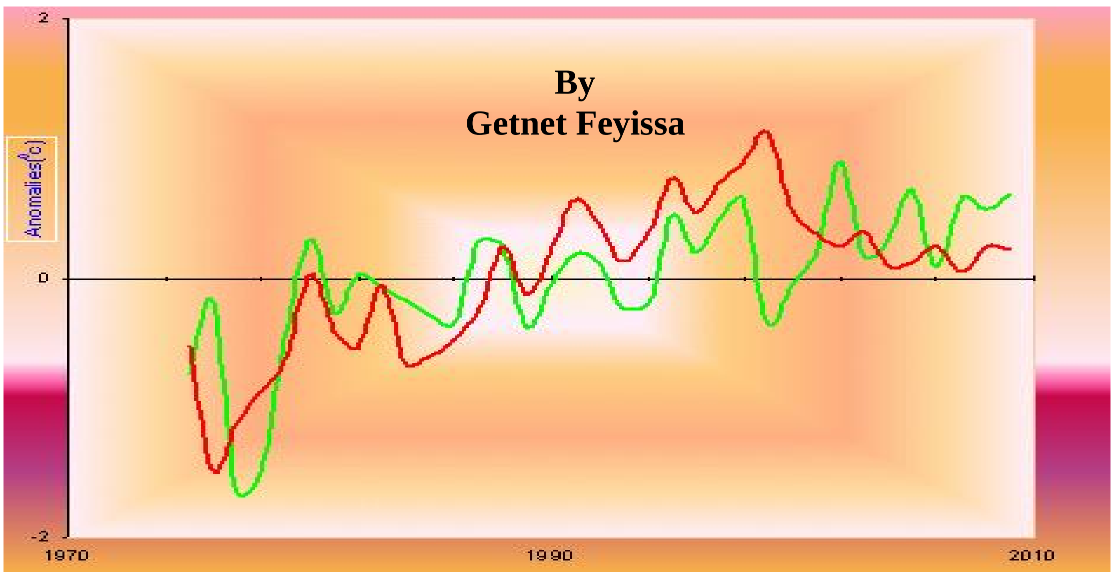
Comparative Analysis of Climate Variability and Impacts in Central Rift Valley and Adjacent Arsi Highlands Using GIS and Remote Sensing



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June, 2010

Comparative Analysis of Climate Variability and Impacts in Central Rift Valley and Adjacent Arsi Highlands Using GIS and Remote Sensing

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Under the guidance of

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C E R T I F I C A T E

This is certified that the dissertation entitled '**Comparative Analysis of climate Variability and Impacts in Central Rift Valley and adjacent Arsi Highlands Using GIS and Remote Sensing'** is a bonafied work carried out by Getnet Feyissa under my guidance and supervision. This is the actual work done by Getnet Feyissa for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

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What Return Shall I Make To The Lord For All His Bounties To Me?Ps 116:12

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List of Acronyms

AOGCM	Atmosphere-Ocean General Circulation Models
CSA	Central Statistical Authority
ESRI	Environmental System Research Institute
DPPC	Disaster Prevention and Preparedness Commission
ETM+	Enhanced Thematic Mapper Plus
GCM	Global Circulation Model
Gg	Giga Gram
GHG	Green House Gases
GIS	Geographical Information System
GPS	Global Positioning System
IDW	Inverse distance weight
ICSSR	Indian Council of Social Science Research
ICRISAT	International crop research institute for the semi arid tropics.
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
NASA	National Aeronautics and Space Administration
MoWR	Ministry of Water Resources
NAPA	National Adaptation Plan of Action
NMSA	National Meteorological Services Agency
SEG	Society of Exploration Geo Physicist
SRTM	Shuttle Radar Topography Mission
TM	Thematic Mapper
UNFCC	United Nations Framework Convention on Climate Change
MSS	Multi Spectral Scanner
UTM	Universal Transverse Mercator
UNEP	United Nation’s Environment Program

Abstract

The problem of climate variability is broadly studied currently from various angles that emanate from seriousness of the problem. The most recent is application of satellite image that is analyzed through Remote Sensing and GIS that flourished with the development of Earth Observing satellites. The impact of Climate variability is high in Ethiopia, where frequencies of extreme events are increasing. The Remote Sensing and GIS based analysis of climate vulnerability in Ethiopia is inevitable where insufficient amount of data is available. The study area extends from Peak of Chilalo Mountain to lowlands of Fentalle with the total area of 7758.3 km^2. The focuses on assessing the degree of climate variability, constructing climate variability index, comparing and contrasting variations in parts of the Rift Valley with that of adjacent highlands, integrating GIS and Remote sensing application in detecting climate change and trend analysis, and finally preparing composite climate variability impact map.. Daily river discharge data for 'Ketar' and 'Keleta' observed from 1980-2009 is also used to support the analysis. NASA's LANDSAT satellite of 1973, 1986, and 2009 with row 54 and 55 and path 168, have been used. Data analyzed from 22 meteorological stations found in the study area since 1975-2009 indicates that temperature is getting increased by 0.37^oC in the rift valley and 0.48^oC in highland and by 0.4^oC in whole areas per 12 years and rain is constant and shows insignificant rise. Rift valleys are suffering from climate variability than adjacent highlands though rainfall variation is increasing in highlands than lowlands. In all this work, various GIS and Remote Sensing softwares have been used. The resultant climate variability impact map along with the land use land cover can serve local planners and scientists as a primary source of information and for policy makers.

Key words: Climate Vulnerability and Change, Vulnerability Index, Normalized Maps, Land Use

1. INTRODUCTION

1.1 Background and Justification

Climate variability and change and its impact is currently an international agenda that attracts of country leaders scientists and peoples and peoples among others around the world. Due attention is given to this issue because of occurrences of damage it might brings to the world following the change. For the world as a whole climate change topic was studied by different angels using various types of evidence in the last 30 years. It has become clear that not only have there been world wide climate changes occurring in last 100,000 years which have undoubtly affected the distribution of crops and live stock but also that recent short term climatic change may be affecting agricultural distribution(Guy, 2003).

Global temperature have been increasing over the past centaury due to the effect of peoples activity which increase green house gases when they are try to make natural areas into some thing else.(Nagle,2002) According to current projections global temperature may stand as much 5.8^{0}C above the 1990 temperature by the year 2100. To place this change in climate in context, the temperature rise that brought the planet out of the most recent ice age was only of the order of 4 to 5^{0}C. Carbon dioxide concentrations in the atmosphere are already higher than at any time during the last 160,000 years. If concentrations continue to rise, the Earth's temperature may become warmer than at any time during the last 40 million years **(**Buchdahl, 2002).

A change in climate can occur in several different ways for example there may be shift in the mean level or gradual trend in climates mean. The variability may be periodic quasi- periodic, non periodic or alternatively it may show a progressive trend (Barry, 1968) There is that regionally relatively fast some times abrupt climate changes can occur. These changes may persist for up to several decades, but often a function of season. These fast changes are poorly understood, but can be of considerable practical importance (Ibid). It is known that about 7000 years ago most of the current Sahara desert received annual rain fall of more than 20 cm per year. But its current annual rain fall is less than 1.3 cm per year. Ethiopia is one of the Sahelian Countries which are affected by frequent drought occurrences (Tylor, 2002). For the IPCC mid-range (A1B) emission scenario, the mean annual temperature will increase in the range of 0.9^{0}C -1.1 ^{0}C by 2030, in the range of 1.7 - 2.1 ^{0}C by 2050 and in the range of 2.7-3.4 ^{0}C by 2080 over Ethiopia compared to the 1961-1990(NAPA,2007).

In developing country, like Ethiopia where the history and records of climatic data is low, the awareness of people about the atmosphere is also low. Ethiopia faces various socio -economic problem resulting from climatic variability and change. The crop fails, shortage of rain fall, the urban are hotter and hotter. Rivers are and springs are drying up, malaria spreads in the areas didn't exist before. Significant climate change vulnerability is observed over Ethiopia in the past 50 years which includes frequency of drought, urban heat island, and flood vibrant climate change based diseases and shift of ecosystems. Various researches currently also concluded there a significant raise of temperature over the country and projections also predicted more changes in the future based on different climate models.

There is an important distinction between climate change and variability i.e. time scale. Climate change is a long term while variability is generally more short term (Cracknell, 2001). Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (Angie, 2009*)*.A GIS framework provides an enhanced ability to assess the possible responses from a range of adaptation strategies to climate change by integrating the outputs from global circulation models and various modeling efforts in agriculture (Liua et al., 2009).

A key difference between climate variability and change is in persistence of "anomalous" conditions. In other words, events that used to be rare occur more frequently (summertime maximum air temperatures increasingly break records each year), or vice-versa (duration and thickness of seasonal lake ice decreasing with time). In statistical terminology, the curve of the frequency distribution representing the probability of specific meteorological events occurring is changed. The curve may be modified either in amplitude, or shifted about a new mean, or both. (IPCC, 2009).Variations of climate due to different factors not leaves the condition as they were. Rather result in many consequences. Sufficient evidence is now available from variety of different studies to indicate that change of climate would have an important effect on agriculture including malaria (IPCC, 1992).

1.2 Significance of the Study

The issue of climate variability and change is widely studied in the world. The impact of the climate brings series damage especially in developing countries. Ethiopia currently faces various problems resulted from climate variation even though the degree of the climate change is not clearly identified. The frequency of the occurrences of climatic hazard is increasing. Ethiopia's land escape is crossed by great East African rift valley which extends from Syria to Mozambique. The areas in the rift valley and out of the rift valley have different climatic condition. Currently climate vulnerability which was limited to semi arid regions is also expanded to the highlands as highland environment is intervened by human intervention.

Variations that occur in small scale have severe impact on human and natural environment. Spread of malaria is a major problem in Ethiopia because most parts of country are getting malaria due to temperature increment. Drought occurs in many parts of the world but it is likely happen in places where the climate is dry and changeable. One of the worst droughts in recent years has been in the Sahel. The changes detected through satellite bring in perfect interpretation and advanced approaches to overcome the problem. Technological advancement developed through time makes the world problem to be studied easily by applying complicate analysis and models.

Quantifying climate variability and change vulnerability is not an easy task but of most important to overcome the problem. Using GIS and Remote Sensing makes the way of study easier and elapsed the time taken to study certain area when compared with the previous studies. GIS and Remote Sensing development shows various studies in assessing climate change in the world. The application of such technologies is highly required in the study areas in order to predict the climatic condition to be happening in the future and to assess the out coming risk where the limited climate change research is conducted.

1.3 Objectives

1.3.1 General objective

To examine and quantify the degree of climate variation in parts of rift valley and adjacent highlands with comparison and to assess the impact resulted from climate variation.

1.3.2 Specific objectives

- To assess the extent, degree and trend of climate variation in the study area
- To compare and contrast climate variability of rift valley and adjacent highlands
- To review predicted climate change projection and to identify vulnerable groups to climate variation in the study area.
- To prepare climate variability index and composite climate variability impact map.

1.4 Limitations and Scope of the Study

Climate change vulnerability analysis is the result of various climatic parameters and high level application of models. Despite various efforts is exerted to make the research more scientific, reliable and applicable some limitations have observed on the process of completion of the work. Full records on climatic elements are not observed and comparison reference year is not set since a detailed work on this area is not undertaken. Except precipitation and temperature data all acquired data for relative humidity and wind speed and other parameters are only found in few stations which is difficult to interpolate.

The number of malaria cases registered is not for long years and the data are not found as that of climatological record to compare it with others. Due to the research covers large study area and vulnerable groups are many in number and takes additional time to analyze in detail each of them conducting detail information on vulnerable groups is not as of climate data The other drawback of the study is lack of yearly carbon emission from various sectors and carbon sequestration by plants in Ethiopia and specifically of the study area since such kind of record is not available yet in the country.

Based on the limitations cited above the scope of this research is limited to

- Review of literature and previous studies and identifying appropriate methodologies
- Identifying characteristics of the study area
- Compilation and analysis of climatic elements and comparing the occurred change.
- Identification of vulnerable groups to climate variation and change. This includes river discharges, malaria out patient's and agricultural disaster from various organizations.
- Classification of land use land cover from land sat satellite images of 1973, 1986, and 2009 to relate with climate variation.
- Qualitative and quantitative analysis of the data
- Developing climate change vulnerability indexes and composite climate change vulnerability mapping
- Recommendations and conclusions

2. RIVIEW OF LITRATURE

2.1 Definition of Terminologies

Climate variability: Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external variability (Fussel and Klein, 2006).

Climate change: A statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change can also be defined as a trend in one or more climatic variables characterized by a fairly smooth continuous increase or decrease of the average value during the period of record (Mukheibir and Ziervogel, 2007).

2.2 Theoretical Background to Climate variability and Change

Since 1750, global-average surface temperature has risen by 0.8^{o}C, with most of the increase occurring in the 20th century, most rapidly since 1970, and continues to rise in the 21st century, by 0.2^{o}C -0.4^{o}C per decade (SEG, 2007). Global warming is expected to continue, with increase projected to be in the range of 1.4^{o}C to 5.8^{o}C by 2100 in comparison to 1990 (Lama and Devkota, 2009). Average annual temperatures in Africa have been rising steadily and during the 20th century the continent saw increase in temperatures of about 0.5^{o}C. Countries in the Nile Basin had an increase of about 0.2^{o}C to 0.3^{o}C per decade during the second half of the century, while in Rwanda temperatures increased by 0.7^{o}C to 0.9^{o}C (Buchdahl, 2002).

CO_2 is the largest individual contributor to the enhanced greenhouse effect, having a positive forcing value of about 1.56Wm-2 (or 60% of the total) over the period 1765 to 1999. That is to say that an additional 1.56Wm-2 of energy is trapped in the atmosphere as a result of the buildup of CO_2 since 1765. To stabilize concentrations at present day levels would require a massive 60% reduction of global CO_2 emissions(ibid)**.**Ethiopia's total gross CO_2 emissions excluding the land use change and forestry has been estimated at 2,596 Gg in 1994. About 88% of this total CO_2 emission came from fossil fuel combustion in the energy sector and the transport (road) sub sector is the main CO_2 embitter within the sector followed by emissions from cement production and biomass burn (Annex 1). The national methane emission totaled about 1,808 Gg in same year as indicated in the annex (MoWR and NMSA, 2001).

Ministry of Water resource and national meteorological agency in 2001 indicated that the land use and forestry sector has been a net sink in 1994 which amounted about-15,063 Gg of CO_2 in Ethiopia. The country's stock of natural forests woodlands shrubs and plantations sequestered about-27,573 Gg of CO_2 in 1994 while the emission of CO_2 due to deforestation was estimated to be 12,510 Gg in the same year. There is a general increasing trend of GHG emissions in Ethiopia in the period 1990-1995.

2.2.1 Temperature Trends

Surface of the Earth has warmed by between 0.4°C and 0.8°C during the last century. This finding does, however, have to be interpreted with care. For example, the observed warming has not been constant, although the steady rise in greenhouse gas concentrations would suggest that any greenhouse-induced warming should have been steady over the past 100 years (Buchdahl, 2002). Figure 2.1 shows the rise of temperature value since 1854.

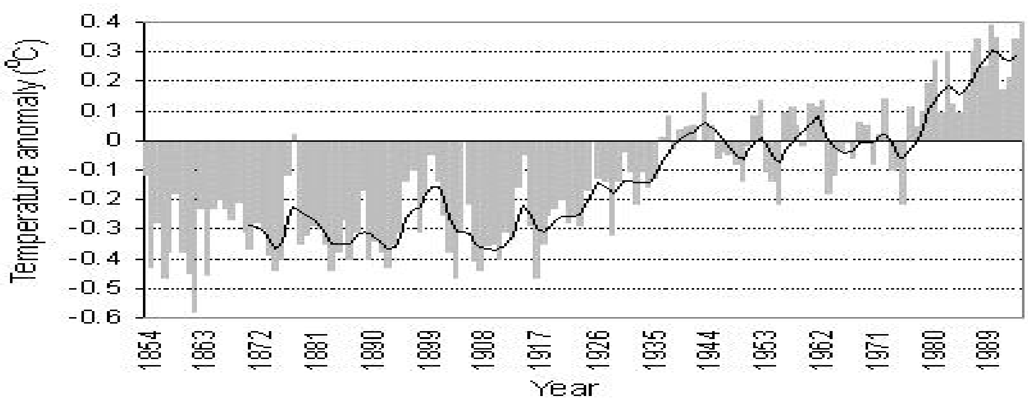


Figure 2.1: Surface temperature rise
Source: Buchdahl (2002).

A research by various authors indicates that there is an increase of temperature over all of the country. Earliest climatological station of Gondar prior to 1993 had an anomaly of -4°C while the result is abruptly increased to 4°C in the preceding years since 2006 (Getnet, 2006).The researches under taken by MoWR and NMSA shows that maximum temperature is continuously rising in Ethiopia as described in Figure 2.2.

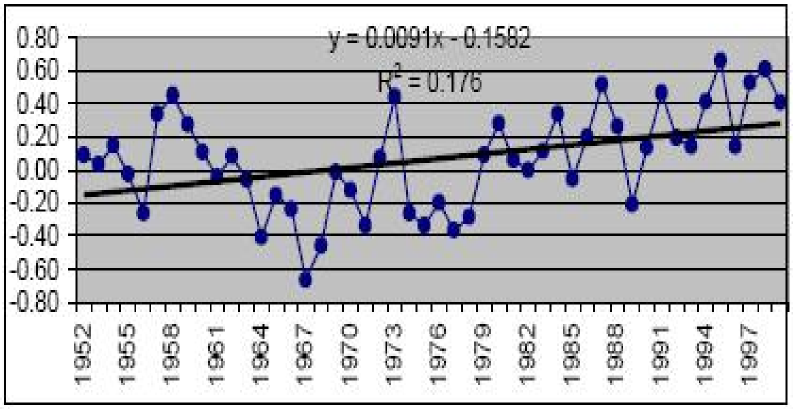


Figure 2.2: Annual Mean Maximum Temperature Variability over Ethiopia
Source: MoWR and NMSA (2001)

2.2.2 Rainfall Trends

Quoting IPCC Siri Ericson, *2008* wrote that Annual rainfall is likely to decrease throughout most of the African region, with the exception of Eastern Africa, where annual rainfall is projected to increase. These changes in the physical environment are expected to have an adverse effect on agricultural production, including staple crops such as millet and maize. Trend analysis of annual rainfall in Ethiopia shows that rainfall remained more or less constant when averaged over the whole country while a declining trend has been observed over the Northern half of the country and Southwestern Ethiopia.

2.2.3 Land cover change versus climate variability

The lack of rain fall in desert areas results in lack of vegetation. As a consequence the surface albedo increases. Hence the desert region reflects more short wave solar radiation into space than the surroundings. In addition desert surfaces are hotter than the surrounding regions and air above them is less cloudy**(**Peng et al., 2002).The prospect of global warming due to increase green house gases and its potential impact on land cover have been studied in numerical experiments since the early 1990.The numerical experiments investigating the relationships between vegetation feed backs and CO_2 induced climate change have demonstrated that vegetation feed backs are potentially significant and must be included in future climate change assessments (ibid).

2.3 Conceptual Frame Work of Vulnerability

The Intergovernmental Panel on Climate Change (IPCC), in its Second Assessment Report, defines vulnerability as the extent to which climate change may damage or harm a system. It adds that vulnerability depends not only on a system's sensitivity, but also on its ability to adapt to new climatic conditions .IPCC'S definition on region's vulnerability to climate variability and change is described by three elements: exposure, sensitivity, and adaptive capacity (IPCC 2001), as follows:

Exposure: The nature and degree to which a system is exposed to significant climatic variations. The exposure of a system to climate stimuli depends on the level of global climate change and, due to the spatial heterogeneity of anthropogenic climate change, on the system's location.

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct or indirect

Adaptive capacity represents the potential to implement adaptation measures that help avert potential impacts (ibid)

2.3.1 Calculating the vulnerability indices

From our conceptual framework, we see that the vulnerability of a given system largely depends on its exposure and sensitivity, which combined provides the potential impact and the potential for effectively coping with the impacts and associated risks.

Vulnerability may be formulated mathematically as follows:

$$V = f\,(I - AC)$$

(-) (+)

Where V is vulnerability, I is potential impact, and AC is adaptive capacity.

A higher adaptive capacity is associated with a lower vulnerability, while a higher impact is associated with a higher vulnerability. Given the above equation, vulnerability is defined as a function of a range of biophysical and socio-economic factors, commonly aggregated into three components that estimate the adaptive capacity, sensitivity, and exposure to climate variability and change (Aymone and Ringler, 2009).

2.3.2 Conceptual Approaches

The conceptual approaches to climate variability are similar with the approaches used for climate change. There are three major conceptual approaches to analyzing vulnerability to climate variability and change: the socioeconomic, the biophysical (impact assessment), and the integrated assessment approaches.

Socioeconomic Approach: The socioeconomic vulnerability assessment approach mainly focuses on the socioeconomic and political status of individuals or social groups (Adger 1999, Fussel 2007). The approach focuses on identifying the adaptive capacity of individuals or communities based on their internal characteristics

Biophysical Approach: The biophysical approach assesses the level of damage that a given environmental stress causes on both social and biological systems. For instance, the monetary impact of climate change on agriculture can be measured by modeling the relationships between climatic variables and farm income and the yield impacts of climate change that can be analyzed by modeling the relationships between crop yields and climatic variables according to various authors.

The Integrated Assessment Approach: The integrated assessment approach combines both socioeconomic and biophysical approaches to determine vulnerability. The vulnerability mapping approach (O'Brien et al., 2004) is the other related example, in which both socioeconomic and biophysical factors are combined to indicate the level of vulnerability through mapping.

2.3.3 Methods for Measuring Vulnerability to climate variability and Climate Change

Based on the previously discussed approaches, there are many methods for analyzing vulnerability to climate change, especially in the biophysical or impact assessment methods.

Econometric Method: The econometric method has its roots in the poverty and development literature. This method use household-level socioeconomic survey data to analyze the level of vulnerability of different social groups.

Indicator Method: The indicator method of quantifying vulnerability is based on selecting some indicators from the whole set of potential indicators and then systematically combining the selected indicators to indicate the levels of vulnerability. These levels of vulnerability may be analyzed at local, national, regional and global scales (Temesgen et al., 2008).To calculate level of vulnerability as literatures depicted we will give equal weight for indicators or different weight.

2.4 Vulnerable Groups to Climate Variability

Drought and famine, flood, malaria, land degradation, livestock disease, insect pests and earthquakes have been the main sources of risk and vulnerability in most parts of the country. Especially, recurrent drought, famine and, recently, flood are the main problems that affects millions of people in the country almost every year. While the causes of most disasters are climate related, the deterioration of the natural environment due to unchecked human activities and poverty has further exacerbated the situation. (NAPA, 2007**)**

2.4.1. Agriculture

People who live on arid or semi-arid lands, in low-lying coastal areas, in water-limited or flood-prone areas, or on small islands are particularly vulnerable to climate change. It is clear that climate change will, in most parts of the world, adversely affect socio-economic sectors, including water resources, agriculture, forestry, fisheries and human settlements, ecological systems, and human health, with developing countries being the most vulnerable (IPCC, 2000). The importance of agricultural activities for the economies of most African countries, combined with the farming sector's reliance on the quality of rains during the rainy season, make countries in the region particularly vulnerable to climate change. Thus, from the point of view of food security, the increasing incidence of drought represents a very serious threat. It has been argued that, in Africa, drought hazard and vulnerability are likely to be the most damaging locus of impacts of climate change (ibid).

2.4.2 Water Resources

Water resources are highly vulnerable to climate variability and change. For example studies conducted on Awash River shows the anticipated changes in runoff (supply) compared with the present-day runoff. According to the results over the whole basin, runoff decreases significantly in warmer and drier scenarios. A 20% decrease in rainfall coupled with a 2°C increase in temperature would result in a 41% decrease in the annual runoff. All models suggested that global warming would result in a general increase in dryness, which would decrease water availability (Kinfe, 1999).

Incremental scenarios were also employed in the study of the two basins. The results from the effect of the prescribed climate change scenarios (i.e., temperature increase by 2^0c and 4^0C, and, ±20%, ±10, and no change in precipitation) indicate that runoff decreases significantly in warmer and drier scenarios over the two basins. Even a temperature increase by 2°C without precipitation change would result in a significant decrease in runoff. It is seen that an increase in precipitation would offset the effects of temperature increase as described in Table 1.

Table 1: Annual Percentage Change in River Runoff

Temperature changes	Basin	Precipitation (%)				
		-20	-10	0	+10	+20
+2°c	Awash	-41	-25	0	+10	+20
	Abay	-37.4	-20.9	-5.9	+10	+27.1
+4°c	Awash	-43	-30	-15	+4	+23
	Abay	-39.2	-26.1	-11.7	+4.1	+20.3

Source: Kinfe and Deksiyos (2000)

2.4.3. Health vulnerability to climate variability and change

The impact of climate variability and change on human health has received increasing recognition since it was first mentioned in the IPCC's First Assessment Report. Major impacts of climate change on human health are likely to occur via changes in magnitude and frequency of extreme events, infectious diseases and ecological disruption. Insect or tick vectors transmit many important diseases, such as malaria, dengue, yellow fever, Sleeping Sickness. Since these organisms are sensitive to temperature, humidity, and rainfall patterns, are responsive to climate change. (Ananram, 2006)

Historical climate record shows a warming of approximately 0.7°C over most part of the continent during the 20th century; a decrease in rainfall over large parts of the Sahel, and an increase in rainfall in East and Central Africa (ibid). Model based geographical projection indicates that global mean increase in temperature in the upper part of the IPCC projected range (3-5°C by 2100) would increase the geographical zone of parental malaria transmission and would expand the affected proportion of the global population from approximately 45% to 60% as cited by Watson and friends in 1988.(Casman and Dawlatabadl,2002).

2.5 Future Climate Change Projection

Most of the predictions are based on the General circulation model (GCM) which uses numerical representation of the atmosphere and its phenomena over the entire Earth, using the equations of motion and including radiation, photochemistry, and the transfer of heat, water vapor, and momentum. According to the IPCC (2001), potential climate changes in Africa would increase in global mean temperatures between 1.5^{0}C and 6^{0}C by 2100. Scenarios indicate future warming across the continent ranging from 2^{0}C per decade to more than 0.5^{0}C per decade. Warming expected to be greatest over semi-arid regions of the Sahara and central and South Africa. Sea levels are projected to rise by 15-95 cm by 2100.

2.5.1Projected Climate Change over Ethiopia

The most widely used method for obtaining information on possible future climate change is to use coupled Atmosphere-Ocean General Circulation Models (AOGCM).

For the IPCC mid-range emission scenario, the mean annual temperature will increase in the range of 0.9^{0}C -1.1 ^{0}C by 2030, in the range of 1.7^{0}C - 2.1 ^{0}C by 2050 and in the range of 2.7^{0}C -3.4 ^{0}C by 2080 over Ethiopia (Figure2.3) as compared to the 1961-1990 .

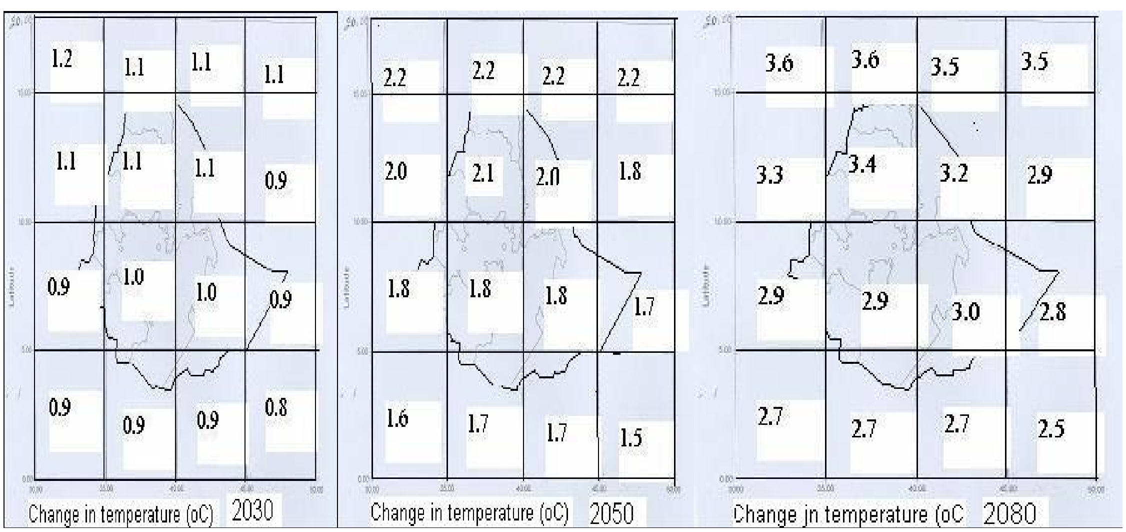


Figure 2.3: Composite changes in temperature (^{0}C) relative to 1961-1990

Source: MoWR and NMSA (2001

2.6 GIS and Remote Sensing Applications in Climate Variability and Change Detection

The key to understanding our dynamic climate is creating a framework to take many different pieces of past and future data from a variety of sources and merge them together in a single system. GIS creates a new framework for studying global climate change by allowing users to inventory and display large, complex spatial data sets. 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). Applications of scientific principles such as GIS and Remote Sensing equipped with GPS in detecting climatic variation over going in the world today both in developed and developing countries. Epidemiological studies also possible by integrating of spatial data with malaria as attribute data (Cracknel, 2001).

3. STUDY AREA

3.1Astronomical location

The study area is found between 7^{0}43’25’’N-9^{0}11’01’’N latitude and 38^{0}43’07” E-40^{0}5’29’’E longitude with the total area of 7758.3 km^{2} shown in Figure 3.1. The study area encompasses four ecological zones that are found in the country. The altitude ranges from lowest and the driest point found in the Fentalle lowland to the highest alpine of Chilalo Mountain found in Arsi zone.

The approach of this study is Meso- climatological that covers a little bit wide area since climate has no administrative boundary and difficult to analyze changes only by limited climate data sources acquired from limited stations. The area is selected due to its dynamism and it is believed to represent the climate change of the whole country since it contains all climate zones found in Ethiopia. Figure 3.1 shows map of study area.

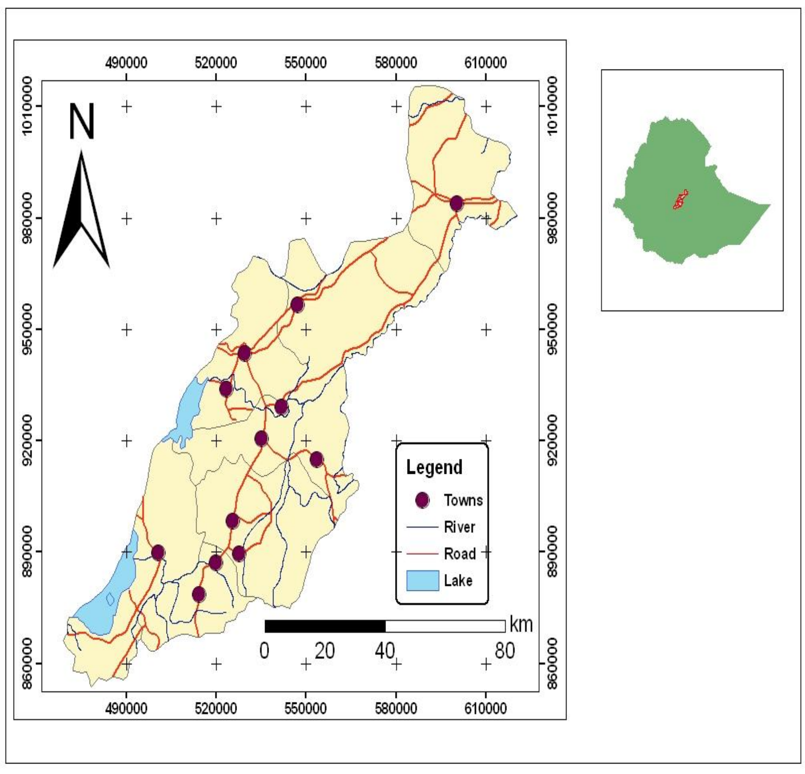


Figure 3.1: Study area map

The false color satellite image of the study area from which land use land cover classes derived is shown in Figure 3.2 with a band combination of 4, 3, 2.

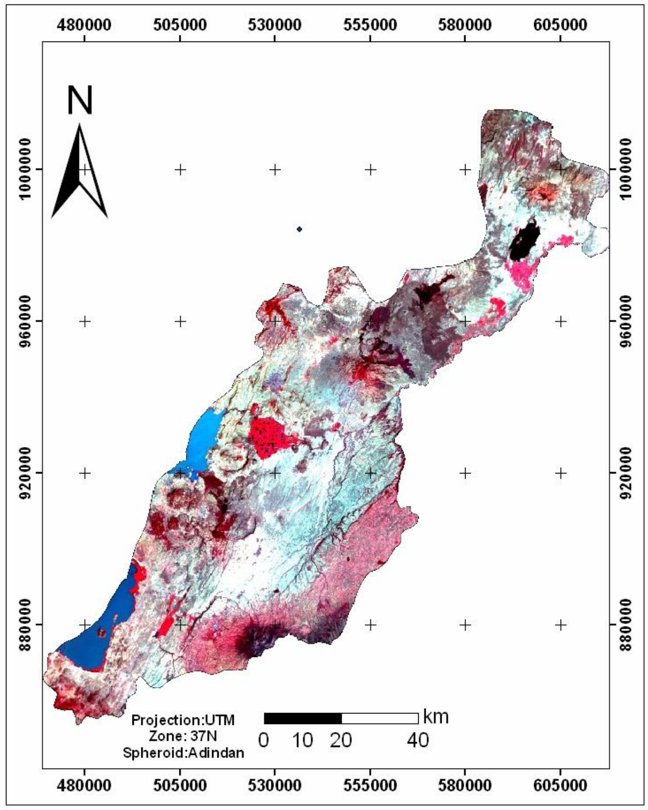


Figure 3.2: ETM+ False Color Composite satellite image (2009)

3.2 Physical characteristics

3.2.1Topography

The study area falls within four ecological zones based on elevation and rain fall using SRTM. These include:

Wurch: Elevation above 3000 meters.

Dega: (Cool, humid, highlands): elevation from 2500-3000 meters.

Weina Dega: (Temperate, cool sub-humid, highlands): Areas between 1500 to 2300 meters, where annual rainfall ranges from 800-1200-mm.

Kolla: (Warm, semi-arid lowlands): Areas below 1500 meters with annual rainfall ranges from 508-800 mm. . The areas fall within these for ecological zones are shown in figure 3.3.

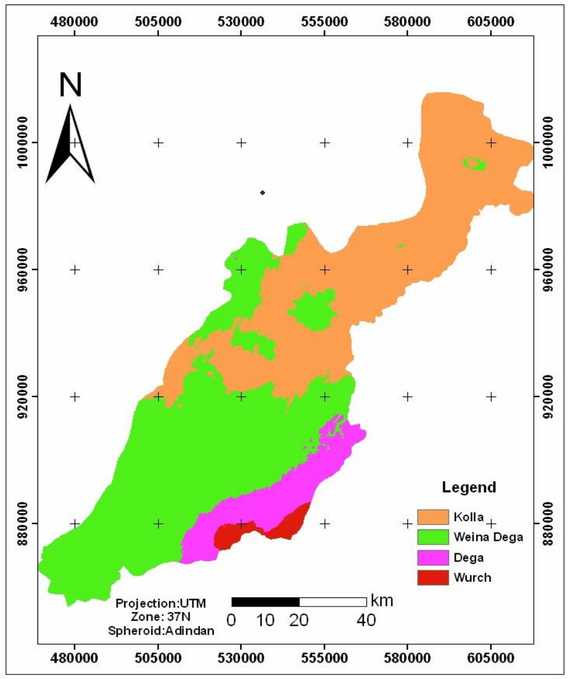


Figure 3.3: Climate region map

Mountains and water bodies

Mount Chilalo is the highest point in the study area with an elevation of 4145 m above sea level.The major rivers in the study area include Awash, Keleta, Kulmsa, Gonde, Dosha and Walkessa. Awash is the most utilized river in the study area. The largest rift valley lake found in the study area is part of Lake Zway This lake is the most northerly of the Main Ethiopian Rift Valley lakes, and is fed principally (Dagnachew et al, 2003) by rivers draining the southeastern and northwestern plateau and escarpments. The largest artificial lake in Ethiopia, koka is also found in the study area. Lake Beseka that is found in Fentalle woreda is also enclosed in the study area.

3.2.2 Climate and vegetation

All ecological climate system is prevailed within the study area that ranges from semi-arid lowlands of Fentalle to Wurch Zone of Chilalo Mountain. The vegetation characteristics of the area are also highly associated with the topography of the region. The rain fall ranges from 543mm in Metehara to 1300mm in Assela and mean temperature of the study area ranges from

14^0C in Asella to 25^0C in Metehara on average. The long rainy season in the summer (June–September; summer monsoon rainfall, locally known as 'kiremt') is primarily controlled by the seasonal migration of the Inter Tropical Convergence Zone (ITCZ) which lies to the North of Ethiopia.

Quoting Makin et al (1997) and Mesfin (1972) the Ethiopian technical report written by Jurg krauer in 1988 stated that average wind speed in the rift valley amounts 1.19m/s and the average annual wind speed all over the country completely vary. Highlands flanking the Rift Valley intercept most of the monsoonal rainfall in the region, resulting in a strong moisture deficit in the rift floor in general and near the lakes in particular. The pattern of the precipitation in the rift floor is more of stormy type with relatively high intensity (up to 100 mm/hr) compared to the highlands with only 60–70 mm/hr (Makin, 1997)

3.2.3 Geology and Soil

The geological map of Ethiopia prepared in 1996 by institute of geological survey of ethiopia indicates that the south western parts of the study area is covered by alluvial and lacustrine deposit (Q), and Plateau basalt (Qb). The central parts of the study area is covered by transitional and sub alkaline basalt(PNa), rhyolitic Volcanic centers(Qr), and Dino formation(Qd).Other rocks include Alkaline Basalt(Nb),Chilalo formation(Nc) that consists trachite, trachy basalt, peralkaline and ryholite, undifferentiated alluvial, lacustrine and beach sediments(Qh),ryholitic volcanic centers(Qr) consisting, obsidian pitchstone, pumice, ignimbrite, tuff, subordinate and Nazreth series(Nn)that consists ignimbrite, unwelded tuff, ash flows, domes and trachite rocks as shown in Figure 3.4

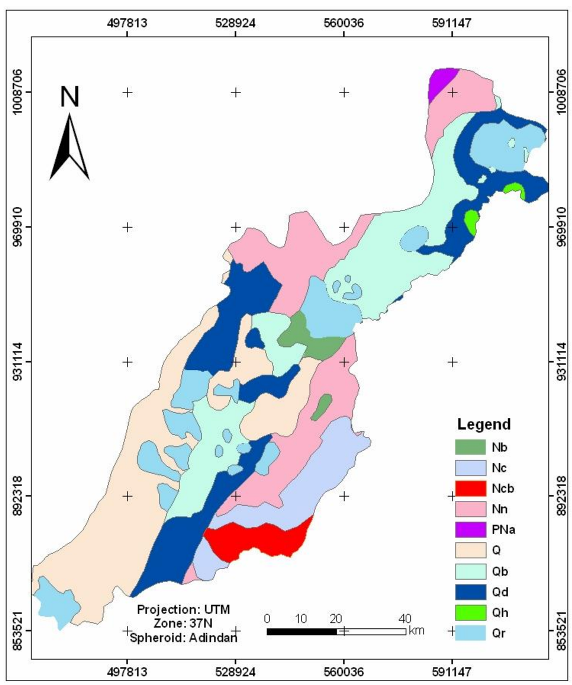


Figure 3.4: Geology map
Source: Geological Survey of Ethiopia (1996)

The FAO classification of 1997of the soils in my study area indicates that large part of the area is covered by andosols and leptosols. Luvisols are also confined in the mountainous region of study area. Figure 3.5 shows soil classification by FAO in 1997.

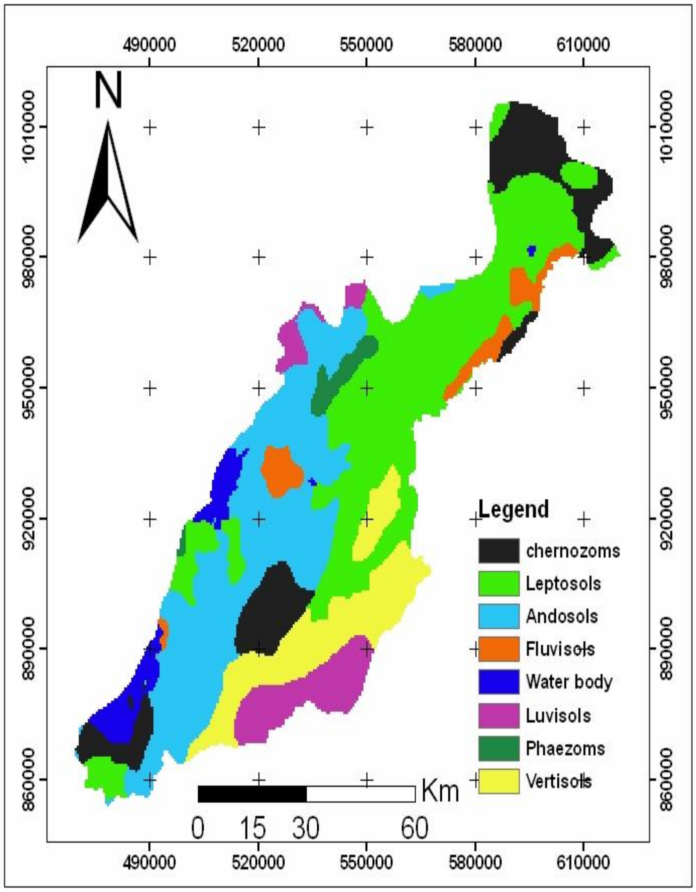


Figure 3.5: Soil map

Source: FAO (1997)

3.3 Population and Economy

According to the census of 2007 the population number is 1,420,900 with average population density of 197 per km^2. The highest population density is in Adama about 346 persons per km^2 and least is for Fentalle that is 77 persons per km^2 (CSA, 2007). In 2005 population density ranges from 74.7 per km^2 in Fentalle to 419 persons per km^2 in Adama district The largest groups of population in the study area earn their lives from agriculture that include both crop farming and livestock rearing. Some government owned largest industries such as Asella malt factory, Wonji and Metehara Sugar factories and Awash Aluminum production industry and other factories in Adama town are among the majors.

4. MATERIALS AND METHODS

4.1 Data Type and Source

Some primary data sources from field observation and with the basic gauging and meteorological data, much of secondary data resources including published and unpublished materials, books, journals, articles, reports, and electronic web sites, which are written on the subject matter of this study, were collected. Photographing, mapping, and graphing are incorporated as supplement techniques

4.1.1Meteorological Station Data

This study depends on data obtained from Meteorological station. This consists a climatic elements record for 35 years. There are about 22 climate stations used to calculate climate change both from nearby stations (Table 3) of the study area and within the study area (Table 2).Nine nearby stations are used in interpolation purpose in order to convert the point data into continuous surfaces and to make the result more reliable(Figure 4.1)

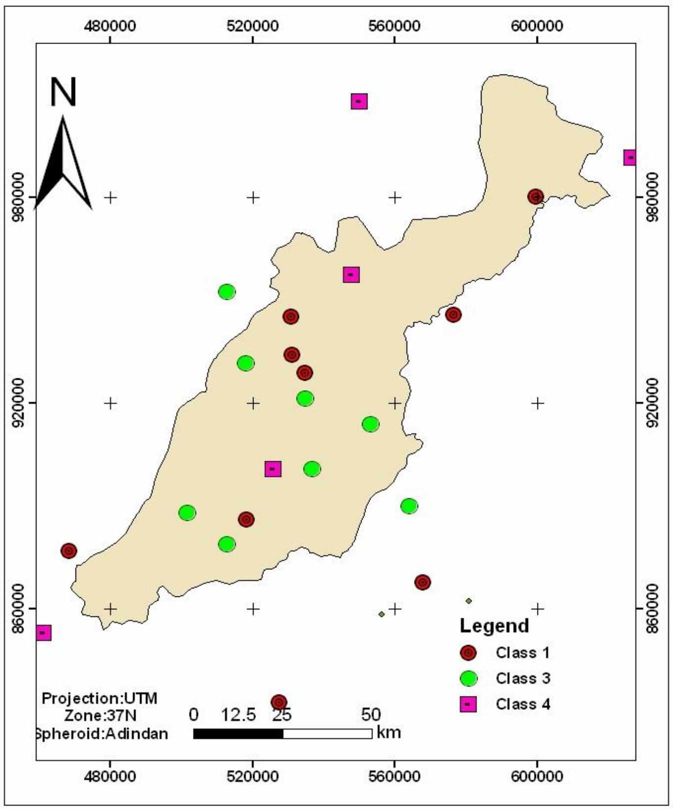


Figure 4.1: Meteorological stations distribution map

There are three meteorological classes used in the study

A.Class1 (Synoptic): These are station at which meteorological observations are made for the purposes of synoptic meteorology.

B. Class 3(0rdinary): These are stations at which only three meteorological elements are observed, i.e. maximum air temperature of the day, minimum air temperature of the day and total rainfall amount in 24 hours.

C. Class 4. (Rainfall recording) records only rain fall amount.

Table 2: Meteorological stations within the study area

Station	Latitude	Longitude	Year opened	Elevation	Class
Etheya	8^o09'	39^o 14'	1975	2060	3
Huruta	7^o 56'	38^o 43'	1968	1640	1
Nazreth	8^o 33'	39^o17	1953'	1622	1
Metehara	8^o 34'	39^o 40'	1979	1250	3
Melkassa	8^o 24'	39^o 19'	1964	1540	1
Wonji	8^o 29'	39^o18'	1951	1540	1
Welenciti	8^o 40'	39^o 26'	1966	1450	4
Ogolcho	8^o 04'	39^o 02'	1964	1760	3
Dhera	8^o 20'	39^o 19'	1976		3
Sire	7^o 13'	38^o 58'	1959	2390	3
Koka Dam	8^o 25'	39^o 10'	1948	1595	1
kulumsa	8^o03'	39^o08'	1966	2200	1
Asella	7^o 57'	39^o 08'	1965	2350	3

Source: NMSA, Compiled by researcher

The climatic elements used are monthly maximum, monthly minimum temperature and monthly mean temperature, monthly record of precipitation, mean monthly relative humidity and mean monthly record of wind speed. However for the following major reasons temperature and rainfall records are extensively used in interpretation climate change.

A) They used for any significant change in obtaining climatological evidence(ICSSR,1983)

B) They are the most popular element in climate change study all over the world(GriffS.J, 1976)

C) The only elements with long time records in the station.

Table 3: Neighboring Meteorological stations used for interpolation

Station	Year opened	Altitude(m)	Class	latitude	longitude
Ziway	1968	1640	1	7^o56''	38^o43'
Dixis	1985	2680	3	8^o03	39^o35'
Modjo	1963	1870	3	8^o37''	39^o07'
Bokoji	1971	2810	1	7^o32'	9^o15'
Koremesh	1987		4	9^o09’	39^o 30
Merti	1977	1250	1	8^o34'	39^o40'
Awash Melka	1987	916	4	8^o59	40^o 09
Bulbula	1967	1700	4	7^o43'	38^o43'
Arsi Robe	1989	2400	1	7^o 51	39^o 37

Source: NMSA, Compiled by researcher

4.1.2 River Run off and Discharge Data

The 25 years river discharges and runoff data for the major rivers found in the study area is acquired from ministry of water resource. Acquiring of the data aims to associate river discharge and runoff with climate change and analyze the result. The major rivers for the study area with discharge records are River Ketar and River keleta. The river discharge data and monthly runoff record for this area is used. The gauge station at Abura is used for Ketar. Keleta’s river discharge from Sire gauge Station.

1.1.3 Satellite Image data:

The satellite imageries used are that of NASA’s/USGS Land Sat that acquired in 1973 1986 and 2009 with 168 path and 54 and 55rows. These satellite images are used specifically for land use land cover change that especially emphasizes on forest cover change that can significant effect on climate variability and climate change. The spectral characteristics of the images are described in Table 4

Table 4: Spectral characteristics of satellite images

Sensor	Number of spectral bands	Spatial Resolution(m)	Date of acquisition
MSS	4	80	Jan 30,1973
TM	6	30	Jan 21,1986
ETM	7	30	Jan 2 ,2009

SRTM with 30m spatial resolution is also used. The SRTM provides the 3D view of the area, topographic characteristics of the study area.

4.1.4 Field Observations: **-**

The field trip was arranged for a week. The trip covers the main parts of the study area that extends from Fentalle lowland to Chilalo Mountain. During the field trip ground truths are collected through GPS, X and Y coordinates of climate stations was also coded and registered. Climatic situation of the study area and Land use land cover patterns are identified. Suspected vulnerable groups such as, malaria out patients', prevalence of natural hazard, flood condition and agricultural damage data are collected

4.1.5 Vulnerable group's Data: The vulnerable groups included agricultural hazard, river discharge and runoff decrement, Malaria prevalence and flood risk.

Agricultural hazard: recorded data of damaged land per hectare due to climate change since 1994 of the some districts of Arsi and East Shewa zone

River run off and discharges of Awash, Keleta and Ketar since 1980

Prevalence number of malaria cases and year to year area coverage of malaria since 1998.

4.2 Data sources

The researcher collected data from various organizations. The meteorological Agency of Ethiopia, Ministry of Water Resource, Ministry of Agriculture, Environmental Protection Authority of Ethiopia, CSA, Disaster Prevention and Preparedness Commission of East Shewa and Arsi zones, health office of Arsi and East Shewa zones are among the major organizations offered the data in any ways or another.

4.3 Land Cover Change Flow Model

Climate variability and change and land use land cover change are highly associated. Assuming the global causes of climate change as constant, local activities such as forest ecosystem deterioration has great influence on climate to vary and change. Carbon emission which is the major cause for climate change and sequestrations is highly controlled by availability of the forest. Even though the mathematical calculation of forest carbon is beyond the scope of this study, it is possible to predict forest cover change versus climate change in the study area. Flow model for land use is described in Figure 4.2

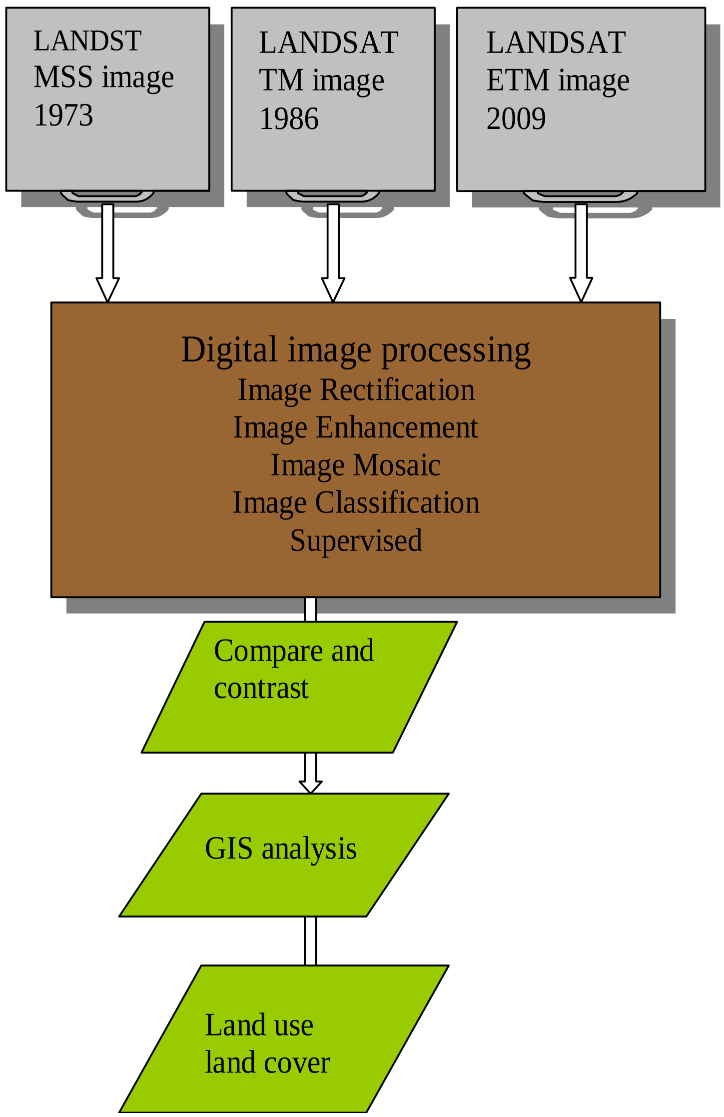


Figure 4.2: Land use land cover flow diagram

4.4 Methodology of Calculating Climate Variability Impact Index

The Methodology used to calculate the climate variability impact index follows the basic approach developed by (Anand and Sen, 1994) for the calculation of the human development index (HDI). To construct the vulnerability index for the districts the steps are described below.

Step 1: Calculate a dimension index of the each of the indicators for a district (X I) by using the formula

(Actual X I – Minimum X I) / (Maximum X I – Minimum X I)

Step 2: Calculate an average index for each of the selected sources of vulnerability viz.

This is done by taking a simple average of the indicators in each category.

Average Index i= [Indicator 1 +………. + Indicator J] / J

Step 3: Aggregate across all the sources of vulnerability by the following formula.

$$\text{Vulnerability Index} = [\sum_{i=1}^{n} (\text{Average Index}_i)^{\alpha}]^{1/\alpha} / n$$

Where,

J = Number of indicators in each source of vulnerability

n = Number of sources of vulnerability (in the present case n = α)

After the values of the index are calculated for all the districts a ranking of the various districts can be carried out to identify the most vulnerable districts in terms of the indicators used for measurement. This analysis will be repeated for different time periods1986-1996, and1997-2009 in order to see how the vulnerability profile has changed over the years for the districts in terms of the indicators used to measure the vulnerability. The general methodology flow chart is given in Figure 4.3.

4.5 Tools and Software's

There are various images processing software developed, which assist in calculating climate change analyses. These include ERIDAS IMAGINE9.2, ARCGIS9.3, Global mapper, 3DEM, EASY GPS and ENVI. Spatial and Geostatistical tools were used for data processing, analyzing and interpreting the result.

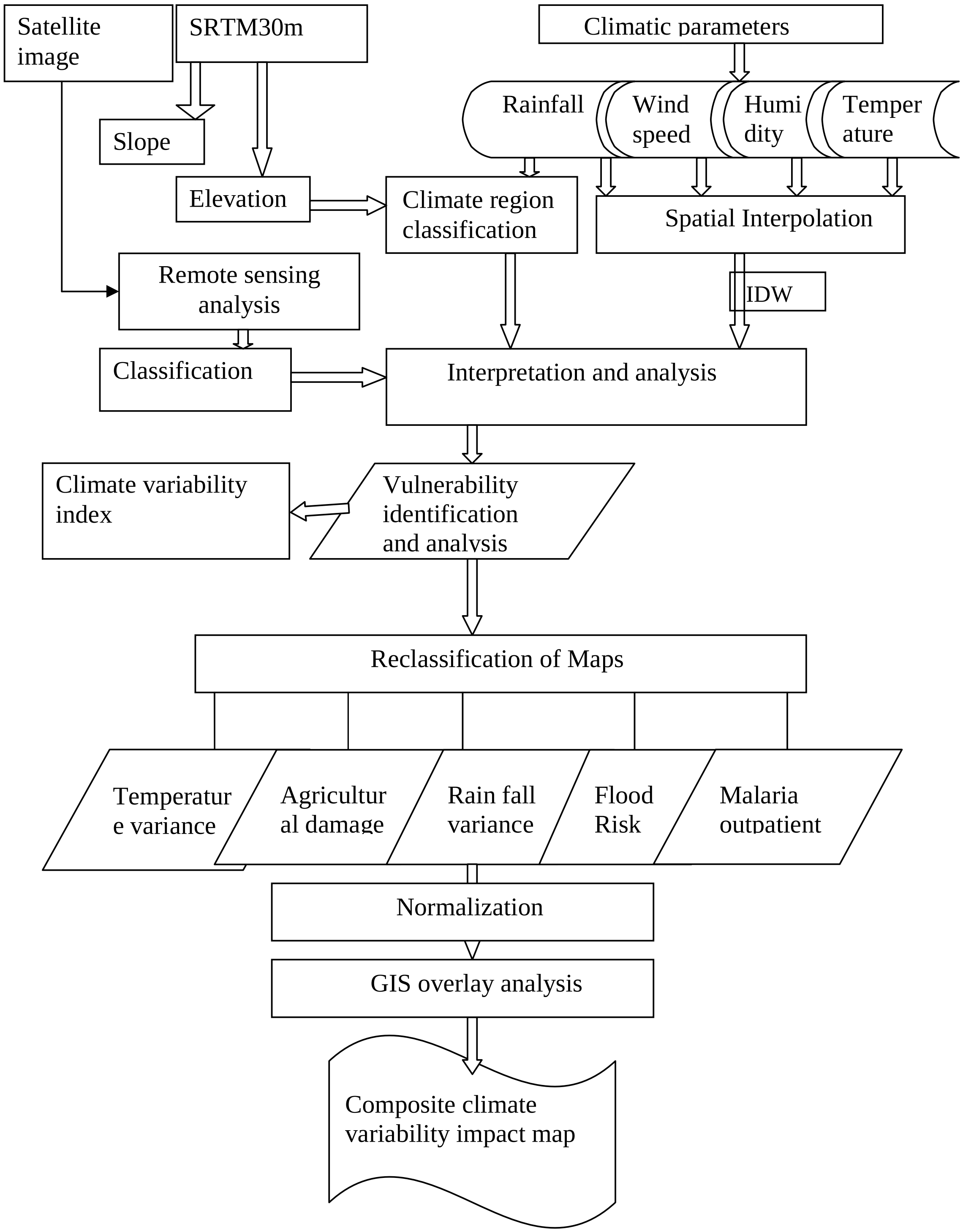


Figure 4.3: General Methodology flow diagram

5. INTERPRETATION AND ANALYSIS

5.1 Trends in Total Annual Rain Fall

Rain fall is the key indicator and element of climate system. It is preferred by various researchers to study climate variation and change for the reason that it is easily interpretable and illustrate what changes are being taking place in environment and easily understandable. In addition changes and variations succeeded rain fall variation have adverse influence on ecosystem. The annual total rain fall for highland stations between 1975 and 1986 was 930.628mm. The total annual between1987-1988 was 916.66mm. While the annual total of 1999-2009 for the station was 944.71mm (Table 5). The values are averaged from Sire, Asella, Huruta, Etheya and Kulumsa which have long record of rain fall. The averaged coefficient of variation for the years 1975 to 2009 was 10.59%.

Table 5: Twelve years averaged annual total rain fall for highland and lowland areas

Year	1975-1986	1987-1998	1999-2009
Highland Rain(mm)	947.25	932.25	960.99
Rift Valley Rain(mm)	826.3	877.96	859

The total annual rain fall averaged from 1975-1986 is 751 mm for rift valley regions under this study. The twelve year average 1987 to 1998 is 863 mm and the total average annual of 1999-2009 is 837 mm. The coefficient of variation for the rift valley stations in 1975 to 2009 was 17.07%. The total annual rain fall of the highland and rift valley is given in Figure 5.1

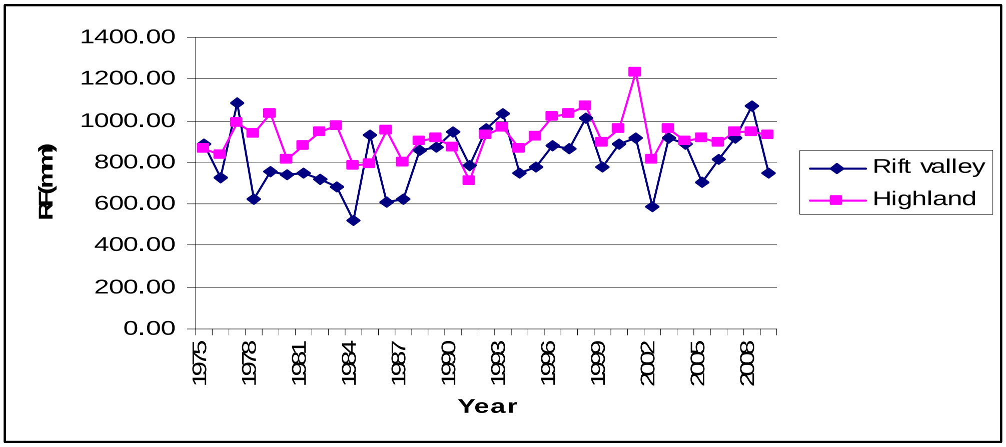


Figure 5.1: Total annual rain fall trends in Rift valley and highland areas

Bulk of rain fall intensity is registered in highland stations such as Asella that read 1130mm average rain fall in the last 35 years while least rainfall is registered in Fentalle lowland with a mean total value of 508mm.The values of all stations are interpolated and changed to the continuous surface in Arc GIS environment as described in Figure5.2

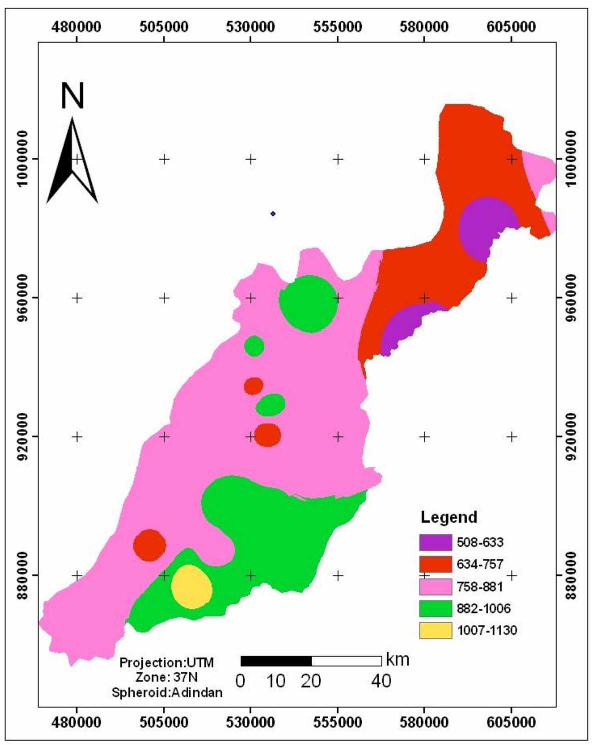


Figure 5.2: Reclassified Rain fall Map (1975-2009)

5.1.1 Trends in Coefficients of Variation

In highland areas coefficients of variation reaches peak in July when all farming activities are boomed. The average coefficient of variation in the last 35 years in July was 57.9%. CV is also highest in the months of December and January at which the harvesting time took place.

In lowland stations the highest CV value is 68% which recorded in September and the lowest is about 15% which is recoded in July (Table 6) Values from 8 stations are used for this analysis

Table 6: Highland and Rift valley regions Coefficient of Variation

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Highland (%)	35.7	36.9	21.1	16.4	20.5	20.3	57.9	15.7	15.4	19.6	41.1	28.8
Rift valley (%)	29.6	22.76	19.30	20.5	9.96	22.9	14.36	25.45	69.5	22.4	48.92	36.2

The monthly coefficient of variation is highest in rift valley than highland areas. In both areas March and April are the months with the lowest CV and September and November are the months with highest CV as indicated in Figure 5.3

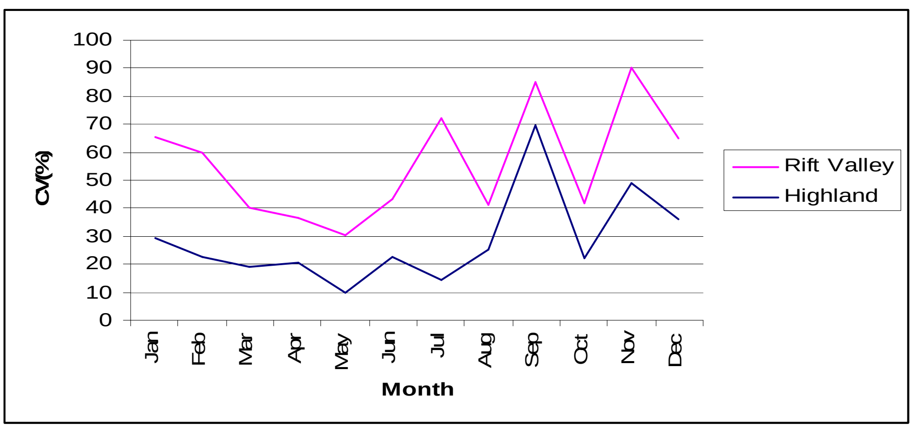


Figure 5.3: Coefficients of variability at highland and rift valley stations

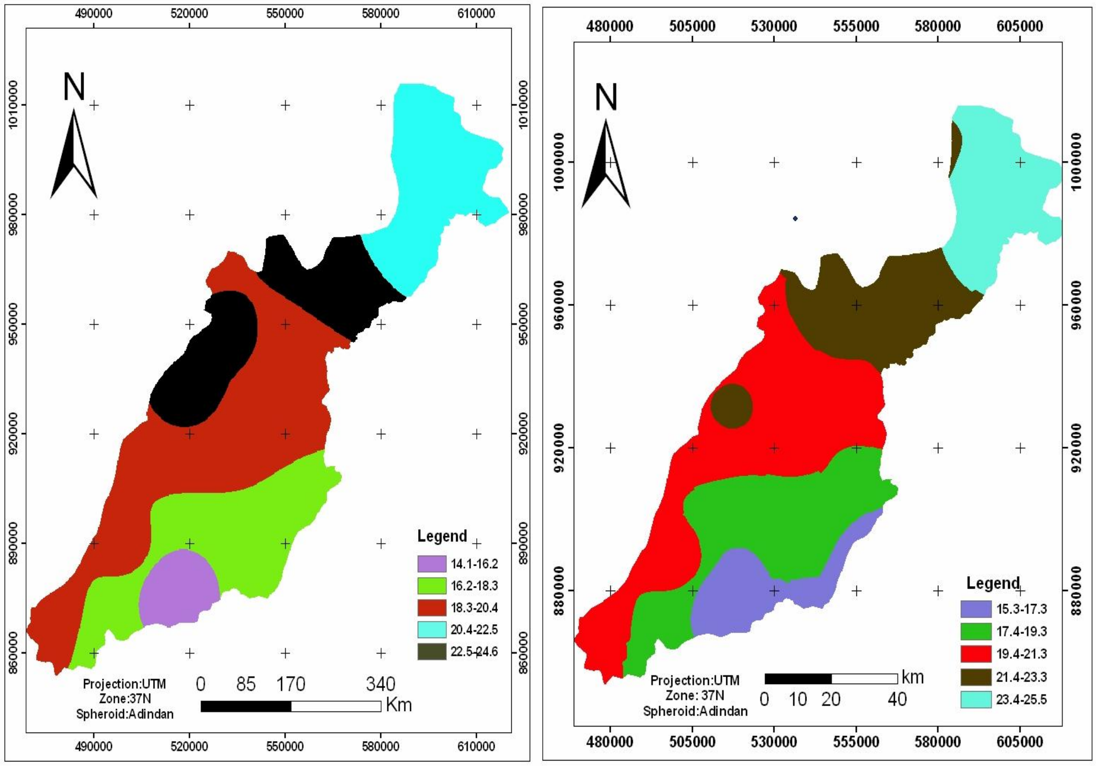
The summary of the survey conducted by UNEP in 1984 for both highland and rift valley stations is shown in the Table 7 .The values are summarized for the years since the establishment of the stations to the time of the technical paper conducted. The mean annual total rainfall summed from highland stations was about 1278mm and those of lowland was 734mm as an average.

Table 7: Pre 1983 Monthly rain fall distribution of the rift valley and highland stations

	Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	mean
Rift valley	Nazreth	10	21	43	60	39	78	193	217	100	24	13	6	804
	Metehara	19	33	32	33	37	38	121	134	44	28	19	5	543
	Ogolcho	12	47	44	85	41	72	132	118	89	32	11	6	689
	Koka Dam	17	25	52	52	38	66	224	201	102	27	13	13	830
	Wenji	9	23	42	59	47	78	192	192	97	48	9	8	804
Highland	Asella	30	55	102	107	116	147	238	243	171	61	20	6	1298
	Bokoji	50	59	76	93	115	130	234	215	120	53	44	14	1203
	Munessa	41	82	108	146	131	130	191	187	189	84	30	14	1333

5.2 Trends in Temperature

Temperature is a key indicator amongst whole climatic elements to show whether the terrestrial or water surfaces are getting hot or cool. It is due to observable changes recognized in mean temperature in the world that significant emphasis is given to the issue of climate change, as discussed in literature review part of this study. Mean temperature of the study area varies from 15.3 ^oC in highland areas to 25.5 ^oC in arid lowlands. Mean temperature value from 1975-1986 was 21.20 ^oC while mean temperature for the year 1987-1998 was 21.72 ^oC and the temperature between1999-2009 was 21.94 ^oC for places included in the study area. The reclassified mean annual temperature is depicted in the Figure 5.4. In 1975 the mean annual temperature was about 21.3 ^oC while it grows to 22.9 ^oC in 2009. Highland areas have an average annual temperature of 16.99 ^oC on average with 16.37^oC in 1975-1986, 17.36 ^oC in 1987-1998 and 17.26^oC in 1999-2009. The survey conducted by UNEP in 1984 for the stations since their establishment to 1984, shows that the highest mean temperature was 24.6^oC and the lowest is 14.1^oC in the study area as depicted in Figure 5.4a.



a) Mean temperature till 1984 b) Mean temperature (1975-2009)

Figure 5.4: Reclassified mean temperature (^{o}C) map

The highland regions experience sharp rise of temperature in 1995-2000 with the highest temperature record of 18.11 ^{o}C in 1999. The lowest temperature record is observed in 1976 with 15.50 ^{o}c. The mean annual temperature rise of both highland and rift valley is indicated in Figure 5.5.

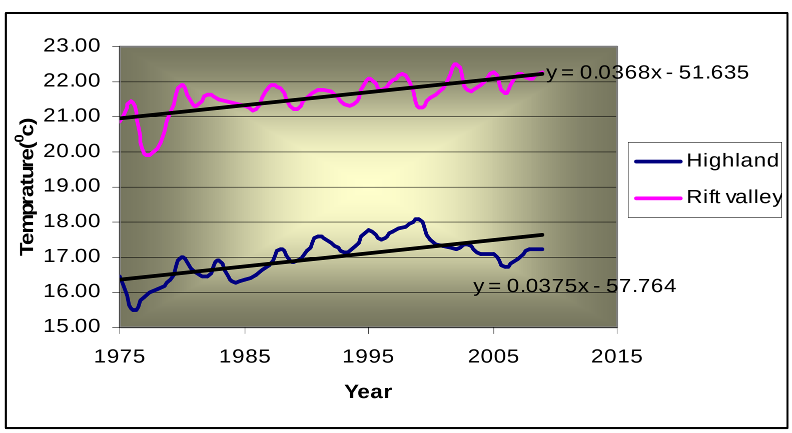


Figure 5.5: Mean temperature rise 1975-2009 over highland and rift valley area

The average maximum temperature within the past 35 years in highland areas was 23.2^{o}C and rift valley 30.08^{o}C. The average annual minimum temperature for highland area was 12.2^{o}C and that of lowland areas was about 14.6 ^{o}C.the maximum and minimum temperature trend in 1975-2009 is described in Table 8

Table 8: Maximum and minimum temperatures of highland stations and rift valley areas

Year	Rift Valley Min(^{o}C)	Highland Min(^{o}C)	Rift Valley Max(^{o}C)	Highland Max(^{o}C)
1975-1986	14.4	11.2	29.7	22.9
1987-1998	14.6	12.6	29.96	23.5
1999-2009	14.8	13	30.53	23.2

5.3 Trends in Wind Speed

Wind speed is the speed of wind, the movement of air or other gases in an atmosphere. It is a scalar quantity, the magnitude of the vector of motion. There is still scientific disagreement on whether wind speed is increased or decreased all over the world. In some parts of the world increasing trend is observed while in others decreasing or constant. The general assumption is that because global warming will reduce the temperature difference, or gradient, between the poles and the equator, mid latitude winds will also be reduced. The research described here suggests the issue is actually more complex. The next few decades under changing climate may see greater variation in seasonal and annual wind speeds, making long-term planning for wind energy purposes problematic (Wind power, 2009).

There is limited record of wind speed in the region. The highest record of wind speed prevailed in parts of rift Valley area is in the months of February and January with average wind speed of 3m/s and 3.25m/s respectively while the lowest wind speed is registered September with 1.67m/s on average. The wind speed reaches its maximum in 2000 and 2001. The average wind speed for the past 15 years in rift valley is 2.15m/s.

The average wind speed for the highland area is acquired only from kulumsa station which only has a record of wind speed since 1980. The average wind speed for this station is 2.25m/s. The highest wind speed is registered in the months of November and October with an average speed of 2.97m/s and 2.65 m/s respectively. The lowest wind speed is registered in September and August with average speed of 1.29m/s and 1.7m/s respectively. Temporal average wind speed variation of wind speed of rift valley and adjacent highland is given in Figure 5.6.

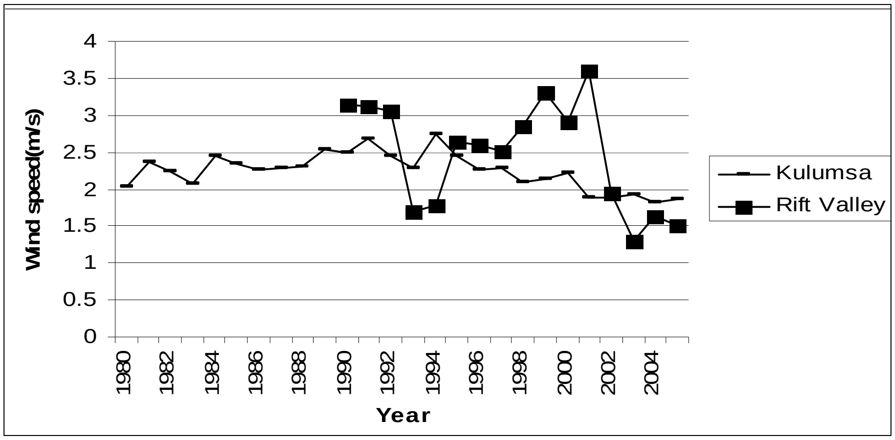


Figure 5.6: Temporal Average wind speed variation for rift valley and highland stations

5.4 Trends in Relative Humidity

Relative humidity is a term used to describe the amount of water vapor that exists in a gaseous mixture of air and water vapor. The relative humidity in the study area doesn't show significant change in lowlands. The Melkassa station has 56.56 mean RH as an average for the periods 1971-1999 the lowland areas have an average RH of 56.71% .The only record used in this research in highland area is that of Kulumsa with the record since 1980. The result shows that from 1980-1992 the average annual RH for the station is 64.76% and this value little decreased to 64.26% for the consecutive thirteen years till 2009.

The three times record per day shows that highest RH is recorded at 6 Local Sideral Time (LST) that reaches about 75% and lowest at 1800 Local Sideral Time about 45% for rift valley areas. There is insignificant variation for this area. Mean relative humidity value averaged from Melkassa, Kulumsa and Nazreth stations has shown in Figure 5.7

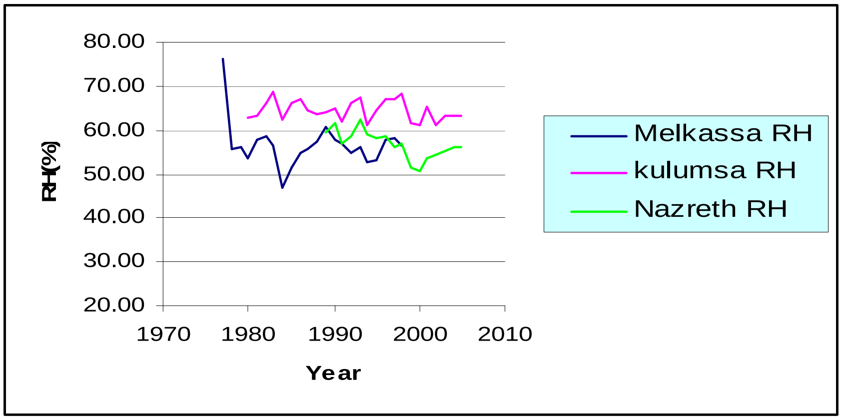


Figure 5.7: Relative humidity

Insufficient data is found on relative humidity comparison. Due to large missed spaces are available there is no interpolation used to generate other RH data based on the first one since the records are widely spaced. However for this case RH value of Nazreth as long record is available comparatively as depicted in Figure 5.8.

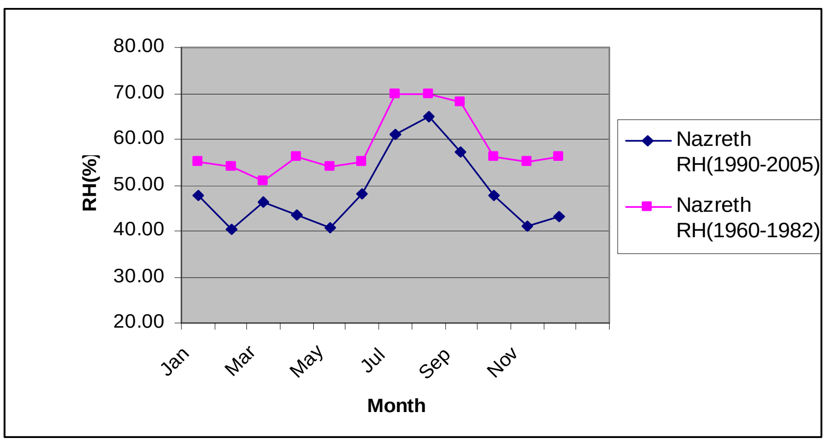


Figure 5.8: Relative Humidity Comparison

Other Parameters of Climate within the Study Area

Vapor pressure, sun shine hours and evapo transpiration are amongst rarely recorded in the study area unless derived. The mean annual vapor pressure in central part of rift valley is around 16mb with a sunshine hour of 70%. For highland areas the vapor pressure is 10.2mb and 61% sunshine hours as derived from Asella station. The potential evapo transpiration is about 1037mm for highlands and 1390 mm annually for rift valley stations. This value is as conducted by UNEP under the ministry of agriculture 1984.

5.5 Impact Analysis

5.5.1 Vulnerability index: Quantitative assessment of impact (vulnerability) is usually done by constructing a Vulnerability index .This index is based on several set of indicators that result in vulnerability of a region. It produces a single number, which can be used to compare different regions (ICRISAT, 2009).The formula to calculate vulnerability (impact) is developed by UNDP to illustrate human development index. Various researchers have also used this formula to calculate vulnerability index to climate change. Of all the value is normalized by the following formula

$$X_{ij} = \frac{x_{ij} - \text{Min}\{X_{ij}\}}{\text{Max}\{X_{ij}\} - \text{Min}\{X_{ij}\}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where X is the separated value in the distribution, Min X_{ij} is the minimum value in the distribution and Max X_{ij} is the maximum value of the mean of the distribution i is the district and j is number of indicators. The value of the normalized equation falls between 0 and 1. 1, with highest value and 0 with least vulnerable area for the indicators with positive relationship with climate change vulnerability. Unless if the indicators are assumed to be negative relation ship with vulnerability, the above formula will diverted to the following as described in equation 2

$$X_{ij} = \frac{\text{Max}\{x_{ij}\} - x_{ij}}{\text{Max}\{X_{ij}\} - \text{Min}\{X_{ij}\}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Once the normalized scores have been completed for entire selected indicators we use the simple average construct vulnerability index by adding all normalized scores

$$VI = \frac{\Sigma_j x_{ij} + \Sigma_j y_{ij.}}{K} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where VI is vulnerability index, i represent the district and j represents indicator and K is the total number of indicators.

5.6 Indicators of climate Variability Impacts

Indicator approach is used to identify climate variability impacts which quantifies vulnerability by selecting some indicators from the whole set of potential indicators and then systematically combine the selected indicators to show the levels of vulnerability.

5.6.1 Hydrologic Response

In order to revise the effect of climate change on hydrology the combined effect of temperature growth with constant regularized but highly variable rainfall result is used .The major rivers with gauge stations within my study area have been selected and analyzed. These are Keleta, and Ketar which drain most parts of the study area. Run off graph of the three rivers is given in Figure 5.9

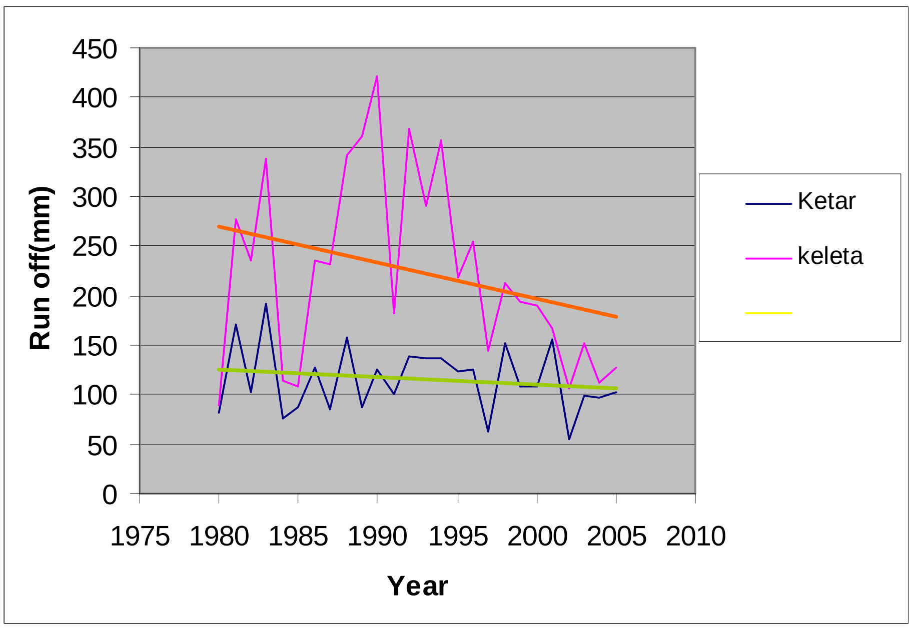


Figure 5.9: Temporal variation of river runoff

The 13 years average runoff for Ketar River in 1980-1992 was 117.3mm while the mean value decreased to 112.3mm in 1993-2005.Similarly the run off value for keleta was 254mm in 1980-1992 and this value is deteriorated to 194mm in 1993-2005.keleta, which it's gauge station is located in highlands shows significant reduction than ketar which drain more semi arid regions of central rift valley.

Correlation between Runoff, Precipitation and Mean Temperature Change

In order to understand the silent reduction of run off in all gauging stations significantly since 1993 despite rain fall is not reduced it is better to see the correlation between constants i.e. Run off with variables temperature values and rain fall record. Typical correlation type for this relation ship is partial correlation that shows the influence of three correlate variables by controlling the third variable to know the degree of relationship of the rest of the two variables. Let x, y and z are the variables represent runoff, precipitation and temperature respectively. Using the following partial correlation coefficient formula; their relation derived as

$$\rho_{XY\cdot Z} = \frac{\rho_{XY} - \rho_{XZ}\rho_{YZ}}{\sqrt{1-\rho_{XZ}^2}\sqrt{1-\rho_{YZ}^2}}.$$

$$\text{Where Pxy} = \frac{\text{Cov(X, Y)}}{\delta x \, \delta y}$$

Cov(X, Y) is covariance of runoff and precipitation in this case and δx δy are their standard deviations .p is partial correlation between run off (X) and temperature(Y) when the work (effect) of rain fall (Z) is controlled. The Result of partial correlation for the years 1980-2005 for River Ketar is 0.177682. However prior to controlling the work of rain fall, the relation in moment correlation coefficient is 0.031498. This indicates temperature has significant influence on river runoff. Similarly the relation between runoff and temperature when the work of rain is controlled is -0.01848. Prior to the control of the work of rainfall the value is -0.03559.

The product moment correlation coefficient between run off and temperature was -0.03559 and this number rise to -0.01848 in partial correlation coefficient when the work of rainfall is controlled. Similarly the Pearson moment correlation coefficient between runoff and rain fall is 0.177477. However this number when the work of temperature is controlled didn’t show considerable change. It shows the partial correlation coefficient value of 0.177682 with only insignificant increment. This indicates that within the past 25 years the relation between temperature and rain fall is high even though rain fall is not decreased. This in turn increases the evaporation and dryness within the basin.

5.6.2 Agricultural damage

The agricultural damage designates the adverse damages occurred on agricultural land within the study area due to excess amount of rain fall or rain shortage or other effects of climate related causes. For these purpose the longest record of agricultural damage where their rate of damage is on average greater than 90% is obtained from zonal DPPC office for each districts since 1994(Table 9)

Table 9: Agricultural damage in hectare in the districts within the study area

Year	Dodota-sire(Hec)	Hetosa(Hec)	Lode-Hetosa(Hec)	Z.dugda(Hec)	Tiyo(Hec)
1994	11,785	1804	4380	5,995	627
1995	8,792	1327	0	9478	0
1996	3904	NA	NA	NA	378
1997	2,463	4000	2463	2463	0
1998	4,016	3716	0	4450	0
1999	17,145	1946	0	44,906	582
2000	14,218	0	0	4331	0
2001	3,927	0	0	5444	0
2002	4,880	1815	0	1853	54
2003	40,826	5405	1365	22,280	1251
2004	1,044	964	0	6689	1140
2005	1,339	5810	1357	5380	0
2006	18,690	960	0	16,496	1355
2008	2,921	1209	0	NA	NA
2010	20,948	4143	2832	42,404	1306
Averaged Damage(Hect)	**10,928**	**2,364**	**886**	**13,244**	**486**
Averaged cultivated land	**46,990**	**32,911**	**21,274**	**31,799**	**25,058**
% of damage	**23.3**	**7.2**	**4.2**	**41.6**	**1.9**

Source: Arsi Zone DPPC Office (2010)

The aggregated damage is increasing from time to time and in certain years extreme damage occurred. In 2004 and 2010 extreme damage is recorded as described in Figure 5.10

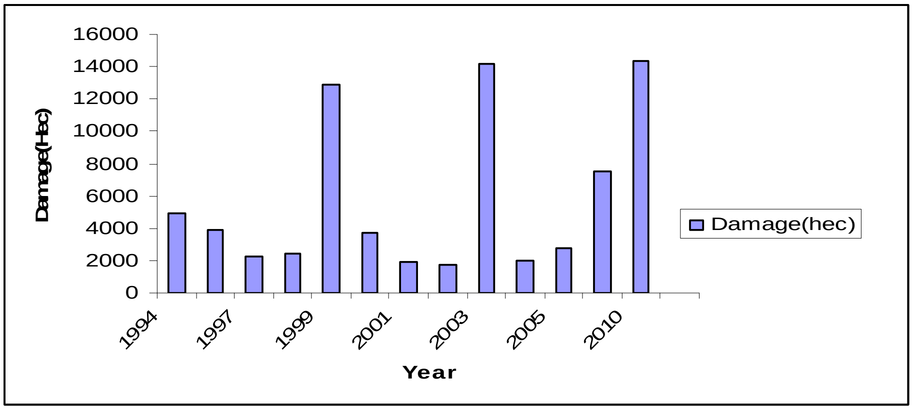


Figure 5.10: Averaged agricultural damage trend for whole districts

In districts found in rift valley rain shortage is occurred frequently and highlands the rain shortage is low. Districts in the rift valley have severed from rain fall shortage than highlands.

5.6.3 Malaria Out patient Density: Climate change and malaria has a great relation today as the temperature of the earth rises and reproduction rate of mosquito species that transmit malaria is increasing. Some highland districts that were malaria free some days are currently getting malaria even the rate of malaria transmission is getting decreased due to effective malaria controlling system in the country. Since complete long record data of outpatients within each district is not found the number explains only that of 3 years the 2007, 2008 and 2009(Table 10). Some highland districts are thought as malaria free before some years back.

Table 10: Only clinical malaria cases 2007-2009

District	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Tiyo	49	66	143	42	30	38	68	65	89	140	36	124
Z-Dugda	1988	2165	1754	900	1923	2122	2507	2721	1739	3445	3820	1887
Sire	31	49	188	79	463	96	0	132	143	180	186	91
Dodota	330	242	309	209	238	1278	254	221	825	1788	973	684
Hetosa	45	55	437	43	54	38	27	51	32	63	58	54
Fentalle	218	136	58	32	336	164	329	186	457	411	542	650
Adama	153	224	204	335	205	170	325	319	557	828	696	386
Boset	206	439	329	23	39	40	45	34	92	189	79	67

Source: Health office of Arsi and East Shewa Zones(2010)

These outpatients' data are normalized to be used in GIS overlay analysis which later used to be taken as one parameter in composite climate change vulnerability map. Most highlands have a normalized value less than 0.343 and the condition is worse for rift valley areas with a normalized value greater than 0.75.

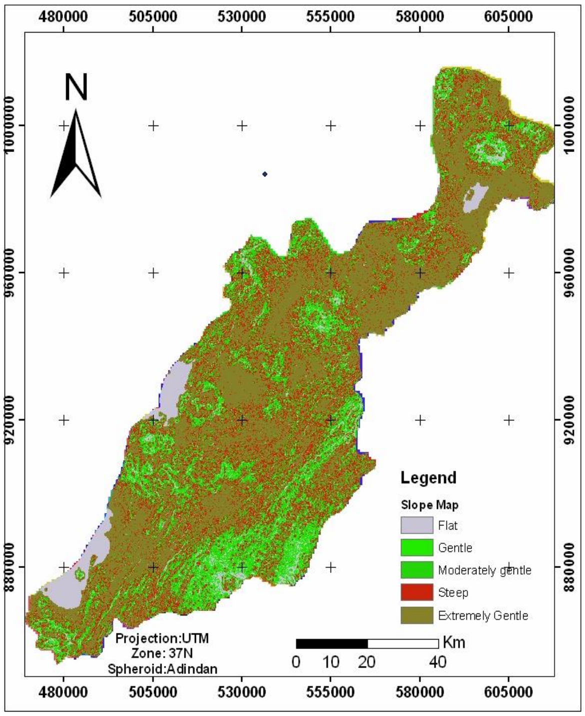
5.6.4 Flood Risk:

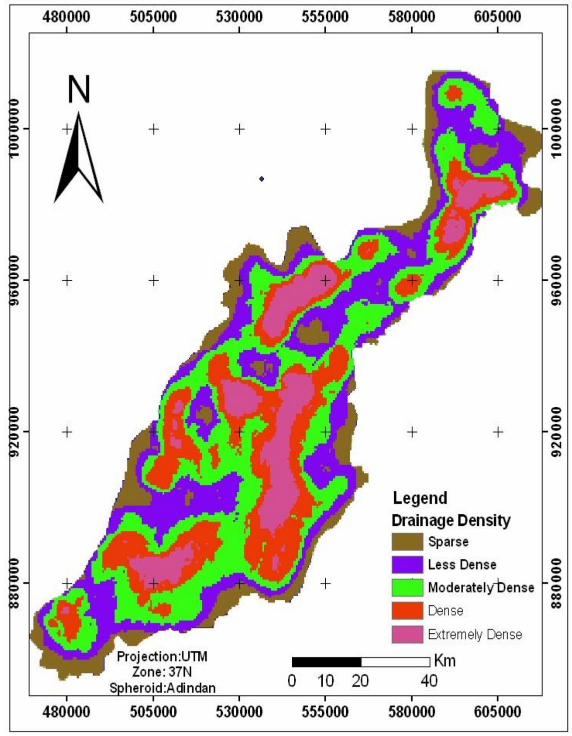
Due to rain fall is expected to increase in east Africa specifically in central Ethiopia flood risk map has to be considered as an indicator of vulnerability to climate change. This is later used to produce composite climate variability impact map of the study area. Flood risk map is prepared using multi criteria evaluation with the parameters consisting drainage density, slope, population density and land use land cover. Drainage density is prepare from 30m SRTM applying the procedures such as filling the gaps, calculating flow accumulation and flow direction and preparing stream order and others. Factors and their weight is given in Table 11

Table 11: Factors Used in Multi Criteria Evaluation to produce Flood Risk Map

Factors	Weight	Sub factors	Ranking
Drainage density Km/km^2	0.2653	12-58 58.1-82 82.1-101 101.1-121 121.1.4-173	5 4 3 2 1
Slope(Degree)	0.5083	0-3.5 3.5-8.5 8.5-15 15-25 25-75	1 2 3 4 5
Population density(pers/km^2)	0.1512	83.2 96.96 118.24 160.05 202.7 323.8 439.3	5 5 4 3 2 1 1
Land use land cover	0.0752	Built up area Farm land Bare land Bushes and shrubs Open forest Dense forest Water bodies	1 2 3 4 5 5 5
Consistency Ratio	0.07		

Weighted overlay results from multi criteria evaluation tells as that plain areas with high population density and high drainage density has a risk to get flood as described in Figure 5.11. The highland areas with steep slope are less risky to flood than the rift valley regions.





a) Slope map

b) Drainage density

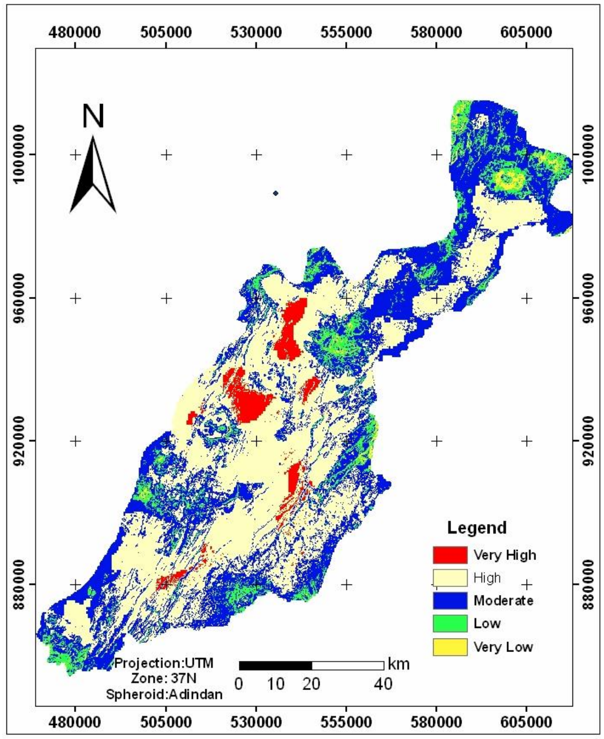


Figure 5.11: Flood risk map

The final method to prepare composite climate change consists all the above mentioned parameters. In the weighted overlay analysis all normalized maps have been used. These five parameters are normalized rain fall variance, normalized temperature variance, malaria out patient's density, agricultural land damage and flood risk areas. The Pearson matrix for parameters is described in Figure 5.12

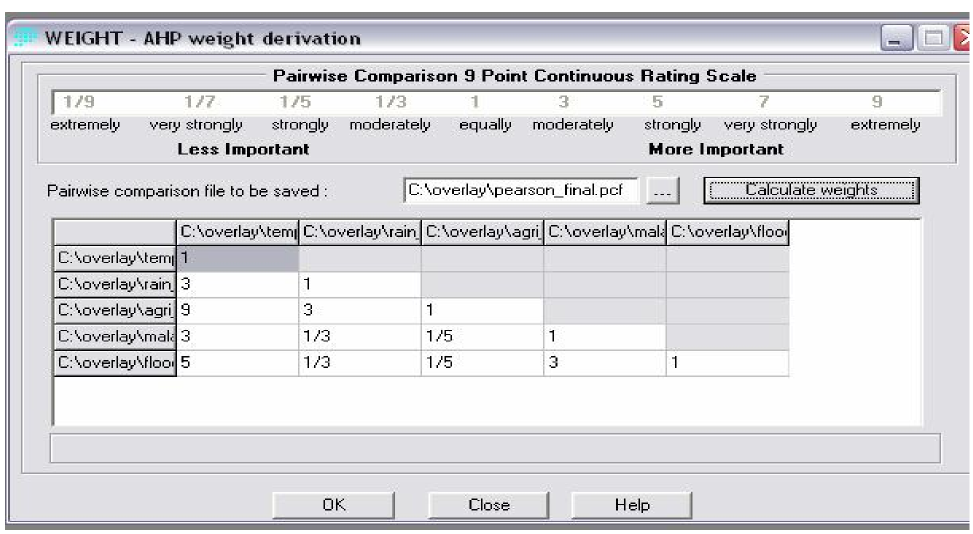


Figure 5.12: Pearson matrix for final vulnerability mapping

5.7 Land use land cover change

Three Land Sat satellite images namely 1973 MSS, 1986 TM and 2009 ETM+ with spectral resolution of 60, 30 and 30m are analyzed to calculate land cover change persisting over the study area. Six major land use classes are identified. These are farmland, built up areas, open forest, dense forest, shrub land, bare land and water bodies (Figure 5.13). A result from change statistics matrices is given in Table 12.

Table 12: 1973 and 1986 land use Comparison (km2)

	Open Forest	Bare land	Built-up area	Bush land	Dense Forest	Water body	Farmland
1973	888.81	1719.07	131.87	597.86	305.21	261.83	3691.87
1986	488.73	1120.75	568.99	575.68	241.19	302.14	4293.48
Change	-400.08	-598.32	437.12	-22.18	-64.02	40.31	601.61

Compared to 1973 Forests and bare lands decreased dramatically in 1986. In contrast to this farmlands and settlements are increased. Figure 5.13 shows the land use land cover change of 1973 and 1986 that derived from MSS of 1973 and TM of 1986.

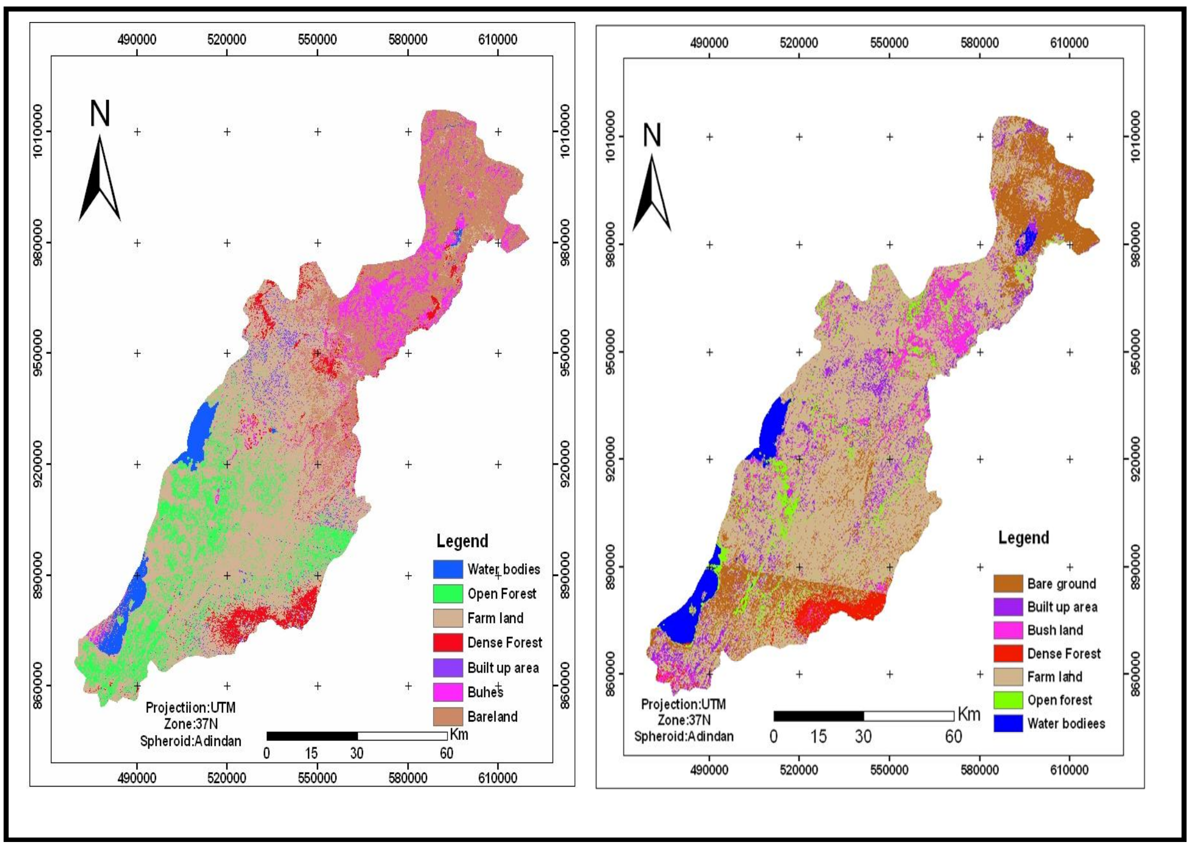


Figure 5.13: Land use land cover map 1973(left) and 1986(right)

Compared to 1986 here again in 2009, forests and shrub lands are decreased in similar pattern whereas farm land and settlements are increased. In 2009 the rate of increment is higher for settlements than any other land use even though the amount of land cover is high for farm lands. This is resulted from high population and expansion of modern industries. Compared to 1986, open forest is decreased by 888 km^2 and bare lands by 1719km^2.This is a tremendous and serious change taken place in the study area than any other land use classes. The changes between 1986-2009 is given in the Table 13

Table 13: 1986 and 2009 land use comparison (km2)

1986-2009	Water bodies	Built up A area	Farmland	Open forest	Bare land	Dense Forest	Bush land
Change	14.62	58.98	1366.18	-252.04	-949.15	-52.9	-186.8

The condition is worse for forest ecosystem than any other land cover. The analyzed Land Sat satellite image in 2009 shows that only small coverage of dense forests is found in pocket and top of the mountains in the study area as indicated in Figure 5.14.

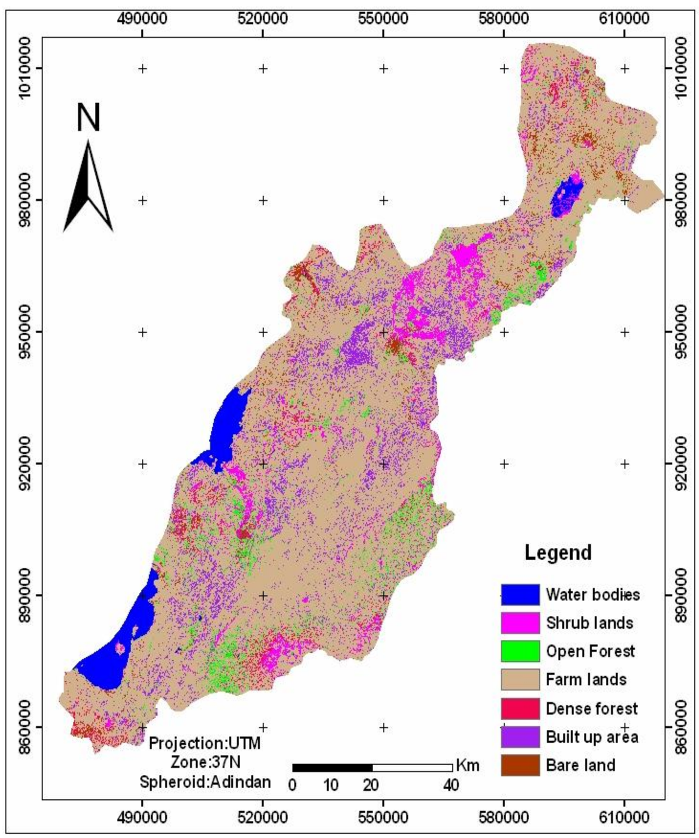


Figure 5.14: Land use land cover map (2009)

6. RESULTS AND DISCUSSION

6.1 Results from climate parameters

Rainfall

The rain fall intensity is not decreased for the past 35 years in study area both in highlands and low lands even though a highly prevailed annual and monthly variation is observed. The total average of annual rainfall of highland stations in 1975- 2009 was 930.2 mm. The period where the highest intensity occurred varies. Since 1975 to 2009 there is no rain fall intensity decrement is observed. As compared to researches conducted by UNEP under ministry of agriculture in 1984 rain fall on highland areas of the study area shows insignificant rise and in rift valley the rain fall amount is little less than the current intensity. This gives additional evidence that rainfall intensity is not decreased in central Ethiopia almost for the past 50 years.

The coefficient of variation in highland area is occurred when agricultural activity is boomed up. The coefficient of variation for lowland stations registered the highest value in September which starts rising in August during summer season. Summer rain has great significance over life of Ethiopian farmers. Since the total economic activity is based on summer rain, the variations occurred in each moment which later leads to climate change can affect the maturity and development of crop stages. The rain starts to fall in the mid of August and fall constantly until 0 mm value is registered in November in almost all parts of my study area. In the areas where agricultural activity is practiced, crops are suffered from the results of variation because crops and other vegetables gets dry before they reach the age of maturity or might stops at their flowering date at the time of rain shortage.

Rain fall in highland areas are depicted as high annual variance than that of rift valley .The highest rain fall variance in mountainous and largest city with a normalized value greater than 0.187 is registered. In the normalized rain fall variance map (Figure 6.1), highest value indicates high variance and lowest value indicating low variance. The year to year rain fall variance for rift valley stations is low. However this does not specify rain fall sufficiency of rift valleys.

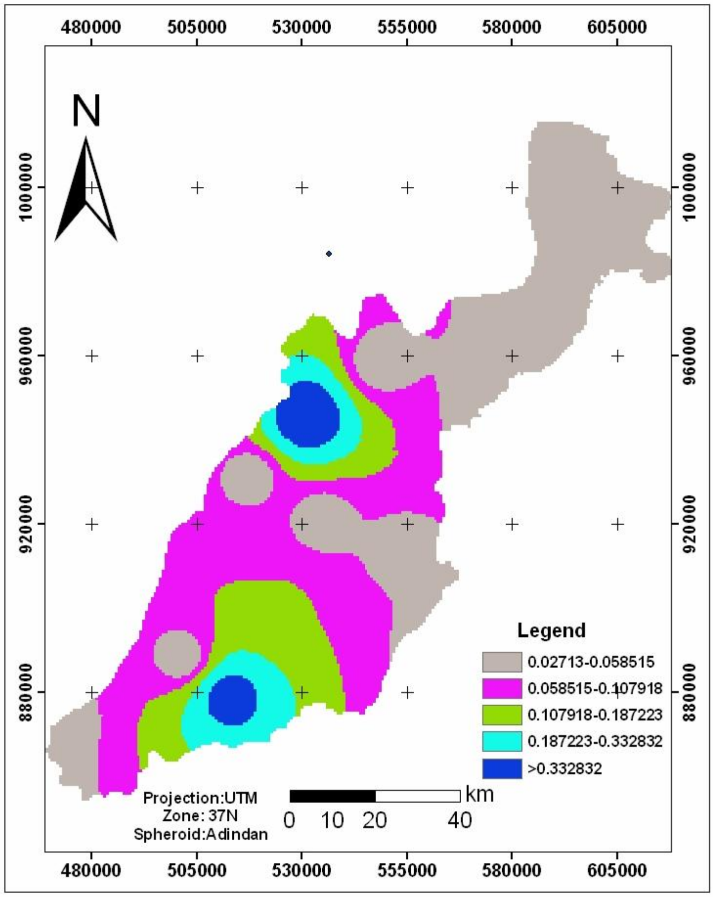


Figure 6.1: Normalized rain fall variance

Temperature

The surveys conducted in the study area points out that there is a sharp rise of temperature both in maximum and a minimum temperature values. When we observe the changes occurred in the rift valley area as aggregated from 8 meteorological stations the temperature is increasing highly even greater than predicted by IPCC. On average temperature is increasing by 0.37 ^{o}C in 12 years in rift valley parts included under this study and by 0.41^{o}C in highlands as compared to prior to 1975 .The normalized temperature variance tells as the highest variance is occurred in largest towns and highland areas than the hot semi-arid regions as indicated in Figure 6.2

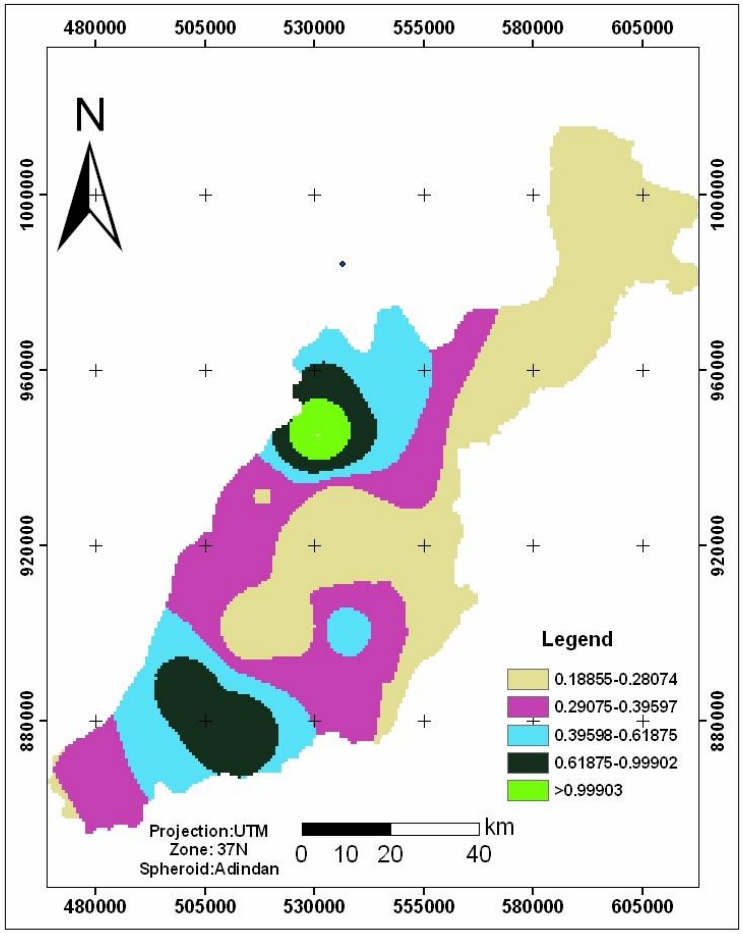


Figure 6.2: Normalized temperature variance

The important tool to understand temperature rise is using anomalies which are derived by subtracting mean from values of separate year for which the period of the study is covered. In this regard in rift valley areas before 1990 an anomaly value was less than zero for many years while the in the preceding years most stations have registered temperature anomalies greater than 0 in ^{o}C. Temperature anomalies has show tremendous rise after 1990 in a higher rate even as Compared to IPCCS prediction for central Ethiopia which is 0.9^{o}C-1.1^{o}C in 2030 as compared to 1961-1990.This Means that the temperature can increase fast than predicted. Figure 6.3 shows temperature anomalies for highland and rift valley.

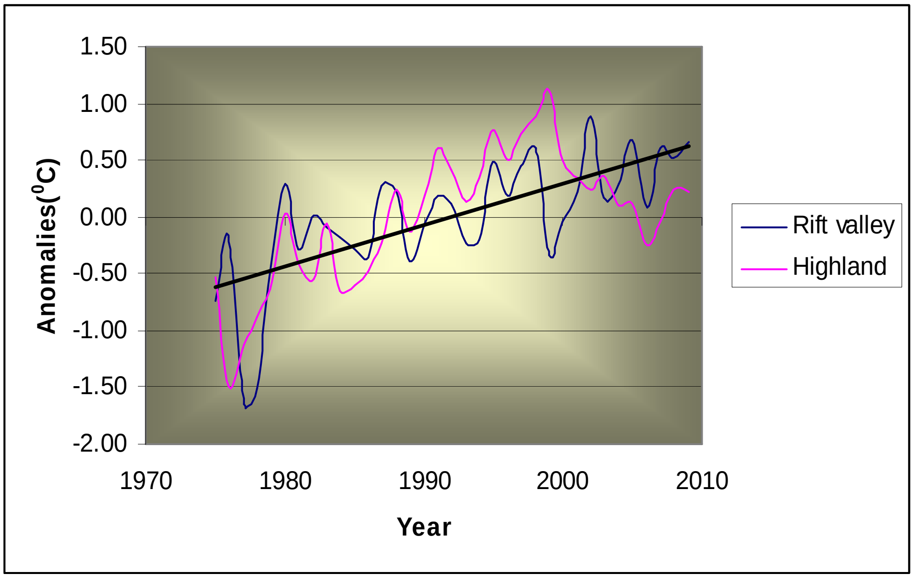


Figure 6.3: Temperature anomalies over rift valley and adjacent Highlands

Minimum temperature observed for highland stations as compared to 1975-1986, is increased by 1.8^{o}c in 1999-2009. In contrast to highland stations minimum temperature in rift valley stations shows insignificant rise of 0.2^{o}C in the same period. The maximum temperature for highland areas doesn't show significant rise however in the rift valley the amount of maximum temperature is still rising. In the rift valley maximum temperatures is increasing in alarming rate than minimum temperature while for highland stations minimum temperatures shows significant increment than maximum temperature. The range of temperature for lowland area is getting small as minimum temperature is rising faster than maximum temperature.

The other investigation is urban heat island which is occurring in the largest town in the study area. Urban heat island is significantly warmer condition of the town than its surrounding rural areas. For instance in Nazreth the Mean temperature is increased by 0.6^{o}C on average in 1999-2009 as compared to 1975-1986. This number is higher than the value which other rift valley stations in mean temperature is being increasing (0.37^{o}C). This condition is expected to increase in the future in a higher rate and expanded to fast growing towns as primary economic activity is decreased and secondary economic activity is boomed up. This increases the amount of carbon emissions which in turn expected to increase and trap heat wave. The condition is worsening in the future as temperature value increases faster.

There is no clear evidence whether wind speed trend decreases or increases in the study area, in some parts it decreased and in others not. Clear indication is not mentioned due to unavailability of wind speed data in most stations as rain fall and temperature. Wind speed and climate change have great correlation. The function of wind is higher especially in drier areas than highland areas as wind is the strong force of erosion in drier parts of the world. Relative Humidity is getting decreased over time. On average there is a 10% difference in the periods of 1960-1982 and 1990-2005 for Nazreth station. This emanates from temperature rise within the region since RH is highly dependent on temperature change.

6.2 Results from Vulnerability Analysis

Vulnerability indicates the potential damage of climate variability on environment that resulted from shifts in climatic elements. In this research work five indicators identified to assess impact of climate variability within the study area. These indicators are the major groups which points out the effect of climate change. These include agricultural damage, flood risk, malaria out patient's density, and other two parameters change in rain fall variance and mean annual temperature variance.

Within the study area in which this study is conducted, districts in semi arid zone such as Ziway Dugda losses about 40% cultivated land crops some years due to scarcity of rain fall and can't withstand rain shortage as highlands due to high temperature increases the dry environment. Districts with sufficient amount of rain fall do not suffered from rain shortage. In Tiyo, for example agricultural land damage is only 1.9% per cultivated land. Highest agricultural damage is occurred in 1999 and 2003 in which almost half the cultivated land got dry due to scarcity of rain fall. The normalized agricultural damaged land value shows that arid parts of rift valley are suffered more than adjacent highlands.

Regarding malaria this study is not focuses on the number of malaria out patients but the spatial distribution of malaria on the lowlands and highlands within the study area where plasmodium Vivax and plasmodium falciparum mosquito is prevailed largely as results from zonal health offices of the study area indicates. The outpatients used in this study are only that of clinical cases it doesn't include confirmed malaria out patients. Previously the researches conducted by ministry of health say some highlands such as Tiyo district were malaria free areas. But currently malaria cases have been started to be reported insignificantly. This is because of the direct effect of climate change since mosquito survival is highly depend on temperature ,as temperature increases malaria transmitting mosquito breeding also increases.

There are projections that predict there might be excess amount of rain fall in the future for east Africa including Ethiopia and specifically to central Ethiopia. The results from flood map indicate that in the high population density areas where the plain topography is prevailed and drainage density is high, the probability of occurrences of flood is high as rain fall increases. In this regard districts such as Adama has high probability to get flood risk since it crossed by large rivers and high population density whereas districts such as Tiyo have low probability to get flood due to steep slope. The hydrologic response also shows that River runoff decreases through time. For instance the mean annual runoff for Keleta River in 1980-1992 was 254 mm while this number decreased to 194mm in the consecutive 13 years. In the succeeding years the value never goes above the mean. The trends over River Ketar also show the runoff is insignificantly decreasing

6.3 Climate Variability Impact Map

Composite climate variability impact mapping and preparation of vulnerability index from the results of aggregated indicators is the final goal of this work. All the indicators are normalized and summed together and this helps to get unit less values that falls in between 0 and 1.Using the indices climate variability impact map is prepared. The results are overlaid Using IDRISI Andes soft ware. No adaptive capacity value is subtracted from the normalized indices since the adaptive capacity under going is similar in all districts in all indicators. The highest normalized value is 1 and indicates extreme vulnerability and lowest normalized value is 0 which indicates no vulnerability. Others fall in between them according to their degree of vulnerability. Table 6.1 is the final normalized vulnerability index value which used to map composite climate variability impact mapping. The composite climate variability impact map is prepared from the normalized scores of all parameters that consists variance in annual temperature and rain fall, malaria outpatient’s density, agricultural damage and flood risk.

Table 14: Normalized scores of all indicators

District	Normalized Scores					
	Variance in annual total rain fall	Variance in mean annual temperature	Agricultural land damage	Malaria out patients density	Sum of the scores	Vulnerability index	Rank
Adama	0.2838	0.4234	0.25	0.0292	0.9864	0.2466	4
Tiyo	0.0666	0.3262	0	0.0028	0.3956	0.0989	6
Hetosa	0.0943	0.2331	0.064343	0.0000	0.391743	0.097936	7
Z.Dugda	0.0965	0.4843	1	1.0000	2.5808	0.6452	1
Fentalle	0.0468	0.1472	1	0.1890	1.383	0.34575	2
Boset	0.1955	0.3226	0.4	0.0277	0.9458	0.23645	5
Dodota-Sire	0.0512	0.0154	0.656555	0.4074	1.13055	0.282639	3

The next step is classifying the results. Ordinary classification of the indices by equal interval might be used. But for a meaningful characterization of the different stages of vulnerability, suitable fractile classification from an assumed probability distribution is used. A probability distribution which is suitable for this purpose is the Beta distribution, which is generally skewed and takes values in the interval (0, 1) that developed by Iyengar and Sudarshan in 1982(ICRISAT, 2009). This distribution has the probability density given by

$$f(z)=\frac{z^{a-1}(1-z)^{b-1},}{\beta(a, b)} \qquad 0<z<1 \text{ and } a,b>0$$

Where $\beta(a, b)$ is the beta function defined by

$$\beta(a, b)=\int_0^1 x^{a-1}(1-x)^{b-1}dx$$

The linear intervals such that each interval has given the same probability weight of 25 per cent.

These fractile intervals can be used to characterize the various stages of vulnerability.

1. Less vulnerable (less impact) if $0 < yi < z1$

2. Moderately vulnerable (moderate impact) if z_1< yi < z_2 ŷ

3. Vulnerable if z_2< yi<z_3 (considerable impact)

4. Highly vulnerable(high impact) if z_3< yi < *1 where* yi is the level or stage of vulnerability and the value of yi here is 0.1377.In the composite climate change map prepared from the normalized values of all indicators with equal 25%probablity distribution the values ranges from

1.0.097-0.2347 less vulnerable to climate variation

2.0.2347-0.3715 Moderately Vulnerable

3.0.3715-0.5083 vulnerable

4.0.5083-0.6452 Highly Vulnerable

The final result indicted that lowland area still highly vulnerable to multiple stresses which are resulted from climate variation than the adjacent highlands. But the highest rate of change is prevailing in the highland areas. Only in the confined places that are found on the top of the mountains the vulnerability is less. Most parts included under the study area are vulnerable or moderately vulnerable to climate variation. The composite climate vulnerability impact map is aggregated from climatic parameters variability and change for 35 years and other parameters with recent history. The final composite climate vulnerability impact map is prepared as depicted in Figure 6.4 below.

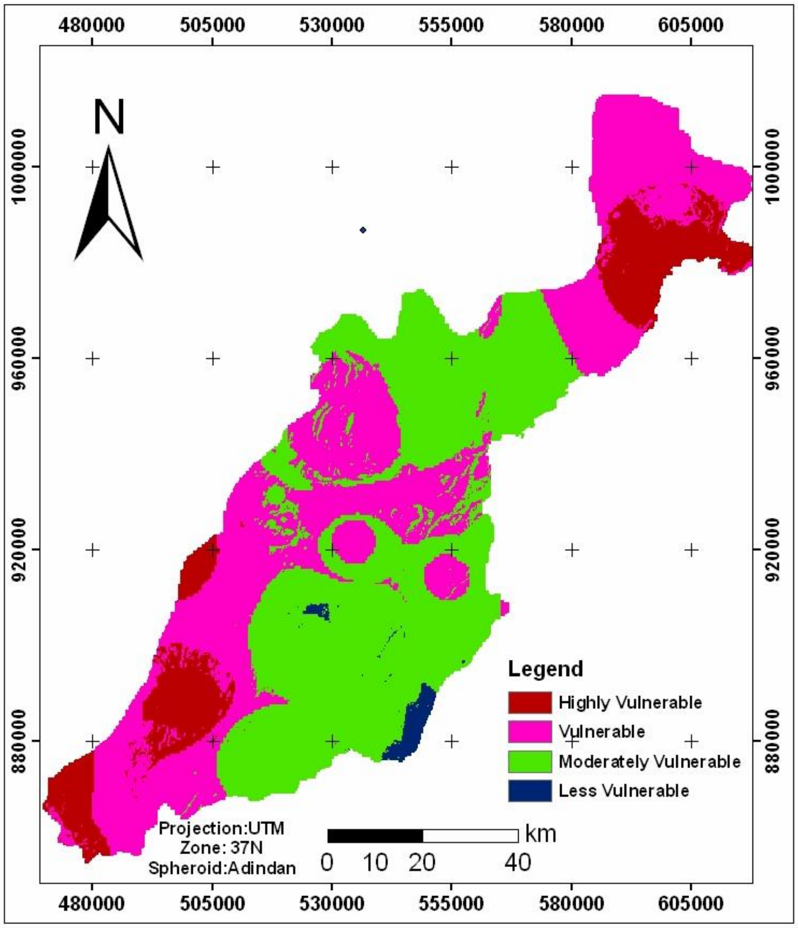


Figure 6.4: Composite Climate variability impact Map

6.4 Causes of climate variation

The major causes of climate variation and change have caused by global warming that resulted from natural and man made factors. The causes are that of land use land cover change. Climate variation and land use land cover change has strong relation ship. Specifically the forest ecosystem has great influence on climate to vary or change or not since carbon sequestration is determined by presence of vegetation as carbon stands first in making the earth's temperature to warm. The forest ecosystem that use to carbon sequestration is the main cause to change the local climate to be modified. Some mountains are now getting devoid of trees as indicated in Figure 6.5.

Figure 6.5: Fentalle Mountain devoid of vegetation

The other cause is Elnino effect. Every two to seven years unusually warm ocean temperate are observed off the western, coast of South America, displacing the nutrient-rich cold water that normally is present. During El Nino episodes the normal pattern of tropical precipitation becomes disrupted; some normally arid tropical areas get abnormally high rainfall while in some areas characterized by abundant and reliable rains become sparse and intermittent. EI Nino Episodes seems to be associated with drought occurrences in Ethiopia. The areas particularly affected during EI Nino years are Eastern and Southern Tigrai, North Wello, South Wello and North Shewa. (DPPC, 1997)

During the main rainy Season Inter-Tropical Convergence Zone (ITCZ) runs North-South along the Ethiopian escarpment. Inter tropical Convergence Zone (ITCZ) is the area encircling the earth near the equator where winds originating in the northern and southern hemispheres come together. Generally, areas to the west of the ITCZ get rain and to the east don't. A west shut of the position of the ITCZ could easily explain the drought nature of the above mentioned areas of the count while the western part of the country being not affected (ibid).

7. CONCLUSION AND RECOMMENDATIONS

Conclusion

Variable climate situation, adverse and extreme events, recurrent drought, unseasonable rain, displaced rain fall intensity, reduced river water are continuously reported from Ethiopia as the prevailing current situation. Some of these situations are indicators of climate change. In central Ethiopia where this study is conducted the situation is even worse. This study deals in quantifying and mapping the degree of climate variation and climate variability impact map in parts of central rift valley and adjacent Arsi highlands that extended from the lowest lowland of Fentalle 780m above mean sea level to 4135m in Chilalo Mountains. Four climatic elements derived from 22 meteorological stations for 35 years along with satellite images acquired in 1973, 1986 and 2009 have been used in analyzing climate variability impacts in the study area. The study aims in identifying the highly vulnerable groups from impacts index. Accordingly, various vulnerable groups which include agriculture, river runoff, malaria expansion, flood risk, and derived variances from temperature and rain fall have been used. Previously detail research is not conducted on climate variability is in the study area and most meteorological stations have short recording history of climate parameters. The only reference used to compare climate dynamism in the study area is the research conducted by UNEP in 1984 for all stations in the country since their time of establishment. In this study which focuses on comparing highland changes with that of lowland areas both areas, though there degree of change vary have faced the problem due to climate change.

The result indicates in all climatic elements considerable variability is observed both in highlands and rift valleys. Temperature is increased in rift valley by 0.37^{o}C between 1975-2009, where as in highland it is increased by 0.41^{o}C. This value is greater than the value predicted by IPCC over Ethiopia and high as compared to the survey conducted in 1984 by UNEP. Annual temperature rise is high in highlands and largest urban areas. In Nazreth the temperature is increased by 0.61^{o}C in the same period which shows fast rise of temperature than the neighboring stations. The degree in which maximum and minimum temperature rate change is varies in highland and rift valleys. In rift valley the maximum temperature is increasing faster than minimum temperature and in highlands the maximum temperature shows insignificant rise. Minimum temperatures, increased in alarming rate in highlands than rift valley regions. The range of temperature for lowland area is getting small as minimum temperature is rising faster than maximum temperature.

The rain fall didn’t decrease in intensity in the past 35 years both in highlands and parts of rift valley. Coefficient of variation is by far highest in rift valley than highlands. The highest coefficient of variation occurs in the peak agricultural period July (57%) in highlands and soon after plants reach their date maturity in September (68%) in the rift valley. Even though few records of short period are used relative humidity is decreasing from time to time. Wind speed doesn’t show significant change within the study area.

The results from five indicators of climate variability impacts results that the damages occurring due to climate change in the study area are increasing from time to time. Rift valley region is severing from the climate variability than highland regions. But the rate of change is highest in adjacent highlands than rift valley regions. The cultivated lands in peripheral lowlands are affected by rain shortage and this reaches up to 40% agricultural land damage per cultivated land in some districts within the rift valley. Previously malaria free districts are getting malaria insignificantly as their temperature is modified and be come comfortable for mosquito breeding and the number of people affected by malaria is increasing in malaria free areas. River discharge and runoff of a river is decreasing as temperature increases. As rain fall is projected to increase in Eastern Africa specifically to central Ethiopia, densely populated rift valley with high drainage density areas could get flood risk.

The composite climate variability impact map which is prepared from climate variability impact index results that lowland areas are more vulnerable than highlands as their normalized value is by far greater for rift valley regions. The possible reason for climate variability in the study area is both global phenomena and locally practiced anti-environment activities. The satellite image result indicates that forests are deteriorating from time to time. In 1973 the forest cover was 1193 km^2 while this number is only 729km^2 in 2009 of which dense forest accounts only 241$km^{2.}$ Global Phenomenon El Nino is another reason for climate variation in central Ethiopia which resulted in extremely high or extremely low rains to be prevailed in some years.

Recommendations

Up on the studies conducted the following conclusions have been drawn to reduce the effect of climate variability within the study area

- High rate of deforestation is prevailing in the study area. The adaptive capacity undertaking to reduce the climate variability and change effect is low. When new seedlings are planted they shouldn't kept until the end of their maturity date due to lack of follow ups and other factors. Due consideration should be given to tree transplanting and reforestation.

- Severe damage is resulted not only from forest change but also from global atmospheric circulation such as El Nino which diverts the direction of wind. Follow up and predictions on El Nino effect should continue in advance to reduce the damage occur in the area and taking the necessary cautions.

- Large and small scale irrigation activities should be implemented in the plain areas where rivers can be irrigable. This helps to overcome the hazards created on agricultural sector in the periods of rain shortage. Developed world are the main carbon emitters and developing countries are severing more since their adaptive capacity is low. Projects undertaken by the community in the study area should be supported by developed nations

- Public participation awareness creation is highly needed in the field of climate variation and change.

Additional meteorological stations are needed to exactly predict the climate change

Variations with full confident level since the available climatic stations are widely spaced.

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ANNEX.

Annex 1: National green house gas inventories (1994)

IPCC TABLE 7B SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1994 (Gg)									
GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_X	CO	NMVOC	SO_2
Total National Emissions and Removals		**2,595**	**-15,063**	**1,808**	**24**	**165**	**7,619**	**396**	**13**
1 Energy	Reference Approach	**2,919**							
	Sectoral Approach	**2,285**		**194**	**3.0**	**84**	**3,368**	**394**	**13**
A Fuel Combustion		2,285		194	3.0	84.0	3,368	394.0	12.1
B Fugitive Emissions from Fuels		0		0		0.04	0.06	0.44	0.7
2 Industrial Processes		**310**		**0**	**0.0**	**0.0**	**0**	**2.3**	**0.2**
3 Solvent and Other Product Use		**0**			**0.0**			**0.0**	
4 Agriculture				**1,540**	**19.7**	**73.8**	**4,003**		
5 Land-Use Change & Forestry		**0**	**-15,063**	**28**	**0.2**	**7.0**	**247**		
6 Waste				**46**	**1.5**				
Memo Items:									
International Bunkers		**NE**							
Aviation		NE							
Marine		33							
CO_2 Emissions from Biomass		**66,757**							

Source: MoWR and NMSA (2001)

D E C L A R A T I O N

I here by declare that the dissertation entitled 'Comparative Analysis of Climate Variability and Impacts in Central Rift Valley and Adjacent Arsi Highlands Using Remote Sensing and GIS' has been Carried out by me under the supervision of Dr. K. V. Suryabhagavan, Department of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2009-2010 as a part of Master of Science programme in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa
Date: June, 2010
(Getnet Feyissa)