THE EFFECT OF CLIMATE CHANGE ON URAN DRAINGE: CASE OF BISHOFTU CITY DRAINAGE

MASTER OF SCIENCE THESIS

ABREHAM AMDE GEBRESELASSIE

HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

OCTOBER, 2018

THE EFFECT OF CLIMATE CHANGE ON URBAN DRAINGE: CASE OF BISHOFTU CITY DRAINAGE

ABREHAM AMDE GEBRESELASSIE

A THESIS SUBMITTED TO THE FACULITY OF CIVIL ENGINEERING AND BUILT ENVIRONMENT,

HAWASSA INISTITUTE OF TECHNOLOGY,

SCHOOL OF GRADUATE STUDIES HAWASSA UNIVERSITY

HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CIVIL ENGINEERING (SPECIALIZATION: HYDRUALICS ENGINEERING)

OCTOBER, 2018

HAWASSA UNIVERSITYSCHOOL OF GRADUATE STUDIES ADVISORS' APPROVAL SHEET (Submission Sheet-1)

This is to certify that the thesis entitled "**The Effect of Climate Change on Urban Drainage: Case of Bishoftu city Drainage"** submitted in partial fulfilment of the requirements for the degree of **Master's** with specialization in **Hydraulic Engineering,** the Graduate Program **Faculty of civil Engineering and Built Environment,** and has been carried out by **Abreham Amde** Id. No **PGHYD/165/07**, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Mr. Desalegn Jawiso ________________ ________________

Chairman Signature Date

Dr. Moltot Zewdie ________________ ________________

Major Advisor Signature Date

Dr. Mulugeta Dadi ________________

____

Co- Advisor Signature Date

Dr. Ing. Netsanet Zelalem ________________ ________________

Internal Examiner Signature Date

Dr. Habtamu Hailu ________________

____

External Examiner Signature Date

Mr. Bereket Amare ________________

____

School of Civil Engineering PG coordinator Signature Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies of the candidate's department.

Date__________ **Stamp of SGS**

DECLARATION

Abreham Amde GebreSelassie, declare that this Thesis is my own original work and that it has not been presented and will not be presented by me to any other university for similar or any other degree award.

It may not be reproduced by any means, in full or in part, except short extracts in fair dealing, for research or private study critical scholarly review or discourse with an acknowledgement, without written permission of the directorate of postgraduate studies, on behalf of both the author and Hawassa University.

Name: **Abreham Amde**

Signature: **____________________**

Place: **Hawassa University, Hawassa**

Date of Submission:

DEDICATION

I dedicate that this thesis manuscript to all my family for nursing me with care and love and for their dedicated partnership in the success of my life.

Acknowledgements

First and for most, Praise and thanks be to the **Almighty God** and his mother **saint Marry** for giving me health and strength to pass through all confronts during my life.

I would like to thank my advisor Dr. Moltot Zewide (PhD) and my co-advisor Dr. Mulugeta Dadi (PhD) for their kind academic advice, continuous support during the data preparation and thesis writing.

My sincere gratitude to Hawassa University for awarding to attend my education and Ethiopia Road Authority (ERA) for sponsorship to follow my MSc. I would also like to thank International Water Management Institute (IWMI) for give me RCM data and Dr Alemeseged Tamiru head of hydrology department in (IWMI). I am also grateful to the Hydrology Department of Minster of Water, Irrigation and Electricity (MOWIE), National Meteorology Service Agency of Ethiopia (NMSAE) and Bishoftu City Administration office for providing me data free of charge.

My special thanks to my family for their love, support and encouragement. I am highly thankful to their blessing, guidance, advice, encouragement, and support are source of my happiness, strength and success.

Table of contents

Contents

List of tables

List of Figures

List of symbols and acronyms

AIMES	Analysis integration and modeling of the earth system
AOGCM	Atmospheric Ocean Global Climate Model
CSA	Central statistics Authority
DEM	Digital Elevation Model
ECMIP	Ensemble Coupled model Inter comparison project
ERA	Ethiopian road authority
GCM	Global circulation Model
GHG	Greenhouse Gas
GIS	Geographical Information System
HSG_S	Hydrologic soil group
IDF	Intensity duration frequency
IGBP	International geosphere biosphere program
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
LAM	Limited area model
NOAA	National Oceanic and Atmospheric Administration
PCMDI	Program for coupled model diagnosis inter comparison
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
RF	Radioactive forcing
SCS	Soil conservation services
SRES	Special Report on Emission Scenarios
SDSM	Statistical Downscaling Method
TAR	Third Assessment Report
WCRP	World climate research programmers
WGCM	Working group on coupled modeling

Abstract

Climate change is a reality that planners and designers of drainage infrastructures must consider. Therefore, the risk should be investigated and quantified properly. The objective of this thesis is to investigate the effect of climate change on Urban Drainage having the case of Bishoftu city drainage. Projection of the future climate is done by using CMIP5 climate model outputs of RCP4.5 and RCP8.5 scenarios and downscaled daily rainfall and temperature data of CMIP5. The future climate projection analysis was done by partitioning the coming 50 years in two periods which are (2020-2040) and (2051-2070) and the 1994-2013 is taken as the base line period. These climate scenarios data were bias corrected for serving as input to the SCS for impact analysis. Using Easy fit software, the rain fall data was fitted to Gumball distribution for the quantile estimation. The quantile estimation of 2, 5, 10, 25, 50 and 100 years return period for the site were found to be 47.818, 60.043, 68.137, 78.363, 85.95, 93.481, 110.884 and 118.365. Respectively. The study area which are Kalhiwet church area and the market area water shed area of the drainage design was done. The hydrologic analysis of rain fall run off is computed by using modified SCS method and the hydraulics parameter is computed by 4.2 Hydraulic tool box software for the two catchment area with RCP4.5 and RCP 8.5 Scenarios of the two time horizon of 2030s and 2060s.

Finally the design discharge amount is change in Market area by RCP 4.5 in 2060 is change by 63.3% and Minimum 18.64% in RCP 4.5Average design discharge, channel width and depth will increase up to 60.8% Max and 16.9% Min , 29.9% Max and 6.05% Min, and 20.21% Max and 6.7% Min depth is changed in KHC respectively. And for the design discharge of market area Max 63.3% and Min 18.64%, the width of channel is changed by 31.16% Max and 8.17% Min, and also the depth of the channel 32.22% Max and 9.09% Min also change. Therefore, the consideration of climate change on drainage is important.

Key words: Bishoftu, Climate Change, RCPs, Drainage Design, SCS

1 INTRODUCTION

1.1 Background of the study

Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns and among other effects that occur over several decades or longer (USEPN, 2017).

Earth's average temperature has risen by 1.5^{0}C over the past century, and is projected to rise 0.5 ^{0}C to 8.6^{0}C over the next hundred years. Small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather. Rising global temperatures have been accompanied by changes in weather and climate. Many places have seen changes in rainfall, resulting in more floods, droughts, or intense rain, as well as more frequent and severe heat waves (NOAA, 2015).

Drainage system is a crucial issue in urban towns, especially for those in the coastal zones, where rivers adjacent to towns experience tidal effect from sea. Drainage system is also affected by the change of land use pattern and human interactions due to urbanizations (Souza et. al, 2011, Goonetilleke et.al, 2005). In addition, the impact of climate change induced sea level rise and change in precipitation pattern, will make drainage system more vulnerable and complex in future years. It is difficult to consider the whole process for solving future drainage problems. Hydrology is the governing backbone of all kinds of water movement so hydrological concept was considered useful for the assessment of future drainage problem (Jha, 2011).

As engineers, we are faced with designing structures and facilities in the context of a climate future which is not equal to the climate past. The future climate is one of more variability and change more and severe droughts and summer and winter storms, and different long-term averages. This will impact the effectiveness of engineering structures and facilities which are influenced, directly or indirectly, by climate change. This includes water supply systems, wastewater treatment plants, hydropower, drainage structures and many others.

Engineers thus have no choice but to consider climate change in their practice in order to adapt and serve the public interest (Lapp, 2016). The Intergovernmental panels on climate change (IPCC) findings indicate that developing countries such as Ethiopia will be more vulnerable to climate change. Climate change may have far reaching implications for Ethiopia due to various reasons. The economy of the country mainly depends on agriculture, which is very sensitive to climate variations. A large part of the country is arid and semi-arid and is highly prone to desertification and drought. The country has also a fragile highland ecosystem which is currently under stress due to population pressure. Forest, water and biodiversity resources of the country are also climate sensitive. Climate change is, therefore, a case for concern (NMSA, 2001).

Although the drainage structure of Bishoftu city where constructed to carry water away from the urbanized areas as quickly and completely as possible minimize the flood impacts for the City but its performance under future climatic change condition is not investigated yet. For that reason, this study mainly deals with the effect of climate change on the Bishoftu city drainage design.

1.2 Statement of the Problem

Climate change is a reality that planners and designers of drainage infrastructures must consider. The cumulative effects of gradual changes in hydrology due to climatic change are expected to alter the magnitude and frequency of peak flows over the service life of drainage infrastructure.

The planning and design of new drainage infrastructure should include development features and sustainable urban drainage systems that provide multiple benefits such as a reduction of localized urban flooding and harmful impacts. Thus, for example, it can expect that urban drainage networks designed for the conditions of the past or present climate will not function as effectively in the future as they do now. Municipalities and other stakeholders must have effective plans or processes in place to ensure that infrastructure services will not be adversely affected by these changes.

As a result of the city`s flat topography which is surrounded by hills and slops, exposure to flood and runoff water is very common. Every year during the rainy season flood overflows the drainage structures and causes extensive destruction to public facilities and individual property in many parts of the City.

Therefore based on the above mentioned and other problems, climate change analysis and estimating its impact is required on drainage design of Bishoftu city with new plausible climate model output for better exploration of climate change effect on drainage design.

1.3 Objective

1.3.1General objectives

The general objective of the study is to assess the effect of climate change on urban drainage: case of Bishoftu city drainage.

1.3.2 Specific Objectives

- To assess the climate change in the study area.
- To evaluate the drainage design (depth and width) for possible climate change scenarios.
- To compare the drainage design parameters with climate change consideration and without.

1.4 Research Questions

- Is there climate change?
- Which drainage design parameter is changing?
- What it look like the future climate compared to the present condition?
- Is drainage design affected by climate change?

1.5 Limitation of the study

The main concerning in the thesis was to assess the effect of climate change on drainage designing

By using RCP4.5 and RCP 8.5 output and by assuming the land cover will remain the same and the storm water only. However, in real world the land cover change, sediment inflow will occur due to natural and human influence and the drainage system are exist in combined form of both storm water and waste water.

The thesis is limited to the some parts of Bishoftu city which are Kalhiwet church and market and this research also does not include structural design of all types of drainage structures but hydrologic analysis and hydraulic parameters determination for drainage structures that are susceptible to climate change are included in the research.

1.6 Significance of the study

This study will provide valuable climate information with the new acceptable release scenario to communities, designers, policy and decision makers, and other respective stakeholders. Designers can implement their proposed ideas using the information. Comparison of historical and future projection climate data can help for planning on adaptation and mitigation policies and strategies.

The major significant of this study is to show the impact of climate change on engineering design and the future impacts on Bishoftu city drainage design and to show the great concern must give for the climate change on design by considering the future climate condition.

Therefore, this study is beneficial to the city for future drainage structures construction to avoid problems by considering climate change on the performances of the existing drainage structures and proposing mitigation measures to avoid improper functioning.

The study is expected to propose appropriate solutions to the drainage design to contribute the sustainability.

1.7 Thesis outline

This thesis divided in to five chapters, Chapter one offer a general introduction about the study with its objective, significant of the study and research questions. The second chapter presents literature review and scientific review. The third chapter provides brief description of the study area including location, topography, climate and population. Moreover, it describes the material and methodology adopted for the study, data screening part and describe how the models are setup and data are analyzed to address the objective. Lastly the fifth chapter presents conclusion and recommendations. In addition to this, references and appendix are attached at the end.

2. LITERATURE REVIEW

This chapter reviews literature on climate changes, how their variations lead to precipitations and to design discharge. Climate change across the world, Africa, Ethiopia and its impacts are also discussed in this section. Prediction of changes in climate for impacts assessment requires climate scenarios generation using appropriate models and this is dealt with in this chapter. The section again looks at runoffs generation and discharge computations for drainage design investigations.

2.1 Climate Change

Climate change is a long-term shift in the statistics of the weather including its averages. For example, it could show up as a change in climate normal expected average values for temperature and precipitation for a given place and time of year, from one decade to the next. We know that the global climate is currently changing. The last decade of the 20th Century and the beginning of the 21st have been the warmest period in the entire global instrumental temperature record (NOAA, 2015).

Climate change refers to a change in the state of the climate that can be identified by using statistical test of the mean, the variability of its properties and it continue for an extended period typically decades or longer. It may be due to natural internal processes or external forcing‘s such as natural climate variability or anthropogenic forcing (e.g., greenhouse gases), or a combination of the two (IPCC2014). Natural and anthropogenic substances that alter the Earth‘s energy budget are drivers of climate change. Radioactive forcing (RF) is the net change in the energy balance of the Earth system (IPCC, 2013).

2.1.1 Overview of climate change

Climate change is the most serious problematic that the entire world is facing today. It is now widely accepted that climate change is already happening and further change is inevitable over the last century between 1906 and 2005, the average global temperature rose by about 0.74^{o}C.

Many studies into the detection and attribution of climate change have found that most of the increase in average global surface temperature over the last 50 years is attributable to human activities (IPCC, 2007). It is estimated that for the 20th Century, the total global mean sea level has raised 12-22 cm. this rise has been caused by the melting of snow cover and mountain glaciers (IPCC, 2013). The IPCC also notes that observations over the past century shows, changes are occurring in the amount, intensity, frequency and types of precipitation globally (IPCC, 2013).

2.1.2 Causes of Climate Change

According to (IPCC, 2007) report Climate change may occur due to both natural (i.e. internal or external processes of the climate system) as well as anthropogenic forcing (ex. increase in concentrations of greenhouse gases). Climate system is dominated by the long-lived greenhouse gases (GHG). The greenhouse gases include Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and halocarbons. Carbon dioxide (CO_2) is the most important anthropogenic GHG. Changes in the atmospheric concentrations of GHGs and aerosols, land cover and solar radiation alter the energy balance of the climate system and are drivers of climate change. They affect the absorption, scattering and emission of radiation within the atmosphere and at the Earth's surface. The resulting of positive or negative changes in energy balance due to these factors are expressed as radiates forcing, which is used to compare warming or cooling influences on global climate (IPCC, 2007).

2.1.3 Climate change in Africa

The Mean annual temperature of Africa in the SRES A1 and A2 scenarios is likely to exceed 2°C relative to the late 20th century (IPCC, 2014B). Under RCP, that exceedance could occur by mid-century across much of Africa and reach between 3°C and 6°C by the end of the century. Projected temperature increases over Africa based on the CMIP5 ensemble. Increases in mean annual temperature over all land areas are very likely in the mid- and late 21st-century periods for RCP2.6 and RCP8.5. The mean annual temperature exceed 2°C above the late 20th-century baseline over most land areas of the continent in the mid-21st century for RCP8.5, and exceed 4°c cover most land areas in the late 21st century for RCP8.5.In regions of high or complex topography such as the Ethiopian Highlands, downscaled projections indicate likely increases in rainfall and extreme rainfall by the end of the 21st century (IPCC, 2014 B).

2.1.4 Climate change in Ethiopia

According to the Ethiopian (NMSA, 2001) study for 42 meteorological stations, the country has experienced both dry and wet years over the last 50 years. Trend analysis of the annual rainfall showed there is a declining trend in the northern half of the country and southern Ethiopia while there is an increasing trend in the central part of the country. However, the overall trend in the entire country is more or less constant.

The study of (NMSA, 2001) at the same year for 40 stations showed that there are very warm and very cold years. However, the general trend showed there is an increase in temperature over the last 50 years. The average annual minimum temperature over the country are increasing by about 0.25 ^{0}c every ten years while average annual maximum temperature is increasing by about 0.1 ^{0}c. The study also noted that the minimum temperature is increasing at a higher rate than the maximum temperature.

Climate model projections under the SRES A2 and B1 scenarios over Ethiopia show warming in all four seasons across the country, which may cause a higher frequency of heat waves as well as higher rates of evaporation (Conway D., 2011).Associated with rainfall and temperature change and variability, there was a recurrent draught and flood events in the country. There was also observation of water level rise and dry up of lakes in some parts of the country depending on the general trend of the temperature and rainfall pattern of the regions.

2.2 Effects of Climate Changes on Engineering Design

Climate change may lead to an increase in the frequency of extreme precipitation events, floods and snowmelt periods experienced by infrastructure. Climate change affect the design factors include temperature, precipitation and water levels, wind loads, and storm surges and wave heights and it requires to examine both the short- and long-term implications on these environmental changing factors.

2.3 Climate Change Modeling

A climate model is used to understand how the climate system works, and how the various components interact with each other. It is used to simulate the present climate, past climate, and the climates of different climatic periods. It can also be used to simulate the future statistical state of the atmosphere a decade or a century into the future, but does not predict the local weather on particular days.

2.3.1 CMIP5 Climate Models

GCM are complex, computer base and mathematical representations of the Earth‘s climate based on fundamental scientific principles. Precipitation, wind, cloudiness, the ocean currents, air and water temperatures, the amount and type of vegetation, the concentration of GHGs and atmospheric aerosols (fine particles) these and other Global climate models are the principal tools used by climate scientists to quantitatively explore potential future climates, globally and regionally (IPCC, 2013).

The WCRP Working Group on Coupled Modeling, with input from the International Geosphere–Biosphere Program's; Analysis, Integration and modeling of the Earth System (AIMES) project, agreed to promote a new set of coordinated climate model experiments. These experiments comprise the fifth phase of the Coupled Model Inter comparison Project CMIP5 (Taylor et al 2012).

2.3.2 Climate Scenario

Scenarios can be described as appropriate, possible, alternative futures and the acceptable indication of what the future could be like over decades or centuries, given a specific set of assumptions. These assumptions include future trends in energy demand, emissions of greenhouse gases, land use change as well as assumptions about the behavior of the climate system over long-time scales. It is largely the uncertainty surrounding these assumptions which determines the range of possible scenarios (Carter et al., 1999).Several sets of scenarios including, the scenarios from the Special Report on Emission Scenarios (SRES) (Nakicenovic & Swart, 2000) and, more recently, the Representative Concentration Pathways (RCP) (van Vuuren et al. 2011) are used in climate research.

2.3.3 RCP – Emission scenarios

In climate research, different types of emission scenarios are used to assess the long-term impact of atmospheric greenhouse gases and pollutants based on assumptions of population growth, economic development level, etc. Scenarios previously approved by the IPCC include (IPCC, 1990), IS92 (Leggett et al., 1992) and SRES (Nakic et al., 2000).

The latest scenarios developed by the research community are denoted by Representative Concentration Pathways (RCPs) (Van Vuuren et al., 2011). There are four RCPs defined by their level of the total radiates forcing pathway in the year 2100, and are Representative for the existing literature about emission scenarios. Each RCP was developed by a different modelling group. Since the RCP had been developed with different, independent models, they are not directly comparable. The definition of the RCPs allows for a parallel development of new socio-economic, technical and policy scenarios that provide insights into the impact of policy decisions on the future climate (Van Vuuren et al., 2011).

RCP 2.6 scenario – Low emissions

This RCP is developed by PBL Netherlands Environmental Assessment Agency. Here radioactive forcing reaches 3.1 W/m^2 before it returns to 2.6 W/m^2 by 2100. In order to reach such forcing levels, determined greenhouse gas emissions reductions would be required overtime. Cropping area increases faster than current trends, while grassland area remains constant. Forest vegetation continues to decline at current trends.

RCP 4.5 scenario – Intermediate emissions

This RCP is developed by the Pacific Northwest National Laboratory in the US. Here radioactive forcing is stabilized shortly after year 2100, consistent with a future with relatively determined emissions reductions. The RCP 4.5 stabilization scenario is a cost-minimizing pathway. It assumes that all nations of the world undertake emissions mitigation simultaneously and effectively, and share a common global price that all emissions to that atmosphere must pay with emissions of different gases priced according to their hundred-year global warming potentials (Forster et al., 2014).

RCP 6 scenario – Intermediate emissions

This RCP is developed by the National Institute for Environmental Studies in Japan. Radioactive forcing is stabilized shortly after year 2100, which is consistent with the application of a range of technologies and strategies for reducing greenhouse gas emissions. Oil consumption remains high, while bio fuel and nuclear play a smaller role than in the other three scenarios. Cropping area continues to change on current trend, while grassland area is rapidly reduced. Natural vegetation is similar to RCP 4.5 scenario.

RCP 8.5 - High Emissions

This RCP is consistent with a future with no policy changes to reduce emissions. It was developed by the International Institute for Applied System Analysis in Austria and is characterized by increasing greenhouse gas emissions that lead to high greenhouse gas concentrations over time.

Table 2.1 Overview of representative concentration path ways

Scenarios	Description	Publication-IA Model
RCP8.5	Rising irradiative forcing leading to 8.5 w/m2 in 2100	Riahi et al. (2007)-MESSAGE
RCP6	Stabilization without overshoot pathway to 6w/m2 stabilization after 2100	Fujino et al. (2006) and Hijioka et al (2008) - AIM
RCP4.5	Stabilization without overshoot pathway to 4.5w/m2 stabilization after 2100	Clarke et al. (2007)- GCAM
RCP2.5	Peak in radiative forcing at ~3 w/m2 before 2100 And decline	Van Vuuren et al (2006,2007)- IMAGE

Source (Van Vuuren et al, 2011)

In all RCPs, atmospheric CO_2 concentrations are higher in 2100 relative to present day as a result of a further increase of cumulative emissions of $CO_2$to the atmosphere during the 21 century (IPCC, 2013). The RCP spans a range of irradiative forcing from 2.6 to 8.5 W m^2 and represents various possible climate outcomes.

2.3.4 Limitations of Climate Change Scenarios

Developing future climate change scenarios is difficult because of some limitations. For

- The problem of small signal ratios in some scenarios for precipitation and other variables,
- The inability of climate model predictions to account for the influence of land cover changes on future climate, and
- The relatively poor representation in many models of some aspects of climate variability that is important for Africa.

2.4 Bias correction

The basic idea of this bias-correction is used to reduce the gap between the daily RCP4.5 and RCP8.5 downscaled and observed Temperature and precipitation data's. Therefore RCP output is bias correct with historical observations before as input for hydrological model. Applying a bias correction to the RCP data often seems necessary to match the RCP data with the observations. Several studies have been performed in which a bias correction method was applied to RCM data. For example, (Hayet al. 2002) applied a gamma transform to correct precipitation data and (Leander and Buishand 2008) applied a power law transform, which corrects for the coefficient of variation (CV) and mean of the precipitation values. (Hayet al. 2002) found that the corrected precipitation data did not contain the day-to-day variability which was present in the observed data set. For this reason, I chosen to apply the power law transform method developed by (Leander and Buishand 2008) in this study.

2.5 Drainage

2.5.1 Types of drainage

There are two types of drainage system includes which are major and minor drainage systems. The minor system, sometimes referred to as the "Convenience" system, consists of the components that historically considered as part of the "storm drainage system". These components include curbs, gutters, ditches, inlets, access holes, pipes and other conduits, open channels, detention basins, and water quality control facilities (Alderson, 2006). According to HEC No. 22, the minor system normally designed to carry runoff from 10-year frequency storm events (FHWA, 2001).

A drainage system will include all the components needed to ensure that the substructure is properly drained, and may be formed of components such as,

• Open ditches,

• Closed ditches with pipe drains

• Drainage through storm water drainage pipes,

• Channels and culverts.

2.5.2 Urban drainage

Technologies for handling urban drainage have been developed over a long period of time, though design criteria have been relatively constant throughout the major urbanization era.

Since the urban drainage should be separate storm water (rain and snow melting) from wastewater (from households etc.) in the sewer systems (Bäckman, 1985). Generally, the urban drainage system should manage rains of return periods of at least 10 years without flooding (Mikkelsen etal. 2001).

2.6 Effect of Climate Change on Urban Drainage

Urban drainage is a vital city infrastructure to cope floods by conveying water away from urban areas. To minimize the flood impacts, the main principle is to carry water away from the urbanized areas as quickly and completely as possible (Chocat et al., 2004; Stahre, 2006).

Urban areas always present some risk of flooding when rainfall occurs. Buildings, roads, infrastructure and other paved areas prevent rainfall from infiltrating into the soil and so produce more runoff. Heavy rainfall produces very large volumes of surface water in any city, which can easily over flow drainage systems (Kalantari.Z, 2014). The drainage system built in the past and today cannot meet the desired capacity in the future; as a result, there will be a substantial increase in flood damage due to more frequent overloading of the drainage system in the future. Although mitigation has been adopted worldwide to tackle climate change impacts, adaptation is necessary to cope with the unavoidable adverse impacts on vulnerable areas (European Commission, 2009; Walsh et al., 2011).

General problems in the urban drainage systems are e.g. related to the system design, cross connections in the system (storm, waste water, and drainage pipes), damage, roots and sediments in the system, infiltration of water into the system, exfiltration of water out from the system, and pollutants and nutrients transported in the system (Berggren, 2007).

2.7 General Design Criteria

Design criteria establish the standards by which a drainage channel shall be design. Based on the drainage characteristics of the catchment and their surroundings it require area and slope of watershed, land use and land cover etc. The design required in three considerations: physical features of the town and surrounding areas, hydrologic and hydraulics aspects of the storm water drainage systems and finally economic considerations drainage system design has three phases, i.e. estimation of the quantity of run-off which reaches to the system (i.e. hydrology of the particular catchment), hydraulic design of system elements and thirdly comparison of different materials that serve the purpose.

2.7.1 Hydrological Equations for Determining Peak Flow

The hydrological study was undertaken in order to compute and evaluate peak discharges for all watercourses related structure. Calculation of these peak discharge values then helps for determination of the hydraulic opening sizes and types of waterway required for the subject area. And when we say that Peak discharge it is the maximum discharge in the study area in cubic meters per second.

The hydrological analysis was undertaken using available maps and aerial photographs together with available Meteorological data. Additional hydrological and geological information has been gathered from site visits to the area. In most cases the mathematical equations that are used to determine peak discharges are Rational and Soil Conservation service, (SCS) methods.

Rational Method: only for drainage areas less than 50 hectares or 0.5 km^2

SCS and other Unit Hydrograph Methods: for drainage areas greater than 50 hectares.

2.7.2 Flood Frequency Analysis

According to Chow et al. (1988), hydrologic systems are sometimes impacted by extreme events, such as severe storms, floods and droughts. The flood frequency analysis is one of the important studies on hydrology. It is essential to interpret the past record of flood events in order to evaluate future possibilities of such occurrences. The knowledge of magnitude and probable frequency of such recurrence is also required for proper design of hydraulic structures (Bikram, 2010).

Probability for future events can be predicted by fitting past observations to selected probability distributions. The primary objective is to relate the magnitude of these extreme events to their frequency of occurrence through the use of probability distributions (Chow et al, 1998).

2.7.3 Hydraulic Capacity

The hydraulic capacity of a storm drain is controlled by its size, shape, slope, and friction resistance. Several flow friction formulas have been advanced which define the relationship between flow capacity and these parameters. The most widely used formula for gravity and pressure flow in storm drains is Manning's Equation (NRCS and ERA, 2001).

2.8 Review of Runoff Models: Rational and SCS Curve Number Models

2.8.1 Rational Method

Peak flow prediction is vital in any hydrologic studies and the rational method is one of the simplest rainfall-runoff methods used. The Irish Engineer, Mulvaney (1850) was the first to publish principles on which the rational method works, although Americans tend to credit Kuichling (1889) and the British crediting it to Lloyd-Davies (1906).

According to ERA drainage design manual 2002 the rational formula is most accurate for estimating the design peak runoff for small catchment areas of up to 50 hectares ($0.5km^2$).

Peak discharge is expressed as:

$$Q = 0.00278CIA$$

Where, Q= Peak flow in cubic meter per second (m3/sec)

C= Dimensionless weighted runoff coefficient

I= Rainfall intensity in millimeters per hour (mm/hr)

A= Drainage area in hectares (ha)

Assumptions for the Rational Method

- Rainfall intensity is constant throughout the basin and within the storm duration.
- The time of concentration, t_c, employed is the time for the runoff to become established and flow from the most remote part of the sub basins to the outlet.
- The computed peak rate of runoff at the outlet point is a function of the average rainfall rate during the time of concentration, that is, the peak discharge does not result from a more intense storm of shorter duration, during which only a portion of the watershed is contributing to runoff at the outlet.

Limitations of the Rational Method

Important factors that determine the magnitude of flood such as antecedent moisture conditions, spatial and temporal rainfall variations are not covered by the rational method. The rational method assumes homogeneous characteristics for the watershed area. Therefore another method is most appropriate when inhomogeneity exists in the watershed or catchment under consideration. The rational method is adequate for peak runoff estimation as a result not concerned with other parts of the hydrograph after peak is reached for a particular design storm.

2.8.2 SCS Curve Number Model

The model developed by the National Resources Conservation Services (NRCS, 1957) within the US department of Agriculture is used for computing abstractions from precipitations. Soil Conservation Service (1964) did a further work on the method of runoff estimates which assumes a relationship between total precipitation, runoff, infiltration and abstractions.

The SCS method for calculating rates of runoff requires much of the same basic data as the rational method namely catchment area, a runoff factor (curve number), time of concentration, and rainfall. However, the SCS method also considers the time distribution of the rainfall, the initial rainfall losses to interception and storage, and an infiltration rate that decreases during the course of a storm. It is therefore, potentially more accurate than the rational method and is applicable when the catchment area is larger than 50 hectares (ERA, 2013).

2.9 Pervious Work on related Topic

2.9.1 Drainage issues

In terms of drainage Bishoftu town is highly susceptible to flood damages by storm-water from its upstream catchments. The topographic nature of the town and insufficient capacity of the drainage system aggravated the problem. Lack of appropriate drainage network design and absence of integrated approach in road and drainage line construction and maintenance have posed serious problem to the inhabitants of the town (Robel Woldyesus, 2015). The municipality of Bishoftu town is currently the storm water drainage and flooding problems of the town are long-lived obstacles for the development of urban life (MS Consultancy, 2006). According to the infrastructure department, Kebele 02, 08, 01, 07 and 06 are the most affected parts of the city.

2.9.2 ERA manual for climate change

A significant amount of scientific work has been undertaken within the last decade and a large body of evidence gathered to conclude that climate change is occurring within Ethiopia. The nature of climate change at a regional level will vary, and specifically within the 12 river basins. Further work is required over the next decade to establish a baseline for the individual river basins and project trends in climate change. The climate science community has developed a suite of models to inform decision makers on future climate. GCMs (Global Climate Models), RCMs (Regional Climate Models), downscaling techniques (both empirical and statistical), and several comprehensive reviews are available on the subject. It should be noted that all projections are stated with reference to a 1970-99 baseline. The study uses a collection of 15 General Circulation Model (GCM) runs to produce projections of climate change for three emissions scenarios. The three emissions scenarios used in the study were A2, A1B and B1, which can be broadly described as High, Medium and Low respectively. The figures quoted here refer to the 'central estimates' (i.e. the median results - A1B) from the 15 GCMs across the 3 emissions scenarios.

Temperature

The central estimates of the mean annual temperature show an increase of between 1.8 and 2.7°C by the 2060's and of 2.3 to 4.2°C by the 2090's. The maximum increases in mean temperature are projected to be between 3.1°C and 5.1°C for the 2060's and 2090's respectively**.**

Precipitation

The projections from the various climate models are broadly consistent in indicating an increase in annual rainfall in Ethiopia. These increases are largely a result of increasing rainfall in the 'short' rainfall season (October-November-December) in southern Ethiopia. The central estimates of annual changes in precipitation show increases of 3 to 9 percent by the 2090's for Ethiopia as a whole. The upper end of this projection shows this increase could be as much as 42 percent. Projections of change in the rainy season (February to May and mid-June to mid-September), which affect the larger portions of Ethiopia (northern/central and southern regions) are more mixed; but they tend towards slight increases the south west and decreases in the north east. The central estimates for rainfall in the 'short' rainfall season (October-November, December) season show increases of between 17 to 36percent by the 2090's, but up to 70 percent at the upper end of the projections. Percentage increases in the ‘short’ rainfall season in the eastern parts of Ethiopia are also significant.

Table 2.2 Recommendation National Precaution sensitive Ranges for Peak Rainfall Intensities and Peak River Flows

Parameter	1999 -2030	2030 – 2060	2060 -2090
Peak rainfall intensity*	10%	20%	20%
Peak river flow	10%	20%	20%

Source (ERA, 2013)

Peak rainfall intensity based on the medium emissions scenarios A1B and median % change in time period obtained from Data Summary table within (McSweeney et al 2008).

An allowance for peak flows, suggests that changes in the extent of flood plain are negligible in steep catchments, but can be dramatic in very flat areas.

3 MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

The study area is located at geographical co-ordinates of 8^{o}45’ to 8^{o}47’ longitudes and 38^{o}56’ to 39^{o}01’ latitude, which is found in East shewa zone of ormiya. It is found 47 Km south of the Addis Ababa and surrounded by Genda Gerba peasant association in the north, Kality peasant association in the east, kurkura peasant association in the west and Wedo & Keta_Jarra peasant association in the south.

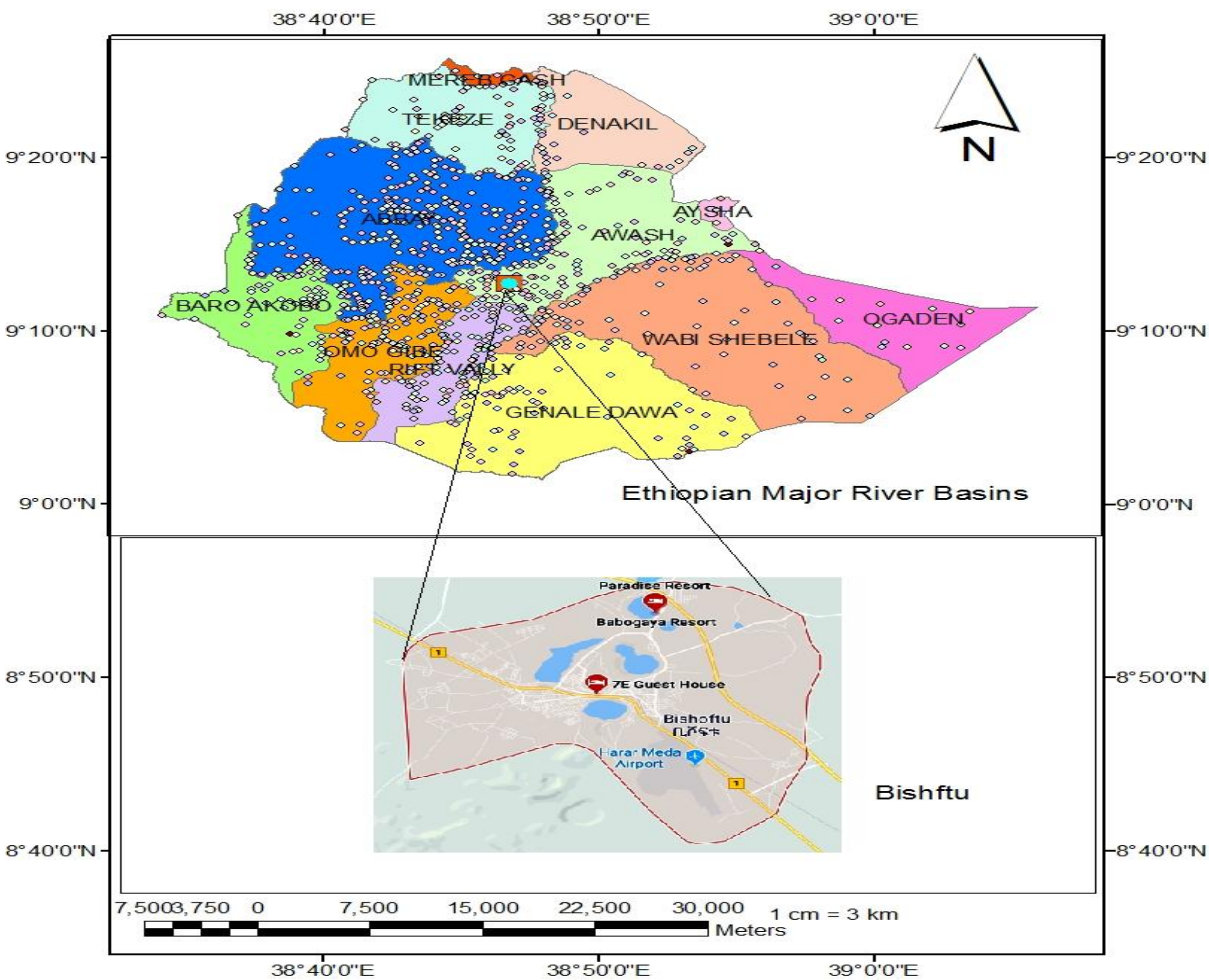


Figure 3.1 Location Map of Bishoftu City

3.1.2 Topography

The elevation of the area ranges from 1885m to 2010m a.s.l. at the top of Lake Bishoftu hill and south west of Lake Hora respectively. The average elevation of the city is 1990 a.s.l.

3.1.3 Population

The population of the city where increased from time to time according to Finance and Economic Development Bureau the total estimated population of the town was 201,408 by the year 2015. From the total population 97,683(48.5%) are Males and 103,725(51.5%) are females.

3.1.4 Climate

The average annual temperature of the city is 19.3^{0}C and the monthly mean minimum and maximum annual temperature ranges from 12.0^{0}C to 26.9^{0}C. May and December are the warmest and coldest months; March and April are also warmer months next to May, where the highest maximum mean temperatures are observed during these three months. On the other hand, the lowest minimum mean temperatures mostly occur from November to February each year.

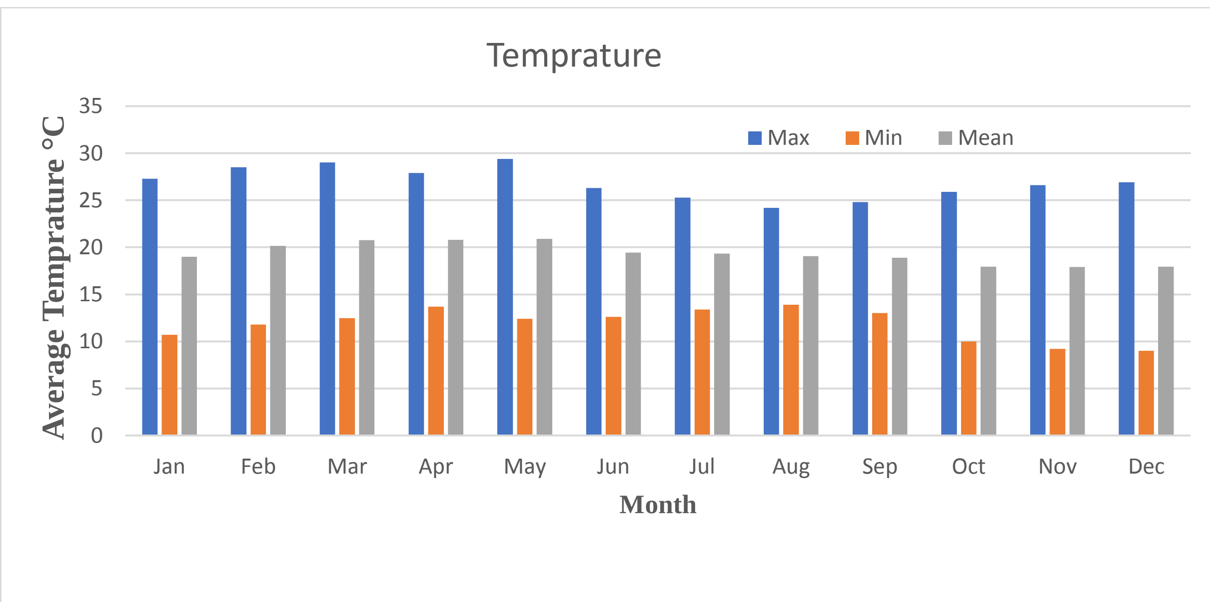


Figure3.2 Monthly Temperature (1994-2013)

3.1.5 Rainfall

The city has six rainy months; from March to April and from June to September that make two rainy seasons of spring and summer respectively. Summer rain accounts for 50 to 90% of the annual rainfall in the area and is relatively stable when compared with other rainfall season.

Winter is a dry season in Bishoftu city. The mean annual rainfall recorded over the ten years (1994-2013) has shown that the month of July is the highest rainy month with a mean annual rainfall of 221.19mm and in November least (8.40mm). The mean annual rainfall is about 835.98mm.

Table3.1 Rainfall data of Bishoftu

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall	10.38	13.94	48.06	54.92	41.86	109.98	**221.19**	197.13	88.15	30.24	**8.40**	11.70	**835.98**

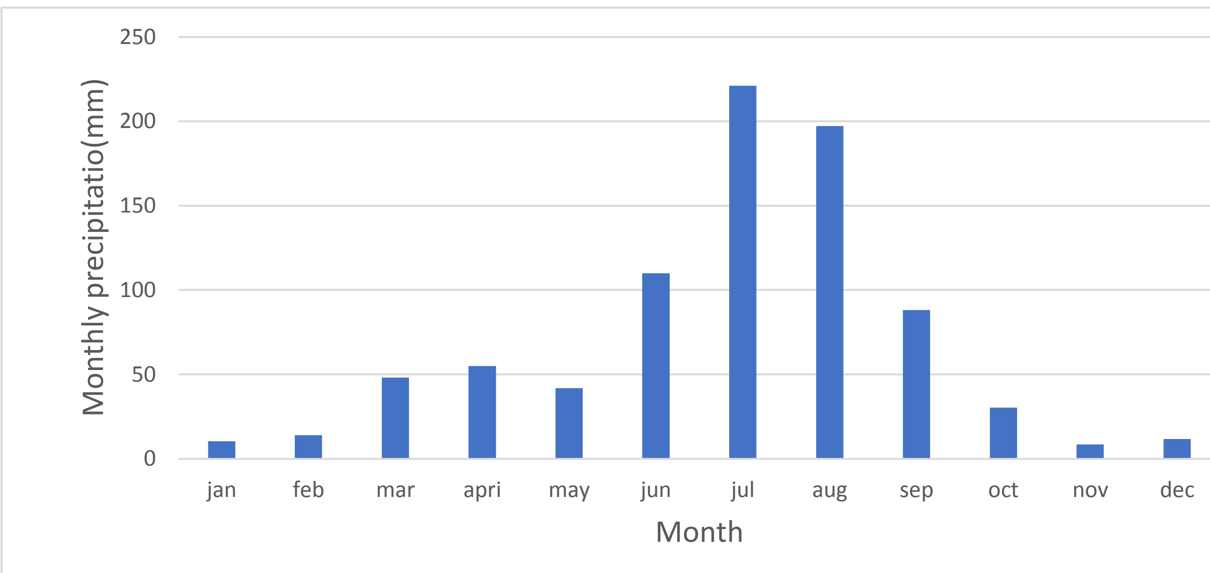


Figure 3.3 Monthly Rainfall of Bishoftu city (1994-2013)

3.1.6 Soil type and Land use land cover

According to the Development plan prepared by National Urban Planning report on Bishoftu, the city is sub divided in three-sub city and nine kebeles. The master plan study reveals that 28.2% of the major portion of the land is covered by the lakes. Residential area and service giving institutions takes the second and the third share in the land use, about 18.7% and 16.5% respectively. Industrial establishment and horticulture also occupy large area.

According to the land use plan, expansion of residential area, manufacturing and storage facilities, horticulture, and recreation service giving and forest areas are planned to show substantial growth. However, the growth dynamitic, which is currently prevailing in the Town, is a major factor to revise the physical plan in the near future. The soil cover is mostly silt clays mixed with sand.

Table 3.2 Land use of Bishoftu City Administration

No	Land use type	Area Covered in Hectare	Percentage (%)
1	Residence	2,826	15.46
2	Commerce	303	1.66
3	Administration	31	0.17
4	Social service	2,553	13.9
5	Agriculture	484	2.65
6	Transport and street road	2,309	12.63
7	Open space	4,467	24.44
8	Recreation	3,115	17.04
9	Manufacturing and storage	1,362	7.45
10	Special function	828	4.53
	Total	18,278	100

Source: Bishoftu Finance & Economic Development Bureau, Profile Report, 2008

3.1.7 Physical Infrastructure

By way of infrastructure rehabilitation, the Municipality of Bishoftu has undertaken various forms and qualities of development schemes. Among these are roads and flood protection structures such as walls and check dams, new and rehabilitated market places, water supply and sewerage developments within the city.

According to (BFEDB, 2008) the city has a total 24 km inner asphalt road, 251.1 km gravel roads and 240.25km drainage ditch within this flood protection structures and reservoirs covering about 10% of the total area that need to be protected.

3.1.8 Road and Drainage Network

The development of road and drainage facilities in the city has significantly increased over the last eight years. The city implemented various projects for the development and improvement of these physical infrastructure. The following table presents the evolutional growth of the road and drainage network in the city over the last five years.

The drainage system infrastructure increased by some 34% over the last five years. However, as per though some areas have enjoyed these infrastructure, others are affected by aggregated storm drainage carried with this facilities.

Table 3.3 Road and Drainage Lines with Their Respectively Length (2002-2007EC.)

Year in E.C	Road type and Drainage Length in km			
	Asphalt	Cobblestone	Gravel	Drainage
2002	6.5	26	66	159.45
2003	22.5	50	52.94	206.95
2004	22.5	66	66.5	206.95
2005	22.5	81	190	216.95
2006	22.5	106	215	224.25
2007	24	127.9	251.2	240.25

Source: Bishoftu Finance & Economic Development Bureau, Profile Report, 2008

3.2 General methodology

To accomplish this study the following methods are carried out.

The first step is preparation of the projected climatological and observed climatological data and collection also carried out in respective office.

The second step was Bias Corrected REGRIDED CMIP5 climate data to the local impact study area based on the grid points which are fitted to the study area by using bias-correction method. Then evaluate the performance of bias-corrected data using descriptive statistics of error measuring techniques such as coefficient of variation (CV), root mean square error (RMSE) and mean absolute error (MAE).The data downscaled by bias-correction power transform method is used to estimate the future climate change and as input in SCS.

The third step was delineating watersheds and getting watershed properties which are area, slope, drainage length and land use land cover.

The fourth step is data quality test.

The fifth step was determine the hydrological and hydraulics parameter for the design corresponding to the RCP4.5 and RCP8.5 climate scenarios predictions which are obtained from CORDEX simulated based on CMIPS climate model output.

3.3 Conceptual Frame work

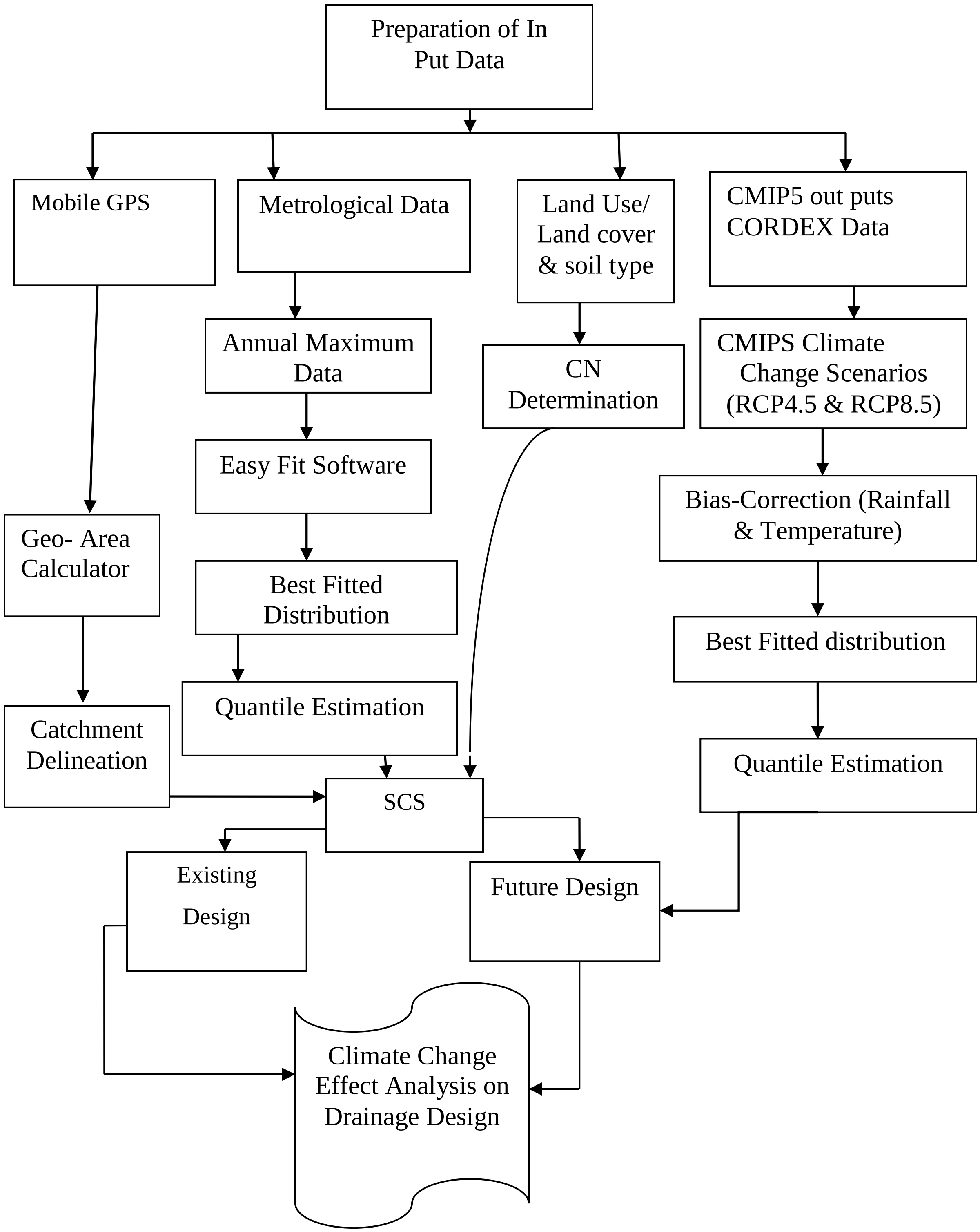


Figure 3.4 General Methodology Flow Chart

3.4 Data Collection

I. Climate data

- ✓ For this study daily observed Meteorological data consisting of precipitation, maximum and minimum temperature, with relatively good quality from 7 selected stations has been collected from National Meteorological Agency database of Ethiopia for the period of 1994-2013.

  This period does not fully overlap with the selected GCM baseline period (1980–2005), it is the historical period available with near time observed daily data and generate future scenarios for two periods of 2020 –2040 (2030s) and2051–2070 (2060s).
- ✓ High-resolution GCM data however downscaled CORDEX Climate data on the CMIP5 simulation for (RCP4.5 and RCP 8.5) for future projection was from IWMI. This downscaled CORDEX data consists of daily precipitation.

Table 3.4: Summary information for the selected meteorological station

No	Location	Longitude	Latitude	Elevation (a.s.l.)	year of data used
1	Bishoftu	$38^{0}59'$	$8^{0}45'$	1900	20
2	Akaki Mission	$38^{0}25'$	$08^{0}56'$	2120	20
3	Chfe Donsa	$39^{0}1232'$	8.97'	2560	20

As shown table above three metrological stations are selected for filling missing data at Bishoftu catchment for climate change effect on drainage design of the city.

II. Spatial Data

A. Digital Elevation Model (DEM)

Since topography was defined by a DEM which describes the elevation of any point in a given area of a specific spatial resolution. The sub-basin Kalehiwet church ranges from 1874 to 1872 meters and market ranges from 1975 to 1972 meters elevation the elevation obtained from drainage base map of Bishoftu and by field survey. And its length, water shed area is calculated by Geo area calculator. It is useful to extract detail information and to verify the image file of the catchment that were obtained from internet and it is easily applicable by phone.

B. Land use land covers data

Land use and land cover data were also collected from field inspection and by helping of Bishoftu Finance & Economic Development Bureau, Profile Report, 2008 for Bishoftu city. My study areas was Kale Hiwot and Market. Therefore the market and residence area of Land use and land cover data were have read the value of curve number from EDDM 2002 and the total area coverage was calculated by Geo- area calculator.

3.5 Data analysis

3.5.1 Filling missing rain fall data

Rain fall data play a central role in determining quantile estimation of design discharge and to perform hydrology analysis and simulation using data of long time's series, so filling in missing data are very important. Missing data is common problem in Hydrology. When missing data appear rain fall data, it might come from different reason. The main are the failure of the observer, interruption or damage of the recording station and instrumental failure can result missing data.

A number of methods are available for estimating missing data. There are station average method, normal ratio method, regression method, inverse distance weighting method and quadrant method. From five methods regression method is used for this study. Linear regression (ordinary Last Square) is very important tool for the statistical analysis of data. It is performed to learn something of the other variable and to estimate or predict values of one variable based of knowledge of another variable, for which more data are available.

The normal ratio and quadrant methods provide a weighted mean, with the former basing the weights on the average annual rainfall at each gauge and the latter having weights that depend on the distance between the gauges where recorded data are available and the point where a value is required. The station average method for filling missing data is conceptually the same as the station average method for estimating a mean precipitation.

This method may not be accurate when the total annual rainfall at any of the n region gauges differs from the annual rainfall at the point of interest by more than 10%. If the total annual rainfall at any of the n region gauges differs from the annual rainfall at the point of interest by more than 10%, the normal ratio method is preferable (Rechard, 1989). However, in this study station average and normal ratio method were used.

For this study, to fill the gaps of the missing data is supported by station average method and normal ratio method. The equation of both station and ratio method is given by:

According to Rechard (1989) these two methods are described below.

$$\%\text{Difference} = \left(\frac{N_X - N_i}{N_X}\right) \times 100 \ldots\ldots 3.1$$

Where: N_x = total rainfall at any regions and Ni = annual rainfall at the point of interest.

The station average method for estimating missing data uses n gauges from a region to estimate the missing point rainfall, P_x at another gauge:

$$P_X = \frac{1}{n} \times \sum_{i=1}^{n} P_i \ldots\ldots 3.2$$

Where: P_i = the rainfall at gauge i. Equation 3.2 is accurate when the total annual rainfall at any of the n regional gauges when the mean difference is less than 10%. If the mean difference is greater than 10%, the normal ratio method should be used by using the following formula.

$$P_m = \frac{1}{n} \times \left[\sum_{i=1}^{n} \left(\frac{N_m}{N_i}\right) \times P_i\right] \ldots\ldots 3.3$$

Where: P_m = missing data at station x,

N_m= normal annual rain at rain gauge for which data are missing, Ni = normal annual rain at gauge i and n is number of nearby gauges.

3.5.2 Stations data record check for consistency

I. Double Mass Curve

A double mass curve is a plot on arithmetic cross-section paper of the cumulative figures of one variable against the cumulative figures of another variable, or against the cumulative computed values of the same variable for a concurrent period of time (James & Clayton, 1960).

The theory of the double mass curve is based on the fact that a graph of the cumulative of one quantity against the cumulative of another quantity during the same period will plot as a straight line so long as the data are proportional to the slope of the line will represent the constant of proportionality between the quantities.

The double mass curve will have a constant slope when the rainfall record is in a constant estimator of the hydro meteorological occurrences over the period of records.

Double mass suggests the method of adjusting an inconsistent record. The change in the regime of the curve can be adjusted as

$$P_a = \frac{b_a}{b_o} P_o \text{……………………………………………………………………………………..} 3.4$$

Where = P_a= adjusted precipitation

P_o= Observed precipitation

b_o= Slope of graph at time P_o was observed

b_1 =slope of graph to which records are adjusted

The method can easily identify which of the neighboring meteorological stations, which are to be filled best correspondence to fill the missing records.

This method used to determine the best realistic correlation out of different stations located near the selected sub-basins and catchments.

3.5.3Testing of outliers

This test helps to avoid those data lie out of the range in between the lowest datum and the highest datum. The lowest datum and the highest datum can significantly affect the magnitude of statistical parameters computed from the data; especially for small samples procedures for trending outliers require judgment involving both mathematical and hydrological considerations. According to the water resources council (1981), if the station skew is greater than +0.4 tests for high outliers are considered first; if station skew is less than - 0.4, test for low outlier are considered first. Where the station skew is between $\pm$4.0 tests for both high and low outlier should be applied before eliminating any outliers from the data set .The following frequency equation can be used to detect high outliers.

The following frequency equation can be used to detect high outliers and lower outliers.

Let $\mathrm{Y} = \log \mathrm{X}$ ……………………………………………………..……………….…3.5

Lowest outlier $\mathrm{RL} = 10^{(\mathrm{YL})}$…………………………………..................……………3.6

Highest outlier $\mathrm{RH} = 10^{(\mathrm{YH})}$……………………………………………….……………3.7

Where, $YL = Y_{average} - K_n \times S_{yn} - 1$

$YH = Y_{average} + K_n \times S_{yn} - 1$

Where, $Y_{average}$ mean of the log transposed data

$S_{yn} - 1$ Standard deviation of the log transposed data

K_n Factor value read from Chow et.al. (1988), page 404, table 12.5.3 for sample

If the logarithms of the value in a sample are greater than YH in the above equation, then they are considered high outliers and it indicate that the maximum over an extended period of time. Therefore, the data series has no outlier and all the data series will be used for the frequency analysis. It is the same as for lower outlier test.

3.5.5. Goodness of fit test

The goodness of fit test where conducted by using Easy Fit software. Easy fit is a data analysis and simulation software, which enables us to fit and simulate statistical distribution with sample data, choose the best model and use the obtained result of analysis to take better decisions. The software can function as a standalone window application or add on for Excel spreadsheet.

The basic idea behind the software is that the distance between data and the distribution under test is measured; and is compared to a certain threshold value. If the distance (called "test statistics") is lower than thresholds value, the distribution is consider as "good" (Hossien and Alireza, 2014).

The software uses well- known goodness of fit test statistics. These are chi-square test and Kolmogorov-Smirnov test.

Chi-Square goodness of fit test is a non-parametric test that is used to find out how the observed value of a given phenomenon is significantly different from the expected value. In Chi-Square goodness of fit test, the term goodness of fit is used to compare the observed sample distribution with the expected probability distribution moreover the test determines how well theoretical distribution fits the empirical distribution. In Chi-Square goodness of fit test, sample data is divided into intervals. Then the numbers of points that fall into the interval are compared, with the expected numbers of points in each interval. It is defined as:

$$X^2 = \frac{(O_i - E_i)^2}{E_i} \quad \text{....3.8}$$

Where, O_i is the observed number of events in class interval i, and E_i is the number of events that would be expected from the theoretical distribution and calculated by;

$$E_i = F(X_1) - (X_2) \ldots\ldots 3.9$$

The Kolmogorov-Smirnov test is used to decide if a sample comes from a hypothesized continuous distribution. It is concerned with the degree of the agreement between the distribution of the observed samples values and some specified theoretical distribution and it determines whether the values in sample can reasonably be thought to have come from a population having a theoretical distribution. The Kolmogorov–Smirnov test statistics D is computed it is based on the largest vertical difference between the theoretical and the empirical cumulative distribution function.

3.5.6 The Extreme Value Distribution or Gumbel Distribution

The Gumbel extreme-value distribution is the most popular distribution and has received the highest application for estimating large events in various parts of the world. This distribution has been used for rainfall depth-duration-frequency studies (Hershfield, 1961).

Extreme value distribution has been also widely used in hydrology and storm rainfall analyses have been carried out most commonly by the EVI distribution (Chow, 1953, and Thomilison, 1980). The probability that an observation will exceed the mean value of the distribution is 1-F(Y). Regarding the estimation of parameters (α and β), Lowery and Nash (1970) concluded that the method of moments has satisfactory results as the other methods.

Extreme value type I or Gumbel and Log Pearson type III distributions are used for rainfall frequency analysis. The distribution which fits better to the data series is finally used to determine the magnitudes of rainfall at various recurrence intervals.

Frequency analysis was used to identify the fittest distribution for this data set. The result of the analysis shows that the data set fitted with Gumbel distribution (EV-I) and the other.

3.6 GCM data analysis

Representative concentration pathways (RCPs) of CMIP5 climate model output stands for a path way in order to provide time dependent projection of atmospheric greenhouses gas (GHG) concentrations. This study only uses the results for the most extreme RCP8.5 and moderate RCP4.5 emission scenarios. The study aims to compare historical and future periods 2020-2040

(2030s) and 2050-2070 (2060s).

These GCM data source are obtained from CORDEX via earth system grid federation (ESGF) which is led by PCMDI. This CMIP5 GCM ensemble model has been provided by world climate research program (WCRP), and this coarse resolution grid data of CMIP5 output has been regrided dynamically by CORDEX according to CMIP5 simulation to a resolution of 0.5degree ($50\times 50Km$).

This grid data has been bias-corrected for each selected meteorological stations of each climate parameters (maximum & minimum temperatures and Rainfall) of three catchments. These grid based point climate data were changed in to areal climate parameters. These daily areal climate variables were used as input to hydrologic model SCS to simulate the future design discharge.

The historical data of this CMIP5 output was put from 1951-2005 and projection period from 2006-2100.The base period for this study has been taken from1994-2013 which is the nearest period. For the two scenarios (RCP4.5 and RCP8.5) from 2020-2070 future projection has been manipulated change under these scenarios.

3.6.1 Bias correction

For this study the CMIP5 products from CORDEX have been corrected by using bias-correction method to fine resolution required by the hydrological model. Therefore, in this study bias correction is used to transform CMIP5 projection from REGRID resolution to local targeted downscaled resolution.

I. Precipitation downscaling

The RCP precipitation data has been downscaled by using a nonlinear power transform method (Leander.R and Buishand.T, 2007) to correct the CV, Standard deviation and the mean of the observed and the simulated baseline RCP data. This nonlinear bias correction method transforms each daily precipitation amount P to a corrected P∗ using

$P^{*} = \alpha P^{b}$……………………………………………………………………………………..3.10

Where, the parameters α and b was determined for the period of the year of 12 months.

The determination of the b parameter could be computed through iteration and the CV of the corrected daily precipitation should match with the CV of the observed daily precipitation

(Terink, et al, 2010). In this way, the CV is only a function of parameter b according to:

CV (P) = f (b)

In which P is the precipitation, CV is the coefficient of variation. With the determined parameter b, the transformed daily precipitation values were calculated using

$$P^* = \alpha P \qquad \text{……………………………………..3.11}$$

Where α is mean of the transformed daily values corresponds with the observed mean and b which was the correction parameters are subsequently applied to the future climate scenarios.

II. Temperature downscaling

The correction of temperature only involves shifting and scaling to adjust the mean and variance (Leander.R & A, 2007).

For each station, the corrected daily temperature T*was obtained as:

$$T^* = \mathrm{T}_{\mathrm{obs}} + \sigma(T_{obs})\frac{\sigma(T_{obs})}{\sigma(T_{Unc})}(T_{Unc} - T_{obs}) + (T_{obs} - T_{Unc}) \qquad \text{……………………………………3.12}$$

Where T unc is the uncorrected daily temperature from CMIP5 model output

T obs is the observed daily temperature from the NMA data set

In this equation an over bar denotes the average over the considered period and σ is the Standard deviation.

3.7 Topographic Maps

Topographic maps were used for determination of catchments details such as area, average slope, length of the main watercourse and difference in elevation computations.

3.7.1 Aerial Photographs and satellite maps.

Geo area Calculator

Geo area is the best tool, when to obtaining some property, and want to calculate area of that property and provide extract calculated area. The application is useful to calculate GPS area or GPS distance with great accuracy. It have two way to measure any GPS area or GPS distance. Or we can either put markers manually on map or record your position using GPS service.

3.7.2 Field Surveys

Field surveys were carried out to gather hydrological and hydraulic data related to the drainage system and the water shed area.

3.9 Hydrological Equations for Determining Peak discharges

3.9.1 The SCS method

Soil Conservation Service (SCS) Curve Number (CN) model estimates precipitation excess as a function of cumulative precipitation, soil cover, land use, and antecedent moisture. SCS developed the method for small and midsized watersheds (< 1000 sq. km) (NRCS, 2004) the method also Considered the initial rainfall losses to interception, depression storage and infiltration rate that decreases during the course of storm and Converts basin storage into something simpler and more manageable (a "curve number" CN).

The SCS runoff equation is a method of estimating direct runoff from24-houror1-day storm rainfall. It is therefore, potentially more accurate than the rational method and is applicable when the catchment area is larger than 50 hectares (ERA, 2011).

The main input variables for the SCS methods:

• Drainage area,

• Weighted runoff curve number (CN),

• Time of concentration (Tc) and

• Design point rainfall (P)

A relationship between accumulated rainfall and accumulated runoff derived by SCS for numerous hydrologic and vegetative cover conditions are important for peak discharge determination. The storm data included total amount of rainfall in a calendar day but not its distribution with respect to time. The SCS runoff equation is therefore a method of estimating direct runoff from 24-hour storm rainfall.

The Curve Number

The potential maximum soil water retention, S, is related to hydrologic soil properties, land cover and management conditions as well as, the soil moisture status of the catchments prior to rainfall event and expressed by a dimensionless response index termed the catchment's curve number (CN).

The CN and S are related as follows

$\mathrm{CN} = 25.4\left(\frac{100}{10+\mathrm{S}}\right)$………………………………………………………………………...3.13

$\mathrm{S} = 25.4\left(\frac{100}{\mathrm{CN}} - 1\right)$……………………………………………………………………....3.14

The CN number is selected according to soil type, moisture condition and land cover/use of the watershed area. As per the recommendation of ERADDM, the average antecedent moisture condition is adopted as a reference for using CN values. In Appendix.

Three basic antecedent rainfall conditions are present for both dependent variables(S and CN)

Normal conditions, AMC (II)

Dry conditions, AMC (I)

Wet conditions, AMC (III)

Time of Concentration

Time of concentration is the time it takes water to flow from the edge of the catchment area to the point of interest. It is a combination of three values in SCS method of determining peak flow rate.

The time of concentration tc is estimated by; (Kirpich formula)

$t_C = 0.0078L^{0.77}S^{-0.385}$ For bare soil or flow in road side ditch

$t_C = 0.0028L^{0.77}S^{-0.385}$For overland flow on concrete or asphalt

$t_C = 0.0014L^{0.77}S^{-0.385}$For concrete channels

Where:

L = L=length of channel/ditch (km)

S = average watershed slope, (m/m)/land slope

tc = time of concentration (min)

Rainfall Runoff Equation

The direct runoff from 24-hour or 1-day storm rainfall using the expression below:

$\mathrm{Q} = \frac{(\mathrm{P}-\mathrm{I})^2}{(\mathrm{P}-\mathrm{I_a})+\mathrm{S}}$…………………………………………………………………………3.15

$\mathrm{Q} = \frac{\left(\mathrm{P}-50.8\left(\frac{100}{\mathrm{CN}}-1\right)\right)^2}{\mathrm{P}+203.2\left(\frac{100}{\mathrm{CN}}-1\right)}$…………………………………………………………………3.16

The calculated time of concentration, unit peak discharge is obtained from **Appendix A** on Figure 4. After unit peak discharge is obtained, design peak discharge is determined using the formula:

Design Peak Discharge $Q_p = Q_u * Q * A$ ……………………………………………………3.17

Where, Qp= Design Peak Discharge, m^3/sec

Q_u=Unit Peak Discharge, m^3/sec/100ha/mm

Q= Direct Runoff, mm

A= Area of the catchment, ha

Hydrological Soil Groups

Soils are classified into hydrologic soil groups (HSGs) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSGs are A, B, C and D

Group. A Soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 7.62mm/hr). Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam or silt loam textures can be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments (NRCS, 2007).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (3.81mm/hr-7.62mm/hr). Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures can be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments (NRCS, 2007).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine-to-fine texture. These soils have a low rate of water transmission (1.27mm/hr to 3.81mm/hr). Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments (NRCS, 2007).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-1.27mm/hr). Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential (NRCS, 2007).

3.10 Hydraulic Equations

3.10.1 Manning's Equation

Discharge is determined for a known opening size of the drainage structure and bottom slope and/or the size of the drainage structure is determined for a known discharge and bottom slope by trial and error method. The Manning's equation can be used for uniform flow in a pipe, and stream channel, but the Manning's roughness coefficient needs to be considered variable, dependent upon the depth of flow.

The Manning's equation is used for calculating the cross-sectional area, wetted perimeter, and hydraulic radius for flow of a specified depth in a pipe of known diameter and/or stream channel cross-section. Manning's equation is applicable for a constant flow rate of water through a channel with constant slope, size & shape, and roughness.

$$Q = \frac{AR^{2/3}S^{1/2}}{n} \qquad \text{3.18}$$

Where, Q is the volumetric flow rate passing through the channel reach in m^3/sec.

A is the cross-sectional area of flow normal to the flow direction in m^2.

S is the bottom slope of the channel in m/m (dimensionless).

n is a dimensionless empirical constant called the Manning roughness coefficient.

R is the hydraulic radius = A/P.

P is the wetted perimeter of the cross-sectional area of flow in m.

Roughness coefficients represent the resistance to flood flows in channels and flood plains (USGS, 2009).

4 RESULT AND DISCUSSIONS

Based on the objective of the research, the result and discussion are presented in three parts. The first part analyses of current climatology pattern and distribution of different climate parameters (rainfall, and maximum and minimum temperature); the second part has tried to analyze the current and projected future trends of these parameters in order to identify the changing climate over the design. And then finally it has been attempted to estimate the impact of climate change on design parameter by analyzing the peak discharge.

4.1 Test results on hydrologic data

4.1.1 Filling missing data

For this study, to fill the gaps of the missing data is supported by station average method and normal ratio method. In addition to this linear regression method for the missing data and it have no significance difference with normal ratio method because of using the maximum monthly metrological data for design and the station is synoptic or level 1 station so the missing data is very small non recorded day's data.

4.1.2 Rainfall data screening and analysis

Rough rainfall data screening of the three meteorological stations was first done by visual inspection of daily rainfall data. Because of long breaking in rainfall records of some stations, absence of length and overlapping period of record; data screening was done in the record of the hydrologic years of 1994 to 2013. Graphical comparison of the rainfall data done by creating time series plotting of daily rainfall. As shown Figure 4 below the three rainfall stations have similar periodic pattern of records.

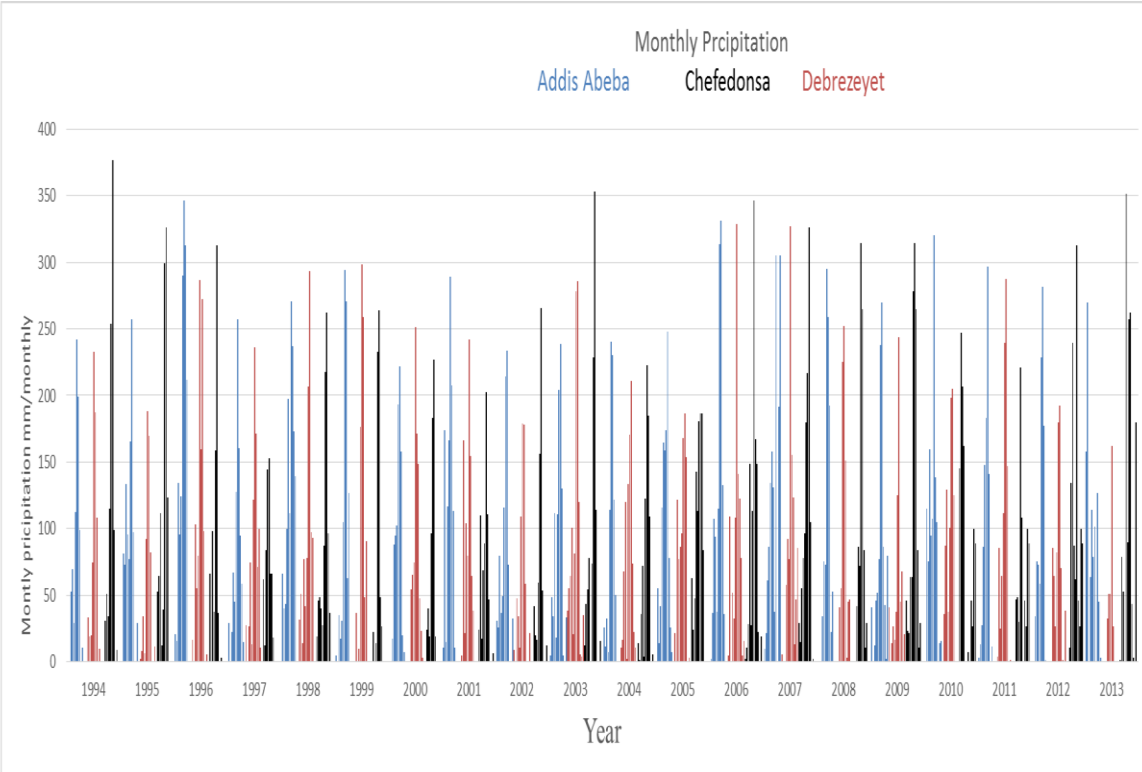


Figure 4.1: Monthly mean rainfall of stations in study area

4.1.3 Test of homogeneity and stationarity

Numerous factors could affect the consistency of rainfall record at a given station. Double mass curve was used to check the homogeneity and consistency of rainfall as well for adjustment of inconsistent data. It is a graph of the cumulative rainfall of interest versus the cumulative rainfall of one or more gauges in the region that has been subjected to similar hydro-meteorological occurrences and is known to be consistent.

The rainfall records of the station x are adjusted by multiplying the recorded values of rainfall by the ratio of slopes of the straight lines before and after change in environment. According to the double mass curves, all the stations were found to be consistent and no need of Correction.

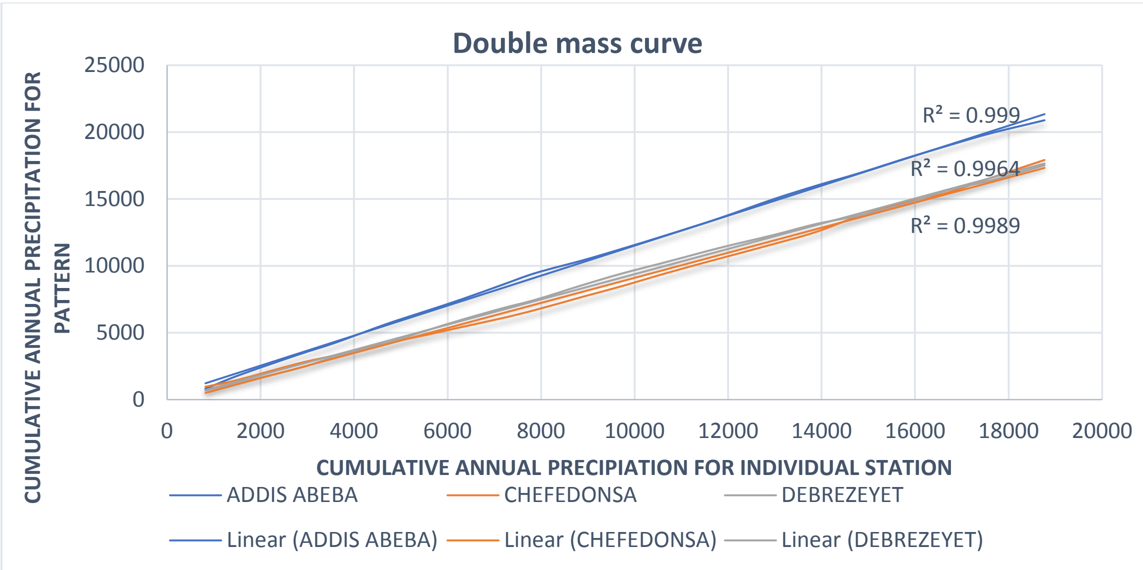


Figure 4.2: Double mass curve for the selected meteorological station

4.1.5 Tests for Outliers

The higher and lower out layer is 92.29 and 25.343 cm respectively. The maximum and the minimum annual rain fall data are 77.5 and 25.334 cm respectively. So there is no high and low outliers at 10% significant level in the annual maximum daily rain fall from 1994-2013 at Bishoftu station.

Hence the standard error of the mean is 6.175 which is less than 10% so we can say that the data series could be as reliable and adequate.

4.1.6 Plotting a distribution

The goodness of fit test by easy fit shows that Gumbel distribution is the best fitted distribution to the sample data and it was ranked in the first place by both test statistics.

Easy fit also estimate parameter for the selected distributions the result of parameters were available in Appendix B please refer it.

4.1.7 Goodness of fit summary

Table 4.1 Fitting distribution and their goodness of statistic test

Fit1

Graphs | Summary | Goodness of Fit

Goodness of Fit - Summary

#	Distribution	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Exponential	0.4668	9	5.0486	9	11.965	9
2	Exponential (2P)	0.20573	7	2.0816	8	0.72625	4
3	Gamma	0.15387	4	0.32431	4	1.2745	5
4	Gamma (3P)	0.16424	5	0.35533	5	1.8268	6
5	Gumbel Max	0.12655	1	0.30706	3	0.06769	1
6	Gumbel Min	0.256	8	1.54	7	2.3657	7
7	Log-Gamma	0.13271	3	0.27925	2	0.25115	2
8	Log-Pearson 3	0.12978	2	0.27525	1	0.26151	3
9	Normal	0.18838	6	0.49777	6	2.6284	8

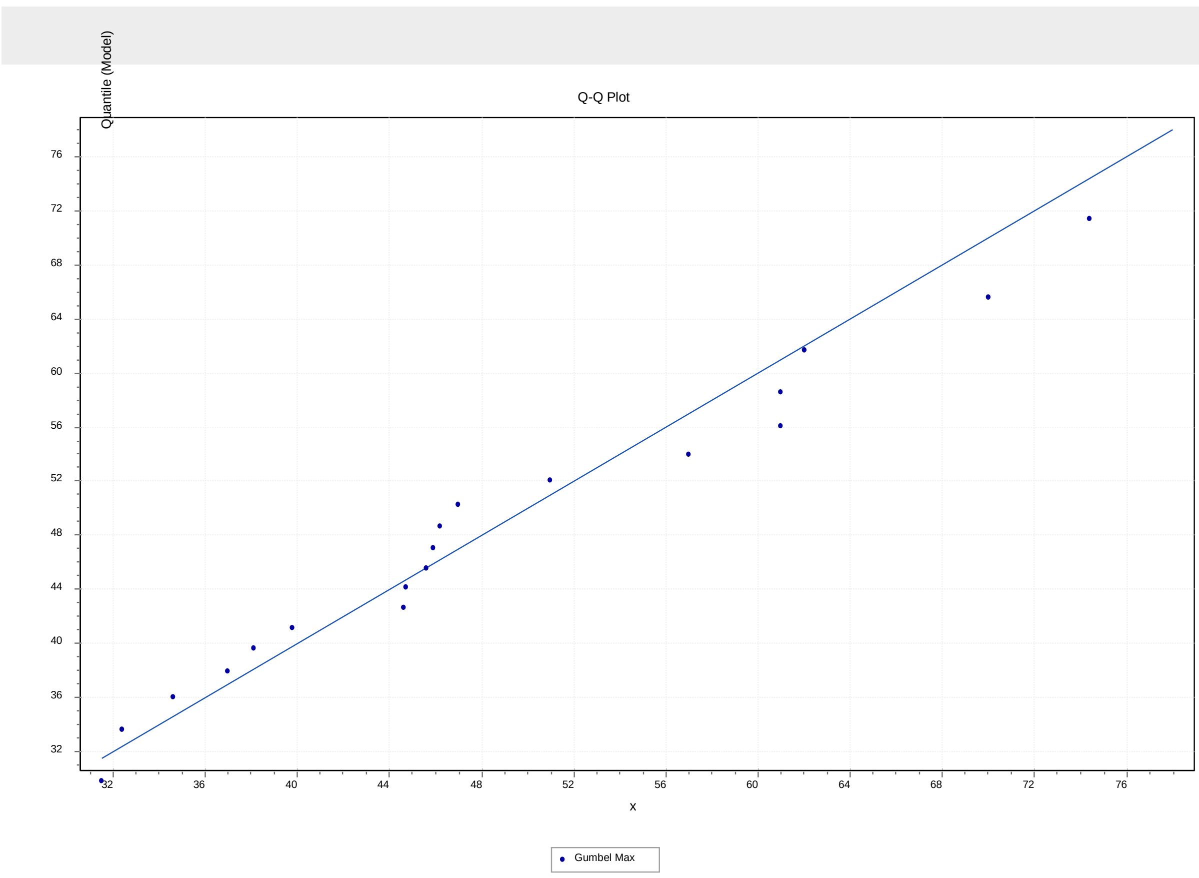


Fig 4.3: Q-Q Plot for 24 h. r Maximum Rain Fall Intensity Predicted using Gumbel Distribution

In additional too easy fit the result of major distribution graph comparison shows that the Log-person 3, Log- person 1 and Log Normal distribution follow the pattern of the recorded rain fall and Normal distribution are lower than the recorded flow. Therefore based on the figure below and Easy fit result the Gumbel is selected for quantile estimation.

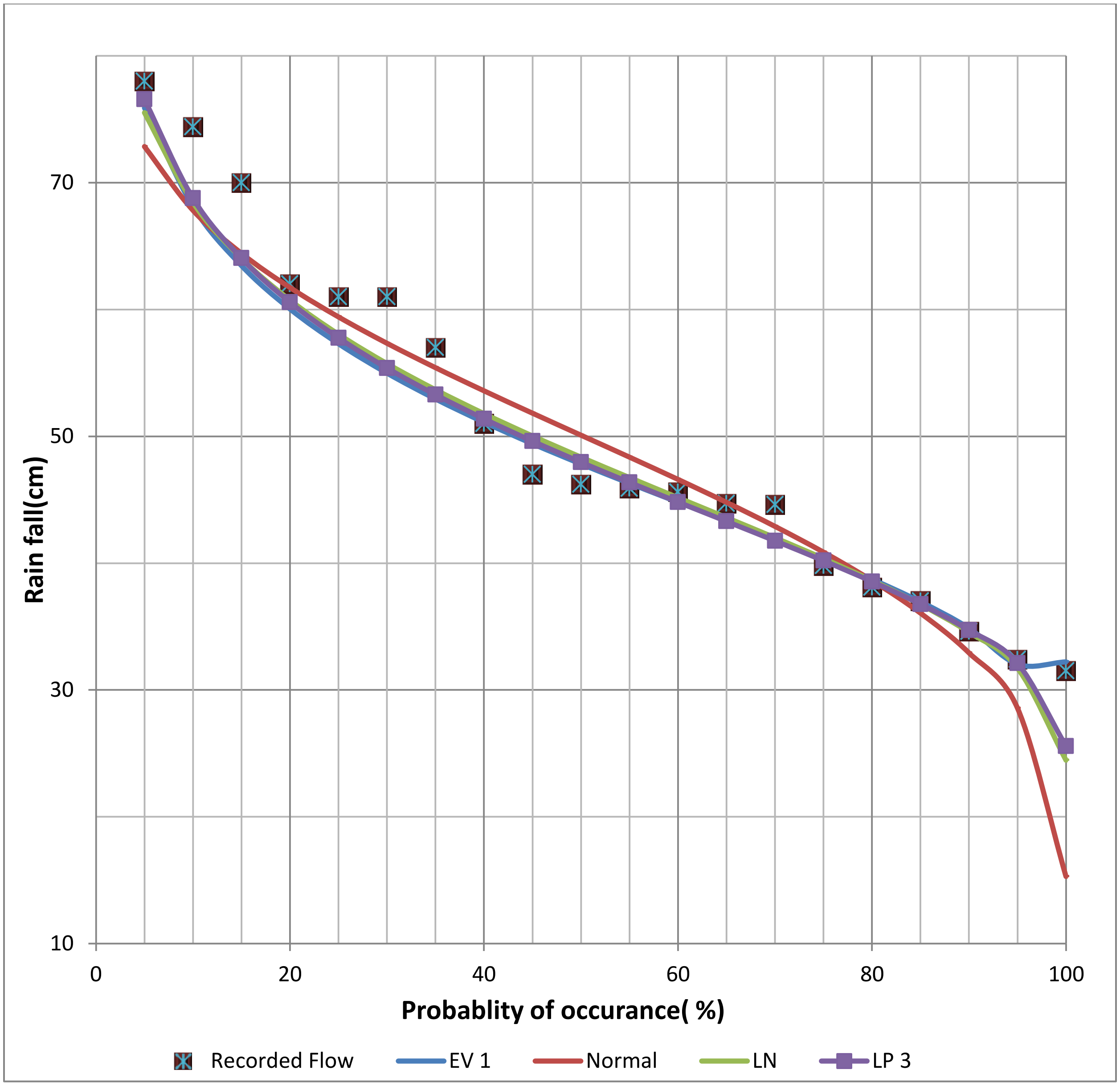


Figure 4.4 Comparison of the Rainfall values to Probability Distribution

4.2 Climate Change Scenario result

4.2.1 Bias correction

In this study bias correction is used to transform CMIP5 projection from REGRID resolution to my study area.

I. Bias correction for Precipitation

The RCP precipitation data has been downscaled by using a nonlinear power transform method and to adjusted the future precipitation the parameters of α and b was found for the year of 12 month is on the table below so the projected precipitation data was corrected before using for analysis by using α and b parameters.

Table 4.2: Corrected factor PCP α and b

month	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
a	15.41937	1.133769	3.582108	2.087751	2.778253	0.669266	0.176234	0.314099	0.141535	0.390149	1.040913	3.720485
b	0.27473	1.992212	0.948189	0.840244	0.720137	1.339322	1.635984	1.434451	1.746528	1.402165	0.811366	0.549104

$P^{*}=\alpha P$…………………………………………………………………………………….....4.1

Where P* is the corrected precipitation α is mean of the transformed daily values corresponds with the observed mean and b which was the correction parameters are subsequently applied to the future climate scenarios. Therefore by using the power transform method the RCP 4.5 and RCP 8.5 for the two time horizon(2020-2040) and (2051-2070) based on the base line period of (1994-2013) was corrected before I used.

II. Bias correction for Temperature

Estimation of bias correction for output CMIP5 projection from REGRID resolution to my study area of temperature using simple linear scaling method to observed average temperature and the observed average temperature. When comparing the historical climatic and generated future climate, it is generally observed that the future of maximum and minimum temperature follows the same increasing behaviors as that of the previously observed condition. But the result shows significant difference from bias uncorrected mean monthly when compared with mean monthly observed data. This result indicates that using both RCP 4.5 and RCP 8.5 output without doing bias correction may lead to uncertainty of hydrological analysis. We do not use a RCP directly first do bias correction.

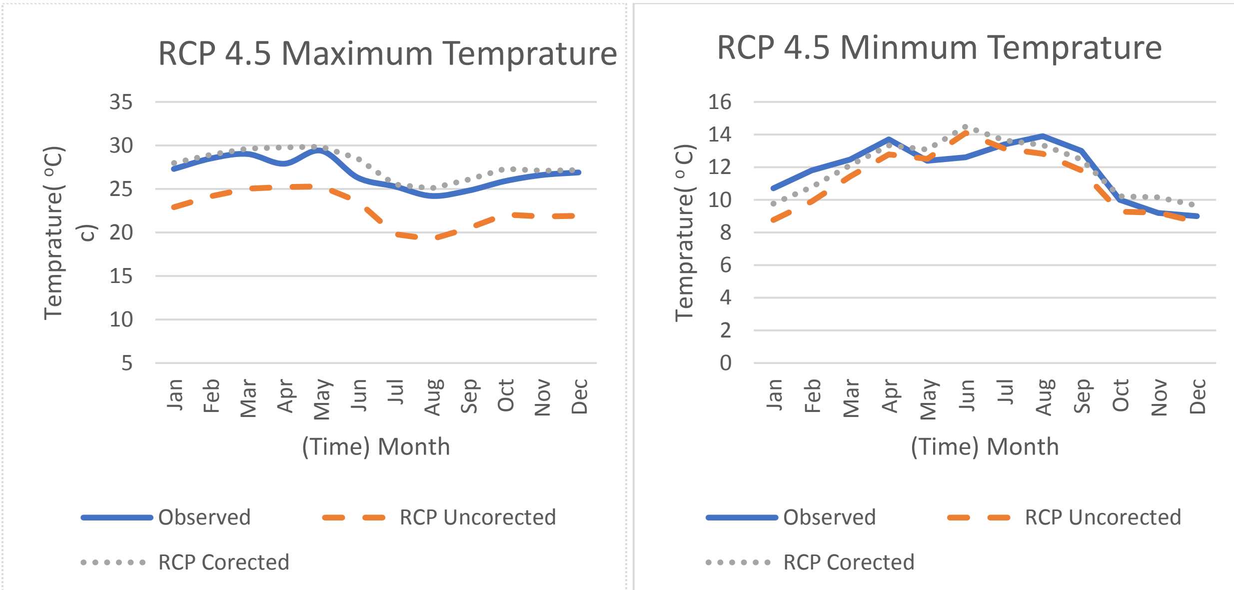


Figure 4.5 Comparisons between Monthly Temperatures Biases Corrected and Uncorrected for the RCP 4.5 and the Observed.

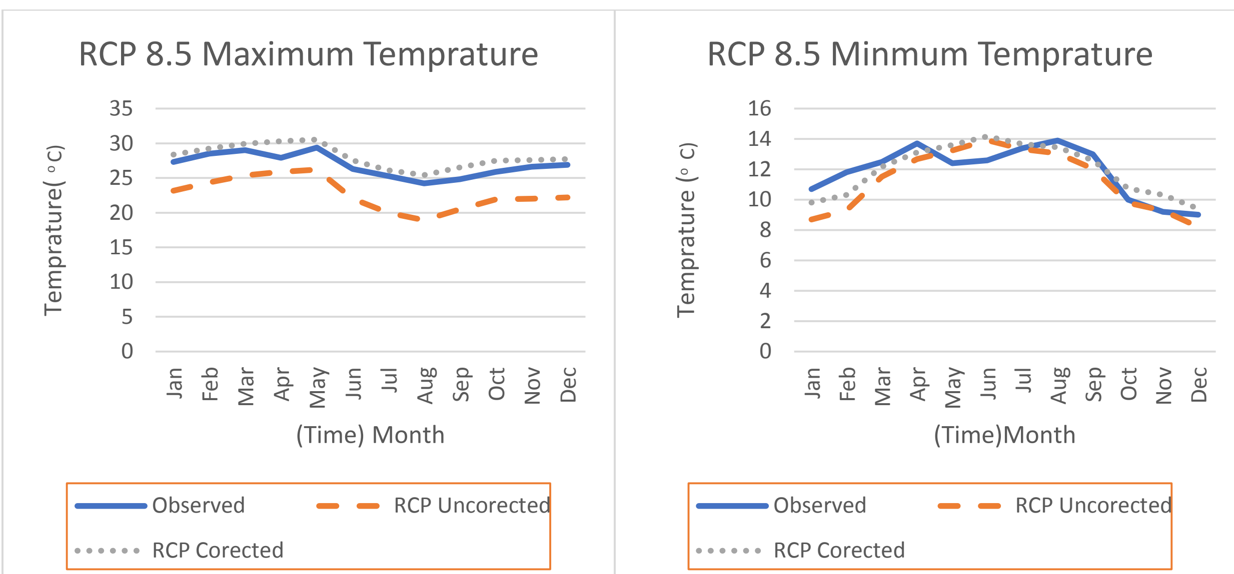


Figure 4.6 Comparisons between Monthly Temperatures Biases Corrected and Uncorrected for the RCP 8.5 and the Observed.

4.2.2 Future projection of Climate Impacts on Precipitation

The corrected RCP precipitation projection exhibited an increase in 5.82% annual mean precipitation in the 2030s but decrease -9.84% in 2060s time periods in RCP 4.5. As it can be seen in figures 4.7 and figures 4.8 in 2030s precipitation increase would be expected during rainy season of January, February, March, May, June and September but it decrease in April and November. In 2060s Precipitation is also expected to increase January, February, September, October, November and December but it decrease March, May and July. The Precipitation change is analyized based on the historical data which was 1994-2013 and for the projected in both RCP 4.5 and RCP 8.5 for the two time horizon which was 2030s (2020-2040) and 2060s (2050-2070).

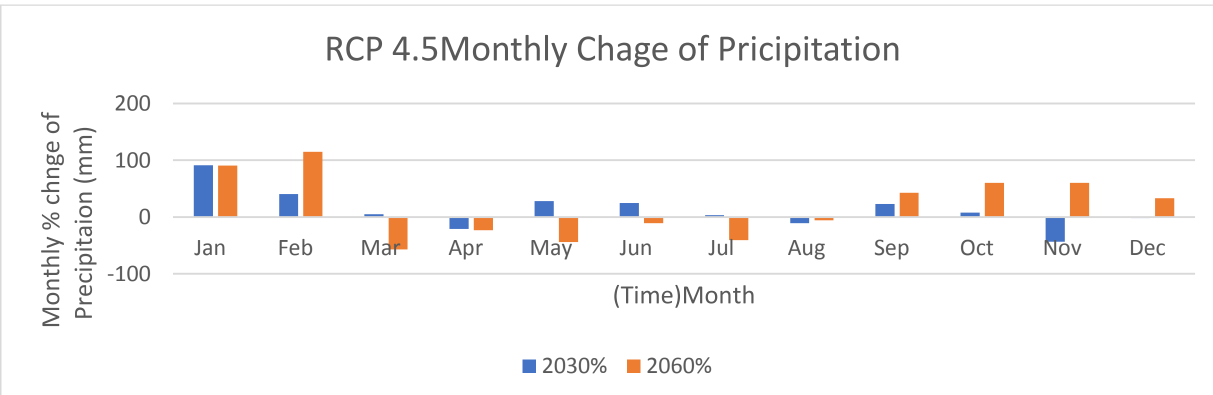


Figure 4.7: Percentage Change in Mean Monthly Precipitation at different Time Horizon under RCP 4.5

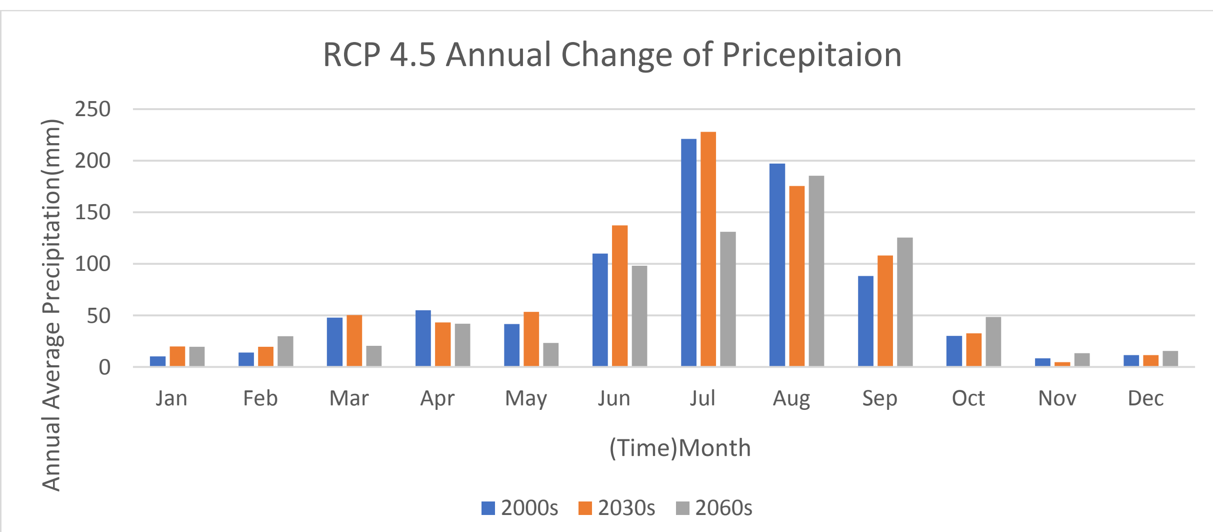


Figure 4.8: Monthly Future Rainfall Distribution for RCP 4.5 Scenario

The analysis of seasonal distribution of rainfall carried out considering the main seasons namely; Kiremt, Bega and Belg. The characteristics of seasonal rainfall pattern for RCP 4.5 scenarios in the three seasons for both bias corrected are presented from figure 4.9. The figure shown in below for bias corrected projections in RCP 4.5 scenarios summarized in table 4.3.

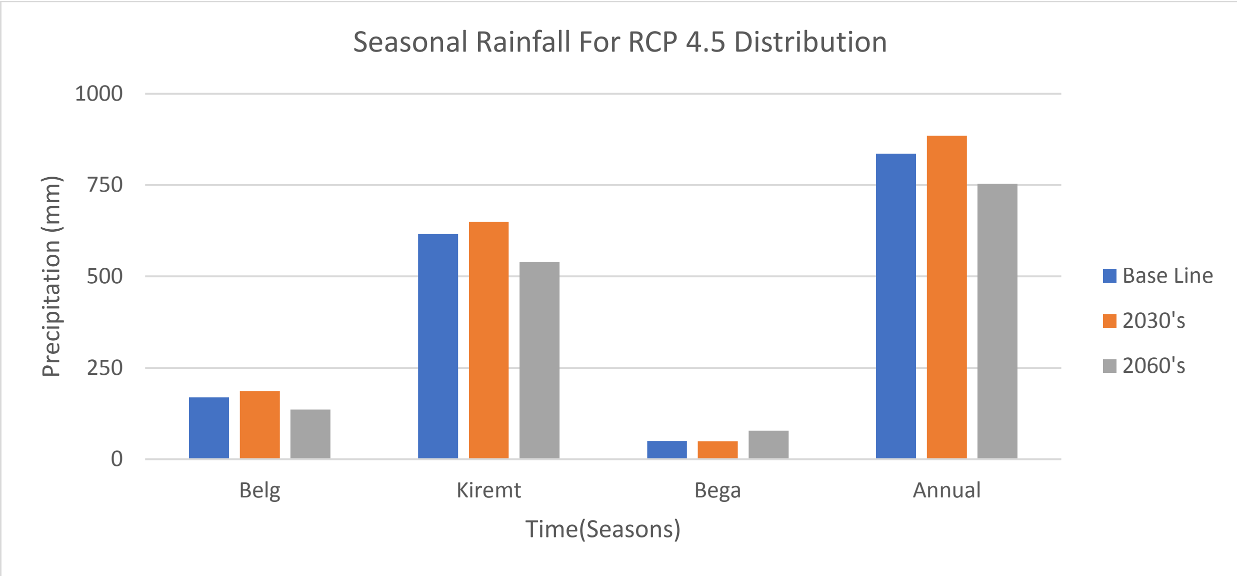


Figure 4.9: Seasonal bias corrected rainfall distribution for RCP 4.5 scenario

The bias corrected seasonal and annual pattern shows that for period 2030's rainfall an increase 10.29% and 2060's there is decrease of-19.71% in Belg season. In Bega, except both of them in rainfall increase by 2.78% and 29.08% for 2030s and 2060s respectively. However, in the case of Belg season the rainfall quantity increase in 2030s and decrease in 2060s.

Table 4.3: Seasonal and Annual Change Rainfall in Percent between Base Line and 2030's and 2060's (RCP 8.5)

Seasonal Change (%)				
Future Projection	Belg	Kiremt	Bega	Annual
2030's	10.29	5.31	2.78	5.83
2060's	-19.71	-12.39	54.12	-9.86

The corrected RCP precipitation projection showed that for the RCP 8.5 decrease mean annual precipitation by -9.73 and -1.97 % of 2030s and 2060s respectively. As it can be seen in figures 5 in 2030s precipitation increase would be expected during January, August, September and November but February, March, April, May, Jun, July, October and December are decrease. In 2060s Precipitation is also expected to increase January, November and September and February, March, April, October, and December, Jun, May and July are decrease.

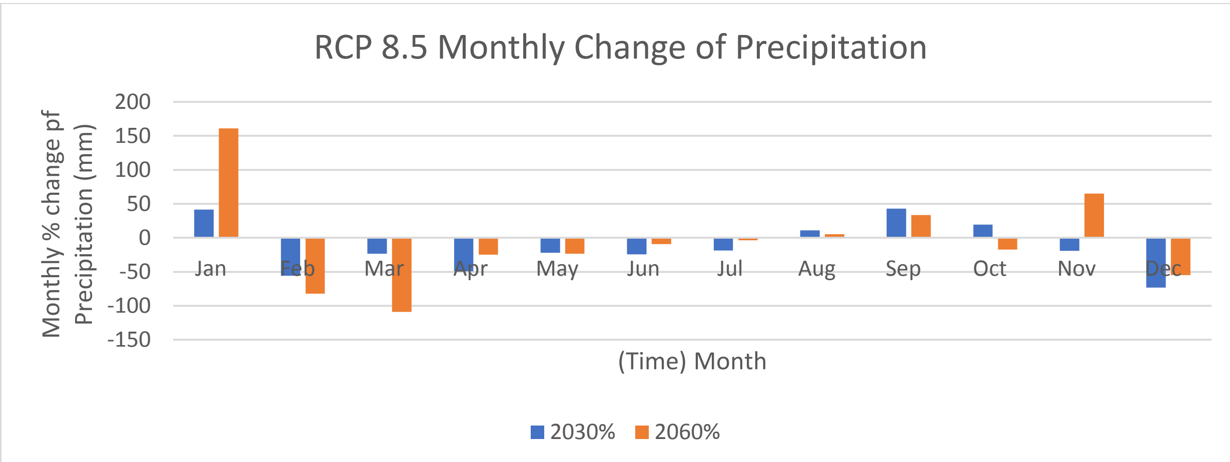


Figure 4.10: Percentage change in mean monthly precipitation at different time horizon under RCP 8.5

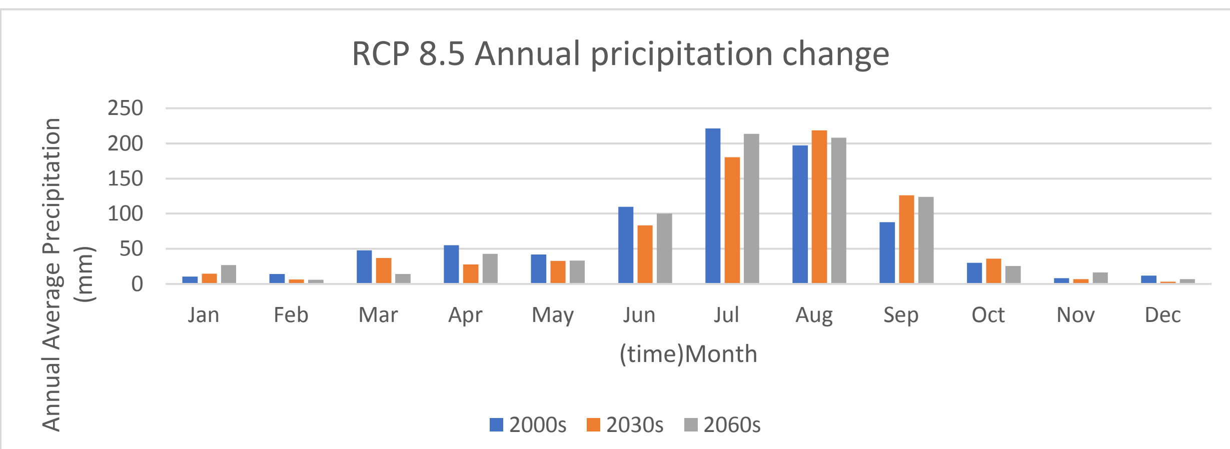


Figure 4.11: Annual precipitation for different time periods

The analysis of seasonal distribution of rainfall carried out considering the main seasons namely; Kiremt, Bega and Belg. The characteristics of seasonal rainfall pattern for RCP 8.5 scenarios in the three seasons for both bias corrected are presented from figure 4.12. The figure shown in below for bias corrected projections in RCP 8.5 scenarios summarized in table 4.4.

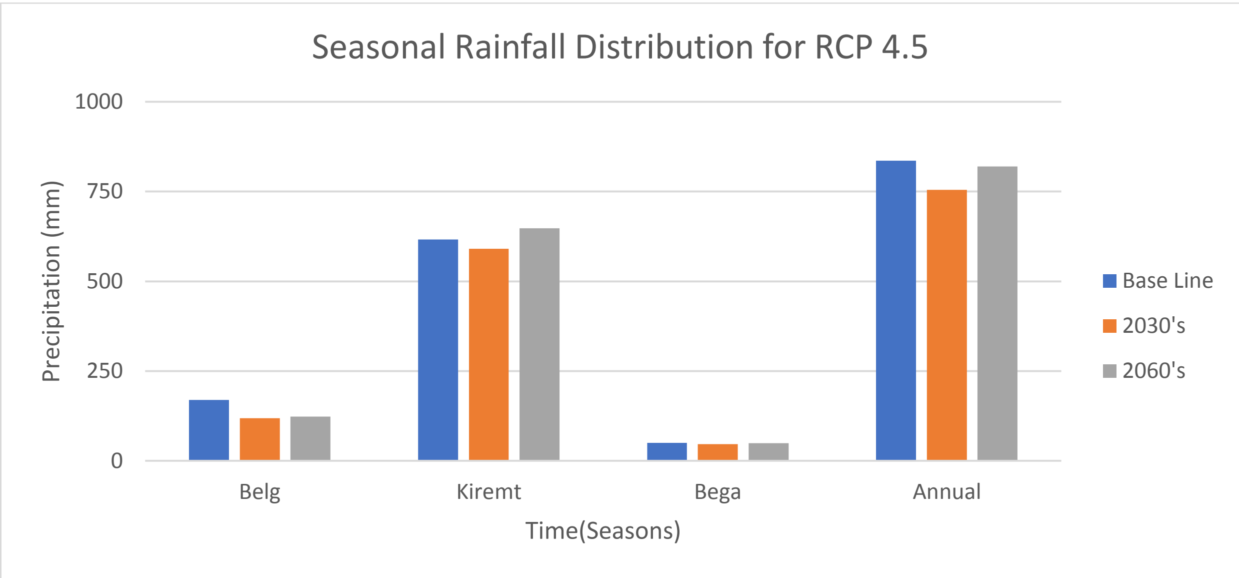


Figure 4.12: Seasonal bias corrected rainfall distribution for RCP 8.5 scenario

The bias corrected seasonal and annual pattern shows that for period 2030’s there is decrease -30.04 and -27.18 % of 2030’s and 2060s respectivelyin in Belg season. And also in Bega, except both of them in rainfall decreas by -9.73% and -1.97% for 2030s and 2060s respectively. However, in the case of kiremt season the rainfall quantity increase in 2030s and decrease in 2060s.

Table 4.4: Seasonal and Annual Change Rainfall in Percent between Base Line and 2030’s and 2060’s (RCP 8.5)

Seasonal Change (%)				
Future Projection	Belg	Kiremt	Bega	Annual
2030’s	-30.04	-4.26	-8.43	-9.73
2060’s	-27.18	5.06	-3.48	-1.97

4.2.3 Maximum and minimum temperature

When comparing the historical climatic variables and generated future climate, it is generally observed that the future of maximum and minimum temperature follows the same increasing behaviors as that of the previously observed condition. Figure 4.13 indicate that relatively, a larger absolute monthly difference from the baseline temperature is found at the month of June, April, September and October. The maximum temperature increases 0.902^{o}C in 2030s and 1.009^{o}C in 2060s also the minimum temperature increases 0.072^{o}C in 2030s and decrease -0.0084^{o}C in2060s under RCP 4.5. The maximum and minumum temprature change is analyized based on the historical data which was 1994-2013 and for the projected in both RCP 4.5 and RCP 8.5 for the two time horizon which was 2030s (2020-2040) and 2060s (2050-2070).

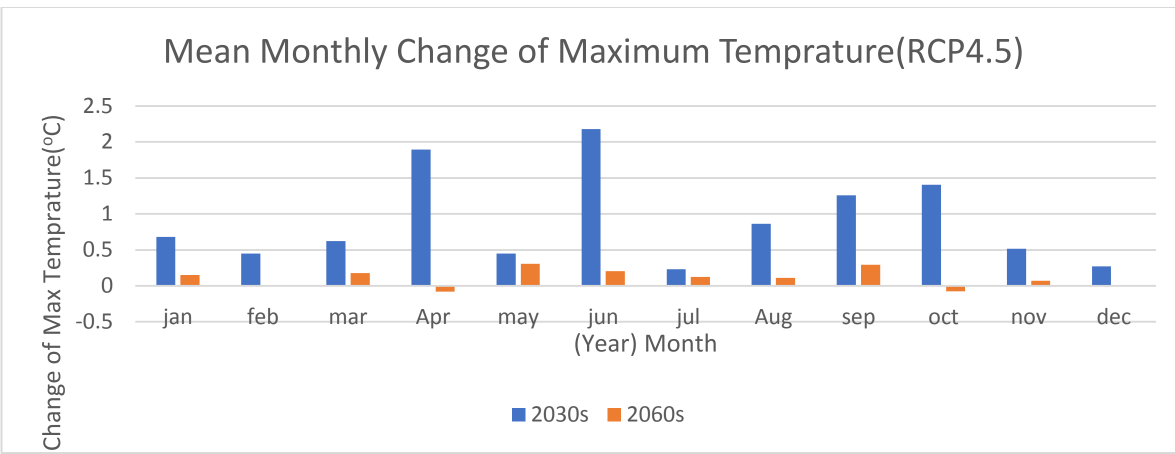


Figure 4.13: Mean Monthly change in Maximum temperature under RCP 4.5

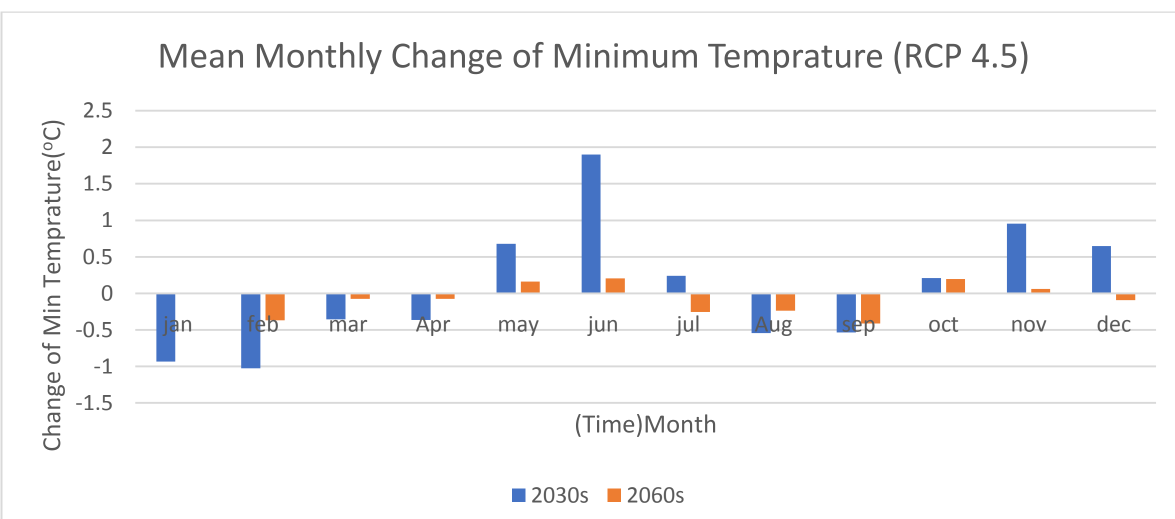


Figure 4.14: Mean monthly change in minimum temperature under RCP 4.5

When comparing the historical climatic variables and generated future climate, it is generally observed that the future trends of maximum and minimum temperature follows the same increasing behaviors or trends as that of the previously observed condition. Figure 4.15 indicate that relatively, a larger absolute monthly difference from the baseline temperature is found at the month of June and April. The maximum temperature increases 1.219°C in 2030s and 0.90°C in2060s also the minimum temperature increases 0.1004°C in 2030s and decrease -0.115°C in under RCP 8.5.

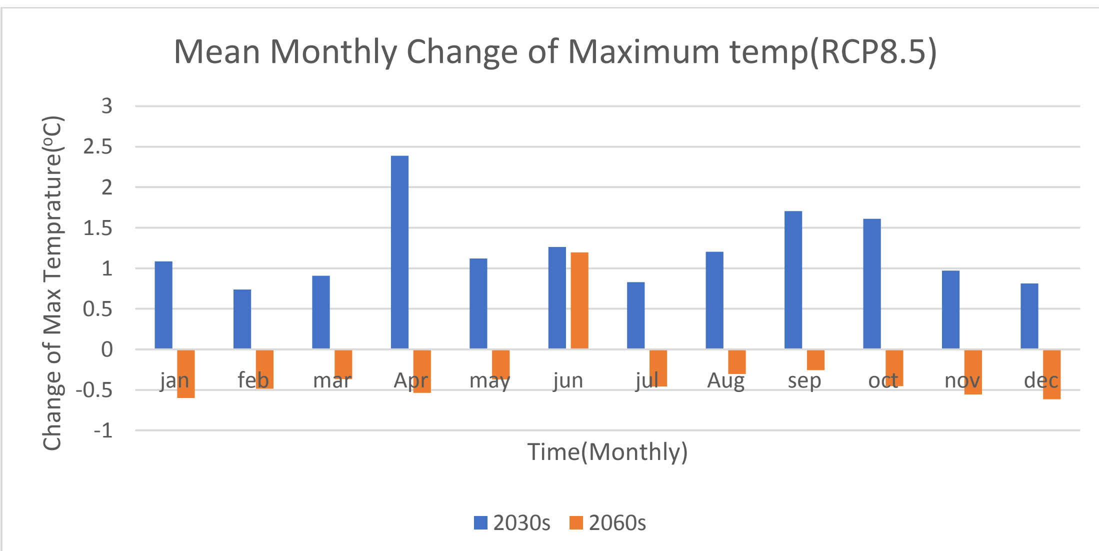


Figure 4.15: Mean monthly change in Maximum temperature under RCP 8.5

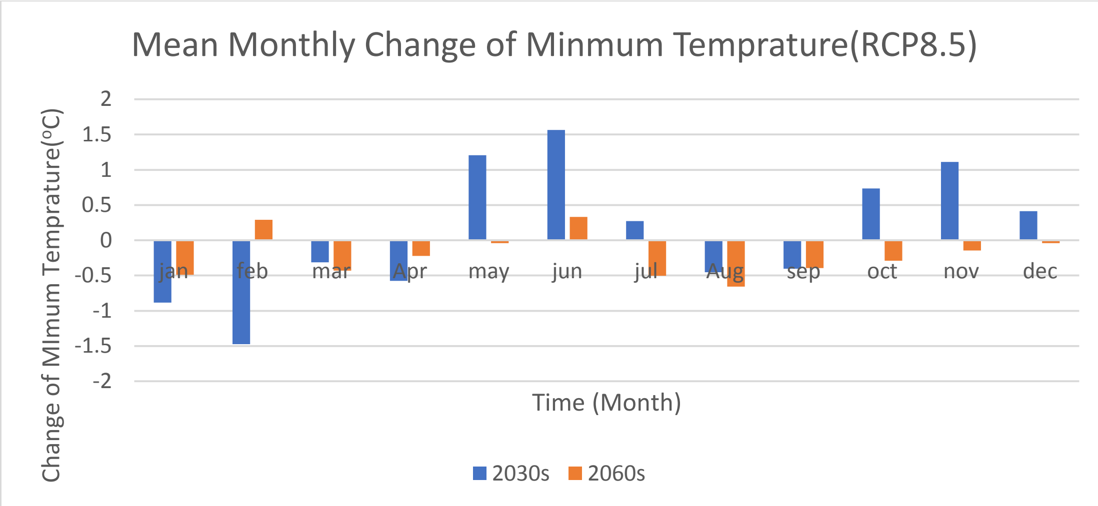


Figure 4.16: Mean monthly change in minimum temperature under RCP 8.5

Generally when comparing the historical climate the maximum and minimum temperature follows the same increasing behaviors as that of the previously observed condition under both RCPs and in the case of the precipitation, the future condition exhibits a fluctuating i.e. it does not reveals a systematic increase or decreasing in the future, this is due to complicate nature of precipitation processes distribution in space and time and its uncertainty under both RCPs.

4.3 Hydrologic Analysis

On Bishoftu city drainage structures the maximum peak flood is computed taking in to consideration of the climate change and the design life span of the structure for 2, 5, 25, 50 and 100 year return period.

Therefore, for the tow case of observed and the projected for the two watershed area is analyzed. And the future is analyzed by considering the two scenario of RCP 4.5 and RCP8.5.

Case 1 during the base line period of 1994-2013

Case 2 during the future period of 2020-2040 and 2050-2070 in RCP 4.5 and RCP8.5

Rainfall Characteristics

Bishoftu receives a mean annual rainfall of about 839.6 mm with a standard deviation of about 148 mm according to the monthly average rainfall data of 20 years from 1994 to 2013.

Maximum Daily Rainfall

In drainage design the short period rainfalls such as the maximum 24-hour rainfall or even the hourly maximum rainfalls are more important than the monthly and annual means. The shortest period rainfall data at Bishoftu is the maximum 24-hr rainfall as obtained from NMA in appendix and the future maximum 24-hour rain fall is obtained from RCP 4.5 and RCP 8.5.

4.3.1 Rainfall Frequency Analysis

As the above I show on the goodness of fit test by easy fit and by the graph shows that Gumbel distribution is the best fitted distribution to the sample data and it was ranked in the first place by both test statistics. The maximum 24 hr. rain fall of observed and maximum rainfall of the projected with RCP4.5 and RCP 8.5 scenario is analyzed by EVI distribution after the bias corrected the result is on the table 4.5below.

Rainfall Frequency Analysis of the future

The maximum rainfall of the observed (1994-2013) and the projected (2020s2040s) and (2050s-2070s)with RCP4.5 and RCP 8.5 scenario is analyzed by EVI distribution because the rain fall value is bias corrected the value of the bias correction is in the table below.

Table 4.5: Future rainfall frequency analysis

R.T	Observed	RCP 4.5		RCP 8.5	
	1994-2013	2021-2040	2051-2070	2021-2040	2050-2070
2	47.818	70.537	55.537	57.681	57.722
5	60.043	91.128	100.656	78.682	85.675
10	68.137	104.761	130.529	92.586	104.182
25	78.363	121.986	168.274	110.154	127.566
50	85.950	134.765	196.275	123.188	144.913
100	93.481	147.449	224.069	136.125	162.133
500	110.884	176.761	288.297	166.020	201.924
1000	118.365	189.362	315.910	178.872	219.031

Design frequency

For drainage structure have been designed for a different return period of years. This is a period at which the design rainfall discharge is equaled preceded.

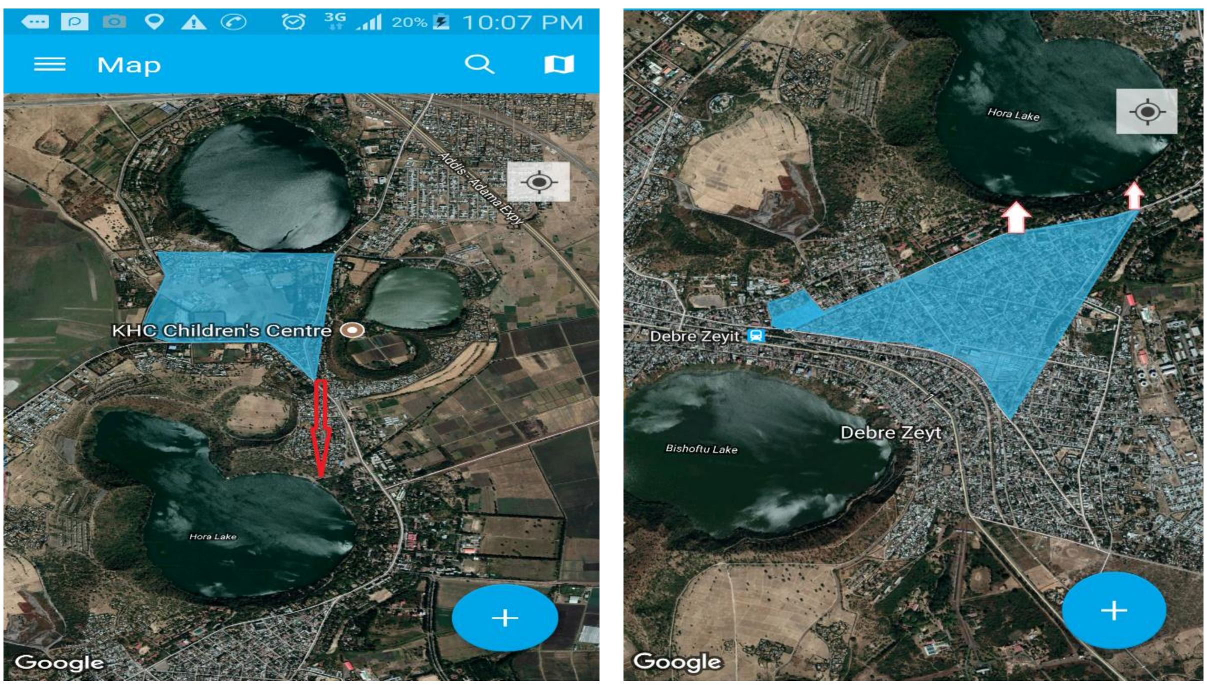
24- Hour Rainfall, P

Bu using the 24-hour rain fall data the 24-hour Depth Frequency relationship have been developed in this section by EVI distribution method has been used on applying the SCS method. Here a 24-hour rainfall for different years of return period is used.

4.3.2 Computation of Catchment Parameters

Catchment Parameters of sample calculation

The watershed area for the two catchment is delineated by using Geo area calculator based on the drainage base map of the city and filed survey. The flow direction map and the catchment areas of the KH and Market are showed in figure15.



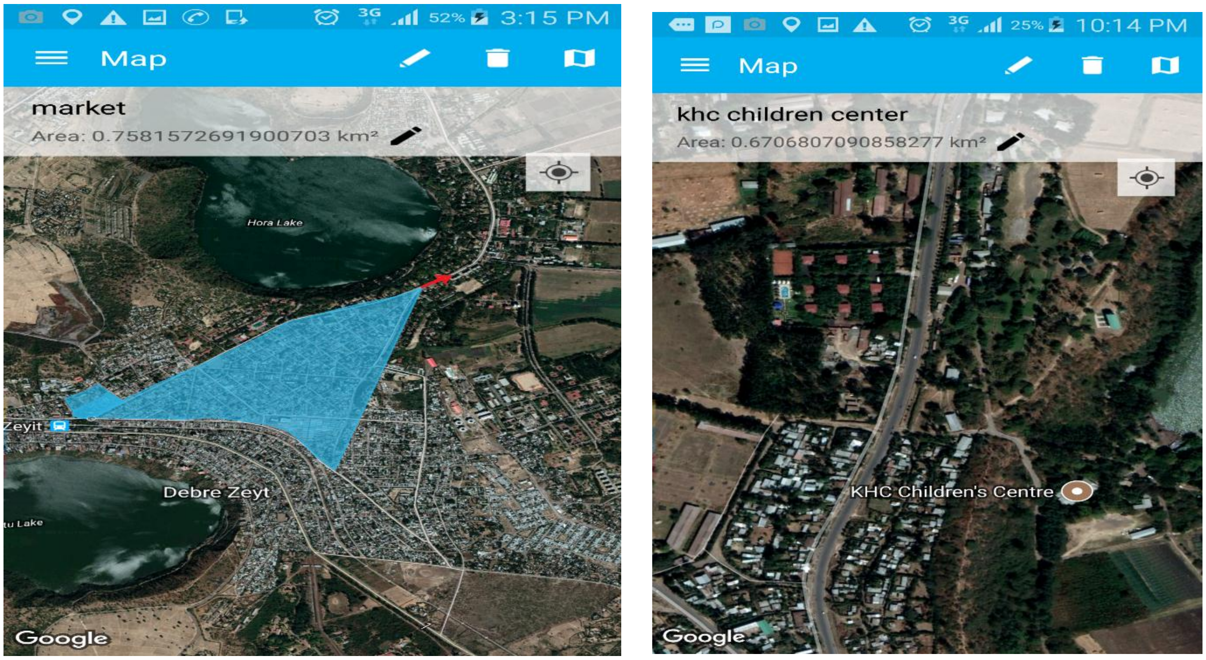


Fig 4.17 flow direction map of the watershed with delineated catchment area

I. Runoff Curve Number

The land use land cover of the sub basin in is done by using field Survey and by helping of Google earth so the estimated land use of the two area are determined for the KHC area within 0.67 km^2

0.134 Km2 is covered by pasture land in poor condition, 0.335 km^2 is covered by Residential district by average size plot size 0.05 hectares or less and the remaining are 0.201 is cover by open space with fair condition of grass cover 50 to 75% under soil group D. And for the Market area which is the total of 0.758 km^2 cover by Residential district by average plot size of 0.05 hectare or less under soil group is 0.0604 km^2 and urban district commercial and business area 0.156 km^2 so the CN is obtained From ERA manual. This land use land cover estimation is not exact it may have some error but the value here is reasonably assigned.

The CN of KHC under hydrological soil group D is computed

Weighted CN= ((89 x 0.134) + (84x0.201))+92*0.335/0.67

= 89

And for the Market

Weighted CN= (0.6064*92 +0.1516*93)/ 0.758

=92.3

II. 24-hour rainfall depth

From the analysis of EVI frequency distribution for 24 hours depth frequency curve shown in Table above, the 25 years return period rain fall is obtained 78.36mm.

III. Time of concentration

To determine the time concentration the catchment characteristic of the two water shed is determined by Google earth, Geo area calculator and filed survey here in below is summarized and by using those 0.94 hr. and 1.108 hr is computed for KHC and market.

KHC Area =0.67km^2

Stream length 1.268 km

H1=1874

H2= 1772

Slope=0.00157

CN=85 and CN wet 96.66

Market Area=0.758 km^2

Stream length 1.673 Km

H1= 1975

H2=1972

Slope= 0.00179

CN=92.6 and CN wet=93.2

A. Peak Runoff

The following equation were used for the estimation of the peak discharge in SCS method is

Design Peak Discharge, $Q_p = Q_u * Q * A$

Where, Q p= Design Peak Discharge, m^3/sec

Q_u=Unit Peak Discharge, m^3/sec/100ha/mm

Q= Direct Runoff, mm

A= Area of the catchment, ha

For the market design of the drainage Q 25 for the RCP 4.5 is increased by 41.5 % in 2030s and also increased by 58.5 % in 2060s again in the RCP 8.5 increased by 34% in 2030s and increase by 44% in 2060s.

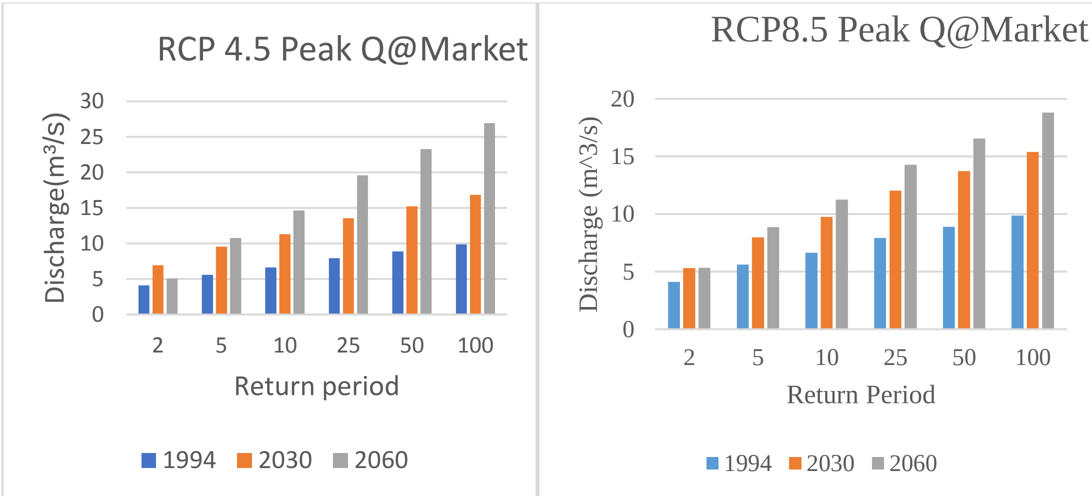


Figure 4. 18 Sample RCP results for Discharge RCP 4.5 and RCP 8.5 Market

For the KHC design of the drainage Q 25 for the RCP 4.5 is increased by 38.65 % in 2030s and also increased by 56.5 % in 2060s again in the RCP 8.5 increased by 31.45% in 2030sand increase by 41.55% in 2060s.

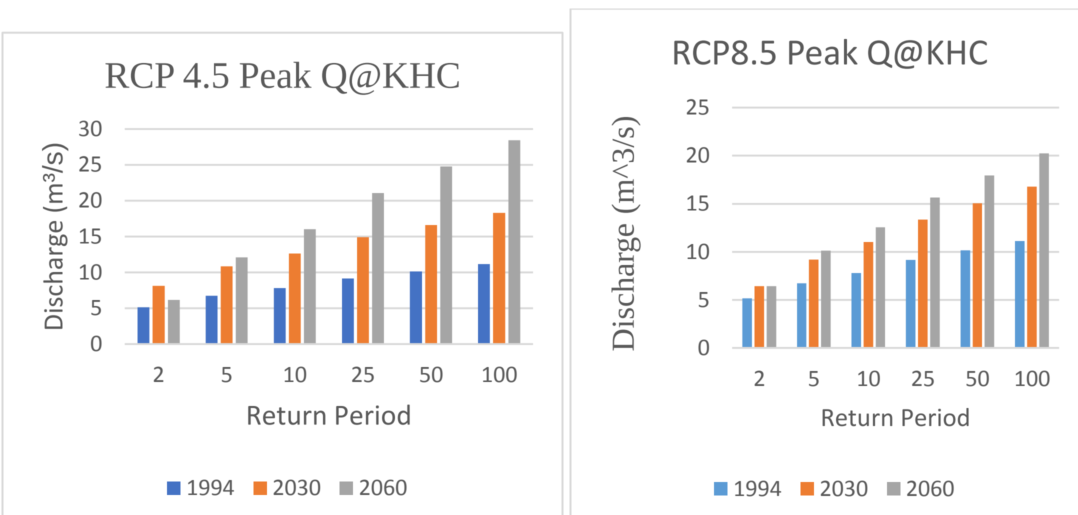


Figure 4. 19 Sample RCP results for Discharge RCP 4.5 and RCP 8.5 KHC

Table 4.6 Design discharge for market and KHC

			Market peak Discharge				
RCP	year	2	5	10	25	50	100
	1994	4.117038	5.618744	6.632245	7.927542	8.896364	9.863127
	2030	6.935021	9.560598	11.3186	13.55379	15.21911	16.87657
4.5	2060	5.060498	10.78807	14.66656	19.60484	23.28326	26.94216
	2030	5.325521	7.968081	9.748023	12.01704	13.71012	15.39657
8.5	2060	5.330583	8.86107	11.24367	14.28028	16.54488	18.7995

		KHC PEAK DISCGRGE					
RCP	year	2	5	10	25	50	100
	1994s	5.148643	6.740847	7.801101	9.14518	10.14461	11.13811
4.5	2030s	8.11624	10.82757	12.62831	14.90738	16.60003	18.28136
	2060s	6.152514	12.0858	16.03884	21.04354	24.76015	28.45124
8.5	2030s	6.432261	9.187089	11.02	13.34152	15.06644	16.78019
	2060s	6.437597	10.10827	12.55173	15.64626	17.94513	20.22878

4.4 Hydraulic Design

The hydraulic design is analysis depend on the value of the hydrological so from this the all parameters of hydraulic design change because to determine the hydraulics parameter of the given drainage type of cross-sectional area as well as the other parameter are dependent on the value of design discharge so in my study under the two time horizon on RCP4.5 and RCP8.5 scenario show that the peak design discharge change overtime and in different scenarios is computed by using hydro tool box.

So the result show that it require addition width and depth of the canal so when we compare the width and the depth of the KHC value in 2030 is increased by 19.2% and 18.9% respectively and for 2060s the width increase by 29.56% and width by 29.31% increased. When we see the RCP 8.5 the width and depth is increased by 14.8% and 15.57% in 2030s and 20.34% width and 20.8% depth is increased in 2060

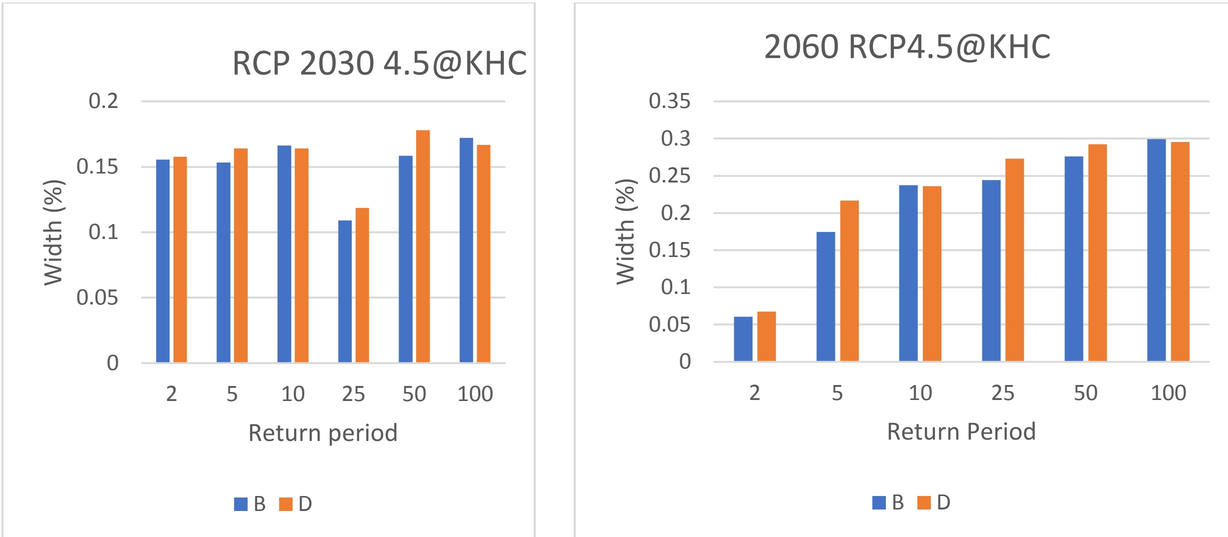


Figure 4. 20 Sample RCP results for Depth and Width of RCP 4.5 and RCP 8.5 KHC

When we compare the width and the depth of the market value in 2030 is increased by 10.9% and 11.18% respectively and for 2060s the width increase by 24.4% and width by 27.7% increased. When we see the RCP 8.5 the width and depth is increased by 12.2% and 14.77 % in 2030s and 17.7% width and 18.76 % depth is increased in 2060

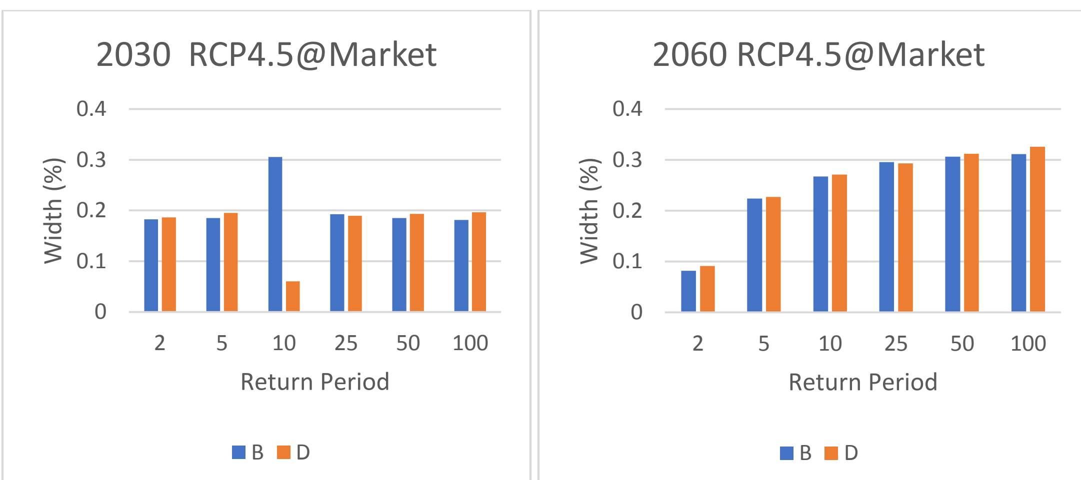
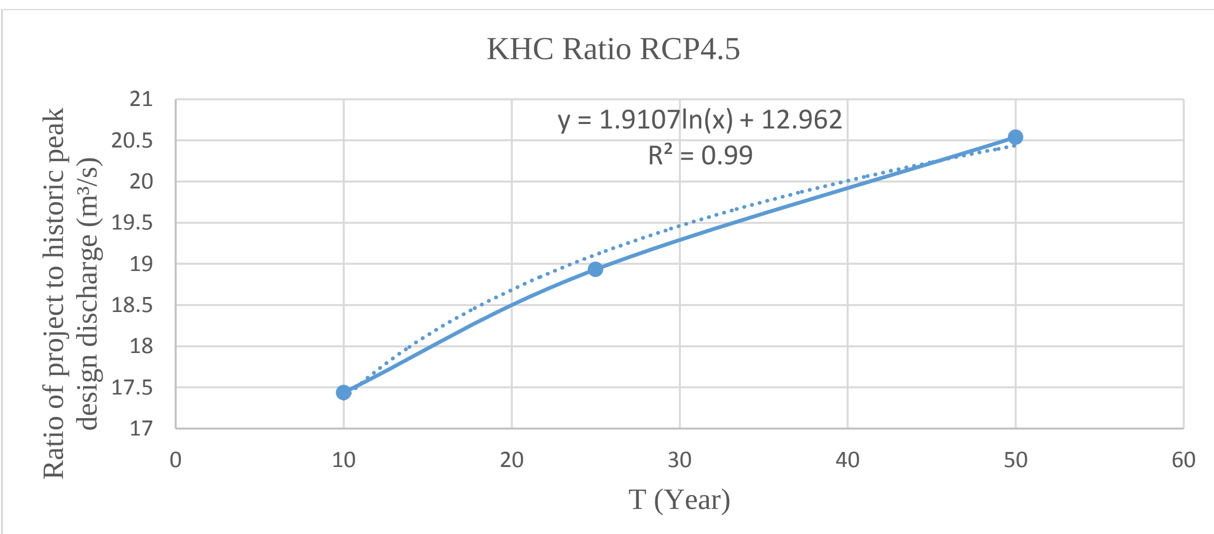


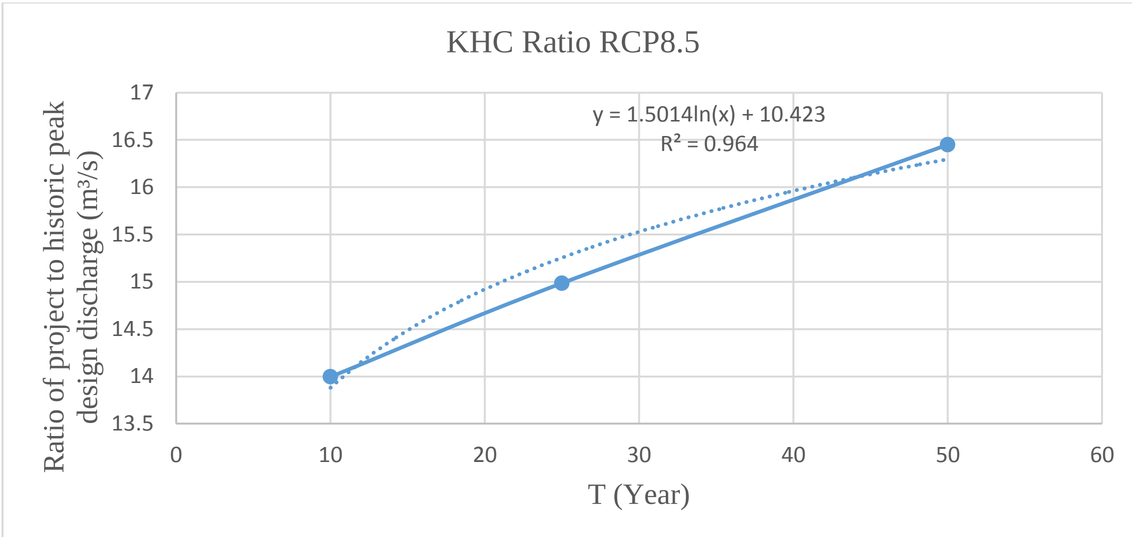
Figure 4. 21 Sample RCP results for Depth and Width of RCP 4.5 and RCP 8.5 Market

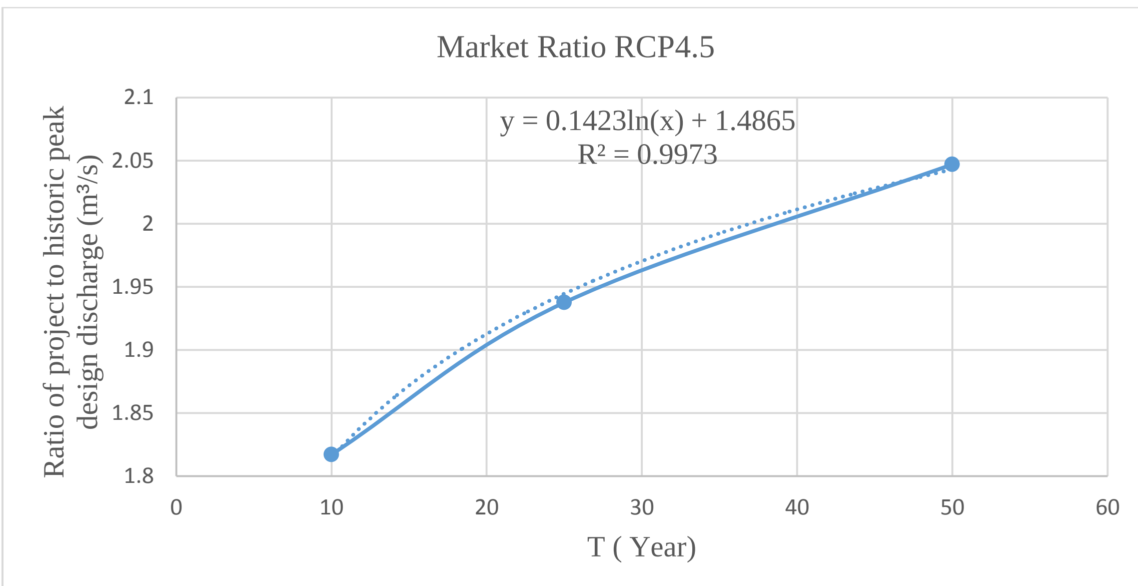
Table 4.7 Hydraulic Parameter for market and KHC

			2	5	10	25	50	100
width %			0.155444	0.153247	0.166161	0.109157	0.158443	0.172122
KHC	4.5	B	0.157706	0.163987	0.164134	0.118541	0.178082	0.166667
2030		D	0.060558	0.174684	0.237382	0.244342	0.275943	0.299061
	4.5	B	0.06746	0.216867	0.236111	0.273183	0.292453	0.295302
2060		D	0.076742	0.10929	0.121406	0.126635	0.127345	0.145038
	8.5	B	0.082031	0.109589	0.121406	0.136905	0.147727	0.139344
2030		D	0.081776	0.136424	0.162096	0.177031	0.182641	0.202036
	8.5	B	0.078431	0.144737	0.164134	0.187675	0.202128	0.198473
width %			2	5	10	25	50	100
Market	4.5	B	0.182663	0.185363	0.305205	0.192308	0.184908	0.180963
2030		D	0.186047	0.195205	0.06015	0.189189	0.193084	0.196676
	4.5	B	0.081739	0.223598	0.267052	0.295597	0.306032	0.311628
2060		D	0.090909	0.226974	0.271137	0.293194	0.312039	0.325581
	8.5	B	0.09589	0.126833	0.13624	0.155779	0.154719	0.144509
2030		D	0.102564	0.139194	0.146758	0.148265	0.159159	0.169054
	8.5	B	0.09589	0.161268	0.179288	0.208481	0.209497	0.214437
2060		D	0.102564	0.172535	0.193548	0.20354	0.217877	0.226667

To design the drainage in the Bishoftu city by considering climate change we can applying depend on this relationship which is describe in the figure below. This is the trend of the study area so we can easily use this equation to design the drainage with climate change.




KHC Ratio RCP8.5
y = 1.5014ln(x) + 10.423
R² = 0.964
Ratio of project to historic peak design discharge (m³/s)
17
16.5
16
15.5
15
14.5
14
13.5
0
10
20
30
40
50
60
T (Year)


Market Ratio RCP4.5
y = 0.1423ln(x) + 1.4865
R² = 0.9973
Ratio of project to historic peak design discharge (m³/s)
2.1
2.05
2
1.95
1.9
1.85
1.8
0
10
20
30
40
50
60
T (Year)

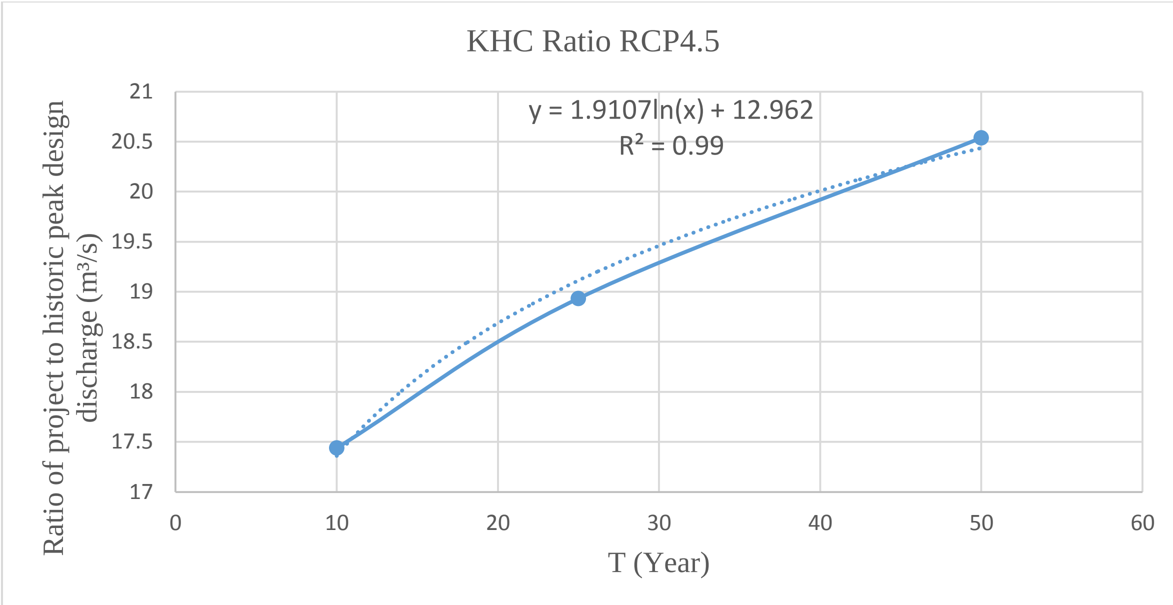


Figure 4.22 Ratio of future over historical instantaneous peak flows versus return period T

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The possible impacts of climate change remain a risk in future development activities especially in developing countries like Ethiopia. Hence it is important to assess the effect of climate change on Bishoftu city drainage design. In this study, the trends of precipitation and temperature have been analyzed for current and two future time horizons (2020-2050) and (2051-2070) then runoff modeling for the three sub watershed can be assed under climate changing which can be evaluated in response to the RCP 4.5 and RCP8.5 scenarios. Power transformation bias correction methods was used to improve the simulation output of RCP with high correlation to the observed data Hydrological model SCS was used to simulate the design discharge. The study shows the effect of climate change in Bishoftu city on dringe design at different recurrent interval. The recorded hydrological data of Bishoftu station is (synoptic) good quality, homogenous and stationary moreover it fit with Gumbel distribution.

The Bishoftu city precipitation is projected to increase by 4.77% in RCP 4.5 2030s and by 1.93% in 2030s of RCP 8.5, and it also decrease by 3.96% and 0.53% in 2030s and 2060s. Under the scenarios of RCP4.5 and RCP8.5 relative to the 1994–2013 base, while much larger variability is seen in the spatial distribution of precipitation.

Max temperature is increased by 0.62^{o}c, 1.48^{o}c, 1.72^{o}c and Minimum temperature is increased by 0.5^{o}c, 1.39^{o}c, 1.14^{o}c, 184^{o}c of RCP 4.5 and RCP 8.5 respectively.

Generally, the projected maximum and minimum temperature shows an increasing trend for the next century, but the precipitation could not able to replicate the historical (observed) data. This is due to complicated nature of precipitation processes distribution in space and time and its uncertainty. The projected precipitation reveals an annual increase for 2040s, but for the case of 2060s decreasing annual precipitation is observed

The recorded metrological data of Bishoftu gauging station is good quality, homogenous and stationary and bias Corrected with the two future time horizons (2020-2050) and (2051-2080) under the response of both the RCP 4.5 and RCP8.5 scenarios again it fit with Gumbel distribution.

The quantile estimation by Gumbel, for difference recurrence time is become 2, 5, 25, 50 and 100 years are 47.818, 60.043, 68.137, 78.363, 85.95, 93.481, 110.884 and 118.365 respectively. The sub water shed along the city has been delineated and calculated by Google Earth with interfacing of The design discharge that shows for different return period under the two time horizons with both future scenarios helps to give a great concern about the climate change effect for drainage design for designer and police maker

Finally the design discharge amount is change in Market area by RCP 4.5 in 2060 is change by 63.3% Max and Minimum 18.64% in RCP 4.5

Average design discharge, channel width and depth will increase up to 60.8% Max and 16.9% Min , 29.9% Max and 6.05% Min, and 20.21% Max and 6.7% Min depth is changed in KHC respectively. And for the design discharge of market area Max 63.3% and Min 18.64%, the width of channel is changed by 31.16% Max and 8.17% Min, and also the depth of the channel 32.22% Max and 9.09% Min also change.

5.2 Recommendation

Generally from this specific study the following main pointes are strongly recommended;

- ✓ To make the evaluation of climate change impact more complete, it is significant to use physically based with higher resolution.
- ✓ Serious consideration should be given to the requirements of storm water management and the need for future up grading of drainage infrastructure capacity (associated with both climate change as well as urbanization) during the initial planning and design stages of development.
- ✓ Further studies which integrate the impact of climate change with land use and land cover change, by plus RCP 2.5 and RCP 6.5climate scenario the drainage design should be undertaken using a physically distributed hydrological modelling
- ✓ Due to the difficult associated with upgrading the hydraulic capacity of urban drainage infrastructure, planners and designers of urban drainage infrastructure should pay particular attention to the effects of climate change.

Reference

Abayneh Alemu (2011) Evaluation of climate change impact on extreme Hydrological event case study: addis ababa and surrounding catchment.

Agnew, L.J., Lyon, S.W., Gérard-Marchant, P., Collins, V.B., Lembo, A.J., Steenhuis, T.S., Walter, M.T. (2006). Identifying hydrologically sensitive areas: Bridging the gap between science and application. Journal of Environmental Management, 78, 63-76.

Arisz, H. and B. C. Burrell, 2006. Planning and design of urban drainage infrastructure considering climate change. In: Proceedings of Canadian Civil Engineer Conference, 9 pp.

Bäckman,, G., Orlando, B., and Burton, I. adaptaion of water managment to climate chage. International union for conseravation of natural and natural resource, Gland & cambridge,UK. 1985)

Berggren, S., & Kansal, S. (2007). Economic Insight into municipal solid waste management in Mumbai: A critical analysis. Int. J. Environment and Pollution, 19(5), 516-517

Bernes C. (2003). A Warmer World, Swedish Environmental Protection Agency and SMHI (SWECLIM), Ödeshög

Beven, K.J, 2000. Rainfall-runoff modelling. The Primer. Wiley, 360 p.

Bishoftu Finance & Economic Development Bureau, Profile Report, 2008

Carter, E. B.; Theodorou, M. K.; Morris, P., 1999. Responses of Lotus corniculatus to nvironmental change. 2. Effect of elevated CO2, temperature and drought on tissue digestion in relation to condensed tannin and carbohydrate accumulation. J. Sci. Food Agric., 79 (11): 1431-1440

Chocat, B. et al., 2006. Toward the sustainable management of urban storm-water. Indoor and Built Environment, 16(3): 273-285.

Chow, V.T. Maidment, D.R. and Mays, L.W. 1988. Applied Hydrology, McGraw Hill, New York, NY.

Christensen, J. H., Boberg, F., Christensen, O. B., & Lucas-Picher, P. (2008). On the need for bias correction of regional climate change projections of temperature and precipitation. Geophysical Research Letters, 35(20).

Clarke M,Rana, A. (2007)- GCAM Coupled Model Inter-comparison Project Phase 5 CMIP5)

Climatic Change (2011).

Conway, D. 2011. Adaptation to climate change in Africa: challenges and opportunities identified from Ethiopia. Global Environmental Change, 21(1), 227-237.

Conway. D., 2005. A water balance model of the Upper Blue Nile in Ethiopia, Hydrological Sciences Journal des Sciences Hydrology, 42(2).

Cubash, U., 2001. Projections of Future Climate Change in Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate.

Cunderlik M. Juraj, October 2003. Hydrologic model selection fort the CFCAS project: Assessment of Water Resources Risk and Vulnerability to Changing Climatic Conditions, Project Report I, 40pp.

Daniel, G (1977). Aspects of Climate and Water Budget in Ethiopia. A Technical Monograph Published for Addis Ababa University. Addis Ababa University.

David Lapp, FEC, P.Eng. Practice Lead, Globalization and Sustainable Development Adaptation Canada 2016: Vulnerability Analysis of Complex Systems – Advances for the Built

DAVID M. Hershfield Rainfall frequency atlas of the united states for durations from 30 minutes to 24 hours and return periods from i to 100-year technical paper no. 40

Detlef. P, Van Vuuren & Jae Edmonds (2011). The representative concentration pathways: an overview.

Environment and Urban Planning Infrastructure Climate Risk Assessment in Canada: An Engineering Strategy for

Ethiopian Road Authority (ERA) Drainage Design Manual. 2002

European Commission, 2009. White paper - Adapting to climate change: towards a European framework for action.

Filippo Giorgi, Colin Jones and Ghassem R. Asrar 2009.Addressing climate information needs at the regional level: the CORDEX framework. MO Bulletin 58(3) 175-183

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D. W., Myhre, G. (2014). Changes in atmospheric constituents and in radiative forcing. Chapter 2 Climate Change 2014. The Physical Science Basis.

Fowler.A., Lamond, J., Bloch, R., Bhattacharya, N., Lopez, A., Papachristodoulou, N., Barker, R. (2007). Five Feet High and Rising, Cities and Flooding in the 21st Century-Policy Research Working Paper. Retrieved August 1, 2014

Hall, J.W. et al., 2009. Engineering Cities: How can cities grow whilst reducing emissions and vulnerability? Newcastle University.

Hershfield, D.M., 1961. Rainfall Frequency Atlas of the United States, Technical Paper No. 40. Weather Bureau, US Department of Commerce, Washington, DC

Hibbard KA, Meehl, Cox & Friedlingstein, 2007. A strategy for climate change stabilization experiments. Volume Eos 88, p. 217–221.

Hijioka P,Vennila, A., & Purushothaman, C. (2008) How Climate Change is going to Affect India. Specifically.Yahoo India News. Retrieved August 1, 2008,

IPCC Technical Summary, 2001. Climate Change 2001: The Scientific Basis. Technical Summary of the Working Group I Report [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 94pp. Lindstrom, G., Johansson, B., Persson, M., Gardelin, M. & Bergstrom, S. (1997). Development and test of the distributed HBV-96 hydrological model, Journal of Hydrology.

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Inter govern-mental Panel on Climate Change [Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (Eds.)]. IPCC, Geneva, Switzerland, 151pp.

IPCC. (2008). Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies. Geneva: IPCC.

IPCC. Climate Change- The IPCC Scientific Assessment, Houghton, J.T., Jenkins, G.J., Ephraums, J.J. (eds.) Cambridge University Press, Cambridge, UK. 1990

IPCC-TGICA, 2007: General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Version 2. Prepared by T.R. Carter on behalf of the Intergovernmental Panel on Climate Change, Task Group on Data and Scenario Support for Impact and Climate Assessment, 66 pp.

Jha, A., Lamond, J., Bloch, R., Bhattacharya, N., Lopez, A., Papachristodoulou, N., Barker, R. (2011, May). Five Feet High and Rising, Cities and Flooding in the 21st Century-Policy Research Working Paper. Retrieved August 1, 2011

Johnson, C., K. McCreary and C. Nelms, 2004. Vancouver Public Library green roof monitoring project. 2004 Green Roof Conference Paper, 9 pp.

Kedir A., 2008. Assessment of Climate Change impacts on the Hydrology of Gilgel Abbay Catchment in the Tana Sub Basin, Ethiopia.

Lapp C. L., Smythe, L. D., Craig, S. B., & Weinstein, P. (2016). Climate change, flooding, urbanization and leptospirosis: Fuelling the fire? Transactions of the Royal Society of Tropical Medicine and Hygiene, 104(10), 631-638. doi: 10.1016/j.trstmh.2010.07.002

Leander K & Buishand A, 2007. Resampling of regional climate model output for the simulation of Extreme River flows. Hydrol, Volume 332(3–4), p. 487–496.

Levi Brekke, B. L. (2013). Downscaled CMIP3 and CMIP5 Climate Projections. Climate Central, 71-96.

Lyon, S.W., Dominguez, F., Gochis, D., et al. (2008). Coupling terrestrial and atmospheric water dynamics to improve prediction in a changing environment, Bulletin of the American Meteorological Society, 89(9), 1275-1279.

McSweeneyBloch, R., Bhattacharya, N., Lopez, A., Papachristodoulou, N., Barker, R. (2007). Five Feet High and Rising, Cities and Flooding in the 21st Century-Policy Research Working Paper. Retrieved August 2003).

Mikkelsen P.S., Viklander M., Linde J.J. and Malmqvist P.-A. (2001). BMPs in Urban Storm water Management in Denmark and Sweden, Contribution to Engineering Foundation Conference: Linking Storm water BMP Designs and Performance to Receiving Water Impacts Mitigation, Snowmass, Colorado, August 19-24, 2001

Moss RH, et al (2010) The next generation of scenarios for climate change research and assessment. Nature 463:747-756

Moss Richard H., Jae A. Edmonds, Kathy A. Hibbard, Martin R. Manning, Steven K. Rose, Detlef P. van Vuuren, Timothy R. Carter, Seita Emori, Mikiko Kainuma, Tom Kram, Gerald A. Meehl, John F. B. Mitchell, Nebojsa Nakicenovic, Keywan Riahi, Steven J. Smith, onald J. Stouffer, Allison M.Thomson, John P.Weyant and Thomas J. Wilbanks, 2010. The next generation of scenarios for climate change research and assessment, Nature, Vol463, 747–756.

Muluneh Bimrew, 2008. Evaluation of impacts of climate change on water resource availability in the catchments of Blue Nile, using hypothetical scenarios.

Natural Resources Conservation Service 2004 National Engineering Handbook Section 5

NMSA,2001 Convention on Climate Change (UNFCCC), National Meteorological Services Agency, Addis Ababa, Ethiopia.

NOAA. national weather service, national climate data centre site on global warming and national oceanic and atmospheric adminsitration: http//www.ncde.noaa.gov/oa/climate/global warming.htm/. 2015.

Riahi .O.F., Giorgi P., Whetton D., Pabon M. and Marius L. Guideline for use of climate scenarios developed from regional climate model experiments, Data distribuation cenetr of intergovernmental panal on climate chanage. 2007.

Riahi K., Gruebler A., Nakicenovic N. Scenarios of long-term socio-economic and environmental
development under climate stabilization. In: Technological Forecasting and Social Change. 2007.

Solomon, S. (2014). Climate change 2014-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC (Vol. 4): Cambridge University Press.

Solomon, S. et al., 2007. Climate Change 2007: The Physical Science Basis, Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.[452-454, 457].

Source: Bishoftu Finance & Economic Development Bureau, Profile Report, 2008

Source: Master plan Report

SOUZA, C.F. & FOLEGATTI, M.V. Spatial and temporal characterization of water and solute distribution patterns. Sci. Agric. Braz., 67:9-15, 2011.

Subhrendu Gangopadhyay, Benjamin L. Harding, Balaji Rajagopalan, Jeffrey J. Lukas, and Terrance J. Fulp A nonparametric approach for paleohydrologic reconstruction of annual streamflow ensembles. water resources research, vol. 45, w06417, doi:10.1029/2008wr007201, 2005

Tarekegn. D &Tadege .A, 2006. Assessing the impact of climate change on the water resource of Lake Tana sub –basin using WAtBAL model.

Taylor, A., Wong, T.H.F., 2002. Non-structural Stormwater Quality Best Management Practices - A Survey Investigating their Use and Value. Cooperative Research Centre for Catchment Hydrology. Technical Report 02/12, Monash University, Melbourne.

Terink, R. Salinger T., Fleming P. Lenhart J., & Merz R., 2010). Climate variability and change: past, present and future–an overview. Climatic Change, 70(1-2), 9-30.

Thomas, R. B., Megahan, W. F. (1998). Peak flow responses to clearcutting and roads in small and large basins, Western Cascades, Oregon: A second opinion, Water Resour. Res., 34(12), 3393–3403.

UNEP (2005) Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies.

V.T.Chow, D. M. ((1988),). “Applied Hydrology”,. McGraw- Hill.

V.T.Chow, D.R. Maidment and L.W.Mays (1988), “Applied Hydrology”, McGraw- Hill.

van Vuuren, Jae Edmonds, Keywan Riahi (2011):The representative concentration pathways: an overview Climatic Change. Japan

Van Vuuren, Stone D. and Knutti, R. Weather and climate. In Modelling The Impact of Climate Change on Water Resources. Fai Fung, Ana Lopez and Mark New, (eds). Blacwell Publishing 2007.

Van.Vuuren.D.P, e. a. (2011). Representative concentration pathways: an overview. In: Climatic Change.109, 5-31

Walsh, C.L. et al., 2011. Assessment of climate change mitigation and adaptation in cities. Proceedings of the Institution of Civil Engineers: Urban Design and Planning, 164(2): 75-84.

Wilby R.L., SP Charles, E Zorita, B Timbal, P Whetton, and LO Mears, 2004. Guidelines for use of climate scenarios developed from statistical downscaling methods.

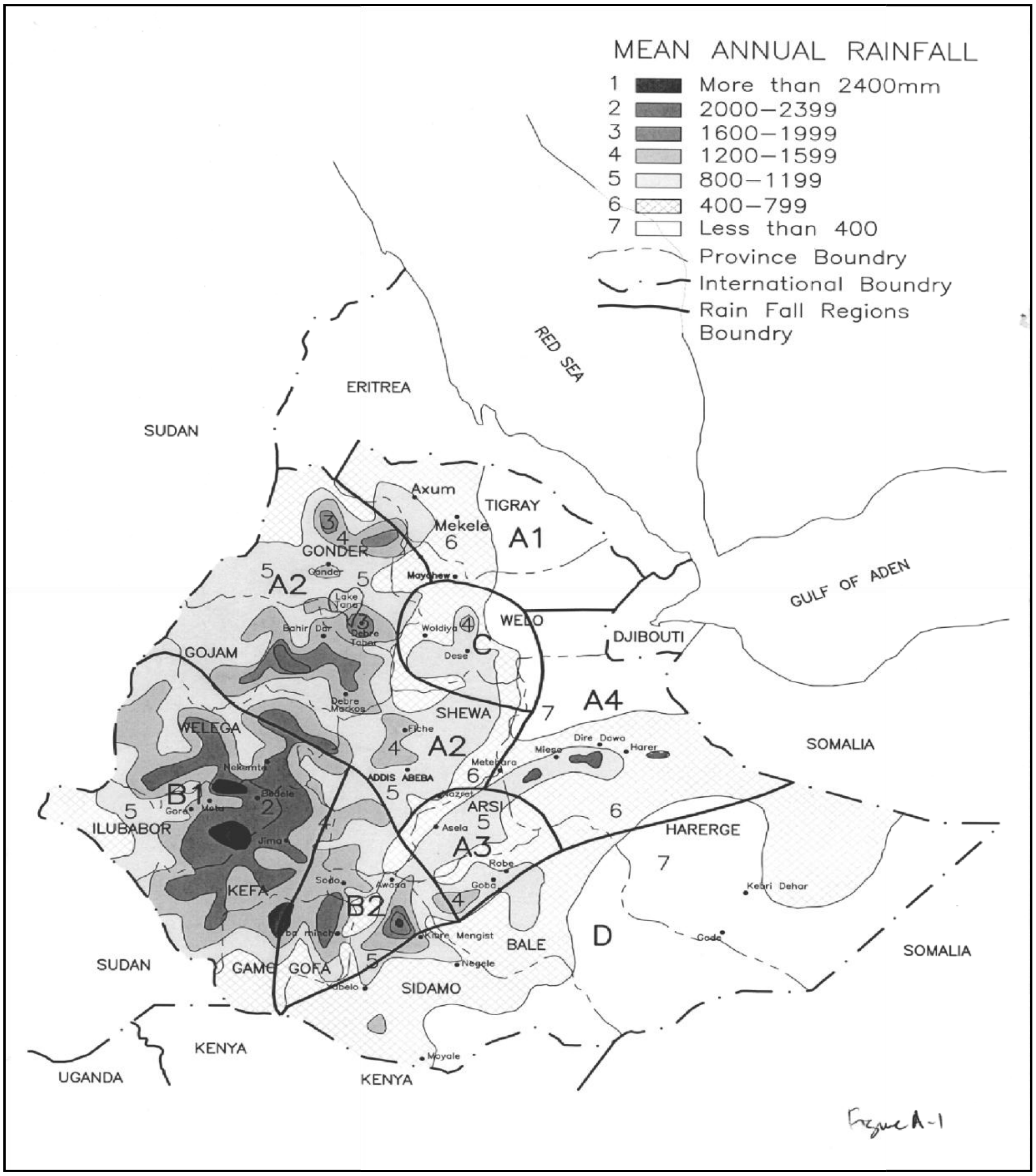
Wilby, R. Dawson L. (2007). SDSM – a decision support tool for the assessment of regional climate changeimpacts, Environ. Modell. Softw, 17, 145–157

Williams, R and Hacket W. 2006. Hydrologic impacts of alternative approaches to storm water management and land development. Journal of the American Water Resources Association, 42(2): 433-455.

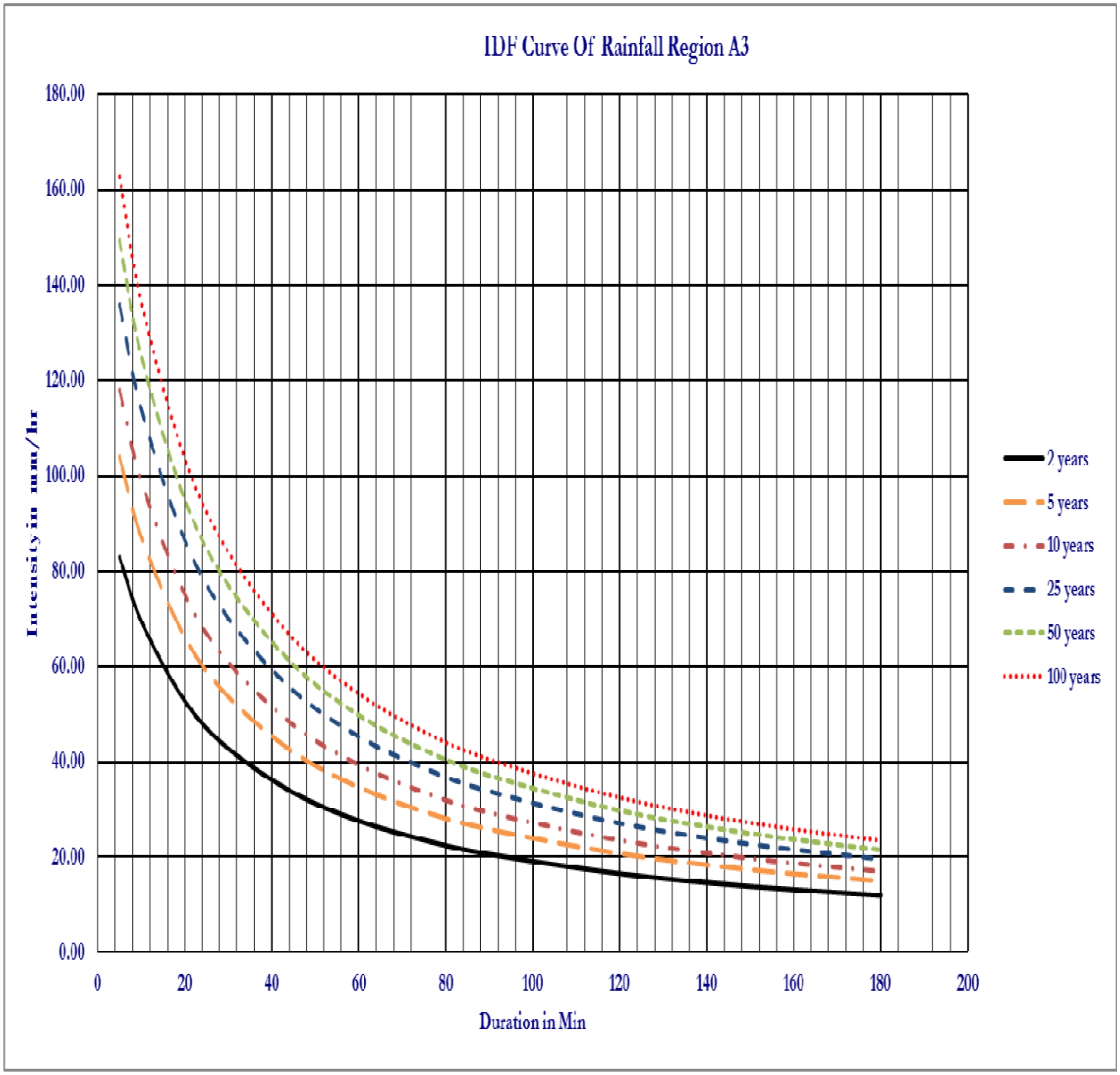
Xu C.Y, Widen E., and Halldin S., 2004. Modeling hydrological consequences of climate change progress and challenges, advances in atmospheric science, 22 (6), 789-798.

Zeray L., 2006. A Climate Change Impact on Lake Ziway Watershed water availability Ethiopia, MSc Thesis, Cologne, Germany.

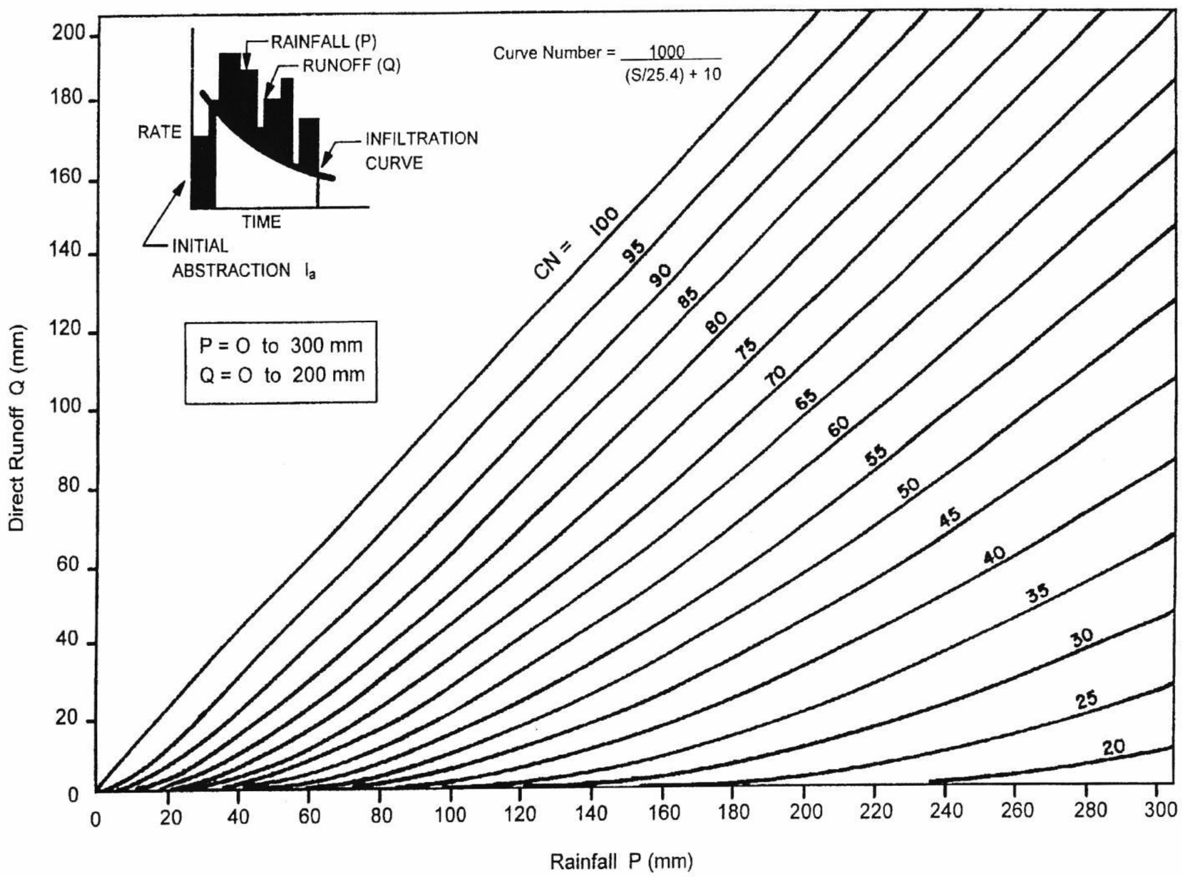
Appendix



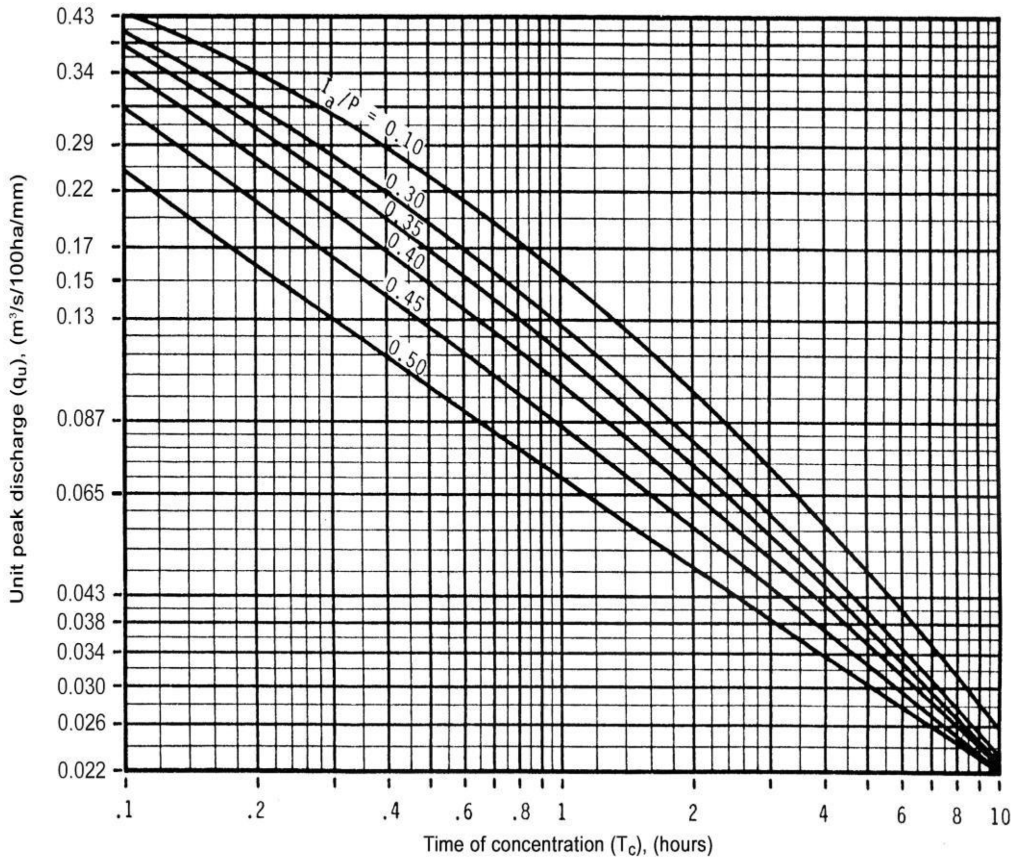
Mean Annual Rainfall for Ethiopia



IDF Curve of Rainfall Region A3



SCS Relation between Direct Runoff, Curve Number and Precipitation.



Unit Peak Discharge, Type II Rainfall

Graphs | Summary | Goodness of Fit

Fitting Results

#	Distribution	Parameters
1	Exponential	λ=0.01996
2	Exponential (2P)	λ=0.05379 γ=31.5
3	Gamma	α=13.111 β=3.8204
4	Gamma (3P)	α=1.4204 β=13.549 γ=30.845
5	Gumbel Max	σ=10.786 μ=43.864
6	Gumbel Min	σ=10.786 μ=56.316
7	Log-Gamma	α=204.91 β=0.01893
8	Log-Pearson 3	α=117.67 β=0.02498 γ=0.9394
9	Normal	σ=13.833 μ=50.09

Maximum daily Rain Fall data for Observed 1994-2013													
year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1994	0	0	10.4	6.2	15.8	18.6	34.6	30.2	23.5	0	9.5	0	34.6
1995	0	1.1	5	11	2.3	19	29.5	32.4	19.1	0	0	11.9	32.4
1996	8.2	0	28.3	17.4	26.5	62	42	54.8	16.9	0.1	4.4	0	62
1997	17	0	23.8	38.2	6.8	23	57	49.6	19	49.1	5.5	0	57
1998	21	21.8	7.7	28.6	21.6	33	30.5	70	22.1	32.8	0	0	70
1999	0.5	0	16.8	0	9.8	78	74	53.6	11.9	24.5	0	0	78
2000	0	0	8.6	15.8	27.2	14	47	27	25	19.6	23.2	2.6	47
2001	0	4.4	39.8	7.6	19.7	21.8	38	28.8	18	21.4	0	0	39.8
2002	5.1	0	20	28	3.7	21.2	44.7	27.9	12.7	0	0	13.7	44.7
2003	38.3	22.9	45.6	29	11.8	19.5	42.6	33.2	34.8	6	3.6	33.2	45.6
2004	3.70884	8.42919	35.2	23	1.4	46.2	28.4	43	16.6	13.4	5.5	0	46.2
2005	10.2	0	26.8	37	14.8	24	22.2	28.3	31	0	2.4	0	37
2006	4.2	55.7	0	23	17.3	20.4	48.1	17.8	36.7	74.4	5.2	6.5	74.4
2007	3.5	0	0	16.7	35.4	20	38.1	17.7	20.4	13.2	10.1585	18.6896	38.1

2008	0	0	0	38	8.9	22.9	37.4	45.9	1.2	16	13.5	0	45.9
2009	17.8	0	11	19.9	10.4	13.6	22	31.5	15.6	28.7	0.6	16.4	31.5
2010	0	8.4	35.7	40.5	7	17.8	38.8	44.6	25.2	0	0	0	44.6
2011	0	3.35993	61	13.8	33.2	17.453	37.1	48	50.7	0	1.2	0	61
2012	0	0	61	15.2	14.2	19.2	19.1	40.3	23.5	1	0	10.9733	61
2013	0	0	0	17.3	28.6	24.6	51	13.3333	0	0	0	0	51
	Total												1001.8
Average Max daily Rain fall													50.09

Maximum daily Rain Fall data for Rcp 4.5 2021-2040													
year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2021	7.77	25.58	2.84	12.69	28.79	20.11	49	75.7	12.66	32.52	4.11	6.44	75.7
2022	0	0	0	60.12	0	115.37	49.32	27.94	11.43	1.65	0	2.41	115.37
2023	21.17	0	0	6.28	8.57	85.76	71.54	34.86	14.37	8.09	3.93	3.16	85.76
2024	0		40.09	45.68	18.43	7.88	66.22	39.02	33.79	29.29	0.42	8.14	66.22
2025	0		0	47.21	37.36	9.22	77.65	35.87	35.28	102.7	4.51	3.53	102.7
2026	13.75	0.12	2.41	10.82	11.76	7.54	33.91	18.56	23.39	5.35	2.34	5.65	33.91
2027	0	2.63	26.84	7.83	10.73	22.6	33.41	57.04	13.5	23.77	15.05	9.03	57.04
2028	0	11.02	0	3.04	18.22	16.94	56.91	12.44	18.89	0.22	6.23	2.02	56.91
2029	11.37	0.03	2.7	4.34	3.24	54.29	85.26	42.76	11.87	0.55	0.14	0	85.26
2030	17.69	0.01	15.79	1.39	9.1	30.08	75.63	39.55	31.09	0.1	0.47	0	75.63
2031	0	0.38	15.27	0	62.43	10.38	29.4	23.05	71.2	10.21	0.74	6.12	71.2
2032	9.4	0	6.84	22.54	9.2	25.53	12.79	15.21	50.96	4.55	1.1	2.29	50.96
2033	8.68	12.82	50.09	14.32	12.32	99.47	10.55	30.8	14.37	3	0.59	0	99.47
2034	13.26	7.82	16.82	9.59	8.36	5.95	31.96	36.88	54.8	9.47	0.14	0	54.8
2035	0	0	3.26	4.02	6.26	23.32	32.59	13.21	55.45	9.47	3	0	55.45
2036	0	0	29.96	2.91	21.63	9	34.24	16.74	5.39	64.38	2.08	15.12	64.38
2037	23.81	52.24	118.72	11.45	8.19	6.53	8.94	29.14	6.76	0	0.24	0	118.72
2038	0	6.88	27.71	10.66	0.76	55.93	93.28	24.92	15.3	0	0.14	0.94	93.28
2039	0	0.19	17.59	4.93	13.94	19.37	44.58	20.71	26.17	5.11	0.24	8.27	44.58
2040	0	1.11	45.96	5.93	9.33	79.94	62.69	79.64	15.11	1.14	1.56	1.38	79.94
Total													1487.3
Average Max RF													74.36

Maximum daily Rain Fall data for Rcp 4.5 2051-2070													
year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2051	0	0	7.38	6.28	10.09	23.55	11.98	13.44	69.03	0.01	0	6.23	69.03
2052	0	0	10.97	6.86	7.53	20.81	7.05	17.61	10.58	16.26	1.07	0.94	20.81
2053	13.26	32.35	15.79	3.96	5.33	39.52	37.33	20.18	10.64	19.84	0.24	10.48	39.52
2054	0	0	0	8.55	5.46	28.45	62.34	17.99	26.07	5.78	0.82	3.06	62.34
2055	0	0	0	25.9	11.38	20.42	16.45	28.63	12.86	74.03	7.53	4.89	74.03
2056	12.09	0.49	0	24.73	3.91	11.36	51.89	28.34	53	12.89	0	4.89	53
2057	17.69	5.17	4.66	8.66	18.04	17.7	53.09	38.55	34.16	5.35	8.87	2.16	53.09
2058	20.63	0	11.49	2.91	20.88	3.64	20.25	12.19	10.32	14.77	1.62	0.94	20.88
2059	6.42	0	2.27	9.97	0	13.36	57.36	102.68	20.06	4.6	7.7	2.75	102.68
2060	0	0	6.57	13.1	8.25	75.14	7.41	30.32	7.19	0	1.93	6.86	75.14
2061	16.64	12.82	16.43	16.44	1.47	16.24	8.53	24.15	17.27	45.02	0.33	3.7	45.02
2062	0	0	6.3	10.18	18.71	12.54	39.16	29.36	78.48	29.6	5.48	6.34	78.48
2063	9.4	14.75	34.92	54.18	2.92	28.54	11.07	13.33	8.9	35.77	24.05	5.53	54.18
2064	17.93	0	22.43	0	5.33	20.46	9.77	36.65	18.56	11.64	2.74	2.29	36.65
2065	24.19	0	0	0	4.26	12.7	8.32	8.33	31.4	7.93	0.42	0	31.4
2066	0	259.31	23.94	10.08	0	26.32	62.63	8.76	19.89	18.67	0.14	4.02	259.31
2067	11.37	0	0	16.44	10.21	45.54	10.17	33.93	13.29	0	0	11.45	45.54
2068	0	0.1	18.1	28.91	0.76	12.35	5.55	32.49	13.36	4.19	9.41	0.65	32.49
2069	27.37	0	8.72	36.96	18.24	40.35	14.82	28.99	87.48	16.19	12.92	12.2	87.48
2070	22.24	0	0.65	1.47	4.4	18.38	37.42	35.36	31.09	4.83	2.91	0.94	37.42
Total													1278.48
Average Max daily Rain fall													63.92

Maximum daily Rain Fall data for Rcp 8.5 2021-2040													
year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2021	0.00	0.00	1.98	17.94	4.33	8.51	8.80	41.94	35.61	16.52	1.10	0.00	41.94
2022	21.02	0.00	2.41	2.21	6.26	23.05	13.97	27.58	33.79	3.06	5.81	0.00	33.79
2023	11.74	2.49	0.00	4.53	14.21	11.77	50.60	46.25	6.34	8.20	0.47	1.38	50.60
2024	0.00	0.00	0.00	5.21	4.68	50.12	37.95	102.36	40.85	9.24	6.50	1.56	102.36
2025	9.40	58.70	11.76	13.96	0.76	12.31	8.00	12.24	15.64	16.42	7.68	0.00	58.70
2026	9.40	6.00	20.72	3.57	22.68	14.88	9.91	9.43	22.76	0.05	5.90	1.73	22.76
2027	7.18	0.00	18.48	6.98	3.69	10.38	30.19	83.84	22.85	26.45	14.13	0.00	83.84
2028	0.00	0.00	13.58	24.28	4.26	14.60	12.38	34.93	16.49	0.87	0.42	5.16	34.93
2029	7.77	0.00	33.93	16.93	8.52	25.29	21.92	19.27	7.30	39.62	1.87	0.00	39.62
2030	0.00	5.17	57.45	3.96	7.48	10.01	36.66	86.78	59.10	0.00	0.14	2.02	86.78
2031	0.00	0.00	0.00	0.00	13.79	9.61	62.92	30.54	23.21	0.00	3.12	0.94	62.92
2032	0.00	0.00	24.95	15.80	10.90	87.59	43.41	62.22	6.70	12.03	0.42	0.00	87.59
2033	0.00	0.00	104.80	29.00	23.11	11.81	16.59	12.67	53.32	2.15	0.63	9.81	104.80
2034	17.31	0.62	6.16	25.99	10.95	3.70	6.42	34.47	39.65	0.00	5.48	5.03	39.65
2035	9.40	0.00	21.41	1.47	4.33	23.14	6.04	60.52	38.58	24.54	1.47	2.02	60.52
2036	19.01	9.35	9.65	3.96	5.01	15.78	32.68	12.24	72.81	17.18	0.08	3.16	72.81
2037	0.00	0.00	0.00	13.10	19.28	13.36	20.66	48.88	16.10	17.59	1.03	3.86	48.88
2038	10.96	2.63	0.00	3.44	22.16	13.96	42.11	39.43	85.27	57.38	0.82	0.00	85.27
2039	7.77	0.00	10.31	9.27	0.00	31.98	60.83	27.04	17.59	9.69	5.71	0.00	60.83
2040	0.00	0.00	0.00	1.39	5.71	32.82	53.09	5.70	16.60	30.62	4.26	0.94	53.09
Total													1231.69
Average Max daily Rain fall													61.58

Maximum daily Rain Fall data for Rcp 8.5 2051-2070													
year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2051	7.77	14.09	15.14	17.36	2.42	77.59	45.04	14.32	13.93	11.49	1.72	8.95	77.59
2052	0.00	2.09	1.69	14.11	5.33	7.13	36.14	39.26	40.50	0.53	22.18	4.02	40.50
2053	0.00	0.00	2.41	26.17	0.00	9.00	14.59	42.84	24.02	0.03	17.47	10.90	42.84
2054	24.60	1.51	10.84	12.59	9.91	38.48	11.92	62.40	18.89	11.26	8.42	7.92	62.40
2055	27.82	0.12	40.83	33.71	14.38	10.27	27.94	18.88	9.60	9.75	24.86	0.00	40.83
2056	0.00	0.77	8.45	4.21	16.33	65.47	86.58	25.27	60.99	31.96	3.44	0.00	86.58
2057	19.01	0.00	27.71	6.74	7.87	10.98	54.96	125.35	65.62	1.10	0.00	0.65	125.35
2058	0.00	0.00	40.09	7.09	2.55	19.24	12.16	21.80	29.77	1.65	2.05	0.94	40.09
2059	16.64	35.12	10.84	33.58	25.35	8.58	141.11	39.34	5.15	0.00	2.29	0.00	141.11
2060	0.00	47.34	52.63	3.96	8.19	26.51	38.48	30.46	24.71	7.19	1.05	11.31	52.63
2061	0.00	0.00	0.00	2.42	1.67	6.47	38.24	44.58	67.04	1.07	0.96	3.16	67.04
2062	6.42	1.51	5.34	43.30	12.46	8.93	35.16	51.99	17.35	0.03	17.09	10.73	51.99
2063	12.09	0.00	0.00	3.70	3.62	9.22	7.92	42.51	40.16	12.70	0.47	3.70	42.51
2064	0.00	3.07	5.21	0.36	7.92	32.13	53.20	20.84	8.99	9.69	0.00	0.00	53.20
2065	23.35	0.00	3.82	11.14	11.33	75.81	95.47	19.27	15.26	27.74	9.44	0.00	95.47
2066	7.77	0.70	0.00	0.00	18.77	27.12	19.65	46.25	15.95	0.04	0.24	0.00	46.25
2067	14.62	0.00	0.00	5.93	17.96	20.59	17.83	7.42	10.90	2.08	1.99	0.00	20.59
2068	0.00	0.77	13.58	4.06	5.14	12.43	17.75	10.86	14.22	8.47	5.86	2.75	17.75
2069	0.00	4.41	9.51	7.55	11.19	18.38	11.86	27.32	77.12	16.52	27.29	0.00	77.12
2070	0.00	0.00	0.00	0.00	4.78	48.69	49.32	47.18	76.52	29.44	0.00	0.94	76.52
Total													1258.36
Average Max daily Rain fall													62.92