ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

SCHOOL OF EARTH SCIENCES

ANALYSING THE RELATIONSHIP OF CLIMATE CHANGE AND VEGETATION COVER CHANGE OVER THE LAST THREE DECADES. IN CASE OF CHILIMO FOREST, WEST SHEWA ETHIOPIA

A Thesis Submitted to The School of Graduate Studies of Addis Ababa University in Partial Fulfilment of the Requirements for The Degree of Masters of Science in Remote Sensing and Geoinformatics

By

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Addis Ababa, Ethiopia

September, 2021

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This is to certify that thesis prepare by **AJEMA NEGESA,** entitled: **"Analysing the relationship of climate change and vegetation cover change over the last three decades. In case of Chilimo Forest, West Shewa Ethiopia"** and submitted in partial fulfillment of the requirements for the degree of Masters of Science in Remote Sensing and Geoinformatics complies with the regulations of the University and meets the accepted standards with respect to the originality and quality.

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DECLARATION

I hereby declare that the dissertation entitled "Analysing the Relationship of Climate Change and Vegetation Cover Change over the last three decades. In case of Chilimo Forest, West Shewa Ethiopia" has been conducted by me under the supervision of Dr. K.V. Suryabhagavan and Dr. Tibebu Kassawmar, school of Earth Science, Addis Ababa during the year 2019 – 2021 as a part of Master of science programme in Remote sensing and Geoinformatics. I further declare that this work has not been submitted to any other university or institution for the award of any degree or diploma.

Place: Addis Ababa

Date: September, 2021

Ajema Negesa

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Acronyms and Abbreviations

ACZ	Agro-climatic zone
CHIRPS	Climate Hazards InfraRed precipitation with Stations
CHIRTS	Climate Hazards InfraRed Temperature with Stations
DEM	Digital Elevation Model
FAO	Food and Agricultural Organization
GHG	Green House Gas
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
LULC	land-use Land-cover
MK	Mann-Kendall
MoA	Ministry of Agriculture
NDVI	Normalized Deference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
OLI-TIRS	Operational Land Image and Thermal Infrared Sensor
SVM	Support Vector Machines
TM	Thematic Mapper
UNFCCC	United Nations Convection on Climate Change
USGS	United States Geological Survey
WBG	World Bank Group
WGS	World Geodetic System
WBG	World Bank Group
XLSTAT	Statistical Software for Microsoft Excel

Abstract

This study was conducted to investigate the relationship of climate change (described in terms of rainfall and temperature) with vegetation cover in Chilimo Forest, over the last three decades from 1990 to 2020. Multi-temporal Landsat imageries of 1990, 2000, 2010 and 2020, Climate Hazard group InfraRed Temperature with Stations (CHIRTS) and Climate Hazard group InfraRed Rainfall with Stations (CHIRPS) were used for this study. Field data and google earth were used to verify remote sensing data. In order to prepare LULC map of the study area support vector machine classification was applied. Accordingly, Pearson correlation coefficient was computed to analyses and quantify the relationship of rainfall and temperature with forest cover, shrubland, grassland and wetland. Mann-Kendall trend test was used to analysis non-parametric trend analysis for rainfall of 1990 to 2020 and temperature of 1990 to 2016. The result examined that there was 6599.16ha (29.43%), 6059.90ha (27.03), 6185.25ha (27.59%) and 5671.37ha (25.29%) of forestland, 1333.98ha (5.95%), 1693.35ha (7.55%), 1028.52ha (4.59%) and 1189.35ha (5.3) of shrubland, 953.31ha (4.25%), 850.89ha (3.79%), 736.23ha (3.28%) and 527.58ha (2.35%) of grassland and 66.78ha (0.3%), 63.09ha (0.28%), 41.22ha (0.18%), and 20.16ha (0.09%) of wetland coverage in 1990, 2000, 2010 and 2020, respectively. Additionally, the result exhibited that natural high forest, shrubland, grassland, wetland and bare land were declined by 2.7%, 0.64%, 1.9%, 0.2%, and 2.21% over the study area from 1990 to 2020. However, the result showed crop land was increased by value of 3.77%, 5.38%, and 1.59% consequently over the study period. Moreover, trend analysis result exhibited that mean, minimum, and maximum dry season and wet season mean and minimum temperature was increased in the study area. The Sen's slope shows mean, minimum and maximum dry season temperature trend analysis result revealed increasing trend with 0.028 ^oC $yr.^{-1}$, 0.036 ^oC $yr.^{-1}$ and 0.031 ^oC $yr.^{-1}$ respectively while wet season maximum temperature analysis result indicated decreasing trend by 0.016 ^oC $yr.^{-1}$ from 1990 to 2016. In contrast, trend analysis result of mean, minimum and maximum dry season rainfall shown decreasing trend with factor of 2.075, 0.067 and 3.52 while annual rainfall trend analysis result examined decreasing and increasing trend from 1990 to 2020. Mann-Kendall trend test analysis for wet and dry season temperature and annual rainfall result was shown increasing trend. Whereas, dry season rainfall Mann-Kendall trend test analysis result shows increasing decreasing trend. Hence, coefficient of determination (R^2) for forest cover, shrubland, grassland and wetland with annual and dry season rainfall result exhibited that R^2 = 0 .61, R^2 = 0 .57, R^2 = 0 .95, R^2 = 0 .62 and R^2 = 0 .98, R^2 = 0 .01, R^2 = 0 .73, R^2 = 0 .28, respectively. Besides, the result examines LULC of the study area was gradually changing for the last three decades since 1990. From the findings of the result there was variability of annual and dry season rainfall as well as wet and dry season temperature over the study area. Based on this finding's vegetation cover were influenced by the effect of rainfall and temperature change which examined in western, north-eastern and central part of the study area. The consequence of examined land-cover change as well as variability of rainfall and temperature cause land degradation, deforestation and loss of forest resource. Indeed, implementing local level land-use planning and community based natural resource management implementation system is recommended to monitor, conserve and rehabilitate vegetation cover.

Key words: Chilimo; Forest biodiversity; Mann-Kendall trend test; Rainfall; Temperature

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Climate is the long-term average of weather indicators across large regions and usually calculated over a 30-year time period for a particular region and period (Shako, 2015; U.S. Environmental Protection Agency, 2016). It refers to regular weather conditions of a particular area and climate change involves changes in the frequency and magnitude of extreme events. The climatic parameters include temperature, rainfall, humidity, sunshine hours, cloudiness, pressure, rainfall, number of rainy days, wind velocity, and others (Patle *et al*., 2019). Any change in one parameter affects the other directly or indirectly and, in turn, it affects the living organisms by unbalancing the ecology of the physical environment (Palmate *et al.*, 2014; Patle *et al*., 2019).

Climate change is the global phenomenon of climate transformation characterized by the changes in the usual climate of the planet regarding temperature, precipitation, wind and other that especially caused by human activities. Rainfall and temperature pattern are varying and, atmospheric carbo dioxide concentrations are increasing due to anthropogenic activities contributing to climate change, which it is resulting in increasing air temperature and changing precipitation regimes, including changes to snowfall and the timing, amount, and inter-annual variability of rainfall (IPCC 2013; IPCC, 2014). Climate change is indisputable, the interactions between climate change, and terrestrial ecosystems have been enduring and accepted as one of the major issues in global change research.

Population dynamics have been a major driver of land-cover change, including forest loss, which leads to climate change in the country. The increase in human population and economic development significantly increases more pressure on forest resource and agricultural lands, arable land, water, energy, a biological resource to provide an adequate supply of food while maintaining the integrity of our system (Palmate *et al.,* 2014; Yan *et al*., 2018). It argued that increased the human effects on biodiversity through environmental change and disturbances such as habitat destruction, pollution, impacts from invasive species, and all these factors have implicated in biodiversity loss. The demand of forest products, resulted in deforestation as the result all the positive functions of forests will disappear (FAO, 2017). Rapid population growth and the expansion of farming and pastoralism under a drier, warmer climate regime could dramatically increase the number of at-risk people in Ethiopia during the next 20 years (USAID, 2012; Echeverria, and Terton, 2016). Rapid urbanization factors for Land-use changes which leads to the spread of erosion, and desertification. Those any change in land use is the major cause for large-scale changes in the associated ecosystem and biodiversity.

Recently Climate change is a major global threat that has already had an observed impact on biodiversity and natural ecosystems (Sinatayehu, 2018; Brak, 2019). Literature revealed that climate variability recognized as an important factor influencing vegetation dynamics under global change (Tucker *et al*., 2001; Qiu and Feng, 2011). Climate change pressures affect the health and function of ecosystems as well as the wide variety of species of biodiversity (National Academy of Sciences, 2020). An increasing in air and water temperatures, altering precipitation patterns, intensifying many natural disturbances, affecting species distribution and survival. Climate variability, especially precipitation and temperature, is more closely associated with changes in phenology, respiration, and ecological balance (Jong *et al*., 2011). According to world meteorological organization, rainfall and temperature are the prime factors in determining the world's climate and the distribution of vegetation types. The rise of temperature and the drop of the average annual precipitations are the main climate changes, which have accelerated predominantly in the past three decades (IPCC, 2014; Joshi, 2019), that have significant pressure on forest ecosystem and vegetation. The temperature and rainfall Change significantly affects the change in the type, distribution, and coverage of vegetation in Ethiopia. Some climate changes may result in increased precipitation and warmth, resulting in improves plant growth and subsequently improves carbon dioxide sequestration.

In recent decades, satellite remote sensing has emerged as an important tool for vegetation assessment and monitoring owing to its ability to provide spatially continuous observations and environmental proxies across geographical boundaries and over wide areas (Rembold and Maselli, 2006). Moreover, in the past four decades, remote sensing and geographical information system techniques have used extensively to detect the type of changes, location of changes, and quantification of changes in land use and land cover. In Eastern Africa Forest resource was under risk and highly fragmented were dramatically expansion of agricultural land at the expense of vegetation cover (FAO, 2017). Birara *et al*., (2018) reported insignificant increasing trend of annual rainfall in north eastern and central Ethiopia while study conducted by Solomon *et al.*, (2019) revealed long-term seasonal trend analysis discussed trend in rainfall of western Ethiopia which shown decreasing and decreasing trends.

The study on the analysis of climate changes relationship with vegetation cover is essential to identify the ecosystem functions for proper planning and management and mitigate climate change. Understanding the responses to climate change vegetation is of paramount importance to the development of forest-based adaptation strategies and measures, as well as to the assessment of the ability of forests and vegetation to mitigate climate change. It is evident from the recent review of literature that no research work has been directed towards the study of the effects of climate change on forest and vegetation cover in study areas. Therefore, this study attempts to evaluate the effect of climate change described in terms of temperature and rainfall on vegetation cover in Chilimo Forest in Western Ethiopia.

1.2. Statement of the problem

Climate change has been aggravated the risk of catastrophic natural hazards all over the world. Though impacts of the change are global, developing countries are more at risk (Mwendwa and Giliba, 2012; Bryan *et al.,* 2013; Kassie, 2014; Mariara and Kabara, 2015). According to the recent Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007; and 2014), there is now strong evidence, which shows that the earth's climate is changing mainly as a result of the increasing concentration of greenhouse gases in the atmosphere that is emitted from various human activities.

Developing countries in general and least developed countries like Ethiopia, in particular, are more vulnerable to the adverse impacts of climate variability and change which contributes to frequent drought, flooding, and rising average temperatures. (Gemoraw and Fentaw 2015; Teshome, 2016). This is due to geographic location, rapid population growth, low adaptive capacity, widespread poverty, availability of limited human, financial, technical, technological, institutional, and infrastructural resources and high sensitivity of their socio-economic systems to climate variability and change (Aklilu and Alebachew, 2009). The variation between sensitivity and adaptive situation also seen between sectors and geographic locations, time and social, economic, and environmental considerations within a country. Africa is one of the most vulnerable continents to climate change and climate variability, a situation intensified by the interaction of multiple stresses, occurring at various levels, and low adaptive capacity (Boko *et al.*, 2007). Study revealed that Ethiopia has prioritized the actions in response to current and projected climate variability and change through establishing a capacity-building program for climate change adaptation (WBG, 2011).

Rapid climate change expected dramatically alter the distribution, function, and disturbance regimes of natural ecosystems (Bachelet *et al.*, 2001; Joshi, 2019). Climate variables, especially temperature and precipitation, are the vital factors that affect the development and ranges of ecosystems. Forests are highly sensitive and subject to climate change (Miko and Andreas, 2014; Brack, 2019). Significant climatic changes occur at all levels, from short-term weather fluctuations creating disturbances (such as frosts) to longer-term changes in average climatic conditions (such as moisture availability or the length of the growing season) or the frequency of extreme events (such as droughts, fires, or intense storms). Changing temperature and precipitation patterns and increasing concentrations of atmospheric carbo dioxide are likely to drive significant modifications in natural and modified forests (Kirilenko and sedjo, 2007). The change in temperature and precipitation patterns will be likely produce a strong direct influence on both natural and the modified forests. Rapid climate change associated with increasing greenhouse gas emissions (IPCC, 2007 and 2014) influences current and future vegetation patterns.

Severe climate changes in climate pattern due to anthropogenic influence had been threating biodiversity and other natural resource (Tessema and Simane, 2020). When climate changes species that have familiarized to specific environmental are highly affected (IPCC, 2014 and Wassie, 2020), climate change also had interactive effects on species loss with species richness (Yan *et al*., 2018). According to IPCC (2007) 20 to 30% of the fauna and flora species are at risk of endangered if temperature reach the level projected to occur by the end of this century.

Recently land and ocean surface temperature have warmed, the spatial and temporal precipitation of have changed, the frequency and intensity of El Nino have increased. These changes have affected the reproduction timing, the length of growing season, species distributions of plant. Since the earths mean surface temperature were projected to warm 1.4 to 5.4 by the end of 21st century (IPCC, 2002). Climate change affect all aspect of biodiversity including high latitude and high-altitude ecosystem also been affected by change in regional climatic factors. Climate is the major factors controlling patterns of vegetation structure, productivity and plant species composition where many forest biodiversity can successfully reproduce and grow only within specific range of temperature and responds specific amounts and seasonal patterns of precipitation and may be displaced or fail to survive if climate changes (Staudinger and Carter, 2013).

Even though, climate change is a global phenomenon, Ethiopia seriously threatened by climate change (Aragie, 2013). The vegetation throughout the study area were subjected to degradation and deforestation for over 2000 years, and the rate of deforestation has been very high, with significant changes in forest cover and biodiversity observed even since the 1970s (Bird Life International, 2020).

In Ethiopia climate change and variability is manifested through the variability and decreasing trends in annual and average rainfall and increasing trend in temperature (Mallie and Gemeda, 2020). According to study conducted in field of climate change impacts on forest landscape, land degradation, forest management, land use land cover change, change detection, and climate vulnerability (Kuria *et al*., 2011; Kassie, 2014; Dong *et al*., 2014; Bowen, 2017; Milkessa *et al*., 2020) rainfall and temperature change were affected forest coverage, grassland, woodland, shrubland and bushland. However, detailed research has needed to explore how vegetation and species responds to rapidly growing environmental change were currently, climate change is severely threatening the country's biodiversity, and the consequences of these effects have not been studied at large (Mengesha, 2020). According to Zhang (2017) since the 1980s, relevant researchers have begun to focus on the vegetation dynamics and their correlation between vegetation and meteorological factors. Recently, many global and regional scale researches have utilized vegetation indices to investigate the vegetation change and land cover change. Detailed studies on climate variability and impacts on vegetation using modern technologies are lacking in Ethiopia (Suryabhagavan, 2017; Mengesha, 2020). The conducted by Minta *et al*., (2018) exhibited rapid land-use land-cover conversion from natural resource to other form of land-use type have significant impact on natural forest resource degradation and deforestation. Accordingly, the result revealed that around 50 to 80% of annual and seasonal variability of rainfall and temperature were observed in Ethiopia (Mengistu and Bayable, 2011). This exhibited that there was significant influence of temperature increase and rainfall decline of rainfall on natural forest, grassland, shrubland, wetland and other vegetation species. Western Ethiopia has been influenced by variability of decreasing and increasing trend of rainfall and seasonal temperature. Therefore, there is a research gap to address the issue of analyzing climate change effect of vegetation and forest cover in the study areas. This study going to investigate the relationship of climate change with vegetation cover using geospatial techniques. Therefore, this is important for making well-informed choices on management regimes for planners and decision-makers that can ensure the sustainability of critical ecosystem services.

1.3. Objectives

1.3.1. General Objective

The overall objective of this study was to evaluate the relationship of climate change and vegetation cover change in Chilimo forest, Dendi district, Ethiopia using geospatial techniques.

1.3.2. Specific objectives

- To investigate land use land cover dynamics for the last three decades during the study period.
- To analyze the trend of temperature and rainfall for the last thirty years since 1990.
- To analyze effects of temperature and rainfall variability on vegetation cover in the study area.

1.4. Research Question

- What is the amount and rate of land-use land-cover change happened for the las three decades?
- What is the trend of rainfall and temperature their relationship with vegetation cover over study period since 1990?
- What is the effect of rainfall and temperature change on vegetation cover for the last thirty years since 1990?

1.5. Significance of the study

Vegetation and forest cover dynamics in western Ethiopia has subjected to degradation, deforestation and endangered that needs detail scientific research for present and future forest conservation planning and management. Moreover, the effects of climate change (rainfall and temperature parameters) on vegetation and forest resource and also how they respond to rapidly increasing climate change have not been studied at large. Hence, this study provides useful data and information about the effects of climatic change on vegetation cover change for the past three decades in Chilimo Forest. Therefore, policy and decision makers, natural resource managers, climatologists, development agents, foresters, environmental experts, researchers and other stakeholders can be used the results of this study.

1.6. Scope of the study

The scope of this research paper was spatially limited only in Chilimo Forest, West Shewa Oromia Regional state of Ethiopia. The study focused on investigating the impacts of climate change impacts on vegetation cover change and forest biodiversity for the past thirty years. Besides, it was also evaluating the trend of land use and land cover change detection in the study areas.

1.7. Organization of the Study

This study is organized into six chapters. The first chapter explains the background of the study, statement of the problem, general and specific objectives, significance and scope of the study. The second chapter describes literature review which emphasis on climate changes and its impact, climate change trend and impact in Ethiopia, forest cover dynamics and assessment and climate change impact on vegetation cover and relationship of rainfall and temperature with forest cover, shrubland, grassland and wetland. The next chapter deals with an overall description of datasets and how the study conducted. The fourth and fifth chapter explain the results and discussion. The final chapters deal with concussion and recommendation.

CHAPTER TWO

2. LITERATURES REVIEW

There are considerable literature and studies documented relating to climate change and its potential impacts on vegetation cover. These studies agreed that climate change has significant impacts on the environment and other ecosystems in general and particularly forest resources with already challenging developing countries.

2.1. General Overview of Climate and Climate changes

Climate defined as long-term averages and variations in weather measured over a period of several decades (WMO, 2021). It decided by the situation of temperature, precipitation, humidity, wind and seasons. The Earth's climate system includes the land surface, atmosphere, the biosphere, the pedosphere, the lithosphere, oceans, and ice. All of these elements together compose the climate system, whose individual components and processes connect and influence each other in diverse ways **(**World Ocean Review, 2005).

Many scholars define climate change in different ways. In general, climate change refers to, significant, long-term changes in the global climate. It is a long-term change in the earth's climate, especially a change because of an increase in the average atmospheric temperature. The World Meteorological Organization defines as Climate describes the average weather conditions for a particular location and over a long period. It is a sweeping change in global climate conditions, including weather phenomena, temperature, and other parameters. Following the emergence and development of the industrial revolution, the global climate has been changing due to the carbon-intensive paths of development pursued by high-resource countries or developed countries (Simane, 2016).

The United Nations Framework Convention on Climate Change (UNFCCC) article 1 defines climate change as:

"a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods" UNFCCC,1990).

Additionally, climate change also a change in the state of the climate that can be selected by changes in the mean and/or the variability of its properties which persists for a longer period, that runs usually for decades or longer. Climate change may because of natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use systems (Kassie, 2014). A significant change happened from one climatic condition to another like changes in temperature, precipitation, wind, and humidity (Lambert, 2010).

2.2. Causes of Climate Change

Climate change may occur from both natural and anthropogenic (human) forces. In fact, there has been an increase in world temperature in the 20th century and continued in the 21st century. It may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Since climate change is the change of global climate conditions, it caused by an influx of greenhouse gases, mostly from fossil fuel emissions around the world. These gases trap heat in the atmosphere and change weather patterns, warming many areas of the globe and causing irregular or inconsistent seasons and weather events.

However, currently, change in climate mainly caused by human activities that release greenhouse gases into the atmosphere. The anthropogenic activities might have contributed significantly to the changes. The widely observed climate changing of the past 50 years has happened primarily due to human activities (Huber and Knutti, 2011). Human activities have been responsible mainly for the emissions of heat-trapping gases such as carbon dioxide, methane, nitrous oxide, ozone, water vapor, and others. Among these, carbon dioxide has noted as the most impactful greenhouse gas emitted (IPCC, 2014). Human activities induced climate change to represent stress, particularly to the many ecological systems already affected by pollution, increasing resource demands, and unsustainable management practices.

For the last five decades, the concentration of carbon dioxide in the atmosphere was increased by approximately 25%, with higher concentration levels being reached each subsequent year (Kay, 2016). Another literature reveals that rainfall, temperature patterns are varying, and atmospheric carbon dioxide concentrations are increasing due to anthropogenic activities contributing to climate change (Joshi *et al.*, 2019). The most vulnerable systems are those with the greatest sensitivity to climate changes and the least adaptability where natural ecological systems are all sensitive to both the magnitude and the rate of climate change (IPCC, 1995).

2.3. Climate Change in Developing Countries

Generally, climate change affects the entire globe, but its impacts are more evident in the developing world than in the developed world. The report by Shafer Michael (2017) shows that scientists have now focused on climate change because Changes in temperature change the great patterns of wind that bring rain and snow around the world, making drought and unpredictable weather as less developed countries will actually suffer. At the beginning of the last decades of the

20th century, the IPCC judged that global mean surface air temperature has been raised by 0.3 to 0.6°C over the last 100 years, with the five global-average hottest years being in the 1980s. it eminent that were global average surface temperature projected to increase 1.5°C to 5.8 °C in the period of 1990 to 2100 years. They also predicted a consequent increase of global mean temperature in the range of 1.5°C to 4.5°C (IPCC, 2013).

The developing countries in general and particularly Africa is a continent under pressure from climate stresses and is highly vulnerable to the impacts of climate change. The United Nations Framework Convention on Climate Change (2007) indicated that many areas in Africa recognized as having climates that are among the most variable in the world on seasonal and decadal time scales. Rainfall in East Africa is known for its inter-annual variability, which has contributed to the devastating droughts and floods (Solomon *et al.*, 2019). The Temperature of the Africa continent higher warming throughout the continent and in all seasons compared with a global average. The Precipitation decrease in annual rainfall in much of Mediterranean, Africa and the northern Sahara, with a greater likelihood of decreasing rainfall as the Mediterranean coast, is approached where the decrease in rainfall in southern Africa in much of the wet rainfall region and western margins as well as increase in annual mean rainfall in East Africa (UNFCCC,2007).

The IPCC (1995) study asserts that the analyses of meteorological data over large areas and over periods of decades or more have provided evidence. The recent temperature has been highest over the mid-latitude continents in wet and spring; Precipitation has increased over land in high latitudes of the Northern Hemisphere, especially during the cold season. Accordingly, global changes in climate variability or weather extremes have occurred over the 20th century. On regional scales, there is clear evidence of changes in some extremes and climate variability indicators (IPCC, 1995).

2.4. Climate System and Observed Trends in Ethiopia

Because the global climate is a connected system climate change impacts are felt everywhere in the world. Ethiopia has historically suffered from climatic variabilities such as repeated rain failures; famines, environmental degradation, and decline in food production have disturbed the country frequently and remain a major challenge (CRGE, 2011). It has experienced greater variability of precipitation and evapotranspiration due to climate change, and hence greater adverse impacts on its economy (IPCC 2012). The long-term climatic change related to changes in precipitation patterns, rainfall variability, and temperature is most likely to increase the frequency of droughts and floods in Ethiopia (Asfaw *et al*., 2017). Mainly due to climate changes, Ethiopia has faced frequent droughts and other environmental-related problems across the country. Similar to Ethiopia, other many African countries have also often suffered from these changes. The problems and challenges occurred associated with climate change have since recently become global trends (Simane, 2017).

There was considerable evidence to show the changing nature of the climate of the country. Ethiopia's First National Communication, analyzed temperature and precipitation data from 1961 to 1990 and identified high spatial and temporal variability which indicated the rate of the change in climate will increase in the future in Ethiopia (Ministry of Water Resources, NMSA,2001). According to the study, Ethiopia has experienced both dry and wet years and a warming trend in temperature over the last 50 years. Climate warming occurred across much of Ethiopia, particularly since the 1970s at a variable rate. The National meteorological agency analyses three decades (1971- 2000) data of temperature and precipitation that shows the year-to-year variation in rainfall over the country (NMA, 2007). The change is broadly consistent with the change in wider African and global trends. The mean annual temperature has increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade (Teyso and Anjulo, 2016). Daily temperature observations show an increasing frequency of both hot days and hot nights (Simane, 2017). The study emphasizes the temperature increment has been most rapid during the period of July-September, at a rate of 0.32°C per decade. Climate models suggest that Ethiopia will see further warming in all seasons (Keller, 2009).

Similar to other Africa countries Ethiopia's development has challenged by increasing the country's vulnerability to climate variability and climate change. Ethiopia has a highly variable tropical climate with results of its varied topography (WBG, 2011). These reports were illustrated that the highland regions are cool and host most of the country's population, while temperatures in the Dallol Depression are some of the hottest on the planet.

According to the World Bank Report, the climate of Ethiopia broadly divided into three zones. Primary, the alpine vegetated cool zones (Dega) are areas over 2,600 meters above sea level, where temperatures range from near freezing to 16 °C. Secondly, the temperate Woina Dega zones, where much of the country's population is concentrated, are areas between 1,500 and 2,500 meters above sea level where temperatures range between 16°C and 30°C. Finally, the hot Qola zone, which encompasses both tropical and arid regions and has temperatures ranging from 27°C to 50°C." (WBG, 2011).

Rainfall shows systematic and irregular variation over time. Literature documented by Seifu and Abdul Karim (2006) described trends as a certain type of systematic change in rainfall series. It also indicated that Inconsistency (systematic error) and non-homogeneity (changes made in nature by humans or by a natural disruptive or similar sudden process) were mainly responsible for the over-year trends. More recent studies indicated the various trend analysis of rainfall at different spatial (e.g., regional and national) and temporal (e.g., annual, seasonal, and monthly) scales which indicated changes in the spatial and temporal variability and trends. According to Daniel (1988); Segele and Lamp (2005) spatially, the amount, seasonal cycle, onset, and cessation times of rainfall have shown variability across the country. The temporal trends of rainfall vary from days to decades, with the magnitude and direction of historic rainfall trends varying from region to region and season to season (Seleshi and Zanke, 2004; Cheung *et al*., 2008).

The Ethiopian Government Climate Resilient Green Economy Strategy document specified future climate change in Ethiopia is uncertain, although scenarios of change show the range of possible outcomes (FDRE, 2011). It also noted that there is a high degree of uncertainty in projections of how global climate change will affect temperature and rainfall patterns in Ethiopia. Climate complexity makes the projections of future rainfall uncertain. However, the models project that current rainfall variability will continue as projections of the change in future annual rainfall range from -25% to +30% by the 2050s (FDRE,2011). The studies also suggest that impacts and costs of climate change on forestry were potentially very significant, with increased incidences of droughts; the negative impact on GDP could be 10% or more by 2050s.

In contrast to other tropical countries, three seasons are common in Ethiopia where during a year rainfall occurs in different seasons (Kefyalew and Tegegn, 2012**)**. According to NMSA Report (2007) described these seasons namely Bega (dry season) which extends from October-January, Belg (short rain season) which extends from (February-May), and Kiremt (long rain season) which extends from June-September. Recent literature revealed the country received most of its rain between March and September (Kefyalew and Tegegn, 2012**)**. It showed that rains start within the south and central parts of the country during the Belg season, then progress northward, with central and northern Ethiopia receiving most of their precipitation during the Kiremt (wet) season.

The studies showed the mean annual temperature distribution over the country varies from about 10^0C over the highlands of northwest, central, and southeast to about 35^0C over northeastern lowlands (Kidane, 2007). National meteorological agency analyses three decades (1971- 2000) data of temperature and precipitation shows the year-to-year variation in rainfall over the country

(NMA, 2007). The historical data of temperature and precipitation from 1961- 1990 for selected stations showed mean annual rainfall shows large spatial and temporal variation (Kefyalew and Tegegn, 2012**)**.

Furthermore, the climate of a particular region is determined through analysis of Climatological variables in a region over a period of 30-years or greater (Shako, 2015). The parameter measured include temperature (maximum and minimum), rainfall, relative humidity, windspeed, atmospheric pressure, sunshine hours and cloudiness. Study showed that main factors in measuring climate change such as temperature (can be measured for the Earth's surface, and sea surface temperature), Precipitation (rainfall, snowfall etc.), biomass and vegetation cover condition and pattern (may be discerned in a variety of ways and give evidence of how ecosystems change to adapt to climate change) (shako, 2015). Studies showed that there is a strong relation between the percent of carbon dioxide in the atmosphere and the Earth's mean temperature.

2.5. Climate change impacts on vegetation cover

At this time global Climate change is already causing impacts on human and natural systems globally. The frequent changes in the climate are often followed by ecosystem changes. The increase of air temperature and variability in precipitation is already obvious in major parts of the world and their effects in biodiversity and ecosystem (Kotir, 2011). Climate change has adverse impacts on ecosystems. When the entire globe warms, the world ecosystem will move. Forests biodiversity and vegetation are subject to several natural disturbances irrespective of climate change, including fires, droughts, storms, snow, and ice. Both in developed and developing countries climate change has the potential to increase both the frequency and the intensity of most of these disturbances, possibly exceeding forest ecological resilience and resulting in permanently altered forests or shifts to non-forest ecosystems (Brack, 2019). Climate change threatened habitats, ecosystems, and species in Africa, and was likely to trigger species migration and lead to habitat reduction. The literature showed up to 50 percent of Africa's total biodiversity is at risk due to reduced habitat and other human-induced pressures (Boko et al., 2007).

The yearly variation of temperature and precipitation combination is a factor behind climate change results from forest fires and other recorded impacts. The studies explained that the impacts of climate change on tropical forests have less extensively studied than temperate forests.

Climate impacts are consequences of climate change on natural and human systems. The effects of climate changes revealed directly and indirectly. The direct effect of climate change manifested by process impacts of climate change disturbance. Whereas, indirect effects are changes in disturbances through climate effects on vegetation and other ecosystem processes not directly related to disturbances, such as an alteration of the disturbance susceptibility through a change in tree species composition, size, density and distribution (Seidl *et al*., 2017)

Climate variability effects produced significant local ecosystem change (Li *et al.*, 2014). The studies documented that the seasonal change of precipitation and temperature affect vegetation distribution. Michael (2017), noted that recent data shows a trend of increasing temperature and rising carbon dioxide levels beginning in the beginning of 19th century. It also suggested that climate change impacts and warming fundamentally changed the forests in western countries where hundreds of plant species will disappear and hundreds more will move thousands of miles. Weiskrantz, (1999) investigated changing climatic variables relevant to the function and distribution of plants including increasing concentrations, increasing global temperatures, altered precipitation patterns, and changes in the pattern of 'extreme' weather events. Highly variable species distribution has resulted from different models with variable bio climatic changes. Changes in long term environmental conditions are known to have had enormous impacts on current plant diversity patterns; further impacts are expected in the future (Sahney *et al*., 2010)

2.6. Vegetation degradation and climate change

Climate variability have a significant effect on vegetation dynamics (Islam et al., 2021), where this study noted that long-term climate changes cause shift in vegetation distribution and dynamic. Degradation of vegetation due to precipitation and temperature, changes the biomass, vegetation species, composition and soil input nutrient sources (Wu *et al*., 2020) and change in the structure of the vegetation community. According to study conducted in sub-Saharan Africa Hiscilo *et al*., (2014), reported a statistically significant decreasing trends in rainfall was observed where vegetation deterioration was identified in the East Africa. They concluded that decadal-scale climate fluctuations or long-term climate change caused changes in rainfall. The precipitation changes and temperature increased have significant impacts on vegetation phenology (Pei *et al*., 2021). Climate change affects a number of variables determine the development and growth of vegetation. Similarly, temperatures changes, decrease water availability and changes to soil conditions will actually makes it difficult to survive which leads to degradation and desertification. Change in precipitation may change moisture regimes (Ali, 2013). The finding of study by Zhihui et al., (2015) shown an increase in rainfall and temperature would significantly and positively contribute to land improvement and conversation from cultivated land grassland and forestland revealed positive improvement of land, the inverse would lead to land degradation. Moreover, Mengistu and Bayable (2011) research result indicated that around fifty to eighty percent (50% to 80%) of annual and seasonal variability observed in Ethiopia. However, agriculture land increase by 250% from 1986 – 2016 while forest land and woodlands have decreased by 72% and 84%, where the speed and scale of land-use land-cover change has been accelerated in the last three to four decades of the 21st century (Berie and Habtamu, 2018). There was variation of vegetation dynamics spatially and temporally against temperature and rainfall.

2.7. Forest cover dynamics and assessment

Climate change makes major threats to forest resource. Literature investigated climate change influences the rich variety of life on earth, and even small changes in climatic conditions can have extensive consequences for biodiversity (Mengesha, 2020). It also illustrated which a number of climate change impacts on biodiversity have observed and expected to increase in the future: species shifting habitats, changes in distribution and life cycles, reproduction timings and growing seasons for plants, as well as the development of new physical traits. Evidence of observed climate change impacts is strongest for natural systems where the changing precipitation are fluctuating hydrological systems leads to rapid global biodiversity loss and many terrestrial species have shifted their geographic ranges, seasonal activities, migration patterns, abundances and species interactions in response to ongoing climate change (IPCC, 2014, Yan *et al*., 2018).

Climate change affect Ethiopian mountain ecosystem, considering species that can only live in these areas may vanish if temperatures continue to rise. It evident that about seventy-five per cent of Ethiopian species are in danger of displacing due to change of climate (Kassahun, 2008).

Climate change affects by Shift in distribution and extent of vegetation and biodiversity dynamics in Ethiopia (Alemayheu, 2016). It also showed that the climate change would influence the species that could survive there and species with small narrow ecological range (e.g., highland bamboo, alpine species) are on the verge of endanger.

According to study by Simachew, (2020), increasing air and water temperatures, altering precipitation patterns, intensifying many natural disturbances, affecting species distribution and survival, among other impacts. Changes in atmospheric carbon dioxide concentrations, changes in the nitrogen cycle and acid rain, climate alterations, and natural land use changes were the major cause of biodiversity decline (Teklu, 2016). Factors inextricably linked with the climate change induced loss of biodiversity would expect to continue at an unchanged increasing pace in the coming decades. Due to the drastic effects of rapid climate change, many species will be unable to adapt (Mengesha *et al*., 2020), very rapid shift is damaging to the variety of life and probably threatened by extinction. It will be expected to worsen biodiversity loss in the future

In Ethiopia, over the last five decades there has been a warming trend in the annual minimum temperature (EPCC, 2015). The increase in minimum temperatures assumed that has been increasing annually at the rate of 0.2°C over the past five decades. This clearly indicates that the rise in the atmospheric temperature will be affect forest resource. As a result, species will be threatened to the extent of local extinction in a given ecosystem when climate conditions are changing too quickly for them to adapt.

As atmospheric carbon dioxide increases over the next century, it was predicted to become one of the major drivers of global biodiversity loss global average temperatures increased by 0.2 °C per decade since the 1970s, global average precipitation increased by 2% in the last 100 years.

2.8. Relationship of Rainfall and temperature with Forest, Shrubland, Grassland and Wetland

Climate change impacts to grassland was caused by increased seasonal, annual, minimum and maximum temperature and reduced rainfall. According to Salimi *et al*., (2021), change of rainfall and seasonal temperature examined as one of the major threats to wetlands. Shrubland has continuously decreased over the last 42 years, spanning from 1973 to 2015 (Wubetu Anleyet *et al.*, 2019). They examine that shrubland has decreased noticeably while bare land has increased rapidly. According to the finding of the study the extent of shrubland in 1995 were 22.9%, but in 2015 decreased to 9.4% of landcover in the study area. This implies there was high decline of shrubland dramatically. Recently the rate and scale of shrubland and grassland decline was increased from the past. Ethiopia has been experiencing the impacts of climate variability and changes, where its change has led to expansion of desertification, loss of wetlands, loss of biodiversity and recurrent droughts (Haileab, 2018), in addition it has been likely to aggravate environmental degradation. Thus, both climate change and land-use land-cover change affect the forest and vegetation cover. Change of rainfall and temperature examined as a major threat of wetland (Salimi *et al.*, 2021). It has been influenced by increasing temperature and changing hydrological patterns.

2.9. The Role GIS for Climate Change Assessment

IPCC (1990) suggests there was a general need to increase the available information and data to support impact studies, particularly in developing countries like Africa. This need could met through enhancing and, where appropriate, establishing integrated monitoring programs including climatological parameters, conducting assessments, at different levels to identify climate change consequences. Data quality needs to be assured and data analyses and their interpretation need carried out carefully. GIS can used for collection and analysis processes of assessing the impacts of climate change (Larsen, 1999). In addition, have a vital role to play in environmental monitoring and ideally suited as a tool for the analysis and presentation of data derived from distributed measurement stations. Recently the problem of climate change was studied with the application of satellite images that is used to analyze through Remote Sensing and GIS techniques that is developed with the development of Earth Observing satellites (Esubalew, 2014).

Though, Reducing the risks caused by climate change (Gizachew and Andualem, 2014), Scientists, policy makers, developers, engineers, and many others have used geographic information system (GIS) technology to better understand a complex situation and offer some tangible solutions (Esubalew, 2014).

Monitoring of vegetation ecosystems could provide early detection or warning of climate change and its impacts. The ground data provide basic importance for monitoring and assessment of vegetation cover and forest areas; however, these should also supplement with remotely sensed observations and geographical information system analysis that should be taken advantage of automatic data transmission and processing systems. More importantly, Geospatial technologies can prepare the data for analysis more quickly and accurately than is normally possible by manual procedures. It also can be a powerful technology for spatial analysis of environmental impact assessment (Elsa and Alexandra, 1996). Remote Sensing and Geographic Information System have found wide application areas in climate change analyses and adaptation (Eniolorunda, 2014).

A GIS based application helps us totalize a scientific understanding of earth systems at a very global scale and results in more thoughtful, informed decision-making (Esubalew, 2014). An equivalent source further explained that GIS creates a replacement framework for studying global climate change by allowing users to inventory and display large, complex spatial data sets. GIS users represent a huge reservoir of knowledge, expertise, and best practices in applying this cornerstone technology to the science of climate change and understanding its impact on natural and human systems (ESRI, 2008). Moreover, they can also analyze the potential interplay between various factors, getting us closer to a true understanding of how our dynamic climate may change in the coming decades and centuries (ESRI, 2008). Identifying areas with a changing climate of rainfall and temperature requires spatial information with higher resolution, which could help better management of the impacts. (Solomon *et al*., 2019)

CHAPTER THREE

3. MATERIALS AND METHODS

3.1.Description of Study Areas

3.1.1. Location and Description

Chilimo forest (the study area) is reserved forest found in Oromia Regional State, western Ethiopia approximately 90 km west of Addis Ababa the capital city and close to Ghinchi town, Capital of Dendi District. Geographically its absolute location extends between the coordinates of 8°43′04″N- 9°17′19″ N latitude and 37°47′39″ E-38°20′47″E longitude covering a total area of 24,000 ha. The altitude of forest area ranges between 2170m to 3054m asl Chilimo forest bordered on the south by Ilfata woreda and on the west by Jeldu woreda (Figure1). The location map of the study area described in Figure 1 was show the shape file of Chilimo reserved forest that had delineated for national priority forest area (source MoA).

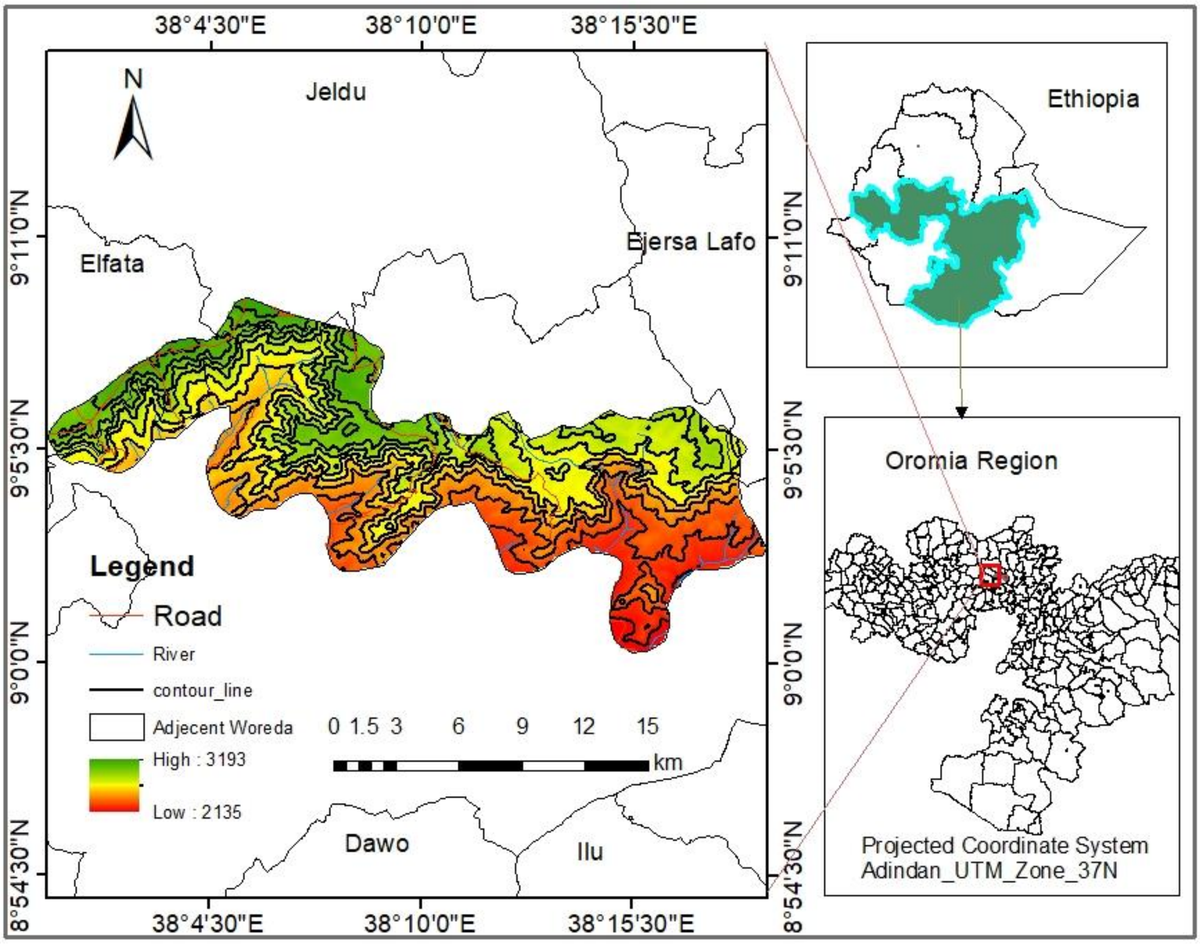


Figure 1: Location map of the study area

3.1.2. Physiography

Topography

The topography consists of areas with steep to gentle slopes. The landscape mainly composed of high densely forest, moderate forest, and plantation forest, agricultural field, grass lands, settlements, hills and shrubs. The slope of the largest part of the study area (67.57%) ranges from zero to 25% and the remaining has slopes above 32.43%. Flat land and steep slopes account to about 25% of the study area. Flat land and gentle slopes are mostly utilized for agriculture, settlement and grazing lands; whereas moderate and steep slopes above 25% slope gradient usually consists of densely forests, moderate and plantation forest, grass land and shrubs.

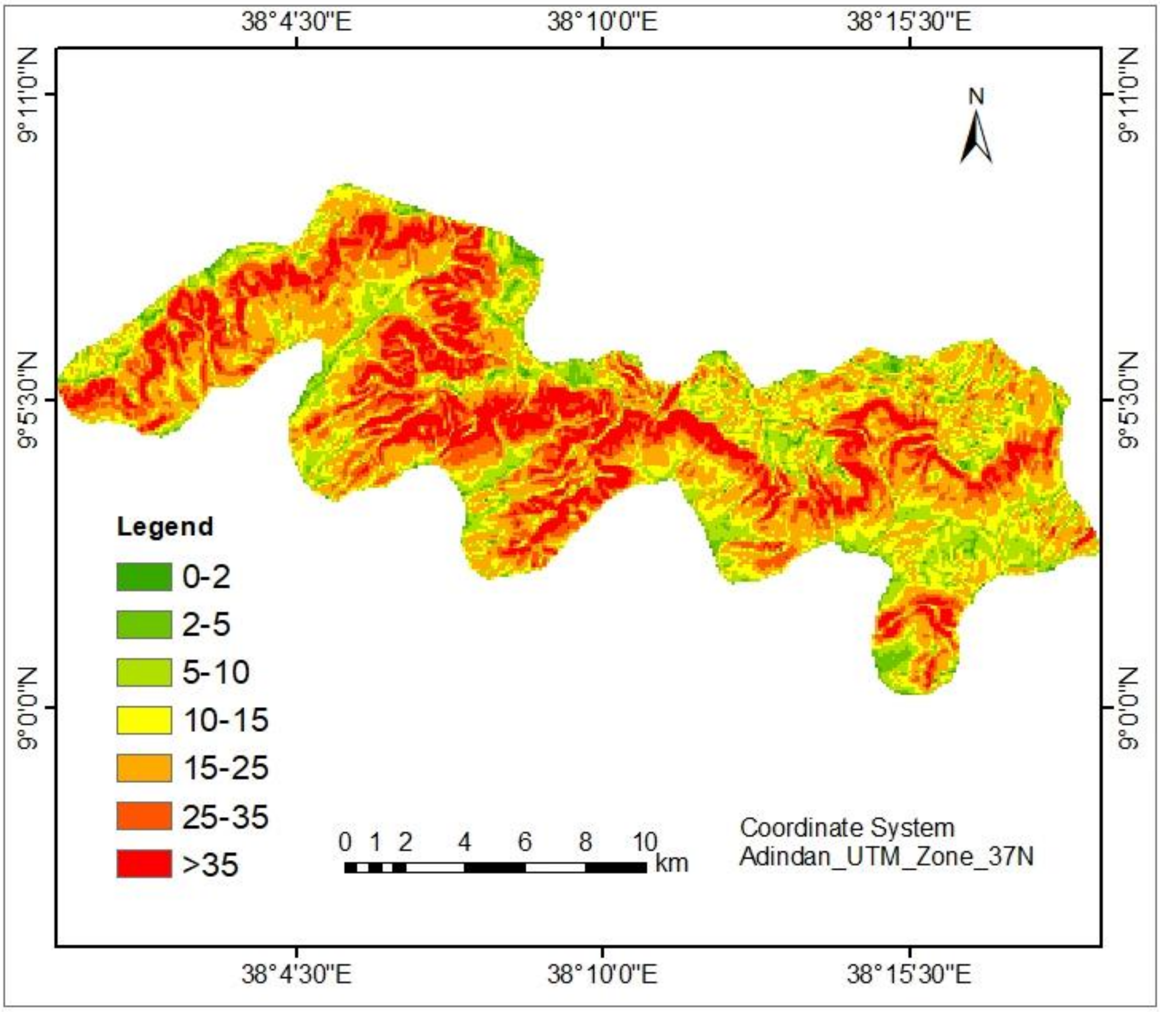


Figure 2: Slope map of the study area

Elevation

The elevation of the study area varies from 2135 m to 3193 m. The Western and north western part of the study areas account the highest elevation (2855 m to 3193 m) whereas Eastern part of the study areas account the lowest elevation (2135 m to 2422). The central, Northern and central western part of study areas ranges from 2422 m to 2855m (Figure 2).

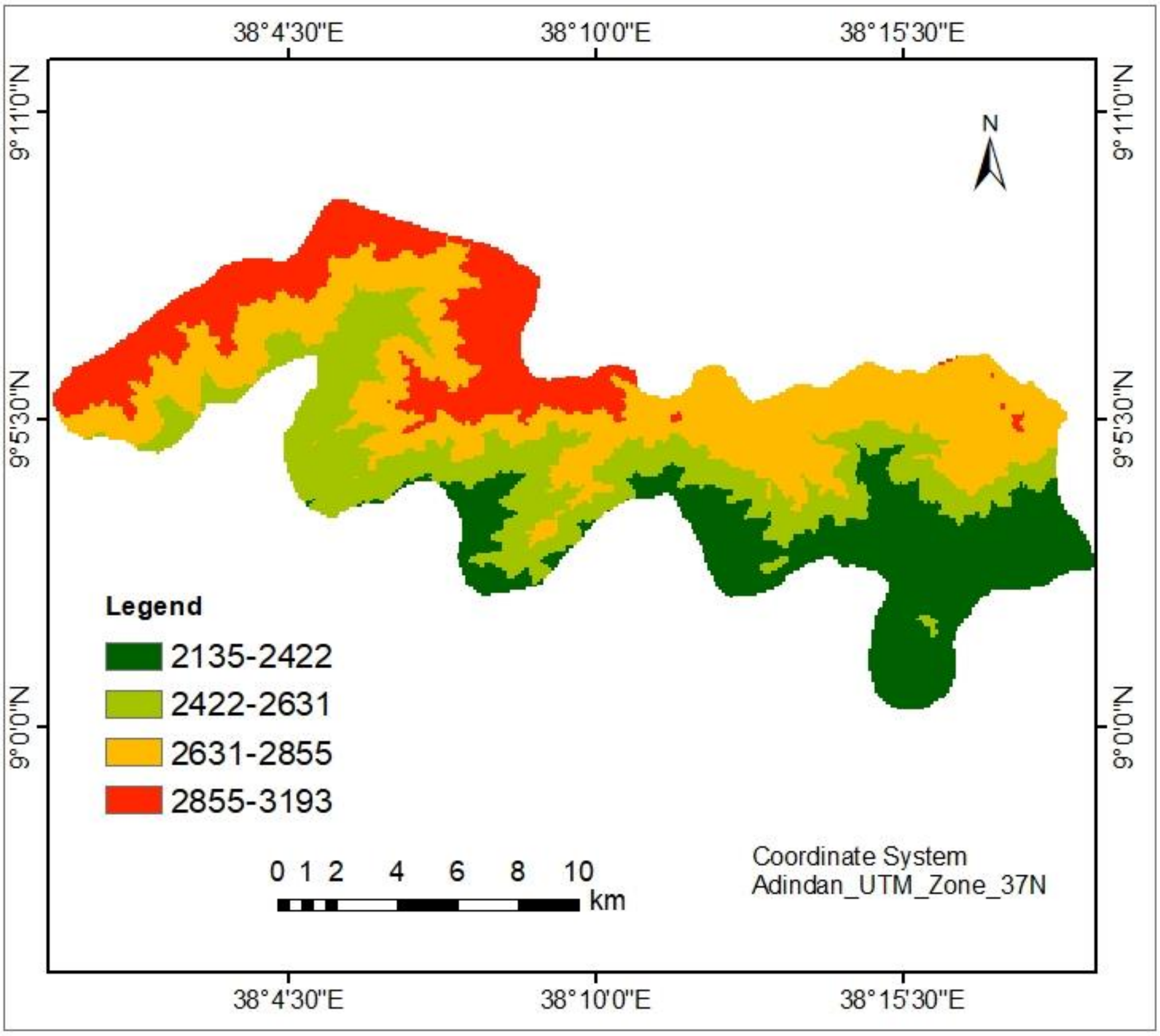


Figure 3: Elevation map of the study area

Climate

In Ginchi and the surrounding Chilimo area, there are five rainy months extending from May-Sept. while, July and August months receive the highest amount of rainfall with the highest peak in August that reaches above 356.34 mm per month at the peak periods. According to climatic data from CHIRPS, the study area gets rain at least five months with variable intensity. The annual precipitation ranges from 852.15 - 1508.43 mm per year ((Figure 4) while 23.37°C and 11.51°C of average maximum and minimum air temperatures per month, respectively (Figure 5 and 6).

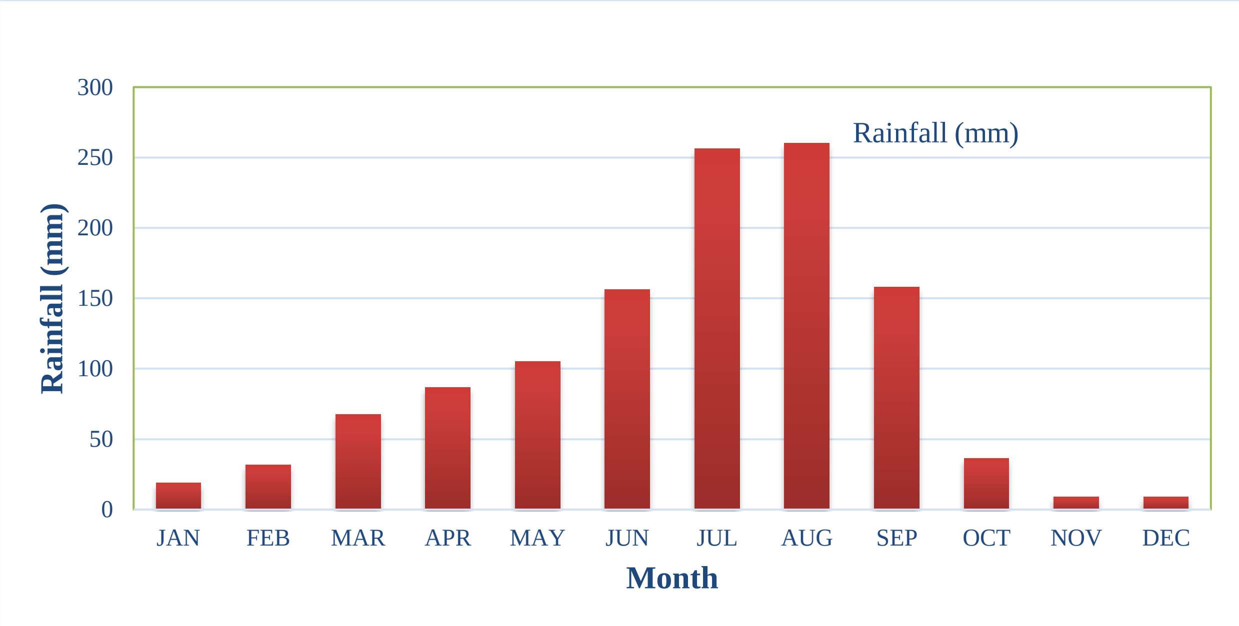


Figure 4: Mean monthly rainfall (1990-2020)

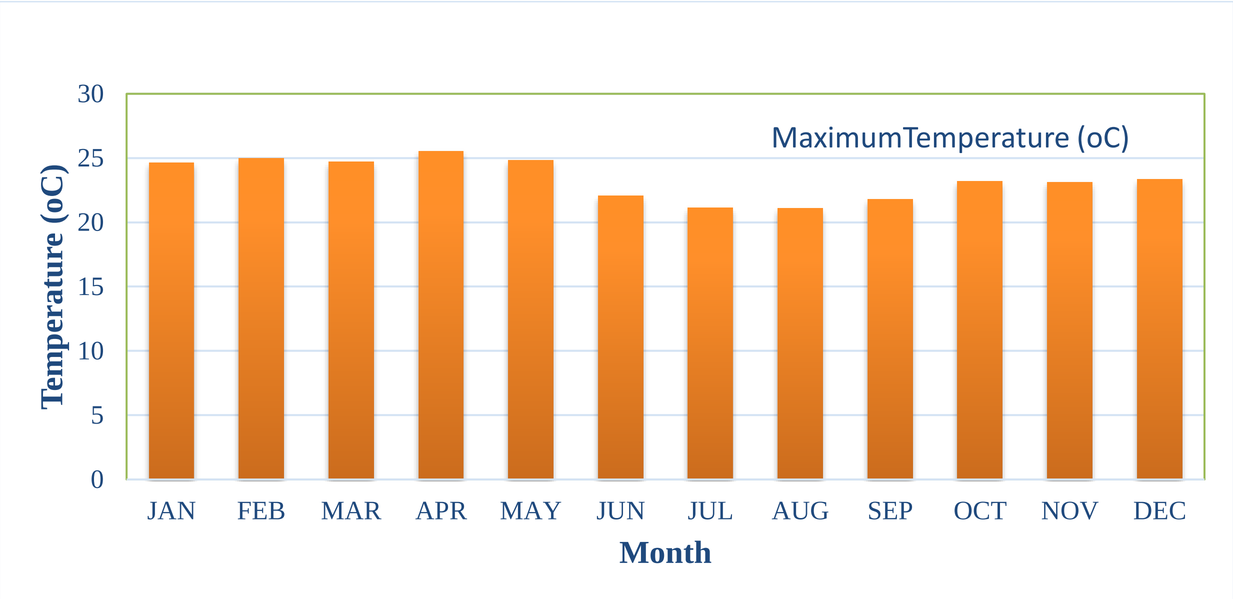


Figure 5: Mean maximum monthly temperature (1990-2016)

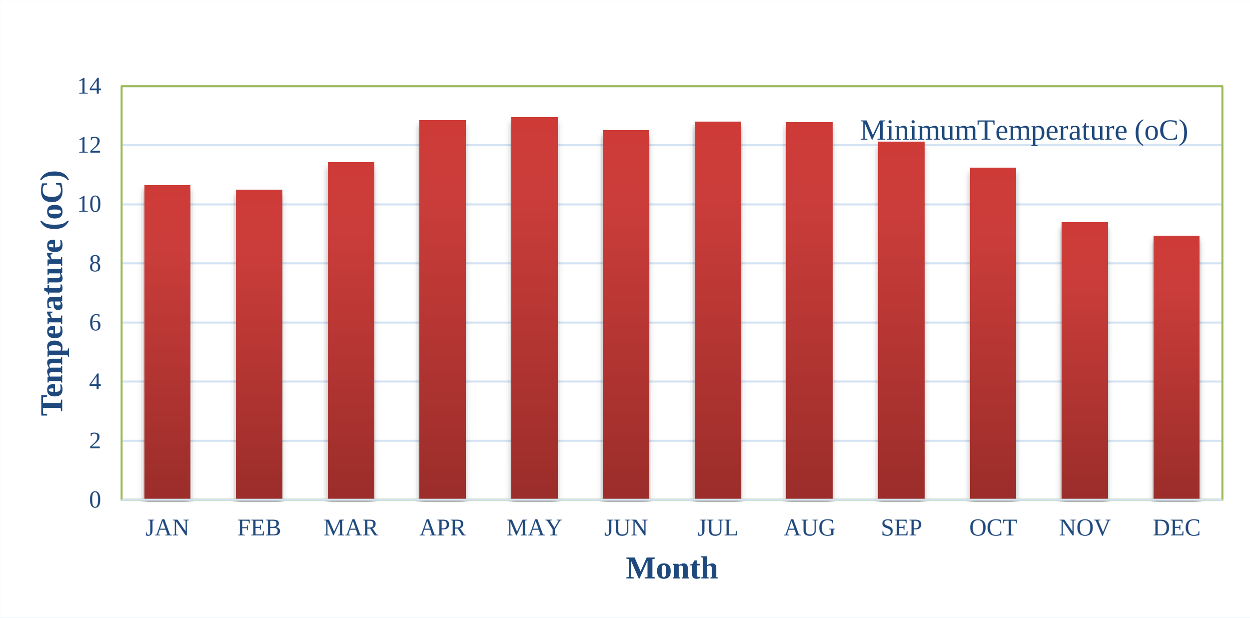


Figure 6: Mean minimum monthly temperature (1990-2016)

Vegetation

Chilimo forest is one of the few remnants of dry Afro-montane Forest that remain on Ethiopian Central Plateau. The forest is montane mixed broadleaf–coniferous, although conifers predominate. The main species in the canopy are Juniperus procera, *Podocarpus falcatus*, prunus africana, *Olea* europaean *subsp.* cuspidata, *Apodytes dimidiata and Ficus spp*. Juniper, Floristically and Podocarpus are the emergent species in the forest. Historically, the entire upland area thought to have been covered by Juniperus–Podocarpus forest, but most of the forest has been cleared and subjected to deforestation. There are also another important species and a number of flowering plant species in Chilimo forest that are endemic. Various types of shrub land now dominate the landscape (Graf et al., 2016).

Agro-climatic zone

In Ethiopia, traditional agro-climatic zone classified from Bereha to Worch, ranging from below 500 m to over 3700 m asl in altitude and from below 500 mm to over 1400 mm annual rainfall. Agro-climatic zone of the area is classified into two which is Dega and Weyena Dega (Figure 5). The largest part of area categorized to Weyena Dega.

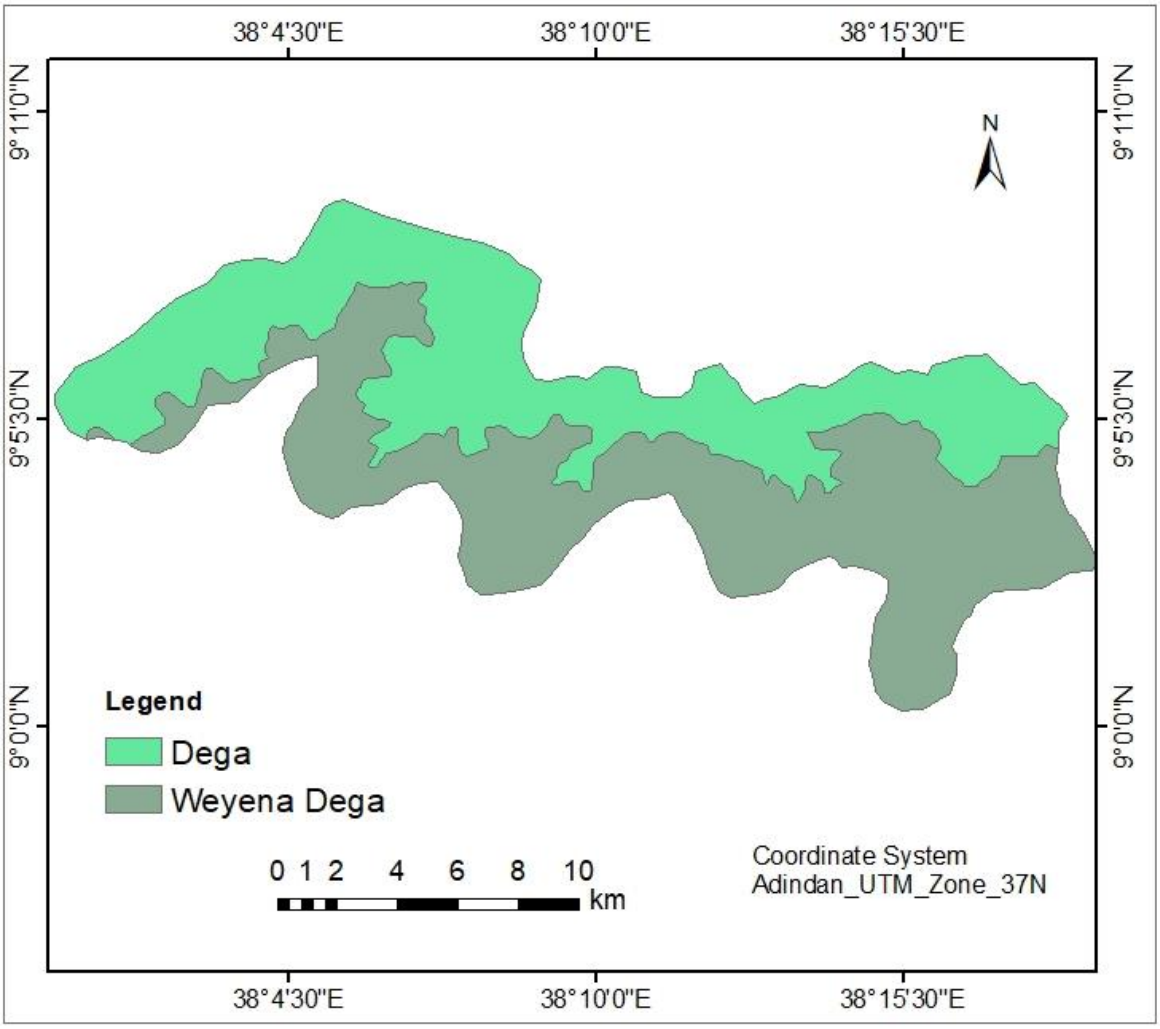


Figure 7: Agro- climatic zone map of the study area

Population

The human population of Dendi Woreda have projected to be 219,534 heads in the years 2017 (Table 1). Among the total population 81.38% live in rural areas, while the remaining 18.62% live in urban areas. (CSA 2017).

Table 1: Population data of the year 2017

Gender	Total population			Rural population			Urban population		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Total	110,696	108,838	219,534	90,229	88,438	178,667	20,467	20,400	40,867
Percent	50.42	49.58	100	50.50	49.50	100	50.08	49.92	100

3.2. Data Acquisition

3.2.1. Satellite Imagery

The data for this study were acquired from primary and secondary data sources. These were collected and used from different data sources. Geographic Information System and remote sensing was used to produce information on the trend and the amount of change taking place over the last three decades in climatic condition. Landsat TM, ETM+ and OLI-TIRS were obtained freely from USGS Earth Resources Observation Systems (http://www.earthexplorer.usgs.gov) of the year 1990, 2000, 2010 and 2020 cloud free scenes for examining land-use land-cover change in the selected study area. The Landsat images were selected in the same vegetation season which is December. All the Landsat images were referenced and projected using UTM WGS 84 Zone 37N. The Landsat image has spatial resolution 30 m. This is commonly used for land-use land-cover change detection and dynamics. The monthly, seasonal, and annual distribution of rainfall is determinant for vegetation growth and productivity in various ecosystems and widely used to evaluate changes in vegetation dynamics (Fensholt *et al*., 2013). In order to examine trends in the spatiotemporal variation of rainfall in the study area, the product of Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) time series data from 1990 to 2020 were used. It was used for obtaining rainfall dataset which freely provided by National Oceanic and Atmospheric Administration's (NOAA's). Spanning 50°S-50° N (and all longitudes), starting in 1981 up to present year, CHIRPS incorporates 5 km resolution satellite imagery with in-situ station data to make gridded precipitation time series for trend analysis and seasonal drought monitoring (Mu *et al.,* 2021)

It provides rainfall datasets based on conjunction geostationary infrared satellite rainfall estimates and rain gauge observations that are interpolated to produce robust precipitation grids (Frunk, 2015). The CHIRPS is updated frequently and provides data at higher spatial and temporal resolutions. It is high quality, temporally consistent, and near real-time precipitation datasets that can help identify environmental changes, quantifies the important role played by warming air temperatures, and play an important role in seasonal drought prediction (Fensholt *et al*., 2013, Frunk, 2015). Monthly gridded precipitation data over the 1990–2020 study periods were downloaded at (http://chg.geog.ucsb.edu/data/chirps/) and the result were used to obtained annual and dry season rainfall data from 1990 to 2020 in the study area.

Accordingly, in order to analysis the trend of spatiotemporal variation of temperature of the study area the product of Climate Hazard Groups InfraRed Temperature with Station (CHRTSmax and CHRTS-daily) time series data from 1990 to 2016 were used. The CHC has developed a quasiglobal (60°S – 70°N), long-term (1983-2016), high resolution (5km), cloud screened archives of geostationary satellite thermal infrared (TIR) observations of monthly mean Tmax and data set of daily maximum and minimum temperatures data record with a dense set of ~15,000 in situ station observations (Funk *et al*., 2019).

Table 2: Description of the satellite images used in this study

Image Type	**Path and Row**	**Resolution**	**Observation Date**
Landsat TM	169 and 54	30 m	12/25/1990
Landsat TM	169 and 54	30 m	12/02/2000
Landsat ETM+	169 and 54	30 m	11/06/2010
Landsat OLI-TIRS	169 and 54	30 m	12/11/2020
CHIRPS		5 km	1990–2020
CHRTSmax and daily		5 km	1990–2016

The software packages used for this study were: ERDAS (Earth Resource Data Analysis System) Imagine 2015, ArcGIS 10.5, ENVI 5.3, QGIS (Quantum GIS) 3.10, and Statistical Software for Microsoft Excel (XLSTAT) software. Those Software were used for pre-processing of Landsat, calculate rainfall and temperature, analysis of zonal statistics, to examine trend and correlation of rainfall and temperature, make the LULC change detection, mapping and analyzing both satellite and field data.

Ground truth data

Data acquired from satellite sensors should be supported and checked with reality by using solid ground truth information. Hence, in the present study ground truth data were collected from the field using handheld Global positioning system GPS for training data for accuracy assessment. Training data that was used to produce land use land-cover map was collected from the field to have a correct spectral value for each class. However, Google Earth (high resolution image) also used to collect information from areas where impossible to accesses.

3.3.Methods of Data Analysis

3.3.1. Image Pre-processing

After satellite image (Landsat image level 1) data were acquired then preprocessing activities have undertaken. This process includes layer stacking, atmospheric and geometric corrections, gap filling (Landsat 7 ETM), and sub setting study areas. The digital image pre-processing helps for the improvement of the quality and interpretability of the digital image so that the image become applicable and ready for further analysis. The correction of satellite images includes radiometric correction based on the radiance and geometric corrections based on the digital number, will be performed for all images. Radiometric correction used to remove sensor or atmospheric noise and to represent accurate ground conditions in an image (Zhang *et al.*, 1999). Also, geometric correction used to remove distortion prevention by the rectification of an image (Wie and Stein 1977). The area of interest (AOI) was prepared for the Chilimo forest to extract required study area from layer stacked images.

3.3.1.1.Image Classification

Image classification is a technique of extracting information from the image based on the reflectance value of an object and produce thematic maps. (Lillesand *et al*., 2004; Richards and Jia, 2006; Gao, 2009). The information class can be grouped into a thematic layer of having similar LULC in the image. The land-use land-cover classification map was performed using support vector machine (SVM). support vector machine is a non-parametric statistical learning method that has recently been used in numerous applications in image processing (Mathur and Foody, 2004; Mustafa *et al.*, 2015). This method is selected because have robustness in classifying homogeneous and heterogeneous land-use and land cover types and gives the best classification result and certainty for land-use land-cover classification (Talukdar *et al*., 2020). Additionally, Avalos *et al*., (2018) noted support vector machine classification methods gives the best classification result and offers better certainty for land-use land-cover classification purpose. Though there are automated image classification techniques, manual or visual image interpretation procedure was used. High-resolution satellite imagery (Google Earth) was used to collect necessary data for areas that is difficult to address. Land-use land-cover classes were represented by code of HF for high forest, MF for mixed forest, PL for plantation forest, SH/B for shrubland/bushland, GL for grassland, WL for wetland, CT for cropland with tree, CWT for crop land without tree, BL for bare land and Other for other land classes (Stepchenko, 2021 and Tibebu *et al*., 2016).

Table 3 presented the types and description of land-use land-cover classes.

LULC Class	Description
High Forest	It represents protected climax natural forests.
Mixed forest	Forest with two or more dominant tree species like deciduous and evergreen forest land
Plantation	Forest predominantly composed of trees established through planting and deliberate seeding mainly eucalyptus.
Shrub/Bush land	land-use encompasses open wood and bushland, dense shrubland and bushland. Also, land with woody vegetation less than 2 meters tall. The shrub foliage can be either evergreen or deciduous
Grass land	Land composed of drained and poorly drained grassland
Wetland	Land composed of swampy, marsh and waterbody areas.
Crop land with Tree	Agricultural lands with very fragmented trees
Crop land without Tree	Agricultural lands with crop and farm land
Bare land	Lands with exposed soil, sand or rocks, and never has more than 10% vegetated cover during any time of the year. Bare ground, bare exposed rocks, quarries and gravel pits.
Other land	Land not classified as forest, shrubland, grassland, wetland, cropland and bare land including roads, settlements and land not classified under previous classed.

3.3.2. Image Reclassification

Since, the objective of this study was to evaluate the amount of forest cover change for the last three decades year, the raster map which was produced as four LULC classes were reclassified into forest and non-forest. Similarly, to examine the effect of rainfall and temperature variability on forest biodiversity thematic map of shrubland, grassland and wetland were prepared. Forest was contained high forest, mixed forest and plantation forest while non-forest contains cropland, bare land and the rest. Those thematic maps were used to assess and analyze the relationship of forest cover transition, shrubland change, grassland conversation and wetland change with seasonal temperature and rainfall and its effect on forest biodiversity in the study area.

3.3.3. Accuracy Assessment

Accuracy was conducted using ground control points from field observations collected by using hand held GPS in addition to Google Earth points (Minta *et al.*, 2018). To classify Landsat image and validate the result reference points from GPS 300 points and from Google Earth points applied to the threshold and to validate the results of 2020 Landsat images. Accuracy assessment using GCP is important to improve the uncertainty of classification (Moraes and Benevides *et al.*, 2021). Classification accuracy assessed by confusion matrix and validated by calculating the kappa coefficient ‘K’, which is an estimate of the overall agreement between the image and ground truth data. Kappa coefficient was computed as follows;

$$K = \frac{N\sum_{i=1}^{r} xii - \sum_{i=1}^{r}(xi + *x + i)}{N^2 - \sum_{i=1}^{r}(xi + *x + i)} \qquad (1)$$

Where, K is the kappa statistic, N is the total number of samples, xii is the number of rows in i and in column i, xi+ is row total for i, and x+i is column total for i. The accuracy assessment is to assess how effectively the pixels were sampled into the land-cove types and how many ground truth pixels were classified correctly (Worku, Binyam and Aramde, 2019).

3.3.4. Validation of CHIRPS and CHIRTS data

Hence, satellite-based rainfall and temperature estimates deliver well timed, repetitive and cost-effective data, recently it has been used as complements or replacing to mereological station data (Muthoni *et al.*, 2019;). But satellite-based rainfall and temperature estimates show different uncertainties with techniques like relative algorithm errors, spatiotemporal sampling errors and satellite instruments themselves. According to Bayable et al. (2021) this result may affect the accuracy and significant error when used in different applications. CHIRPS and CHIRTS satellite rainfall and temperature data validation was done by monthly, seasonal and annual time scales for Ginchi, Jeldu, Abdisalam, Wolenkomi, Kimoye and Dertu stations with the corresponding meteorological gauge station data. The strength of linear relationship between meteorological station rainfall and temperature data and CHIRTS and CHIRPS was computed by Pearson correlation coefficient with ranges from negative one to positive one. The result values greater than 0.5 are considered as acceptable performance (Bayable *et al*., 2021).

3.3.5. Establishment of the Relationship

Linear regression analysis was used to describe the relationship between dependent variables and independent variables. According to this study forest cover, shrubland, grassland and wetland considered as dependent variable were temperature and rainfall as independent variable. The simple linear regression method uses one variable and test the response of another variable to it.

Thus, regression coefficient value exhibits relationship and their change response. These techniques were used to investigate relationships between two variables associated with their change. In short linear regression analysis were used to analyze the trends of the meteorological factors and ecological indicators.

To investigate the relationships between two or more variable at a time over the past 30 years' correlation were conducted (temperature and rainfall). A Pearson correlation coefficient is a numerical indicator that shows the relationship between tow variables. Pearson correlation (PCC) was applied to test the correlation between vegetation cover with mean annual rainfall and mean dry season temperature (Worku *et al*., 2019). In this study area mean annual rainfall and mean wet and dry season temperature has been used to test the relationship between vegetation cover with rainfall and temperature to analyze the impacts of rainfall and temperature on vegetation and forest biodiversity. The Pearson correlation coefficient measure the strength of a linear relationship between paired variables and a PCC is numerical indicators that show the relation between two variables. The Pearson correlation coefficient value (r) empirical relations were calculated as the following;

$$r_{xy} = \frac{\sum_{i=1}^{n}(xi-xm)*(yi-ym)}{\sqrt{a\sum_{i=1}^{n}(xi-xm)^2\sum_{i=1}^{n}(yi-ym)^2}} \qquad (2)$$

Where r_{xy} is the simple correlation coefficient of variable x and y, xm and ym is the means of two variables. The correlation coefficient can range from -1 to 1, where 1 indicates a perfect positive relationship, -1 indicates a perfect negative relationship and 0 indicates no relationships exists (cite). The value of the correlation coefficients (r) can be classified as weak, low, moderate and strong with ($0<|r|\leq0.3$), ($0.3<|r|\leq0.5$), ($0.5<|r|\leq0.8$) and ($0.8<|r|\leq1$) range values respectively.

3.3.6. Trend analysis for temperature and rainfall

Trend is described as a change in a variable overtime which detected by different statistical test method called parametric and non-parametric tests. Trend analysis can detect statistically significant trend in climatological time series (rainfall and temperature). These analyses are very important parameters for analyzing long term climate change. The trend of rainfall and Temperature data was analyzed by non-parametric statistical test using Mann-Kendall trend test estimator which used to detecting climatic variables trend to show whether the time series of trend of rainfall and temperature increasing, decreasing and non -existent (Seifu and Abdulkarim, 2006; Cheung *et al*., 2008; Solomon Gebrechorkos *et al*., 2019). According to those study conducted Mann- Kendall statics computed as

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(yj - yi) \qquad (3)$$

The trend test is applied to a time series yi (ranked from i= 1,2,3, --- n-1) and yj, (from j= i+1, i+2, i+3, …n). Each of the data points Yj is taken as reference point, which is compared with the rest of the data point's yi, so that,

$$\text{sign}(yj - yi) = \begin{cases} 1, \text{if } (yj - yi) > 0 \\ 0, \text{if } (yj - yi) = 0 \\ -1, \text{if } (yj - yi) < 0 \end{cases} \qquad (4)$$

yj and yi are the sequential data values, and n is the length of the data set (Worku, Binyam and Aramde ,2019; Samson, 2020).

To determine true slope of an existing trend like the change per year and dry season amount of change of rainfall and temperature Sen's slop non parametric method were used.

When the trend is linear Sen's slop computed as the following;

$$f(t) = Q(t) + B \qquad (5)$$

Where Q is the slope and B is a constant. Therefore, the Sen slope estimator is computed as

$$B1 = \text{Median}[\frac{(yj-yi)}{(xj-xi)}] \qquad (6)$$

For all j>I and i=1, 2,…,n-1 and j=2,3,…,n; i.e. computing the slope for every pair of data used to compute S equation. The median of slope is the Sen slope estimator.

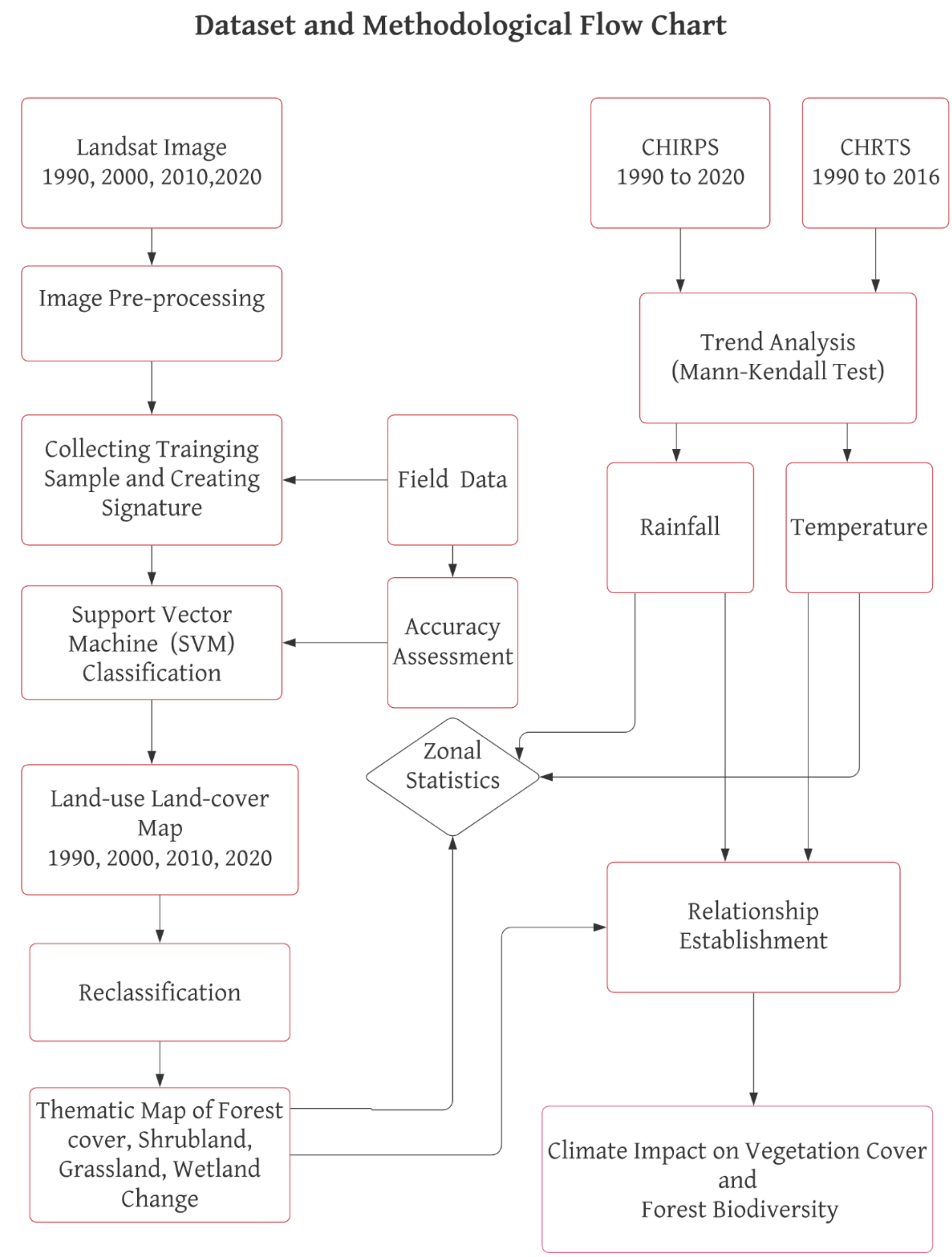


Figure 8: Dataset and methodological flow chart

CHAPTER FOUR

4. RESULTS

4.1. Land-use and Land-cover Change

The spatial and temporal patterns of various land-use and land cover types for 1990 to 2020 was represented in Figure 9. The land-use land-cover classes spatial extent is explained in Table 3. The results illustrated that the dominant land-use and land cover classes were crop land with/out tree and other in 1990. From the total area of 22422 ha, crop land with and without tree accounted for 10823.3ha and other land accounted for 11598.7 ha (51.73 %). The other LULC classes high, medium and plantation forest cover about 3214.26ha, 1253.52ha, and 2153.52ha respectively. Bush/shrub land, grass land with wet land cover about 10.5% from the total coverage with 1333.98ha, 953.51ha, and 66.78ha of land respectively. The natural Forest (high forest) was found very densely in the middle part of study areas with large extent to Eastern part of study area. The south western part of study areas was covered by middle forest and shrub/bush land where also found in Eastern part of study area. Bare land and other land were cover about 11.8% from total coverage with 1315.53ha and 1330.02ha respectively. In 2000, High Forest was accounted for about 2868.12ha from the total land coverage. Middle forest, shrub land/bush, plantation and grass land take share of 1692.72(7.54%), 1693.35(7.55%), 1499.22(6.69%), and 850.89(3.79%) respectively. Accordingly, crop land without tree, crop land with tree, bare land and other land covered areas of 7194.15ha, 4341.33ha,1442.7ha and 776.43ha. The results shown there has been a significant decrease in the areas of high forest (natural forest) and and plantation forest with 4.46 percent. Accordingly, the results also shown that there has been an increase in the areas of crop land with 845.55ha of land from the previous period.

Land-use and land cover classified map of 2010 illustrated that high forest land coverage was about 2746.62ha (12.25%) of the total area whereas mixed forest, plantation and shrub land accounted 1341.09, 2097.9 and 1028.52 respectively. Accordingly, crop land without tree accounted very high coverage of the total land cover with 8401.59ha (37.47%), whereas crop land with tree land cover was accounted 3899.97ha (17.39%) of the total coverage the study areas. The remaining LULC shared around 2906.31ha (12.96%).

Additionally, land-use and land cover classified map of 2020 showed that high forest land coverage was about 2596.86ha (11.58%) of the total area whereas mixed forest, plantation and shrub land accounted 1402.2ha, 1672.56ha and 1189.35ha respectively. Accordingly, crop land without tree accounted very high coverage of the total land cover with 8757.36ha (39.06%). Wet land was the smallest LULC class followed grass land (Figure 9 and Table 4).

Table 4: Land-use and land-cover change areas during 1990 to 2020

LULC Type	**1990**		**2000**		**2010**		**2020**	
	Area(ha)	Area (%)	Area(ha)	Area (%)	Area(ha)	Area (%)	Area(ha)	Area (%)
HF	3214.26	14.34	2868.12	12.79	2746.62	12.25	2596.86	11.58
MF	1231.29	5.49	1692.72	7.55	1341.09	5.98	1402.2	6.25
PF	2153.52	9.60	1499.22	6.69	2097.9	9.36	1672.56	7.46
SH/B	1333.98	5.95	1693.35	7.55	1028.52	4.59	1189.35	5.30
GL	953.31	4.25	850.89	3.79	736.23	3.28	527.58	2.35
WL	66.78	0.30	63.09	0.28	41.22	0.18	20.16	0.09
CT	4474.71	19.96	4341.33	19.36	3899.97	17.39	4380.84	19.54
CWT	6348.6	28.31	7194.15	32.09	8401.59	37.47	8757.36	39.06
BL	1315.53	5.87	1442.7	6.43	1013.67	4.52	819.75	3.66
Other	1330.02	5.93	776.43	3.46	1115.19	4.97	1055.34	4.71
Total	**22422**	**100**	**22422**	**100**	**22422**	**100**	**22422**	**100**

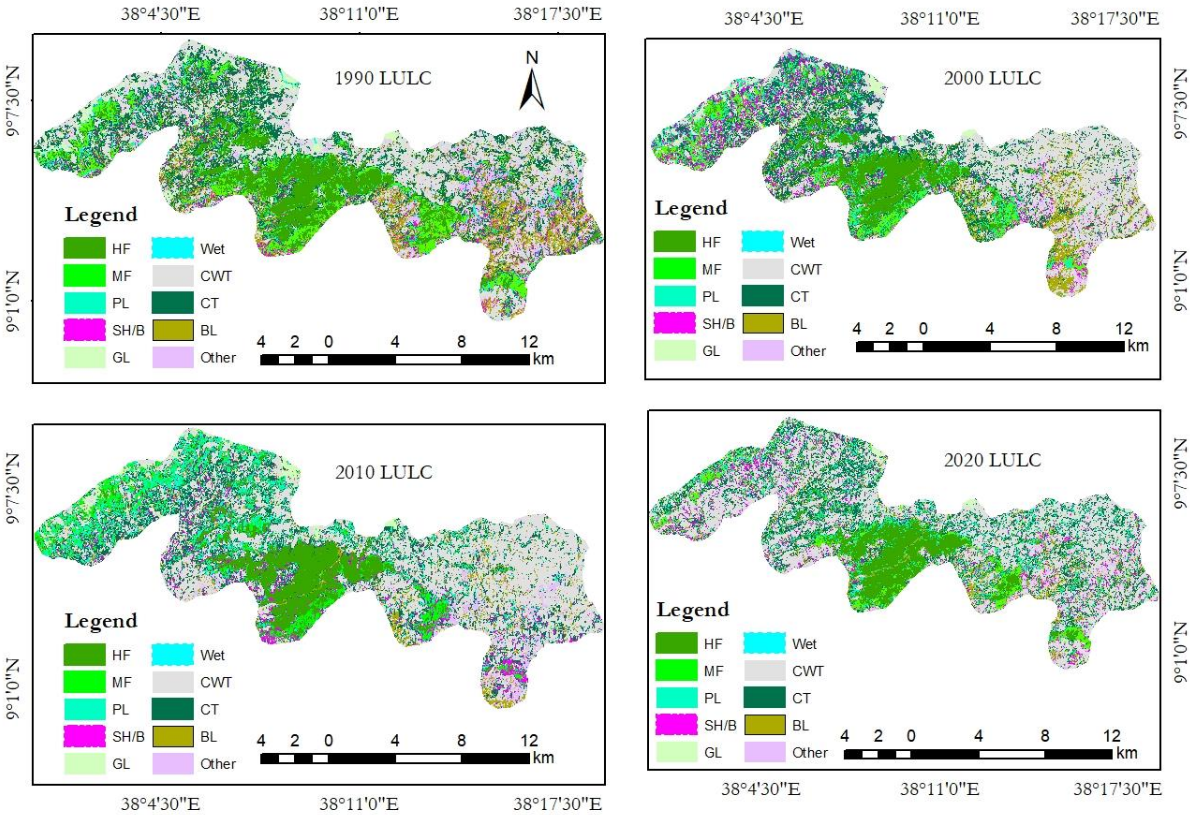
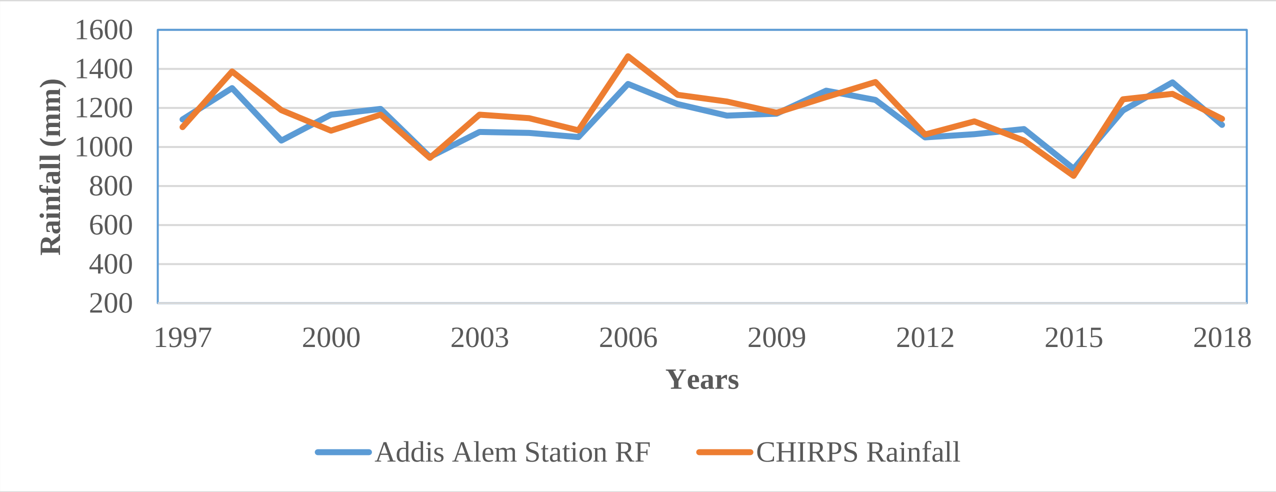


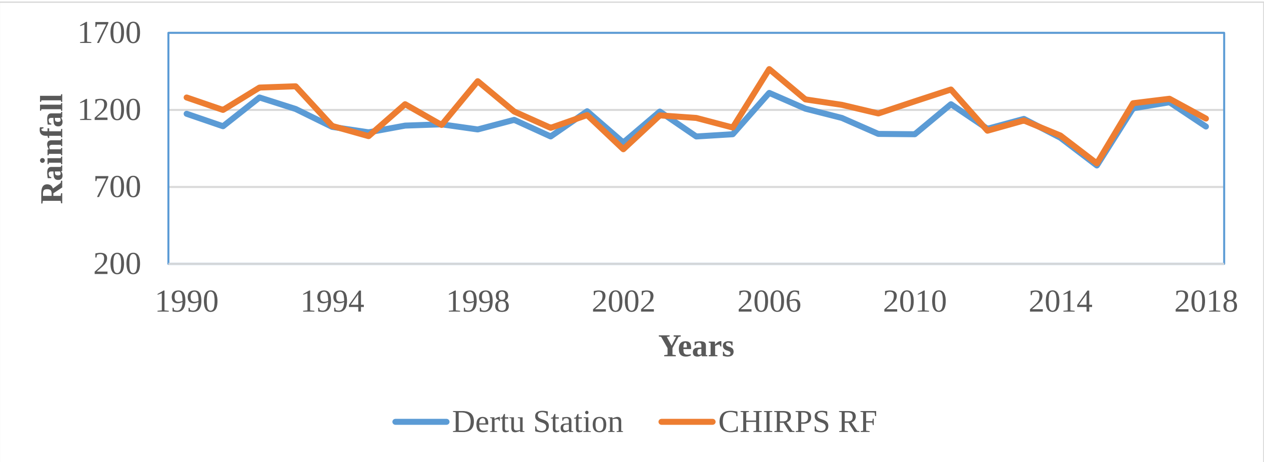
Figure 9: Land-use and land-cover map of 1990, 2000, 2010 and 2020

4.2. Accuracy and validation of CHIRPS and CHIRTS data

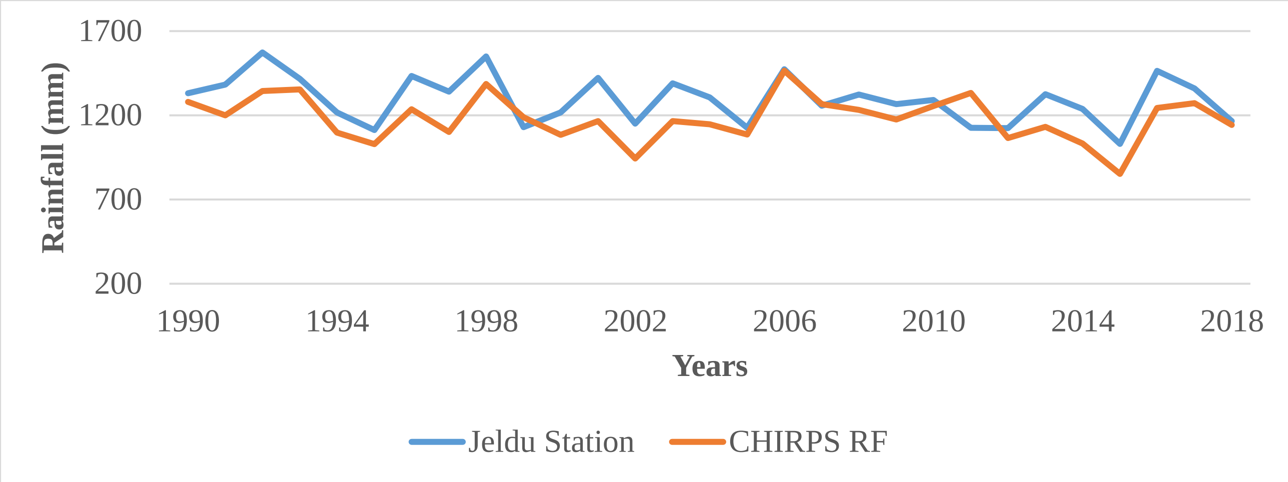
The accuracy assessment result for land-use land-cover shows that, for 1990, 2000, 2010 and 2020 overall accuracy was 87.7%, 88.5%, 88.9 % and 90.3% and kappa was 0.85, 0.83. 0.86 and 0.89, respectively (Appendix 1). According to Wanga and Ndambuki, (2017), the result of overall accuracy of the map is acceptable. Accordingly, the results of the validation of CHIRPS rainfall and CHIRTS temperature data using meteorological gauge station data at annual and seasonal time scales at the stations of Addis Alem, Jeldu, Kimoye and Wolenkomi stations was presented in Figure 10 and Figure 11 respectively. The results showed a good agreement between meteorological gauge station and CHIRPS rainfall and CHIRTS temperature on annual and seasonal time scale. Thus, the results of Pearson correlation coefficient values between meteorological station rainfall and temperature data and CHIRTS and CHIRPS was showed values greater than 0.7 that were considered as acceptable performance.



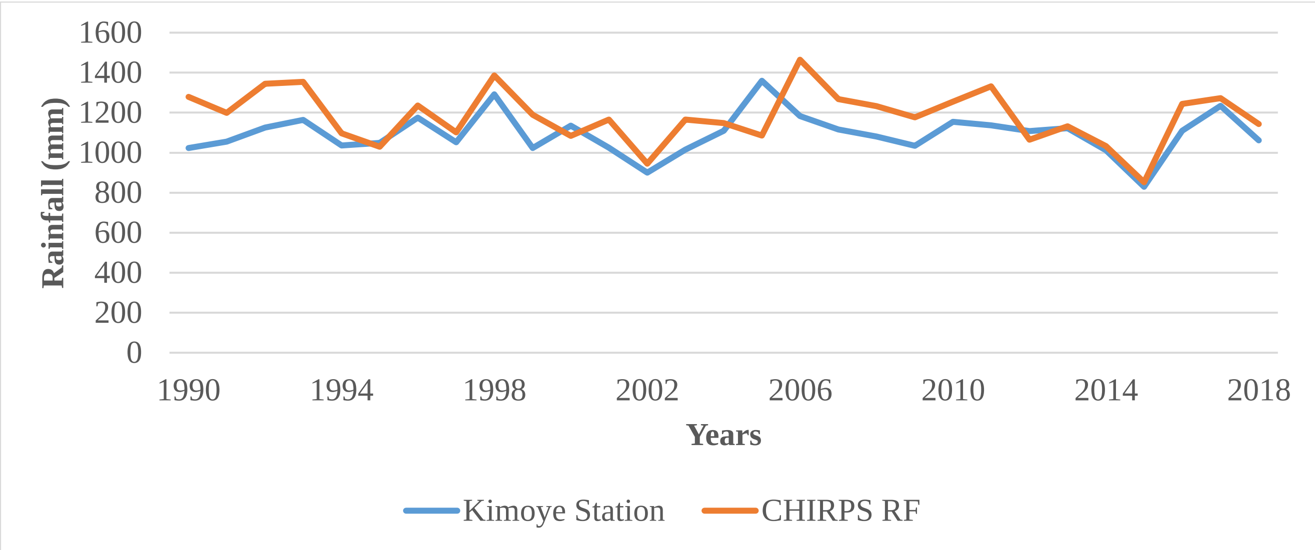
a)



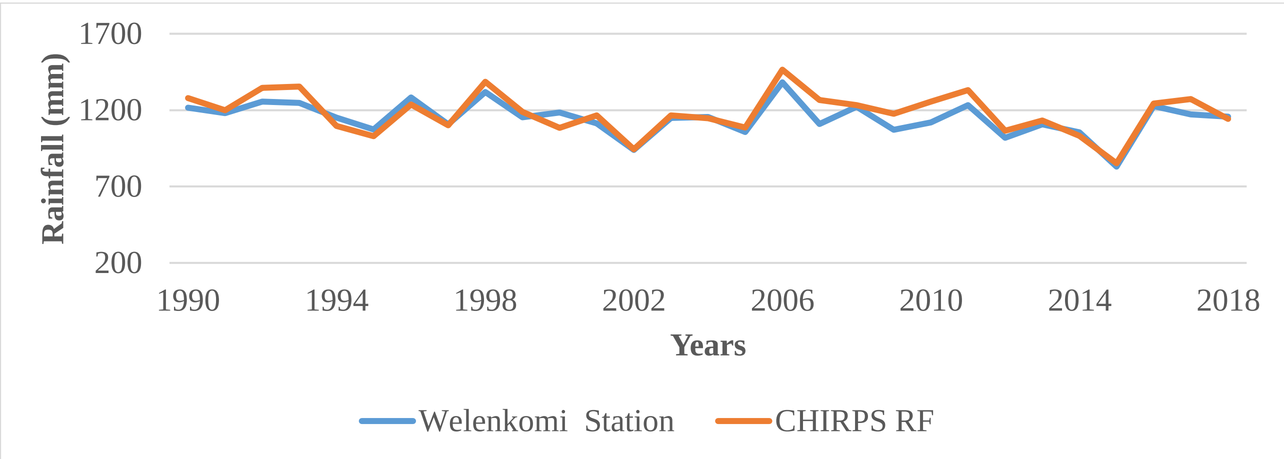
b)



c)

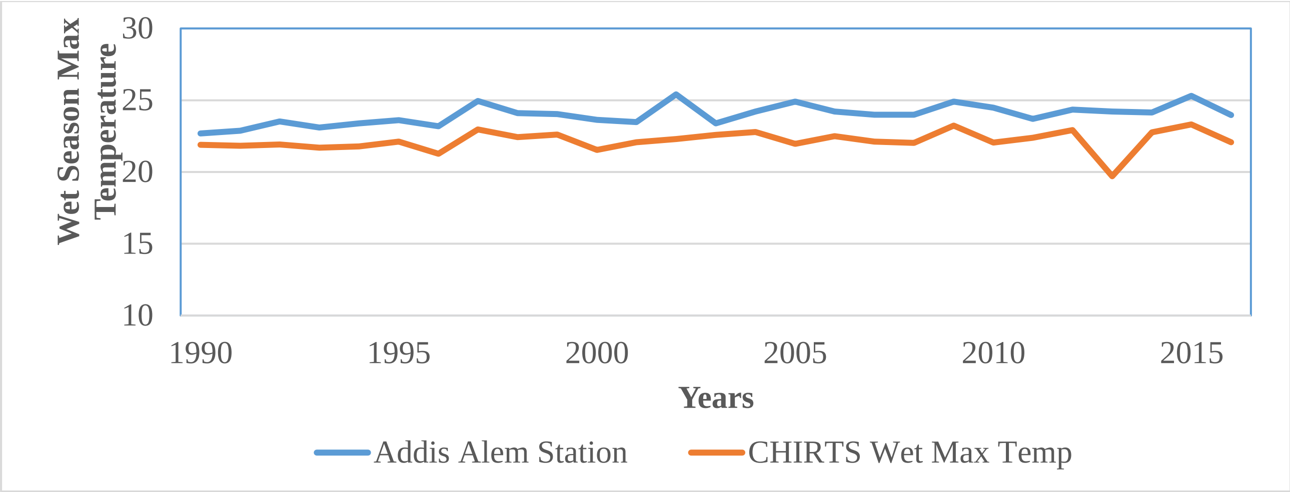


d)

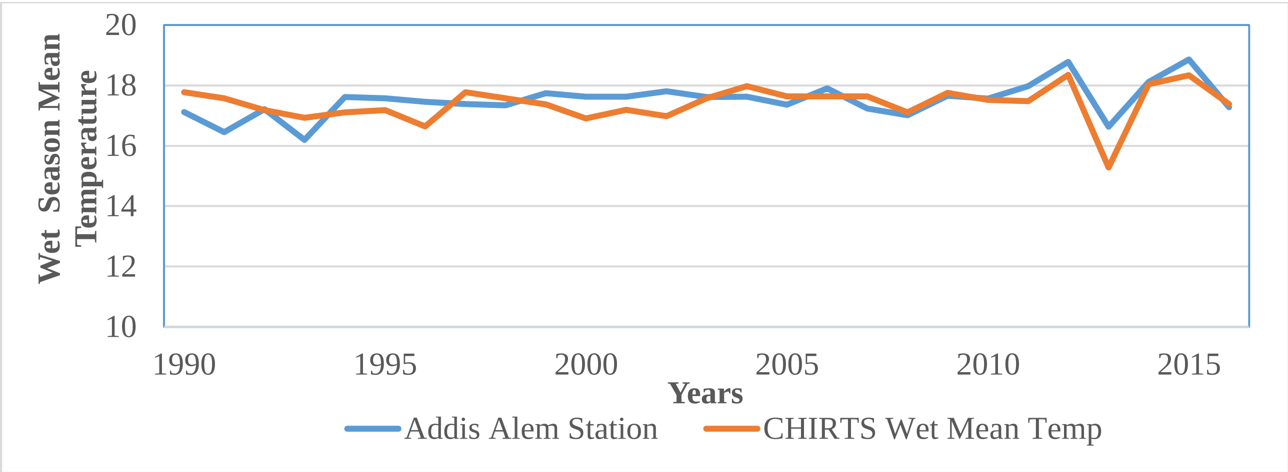


e)

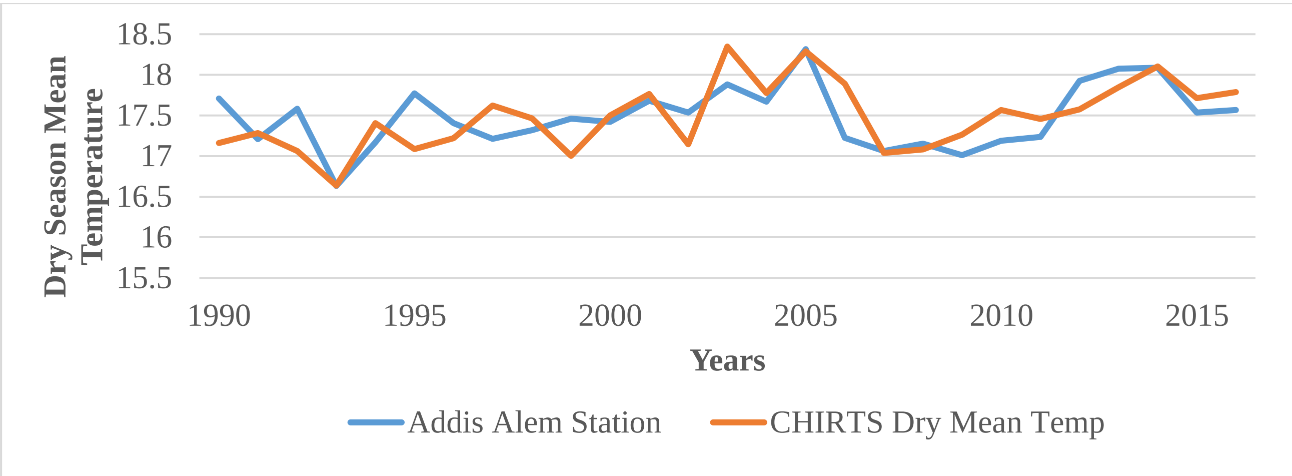
Figure 10: Graphical comparison of mean annual CHIRPS and mereological station rainfall in Addis Alem (a), Dertu (b), Jeldu (c), Kimoye (d) and Wolenkomi (e) respectively.


Wet Season Max Temperature
30
25
20
15
10
1990
1995
2000
2005
2010
2015
Years
Addis Alem Station
CHIRTS Wet Max Temp

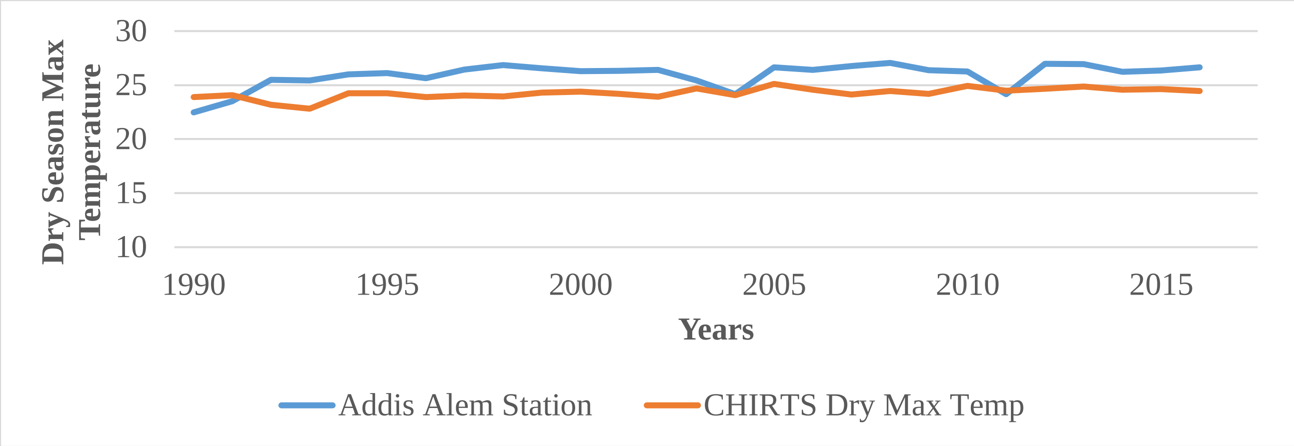
a)


Wet Season Mean Temperature
20
18
16
14
12
10
1990
1995
2000
2005
2010
2015
Years
Addis Alem Station
CHIRTS Wet Mean Temp

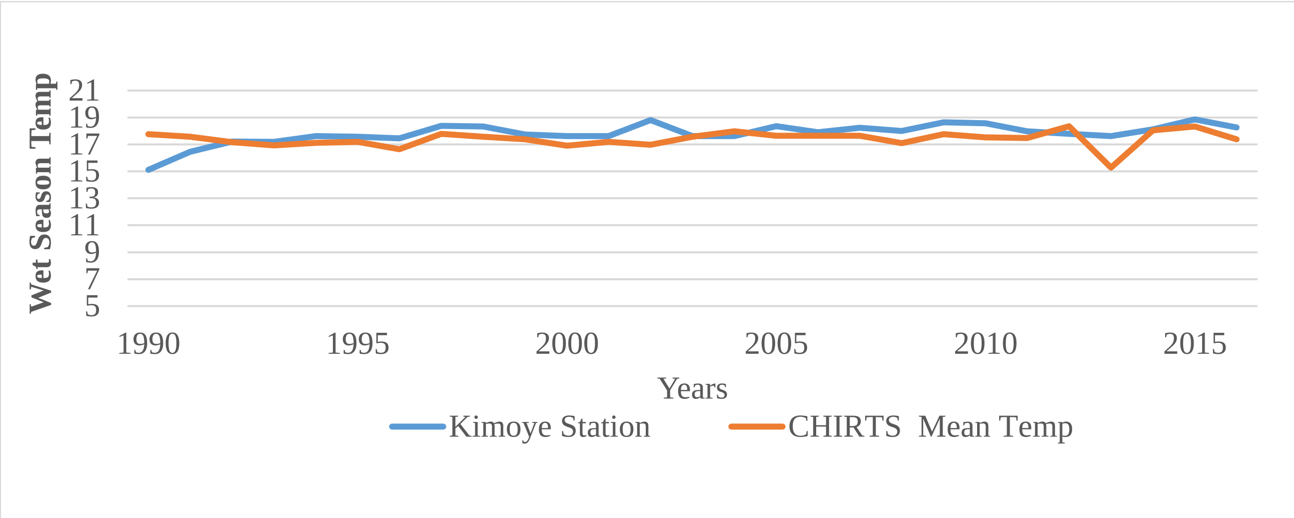
b)


Dry Season Mean Temperature
18.5
18
17.5
17
16.5
16
15.5
1990
1995
2000
2005
2010
2015
Years
Addis Alem Station
CHIRTS Dry Mean Temp

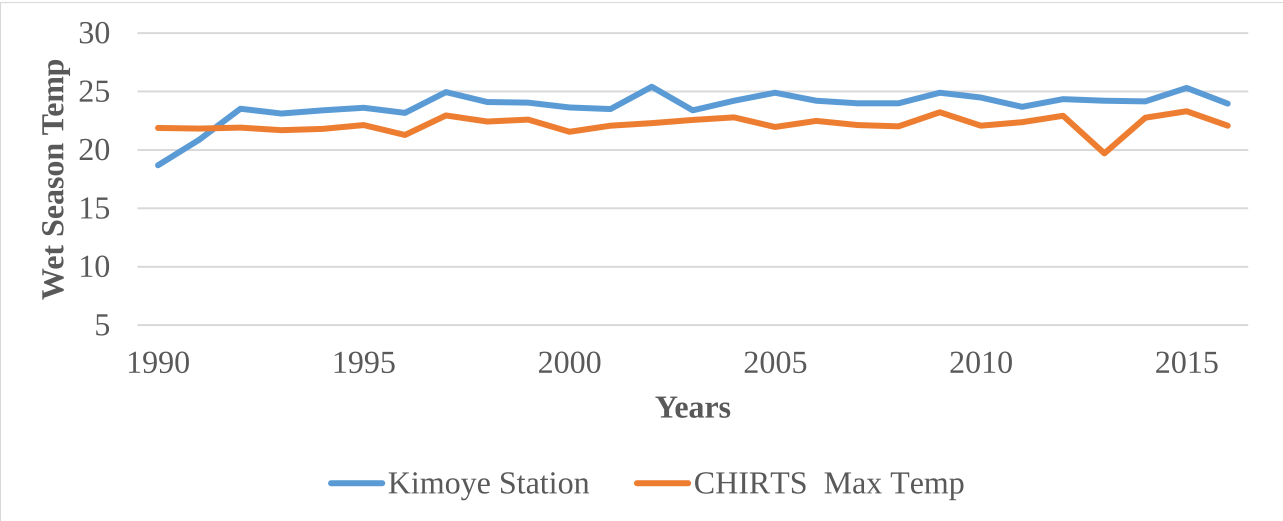
c)


Dry Season Max Temperature
30
25
20
15
10
1990
1995
2000
2005
2010
2015
Years
Addis Alem Station
CHIRTS Dry Max Temp

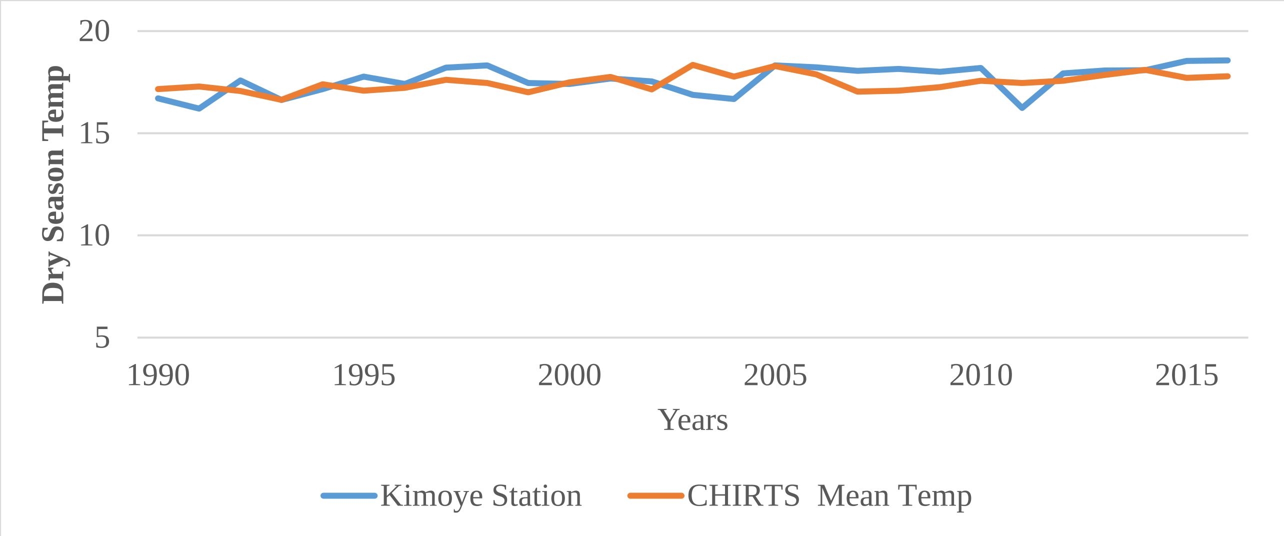
d)


Wet Season Temp
21
19
17
15
13
11
9
7
5
1990
1995
2000
2005
2010
2015
Years
Kimoye Station
CHIRTS Mean Temp

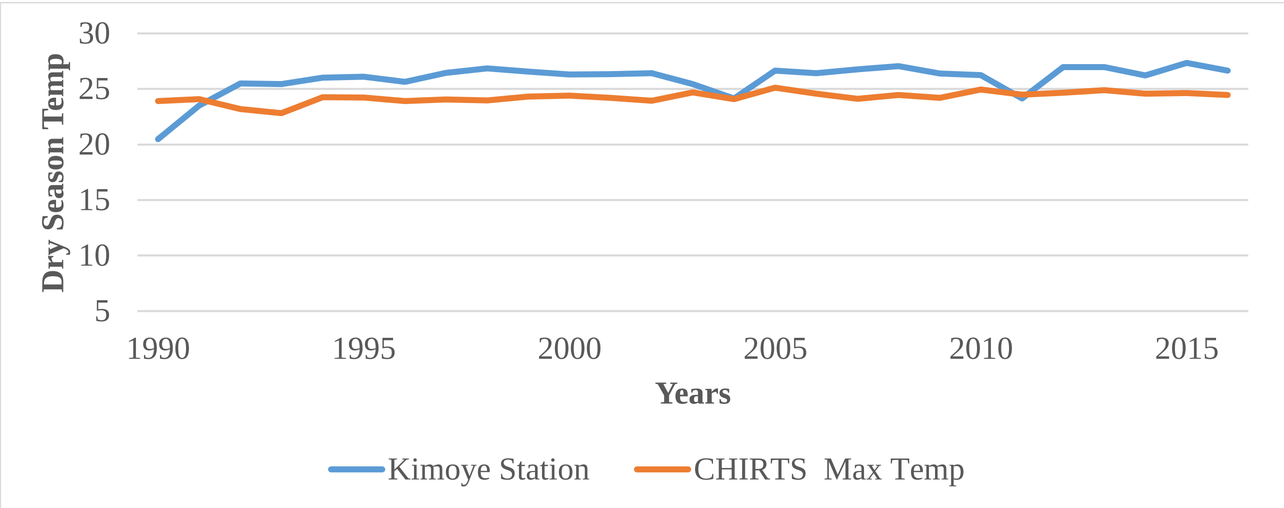
e)


Wet Season Temp
30
25
20
15
10
5
1990
1995
2000
2005
2010
2015
Years
Kimoye Station
CHIRTS Max Temp

f)



g)



h)

Figure 11: Graphical comparison mean wet and dry season, Maximum CHIRTS and mereological station temperature in Addis Alem (a-d), Kimoye (e-h).

4.3. Trend and rate of land-use and land-cover change

Land-use and land-cover trend of the study area shows a significant change from 1990 up to 2020 years. The results further identified that high forest, plantation forest, grass land, crop land with tree and wet land from 1990 to 2000 have declined by 346.14ha (1.54%), 654.3ha (2.92%), 102.42ha (0.46%), 133.38ha (0.59%) and 555.59ha (2.47%) respectively. Additionally, wet land decreased by 3.69ha (0.02%). However, shrub/bush land, crop land and bare land increased by 359.37(1.6%), 845.55ha (3.77%), and 127.17ha (0.57%) during the 1990 to 2000 years. In the study period of 2000 to 2010, the events of plantation forest and crop land increased by 598.68ha (2.67%) and 1207.44ha (5.39%) whereas high forest, mixed forest, shrub/bush land, bare land and other land decreased by 121.5ha (0.54%), 351.63ha (1.57%), 664.83ha (2.97%), 301.86ha (1.35%) and 214.83ha (0.96%) respectively. Additionally, grass land and wet land declined by 114.66ha (0.51%) and 21.87ha (0.10) during the study period.

In the last period (2010-2020), high forest, plantation forest, grass land and bare land have decreased by 149.76ha (0.67%), 425.34ha (1.09%), 208.44ha (0.93%) and 167.49ha (0.75%), whereas shrub/bush land, crop land and other land increased by 160.83ha (0.72%), 836.64ha (3.73%) and 280.8ha (1.25%). The land-use and land cover change trend from the initial year to final year shows decrease in high forest, plantation forest, shrub/bush land, grass land, wet land, crop land with tree and other land by 617.74ha (2.75%), 785.61ha (3.5%), 144.63ha (0.65%), 425.52ha (1.9%), 26.19ha (0.12%), 93.87(0.42%) and 274.68ha (1.23%) respectively. In contrast, mixed forest, crop land and bare land show increased by170.91ha (0.76%), 2408.76(10.74%) and 167.49ha (0.75%) respectively. The land-use and land-cover change during 1990-2000, 2000-2010, and 2010-2020 shown in Figure 10.

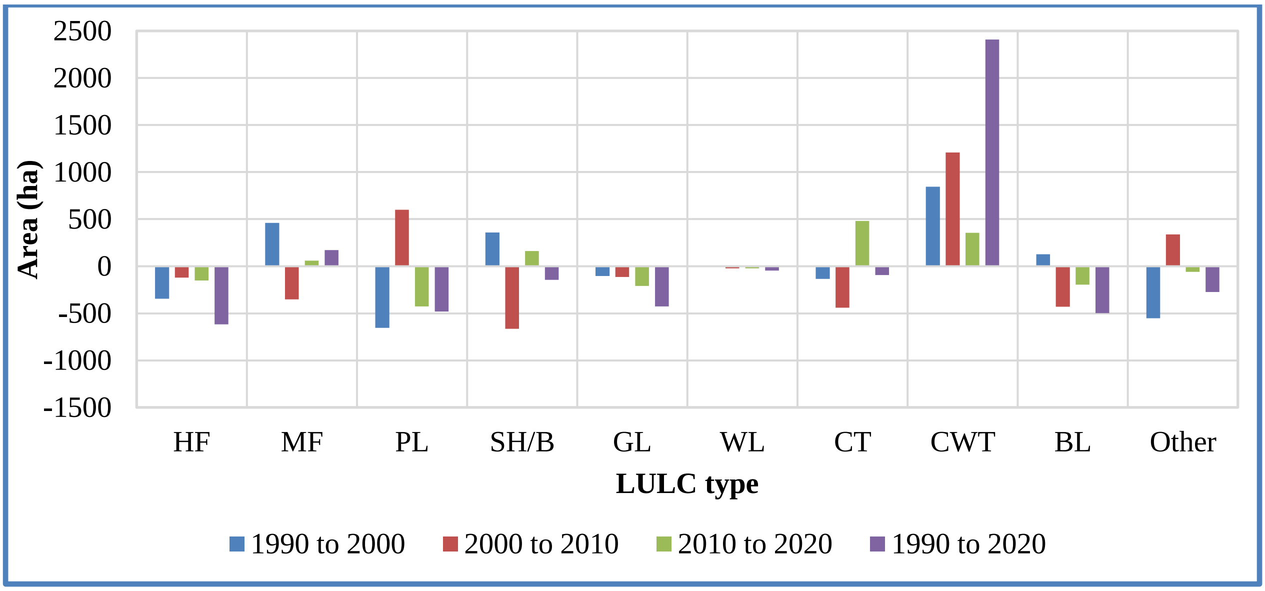


Figure 12: Extent and trend of land-use and land-cover changes

The rate of land-use land-cover change was gradual change for the last thirty years since 1990. High forest land in the first periods show a significant decreasee with 34.61ha yr.$^{-1}$. In the second and third period also decrease by 12.15ha yr.$^{-1}$ and 14.97ha yr.$^{-1}$ respectively. From the initial period to final high forest land decrease with 61.74ha yr.$^{-1}$. This indicate that forest land cleaned for agricultural purpose (crop activity). Mixed forest, shrub/grass land, crop land and bare land in the first period increase with 46.14ha yr.$^{-1}$, 35.94ha yr.$^{-1}$, 84.55ha yr.$^{-1}$ and 12.72ha yr.$^{-1}$ respectively. But in the second period mixed forest and shrub/bush land decrease with 35.16ha yr.$^{-}$

[1] and 66.48ha yr.$^{-1}$ respectively. Plantation forest increase with 65.43ha yr.$^{-1}$ and 42.53ha yr.$^{-1}$ in the first and third period respectively, but it increases in the second period with 59.86ha yr.$^{-1}$. From the initial periods to the last period wet land was continually decrease and crop land without tree was continually increase with spontaneous way. From 1990 to 2020-year significant change was recorded crop land with average rate of 240.87ha yr.$^{-1}$ following high forest, bare land, plantation forest and grass land respectively. These results illustrate the demand for agricultural purpose was very high in all throughout the study periods.

4.4. Forest cover change

Forest and non-forest change result illustrated that a high coverage of forest cover examined in the first period (1990) with 6599.16ha and the smallest amount of forest coverage were observed in the final study period with 5671.37ha. However, in the second period and third period relatively similar forest coverage was shown with 6059.90ha and 6185.25ha, respectively. The result of forest and non-forest cover change statistics reveal in the initial period 1872.36ha (8.35%) of forest coverage was changed into non-forest while 4726.53ha (21.08%) was unchanged. Similarly, in the same study period 1348.22ha (6.01%) non-forest areas were changed to forest while 14474.89ha (64.56%0 was stay unchanged. Accordingly, in the second period 1727.60ha (7.70%) of forest areas changed into non-forest areas whereas 4332.33ha (19.32%) was stay unchanged. Similarly, in the same study period 1852.47ha (8.26%) non-forest area changed to forest cover whereas 14509.60ha (64.71%) was stay unchanged. This result indicate relatively similar significant change were observed in the initial and second study period of forest cover to non-forest area with 8.35% and 7.70% respectively. Moreover, in the final period the amount of change from forest to non-forest and non-forest to forest cover coverage was 938.07ha (4.18%) and 1950.56ha (8.70%) respectively. In this period table forest shows significant by covering 3720.78ha (16.59%) while table non-forest shows increase with 15812.59ha (70.52%). Furthermore, the amount of change from forest to non-forest areas from initial to final year was 2932.29ha (13.08%) and from non-forest to forest covers 1584.36ha (7.07%). In this period decrease was revealed from forest cover to non-forest cover change which table forest shows decrease with 4086.9ha (18.23%) while table non-forest was 13818.45ha (61.63%) (Figure 11 and Table 5).

Table 5: Forest and non-forest change statistics (1990 to 2020)

LULC type	1990 to 2000		2000 to 2010		2010 to 2020		1990 to 2020	
	Area(ha)	**Area (%)**	**Area(ha)**	**Area (%)**	**Area(ha)**	**Area (%)**	**Area(ha)**	**Area (%)**
Table forest	4726.53	21.08	4332.33	19.32	3720.78	16.59	4086.9	18.23
Forest to non-forest	1872.36	8.35	1727.6	7.70	938.07	4.18	2932.29	13.08
Non-forest to forest	1348.22	6.01	1852.47	8.26	1950.56	8.70	1584.36	7.07
Table non forest	14474.8699	64.56	14509.6	64.71	15812.59	70.52	13818.45	61.63
Total	**22422**	**100**	**22422**	**100**	**22422**	**100**	**22422**	**100**

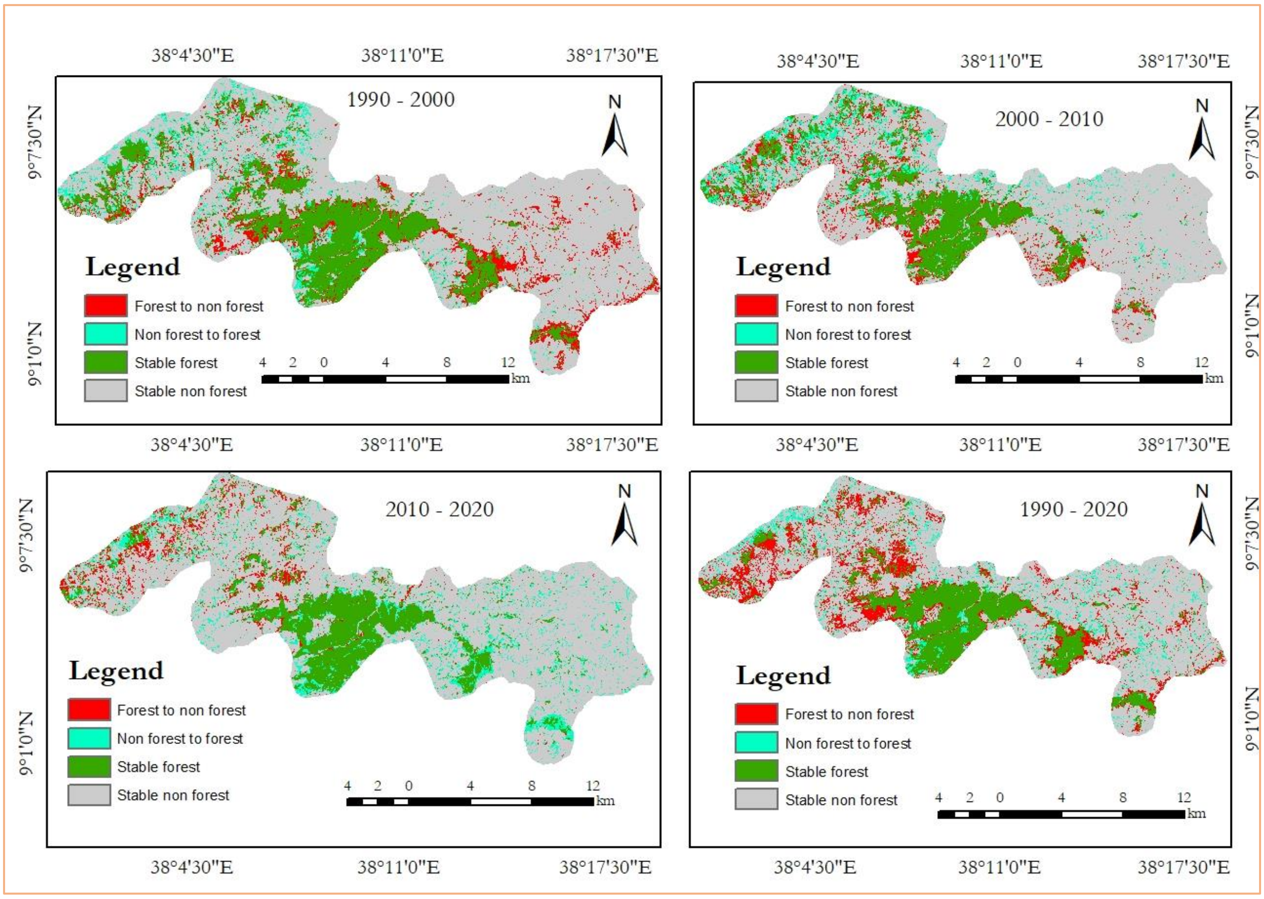


Figure 13: Forest cover change of 1990 to 2000, 2000 to 2010, 2010 to 2020 and 1990 to 2020

4.5. Temperature Trend

4.5.1. Trend of Seasonal Temperature

The result examined from Mann-Kendall test shows that mean, minimum and maximum temperature for dry season significant increasing trend with a change factor of 0.026, 0.039 and 0.037 respectively (1990-2016). In wet season temperature indicate insignificant increasing trend of mean and minimum temperature with a changing factor of 0.011 and 0.0012 while maximum temperature result show decreasing trend with changing factor of 0.0103.

The Mann-Kendall trend test result illustrated that the mean, minimum and maximum temperature for dry season were ranges 16.64°C - 18.35 °C, 10.74 °C - 13.28 °C and 22.82 °C – 25.11 °C, respectively. Similarly, the result of mean, minimum and maximum temperature for wet season were ranges 15.28 °C – 18.28 °C, 6.63 °C – 10.31 °C and 17.7 °C – 23.31 °C, respectively (Figure 12 and Table 6).

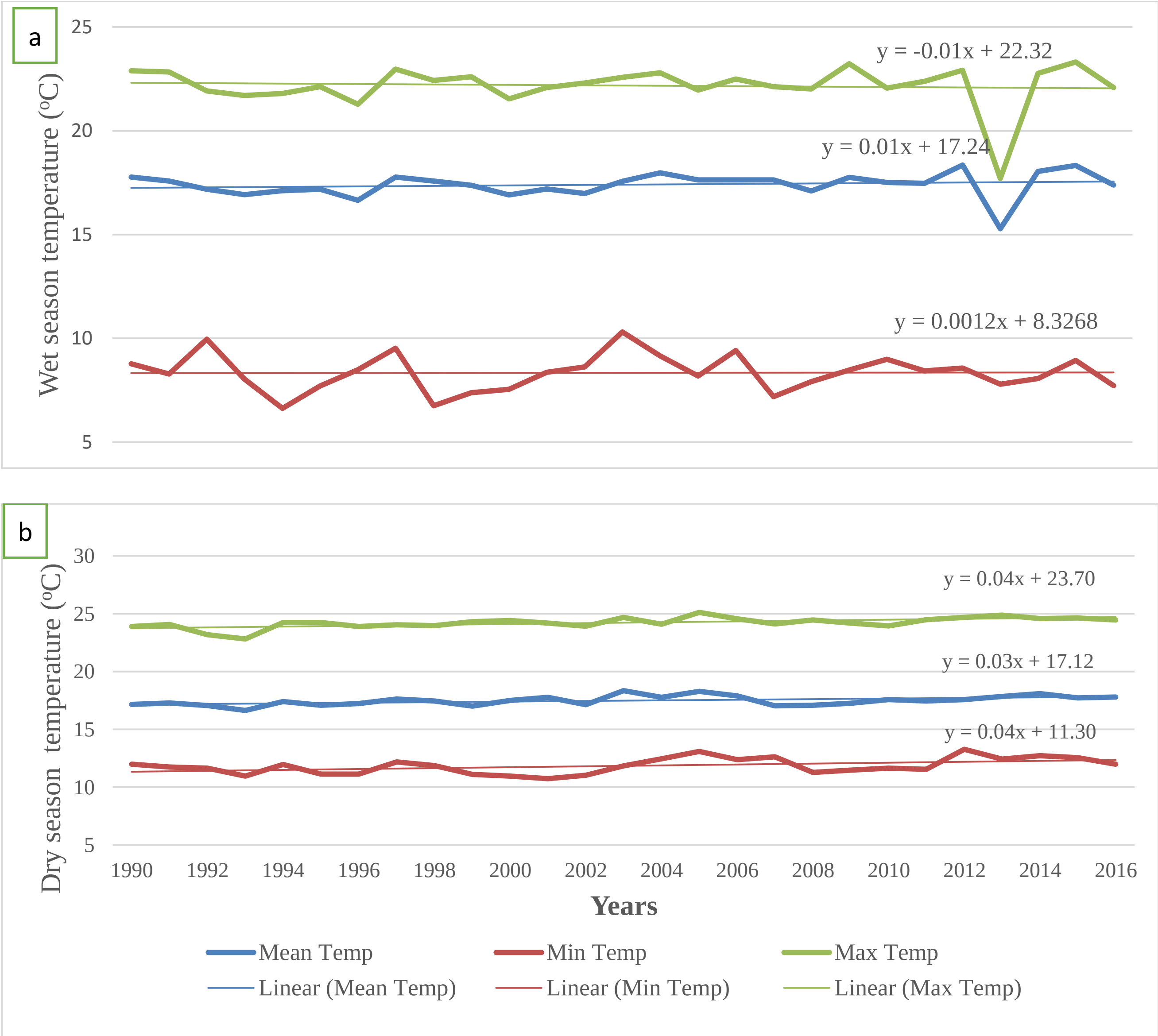


Figure 14. Trend line of mean, minimum and maximum temperature for wet (a) and dry season (b)

Table 6: Mann-Kendall test and Sen's slope of mean, minimum and maximum temperature for wet and dry season, at a significance level of α=0.05

Variables	Wet Season			Dry Season		
	Mean	Min	Max	Mean	Min	Max
Kendall's tau	0.211	0.009	0.103	0.379	0.271	0.464
P-value	0.128	0.967	0.453	0.005	0.048	0.001
Mean	17.4	15.28	18.28	17.48	16.64	18.35
Min	8.34	6.63	10.31	11.85	10.74	13.28
Max	22.18	17.7	23.31	24.22	22.82	25.11
Sen's Slope (^oC/yr.)	0.021	0.001	0.016	0.028	0.036	0.031

Moreover, the Mann-Kendall test result revealed that mean, minimum and maximum temperature of dry season indicated that statistically significant change with P-value of 0.005, 0.048 and 0.001, respectively. Hence, the p-value is less than significant level 0.05 then the null hypothesis is accepted. Accordingly, the risk to reject the null hypothesis of wet season temperature while it is 0.52%, 4.99% and 0.05% for the mean, minimum and maximum temperature, respectively. Accordingly, in wet mean, minimum and maximum temperature increment were statistically insignificant with p-value of 0.123, 0.967 and 0.453, respectively. Thus, the p-value is greater than significant level of 0.05 then the null hypothesis is accepted. So, the risk to reject the null hypothesis Ho while it is true for the mean, minimum and maximum of wet season 12.8%, 96.71% and 46.55%, respectively.

The Man-Kendall trend analysis Sen's slope result showed that mean, minimum and maximum temperature dry season 0.028^oC yr.$^{-1,}$ 0.036 ^oC yr.$^{-1}$ and 0.031 ^oC yr.$^{-1}$respectively. In wet season the Sen's slope indicated that mean, minimum and maximum temperature increased with 0.021 ^oC yr.$^{-1}$, 0.001 ^oC yr.$^{-1}$ and 0.016 ^oC yr.$^{-1}$ respectively. Furthermore, linear regression trend and 5-year moving average line for mean wet and dry season temperature data series was calculated (Figure 13).

Figure 15: Wet (a) and Dry season temperature (b) and equivalent linear regression trend line and 5-year moving average line plotted (1990 – 2016)

4.6. Trend of Annual and Dry Season Rainfall

Mann-Kendall trend test were computed to statistically analysis the trend of annual and seasonal rainfall of study period (1990 – 2020). The annual rainfall both in winter and dry seasons were statically significant trend in the study period. There was an increasing trend of mean, minimum and maximum annual and dry season rainfall in the study area. The trend line show that a positive significant increasing of value of annual mean and maximum rainfall changed with the changing factor of 0.02 and 0.12, respectively while minimum annual rainfall indicated negative decreasing value with a changing factor of 0.71. Accordingly, the trend line of mean, minimum and maximum dry season rainfall indicated negative decreasing value with a changing factor of 1.15, 0.51 and 2.04, respectively (Figure 14).

Figure 16: Trend line of mean, minimum and maximum Annual (a) and dry season rainfall (b) from 1990 to 2020

Table 7: Mann-Kendall test and Sen's slope of mean, minimum and maximum of annual and dry season rainfall, at a significance level of α=0.05

Variables	Annual Rainfall			Dry Season Rainfall		
	Mean	Min	Max	Mean	Min	Max
Kendall's tau	0.028	0.032	0.052	-0.168	-0.075	-0.18
P-value	0.84	0.814	0.696	0.19	0.57	0.15
Min	852.94	754.54	958.84	160.68	144.54	196.86
Max	1471.64	1363.62	1633.86	395.67	314.37	515.34
Mean	1208.56	1091.26	1309.82	250.06	213.82	298.77
Sen's Slope (oC/yr.)	0.791	0.619	1.165	-1.46	-0.65	-2.06

In addition, the result revealed that mean, minimum and maximum annual rainfall show that statistically increasing trend with p-value of 0.84, 0.81 and 0.69, respectively. As the calculated p-value is greater than the significance level 0.05, one cannot reject the null hypothesis. The risk to reject the null hypothesis Ho it is true is 83.99%, 81.37% and 69.58% for annual mean, minimum and maximum annual rainfall, respectively. Accordingly, the Man-Kendall trend test result indicated that statistically insignificant trend with p-value of 0.16 and 0.84 for mean and maximum dry season rainfall while minimum dry season rainfall result show statistically insignificant increase with p-value of 0.74. The risk to reject the null hypothesis Ho while it is true is 16.51%, 73.63% and 83.99% for mean, minimum and maximum dry season rainfall, respectively. Hence, the result of p-value is greater than alpha value that indicated scientifically there is no significant trend for both of annual rainfall as well as dry season rainfall for the last thirty years in the study area (Table 7).

The Mann-Kendall trend test analysis Sen's slope estimator result indicated that there was an increasing trend of annual mean, minimum and maximum annual rainfall with 0.79mm, 0.62mm and 1.16mm per decade, respectively. Similarly, dry season rainfall Sen's slope estimator result indicated decreasing trend of mean, minimum and maximum rainfall with 1.46mm, 0.65mm and 2.06mm, respectively, per decade. Additionally, for the seek to understand inter seasonal and inter annual rainfall variability the linear regression trend and 5- year moving average line for annual and dry season rainfall data series was calculated. According to the computed Figure the annual rainfall indicates inter annual and dry season rainfall show inter seasonal variability. The variability is sketched by the periodic fluctuations between consecutive dry season and annual years rainfall. Thus, as illustrated in the following (Figure 15) higher inter seasonal rainfall was observed in the study area.

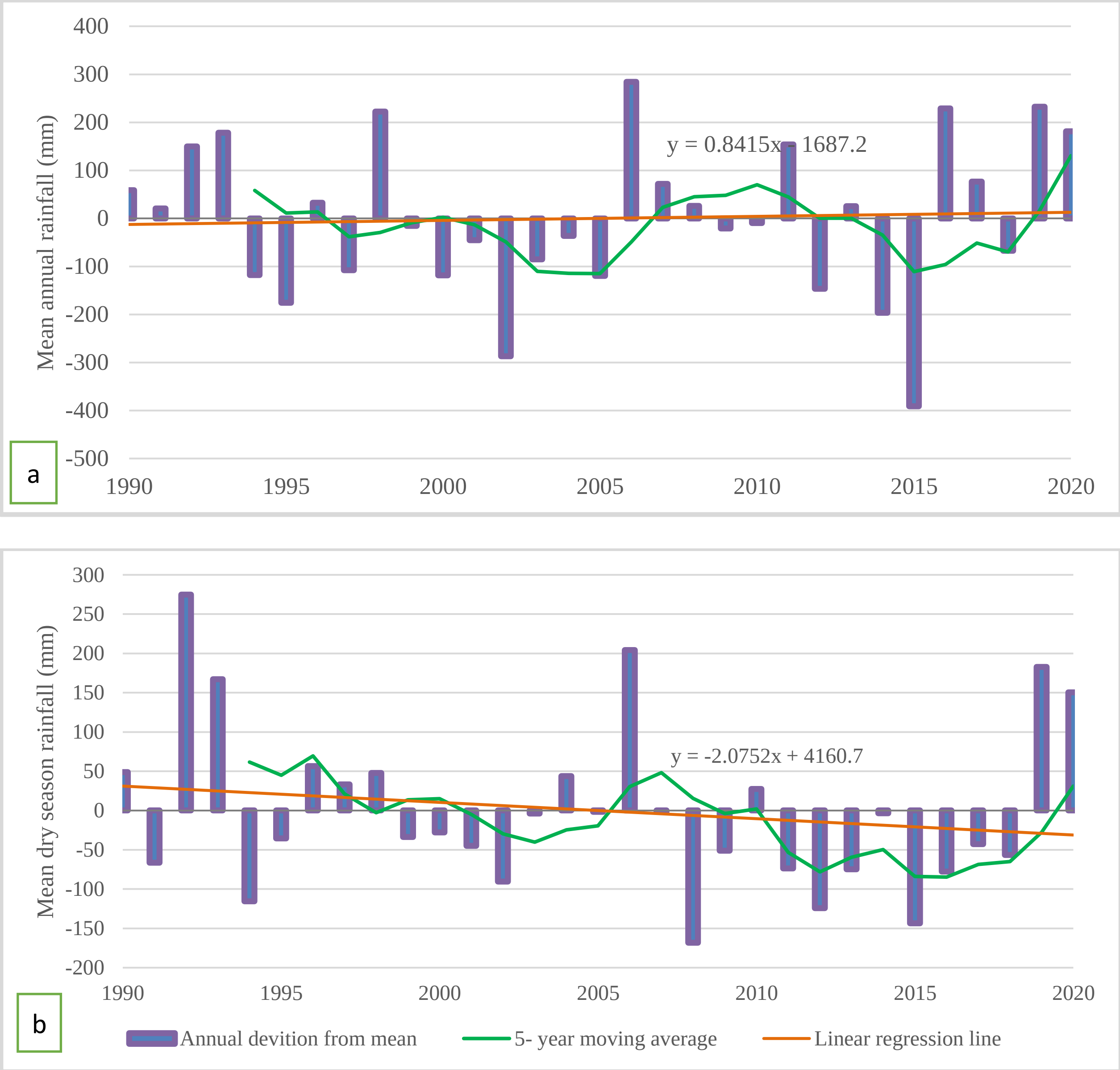


Figure 17: Mean annual rainfall (a) and Dry season rainfall (b) and equivalent linear regression trend line and 5-yaer moving average line plotted (1990 – 2020)

4.7. Relationship of forest cover and temperature with seasonal variation

The relationship of forest cover and seasonal temperature were evaluated by correlation between them. The Pearson correlation result between mean wet season temperature and forest cover revealed that forest cover and wet season temperature have a weak positive correlation (r= 0.1). However, the correlation between mean dry season temperature and forest cover change indicated that moderate and negative correlation (r= -0.78) (Table 8). The result illustrated that the forest cover had shown low temperature over the study areas. Since, the study area categorized as Dega and Weyena Dega climatic zone, the forest cover and temperature map indicated that areas with lower temperature and Dega climatic zone had shown high forest, while, non-forest areas and Weyena Dega zone had shown relatively higher temperature. According to Figure 16 and 17 showed higher forest coverage with lower temperature were have been observed in the central and north-western of the study area over the study period. Besides, in the eastern and southern low land part of the study areas were covered by sparse forest and non-forest have been indicated relatively high temperature throughout the study period.

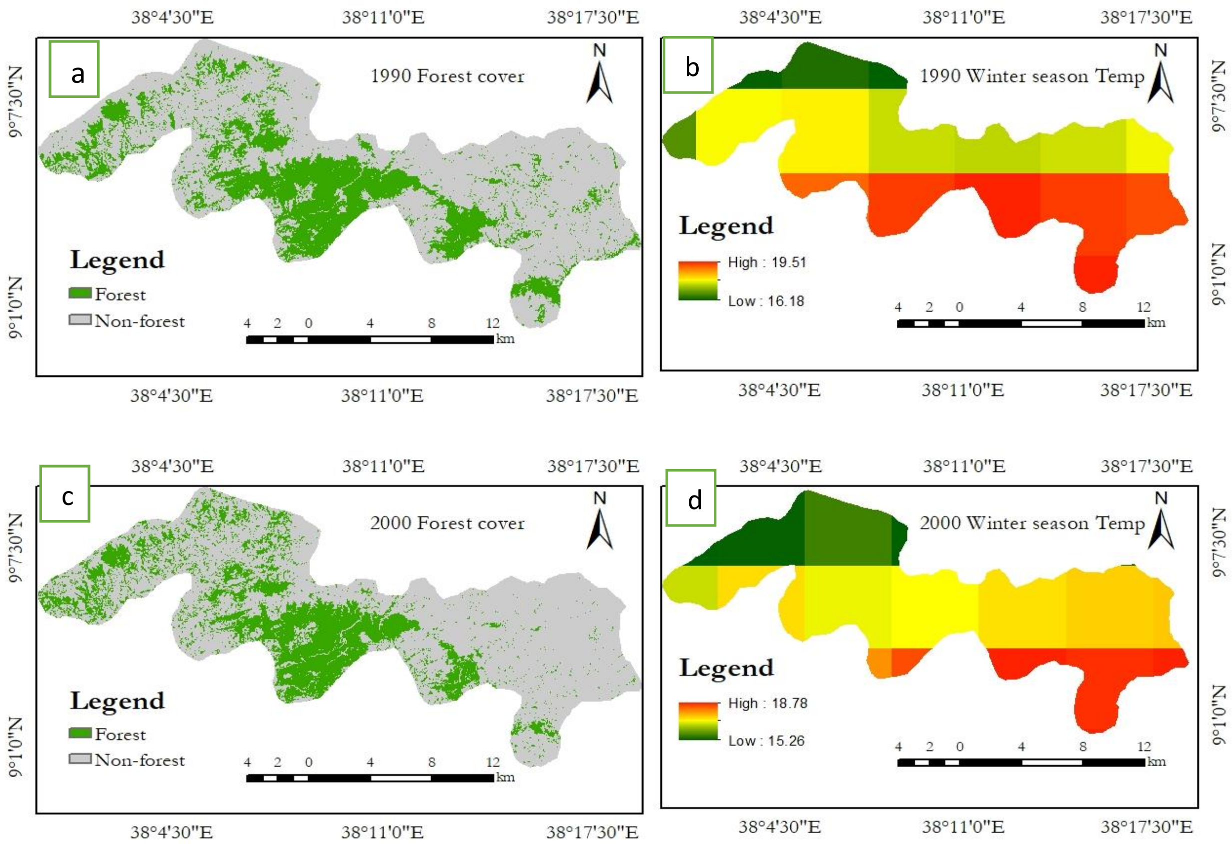


Figure 18: Forest cover (a and c) and wet season temperature (b and d) from1990 to 2000

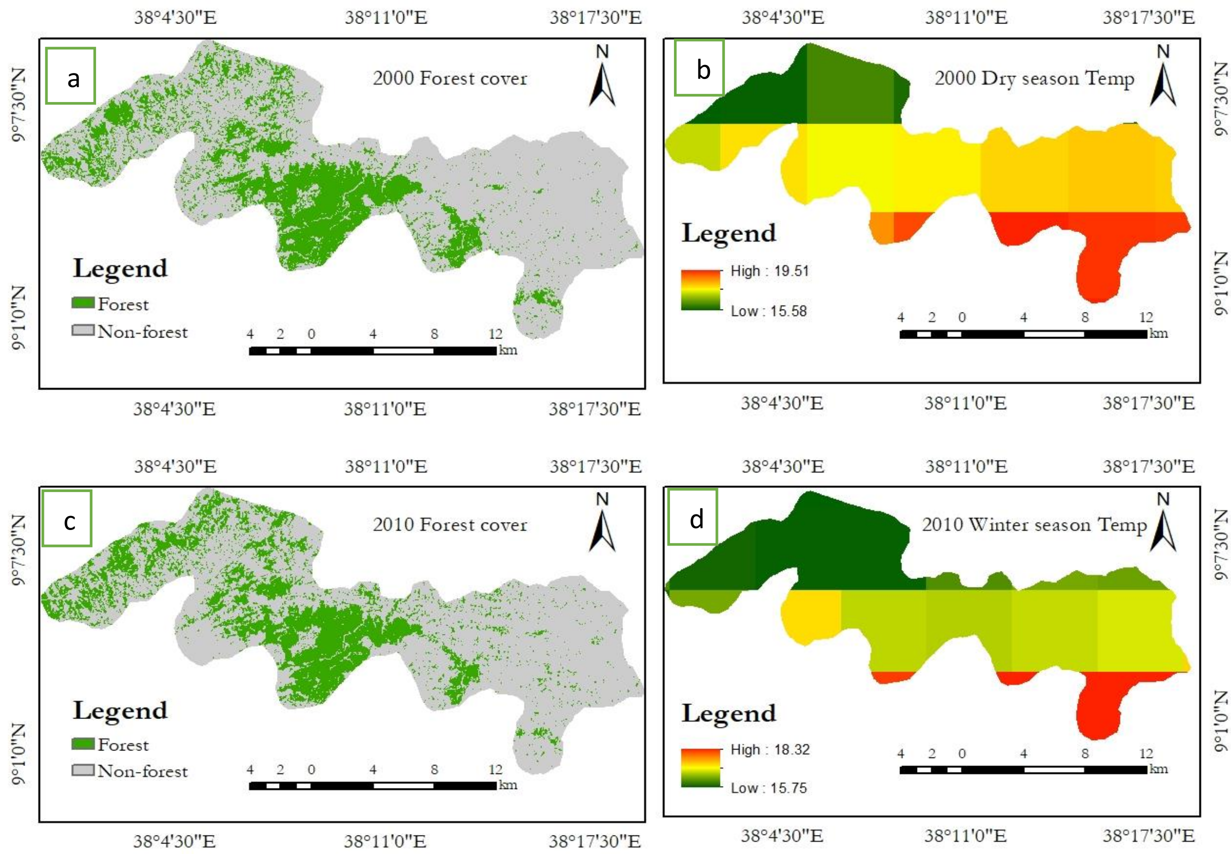


Figure 19: Forest cover (a and c) and dry season temperature (b and d)from 2000 to 2010

Table 8: Relationship of seasonal temperature with forest cover at significance level of α= 0.05

	P	R	R2
Forest cover vs Wet season Temperature	0.936	0.10	0.01
Forest cover vs Dry season Temperature	0.486	0.72	0.52

4.8. Relationship of Shrubland/Bushland, Grassland, wetland and temperature with seasonal variation

The correlation result between mean wet season temperature and shrubland showed that shrubland and wet season temperature have a weak positive correlation (r= 0.11). Likewise, the correlation between mean dry season temperature and shrubland change indicated that moderate correlation (r= 0.72) (Table 9). The result illustrated that the significant relationship with temperature and shrubland over the study areas. Figure 18, showed low shrubland resource were have been observed in the western and north-eastern of the study area over the study period. The correlation coefficient result of dry season temperature and grassland have positive moderate correlation with value of r= 0.62 while the result with wet season temperature and grassland showed strong positive correlation (r= 0.99). Accordingly, wetland with wet season temperature correlation result examined that weak positive correlation (r= 0.17) whereas, the correlation result between mean dry season temperature exhibited moderate positive correlation (r= 0.67). The result illustrated that the high temperature had shown decreasing wetland over the study areas.

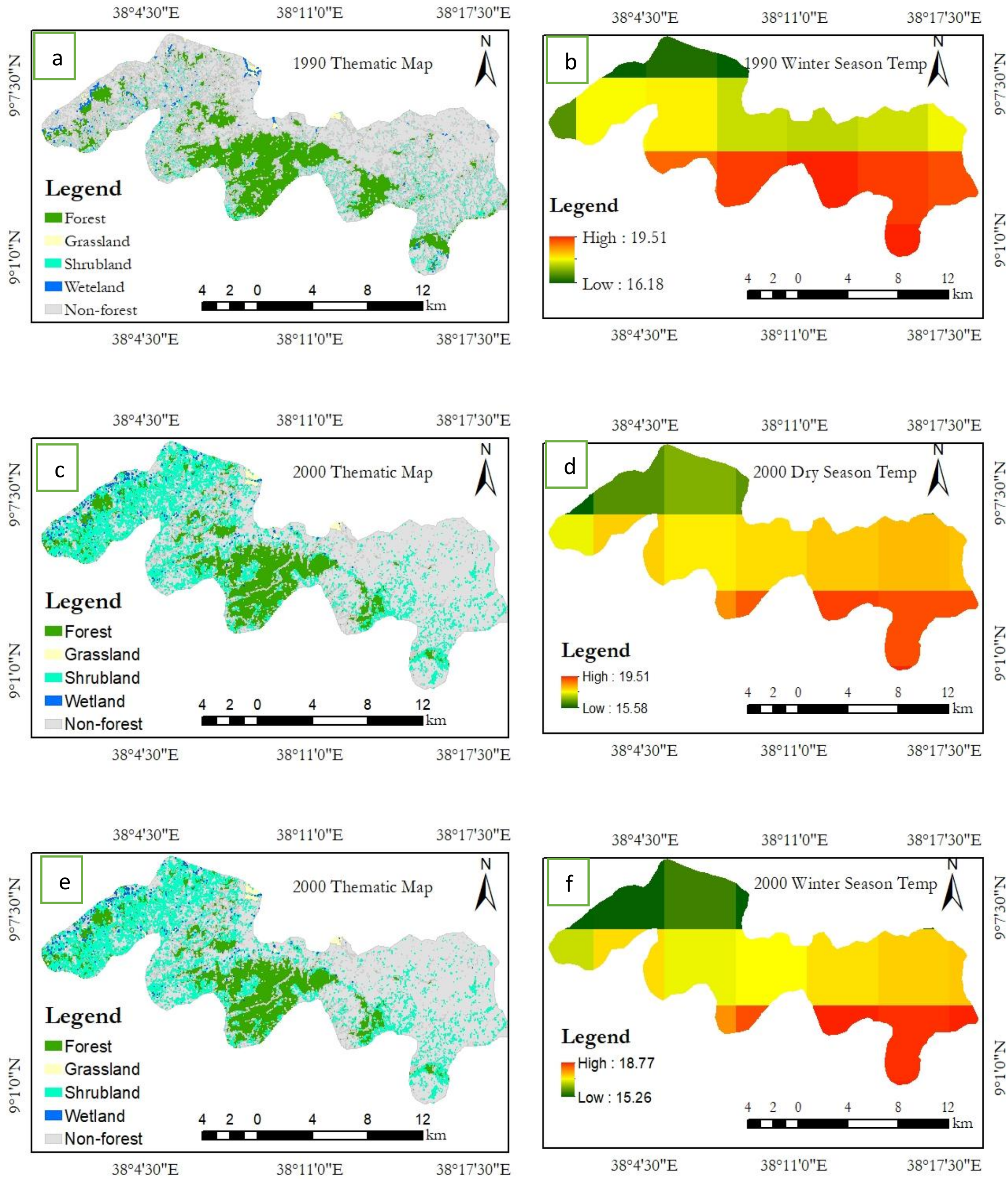


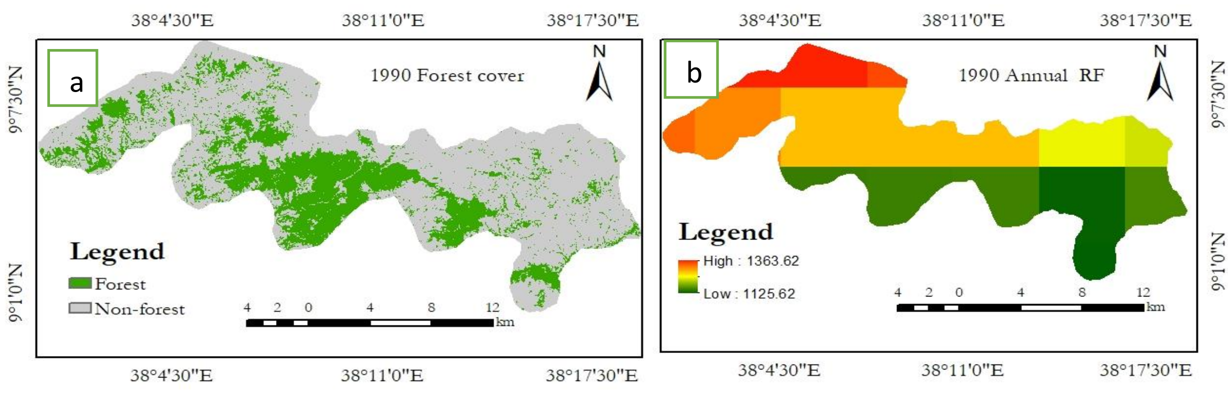
Figure 20: Wet (b and f) and dry season temperature (d) with shrubland, grassland and wetland (a, c and e) 1990 and 2000

Table 9: Relationship of seasonal temperature with shrubland, grassland and wetland at significance level of α= 0.05

	P	R	R^2
Shrubland *vs* Wet Season Temperature	0.93	0.1	0.011
Grassland vs Wet Season Temperature	0.014	0.99	0.99
Wetland vs Wet Season Temperature	0.88	0.17	0.03
Shrubland vs Dry season Temperature	0.49	0.71	0.51
Grassland vs Dry season Temperature	0.57	0.59	0.35
Wetland vs Dry season Temperature	0.53	0.67	0.45

4.9. Relationship of Rainfall and forest cover

The correlation between forest cover and mean annual rainfall indicated that forest cover and mean annual rainfall have a moderate and negative correlation (r= -0.78). Accordingly, mean dry season rainfall and forest cover have a strong and negative correlation (r= -0.99) (Table 10). From the analysis, it was observed that high rainfall had shown in Dega climatic zone over the study years. Hence, high reserved forest observed in the central part of the study area, relatively high amount of rainfall has been observed in high land (Dega) part including the central and western part of the study area. The dry season rainfall map Figure 19 and 20 indicated that an area with high rainfall values had shown high forest cover, while an area with low rainfall value had sparse forest coverage shown over the study area. This result indicated that high rainfall perhaps shown relatively high forest coverage, subsequently an area with low rainfall had indicated relatively low forest cover. In addition, the results have revealed that there is insignificant relationship between mean annual rainfall with p-value 0.34 which is higher than significant level alpha 0.05, while dry season rainfall have a significant relationship with forest cover as p-value 0.049 is lower than significant level alpha 0.05.



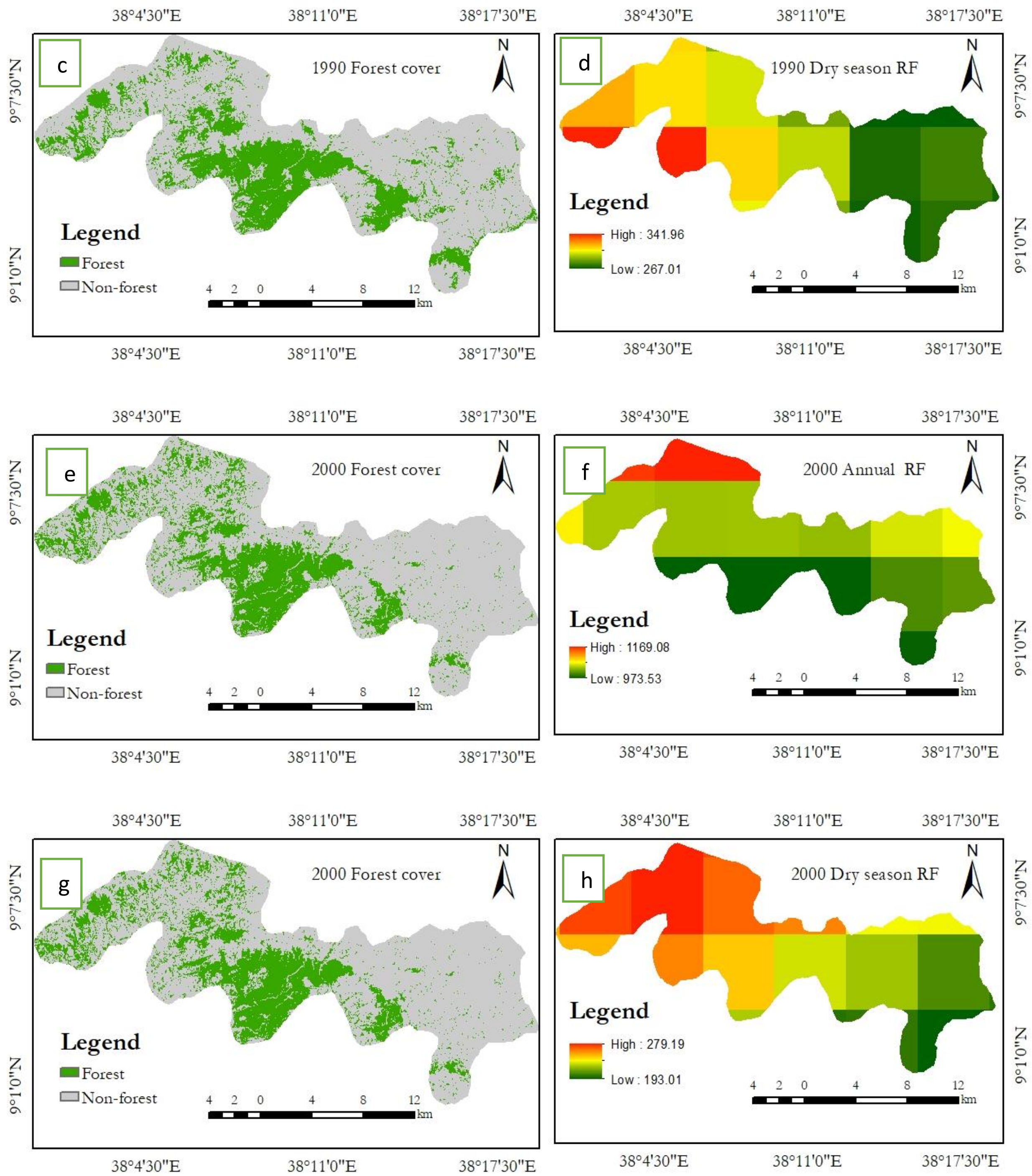


Figure 21: Annual (b and f) and dry season rainfall (d and h) with forest cove 1990 (a and c) and 2000 (e and g).

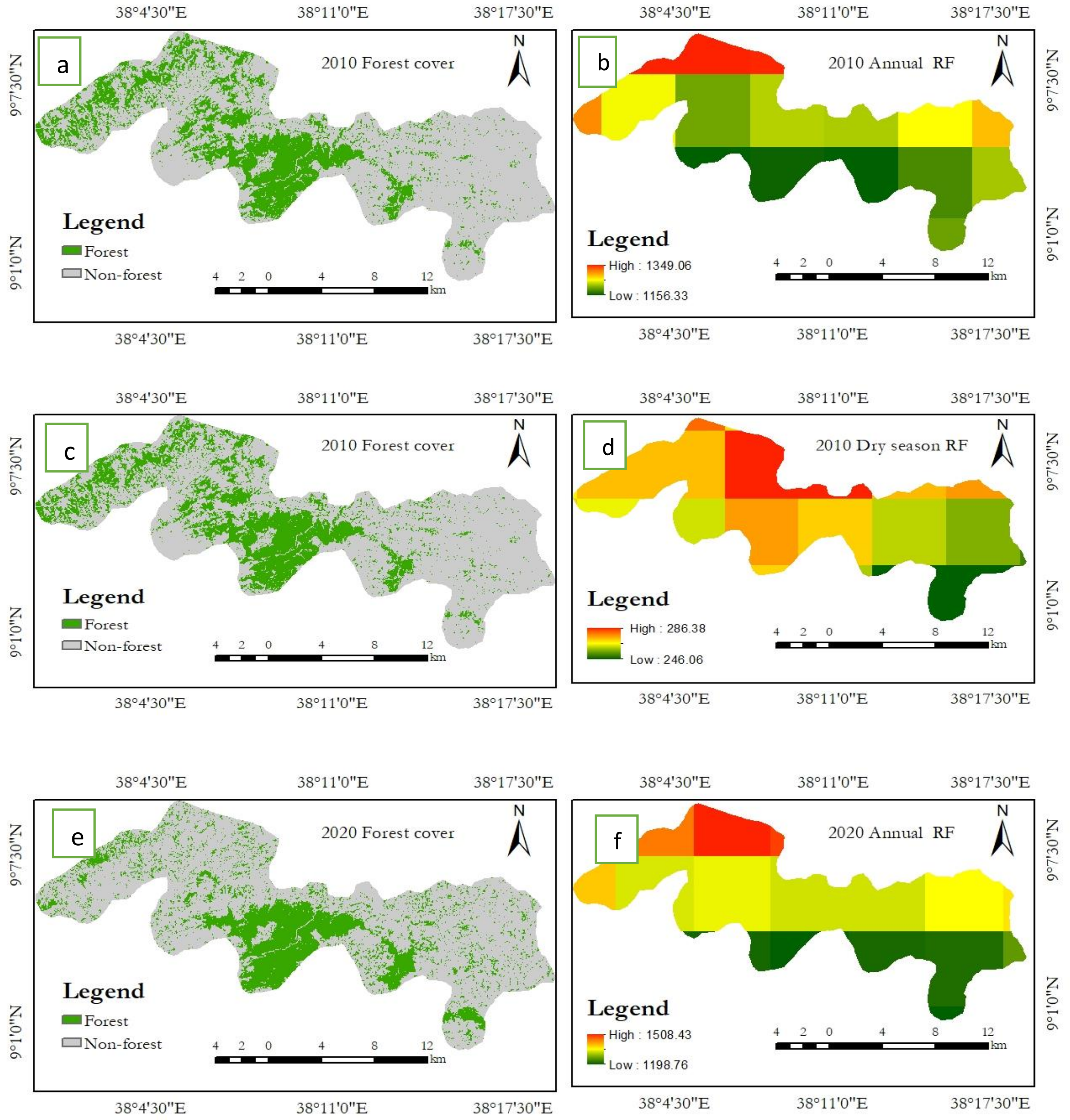


Figure 22: Annual (b and f) and dry season (d) rainfall with forest cover 2010 (a and c) and 2020 (e)

Table 10: Relationship of annual and dry season rainfall with forest cover at a significance level of alpha = 0.05

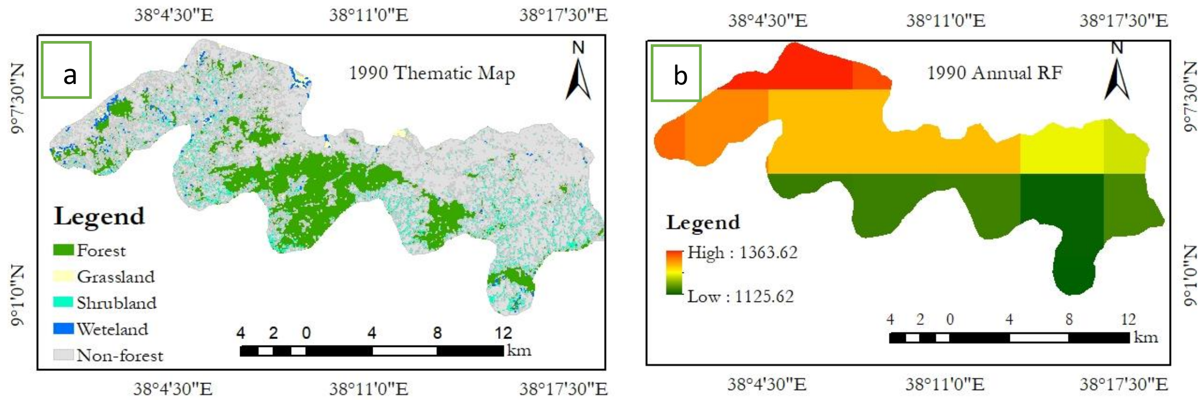
	P	r	R^2
Forest cover *vs* Annual rainfall	0.222	-0.78	0.61
forest cover vs Dry season rainfall	0.009	-0.99	0.98

4.10. Relationship of Rainfall and Shrubland, Grassland and wetland resource

The Pearson correlation result between shrubland and mean dry season rainfall indicated that shrubland and mean dry season rainfall have a weak positive correlation (r= 0.1) with p-value of 0.9. likely, mean annual rainfall and grassland have a moderate positive correlation (r= 0.75). The correlation result between grassland and mean dry season rainfall indicated that grassland and mean dry season rainfall have a strong positive correlation (r= 0.85) with p-value of 0.14. Accordingly, mean annual rainfall and grassland have a strong positive correlation (r= 0.97) (Table 11). From the analysis, it was observed that both mean dry season rainfall and annual rainfall with grassland have strong relationship over the study period. Similarly, the Pearson correlation result between annual rainfall and mean dry season rainfall with wetland examined that there was moderate relationship with p-value of 0.2 (r= 0.79) and 0.46 (r= 0.54), respectively. Hence, the results have exhibited that there is insignificant relationship between mean annual rainfall and mean dry season rainfall with shrubland and wetland where their p-value is higher than significant level alpha 0.05, but annual rainfall have a significant relationship with grassland as p-value 0.02 is lower than significant level alpha 0.05.

Table 11: Relationship of annual and dry seasonal rainfall with shrubland, grassland and wetland at significance level of α= 0.05

	P	R	R^2
Shrubland *vs* Annual rainfall	0.24	0.75	0.57
Grassland vs Annual rainfall	0.024	0.97	0.95
Wetland vs Annual Rainfall	0.2	0.79	0.62
Shrubland vs Dry season rainfall	0.9	0.10	0.01
Grassland vs Dry season rainfall	0.145	0.85	0.73
Wetland vs Dry season rainfall	0.46	0.53	0.28



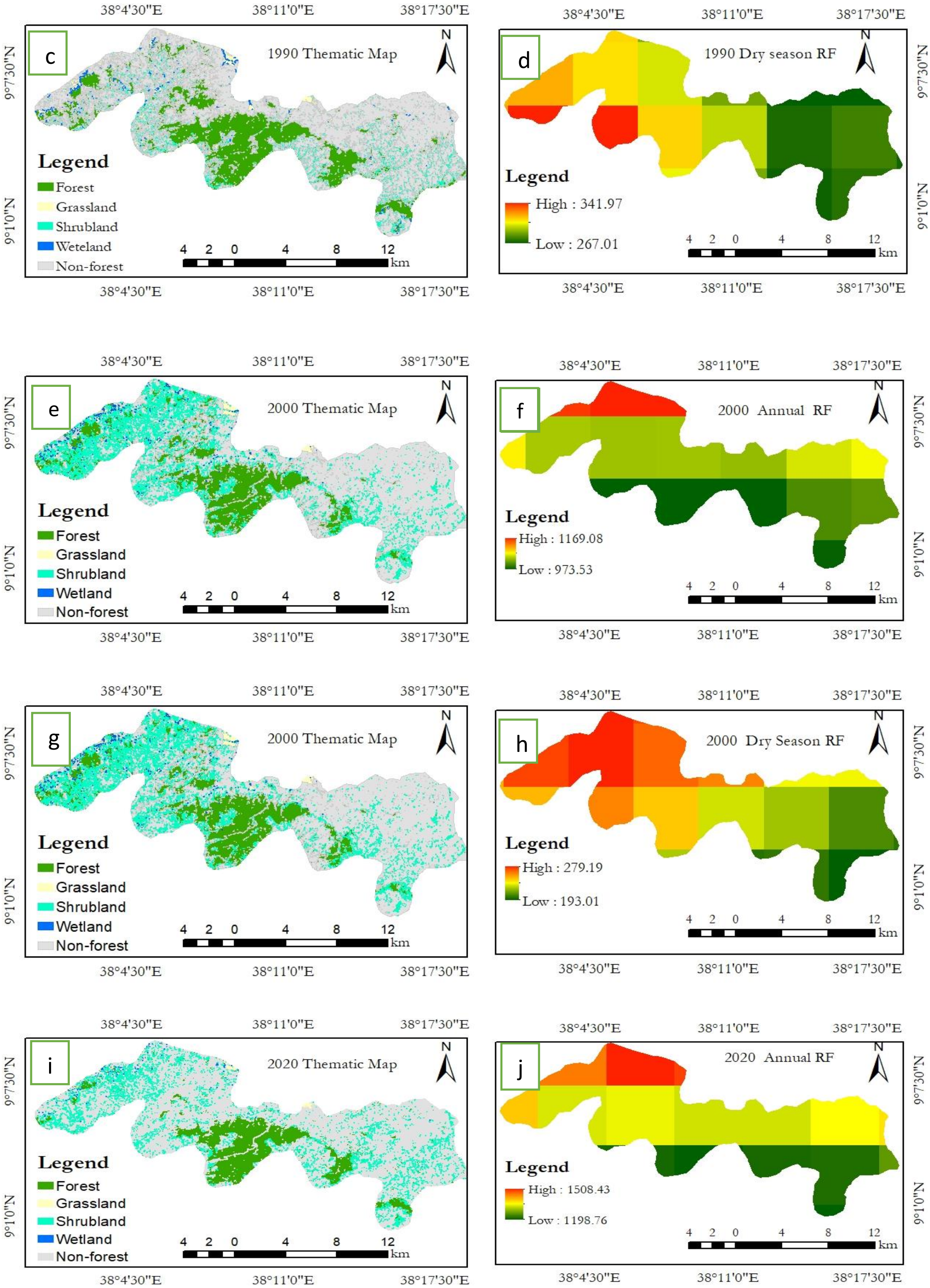


Figure 23: Annual (b,f and j) and dry season (d and h) rainfall with shrubland, grassland and wet land 1990 (a and c), 2000 (e and g) and 2020 (i).

4.11. Effect of Temperature on Forest Cover Dynamics.

According to Pearson correlation result between temperature and vegetation cover indicated that there was positive correlation in the study area. The correlation coefficient and coefficient of determination for wet season temperature and forest cover showed that weak positive relationship by 0.11 and 0.011 with p-value of 0.94. Similarly, dry season temperature and forest cover indicated that moderate relationship with correlation coefficient and coefficient of determination 0.72 and 0.52 respectively, with the p-value of 0.48. The coefficient of determination revealed that 52% variability in dry season temperature could have effects on vegetation cover change during the study period, while 1.1% of variability of wet season temperature probably influence vegetation dynamics. Furthermore, the results of Zonal statistics for mean, minimum, and maximum wet season temperature with forest cover in Figure 23 indicated that wet season temperature were decreased during the study period (1990, 200 and 2010), whereas dry season temperature result were shown that decreasing trend of with decreasing of forest cover for 1990, 2000 and 2010 study years.

Table 12: Zonal statistics of mean, minimum and maximum Wet and dry season temperature with forest and non-forest areas.

Year	LULC	Area (ha)	Wet Season Temperature			Dry Season Temperature		
			Mean	Min	Max	Mean	Min	Max
1990	Forest	6093.63	18.09	16.18	19.51	17.50	15.26	19.02
	Non-forest	15822.84	17.83	16.18	19.51	17.22	15.26	19.02
2000	Forest	6059.9	17.19	15.26	18.56	17.82	15.58	19.34
	Non-forest	16362.1	17.42	15.26	18.78	18.08	15.58	19.51
2010	Forest	6185.25	16.43	15.75	18.12	16.41	15.51	18.33
	Non-forest	16236.75	16.60	15.75	18.12	16.58	15.51	18.33

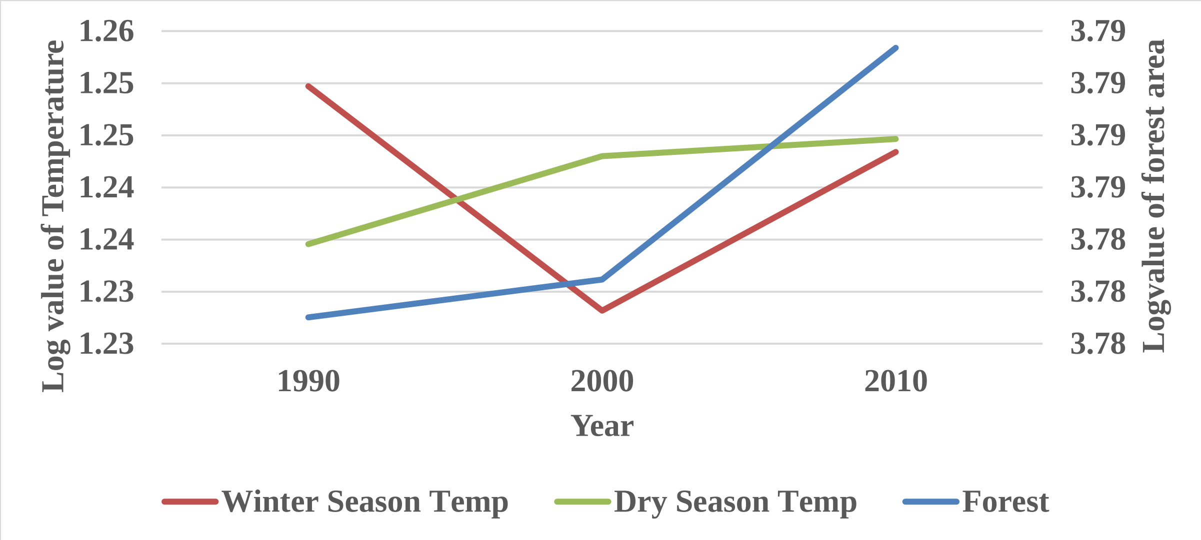


Figure 24: Log value of wet and dry season temperature with forest area

4.12. Effect of Temperature on Shrubland, Grassland and wetland dynamics.

According to Pearson correlation result between temperature and grassland, shrubland and wetland indicated that there was positive correlation in the study area. Whereas, dry season temperature and shrubland indicated that moderate relationship with correlation coefficient and coefficient of determination 0.71 and 0.51 respectively, with the p-value of 0.49. The coefficient of determination revealed that 51% variability in dry season temperature is probably could be influence shrubland change during the study period, while 1.1% of variability of wet season temperature caused shrubland resource dynamics. Likewise, the correlation coefficient and coefficient of determination for grassland with dry season revealed moderate positive correlation by 0.59 and 0.35, respectively while, wet season temperature indicated that strong positive correlation with correlation coefficient and coefficient of determination 0.99 and 0.99 (p-value= 0.014), respectively. Thus, the result showed that wet season temperature has weak correlation with wetland by correlation coefficient and coefficient of determinations 0.17 and 0.03, respectively. Accordingly, the Pearson correlation result between dry season temperature and wetland shown moderate relationship with correlation coefficient 0.67 and coefficient of determination 0.45. This result implies that there was 45% of dry season temperature variability which affect different species of biodiversity over the study area. However, the zonal statistics for mean wet and dry season temperature result shown that decreasing and increasing trend of with decreasing of forest cover for 1990, 2000 and 2010 study years.

Table 13: Zonal mean, minimum and maximum wet and dry season temperature with shrubland, grassland, wetland and non-forest areas.

Year	LULC	Area (ha)	Wet Season Temperature			Dry Season Temperature		
			Mean	Min	Max	Mean	Min	Max
1990	Shrubland	1333.98	18.42	16.18	19.51	17.88	15.26	19.02
	Grassland	692.01	17.44	16.18	19.51	16.75	15.26	19.02
	Wetland	64.53	17.35	16.18	19.51	16.61	15.26	19.02
	Non-forest	14793.15	17.83	16.18	19.51	17.22	15.26	19.02
2000	Shrubland	1693.35	17.01	15.26	18.78	17.59	15.58	19.51
	Grassland	850.68	16.74	15.26	18.56	17.29	15.58	19.34
	Wetland	63.09	16.46	15.26	18.54	16.96	15.58	19.34
	Non-forest	13754.98	17.42	15.26	18.78	18.08	15.58	19.51
2010	Shrubland	1028.52	16.65	15.75	18.12	16.65	15.51	18.33
	Grassland	736.02	16.07	15.75	18.12	15.96	15.51	18.30
	Wetland	41.22	16.09	15.75	18.02	15.99	15.51	18.25
	Non-forest	16236.75	16.60	15.75	18.12	16.58	15.51	18.33

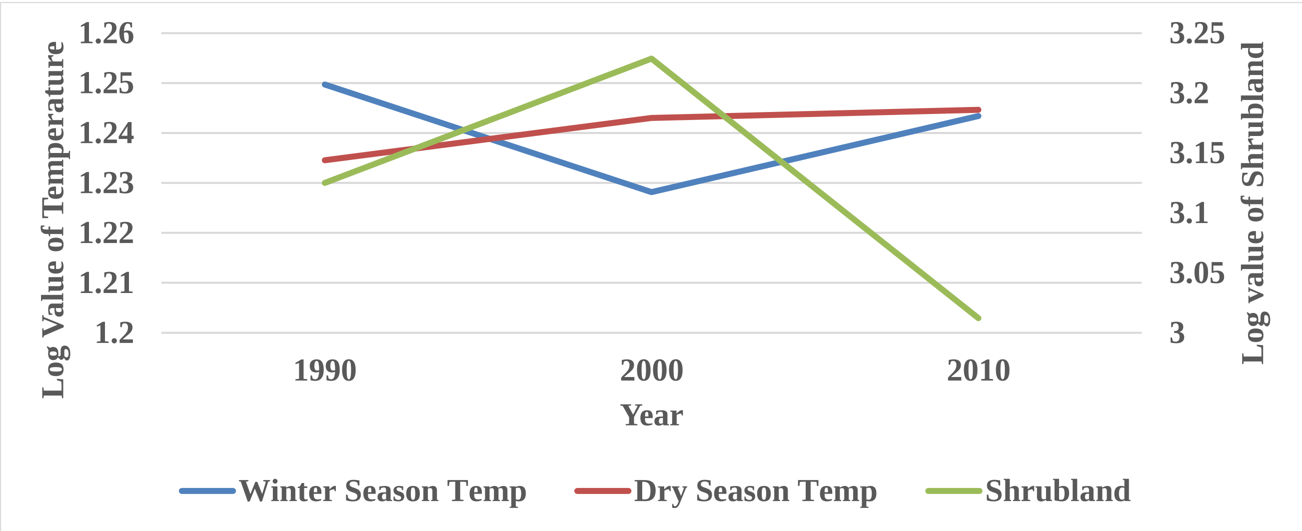


Figure 25: Log value of wet and dry season temperature with shrubland

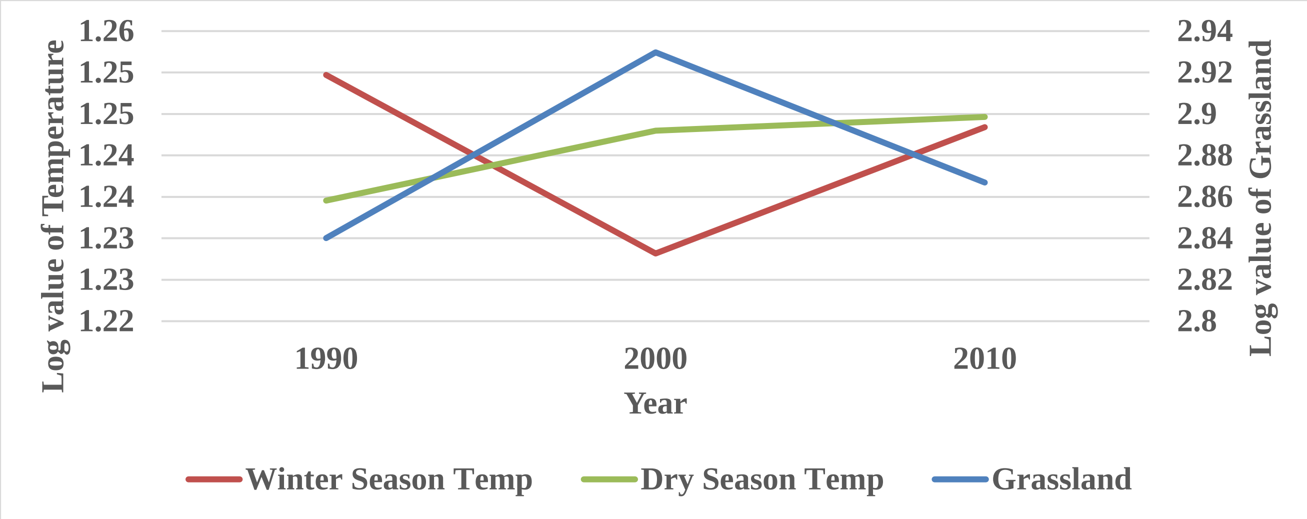


Figure 26: Log value of wet and dry season temperature with grassland

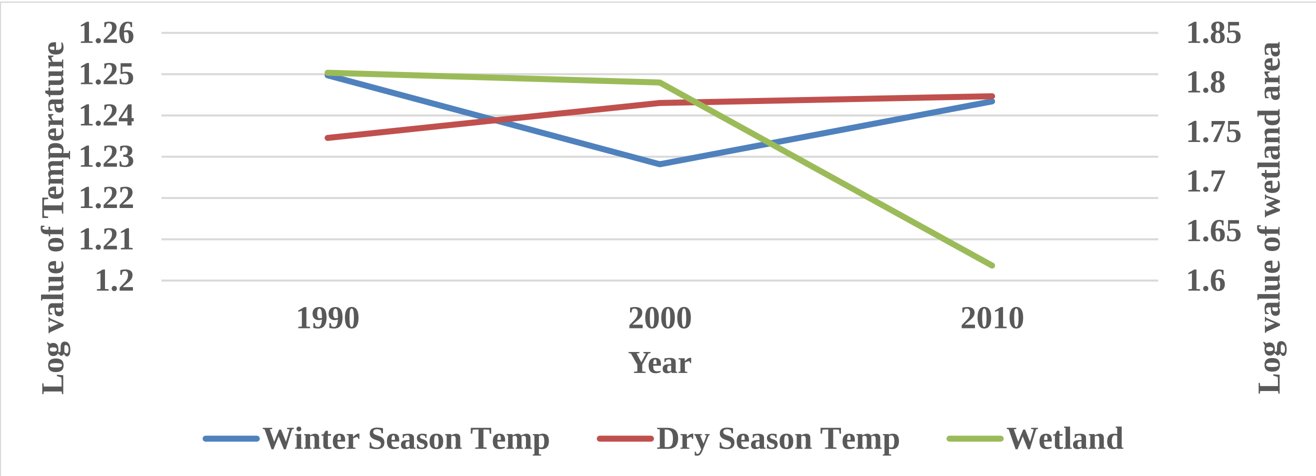


Figure 27: Log value of wet and dry season temperature with wetland

4.13. Effect of Rainfall on Forest cover dynamics

In the study area the Pearson correlation result revealed that there was a strong negative correlation of vegetation cover with dry season rainfall. The correlation coefficient and coefficient of determination for vegetation cover change and dry season rainfall strong relationship by value of -0.95 and 0.90 with p-value of 0.049. Similarly, annual rainfall and vegetation cover change indicated that there was moderate negative relationship with correlation coefficient and coefficient of determination -0.66 and 0.44 with p-value of 0.34. The coefficient of determination shows that 90% variability in dry season rainfall as well as 44% variability in annual rainfall which had effect on vegetation cover change in the study area. The results of zonal statistics of annual rainfall and dry season rainfall with forest cover revealed that annual and dry season rainfall were decreased during the study period of 2000 and 2010.

Table 14: Zonal statistics of mean, minimum and maximum annual and dry season rainfall with forest and non-forest areas.

Year	LULC	Area (ha)	Annual Rainfall			Dry Season Rainfall		
			Mean	Min	Max	Mean	Min	Max
1990	Forest	6093.63	1234.15	1125.62	1363.62	298.02	267.01	341.97
	Non-forest	15822.84	1243.13	1363.62	1363.62	289.25	267.01	341.97
2000	Forest	6059.9	1029.63	973.53	1169.08	248.26	199.69	279.19
	Non-forest	16362.1	1037.65	973.53	1169.08	236.05	199.69	279.19
2010	Forest	6185.25	1217.69	1156.32	1349.06	272.52	246.06	286.38
	Non-forest	16236.75	1218.64	1156.32	1349.06	266.83	246.06	286.38
2020	Forest	5671.62	1310.8	1198.75	1456.31	335.36	267.59	386.62
	Non-forest	16750.63	1331.94	1198.75	1508.43	332.94	267.59	386.62

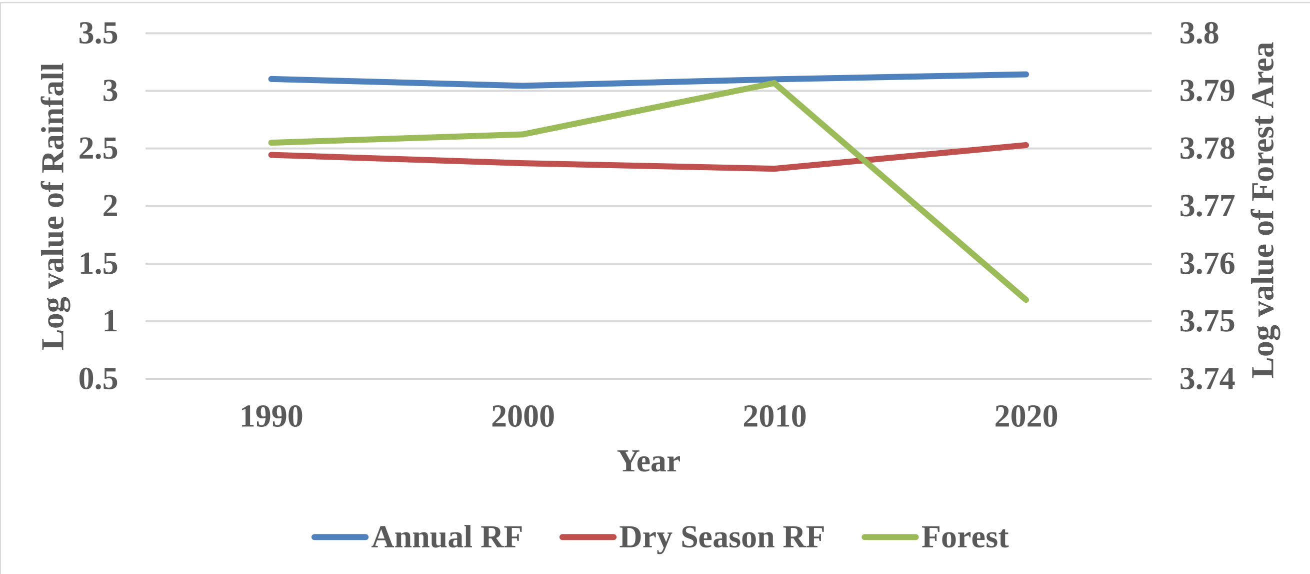


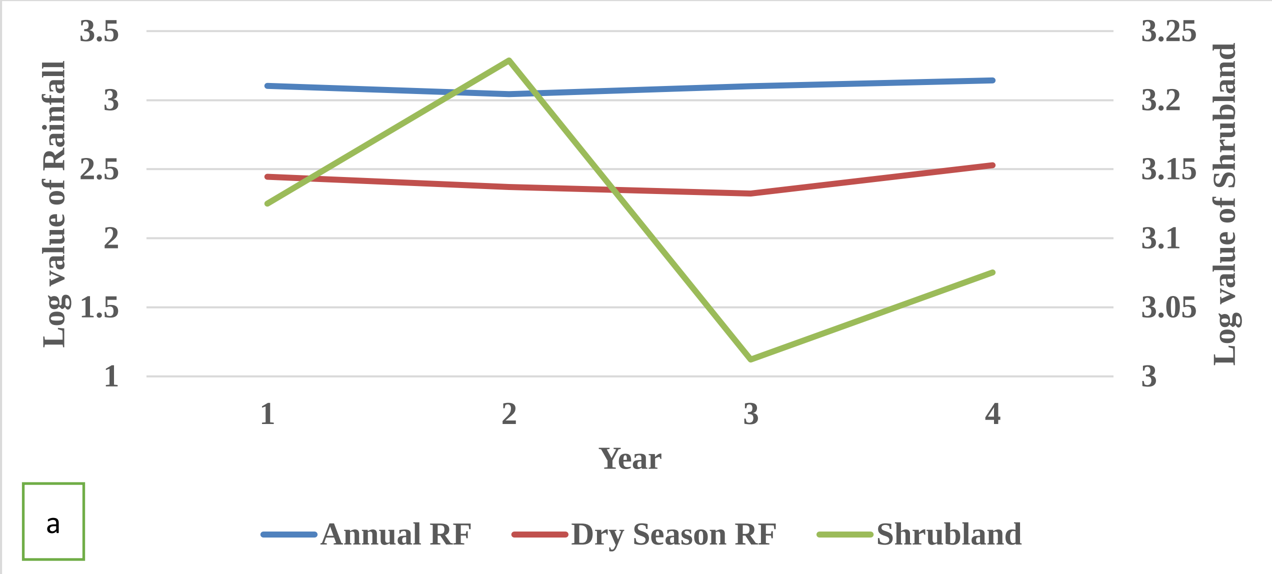
Figure 28: Log value of annual and dry season rainfall with forest area

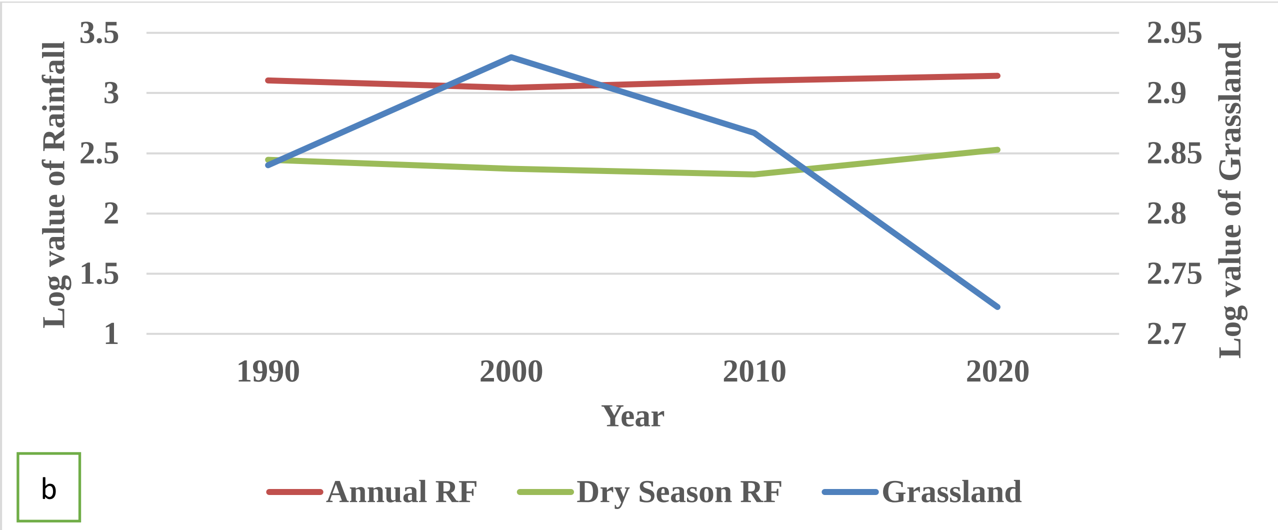
4.14. Effect of Rainfall on Shrubland, Grassland and wetland dynamics.

Pearson correlation result exhibited that there was a strong positive correlation between annual and dry season rainfall and grassland. The correlation coefficient and coefficient of determination for grassland change and annual rainfall strong relationship by value of 0.97 and 0.95 with p-value of 0.02. In the same way, correlation coefficient and coefficient of determination between grassland and dry season rainfall showed strong relationship 0.85 and 0.73, respectively with p-value of 0.46. The analysis from this result indicate there was significant relationship between annual rainfall and grassland. Hence, annual rainfall and shrubland change indicated that there was moderate relationship with correlation coefficient and coefficient of determination 0.75 and 0.57 with p-value of 0.24. The coefficient of determination shows that 57% variability in annual rainfall as well as 1% variability in dry season rainfall which had effect on shrubland change in the study area. Also, the result of coefficient of determination of annual and dry season rainfall with wetland indicated there was variability of rainfall by 62% and 28%, respectively over study years. Accordingly, the results of zonal statistics of annual rainfall and dry season rainfall with forest cover revealed that annual and dry season rainfall were decreased during the study period of 2000 and 2010 while last study period indicated increasing trend with decline of grassland and wetland observed in the study area.

Table 15: Zonal statistics of mean, minimum and maximum annual and dry season rainfall with shrubland, grassland, wetland and non-forest areas.

Year	LULC	Area (ha)	Annual Rainfall			Dry Season Rainfall		
			Mean	Min	Max	Mean	Min	Max
1990	Shrubland	1333.98	1208.96	1125.62	1363.62	291.67	267.01	341.97
	Grassland	692.01	1275.91	1125.62	1363.62	300.76	267.01	341.97
	Wetland	64.53	1284.39	1125.62	1363.62	301.75	267.01	341.97
	Non-forest	14793.15	1243.13	1363.62	1363.62	289.25	267.01	341.97
2000	Shrubland	1693.35	1055.95	973.53	1169.08	254.99	199.69	279.19
	Grassland	850.68	1069.49	973.53	1169.08	260.52	199.69	279.19
	Wetland	63.09	1085.81	973.53	1169.08	267.17	210.63	279.19
	Non-forest	13754.98	1037.65	973.53	1169.08	236.05	199.69	279.19
2010	Shrubland	1028.52	1201.14	1156.32	1349.06	268.39	246.06	286.38
	Grassland	736.02	1259.01	1156.32	1349.06	274.59	246.06	286.38
	Wetland	41.22	1259.54	1156.32	1349.06	275.27	246.06	286.38
	Non-forest	16236.75	1218.64	1156.32	1349.06	266.83	246.06	286.38
2020	Shrubland	1189.35	1335.2	1198.75	1456.31	336.04	267.59	386.62
	Grassland	527.58	1348.3	1198.75	1508.43	342.84	267.59	386.62
	Wetland	20.16	1402.83	1235.15	1456.31	362.98	295.53	386.62
	Non-forest	15013.3	1331.94	1198.75	1508.43	332.94	267.59	386.62





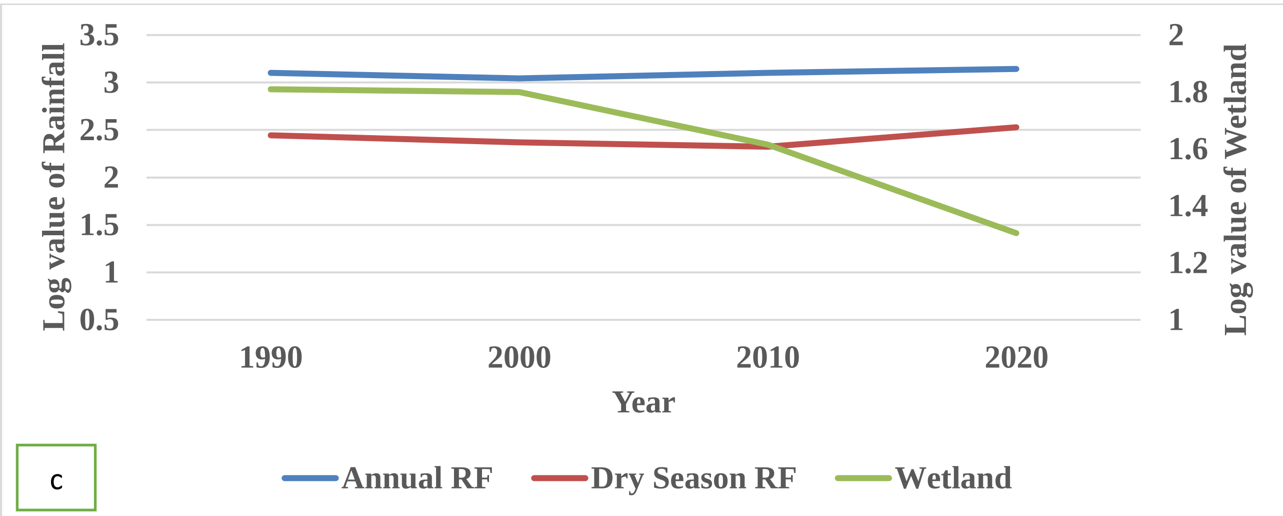


Figure 29: Log value of annual and dry season rainfall with shrubland (a), grassland (b) and wetland (c).

CHAPTER FIVE

5. DISCUSSION

In the present study, land-use land-cover change was assessed by using geospatial technology which used to monitoring change on the vegetation cover of Chilimo forest. The study of land-use land-cover change over the past is vital to analysis the adverse impact of climate change (Thapa, 2021). The result revealed that there was a decline of high forest, grass land and wet land in average while crop land and other land increase in average. Hence, medium forest and shrub/bush land increasing in the first and last period then declined in second study period. But, plantation forest and other land decreasing in the first and last study period then increasing in the second study period. In contrast high forest, grass land and wet land indicated a continuous decrease in the study area since 1990. Similarly, crop land without tree shows a continuous increment in the study area since 1990. The research conducted on dynamics of land-use land-cover in Dendi-Jeldu hilly-mountainous areas reported that in the period between 1957 to 2014 were cultivated land increased by 170% forest land and woodland decline by 73% and 100% respectively (Minta *et al*., 2018). Bare land indicated a moderate increase in the first period but decreasing for the next both periods. Nevertheless, land-use land-cover change was continually changing for the last thirty years since 1990 (Appendix 2). This illustrates the high influence of anthropogenic activities including inappropriate land-use planning system.

The land-use land-cover change detection results indicated significant conversion from high forest, plantation forest, shrubland, grassland, cropland, bare land and other land. Hence, one land-use land-cover type was changed into another land-use land-cover type and vice versa. According to Yan *et al*., (2018) studied those anthropogenic activities have diverse impacts on land-use land-cover change which increase pressure on agricultural lands and other resources. This is the results of lack of effective land-use land-cover planning system, which is vital for decreasing the pressure on resource and maintaining the integrity of our system and protecting natural environment. UNEP (2014) reported a continuous expands of cropland and agricultural purpose were observed at the expense of decreasing of forest resource, shrubland, grassland and wetlands. The study suggests increasing the change of land-use land-cover were the result of increasing demand of agriculture which leads to deforestation. This result also consistent with the study conducted by Hassan *et al*., (2016) suggests agricultural areas was increased resulting in substantial decline of forest resource and barren land. Garedew *et al.*, (2009) conducted study in central Rift Valley of Ethiopia that land-use land-cover changed rapidly in which agricultural areas exposed to rapid deforestation.

Hence, this study implies that forest coverage was declining through the study period shows that high amount of forest cover was observed in the initial period with 6599.16 (29.43%) while the small amount was indicated in the final study period with 5671.37ha (25.29%). Moreover, the forest non-forest result revealed that there was insignificant increasing of forest coverage during the second (2000) and third study periods (2010). During 1990 relatively high amount of vegetation cover was cleaned in western part of the study area. Highest amount of Chilimo forest land was lost during 1984 to 1998, especially the change of government in Ethiopia in 1991 highly contributed for illegal use of the forest products and vegetation area land grabbing (Siraj *et al*., 2018). Similarly, loss of forest cover (deforestation) was recorded in the north western part of the reserved forest. Accordingly, afforestation (change of non-forest to forest area) was recorded in eastern and north eastern part including surrounding the central reserved forest area. This is due to the change in management practice of natural resource and the involvement of community-based conservation measures. Progressive expansion of eucalyptus plantation was experienced by local community and examined during 2008 and 2015 deforestation decreased in the study area (Minta *et al*., 2018). Furthermore, the government was introduced nationwide community based integrated watershed management development campaign which contributed for the reforestation.
The rate of forest cover change result shows the decline of forest biodiversity during the three study periods. During the first study period (1990 to 2000) 1872.36ha of forest area declined at the expense of other land-use land-cover types. Unlikely, in the third study period 1950.56ha non-forest land was changed to vegetation area (afforestation). This finding indicated that increasing of plantation forest while high forest, shrubland and grassland were showing deforestation. This shows that the local community was planted Eucalyptus species in the study area.

In addition, cropland without tree revealed that increasing trend in all study periods with 2408.76ha (10.74%) in average. This finding shows the transformation of other LULC classes into cropland (agricultural land) throughout the study years. This result is inline with Fikere *et al*., (2021) who reported that an alarming decline forestland while cropland was rapidly increased. Similarly, from the report of FAO (2017) that the forest resource in East Africa was under risk and highly fragmented due to a huge demand of agricultural lands at the expense of vegetation resource. The impacts significantly reduced the natural forest leads to potentially threated species of different habitat like herbs, ferns, bamboo, shrub and tree. Deforestation negatively affects the structure and function of the ecosystem and thereby lower its capacity including extinction of biotic communities leading to biodiversity loss, soil erosion and decline fertility of soil (Wachiye *et al*., 2013; zornoza *et al*., 2015 and Siraj *et al*., 2018). The document by Garedew *et al*., (2009) discussed rapid increase of agricultural areas and inappropriate land-use planning exposed forest resource degradation and deforestation that contribute for recurrent drought and climate variability.

The analysis of mean, minimum and maximum seasonal temperature result indicated that a statistically insignificant/significant trend for the twenty-six years since 1990. The Mann-Kendall trend test show a significant increasing trend of mean, minimum, and maximum dry season temperature and insignificant increasing trend of mean, minimum and maximum wet season temperature during the study periods. These results are in agreement with the finding by Belay *et al*., (2021) who investigated climate variability and trends in southern Ethiopia and revealed that insignificant increasing trend of mean annual, minimum and maximum temperature since 1983-2016. The study conducted by Endalew Assefa and Wagaye Bahiru (2020) revealed significant decreasing and increasing trend of annual and seasonal mean temperature at different weather station. Arragaw Alemayehu *et al.,* (2020) conducted study on temperature and rainfall trends observed that statistically significant and non-significant decreasing trend of mean annual minimum and mean maximum temperature. It also showed the statistically decreasing trends of seasonal temperature and increasing trend of annual and seasonal rainfall. From the study of Chilimo forest study area, the trend analysis of mean, minimum and maximum annual and dry season rainfall result indicated that insignificant increase/decrease over the last thirty years. The mean and maximum dry season rainfall result revealed that insignificant decrease while minimum dry season rainfall shows insignificant increase for the last three decades in the study area. According to Birara *et al*., (2018) and Asfaw *et al*., (2018) reported insignificant increasing trend of annual rainfall in north Eastern and Northcentral Ethiopia. This result also consistent with the study conducted by Solomon Gebrechorkos *et al*., (2019) in East Africa reported that long term seasonal trend analysis showed insignificant increasing trend in rainfall in western part of Ethiopia.However, Gummadi *et al*., (2017) reported that trend of annual rainfall over the Eastern and Northern part of the country while increasing trend were observed in seasonal rainfall amounts in some areas. It also was revealed annual extreme rainfall events in central, western and southwestern part of Ethiopia covering different parts of Oromia. Similarly, Bayable *et al*., (2021) observed that annual rainfall showed insignificant decreasing trends in Eastern Ethiopia since 1983 to 2019.

The analysis of Pearson correlation coefficient result revealed that mean of dry season temperature with forest cover, shrubland, grassland and wetland have indicated moderate correlation coefficient with value of 0.72, 0.71, 0.59 and 0.67. This result showed dry season temperature has a relationship with vegetation cover change which influence the forest natural resource during the study years. Similarly, wet season temperature resulted that weak positive correlation with forest cover, shrubland and wetland for the study periods. This weak relationship with wet season temperature infers forest cover change and decline of shrubland, grassland and wetland resource during wet season probably not influenced by wet season temperature. This suggests that dry season temperature could be affects the vegetation dynamics which leads to deforestation. The study was presented around 2932.29ha (13.08%) of forest cover land transformed to non-forest land in the different part of the study area while shrubland, grassland and wetland also showed decline and transformed to no forest land. Accordingly, forest and shrubland transformation statistics result showed during 1990 to 2020 years forest and shrubland coverage converted to non-forest area in western, central and north eastern part of study area. Arragaw Alemayehu *et al*., (2020) and Bayable *et al*., (2021) finding showed the mean annual, minimum and maximum temperatures increasing significantly and noted decreased annual rainfall at expense of forest and woodland reduction and caused deforestation and drought.

Furthermore, the Pearson correlation coefficient result presented that dry season rainfall with forest cover and grassland have indicated strong negative and positive correlation coefficient with value of -0.95 and 0.85, whereas shrubland showed weak positive correlation coefficient. Accordingly, annual rainfall shows moderate negative correlation (r= -0.66) with forest cover for the last three decades. However, result exhibited that there was strong positive relationship with annual rainfall and grassland while shrubland and wetland indicated moderate relationship. This result indicated that annual and dry season rainfall have strong insignificant relationship forest cover, shrubland and wetland.

Coefficient of determination between temperature with forest cover, shrubland, grassland and wetland for wet and dry season temperature was calculated where the result between forest cover, shrubland, grassland, wetland and dry season temperature was 0.52, 0.51, 0.35 and 0.45 with p-value of 0.94, 0.49, 0.57 and 0.53. This result indicated that 52 %, 51%, 35% and 45% of dry season variability could be influence the vegetation dynamics of the study area. This implies dry season temperature probably contributed to forest resource and biodiversity degradation and deforestation. However, coefficient of determination between mean wet season temperature and forest cover, shrubland and wetland was 0.1, 0.01 and 0.03 and exhibited an insignificant relationship. This result showed that 1.1% and 3% of wet season temperature variability was observed whereas grassland revealed 99% of variability over the study period. This means the influence of wet season temperature on vegetation cover and shrubland was insignificant during study years since 1990. In addition, dry season mean rainfall with forest cover and grassland indicated strong relationship by r= -0.95 and 0.85 with p-value 0.049 (R^2 = 0.90) and 0.145 (R^2 = 0.73) while shrubland show weak relationship. This result shows 90% and 73 % of dry season rainfall variability has critical contributions for forest cover and grassland change. The change of increasing temperature and decreasing trend in rainfall was significantly impacted on land cover and vegetation (Asaminew Abiyu et al.,2019). Accordingly, annual mean rainfall with forest cover, shrubland, grassland and wetland showed coefficient of determination 0.44, 0.57, 0.95 and 0.62 which indicated 44%, 57%, 95% and 62% of annual mean rainfall variability could be influence vegetation dynamics in the study area. According to by Tenaw Geremew and Habte Jebessa (2018) exhibited that temperature and rainfall were the major factor for controlling the seasonality vegetation growth and shift phenology the patterns across ecoregion of Ethiopia.

The rapid decline of forest resource driven the loss of biodiversity, soil fertility and water availability (Melesse Genete, 2021). According to Salimi *et al*., (2021), change of rainfall and seasonal temperature examined as one of the major threats to wetlands. Since forests, woodland, shrubland, wetland and grassland are increasingly affected as the result of climate change and in particular it is expected to impact on forest biodiversity. Rainfall dynamics affect soil moisture which intern affect temperature of the earth surface. The study conducted by Minta *et al*., (2018) exhibited rapid land-use land-cover transformation from natural habitat to other land-use type could likely have a significant impact on biodiversity and degradation. As the consequence of examined land-cover change and variability of rainfall and temperature Ethiopia has been facing rapid land degradation, deforestation, loss of habitat, and other environmental problems. The result of this consequence has been threat plants in terms of either their existence or ability to function for survival (Aden Abdurahaman and Tekalign Tafese, 2019). Grassland, natural forests and wetland destroyed and converted to cropland that this alteration had seriously impacted vegetation coverage and forest biodiversity (Asaminew Abiyu *et al*., 2019)

CHAPTER SIX

6. CONCLUSION AND RECCOMMENDATIONS

6.1. Conclusion

This study investigated the impacts of rainfall and temperature change on vegetation cover and forest biodiversity in national reserved priority Chilimo forest western part of Ethiopia. The result of climate variability had adverse impacts on vegetation cover which currently a critical problem than in the previous as a result of affecting species distribution and survival. The findings of the study observed that there is rapid change of land-use land-cover types in the study area over the last three decades since 1990. The demand for increased agricultural land and forest products due to rapid population growth and increasing anthropogenic activities was contributed for expansion of crop land which has been shifting forest resource, grassland and wetland all over in the study periods. The western and north eastern part of study area forest resource was declined in the first period. However, shrubland and bare land increased in the first decade while it was declined from initial to last study periods by 144.63ha (4.82%) and 496.35ha (16.54%). The result indicated that cropland was expanded by 80.29% while other LULC was significantly decreased for the last three decades in the study area since 1990. The existence of forest cover, shrubland, grassland and wetland conversion to implies there was rapid reduction of forest resource and habitat species (forest biodiversity) during the study periods.

Although, Trend line of seasonal temperature shows different patterns in the study area. The temperature exhibited there was a significant trend of mean, minimum and maximum dry season temperature with 0.028 $^{o}C\ yr.^{-1}$, 0.036 $^{o}C\ yr.^{-1}$ and 0.031 $^{o}C\ yr.^{-1}$ respectively and non-significant increasing trend of mean and minimum wet temperature of during the study period over study years. Thus, it is possible to conclude that during wet season annual rainfall shows increasing it could decline the temperature of the study area. The Mann-Kendall trend test result revealed there was a insignificant trend of mean, minimum and maximum annual and dry season rainfall in the study area from 1990 to 2020. The trend of rainfall augmented insignificant by 0.799 mm, 0.62mm and 1.16mm per year during the study years. However, the mean, minimum and maximum dry season rainfall trend was decreased with 1.46mm, 0.65mm and 2.06mm per year. This result concluded that there was a significant effect of annual and dry season rainfall on vegetation cover over the study years since 1990.

The Pearson correlation coefficient result exhibited moderate and weak positive relationship in dry and wet season temperature with forest resource and shrubland. While, the correlation coefficient with grassland indicates strong positive relationship. Accordingly, dry season rainfall correlation coefficient show there was moderate positive relationship with grassland and wetland, while forest indicate negative relationship. The coefficient of determination indicates 52%, 51%, 35% and 45% variability in dry season temperature that probably influence forest resource coverage, shrubland, grassland and wetland which leads to significant impacts on different species of forest biodiversity in the study area since 1990. Similarly, in wet season temperature coefficient of determination of 1.1%, 99% and 3% variability of temperature observed over the study area. From the analysis vegetation dynamics examined in western, north-eastern and central part of the study area.

The result of Pearson correlation coefficient examined for annual rainfall and shrubland, grassland and wetland show strong and moderate positive relationship while forest land exhibited negative relationship. Likely, the correlation coefficient result for dry season rainfall with forest land show strong negative relationship while others indicate positive relationship. The coefficient of determination result revealed 44%, 51% and 62% variability of annual rainfall with forest, grassland and wetland over the study area. Furthermore, dry season rainfall coefficient of determination examined 90%, 73% and 28% variability of rainfall investigated. Therefore, from this result findings this study concluded that forest cover, shrubland, grassland, and wetland in western, north-eastern, central and other part of study area was declined with decrease rainfall over the study area. Besides, mean temperature was increased with critical cause and contribution for change in type, distribution and coverage of vegetation in the study area for the last three decade.

6.2. Recommendation

- As the result of increasing anthropogenic activities and rapid population growth farming and agricultural land was highly expanded. As a result, it significantly increases more pressure and affect natural forest. Thus, it is recommended to promote sustainable management practice, monitor the implementation of afforestation strategy, developing and implement community based sustainable local level land use planning, monitoring the implementation of community based natural resource management should be undertaken to maintain and control the reduction and decline of forest resource in the study area.
- The effect of rainfall and seasonal temperature variability on vegetation cover change has diverse impact on socio-economic value of community and leads to deforestation and drought. These should be considered for further study and analysis in the study area.
- Monitoring vegetation change and analysing responses to climate extremes variation are critical to understanding regional climate change. Hence, the effects of climate change on vegetation species could be further research and evaluation in the study area.

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Appendices

Appendix 1: Statistical information of accuracy assessment for the year 1990, 2000, 2010 and 2020.

Confusion matrix for LULC map of 1990.

Classification data	Reference data											User Accuracy
		HF	**MF**	**PL**	**SH/B**	**GL**	**WL**	**CT**	**CWT**	**B**	**Other**	**total**	
	HF	52	1	2	1	1	0	0	0	0	1	57	**88.1**
	MF	2	33	1	1	0	0	1	0	0	0	38	**86.8**
	PL	1	1	31	0	0	0	1	1	0	1	36	**86.1**
	SH/B	1	0	1	27	1	1	0	0	0	0	31	**87**
	GL	0	1	0	1	16	1	1	0	0	0	19	**76.2**
	WL	0	1	1	0	1	20	1	1	0	0	25	**80**
	CT	0	1	1	0	0	0	54	3	1	1	62	**90**
	CWT	0	1	0	1	0	0	2	64	1	0	70	**94.1**
	B	0	0	0	1	1	0	0	1	22	0	25	**88**
	Other	0	0	0	0	0	0	1	1	1	17	20	**85**
	total	56	39	37	32	20	22	61	71	25	20	385	
	Producer accuracy	**92.8**	**84.6**	**83.7**	**84.3**	**80**	**90.9**	**88.5**	**90.1**	**88**	**85**	**87.7**	

Confusion matrix for LULC map of 2000.

Classification data	Reference data											User Accuracy
		HF	**MF**	**PL**	**SH/B**	**GL**	**WL**	**CT**	**CWT**	**B**	**Other**	**total**	
	HF	55	2	1	0	0	0	0	0	0	0	58	**94.8**
	MF	2	36	1	1	1	0	1	0	0	0	42	**85.7**
	PL	1	1	35	1	0	0	1	1	0	0	40	**87.5**
	SH/B	1	2	1	34	1	0	0	0	0	0	39	**87.2**
	GL	0	0	0	1	20	1	1	1	1	0	25	**80**
	WL	0	0	0	0	1	20	0	1	0	0	22	**90.9**
	CT	0	0	1	1	0	0	54	2	0	0	58	**93.1**
	CWT	0	0	0	0	0	0	2	62	1	1	66	**93.9**
	B	0	0	0	0	1	0	0	2	21	2	26	**80.7**
	Other	0	0	0	1	0	1	1	1	3	16	23	**69.56**
	total	59	41	39	39	24	22	60	70	26	19	399	
	Producer accuracy	**93.2**	**87.8**	**89.7**	**87.2**	**83.3**	**90.9**	**90**	**88.5**	**80.7**	**84.2**	**88.5**	

Confusion matrix for LULC map of 2010.

Classification data	Reference data											Accuracy
		HF	**MF**	**PL**	**SH/B**	**GL**	**WL**	**CT**	**CWT**	**B**	**Other**	**total**	**User accuracy**
	HF	52	1	1	1	0	0	0	0	0	1	56	92.8
	MF	1	27	1	0	0	1	0	0	0	0	30	90
	PL	0	1	24	0	0	0	2	1	0	0	28	85.7
	SH/B	1	1	1	27	1	0	1	1	0	0	33	81.8
	GL	0	0	0	1	16	0	1	1	0	0	19	84.4
	WL	0	0	1	0	0	18	0	0	0	0	19	94.7
	CT	0	1	1	0	0	0	46	3	0	1	52	88.5
	CWT	1	1	0	0	0	0	2	63	1	0	68	92.6
	B	0	0	0	1	1	0	0	1	23	0	26	88.5
	Other	0	0	0	0	0	0	1	1	2	17	21	80.9
	total	55	32	29	30	18	19	53	71	26	19	352	
	producer accuracy	**94.5**	**84.3**	**82.7**	**90**	**88.9**	**94.7**	**86.8**	**88.7**	**88.5**	**89.4**	**88.9**	

Confusion matrix for LULC map of 2020.

		Reference data											User Accuracy
Classification data		HF	MF	PL	SH/B	GL	WL	CT	CWT	B	Other	total	
	HF	59	1	1	1	0	0	0	0	0	1	63	**93.6**
	MF	1	35	1	1	0	0	1	0	0	0	39	**89.8**
	PL	1	1	37	0	0	0	1	0	0	0	40	**92.5**
	SH/B	1	0	1	29	0	1	0	0	0	0	32	**90.7**
	GL	0	1	0	1	24	1	1	1	0	0	29	**82.6**
	WL	0	0	0	0	1	21	1	1	0	0	24	**87.5**
	CT	0	0	2	1	0	0	59	2	0	1	65	**90.8**
	CWT	0	1	0	0	0	0	2	63	1	1	68	**92.6**
	B	0	0	0	0	1	0	0	1	25	0	27	**92.5**
	Other	0	0	0	1	0	0	0	2	2	21	26	**80.8**
	total	62	39	42	34	26	23	65	70	28	24	413	
	producer accuracy	**95.2**	**89.7**	**88.9**	**85.3**	**92.4**	**91.3**	**90.8**	**90**	**89.3**	**87.5**	**90.3**	

Appendix 2: Land-use land-cover transition matrix.

Land-use land-cover transition matrix (1990-2000)

		Land-use and land-cover (2000)										
Land-use and land-cover (1990)		**BL**	**CT**	**CWT**	**GL**	**HF**	**MF**	**Other**	**PL**	**SH/B**	**WL**	**Total**
	BL	233.25	213.23	744.95	5.9165	1.1542	14.4	42.7736	11.9437	26.9084	0.09481	1294.58
	CT	321.92	1488.6	1112	151.84	134.11	309	104.596	360.112	511.438	15.4802	4509.24
	CWT	319.65	1191.9	3968.7	237.39	41.213	59.2	226.899	85.3115	290.544	10.5794	6431.42
	GL	15.433	171.7	200.1	302.69	5.5803	50.8	12.8369	39.9217	104.797	18.6792	922.544
	HF	60.185	135.2	38.447	5.4486	2389.6	213	26.4326	338.288	36.2648	1.55354	3244.86
	MF	19.141	141.32	66.341	19.597	81.525	503	38.8536	179.956	168.43	4.06967	1222.63
	Other	49.104	226.93	654.86	22.039	0.2626	34.3	170.901	21.4607	120.631	0.444	1300.91
	PL	131.78	459.02	167.89	30.312	242.9	395	61.3002	358.974	249.533	6.64001	2103.03
	SH/B	243.21	327.62	338.87	41.115	8.2998	104	54.1361	44.6286	139.488	1.21698	1302.23
	WL	0.1913	2.5841	6.6102	23.173		15.5	1.82604	2.33517	10.0373	2.39198	64.6537
	Total	**1393.9**	**4358.1**	**7298.8**	**839.52**	**2904.6**	**1698**	**740.555**	**1442.93**	**1658.07**	**61.1498**	**22396.1**

Land-use land-cover transition matrix (2000 - 2010)

		Land-use and land-cover (2010)										
Land-use and land-cover (2000)		**BL**	**CT**	**CWT**	**GL**	**HF**	**MF**	**Other**	**PL**	**SH/B**	**WL**	**Total**
	BL	**199.67**	268.79	740.55	3.57	20.45	4.09	29.50	61.78	65.63	0.00	1394.03
	CT	175.60	**1349.80**	1568.00	57.11	106.44	130.88	135.01	616.27	210.81	7.30	4357.22
	CWT	385.02	775.77	**5251.38**	112.72	16.10	30.28	451.62	200.71	72.87	3.33	7299.79
	GL	13.51	150.02	175.93	**279.30**	7.56	55.77	68.89	46.82	37.99	4.24	840.05
	HF	21.81	117.11	34.44	9.48	**2283.80**	157.89	1.77	198.70	73.91	5.70	2904.60
	MF	26.21	330.81	141.06	105.84	81.42	**471.15**	51.87	230.12	253.34	6.06	1697.89
	Other	41.30	145.51	251.57	5.14	0.00	12.17	**212.31**	53.96	18.46		740.42
	PL	17.48	220.65	102.73	41.52	235.68	287.07	14.05	**377.76**	138.41	7.46	1442.82
	SH/B	48.77	481.26	286.32	95.29	7.82	173.20	127.38	303.25	**130.65**	4.19	1658.14
	WL	1.33	9.89	6.53	20.87	1.19	7.28	1.40	5.19	5.55	**1.84**	61.07
	Total	**930.70**	**3849.61**	**8558.52**	**730.83**	**2760.46**	**1329.77**	**1093.81**	**2094.58**	**1007.61**	**40.13**	**22396.02**

Land-use land-cover transition matrix (2010 - 2020)

Land-use and land-cover (2010)	Land-use and land-cover (2020)										
	BL	**CT**	**CWT**	**GL**	**HF**	**MF**	**Other**	**PL**	**SH/B**	**WL**	**Total**
BL	169.83	190.21	325.70	13.85	7.94	28.56	106.47	47.88	39.91	0.27	930.61
CT	120.39	1054.45	1568.27	74.00	51.79	242.01	157.86	317.67	260.78	2.38	3849.58
CWT	409.02	1671.33	5242.16	62.48	14.05	174.75	382.86	344.42	254.34	2.34	8557.75
GL	4.59	136.79	170.13	173.18	2.29	114.69	13.02	31.89	75.26	8.28	730.12
HF	26.53	215.82	23.06	0.88	2069.59	90.85	2.41	321.83	9.24	0.18	2760.38
MF	6.76	193.68	214.88	46.81	287.62	300.27	45.68	79.18	152.19	2.82	1329.87
Other	9.39	74.39	573.15	78.09	0.43	46.59	181.13	13.82	116.26	0.53	1093.78
PL	24.53	535.76	668.89	46.35	88.17	146.22	91.62	320.50	170.71	1.97	2094.71
SH/B	21.39	249.84	120.14	17.54	91.52	239.06	27.67	148.88	91.09	0.55	1007.68
WL	0.66	14.81	3.38	0.28	0.61	10.49	0.59	6.72	2.31	0.28	40.13
Total	**793.08**	**4337.08**	**8909.76**	**513.46**	**2614.01**	**1393.48**	**1009.30**	**1632.77**	**1172.08**	**19.59**	**22394.61**

Land-use land-cover transition matrix (1990 - 2020)

Land-use and land-cover (1990)	Land-use and land-cover (2020)										
	BL	**CT**	**CWT**	**GL**	**HF**	**MF**	**Other**	**PL**	**SH/B**	**WL**	**Total**
BL	149.45	240.72	701.98	2.88	1.40	32.26	81.07	46.72	38.30	0.05	1294.84
CT	147.51	1406.12	1790.86	75.16	57.71	205.76	159.78	405.73	258.97	2.45	4510.05
CWT	196.03	1098.65	4120.32	109.07	22.80	129.51	251.60	297.23	198.20	7.81	6431.23
GL	16.73	180.54	366.21	152.38	12.12	47.28	18.98	62.21	61.18	4.87	922.51
HF	35.70	325.57	139.79	10.94	2138.70	171.48	29.43	336.17	56.93	0.09	3244.80
MF	15.01	106.13	211.98	39.93	176.80	398.64	68.70	79.57	124.67	0.97	1222.39
Other	48.06	142.04	716.28	28.87	0.22	33.68	200.53	32.23	98.81	0.26	1300.97
PL	62.77	469.30	436.44	49.43	191.60	282.39	103.81	286.41	219.16	1.81	2103.11
SH/B	121.88	362.42	415.76	30.58	12.52	79.08	94.43	84.67	100.67	0.27	1302.29
WL	0.22	6.50	10.35	14.18	0.11	13.57	1.34	1.92	15.53	0.97	64.70
Total	**793.36**	**4338.00**	**8909.96**	**513.42**	**2613.99**	**1393.64**	**1009.68**	**1632.85**	**1172.42**	**19.56**	**22396.88**

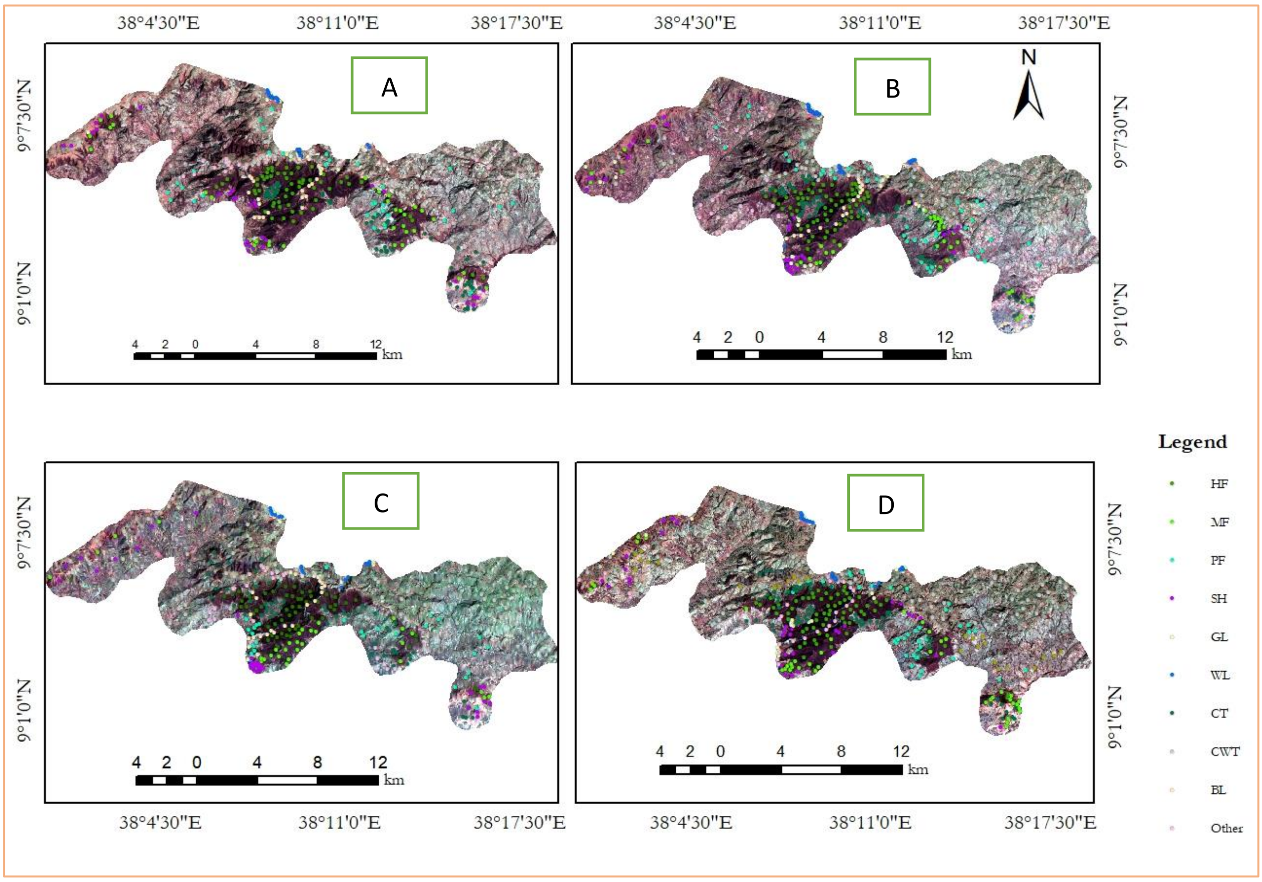
Appendix 3: Mean, minimum and maximum Temperature for wet and dry season (1990 to 2020)

year	Wet Season Temperature			Dry Season Temperature		
	Mean Temp	**Min Temp**	**Max Temp**	**Mean Temp**	**Min Temp**	**Max Temp**
1990	17.77	8.78	22.892	17.16	12.00	23.90
1991	17.57	8.29	22.828	17.28	11.75	24.07
1992	17.18	9.96	21.916	17.06	11.64	23.18
1993	16.93	8.04	21.694	16.64	10.97	22.82
1994	17.11	6.63	21.792	17.40	11.96	24.25
1995	17.19	7.71	22.118	17.08	11.14	24.24
1996	16.64	8.49	21.278	17.22	11.13	23.90
1997	17.78	9.53	22.964	17.62	12.19	24.05
1998	17.57	6.76	22.42	17.46	11.88	23.97
1999	17.37	7.38	22.602	17.00	11.12	24.32
2000	16.91	7.55	21.54	17.50	10.97	24.40
2001	17.20	8.36	22.08	17.76	10.74	24.19
2002	16.98	8.63	22.302	17.15	11.04	23.93
2003	17.57	10.31	22.578	18.35	11.85	24.68
2004	17.98	9.16	22.792	17.78	12.45	24.08
2005	17.64	8.19	21.966	18.29	13.09	25.11
2006	17.63	9.42	22.494	17.89	12.39	24.57
2007	17.64	7.19	22.118	17.04	12.63	24.12
2008	17.10	7.91	22.018	17.08	11.28	24.45
2009	17.76	8.47	23.232	17.27	11.48	24.19
2010	17.52	8.99	22.06	17.57	11.64	23.94
2011	17.48	8.44	22.378	17.46	11.55	24.50
2012	18.35	8.57	22.92	17.57	13.28	24.67
2013	15.28	7.79	17.702	17.85	12.42	24.88
2014	18.04	8.06	22.762	18.10	12.73	24.58
2015	18.33	8.94	23.312	17.71	12.55	24.63
2016	17.38	7.73	22.076	17.79	11.99	24.45

Appendix 4: Mean annual, minimum and maximum annual rainfall and dry season (1990 to 2020)

	Annual Rainfall			Dry Season Rainfall		
year	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
1990	1270.04	1157.25	1363.62	278.75	267.011	312.31
1991	1233.29	1041.29	1381.52	216.61	184.8	251.389
1992	1380.03	1275.94	1553.49	336.906	275.993	462.11
1993	1346.27	1154.26	1633.86	395.67	314.37	515.347
1994	1109.26	1027.21	1159.44	189.06	166.199	222.651
1995	1051.149	978.528	1159.44	230.55	193.354	277.506
1996	1249.67	1137.03	1299.32	280.087	226.185	322.796
1997	1108.187	941.089	1233.3	265.168	219.161	333.467
1998	1425.28	1196.7	1518.67	277.055	230.815	322.093
1999	1205.69	1043.48	1286.67	234.08	169.189	312.4
2000	1105.899	1007.7	1168.22	235.029	205.808	268.425
2001	1134.08	1035.4	1289	221.32	178.348	262.504
2002	931.44	899.763	1022.55	200.92	177.876	240.399
2003	1174.818	1020.39	1300.75	290.45	228.294	348.713
2004	1178.718	1062.54	1274.43	273.436	242.48	309.276
2005	1108.85	1018.79	1162.32	250.708	208.172	280.969
2006	1471.64	1324.39	1619.64	356.49	298.797	424.935
2007	1284.22	1159.53	1377.45	251.07	211.904	285.539
2008	1229.98	1098.8	1426.48	160.68	144.547	196.864
2009	1198.399	1066.04	1267.32	221.688	163.288	268.77
2010	1261.996	1217.17	1321.8	210.838	246.063	286.38
2011	1356.99	1212.44	1441.4	210.838	182.941	244.51
2012	1080.92	955.757	1153.77	185.998	165.764	207.714
2013	1151.85	1029.68	1231.99	211.603	187.898	242.223
2014	1029.08	907.195	1181.37	245.56	201.956	304.235
2015	852.94	754.543	958.84	173.75	153.072	205.034
2016	1266.97	1158.32	1340.17	211.65	193.072	232.679
2017	1291.39	1170.45	1357.36	229.7	198.112	255.763
2018	1156.61	1050.3	1258.84	220.72	196.6	274.072
2019	1429.46	1283.86	1552.55	347.569	304.808	414.048
2020	1390.329	1236.9	1515.28	337.95	291.755	376.846

Appendix 5: Accuracy assessment points of 1990 (A), 2000 (B), 2010 (C) and 2020 (D).



Appendix 6: One False Color Composite (FCC) scene scanline error of Landsat 7(2010) (A) and one scene of gap filled Landsat 7 (2010) (B) and clipped FCC image of Chilimo forest for 2010 (C)