Assessing the Impact of Climate Change on Surface Water Resources Availability: the Case Awash Bello Watershed, Awash basin

By

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This is to certify that the thesis prepared by Tadele Tesfaye, entitled: Asseesing the Impact of Climate Change on water Resources Availability of Awash Bello watershed and submitted in partial fulfilment of the requirements of the degree of Master of Science (Water Resource Management) complies with the regulations of the university and meet the accepted standards with respect to originality and quality.

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DECLARATION

I, the undersigned, hereby declare that this thesis entitled, "Assessing the Impact of climate Change on Water Resource Availability of Awash Bello Watershed, Upper Awash Sub-Basin, Ethiopia" is my own work, and that all the sources I have quoted indicated or acknowledge by means of completed reference.

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ABSTRACT

The sign of climate change and its impact is revealing on different natural and synthetic systems. The objective of this study was to analyse and quantify the impacts of climate change on stream flow in awash Bello watershed, upper Awash River basin, Ethiopia. Ensemble mean of six Coordinated Regional Climate Downscaling Experiment (CORDEX) Africa regional climate models operating under two alternative scenarios of Representative Concentration Pathways (RCP 4.5 and RCP 8.5) was used. The period from 1990 to 2010 was used for the analysis of the baseline scenario while the periods (2031–2070) and (2071–2100) were used for future scenarios analysis. The impact assessment on stream flow was done using soil and water assessment tool (SWAT) hydrological model. The statistical performance of the SWAT model in simulating the stream flow was shown with coefficient of determination R2 of 0.91, R-Factor of 0.62 and Nash-Sutcliffe Efficiency (NSE) of 0.87 for monthly calibration and R2 of 0.79, R-Factor of 0.56 and ENS of 0.67 for monthly validation periods. Mean monthly changes in precipitation and temperature (maximum and minimum) were used to quantify these impacts. The result of bias-corrected precipitation and temperature disclosed a logical increase in all future periods for both RCP 4.5 and RCP 8.5 scenarios. These changes in climate variables created an increase in mean annual stream flow by 14.5 and 19.1% for RCP 4.5 and by 4.7 and 6.9% for RCP 8.5 scenarios of the 2070s and 2100s, respectively. This result provides valuable information for guiding current and future water resource management in the awash Bello watershed and similar other areas in all awash basin as well as in Ethiopia.

KEYWORDS: - Climate change; Bias Correction; CORDEX Africa; GCM; RCM, SWAT model

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Contents

Lists of TABLES

List of Figures

ACRONYMS AND ABBREVIATIONS

ANPS	Agricultural None Point Source
AOGCM	Atmospheric General Circulation Model
BCCR	Bjerken Center for Climate Research Norway
CanESM2	Canadian Earth system Model second generation
CCCMA	Canadian Center for Climate Modeling and Analysis Canada
CCIS	Canadian Climate Impact Scenario
CMhyd	Climate Model data for hydrologic modeling
CIRO	Common wealth Scientific and Industrial Research Organization of Australia
CMIP3	Coupled Model Inter Comparison Phase 3
CN	Moisture condition curve Number
CNRMF	Centre National de Recherches Meteorologiques France
Co_2	Carbon dioxide
CSA	Central Statistic Authority
DDC	Data Distribution Center
DEM	Digital Elevation Model
ESCO	Soil Evaporation Compensation Factor
ERDAS	Earth Resource Data Analysis System
FAO	Food and Agriculture Organization
GCM	General Circulation Model
GFDL	Geophysical Fluid Dynamics Laboratory USA
GHG	Green House Gas
GIS	Geographical Information System
GPS	Global Positioning System
GHG	Green House Gas

GW Delay	Groundwater Delay time
GW Revamp	Groundwater Revamp Coefficient
GWOMN	Threshold water Depth in the shallow aquifer for flow
IFRC	International Federation of Red Cross
IPCC	Intergovernmental Panel on Climate Change
m.a.s.l	Meters above sea level
MOA	Ministry of Agriculture
MOWRIE	Ministry of Water Recourse Irrigation and Electric city
NCEP	National Center for Environmental Programs
NGO	None Governmental Organization
NMA	Ethiopian National Meteorological Agency
NSE	Nash- Sutcliff efficiency
PBIAS	Percent Bias
	RCA Rossby Centre Regional Climate model,
RCM	Regional Circulation Model
RCP	Representative Concentration Pathway
RS	Remote Sensing
SCS	Soil Conservation Service
SDSM	Statistical down scaling Model
SRES	Special Report on Emissions Scenario
SWAT	Soil and Water Assessment Tool
TIN	Triangulated Irregular Network
UK	United Kingdom
UNFCCC	United Nation Framework Convention on Climate Change

UNOCHA	United Nation Office for the Coordination of Humanitarian Affaires
USA	United State of America
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WCRP	World Climate Research Program
WMO	World Meteorological Organization

1. Introduction

1.1 Background

According to the Intergovernmental Panel on Climate Change (IPCC 2007) reports that the CO2 tone in the atmosphere will double by the 21st century, and that the average global temperature will rise by 1.4 to 5.8 ° C until 2100. With rising sea levels, now precipitation (update ± 20%), improving the climatic conditions of the golf box climate is the incidence of marriage cry on Earth's antenna rise.The of findings (IPCC 2013) show that developing countries such as Ethiopia are more vulnerable to climate change. Climate change impact has a significant impact on Ethiopia due to its inflexible modification of economic structure and its heavy reliance on agriculture. Increased industrial activity and unnecessary deforestation during the last century and a half have increased the three concentrations of carbon dioxide in the Earth's atmosphere. This initiated a large-scale atmospheric process (among other variables) that changed the temperature and precipitation of the two Earths (Yohannes 2013). Changes in the Earth's climate system upset the delicate balance of the water cycle and eventually lead to risky events (floods, droughts, heat waves, summers, etc.) (Ashley et al. 2005).In the past century, changing climate is quite convincing based on several studies (Carrier et al. 2016) and (IPCC 2014) which has led to increasing temperature in some places while increasing precipitation at the other places (Kalra nd Ahmad 2012). It is a natural disaster that is destroyed in flooded areas and countries. Seeing the impact of the flood population on the aesthetic nature of social downloads (Smith, 1999) and kills me more than any other natural phenomenon (Dilley et al. 2005). There is a flood and its okay in all parts of the world. The closure of research housing and meteorological variables can be beautiful, flood-prone stories and storms (Ahmad et al. 2010) and eventually, it becomes a major concern around the globe. Studies done globally indicate that altercated meteorological variables have great potential to change the frequency and intensity of extreme events especially floods (Dobler et al. 2012).The increase in temperature accelerates the evapotranspiration process which further influences the amount of precipitation and ultimately contributes to the modification of seasonal runoff.

Current year-end discrepancies in spills are expected to change under climate change scenarios in many parts of the world (Dobler et al. 2010). Floods are the second major natural disaster after the Ethiopian drought (IFRC 2010) this is primarily associated with the national topography of highland mountains and lowland plains with natural drainage systems formed by major river basins (NMA 2012).The country received about 80% of the rainy season, which was concentrated in the three months from June to September. During this season, the major perennial rivers and their numerous tributaries that form the country's drainage system begin in the central highlands and flow towards the surrounding or surrounding lowlands, carrying peak discharges (FDPPA 2007). Heavy rains are common in most parts of the country. Large-scale floods are rare and confined to lowland areas where major rivers intersect neighboring countries, as the country's terrain is fairly steep with well-defined waterways (Daniel 2007). However, heavy rainfall in the highlands can cause floods in settlements near any area of the river course. This flood damages crops, and agricultural soil distractions temporarily expel people from their normal dwellings, deaths of living and precious human lives, bridges, power and communication lines, and various parts of the country. Causes distractions for roads and other structures (Kefyalew 2003).

In the last few decades, the frequency and magnitude of flood in the country have increased rapidly as a result of climate change as well as land-use change (Zewde 2004).While the damage intensifying with increasing population due to increasing land and forest degradation, encroachment of people to settle in close proximity to the flood prone areas (Semu 2007).In addition, activities in the catchment such as land clearing for agriculture may increase the magnitude of flood which increases the damage to the properties and life of human and animals (Kebede 2012). Where as its intensity and return period generally are affected by volume and time of upstream surface runoff and river or flood conditions, physical characteristics of watershed (area, morphology), hydrological characteristics of the watershed (rainfall, storage, evapo-transpiration), and human activities causing and intensifying the flood flows (Zadeh et al 2005).

In the Awash River basin in Ethiopia, the problem of short-term over-rainfall followed by high-flow river flooding is a major concern. Major rainy season (June, July, August, September). The floodplains of the Awash River extend to certain areas that are not normally covered with water. Rivers or flash floods usually occur in the lowland, flat terrain areas of the Awash River basin. Heavy rainfall in the highlands of the Awash River basin causes floods downstream and damages settlements near any section of the river (Feyissa 2007).

1.2 Statements of the Problem

Ethiopia is suffering from the effect of recurrent drought and flood due to climate change. Research on Awash River Basin indicated that the basin would be significantly affected by the changing climate; that is, a considerable water deficit is projected for the future by employing GCM models. All the models suggested that global warming would result in a general increase in dryness, which would decrease water availability. In addition, a 20% reduction in basin rainfall and a 2 ° C increase in temperature will reduce annual runoff by 41%. Even a temperature rise of 2 ° C without changes in precipitation will reduce annual runoff by 9%. On the other hand, a 10% increase in precipitation offsets the temperature rise of 2-4 ° C, resulting in surplus runoff in the range of 4-12% (Kinfe 1999) In general, warming of the Awash River basin simulated by various models results in a significant reduction in annual runoff of the entire basin (Kinfe 1999). According to (Feyissa 2007) the Awash River basin in Ethiopia is of great concern due to the flooding of rivers due to short periods of excessive rainfall followed by heavy river flow. Main rainy season (June, July, August, September). The floodplains of the Awash River extend to certain areas that are not normally covered with water. Rivers or flash floods usually occur in the lowland, flat terrain areas of the Awash River basin. Heavy rainfall in the highlands of the Awash River basin causes floods downstream and damages settlements near any section of the river.

Generally many research have been done in Ethiopia as well as in awash basin on the impact of climate change on water resources using different models like Weap, BHV,CMIP, HadGEM2-A and SWAT by different methods which is not exactly the same with my study. What is confident about study zone in general and study area of awash Bello watershed in particular is that, our climate is changing. So far, however there is no single study has been done in the area about future water availability by RCM under RCP climate change scenario, this was the drawbacks of those study but this study try to assess the impact of climate change on surface water resource at study area. This threat accentuates the need for effective and sustainable water resource management through enhanced appreciative of the hydrologic execution in the catchment. Therefore this study was aimed mainly to, (1) downscale the GCM to RCM using cordex data output to obtain monthly simulations of awash Belo watershed climate variable and to develop climate change under RCP scenarios for two future time slices until year 2100 (2) estimate the monthly, seasonal and annual Runoff of study area under RCP scenarios for different future time slices.

The different hazards happening in the study area is not different from the country's context. In the awash Bello catchment the available land and surface water resources are not utilized effectively to improve the livelihood and socioeconomic conditions of the inhabitants. During the summer season in the catchment there is flood hazards that affect and displace society live around the catchment, inversely during the winter or sometimes during belg season there is shortage of water for drinking and irrigation purpose in the streams. The existing land and surface water resources system of the area is adversely affected by rapid growth of population and climate change. Awash Bello catchment is located around sabeta awash area which is known as spreading of different types of industry which are the result of climate change more in future. To identify the major problems surface water assessment should be assessed and the river flow (runoff) analysis should also be carried out. In contrast to the assessment of variations of the climate driving force for regional hydrology, the trends and impacts may be different on a watershed to watershed or from sub-basin to sub-basin scale. Therefore, in order to focus on the assessment of the relationships between climate change, surface water availability and water demand –supply management on the catchment scale integrated hydrological components required.

1.3 Objective of the study

1.3.1 General objective

The general objective of this thesis was to assess the impacts of climate change on surface water resources availability of the Awash Bello watershed.

1.3.2 Specific objectives

The specific objectives were:

- To Estimate the current available surface water resource potential using the SWAT model in the Awash Bello Watershed.
- To estimate the monthly, seasonal and annual Runoff of study area under future climate change RCP scenarios
- Compare the current and future simulations of the Awash Bello Catchment to assess the impact of climate change on Surface water resources in the watershed.

1.4 Scope of the study

The scope of the study is concentrated on the Awash Bello watershed area of the Awash River Basin This research therefore extends the integration of a hydrologic model swat with a newly developed climate downscaling methodology for the purpose of determining future water availability .

1.5 Significance of the Study

The significance of investigating climate change and their impacts on hydrology has been highlighted by many researchers for planning and sustainable management of natural resources in many parts of the world. Climate change Particularly regarding with water resource use sectors as Awash Bello river is the source of water for Koka dam, which is the source of hydro power, irrigation and domestic use Therefore, the contribution of this research is with the objective of downscaling climate scenario and assessing future available water resources which has different use Understanding the types and impacts of climate change is an essential indicator for resource base analysis and development of effective and appropriate use for sustainable management of natural resources in the basin in general and at the study area in particular.

2. Literature Review

2.1. Over view of Climate Change

Climate change is the most serious problem facing the world today. Today, it is widely accepted that climate change is already happening and that further changes are inevitable. In the last century (between 1906 and 2005), the average global temperature rose by about 0.74 o C. This happened in two phases, from the 1910s to the 1940s and from the 1970s to the present. Many studies on the detection and attribution of climate change have found that most of the rise in average surface temperature over the last 50 years is due to human activity (IPCC 2007).

It is estimated that in the 20th century, the average sea level of the entire world rose by 12 to 22 cm. This rise is due to snow cover and melting of mountain glaciers (both falling in both hemispheres) (IPCC, 2013). The IPCC (2013) also points out that precipitation, intensity, frequency, and types of precipitation are changing globally, as observations over the last century have shown.

At this point, it is worth mentioning the role and mission of the Intergovernmental Panel on Climate Change (IPCC). The World Meteorological Organization and the United Nations Environment Program established the IPCC in 1988. Its role is to provide comprehensive, objective, open and transparent scientific, technical and socio-economic information related to understanding the scientific basis of risk. Is to evaluate based on. Anthropogenic climate change, its potential impact, and adaptation and mitigation options. Among the various assessments conducted by the IPCC published in 2007, predicted global warming ranges from 0.6 to 4.0 oC and predicted sea level rise ultimately ranges from 0.18 to 0.59 m it is described as within the range. Next century (IPCC, 2013).

The IPCC Fifth Assessment Report (AR5) concludes that most of the global mean temperature rises observed since the mid-20th century are very likely due to the observed rises in anthropogenic greenhouse gas concentrations. I attached it. It was well known that carbon dioxide (CO_2) is the most important anthropogenic GHG. Annual emissions increased by about 80% from 21 to 38 gigatones (Gt) between 1970 and 2004, accounting for 77% of total anthropogenic GHG emissions in 2004. The rate of increase in CO_2-eq emissions is higher in the last decade from 1995 to 2004 (0.92 GtCO2-eq per year) than in the period before 1970 to 1994 (0.43 GtCO2-eq per year) (IPCC 2013).

2.2 Climate Models and Tools

Warming of the climate system and change in its state variables are highly related to the atmosphere-land ocean system. The climate modelling science integrates these complex systems with the Global Circulation Models (GCMs) to simulate future climate changes and forecast it for two decades and centuries. GCMs are the most widely used models in climate change studies for evaluation, simulation and projection of the different climate change scenarios (IPCC 2007). Climate change scenarios developed from General Circulation Models (GCMs) are the initial source of information for estimating plausible future climate changes. Most GCMs have a horizontal resolution of between 250 and 600 km, and 10 to 20 vertical layers (Bates et al. 2008). The spatial resolution of GCMs is too coarse to resolve regional scale effects. Therefore downscaling is required.

Downscaling of future climate from coarse resolution GCMs to regional scale to assess future impacts on the environment, society and economy require a baseline data corresponding to present day observed climate data. The world meteorological organization (WMO 2009) recommends a 30 year normal period as a baseline just to cope weather variability and superseded by a new 30 year period 1971/2000 as a new normal period for downscaling (Bates et al. 2008). Correspondingly, a 30-year normal period is required to compare the downscaled climate data with the observed ones (WMO, 2009). This can help to build confidence in future downscaling above all the data are used for calibration and testing GCMs.

2.2.1. General circulation model (GCM)

Both global and regional climate models are important tools that help us understand the many processes that govern the climate system. Climate is one of the most difficult geophysical systems to simulate due to the number of interacting components and the range of temporal and spatial scales of the processes involved (their complexity). (Laprise 2008). The global climate model, also known as the general circulation model (GCM), is the most complex climate model because it aims to represent the key components of the climate system in three proportions..

According to IPCC (2010), GCMs are the vital resource used to achieve climate change experimentations regionally, globally and very fine scale up to point climate pattern from which climate change scenarios are derived; but they have main drawbacks because of their coarse resolution. Most of the time they lack producing of current climate trend including the most important statistical parameters like mean and variance.

GCM uses a three-dimensional grid on Earth to represent climate. It typically has a horizontal resolution of 250-600 km, 10-20 vertical layers in the atmosphere, and in some cases 30 layers in the ocean (IPCC 2010). Therefore, their resolution is fairly coarse compared to the size of the exposure unit in most effect assessments. In addition; several physical processes, such as those related to clouds, also occur on a small scale and cannot be modelled properly. Instead, a technique called parameterization requires a large-scale averaging of known properties. This is one source of uncertainty in GCM-based simulations of future climate (IPCC 2007). Nowadays, GCMs only included a representation of the atmosphere, the land surface, sometimes the ocean circulation, and a very simplified version of the sea ice. A few years ago, GCMs take more and more components into account, and many new models now also include sophisticated models of the sea ice, the carbon cycle, ice sheet dynamics and even atmospheric chemistry (IPCC 2013).

2.2.2 Regional climate model

A regional climate model (RCM) is a climate model of higher resolution than a global climate model (GCM). It can be nested within a global model to provide more detailed simulations for a particular location. Local climate change is influenced heavily by local topographical features like a mountain. Due to their coarse resolution, small-scale topographical features are not picked up by GCMs. RCMs have a higher resolution than a GCM (~ 25 km) even less and are influenced by a smaller scale of topographical features (IPCC 2013). It is much more computationally intensive to run an RCM so they are usually run over a limited area.

Regional models have been used to conduct climate change experiments for many regions of the world. These methods of obtaining sub-grid scale estimates (commonly down to 50 km resolution or less) are able to account for important local forcing factors such as surface type and elevation, which conventional GCMs are unable to resolve (IPCC 2013). They have the advantage of being physically based, but are also highly demanding computer time. For this reason, until recent years there had been very few simulations for a sufficient period of simulated years to allow meaningful climate change statistics to be extracted. Furthermore, the commonest approach, nesting, is still heavily reliant on specialized GCM outputs for its boundary conditions. GCMs do not always make available good simulations of the large scale flow and there can be inconsistencies between the behaviour of the physical parameterizations in the driving model and in the finer grid of the regional model (IPCC 2007).

Any regional climate modelling tactic affords a rise of resolution over a region of the globe of about one order of magnitude compared to GCMs, with a regional grid-point spacing of a few tens of km in the horizontal, for operational use on climate timescales (Laprise 2008).

2.3. Downscaling Techniques

Downscaling or regionalization is a term given to the process of deriving finer resolution data for a particular site from a coarser resolution GCM or RCM dataset. Regional climate models (RCMs) are powerful tools for describing regional and smaller climate conditions, but they still contain serious systematic errors (Jakob et al 2011). Predictions of current or future period GCM and RCM climate variable estimates, obtained directly from simulations of GCM and RCM outputs, are due to the inherently coarse spatial resolution of both results and the resolution of many subs. It has limited value for any study. Grid scale. This characteristic makes the outputs are always unreliable at the individual grid. To solve this problem spatial downscaling methods have been proposed. The methods used to convert GCM or RCM outputs into local meteorological variables used for hydrological modelling or any other regional climate study are referred to as downscaling techniques (wood et al., 2004). Recently, there are different types of downscaling methods to provide very fine scale GCM and RCM results at point scale; for instance, some of the methods are mentioned in (Jakob et al. 2011) as linear and nonlinear empirical-statistical downscaling techniques. The other downscaling technique which is referred to as dynamical downscaling method is mainly applied to derive regional scale information from GCMs (Jakob et al 2011). Particularly, small-scale patterns of daily precipitation are highly dependent on model resolution and parameterization and can often not be used directly in climate change impact assessment studies (Fowler et al 2007).

Recently, the availability of regional GCM-based climate scenarios for different part of the world tremendously increased; it is possible to mention canESM2. Recently this regional climate model is available for Ethiopia. However, due to the error characteristics of GCMs, it is not possible to use directly for any climate change study in the region, there is a need to convert GCM outputs into at least a reliable daily rainfall series at the scale of the watershed to which the hydrological impact is going to be investigated. Therefore to overcome this drawback downscaling should be employed before using the results of this GCM (Dibike and Coulibaly 2005).

2.4 Climate Scenario

Climate scenario refers to a plausibly future climate that has been constructed for explicit use in investigating the potential consequence of anthropologic climate change (Houghton et al 2001).It is significant to highlight that, unlike weather forecast, climate scenarios are not predictions. Weather forecasts make use of information to the observed state of the atmosphere and calculate, using the law of physics, how this state will involve during the next few days, producing a prediction of the future forecast. In contrast, a climate scenario is a plausible indication of what the future could be like over the decades or centuries, giving a specific assumption. These assumptions include future trends in energy demand, emissions of greenhouse gases, land use change as well as assumption about the behaviour of climate system over long time scales. It is largely the uncertainty surrounding this assumption which determines the range of possible scenarios (Carter, 2007). Various types of climate scenarios are used in impact assessment. The most common scenarios types are applied based on the outputs from the climate models and the other types have been applied in reference to, or in conjunction, with model based scenarios.

I. Scenarios based on outputs from climate models: Climate models at different spatial scale and levels of complexity provide the major source of information for constructing scenarios. The most common method of developing climate scenarios for quantitative impact assessment is to use results from General Circulation Models (GCM).

II. Hypothetical Scenarios: The climate scenarios applied in reference to, or in conjunction, with model based scenarios, a hypothetical scenario. This scenario describes techniques where a particular climate (or related) elements are changed by arbitrary amounts. For example, adjustment for baseline temperature by +1, +2, +3, +4oC and baseline precipitation by ±5, 10, 15 and 20 percent could represent various magnitude of future change (Carter et al., 2007). This scenario provides information in an ordered range of climate changes and can readily be applied in a consistent and replicable way in different studies and regions, allowing for direct Inter comparisons of results. However, such scenarios do not necessary present a realistic set of changes that are physically plausible. They are usually adapted for exploring system sensitivity prior to the application of more credible, model based scenario (Carter et al., 2007).

2.4.1 Representative concentration pathways (RCP) and IPCC AR5 Scenarios

A typical concentration pathway (RCP) is the greenhouse gas (GHG) concentration trajectory adopted by the IPCC for AR5 in 2013. These are the values of radioactive forcing (the atmosphere caused by its composition compared to the pre-industrial period). The RCP replaces the forecasts of the Special Report (SRES) on Emission Scenarios, published in 2000 and used in the IPCC Third Assessment Report (TAR) and Fourth Assessment Report (AR4). SRES describes the emission scenario. Emission scenarios represent future atmospheric emissions of GHGs that provide input to climate models. To be produced requires assumptions about economic and demographic growth patterns, technological developments, and future energy consumption. SRES is complemented by a socio-economic story that helps in its interpretation. Although they have been widely used, various new scenarios have been published after more than a decade of climate change research, new economic data and technological developments (Moss et al 2010).

The new scenarios, rather than using storylines, use radioactive forcing trajectories, which are not related with unique socio-economic scenarios, but can result from many combinations of demographic, economic and technology futures. Since climate models require data on concentrations of radioactively active constituents in the atmosphere, the research community identified a specific emission scenario as pathway towards achieving each radioactive forcing trajectory. This step was necessary to make them usable in climate modelling and compare them with the old SRES scenarios. A selection process took place in order to identify the final RCPs, with criteria established by the research community. The main criteria adopted were the compatibility with the complete range of emission scenarios existing in literature; a manageable and even number of scenarios (in order to avoid a central one to be taken as 'best estimate'); a clear separation of the radioactive forcing trajectories on the long term, to make them distinguishable. The IPCC Working Group III used these criteria in 2007, in order to identify the first 32 potential candidates and then to make the final choice on four of them. The four RCPs selected in the IPCC AR5 (RCP 2.6, RCP 4.5, RCP 6, RCP 8.5) are named after the range of radioactive forcing values at the end of the century (2100) relative to pre-industrial values (+2.6, +4.5, +6.0 and +8.5 W/m2). The main characteristic of each scenario is described as follows:-

RCP 2.6: was developed in the Netherlands by the IMAGE modelling team. The emission path is representative of scenarios in literature that lead to very low GHGs levels, It is also known as the "peak-and-decline scenario", reaching a maximum of radioactive forcing around mid-century (+3.1 W/m2) and then declining.

RCP 4.5: was developed in the United States by the Joint Global Change Research Institute (JGCRI). It is a stabilization scenario in which the total radioactive forcing is stabilized, without overshoot (without reaching a peak), shortly after 2100 (Clarke et al., 2007).

RCP 6.0: was developed in Japan at the National Institute for Environmental Studies (NIES). It is again a stabilization scenario that predicts that the total radioactive forcing will stabilize, without overshoot, shortly after 2100 thanks to the application of some technologies and strategies to reduce GHGs emissions. The stabilization of radioactive forcing will take place like in RCP4.5, but with a higher value of GHGs concentration (Fujino et al 2006).

RCP 8.5 was developed in Austria at the International Institute for Applied System Analysis (IIASA) using MESSAGE-MACRO, a model that incorporates energy supply with a non-linear macroeconomic model. This RCP presents increasing GHGs emissions over time and is representative of scenarios in literature that show high GHGs concentrations (Riahi et al., 2007). Another interesting new feature of the RCPs, with regarding to the SRES, is that there was an attempt to go beyond 2100 with the projections. The Extended Concentration Pathway (ECPs) were developed extending GHGs concentrations and emissions time series. The ECPs radioactive co2 temperature SRES name forcing (ppm) anomaly (ºC) pathway equivalent RCP8.5 W/m2 are defined up to 2300 and are intended as a basis for longer-term simulations, compared to the traditional time frame of the XXI century. Besides the characteristics mentioned above, other scientists, non-governmental organizations, policy makers, and journalists use scenarios also in order to have a common framework through which they can communicate and discuss climate change.

2.4.2 Bias Correction Methods

A number bias correction methods, starting from simple scaling method up to the more complex distribution mapping method, have been developed to correct biased RCM outputs (Teutschbein. C, Seibert J. et al., 2012). (Zollo, A.L., et al., 2014 and Ramos M., et al., 2016) the scaling method basically having linear or nonlinear alternatives that adjust the climatic factors based on the change between observed and model simulated means in a linear or nonlinear equations, such as the linear scaling method (LS) and the power transpiration technique (PT) (Lenderink G. Buishand A. et al., 2007). Distribution mapping also include distribution-based and distributionfree quantile mapping methods, comparing the statistical distribution of RCM-simulated climatic factors to the distribution of recorded data. Distribution-based quantile mapping is considered that climatic factors follows a certain distribution, such as Gamma and Gaussian distributions (Chen J. et al., 2013) and (White R., et al2013), while the distribution-free quantile mapping method applies the empirical distribution (Chen J. et al., 2013). Choosing an appropriate bias correction method is important for arranging proper and reliable inputs for impact analysis of an area. Based on (G.H.Fang, et al., 2015) uses five precipitation bias correction (LS, LOCI, PT, QM, DM) and three temperature bias correction (LS, VARI, DM) methods for correct the row RCM data and to evaluate their performance for hydrological impact study and conclude that Different precipitation correction methods show a big difference in downscaled precipitations while different temperature correction methods show similar results in downscaled temperatures. For precipitation, the PT and QM methods carried out efficiently in terms of the frequency-based indices; while the LOCI method satisfactorily achieved in terms of the time-series-based indices for temperature, all correction options worked in similar in adjusting raw temperature. Biases in climate model simulations are commonly detected by validation with observations where the observations were considered to be “true” and unbiased (Ménard R.et al., 2010). (Sahilu G. and Nigussie A. et al., 2015) can validate that bias correction efficiently reduce any tendency to overestimate or underestimate the mean of downscaled variables. Under this investigation the power transformation method for precipitation and variance scaling bias correction method for temperature used and perform well in adjusting the row RCM data in comparison with the observed metrological data for each stations.

2.4.3 Performance Evaluation of Bias Correction Methods

The ability of RCMs to simulate climate conditions at a particular location can be evaluated using a variety of techniques (Flato G. et al., 2013). However, no single evaluation method or performance criteria is considered superior; rather, the integrated application of different methods and measures that result a comprehensive overview of model ability. The performance evaluation of corrected precipitation data sets was checked with frequency-based indices and time serious performance against the recorded precipitation data. The frequency-based indices considering mean, median, standard deviation (SD), 90th percentile, probability of wet days and intensity of wet days (Belete B. et al., 2016). The time serious-based includes the NashSutcliffe measure of efficiency (NSE) Nash and Sutcliffe, (1970), the root-mean-square error (RMSE) and the percent bias (PBIAS)

2.5. Climate Projections for the Awash Basin

Several climate modelling exercises have been conducted in Ethiopia, particularly for the Awash Basin. Most of the studies consistently predict an increase in temperature. However, the projections for precipitation are inconsistent in which increase or decrease in rainfall amount has been predicted by different models. This is due to the inherent uncertainty of climate models and processes. This implies the need to use climate models and scenarios that capture a full spread of model predictions.

The dynamically downscaled regional climate multi-model outputs of SDSM for RCP scenarios (RCP4.5 and RCP8.5) used. RCP8.5 scenario gives predictions that correspond to the business-as-usual development pathways. The RCP4.5 represents the middle situation.

2.6 The Predictable Impacts from Climate Change

The increasing awareness that enhanced levels of greenhouse gases of direct/natural or indirect anthropogenic origin in earth's atmosphere might change the climate of different regions of the world, in the long run, has recently prompted a great deal of research into the projection of regional responses to global climate change (NRC, 2010). Numerous general circulation model (GCM) experiments and studies indicate that a substantial rise in global temperature would be expected because of a doubling of carbon dioxide (CO2) concentrations. As a result, climatic processes are likely to intensify, including the severity of hydrological events such as; droughts, flood waves, and heat waves (You et al 2010). These projected effects of possible future climate change would meaningfully affect many hydrologic systems, which in turn affect the water availability and runoff and the flow in rivers.

2.7. Climate Change Studies in Ethiopia

According to UNDP global climate change study (date of visit 2019) which has been conducted in University of Oxford for entire Ethiopia have acknowledged that, the recent climate trend showed that mean annual temperature has increased by 1.3°C between 1960 and 2006, a mean rate of 0.28°C per decade. The rise in temperature in Ethiopia has been most rapid in July, August and September (JAS) at a rate of 0.32°C per decade. Daily temperature observations show significantly increasing trends within the frequency of hot days, and far large increasing trends within the frequency of hot nights (temperature exceeded on 10% of days or nights within the current climate of that region and season). The frequency of cold seven days has decreased significantly altogether seasons except December, January and February (DJF). The frequency of cold nights (temperature below that 10% of days or nights are recorded in current climate of that region or season) has decreased sooner and significantly altogether seasons.

Regarding the precipitation trend for current time there's not a statistically significant trend in observed mean rainfall in any season in Ethiopia between 1960 and 2006. Decreases in JAS rainfall observed within the 1980s have shown recovery within the 1990s and 2000s. Additionally to current global climate change, trend UNDP global climate change study investigated the change in climate for future case; this study investigated GCM projections of future climate in Ethiopia. Consistent with the result, the mean annual temperature is projected to extend by 1.1 to 3.1°C by the 2060s, and 1.5 to 5.1°C by the 2090s. Under one emissions scenario, the projected changes from different models span a variety of up to 2.1°C. Moreover, a little increase in annual precipitation is predicted over the country (NMA, 2012).

Research on Awash basin indicated that the basin would be significantly suffering from the changing climate; that’s, a substantial water deficit is projected for the longer term by employing GCM models. All the models suggested that heating would end in a general increase in dryness, which might decrease water availability. Moreover, a 20% decrease in rainfall within the basin including a 2°C increase in temperature would end in a 41% decrease within the annual runoff. Even a temperature increase of 2°C without precipitation change would end in a 9% decrease in annual runoff. On the opposite hand, a rise of precipitation by 10% would offset a 2 to 4°C increase in temperature and end in a surplus of runoff starting from 4 to 12% (Kinfe 1999).

In general, warming within the awash basin simulated by various models would end in a considerable decrease in annual runoff over the basin (Kinfe 1999). With annual warming temperature in Ethiopia within the 2020s are going to be 1.2 oC with a variety of 0.7–2.3 oC and in 2050s it'll be 2.2oC, with a variety of 1.4–2.9oC. The regional differences in warming are relatively modest. Warming are going to be related to greater frequency of warmth wave events and is probably going to steer to higher rates of evaporation. Moreover, their study justified that climate models show different projections of annual rainfall over Ethiopia, with some models projecting more rain, others less, but with a bent for slightly wetter conditions. There are very small changes in multi model average annual rainfall for the 2020s (+0.4%) and 2050s (+1%). global climate change |temperature change"> global climate change impact on water resource of Lake Tana sub-basin was assessed supported CCCM and GFCD3 UK89 climate change prediction. The CCCM and GFCD3 GCMs predict a discount of annual runoff by 18.2% and 12.6% respectively, while UKMo GCM predicts wetter condition and as results of a rise in 2.5% in annual runoff (Deksyos and Abebe, 2006).

2.8 Hydrological Modelling

Hydrological models are used to simplified, conceptual of the hydrologic cycle and identifying hydrologic prediction, and understanding of hydrologic processes. According to Lenhart et al. (2002), hydrological modelling is a powerful technique of hydrological systems investigation for both the research hydrologist and practicing water resources engineers involved in the planning and development of an integrated approach for the management of water resources. The purpose of using a model is to establish baseline characteristics whenever data is not available and to simulate long-term impacts that are difficult to calculate, especially in ecological modelling.

Effective basin management and ecosystem restoration require a complete understanding of the hydrological processes of the basin. Spatial and temporal variations in soil, vegetation, and land use practices make the hydrological cycle a complex system. Therefore, mathematical models and geospatial analysis tools are needed to study hydrological processes and responses to land use and climate change (Dilnesaw, 2006). Based on the process description, hydrological models can be divided into three main categories (Cunderlik and Burn, 2003).

i) Lumped models

According to Cunderlik and Burn (2003) in these models, parameters do not vary spatially within the basin and do not represent physical features of hydrologic processes. The basin response is evaluated only at the outlet not include other sub-basins. The impact of spatial variability on the model parameters is evaluated by using certain procedures for calculating effective values for the entire basin.

ii) Semi-distributed models

In semi-distributed models, parameters are partially allowed to vary in space by dividing the basin into a number of smaller sub-basins. The main advantage of semi-distributed models is their more identify physically based structure and the lesser amount of input data when we compare to others. Some hydrological models such as; HEC-HMS, SWAT, HBV are in the domain of semi-distributed hydrological models (Cunderlik and Burn, 2003).

iii) Distributed models

In distributed models, parameters are allowed to vary in space at a resolution usually chosen by the user. Distributed modelling approach attempts to incorporate data concerning the spatial distribution of parameter variations together with computational algorithms. This model generally requires large amounts of data for parameterization (Cunderlik and Burn, 2003).

2.8.1. Hydrological Model Selection Criteria

There are a number of criteria which can be used for choosing the right hydrologic model. These criteria are mainly dependent on the use of the model. Furthermore, some criteria are also user dependent such as: personal preference; computer operation system; input/output management and structure etc. (Cunderlik 2003) suggested four criteria for the selection of hydrological models. These are: (1) required model outputs for the needed purpose, (2) different hydrological processes that are required to be modeled for the desired purpose, (3) availability of input data and (4) Price depending upon the above selection criteria for this research Soil and Water Assessment Tool (SWAT) was selected because:

i) SWAT is public or open source domain software actively supported by the USDA (United States Department of Agriculture) ARS (Agricultural Research Service) at the Grass-land, Soil and Water Research Laboratory in Temple, Texas, USA.

ii) SWAT is a river basin scale, a continuous time, a spatially distributed model developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time (Neitsch et al., 2005).

iii) SWAT can analyze both small and large watersheds by subdividing the area into homogenous parts. SWAT use hydrologic response units (HRUs) to describe spatial heterogeneity in terms of land cover, soil type and slope within a watershed. The SWAT system embedded within geographic information sys-tem (GIS) that can integrate various spatial environmental data including soil, land cover, climate and topographic features.(Lenhart,T et al., 2002).

2.9 Hydrological Model used in Ethiopia and in Awash Basins

i. . Impact of land-use changes on the hydrological response of the Chalk Mountains (Ethiopia) a new approach to addressing the land-use dynamics of model SWAT the catchments of the Chalk Mountains (Ethiopia) have been in the last few decades. These dynamics were addressed by five land-use maps based on aerial and satellite imagery interpretations, but climate and flow data for several years were available. The data available in the test application was carefully analysed and found to be limited in quantity and quality. LUPSA was applied to the SWAT model from 1973 to 2003 to provide annual land use renewals. Annual LUCs fluctuated between -6% and + 360% per class. The impact of land dynamics on the hydrological response was observed and indicated by daily flow, total annual runoff, and peak flow. It also increased the proportion of low flow rates, causing more water stress. Given the high degree of uncertainty, SWAT was unable to produce reliable results due to poor data quality. Nonetheless, the implementation of land cover dynamics in SWAT has made significant changes in model output and has shown improved capabilities for dealing with impacts on water resources. Further model testing is highly recommended (Friedrich J. Koch et al 2012).

ii. Prediction of runoff using the SWAT model and evaluation of the Boru Dodota Spate Irrigation scheme in the Alsizone in southeastern Ethiopia (upper Awash River) Performance analysis results show good agreement between monthly mean simulations and measurements. Shown. 0.71 for Nash-Satcliff model efficiency (NSE) calibration and 0.73 for validation period. In addition, the coefficient of determination (R ^ 2), 0.73 and 0.76, were obtained over the same period. Next, the calibrated parameters of the gagged catchment were used to estimate the runoff of the non-gagged catchment. The simulated average monthly and average annual water yields of the Bol River basin were found to be 0.53 and 6.4 m ^ 3 / s, respectively. The reliable rainy season water yield of 70% of the catchment area was 3.4 m ^ 3 / s, and the crop water requirement in the command area was 1.2 l / s / ha. Water yields from catchments can only irrigate 2,842 ha of the pre-designed 5,000 ha of the Boru Dodota spate irrigation scheme. In conclusion, the SWAT model can be used to analyse ungagged basin runoff in areas with similar hydropower. Meteorological characteristics similar to the Keleta basin in this area. The information obtained can then be used to redesign the spat system or conventional irrigation system (Teso .E et al, 2014).

2.10 SWAT Model Description

Soil and Water Assessment Tool (SWAT) is a physically-based continuous-event hydrologic model developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time (Arnold, 1998). The SWAT (Soil and Water Assessment Tool) (Arnold et al., 1998) model developed in the early 1990's by the U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS) to overcome all limitations of previous model. In the SWAT model, the modeling or estimation of flow, sediment or nutrient transport of the watershed is done by dividing the watershed into sub basins and the land areas in the sub basins are also sub-divided again into one or more land units, possessing similar land use, soil type and applied management strategies. These similar land units in land use, management and soil attributes are called Hydrologic Response Units (HRUs). The HRUs are helpful for a better estimation of the loadings (flow, sediment, pollutants) from the sub basins. The Arc SWAT extension of Arc GIS is a graphical user interface for the SWAT model (Arnold, 1998). To create a SWAT dataset, the interface will need to access Arc GIS compatible raster (GRIDs) and vector datasets (shape files or feature classes) and database files which provide certain types of information about the watershed. SWAT model designed to route water and sediments from individual watersheds through the river systems. It can incorporate the tanks and the reservoirs/check dam off-stream in addition to streams. The agricultural areas can be integrated with respect to their management practices (Arnold et al., 1998). SWAT model can satisfactorily estimate sediment yield for even poorly gauged catchments (Ndomba and Griensven, 2011). The model uses SCS curve number and Green Ampt method having daily rainfall data as input to generate surface run off whereas modified universal soil-loss equation (MUSLE) used to predict sediment loss. Soil Conservation Service curve number use land use ,soil permeability and antecedent moisture conditions (SCS, 1972) whereas Green Ampt computes infiltration as function of wetting front metric potential and effective hydraulic conductivity (Green Ampt, 1911).

2.11 Hydrological Process in SWAT

SWAT simulates different hydrological processes through integrating spatial variation in topography, soil, land use, slope and other watershed characteristics. The simulated hydrological process encompasses runoff, infiltration, Lateral flow, channel routing, and percolation to shallow aquifers, deep aquifers and evapotranspiration (Arnold et al., 1998). From these hydrological process the surface runoff, lateral flow (subsurface flow), base flow (return flow) contribute to the stream flow in the main channel whereas water that enters deep aquifer is assumed to be lost out of watershed under investigation. All the hydrological process raised above are simulated in surface, soil, vadose (intermediate) zone, shallow and deep aquifers as shown in Figure 1

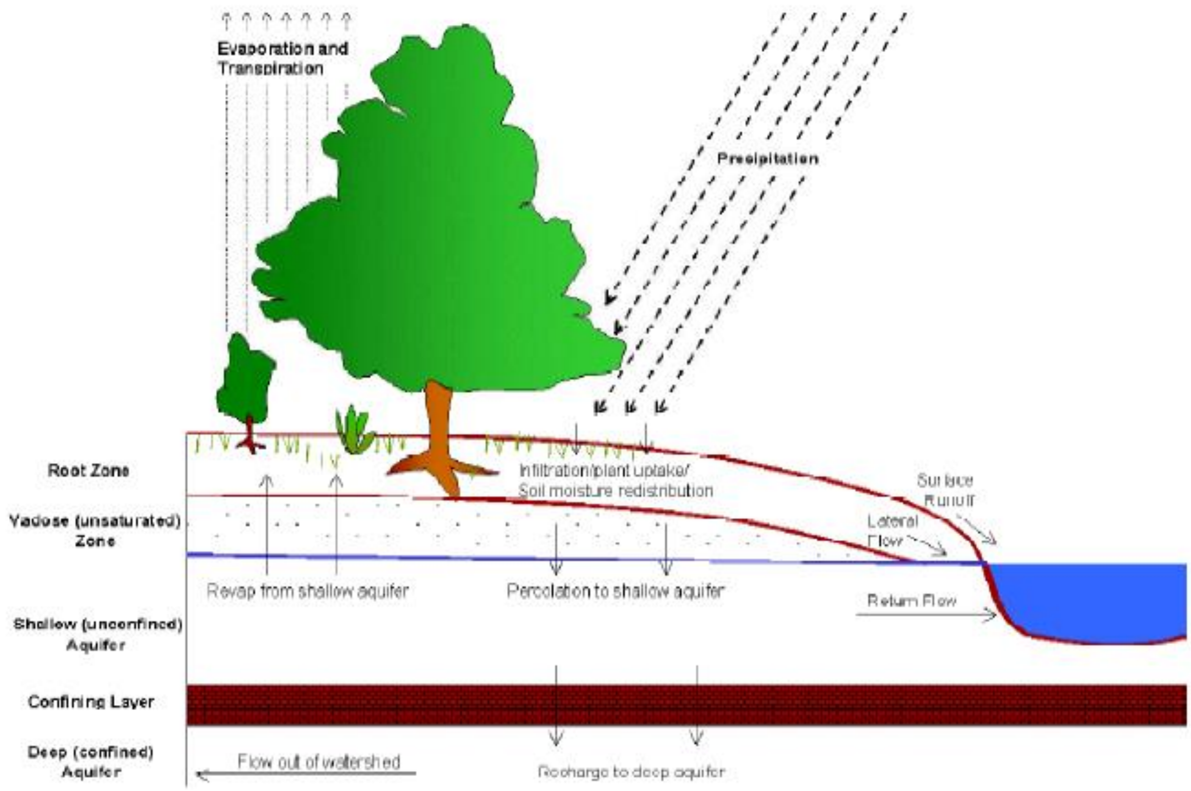


Figure 1 Schematic representation of the hydrological cycle (Neitsch et al 2005)

3. MATERIALS AND METHODS

3.1 General Description of the Study Area

3.1.1 Location

The study area Awash Bello Watershed is located between 8° 45'to 9° N latitude and 38° to 38° 30' E longitudes, in the western catchments of Upper Awash Basin, and the mean altitude is 2060m.a.s.l. The area is generally known as a floodplain composed of fertile soil formed by alluvial deposit and hence, is suitable for different types of crop production. There is also good grazing land incorporated within the whole area coverage of the watershed and hence, suitable for livestock and other animal population. Administratively, the Study Area is under the full jurisdiction of Oromia Regional State, South west shewa and West Shewa Zone. Bello watershed is included fully and/or partially in six woreda which are found some in West Shewa zone and some of them in Southwest Shewa zone and these woreda are namely:Dandi, sabeta, Walmara, Addis Alem, DAwo and Teji. The area is accessible in two directions: one is along the asphalt road from Addis Ababa to Ambo and the other is from Addis Ababa to Waliso and is found at about 50kms road distance to the west of Addis Ababa. The whole catchment area of the upper Awash m/kunture watershed cover is about 3,500km2 and in this study the interest area covers about half (1511.85km2) of the whole area . The total population of the study area according to the 1994 census is estimated at 107,000 and almost all are farmers.

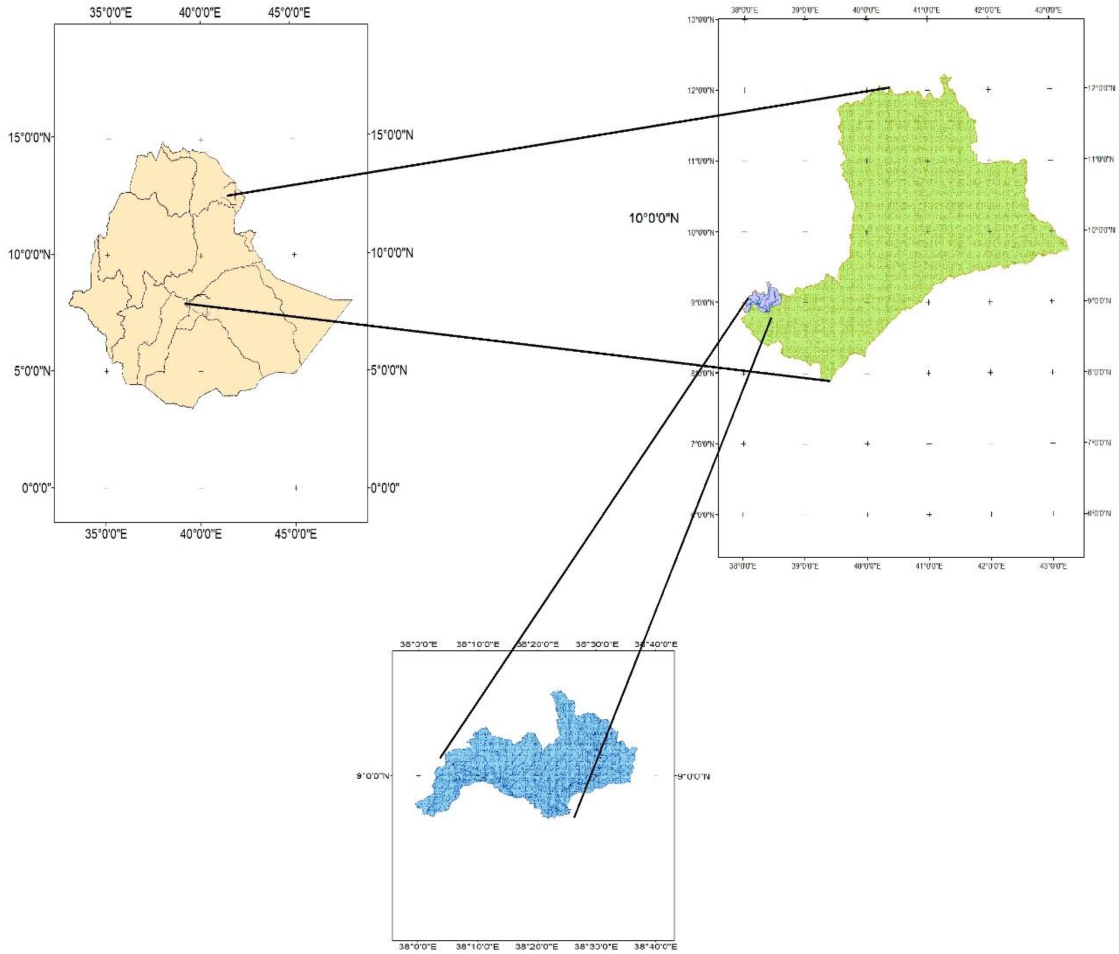


Figure 2 study area or watershed of awash Bello

3.1.2 Climate

The climate in the study area falls, as a whole, into the Inter-Tropical Convergence Zone (ITCZ). Annual rainfall ranges from 800mm to 1000mm on the plain area and amounts to 1200mm on the mountainous area. There is a considerable variation of rainfall year by year. Approximately about 70% of the annual rainfall occurs during the rainy season which extends from June to September. This constitutes one of the restrictions to agricultural development in the study area. The fluctuation of monthly mean temperatures is relatively small. The daily mean temperature ranges between 12.10c and 16.00c in the mountainous area, and between 15.90c and 17.20c in the plain area. However, the daily fluctuation of temperature is remarkably great. The minimum and maximum temperatures in a day record show 4.1oC and 28.5oC in the plain area. The monthly average relative humidity is 54.3 %.The monthly average wind velocity is 1.7 m/s in the plain area. The average sunshine duration is 7.8hr/day (Feyissa, 2007).

3.1.3 Present Land Use

The study area is densely settled and is intensively used. The farming is agro-pastoral, with livestock providing the power required for land preparation. Teff is the major crop in the area and is cultivated on both the upland and in the seasonally inundated area. Based on the field survey and aerial photo interpretation, eleven land use classes are identified based on broad classes of use, the type of cropping and the spatial intensity of cultivation (the proportion of the unit occupied by cultivated fields in any one year). The agricultural land for crop cultivation accounts for 78.4% of the study area. The grazing land, most of which is seasonally inundated is accounted for 11.9 % of the study area. The remaining 9.7 % of the area is accounted for by villages, tracks, and woodlots. Flood irrigation is practiced on a limited area of the Holota flood plain. A single irrigation application is given by cutting a channel through the river levee. As a result of increasing pressure of population on the land resources of the Study Area, there has been considerable encroachment of grazing areas by cultivation (Feyissa, 2007). The overall watershed delineation and HRU definition simulation in the awash Bello sub basin gave a watershed area of 1582.78 km^2 which resulted in 40 sub-basins. The watershed delineation of the area gave minimum, maximum and mean elevations in the basin of 1790, 3060, and 2170.51 m.a.s.l respectively. The area coverage by each land use type is presented in Table 3. SWAT slope computation using the DEM data indicated that Less than 0-3% ,16.033% ,3-8%, 34.5 %, 8-15 %22.47%, 15-30% and 30-50%, 8.34% of the water shed ...

Table 1 Slope classes and area coverage

Slope classes	Range %	Area Ha	coverage %
Flat or almost flat	0-3	250641	16.03312
Gently sloping	3-8	539334	34.50037
Sloping	8-15	351287	22.47129
Moderately steep	15-30	291600	18.65321
Steep	30-50	130408	8.342001
Total		1563270	100

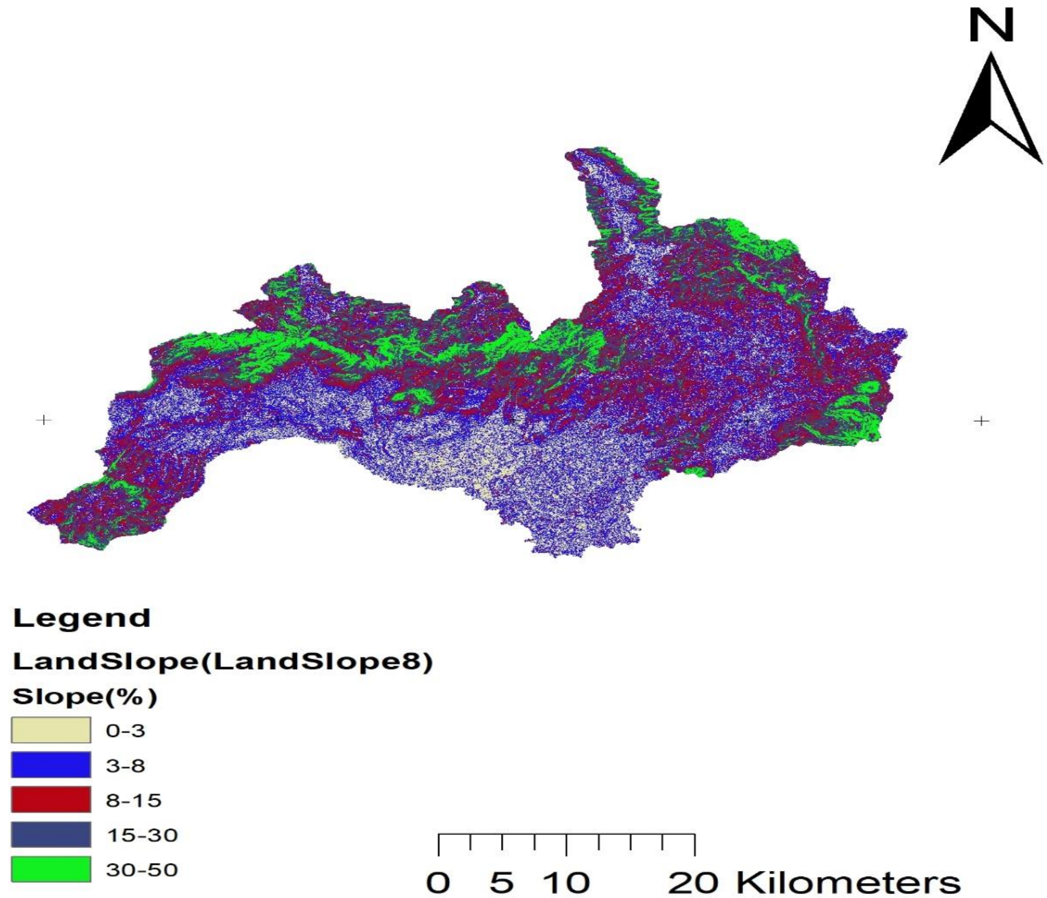


Figure 3 classes of slope Source (DEM)

The land use/land cover map of the study area was collected from MoWRIE GIS department which was obtained in shape file format. The land use/cover data reclassified according to the SWAT land use/cover type. Redefining was done based on the data collected from physical observation during field visit and personal judgment. A look up table that identifies the 4-letter SWAT code for the different categories of land cover/land use were prepared so as to relate the grid values to SWAT land cover/land use classes. SWAT calculated the area covered by each land use. The different land use/cover types are presented in Table.2

Table 2 Land use types and their areal coverage at Awash Bello sub basin

Land use/land cover types and area of watershed			
land use code	Area (KM2)	Percentage of area	Description of code
FRSE	510.90	33.79191745	Forest-Evergreen
FRST	555.23	36.72398968	Forest-Mixed
AGRL	367.08	24.27938356	Agricultural Land-Generic
WATR	12.30	0.813545869	Water
URLM	66.39	4.391163437	Residential-Med/Low Density
EUCL	510.90	33.79191745	Eucalyptus
Total	1511.99	100	

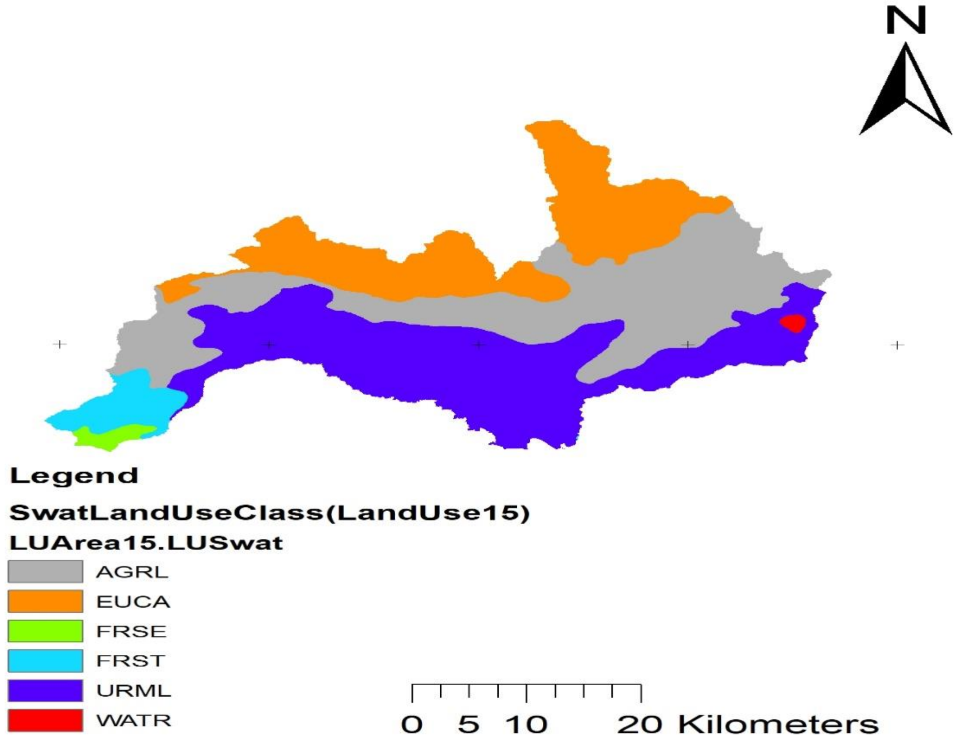


Figure 4 Land use/Land cover map of the study area (source shape file obtained from (MOWIE)

It is annually inundated for several months and poorly drained, which severally hinders proper land use and a comfortable rural life of the farmers in the plain and reduces productivity although the plain is blessed with large land resources. Such situation renders the agriculture in the plain hazardous. The yield of crops is low and unstable and kinds of crops cultivated are limited. Accordingly, the agricultural production potential of the plain is not properly exploited. The farmers in the plain have to live at subsistence level. Proper assessment of the plain and flood hazard zonation would definitely help in promoting agricultural development which directly brings the improvement of the low living standard of the community in the area.

3.1.4 Soils

The Soil data was also collected from the Ethiopian (MoWIE), GIS department. However, this data was only in shape file format and the characteristics of the soils needed by the SWAT. Soils data are classified by the FAO soil classification system (1990) and mapped by 15 mapping units defined based on combination of soil and land form characteristics. The soils do not show extensive variation, and are limited to the four main classes of vertisols, and luvisoils. Vertisols are by far the dominant soil class accounting for 56% of the study area and including all the upland plains where as the rest 44% luvisols, all the seasonal swamps, and most of the alluvial cover flood plains and terraces. The exceptions are the mapping units on the awash Bello flood plain and adjacent terraces, where dark clays are buried under reddish brown alluvium deposited by the awah river (JICA, 1996). Vertisols are generally chemically fertile soils but have specific physical properties which demand careful management. They are extremely hard when dry and very sticky and plastic when wet, thus restricting the period when tillage can take place. Although water enters the soil rapidly in the dry state down the surface cracks, permeability is extremely low when the cracks are closed, leading to impeded drainage. The soils have a high water holding capacity which makes them well suited to cropping on residual moisture at the end of the wet season. (Fayissa, 2007).

Most of the area in the watershed is covered by Teff, lentil, stepmother and etc. at lower part and durum wheat at higher part. The majority of the land was covered by soil type chromic luvisols and Eutric Vertisols (Fayissa 2007).The SWAT result for the soils' area Coverage in the watershed is shown in Table 3.

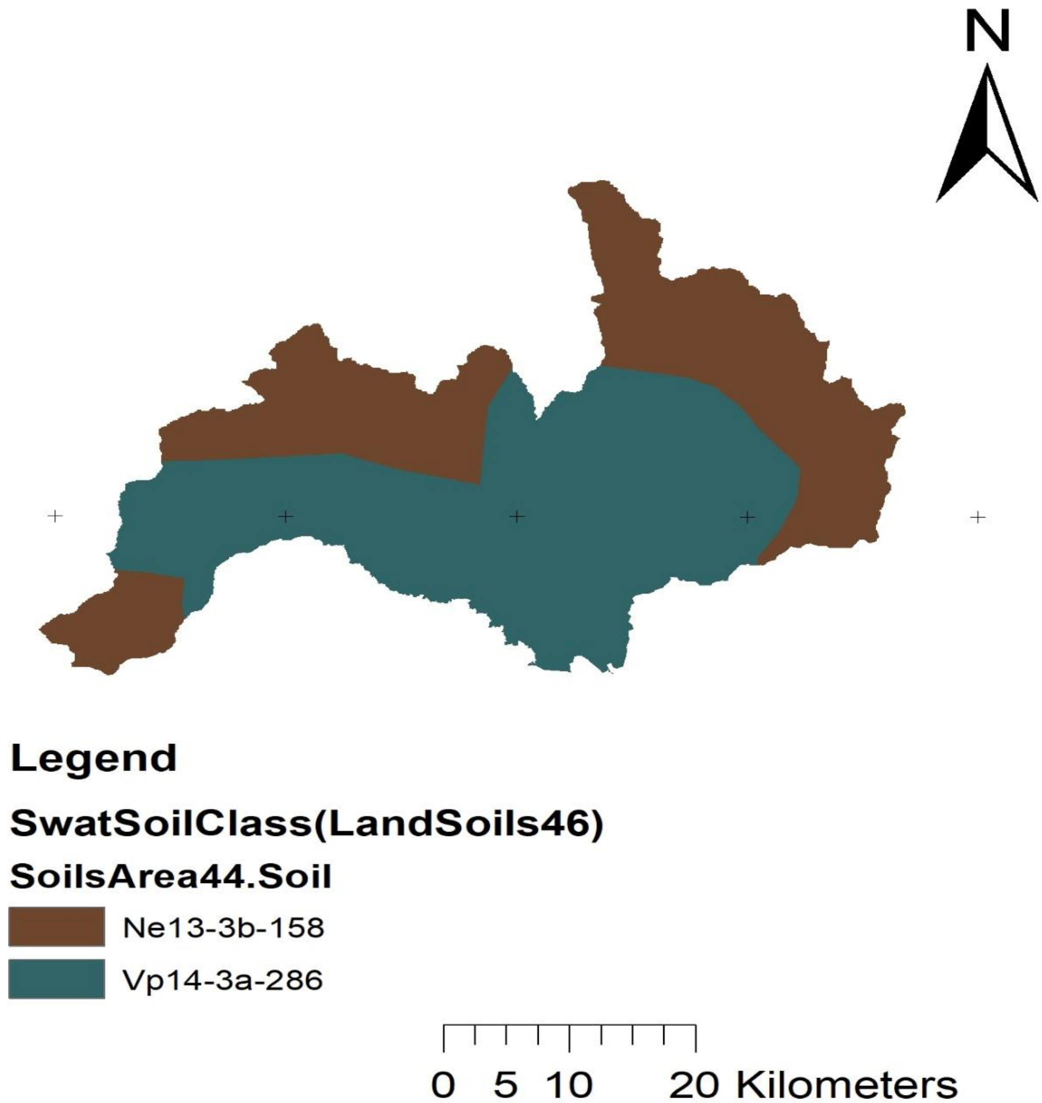


Figure 5 Soil classes

Table 3 Soil type and area coverage

Soil type	Area coverage ha	% coverage of area	Description of Code
Ne13-13b-158	665.236	44	Chromic Luvisols
Vp14_13a_286	846.664	56	Eutric Vertisols

3.1.5 Flooding problem

Extending over the low-lying and depressed lands Bello Plain is annually inundated especially during the rainy period from July to September. The inundated areas in the Bello plain are the Dilu Meda and Gabar Meda. The inundation in these areas basically results from the flooded water that spills over the rivers because the discharge capacity is insufficient for the high rainy season flow. Moreover, the inundated water in both these areas cannot be drained easily due to the small carrying capacity of the Awash in the downstream of the Bacho Plain and the small drainage capacity of the bridges and culverts. The main and serious constrains in the study area are the occurrence of recurrent inundation and floods. A considerable number of farmers in the study area have the lands located in the inundation area. Their farming is constrained by the risks of crop losses by floods and inundation that occur several times every rainy season. The sociological damages caused by inundation are also serious. Some settlements are often isolated during the rainy season due to floods and inundation and the life is completely disrupted. Therefore, any agricultural development activities should incorporate flood control systems (mechanism) and consider it as the prior activities (Feyissa, 2007).

3.2. Data Collection

3.2.1. Meteorological data

Meteorological data is needed by the SWAT model to simulate the hydrological conditions of the basin. The meteorological data required for this study were collected from the Ethiopian National Meteorological Services Agency (NMSA). The meteorological data collected were precipitation, maximum and minimum temperature, relative humidity, wind speed and sunshine hours from one station and precipitation and maximum and minimum temperature from three stations, which are within the study area, were collected . The other problem in the weather data was inconsistency in the data record. In some periods there is a record for precipitation but there will be a missing data for temperature, and vice versa. As the SWAT model requires data of the same periods of record, the weather data used for the study was set from 1990-2010.

Meteorological data was require for two purposes, first, the data were used to downscale the GCM data using CMhyd(Climate Model data for hydrologic modeling) and secondly, it will be used as input to the SWAT model for simulation of hydrological processes and to produce runoff of the watershed.

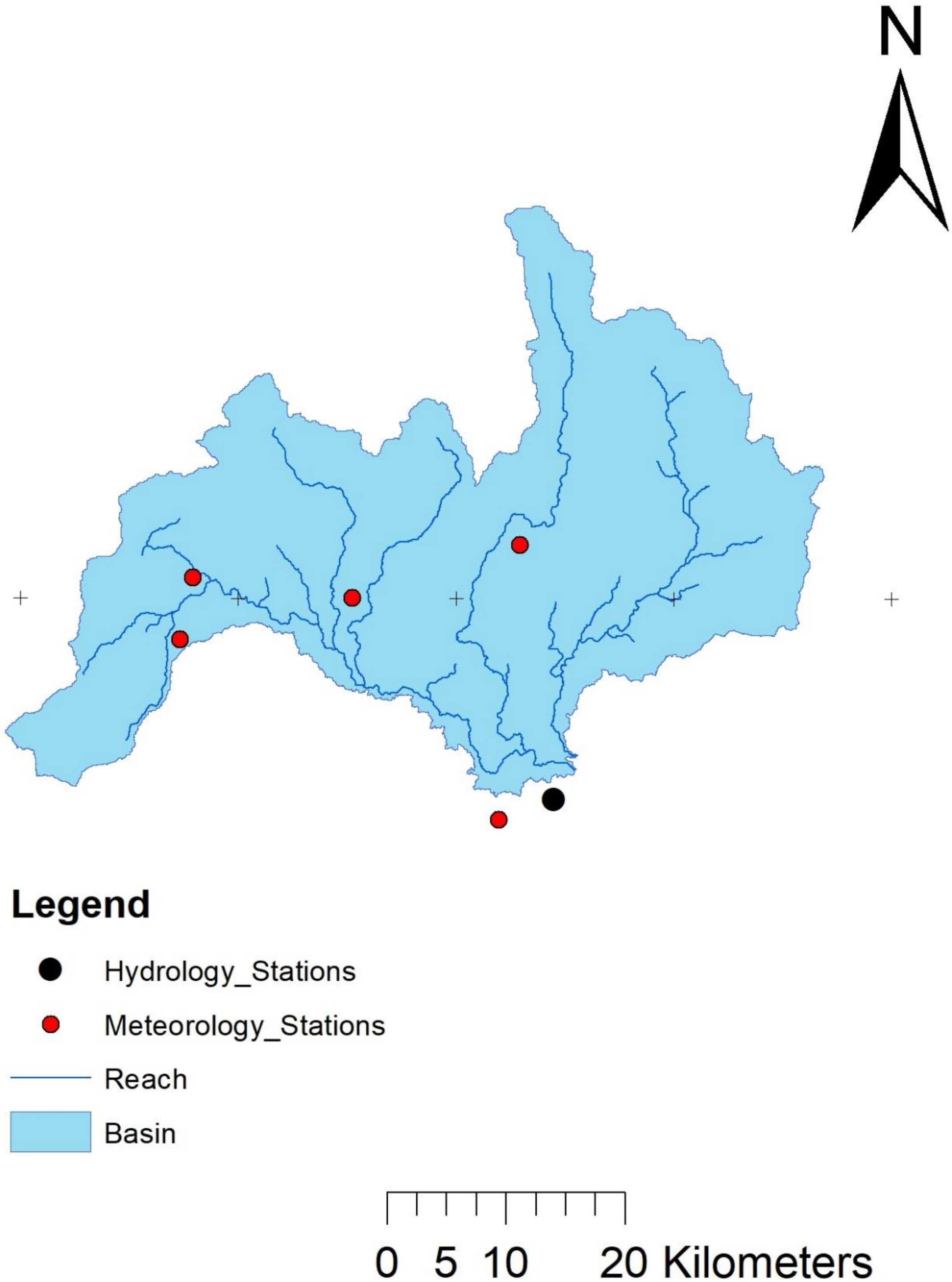


Figure 6 Hydro metro station in the watershed

3.2.2 Hydrological data

Awash Bello River flow data were requisite for calibrating and validating the SWAT model. There is one gauging station at the outlet of the river and the geographic location of the station is at latitude 8° 50' 54.35'' N and longitude 38° 24' 36.62'' E. Daily stream flow discharge data of (1990-2010) for this station was collected from the Hydrology Department of Ministry of Water Irrigation and Electricity of Ethiopia.

3.2.3 Spatial data

The spatial data include digital elevation model (DEM), the digital stream network, land use and land cover and soil data. The high-resolution DEM (30 by 30 m) was used as input data in SWAT to delineate watersheds. All the above data was obtained from the Ministry of Water Irrigation and Electricity of Ethiopia.

3.2.4 Climate Change Scenario Data

Climate change scenarios were developed using multiple GCMs as lateral boundary condition and downscaled by RCMs. The raw RCMs data (Table 3.1) was acquired from CORDEX Africa (Coordinated Regional Climate Downscaling Experiment).Data quality analysis and bias correction was performed using CMhyd quality control operation like missing data. Since the climate models ensemble is recommended for hydrological studies (Teutschbein and Seibert, 2010), ensemble mean of six statistically bias corrected RCMs rainfall and temperature output were used as input in the calibrated SWAT model to project future water resources condition. Each of these six RCMs were forced with Representative Concentration Pathways (RCPs) which represent medium (RCP4.5) and high (RCP 8.5) levels of radioactive forcing of greenhouse gases (GHGs) (Moss et al., 2010). These emission scenarios (RCP4.5 and RCP8.5) are used assuming these scenarios represent a broad range of uncertainties with regard to possible future pathways. The future simulation of water resources condition of RCMs was compared with the observed water resources condition. The future climate was divided into two temporal blocks to represent near-term (2031-2070) and long-term (2071-2100) climate condition.

Table 4 Description of GCMs and RCMs used in this study

No	Driving GCM	RCMs	Acronym	Institute of RCM
1	CNRM-CM5	CCLM	CCLM4(CNRM-CM5)	Climate Limited-Area Modelling (CLM) Community
2	EC-EARTH	RCA	RCA4(EC-EARTH)	Rossby Centre Regional Climate model,(RCA)
3	EC-EARTH	REMO	REMO(EC-EARTH)	Climate Limited-Area Modelling (CLM) Community
4	MPI-ESM-LR	RCA4	RCA4(MPI-ESM-LR)	Rossby Centre Regional Climate model,(RCA)
5	CNRM-CM5	RCA4	RCA4 (CNRM-CM5)	Rossby Centre Regional Climate model,(RCA)
6	MPI-ESM-LR	REMO	RCA4(MPI-ESM-LR)	Max Planck Institute (MPI), Germany

3.3. Method of Data Analysis

3.3.1. Filling missing data

Some precipitation stations may have short breaks in the records because of absence of the observer or because of instrumental failures. It is often necessary to estimate or fill in this missing record. The missing precipitation of a station was estimated from the observations of precipitation at some other stations as close to and as evenly spaced around the station with the missing record as possible. Here, the station whose data was missing is called interpolation station and gauging stations whose data are used to calculate the missing station data are called index stations. There are methods to fill in missing data. These are: arithmetic mean method, normal ratio method and inverse distance weighing method. Arithmetic mean method can be used to fill in missing data when normal annual precipitation is within 10% of the gauge/station for which data are being reconstructed. The normal ratio method is used when the normal annual precipitation at any of the index station differs from that of the precipitation station by more than 10%. In the absence of normal annual rainfall for the stations inverse distance weighing method can be used to fill the missing data. In this study by using Microsoft excel the regression formula is used to calculate the missing data of stations before the data is used.

3.3.2 Test for consistency of data

Similar to estimating missing data, consistency test occurs when the selected station of recorded data is inconsistent over a period of time and adjustment of the measured data are necessary to provide a consistent record. It is used, when the recorded parameters are not related to the time change. In addition, the consistency test related to time series data obtained good results of the model outputs.

The variation of the recorded data and interpolation for the missing stations were tested by the double-mass curve technique for this study. This technique can easily identify which of nearby precipitation stations are to be filled better corresponds to fill the missing observed data at the station.

The double-mass curve is a graph of the cumulative value at each station versus the combined cumulative values of a nearby station; it has been subjected to similar meteorological occurrences and is known to be consistent. If a precipitation record is a consistent estimator of the meteorological occurrences over the period of record, the double-mass curve will have a constant slope. If the slope is evident, then the record precipitation data needs to be adjusted (McCuen, 1998). Therefore, we have to correct the slope of recorded precipitation using the equation:

$$P_{cx} = P_x * \frac{Mc}{MA} \quad (3.1)$$

Where: P_{cx} is the corrected precipitation at any time period, P_x is originally recorded precipitation at a time period, M_C is the corrected slope of the double mass curve and M_A is the original slope of the double mass curve.

3.3.3 The SWAT hydrologic model

The SWAT model was chosen in this study because of the fact that it can continuously and physically simulate hydrological processes (Arnold, et al, 1988). His work is due to the fact that hydrological processes can be continuously and physically simulated. (Arnold, et al, 1988). These features are needed to simulate the impact of climate change on water resources. In addition, SWAT coordinates and validates the study area (Näschen, et al, 2018). The model follows a semi-distributed approach by dividing the catchment area into sub collection areas based on the thresholds defined by the modeller.

This threshold defines the minimum drainage area required to generate a stream, or whenever two streams merge. In the next step, the Hydrological Response Unit (HRU) divides the watershed into unique combinations of soil type, slope and land use. Again, the modeler must set a minimum threshold for the absolute or relative area covered by the contained HRU. In this study, sub-water bodies were discretized into HRUs, while each soil type, slope class, or land use unit covering less than 10% of the area within a single sub water body was ignored. The model is divided into two parts. First, the land phase that considers the entire process from the arrival of raindrops to the surface of the earth. From here, the second phase begins, taking into account the routing and in-stream processes of water, sediments, nutrients, and organic chemicals.

Therefore, most hydrological processes of SWAT are calculated at the HRU level and the spatial location of the HRU in the small basin is no longer considered, but all single HRU calculations are done to efficiently calculate the process. It is calculated as a centralized sum of. Within the sub catchment area. In general, the SWAT model solves the water balance equation for each HRU, sums the HRU calculations for each sub-water body, and at the same time integrates climate station data at the sub-water body level. Single watersheds are linked through a channel process that calculates the movement of water from a spatial unit. As long as water is near or on the surface, it can evaporate according to atmospheric conditions (Monteith, et al, 1977). Once water enters the soil, it can move vertically according to storage routing techniques based on physical soil parameters, or horizontally using a kinematic storage model (Sloan, et al, 1984).). When water penetrates, it passes through the Vadose Zone into an unconfined aquifer, where it either leaves as a capillary growth due to the water demand of surface plants, or moves laterally as the return flow flows into reach. To do. The third option is to further penetrate the confined aquifer, from which water is treated as a source of spillage into other catchment areas. A more detailed explanation of the theoretical background is given by (Neitsch et al. 2009).

The data required for this study consist of (i) daily meteorological data, (ii) spatial data (DEM, soil maps and characteristics, and LULC), and (iii) flow / river flow data. Daily meteorological data from four meteorological stations located within and near the basin boundary were collected from the Ethiopian National Meteorological Agency (NMA). This study used a 30x30 resolution DEM obtained from MOWIE. Soil maps, key soil data and LULC maps were obtained from MoWE (Ministry of Water Energy, Ethiopia).The stream flow, daily, data of the watershed at Bello gaging station was found from Hydrology department of the MoWE. This data (discharge/stream flow) has been employed in Arc SWAT model sensitivity, testing and verification analysis. The standard procedure of ArcGIS interface Arc SWAT hydrologic model was applied to delineate the watershed, determination of hydrological response units (HRUs), sensitivity analysis, model calibration and validation and sensitivity analysis. Arc SWAT hydrologic model was be calibrated and validated for the study area of awash Bello watershed.

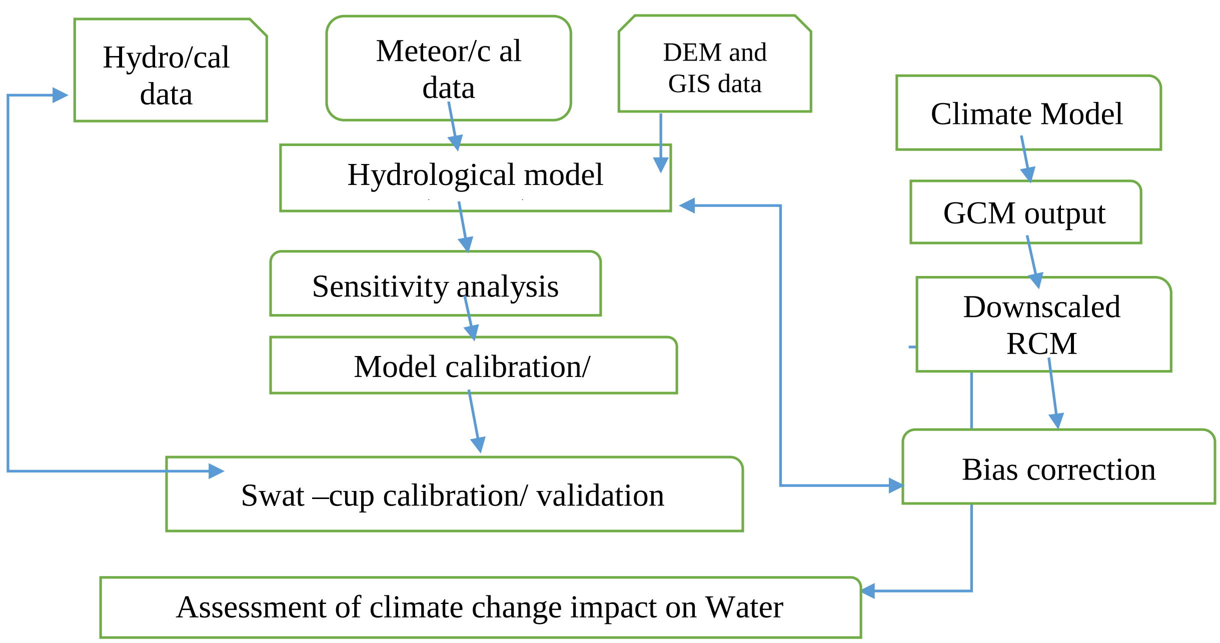


Figure 7 Schematic illustration of the general approach for SWAT Model

3.3.3.1 Watershed delineation

ARCSWAT used digital elevation model (DEM) data to automatically delineate basins into several hydrologically connected sub-basins. The first step in portraying the basin was to load a properly projected DEM. A mask is created on the DEM around the study area to reduce the processing time of the GIS function. The polyline stream network dataset then burns in, forcing the SWAT sub basin reach to follow a known stream reach. River network burn-in improves hydrological segmentation and depiction of small watersheds. After the DEM grid load and stream network were overlaid, the DEM map grid was processed to remove the non-drained zone. Initial stream networks and sub basin outlets defined based on the basin threshold approach. The interface lists a minimum, maximum and suggested threshold area. The smaller the threshold area, the more detail the drainage network delineate by the interface but the slower the processing time and the larger memory space required. In this study, defining of the threshold drainage area was done by successive re-run of the stream and outlet definition routine from the suggested to the minimum are until known smaller streams was created (http://www.brc.tamus.edu/swat).

3.3.3.2 Importing Weather Data

Weather data used in a watershed simulation was imported in order to provide the moisture and energy inputs that control the water balance and determined the relative importance of the different components of the water cycle. The weather data required by ARCSWAT consist of daily precipitation, maximum/minimum temperature, solar radiation, wind speed and relative humidity. In txt format the climatic input variables imported together with their weather location and based on data availability.

3.3.3.3 Hydrologic Response Unit Analysis

The Hydrological Response Unit (HRU) was a concentrated land area within a sub-basin, consisting of a unique combination of land cover, soil, and management. With HRU, the model can reflect differences in different land covers, soil evapotranspiration and other hydrological conditions. Runoffs are estimated individually for each HRU and routed to get the total runoff in the basin. This improves the accuracy of flow forecasts and greatly improves the physical description of the water balance. Land use and soil data in projected shape file format loaded into the Arc SWAT interface. Determine the area and hydrological parameters of each land-soil category simulated within each sub-basin A land cover / land use class defined using a lookup table that identifies the four-letter SWAT code for various categories of land cover / land use to associate grid values with SWAT land cover and use classes. After land use SWAT codes were assigned to all map categories, the area covered for each land use was calculated and reclassified. The land slope class is also integrated into the definition of hydrological response units. The DEM data used during basin depiction is also used for gradient classification. Due to the wide range of gradients between sub basins, multiple gradient classification operations take precedence over a single gradient classification. Five gradient classes (0-3, 3-8, 8-15, 15-30, and 30-50%) apply based on the proposed minimum, maximum, mean, and median gradient statistics for the basin. And the gradient grid has been reclassified (MOA, 2005).After their classification of the land use soil and slope grids overlay operation was performed (http://www.brc.tamus.edu/swat).

3.3.3.4 Sensitivity analysis

Because the basin process is affected by a number of parameters, the sensitivity analysis is performed using the Sequential Uncertainty Fitting (SUFI-2) algorithm to determine the key parameters that affect the stream flow for calibration within SUFI-2. Identified (executable) after iteration). The sensitivity parameters for this study were determined using an approach that considers the sensitivity of one parameter in relation to the other parameters under consideration (Abbaspour, et al. 2012). We used t-stat, which gives the sensitivity of the parameter and the measured value of the p value, and the significance of the sensitivity of that parameter, to rank the various parameters that might affect the stream flow. However, generalized status cannot be assumed because these parameters vary from basin to basin, depending on general terrain characteristics and activity present in the basin. In the initialization of the sensitivity analysis, the parameters obtained and the final parameters selected based on the t-stat and p values. Following the sensitivity analysis, the model was calibrated using the most sensitive parameters selected.

3.3.3.5 Calibration and validation of SWAT model

Hydrological modelling Complex processes that occur in the basin, coupled with the inherent uncertainties of parameters, inputs, and measurement data, require the hydrological model to be calibrated and validated to minimize prediction errors (Abbaspour, et al. 2007) One of the most widely accepted algorithms. Hydrological settings were calibrated and validated using a sequential uncertainty fitting (SUFI-2) that operates based on the Latin hypercube sampling procedure (Abbaspour, et al. 2006).). A split sample procedure using monthly stream flow data from the wash Bello stream gauges for the 1990-2000 and 2001-2006 periods was taken for the first three years, respectively, during both calibration and verification warming periods is used for calibration and verification.

The SUFI-2 algorithm can now be operated within a SWAT calibration and uncertainty procedure (SWATCUP) environment. Several model simulations were performed, with

a minimum of 500 simulations being performed in each run, as suggested by (Abbaspour, et al 2007). After each run, the simulation results were compared to the model's performance in the simulation of the observed variables of interest and the observed variables determined for the four objective functions. The choice of objective function is determined by the purpose of the particular study, so no objective function is universally applicable in all situations (Abbaspour, et al. 2004).However, in this study, Nash-Sutcliffe (NSE) (Abbaspour, et al., 2004) [Equation (3.1)], coefficient of determination (R2) (Setegn et al. 2008) [Equation (3.2)], percent bias (PBIAS).) (Moriasi et al.2007) [Equation (3.3)] and RMSE Observation Standard Deviation Ratio 2(RSR)) (Moriasi et al.2007) [Equation (3.4)] were used to evaluate the performance of the model. SWAT performance was assessed using statistical measures to determine the quality and reliability of predictions when compared to observations. Coefficient of determination (R2) and Nash-Sutcliffe simulation efficiency (ENS) were the goodness of fit measures used to evaluate model prediction. The R2 value is an indicator of strength of relationship between the observed and simulated values. The Nash-Sutcliffe simulation efficiency (ENS) indicates how well the plot of observed versus simulated value fits the 1:1 line. If the measured value is the same as all predictions, ENS is 1. If the ENS is between 0 and

1, it indicates deviations between measured and predicted values. If ENS is negative, predictions are very poor, and the average value of output is a better estimate than the model prediction (Nash and Sutcliffe, 1970).

$NSE = 1 - \frac{\sum_{i=1}^{n}(Oi-Si)^2}{\sum_{i=1}^{n}(Oi-O)^2}$ - - - - - - - - - - - - - - ------- - -- -------- - - -- ---------Eqn 3.4

R^2 = $[\frac{\sum_{i=1}^{n}(Oi-Si)(Si-S)}{\sum_{i=1}^{n}(Qi-O)^2)^05(\sum_{i=1}^{n}(Si-S)^2)^0.5}]^2$ $- - - - - - - - - - - - - - -$ Eqn 3.5

PBIAS= $\frac{\sum_{i=1}^{n}(Oi-Si)*100}{\sum_{i=1}^{n} Oi}$- - - - - - - - -- - - - - - - - - - - - - - - - - --------------------Eqn3.6

RSR=$\frac{\sqrt{\sum_{i=1}^{n}(Oi-Si)^2}}{\sum_{i=1}^{n}(Oi-O)^2}$---

Eqn3.7 where;

Oi = observed variable, Si = simulated variable, O = mean of observed variable, S = mean of simulated variable, n = number of observations under consideration Based on the values of the performance parameters above, the following guideline table for a performance rating of a general watershed simulation model is set up [Moriasi et al, 2007].

Table 5 Model performance rating based on the range of values for R^2, NSE and PBIAS

Performance rating	R^2	NSE	PBIAS (%)
Very good	0.0$\leq RSR \leq 0.5$	0.75$< NSE \leq$ 1.00	PBIAS$\leq \pm 1.00$
Good	$0 < RSR \leq 0.60$	0.65$< NSE \leq$ 0.75	$\pm 10 \leq PBIAS < \pm 15$
Satisfactory	0.60$< RSR \leq$ 0.70	0.50$\leq NSE \leq$ 0.65	$\pm 15 \leq PBIAS < \pm 25$
Unsatisfactory	RSR$>$ 0.70	$NSE < 0.50$	PBIAS$\geq$ 25

4. Results and Discussion

4.1 Sensitivity Analysis

The results of the sensitivity analysis showed the sensitivity and parameter limits of the parameters that are important for automatic calibration activity. AlphaBf and GwDelay were the most sensitive parameters affecting the contribution of base flow, while Cn2, Esco, and Ch_N2 were one of the most sensitive parameters affecting surface runoff. From 18 parameters, the 10 most sensitive parameters selected for calibration, their ranking and description are displayed in Table 7.

Table 6 Sensitive parameter ranking and final auto- calibration result

No	Parameter	Parameter value	Min value	Max value
1	CN2.mgt	85.87	35.00	98.00
2	ALPHA_BF.gw	0.50	0.00	1.00
3	GW_DELAY.gw	215.85	30.00	450.00
4	GWQMN.gw	0.38	0.00	2.00
5	SOL_Z(..).sol	2261.77	0.00	2966.25
6	EsCO.hru	0.85	0.00	1. 00
7	CH_N2.rte	0.24	-0.01	0.30
8	SOL_AWC(..).sol	0.56	0.00	1.00 00
9	SURLAG.bsn	5.74	0.05	24.00
10	EPCO.hru	0.04	0.00	1.00
11	GW_REVAP.gw	0.15	0.02	0.20
12	SOL_K(..).sol	505.00	0.00	2000.00
13	CH_N1.sub	2.18	0.01	30.00
14	CH_L2.rte	3.70	-0.05	500.00
15	RCHRG_DP.gw	0.31	0.00	1.00
16	SLSUBBSN.hru	67.05	10.00	150.00
17	CH_K1.sub	162.75	0.00	300.00
18	SOL_BD (..).sol	1.67	0.90	2.50

4.2 Model Calibration

The calibration of the model was done for eight years (1993 to 2000), 1990 was taken for warming period using flow data at Awash Bello flow station. The performance of the model was evaluated using R2, NSE, R-Factor statistical measures for calibration. After calibration the model R2 = 0.91, NSE=0.87 and R-factor =0.62. According to Santhi et al. (2001) stated that efficiency values greater than or equal to 0.50 are considered acceptable for SWAT model application. Hence, it is observed that SWAT exhibited strong performance in representing the hydrological conditions of the watershed It can be seen flow hydrograph (figure, 8) that the simulated flows almost replicate the observed flows except peak values are slightly underestimated during 1993, 1997 and 2000 .This may be due to unreliable precipitation data given as an input to the model or gauged flow used for the calibration. However, the overall flow trend is well simulated by the model; especially in such cases of the study area where rainfall has temporal variability is quite significant.

Table 7 calibration parameter ranking and final auto- calibration result

parameter	Fitted value	Min value	Max value
CN2.mgt	-0.12	-0.20	-0.09
ALPHA_BF.gw	0.88	1.00	0.97
GW_DELAY.gw	211.31	30.00	316.65
GWQMN.gw	0.05	0.02	0.05
SOL_Z(..).sol	2261.76	0.00	2966.25
EsCO.hru	0.08	0.00	0.13
CH_N2.rte	0.08	-0.01	0.25
SOL_AWC(..).sol	0.22	0.00	0.46
SURLAG.bsn	2.81	0.05	4.06
EPCO.hru	0.19	0.00	0.26

Table 8 Summary of the quantitative model performance analysis for the calibration and validation period.

Criteria	Calibration (1993– 2000)	Validation (2001–2006)
Coefficient of determination (R2	0.91	0.79
Nash–Sutcliffe efficiency (NSE)	0.87	0.67
R-factor	0.62	0.56

The two rainfall seasons, Kiremt and Belg, which contribute the largest share of the total rainfall, are well explained by the simulated result. So SWAT proved to perform well in simulating the flows of awash Bello Sub watershed.

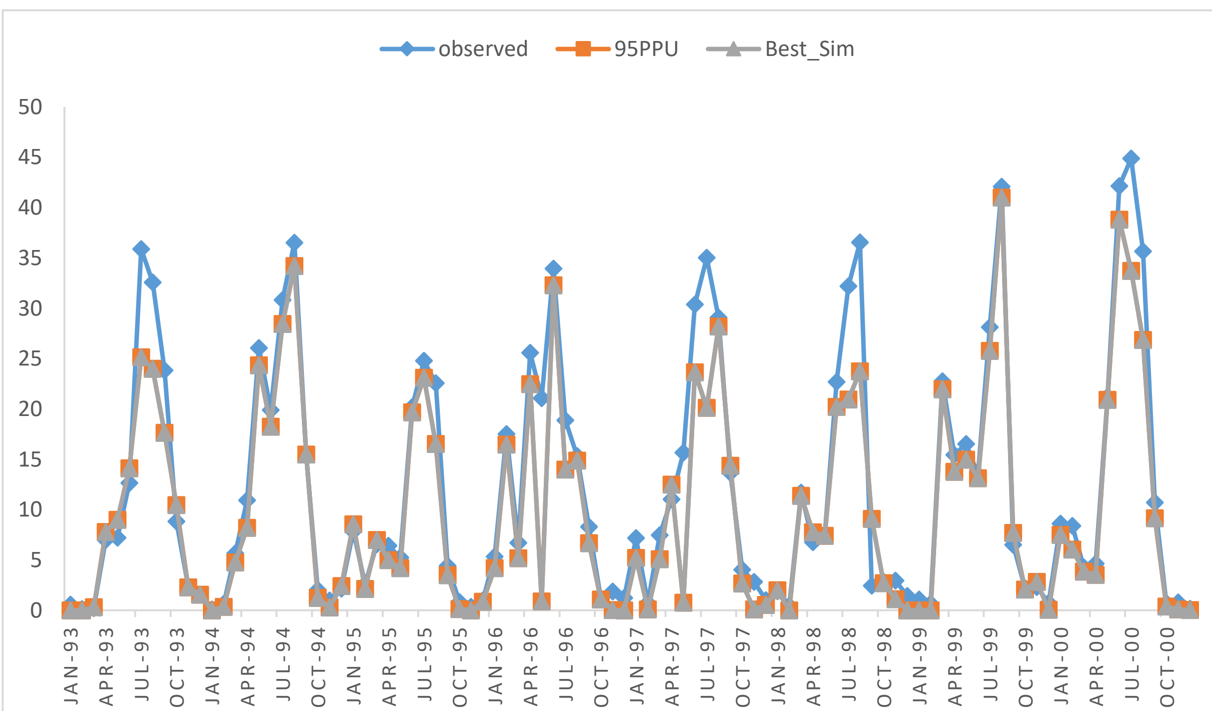


Figure 8 Observed and simulated flow hydrograph for the calibration period (1993-2000)

4.3 Model Validation

The validation of the model at the Awash Bello station gauging station was done for an independent data set of six years from 2001 to 2006.with one year warming period (2000) .The figure 9 shows that the model replicated the observed flows well. However, it couldn't able to catch the peak flows. Table 9 shows the validation statistics of the simulated flow. The R2 was found to be 0.79, which shows it is slight good correlation with the gauged flow. This ensures that the simulated flow follows the same trend with the gauged flow in the time serious Even though the model overestimated the flow end of 2002, before middle of 2003 and underestimate of middle 2005, and the overall trend of the flow is well simulated by the model. Both the R^2 and NS values fulfilled even above the minimum requirement of R^2 >0.5 and ENS > 0.5, ENS which is recommended by Santhi et al (2001). These results show that the model has again simulated the flow well resulting in best fit curves to the gauged flow within this time period.

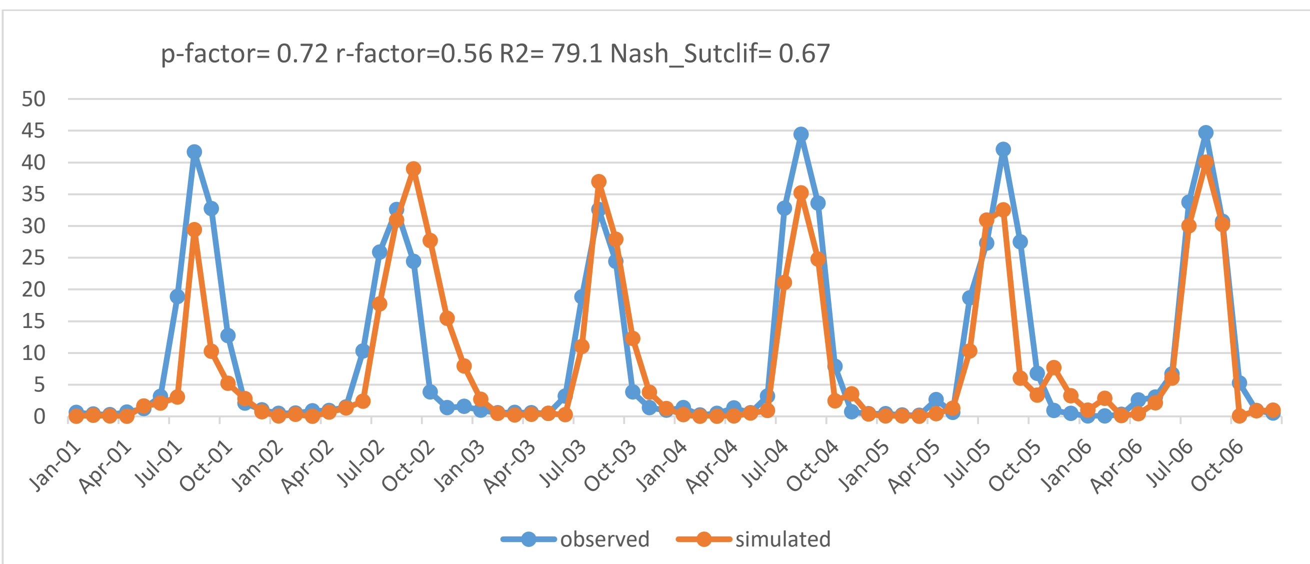


Figure 9 Observed and simulated flow hydrograph for the validation period (2001-2006)

4.4 Future Climate Changes on Rainfall and Temperature

a) Change in Rainfall:-A monthly average of regional climate model runs taken from the CORDEX of bias corrected results of the rainfall, a maximum and minimum temperature are shown in below. The projected changes in monthly rainfall, minimum and maximum temperatures for the period from 2031s to 2070s for mid-term scenarios and 2071-2100 for long term scenarios are indicated in figure 4.8. The analysis showed that there is likely increment in rainfall and temperature in the study area. Generally Rainfall shows the likely increasing within the range of 6.1–9.2% and 3.2–4.95% for both RCP 4.5 and RCP 8.5 scenarios of bias corrected, respectively. This result clearly implies that wet condition is likely the prevailing weather of the future in the sub-basin, this also confirmed in the study result of (Cook & Vizy, 2013; Gebremeskel & Kebede, 2017; IPCC, 2013; Kebede et al., 2013; Kim et al., 2008; Kim & Yu, 2012; Osima, 2018; Weller & Cai, 2013. Most of the individual RCMs projected an increase of mean monthly rainfall (Table 10) except CCLM4 (CNRM-CM5) under RCP8.5 (2031-2070) models. Individual RCMs projection of future rainfall ranged from 3.2% (REMO (MPI-ESM-LR) to 6.1% (RCA4 (MPI-ESM-LR) for the near-term under RCP4.5 and from 4.95% (REMO (EC-EARTH) to 9.2% (REMO (EC-EARTH) for the long-term under RCP4.5&8.5 scenario. The rest projected future rainfall had relatively almost same spatial pattern with the observed rainfall.

Table 9 Change of percentage monthly precipitation compared with baseline period for RCMs models RCP4.5 (2031-2070) scenarios

BASELINE1990-2010)	CCLM4(CNRM-CM54.5)	RCA4(CNRM-CM54.5)	RCA4(EC-EARTH4.5)	REMO(EC-EARTH4.5)	RCA4(MPI-ESM-LR4.5)	REMO((MPI-ESM-LR4.5)
0.8383	1.696	2.018	0.837	0.837	0.429	0.842
1.0660	0.476	0.607	0.494	0.494	2.423	1.545
2.0019	0.933	0.888	1.542	1.542	1.042	2.301
2.8111	2.864	3.338	2.444	2.444	2.651	1.856
2.5551	2.413	2.434	1.510	1.510	1.504	3.038
5.4245	5.169	4.969	5.230	5.230	5.017	2.909
7.9442	7.220	6.657	7.633	7.633	8.231	7.136
7.5244	7.742	8.051	7.098	7.098	8.222	7.740
3.4449	4.121	5.320	3.620	3.620	4.003	6.113
0.8901	0.940	1.132	2.163	2.163	0.993	2.223
0.3535	0.284	0.333	0.493	0.493	0.294	1.095
0.3846	0.593	0.639	0.457	0.457	0.105	0.594

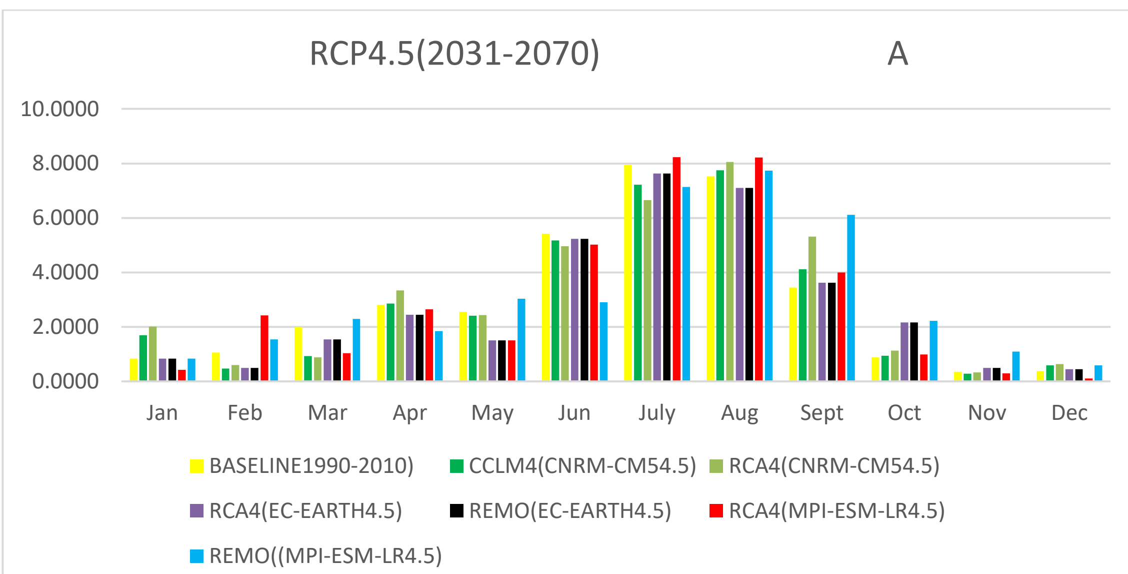


Figure 10 Change of percentage monthly precipitation compared with baseline period for RCMs models RCP4.5 (2031-2070) scenarios.

Table 10 Change of percentage monthly precipitation compared with baseline period for RCMs models RCP4.5 (2031-2070) scenarios

month	BASELINE1990-2010)	CCLM4(CNRM-CM54.5)	RCA4(CNRM-CM54.5)	RCA4(EC-EARTH4.5)	REMO(EC-EARTH4.5)	RCA4(MPI-ESM-LR4.5)	REMO((MPI-ESM-LR4.5)
Jan	0.838	0.751	2.018	0.308	0.907	1.839	2.095
Feb	1.066	0.476	0.607	0.511	0.667	0.742	1.286
Mar	2.002	0.787	0.888	1.701	1.362	1.403	1.257
Apr	2.811	2.847	3.338	2.536	2.850	2.753	2.110
May	2.555	2.075	2.434	1.547	2.023	2.463	2.289
Jun	5.425	5.415	4.969	4.750	5.269	5.204	5.427
July	7.944	7.406	6.657	7.420	9.559	7.242	7.023
Aug	7.524	8.369	8.051	6.920	8.268	7.652	7.177
Sept	3.445	4.053	5.320	3.399	4.086	3.887	3.699
Oct	0.890	0.979	1.132	2.346	1.426	1.306	1.233
Nov	0.354	0.203	0.333	0.510	0.223	0.457	0.651
Dec	0.385	0.381	0.639	0.608	0.353	0.265	0.649

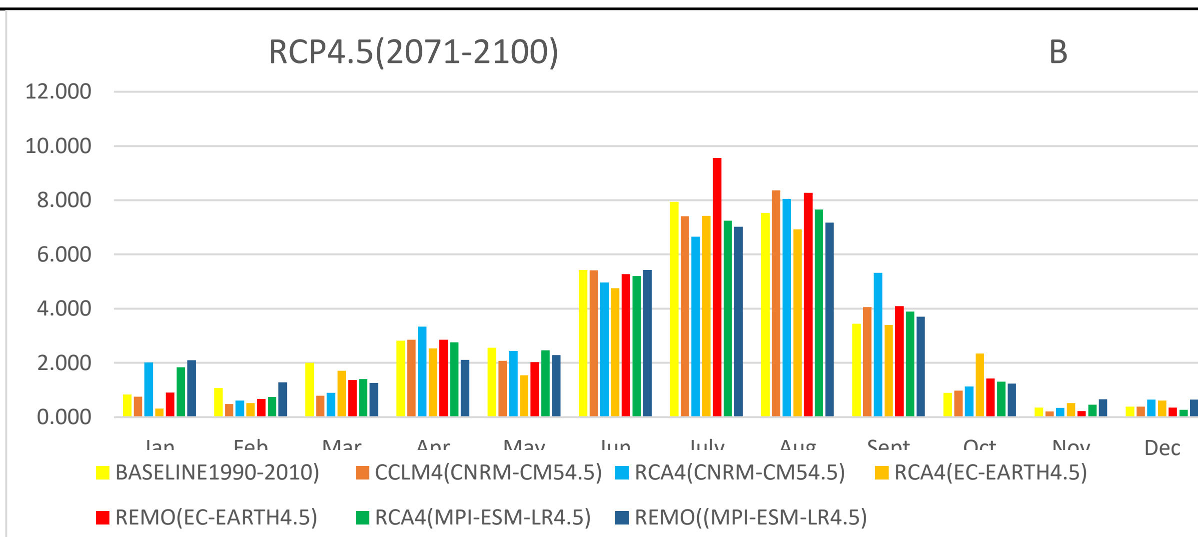


Figure 11 Change of percentage monthly precipitation compared with baseline period for RCMs models RCP4.5 (2071-2100) scenarios.

Table 11 Change of percentage monthly precipitation compared with baseline period for Models RCP8.5 (2031-2070) scenarios

Month	BASELINE1990-2010)	CCLM4(CNRM-CM58.5)	RCA4(CNRM-CM58.5)	RCA4(EC-EARTH8.5)	REMO(EC-EARTH8.5)	RCA4(MPI-ESM-LR8.5)	REMO((MPI-ESM-LR8.5)
Jan	0.838	2.104	1.258	0.542	0.537	0.429	1.500
Feb	1.066	0.512	1.087	0.564	0.684	2.423	2.201
Mar	2.002	0.826	1.262	1.806	2.142	1.042	1.118
Apr	2.811	2.593	2.679	2.657	3.245	2.651	2.348
May	2.555	2.465	2.437	1.856	2.334	1.504	2.162
Jun	5.425	5.576	5.408	5.508	5.138	5.017	5.745
July	7.944	7.348	8.066	7.784	8.460	8.231	7.605
Aug	7.524	7.620	7.593	7.275	7.775	8.222	7.386
Sept	3.445	4.227	3.638	3.401	3.773	4.003	3.827
Oct	0.890	0.913	1.179	2.688	1.078	0.993	0.971
Nov	0.354	0.301	0.249	0.491	0.315	0.294	0.984
Dec	0.385	0.435	0.769	0.588	0.274	0.105	0.524

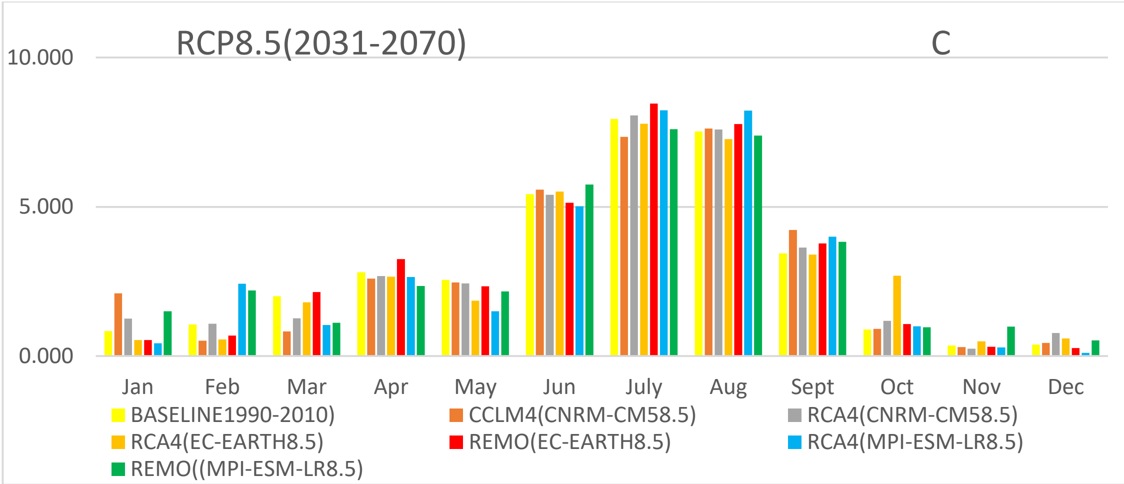


Figure 12 Change of percentage monthly precipitation compared with baseline period for RCMs models RCP8.5 (2031-2070) scenarios

Table 12 Change of percentage monthly precipitation compared with baseline period for RCMs models RCP4.5 (2031-2070) scenarios

Month	BASELINE1990-2010)	CCLM4(CNRM-CM58.5)	RCA4(CNRM-CM58.5)	RCA4(EC-EARTH8.5)	REMO(EC-EARTH8.5)	RCA4(MPI-ESM-LR8.5)	REMO((MPI-ESM-LR8.5)
Jan	0.838	0.104	1.503	0.741	0.907	2.011	1.267
Feb	1.066	0.512	0.563	0.597	0.667	1.519	0.944
Mar	2.002	0.826	0.441	1.066	1.362	1.201	1.282
Apr	2.811	2.593	2.215	2.363	2.850	2.372	2.460
May	2.555	2.465	2.609	1.721	2.023	1.748	1.826
Jun	5.425	5.576	4.953	4.532	5.269	5.117	5.786
July	7.944	7.348	7.686	7.589	9.559	7.393	8.330
Aug	7.524	7.620	7.552	6.655	8.268	7.706	7.299
Sept	3.445	4.227	3.672	3.485	4.086	3.933	4.090
Oct	0.890	0.913	0.831	3.339	1.426	1.156	0.983
Nov	0.354	0.301	0.215	0.391	0.223	0.461	0.861
Dec	0.385	0.435	0.421	0.578	0.353	0.154	0.477

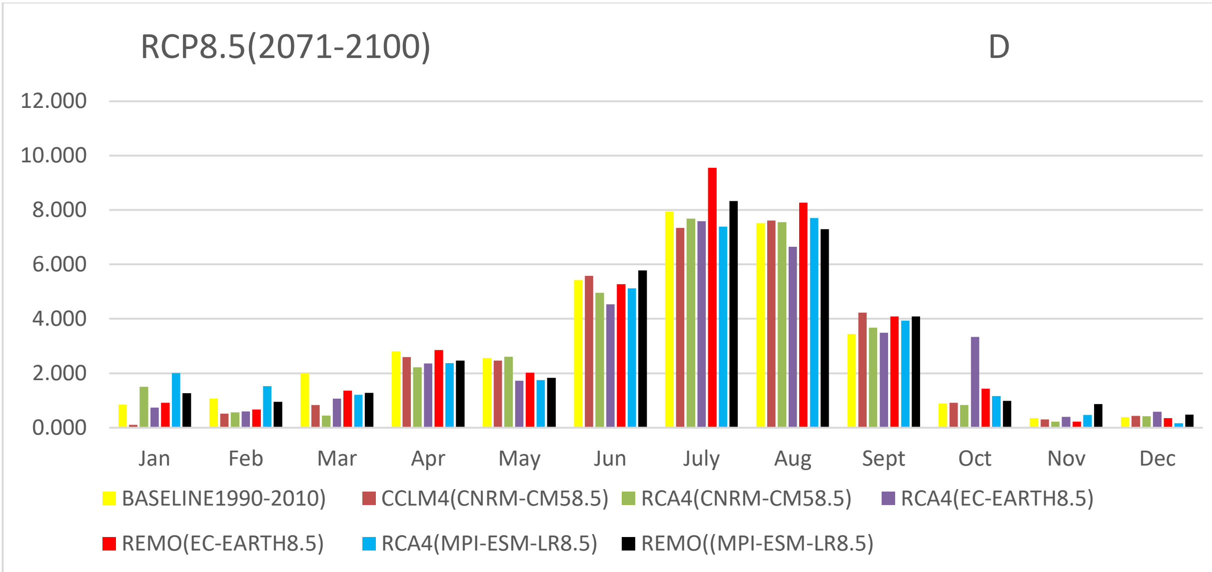


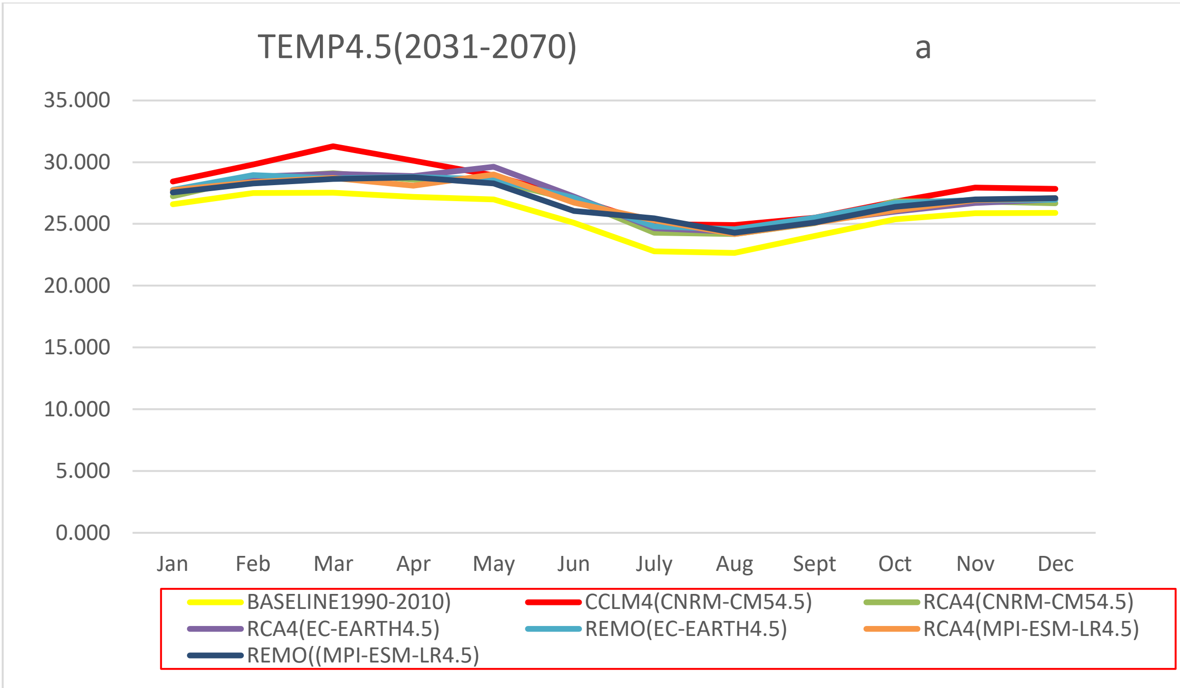
Figure 13 Change of percentage monthly precipitation compared with baseline period for RCMs models RCP8.5 (2071-2100) scenarios

b) Climate Change in Maximum Temperature: - The current research data revealed that the downscaled rainfall, maximum, and minimum temperatures increased in both emission scenarios. Monthly mean temperatures of the future periods (the 2031s, and 2071s) for Six RCM models with RCP4.5 and RCP8.5 emissions scenarios are given in Figure below. The bias corrected outputs of ensemble mean of RCMs showed average monthly temperature increase. For the sub basin, the near term average monthly temperature under RCP4.5 and RCP8.5 increases by -1.50 ◦C and -2.27 ◦C, respectively, in the 2031s. In long term, the monthly Maximum temperature increases by -1.54 ◦C under RCP4.5 and -3.4◦C under RCP8.5; by the end of the century. In the Awash River basin, the study also found that in mid-century minimum and maximum temperature increases range from -1.8 to -1.6 ◦C (RCP 4.5) to -2.6 to -2.1 ◦C (RCP8.5), respectively, while end-of-century increases vary from 2.4 to 2.0 ◦C (RCP 4.5) and -4.6 to -3.7 ◦C (Bekele et al.,2019). This shows the previous report overestimated Maximum temperature (RCP4.5) and underestimate (RCP8.5) compared to the present results. Similarly, the finding (Jilo et al., 2019) argued that the mean annual maximum and minimum temperatures would increase under RCP4.5 and under RCP4.5 scenarios. Most of the individual RCMs projection an increase of mean monthly Maximum temperature (Figure 14) CCLM4 (CNRM-CM5) models under RCP8.5 and 4.5 (2031-2070) by -4.6◦C and -

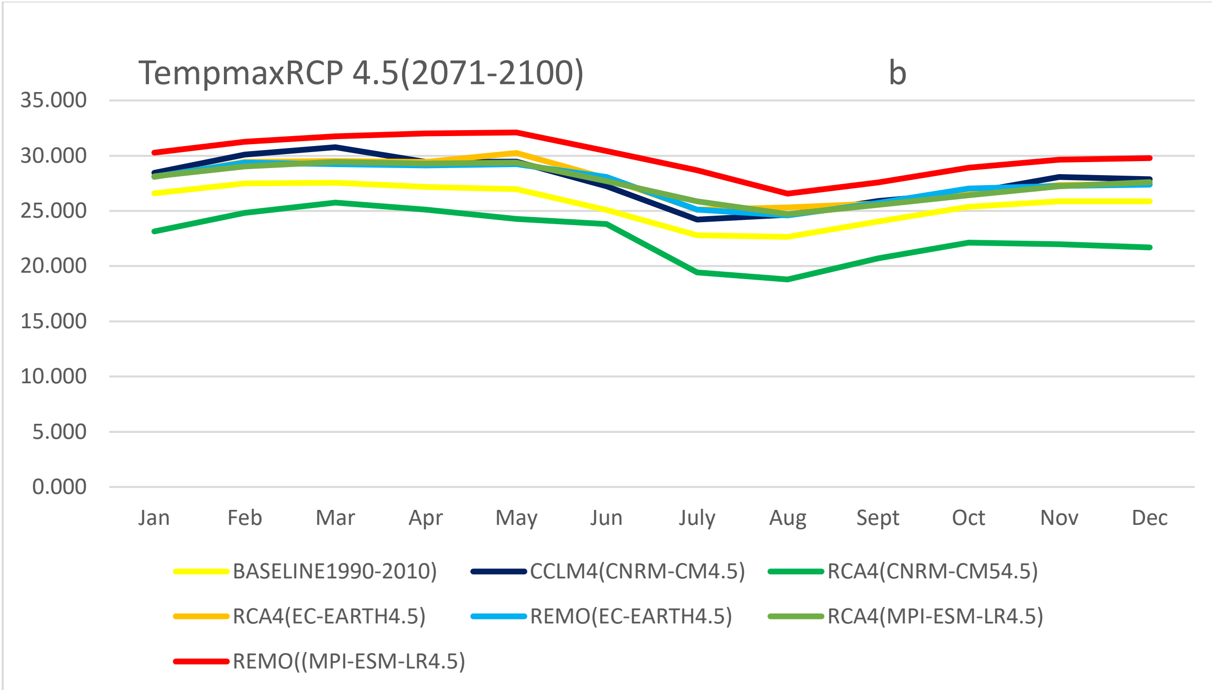
2.17◦C respectively. During long term maximum temperature of Individual RCMs projection of future ranged from -4.3◦C (REMO (MPI-ESM-LR) to -4.6◦C (RCA4 (MPI-ESM-LR) under RCP4.5 and RCP8.5 respectively. Generally As it depicted in Figure below, the observed mean monthly maximum temperature shows under estimation compared with Future scenarios on monthly basis.

Table 13 bias corrected Change of monthly maximum temperature compared with baseline period for individual RCMs models a)RCP4.5(2031-2070), b)RCP4.5 (2071-2100), c)RCP8.5(2031-2070), d)RCP8.5 (2071-2100)scenario

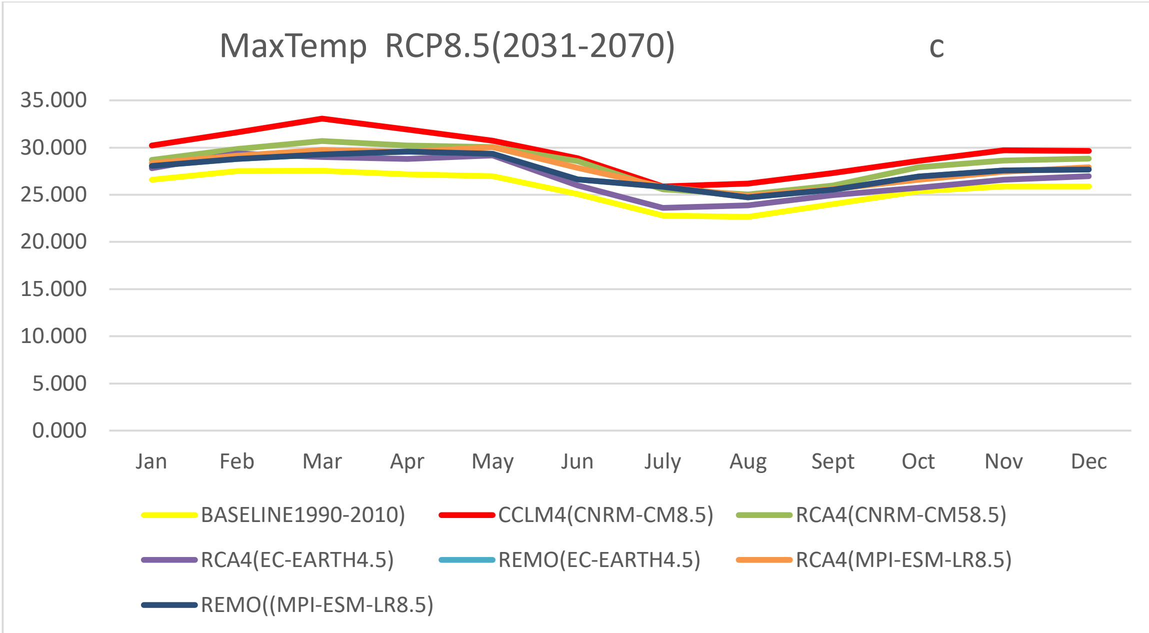
(A) Month	BASELINE1990-2010)	CCLM4(CNRM-CM54.5)	RCA4(CNRM-CM54.5)	RCA4(EC-EARTH4.5)	REMO(EC-EARTH4.5)	RCA4(MPI-ESM-LR4.5)	REMO((MPI-ESM-LR4.5)
Jan	26.606	28.428	27.241	27.540	27.750	27.724	27.5431
Feb	27.494	29.795	28.721	28.829	28.939	28.374	28.2700
Mar	27.536	31.272	29.113	29.060	28.701	28.725	28.6409
Apr	27.183	30.105	28.579	28.871	28.801	28.089	28.7586
May	26.972	28.913	28.480	29.631	28.606	29.002	28.2865
Jun	25.080	27.058	26.953	27.209	27.104	26.722	26.0473
July	22.796	24.975	24.293	24.644	24.797	25.309	25.4548
Aug	22.662	24.900	24.171	24.355	24.574	24.196	24.2844
Sept	24.030	25.515	25.060	25.187	25.510	25.083	25.1081
Oct	25.377	26.789	26.837	25.994	26.704	26.114	26.3788
Nov	25.875	27.929	26.828	26.703	26.923	26.940	26.9710
Dec	25.881	27.835	26.669	26.976	26.949	27.098	27.0834



(B) Month	BASELINE1990-2010)	CCLM4(CNRM-CM4.5)	RCA4(CNRM-CM54.5)	RCA4(EC-EARTH4.5)	REMO(EC-EARTH4.5)	RCA4(MPI-ESM-LR4.5)	REMO((MPI-ESM-LR4.5)
Jan	26.606	28.449	23.128	28.082	28.110	28.132	30.279
Feb	27.494	30.114	24.818	29.438	29.363	29.030	31.262
Mar	27.536	30.757	25.758	29.512	29.230	29.429	31.768
Apr	27.183	29.442	25.127	29.441	29.127	29.291	32.016
May	26.972	29.478	24.278	30.261	29.222	29.383	32.107
Jun	25.080	27.221	23.818	27.960	28.070	27.689	30.422
July	22.796	24.202	19.434	25.115	25.110	25.862	28.679
Aug	22.662	24.658	18.782	25.311	24.602	24.698	26.578
Sept	24.030	25.889	20.702	25.654	25.725	25.546	27.578
Oct	25.377	26.621	22.141	26.525	27.016	26.406	28.920
Nov	25.875	28.084	21.977	27.360	27.257	27.233	29.645
Dec	25.881	27.876	21.691	27.471	27.384	27.603	29.787



(C) Month	BASELINE1990-2010)	CCLM4(CNRM-CM8.5)	RCA4(CNRM-CM58.5)	RCA4(EC-EARTH8.5)	REMO(EC-EARTH8.5)	RCA4(MPI-ESM-LR8.5)	REMO(MPI-ESM-LR8.5)
Jan	26.606	30.228	28.705	27.810	28.036	28.354	28.036
Feb	27.494	31.595	29.855	29.372	28.799	29.144	28.799
Mar	27.536	33.072	30.694	28.999	29.268	29.750	29.268
Apr	27.183	31.905	30.211	28.805	29.577	29.549	29.577
May	26.972	30.713	30.053	29.174	29.336	30.063	29.336
Jun	25.080	28.858	28.551	25.992	26.629	27.861	26.629
July	22.796	25.875	25.588	23.592	25.834	25.843	25.834
Aug	22.662	26.190	25.040	23.886	24.739	24.905	24.739
Sept	24.030	27.315	25.969	24.961	25.532	25.597	25.532
Oct	25.377	28.589	27.902	25.747	26.929	26.602	26.929
Nov	25.875	29.729	28.635	26.597	27.577	27.443	27.577
Dec	25.881	29.635	28.821	26.968	27.690	27.910	27.690



(D) Month	BASELINE1990-2010)	CCLM4(CNRM-CM8.5)	RCA4(CNRM-CM58.5)	RCA4(EC-EARTH8.5)	REMO(EC-EARTH8.5)	RCA4(MPI-ESM-LR8.5)	REMO((MPI-ESM-LR8.5)
Jan	26.606	30.228	28.449	30.133	27.750	30.607	30.279
Feb	27.494	31.593	30.114	31.360	28.939	31.518	31.262
Mar	27.536	33.069	30.757	31.933	28.701	32.016	31.768
Apr	27.183	31.913	29.442	31.627	28.801	32.150	32.016
May	26.972	30.711	29.478	32.180	28.606	32.903	32.107
Jun	25.080	28.860	27.221	29.865	27.104	31.521	30.422
July	22.796	25.877	24.202	27.466	24.797	29.165	28.679
Aug	22.662	26.187	24.658	27.218	24.574	27.194	26.578
Sept	24.030	27.315	25.889	27.736	25.510	27.928	27.578
Oct	25.377	28.586	26.621	27.847	26.704	28.809	28.920
Nov	25.875	29.731	28.084	28.938	26.923	29.385	29.645
Dec	25.881	29.634	27.876	29.407	26.949	29.546	29.787

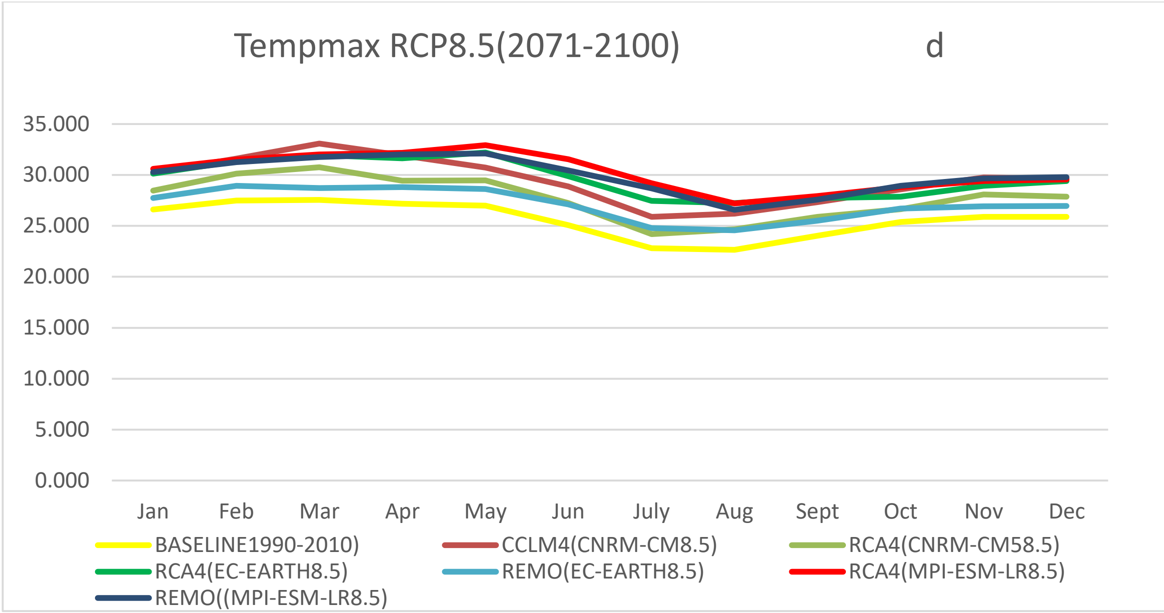
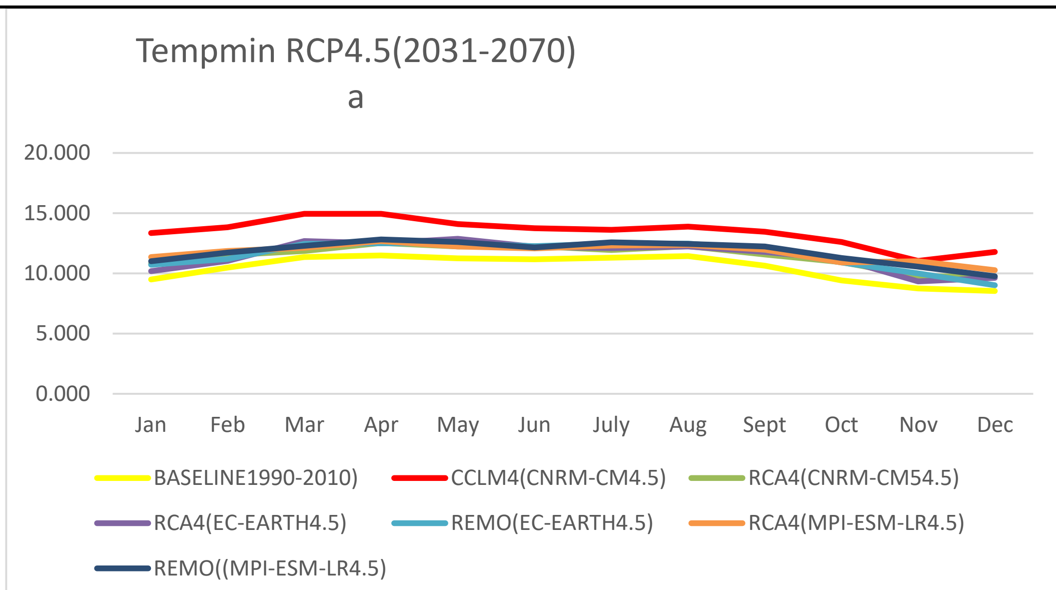


Figure 14 bias corrected Change of monthly maximum temperature compared with baseline period for individual RCMs models a)RCP4.5(2031-2070), b)RCP4.5 (2071-2100), c)RCP8.5(2031-2070), d)RCP8.5 (2071-2100)scenarios

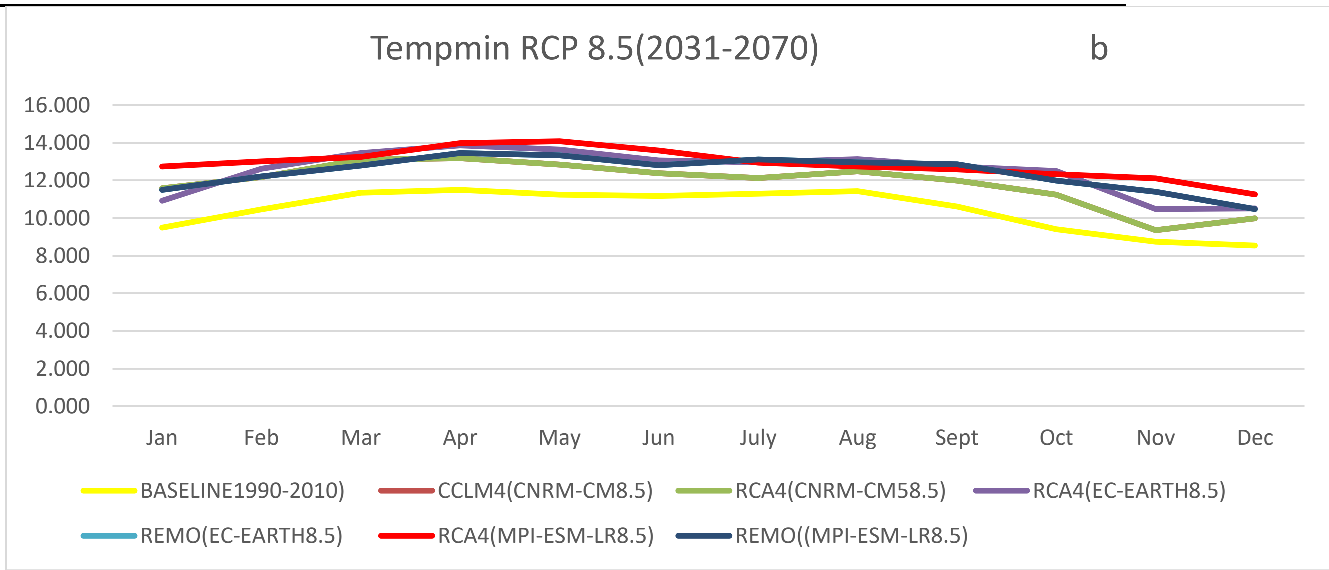
c) Climate Change in Minimum Temperature:- The projected six RCM downscaled from three GCM and bias corrected model data series of the individual RCMs projection showed an increase of mean monthly Minimum temperature (Figure below) CCLM4 (CNRM-CM5) and RCA4 (CNRM-CM5) models under RCP4.5 and 8.5 (2031-2070) by -2.997◦C and -2.5◦C respectively. During long term maximum temperature of Individual RCMs projection of future ranged from -2.0◦C (RCA4 (CNRM-CM5) to -4.6◦C (RCA4 (MPI-ESM-LR) under RCP4.5 and RCP8.5 respectively. Generally As it depicted in Figure 4.16, the observed mean monthly minimum temperature shows under estimation compared with Future scenarios on monthly basis

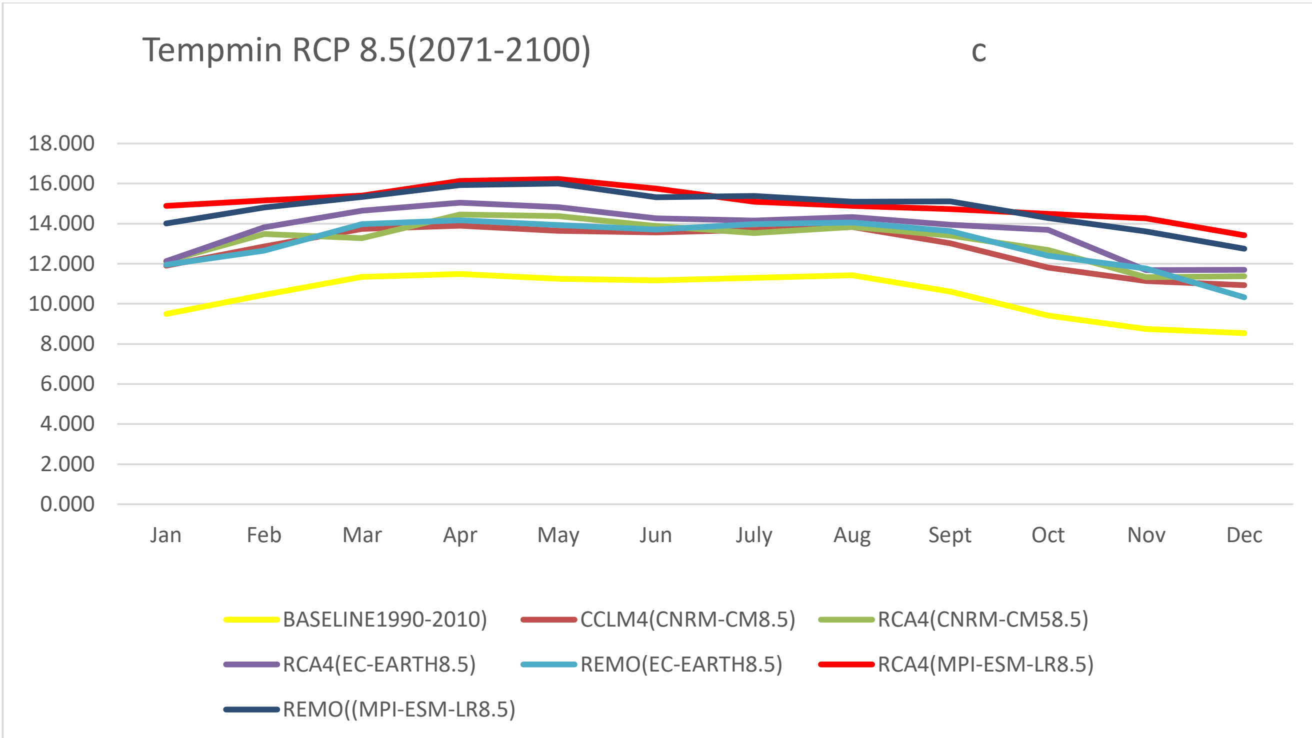
Table 14 Bias corrected Change of monthly minimum temperature compared with baseline period for individual RCMs models a)RCP4.5(2031-2070), c)RCP4.5(2071-2100), b)RCP8.5(2031-2070), d)RCP4.5 (2071-2100)scenarios.

A) Month	BASELINE1990-2010)	CCLM4(CNRM-CM4.5)	RCA4(CNRM-CM54.5)	RCA4(EC-EARTH4.5)	REMO(EC-EARTH4.5)	RCA4(MPI-ESM-LR4.5)	REMO((MPI-ESM-LR4.5)
Jan	9.499	13.350	10.786	10.167	10.722	11.349	11.013
Feb	10.458	13.826	11.496	11.039	11.191	11.847	11.726
Mar	11.344	14.935	11.861	12.686	12.426	12.115	12.287
Apr	11.493	14.938	12.506	12.492	12.499	12.687	12.820
May	11.244	14.090	12.238	12.870	12.463	12.227	12.605
Jun	11.167	13.734	12.249	12.201	12.248	12.076	12.142
July	11.297	13.618	11.941	12.094	12.463	12.311	12.582
Aug	11.435	13.872	12.257	12.237	12.462	12.349	12.446
Sept	10.620	13.457	11.566	11.770	11.960	11.952	12.237
Oct	9.410	12.585	10.912	11.162	10.897	10.886	11.256
Nov	8.747	11.023	9.742	9.322	9.982	10.993	10.550
Dec	8.532	11.785	9.717	9.625	9.017	10.268	9.761



B) Month	BASELINE1990-2010)	CCLM4(CNRM-CM8.5)	RCA4(CNRM-CM58.5)	RCA4(EC-EARTH8.5)	REMO(EC-EARTH8.5)	RCA4(MPI-ESM-LR8.5)	REMO((MPI-ESM-LR8.5)
Jan	9.499	11.899	12.133	12.126	11.956	14.894	14.007
Feb	10.458	12.858	13.484	13.821	12.662	15.160	14.810
Mar	11.344	13.744	13.272	14.646	13.986	15.395	15.344
Apr	11.493	13.893	14.456	15.054	14.174	16.134	15.932
May	11.244	13.644	14.376	14.833	13.930	16.232	15.999
Jun	11.167	13.567	13.886	14.264	13.707	15.743	15.321
July	11.297	13.697	13.538	14.163	13.980	15.090	15.382
Aug	11.435	13.835	13.838	14.335	14.061	14.891	15.099
Sept	10.620	13.020	13.399	13.946	13.621	14.727	15.105
Oct	9.410	11.810	12.682	13.693	12.393	14.485	14.285
Nov	8.747	11.147	11.336	11.686	11.766	14.260	13.617
Dec	8.532	10.932	11.376	11.705	10.328	13.417	12.745





(C) Month	BASELINE1990-2010)	CCLM4(CNRM-CM8.5)	RCA4(CNRM-CM58.5)	RCA4(EC-EARTH8.5)	REMO(EC-EARTH8.5)	RCA4(MPI-ESM-LR8.5)	REMO((MPI-ESM-LR8.5)
Jan	9.499	11.588	11.588	10.926	11.504	12.744	11.5039
Feb	10.458	12.172	12.172	12.621	12.205	13.010	12.2054
Mar	11.344	13.088	13.088	13.446	12.795	13.245	12.7946
Apr	11.493	13.175	13.175	13.854	13.454	13.984	13.4537
May	11.244	12.841	12.841	13.633	13.329	14.082	13.3287
Jun	11.167	12.382	12.382	13.064	12.806	13.593	12.8058
July	11.297	12.124	12.124	12.963	13.111	12.940	13.1108
Aug	11.435	12.487	12.487	13.135	12.961	12.741	12.9611
Sept	10.620	11.993	11.993	12.746	12.854	12.577	12.8545
Oct	9.410	11.240	11.240	12.493	11.998	12.335	11.9975
Nov	8.747	9.357	9.357	10.486	11.389	12.110	11.3890
Dec	8.532	9.985	9.985	10.505	10.480	11.267	10.4797

(D) Month	BASELINE1990-2010)	CCLM4(CNRM-CM4.5)	RCA4(CNRM-CM54.5)	RCA4(EC-EARTH4.5)	REMO(EC-EARTH4.5)	RCA4(MPI-ESM-LR4.5)	REMO((MPI-ESM-LR4.5)
Jan	9.499	11.588	10.772	10.683	10.756	11.573	11.504
Feb	10.458	12.172	12.433	12.308	11.462	11.955	12.205
Mar	11.344	13.088	13.961	13.058	12.786	12.697	12.795
Apr	11.493	13.175	13.927	13.270	12.974	13.348	13.454
May	11.244	12.841	12.798	13.352	12.730	13.048	13.329
Jun	11.167	12.382	13.525	12.722	12.507	12.825	12.806
July	11.297	12.124	13.237	12.632	12.780	12.782	13.111
Aug	11.435	12.487	13.254	12.771	12.861	12.701	12.961
Sept	10.620	11.993	12.442	12.291	12.421	12.525	12.854
Oct	9.410	11.240	11.134	11.934	11.193	11.637	11.998
Nov	8.747	9.357	11.124	9.893	10.566	11.362	11.389
Dec	8.532	9.985	10.649	10.208	9.128	10.990	10.480

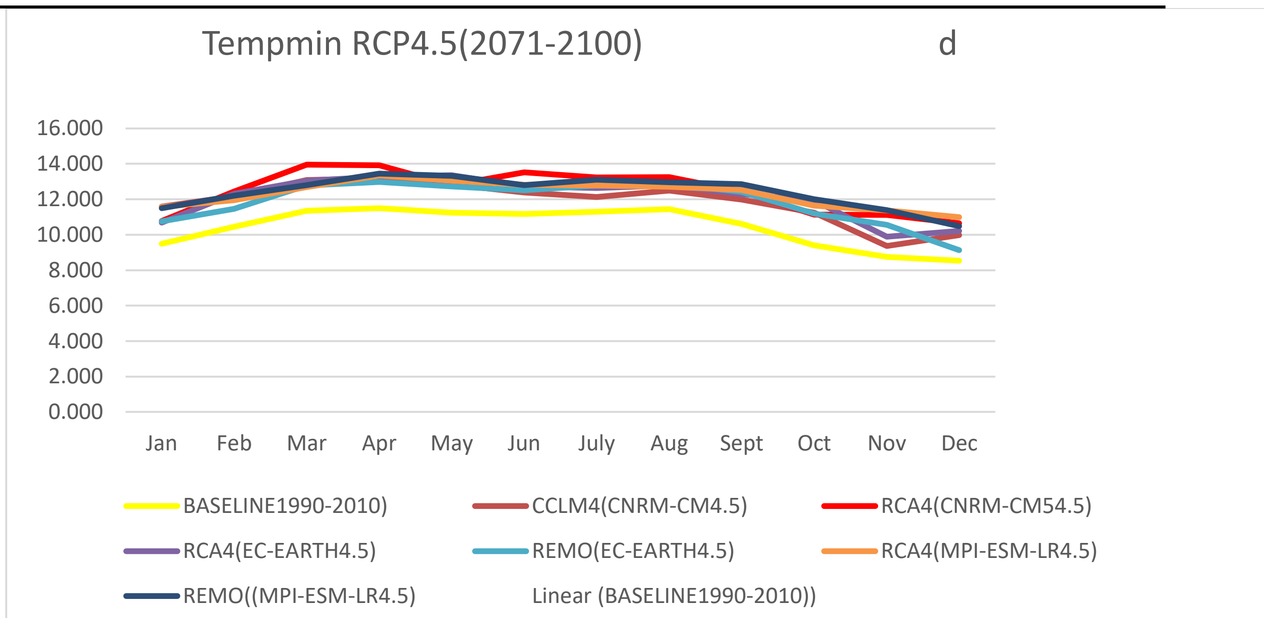


Figure 15 Bias corrected Change of monthly minimum temperature compared with baseline period for individual RCMs models a)RCP4.5(2031-2070), c)RCP4.5(2071-2100), b)RCP8.5(2031-2070), d)RCP4.5 (2071-2100)scenarios

Figure 14 and 15 presents the monthly mean temperatures of the awash Bello catchment obtained from projected climate data according to RCPs 4.5 and 8.5. It shows a Continuous increase in projected temperatures up to 2100 when compared to the value observed during the baseline period (1990–2010), i.e., 24.9 ◦C, regardless of the climate scenario. This increase in temperature was more marked in RCP 8.5, which is the most pessimistic scenario (IPCC, 2013). Indeed, the highest temperatures were observed during RCP 8.5. Thus, by Horizon 2071, the mean temperature in the watershed will be 30.9 ◦C during the month of March (hottest month) and 30.6 ◦C in July (coolest month). For RCP 4.5, the temperatures will be 30.2 ◦C and 27.2 ◦C for the months of March and July, respectively. According to the conclusions of (Sylla, 2015) for the West African region, our analysis for the awash Bello Watershed showed significant variations in extreme values (low and high temperatures). Thus, for the extreme months (March and July), we observed average variations around -1.8 ◦C and the other months showed average increases of -4.6 ◦C in Horizon 2071-2100 under RCP8.5.

4.5 Climate Change Impact on Hydrologic components

4.5.1 Impact of climate change on future surface water availability

Changes in climate (precipitation and temperature) can have a significant effect on the quality and balance of surface water. After calibration and validating the hydrological model with the historical records and bias correction of the meteorological variables of downscaled GCM output, the next step is the simulation of river flows in the watershed. Also, subsequently the hydrological model was used to identify possible trend in the simulated river flow. Impact of climate change on water availability was assessed based on climate change scenarios using RCM model output which was downscaled from GCM model for the watershed. Based on this, the hydrological impact of the awash Bello sub-basin was analysed using the SWAT model for the future RCP4.5&8.5 scenario (2031s and 2071s). The SWAT simulation for the 1990–2010 period was used as a baseline period. Even if, it is definite that in the future land use changes will also take place. Therefore, Table 16 show that percentage change of precipitation and evaporation for future near term annual change increasing trend from -18.41% to 19.71% for precipitation (2031-2070) and 67.97% to 75.75% for evaporation by (2031-2070) and long term mean annual change increasing trend from -14.33 to -12.13% precipitation 2071s to 2100s and -76.22–75.85% evaporation 2071s–2100s.

The change in rainfall and temperature in the future climate scenarios triggers a change on different water balance components. Projected surface run-off showed a decline under near term 2031-2070 (RCP4.5) future climate scenarios and incremental the rest all future climate scenarios and RCMs considered, but in different magnitude. The climate scenario of 2031-2070 under RCP4.5 would be characterized by reduction of surface runoff (25.99%). In the near term and long-term climate change scenarios (2071-2100) under RCP(4.5 and 8.5) and 2031-2070 under RCP(8.5) considered as an incremental of -37.77%,-6.64% and -33.99% surface runoff is projected respectively (Table 16), mainly attributed to the higher rainfall projected in the long term climate change scenarios than the near term scenarios. The reduction in surface runoff is could be not only owing to reduction in rainfall, but this could be attributed to the increase in temperature and further increase of evapotranspiration. Seasonally, the main rainy season (June – September) would be characterized by higher incremental of surface runoff in the future climate condition (Table 16).

Table 15 Mean annual water balance components under different projected climate change scenarios and baseline climate condition.

	Baseline (1990 – 2010)	Near-term 2031-2070 (RCP4.5)	Near-term 2031-2070 (RCP8.5)	Long-term 2071-2100 (RCP4.5)	Long-term 2071-2100 (RCP8.5)
Rainfall(mm yr^{-1})	995.74	1179.01(-18.405%)	1191.9(-19.705%)	1138.46(-14.33%)	1116.46(-12.134%)
Surface runoff (mm yr^{-1})	146.05	108.08(25.997%)	195.57(-33.9%)	195.38(-37.776%)	155.49(-6.46%)
Actual ET(mm yr^{-1})	334.61	562.04(-67.97%)	588.08(-75.75%)	589.66(-76.22%)	588.4(-75.85%)
Total water yield(mm yr^{-1})	620.27	592.65(4.46%)	578.9(6.67%)	524.76(15.42%)	500.26(19.35%)

4.5.1.1 Impact on Monthly Flow Volume

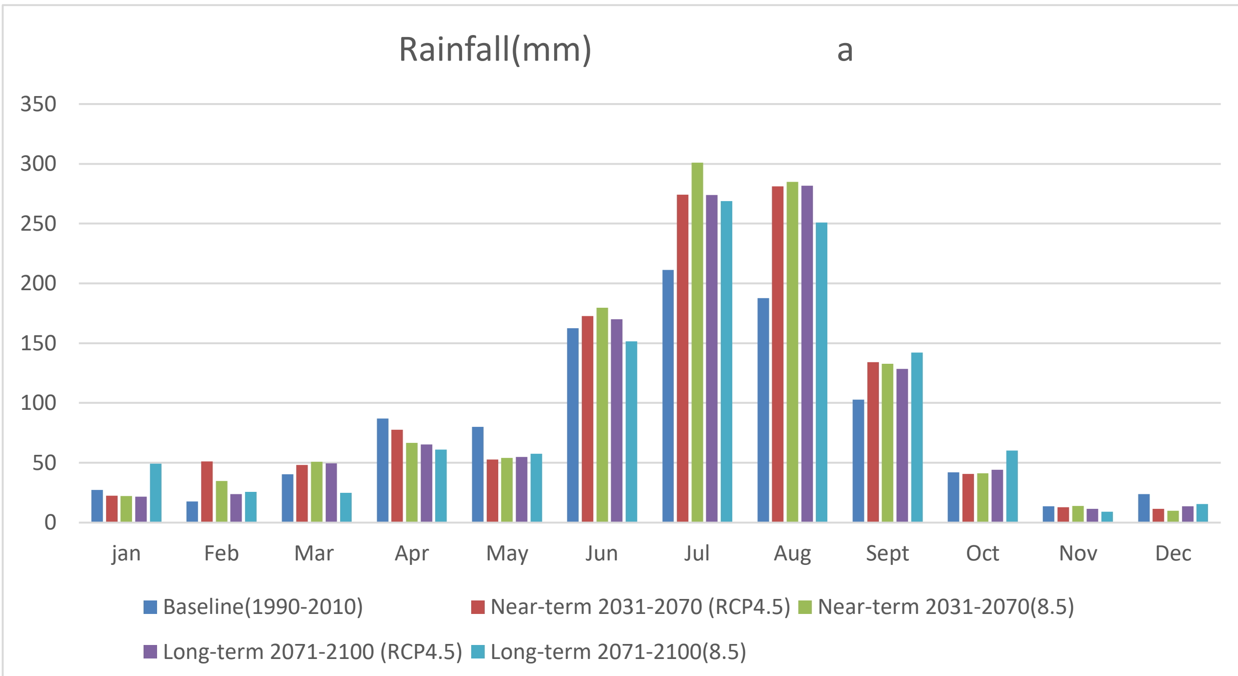
The impact of climate change was analyzed taking the 1990-2010 river flow as the baseline flow against which the future flows for the 2031s, 2070s and 20100s compared. Mean monthly change of stream flow clearly shows the season which possibly impacted highly with climate change. The high-flow months from July to September will be impacted highly for both RCP 4.5 and RCP 8.5 scenarios (Figure 17). For example, August stream flow is expected to increase by -2.67 and 2.9% in 2031s and 2071s RCP 4.5 scenario, respectively. Similarly, the stream flow increment expected to change by -91.8 and -27.1% for 2031s and 2071s, respectively of RCP 8.5 scenario for the bias-corrected simulation. Time series surface flow for near- and end of the century under both scenarios also predicts an increasing trend even if variations in the fluxes between years are observed (Figure 17).

Table 16 Mean monthly water balance components under different projected climate change scenarios and baseline climate condition.

Month	Baseline(1990-2010)	Near-term 2031-2070 (RCP4.5)	Near-term2031-2070(8.5)	Long-term 2071-2100 (RCP4.5)	Long-term 2071-2100(8.5)
Jan	2.94	1.11(62.244%)	3.62(-23.3%)	1.95(33.7%)	14.36(-88.44%)
Feb	2.27	2.75(21.14%)	3.83(-68.7%)	0.77(66.1%)	1.71(24.7%)
Mar	2.33	2.3(1.3%)	1.46(37.3%)	1.33(43.3%)	0.53(77.3%)
Apr	9.1	3.75(58.8%)	3.03(66.7%)	2.85(68.7%)	3.88(57.4%)
May	8.94	0.99(88.8%)	1.15(87.1%)	1.32(43.3%)	1.17(86.9%)
Jun	20.22	10.33(48.99%)	18.2(9.9%)	11.69(42.2%)	10.46(48.3%)
Jul	38.15	34.67(9.12%)	76.99(-101.8%)	31.67(16.9%)	51.78(-35.7%)
Aug	36.74	37.72(-2.67%)	70.4(-91.8%)	35.64(2.9%)	46.68(-27.1%)
Sept	14.25	6.94(51.29%)	12.98(8.9%)	5.82(59.2%)	15.07(-5.7%)
Oct	7.5	2.02(73.1%)	2.95(60.7%)	1.41(81.2%)	7.57(0.93%)
Nov	0.59	0.24(59.3%)	0.46(22.03%)	0.32(45.8%)	0.24(59.3%)
Dec	3.02	0.26(91.4%)	0.44(85.3%)	0.62(79.5%)	2.04(32.45%)

The results of this study are consistent with climate change impact assessment studies in other regions and local area. As (Abtew and Melesse 2009; Anwar et al., 2016; Basheer et al., 2015; Dessu & Melesse, 2013; Dile et al., 2018). According to (Dile et al., 2018), seasonal average discharges have been on the rise in the Awash River between 2070 and 2100. As the study of (Basheer et al., 2015) states, river flow is more sensitive to rainfall and temperature changes and will increase significantly in the future.
Huntington (2006) also found that increased precipitation and evapotranspiration lead to

increased hydrological processes such as stream flow. Similarly, (Woldesenbet, et al. 2018) finds a statistically significant increase in river flow annually and during the major rainy seasons. According to Mekonnen et al. (2018), it became clear that in the future, the flow of streams will increase during the heavy rainy season (JJAS), and extreme outflows may cause future floods. Rainfall and distribution during the rainy season are the main causes of increased runoff. Bekele et al. (2019) showed that precipitation is a major factor influencing runoff, and that precipitation trends influence runoff trends.



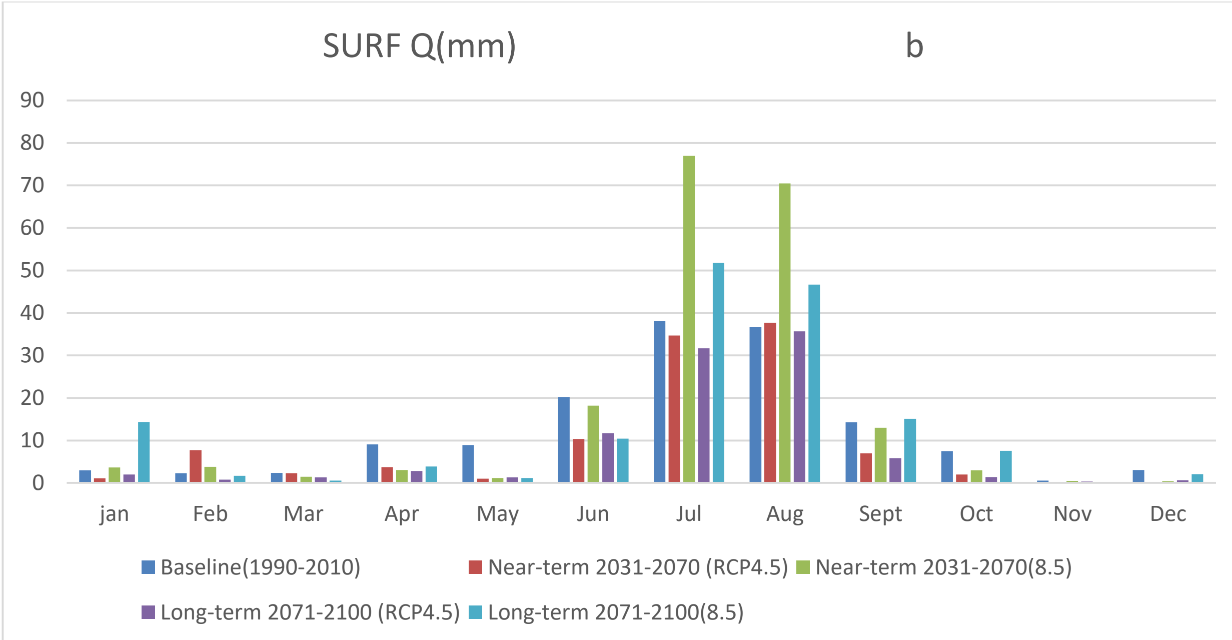


Figure 16 Mean monthly water balance components (a rainfall) and (b surface runoff) under different projected climate change scenarios and baseline climate condition.

4.5.1.2 Impact on Mean Seasonal Flow Volume

In this section, the impacts of climate change on the seasonal flow volume are presented so as to foresee its consequence on the socio-economic condition of the area. As discussed in above section, there are three seasons in the study area: Kiremit (rainy and scenario cropping season), Belg (small rain season) and Bega (dry season). Figure 18 exhibit the implication of climate change on the river flow in these seasons. For RCP8.5 and 4.5 Near term 2031-2070 and 2031-2070 scenario the flow volume in kiremt season were increase respectively where as long term RCP 4.5 scenario were decline under RCP 4.5 by 10%. Belg seasons may increase by -123 and-6.25% in 2031 for RCP4.5 and RCP8.5 scenario respectively, during long term 2071 decline under RCP4.5 by 39.2% while increase under RCP8.5 by -243.2%. that expected to show the larger share in an increase flow volume for both scenario and in Bega season may an increase in long term (2071-2100) for RCP4.5 and RCP8.5by -57% and -83% respectively. While for near term (2031-2070) may increase by -110% and -137.7% under RCP4.5 and RCP8.5 scenario respectively.

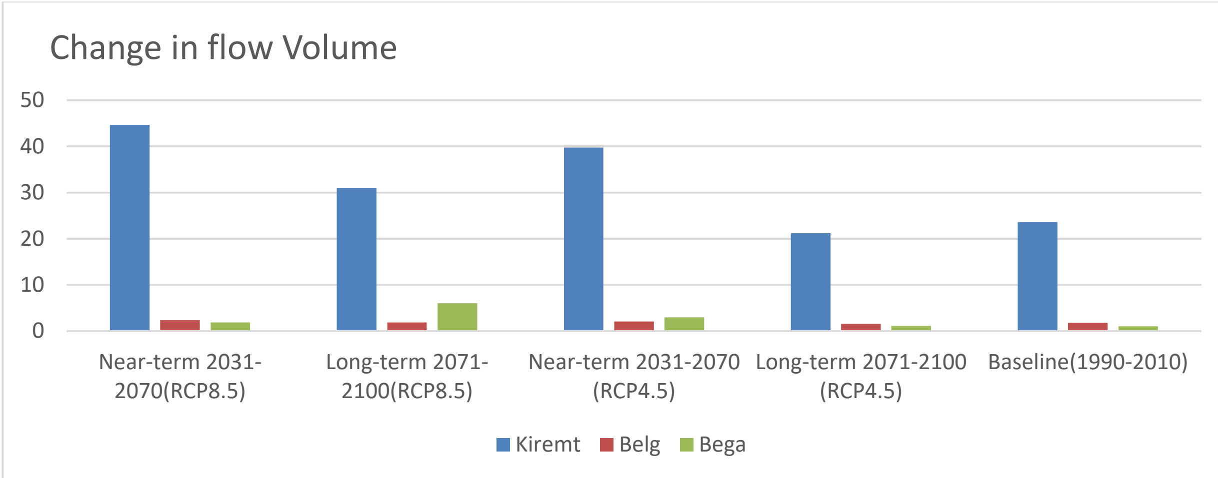


Figure 17 changes in seasonal flow volume in respect to base line climate RCP 4.5 &8.5

Table 17 Mean seasonal water balance components under different projected climate change scenarios and baseline climate condition.

	Kiremt	Belg	Bega
Near-term 2031-2070(RCP8.5)	44.6575	2.3675	1.8675
Long-term 2071-2100(RCP8.5)	30.9975	1.8225	6.0375
Near-term 2031-2070 (RCP4.5)	39.77375	2.0925	2.99125
Long-term 2071-2100 (RCP4.5)	21.205	1.565	1.075
Baseline(1990-2010)	23.58	1.76	0.99

5. Conclusion and Recommendation

5.1 Conclusion

Nature and especially climate is not easy to be exactly forecasted even with the advanced technologies of the21st century. Human beings, at larger scale, are still in the hands of climatic influences, where extreme events of floods and droughts keep on claiming many lives all over the world. Hence, attempts should continue to at least accommodate, if not prevent, ourselves from the enormous danger in the future. The present study investigated the impacts of climate change on surface water resource availability at awash Bello watershed in the upper Awash Basin, Ethiopia. The Ensemble RCMs of RCA-4, CCLM-5 and REMO in CORDEX Africa derived from the MPI ES-LR,CCNRM and ICHEC-ES Global Climate Model were used for RCP4.5 and RCP8.5 by the 2031-2070s and by the 2071-2100s as compared to the baseline period (1990– 2010). The physically based semi-distributed SWAT model was used to assess the impact of climate change on water resource availability of awash Bello watershed of upper Awash River basin in Ethiopia. The result of bias-corrected precipitation and temperature disclosed a logical increase in all future periods under both scenarios of RCP 4.5 and RCP 8.5. The study also confirmed that SWAT is a useful tool for assessing the impacts of climate change on the hydrological cycle in the sub-basin. The awash Bello watershed was delineated into 40 sub-basins and further divided into 134 Hydrological Response Units (HRUs).The sensitivity analysis has identified 10 fundamental parameters (i.e., Cn2, ESCO, GWQMN, ALPHA_BF, Revamp, Ch_K2, SOL_AWC,EPCO,SOL_Z and SURLAG) that control the surface and subsurface hydrological processes of the basin. However, CN2, ESCO and ALPHA_BF were found to be highly sensitive parameters than other parameters.

Comparing the climate change simulations of the 2031s and 2071s to baseline (1990–2010), the RCP 8.5 emission scenario leads to more monthly precipitation and temperature than the RCP 4.5 emission scenario, subsequently leading to differences in stream flow in the watershed. Projections of future periods mean monthly stream flow show the likely increase by 14.5 and 19.1% for RCP 4.5 scenarios and by 4.7 and 6.9% for RCP 8.5 scenarios of the 2031s and 2071s, respectively. The high-flow months of July to November are highly impacting both RCP 4.5 and RCP 8.5 scenarios in a similar manner. The onsite and offsite water harvesting structures, micro-dams for flood control, domestic and agricultural water use must be conserved and water must be utilized, particularly during the high flow months, in order to alleviate poverty and food insecurity in the area. However, this study is still useful as it gives an insight into the stream flow sensitivity of the awash Bello watershed to changes in climate. In future, therefore, further study, especially model uncertainty analysis, and the use of multiple climate model and land use change are.

The minimum temperature varies between 1.8 and -4.6 ºC of change at 2031 s found to be -4.2 and 2.0 ºC at 2071 s rcp4.5 and rcp8.5 scenario. The variation of the maximum temperature varies between -4.1 and -2.0ºc change at 2031s found to be -2.1 ºC and -4.2 ºC at 2071s in awash Bello watershed. The hydrological impact of the awash Bello basin was analysed with respect to two forty year's period baseline (199–2010), near term (2031–2070), long term (2071–2100) RCP4.5 and RCP8.5 climate change scenario. The percent of mean monthly change of RCP4.5 and RCP8.5 scenario simulation on overall increasing pattern of precipitation and from -6.1 to-9.28 at 2031 s and -3.2 to -4.95 at 2071s, respectively. The results of Awash Belo watershed concluded that the SWAT model accurately tracked the measured flows and simulated well the monthly water yield. The study make the recommendation that SWAT model can be effectively used for assessing the water balance components of a river basin such as surface runoff, lateral flow, base flow and evapotranspiration. The simulated stream flow was found very close in agreement with measured stream flow. The RCP8.5 scenario was changed by a higher magnitude than the RCP4.5 scenario because RCP8.5 had a higher greenhouse gas emission scenario with a higher degree of global. Finally this study gives support and increase awareness on the possible future impacts of climate change on basin water balance.

5.2 Recommendation

- This investigation was done based on weather data gathered from meteorological agency used as an input in model simulation, however these data's have series of gaps which are missed thus can influence the result of model output so the representatives organization has to bridge the way of holding these data's
- The identified critical watershed showed of serious vulnerability to runoff during summer season and water shortage during winter seasons this can affect the society/farmer around or just downstream of the outlet. Thus it needs urgent sustainable management practices of watershed management.
- The model simulations considered only future climate change scenarios assuming all other things constant. But change in land use scenarios, soil, management activities and other climate variables will also contribute to surface runoff therefore it is better if consider this changes for future climate change predictions.
- The model found to be good in simulating the run off for the study area thus can be used as a research tool for further analysis in the future in water resource availability of other different watershed in the presence of the required input data for the model.

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