ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Civil Engineering and Architecture

Department of Geomatics Engineering

IMPACT ASSESSMENT OF ANTHROPOGENIC ACTIVITIES AND CLIMATE ON LAND USE/COVER CHANGE: A CASE STUDY OF BAMBASI WEREDA, ETHIOPIA

A Thesis

Submitted to the school of Civil Engineering and Architecture of Adama Science and Technology University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Geodesy and Geomatics Engineering

BY:

TAMAM EMIRU

Advisors:

Dr. HASAN RAJA NAQVI

Mr. NEGARA DINSA (M.Sc.)

October, 2016

ADAMA, Ethiopia

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Declarations

I ……………….. , Registration Number/I.D. Number………………., do hereby declare that this Thesis is my original work and that it has not been submitted partially; or in full, by any other person for an award of a degree in any other university/institution.

Name of Participant……………….Signature……………………. Date…………….

This Thesis has been submitted for examination with my approval as School supervisor.

Name of Advisor……………………Signature……………………. Date……………

Name of Co-Advisor…………………Signature…………………….Date…………….

APPROVAL

The undersigned certify that they have read and hereby recommend to the Adama Science and Technology University to accept the Thesis submitted by TAMAM EMIRU, and entitled “IMPACT ASSESSMENT OF ANTHROPOGENIC ACTIVITIES AND CLIMATE DYNAMISM ON LAND USE/COVER CHANGE: A CASE STUDY OF BAMBASI WEREDA, ETHIOPIA”, in partial fulfillment of the requirements for the award of a Degree of Masters of Science in Geodesy and Geomatics Engineering.

Name of Supervisor …………………..……………… Signature………………….

Date………………………

Name of Internal Examiner …………………………. Signature…………. ……..

Date……………………...

Name of External Examiner ………………………….. Signature…………. ……..

Date……………………....

Name of Head of Department ………………………. Signature………………….

Date……………. ………..

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ABSTRACT

Land use/cover changes have impacts on a wide range of environmental and landscape attributes including the quality of water, land and air resources, ecosystem processes and function, and the climate system itself through greenhouse gas fluxes and surface albedo effects. The main objective of this study was to investigate the impact of anthropogenic activities & climate on the land use/cover change in the Bambasi wereda over a period of 28 years. The approach of supervised classifications through the maximum likelihood algorithms was used to analysis the changes in land use/cover. In the period of 28 years' time , Urban or built-up & range land were increased, on the other hand barren land, forest land and water bodies were declined throughout 28 years, respectively. In the period of 1987-2015, the increase of urban or built-up was because of population growth from 28.063 thousand in 1987 thousand to 64.25 thousand, and because of national resettlement plan and accompanying increases in human and livestock populations. The increased area of range land and decrease in forest land, water bodies and barren land have been noticed because of decrease in average temperature and average rainfall, forest deforestation, clearing forest for agricultural, During the 1987-2015 period, the increased of rangeland and the decrease of forest cover, barren land and water bodies had been because of climate variation like temperature and rainfall through the activities of human such as unrated wildfire, agricultures expansion, shifting cultivation, and grazing, charcoal and wood for fuel and wood for constructions. This case study analysis indicates that the impact of anthropogenic activities and climate are believed to be the major driving force for the change of land use/cover in the Bambasi wereda.

Keywords: Anthropogenic, GIS, Remote sensing, Land use/cover change, NDVI

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List of Acronyms

CSA-----------------Central Statistical Agency of Ethiopia

ETM-----------------Enhanced Thematic Mapper Plus

FAO----------------- Food and Agricultural Organization for United Nation

FCC----------------- False Color composite

FRA----------------- Global Forest Resource Assessments

GIS------------------Geographical Information System

Land use/cover-- Land use and land cover

LULCC-------------- Land use and land cover change

NASA--------------- National Aeronautics and Space Administration

NDVI----------------Normalized Difference Vegetation Index

NMSA-------------- National Meteorological Service Agency of Ethiopia

OLI------------------ The Operational Land Imager

TCC----------------- True Color composite

TM------------------ Thematic Mapper

USGS--------------- U.S Geological Survey

CHAPTER ONE

1. Introduction

1.1. Background of the study

The pace, magnitude and spatial reach of human alterations of the Earth's land surface are unprecedented. Land-use and land-cover changes are so pervasive that, when aggregated globally, they significantly affect key aspects of Earth System functioning [1]. Land use and land-cover changes have impacts on a wide range of environmental and landscape attributes including the quality of water, land and air resources, ecosystem processes and function, and the climate system itself through greenhouse gas fluxes and surface albedo effects [2]. Due to anthropogenic activities, the Earth surface is being significantly altered in some manner and man's presence on the Earth and his use of land has a profound effect upon the natural environment thus resulting into an observable pattern in the land use/land cover over time [3].

On the other hand, the direct impacts of climate change such as an increase in average temperature or a change in rainfall patterns have caused serious problems in the country. From this, climate (temperature and rainfall) has serious effects on the land use and land cover over a time span. The main longer-term impacts include: changing rainfall patterns affecting agriculture and reducing food security; worsening water security; decreasing fish resources in large lakes due to rising temperature; shifting vector-borne diseases; rising sea level affecting low-lying coastal areas with large populations; and rising water stress [4], [5]. The climate variations have direct or indirect impact on land use and land cover. For example, Vegetation on land influences water cycling and climate through a variety of mechanisms, including the evaporation and transpiration of water, the reflectance or absorption of incoming solar radiation and the transfer of momentum with atmospheric flows [6]. Land-cover changes can influence climate change through biogeochemical cycles, especially the carbon (C) and nitrogen (N) cycles. Several primary greenhouse gases that influence climate change are directly involved in ecological systems [7].

According to the Report of FAO (2015) based, Forests and forest management have changed substantially over the past 25 years. Globally, the extent of the world's forest continues to decline as human populations continue to grow and demand for food and land increases, the rate of net forest loss has been cut by over 50 percent. Based on these Report in 1990 the world had 4128 million ha of forest; by 2015 this area has decreased to 3999 million ha. This is a change from 31.6 percent of global land area in 1990 to 30.6 percent in 2015. These was a net loss of some 129 million ha of forest (natural and planted) from 1990 to 2015, representing an annual rate of –0.13 % and a total area about the size of South Africa. Average per capita forest area declined from 0.8 ha to 0.6 ha per person from 1990 to 2015. While per capita forest area decline is greatest in the tropics and subtropics, it is occurring in every climatic domain (except in the temperate domain) as population's increase and forest land is converted to agriculture and other land uses. And also, the report FAO (2015) based shows that the status of forest in Ethiopia covers about 15.114 million ha or 13.79% of the total land in the year of 1990; by 2015 this area of forest cover was declined to 12.499 million ha or 11.4% of the total land. And also, among the top ten wood removal in the world in the year of 2011, Ethiopia were ranked number six by removing of 104.209 million m^3 and with 97.2% were removed for wood fuel usage out of total wood removed. So in general, these all loss of forest is because of human activities and variation in climate like rainfall and temperature in a country level and regional or local level. The impact of climate on Ethiopia is more pronounced by alarming loss of forest resource [4].

Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. Viewing the Earth from space is now crucial to the understanding of the influence of man's activities on his natural resource base over time. Over the past years, data from Earth sensing satellites has become vital in mapping the Earth's features and infrastructures, managing natural resources and studying environmental change [3].

According to the Report of USGS (2012) based, LULC connections with weather and climate require general knowledge of past LULC patterns and changes, detailed data and information on current LULC patterns and dynamics, and an understanding of the plausible scenarios and resulting LULC patterns associated with change 20–100 years into the future. To the extent possible, spatially explicit LULC products are used because they offer the ability to evaluate the geographic variability and complexity of climate and LULC impacts [7].

Earlier, when there was no remotely sensed data and the assistance of computers, land use/land cover change was detected with the help of tracing paper and topographic sheet. But then this method was tedious and studying large areas required lot of effort and time. Conventional ground methods of land use mapping are labor intensive, time consuming and are done less frequently. Thus, with the advent of satellite remote sensing techniques, preparing accurate land use land cover maps and monitoring changes at regular intervals of time is relatively simpler [8].

Today, Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management [3]. These both techniques are suitable to analyze the changes by integrating spatial (i.e. satellite image) and non-spatial (i.e. rainfall and temperature) data. Remote sensing techniques offer benefits in the field of land use/ land cover mapping and its change analysis. One of the major advantages of remote sensing systems is their capability for repetitive coverage, which is necessary for change detection studies at global and regional scales [9]. Long-term surface albedos are required by climate, biogeochemical, hydrological, and weather forecast models at a range of spatial and temporal scales. The albedo varies as a result of solar illumination, snowfall, inundation, vegetation growth, littoral variation, and with natural and anthropogenic disturbance and land cover and land use change. Improving the spatial detail and precision of surface albedo measures using Landsat is especially important in understanding the impacts of local land cover change [10].

The changes in land use/ land cover due to natural and human activities can be observed using current and archived remotely sensed data [4]. The use of satellite based remote sensor data has been widely applied to provide a cost-effective means to develop LC coverage's over large geographic regions [11]. Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest [3]. Several method of change detection analysis developed to understand land use and land cover change. One of the several approaches is post-classification comparison method is used frequently to detected the changes in land use and land cover using GIS and remote sensing technique. This is the most obvious method of change detection which requires the comparison of independently produced classified images [12].

According to C. Petit et al., T. (2001) based, Post classification comparison is often used to detect land-cover changes between two images Image differencing was performed by subtracting the reflectance's of the red band of the two dates, as (red reflectance of 2nd date) – (red reflectance of first date). The red spectral band was selected as the study area is located in a semi-arid region and the three images were acquired in the dry season. The vegetation was too low in stature and structure to use the near-infrared (NIR) band, which is mostly related to the amount of green biomass. Two thresholds (a positive and a negative one) in the histogram of the difference values were chosen to distinguish between change and no-change areas. The choice of thresholds was guided by field-based descriptions of patches of land-cover change and by a visual interpretation of successive aerial photographs. The dominant changes showed an increase in the reflectance of the red band, indicating a decrease in vegetation cover. Asymmetric thresholds were required as areas affected by a decrease in vegetation cover were much more widespread than areas affected by an increase in vegetation cover [13]. Also, non-irrigated crops planted every year in regions where vegetation is constrained by moisture, temperature, or poor soil conditions will result in relatively low NDVI max values and low NDVI sd values. The annual NDVI $_{\textbf{ann-max}}$ time series eliminated cloud and cloud shadow effects, and allowed for visualization and analysis of inter-annual cropland dynamics such as crop/fallow rotation, changes in cropping practices (e.g., crop/fallow to irrigated), and land use conversion (e.g., cropped land to CRP) [14]. The mask of no-change pixels from image differencing was applied to the first date classification and the mask of change pixels to the second date classification. The land-cover change map with 'from' and 'to' identifiers was produced by combining land-cover map from the first data with the enhanced land-cover map for the second date [13].

This change detection method combining the post classification and image differencing technique s eliminate s commission errors often generate d by the post classification comparison technique. A high omission error in the post classification change detection technique compared to the image differencing technique indicate s either that the threshold values applied to the difference image are too low, leading to an over estimation of changes, or that an important proportion of change s are land cover modifications (i.e. changes of condition within a land-cover category) rather than land-cover conversions (i.e. changes from one class to another) [13].

1.2. STATEMENT OF THE PROBLEM

Impact of Anthropogenic activities and climate variation leads to several environmental consequences directly and indirectly. Land use and land cover (LULC) play critical roles in land surface-atmosphere interactions and thus influence climate. These impacts are evident on local, regional, and global climate [7].

In Bambasi Wereda, Due to the anthropogenic activities such as expansion of agricultural land, expansion of the town, road construction, deforestation, resettlements , shifting cultivation, forest fire and many other human activities are causes in increased land consumption, modification and alteration of the land use and land cover over a time. For example, according to the report of REDD+ (2015) based the forests are open for all members of the community since 1991, which means that nobody is responsible for forest resources in Bambasi wereda and dense forest was cut in multiple places as a results of shifting cultivation for the seeking of new fertile land with the objective of increasing the production of crop like maize and sorghum and more in general oil seed like sesames. The final conclusion of this reports shows that the main drivers of deforestations in Bambasi wereda were found to be agricultural expansions and the growth of settlements.

In addition to the above study, the report of UNEP (2012) based shows LULC changes in Anbessa forest, which is found in Bambasi wereda is very dramatic, i.e., a conversion of natural, dense forest to degraded croplands within a very short period of time. The main driving force was the national resettlement plan and accompanying increases in human and livestock populations. There was a drastic deforestation between 1972 and 2005, i.e., a total decrease in the aerial extent of the forest by 54%. On the other hand, there was no cropland in 1972 but between 1986 and 2005, the cropland established accounted for 5546 ha, which is a change of

53% in land cover. Similarly, there was a decrease (by 18%) in the area of CTW (i.e. Combretum– TerminaliaWoodland) during the same period [15].

And also according to the report of UNEP (2012) based diverse rainfall and temperature patterns are largely the result of Ethiopia's location in Africa's tropical zone and the country's varied topography. Variations in precipitation throughout the country are the result of differences in elevation and seasonal changes in the atmospheric pressure systems that control the prevailing winds. Because of these factors, several regions receive rainfall throughout most of the year, but in other areas precipitation is seasonal. In the more arid lowlands, rainfall is always meager. In January the high pressure system that produces monsoons in Asia crosses the Red Sea. Although these northeast trade winds bring rain to the coastal plains and the eastern escarpment in, they are essentially cool and dry and provide little moisture to the country's interior. Their effect on the coastal region, however, is to create a Mediterranean-like climate. Winds that originate over the Atlantic Ocean and blow across Equatorial Africa have a marked seasonal effect on much of Ethiopia [15]. Seasonal patterns, such as wet and dry seasons, influence the ways that LULC interacts with climate [7].

The report of USGS (2012) based reveal that LULC changes can modify the interactions between land surfaces and the atmosphere. For example, with replacement of forests by barren surfaces, agriculture, or urban areas, an existing land surface-atmosphere feedback loop may be substituted with a modified loop. Land-use changes within a particular land-cover type may further complicate the ability to understand and describe the forcing’s and feedbacks. Replacement of rain fed agriculture (which already replaced natural grasslands) with irrigated agriculture is an example of such a change. In some cases, single-crop land use (one crop per year) has changed to multi-crop land use (three crops per year). These types of changes may alter local and regional scale climate [7].

The report of USGS (2012) based reveal that Climate variations also affect LULC through direct effects on vegetation growth and structure and indirectly through human adaptation to climate change. For example, droughts may cause water stress in vegetation that may lead to more surface heating and less evapotranspiration. The stressed vegetation may be subject to fire, which will influence the radiation balance immediately after the fire, and perhaps vegetation with a different albedo will regrow. Drought is one type of climate extreme that influences land use and impacts human livelihoods. Increased duration of fire seasons accompanied by drought conditions leads to increased wildfire potential. Land-use conversion to cropland, cropland sustainability, and increased growing season temperatures were identified as agricultural topics that were impacted by climate and land-use change [7].

Recent studies of Gurmessa (2015) based, the consequences of climate change will be most severe for the world's poorest countries like Ethiopia. Africa is highly vulnerable to climate change with the areas of particular concern being water resources, agriculture, health, ecosystems and biodiversity, forestry and coastal zones. Agricultural production, including access to food, in many African countries and sub-regions is projected to be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent [4].

Therefore, the impact of anthropogenic activities and climate (i.e., rainfall and temperature) on land use and land cover remain the main problem of the interest of the research.

1.3. OBJECTIVE OF THE STUDY

1.3.1. General objective

To analysis the impact of anthropogenic and Climate on land use and land cover change of Bambasi wereda using remote sensing and geographic information system.

1.3.2. Specific objective

- To investigate how anthropogenic activities are affecting the land use and land cover change within specified years.
- To investigate the impact of rainfall and temperature on land use and land cover change in the required years.
- To produce the Land use and land cover change map for the year 1987, 2001 and 2015.

- To produce the NDVI map for vegetation health within required years.
- To point out the relationship between land use and land cover change result with temperature, rainfall, NDVI value and Population data.
- To identify the changes made in land use and land cover through the year of 1987 to 2015.

1.4. RESEARCH QUESTION

- How can anthropogenic activities are effecting the land use and land cover change?
- How can rainfall and temperature changing the land use and land cover?
- What is the area covered for the land use and land cover change with specified period of years?
- What are the changes made in land use and land cover change within the required years
- What is the purpose of producing the NDVI map for vegetation health?

1.5. SIGNIFICANCE OF THE STUDY

Land use and land cover change studies are important tool for land manager and decision makers in formulating appropriate land use policy as well as locating development program for sustainable use of land cover in the study area. The result of this study would provide information relevant to contribute in the vegetation management plan relating with climate variation and anthropogenic activities. In addition to this it Provide information on the status and dynamic of land use and land cover change of area. On the other hand the study would provide information on the use of GIS and remote sensing using satellite imagery for analysis of land use and land cover, sustainable management and conservation.

1.6. SCOPE OF THE STUDY

This study deals with the land use and land cover change analysis using remote sensing and Geographical information system(GIS) in Bambasi Wereda, Asossa Zone of Benishangul Gumz region between the year 1987 to 2015. Land use and land cover change were assessed in terms of land use and land cover change by combining different spatial data sources (remotely sensed satellite images, Google earth and boundary shape file) and non-spatial data source (population size and Climate data such as rainfall and temperature). Ultimately the study will investigate the landscape changes during the time and the causes which are responsible for it.

1.7. STRUCTURE OF THE THESIS

This thesis has five broad chapters. The first part includes detailed discussion of the background and the general over view of land use/cover change and historical trends. In this chapter also statements of the problem, objective of the study, research questions, significance of the study and scope of the study has included. In the second chapter of the related literature of impacts of anthropogenic activities and climate on land use/cover change has been discussed. Then, on chapter three, the data uses for the entire study and the method that helps to accomplish the thesis identified and discussed in detail and also the descriptions of the study area such as location, populations, climate, topography and status of economic activity has been discussed in detail. To this end, on chapter four, results and discussions of land use/cover change, NDVI based change detection, and drivers of land use/cover change has shown and discussed in detail. Lastly, on chapter five, for this study setting of conclusions and recommendation for study area of Bambasi wereda. This is the general structure of these thesis study, having with the title of “impact assessments of anthropogenic activities and climate on land use/cover change, a case of Bambasi wereda, Ethiopia” for the past 28 year.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Definitions of Terms

2.1.1. Land use and Land cover

Many researchers and scholars was define the terms of land use and land cover change in many ways and also different reports shows those terms in a different way of explanation. For example, on the study of COFFEY (2013), land use is commonly defined as a series of operations on land, carried out by humans, with the intensions to obtain product and/or benefits through using land resource. Land cover is commonly defined as the vegetation (natural or planted) or manmade constructions (building, etc.) which occur on the earth surface. Water, ice, bare rock, sand and similar surface also count as land cover. Land use refers to the purpose the land service, for example, recreation, wildlife habitat or agriculture; it does not describe the surface cover on the ground. For example, recreational land use could occur in a forest, shrub land, grass land or manicured lawns. Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil, or other; it does not describe the use of land, the use of land may be different for lands with the same cover type. For instance, a land cover type of forest may be used for timber production, wildlife management or recreation; it might be private land, a protected watershed or a popular state park. In short, according to this study, land use indicates how people are using the land, whereas land cover indicates the physical land type [16].

Based on the study done by E.F.Lambin et al. (2000), The term land cover refers to the attributes of a part of the Earth's land surface and immediate subsurface, including biota, soil, topography, surface and groundwater, and human structures. Land use refers to the purposes for which humans exploit the land cover. Forest, e.g., is a type of land cover that is dominated by woody species and may be exploited for land uses as varied as recreation, timber production or wildlife conservations [2]. Land-cover modifications changes in the structure of an extant cover of a short duration (such as forest succession under slash-and burn cultivation) are also widespread [1].

In addition to this, the study of Jansen (2005) also define the term land use and land cover in a good way of explanation. Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. Land use defined in this way establishes a direct link between land cover and the actions of people in their environment. The following examples are a further illustration of the above definitions: “grassland” is a cover term, while “rangeland” or “tennis court” refer to the use of a grass cover; and “recreation area” is a land use term that may be applicable to different land cover types: for instance sandy surfaces, like a beach; a built-up area like a pleasure park; woodlands; etc. The definition of land cover is fundamental, because in many existing classifications and legends it is confused with land use, Land cover is the observed biophysical cover on the earth’s surface. When considering land cover in a very pure and strict sense, it should be confined to the description of vegetation and man-made features. Consequently, areas where the surface consists of bare rock or bare soil are land itself rather than land cover [17].

2.1.2. Land use and Land cover Change

In addition to the above researcher Meyer and Turner II (1992) were also define the term land use and land cover change by adding new term called change in attractive way of clarification and revealing very persuasive example to studies. Land use and land cover change are deals with the alteration of the land surface and its biotic cover. Land use change contributes to both kind of global change: to such systematic changes as trace-gas accumulation and to such cumulative or patchwork impacts as biodiversity loss, soil degradation and hydrological change. In addition to this land use and land cover change is a hybrid category. Land use denotes the human employment of the land and land cover denotes the physical and biotic character of the land surface. Thus, the cumulative of this two are proximate sources of change: human activities that directly alter the physical environment. These activities reflect human goals that are shaped by underlying social driving forces. Proximate sources change the land cover, with further environmental consequences that may ultimately feedback to affect the land use. Land cover changes take two forms: conversion from one category of land cover to another and modification of condition within a category. The problem will vary with the categories of cover used: the broader and fewer the categories, the fewer the instances of conversion from one to another [18].

2.1.3. Anthropogenic

According to the dictionary of Merriam Webster the term Anthropogenic defined as relating to, or resulting from the influence of human being on the nature, which also said to be anthropogenic pollutants. And also in the website of Wikipedia, the term anthropogenic designates an effect or objects resulting from human activity or produced by humans. Anthropogenic impact the environments includes impacts on biophysical environments, biodiversity, and other resources. This includes deforestation, agricultural expansions, population growth, production of wood, forest fire, industrial expansions, urban expansions, shifting cultivation, grazing, and etc.

Definition of the term Anthropogenic Climate Change is human activities already have noticeably changed global climate. This is a statement about the past and about what we can observe now [19]. Climate change is a global environmental threat and is occurring due to increasing concentrations of carbon dioxide (CO_2) in the atmosphere as a result of anthropogenic (human) activities that include deforestation and changes in land use. Climate change is believed to be the cause of increases in drought frequencies and irregularity in climatic patterns, which are causing changes in settlement patterns globally [20].

2.2. THE CAUSES OF LAND USE AND LAND COVER CHANGE

According to E.F. Lambin et al. (2001) study based, deforestation is linked to the increased presence of shifting cultivators, triggering mechanisms invariably involve changes in frontier development and policies by national governments that pull and push migrants into sparsely occupied areas. Immigration is triggered by government decisions to open the frontier through settlement schemes, development projects, and plantations or through extractive industries, basically timber, with the spin-off consequences of ‘‘spontaneous’’ colonization. In either case, infrastructure development follows in the form of roads, electrification, health services and/or potable water, which attracts land seeking families, and consolidates occupation. The deeper reasons for the government decisions include the desire to secure territorial claims and national political support, to attract international capital, to facilitate market opportunities, or to promote the interests of specific groups through exploiting natural resources controlled by the state.

Weakened indigenous pastoral systems undermine local economies and resource institutions or precipitate urban migration with rural remittances, either of which may lead to land alienation and conversion, with concentration in the remaining areas, local overstocking and degradation. Alternatively, exclusion and reduced grazing lead to changes in species diversity, vegetation cover and plant production, with implications for biodiversity conservation and/or animal production. In wetter rangelands reduced burning leads to increasing woodlands. Agricultural intensification and mechanization from the mid-20th century removed the nutrient connection between arable lands and livestock, separating cultivated plains from mountain and forest areas used for grazing. Land scarcity changes land–labor ratios, driving up the intensity of cultivation and, where possible, shifting production toward the market and to higher value products. Markets trigger commercial intensification of agriculture in a commodification pathway. Investments in crops or livestock modify the factors and value of production per hectare. Economic differentiation, wage labor, contract farming and other adjustments follow. This pathway is linked to external sources of demand and its sustainability is tied to the vagaries of the market. Collapses in product markets and/or subsidy programs supporting these markets trigger collapses or changes in production systems. Significant land-use intensification can also be driven by intervention, usually in state-, donor-, or NGO sponsored projects intended to promote development in a region or economic sector, usually through commercial agriculture for national and international markets that increase income for the participants and the state. Generally, According to thsese paper agricultral intensfication is caused by increase in population by the way of migration, and urbanization also affects land change elsewhere through the transformation of urban-rural linkages. It calls for advances that capture the generic qualities of both socio-economic and biophysical drivers as well as the place-based, human-environment conditions that direct land-use and land-cover change [1].

According to the research conducted in Nigera by Awoniran D. R. et al., (2014), conclude this opinion with the saying of, the Changes in the patterns of land use/land cover are a reflection of increasing anthropogenic pressure on landscape which needs to be seriously addressed. Rapid population growth and its twin brother, urbanization remain the major causes of environmental degradation [21].

And also, the study which is conducted by Oroda (2011) reveal that sedentarization has come about as a means of solving other environmental and socio-economic problems such as frequent droughts; poor, unreliable and unevenly distributed rainfall; poor soils and insecurity, it has brought about its own unique problems. Direct human activities on the natural resources around the settlements include over-exploitation of tree and large shrubs causing land degradation. The high frequency of crop failures has led farmers to resort to environmentally destructive forms of livelihoods such as charcoal burning and wood-fuel harvesting. The opening up of the new farmlands has resulted in vegetation clearing and subsequently soil degradation through erosion, both wind and water. The complete disappearance in the area under closed shrubland might have resulted from opening up of land for grazing and crop production. The need for grazing usually leads to clearing of the bushes to enhance grass growth. It may also be explained by an increase in demand for woody vegetation for construction of homesteads and livestock enclosures as well as for wood-fuel as a result of increased population [20].

2.3. THE IMPACT OF ANTHROPOGENIC ACTIVITIES ON LAND USE/COVER CHANGE

The land use/land cover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space [3]. As population increases more and more land is used for construction purpose , agriculture and resettlement area also increase. During these processes human activities such as agricultural intensifications, deforestation, forest fire intentionally and unintentionally, cutting trees for fuel and the like are directly and indirectly change the land use and land cover of any specific area. Forest fire is another key process acting on land cover changes, the vegetation structure, the energy balance and emissions of greenhouse gases. Anthropogenic forest fires, logging and drought act in a positive loop on increasing forest vulnerability and susceptibility to subsequent burning while deforestation and smoke can inhibit rainfall, exacerbating the potential for a dry climate. Smoke and reduced rainfall has a direct impact on human health and living, disrupting transport at local and regional level. And also, flood and drought hazards represent the integrated impacts due to changes in rainfall across the basin [22].

According to the study of Behailu (2010) based, the current trend of Land use/cover change has a visible environmental impacts on the surrounding ecosystems, land resources, structure and pattern of the area and hence quality of life. The selected study area is part of the 1984/85 resettlement area in the southwestern lowlands and characterized by its fertile land and fragile environment and hence drew the attention of many institutions to make an investment in the area. Besides, the area has undergone large land use/cover change dynamic in the last few decades. As seen from the result, the vegetation cover especially the natural forest is changing drastically. Compared to the other classes cultivated land and settlement increased after the 1984/85 resettlement. This increase implies the over exploitation of natural resources on behalf of agriculture and settlements. This is confirmed by the decreasing areas of forest and also coincides with the overall vegetation cover decrease in the study areas. This dangerous trend probably is a result of the pressure poised by population growth and the changing functionality of the ecosystem of the area. Expansion of cultivated land and settlements in the study area has led to rapid changes in landscape dynamics. Generally Bahailu (2010) conclude his idea as, changes in policy, land use and management affect the states, properties and functions of the ecosystems, which in turn, affect the provision of ecosystem services and hence human well-being. Furthermore, biophysical alterations and social forces generate different responses in different environments [23].

On the other hand, the studies of Netsanet (2007) reveal that, Land cover changes may occur due to various factors, which may be broadly divided into natural and human induced or anthropogenic causes. Land Use and Land Cover dynamics is a result of complex interactions between several biophysical and socio-economic conditions. The effects of human activities are immediate and often radical, while the natural effects take a relatively longer period of time. The difference in increase by households and land cover change indicates the pressure on forest land cover and related biodiversity. This implies that population pressure is believed to be one of the major driving forces for the changes in the study area. In the case of her study, the major driving force to changes in Land use/cover change is increased population change [24].

2.4. THE IMPACT OF CLIMATE ON LAND USE/COVER CHANGE

Most of land use change scenarios described in the literature only address human drivers of deforestation and do not consider the stress of climate change in land use change patterns. Climate change can be understood most easily in terms of annual or seasonal averages of temperature and precipitation. Temperature increases and disruption in the energy and water cycles have the potential to seriously hamper the functioning of the Amazon as a forest ecosystem, reducing its capacity to retain carbon, increasing its soil temperature, and eventually affecting the regional hydrological cycle. In simple terms, the increase in temperature induces larger evapotranspiration in tropical regions which tends to reduce the amount of soil water, even when rainfall does not reduce significantly. This can trigger the replacement of the present-day vegetation by other vegetation types more adapted to drier conditions. Changes in humidity (e.g. precipitation amount, frequency) and increases in temperature can cause forest decline [22].

According to the report of USGS (2012) based, Land-cover change (for example, forest or grassland to agriculture) and land-use and management practices (for example, crop choice, fertilization rates, type of tillage, and use of irrigation) can change the soil conditions that affect the rates of release of SOC (soil carbon stock) and N2O. The release rates also are influenced by the type of soil (for example, soil texture, water holding capacity, permeability, organic matter content, drainage, and erosion rate) and the seasonal patterns of soil moisture and temperature. The patterns of soil moisture and temperature are expected to change with changes in climate. Land- management practices also may be adjusted with climate change (for example, influences of drought or floods on agriculture) and by human attempts to mitigate the drivers of climate change (for example, making biofuels with feed stocks from croplands, grasslands, or forests to use as alternatives to fossil fuels). In general, conversion of native forest or grassland to cropland results in a large loss of soil carbon (presumably to the atmosphere and within the first few years after conversion). Conversely, converting cropland into forest or grassland can store atmospheric carbon in the soil, but it may take 70 or more years and the new "equilibrium" may be at a lower level of SOC than in an ecosystem that was never disturbed [7].

The study of Oroda (2011) pointing out that grassland fluctuation is highly rainfall dependent and therefore the changes observed in the grassland cover can be attributed to drought conditions rather than changes in land use. The general decrease in the grass cover in the study area could be an indicator of decreasing rainfall in the area. There is, therefore, a need to related land cover changes and climatic variability in the study area. A good proportion of the grassland may have, however, been converted to agricultural production (crop production) because agriculture has expanded more towards the marginal areas. Part of the grassland may have, however, been converted to shrub land due to over use of grasslands by livestock, particularly cattle and sheep [20].

2.5. THE RELATIONSHIP BETWEEN NDVI AND LAND USE/COVER CHANGE

Healthy green vegetation has distinctive reflectance in the visible and near-infrared regions of the spectrum. At visible and in particular red wavelengths, plant pigments strongly absorb the energy for photosynthesis, whereas in the near-infrared region, the energy is strongly reflected by the internal leaf structures. This strong contrast between red and near-infrared reflectance has formed the basis of many different vegetation indices. The NDVI is the example of the most common vegetation indices to analyze the green cover of photosynthetic vegetation in image processing [25]. The NDVI process creates a single-band dataset that mainly represents healthy biomass. This index output values between −1.0 and 1.0, where any negative values are mainly generated from clouds, water, and snow, and values near zero are mainly generated from rock and bare soil [26] [25].

The study conducted by S.K Maxwell and K.M Sylvester (2012) in Southwestern Kansas shows that, land that was never cropped had relatively stable NDVI $_{\textbf{ann-max}}$ values over the entire 27-year period where values typically ranged from 0.3 to 0.6. In contrast, cropped land generally had very high NDVI values (>0.7) at least once over the 27-year period, and/or the maximum annual NDVI values were highly variable from year-to-year. CRP land is land that was originally cropped but was converted at some point to grassland. CRP land is land that the U.S. government pays land owners not to plant crops on for a period of 10 to 15 years in an effort to improve environmental quality, such as to reduce soil erosion and improve water quality and wildlife habitat [14].

2.6. REMOTE SENSING AND GIS AS A TOOL FOR LAND USE /COVER CHANGE ANALYSIS

Satellite Remote Sensing play an important role in generating information about the latest land use-land cover pattern in an area and its temporal changes. And also, the use of GIS has also been recognized for detecting and mapping land use and land cover changes [27]. The information being in digital form can be brought under Geographical Information System (GIS) to provide a suitable platform for data analysis, update and retrieval. According to Bill (2008), Remote Sensing and GIS techniques offer highly sophisticated methods and tools for decision makers. A particularly important application of remote sensing data is the generation of land use and land cover maps. Thus, the integration of remotely sensed data with GIS data has the potential to improve the accuracy of results. The main advantage of GIS is that changes can be detected more clearly than with other techniques using multi-source data [27]. Since the 1970s, remote sensing data are available on a more or less regular basis and at an acceptable quality level. In the last decades, remote sensing has evolved to be a very innovative and powerful methodology for tasks in the field of land use documentation and land change monitoring [28]. Geographic Information Systems (GIS) along with remote sensing technology could provide new opportunities to model and evaluate wildlife habitat suitability. Especially with the availability of low cost and timely satellite images as well as recent advances in GIS and remote sensing technology, the use of remotely sensed data for natural resource management becomes more feasible and efficient [29].

Post-classification change analysis is the process by which two or more classified LC maps, representing distinct moments in time, are overlaid to determine whether a change in the assigned LC class has occurred on a pixel-by-pixel basis [30] [12]. Post-classification comparison is a useful technique for extracting land use and land cover information. It is a common method in change detection. Post-classification requires the comparison of independently produced classified changes. It could be that the produced map shows the complete matrix of changes by coding the classification results for time 1 and time 2. Moreover, the subset of changes is observed by selective grouping of the classification results. In post-classification comparison, the images are classified separately, pixel by pixel, on two dates, minimizing the atmospheric and sensor differences between the two dates. Post-classification comparison includes two scheme classification and unsupervised classification algorithms. Supervised classification is a process when the analyst selects a number of areas for an image and then identifies the type of each phenomenon on the computer screen. The maximum likelihood algorithm was used to provide a consistent classifier for multi-date classification. They indicated that the classification accuracy increased, especially after applying the post-classification procedure [27].

The primary determinant of the accuracy of the resulting map of LC change (LCC) is the accuracy associated with each individual LC classification. However, quantifying error in the resulting map of change requires more than simply understanding the magnitude and pattern of error present in each individual LC map. It is also necessary to understand how these patterns of error interact over time [30].

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. DESCRIPTION OF THE STUDY AREA

3.1.1. Locations of the study area

Bambasi Wereda is one of the 20 weredas in the Benishangul-Gumuz Region of Ethiopia. Part of the Asosa Zone, it is bordered by the Mao-Komo special wereda on the southwest, Asossa in the northwest, Oda Buldigilu in the northeast, and by the Oromia Region in the southeast. This woreda and its only town, Bambasi, are named for the tallest point in this zone, Mount Bambasi. Rivers include the Dabus, which originates in this wereda. The administrative center of Bambasi Wereda is Bambasi town. Geographically, Bambasi wereda is found between the geographical coordinate of 9° 32’-10°05’ N of latitude and 34°24’-34°50’ E of longitude (figure 1).

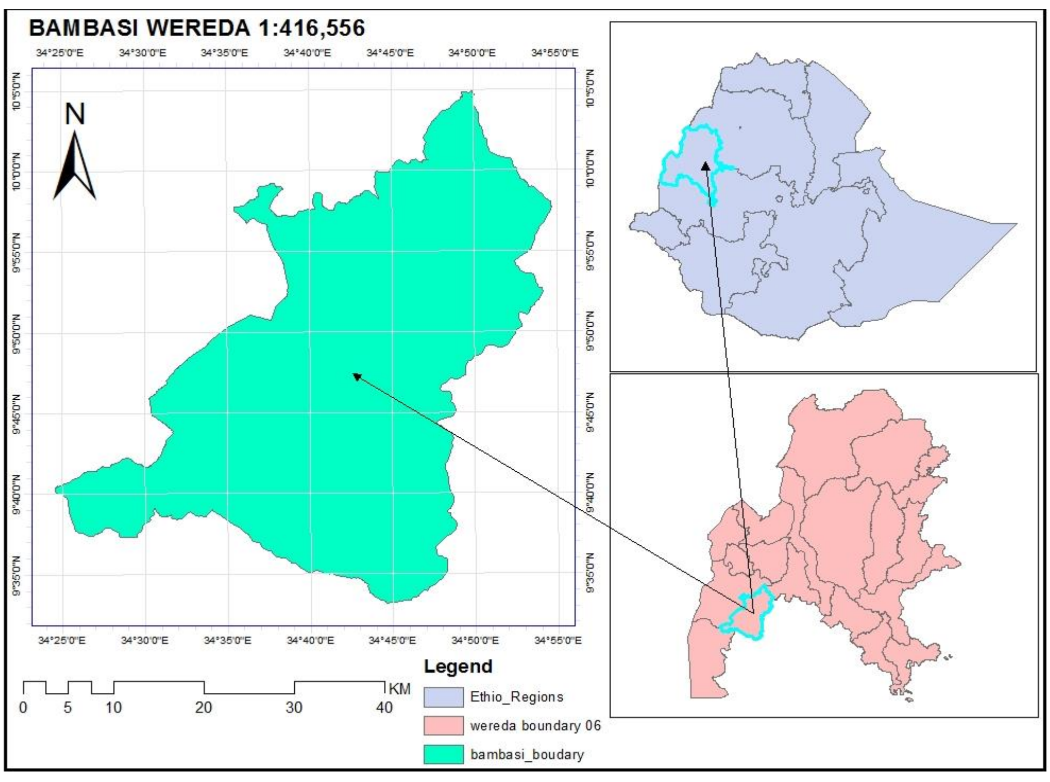


Figure 1: LOCATION OF BAMBASI WEREDA

3.1.2. Population of Bambasi Wereda

Based on the 2007 national census conducted by CSA, the total population of the wereda has 40,985 and out of that 20,758 were men and 20,227 were women. The 19.18% (7,861) of its population were urban dwellers and 80.20% (33,124) of its population were rural dwellers. With an area of 1455.58 square kilometers, Bambasi Wereda has a population density of 28.16 people per square kilometer. During this time Population of Bambasi wereda based on the religion distribution were orthodox Christianity followers (29.262%), protestant (3.83%), catholic (0.205%), Muslims followers (66.69%), traditional religion followers (0.01%) and others (0.004%). Based on the Population Projection of Ethiopia for All Regions at Wereda Level from 2014 – 2017 which is conducted by CSA (2013), the total population of Bambesi wereda in the year of 2015 was 64.25 thousand, and from this 17.44 thousand of its population were urban dwellers and 46.81 thousand its population were rural dwellers. With an area of 1455.58 square kilometer, the population density of Bambasi wereda was 44.14 people per square kilometer.

3.1.3. Climate

The rainfall and temperature data collected by the national Meteorological Agency of Ethiopia, the climate of the region comes under the influence of the tropical monsoon from the Indian Ocean, characterized with high rainfall in the wet period from May to April and a dry period from November to March. The mean annual temperature of the region varies from 20°C to 25°C and annual monthly temperature varies throughout the year from 25°C to 33°C. The absolute maximum temperature occurs in mid-march and is about 33°C and the absolute minimum temperature occurs in December and is about 14°C. The annual rainfall of the Region in the middle elevation (1300-1500m) varies from 900-1500mm, at higher elevation (1500-2217 m), it ranges from, 900-2000mm, at lower elevation (1002-1300 m), its varies from 900-1000mm (figure 2 and 3).

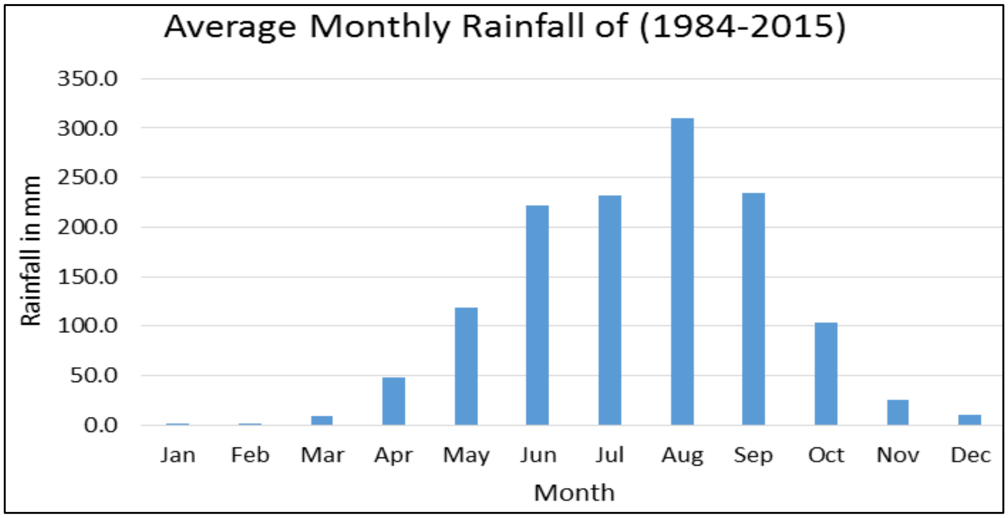


Figure 2: Average Monthly Rainfall of Bambasi wereda

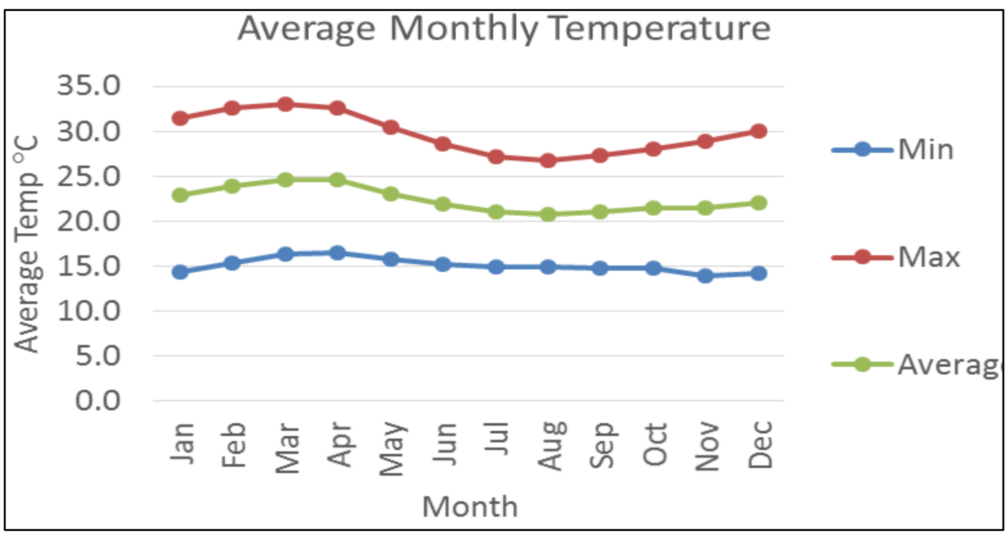


Figure 3: Average Monthly Maximum & Minimum Temperature

3.1.4. Topography of Bambasi wereda

Topography is an integral part of the land surface. It influences soil formation, drainage, run off, erosion, exposure and accessibility etc. The topography of the study area is in the lower piedmont Bambasi Wereda, between 1100 to 2200 m above Msl and the flood plain of below 1100 m contours. The plain is gently inclined North-wards and prone to flood and water logging during the wet season from June to September, and it is also causing the soil erosions that results in degradation of soil. The soil degradation decreases the fertility, then minimize the crop production which causing forest degradation and the social problem in the study area.

3.1.5. Status of Economic activity of Bambasi Woreda

According to the 2007 Population and Housing Census, the term economic activity status refers to the size and distribution of the work force of economically active and non-active populations. Persons aged ten years and over who were engaged or available to be engaged in the production of economic goods and services during a given reference period were classified as economically active, while those who were neither engaged nor available to be engaged in the production of economic goods and services during a given reference period were considered as economically non-active. Production of goods and services for own consumption or own use is considered as economic activity. These include production of primary products (agriculture, hunting, fishing, forestry and logging, and mining and quarrying), for own consumption; processing of primary products by the producers themselves; production of other commodities where part of it is sold on the market; and own account construction and fixed asset formation.

Based on the reports of CSA (2007), the populations aged 10 and above, economically active in urban-rural residence has rate of 71.8%, and also the rate economically inactive population aged 10 year and above were about 28.2%. From the population of economically active person aged 10 years and above in the Bambasi wereda the rate of employed persons were 98.8% and the rate of unemployment’s person were only 1.2%. The main economic base of the Bambasi wereda is farming, where major crops are maize and sorghum and oil seeds like sesame.

3.2. METHODS

3.2.1. Descriptions of Data Used

Remote sensing and Geographic Information Systems (GIS) are useful and cost-effective technologies for investigating environmental changes caused by human activities or natural phenomena in general, and for land use/land cover change analysis in particular. The advantages of remote sensing include the ability to cover large areas with high spatial detail and high temporal frequency, the robustness of satellite image classification, improvements on the spatial and spectral characteristics, and the acquisition of valuable multi-temporal datasets comprising different kinds of optical data, while GIS is powerful in mapping and analyzing the emerging patterns [31].

The data used for this study include satellite images, ancillary data such as Temperature, rainfall, population size, administrative boundary map and Google Earth© images. The Landsat images were selected from the existing archives based on their limited cloud coverage, spatial and temporal extent. In general, remote sensed satellite imageries which is obtained from USGS website (https://earthexplorer.usgs.gov/register/?return), which was used to extract the land use and land cover change for three decades. For the purpose of this research different types of software and materials was used to accomplish the desired objective of these study. The techniques of remote sensing have been remarkably developed and analysis of the imageries has greatly contributed to identify the phenomena on the earth surface. For this study the time series satellite images of the study area, the climate data such as temperature and rainfall, the ground control point collected from the aerial photograph and using GPS instruments by asking the known elders about the entire nature of land use/cover in the study area and different tabular data was used as input for this study to achieve the desired objective. The general method followed in this study was showed on Figure 4.

Table 1: The Details of data used

Data Used	Data type	Resolution	Date Acquired	Source
LANDSAT TM-5	Raster GeoTiff	30 X 30	1987-01-13	USGS
LANDSAT ETM-7	Raster GeoTiff	30 X 30	2001-01-11	USGS
LANDSAT-8 OLI	Raster GeoTiff	30 X 30	2015-01-26	USGS
Monthly Temp. Max & Min	Excel file	-	1984 - 2015	NMSA
Monthly Rainfall	Excel file	-	1984 - 2015	NMSA
Population data	Excel and PDF	-	**1987,2001,2015**	CSA
Boundary Shapefile	Vector	1:434633	2015	CSA

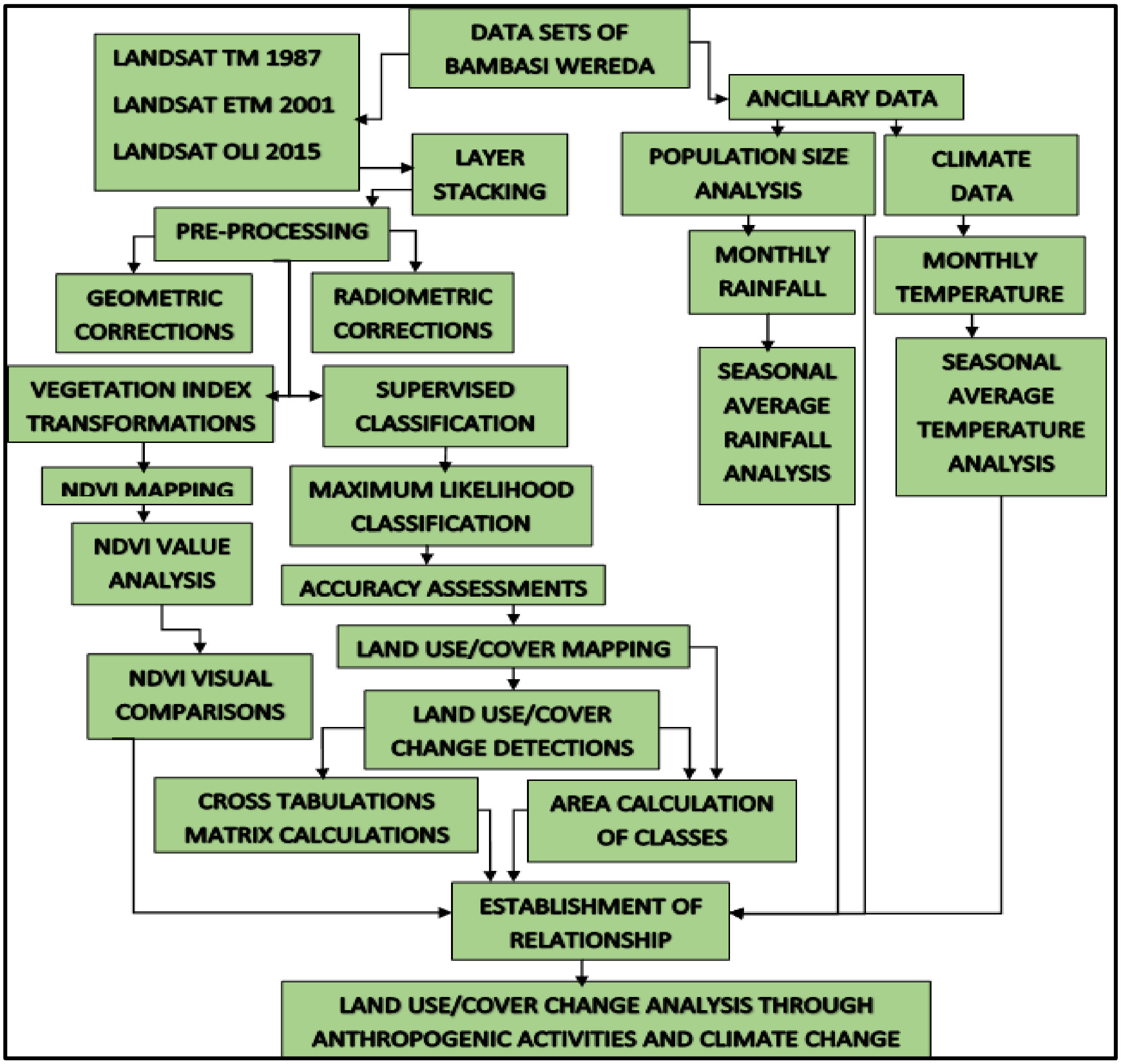


Figure 4: FLOW CHART DIAGRAM OF STUDY

3.2.2. Preparation and Preprocessing Remote Sensing and GIS data

Image preprocessing and Enhancements: - Preprocessing functions involve those operations that are normally required prior to the main data analysis and extraction of information. Pre-processing operations, sometimes referred to as image restoration and rectification, are intended to correct for sensor- and platform-specific radiometric and geometric distortions of the image [32]. So in general based on the acquired satellite image, the preprocessing procedure was conducted using software of Erdas imagine 2014 and ArcGIS 10 to achieve the desired objective.

Image enhancement, is solely to improve the appearance of the imagery to assist in visual interpretation and analysis. Enhancements are used to make it easier for visual interpretation and understanding of imagery [32]. The advantage of digital imagery is that it allows us to manipulate the digital pixel values in an image. With large variations in spectral response from a diverse range of targets (e.g. forest, deserts, snowfields, water, etc.) no generic radiometric correction could optimally account for and display the optimum brightness range and contrast for all targets. Thus, for each application and each image, a custom adjustment of the range and distribution of brightness values is usually necessary [32]. Based on different researcher histogram equalization is the most common technique to make pixel value of different feature or land cover easy to identify before classification of land use and land cover using supervised classification algorithm [32]. During enhancing the satellite image, the amount of information was visually interpreted from the satellite image both in the color of true color composite (TCC) and False color composite (FCC) using Erdas imagine 2014 software. The false color band combination used for the layer stack image of 1987 and 2001 were 4, 3, 2, and for layer stacked image of 2015 were 5, 4, 3, this because of the near infra-red, red and green for Landsat OLI were found in the region of band 5, band 4 and band 3, respectively. False color, also called Near Infrared or NIR, or 4, 3, 2: it is frequently used for studying vegetation [33].

Table 2: band combination and reflectance color

Ground Cover Type:	**In Natural Color (3,2,1), appears:**	**In False Color: (4,3,2), appears:**	**In Pseudo Natural Color (7,4,2), appears:**
Trees and bushes	Olive Green	Red	Shades of green
Crops	Medium to light green	Pink to red	Shades of green
Wetland Vegetation	Dark green to black	Dark red	Shades of green
Water	Shades of blue, green, and brown	Shades of blue	Black to dark blue
Urban areas	White to light blue	Blue to gray	Lavender
Bare soil	White to light gray	Blue to gray	Magenta, Lavender, or pale pink

Note: Adopted from NASA tutorial (2013)

Table 3: Uses of Landsat Spectral Bands

Band	Uses of Landsat Spectral Bands
1: 0.45- 0.52 µm (Blue)	Mapping coastal waters, differentiating between soil and plants, classifying forests, and identifying manmade objects such as roads
2: 0.52 - 0.60 µm (Green)	differentiating between types of plants, the health of plants and manmade objects
3: 0.63 - 0.69 µm (Red).	Discriminating among different kinds of vegetation and useful for mapping boundaries of soil types and geological formations.
4: 0.76 - 0.90 µm (Near infrared)	crop identification, for distinguishing between crops and soil, and for seeing the boundaries of bodies of water
5: 1.55 - 1.75 µm (Mid-Infrared)	Sensitive to the amount of water in plants (turgidity), useful for studies of drought and plant vigor and useful for discriminating
7:2.08 - 2.35 µm (Mid-infrared)	Particularly helpful for discriminating among types of rock formations and for observing vegetation moisture content

Note: Adopted from NASA tutorial (2013).

Landsat imagery provided by the USGS includes a UTM projection and a WGS84 datum and ellipsoid respectively. Thus; a geometric correction was necessary. Therefore; the Landsat imagery remote sensing data needed to be projected to UTM projection, to Datum of Adindan Ethiopia with UTM zone of 36 in the northern hemisphere.

3.2.3. Land use and Land cover Mapping

Digital image classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their data file values. Image Classification is usually performed on multi-channel data sets and this process assigns each pixel in an image to a particular class or theme based on statistical characteristics of the pixel brightness values [32]. The approaches taken to perform digital image classification algorithm in remote sensed data for these study was applied by supervised classifications. In a supervised classification, the analyst identifies in the imagery homogeneous representative samples of the different surface cover types of interest. Supervised training is closely controlled by the analyst. The selection of appropriate training areas is based on the analyst's familiarity with the geographical area and their knowledge of the actual surface cover types present in the image. The numerical information in all spectral bands for the pixels comprising these areas are used to "train" the computer to recognize spectrally similar areas for each class. The computer uses a special program or algorithm (of which there are several variations), to determine the numerical "signatures" for each training class. Once the computer has determined the signatures for each class, each pixel in the image is compared to these signatures and labeled as the class it most closely "resembles" digitally. A supervised classification was used through Maximum Likelihood algorithm and the maximum likelihood algorithm assumes that the histograms of the bands of data have normal distributions [32]. This classifier is based on Bayesian probability theory. Maximum Likelihood Classification is a statistical decision criterion to assist in the classification of overlapping signatures; pixels are assigned to the class of highest probability [34]. A land use/cover classification map was created using the maximum likelihood classification method, one of the most well-known parametric classifiers used for supervised classification [31]. Maximum likelihood algorithm (MLC) is one of the most popular supervised classification methods used with remote sensing image data. This method is based on the probability that a pixel belongs to a particular class. The basic theory assumes that these probabilities are equal for all classes and that the input bands have normal distributions. However, this method needs long time of computation, relies heavily on a normal distribution of the data in each input band and tends to over-classify signatures with relatively large values in the covariance matrix [35].

The classification system of land use and land cover mapping from satellite image was prepared based on outlined by ANDERSON et al., (1976) of level one (I) and these are includes Urban or built up land, rangeland, forest land, water and barren land. Based on paper of ANDERSON et al., (1976), the selected land use/cover type was defined as follows. Firstly, Urban or Built-up Land is comprised of areas of intensive use with much of the land covered by structures. Included in this category are cities, towns, villages, strip developments along highways, transportation, power, and communications facilities, and areas such as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas. Secondly, Rangeland historically has been defined as land where the potential natural vegetation is predominantly grasses, grass like plants, forbs, or shrubs. Thirdly, Forest Lands have a tree-crown areal density (crown closure percentage) of 10 percent or more, are stocked with trees capable of producing timber or other wood products, and exert an influence on the climate or water regime. Fourthly, Water bodies includes all areas within the land mass which are covered by water, provided that, if linear, they are at least 1/8 mile (200 m) wide and, if extended, cover at least 40 acres (16 hectares). And finally, Barren Land is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover. In general, it is an area of thin soil, sand, or rocks. Vegetation, if present, is more widely spaced and scrubby than that in the Shrub and Brush category of Rangeland. Unusual conditions, such as a heavy rainfall, occasionally result in growth of a short-lived, more luxuriant plant cover. Wet, non-vegetated barren lands are included in the Non-forested Wetland category. Land may appear barren because of man's activities. When it may reasonably be inferred from the data source that the land will be returned to its former use, it is not included in the Barren category but classified on the basis of its site and situation. Agricultural land, for example, may be temporarily without vegetative cover because of cropping season or tillage practices. Similarly, industrial land may have waste and tailing dumps, and areas of intensively managed forest land may have clear cut blocks evident. When neither the former nor the future use can be discerned and the area is obviously in a state of land use transition, it is considered to be Barren Land, in order to avoid inferential errors [36].

3.2.4. Accuracy Assessment

Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of the classification process. Usually, the assumed-true data are derived from ground truth data. Land use and land cover map resulting from remote sensing always contain some kind of errors due to numerous factors which ranges from classification technique to method of satellite data capture. In order to wisely use the land use/cover maps which are derived from remote sensing and the accompanying land resource statistics, the errors must be quantitatively explained in terms of classification accuracy. Whether the output meets expected accuracy or not is usually determined by the users themselves depending on the type of application the map product will be used latter. Accuracy levels that are acceptable for certain task may be unacceptable for others [37]. The most common accuracy assessment method is the preparation of a classification error matrix (or confusion matrix). Error matrix compares, on a category-by-category basis, the relationship between known pixel reference data and corresponding results of an automated classification. Class-wise accuracy assessment will therefore yield important information as to the categorical distribution of the overall error. The percentage correct for a given class is simply the diagonal entry for that class in the error matrix divided by the total number of pixels classified as such in the reference data. Note that the class percentage 'correct' is also frequently referred to as the producer's accuracy, while the user's accuracy is the ratio expressed in % of the class diagonal entry and the column marginal (total interpreted as such) for the same class. The user's accuracy is biased towards categories with a small number of samples, and the producers and overall accuracies are biased towards categories with a large number of samples. Sometimes it is better to concentrate the sampling on the categories of interest and increase their number of samples while reducing the number of samples taken in the less important categories. Also it may be useful to take fewer samples in categories that show little variability such as water or forest plantations and increase the sampling in the categories that are more variable such as un-even-aged forests or riparian areas. Again, the object here is to balance the statistical recommendations in order to get an adequate sample to generate an appropriate error matrix with the time, cost, and practical limitations associated with any viable remote sensing project. In addition to this the Kappa Coefficient expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification [32]. KAPPA is also a powerful technique in its ability to provide information about a single matrix as well as to statistically compare matrices. The result of performing a KAPPA analysis is a KHAT statistic (an estimate of KAPPA), which is another measure of agreement or accuracy. The KHAT statistic is computed as [38];

$$\hat{K} = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} * x_{+i})},$$

where r is the number of rows in the matrix, xii is the number of observations in row i and column i, xi+ and x+i are the marginal totals of row i and column i, respectively, and N is the total number of observations.

According to Anderson (1976), during the classification of land use/cover 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. Thus, 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 [36].

3.2.5. Conversion of DN to TOA Reflectance and NDVI Mapping

Radiometric Calibration: - Radiometric corrections may be necessary due to variations in scene illumination and viewing geometry, atmospheric conditions, and sensor noise and response. Also, it may be desirable to convert and/or calibrate the data to known (absolute) radiation or reflectance units to facilitate comparison between data [32]. To make the Landsat 5 TM and Landsat 7 ETM free of problem from Atmospheric condition and Scene illumination calibration of the Landsat imagery needed. The document of Chander (2003) provides Landsat data users with methods and parameters for converting the digital numbers from the image data to useful quantities such as spectral radiance (Lλ), and top-of atmosphere (TOA) reflectance (ρP). Historically, L5 TM calibration information has been presented in radiance units of mW/(cm2.sr.µm). To maintain consistency with L7 ETM+, this discussion uses radiance units of W/(m2.sr.µm) [39].

Conversion to Radiance for Level 1 products: - Calculation of radiance is the fundamental step in putting image data from multiple sensors and platforms into a common radiometric scale.

During Level 1 (L1) product generation, pixel values (Q) from Level 0 (L0) (raw) unprocessed image data are converted to units of absolute radiance using 32-bit floating-point calculations. The absolute radiance values are then scaled to 8-bit values representing calibrated digital numbers (Qcal) before output to the distribution media. Conversion from calibrated digital numbers (Qcal) in L1 products back to at-sensor radiance (Lλ) requires knowledge of the original rescaling factors [39]. The equation used to perform a Qcal to radiance conversion for a L1 product is as follows [40]:

$$\boldsymbol{L_\lambda = \left(\frac{Lmax_\lambda - Lmin_\lambda}{Qcalmax - Qcalmin}\right)(Qcal - Qcalmin) + Lmin_\lambda} \text{--------------}\mathbf{equ1}$$

For Landsat 5 and Landsat 7, the above equation is also expressed as:

$$\boldsymbol{L_\lambda = G_{rescale} * Q_{cal} + B_{rescale}} \text{--}\mathbf{equ2}$$

$$\boldsymbol{G_{rescale} = \left(\frac{Lmax_\lambda - Lmin_\lambda}{Qcalmax_\lambda - Qcalmin_\lambda}\right)} \text{---}\mathbf{equ3}$$

$$\boldsymbol{B_{rescale} = Lmin_\lambda - \left(\frac{Lmax_\lambda - Lmin_\lambda}{Qcalmax - Qcalmin}\right) * Qcalmin} \text{------------------}\mathbf{equ4}$$

Table 4: Definition of terms used at time of Radiance conversions, where:

Lλ	The Spectral Radiance at the sensor's aperture in W/ (m2.sr.µm)
Qcal	The quantized calibrated pixel value in Digital Number (DN)
Qcalmin	The minimum quantized calibrated pixel value (DN=0) corresponding to
Qcalmax	The maximum quantized calibrated pixel value (DN=255) corresponding to
Lminλ	The spectral radiance that is scaled to Qcalmin in W/ (m2.sr.µm)
Lmaxλ	The spectral radiance that is scaled to Qcalmax in W/ (m2.sr.µm)
Grescale	The rescaled gain (the data product "gain" contained in the Level 1 product
Brescale	The rescaled bias (the data product "offset" contained in the Level 1 product

Note: The Lmax, Lmin, Qcalmin, and Qcalmax information from attached metadata file were used.

<u>Conversion of Radiance to TOA Reflectance</u>: - A reduction in scene-to scene variability can be achieved by converting the at-sensor spectral radiance to exo-atmospheric reflectance [39]. The equation used to convert radiance to TOA reflectance was as follows:

$$\boldsymbol{\rho_\lambda = \frac{\pi * L_\lambda * d^2}{ESUN_\lambda * \cos\theta}}$$ --**equ5**

Where: $\boldsymbol{\rho_\lambda}$=Unit less Planetary TOA reflectance surfaces

π= Mathematical constant approximately equal to 3.14159[unit less]

$\mathbf{L_\lambda}$=Spectral radiance at the sensor's aperture [W/ (m^2sr μm)]

d= Earth-Sun distance [astronomical units]

$\boldsymbol{\theta_s}$=Solar zenith angle [degrees] or (θs =90° - Sun Elevation)

$\mathbf{ESUN_\lambda}$**=**mean Exo-atmosphere solar irradiance

Table 5: Constant used in Equation 1 and 5

Year	Band	Lmax	Lmin	Qcalmax	Qcalmin	ESUN
Landsat 5 TM 1987	3	264	-1.17	255	1	1536
	4	221	-1.51	255	1	1031
Landsat 7 ETM 2001	3	152.9	-5	255	1	1533
	4	241.	-5.1	255	1	1039

Note: 1, Lmax, Lmin, Qcalmax, Qcalmin and sun elevation are obtained from the Metadata file of both from Landsat 1987 and 2001. ESUN are cited from Chander (2010) and d value are as reported in a free spreadsheet file, provided by NASA (available from the url: http://landsathandbook.gsfc.nasa.gov/excel_docs/d.xls, accessed 2012/05/18

2, the sun elevation for 1987 and 2001 Landsat were 41.33185523 and 46.69651022, respectively, and the earth sun distance (d) was 0.98354 and 0.98345, respectively.

<u>Normalized Differentiate Vegetation Index (NDVI) Mapping</u>: - After the band 3 and 4 radiometrically corrected and enhanced the preparation of NDVI mapping procedures was followed and in vegetation area. Healthy vegetation reflects strongly in the near-infrared portion of the spectrum while absorbing strongly in the visible red. Cloud contaminated pixels has lower NDVI values, and measures like the timing of 'green up' or peak maturity would appear later than they actually occurred as stated on LANDSAT 8 DATA USERS HANDBOOK. The band 4 and band 3 of the satellite data in Erdas Imagine model was employed. Researchers are using the popular NDVI method for monitoring the temporal changes in vegetation area and its health. It has been used to prepare spectral vegetation indices which separate green vegetation using Landsat data [24]. The Normalized Difference Vegetation Index (NDVI) was estimated from Landsat 5 and Landsat 7 of red (band 3) and infrared (band 4) wavelengths using the following equation [41].

$$\boldsymbol{NDVI = \left(\frac{NIR_4 - Red_3}{NIR_4 + Red_3}\right)} \text{---}\mathbf{equ6}$$

On the other hand the study of D.P.Roy el al., (2014) reveals that the dynamic range of the Landsat 8 OLI is improved compared to previous Landsat sensors, reducing band saturation over highly reflective surfaces such as snow or cloud. The OLI and TIRS designs incorporate technical advancements that improve their performance over the previous Landsat sensors. Significantly, like the Advanced Land Imager (ALI) on EO-1, both the OLI and TIRS are push-broom sensors with focal planes aligning long arrays of detectors across-track. This provides improved geometric fidelity, radiometric resolution and signal-to-noise characteristics as D.P.Roy et al (2014) cite from Irons et al., (2012). The OLI and TIRS data for each WRS-2 scene are merged to create a single product containing the data from both sensors. The data from both sensors are radiometrically corrected and co-registered to a cartographic projection with corrections for terrain displacement resulting in a standard orthorectified digital image called the Level 1 product as revealed on LANDSAT 8 (L8) DATA USERS HANDBOOK provided By USGS in June, (2015). Therefore, since the data are radiometrically calibrated, it is possible to compute the NDVI with Landsat 8 OLI of near infrared (Band 5) and red (band 4).

The Normalized Difference Vegetation Index (NDVI) was estimated from Landsat 8 OLI sensor of red (band 4) and near infrared (band 5) wavelengths using the following equation [42].

$$\boldsymbol{NDVI = \left(\frac{NIR_5 - Red_4}{NIR_5 + Red_4}\right)}\text{---}\mathbf{equ7}$$

3.2.6. Change Detection Analysis

The cloud and cloud shadow classes of all dates were grouped into a general cloud class: this area was masked out for subsequent analyses. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multi-temporal data sets [12]. During the change detection was analyzed the post-classification comparison method will be used to identify the change rate of land use and land cover from multi-temporal imageries using ArcGIS 10 software. According to Singh (1989), the post-classification comparison method is the most obvious method of change detection which requires the comparison of independently produced classified images. Post- classification comparison holds promise because data from two dates are separately classified, thereby minimizing the problem of normalizing for atmospheric and sensor differences between two dates [12]. For performing land use/cover change detection, a post-classification detection method was employed. A pixel-based comparison was used to produce change information on pixel basis and thus, interpret the changes more efficiently taking the advantage of ‘‘-from, -to’’ information [35]. Classified image pairs of two different decade data were compared using cross-tabulation in order to determine qualitative and quantitative aspects of the changes for the periods from 1987 to 2015. The resulting change maps were accompanied by the respective cross tabulation matrices showing the change pathways, in order to determine the quantity of the conversions [31].

The classified images were compared in three periods, i.e., 1987–2001, 2001–2015 and 1987–2015. The exact duration of each time interval was constrained by the availability of cloud-free scene over the study area. Detection of land cover changes was achieved by overlay and post-classification comparison of the land cover/land use maps of the different time periods at wereda scales. The original resolution of the satellite images was preserved, in order to attain the maximum quality of spectral data during the classification process. Change statistics were computed by comparing image values of one data set with the corresponding value of the second data set in each period. The values were presented in terms of hectares and percentages. The percentage of Land use/cover changes were calculated using the following equation [43]:

$$\boldsymbol{Percentage\ of\ LULC\ change} = \left(\frac{\boldsymbol{Area_{final\ year} - Area_{initial\ year}}}{\boldsymbol{Area_{initial\ year}}}\right) \text{--------------------Equ 8}$$

Where: Area is extent of each Land use/cover type. Positive values suggest an increase whereas negative values imply a decrease in extent. Land use/cover change conversion matrix between 1987 and 2001, and 2001 and 2015 was generated using ArcGIS 10 software and compiled in a matrix table, and the values were presented in terms of hectares [43].

3.2.7. Correlation of Land use/cover and NDVI value change with population, rainfall and Temperature

Descriptive method of data for population size and climate data (i.e. temperature and rainfall) was used. The impacts of anthropogenic and climate on land use and land cover of the study area was analyzed and establish their relationship with land cover (such as rangeland, forest cover, barren land and etc.) for three decade on-site study area. During the analysis of impact assessment of anthropogenic and climate on the land use/cover change, the software's that helps to analysis and make relationship with land use and land cover was performed by Microsoft Excel.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. LAND USE AND LAND COVER MAPPING

From the independent image classification of the three periods satellite imagery (1987 TM, 2001 ETM, and 2015 OLI), six different land uses and land cover classes(Urban or Built-up land, range land, forest land, Water bodies and Barren land) identified. For all of the satellite imagery (1987, 2001 and 2015) the land use/cover categories of barren land includes agriculture land, bare soil, sand area, thin soil, rocky land and more widely spaced shrub and brush land. In case of agricultural land during the month of January the fields are temporary without crop or without any vegetation. Thus agricultural field has the same spectral value with that of barren land.

4.1.1. Land Use and Land cover Classification for 1987

The 1987 image classification results shows that water bodies covered 0.34 % of the study area. The classification result also shows that 47.91% of the area was covered by range land which was mainly found at northeast and north south sides of Bambasi town. During this time, 46.88 % of the land was covered with barren land and the 3.96% of the area covered with forest land and majority of the forest cover was found in the south part of Bambasi town which is higher in altitude called mount bambasi or Abba mottii terara with local language. On the other hand, the results of the image classification revealed that the urban or Built-up land was about 0.91% of the total (shown on table 6). During this time the dominant land use/cover type was range land followed by barren land and the least land use/cover type was water bodies followed by urban or built-up land in the Bambasi wereda (land use/cover map shown on fig 5)

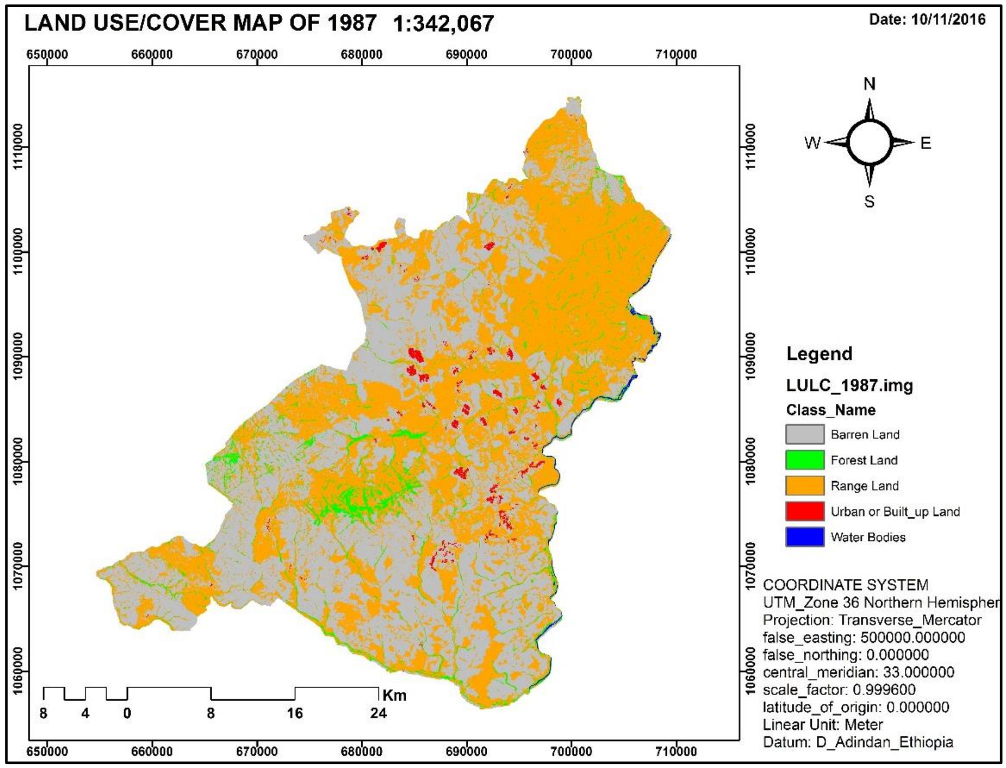


Figure 5: LAND USE/COVER MAP OF BAMBASI WEREDA IN 1987

Table 6: 1987 LAND USE/COVER AREA IN (ha) & (%) for Bambasi wereda

Land use/cover type	Area (ha)	Area (%)
Urban or Built-up Land	1328.58	0.91
Range Land	69733.17	47.91
Forest Land	5757.21	3.96
Water Bodies	495.27	0.34
Barren Land	68235.03	46.88
Total	145549.26	99.99

4.1.2. Land Use and Land Cover Classification for 2001

The 2001 image classification results show that the urban or built-up land cover 1.11 % of the total area of the study area. During this time urban or built-up land was increased when compared with the 1987 image classification results of the cover in urban or built land. The classification results also show that 52.28 % of the area was covered with range land. During this time, 3.72 % of the land was covered with forest land and on the other hand water bodies were covers about 0.34 % of the total land. In addition to this barren land covers about 42.53 % of the total land (shown on table 7). The land use/cover map is shown on figure 6.

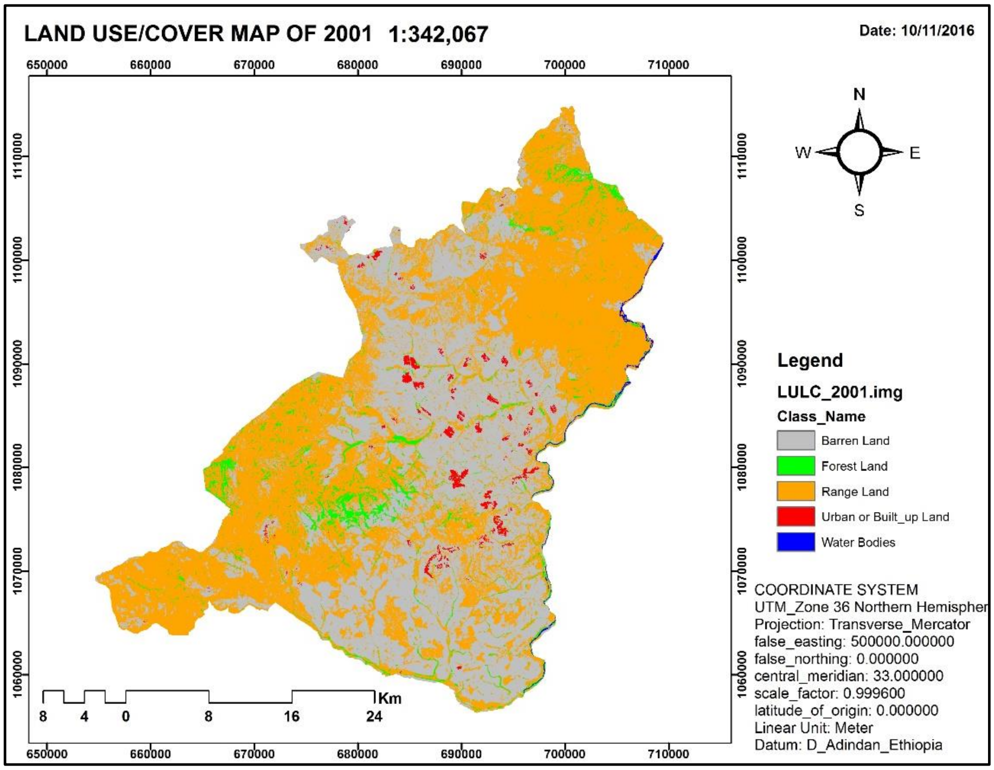


Figure 6: LAND USE/COVER MAP OF BAMBASI WEREDA IN 2001

Table 7:2001 LAND USE/COVER Area in (ha) & (%) for Bambasi wereda

Class Name	AREA (Ha)	AREA (%)
Urban or Built-up Land	1620.18	1.11
Range Land	76100.40	52.28
Forest Land	5414.76	3.72
Water Bodies	494.28	0.34
Barren Land	61902.81	42.53
TOTAL	145532.43	99.98

4.1.3. Land Use and Land cover Classification for 2015

The 2015 image classification results show that urban or Built-up land, forest land, water bodies and barren land was covers 1.255 %, 3.055 %, 0.345 and 37.472%, respectively, of the total land of the study area. The classification results also show that 57.874 % of the area was covered with the class of range land (shown on figure 7 and Table 8).

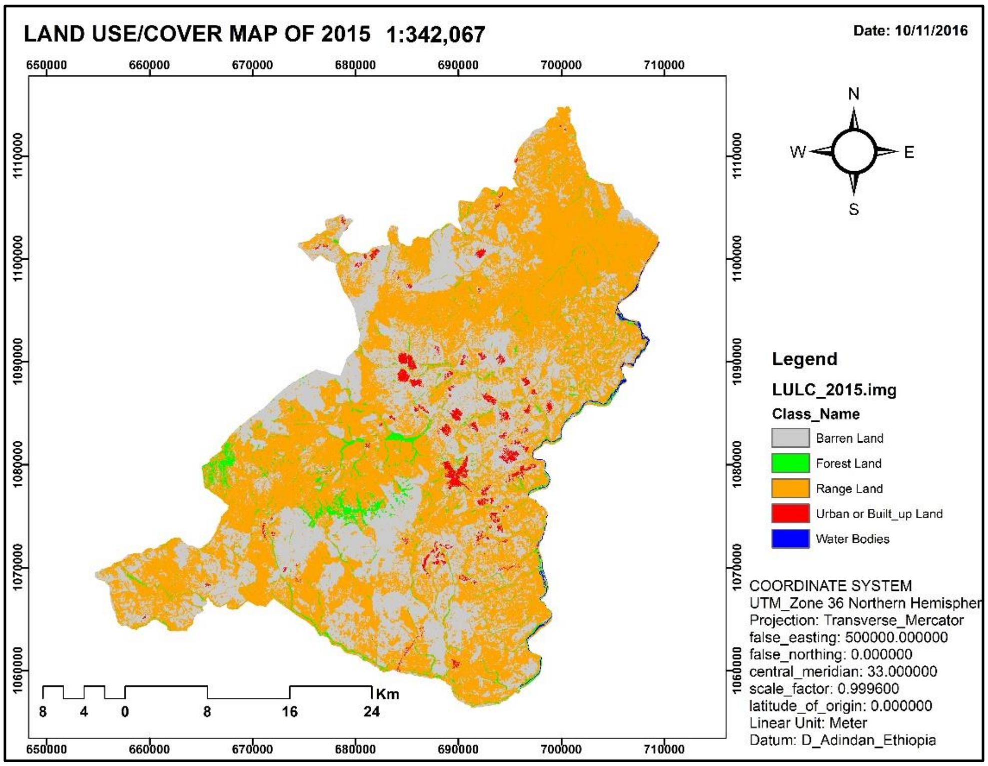


Figure 7: LAND USE/COVER MAP OF BAMBASI WEREDA IN 2015

Table 8: 2015 LAND USE/COVER Area in (ha) & (%) for Bambasi wereda

Class Name	AREA (Ha)	AREA (%)
Urban or Built-up Land	2282.22	1.57
Range Land	84220.65	57.86
Forest Land	4436.28	3.05
Water Bodies	493.02	0.34
Barren Land	54117.09	37.18
Total	145549.26	99.99

The overall image classification results are very important in describing the coverage of land use/cover classes in each period. The result of the classification arranged in the excel sheet for the year of 1987, 2001 and 2015(shown on table 9).

Table 9: Summery of Land use/cover Class Statistics of 1987, 2001 and 2015 for Bambasi wereda

Land use/cover	**1987**		**2001**		**2015**	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Built-up Land	1328.58	0.91	1620.18	1.11	2282.22	1.57
Range Land	69733.17	47.91	76100.40	52.28	84220.65	57.86
Forest Land	5757.21	3.96	5414.76	3.72	4436.28	3.05
Water Bodies	495.27	0.34	494.28	0.34	493.02	0.34
Barren Land	68235.03	46.88	61902.81	42.53	54117.09	37.18
TOTAL	145549.26	99.99	145532.4	99.98	145549.26	99.99
Unclassified	11.43	0.01	28.26	0.02	11.43	0.01

4.1.4. Accuracy Assessments

Accuracy of Land use/cover can be described using percentage. The higher the percentages of the accuracy were the better the classifications. In this study, accuracy assessment was performed for the MLC classified maps of all three time periods (i.e., 1987, 2001 and 2015). Stratified random sampling design was adopted for the accuracy assessment. Only five categories, Built-up, rangeland, forest land, water body and barren land were considered for accuracy assessment with the minimum of 50 sample points for each considered category, as recommended by Congalton.

Interpretation is based on aerial photographs and field verification. Overall accuracy, user's and producer's accuracies, and the Kappa statistics were derived from the error matrices to find the reliability and accuracy of the maps produced [38], using Erdas Imagine 2014. To determine the overall accuracy of image classification from the image were performing error matrix. Thus, Using an error matrix to represent accuracy has been recommended by many researchers and should be adopted as the standard reporting convention. Perhaps the simplest descriptive statistic is overall accuracy which is computed by dividing the total correct (i.e., the sum of the major diagonal) by the total number of pixels in the error matrix [38].

With addition to aerial photograph, sample data or reference coordinate are randomly collected using GPS instruments for each of the land use/cover category by asking alive key witness persons (for example, kebele leaders, respected elders and many others), who was lives for long period of time in the study site, and they was volunteers in the validation or approval of the classified land use/cover map for the year of 1987, 2001 and 2015.

The overall classification accuracy of land use/cover for all the period (i.e. 1987, 2001 and 2015) was found to be good, as the recommendation stated by both Congalton (1991) and Anderson (1976). As a result, the overall classification accuracy of the land use/cover for 1987, 2001 and 2015 calculated had found as 89.57%, 88.60% and 86.59%, respectively. And also, the conditional Kappa statistics results for the periods of 1987, 2001 and 2015 was found as 0.8641, 0.8538 and 0.8294, respectively (shown on Table 10, 11 and 12).

Table 10: Confusion Matrix of 1987 Land use/cover classification Accuracy per pixel

Classified Data	BUL	RL	FL	WB	BL	Classified Total	User accuracy
BUL	22	0	0	0	1	23	95.65%
RL	0	58	1	0	2	61	95.08%
FL	0	6	25	0	0	31	80.65%
WB	0	0	1	30	0	31	96.77%
BL	5	6	0	0	54	65	83.08%
Reference Total	27	70	27	30	57	211	
Producers accuracy	81.48%	82.86%	92.59%	100%	94.74%		

- Note: the Overall Classification Accuracy 1987= (189/211)*100 = 89.57% and the Overall Kappa Statistics = 0.8641 and for each of the classes, BUL= 0.9501, RL= 0.9264, FL= 0.7781, WB= 0.9624, and finally for BL= 0.7681
- Where, BUL = Urban or Built-up land, RL= Range land, FL = Forest land, WB = Water bodies and BL= Barren land.

Table 11: The Confusion Matrix of 2001 Land use/cover classification Accuracy per pixel

Classified Data	BUL	RL	FL	WB	BL	Classified Total	Users accuracy
BUL	26	0	0	0	1	27	96.30%
RL	0	61	2	0	0	63	96.83%
FL	0	1	37	0	0	38	97.37%
WB	0	0	1	32	0	33	96.97%
BL	5	14	2	0	46	67	68.66%
Reference Total	31	76	42	32	47	228	
Producers accuracy	83.87%	80.26%	88.10%	100%	97.87%		

- Note: the Overall Classification Accuracy of 2001 = (202/228)*100 = 88.60% and the Overall Kappa Statistics was = 0.8538 and for each of the classes, BUL= 0.9571, RL= 0.9524, FL= 0.9677, WB= 0.9647 and BL= 0.6052.

Table 12: The Confusion Matrix of 2015 Land use/cover classification Accuracy per pixel

Classified Data	BUL	RL	FL	WB	BL	Classified Total	User accuracy
BUL	35	0	0	0	0	35	100.00%
RL	0	60	2	0	11	73	82.19%
FL	0	1	41	0	0	42	97.62%
WB	0	0	2	34	0	36	94.44%
BL	6	7	4	0	43	60	71.67%
Reference Total	41	68	49	34	54	246	
Producers accuracy	85.37%	88.24%	83.67%	100%	79.63%		

- Note: The Overall Classification Accuracy of 2015= (213/246)*100= 86.59% and the Overall Kappa Statistics = 0.8294 and the Conditional Kappa for each Category, BUL= 1, RL= 0.7539, FL= 0.9703, WB= 0.9355 and BL= 0.637

- Where, BUL = Urban or Built-up land, RL= Range land, FL = Forest land, WB = Water bodies and BL= Barren land.

4.1.5. LAND USE AND LAND COVER CHANGE DETECTION

Figure 8 and 9, and Table 13, shows the surface distribution (in ha) and the evolution of the proportion of each land use /cover class in the different time periods. Both Range land and Barren land are the largest land cover types in the district throughout the 28 years. Urban or Built-up land and water bodies occupied the least area in the 1987 and 2001 and by the end of the study period urban or built-up land and water bodies continues to become the smallest land cover types in the district. Trends can be observed in the land cover classes undergoing the largest change namely urban or built-up land, rangeland, forest land, and barren lands from 1987 to 2015. Bare lands and forest cover decreased greatly in the second time intervals (i.e. 2001-2015). Urban or built-up land and Rangeland more increase significantly in the second time interval compared with the first time interval. Same with barren land and forest cover, water bodies was decreased in the second time interval (i.e. 2001-2015) of the study time period. Based on report UNEP (2012), This change was because of national resettlement plan and accompanying increases in human and livestock populations and drastic deforestation between 1972 and 2005, there was no cropland in 1972 but between 1986 and 2005, the cropland established accounted for 5546 ha, which is a change of 53% in land cover. The other reason, this change was because of the farmers clearing forest for agricultural fields with the demand of fertile soil for crop production and when the land was degraded the farmers abandoned the land, this was causes probability increasing rangeland, decreasing water bodies, barren land and forest cover.

In the period from 1987- 2001, urban or Built-up land and Range land increased by 21.95% and 9.13%, and the increased areas are amounts to 291.60 ha and 6367.23 ha, respectively. In contrast with built-up and range land, forest land, water bodies and Barren land decreased by 5.95%, 0.20% and 9.28%, respectively, in the same period. In contrast with first time interval (1987-2001), in the period from 2001-2015 the changes in urban or built-up land and rangeland area increased by 40.86% and 10.67%, respectively. During this time interval (i.e. 2001-2015) forest cover, water bodies and barren land decreased by 18.07%, 0.25% and 12.58%, respectively (shown on figure 8 and 9 and on table 13).

Table 13: Land use/cover change detection of Bambasi Wereda between 1987 and 2015

Land use/cover type	Change in (1987-2001)		Change in (2001-2015)	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Built-up Land	291.60	21.95	662.04	40.86
Range Land	6367.23	9.13	8120.25	10.67
Forest Land	-342.45	-5.95	-978.48	-18.07
Water Bodies	-0.99	-0.20	-1.26	-0.25
Barren Land	-6332.22	-9.28	-7785.72	-12.58

Note: 1. BUL = Urban or Built-up land, RL= Range land, FL = Forest land, WB = Water bodies and BL= Barren land

Table 14, presents all the results of the cross tabulation matrices of the land cover/land use change for Bambasi wereda in the period (1987-2015). Considering the entire study period of 28 year at once, 1010.9 ha urban or built-up lands remained stable, 1271.3 ha of new urban or Built-up land were created at the expense of rangeland, forest land and barren land, but 317.7 ha of urban or built-up land were lost to rangeland areas (170.8 ha), forest land (1.7 ha), and Barren land areas (145.2 ha). During this time interval, 47978.4 ha range land remained constant, 36242.3 ha of new range land were created at the cost of barren land (33651.5 ha), forest cover (2394.7 ha), urban or built-up land (170.8 ha) and water bodies (25.2 ha), but 21754.8 ha of range land were lost to barren land (19914.4 ha), forest cover (1428.8 ha), urban or built-up land (371.1 ha) and water bodies (40.5 ha). In the case of forest cover also, 2625.3 ha area were remained constant, and 1811 ha of new forest cover were gained at the expense of range land (1428.8 ha), barren land (336.2 ha), water bodies (44.2 ha) and urban or built-up land (1.7 ha), but 3131.9 ha of forest cover were lost to range land (2394.7 ha), barren land (667.6 ha), water bodies (61.8 ha) and urban or built-up land (7.7 ha). In the case of water bodies, 368 ha area were remained constant throughout this 28 year, and 125 ha of new water bodies were created at the costs of forest cover (61.8 ha), range land (40.5 ha) and barren land (22.7 ha), but 127.3 ha of water bodies were losses to barren land (578 ha), forest cover (44.2 ha), range land (25.2 ha) and urban or built-up land (0.1 ha). Beside the above land use/cover type in this time interval, 33332.1 ha barren land were remained constant in the Wereda, and 20785 ha of new barren land area were gained at the expense of range land (19914.4 ha), forest cover (667.6 ha), urban or built-up land (145.2 ha) and water bodies (57.8 ha), but during this time, 34902.9 ha of barren land were losses to range land (33651.5 ha), urban or built-up land (892.4 ha), forest cover (336.2 ha) and water bodies (22.7 ha).Rangeland, barren land and forest cover areas were the land use/cover categories that expanded the most over other land use/cover types, with 36242.3 ha and 20785.0ha and 1811 ha, respectively. During this period of 28 years, the areas of barren land, rangeland and forest lands were experienced the greatest absolute reduction in area, with 34902.9 ha, 21754.8 ha and 3131.9 ha, respectively. In relative terms, the reduction of forest land (54.40%) and barren land (51.15%) is larger magnitude than the 31.20% and 25.7% decrease in range land and water bodies relative to the 1987 surface area of the respective land use/cover. In contrast with 1987 land use/cover surface area, in the 2015 of land use/cover type surface area, range land and urban or built-up land were increased by 14487.48 ha and 953.64 ha, respectively, but barren land, forest cover and water bodies were decreased by 14117.9 ha, 1320.93 ha and 2.25 ha, respectively(Table 14).

Table 14: Tabulation matrices and Nature of the land use/cover changes in the Bambasi Wereda from 1987 to 2015 in (ha)

Period 1987-2001	BUL	RL	FL	WB	BL	Total (2001)	Expansion
BUL	1011.2	177.2	1.8	0.0	429.9	1620.2	609.0
RL	57.6	44739.4	2381.5	50.0	28867.6	76096.1	31356.7
FL	5.5	1929.4	2804.3	45.7	629.4	5414.3	2610.0
WB	0.1	49.2	49.0	375.0	20.3	493.7	118.5
BL	254.1	22826.7	518.8	23.4	38279.0	61901.9	23622.9
Total (1987)	1328.5	69721.9	5755.3	494.2	68226.2	145526.1	
Reduction	317.3	24982.6	2951.0	119.1	29947.2		
Period 2001-2015	BUL	RL	FL	WB	BL	Total (2015)	Expansion
BUL	1129.7	120.6	14.4	0.2	1017.4	2282.3	1152.5
RL	235.4	53225.9	2133.0	35.2	28580.7	84210.2	30984.2
FL	4.1	1488.4	2635.5	8.2	298.7	4434.9	1799.5
WB	0.0	40.1	15.2	415.1	21.6	492.0	77.0
BL	251.0	21221.0	616.2	35.0	31983.6	54106.8	22123.2
Total (2001)	1620.2	76096.1	5414.3	493.7	61901.9	145526.2	
Reduction	490.5	22870.2	2778.8	78.6	29918.3		
Period 1987-2015	BUL	RL	FL	WB	BL	Total (2015)	Expansion
BUL	1010.9	371.1	7.7	0.1	892.4	2282.2	1271.3
RL	170.8	47978.4	2394.7	25.2	33651.5	84220.7	36242.3
FL	1.7	1428.8	2625.3	44.2	336.2	4436.3	1811.0
WB	0.0	40.5	61.8	368.0	22.7	493.0	125.0
BL	145.2	19914.4	667.6	57.8	33332.1	54117.1	20785.0
Total of 1987	1328.6	69733.2	5757.2	495.3	68235.0	145549.3	
Reduction	317.7	21754.8	3131.9	127.3	34902.9		

- Note: 1. BUL = Urban or Built-up land, RL= Range land, FL = Forest land, WB = Water bodies and BL= Barren land.

- ➢2. Cloud and shadow class is constant in tables 1987-2001 and 2001-2015 was 34.56 ha and for table 1987-2015 was 11.43 ha.
- ➢3. The values on the diagonal represent the amount of each land use/cover class that did not change, while the remaining values refer to the expansion or reduction of the classes.

The internal conversions between land use/cover types from (1987-2001) and the area (ha) taken by corresponding types in such reduction or expansions conversions were presented in table 14. During this time interval, cross tabulation matrices results shows the expansion 609 ha new urban or built-up land were created at the expense of barren land (429.9 ha), range land (177.2 ha) and forest land (1.8 ha), but 317.3 ha of urban or built-up land lost to barren land (245.1 ha), range land (57.6 ha) and forest cover (5.5 ha). During this time, the range land also gain 31356.7 ha at the cost of 28867.6 ha of barren land, 2381.5 ha of forest cover, 57.6 ha built-up land and 50 ha of water bodies, but 24982.6 ha of range lost to 22826.7 ha barren land, 1929.4 ha of forest land, 177.2 ha of built up land and 49.2 ha of water bodies. The forest cover were gain 2610 ha at the cost of 1929.4 ha of range land, 629.4 ha of barren land, 45.7 ha of water bodies and 5.5 ha of urban or built-up land but 2951 ha of forest cover lost to 2381.5 ha of range land, 518.8 ha of barren land, 49 ha of water bodies and 1.8 ha of urban or built-up land. During this time interval Water bodies gain 118.5 ha at the expense of 49.2 ha of range land, 49 ha of forest cover, 20.3 ha of barren land and 0.1 ha of urban or built-up land but 119.1 ha of water bodies lost to 50 ha of range land, 45.7 ha of forest cover and 23.4 ha of barren land. Beside this barren land also gain 23622.9 ha at the expense of 22826.7 ha of range land, 518.8 ha of forest cover, 254.1 ha of urban or built-up land and 23.4 ha of water bodies but 29947.2 ha of barren land lost to 28867.6 ha of range land, 629.4 ha of forest cover, 429.9 ha of urban or built-up land and 20.3 ha of water bodies.

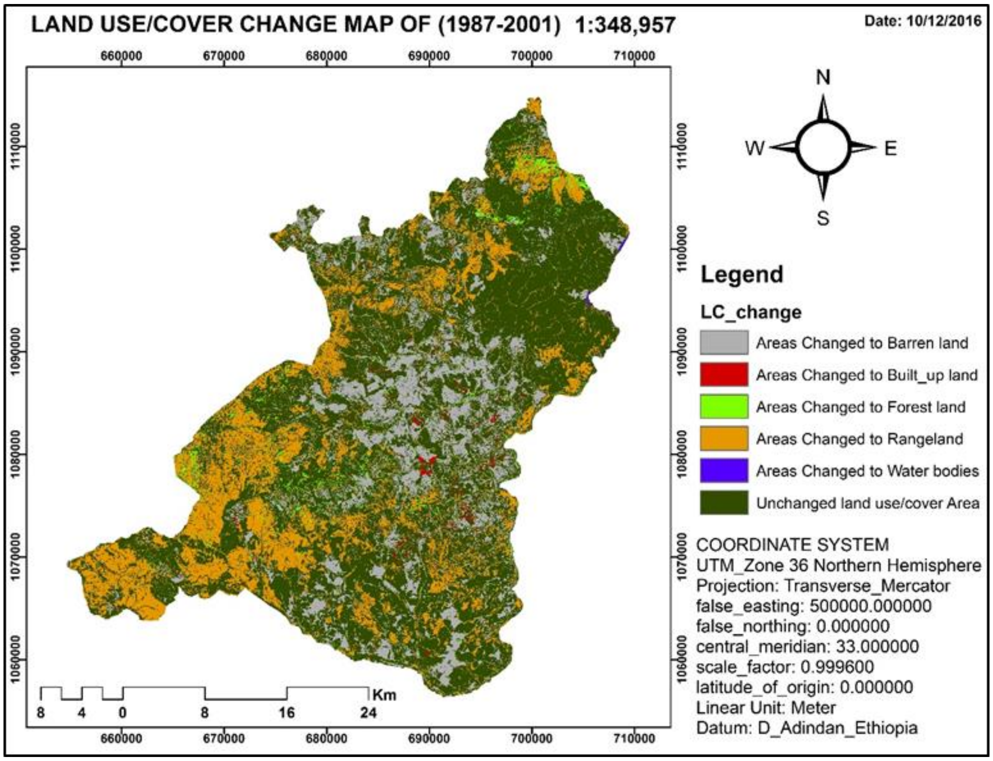


Figure 8: LAND USE/COVER CHANGE OF BAMBASI WEREDA IN (1987-2001)

The internal conversions between land use/cover types from (2001-2015) and the area (ha) taken by corresponding types in such loss or gain conversions were presented in table 14. During this time interval, cross tabulation matrices results shows, urban or built up land gain 1152.5 ha at the expense of barren land (1017.4 ha), range land (120.6 ha), forest cover (14.4 ha) and water bodies (0.2 ha), but 490.5 ha of urban or built-up land were lost to barren land (251 ha), range land (235.4 ha) and forest cover (4.1 ha). The range land also gain new 30984.2 ha of area at the expense of barren land (28580.7 ha), forest cover (2133 ha), urban or built-up land (235.4 ha) and water bodies (35.2 ha), but at this time interval 22870.2 ha range land were lost to barren land (21221 ha), forest land (1488.4 ha), urban or built-up land (120.6 ha) and water bodies (40.1 ha). During this time interval forest cover gain 1799.5 ha of new area at the cost of range land (1488.4 ha), barren land (298.7 ha), water bodies (8.2 ha) and urban or built-up land (4.1 ha) but 2778.8 ha of forest cover were lost to range land (2133 ha), barren land (616.2 ha), water bodies (15.2 ha) and urban or built-up land (14.4 ha). On the other hand water bodies gain 77 ha of new area at the expense of range land (40.1 ha), barren land (21.6 ha) and forest cover

(15.2 ha) but during this time interval 78.6 ha water bodies were lost to range land (35.2 ha), barren land (35 ha), forest cover (8.2 ha) and urban or built-up land (14.4 ha). Beside the above land use/cover type barren land also gain 22123.2 ha of new area at the cost of range land (21221 ha), forest cover (616.2 ha), urban or built-up land (251 ha) and water bodies (35 ha) but 29918.3 ha of barren land were lost to range land (28580.7 ha), urban or built-up land (1017.4 ha), forest cover (298.7 ha).

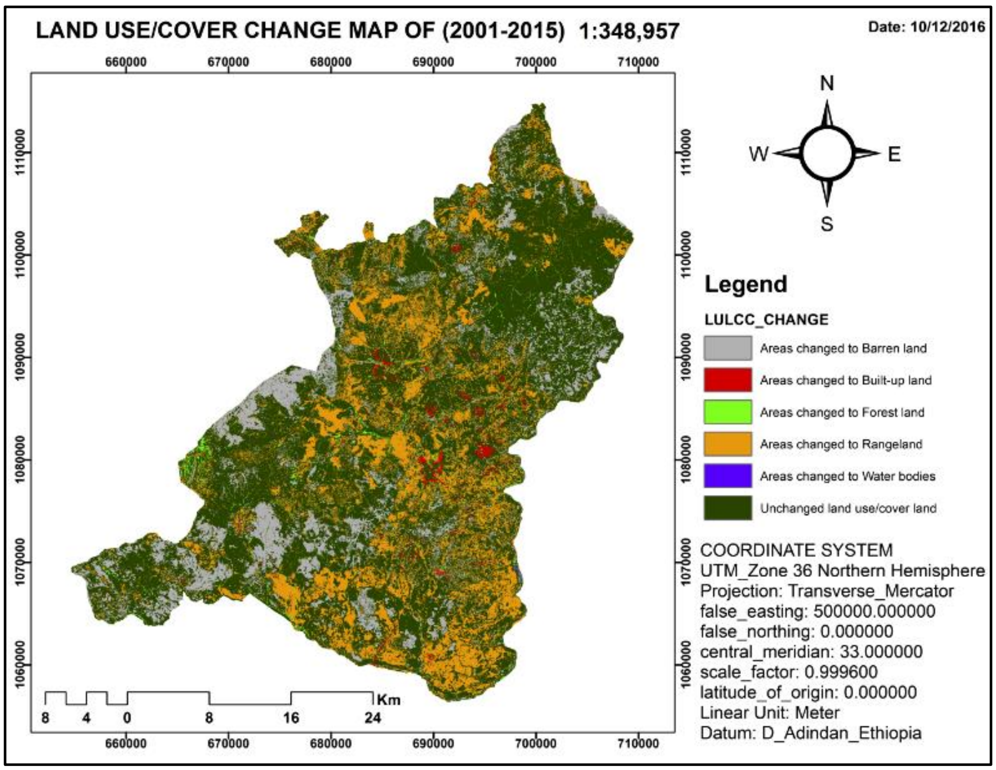


Figure 9: LAND USE/COVER CHANGE OF BAMBASI WEREDA IN (2001-2015)

4.2. NDVI BASED CHANGE DETECTION

The following map reveals the difference in NDVI value between 1987 and 2015 images, however, NDVI image differencing cannot provide detailed change information. It can only show the information of increase or decrease in NDVI value. The negative threshold indicates loss in NDVI and positive threshold indicates area of increase in NDVI. The higher the positive values in the NDVI values the higher the intensity of the forest cover and the less the positive values the less the forest cover. This NDVI value was supports the value of land use/cover change shown above, particularly the forest cover, range land & barren Land. During the time interval of 1987-2001 the value of NDVI was decreases from 0.752932 in 1987 to 0.726052 in the year of 2001(shown on figure 11). And also during the time interval of 2001-2015 the NDVI value decreases from 0.726052 in the year of 2001 to 0.500976 in the year of 2015. The results shown on figure 10 and 11 proves the decreases in vegetative area (forest cover) and the decreases of non-vegetative (i.e. barren land and water bodies) which shown on the land use/cover change throughout this 28 years. When the value the NDVI decreases from time to time in that area the vegetation or forest cover were also decreases and also this indicates that forest degradation was occurred through grazing, shifting cultivation, deforestation, expansion of agricultural land at the expense forest cover, the increased demand of wood fuels and charcoal production, urban or built-up expansion and intentional forest fire occurrences in the study area (the results are shown figure 10 and 11).

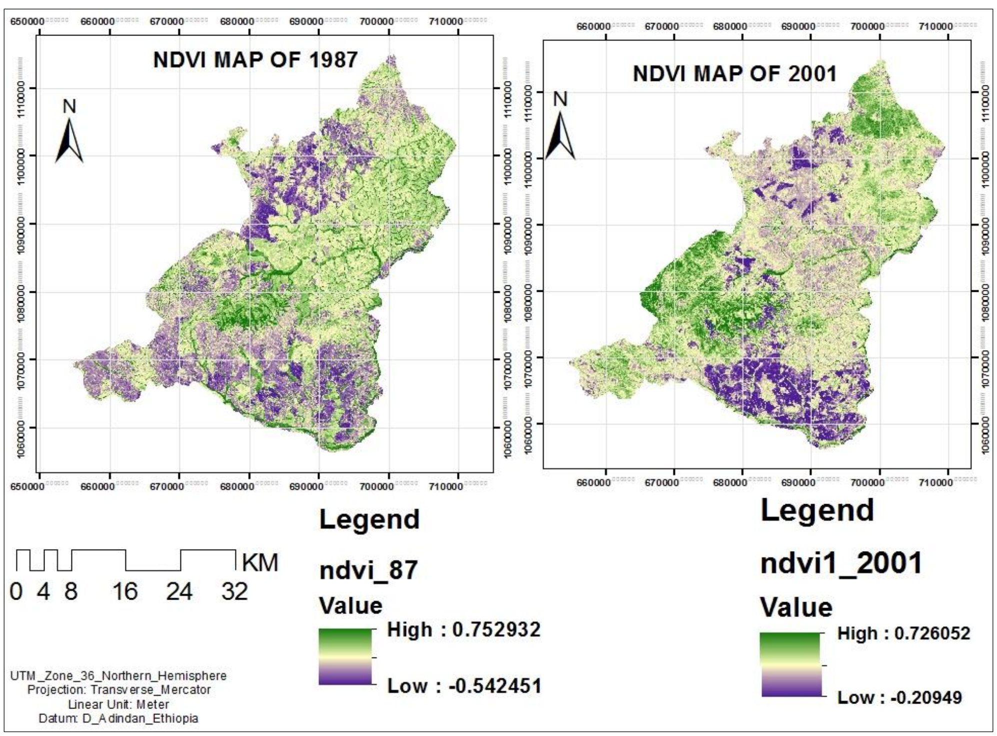


Figure 10: NDVI MAP OF BAMBASI WEREDA IN 1987 AND 2001

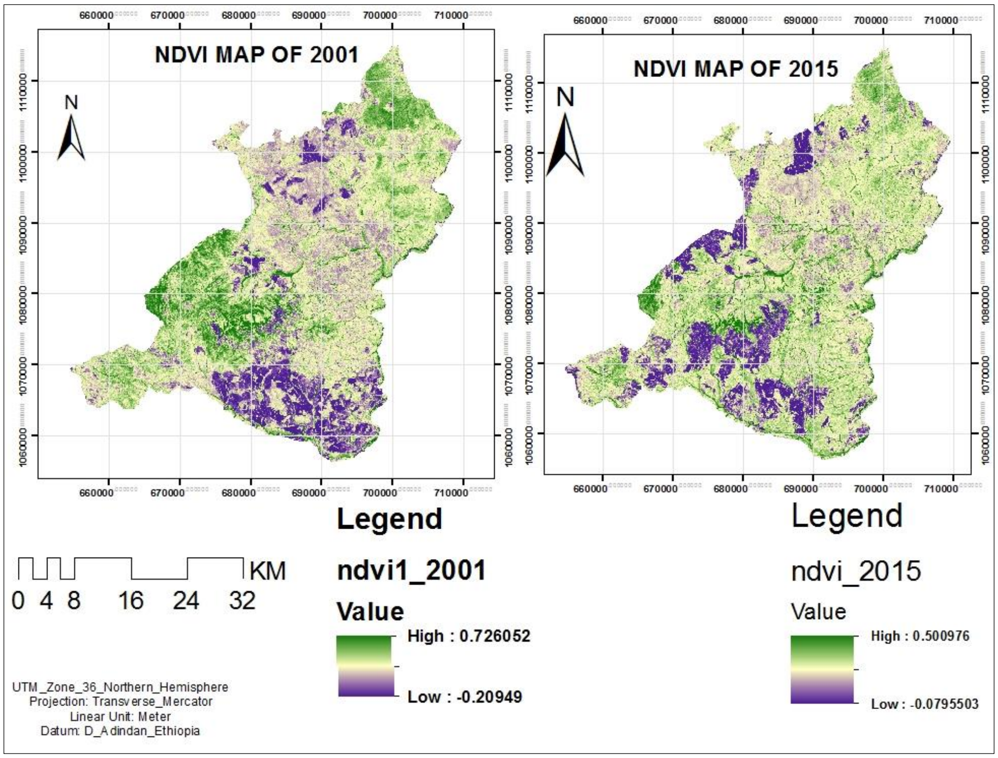


Figure 11: NDVI MAP OF BAMBASI WEREDA IN 2001 AND 2015

4.3. DRIVERS OF LAND USE/COVER CHANGE IN BAMBASI WEREDA

4.3.1. Impact of Anthropogenic activities on Land use/cover change

The anthropogenic activity is one of the factors which cause land use/cover changes in the study area. According to the 2007 population and housing census, Information on migration of a population is of direct interest to planning and implementing agencies as well as academic institutions, because migration has a direct effect on the geographic distribution of the population. Moreover, migration has an interaction with other demographic forces as well as other aspects of social and economic changes [44].

Population growth has long been considered as a major factor leading to land use/cover change [45]. For example during 1987-2001, the population increased from 28.062 thousand to 42.4 thousand in the study area. The growth rate of rural and urban were 2.23% and 4.11% per year, respectively, between 1984 and 1994. The same between 1994 and 2007 both urban and rural growth were at the rate of 3% per year. In addition to this between the year of 2001 and 2015 the populations of Bambasi Wereda increased from 42.4 thousand to 64.25 thousand, this means that throughout of 28 year, the study area populations has increased about 36.19 thousand.

Fast population growth and the consequent high pressure on resources are expected to have an adverse effect on the existing natural resources of the area. Such rapid population growth in the area has already exerted pressure on the existing land resources through increasing the demand for food, wood for fuel and construction purposes, and other necessities. Substantial increases in demand for food have resulted in an expansion of croplands by encroaching on uncultivated areas, including forests, shrub and marginal lands. The expansion of croplands toward forest, shrub and marginal lands, including continuous and over cultivation, has resulted in deforestation and soil degradation. Similarly, increased demands for fuel wood in the absence of alternative sources of energy have led to the destruction of forests [46]. According to the report of Getu (2011) based, the area covered with forest identified in Bambasi wereda were Anbessa Chaka, Mender 42 and Aba Moti Terara Forests. Despite the government's early initiation, an absence of responsibility and ownership developed by the community towards the forest has contributed to its destruction and damage, in spite of benefits brought about by its existence. Beside this in the study area Fires occur regularly. Communities ignite fires deliberately in order to hunt wild life, to harvest honey, and to collect wood. Large areas encompassing several kebeles can be affected by a fire and forest areas were also set alight for charcoal production. Degraded forest is widespread, especially close to the settlements. This may be due to the dry climate and the regular occurrence of fires [47]. This is the main causes of the clearance of 1320.93 ha forest cover in the Bambasi Wereda in the term of 28 year.

On the other hand, the reason for the increase urban or built-up land throughout the 28 year was firstly, due to the resettlement program in the study area. Because of the drought and famine in 1984, the government has been set in motion a resettlement policy that was initially designed to relocate 1.5 million people from areas in the north, most severely affected by drought and famine to areas in the west and south that had experienced adequate rainfall [48]. Secondly, the increase of population because this settlement schemes and through the opening new refugee camp in 2012 because of the war in south Sudanese. UNHCR and the regional government surveyed and selected a third refugee camp in Bambasi woreda which is 10 km to the south east direction of Bambasi town. It is large enough to be able to host up to 40,000 people, but immediate contingency plans are for a population of approximately 20,000. When the camp opens all new arrivals and all refugees in Ademazine transit Centre will be relocated to Bambasi Wereda [49]. And finally, the population growth of Bambasi Wereda between 1987 and 2001 was increased by 14.34 thousand which were 28.062 and 42.4 thousand in the year of 1987 and 2001, respectively. During the period of 2001-2015, the population increased by 21.85 thousand which were 42.4 and 64.25 thousand in the year of 2001 and 2015, respectively. The increase of population by 36.19 thousand throughout the study period there were the need of new houses, new cultivation and more generally basic needs. The comparison of urban and rural for instance, in 1987 urban dwellers were 2.812 thousand and rural dwellers were 25.251 thousand, respectively. And in 2001 urban and rural dwellers were increased to 5.122 and 37.278 thousand, respectively, and in 2015 the number of urban and rural dwellers were increased to 17.44 thousand and 46.81 thousand, respectively (shown on table 15).

Table 15: Population size of Bambasi Wereda between 1987 and 2015

Wereda Name	urban+rural	Urban	Rural
Bambasi 1987	28063	2812	25251
Bambasi 2001	42400	5122	37278
Bambasi 2015	64250	17440	46810

Source: Central statistics Agency of Ethiopia (CSA)

According to the reports of REDD+ (2015), currently, the deforestation and forest degradation is increasing mainly due to settlement programs and associated forest clearing to cropland expansion in lowland bamboo thicket since 1977 (Assosa, Bambesi and Pawe special Woredas), increased demand of fuel wood and construction. Earlier, deforestation was mainly caused by the government’s assistance to legal settlements of people from Amhara region following the severe 1984/85 famine in Ethiopia. During that year some 20,000 households were settled in Bembasi wereda. Several underlying causes of deforestation and forest degradation that include commercial agriculture investment, immigration, high population growth, weak institutional capacity for natural resource management, less public awareness and weak policy and legal frameworks. This report also shows that Wild fires are lit for several reasons, such as honey collection, searching for cavies, hunting, improvement of grazing lands, clearing new farm land and for charcoal making.

It is more unsustainable practice, as it requires uprooting of tree stumps and complete clearance of the former forest vegetation and root systems. As a consequence there are large tracts of lands impacted by erosion with substantial loss of fertile topsoil layers and rivers are filled with sediments. The major causes for deforestation and forest degradation twenty years ago were related to over grazing, bad farming practices, tree cutting for construction and fuel wood purposes, shifting cultivation and other wasteful use of natural resources [50].

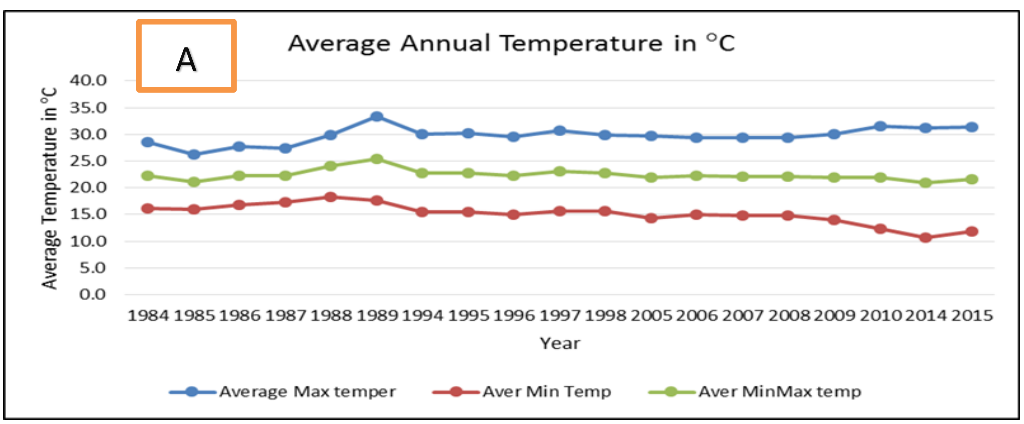
4.3.2. Impact of climate variation on Land use/cover change

The land use/cover change occurred due to different combined effect of anthropogenic and natural causes. Global warming causes a decrease in rainfall and an increase in extreme climate conditions, such as long periods of drought leading to severe water scarcity and increased desertification. Increased fuel loads, longer fire seasons and the occurrence of more extreme climate conditions as a consequence of a changing climate are expected to result in increased forest fire activity. A changing climate also alters the disturbance dynamics of native forest insect pests and pathogens, as well as facilitating the establishment and spread of introduced pest species. Such changes in disturbance dynamics, in addition to the direct impacts of climate change on trees and forest ecosystems, can have devastating effects and can increase forests' susceptibility to other disturbances [51].

Different researcher explain more the effects of anthropogenic on land use/cover causes but not explains direct or indirect impact of climate change on land use/cover change. But some of the researcher shows some direct and indirect impact of climate variation on the land use/cover change. For example on the reports of UNEP (2012) reveals that, Temperature and rainfall, in combination with topography and soils determine moisture availability which determines vegetation and agricultural productivity [15]. In addition to this Mohammed (2011) study reveals that deforestation stimulates higher accumulation of CO_2 (carbon dioxide) on the atmosphere, these would continue depleting the ozone layers, which caused an increase of temperature on the atmosphere. The current serious issue in the study area was higher increase of temperature and climate changes, which affect the day to day activities and continued its impact on social, economic and environments [52]. The report of FRA (2010), reveals that the Changes in the structure and functioning of natural ecosystems and planted forests (due to changes in temperatures and rainfall regimes) and extreme events and disasters. And also, Climate change – in particular increased temperatures and levels of atmospheric carbon dioxide, as well as changes in precipitation and the frequency and severity of extreme climatic events – is having notable impacts on the world's forests and the forest sector. Climate change is predicted to increase the likelihood of pest establishment in new locations and also to increase the severity of impacts of both native and introduced pests [51]. According to the reports of UNEP (2012), in the Middle and higher altitudes (above 1,500 meters) receive substantially greater falls than do the lowlands, except the lowlands in the west where rainfall is high. Generally average annual rainfall of areas above 1,500 meters exceeds 900 mm. In the lowlands (below 1,500 meters) rainfall is erratic and averages below 600 mm [15]. Many times do some humans and livestock alike drown in the floods which can rise quickly as a consequence of high rainfall in the highlands, which then comes flushing down the river and overflow large lowland areas in Gambella and Benishangul-Gumuz regions, in particular [50].

Temperature variation spatially and seasonally depends on latitude, altitude, humidity and wind regime. The average annual temperature and annual precipitation of Bambasi wereda are shown in Figure 12, which indicates that the temperature fluctuation was stable and smaller than the precipitation fluctuation. It is demonstrated by variations of monthly temperature and total precipitation in Figure 12, and precipitation reached the bottom in 1995 and then increased significantly. Based on this truth in Bambasi wereda the comparison of temperature and precipitation data within the time frame considered in this study, i.e. between 1987 and 2015, shows that the average minimum and maximum temperatures to be 10.6 ºC (in 2014) and 33.3 ºC (in 1989), respectively, (shown on figure 12 of A). The highest mean monthly temperature was recorded for the months of March (33 °C), April and February (32.6 ºC), January (31.5 ºC), May (30.4 ºC), and December (30 ºC) (shown on Appendices 1&2). The rainfall data between 1984 and 2015 shown in Figure 12 of C, are based on data from Bambasi wereda meteorological station. The total annual rainfall was between 891 mm and 2094 mm with mean annual rainfall throughout the study year in the Bambasi wereda. Four months (December, January, February and March) receive the least amount of rainfall. More than 76% of the total rainfall occurs between June and September (kiremt season), when cropping normally takes place. Twenty two percent of the total amount of rainfall occurs in the months of April, May, October and November. And less than 2% occurs in January, February, March and December (shown on figure 12 of B). The highest and lowest rainfall occurred in the years 1985& 1994 with annual rainfall of 2093.5 mm and 891.9 mm, respectively(shown on figure 12 of C).

The comparisons of rainfall and maximum temperature for the study period shows, during 1989 the average annual maximum temperature was recorded, and the annual rainfall was also recorded as high but after the year of 1989 through 2015 the annual average maximum temperature continues with the record between 25°C and 35°C, while the rainfall were decreased from 2000 mm to 1000 mm between 1989 and 2015. The increment of temperature and the decrement of rainfall have the negative impact on crop production, growth of vegetation, water level and generally sustainability food security on study area. And also causes forest fire through different mechanisms which then changed drought, degradation of forest, degradation of soil through flood or soil erosion.



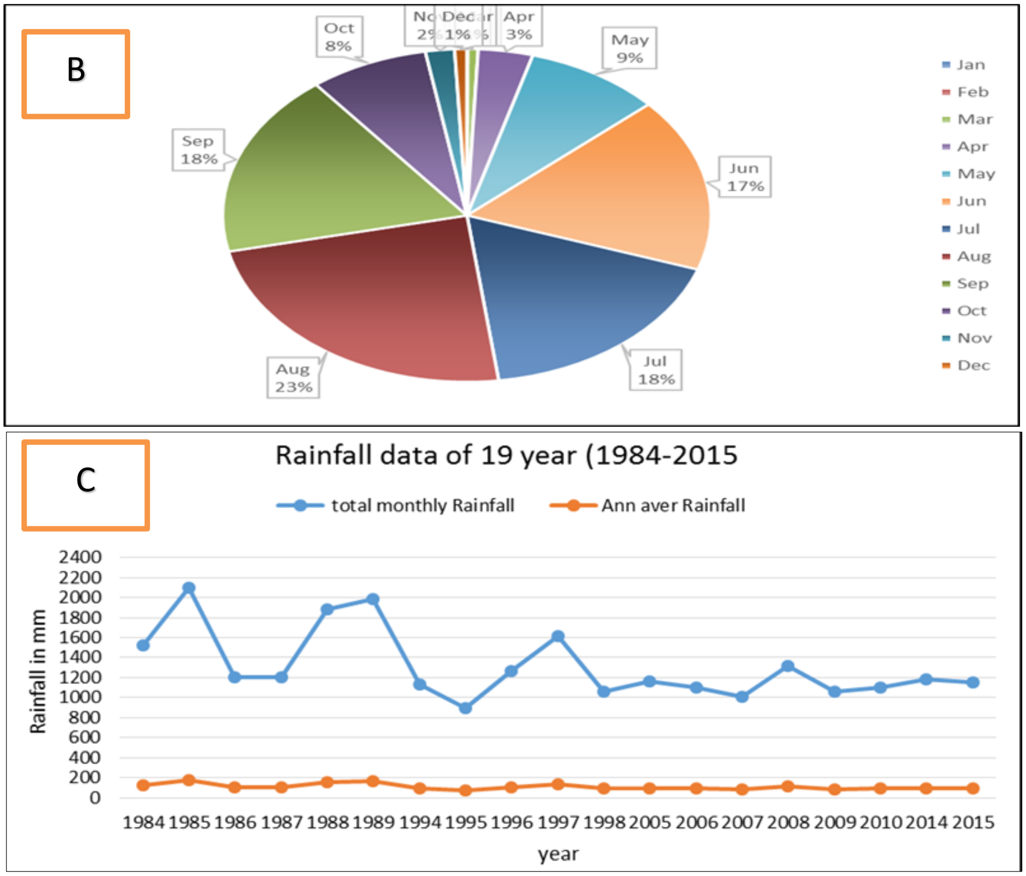


Figure 12: A, the Average temperature; and C, Percent of average Monthly rainfall B, the Average Rainfall in year (1984-2015) of Bambasi wereda

4.3.3. Land use/cover and NDVI Change and correlation with rainfall, temperature and Population growth analysis

During the time interval of 1987- 2001, urban or built-up land and range land increased by 291.60 and 6367.23 ha, respectively, and forest land, water bodies and barren land were decreased by 342.45, 0.99 and 6332.22 ha, respectively. The NDVI value also shows some changes, as the value of NDVI in 1987 shows high and low values which were 0.752932 and -0.542451, respectively. In 2001 this NDVI values with high and low have been decreased to 0.7260552 and -0.20949. During this time interval there were increase of urban or built-up land because of population growth from 28.063 thousand to 42.4 thousand from 1987 to 2001, respectively. The NDVI values have been decreased through the time span and forest cover have been noticed decline during the same time period was due to the increase of average temperature from 21.99 °C in 1984-1987 to 23.33 °C in the 1988-1998, and also because of decline in average rainfall from 125.4 mm (1984-1987) to 116.98 mm (1988-1998). During the period of (2001-2015), Urban or built-up land and range land increased by 662.04 ha and 8120.25 ha, respectively, and forest land, water bodies and barren land were decreased by 978.48 ha, 1.26 ha and 7785.72 ha, respectively. The value of NDVI with high and low value were 0.726052 and -0.20949 in the 2001 and 0.500976 and -0.0795503 in the 2015. Due to the growth of, urban or built-up land was increased between 2001- 2015. The increase of range land and decrease of forest land, NDVI value, water bodies and barren land were due to the decrease of average temperature from 23.33°C in 1988-1998 to 21.84°C in the 2005-2015, and also due to the decrease of average rainfall from 116.98 mm in the (1988-1998) to 94.64 mm in the (2005-2015). The NDVI value shows the existence of vegetation or biomass and also determines the greenness of the land when its value was above 0.1. Between periods of 1987 to 2015 the value NDVI decreased from 0.752932 to 0.500976 in year of 2015. These results of land use/cover changes in Bambasi wereda was because of the combined effect of population growth and its activity and climate (i.e. temperature and rainfall) during the past 28 year. Increasing urbanizations and change in land use/cover changes leads to global warming that disturbs the local climate conditions such as temperature and rainfall pattern and it ultimately impacts on natural landscape and vice-versa.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSIONS

This study has revealed that the recent advancements in spatial technology, namely remote sensing and GIS are powerful tools for evaluating land use and land cover changes. Various data types, specifically satellite images, rainfall, temperature, population size and related literature provided valuable data for this study. The foundation of this research comprises the impact of anthropogenic activities and climate on the land use/cover change between 1987 and 2015 for the study area of Bambasi weredea. The study covers over the past 28 years with the time period of 1987, 2001 and 2015. This time periods were chosen based on the availability of satellite imageries for classification and change detection.

The results of the analysis shows that interpretations accuracy of the land use/cover categories of the time 1987, 2001 and 2015 were 89.57%, 88.60% and 86.59%, respectively.

The comparison made for the results of Land use/cover change of different categories shows variation during the two periods, 1987 to 2001 and 2001 to 2015. The tabulation or transition matrices highlight the dominant dynamic events and the internal conversions between land use/cover types during the study period and reveal two distinct transition phases. During the first time interval (i.e. 1987-2001) urban or built-up land was increased by 21.95% through acquired of range land and barren land. The increase built-up land was occurred as a results population growth from 28.063 thousand 42.4 thousand between the year of 1987 and 2001. On the other hand, range land increased by 9.13% at the expense of forest cover, water bodies and barren land. The increase of range land and decrease of forest land, water bodies and barren land were due to the increase of average temperature from 21.99 °C in 1984-1987 to 23.33 °C in the 1988-1998. And also the NDVI values and average rainfall have noticed with decreased from 125.4 mm in the (1984-1987) to 116.98 mm in the (1988-1998). During the second time interval (i.e. 2001-2015), urban or built-up land has increased by 40.86%. The increase of urban or built-up land occurred as a results of population growth from 42.4 thousand to 64.25 thousand between the 2001 and 2015 time interval. And also, the range land had increased by 10.67% at the expense of barren land and forest land. Interestingly, during 1987-2015 time period, the increased of range land and the decrease of forest land, barren land and water bodies resulted from climate variation like temperature and rainfall through the human activities such as unrated wildfire, agricultures land expansion, shifting cultivation, and grazing, charcoal production for fuel, wood for fuel and wood for construction of house.

Land Use/Cover changing aspects is a result of complex interaction between several anthropogenic activities and natural causes through climate variation (temperature and rainfall). The effects of human activities are immediate and often radical. The difference in increase by population and land cover change indicates the pressure on land use/cover and related biodiversity. This infers that population pressure is believed to be one of the major driving forces for the changes in the study area. This case study analysis indicates that the impact of anthropogenic activities and climate are believed to be the major driving force for the change of land use/cover and vice-versa in the Bambasi wereda. The NDVI values were decreased throughout the time period. The urban land and other landscape changes have been noticed through climate and human activities for development in Bambasi wereda.

5.2. RECOMMENDATIONS

In the study area Bambasi wereda there has been land use and land cover changed observed during the last 28 year of period. As the study area is located in the low land area, where relatively high rainfall and high temperature are found, which causes land use/cover change (particularly, forest cover) influenced the area along with the human factors. In particular, land managers and others may need to assess whether changes in climate would push advantageous LULC conditions beyond the point that they provide the necessary goods and services. Future LULC management strategies may require methods that incorporate an Evaluation of how climate and LULC change effects can combine to influence a wide range of social and economic benefits as well as ecological factors such as the migration of species, shifting mosaics of wetlands, and disturbances on climate-biology relations [7]. Therefore, the following recommendations are required to improve the land use and land cover status of the study area of Bambasi wereda.

- Improving the productivity of the agricultural sector through technical intervention, creating off-farm employment opportunities for the population, and reducing human and livestock population pressure on the land. The local people must be involved in all development activities and resource conservation in order to ensure sustainability.
- Establishing appropriate institutional arrangement/ framework with adequate budget and trained man power is important to develop and implement sustainable forest resource management programs at all levels.
- Restricting population growth to reduce the pressure on land use/cover change through teaching of family planning for urban and rural dwellers.
- Encouraging greater involvement of the civil society in forestry activities at both the wereda and kebele level and acknowledging/rewarding those individuals/institutions with better performance in forest rehabilitation is important.
- Priority should be given to preventing forest degradation – including by limiting grazing in forest lands – and promoting a forestation and reforestation (including trees outside forests) for environmental protection and local wood supply, especially fuel wood.
- Since forest influences water quantity and especially quality, managing the forest for water conservation is an appropriate goal. Forestry decision-makers need to promote the incorporation of forest management in national and regional strategies, plans and programs related to river, watershed and groundwater management; and to work with international and national organizations and institutions to increase understanding of hydrological and environmental services of forests.
- A continuous monitoring system could be possible made to understand the Land use/cover changes and to identify the areas under Land use/cover change in study area
- It may be note that land use/cover change analysis in Bambasi wereda with GIS and Remote Sensing techniques may help the policy maker of the government and the local authority for development of the certain area.
- The wereda administrative should have to give training for the community about the impact of forest fire, ways to increase crop productions, ways to conserve the remaining forest, family planning, effects of shifting cultivation and extra.

REFERENCES

[1] E.F. Lambin et al, "The causes of land-use and land-cover: Moving beyond the myths," *Global Environmental Change,* p. 261–269, 2001.

[2] E.F. Lambin et al., "Are agricultural land-use models able to predict changes in land-use intensity?," *Agriculture, Ecosystems and Environment,* p. 321–331, 2000.

[3] A. O. ZUBAIR, "CHANGE DETECTION IN LANDUSE AND LAND COVER USING REMOTE SENSING DATA AND GIS (A case study of Ilorin and its environs in Kwara State.)," *A PROJECT SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY, UNIVERSITY OF IBADAN IN PARTIAL FULFILMENT FOR THE AWARD OF MASTER OF SCIENCE (MSc) DEGREE IN GEOGRAPHICAL INFORMATION SYSTEMS,* no. MATRIC NO. 131025, 2006.

[4] F. Gurmessa, "Forest loss and climate change in Ethiopia," *Research Journal of Agriculture and Environmental Management.,* vol. Vol. 4(5), no. ISSN 2315 - 8719© 2015 Apex Journal International, pp. pp. 216-224,, 2015.

[5] A. P. Forum, "Climate Change and Africa:," in *8th meeting of the Africa partnership forum*, Berlin, Germany. Pp. 28., 2007.

[6] St e f f e n, Global Change and the Earth System, A Planet Under Pressure, Stockholm: The IGBP Series, 2003.

[7] USGS, "National Climate Assessment Technical Report on the Impacts of Climate and Land Use and Land Cover Change," USGS, Virginia, 2012.

[8] B. MAJUMDER, "LAND USE AND LAND COVER CHANGE DETECTION STUDY AT SUKINDA VALLEY USING REMOTE SENSING AND GIS," *A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF TECHNOLOGY, DEPARTMENT OF MINING ENGINEERING NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA ,* 2010.

[9] Mahmoodzadeh, "Digital Change Detection Using Remotely Sensed Data for Monitoring Green Space Destruction in Tabriz," *Int. J. Environ., Management and Planning Organization of East Azerbaijan Province, Tabriz, Iran,* Vols. 35-41, no. ISSN:1735-6865, p. Res. 1 (1), 2007.

[10] D.P. Roy et al., "Landsat-8: Science and product vision for terrestrial global change research," *Remote Sensing of Environment,* pp. 154-172, 2014.

[11] Ross S. Lunetta et al., "Land-cover change detection using multi-temporal MODIS NDVI data," *Remote Sensing of Environment,* p. 142–154, 2006.

[12] A. Singh, "Digital change detection techniques using remotely-sensed data," Vols. 10:6, 989-1003, 1989.

[13] T. S. a. E. L. C. Petit et al., "Quantifying processes of land-cover change by remote sensing:resettlement and rapid land-cover changes in south-eastern Zambia," *int. j. remote sensing , 2001 , vol. 22, no. 17,,* 2001.

[14] Susan K. Maxwell and Kenneth M.Sylvester, "Identification of“ever-cropped”land (1984–2010) using Landsat annual maximum NDVI image composites: Southwestern Kansas case study," *Remote Sensing of Environment,* vol. 121, p. 186–195, 2012.

[15] UNEP, "Capacity building for Access and Benefit Sharing and Conservation and Sustainable Use of Medicinal Plants (Ethiopia ABS CSUMP)," Institute of Biodiversity Conservation (IBC)/Ethiopian Environmental Protection Agency (EPA), Ethiopia, 2012.

[16] R. COFFEY, "The Difference Between Land use and Land cover," 2013.

[17] A. D. G. a. L. J. Jansen, "Land Cover Classification System Classification concepts and user manual Software version2," *FAO/UNEP,* 2005.

[18] William B.Meyer and B.L.Turner.II, "HUMAN POPULATION GROWTH AND GLOBAL LAND-USE/COVER CHANGE," *Annu.Rev.Ecol.Syst.,* vol. 23, pp. 39-61, 1992.

[19] s. rahmstorf, "Anthropogenic Climate Change: Revisiting the Facts," 2005.

[20] A. S. K. Oroda, "THE IMPACT OF INCREASED POPULATION AND SEDENTARIZATION OF THE PASTORAL COMMUNITIES ON THE LAND COVER AND THE RESOURCES OF MOUNT MARSABIT FOREST AND THE SURROUNDING LANDS," *A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTER OF ENVIRONMENTAL SCIENCES, KENYATTA UNIVERSITY,* 2011.

[21] Awoniran D. R. et al., "Assessment of environmental responses to land use/land cover dynamics in the Lower Ogun River Basin, Southwestern Nigeria," *African Journal of Environmental Science and Technology,* pp. 152-165, 2014.

[22] CIAT and GCP, "Climate Change and Land Use Change in Amazonia, A report for the Amazonia Security Agenda Project," International Center for Tropical Agriculture (CIAT) and the Global Canopy Programme (GCP), Brazil, 2013.

[23] a. Behailu, "Land Use and Land Cover Analysis and Modeling in South Western Ethiopia: The Case of Selected Resettlement Kebeles in Gimbo Woreda," *Addis Ababa University School Of Graduate Studies,* 2010.

[24] M. D. NETSANET, "LAND USE AND LAND COVER CHANGES IN HARENNA FOREST AND SUROUNDING AREA, BALE MOUNTAINS NATIONAL PARK, OROMIA NATIONAL REGIONAL STATE,ETHIOPIA.," 2007.

[25] Ardavan Ghorbani, Amir Mirzaei Mossivand and Abazar Esmali Ouri, "Utility of the Normalised Difference Vegetation Index (NDVI) for land/canopy cover mapping in Khalkhal County (Iran)," *Annals of Biological Research,* vol. 12, no. ISSN 0976-1233 , pp. 5494-5503, 2012.

[26] Bayes Ahmed, Md. Kamruzzaman, Xuan Zhu, Md. Shahinoor Rahman and Keechoo Choi , "Simulating Land Cover Changes and Their Impacts on Land Surface Temperature in Dhaka, Bangladesh," *Remote Sens. ,* vol. doi:10.3390/rs5115969, no. ISSN 2072-4292, pp. 5969-5998; , 2013.

[27] K. Abdullahi and Lalit, "Investigating the Use of Remote Sensing and GIS Techniques to Detect Land Use and Land Cover Change: A Review," *Advances in Remote Sensing,* pp. 193-204, 2013.

[28] A.-H. a. R. Bill, "LAND COVER CHANGES IN THE REGION OF ROSTOCK - CAN REMOTE SENSING AND GIS HELP TO VERIFY AND CONSOLIDATE OFFICIAL CENSUS DATA?," *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B8. Beijing ,* 2008.

[29] A. D. WALLELIGN, "ASSESSMENT OF LAND USE LAND COVER DYNAMICS AT BALE MOUNTAINS NATIONAL PARK USING GIS AND REMOTE SENSING," *Science in GIS and Remote Sensing in Earth Sciences,* 2007.

[30] Burnicki et al., "Propagating error in land-cover-change analyses: impact of temporal dependence under increased thematic complexity," *International Journal of Geographical Information Science,* pp. Vol. 24, 1043–1060, 2010.

[31] H. T. a. M. K. Tran et al., "Dynamics of Land Cover/Land Use Changes in the Mekong Delta, 1973–2011: A Remote Sensing Analysis of the Tran Van Thoi District, Ca Mau Province, Vietnam," *Remote Sens.,* pp. 2899-2925; doi:10.3390/rs70302899, 2015.

[32] R. V. J. V. O. S. T. J. W. T. L. P. Willekens, Introduction to Satellite Remote Sensing, LEUVEN, 2005.

[33] NASA, "findig or downloading Landsat Data From the U.S. Geological Survey's Global Visualizations Viewer Website," *tutorial,* 2013.

[34] T. A. S. a. S. S. Subhash et al., "Comparison of Different Image Classification Techniques for Land Use Land Cover Classification: An Application in Jabalpur District of Central India," *International Journal of Remote Sensing and GIS,* pp. 26-31, 2012.

[35] K. J.S. Rawat and Manish, "Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand,India," *The Egyptian Journal of Remote Sensing and Space Sciences,* p. 77–84, 2015.

[36] J. R. ,. E. .. H. J. T. .. R. a. R. E. .. W. ANDERSON et al., A Land Use and Land Cover Classification System for Use with Remote Sensor Data, WASHINGTON: UNITED STATES GOVERNMENT PRINTING OFFICE, 1976.

[37] B. S. Muzein, "Remote Sensing & GIS for Land Cover/ Land Use Change Detection and Analysis in the Semi-NaturalEcosystems and Agriculture Landscapes of the Central Ethiopian Rift Valley," 2006.

[38] R. G. Congalton, "A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data," *REMOTE SENS. ENVIRON.,* pp. 37:35-46, 1991.

[39] A. S. G. C. Md. Obaidul Haque, "Radiometric & Geometric Assessment of the Data from RapidEye Constellation of Satellites," in *JACIE Meeting*, USA, 2010.

[40] L. a. Munafò, "Development of a Methodology for Land Cover Classification in Dar es Salaam using Landsat Imagery," *Adapting to Climate Change in Coastal Dar es Salaam Project,* pp. 254-773, 2012.

[41] J. S. a. J.-C. J.-M. n. Y. Julien et al, "Land use classification from multitemporal Landsat imagery using the Yearly Land Cover Dynamics (YLCD) method," *International Journal of Applied Earth Observation and Geoinformation,* p. 711–720, 2011.

[42] Peng Li et al., , "Cross-Comparison of Vegetation Indices Derived from Landsat-7 Enhanced Thematic Mapper Plus (ETM+) and Landsat-8 Operational Land Imager (OLI) Sensors," *Remote Sens.,* pp. 310-329, 2014.

[43] K. T. S. D. T. T. K. Mengistie et al., "Land Use/Land Cover Change Analysis Using Object-Based Classification Approach in Munessa-Shashemene Landscape of the Ethiopian Highlands," *Remote Sens. ;,* pp. volume 5, 2411-2435, doi:10.3390/rs5052411, 2013.

[44] CSA, "Summary and Statistical Report," United Nations Population Fund (UNFPA), Addis Ababa, 2007.

[45] Xing Wu et al, "Land Use/Cover Dynamics in Response to Changes in Environmental and Socio-Political Forces in the Upper Reaches of the Yangtze River, China," *Sensors,* pp. 8104-8122, 2008.

[46] D. A. Mengistu, "Remote sensing and gis-based Land use and land cover change detection in the upper Dijo river catchment, Silte zone, southern Ethiopia, Working papers on population and land use change in central Ethiopia, nr. 17," NUFU-funded research and collaboration , Addis Ababa, 2008.

[47] Z. Getu, "Strengthening Sustainable Livelihoods and Forest Management Programme (SSLFM)," FARM-Africa and SOS Sahel, Addis Ababa, 2011.

[48] B. G. MORODA, "THE IMPACT OF RESETTLEMENT ON WOODLAND VEGETATION: THE CASE OF CHEWAKA RESETTLEMENT AREA, SOUTHWESTERN ETHIOPIA," *ENVIRONMENTAL SCIENCE PROGRAM ,* 2007.

[49] D. Masika, "Emergency appeal operation update Ethiopia: Population Movements," International Federation of Red Cross and Red Crescent Societies, Asosa, Benishangul-Gumuz region, 2012.

[50] REDD+, "Study of causes of deforestation and forest degradation in Ethiopia and the identification and prioritization of strategic options to address those," Oy Arbonaut Ltd,The Federal Democratic Republic of Ethiopia, REDD+ Secretariat, Ministry of Environment and Forest, Ethiopia, 2015.

[51] FRA, "Global Forest Resources Assessment," FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, Rome, 2010.

[52] A. MOHAMMED, PERCEPTION OF LOCAL COMMUNITY TOWARDS DEFORESTATION: THE CASE OF EDIGETBER AND SELAMBER KEBELE AROUND WOLKITE TOWN, GURAGE ZONE, SNNPRS, ADDIS ABABA: Addis Ababa University, 2011.

[53] E. Y. Akingbaso, "Land Use - Cover Change Assessment Framework: Famagusta North Cyprus," 2014.

[54] Atalel Getu Sahalu, "ANALYSIS OF URBAN LAND USE AND LAND COVER CHANGES: A Case Study in Bahir Dar, Ethiopia," 2014.

[55] A. a. J. L. J. Di Gregorio, " Land cover classification system: LCCS: classification concepts and user manual," *Food and Agriculture Organization of the United Nations Rome.,* 2000.

[56] FAO/UNEP, "The Future of Our Land FACING THE CHALLENGE," *FAO/UNEP,* 1999.

[57] A. P. K. P. P. K. M. S. S. Palmate, "Climate change impact on forest cover and vegetation in Betwa Basin, India," 2014.

[58] Brown et al., "Modeling the relationships between landuse and landcover on private lands in the Upper Midwest, USA," *Journal of Environmental Management (2000)59,247–263,* 2000.

[59] J. Li, "Analysis of Land Use and Land Cover Changes, and Their Ecological Implications in Wuhan, China," *Journal of Geography and Geology,* 2011.

[60] CSA, The 1994 population and housing census of Ethiopia for Benishangul-gumz region volume I statistical report, Addis Ababa: CSA, 1996.

[61] FAO, "Global Forest resources assessment 2015, How are the world’s forests changing?," ROME, 2015.

Appendices 1: Monthly Maximum Temperature of Bambasi Wereda from 1984-2015

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1984	30.9	33	32.9	32.7	29.6	24.7	25.2	26.1	26	27.4	26.7	26.4	28.5
1985	25.9	27	27.1	25.2	25.3	25.9	26.2	26.5	26	26.5	25.9	26.9	26.2
1986	27.9	30	31.2	31.9	28.4	26.3	25.7	25.4	26	25.9	26.8	27.2	27.7
1987	28.2	29	27.8	28.1	26.8	26.1	26.2	26.8	27	27.5	27.9	28.4	27.4
1988	28.4	29	30.1	30	29.8	30.4	29.9	28.3	28	28.4	28.8	36.6	29.8
1989	37.7	37	38.6	39.7	39.2	36.4	27.7	26.6	27	27.1	28.7	34.5	33.3
1994	33.6	33	32.4	35.1	36.2	25.8	25.1	25.9	27	28.4	28	30.5	30.1
1995	32	33	33.2	32.7	31.7	28.9	27.4	27.1	28	28.8	29.6	30.5	30.2
1996	30.6	34	33.6	32.4	28.3	27.1	26.5	26.2	28	28.6	29.1	30.3	29.5
1997	31.6	33	33.2	33.4	30.6	29.3	28.5	27.2	30	30.7	30.9	29.9	30.6
1998	32.6	34	32.5	31.8	32.1	29.8	27.6	25.3	29	27.8	28.6	28.7	29.9
2005	31.7	33	33.1	32.4	30.5	28.6	25.6	26.1	27	27.5	30.4	29.8	29.7
2006	32.8	33	33	32.3	29.7	27.8	25.8	25.6	27	28.1	28.9	30.3	29.4
2007	31.5	33	33.7	32.5	28.1	26.4	25.3	25.9	27	29.2	29.4	30.5	29.4
2008	32	33	33.8	29.5	28.2	27.1	25.8	26.5	28	28.1	30.3	29.9	29.3
2009	33	34	34.8	32.5	29.3	28.5	26.7	27.1	29	27.4	28.8	29.1	30.0
2010	32.3	34	35.2	36.2	30.5	33.2	32.1	26.9	29	29	30.1	28.8	31.5
2014	31.9	34	34.6	35.8	31.1	32.3	30.8	28.4	26	27.6	30.8	31.3	31.2
2015	33.1	35	35.5	36.1	32.5	29.7	27.4	29.7	27	29.3	29.9	30.5	31.4
Average	31.5	32.6	33.0	32.6	30.4	28.6	27.1	26.7	27.4	28.1	28.9	30.0	

Source: National Meteorology Service Agency (NMSA)

Appendices 2: Monthly Minimum Temperature of Bambasi Wereda from 1984-2015

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1984	15.6	15.4	16.6	17.6	16	16.9	15.2	15.4	16	17	15.7	16.1	16.1
1985	15.8	16.7	17.1	15.2	14.9	15.7	16	15.9	16	15.7	15.9	16.5	16.0
1986	17.6	18.6	18.3	17.9	17.9	16.2	15.5	15.1	15.4	15.6	16.8	16.9	16.8
1987	18.2	18.1	17.7	17.2	16.6	16.4	15.9	16.9	16.9	16.8	17.8	18.1	17.2
1988	18.2	18.4	18.7	18.8	18.7	18.7	18.4	17.4	17.2	17.3	17.9	18.8	18.2
1989	18.8	18.3	18.3	18.9	18.7	17.5	16.7	16.5	16.1	17.2	16.5	17.7	17.6
1994	14.6	15.8	16.9	17.2	17	16.4	15.2	15.3	15.2	14.4	14.3	13.2	15.5
1995	14.7	15	16.2	16.1	17.1	16.5	15.5	15.4	15.6	14.3	15	13.5	15.4
1996	14.4	15.5	15.6	15.8	16.1	15.8	15.5	14.9	15.1	14.5	13.8	13.6	15.1
1997	15	15.9	16.4	16	16	14.9	15.3	15.8	15.9	15.8	15.9	14.4	15.6
1998	15.8	16.5	17.3	19.2	15.7	15.2	15.6	16	15.5	15.3	13.4	12.9	15.7
2005	12.4	14.7	15.3	16.1	13.9	14.5	15.3	13.5	15.3	14.7	12.9	13.7	14.4
2006	12.7	14.4	15.9	15.8	16.7	16	16.1	15.4	15.6	14.8	12.6	13.3	14.9
2007	11.6	14	16.1	16.3	16.3	15.7	15.8	15.4	15.1	14.3	12.9	13.5	14.8
2008	13.2	13.9	15.8	15.8	15.8	15.5	15.3	15.8	15.4	14.6	12.7	14	14.8
2009	13.2	14.8	15.7	15	13.7	14.2	11.4	14.3	13.9	14.2	12.3	14.6	13.9
2010	14.5	14.7	15.6	16.1	12.5	10.5	10.5	10.2	11.3	10.7	9.8	12.3	12.4
2014	6.7	10.9	13.5	14.2	12.6	11.3	12	11.9	9.4	11.1	7.7	6.1	10.6
2015	9.3	10.2	13.7	14.5	13	12.1	13.3	12.6	10.5	12.3	10.4	9.9	11.8
Average	14.3	15.4	16.4	16.5	15.7	15.3	15.0	14.9	14.8	14.8	13.9	14.2	

Source: National Meteorology Service Agency (NMSA)

Appendices 3: Monthly rainfall of Bambasi wereda of 19 years (1984-2015)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	Average
1984	0.0	3.3	3.0	30.0	83.2	364.2	182.0	452.7	235.8	93.0	55.7	17.0	1519.9	126.7
1985	0.0	0.0	9.1	150.0	132.4	279.0	482.3	575.1	187.6	109.0	19.0	150.0	2093.5	174.5
1986	0.0	0.0	0.0	46.6	17.5	355.6	242.7	271.0	172.0	94.9	0.0	0.0	1200.3	100.0
1987	0.0	0.0	1.8	54.3	186.2	196.0	305.7	212.0	115.2	119.6	12.9	0.0	1203.7	100.3
1988	0.0	0.0	19.8	49.5	80.0	184.6	60.6	526.1	773.8	168.0	0.0	17.2	1879.6	156.6
1989	0.0	0.0	0.0	38.7	44.9	212.4	486.7	463.4	522.7	139.7	63.7	12.7	1984.9	165.4
1994	0.0	0.0	18.2	29.8	65.7	180.9	150.7	277.6	287.0	110.2	13.5	0.0	1133.6	94.5
1995	0.0	0.0	19.0	28.3	88.4	163.5	154.9	199.9	130.1	53.7	50.5	3.6	891.9	74.3
1996	0.0	0.0	28.9	31.9	189.9	222.1	272.7	221.7	229.9	61.9	2.3	0.0	1261.3	105.1
1997	0.0	0.0	30.4	59.8	98.7	277.5	268.6	446.5	173.1	163.8	93.2	0.0	1611.6	134.3
1998	0.0	0.0	18.4	12.6	89.2	193.8	220.1	272.8	164.7	49.7	42.5	0.0	1063.8	88.7
2005	0.0	0.0	15.4	26.7	121.8	162.7	224.2	283.4	161.5	107.5	59.4	0.0	1162.6	96.9
2006	0.0	0.0	0.0	32.5	138.3	156.1	193.2	267.1	157.0	157.6	0.5	0.0	1102.3	91.9
2007	0.5	0.0	0.0	81.0	145.8	180.3	162.9	200.6	157.3	68.7	12.8	0.0	1009.9	84.2
2008	9.9	0.0	3.5	96.5	220.2	225.1	230.1	255.7	172.2	90.8	9.0	0.0	1313.0	109.4
2009	0.0	0.0	3.4	56.2	139.5	219.3	169.8	199.6	162.1	101.0	7.8	0.0	1058.7	88.2
2010	0.0	0.0	0.0	7.5	127.8	245.3	204.3	265.2	159.7	86.6	6.7	0.0	1103.1	91.9
2014	0.0	0.0	0.0	39.6	140.2	198.4	196.7	252.1	250.9	95.2	12.3	0.0	1185.4	98.8
2015	0.0	0.0	0.0	28.9	136.8	201.8	189.5	239.7	248.8	90.7	17.5	0.0	1153.7	96.1
Average	0.5	0.2	9.0	47.4	118.2	222.0	231.5	309.6	234.8	103.2	25.2	10.6		

Source: National Meteorology Service Agency (NMSA)