the increasing demand for croplands, grazing land, construction poles and fuel wood including charcoal production are the main reason for the uncovering of the lands of Ethiopia.

In addition, forests are cleared to acquire construction materials, to provide source of energy, to make space for grazing, farming, and building and layout infrastructures networks and to supplement raw materials such as an input for agricultural production and livestock grazing (Mesfin, 1999).

In Ethiopia, forests, woodlands and mixed-use landscapes are often targeted for agricultural expansion as a means to maximize benefits from land-based investments while avoiding the displacement of cropland. Increased investment is welcomed by host country governments for its opportunity to stimulate rural economies while fostering national economic development (Bank, 2011).

2.5 Forest and climate change mitigation

In the late 1970s scientists initiated discussions on global environmental problems, which exceeded the scope of national and regional government. At the beginning this was primarily the threat of ozone layer depletion and the danger of human exposure to excessive ultraviolet Radiation. The next global problem is climate change and related issues. Human activity is the cause of both these hazards (IPCC, 2007).

Ethiopia is still one of the least developed countries and its economy is depends on agriculture which is sensitive to climate change variability. According WorldBank, (2011), current estimates indicate the country's forest cover is 12.1%.in addition to these EFAP report estimates that forest and woody vegetation are disappearing at rate of 150,000ha to 200,000ha annually (EFAP, 1994). Forest cover has been declining rapidly and only remaining forest is confined to some areas especially in the south and south western part of the country, which are less populated (Tesfaye, 2002).

2.6 Rainfall and Temperature Variability on Local Climate

It is now evident that the climate has been changing and this climate change is caused by human activities in relations to the biosphere (Pongratz and Caldeira, 2012).

2.7 Land use and land cover mapping

Remote sensing data can provide land cover information rather than land use information. The properties measured with remote sensing techniques related to land cover, from which land use can be inferred, particularly with ancillary data or a prior (already known) knowledge (Basudeb, 2011).

Identifying, delineating and mapping and subsequent monitoring studies, resources management, and planning activities this identification of land cover establish the baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for baseline thematic maps (Basudeb, 2011).

2.8 Biosphere Reserve (BR)

The origin of Biosphere Reserves goes back to the "Biosphere Conference" organized by UNESCO in 1968. This was the first intergovernmental conference examining how to reconcile the conservation and use of natural resources, thereby foreshadowing the present-day notion of sustainable development. The ample range of choices for managing biodiversity conservation and the diverse options for economic development of rural people living in and/or around the protected area demanded an inclusive, hybrid, heterodox and flexible approach to achieve sustainability (Fausto, 2011).

Biosphere reserve is intended to fulfil three basic functions, which are complementary and mutually reinforcing conservation function; development function and logistic function (MAB, 2010).

Biosphere reserve is a unique concept which includes one or more protected areas and surrounding lands that are managed to combine both conservation and sustainable use of natural resources. To date, 563 biosphere reserves in 109 countries have been included in the World Network of Biosphere Reserves (UNESCO, 2011).

For countries like Ethiopia, where the lives of the greatest proportion of the population attached with the natural resources as a basis of livelihood, the concept of biosphere reserves would be ideal for many reasons. As pressures from population growth, development programs and projects and investments increase, there occur unprecedented changes to the environment, which in turn result in unsustainable use of the resource base. Taking this in to account, Ethiopia has already dedicated two important biodiversity areas (Kaffa and Yayu), which are of significance importance to the world, and joins the International Network of Biosphere Reserves as of July 2010 (UNESCO, 2010).

2.9 Geographic Information System (GIS) and Remote Sensing

Different authors defined GIS from different perspectives. Burrough,and MC Donnel, (1986) define “GIS is a Powerful tool for collecting, storing, retrieving, as well, transforming and displaying spatial data from the real world for a particular set of purpose”. On the other hand, Eastman, (2001), define “GIS is a specific information system applied to geographic data and is mainly referred to as a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modelling and display of spatially-referenced data for solving complex planning and management problems”.

Remote sensing is a cost-effective technology for mapping land cover and land use and for monitoring and managing land resources. The remote sensing literature shows that a tremendous number of efforts have been made for mapping, monitoring, and modelling land cover and land use at the local, regional and global scales (Chandra and Gri, 2012). It has a tremendous advantage over ground survey methods due to the large area coverage of its data and the ability to map inaccessible areas (Baban, 1999).

The frequency (temporal resolution) at which remotely sensed images are acquired also renders the technology suitable for monitoring LULC changes. Images of the same area acquired on different dates (multi-temporal) can be quickly analysed to quantify these changes. Remote sensing data thus provides detailed, accurate, cost effective and up-to-date information with respect to different vegetation types and land uses. Remote sensing data have proven to be useful in data-poor regions where recent and reliable spatial information is lacking (Donge *et al*., 1997).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location of the study area

Kaffa zone lies between 7°23' to 7°49'N latitude and 35°48' to 36°78'E longitude (NABU, 2010). The zone is bordered by Oromiya Region in the North and North West, Konta Special Wereda in the East, South Omo Zone in the South, Bench-Maji zone in the West and Southwest and Sheka zone in the West. Bonga, the capital of Kaffa Zone, is situated at 440 kilometres Southwest of Addis Ababa and 105 kilometres south of Jimma (NABU, 2010).

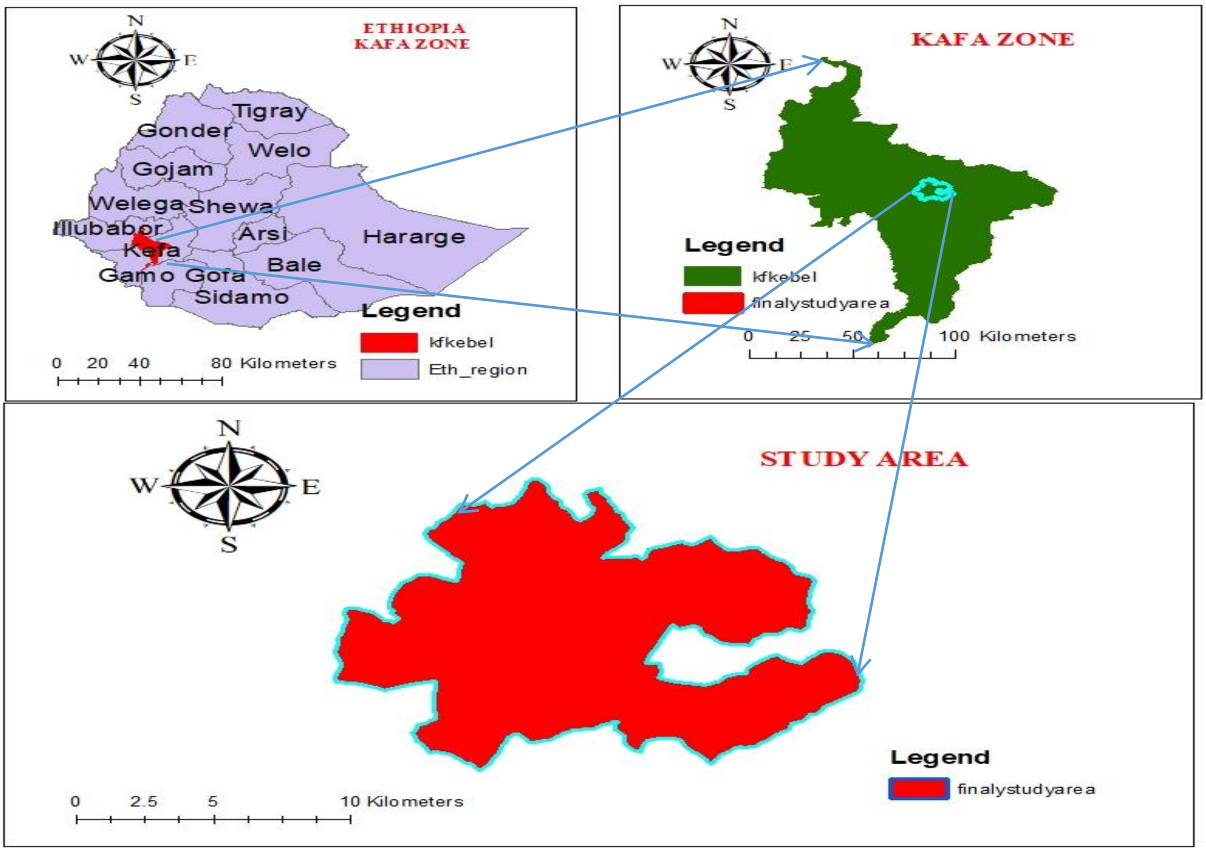


Figure 3 1 : location map of study area

3.1.2 Geology, topography and soil

The Kaffa Zone situated in the Western plateau of the highlands on the Tertiary layers, consisting mainly of sandstone and limestone, and of Tertiary volcanic rocks (NABU, 2017)

According to the soil map produced by the WBISPP (2004), the dominant soils in the Kaffa Zone are dystricnitosols (Nd). Adiyo, the south western part of Telo and north and northwest of the Gewata woredas are dominated by orthicacrisols (Ao). In addition, eutricfluvisols (Je), chromic luvisols (Lc), chromic vertisols (Vc) and pellicvertisols (Vp) can be found in the Kaffa BR to varying degrees (EWNHS, 2008).

3.1.3 Climate

The climate is characterised by a bimodal rainfall pattern, with the main rainy season between June and September and a short rainy period from February to April. Kaffa receives its rainfall from the Southwest monsoon, which reaches its maximum intensity during July and August. The average annual rainfall ranges from 1500 mm in the lowlands up to 2000 mm at the highest elevations (EWNHS, 2008).

3.1.4 Vegetation

According to the IBC (2005), there are five main habitat types in the Kaffa Zone:

1. Evergreen montane forest and grassland complex: This complex habitat occurs between altitudes of 1900 and 3300 masl. It includes much of the highlands located within the proposed buffer area of the BR. This habitat occurs in areas which are often densely populated, leading to pressures from expansion of arable land.

2. Moist evergreen montane forest: This habitat occurs between 1500 and 2600 masl. This kind of forest is of global conservation significance due to the occurrence of wild Coffee Arabica. In addition to deforestation for arable land, timber extraction is a major threat to this habitat.

3. Wetlands: A complex system of wetland habitats occurs between 900 and 2600 masl. These sensitive ecosystems are importance for the local communities, for example in providing materials for building shelter, for grazing and freshwater supply. At the same time wetlands are also increasingly under pressure due to intense grazing and other land uses.

4. *Combretum-Terminalia* woodland: IBC (2005) has classified some areas of the Kaffa BR as *Combretum-Terminalia* woodland, which were later corrected to bamboo forests by Dresen (2011)

5. Sub-Afro alpine habitat: This habitat occurs at altitudes higher than 3200 masl. This vegetation type is under severe threat due to agricultural expansion. Indigenous tree species such as *Hagenia abyssinica* are under high pressure.

Bonga forest has the highest density of trees with a diameter of more than 10 cm and has the richest site with more than seventy species (Nune, 2008). The habitat type in these areas was characterized by moist evergreen montane forest.

3.1.5 Population and socio economic aspect

Based on SNNPR, Kaffa zone finance and economic department report of 2013, the total population of the Kaffa zone was about 1,041,754. From these Gimbo woreda 108, 571, Decha 188, 685 and the zone capital Bonga town accounts 27,634. The population density of the zone is about 98 persons per square kilometre.

The highly diverse fauna and flora occurring in complex habitats are of international conservation value and of economic value to the local communities. Existing studies of the region's flora, fauna, biomass and biodiversity have documented a high diversity of species (300 species of mammals including 14 carnivores and 8 primates, 300 bird species, 244 plant species and more than 110 tree species) (NABU, 2014).

Main economic activities in the area are dominated by agriculture that contributes approximately 41% to the GDP, 80 % of exports and 80 % of the labour force. Other sectors include services and tourism, manufacturing and trade. Agriculture forms the backbone of the economy with most of the other sectors (i.e. trade and tourism) being dependent on its strong backward and forward linkages (UNESCO, 2010).

3.2 Data sources and methods of data collection

Primary data was collected from Field visit was carried out to get an overview of the study area, identify various forest cover types and to record GPS readings concerning various features and forest cover types. These data were used for designing the final image classification, verifying sample sites and for land cover map validation. Cloud free Satellite imageries (Landsat 5 TM of 1986, 1990, Landsat 7 ETM+ of 2010 and Landsat 8 OLI 2016, 2018 imagery) with 30 m by 30 m spatial resolution were downloaded from United States geological survey sites http://earth explorer.usgs.gov/.

To show the variability of climate condition the recorded temperature and rainfall data are taken from Ethiopian metrological agencies.

Secondary data for thesis collected from Zonal department of forest and environmental protection sectors and different stakeholders which work in the biosphere reserve and different literatures reviewed to get confidential result of our study.

3.3 Sample Size and Sampling procedure

Biosphere reserves aim to manage their resources in an integrated manner by considering conservation in land and resource planning and use. This was achieved through dividing the reserve into three types of areas, known as “zones” (NABU 2010).

Core zones: Every biosphere reserve must contain one or more core zones that are highly protected by law. Their aim is to conserve biodiversity in a minimally disturbed ecosystem. Only monitoring, non-destructive research and other low-impact uses (such as education) are allowed to take place in the core zones. Therefore, settlement, agriculture, harvesting of any sort of products (except traditionally accepted non-destructive uses) are prohibited. In Ethiopia the core zone must comprise at least 3% of the total area (NABU 2017).

Buffer zones: These, as their name suggests, usually buffer or surround the core zones. Their role is to minimise the negative impact of human activities on the core zones. Activities in the buffer zones must be compatible with the conservation of the core zones and contribute to research, education and conservation of traditional land-use models. They also function as essential ecological corridors, connecting ecosystems to allow the movement of wildlife. These zones can only be used for activities compatible with conservation objectives, such as environmental education, ecotourism, recreation and research (NABU 2010).

Transition zones: These have a central function in enabling sustainable development. Here people live and make a living. They accommodate more high-impact and economic land-uses and may contain a variety of agricultural activities, settlements and other land use types.

Transition zones may contain towns, farms, fisheries and other human activities. Local communities, management agencies, scientists, non-governmental organisations, cultural groups, economic interest groups and other stakeholders work together to manage and sustainably develop the area‘s resources. In Ethiopia the transition areas must comprise at least 45% of the total area.

According to UNESCO (2010) the Kaffa biosphere Surface area (terrestrial and marine): 540,631.10 ha, Core area(s) 41,319.10 ha, Buffer zone(s) 161,427 ha Transition area(s): 337,885 ha. With perspective of the above statement Kaffa BR is divided in to three zones. Due to data limitation on metrological station, near to urban town that leads to high rate of deforestation for energy consumption and settlement and accessibility to road, Bonga and surrounding area were selected for the final study,

3.4 Data collection process

The various land-cover types were identified through satellite image manipulation and by observing exactly available land cover type in the study area and GPS recording on important forest cover boundaries of the study area.

Field visit was carried out to get an overview of the study area, to identify and to record GPS readings concerning various land use/cover features and forest cover types. These data were used for designing the final image classification, verifying sample sites and for land cover map validation. In addition, photographs were taken from the four land use and land cover of the study area and other essential information were generated, which helped to support in the identification and quantifying of forest cover change and mapping.

3.5 Method of data processing and analysis

The procedure followed in this study is presented using the flow chart (Figure 2). It shows the steps followed beginning from the acquisition and classification of multi temporal satellite image of the study area. Analysis of linear regression trend is carried out by using ArcGIS v 10.4.1 Software, which can simulate trends in each grid (Stow *et al*., 2006). ArcGIS was used to reflect different periods of vegetation cover characteristics. In this study, using ArcGIS software we get the relative and these indicated as the relative NDVI change in every pixel point.

$$\theta(slope) = \frac{n \times \sum_{i=1}^{n} iNDVIi - \sum_{i=1}^{n} i \sum_{i=1}^{n} NDVIi}{n \times \sum_{i=1}^{n} i^2 - \left(\sum_{i=1}^{n} i \right)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

Where i is the annual number; n is monitoring period (the cumulative number of years); NDVI as NDVI mean value of the i^{th} year; slope is each pixel NDVI trend of the slope, if Slope θ >0 then the pixel NDVI value in n years is increasing otherwise it is decreasing. This study was categorized into a significant increase, slight increase, essentially the same, slightly reduced and a significant reduction, and the statistics of the study area in 1986-2018 vegetation changes and the percentage of each class area

3.5.1 Image classification

Land sat images downloaded from United States geological survey sites were first rectified, geometrically corrected and geo-referenced to UTM WGS 1984 projection. For land cover classification supervised classification was employed on ERDAS Imagine version 9.2 ArcGIS 10.4.1 software using the decision rule of maximum likelihood classifier algorithm. During the fieldwork, various land cover classes were taken and recorded based on systematic sampling using GARMIN 64 GPS device. These samples were used as representative signatures for the various land cover types identified and ground control points were taken for each land use types.

3.5.2 Post Classification

To examine the forest cover change and the rate of its changes, post classification comparison change detection method were employed. Four aspects of forest cover change detection characteristics were identified such as; detecting the changes, identifying the nature of the changes, measuring the temporal and areal extent of the changes, and assessing the spatial pattern of the change.

3.5.3 Post classification change detection

In this change detection method, 1986, 2010 and 2018 land use land cover classified images were used and reclassified these land use land cover with spatial analyst of ArcGIS 10.4.1 and ERDAS 9.2 software.

Extracted the area of changes through direct comparison of the individual classified imagery and compared based on statistical data that derived from each individual images. Besides to this, land use/land cover change detection matrix had generated to examine the trends and pattern of land use/land cover change of an area as well as specifically forest cover change detection. The rate of forest cover change also computed using equation developed from (Berhan, 2007)

$$r = \frac{Q_2 - Q_1}{t} \quad \text{.......} \quad (3.2)$$

Where: R is rate of forest cover change, $Q_2$is Recent year forest covers in ha, $Q_1$is Initial year forest cover in ha, and t is interval year between Initial year and recent year.

From the land use/ land cover map images, 1986, 2010 and 2018 forest cover map of the study area were generated.

3.5.4 Spectral change detection methods

According to Chen (2000), a large number of techniques are in the spectral change identification category. Spectral change detection techniques rely on the principle that land cover changes result in persistent changes in spectral signature of the affected land surface.

The use of NDVI is considered to be appropriate for the purpose of forest monitoring (Huete *et al.,* 2002). Although NDVI might be affected by soil background and a saturation effect at high biomass levels, it captures seasonal and inter-annual changes in vegetation status (Verbesselt *et al.,* 2012). Based on Chen *et al., (*2008) and Verbesselt *et al.,* 2012), NDVI can be calculated.

Spectral change detection methods are the numerical indicator, which used in the visible and near infrared electromagnetic spectrum of an image which is applied for the analysis of remotely sensed satellite images on an area and assess the presence and the absence of green live vegetation. The ratio is differenced with the division of digital number of one band by the corresponding digital number of another band of an image. Therefore, depending on the reflectance characteristics of vegetation which can be explain the healthiness and identify of the level of vegetation cover of an area.

NDVI is the most common and widely applicable that used index for the forest cover change detection. The value of NDVI in vegetation change analysis is between -1 and +1. In this -1 value is indicated low vegetation content and +1value indicated high vegetation content. The NDVI is calculated from reflectance measurements in the red and near infrared (NIR) portion of the spectrum. The NDVI empirical analysis computed using the formula developed by Berhan, (2007).

$$RNDVI = \frac{NIR - RED}{NIR + RED} \text{ where } (0 < NDVI > 1) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.4)$$

$$GNDVI = \frac{NIR - GREEN}{NIR + GREEN} \text{ where } (0 < NDVI > 1) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.5)$$

Where RED is visible red reflectance, and NIR is near infrared reflectance. The wavelength range of NIR band is (750-1300 nm), Red band is (600-700 nm), and Green band is (550 nm). The NDVI is motivated by the observation vegetation, which is the difference between the NIR and red band; it should be larger for greater chlorophyll density. It takes the (NIR - red) difference and normalizes it to balance out the effects of uneven illumination such as shadows of clouds or hills.

The vegetation condition was explained by the NDVI values of -1 and +1 which is the green healthy or high amount of vegetation cover have the positive portion of NDVI values. In this study, NDVI analysis was computed with Arc GIS 10.4.1 software and automatically calculated the Maximum, Minimum, mean and standard deviation values were derived and summarized the forest cover change trend of the study area.

3.5.5 Spectral change detection methods with climate variability

It is possible to explain the closeness of a relationship between geographic features, and closely related to the degree of mutual determination between geographical elements. In this study of NDVI correlation with average annual temperature and precipitation was carried out by-pixel spatial correlation, the correlation coefficient used to reflect the sequence of climatic factors and NDVI degree of correlation, the range of correlation coefficient varies from −1 to 1 and the graphical representation shows as the relationship of annual temperature and precipitation with NDVI value.

3.6 Logical frame work of the study area

The procedure followed in this study is presented using the flow chart (Figure 3-2). It shows the steps followed beginning from the acquisition and classification satellite image of the study area to the extraction of the required information both primary and secondary data to answer the research questions.

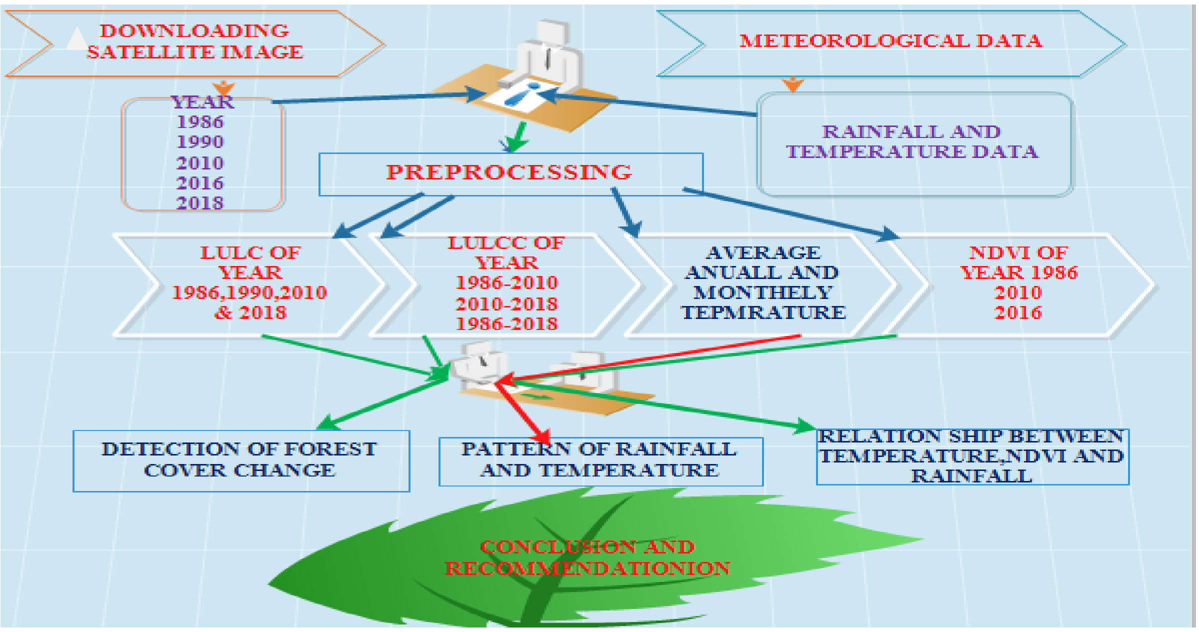


Figure 3 2: logical frame work of the study

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Image pre-processing

Image downloaded data files from United States geological survey sites; we registered for a free account. Fortunately, the USGS provides free tools and services to access processed Landsat satellite image of different bands from USGS Landsat TM (1986, 1990), ETM+ (2010, 2016) and OLI 8 (2018). Downloaded image was seen as at Annex I.

4.1.1 Image projection

Downloaded satellite image of 1986, 1990, 2010, and 2018 from USGS. The ArcGIS project tool changes the projected coordinate system of downloaded data to made projection to WGS_1984_UTM_Zone_37N. Figure 4-1 below shows as projected image of 1986, 1990, 2010 and 2018 of the study area within ArcGIS, every data set has a coordinate system, which is used to integrate it with other geographic data layers with in a common coordinate framework such as map. Coordinate systems enabled as to integrate data sets with in maps as well as to perform various integrated analytical operations such as overlaying data layers from disparate sources and coordinate system.

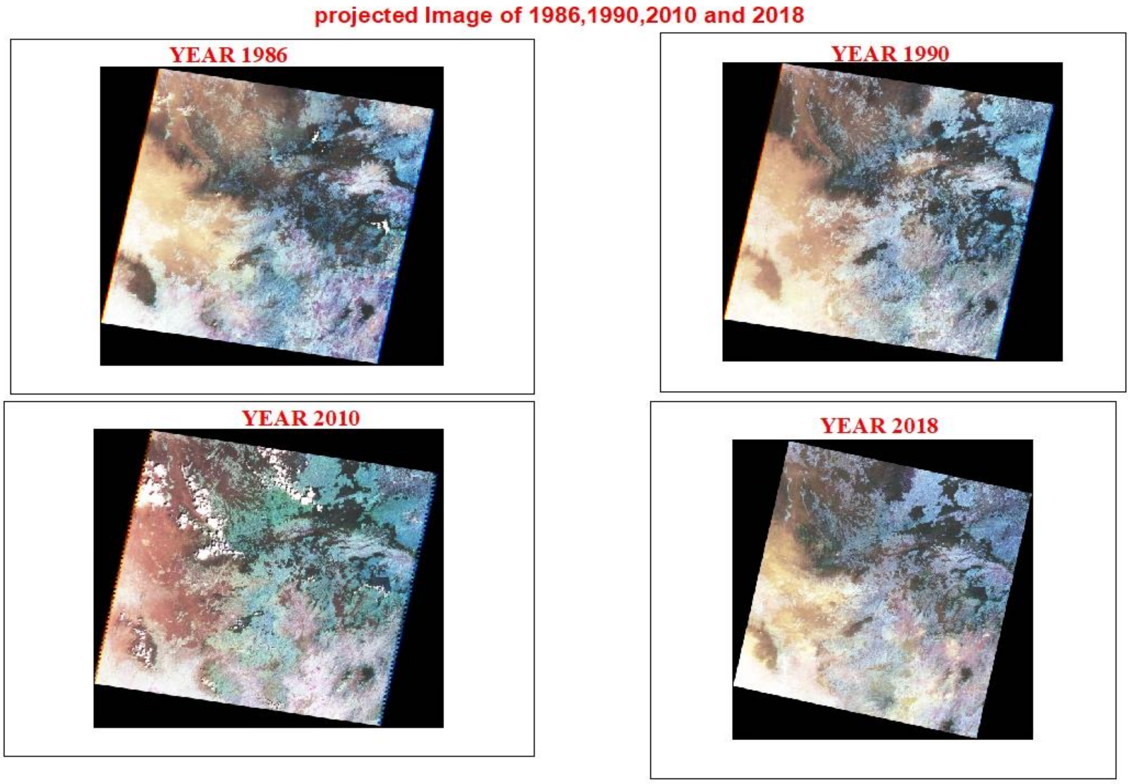


Figure 4 1 Projected image of 1986, 1990, 2010 and 2018 (Computed using ArcGIS 10.4.1 software)

4.1.2 Histogram image

Histograms have the advantage of being a visually strong graph type used to display continuous data in ordered columns. Histograms are useful for larger sets of data points and frequency distribution where the source data values are grouped into class intervals. In these we done histogram image using ArcGIS 10.4.1 software. See figure 4-2 for histogram image and analysis done in layer properties dialog box and accessed histogram on the symbology tab.

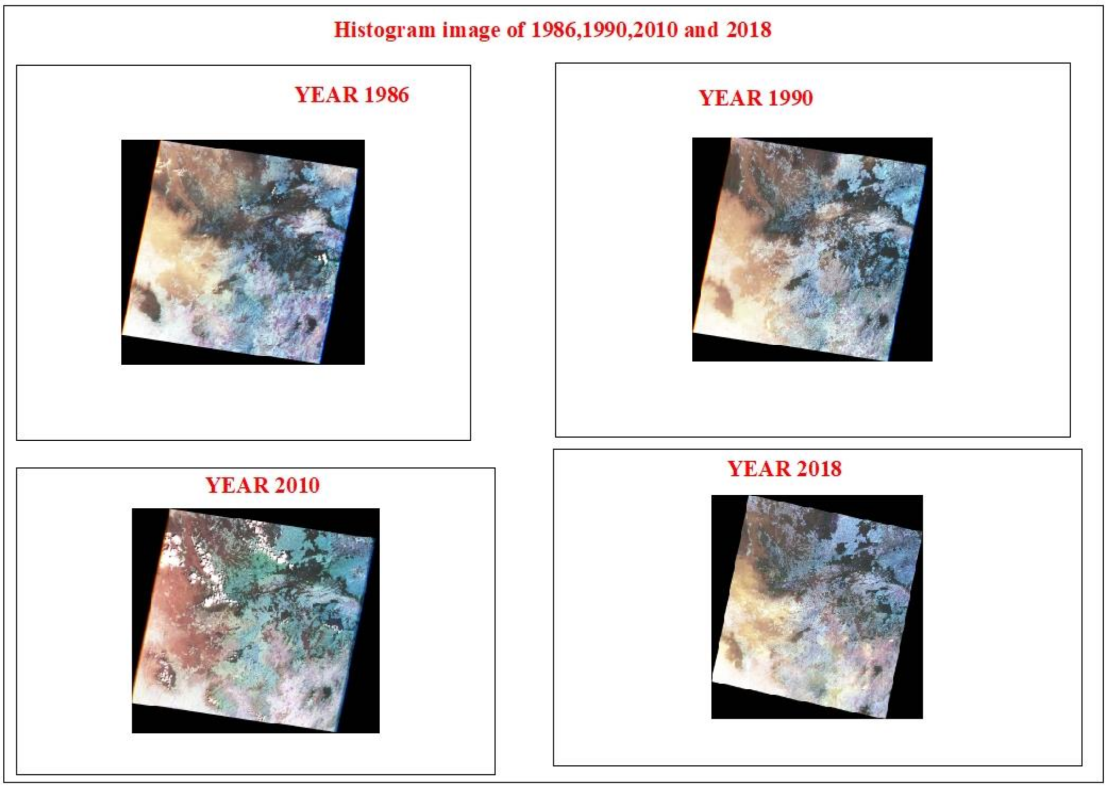


Figure 4 2 : Histogram image of year 1986, 1990, 2010 and 2018 (Computed using Arc GIS)

4.1.3 Layer stacking

In figure 4-3 we see that layer stacking image of year 1986, 1990, 2010 and 2018. Layer stacking is a process of combining multiple images in to a single image. In order to do these we first done image resampling of various pixel sizes, extent and projection to build a new multi band file from geo referenced images. For climate analysis we stack image of band three and four images and for land use land cover change we stack all bands in to one resolution.

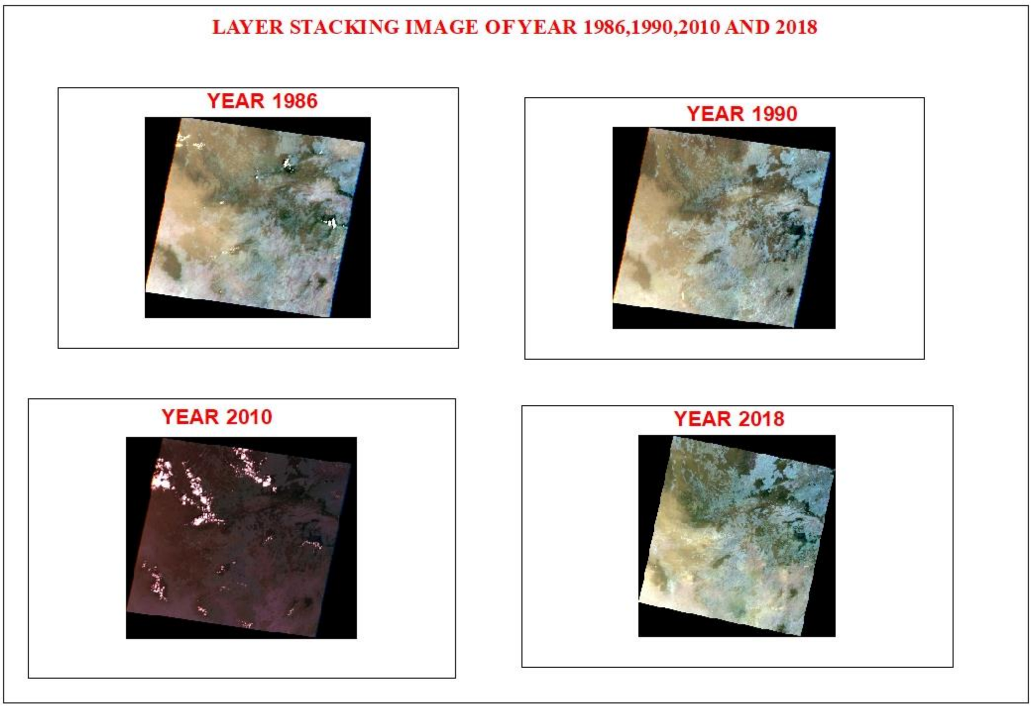


Figure 4 3: layer stacking of year 1986, 1990, 2010 and 2018 (Computed using ArcGIS)

4.1.4 Layer subset

After specifying our data sets of study area as we seen in figure 4-4 of sub set image 1986.2010 and 2018 we create definition query. Definition query means expressing our data from stacked images to select subset of features for the layers display.

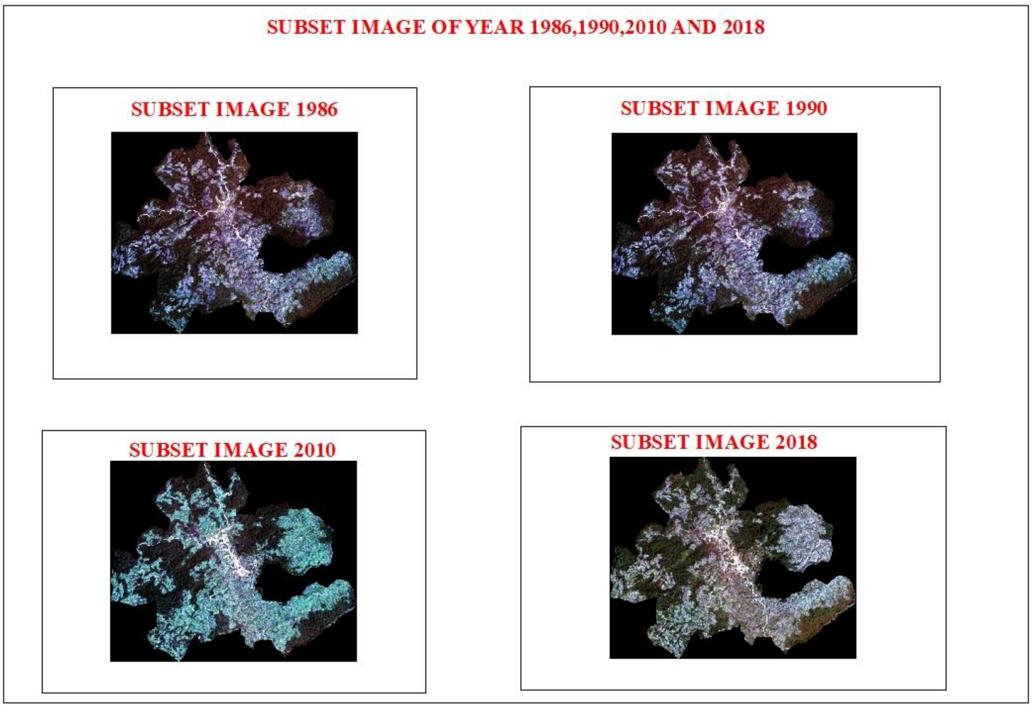


Figure 4 4: Image subset of year 1986, 1990, 2010 and 2018 (Computed using ArcGIS and ERDAS)

4.1.5 Supervised classification

During the field work various land cover classes were taken and recorded based on systematic sampling using Garmin 76 gaps devise. These samples were used as representative signatures for the various land cover types identified.

The final task in pre-processing of satellite image analysis was supervised classification. In figure 4-5 shows as once the training samples are created, the Interactive Supervised Classification tool allowed as to perform a supervised classification without explicitly creating a signature file. Also, this tool accelerates the speed of the classification. Internally, it calls the Maximum Likelihood Classification tool with default parameters. During the classification, it makes use of all the bands available in the selected image layer. There are two primary types of classification algorithm applied to remotely sensed data.

These are unsupervised and supervised. Unsupervised classifications algorithms such as soda (iterative self-organizing data analysis) are used several users defined statistical parameters in an iterative fashions or some percentage of pixels remain unchanged or maximum number of iteration have been performed.

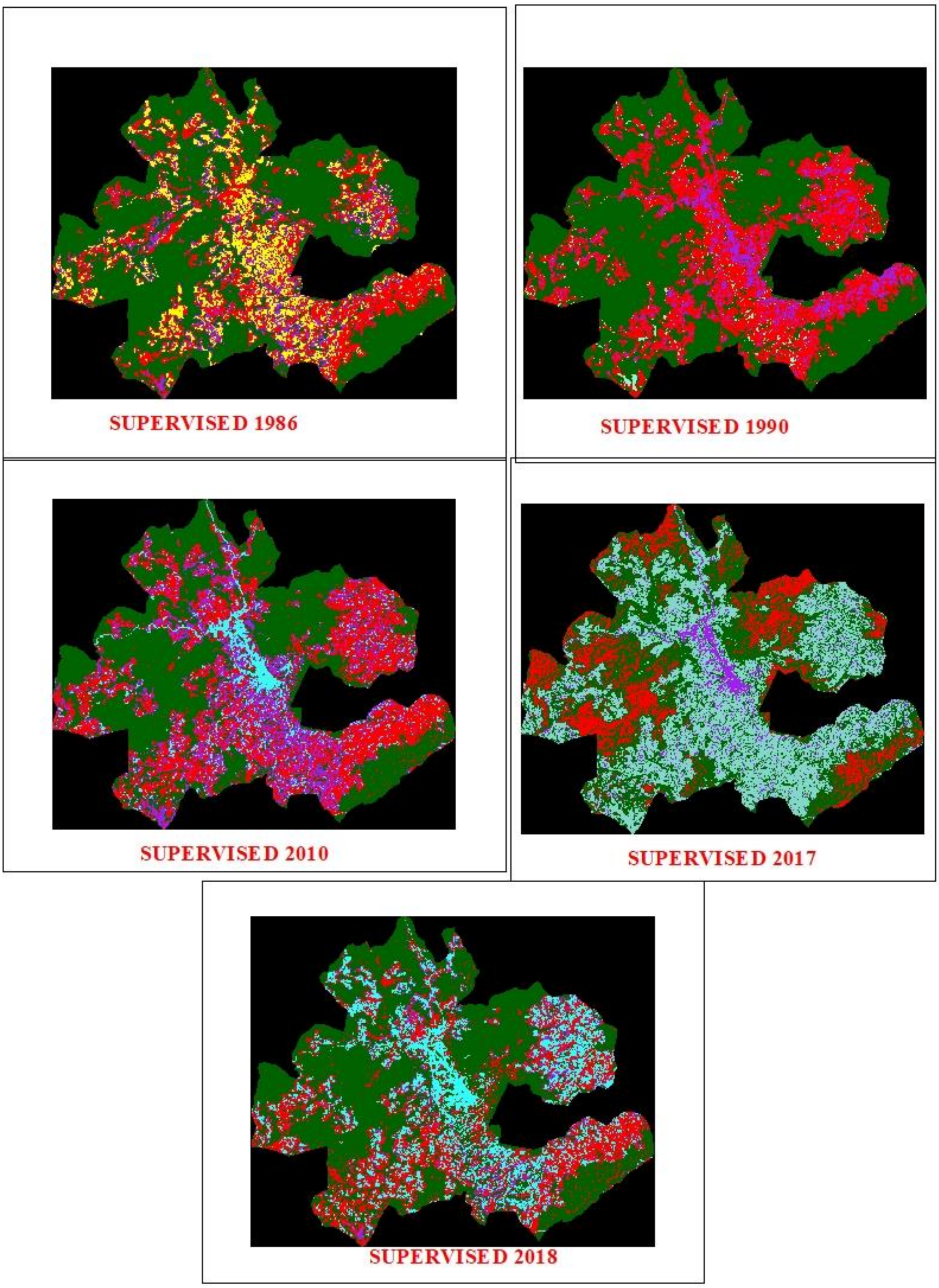


Figure 4 5: Supervised image of year 1986, 1990, 2010 and 2018 (Computed using ArcGIS and ERDAS software)

4.2 Land use land cover classification

Image classification is the process of sorting pixels into finite number of individual classes, or categories of data based on their data file values. If a pixel satisfies ascertains set of criteria, then the pixel is assigned to the class that corresponds to those criteria. In our study we classified the land use land cover change as settlement, farm land, forest and wetland.

4.2.1 Land use land cover classification of 1986

The land use/Land cover classification in 1986 as shown in figure 4-6 all data sets of image 1986 image with its process reflected forest cover and farmland areas cover in large areas with smaller areas of settlement with minimal wetland. The green colour represented forest cover which covered various areas in the region while red was a representation of farmland which also dominated in the region during this year. The middle region had quite a large area with settlement that appeared.

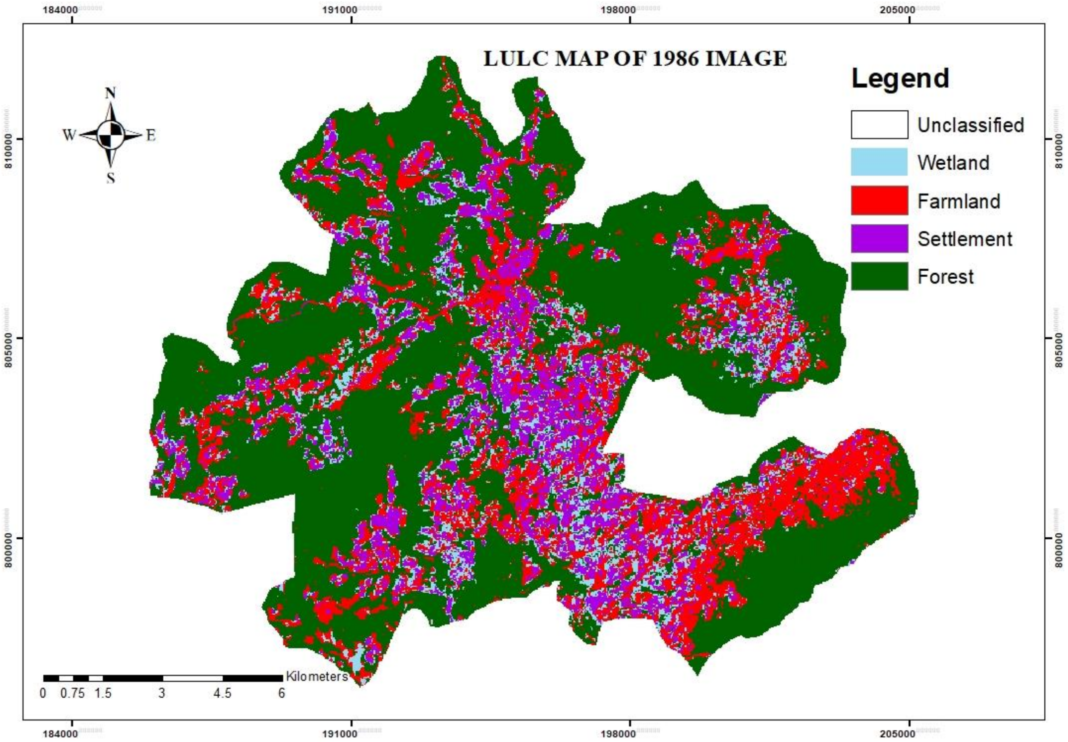


Figure 4 6: Land use land cover change of 1986 image (Computed using GIS and ERDAS)

4.2.2 Land use land cover classification 0f 1990

Land use land cover classification of 1990 image there was little difference with 1986 image. Fig land use land cover change of 1990 below clearly illustrated the land use land cover classification of 1990 image. In this projected year there was resettlement in different Keble of the study area due to these the settlement area was quite lower with that of 1986 image. In general forest take larger area of the study area next farmland. The area of wetland also decreased and farmland take the largest one.

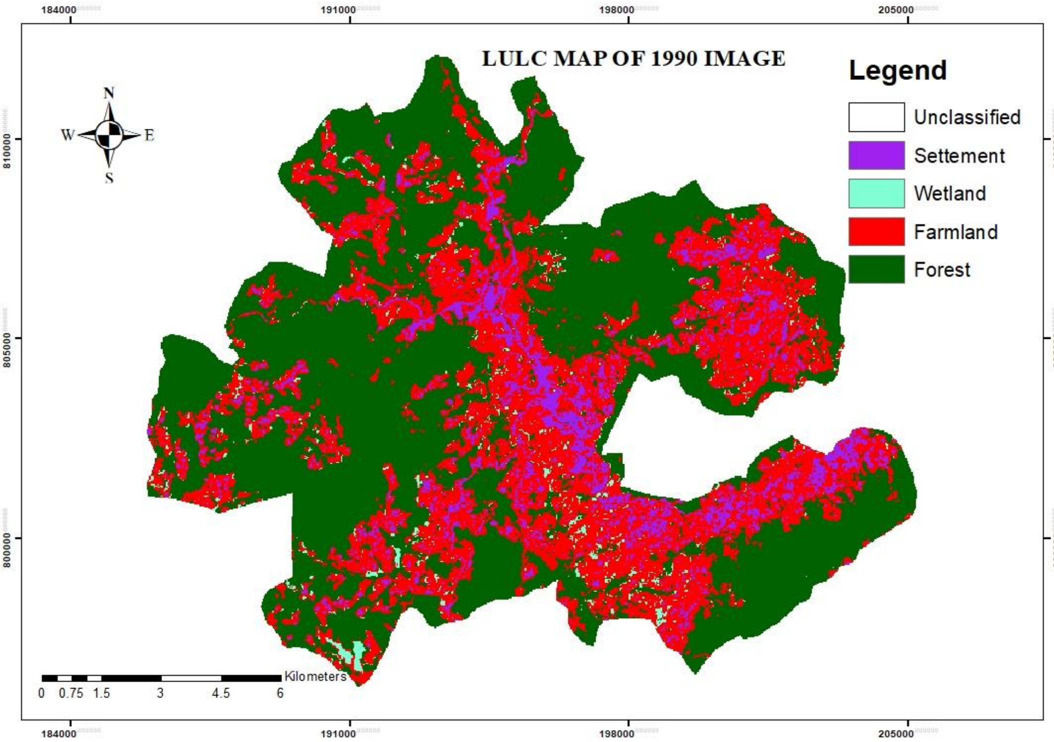


Figure 4 7: Land use land cover image of 1990 (Computed using GIS and ERDAS)

4.2.3 Land use land cover classification of 2010

In 2010 supervised image classification forest and farmland took the highest area coverage. Next to that settlement and wetland took the list area coverage. In figure 4-8 land use land cover change of 2010 illustrated that the red color that of settlement disturbs the crowded forest coverage green colour.

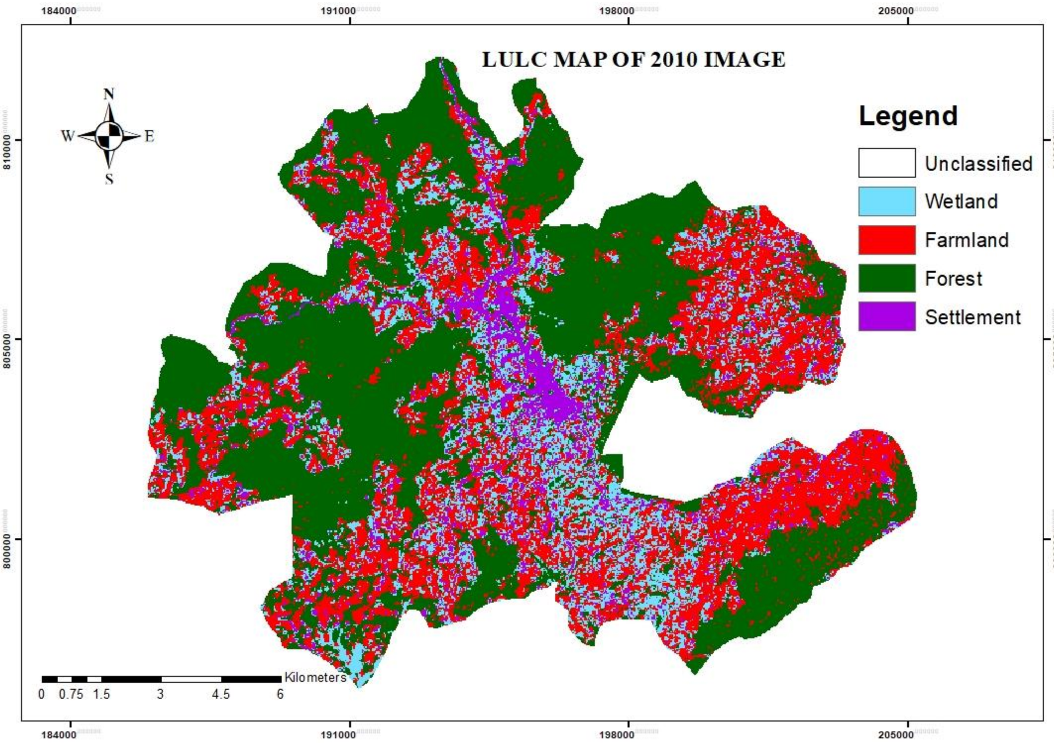


Figure 4 8: Land use land cover change of 2010 image (computed using GIS and ERDAS)

4.2.4 Land use land cover classification of 2018

In figure 4-9 illustrated that the green area cover most area of the study area next to forest area coverage farmland and settlement take the remaining area coverage with that of wetland.

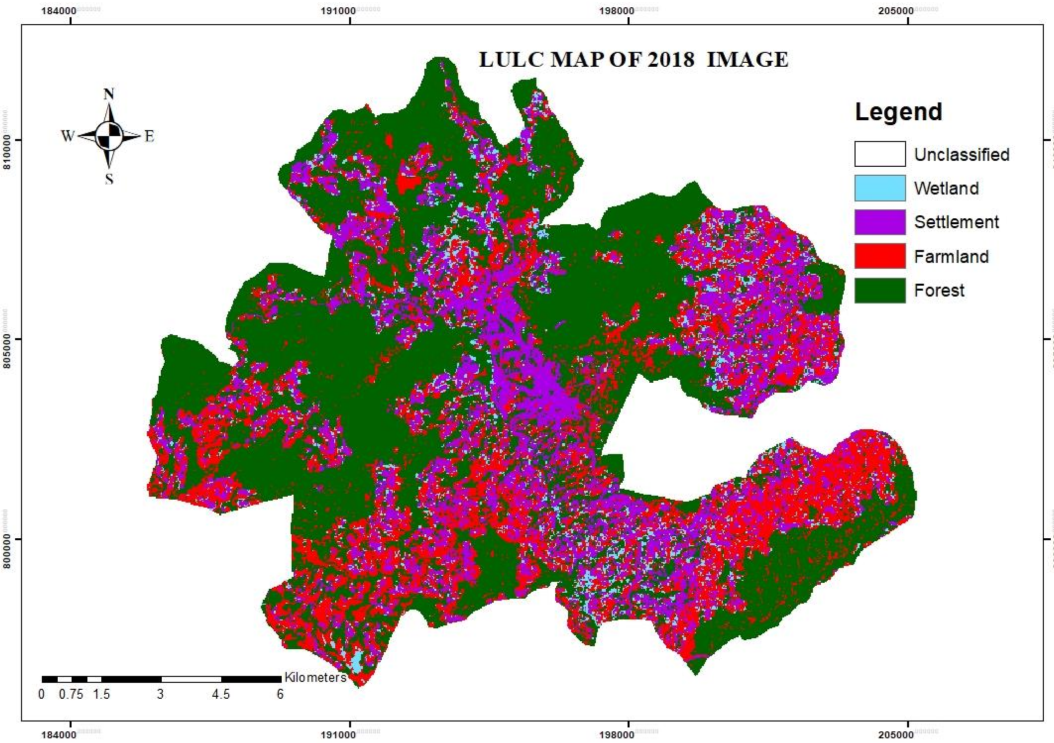


Figure 4 9: All data sets of 2018 images (Computed using GIS and ERDAS)

4.3 Land use land cover change

4.3.1 Land use land cover change 1986-2010

The major land cover changes observed during this period had been the reduction in the area of both categories of forests and wetland. A considerable increase in the overall areas of settlement and farmland has been registered. Table 4-1 and figure 4-10 land use land cover change of image 1986-2010 illustrated these change.

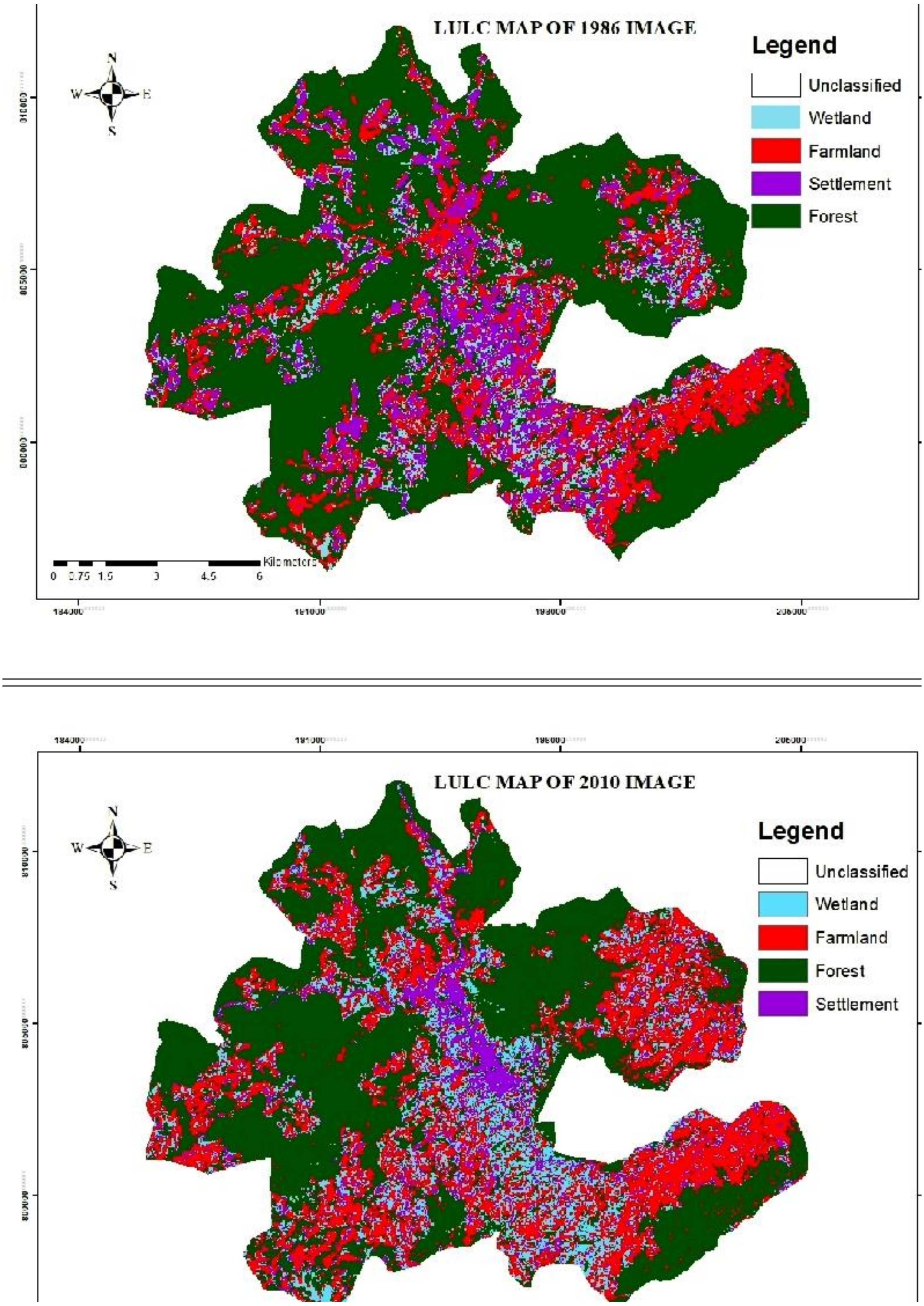


Figure 4 10: Land use land cover map of 1986-2010 (Computed using GIS and ERDAS)

Table 4-1: Change matrix of image 1986 and 2010 land use land covers change.

	Year 2010						
	LULC	Wetland	Farmland	Settlement	Forest	Grand Total	Loss
Year 1986	Wetland	255.15	537.57	315.27	471.87	1579.86	1324.7
	Farmland	271.89	1803.69	775.62	642.42	3493.62	1689.9
	Settlement	332.64	792.9	637.56	314.19	2077.29	1439.7
	Forest	366.75	1192.86	715.32	7723.2	9998.1	2274.9
	Summary	10419.57					
	Grand Total	1226.43	4327.02	2443.77	9151.7	17148.87	
	Gain	971.28	2523.33	1806.21	1428.5		
	Net change	-353.43	833.4	366.48	-846.5		
	Net persist	-1.38519	0.462053	0.574816	-0.11		

(computed using ArcGIS, ERDAS and Microsoft excel)

4.3.2 Land use land cover change mapping 2010-2018

The major changes observed in this period were decreased in the overall area of forest of net change -322 ha. Also farmland wet land decreased in overall area coverage of -138ha and -353ha respectively. The area of settlement increased by 814.32 ha. Table 4-2 and figure 4-11 land use land cover change of 2010-2018 illustrated the overall change observed during those years.

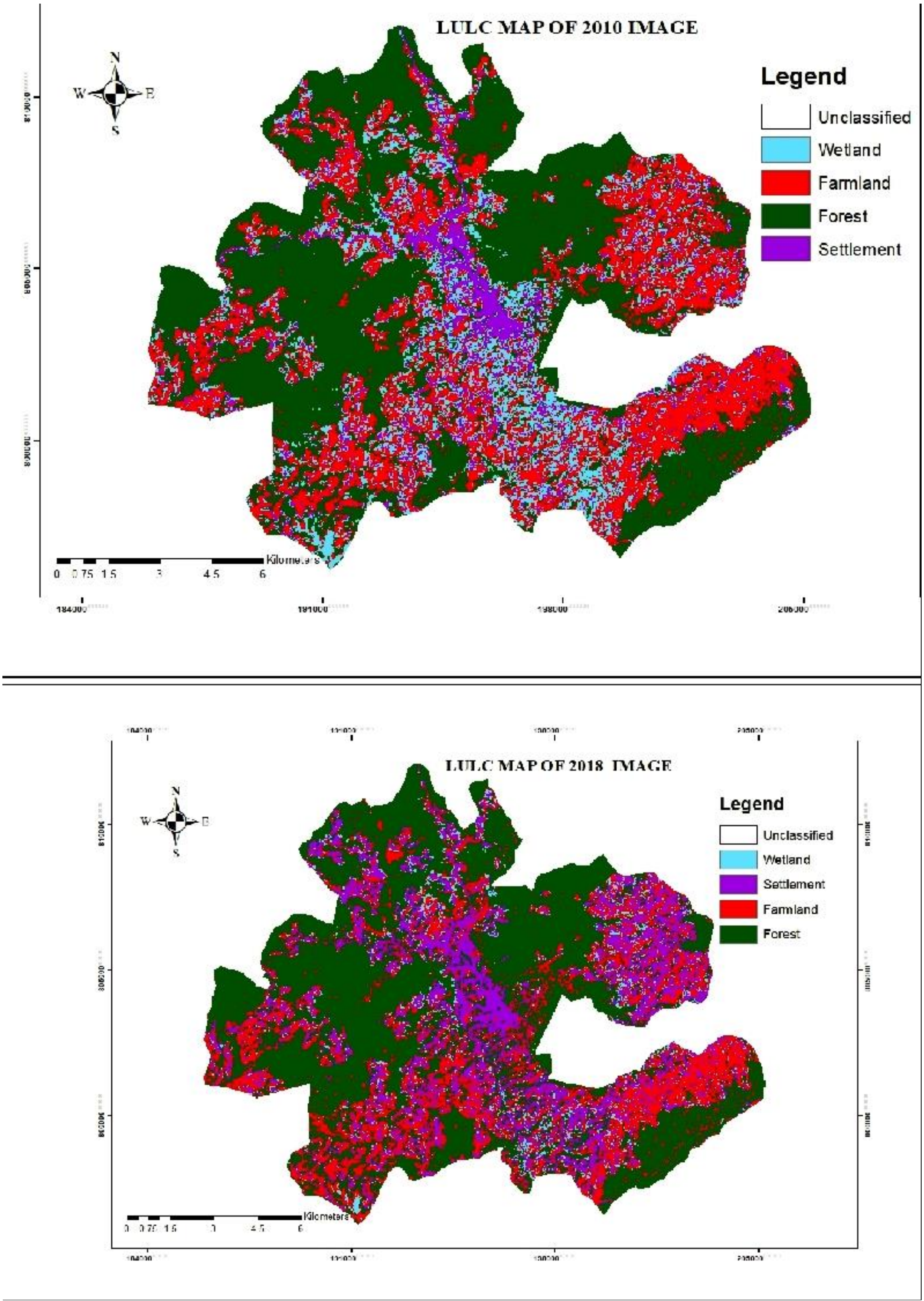


Figure 4 11: Land use land cover change map of 2010-2018 (Computed using GIS and ERDAS)

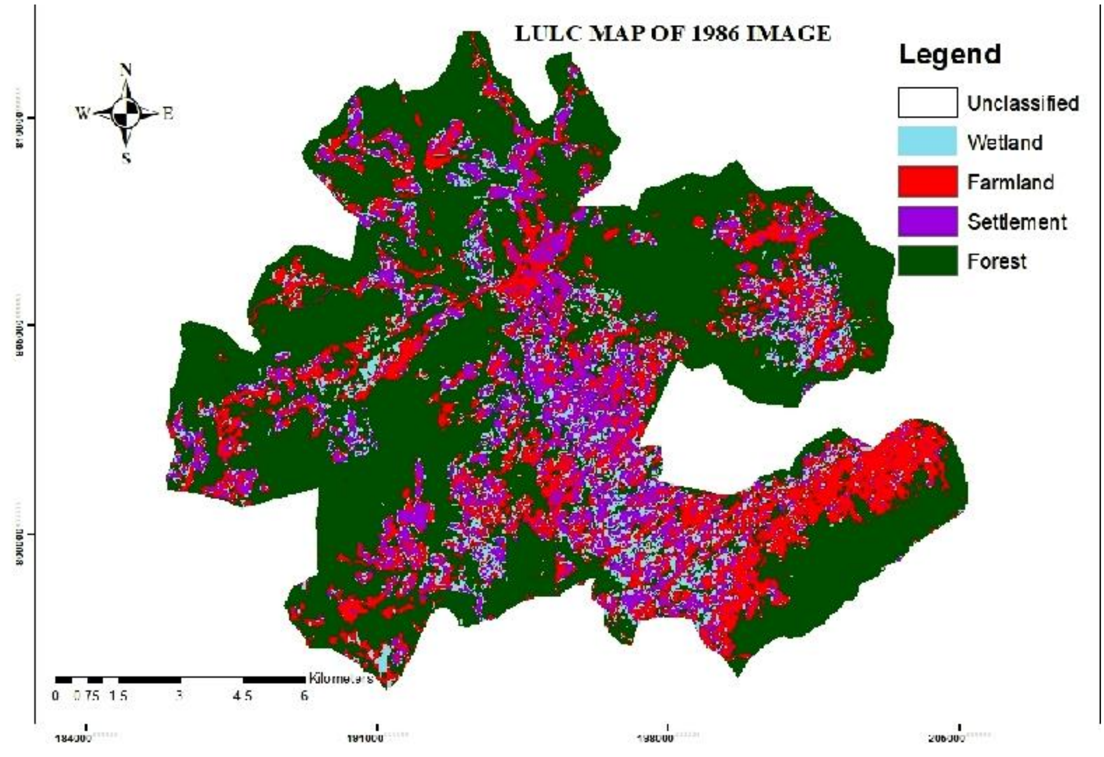
Table 4-2: Land use land cover change confusion matrix of 2010 and 2018 image

	Year 2018						
Year 2010	LULC	Wetland	Farmland	Forest	Settlement	Grand Total	Loss
	Wetland	127.8	334.53	290.25	473.4	1225.98	1098.18
	Farmland	398.79	2141.1	462.51	1322.73	4325.13	2184.03
	Forest	168.57	886.5	7739.37	348.75	9143.19	1403.82
	Settlement	177.12	824.58	328.86	1112.31	2442.87	1330.56
	Summary	11120.58					
	Grand Total	872.28	4186.71	8820.99	3257.19	17137.17	
	Gain	744.48	2045.61	1081.62	2144.88		
	Net Change	-353.7	-138.42	-322.2	814.32		
	Net Persist	-2.76761	-0.06465	-0.04163	0.73209807		

(Computed using ArcGIS, ERDAS and Microsoft excel)

4.3.3 Land use land cover change 1986-2018

While considering the whole range of time under consideration, the reduction in the area converged by both forest and wetland coverage were remarkable, Image differencing of the two extreme times, 1986 and 2018 indicated that forest cover reduced from 1171 ha and vast decrement on wetland 707.13 ha. There was considerable increment on settlement by 1182.06 ha. See figure 4-12 and table 4-3 for illustration.



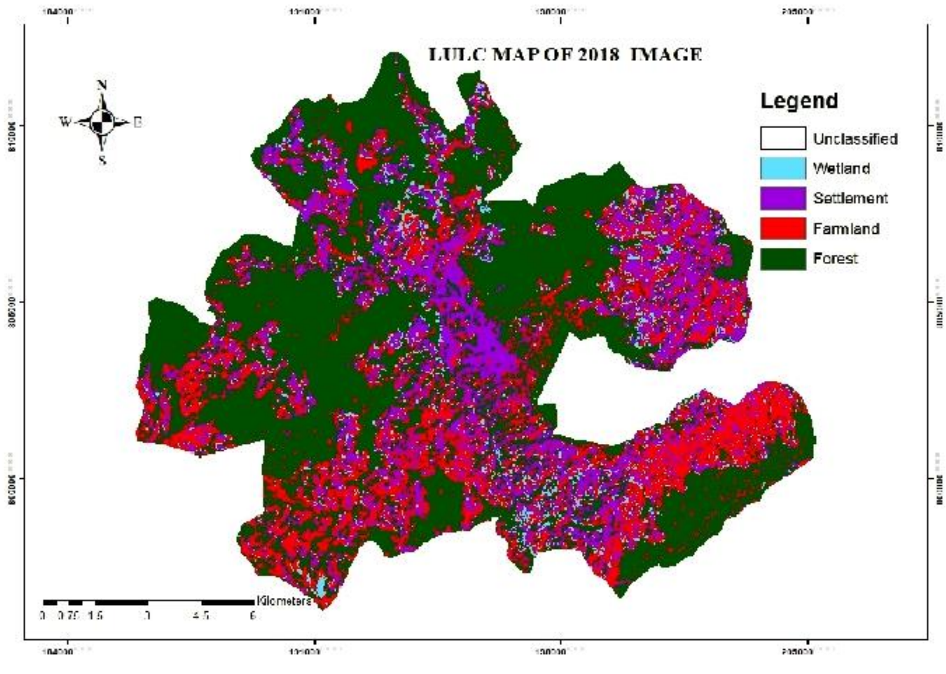


Figure 4 12: Land use land cover change 1986-2018 (Computed ArcGIS, ERDAS and Microsoft excel)

Table 4-3: land use land cover change confusion matrix of 1986 and 2018 image

	Year 2018						
	LULC	Wetland	Farmland	Settlement	Forest	Grand Total	Loss
Year 1986	Wetland	151.11	423.27	476.1	529.29	1579.77	1428.66
	Farmland	243.36	1679.13	976.86	595.17	3494.52	1815.39
	Settlement	145.35	557.1	998.55	376.47	2077.47	1078.92
	Forest	332.82	1531.98	808.02	7337.7	10010.52	2672.82
	Summary	10166.49					
	Grand Total	872.64	4191.48	3259.53	8838.63	17162.28	
	Gain	721.53	2512.35	2260.98	1500.93		
	Net Change	-707.13	696.96	1182.06	-1171.89		
	Net Persist	-4.67957	0.415072	1.183776476	-0.15971		

Computed using ArcGIS, ERDAS and Microsoft excel

4.4.4 Net change of land use land cover change of study area

From below tables 4-3 and figure 4-13 net change of study area with above mentioned data sources we can understand that the following outcomes are presented as output to overcome specific objective one.

Farm Land

Areal coverage of farm land was consisted 3496.23 ha, 5881.5 ha, 4325.13 ha and 4193.91 ha in the years of 1986, 1990, 2010 and 2018 respectively. An increasing trend of farm land in the year 1986 to 1990 year was decreased in 2010 and little change was recorded in 2018.

In the first period of interval between 1986 and 2010 the net change of farmland was increased to 833.4 hectare but between 2010 and 2018 net change was decreased to 138.42ha and also increased by increasing rate 696.96ha between 1986 and 2018 respectively. Beyond this increasing trend there is also the conversion form land in to another land cover classes,

Proportionally in the second period of the study between 2010 and 2018 about net change of 696.96ha

Wetland

The total area under wetland was the smallest among land cover types of the study area which constituted about 1580.76ha, 1225.98ha and 873 ha in the years of 1986, 2010 and 2018 respectively.in these research finding the net change in the year between 1986-2010 the reduction of wetland coverage was 353.43 and almost the value of these was similar to 2010-2018 year. In the year of 1986-2018 the net change was decreased to 707.13. These indicate that most of the area converted to other land cover types.

Settlement

The areal extent of settlement was constitute 2077.83 ha, 2442.87 ha and 3260.16 ha in the years of 1986, 2010 and 2018 respectively. This figure reveals that the area was increased by 365.04 ha between 1986 and 2010, but it was dramatically increased 814.32 ha between 2010 and 2018.

Forest

The main focus of the present study was relay on perspective of spatial and temporal distribution, historical pattern, past and current on-going process of deforestation of study area.

Based on different data types and sources with integrated of different methodological approach and application of various tools that attempted to described the magnitude of forest change as well provide tangible picture of past and current situation of forest resource of the study area through map, and quantitative and qualitative statistical results the land use land cover matrix shows that the pattern of forest area was decreased from 9998.1 ha to 9151.7 ha between the year of 1986 and 2010 as well as it was reduced in to 8820.99 ha in 2018 in the study area respectively. This figure indicated Net change of decline of forest area by 846.45 ha and 322.2ha in interval of the 1986-2010 and 2010-2018. Between the year of 1986 and 2018 there was reduction of 1171.89ha was changed in to other land cover classes.

Table 4-4: Net change of the study area

LULC	Net change (Gain-loss)		
	1986-2010 (Ha)	2010-2018 (Ha)	1986-2018 (Ha)
Wetland	-353.43	-353.7	-707.13
Farmland	833.4	-138.42	696.96
Settlement	366.48	814.32	1182.06
Forest	-846.45	-322.2	-1171.89

(Computed from GIS and ERDAS)

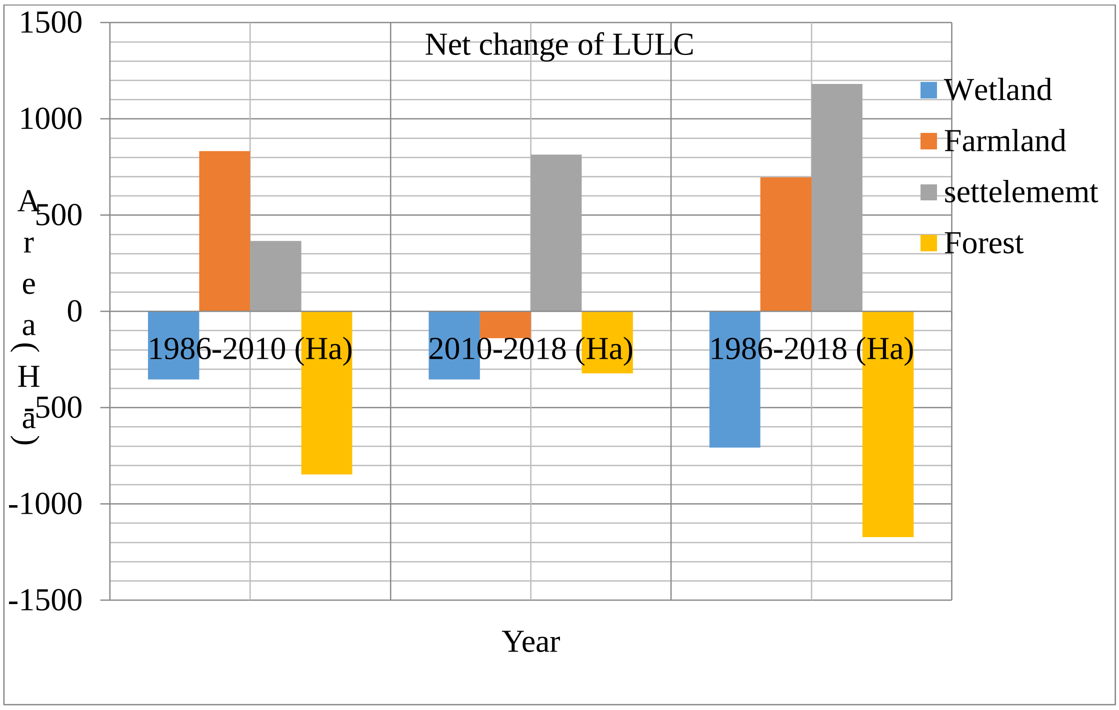


Figure 4 13: Net change land use land cover 1986-2018

4.4 Analysis of Rainfall and temperature trends

4.4.1 Analyzing rainfall pattern and discussion

As shown in figure 4-14 after applying year to year moving averages to filter out the irregular fluctuations between successive rainfall observations, annual rainfall trend lines were drawn leaving only a few peaks and depression. Thereafter, from Annex I of metrological data the linear regression was applied to show the trend, intercepts, slopes and regression lines.

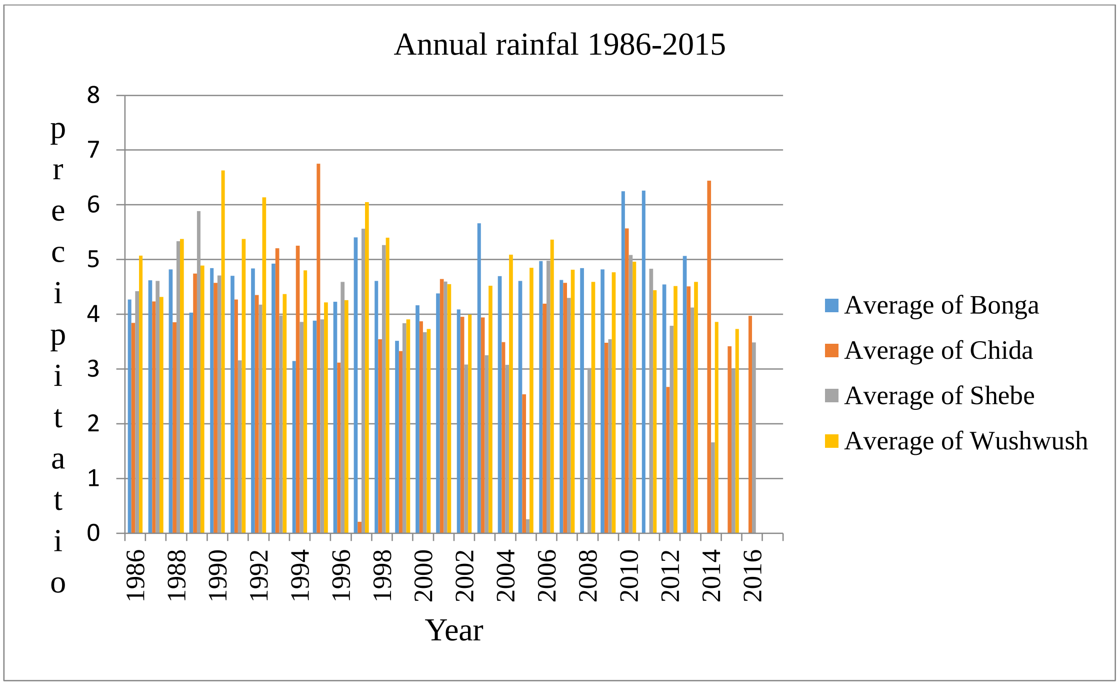
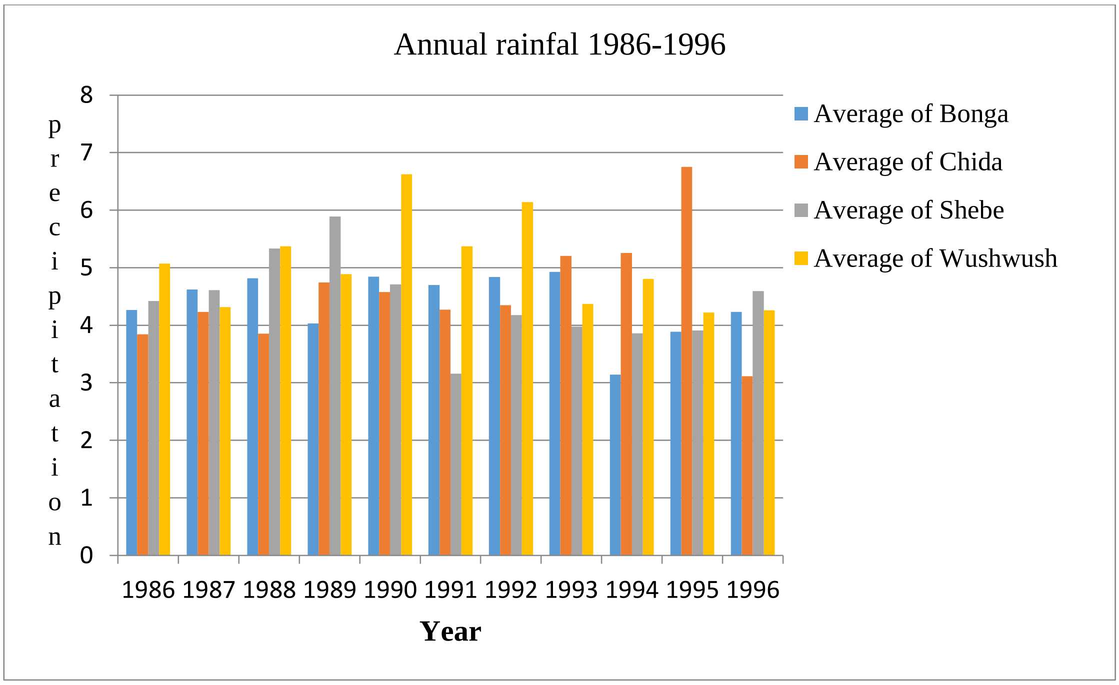


Figure 4 14: Annual rainfall of four stations 1986-2015



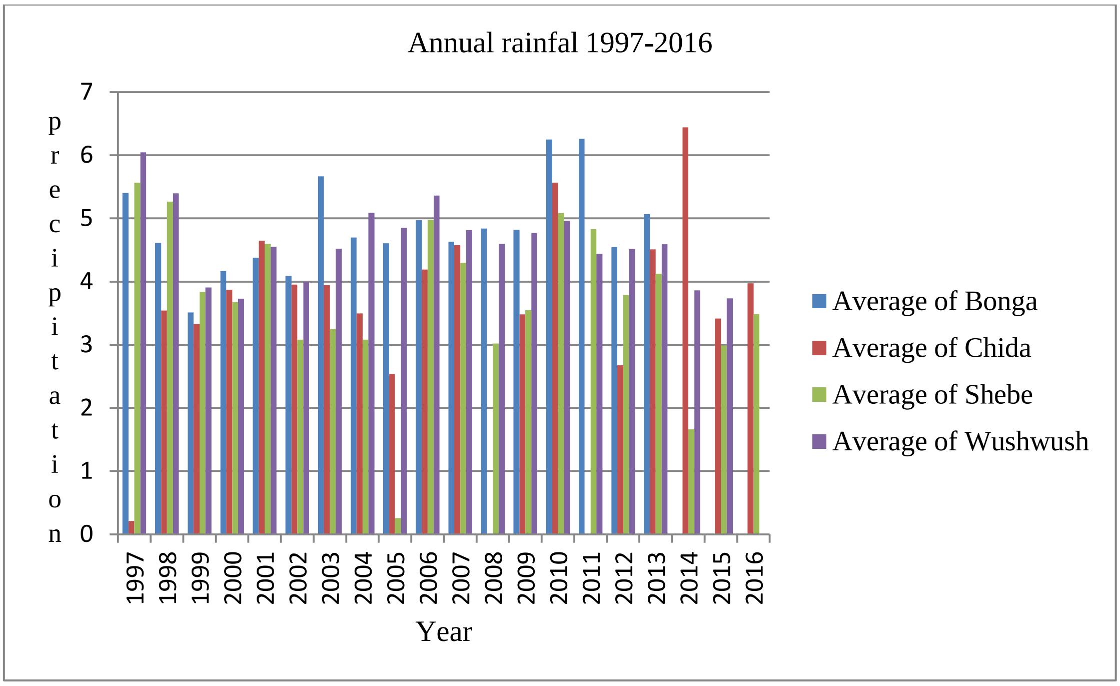


Figure 4 15: Annual rainfall of four stations1986-1996 and 1997-2016

In Bonga stations figure 4:17, relatively nearer to study area although, relative variability experienced upward trend (0.0344 mm) but absolute variability showed a positive trend of fluctuation.

Equally, absolute variability of annual rainfall is represented graphically against time in figure 4-15, the period from 1986 to 1996 showed a rapid fluctuation in rainfall then went up in 1996 which was the highest absolute variability value recorded for the period. From 1996 to 2002 it had frequent fluctuation in between the period. Similarly, on the year 2003up to 2008 show relative variability of annual rainfall. A noticeable phase can be seen in 2010 and 2011 with a highest in annual rainfall. However, it exhibits frequent ups and down within the study period and this turnover picked up at 2014.

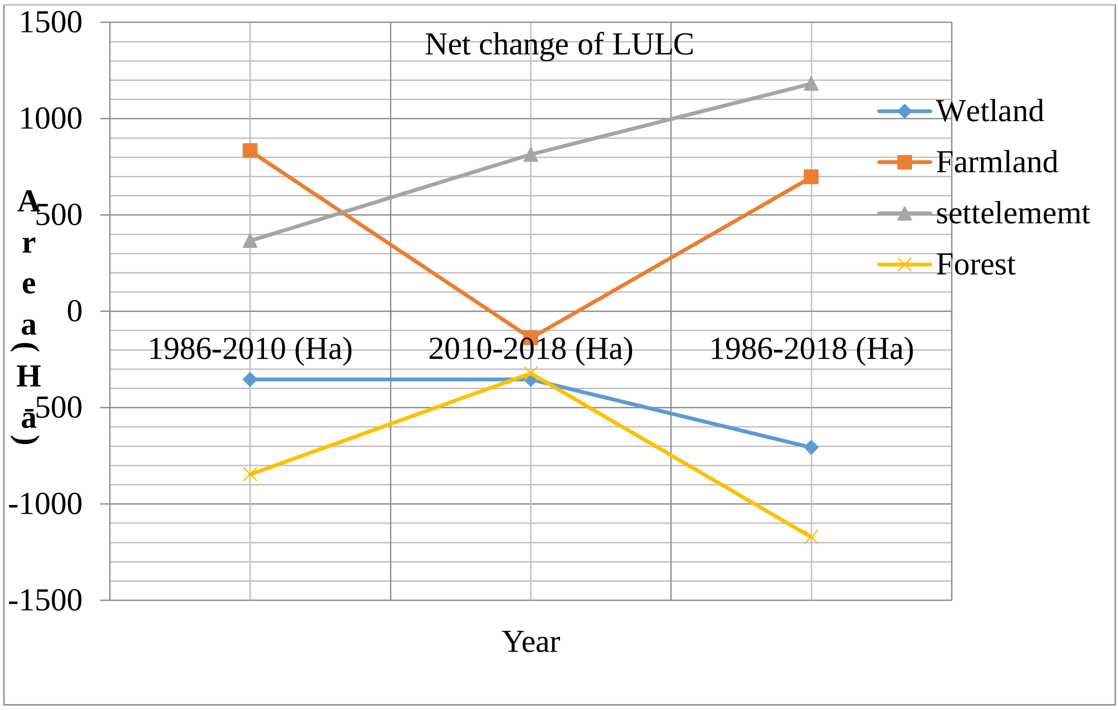


Figure 4 16: Net change of land use land cover

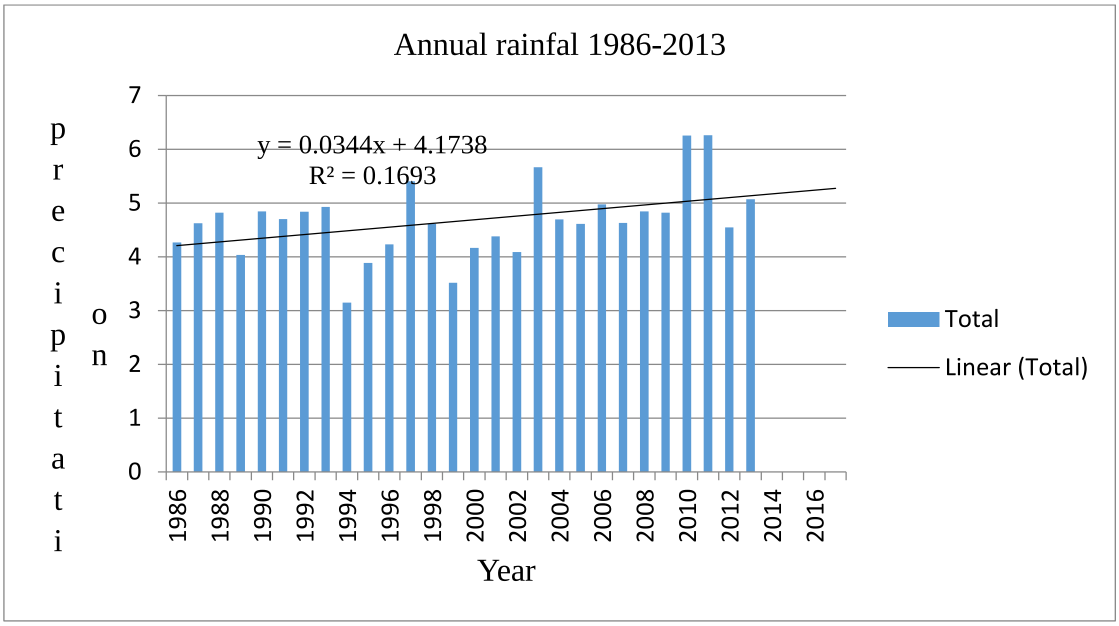
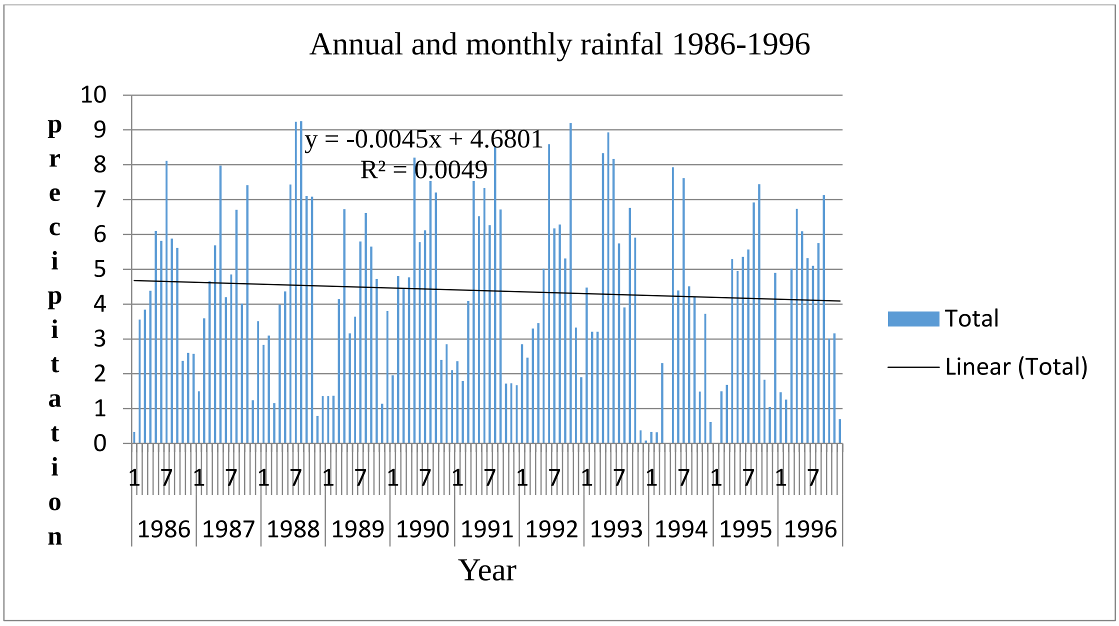


Figure 4 17: Annual Bonga rain fall 1986-2013

The result generated as graphs in figure 4-17, showed that rainfall possess a fluctuated trend which means that the study area is getting wet only by 0.0323 mm annually. The annual rate of increase in rainfall totals (0.0323 mm) has implication for other component of weather and climate this is because this decrease in annual rainfall totals will make the area fluctuated trend of rainfall.



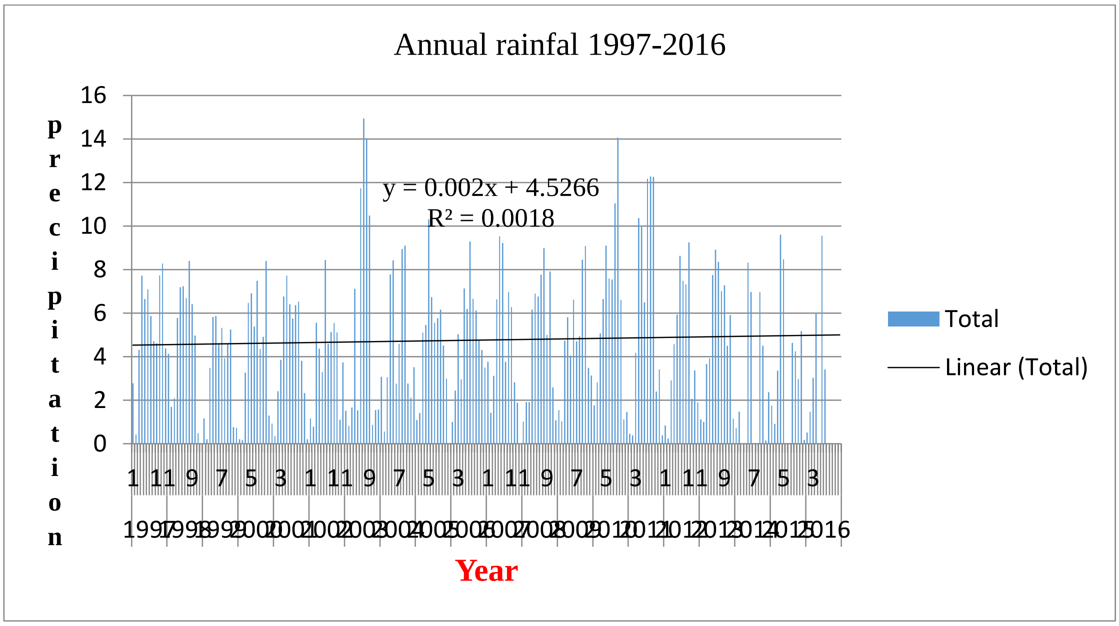


Figure 4 18: Annual and monthly Bonga rainfall between 1986-1996 and 1997-2016

From the result, figure 4:16, figure 4:17 and figure 4:18, we can say notice that the fluctuation not only in the study area but also in the neighbouring negative impact have adverse effect on the study area, these briefly seen in figure 4:16 known for is experiencing increase in settlement and will fluctuate the rate of rainfall.

4.4.2 Analyzing maximum temperature and trends

The time series analysis procedure that we have adopted in this study consists of first fitting a simple linear regression models to the corresponding times series.

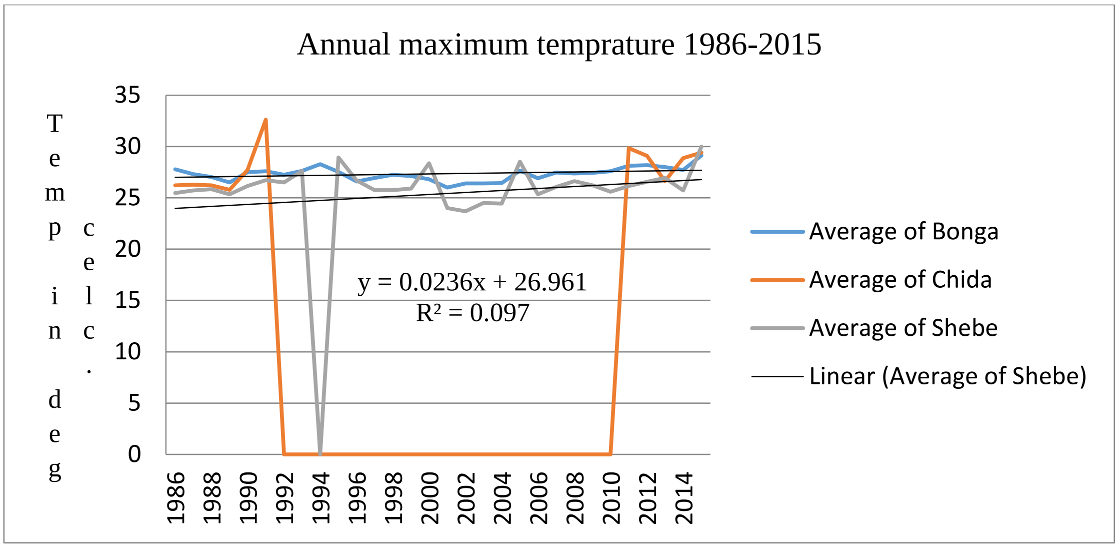
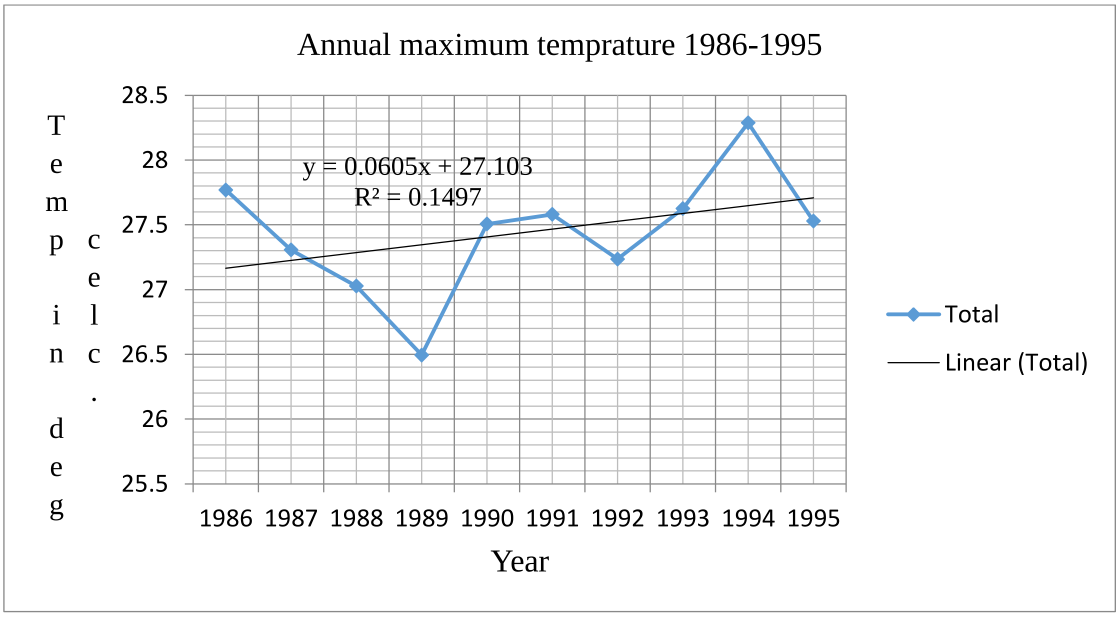


*Figure 4 19*1: Annual maximum average temperature of three stations for duration between 986 - 2015

From the Microsoft excel output of figure 4-20, we can conclude that there is a statistically significant positive trend in the annual average Temperature Time Series estimate of the slope is 0.0236 degrees Celsius/ year (1986-2015). In overall trend we can see that the maximum average temperature was unlike minimum temperature and rainfall trend analysis it was positive value and these were indication of increase atmospheric temperature.



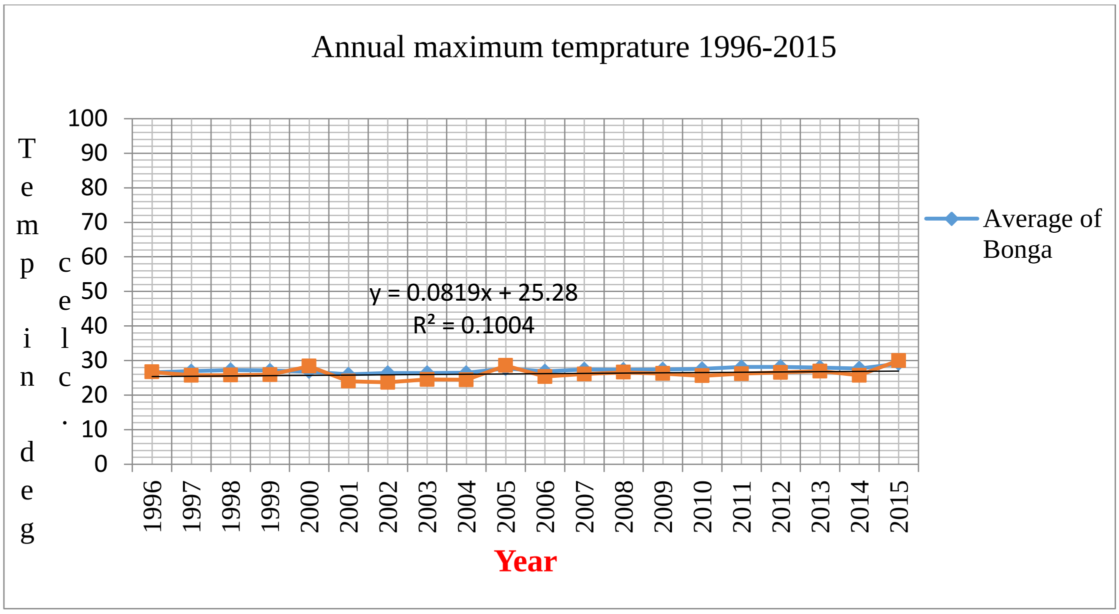


Figure 4 20: Annual maximum temperature of three stations 1986-1995 and 1996-2015

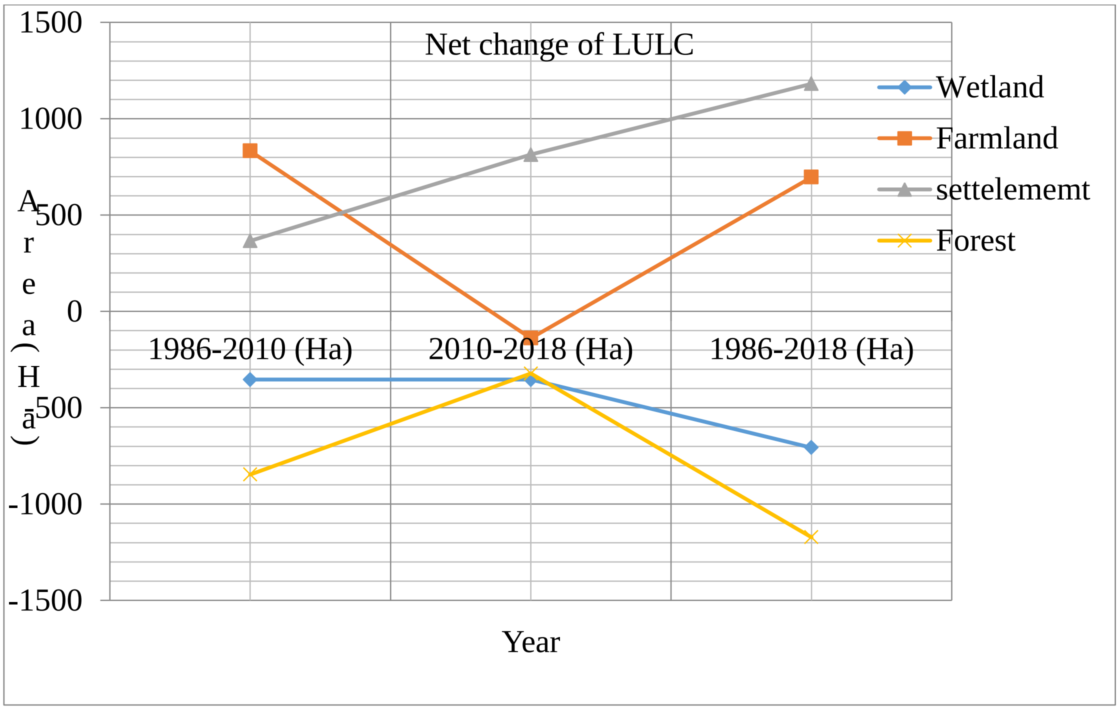


Figure 4 21: Net change of land use land cover of three stations

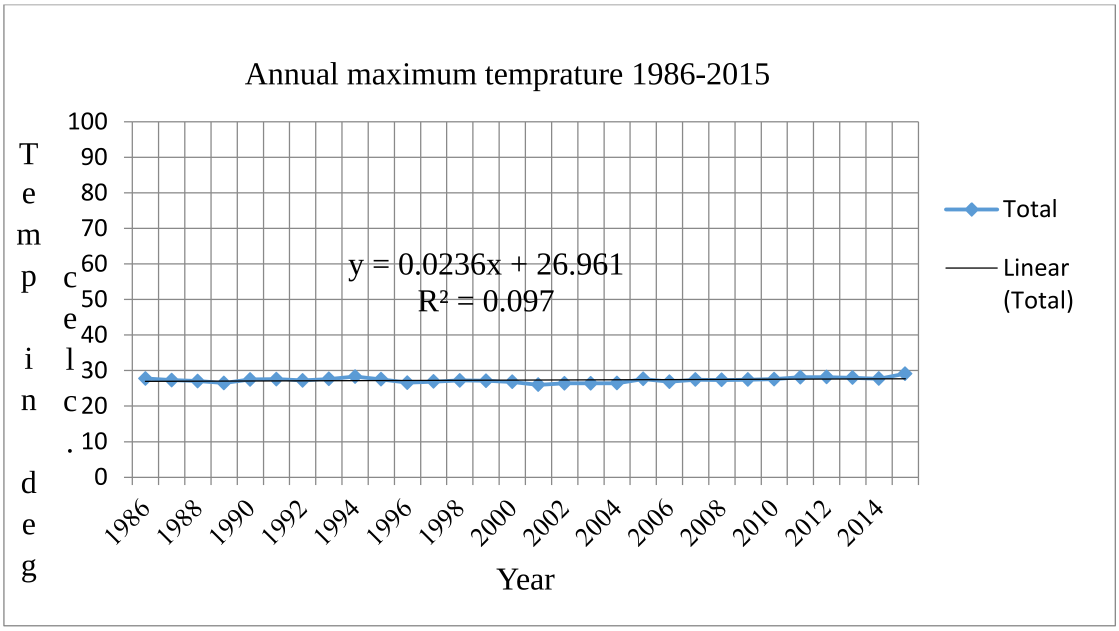
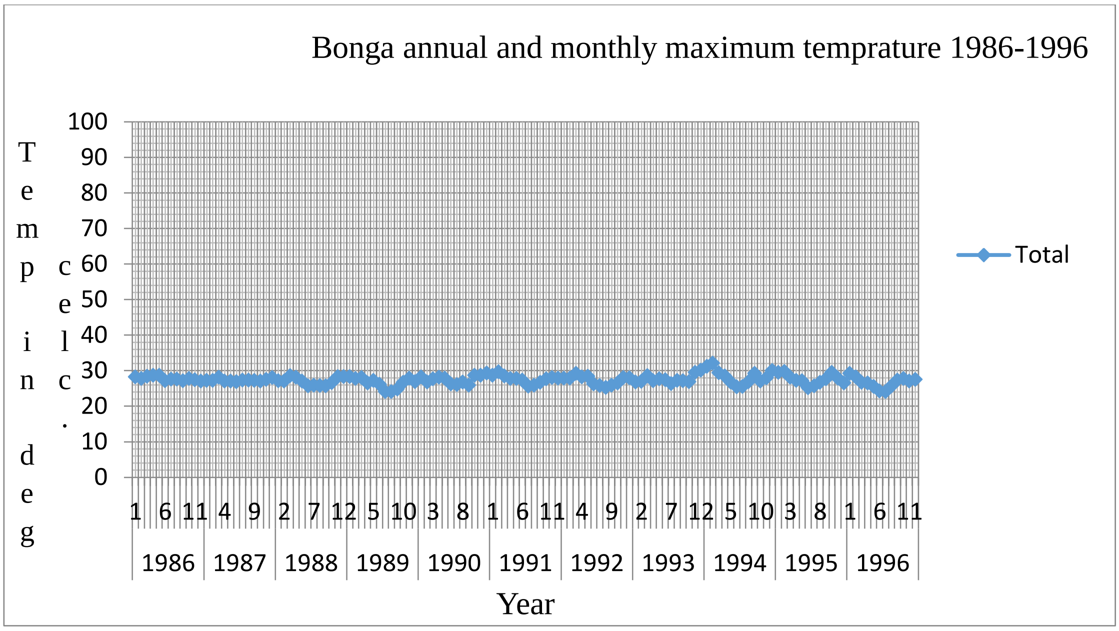


Figure 4 22: Annual Bonga annual maximum temperature 1986-2015

In the year of 1986-2015 the highest average maximum temperature reading was recorded at Bonga station in the year of 2008 that was 29.1^{o}C and the maximum value exceeds up to 38.5^{o}C in these year we see that there was great difference from year of 1987 up to 1993.



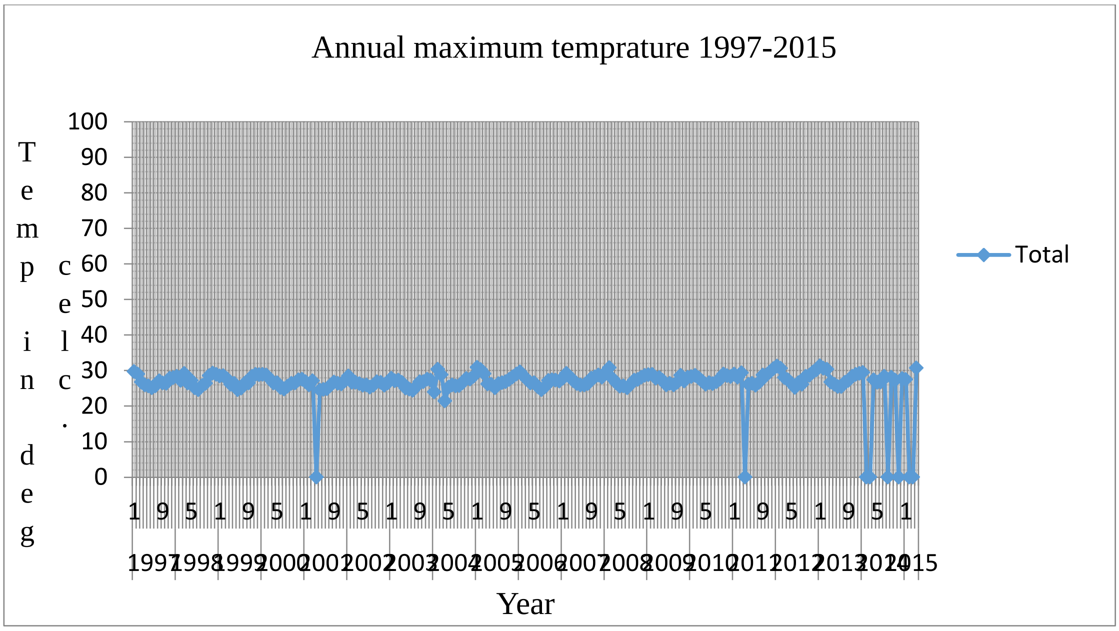


Figure 4 23: Bonga maximum temperature year 1986-1996 and 1997-2015

From 1986 up to 1993 the maximum temperature was in stable condition below 32^{o}C but these values exceed to 34^{o}C at 1993. From 1994 up to 2006 the maximum temperature was relatively good but at the year of 2008 the highest maximum temperature was recorded 38oc these value was the highest of three decades.

Unfortunately the value decreased to 31.9 in 2009 and this give a notice for growth of vegetation starting in year 2010 see figure 4-23, from 2010 to 2015 there was up and down trend of temperature throughout the years.

4.4.3 Analyzing minimum temperature and trends

The trends of monthly average maximum temperature over different years were obtained using linear regression best fit lines.

The annual average of monthly minimum temperatures showed a decreasing trend having an annual decrease of -0.0079 ^{0}C per year, as shown in figure 4-22. The linear equation was y =-0.0079 x+12.128. This implies that at study area and neighbouring station annual average minimum temperature decreased by 0.0079 ^{0}C between 1986 - 2014.

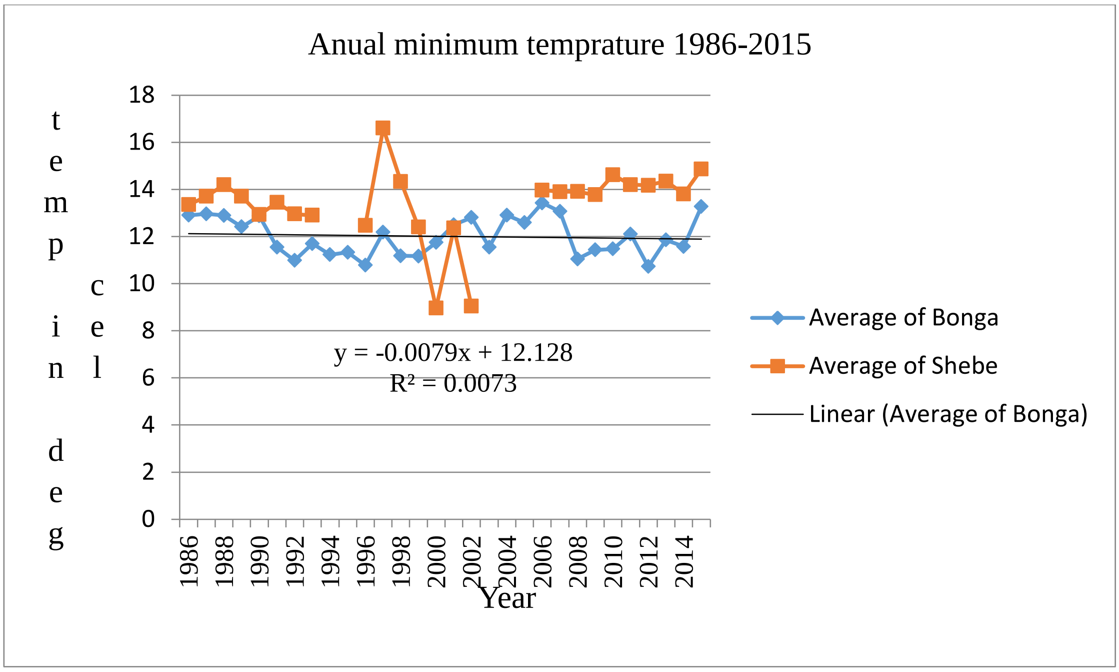
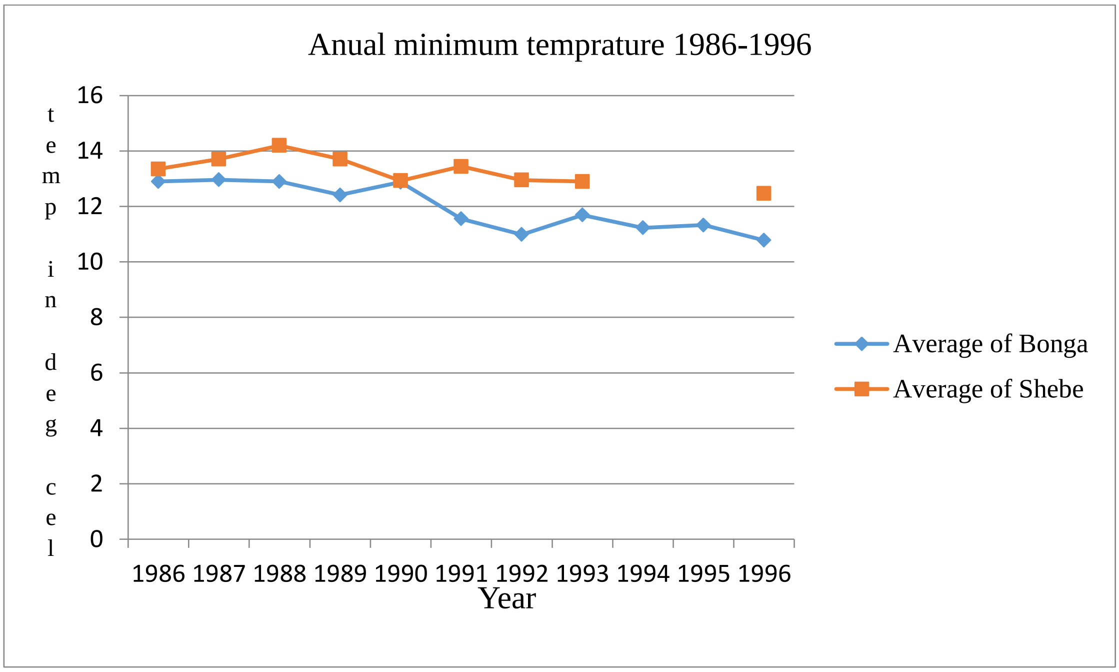


Figure 4 24: Annual minimum temperature of Bonga and Shebe



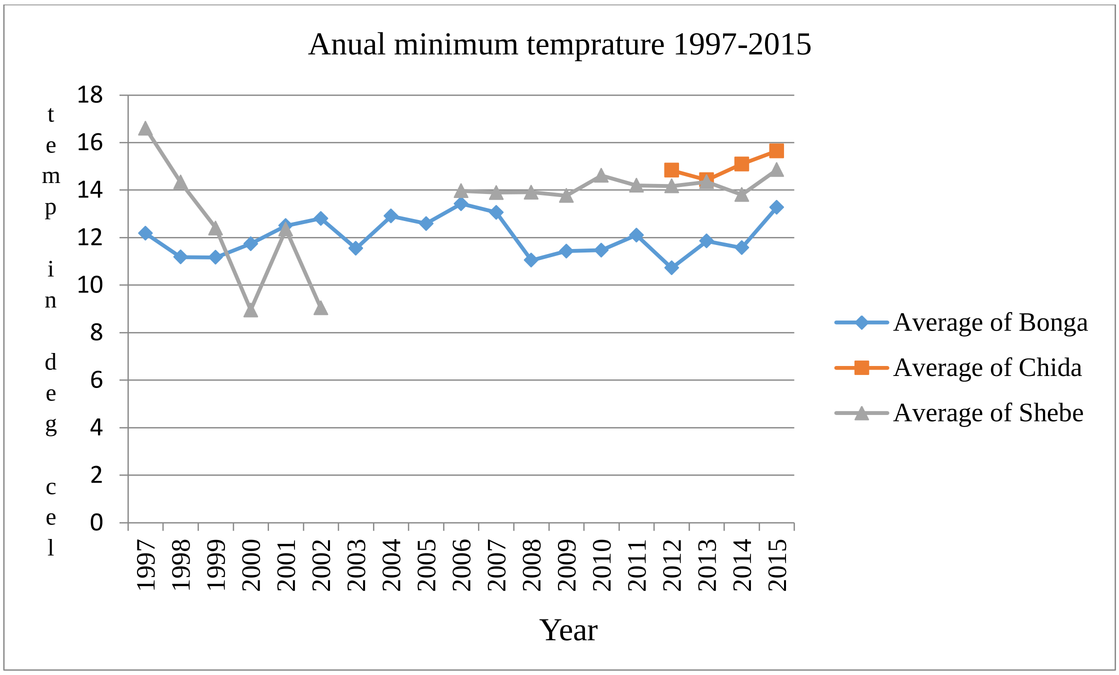


Figure 4 25: Annual minimum temperature of Bonga and Shebe stations for the duration of 1986-1996 and 1996-2015

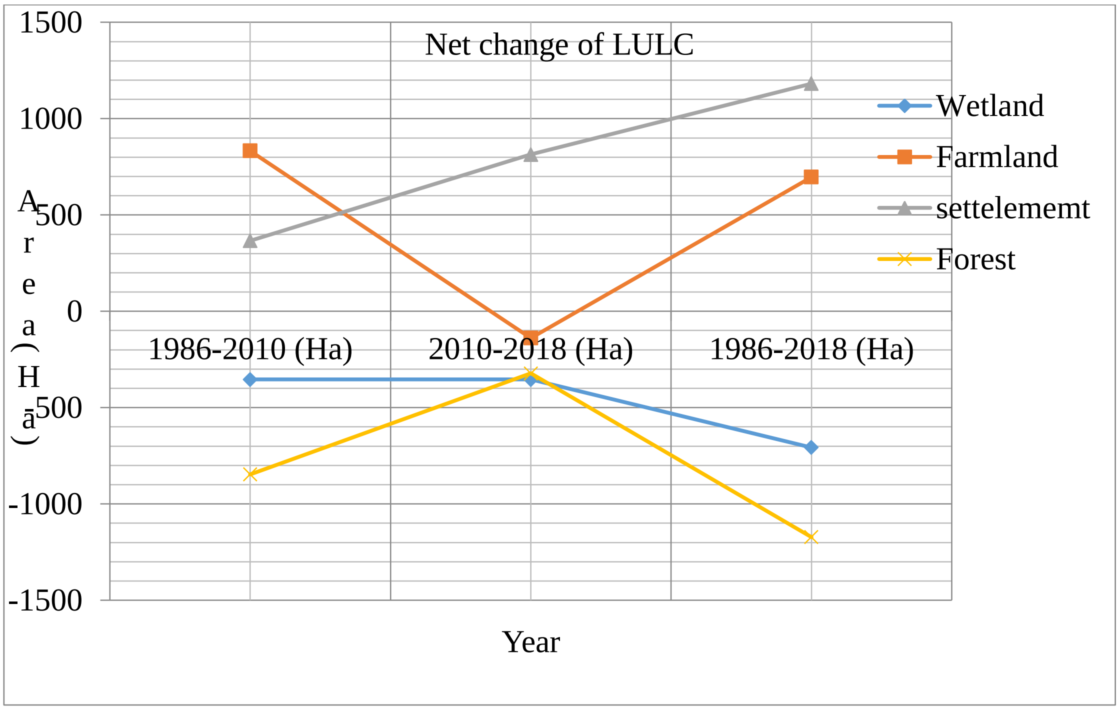


Figure 4 26: Net change of land use and land cover of Bonga and Shebe

In the year 2010 up to 2010 there was incremental trend that was basically related to figure 4-26 of land use land cover change.

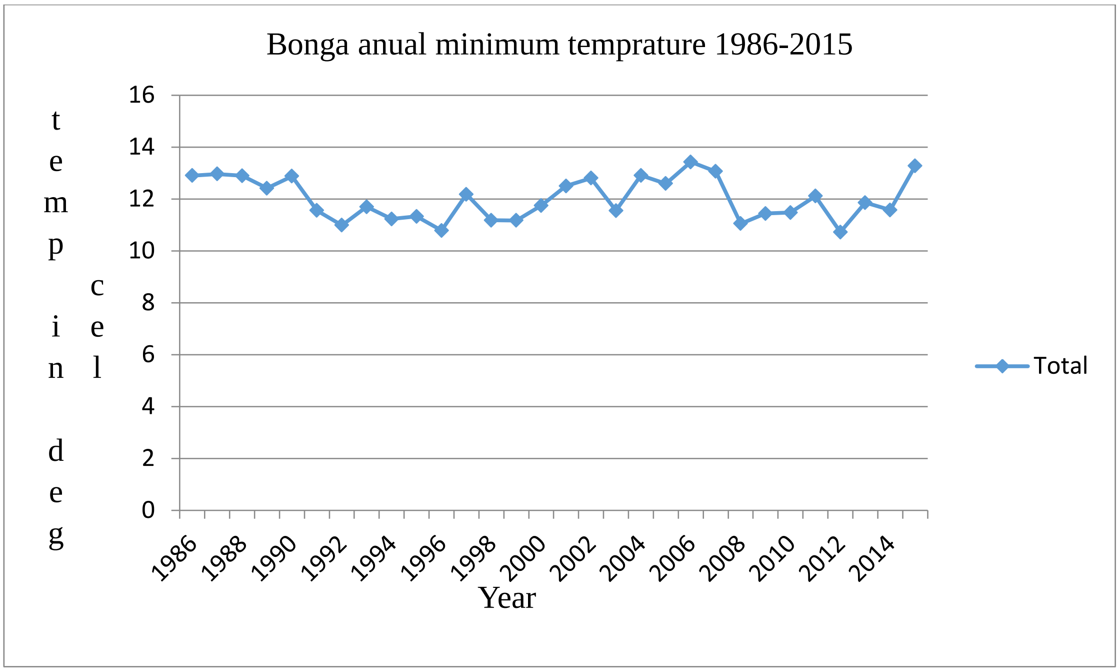
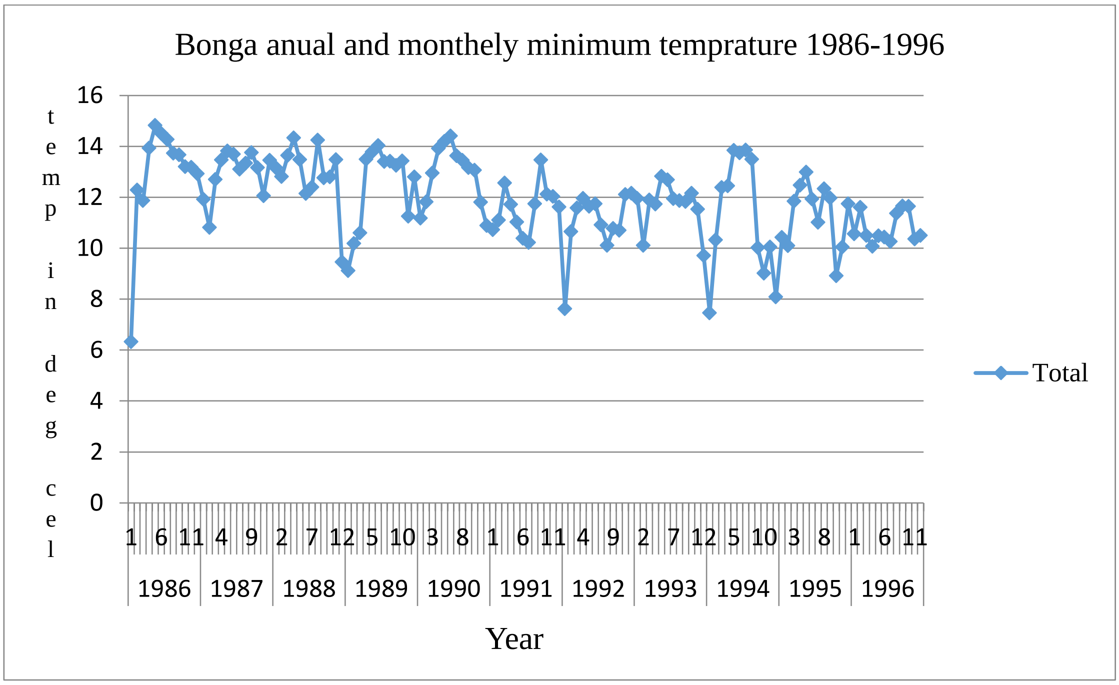


Figure 4 27: Bonga Annual minimum temperature trends between 1986 -2015



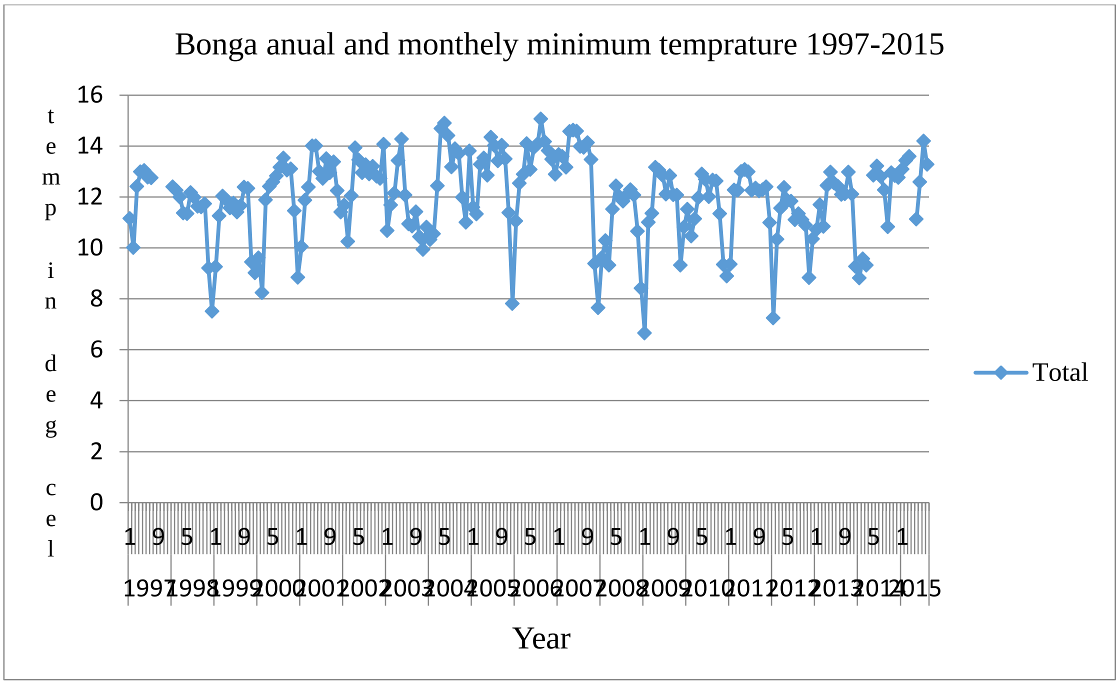


Figure 4 28: Bonga minimum temperature trends of year 1986 -1996 and 1997-2015

The statistical summary of annual minimum temperature recorded at Shebe station 9.03 mm and 8.95mm at year of 2000 and 2002. In figure 4-27 and figure 4-28 of Bonga station we can analyse yearly based annual minimum temperature and with the base of that the study area temperature were not stable in those three decades in the year of 1986-1996 the temperature decreased annually -0.2315 but in the year 1997 up to 2005 there was increasing trend of 0.143 but in the year of 2005-2009 these decreasing trend seen in the graph that was -0.4689.

4.5 Relation between rainfall temperature and forest change

As indicated earlier, spectral band ratio is one of the most common mathematical operations applied to multi-spectral data. Ratio image were calculated as the divisions of digital number values (0 -255) in one spectral band by the corresponding pixel value in another band.

Based on the reflectance pattern of vegetation, different models of vegetation indices were developed to explain the healthiness, vegetation cover and biomass condition of vegetation.

The NDVI index, calculated relatively simply by means of spectral bands 3 and 4(NDVI =NIR - red/NIR + red), is highly useful in the analysis of vegetation quality .in theory, its values range from -1 to +1, but in practice the actual values range from approximately -0.8 to+ 0.9.the negative values mean barren area (no vegetation), with sand, barren rock or water, while positive values means areas covered with vegetation. In general, positive values up to 0.1 mean low and very low-density vegetation, while values in the 0.11 - 0.2 and 0.21 - 0.3 ranges mean vegetation with average and relatively high density.

In general, values above 0.3 indicate that vegetation with very high density. Forest ecosystems match values around 0.6, at least as far as the temperate region is concerned (earth observatory. nasa.gov.)

The present study used monthly climate data year-on-year with a view to quantifying the climate's temporal fluctuation over a time span of three decades. Therefore, we obtained and processed average monthly temperature and precipitation data from the Ethiopian metrological agency climate data platform. The data originate from four station located close to the study area (Bonga, Wushwush, Shebe, and Chida station). Most of the data available encompassed the entire time span analysed, with the exception of anew monthly rescored missing were artificially extrapolated using the data available throughout from the neighbouring station. In most case, to understand these we try to assess the NDVI of the study area for Bonga station

4.6 NDVI change detection

4.6.1 Normalized vegetation index of 1986 image

After pre-processing downloaded image of band three and band four we can calculate and get value ranges from 0.06 to 0.64. The Normalized Difference Vegetation Index values were calculated in 1986 values was as high as 0.4-0.6 which was in many areas of the region. This showed in this year the vegetation was quite healthy and so was of high quality. The middle and some part of study area which is red one ranges from 0.06-0.26 had low NDVI values meaning that the area had poor vegetation performance. Figure 4-29 and figure 4-30 below illustrates that the pre-processing steps and the final output image of NDVI 1986 images.

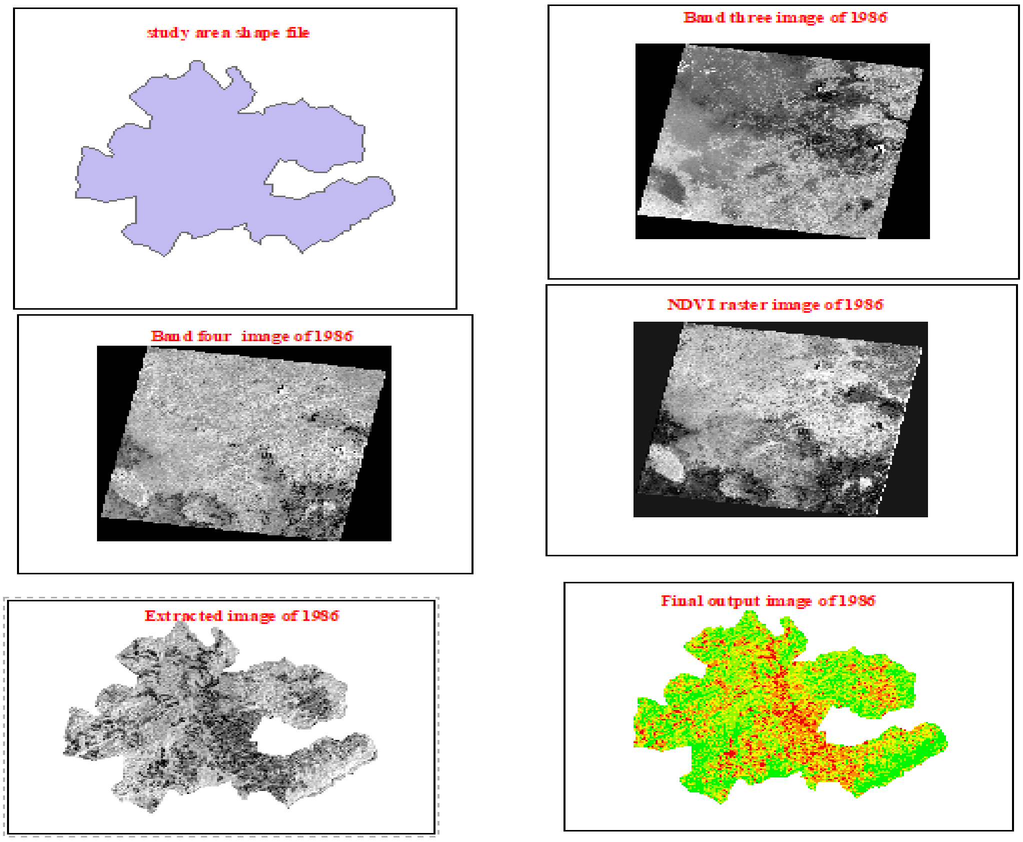


Figure 4 29: NDVI image pre-processing of 1986

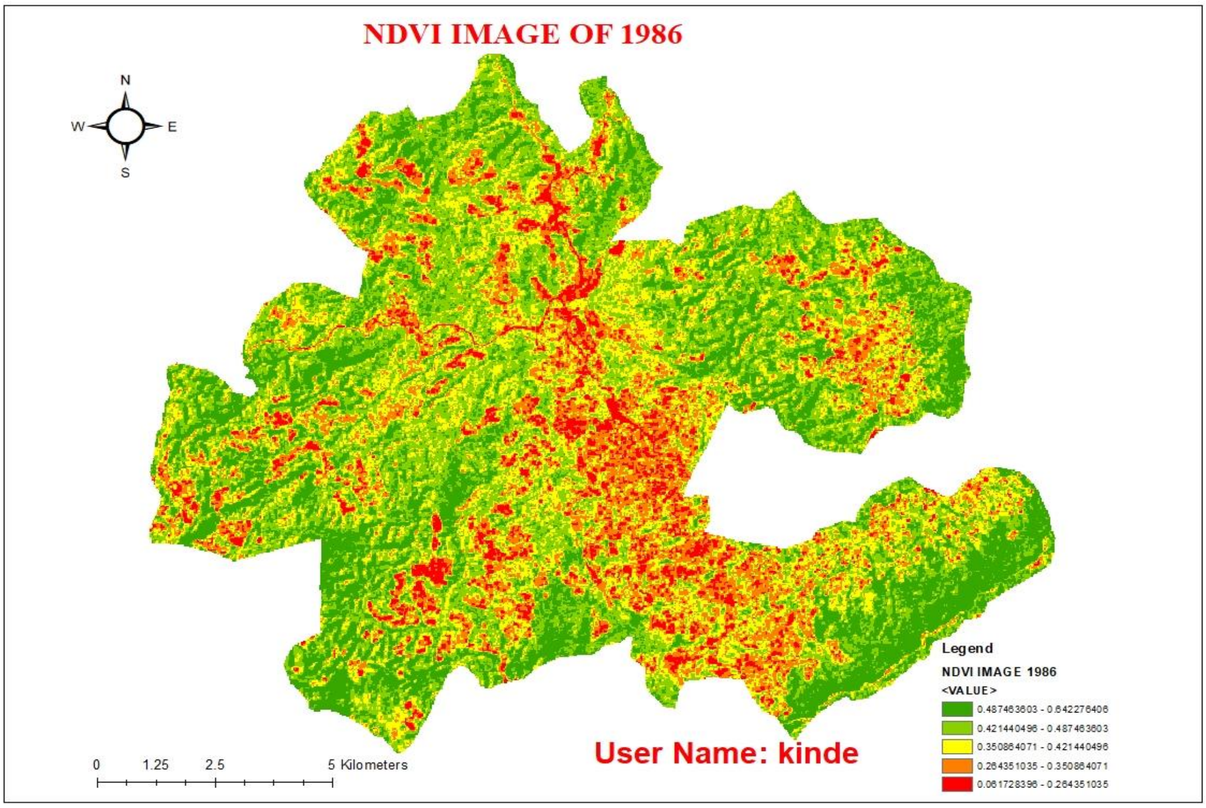


Figure 4 30: NDVI image of 1986 (computed using GIS)

4.6.2 NDVI of 2010 image

In figure 4-31, we create raster calculation of NDVI value using band three and four images and using those value in fig we recognise that NDVI values in the year 2010 were minimum value 0.00 and maximum value were 0.77 and the mean was 0.59. These indicate that in average the vegetation was healthier than that of 1986. High in very most areas and in middle part of the area had low values which reflected poor performance of vegetation.

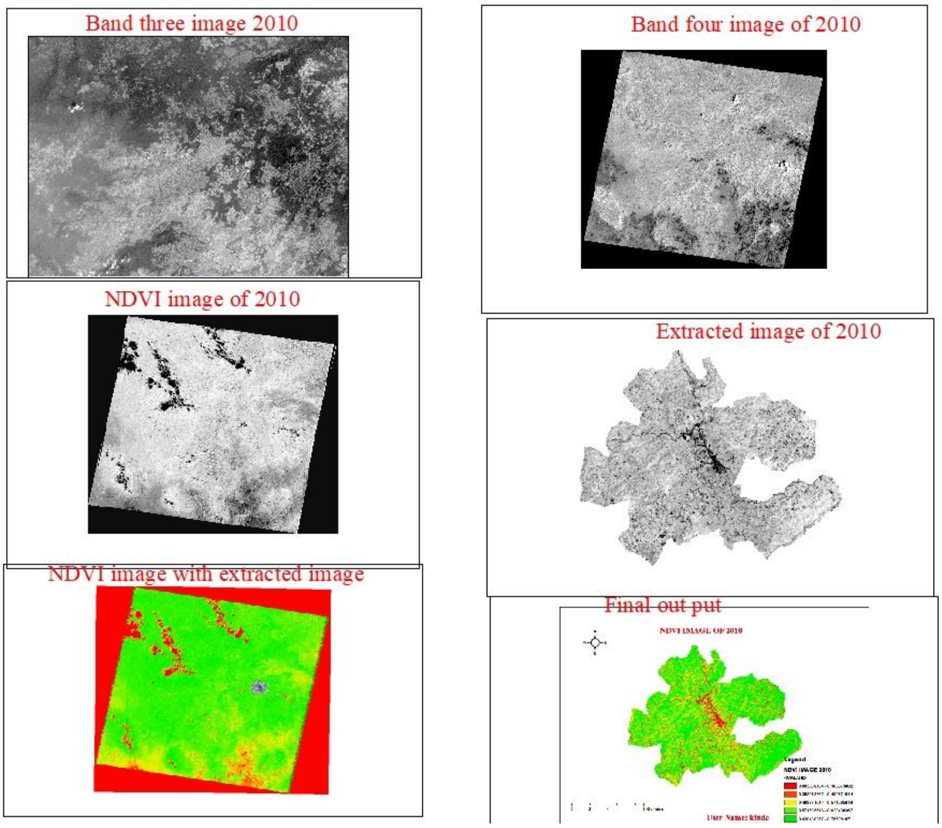


Figure 4 31: NDVI image pre-processing of 2010 (computed using GIS)

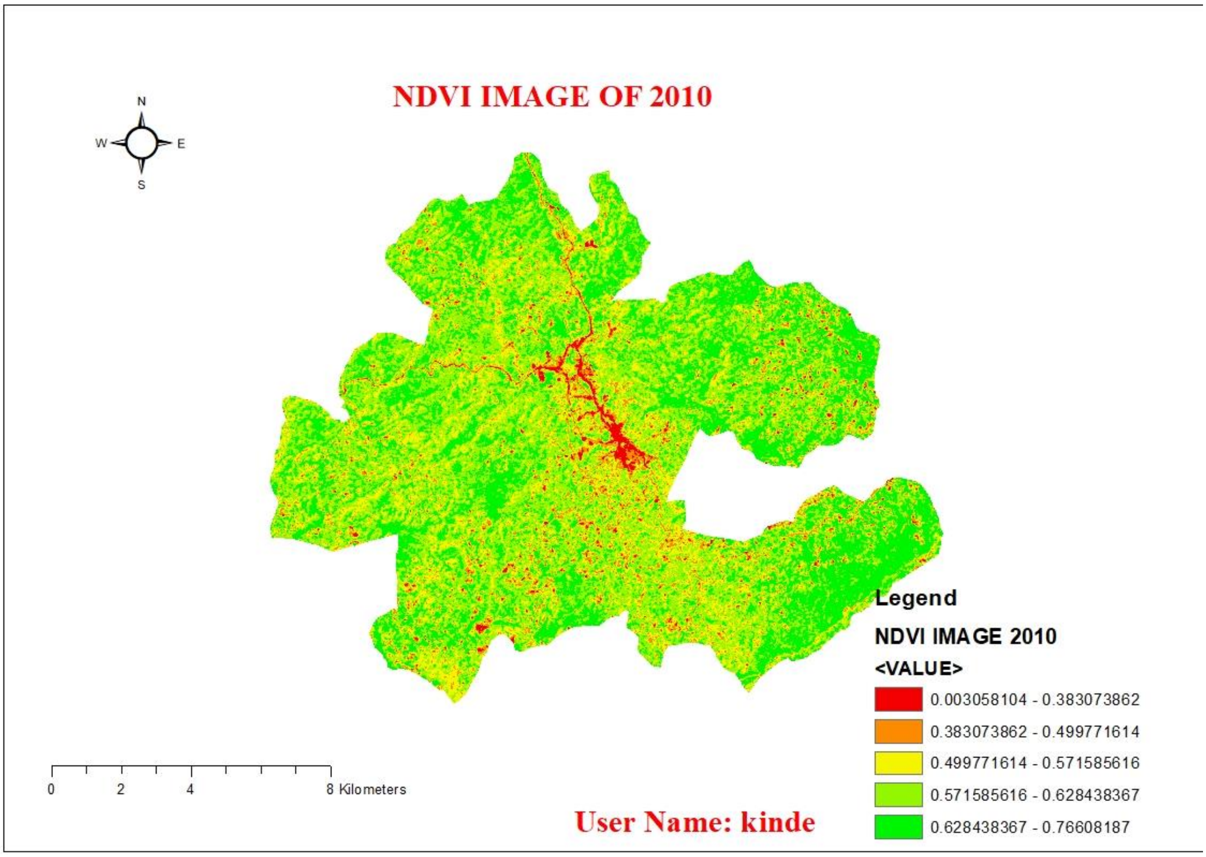


Figure 4 32: NDVI image of 2010 (computed using GIS)

4.6.3 NDVI of 2016 image

The NDVI Values that were calculated for the year 2016 Landsat imagery reflected that vegetation cover had values between -0.075 and 0.12. From the results it is clear that a large area had not healthy vegetation. It was clear that there was almost no healthy vegetation in the region. A very large area had values between -0.025 and 0.074 which does not describe a healthy region and a very small region with values from 0.1 and 0.12 which would be considered healthy.

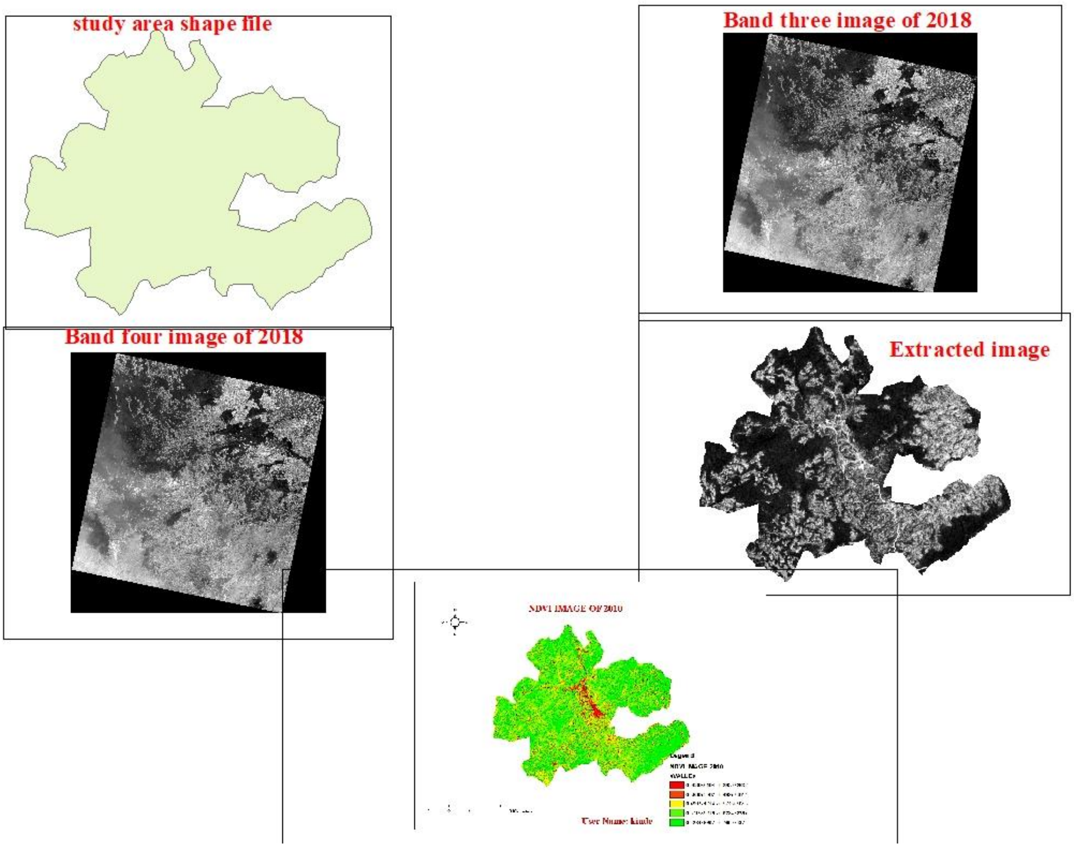


Figure 4 33: NDVI Pre-processing of 2016 image

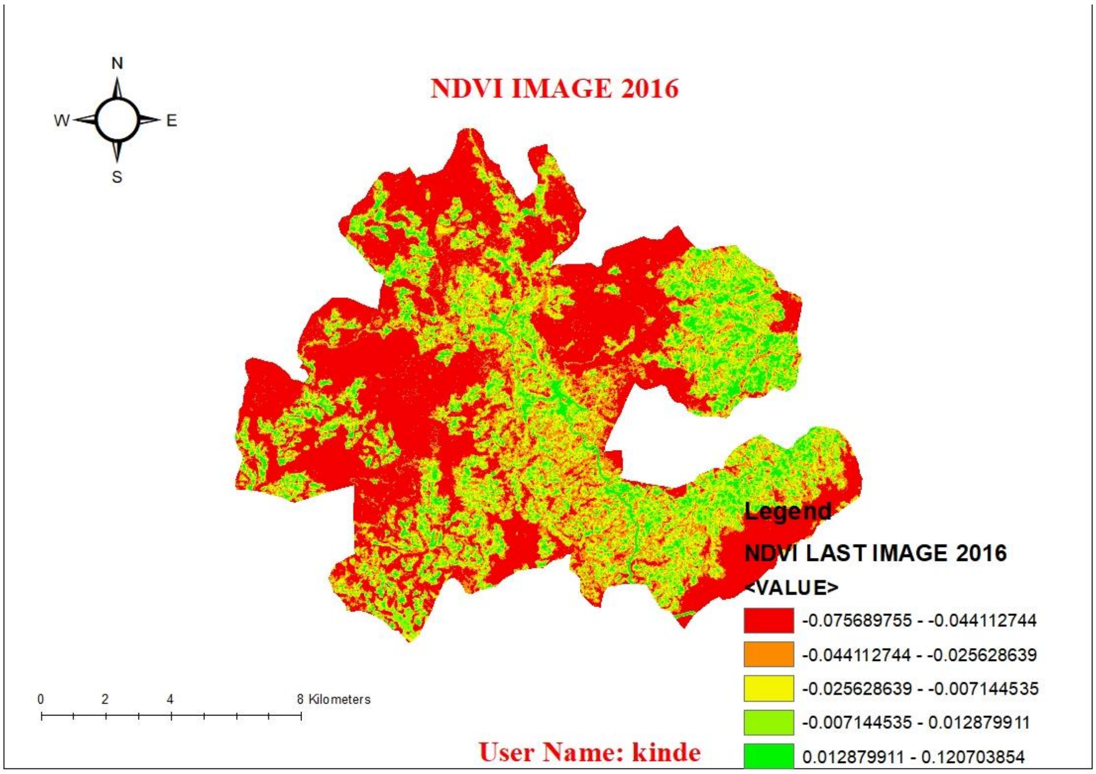
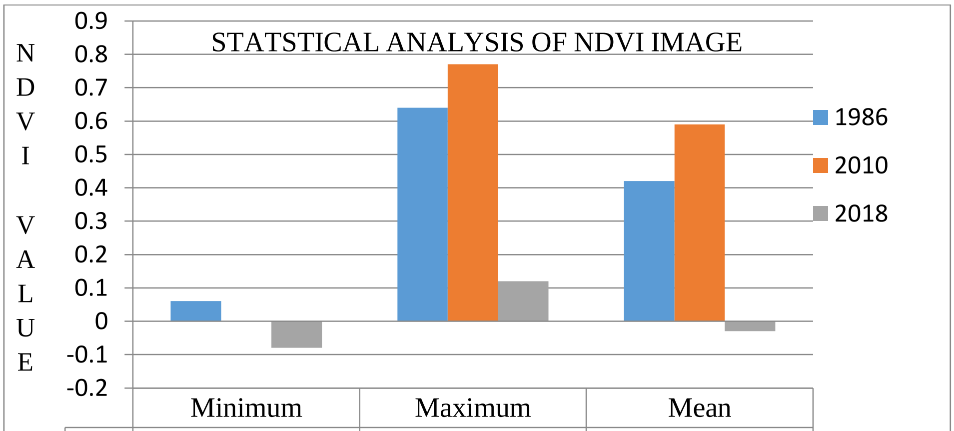


Figure 4 34: NDVI image 2016 (computed using GIS)

4.6.4 Stastical analysis of NDVI image of 1986, 2010 and 2016 image

Figure 4-35 below illustrates NDVI image differencing gives overall information about the healthiness of vegetation cover in the study area based on NDVI value. From this study ETM+ (band 4 and band 3) were used. The new version ERDAS imagine software automatically calculate. The negative threshold value indicates loss in NDVI and positive threshed indicates area of increased NDVI (restoration or healthily vegetation).

In consecutive years the value of minimum, maximum and mean value fluctuates and in general it means that the overall vegetation is not in stable condition. In 1986 we conclude the disturbance rate of the vegetation was higher than that of 2010. When we compared to 2010 and 2018 image statistical value the minimum value of 0.06 in 2010 was decreased to 0 and the maximum value decreased from 0.77 to 0.12. These indicate that there was highly unprotected destruction of vegetation in 2016. In general based on the below statistic most part of study area was relatively disturbed when we compare with previous years. .



	Minimum	Maximum	Mean
1986	0.06	0.64	0.42
2010	0	0.77	0.59
2018	-0.08	0.12	-0.03

Figure 4 35: Stastical analysis of NDVI image (computed from GIS)

4.6.5 Relationship of 1986 temperature NDVI and rainfall

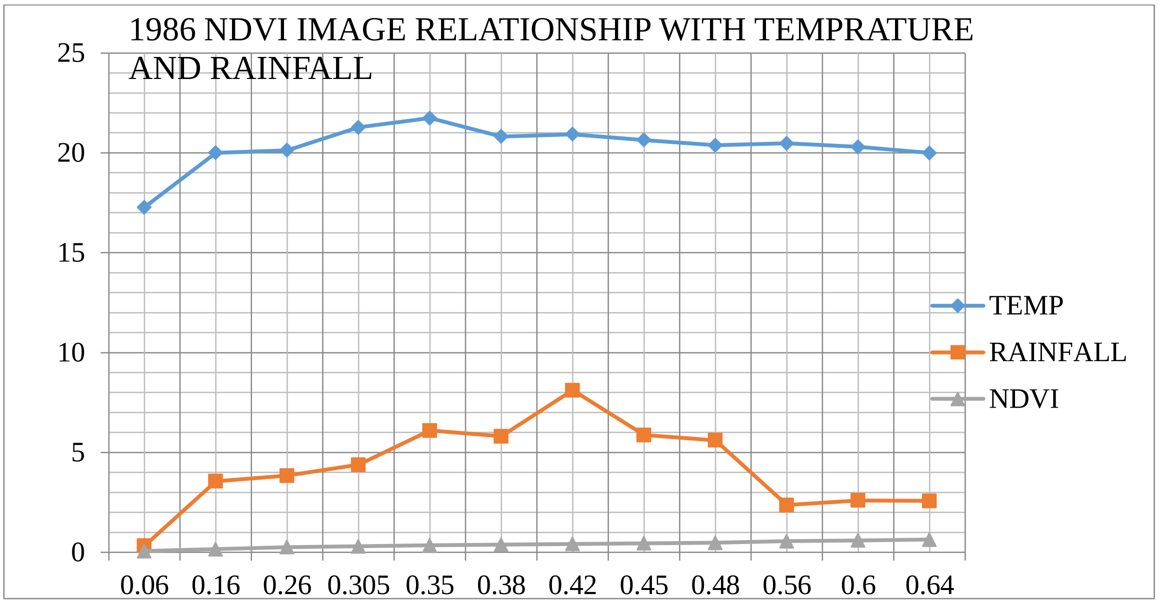


Figure 4 36: Graph of NDVI, temp and precipitation

From them analysis done as shown in figure 4-36 it was clear that when the rainfall was high the temperatures were low and thus the NDVI values were high. Year 1986 had a lot of rainfall which was experienced in the region and the temperatures were not high except for a small region in the area. The NDVI values reflected healthy vegetation which was brought about by the high rainfall and favourable temperature.

4.6.6 Relationship of 2010 temperature NDVI and rainfall

From this analysis done as shown in figure 4-37 it was clear that when the rainfall was high the temperatures were low and thus the NDVI values were high. This year had a lot of rainfall which was experienced in the region and the temperatures were not high except for a small region in the area. The NDVI values reflected healthy vegetation which was brought about by the high rainfall and favourable temperature.

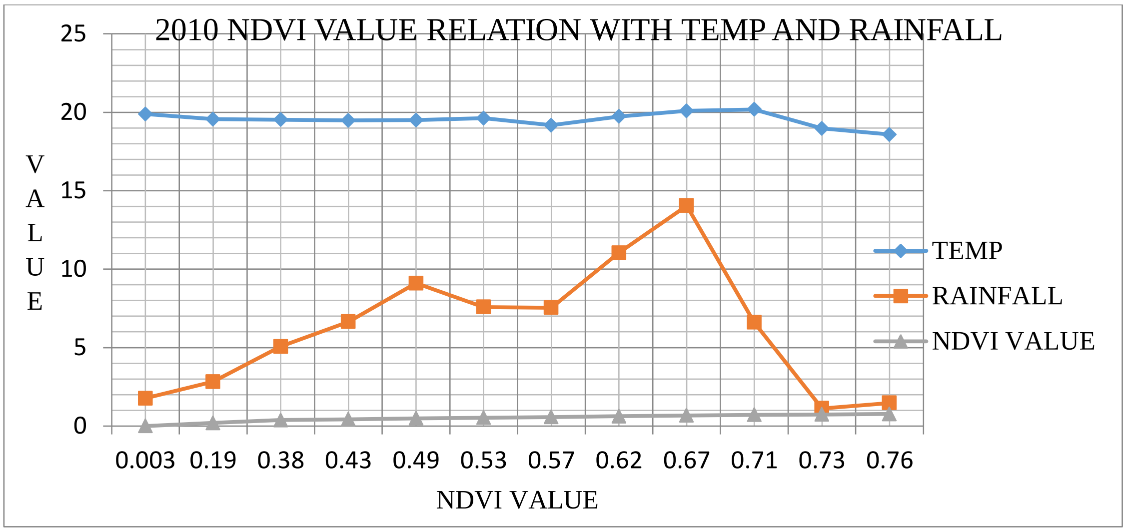


Figure 4 37: 2010 NDVI value relation with temperature and rainfall

4.6.7 Relationship of 2016 temperature NDVI and rainfall

From the observations as shown in figure 4-38, in the year 2016 the temperatures were high in most of the region, where the NDVI value was below zero. These indicate that most of the study area covered with unhealthy vegetation and rainfall experienced was minimal causing vegetation to be unhealthy in most of the region.

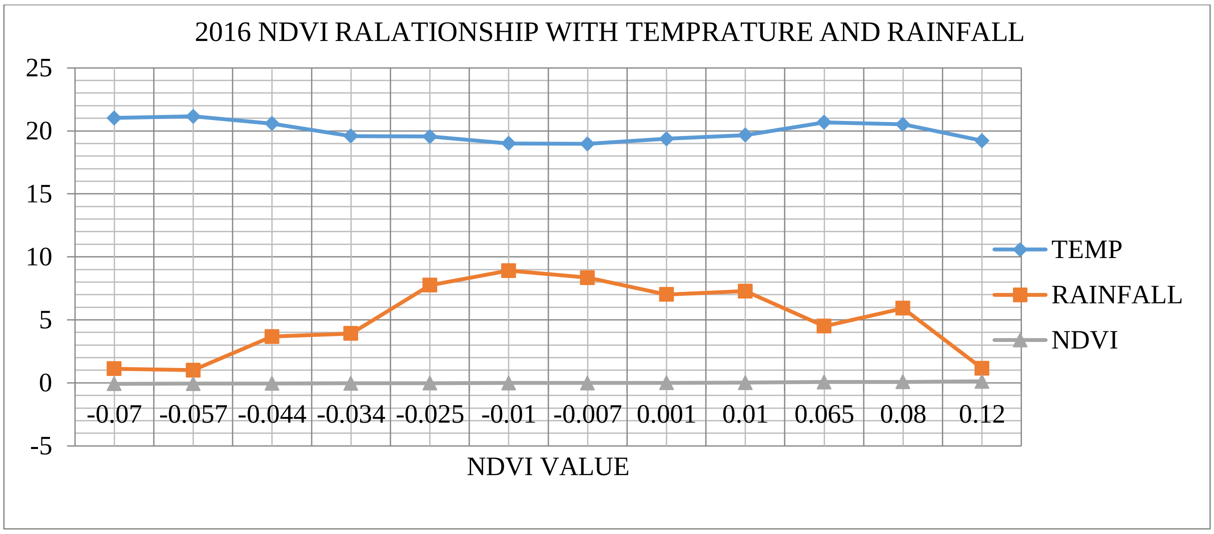


Figure 4 38: 2016 NDVI relationship with temperature and rainfall

In summary there was a clear indication of significant relationship between temperature, rainfall and NDVI. This showed the land use land cover change areas with high temperatures, had low rainfall and so registered low NDVI readings while land use land cover change areas with low temperatures had high rainfall and so registered high NDVI readings. To simplify these understanding if we see year 2010 minimum NDVI value was 0 and maximum value was 0.77 using these value as bench mark we can make theoretical concept of temperature and rainfall, the maximum temperature recorded in the year was 20.18 degree celiceus like that the maximum rainfall was recorded 14.05 mm these value was highest when we compared to year 1986 and 2016 but the NDVI value was 0.77 these also indicates if the two parameter was increases the NDVI value does not decreased that means there is no vegetation that were unhealthy.

CHAPTER FIVE

CONCULUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study tries to give emphasis on using integrated techniques of GIS and remote sensing for forest change detection start from data extraction up to final map generation. In order to quantitatively explain correlation between forest cover change and climate variability both NDVI and metrological data's were done using ERDAS imagine software 9.2, ArcGIS and pivot table in Excel 2010.

The limitations of missed metrological data were corrected by interpolating neighbouring station. For land use land cover change multi-criteria comparison and weighted overlay method were used. The present study area is composed of four major land use/land cover types, forest, settlement, wetland and farm land.

From the result of analyses, the magnitude of land-use/ land-cover in general and forest cover change in particular was observed between the year 1986 and 2018 in the study area. Particularly, expansion of settlement and farmland resulted in decline of both forest land wetland land coverage were observed. In relation to this, currently, from overall condition of the forest cover land was up and down growth rate.

The findings of NDVI and net land use land cover change indicated that from the total area of the forest land about 10020.33 ha of land were covered with forest in 1986. But, this figure declined to 8851.23 ha in the year 2016 decreased by 1169 ha. and the NDVI value of 1986 were minimum 0.06 and the maximum value were 0.64 but in the year of 2018 these value were reduced to minimum value of -0.08 and maximum of 0.12.

With perspective of this the study area was at high and moderate risk respectively. Yet the temperature and rainfall pattern trend in three decades were fluctuated continuously. The linear regression shows as there was continues fluctuation of rainfall and minimum temperature and increase of maximum temperature. These also indicates if the two parameter was fluctuates each other there was negative effect on the NDVI value but the rainfall and temperature exceeds at the same time the NDVI does not decreased that means there is no vegetation that were unhealthy.

5.2 Recommendations

From the whole study of GIS and Remote sensing techniques are vital tools for forest cover change detection and its relation with climate change. It had been recognised that the land use land cover change of study area has declined. As well as these the recorded metrological data and result shows as the variability of annual temperature and rainfall these directly related to the vegetation index value. The following feasible recommendations are forwarded based on the findings and conclusions.

- ✓ Classification and delineation of all areas in to different land use categories using GIS and remote sensing tools based on their ecological sustainability, potential for economic uses and social justice.
- ✓ To protect the forest resources from further destruction to realize the impact of deforestation as well as how to use this precious resource with sustainable manner awareness creation companies especially for Manja tribe who are dwelling along the margin and inside forest area should be indispensable phenomenon.
- ✓ Recognition of the customers rights of the local community over their lands, their life styles especially for Manja tribe strongly depend on forest and crucial contribution of their knowledge for sustainable uses incorporation of such issue in relevant federal regional laws.
- ✓ Population growth is identified as problem in the study area, thus to prevent the population pressure and its impact on the forest resources and there by improve the living condition of the inhabitants and technology usage awareness creation campaign should be introduced.
- ✓ Lastly, it is strongly advisable to go further research and these kind of research will be benefit the forest cover change detection efficient as well as in order to provide sound information to take appropriate measure to combat the problem of forest cover change and climate variability.

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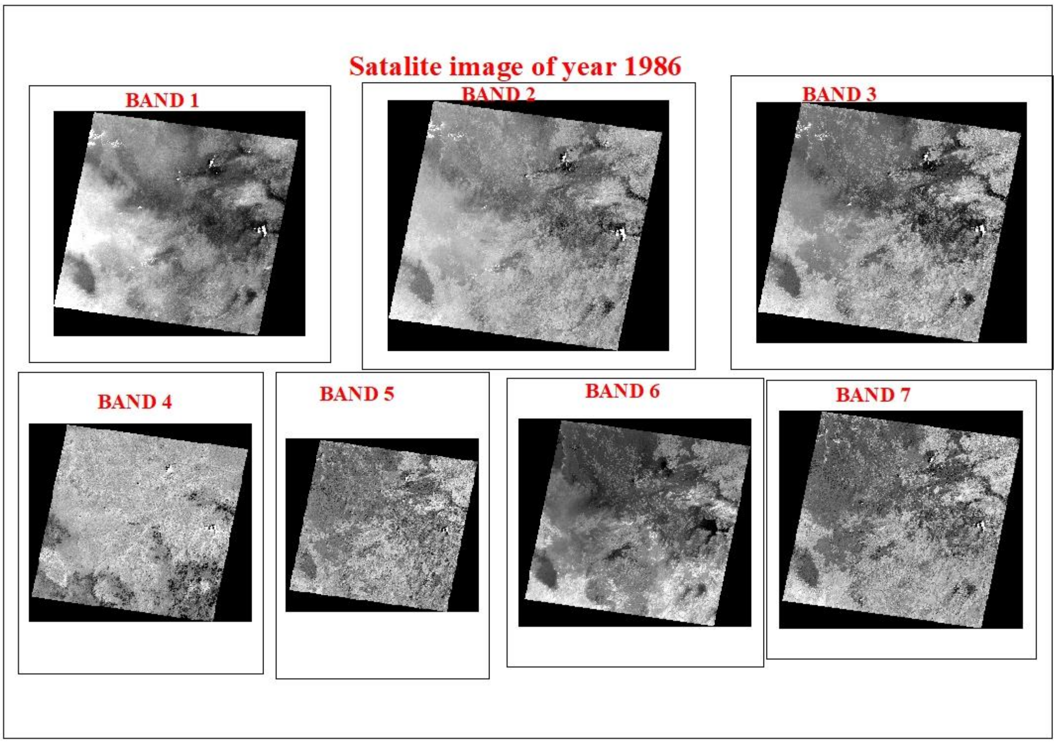
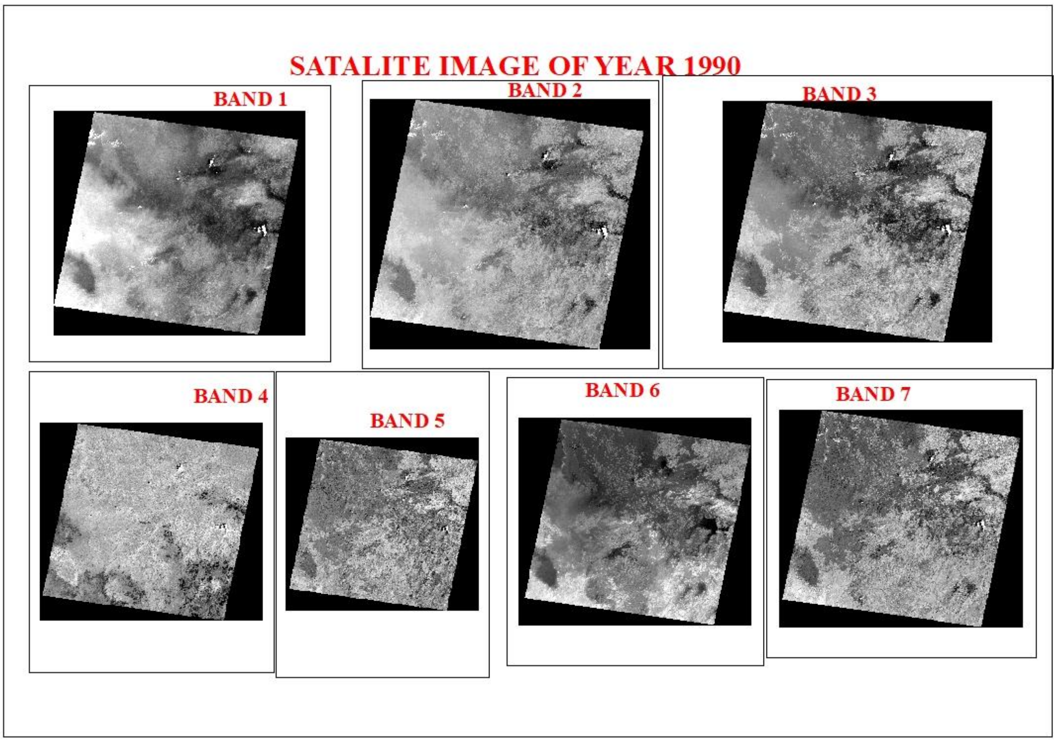
ANNEX I

SATALLITE IMAGE

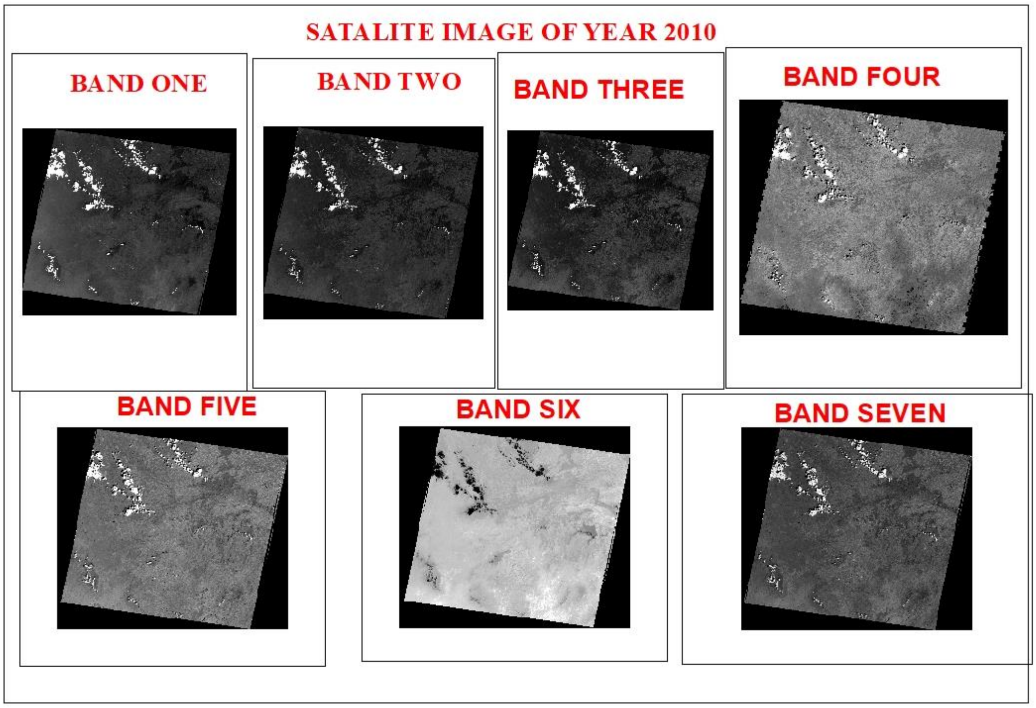
Satellite image of year 1986



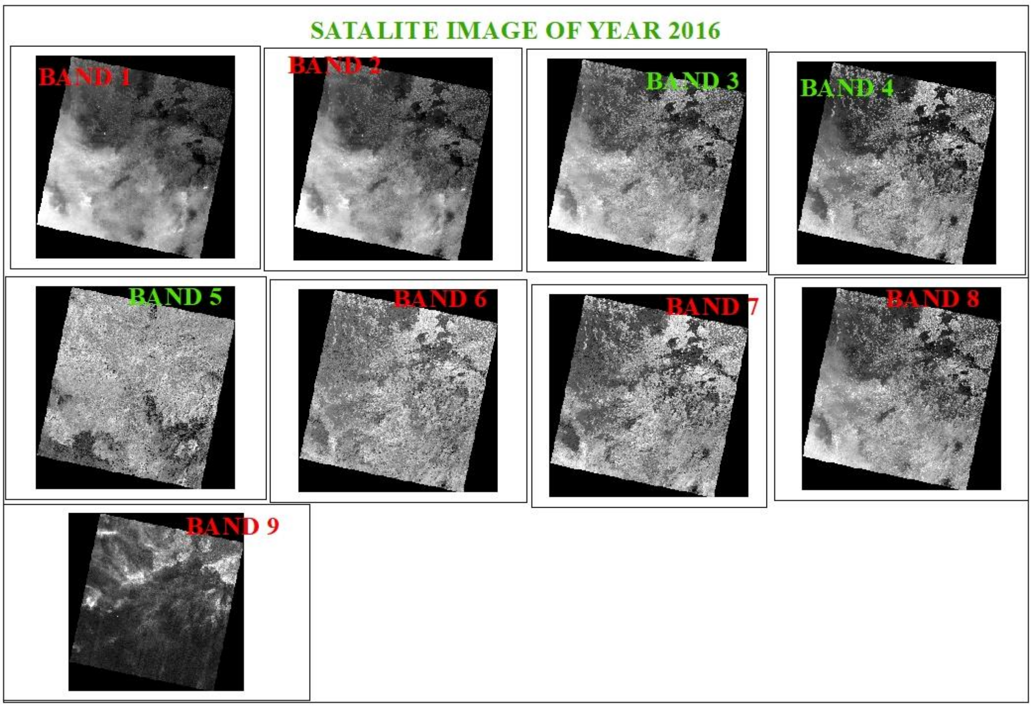
Satellite image of year 1990



Satellite image of year 2010



Satellite image of year 2016



Satellite image of year 2018