AFRICA CENTER OF EXCELLENCE FOR WATER MANAGEMENT
ADDIS ABABA UNIVERSITY

LAND USE LAND COVER AND CLIMATE CHANGE IMPACT ON SURFACE HYDROLOGY IN BORKENA WATERSEHD, AWASH BASIN, ETHIOPIA

M.SC. THESIS

BY

ESAYAS ABEBE

ADVISOR

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ADDIS ABABA UNIVERSITY

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DECLARATION

I hereby declare that this Master of Science thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been appropriately admitted.

Name: **Esayas Abebe**

Signature: ____________________________

Date: June - 28- 2020

EXAMINERS THESIS APPROVAL SHEET

We undersigned members of the Board of Examiners of the final open defense by Esayas Abebe Worku have read and evaluated his thesis entitled **"Land Use Land Cover and Climate Change Impact on Surface Hydrology In Borkena Watershed, Awash Basin, Ethiopia"** and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Masters of Science in Water Management (hydrology and water resources).

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ABBREVIATIONS AND ACRONYMS

°C	Degree Celsius
ARCGIS	Aeronautical Reconnaissance Coverage geographic Information System
ARS-USDA	Agricultural Research Service of United States Department of Agricultire
CORDEX	Coordinated Regional Climate Downscaling Experiment project
DEM	Digital elevation model
EC	End Century
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resource Data Analysis System
EROS	Earth Resources Observation and Science
FAO	Food And Agriculture Organization
GCM	General Circulation Model
GCP	Ground control points
GeoTIFF	Geostationary Earth Tagged Image File Format
GIS	Geographic Information System
GUI	Graphical User Interference
HRS	High Rainy Season
HRU	Hydrological Response Unit
IPCC	Intergovernmental Panel on Climate Change
LRS	Low Rainy Season
LULC	Land use land cover
LULCC	Land use land cover Change
MoWIE	Ministry of Water Resources, Irrigation and Energy
MC	Mid Century
MSS	Multi Spectral Scanner
NMA	National Meteorological Administration
NSE	Nash Sutcliffe efficiency
PBIAS	Percent of Bias
RCM	Regional Climate Model
RCP	Representative concentration pathways
SCS	Soil Conservation Service
STRM	Shuttle Radar Topography Mission
SWAT	Soil Water Assessment Tool
SWAT-CUP	soil Water Assessment Tool Calibration and Uncertainty Analysis Program
TM	Land sat Thematic Mapper
USGS	United States Geospatial Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System

ABSTRACT

The rapid land use/land cover and continuous change of climate have direct impact on catchment hydrology. This study assessed the individual and coupled impact of land use land cover and climate change impact on hydrological components of Borkena watershed, Awash basin, Ethiopia.

The land use land cover data were obtained from Land Sat image and processed by ERDAS IMAGINE 2014 software for years 1994, 2007 and 2018. The coordinated regional climate downscaling experiment (CORDEX)-Africa data outputs of ensemble average two RCMs derived from MPI-ESM-LR, and EC-EARTH under intermediate and high emission scenarios were analyzed in two-time frames: mid-century and end-century. Both time frames were analyzed using both RCP scenarios from the baseline period (1974-2004). Semi distributed physically-based hydrological (Soil and Water Assessment Tool) model in the ArcGIS interface was used to realize the purpose of assessing the impact of these changes.

The highest gain in land use land covers are agriculture and urbanization, the highest losses are forest land followed by shrubland and grassland were observed in the study area. The calibration and validation were done by SWAT CUP which was evaluated using three criteria;R^2, NSE, and PIAS (0.667, 0.67, and 2.2%) respectively during calibration and (0.71, 0.69 and -14.22 %) during validation, indicating that a good agreement between observed and simulated streamflow. Due to a decreased in rainfall by 14.56% (mid-century) and 16.51% (end century) under RCP4.5, The change in mean annual surface runoff is predicted to decrease. The annual decreasing change in surface runoff was 21.45% and 30.66% in MC and EC under RCP 4.5 scenario respectively, similarly under RCP8.5 the 22.45% and 30.0% in MC and EC respectively. The mean annual and seasonal surface runoff amplified with combined land use land cover and climate change response compared to climate change impact alone. On the other hand; evapotranspiration has reduced due to the expansion of agriculture and urbanization.

Generally From the result, the SWAT model has the capability to simulate the rainfall-runoff for Borkena watershed and LULC change had more impact than climate change on water balance components. These changes need to be mitigated through land management and afforestation, to reduce the surface runoff and increase the availability of water for the future.

Keywords: Borkena watershed, remote sensing, ArcSWAT, LULC, Climate change, RCP, streamflow.

1 INTRODUCTION

1.1 Background

Water resources are very crucial renewable possessions which are the basis for the survival and development of a society. For human welfare and industrial developments have been dependent on adequate supplies of suitable water. Conversely, too much water results in socioeconomic damages and loss of life due to flooding. The liveliness of natural ecological systems is dependent on mankind's stewardship of water resources. Proper utilization of the available water necessitates valuation and managing the quantity and quality of the available resources both spatially and temporally (Dilnesaw, 2006).

Establishing relationship among various environmental parameters is the central focus of hydrological modeling from its simple form of unit hydrograph to rather complex models based on fully dynamic flow equations. Models are generally used as efficacy in various areas of water resource improvement, in assessing the available resources, in studying the impact of human interference in an area such as land use change, climate change, deforestation, and change of watershed management. An understanding of hydrological processes is essential to examine the impacts of land use and land cover, and climate changes on water resources.

Land cover and climate changes commonly are highly pronounced in evolving countries that are characterized by agriculture based economies and rapidly increasing human population. These changes may have immediate and long-lasting impacts on global hydrology and change the long term balance between rainfall and evapotranspiration and the resultant runoff. In the short-term, destructive land use change may affect the hydrological cycle either through increasing the water yield or through diminishing or even eliminating the low flow for certain circumstances. The long-term decline in evapotranspiration and water recycle arising from land cover changes may initiate a feedback mechanism that results in a decline of rainfall.

Recent studies indicate that intense land use changes affect local, regional, and global ecosystems and environmental processes (Abineh et al., 2015; Hassen et al., 2015)) that shows the change of land covers over the area. Meanwhile, climate change led to more frequent extreme events. Higher temperature induces a higher amount and intensity of precipitation which affects hydrology (Gashaw et al., 2018). The mutual consequence of the land use and climate change on catchment hydrology has a direct impact by increasing hydrological extreme events.

1.2 Problem of Statement

The rapid land use/land cover changes caused by the clearing of the forest for agricultural, urbanization and industrialization are presumed to adversely affect the hydrologic response of the Ethiopian's River Basins ((Gashaw et al., 2018;Tesfa, 2018). This is shown by reduced stream flow during dry periods and increased flash floods in wet seasons. In addition the climatic change from time to time, has a direct impact on the hydrology of the catchment (Shiferaw et al., 2018).

Awash River is one of the river basins in the country, which is immense pressure due to high population increase, urbanization, industrialization, agriculture and this leads the basin to be under the increase and decrease of hydrological pattern within the basin from time to time because of changes in land use/cover and climate change. This continuous change in land cover and climate has influenced the water balance in the basin by increasing hydrologic extreme events like flooding and hydrologic drought to downstream areas of the river.

Borkena River is one of the tributaries to Awash basin which has been faced problems stated above. Although several studies have evaluated hydrologic responses to climate and land use change in the basin, no study entirely focuses on Borkena watersheds to account for local trends in land use change, potential climate change, and their scenario. Therefore, a systematic kind of hydrological processes under changing climate and land use in watersheds of various sizes is needed for developing sustainable water resources management in the state.

Therefore, this research has analyzed the change in land use/cover and climate change impact on the surface hydrology of Borkena catchment using the SWAT model for sustainable water management of the catchment.

1.3 The objective of the Study and Research Questions

1.3.1 General Objective

The key objective of this study is used to realize the coupled and lonely effect of land use land cover and climate change on the catchment hydrology in the Awash basin, specifically Borkena watershed.

1.3.2 Specific Objective

- To analyze the temporal variation of the LULCC of the watershed.
- Understanding of the temporal trend of hydrological and climatic components in Borkena watershed.
- Asses the capability of the SWAT model, in assesing the impact of LULC and climate change in Borkena watershed.
- Assess the impacts of climate and land use land cover change using the SWAT hydrological model.

1.3.3 Research Questions

- Is there any trend in land use land cover and climate changes in the catchment?
- Does the change in land use/cover and climate have a significant effect on catchment hydrologic response?
- How much does the change affect the flow from decade to decade?

- Are there any ways that mitigate the impacts of LuLc and climate change on hydrology of the catchment?

1.4 Significance of the Study

Land use land cover and climate change in the Awash basin is very high. This change and the impact have been estimated using semi-distributed models allowing the watershed to get vital information from the watershed. Hence estimating the consequence of land use land cover and the climate change on the response of catchment hydrology can motivate the policy makers and experts in sustaining the water management and utilization of water in the catchment.

1.5 Scope of the Study

The results of this would contribute to water resources management efforts in Boekena watershed. Application up to date climate change scenarios will help to gain new insight about water resources problems and advising a compatible solution. It is not possible to cover the whole aspects of the study area with seated objectives due to time and resource restrictions. So, it is better to limit the scope of the problem to a manageable objective.

Hence this study focuses on the impact of land use land cover and climate changes on surface hydrology (surface runoff, Evapotranspiration), so it didn't include groundwater hydrology and the rest surface hydrology components. The new plausible climate scenario outputs of enhanced greenhouse gases for medium and high emission scenarios (RCP 4.5 and RCP 8.5) were used as inputs for hydrological model (SWAT) for estimating the hydrology.

This study assesses the impact of climate change on these global scenarios as inputs and assuming the future land use land cover remains the same as land use the land cover of 2018.

2 LITERATURE REVIEW

2.1 Overview of Land use Land Cover Change

Land use refers to the intended use or management of the land cover type by human beings (FAO, 1998). On the other hand land cover refers to the physical and biophysical cover over the surface of the earth, including distribution of vegetation, water, bare soil, and artificial structures Land use refers to the intended use or management of the land cover type by human beings (FAO, 1998).

Land use change in Africa included the conversion of 75 million hectares of forest to agriculture and pasture between the years 1990 and 2010, a rate second only to that in South America (FAO, 2010). In East Africa, nearly 13 million hectares of the original forest was lost over the same 20 year period, and the remaining forest is fragmented and continually under threat (FAO, 2010). In most developing countries population growth has been a dominant cause of land use and land cover change than other forces (Sage, 1994; Tesfa, 2018). There is a significant statistical correlation between population growth and land cover conversion in most African, Asian, and Latin American countries (Meyer, 1994; Tesfa, 2018).

In Ethiopia, the land is used for agricultural purposes, for construction of buildings and roads and extra purposes. In the country most of the land is used for subsistence farming. With the population growth and slow technological adoption which can increase production, there is deforestation for more production which means the conversion of forest to agricultural land and expansion of urban settlements.

The researches conducted by different researchers in different parts of the country indicate that there were LULC changes in the country. For instance Daniel (2017) identified that decrease of natural vegetation and expansion of agricultural land and settlement and decline shrubland in Kelete watershed, Awash basin, Ethiopia. According to his study the rapid population increase, rainfall variability, and soil fertility decline was the main cause for change land use a land cover over the watershed. Similarly Tesfa (2018) due to the expansion of cultivated and settlement, grassland was changed to agricultural land due to an increase of population growth leads to high demand for cropland in the area over the years in Ribb River watershed. The other research indicated that the expansion and intensification of agricultural land are due to population growth (Efrem, 2010) in the semiarid of Central Rift Valley of Ethiopia and (Molla, 2014) Concluded that LULCC dynamics in the Central Rift Valley Region of Ethiopia was due to population pressure which caused agricultural expansion into more severe land degradation.

2.2 Overview of Climate Change

(IPCCII,2007) defines climate change as a change in the state of the climate that; can be identified by changes in the mean and/or the variability of its properties and that perseveres for an extended period, typically decades or longer.

In the context of global climate change, most of Africa has also experienced a significant warming trend over the past decades and the trend is expected to continue in the future (Hulme et al, 2011; Mango et al, 2015). The rising temperature accompanied by altered precipitation patterns and intensity may have substantial hydrological consequences such as accelerating the hydrological cycle and increasing the frequency of occurrence of hydrological extremes.

According to the international panel of climate change (IPCCII, 2007), findings developing countries, such as Ethiopia will be more vulnerable to climate change. Because of the less flexibility to adjust the economic structure and is largely dependent on agriculture, the impact of climate change has far reach implication in Ethiopia. Upward trends in annual air temperature and downward trends in annual rainfall have been observed over Ethiopia between 1948 and 2006 (Jury et al., 2013), whereas (World Bank, 2008) reported that Ethiopia will see further warming of 0.7°C and 2.3°C by the 2020s and between 1.4°C and 2.9°C by the 2050s (Belay et al., 2016). The changes in both temperature and precipitation exhibit remarkable regional variability (Belay et al., 2016).

2.3 Land use/cover change Impact on Hydrology

The land cover change, in many parts of the world has become a global issue, as a result, contributed to the present complete transformation of land cover types. This continuous change in land cover also may have both immediate and long-lasting impacts on hydrological processes and the local and regional water balance by altering the balance between precipitation, evapotranspiration (ET), and the resultant run-off. The land-use change, which is mostly induced by human activities, alerts the hydrologic cycle; which has direct effects on the hydrological process of the watershed. Evapotranspiration is one of the most significant components of the hydrologic budget, which is a combination of two sub-processes: evaporation and transpiration (Haile, 2015). Evaporation is water loss from open water bodies, wetlands, bare soil, snow cover etc., while transpiration is water loss from living plant surface (Haile, 2015). Therefore, land use characteristics influence evapotranspiration. Recent studies revealed that land use land cover and climate changes, crop rotation, and crop types mainly influence evapotranspiration in a watershed. Li et.al, (2009), studied the impact of land use change and climate variability on hydrology on agricultural catchment between 1972-2000 on the Loess Plateau of China revealed that the land use conversion from shrubland and sparse woodland to medium and high grassland climate variability decreased ET and soil water content.

One of the LULC change impacts on the hydrological process is a surface runoff, it affects runoff in the form of accelerated or retarded overland flow as a result of slow or fast infiltration rate and initial abstraction due to canopy cover (Gashaw et al., 2018).

LULC changes alter vegetation cover and surface roughness that affect the timing and magnitude of surface runoff and groundwater discharge, leading to changes in streamflow, and magnitude and frequency of floods (Pai, 2011; Schilling, 2014). Urban areas have large paved areas in the landscape that increase impervious surfaces. Therefore, little rainfall can soak into the soil profile, which produces greater surface runoff (Jacobson, 2011). Similar results were shown in the Cedar River basin, in which surface runoff was predicted to increase due to projected urban expansion (Wu et al., 2013).

Deforestation may also cause greater runoff. In East Africa, (Baker, 2013) reported that due to land conversion from forest to agricultural land increased surface runoff.

Gashaw et al. (2018) showed that the decrease in vegetation area and increasing agricultural land decreased streamflow in the Gummera watershed in Ethiopia. Mekonnen (2018) also reported the expansion of cultivated land at the expense of shrubland and forest increases the streamflow and increase the surface runoff in the northern river basin.

The growth of population and its effect on the land use-cover change have been influencing the hydrology of the sub-basin by changing the magnitude of streamflow melka kutire sub-basin(Yitea and Van , 2015). Similarly According to Samuel et al. (2018) the increased agriculture and decrease forest have an increase in surface runoff, and groundwater decreased during the study period on the upper awash basin.

The progressively changing land use and land cover pattern along with climate variability result in food insecurity and declining water availability, and cause erratic rainfall over the country finally leading to poverty and environmental damage (Deribew et al., 2019).Impacts of land use and cover changes on surface hydrology, surface energy balance, and surface roughness are not straightforward but rather complex to warrant any generalization as it is dependent on the scale of the watershed, seasons, soil and climatic condition of the study area (Ungtae, 2008). The knowledge about the impact of land use/cover changes on hydrology, especially on the scales that are most relevant for local actors, such as farmers and living people downstream of the watershed is still under the complications. Subsequently, many insights into the consequences of land use/cover on hydrology have been elucidated at small spatial, observable scales (Ungtae, 2008).

2.4 Climate Change Impact on Hydrology

Potential impacts of changes in climate such as precipitation and temperature may cause variations in hydrological processes including evapotranspiration, surface runoff, timing and magnitude of streamflow, and flood events (Woldesenbet, 2017). Alterations in major climate variables are identified as an important climate change consequence and this will lead in turn to changes in the land cover type, vegetation, and hydrological regimes. Variation in temperature and precipitation were found influential in streamflow trends in various regions across Ethiopia (Shiferaw et al., 2018). Temperature variation and wind speed affect evaporation and transpiration sub-processes, which influence surface and subsurface water budgets(Zhang et al., 2016).

Precipitation is the source of water in the watershed and the available water is the difference between the precipitation and the loss as evapotranspiration. Available water contributes to surface runoff and streamflow. Therefore, increased precipitation may lead to an increase in surface runoff, while a decrease in precipitation can result in the opposite effects. Studies conducted by (Shiferaw et al., 2018) showed that under future climate scenarios (RCP4.5 and RCP8.5), the Illala watershed of Northern Ethiopia will experience an increase in temperature, result in surface runoff reduction.

Increasing temperature and variability in patterns of precipitation affect the hydrology and water resources of watersheds since they are closely linked to climate (Zhang et al., 2016). Temperature increases at the Lake Ziway watershed and UBN in Ethiopia affected hydrological processes by increasing evapotranspiration (Zhang et al., 2016). Runoff decreased by over 18% for a increase of evapotranspiration by 30% on selected catchments in the Blue Nile basin (Haileyesus, 2017).

2.5 Future Emission Scenario

The fifth assessment report (AR5) in 2014 of IPCC adopted RCPs which is representative pathways. These scenarios are a set of greenhouse gas concentration and emissions paths way designed to support research on the impacts of climate change, and potential policy responses to (Vuuren et al., 2011). The four selected RCPs to include one mitigation scenario leading to a very low forcing level (RCP2.6), two medium stabilization scenarios (RCP4.5/RCP6), and one very high baseline emission scenario (RCP8.5). According to the fifth assessment report in IPCC the four RCPs have different assumptions of radiative forcing in the year 2100 with a mission of 3, 4.5, 6, and 8.5 W/m2. RCPs allows for parallel development of new socio-economic, technical, and policy scenarios that provide insights into the impact of policy decisions on the future climate (Vuuren et al., 2011).

2.5.1 Bias Correction

It is documented that the analysis of future climate impact involves large uncertainties (Zhang et al., 2016). These uncertainties are due to several factors including different types of emission scenarios, hydrologic modeling setup, downscaling, and bias correction methods (Jha , 2015). Therefore, to decrease these uncertainties of the model bias correction is required. Bias correction procedures employ a transformation algorithm for adjusting RCM output. The underlying idea is the identification of possible biases between observed and simulated climate variables, which is for correcting both control and scenario RCM runs. Bias correction methods are assumed to be stationary i.e. the correction algorithm and parameterizations for current climate conditions are also valid for future conditions. Teutschbein et al. (2012) listed several bias correction methods in the table below, and provide a detailed discussion and state that a method performs well for current conditions is likely to perform better for changed conditions than a method that already performs poorly for current conditions.

Table 2.1: Bias Correction Methods for Precipitation and Temperature

Bias Correction for Precipitation	Bias Correction for Temperature
Local Intensity Scaling (LOS)	Linear Scaling (LS)
Daily bias correction (DBC)	Daily translation (DT)
Power Transformation (PT)	Variance scaling (VS)
Distribution Mapping (DM)	distribution Mapping (DM)
Empirical quintiles Mapping (EQM)	Empirical Quintiles Mapping (EQM)

2.6 Hydrological Models

Hydrologic models are a relatively complex mathematical description of the hydrologic cycle (Linsley, 1982). They describe the actual physical processes of the hydrologic cycle and represent the behavior of the catchment in transforming a hydrologic input (rainfall) into output (streamflow or runoff). Streamflow models are therefore mathematical expressions that simulate streamflow or runoff like the way a catchment would operate on the same rainfall event. Hydrologic models provide a framework to investigate the relationship between human activities, climate, and water resources (Beven, 2012).

There are many different reasons why modeling of the rainfall-runoff processes of hydrology is required. The main reasons behind are a limited range of hydrological measurement techniques and a limited range of measurements in space and time (Beven, 2012). Therefore, it is necessary to develop a means of extrapolating from those available measurements in space and time to ungauged catchments and into the future to assess the likely impact of future hydrological change. Hydrological models are characterizations of the real-world system. The researchers use a wide range of hydrological models; however, the applications of those models are highly dependent on the purposes for which the modeling is made. Beven (2012) stated that many rainfall-runoff models are carried out purely for research purposes as a means of enhancing knowledge about hydrological systems. He also adds that other types of models are developed and employed as tools for simulation and prediction aiming ultimately to allow decision-makers to improve decision making about hydrological problems. Before developing the hydrological models, it is vital to understand how the catchment responds to rainfall under different conditions.

Based on the process description, the hydrological models can be classified into three main categories (Shaw, 1998).

Lumped model; in lumped models, the entire river basin is taken as a single unit where spatial variability is disregarded and hence the outputs are generated without considering the spatial processes. The parameters often do not represent the physical features of hydrologic processes and usually involve a certain degree of empiricism.

Distributed models; Parameters of distributed models are fully allowed to vary in space at resolution chosen by the user. The distributed modeling approach attempts to incorporate data concerning the spatial distribution of parameters together with computational algorithms to evaluate the influence of this distribution on simulated precipitation runoff behavior. Distributed models generally require a large amount of data. Beven (2012) explains that the distributed model does have some problems with its non-linearity, scale, uniqueness, and uncertainty.

Semi distributed models; to overcome the difficulties of fully distributed another semi-distributed are a compromise between lumped and fully distributed. According to (Moradkhani & Sorooshian, 2008) the algorisms in semi-distributed conceptual models are simple but physically based. Parameters of semi-distributed models are partially allowed to vary in space by dividing the basin into several smaller sub-basins. The main advantage of these models is that their structure is more physically based than the structure of lumped models and needs fewer input data than fully distributed models. SWAT, HEC-HMS, and HBV are Considered as semi-distributed models.

2.7 Hydrological Model Selection Criteria

Many criteria can be used for choosing the right hydrologic model. These criteria always project dependent, since every project has its specific requirements and needs. Further, some criteria are user-dependent, such as the personal preference for the graphical user interface (GUI), computer operating system, input out management system and structure. The four fundamental criteria that must be considered for model selections are:

- Predict the impact of land management practices on water, sediment, and agricultural yields in large complex watersheds with varying soils, land use, and management conditions over long periods
- Requires specific information about weather, soil properties, topography, vegetation, and land management practices in the watershed.
- Hydrological processes that need to be modeled to estimate the desired outputs adequately (Is the model capable of simulating single event or continuous processes?)
- Available of input data (Can all the inputs required by the model be provided within the time and cost constraints of the project?

In addition, the model must be readily and freely available within available documentation and should be applied over a range of catchment sizes from large to global.

For this study SWAT (semi-distributed model) is selected because its structure is more physically based than the structure of the lumped model, freely available, and meets the objective of this study in addition to the above criteria.

2.7.1 Application of SWAT Model in Watershed Study

The Soil Water Assessment Tool (SWAT), a semi-distributed, continuous-time, process-based hydrology, and water quality model was developed by Dr. Jeff Arnold and his team at the Agricultural Research Service of the United States

Department of Agriculture (ARS - USDA) to analyze the impacts of land use changes on discharge, erosion, sedimentation, and water quality in gauged and ungauged watersheds (Arnold et al., 1998). The special feature of SWAT is the use of HRUs where designated land use, soil type, and slope information can be grouped into files for each sub-basin. Outputs at the HRU level are aggregated at the sub-basin level and eventually delivered from upstream to downstream sub-basin via channel routing (Arnold et al., 1998). This approach is fairly useful back in the time when computational speed was still quite slow (Arnold et al., 1998). On the other hand, users can assign one HRU per each sub-basin so that the SWAT project will be closer to a physically-based model (instead of semi-physically-based) with given modern computer technology.

SWAT model has been applied in agricultural watersheds and has been successfully calibrated and validated in many areas of the world. SWAT has been applied globally on various subjects including LULC change (Shiferaw et al., 2018; Woldesenbet, 2017).

The studies indicated that; the SWAT model is capable of simulating the hydrologic process from the complex and data-poor watershed with reasonable model performance statistical values. Getachew (2012), was applied the SWAT model on Lake Tana Reservoir Water Balance and reported that the overall model performance was satisfactory. Similarly, Tibebe

(2010) also applied SWAT model to evaluate surface runoff generation and soil erosion rates for a small watershed (Keleta Watershed) in the Awash River basin, Ethiopia, and recommended that the SWAT model provides a useful tool for soil erosion assessment from watersheds and facilitates planning for sustainable land management (Damtew, 2015). He was applied SWAT model for hydrological modeling of Katar watershed, Lake Ziway catchment, and recommended the use of the SWAT model for further future research. The above literature review indicated that the SWAT model is capable of simulating the hydrological process with reasonable accuracy and can be applied to large and complex watersheds. Shiferaw (2016) recommended that the SWAT model can be effectively used for assessing the water balance components of a river basin.

2.7.2 Model Description

SWAT development is to assess and 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 developed by Dr. Jeff Arnold. SWAT requires specific information about weather, soil properties, management practices, vegetation, and topography of the watershed. It is a physically-based model which uses the physical process associated with water movement, sediment movement, crop growth, and nutrient cycling. The simulation process of a watershed using SWAT can be grouped into two main phases.

SWAT land phase hydrologic cycle simulation

This phase controls the loadings like the amount of water, sediment, nutrient, and pesticides to the main channel in the sub-basin. The hydrologic cycle simulated by SWAT is based on the water balance equation as:

$$SW_t = SW_o - \sum_{t=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \qquad (1)$$

Where, SW_o is the initial soil water content on day i, R_day is amount of precipitation on day i, Q_{surf} is amount of surface runoff on day i, W_{seep} is the amount of water balance entering the vadose zone from the soil profile on day i, Ea is amount of evapotranspiration on day i, Q_{gw} is the amount of return flow on day i, and SW_t is the final soil water content. All parameters are in mm depth of water.

SWAT Water or Routing phase simulation

Once SWAT determines the loadings of water to the main channel, the loadings are routed through the stream network of the watershed. In addition to keeping track of mass flow in the channel, SWAT models the transformation of chemicals in the stream and stream bed.

A brief description of some of the key model components are provided in this study. More detailed descriptions of the different model components are listed in (Neitsch, 2010). Surface runoff occurs whenever the rate of precipitation exceeds the rate of infiltration. Using daily or sub-daily rainfall, SWAT simulates surface runoff volumes and peak runoff rates for each HRU. The SCS curve number equation is:

$$Qsur = \frac{(R_{day} - 0.2s)^2}{(R_{day} + 0.8s)}) \qquad (2)$$

In which, Q_{sur} is the accumulated runoff or rainfall excess (mm), R_{day} is the rainfall depth for the day (mm), S is the retention parameter (mm). The retention parameter is defined by equation:

$$S = 25.4(\frac{100}{CN} - 10) \tag{3}$$

where CN is curve number

3 MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

This study was conducted in Borkena Watershed, 375km northeast of Addis Ababa which is one of the tributary for Awash river. It is permanent river that flow through South Wollo Zone down from Kutaber, through Cheffa swam area and then Awash river. Geographically the Watershed is located within UTM 37 zone of coordinates in between 1154573 m to 1249932 meters North and 558396 m to 603953 meters East in UTM coordinates. The watershed touches 3 administrative zones (South Wollo, Oromia, and North Shewa) with total spatial area coverage of 1684.2 km^2. The watershed is named by the name of river Borkena at the head work (Borkena Sakei) at this location.

3.1.2 Topographic Feature

Based on the 30x30m resolution DEM, the study area has low to high relief differences with an altitude range of 1350 to 3554 meters above sea level. In this watershed we can find different terrains including flat Alnsha plain followed by another large Borumeda plain. The right side is a very step ridges including Tossa mountain chains. The topographic feature becomes steep mountain ridges on both sides after Dessie town (Zonal capital of South Wollo). After Dessie, the topographic feature again becomes a very flat plain along the main river courses starting from Harbu up to the Borkena Sakei site at Artuma area, below Kemissie.

The Watershed has marked topographic variation. All types of slopes are present. Specially the mountainous part is very steep slope.

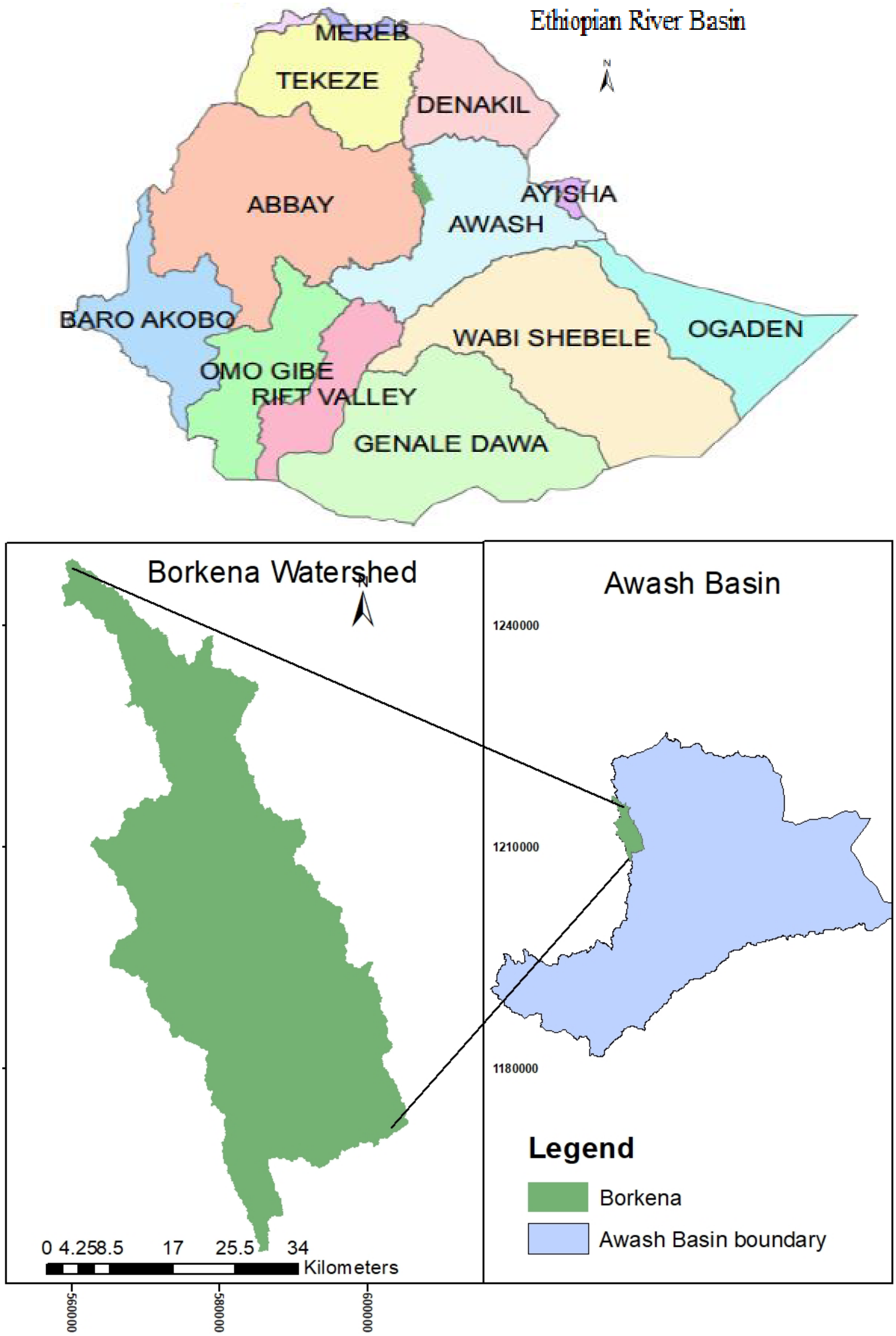


Figure 3.1: Location of Study Area

3.1.3 Socio-Economic Conditions

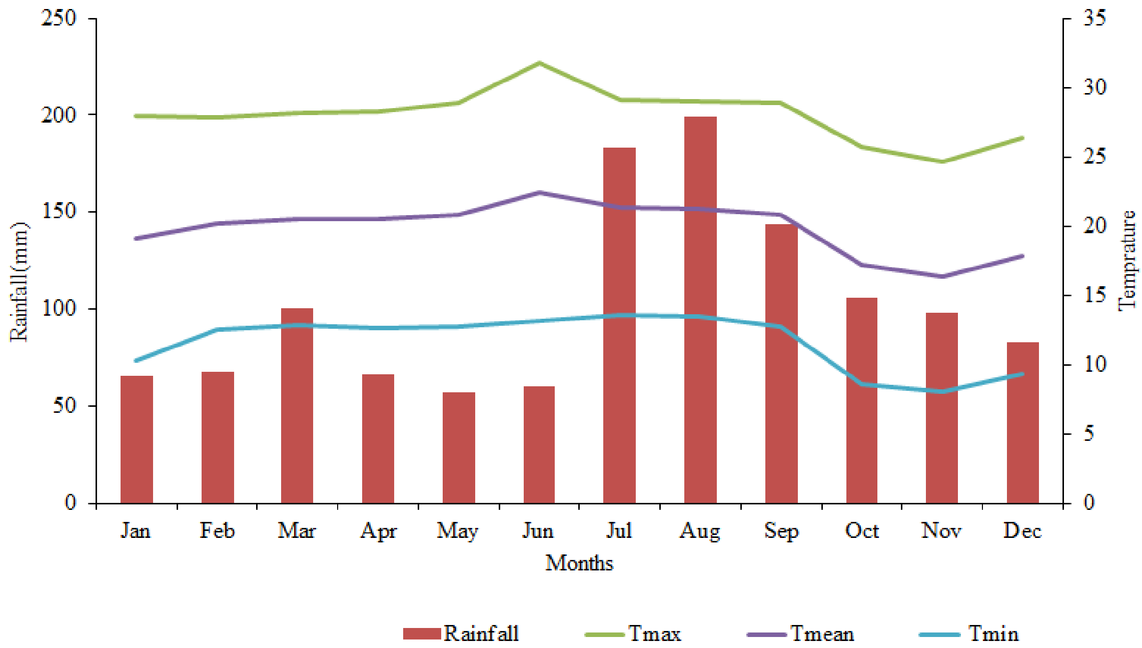
The farming system in the watershed comprised field crop production, livestock rearing and tree growing (special to Kutaber). Agriculture was the main economic base of the community in the rural areas of the watershed. Both crop production and livestock rearing, mixed agriculture, is carried out with almost equal emphasis. The towns mainly Dessie, Kombolcha and Kemisie are almost on the way of development. Kombolcha is industrial town of the region with different factories and future industrial reserve areas.

3.1.4 Climate

The rainfall distribution in the Borkena watershed varies from higher altitudes in the mountainous regions to the low land areas. The monthly rainfall distributions of the study area indicate that July, August, and September are the wettest months of the year in all the selected stations. The mean monthly climate of the Borkena watershed (1987-2018) is shown in the graph below. The mean annual rainfall (1987-2018) of the study area as shown in varies from around 1230mm and mean annual temperature varying from 17.7°c to 22.43°c as shown below.

3.1.5 Land use Land Cover of Study Area

The dominant land cover of the study area is listed in the table below. The maximum proportional coverage of the study area is agriculture.The land use land cover of the study area as reviewed from different study over the area and LULC obtained from MoWIE is shown below table 3.1.



(Source : NMA, 2001)

Figure 3.2: Long-term (1987-2018) Monthly Mean Climate of Borkena Watershedimg:b

Table 3.1: Land Use Land Cover Description of the Study Area

Item	Descriptions
Settlement	Areas where the dominant area covered by building and houses
Water land	Permanent open water, lakes, reservoirs and streams
Wet land	The area in which covered by the swamp
Grass land .	Landscapes that have a ground story in which grasses are the dominant vegetation forms.
Bar land .	Areas with little or no vegetation cover consisting of exposed soil and/or bedrock
Shrub land .	This category includes low woody plants, generally less than three meters in height, usually with multiple stems, and grow vertically.
Forest land	Areas composed of forest land and transplanted
Agriculture	Areas covered with annual crops followed by harvest and bare soil period

3.2 Data Collection

The data required for the study included:

- Land use land cover;

- Geophysical data : topographic and soil survey maps, and satellite imagery;
- Digital elevation model;
- hydro-meteorological data: stream flow and weather variables;

3.2.1 Land use Land Cover

The the classified LULC map of the study area were found from MoWIE in which taking it as references for classifying satalite image.

3.2.2 Land Sat Images

In this study Land Sat images were used for mapping the LULC map of the Borkena catchment. The characteristics of the images used in this research were presented in the following. For this study Land sat images of 1994, 2007, and 2018 were downloaded from the United States Geological Survey (https:earthexplorer.usgs.gov/) website in GeoTIFF file format. The Selection of the Land sat satellite images data was influenced by the quality of the image especially for those with limited or low cloud cover and also to prevent seasonal variation of vegetation coverage. Therefore, the images were almost cloud-free and almost in the same annual season.

Table 3.2: Land Sat Data Acquisitions

S. no.	Year	Space Craft_Id	Sensor ID	Resolution	Path/row	Acq. Date
1	1994	Landsat_5	TM	30m/ B 6(120m)	168/052	28-02-1994
.	.	Landsat_5	TM	30m/ B 6(120m)	168/053	28-02-1994
2	2007	Landsat_8	MSS	30m	168/052	12-03-2007
.	.	Landsat_8	MSS	30m	168/053	12-03-2007
3	2018	Landsat_8	OLI_TIRS	30m/15m	168/052	01-02-2018
.	.	Landsat_8	OLI_TIRS	30m/15m	168/053	0 1-02-2018

3.2.3 Soil and Slope of the Study Area

The soil data was one of the important data used in the SWAT model for considering the physiographic condition of the study area. This was done because the watershed has different landforms that have strong relations with that of soil characteristics. As per the variety of landforms within the watershed, the soil characteristics are different for most of the mapping units. According to the FAO/UNESCO soil classification system the study area comprises four major soil types, which include Eutric Vertisols, Eutric leptosols, Fabric leptosols, and lithic leptosols. The soil raster data set was taken from Ethiopian MoWIE.

The slope of the study area was developed from the digital elevation model which obtained from USGS EROS archive SRTM. The study area was classified into four as shown below in figure 3.3 and the proportional coverage is listed in the table 3.3 below.

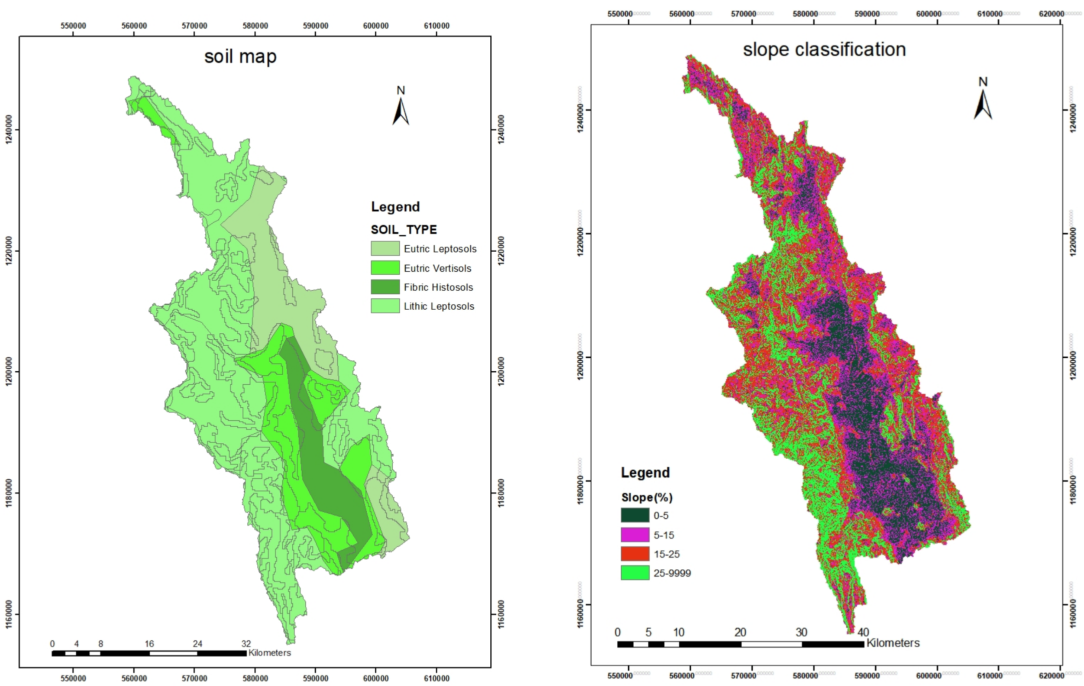


Figure 3.3: Soil Classification of the Study Area

Table 3.3: Proportional Area Coverage of Soil and Topography of Borkena Watershed

Soil Type	Area Ratio(%)	slope(%)	Area Ratio (%)
EUVERTISOLS	18.10	0-5%	18.64
FBHISTOSOLS	9.86	5-15%	24.83
EULEPTOSOLS	17.21	15-25%	32.53
LTLEPTOSOLS	54.83	>25%	24.00

[a] sources MoWIE LULCM

3.2.4 Digital Elevation Model

The topography of any point in the watershed can be described by the Digital Elevation Model (DEM). The DEM used to delineate the watershed boundary, stream network, and create sub-basins. The digital elevation model of the Awash River basin or specifically Borkena watershed has been obtained from the Shuttle Radar Topography Mission and had been downloaded from http://www.usgs earth explorer/DEM/srtm/30m. The satellite data downloaded from srtm were mosaic because the study area is found in different paths. The downloaded satellite data was projected to WG84 UTM Zone 37 to create an overlay with soil and land use raster data set using GIS 10.4.1 before mosaicking.

3.2.5 Meteorological Data

The meteorological data required are daily precipitation, daily maximum and minimum temperature, daily solar radiation, daily wind speed, and daily relative humidity. All data have been obtained from the Ethiopian national meteorological agency. The following stations are recorded meteorological stations found within and near the study area.

Table 3.4: Gauged Rainfall Stations In and Around Borkena WaterShed

station name	elevation	X(°)	Y(°)	recorded year
Ancharo	2000	39.630	11.050	1986-2019
borumeda	2720	39.467	11.360	1986-2018
Cheffa	1466	39.819	10.840	2003-2018
cheffa_robit	1512	39.900	10.830	2005-2018
combolcha	1857	39.717	11.083	1986-2018
Dessie	2553	39.638	11.110	2008-2009
Haik	1985	39.680	11.305	1986-2019
Harbu	1507	39.786	10.923	1987-2019
Kemisse	1435	39.860	10.716	2005-2019
Majete	2000	39.850	10.500	1988-2018

Based on the length of recorded data and quality of meteorological data obtained from the NMA Ancharo, Combolcha, Guguftu, Borumeda, Majete, and Harbu were selected for the analysis and the rest rainfall stations were used for filling climatic data.

3.2.6 Hydrological Data

The time series of hydrological data (streamflow) which are used for calibration and validation of the model and to generate the representative model parameter was obtained from the ministry of MoWIE historically recorded near to the outlet of the study area which is downstream of the swamp.

Table 3.5: Gauged Hydrological Data at Borkena Watershed

Station	Recorded time	Latitude(°)	Longitude(°)
D/s of Swamp	1998-2015	10.63	39.633

3.3 Data Processing

3.3.1 Gap Filling

Having investigated the quality of all recorded climatic data, the first step was filling the missing time series data using different techniques. This missing time series data is due to the failure of the observer to make the necessary visit to gauge, vandalism of recorded gauges or instrument failure (mechanical or electrical malfunctions) may result in missing data.

According to Richard (1998), there are several methods for estimating missing rainfall data. These are; station average method, normal ratio methods, quadrant methods, inverse distance weighting methods, and regression method. Among these methods, the normal ratio method has been applied in this study.

Normal Ratio Method

The normal-ratio method is conceptually simple, that the average annual catch is used to derive weights for the rainfall depths at the individual station. In this method, the precipitation amounts at the neighboring stations are weighted by the ratios of their normal annual precipitation data as follows:

$$P_t = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{N_t}{N_i}P_i\right) \tag{4}$$

Where:

P_t = precipitation at the target station location;

P_i = precipitation at neighboring station;

N_t = average annual rain at target station;

N_i = average annual rain at neighboring stations; and

n = number of neighboring stations

Consistency check

The double mass curve technique was used to check whether the collected rainfall data from the Ethiopian meteorological station were consistent and homogenous through the selected period of study and reveals if the correction was needed. The recording rain gauge station may have changed during the period of record as a result of the shifting of rain gauge to a new location, change due to change in the ecosystem such as forest, and occurrence of observational error from a certain date. This technique is based on the principle that when each recorded data comes from the same parent population, they are consistent.

The precipitation of station x (doubtful station) can be corrected using the following formula;

$$P_{tc,x} = \frac{M_c}{M_a} P_{tx} \tag{5}$$

Where, $P_{tc,x}$= corrected precipitation at any time period t at station x, P_{tx}=original recorded precipitation at time period t at station x, M_c= Corrected slope of double mass curve, M_a= original slope of the double mass curve.

To investigate whether there was inconsistency for gauging stations in the catchment a group of six stations was chosen. The cumulative values of the target stations were plotted against the cumulative average surrounding stations using the Microsoft Excel spreadsheet.

The records of these stations did not show inconsistency since the graph was found to follow a nearly straight line and therefore, these stations had no recording problems or subjected to any external factors during the study period.

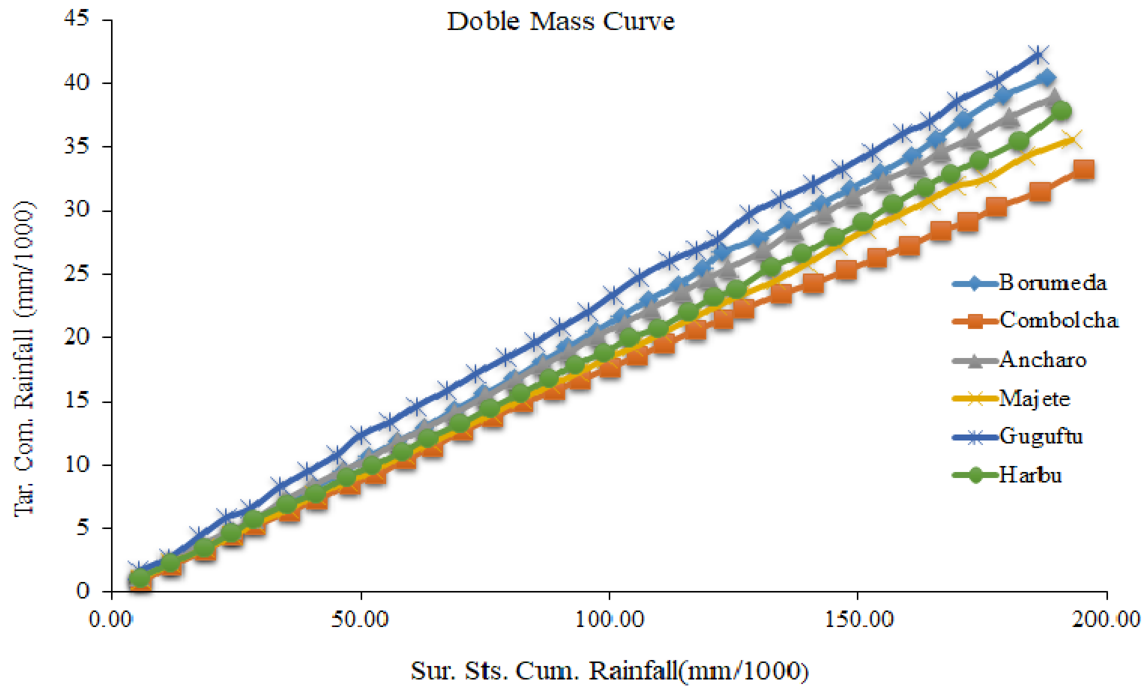


Figure 3.4: Consistency Check From Neighboring Stations

Homogeneity Test

Homogeneity is an important issue to detect the variability of the data. In general when the data is homogeneous, it means that the measurements of the data are taken at a time with the same instruments and environments. However, it is a hard task when dealing with rainfall data because it is always caused by changes in measurement techniques and observational procedures.

$$P_i = \frac{P_{iav}}{P_{av}} 100 \tag{6}$$

wehre; P_i=Non dimensional Value of precipitation for the month in station i, P_{iav} =Over years averaged monthly precipitation for the station i, P_{av}= the over years averaged yearly precipitation of the station i

In the Borkena watershed there are two rainy seasons; heavy rainfall from Jul-August and small rainfall from October-February. The data recorded

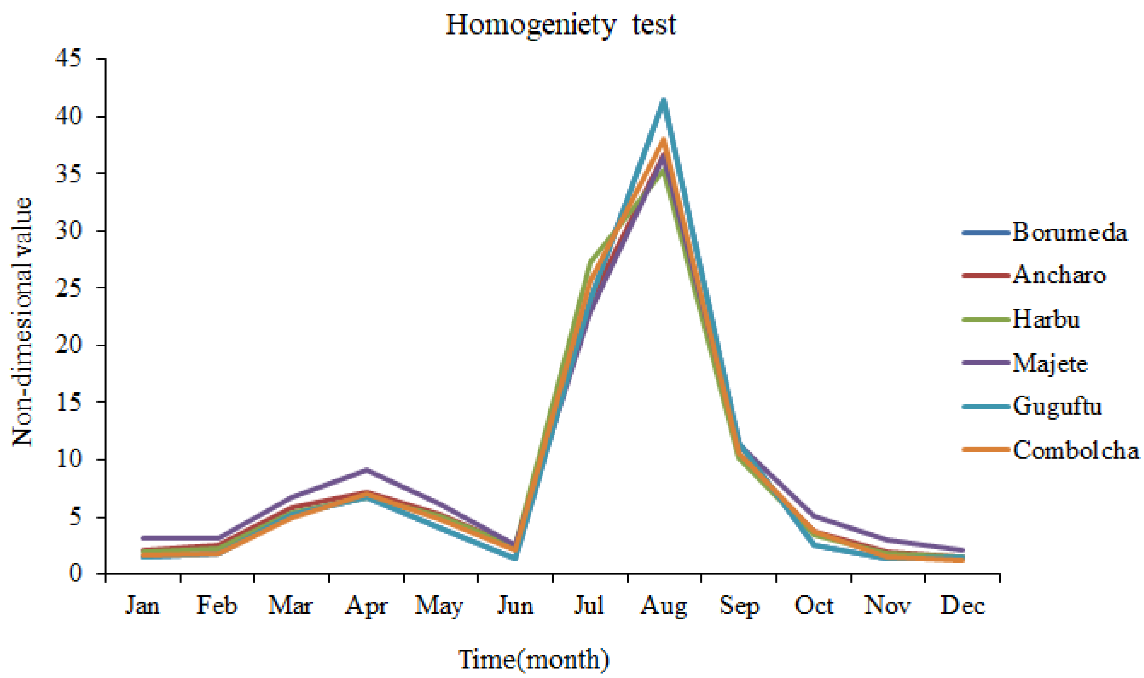


Figure 3.5: Non Dimessional Homogeniety Test

in the selected stations of the study area shows that a bi-modal rainfall pattern which has two peaks for two rainy seasons. The selected stations are also plotted for comparison with each other. Figures below show the result of homogeneity analysis. As it is shown in Figure same-modes and pattern of the stations are observed and hence group stations selected are homogenous.

Studies using inhomogeneous time series as inputs result in biased outputs. Estimations of missing data, consistency check, and homogenization are therefore vital where meteorological stations are scarce and the observed data for ensuring the quality of data for representing the study area.

3.3.2 Future Climate Data

Future climate change is projected to have significant impacts on water resources availability in many parts of the world. In this study RCP 4.5 as Medium stabilizing scenario and RCP 8.5 as very high stabilizing scenario were considered. The datasets from CORDEX Africa are freely accessed from https://esgf-data.dkrz.de/search/esgf-dkrz/. The future climate was simulated by the daily time series of precipitation and temperature (maximum and minimum). The data was derived from three regional climate models (RCMs) and three global climate models (GCMs) named as MPI-ESM-LR, EC-EARTH, and CanESM2 for 2041 to 2100 period. The table below shows the models with their special resolutions.

Table 3.6: Description of RCMs Considered in this Study

GCM	RCM	S.R(km)	CORDEX modeling center
EC-EARTH	RACMO22T	50X50	Rossby Centre, Swedish Meteorological and
.	.	.	Hydrological Institute (SMHI), Sweden
MPI-ESM-LR	REMO2009	50X50	Climate Service Center (CSC), Germany
CanESM2	RCA4	50X50	Canadian Centre for Climate Modelling and
.	.	.	Analysis

3.3.3 Bias Correction of Future Climate Data

The output of GCM and RCM models is full of bias that leads to obstructs the climate change study which needs to be corrected using the recommended methods before they use for further analysis (Teutschbein et al., 2012). For this study, the bias correction and extraction of climate variables were implemented using the climate model data for the hydrologic modeling (CMhyd) tool (Rathjens et al., 2016). The correction method is applied by comparing the daily observed precipitation and temperature at each station with the nearest grid point of RCM considering the grid points as a single station on the watershed. The tool offers all bias correction methods listed in the table above. The systematic error (bias) in the precipitation and daily maximum & minimum temperature scenarios from CORDEX have been corrected by power transformation and linear scaling in daily time series respectively. According to Amaury et al. (2018) no substantial differences can be identified from the results of the temperature-corrected methods. Therefore for temperature, the simplest method which is the linear scaling method was used. For precipitations the bias correction depends on the selection of corrected methods.

The best method for precipitation bias correction is power transformations (Amaury et al., 2018).

The basic principle was to fit the parameters of transfer functions of RCM-simulated data to that of observed data based on the monthly mean value. For temperature, the LS method implements a constant corrected factor that is estimated by the difference between original RCM simulations and observations.

$$T_h^c = T_h + (\mu T_{obs} - \mu T_h) \tag{7}$$

where $\mu =$ is determined by the mean. T_h^C = corrected temperatur,T_h= original RCM out put and T_{obs} = observed temprature.

$$P_h^c = smP^b h \tag{8}$$

Where,

$$sm = \frac{\mu(Pobs)}{\mu(P^b, h)} \tag{9}$$

μ = mean, sm = scaling factor, b= exponent, P_h^c= corrected preciptations, h = original RCM preciptaions out put, P_{obs} = observed preciptation.

Generally, during bias correction, the following steps were conducted:

select observed parameters: The user needs to select a variable and then provide the path to the gauge location file.

Bias correction methods: there are different methods to correct the climate data from (Teutschbein et al., 2012).

Select simulated climate data: CMhyd supports two data formats for

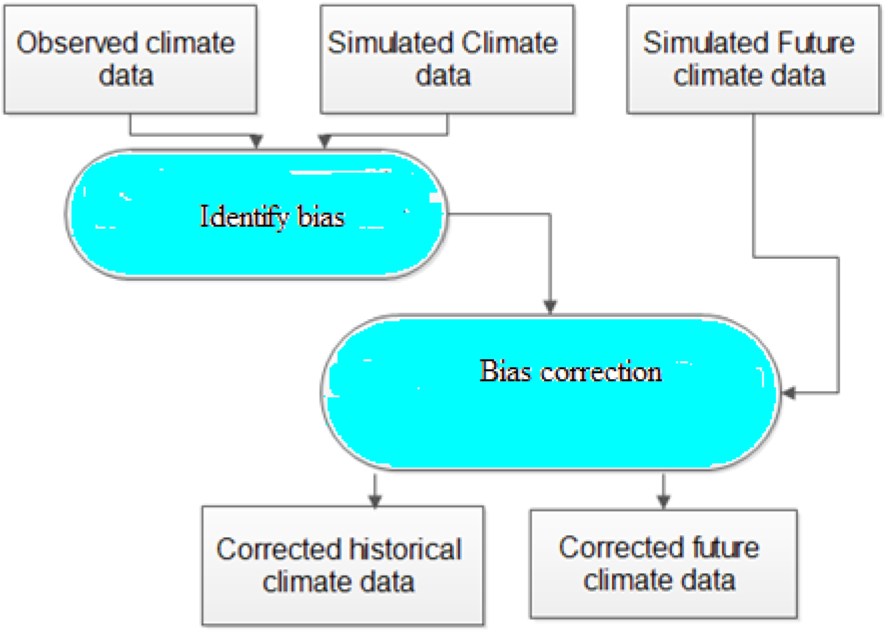


Figure 3.6: Description of RCMs Considered In This Study

simulated climate data For this study I used the netCDF data.

Set output directory: create the subfolder to save the output corrected climate data using recommended methods

Processing: it includes the; pre-processing, check the files, check the overlapping time period and start simulating.

3.3.4 Land Use Land Cover Classification

All the scenes obtained from the EROS Data Center were already geo-referenced to the Universal Transverse Mercator (UTM) map projection (Zone 37), WGS 84 datum and ellipsoid. All preprocessing and image classification was conducted using ERDAS Imagine software, 2014 version (ERDAS 2014). Since the multispectral and panchromatic bands for land sat_8 imagery are acquired independently, the High Pass Filter (HPF) image fusion method was applied to enhance the resolution of multispectral bands. HPF method outperformed Hue-Intensity-Saturation or the principal component method. In addition, it is suitable for multi-sensorial and multi-temporal satellite images data. The pan-sharpened scenes were mosaicked to cover the study area.

Generally, before classification of land use land cover of 1994, 2007 and 2018, pre-processing of satellite image were made via ERDAS IMAGINE 2014.

1. Layer stacking to combine similar bands into one image
2. Mosaicking different layers of satellite image into one layer because the study area was found in between two paths .i.e 168052 and 168053.
3. Radiometric correction like noise reduction, histogram matching, periodic noise removal, and distrip TM data were made.
4. Masking the area of interest with the help of shapefile obtained from ArcGIS for the purpose of reducing the computer running time.

Once finished the preprocessing, classification was done; where the classification of the covers comprises a list of all land-cover types present in the study area that could be clearly identified from the satellite images. False-color composites were used to improve the visual interpretation of satellite images and facilitate the identification of LULC features. Training sites were developed from the reference data of Google Earth, GCP collected from field, and the LULC map obtained from the ministry of water irrigation and electricity to create a signature for each land-cover type on the downloaded and pre_processed satellite data. Signature separability was determined during the preliminary classification. The pre-processed satellite images were then classified using supervised classification under the algorithm of Maximum Likelihood to identify Agricultural area, settlement, forest, shrubland, grassland, wetland, and barren land.

3.3.5 Check Accuracy of Classified Image

The last steps in the classification and developing land use land cover maps from satellite images were accuracy assessment. The importance of accuracy assessment is to verify the classified image of how pixels correctly sampled and matched with land use land cover class. This was done by most areas with high-resolution images, Google earth, and ground truth point collection to sample the trial points. Therefore for assessing the accuracy of the LULC map of 2018 both the ground truth points and google Earth were collected during fieldwork and the remaining two time periods the google earth was used to verify the accuracy of classified images.

One of the most common means of expressing classification accuracy is the preparation of a classification error matrix (sometimes called a confusion matrix or a contingency table). Error matrices compare, on a category-by-category basis, the relationship between known reference data (ground truth) and the corresponding results of automated classification. Such matrices are square, with the number of rows and columns equal to the number of categories whose classification accuracy is being assessed (Lillesand et al., 2004).

Overall map accuracy was computed by dividing the total correct by the total number of pixels in the error matrix. The error of omission is the type on the ground not found on the classified. percentage of commission indicates pixels that were placed in a given class when they actually belong to another. Many ways are available to look at the thematic accuracy of a classified image. The overall, producer, user accuracy and Kappa criteria were investigated for the classified image.

The general formula used to evaluate the accuracy of each classified image for overall and kappa values (Lillesand et al., 2004) :

$$O.A = \sum_{k=1}^{q} \frac{n_{kk}}{N} * 100 \tag{10}$$

$$K = \frac{(N \sum_{k=1}^{q} n_{kk}) - (\sum_{k=1}^{q} nk_{+}n_{+}k)}{N^2 - (\sum_{k=1}^{q} nk_{+}n_{+}k)} * 100 \tag{11}$$

Where: N is total number of reference points, q is number of rows in the matrix, n_{kk} is sum of correctly classified cells, $n_{+}k$ is the total for row i and nk_{+} is the total for column i.

3.3.6 Detection of Land Use/Land Cover Change

Post classification

Post classification was applied to determine the change in land use land cover of the study area. The change detection of land use land cover was evaluated using ARCGIS software and Microsoft excels. The changes were done for three time periods. The three-time periods are classified into three-time intervals .i.e from 1994 - 2007, 2007- 2018, and 1994 -2018.

Rate of land cover change

Because of its better estimation and biological meaning, the formula derived from the Compound Interest Law was applied in order to compute the annual rate of change of LULC at different time periods (Puyravaud, 2003).

$$R = \frac{1}{(t_2 - t_1)} ln\left(\frac{A_2}{A_1}\right) \tag{12}$$

Where R is annual rate of change, and A_1 and A_2 are the area coverage of a land cover at times t_1 and t_2 respectively. This equation provides a standard method for making LULC change comparisons that are insensitive to the differing time periods between observation dates.

3.4 Setting SWAT Model

3.4.1 Watershed Delineation and HRU Definition

The digital elevation dataset (DEM), raster LULC map, raster soil map, and weather data were processed using the ArcSWAT which is the interference of ArcGIS. The processes are clipping, projecting, transfer from

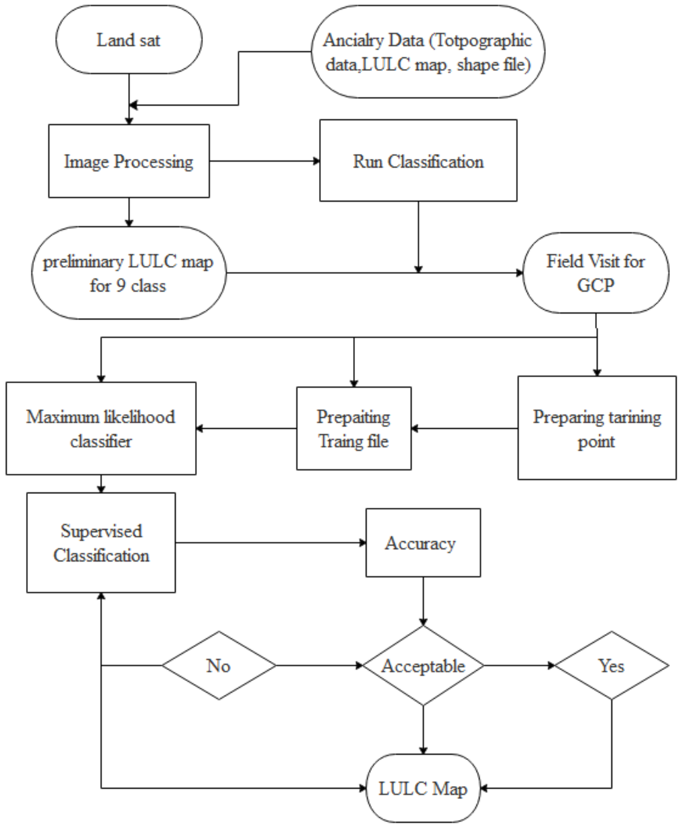


Figure 3.7: Conceptual framework for LULC Classification of the Study Area

vector to raster. The watershed delineation was carried out based on the digital elevation model (DEM). The default threshold sub-basin area that is suggested by the model is used to define the minimum drainage area to form the origin of the stream. In addition to the stream definition, land cover, soil and slope data ware used to generate the hydrologic response units (HRUs), and the classifications of soil addressed by FAO was applied in the ArcSWAT to connect the data with the SWAT database. The watershed is divided into 28 sub-basins and 223 hydrologic response units (HRUs). The total area of the delineated watershed is measured as 1684.2 Km^2 while the delineated watershed and sub-basins are depicted in the Figure below.

3.4.2 Writing Input Table

Once I have defined the HRU the next step was writing the input table. All prepared weather data have been loaded from the file by selecting

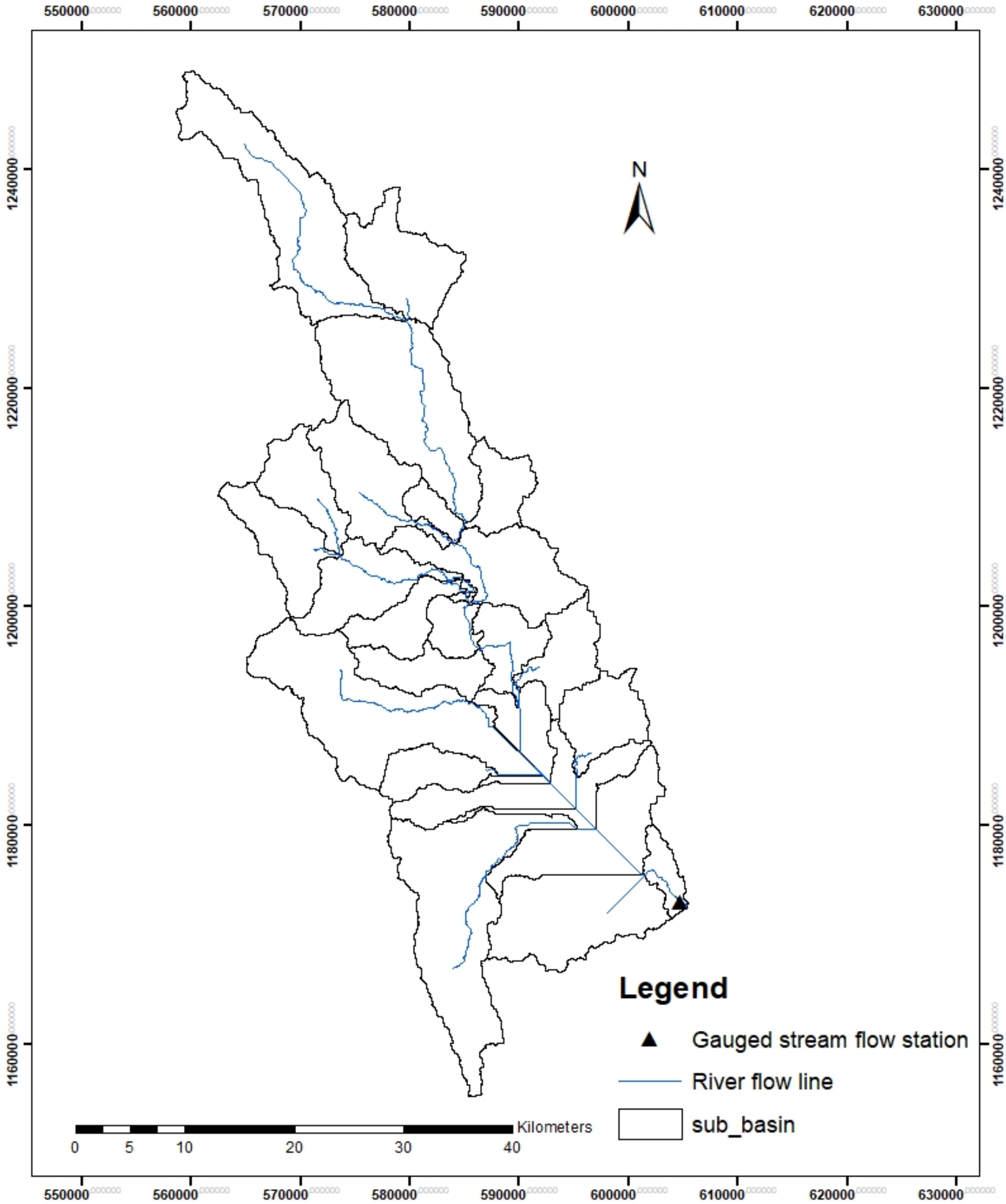


Figure 3.8: Sub Basin and HRU

the write input table in the software. Under this option all the selected weather stations were loaded including their values. once compltеted loading the writing input tables, the database was updated.

3.5 Run SWAT Simulation

The Run SWAT icon, which is located under the SWAT simulation menu, was set the recorded historical time series data with a daily. The average printout option “nyskip” (number of years to not print output) was also set to 3 years as a warm-up period for the model. The value of 3 in the “nyskip” operates the first output from the simulation as a start point of 01/01/1990. After the rest of the parameters were left as default values, the “Run SWAT” icon was activated and the simulation was run.

3.5.1 Sensitivity Analysis

The SWAT model data preparations were done using the ArcSWAT2012 tool in the ArcGIS environment, whereas parameter sensitivity analysis and model calibration and validation were executed using the SWAT-CUP interface Sequential Uncertainty Fitting (SUFI-2) algorithm. Parameter sensitivity analysis was done to select the most sensitive parameter for the study area. This was done by selecting 18 parameters that I have reviewed from different literature studied in Ethiopian river basins (Tibebe, 2010; Woldesenbet, 2017; Tsegaye, 2010). To find the most sensitive parameters in SWAT-CUP, there are two types of sensitivity analysis methods. The first one is global sensitivity and one at a time sensitivity; it should be performed one parameter at a time only. But global sensitivity is performed after iteration. For this study global sensitivity analysis was used and the most sensitive parameters were measured using t-stat values where the values are more sensitive for larger in absolute of t-stat values. P-values are used to determine the significance of the sensitivity where the parameter becomes significance if the value is close to zero (Khairi Khalid et al, 2016).

3.5.2 Calibration and validation

Calibration is the process of optimizing the model parameters to get the best estimate of the real data from observed flow data. While model validation is the process of justifying the suitability of this calibrated model i.e. without changing the value of parameters estimated during the calibration process to predict the flow, tested beyond the calibration period.

The initial parameters for the model's input were taken from the default of lower and upper bounds found in the SWAT database and from earlier studies in the basin. The calibrated parameter was completed with the help of SWAT CUP. This was done until attaining the recommended parameters using a manual and automatic calibration strategic approach with the result as shown table below. After completing all the calibration and attain the recommended parameter, the next step was validation of the calibrated parameter which involves running a model using parameters obtained during the calibration and comparing the prediction to independently observed data in which was not used in the calibration process.

Simulations set up using the 2007 LULC map were used to calibrate daily streamflow. All of the daily data were summarized into monthly intervals for the model-evaluation procedure. Different parameter values were applied for the watersheds. SWAT-CUP (Calibration and Uncertainty Procedures) is a separate program developed for calibration of SWAT (Abbaspour et al., 2015). In the current study, the Sequential Uncertainty Fitting version 2 (SUFI-2) algorithm was applied in the SWAT-CUP software package for model calibration, validation, and sensitivity analysis. From the available data and the quality of recorded stream flow the recorded data was classified into three periods via warm-up period, calibration, and validation periods. Therefore the warm-up periods are one year (1997- 1998), the calibration periods six years (1998 - 2003), and for validation 4 years (2004- 2007)

3.5.3 Model Performance Evaluation

To compare the model output and observations, model efficiency criteria are used. The efficiency of the model in simulating streamflow was evaluated visually and by using the Nash-Sutcliffe efficiency (NSE), Percent bias (PBIAS), and coefficient of determination (R^2) values. All the daily data were summarized into monthly intervals for the model-evaluation procedure.

$$ENS = 1 - \left(\frac{\sum_{i=1}^{n}(Q_{obs} - Q_{sim})^2}{\sum_{i=1}^{n}(Q_{obs} - Qm_{obs})^2}\right) \tag{13}$$

$$PBIAS = 1 - \frac{\sum_{i=1}^{n}(Q_{obs} - Q_{sim})}{\sum_{i=1}^{n} Q_{obs}} * 100 \tag{14}$$

$$R^2 = \frac{\sum_{i=1}^{n}(Q_{obs} - Q_{sim})(Q_{obs} - Qm_{sim})}{\sqrt{\sum_{i=1}^{n}(Q_{obs} - Q_{mobs})^2}\sqrt{\sum_{i=1}^{n}(Q_{sim} - Qm_{obs})^2}} \tag{15}$$

Where Q_{obs} and Q_{sim} are the measured and simulated data, respectively, m represents mean and n is the total number of data records.

According to Moriasi (2007), The optimal value of Ens is 1.0. As Ens approaches 1.0, the model simulates the measured data more accurately. When Ens is negative, the model is a worse predictor than the measured mean. On the other hand, the optimal value for PBIAS is zero. Low-magnitude values indicate accurate model simulation; positive values indicate model underestimation bias, and negative values indicate model overestimation bias.

Table 3.7: Model Performance Evaluation Criterion

Performance rating	NSE	PIAS	R2
unsatisfactory	<0.5	>25	<0.5
Acceptable	0.5<0.65	15 to 25	0.5<0.6
Good	0.65<0.75	10 to 15	0.6<0.7
Very good	>0.75	<10	>0.7

[a] (source: Moriasi, 2007)

As mentioned earlier, future climate data of the ensemble average of model output was used to evaluate the precipitation and temperature change in meteorological events. In this study, three different scenarios (climate change only, LULC change only, and climate and LULC change combined) to assess the separate and combined impacts of the climate change and/or LULC change under the RCP 4.5 and 8.5 scenarios. Simulations based on altering LULC for the same climate condition and altering climate conditions for the same LULC were used. Changes between the results of these runs and the baseline period revealed the effect of change of LULC or climate on surface hydrology components. LULC of 1994 and historical climate data were used for baseline simulation.

- Scenario 1 (Baseline): using 1994 LULC and climate data from 1972 to 2003
- Scenario 2: Using 1994 LULC map under 2041 -2070/2071-2100 climate data
- Scenario 3: using 2018 LULC Map under 2041-2070/2071-2100climate data

To evaluate only the impact of climate change, under Scenario1 was simulated with the assumption that the future LULC would be the same as the current LULC 1994 i.e. scenario1 and scenario2. The impact of only LULC change was evaluated by comparing simulation 3 and simulation 2, considering climate change remained unchanged. Finally, to evaluate the combined impact of climate and LULC change, under Scenario 3 was simulated by considering the future LULC is the same as LULC 2018. The current LULC maps were used because it is difficult to develop realistic land use and world market scenarios for a period of more than 20 to 30 years (Roosmalen, 2009).

3.5.4 Model Simulation

To simulate the land effect of land use land cover and climate change on the catchment hydrology have adjusted all the parameters generated during the calibration in the SWAT software.

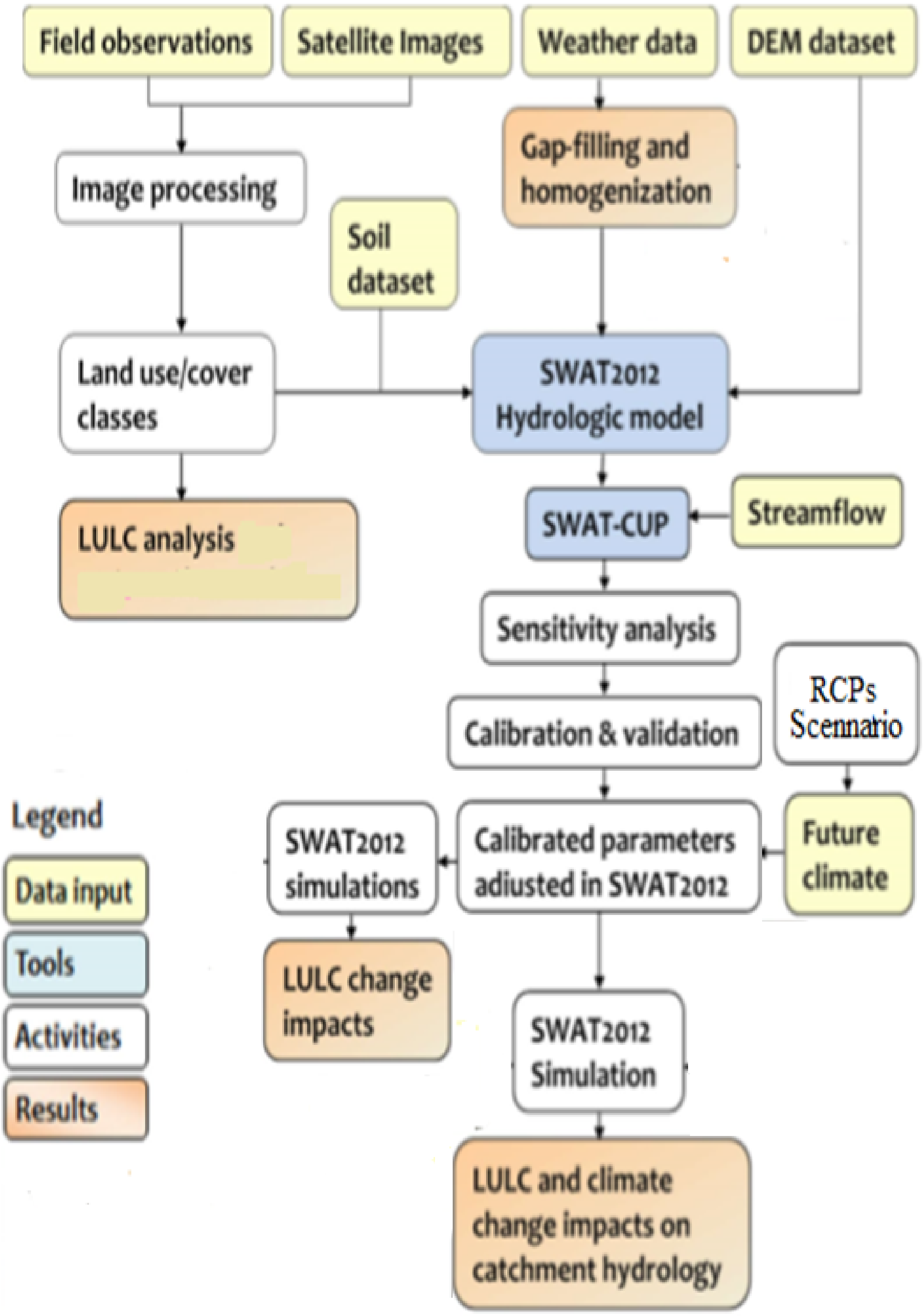


Figure 3.9: Conceptual Frame Work of Study

4 RESULT AND DISCUSSION

4.1 Land Use Land Cover

4.1.1 Land Use Land Cover Classification Accuracy

Overall, producer, user accuracy and Kappa value were used to assess the accuracy of classified map. Therefore, the result of accuracy assessment have tabulated as shown table 4.1 below. Because the accuracy of the land use land covers are found with in the acceptable range, the classified map is used for further analysis.Table 4.2 is the statistical result accuracy assesment for LULC map of 2018 and the other two land cover maps of accuracy results are found in appendix B.

Table 4.1: Result of LULC Accuracy Assessment with Selected Criteria

Year	K(%)	Over all Accu.
1994	77.70	83.97
2007	80.90	85.20
2018	85.23	87.50

[a] values are in %.

Table 4.2: Accuracy Assessment Result for 2018 LULC Map

	Reference												
Class	Bar	wat	Wet	For	Gr	Shr	Agr	Setl	Tot.	E.o	P.A	E.c	Uac.
Bare	25	0	0	0	0	0	3	2	30	7.4	100	16.66	83.33
wat	0	4	0	0	1	0	0	0	5	0	100	20	80
Wet	0	0	10	0	1	0	0	0	11	0	85.71	9.09	90.91
For	0	0	0	25	0	3	1	0	29	0	100	13.79	86.21
Gr	0	0	0	0	25	2	1	2	30	16.66	92.31	16.66	83.33
Shr	0	0	0	0	2	35	3	0	40	14.63	89.29	12.5	87.5
Agr	0	0	0	0	1	1	35	0	37	18.61	90.91	5.41	94.59
Setl	2	0	0	0	0	0	0	16	18	20	77.78	11.11	88.89
Tot.	27	4	10	25	30	41	43	20	200	.	.	.	.

[a] Bar = Bareland, Wat= Water, Wet =Wetland, For = Forest, Gr = Grassland

[b] Shr = shrubland, Agr = Agriculture, setl = setlement, E.O =Error of omissions

[c] E.c= Error of Commissions, Uac = User Accuracy, p.A = Producer Accuracy

4.1.2 Land Cover Maps

The statistical value shown table 4.3 and and clissified maps shown in figure 4.1 stated that, LULC change have significantly detected over the study periods. The agriculture and urban have increased in change and on the contrary shrubland and forest have significantly decreased from time to time.

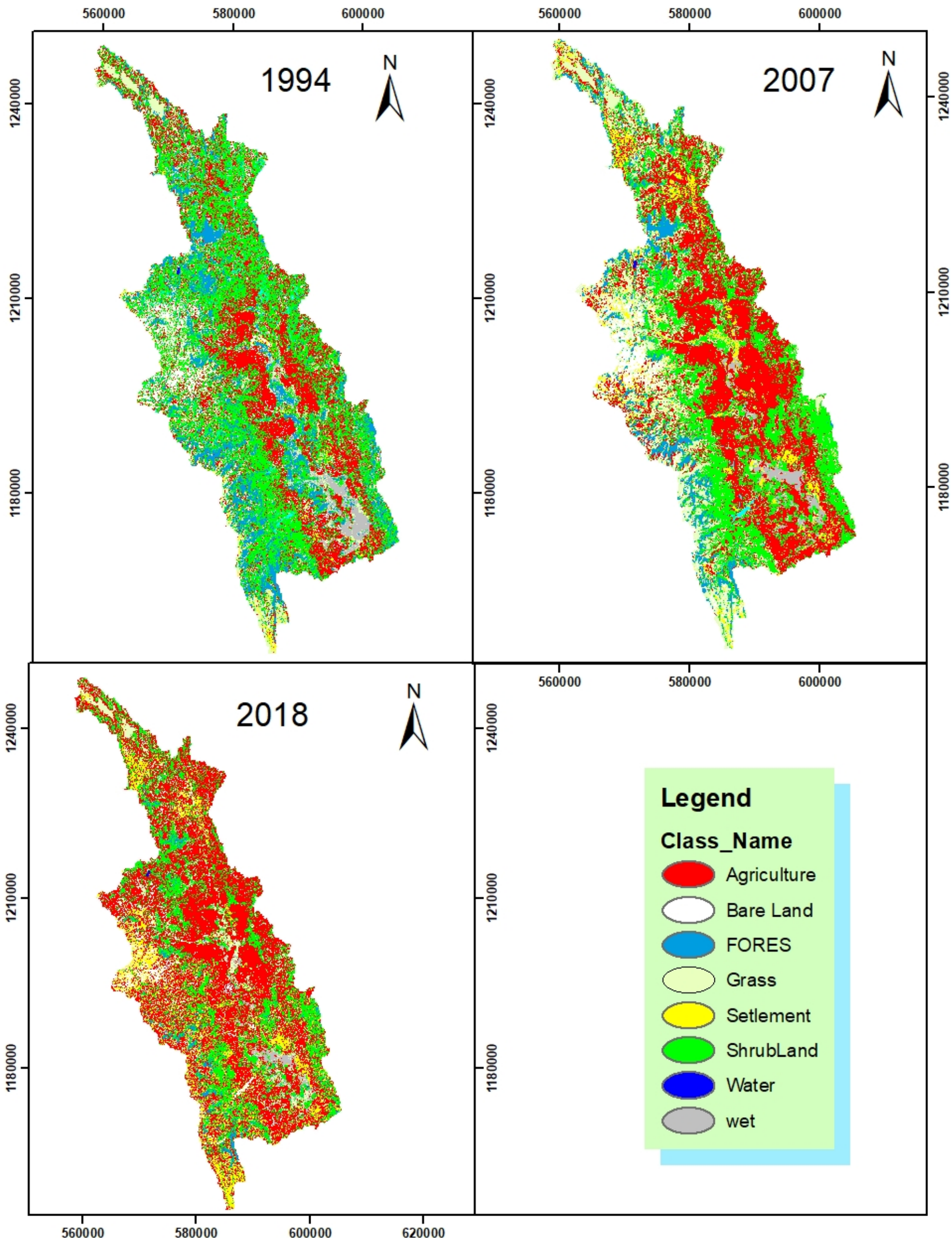


Figure 4.1: Land Use Land Cover Map of Borkena Watershed

Table 4.3: Proportional Land Coverage at Different Period

Year	Setl	Wat	Wet	Gr	Bar	shr	For	Agr
1994	4.10	0.03	2.26	12.41	3.71	33.15	10.04	34.27
2007	6.36	0.03	2.35	17.83	4.46	25.73	7.72	35.53
2018	10.93	0.06	2.61	6.00	5.17	22.68	2.73	49.82

[a] Abbreviations are the same in Table:4.2 and values are in %

4.1.3 Land Use Land Cover change Detection

Post Classification

According to land use, land cover classification obtained from three time periods (1994, 2007, 2018) the change detection was assessed using the methods stated above. The analysis was done based on the persistence

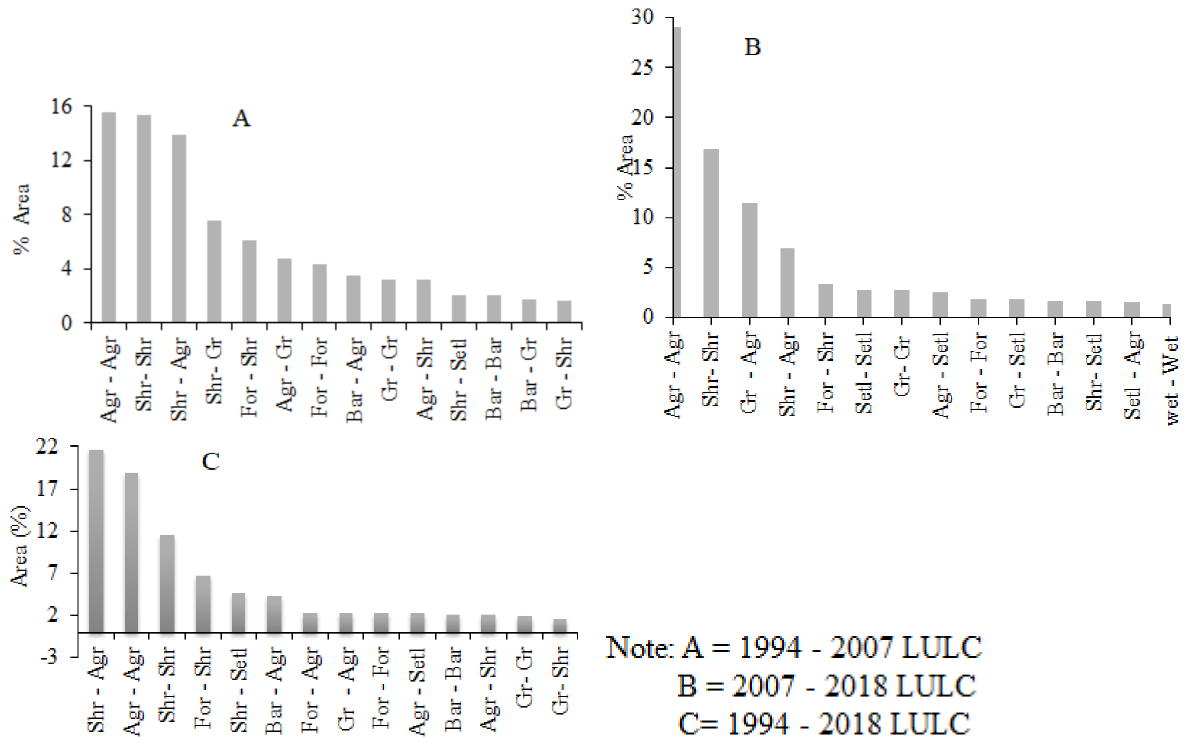


Figure 4.2: Land Lse LandCcover change Detection

and transformation of LULC (one type to other type). Therefor from the result shown Figure 4.2 below. The maximum persistence were detected on agriculture and shrubland with 15.71% and 15.34% respectively between 1994 and 2007. On the contrary the maximum transformed LULC were shrubland to agriculture (13.91%). From 2007 - 2018 the maximum persistence were agriculture and shrubland (29.07% and 16.92%) respectively and the maximum transformed from grassland to agriculture with a value of 11.5%. on the contrary from 1994 - 2018 the transformed LULC was shrubland to agriculture (21.7%) and next to it, persistence with a value of shrubland and agriculture (18.8% and 11.23%). This is due to the rapid increase in population numbers from 1994 to 2018 population census obtained from the Amhara region. This leads to the change of land use land cover enlarged of change detection.

Rate of change of land use land cover

The rate of land use and land cover change throughout the selected periods for the Borkena watershed showed periodic fluctuations. The annual rate of change in forestland in the watershed slowed down from -3.74% in 1994-2007 into -7.41% in 2007-2018, suggesting an increase in agricultural expansion over time. High annual rates of decline of grassland were observed during the periods 1994-2007 (2.8%) and 2007-2018 (-6.7%). This is because the increase in agriculture and settlement has a direct impact on forest and grassland.

The annual rate of de-vegetation of shrubs increased from -1.95% during 1994-2007 period to -1.13% during the 2007-2018 period. Forest deforested at a higher annual rate during the periods 2007 - 2018 (-7.44%), but reforested at a higher annual rate during the period 2007-2018 which indicates that the shrubland increase in the period. There is a high increase in settlement cover from 2.37% in 1994-2007 to 5.73% from 2007-2018 signifying the increase in population number. In the year 1994- 2018 the change of land use land cover was higher as compared to the decadal change. From the graph shown below the increase of one land cover has a direct impact on the other. i.e the expansion of agriculture has a direct impact on forest and shrubland and settlement has also an impact on other components of land use land cover. The annual rate of change of settlement and agriculture were increased by 4.1% and 1.6% respectively. on the contrary the forest, grass, and shrubland have annually decreased by 5.4%, 3.05%, and 1.6% respectively. The increments of agriculture and settlement have a negative impact on the forest, shrubland, and grassland.

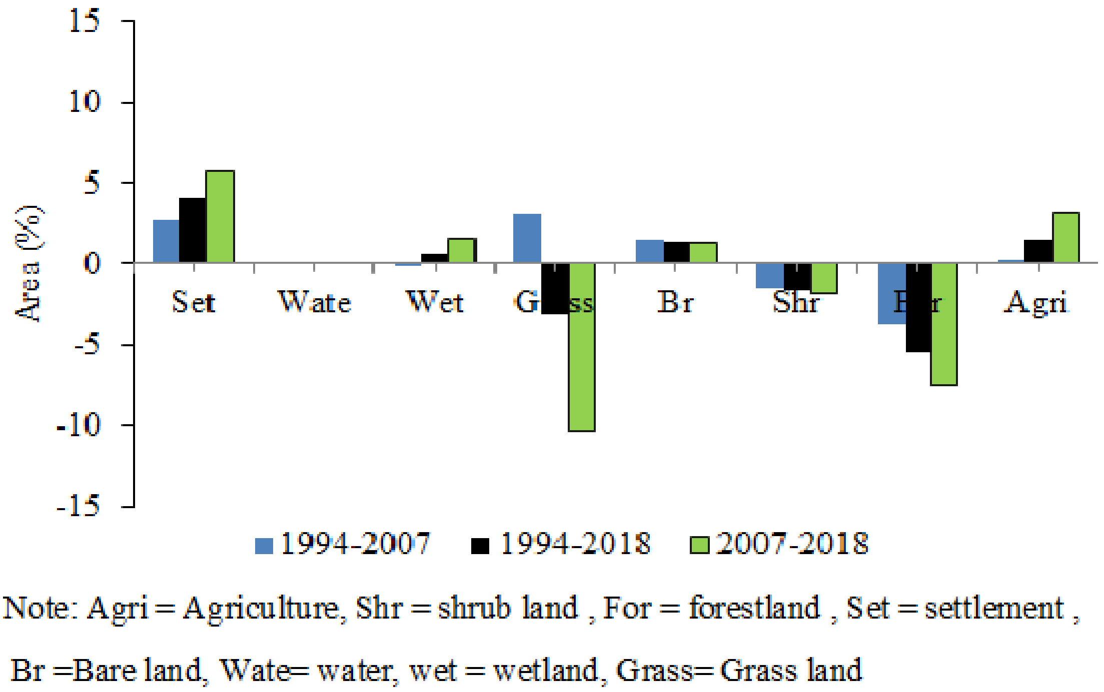


Figure 4.3: Rate of Land use Land Cover Change

This is because the expansion of the population has an impact on land use land cover. Generally significantly increasing rates were observed in urban/settlement, and agriculture and a decreasing rate were observed in forest, grassland, and shrubland.

4.2 Sensitivity, Calibration and Validation Analysis

The result of sensitive parameters are reduced from 18 flow parameters to 7 (R - CN2, R - CHN1, R - CHS1, SLSUBBSN, SOL _ ZMAX, V_ GW_DELAY, and V_GWQMN) and these are the most sensitive parameters for study area according to the t and p test value.

From the result the calibrated and validated result showed that good agreement in between observed and simulated values. The efficiency criterion of the model were evaluate and has the results (NSE =0.67 and

$R^2 = 0.67$) for calibration and (NSE = 0.69 and $R^2 = 0.71$) for validation and PBIAS were less than 25% which is an acceptable model for furtherr analysis.

Table 4.4: Definations of Calibrated Parameters With Their Calibrated Value

Parameters	Range	Description	Cal. V.
r___CN2.mgt	28-98	SCS runoff CN for moisture condition II	0.4
v___GW_DELAY.gw	30-450	Groundwater delay (days)	0.08
v___GWQMN.gw	0-5000	Threshold depth of water in the shallow aq-	508.53
.	.	uifer required for return flow to occur (mm)	.
r___SLSUBBSN.hru	0-1	Average slope length	14.1
r___SOL_ZMX.sol	0-3000	Maximum rooting depth of soil profile	1613.51
r___CH_S1.sub	0-20	Average slope of tributary channels.	0.3
r___CH_N1.sub	0-20	Manning's "n" value for the tributary channels	10.63
.	.	depth of soil profile	.

The comparisons between simulated and observed monthly streamflow values in the period of calibration (1/1/1998-12/31/2003) and validation (01/01/2004-12/31/2007) are shown in Figure 4.4. A clear consistency can be seen between simulated and observed values. The ENS, R^2 and PBIAS values for the monthly statistical value derived from daily calibration and validation is tabulated as shown Table 4.5 below. All of the ENS and R^2 values for streamflow are greater than or equal to 0.6, and the PBIAS values are within the recommended range, which suggests good model performance and has a good agreement between observed and simulated value. The SWAT model, therefore, is used to evaluate the hydrological responses to LULC and climate changes in Borkena watershed.

Table 4.5: Comparisons Criteria Between Observed and Simulated Value

Conditions	R2	NSE	PBIAS	Av. obs. (m3/s)	Av. sim. (m3/s)
calibration	0.67	0.67	2.23	14.01	13.69
validation	0.71	0.69	-14.22	9.69	11.07

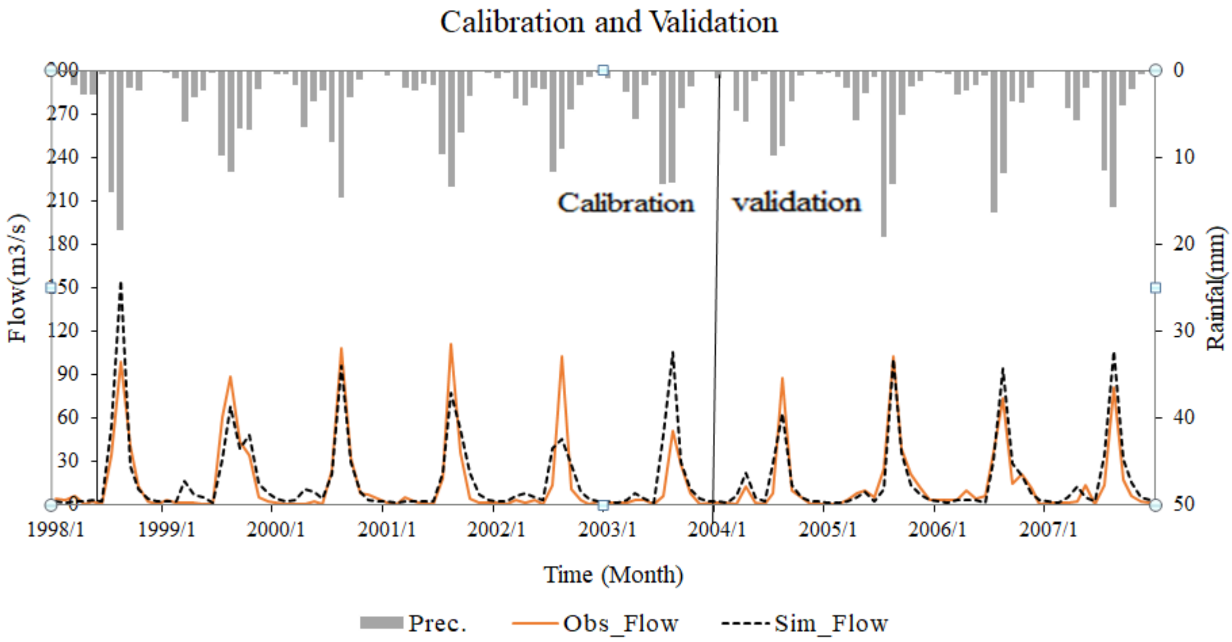


Figure 4.4: R/P Between RainFall and Stream Flow During Calibration and Validation

4.3 Base Line and Future Climate Data

4.3.1 Base Line Climate Data

4.3.1.1 Downscaled Rainfall and Temperature Data for Baseline Period

For the analysis of this study the Downscaled raw rainfall and temperature (maximum and minimum) from subjective selected RCM models (MPI-ESM-LR, EC-EARTH, CNRM-CM5, and CanESM2) for historical baseline (1972-2003) were considered.

Rainfall

The investigations of historical climate data from downscaled RCM climate models have a statistically large bias to predict the future climate which needs correction. The annual rainfall over the study area demonstrates statistically tabulated below in the table in which the maximum bias was detected in CanESM2 (67.77%) and the minimum bias was in MPI-ESM-LR (6%) worst and best respectively. Most of the statistical values table below indicates that the model predicted rainfall over the study area has no good agreement with the observed rainfall without corrections.

Table 4.6: Relationship Between Predicted and Observed Rainfall

Conditions	Models	A.Aver.	sd	CV	Bias
.	observed	1162.36	129.42	11.13	0.00
Before correction	EC-EARTH	1536.08	231.73	15.09	32.15
.	CNRM-CM5	1384.40	321.16	23.20	19.10
.	CanESM2	374.60	196.22	52.38	-67.77
.	MPI-ESM-LR	1232.11	168.67	13.69	6.00
After correction	EC-EARTH	1142.06	243.55	21.33	-0.87
.	CNRM-CM5	1162.09	210.90	18.15	-1.15
.	CanESM2	1174.15	392.72	33.45	0.89
.	MPI-ESM-LR	1161.26	125.11	10.77	-0.22
.	ensemble	1160.67	95.02	8.19	-0.27

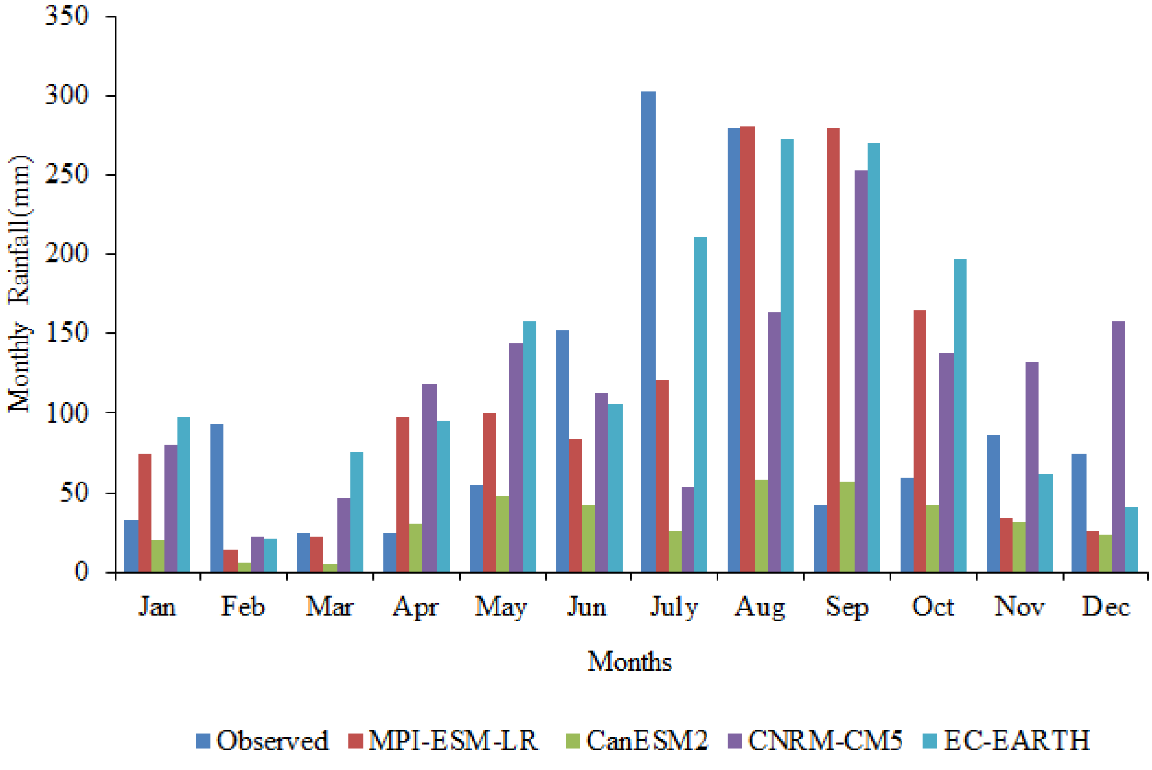


Figure 4.5: Projected Mean monthly Rainfall Before Bias Correction

Temperature

The downscaled raw maximum and minimum temperature for the baseline period using the selected model were not good enough to use for further analysis while comparing it using the observed maximum and minimum temperature. Statistically MPI-ESM-LR, CNRM-CM5, EC-EARTH and CNRM-CM5 were predicted throughout the year for minimum temperature and in maximum temperature. The maximum bias was observed on CanESM2 model in which from May to October shows over prediction and for minimum temperature no significant over prediction was detected. The difference between predicted and observed minimum temperature in EC-EARTH model output was ranged -6.48 to 7.13 °c, in MPI-ESM-LR -8.08°c to 8.07°c CNRM-CM5 and CanESM2 have -7.13°c to 8.55°c respectively. The predicted value by the model have large difference from observed maximum temperature, Which for CNRM-CM5 (-7.77°c to 13.52°c) followed by EC-EARTH (-6.77 to 13.02°c) for MPI-ESM-LR (-11.02 to 10.23°c). The model error is calculated as difference between monthly average observed and downscaled data was used to evaluate the performance of simulated temperature. The MPI-ESM-LR model over predicts the maximum and minimum temperature. For furhter information about temprature data before and after correction refer Appendex C.

For further use the differences in downscaled precipitation and temperature are too large to ignore and the biases should be corrected.

4.3.1.2 Bias Correction Results of Rainfall and Temperature After bias-corrected, the selected RCM models, in terms of bias and other statistical parameters have a good agreement for further analysis. Comparative plots and performance statistics showed that bias and coefficient of variation were reduced to a great extent by correction.

As pointed out from Figure 4.5 above and table 4.6, there was some bias in between observed and simulated /predicted rainfall of the overlapped period, from subjective selected models MPI-ESM-LR output was best in relative to other types of RCM models in apprehending the temporal variation of observed rainfall. Even though the statistical and graphical plots indicate good agreement for MPI-ESM-LR model, “climate change”

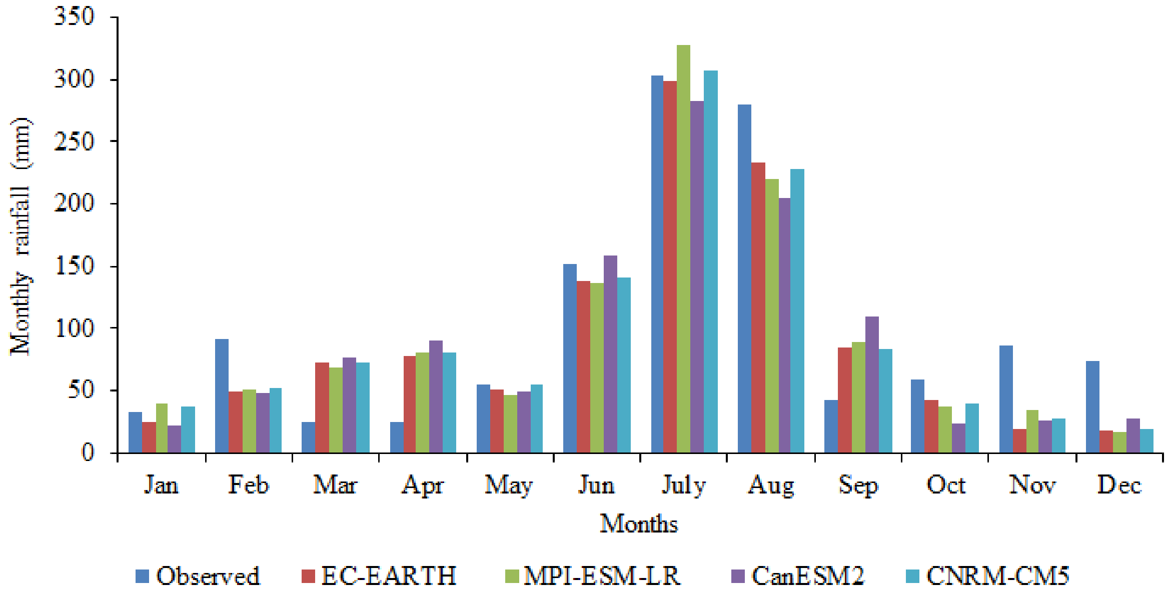


Figure 4.6: Dynamically Downscaled Climate Models Simulations and Gauged Rainfall Data at Monthly Base After Bias Corrected

impact studies may benefit from ensemble simulated of rainfall as obtained from multiple models instead of simulated rainfall from a separate model which only captures certain aspects of rainfall satisfactorily (Haile & Rientjes, 2015). Therefore, the ensemble average of MPI-ESM-LR and EC-EARTH model output (RCP 4.5 and RCP 8.5) were considered to study the impact of future climate change on hydrology. For ensemble average outputs as an example, percent BIAS value has decreased to -0. 27% for rainfall. Other statistical indicators have also improved to a reasonable level after bias correction.

Similarly the biases in maximum and minimum temperature were reduced after bias corrected. as shown appendix C, the observed and simulated temperature data were fitted.

4.3.2 Future Climate Projection

The future projections of precipitation and temperature were projected using the six selected meteorological stations under the two RCMs. While projecting the future climatic variables two-time frames were considered.

i.e MC(2041-2070) and EC(2071-2100). The analysis was done based on the downscaled and bias-corrected ensemble average of RCMs values. From results shows that Borkena watershed will unquestionably experience less rainfall and greater temperatures in the future for both emission scenarios.

Projected Rainfall

From the result table below the annual mean projected rainfall and temperature under two RCPs scenarios showed significant change with a general reduction for rainfall under both scenarios. The maximum change of annual rainfall under RCP4.5 is decreased by 14.51% in MC and 16.51% in EC.

Under RCP 8.5 similar to that of RCP4.5 indicating decreasing of annual rainfall was detected with decreasing value of 24.54% in MC and 31.66% in EC. However, the monthly rainfall projection in both time horizons didn't show a consistent change. For RCP 4.5 under both time frames the projected rainfall showed an increasing change from August to December and then there were decreased for rest months of the year. Similarly in the RCP 8.5 scenario, the expected increasing rainfalls were from October to December and for the rest months decreasing of rainfall were detected excluding July. But the maximum expected decrease of rainfall were pronounced in January, February, and March on the contrary the maximum expected increase of rainfall were expected from October to November under both scenario both time frames. Kerim et al. (2016), assessed the impacts of climate change under RCP scenarios on water allocation for current and future in the upper Awash river basin also found streamflow decreased due to precipitation decreases in the future period under RCP4.5. To ensure the analysis of annual decrease and increase further analysis has been conducted using seasonal values. Under RCP 4.5 scenarios MC, in main rainy and a dry season the trivial increasing were detected and for rest season under both scenarios follows decreasing change. Generally the change of rainfall were higher in with a maximum decreasing rate of low rainy seasons in both scenarios.

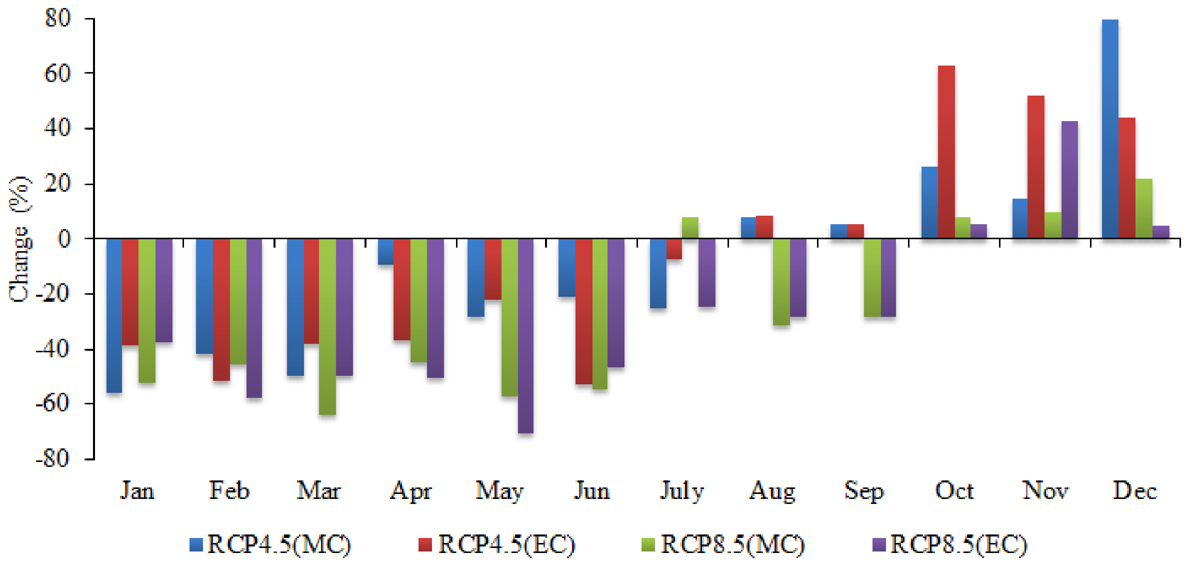


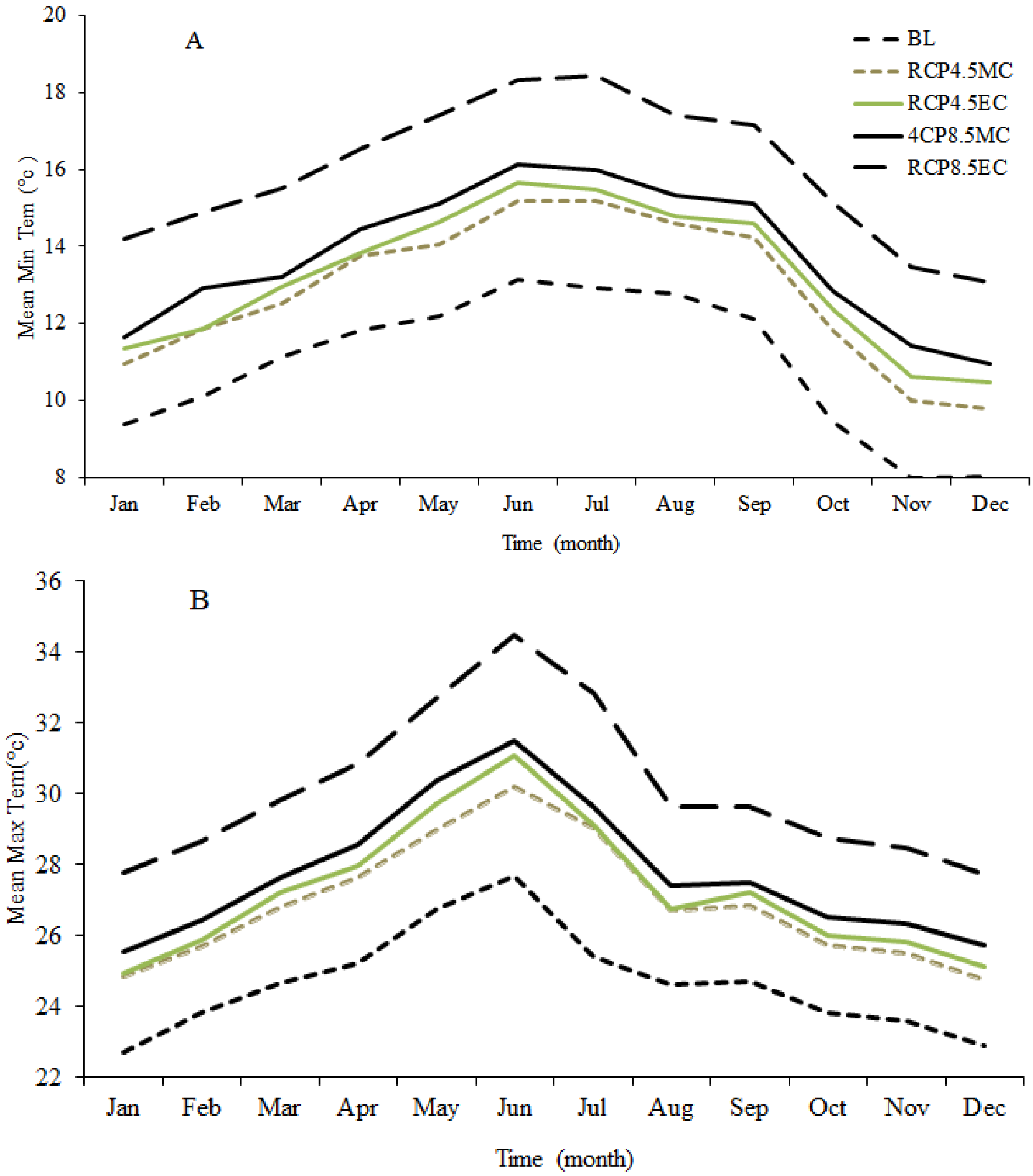
Figure 4.7: Seasonal Change of Projected Rainfall

Projected Temperature

The analysis of future temperature was performed using downscaled temperature based on the baseline period of the mean annual, monthly, and seasonal temperatures to ensure and verify the change of temperature in the study area.

The annual mean minimum temperature showed an increasing change. Under RCP4.5 scenario of mid-century it will increase 1.90 °c and by 2.29 °c at the end century. Similarly, under RCP8.5 it is projected to increase by 2.83 °c and 5.03°c in mid-century and end century respectively . Shiferaw et al. (2018) verified the Modeling hydrological response under climate change scenarios in Ilala watershed, Northern Ethiopia, and found increases in maximum and minimum temperatures under the two RCPs analyzed (RCP 4.5 and 8.5) at the end of the 21st century.

Similarly, annual mean maximum temperatures were increased by 2.24 °c and 2.58 °c in mid-century and end century time frame respectively in medium emission scenario. For high emission scenario it has been increased by 3.11 °c in mid-century and 5.46 °c for end century time



A= Projected Mean Monthly Min Tem.vs BL Mean Min Tem.in Two Scenarios;

B= Projected Mean Monthly Max Tem.vs BL Mean Max Tem.in Two Scenarios

Figure 4.8: Projected Mean Monthly Min and Max Tem. vs BL Mean Min and max Tem In Two Scenarios:

periods.

The the mean annual and monthly mean temprature were assed to ensure the change of temperature in the study area. The mean annual temprature were increased by 2.69 °c and 2.97 °c in mid-century and end century time frame respectively in medium emission scenario. For high emission scenario it has been increased by 2.42 °c in mid-century and 5.25 °c for end century time periods. similarly annual monthly temperature was also assed to ensure the change of temperature in the study area. From the result plotted in Figure 4.8, the mean annual minimum temperature under RCP4.5 increased by in June with a value of 3.61°c and 3.71°c in MC and EC respectively. Similarly in RCP8.5 the maximum change was detected in July with a magnitude of 4.2 °c and 7.2 °c in the MC and EC respectively.

Table 4.7: Precipitation and Temperature of Two Time Frame Under the RCPs

senario	RCP 4.5	RCP8.5	RCP4.5 (%)	RCP8.5 (%)
preciptations (BL)	1306.743	1306.743	_	_
MC	1176.670	987.200	-14.56	-24.53
EC	1211.610	892.940	-16.52	-31.66
Temprature (BL)	17.800	17.800	0	0
MC	19.870	20.760	2.06°c	2.97°c
EC	20.230	23.050	2.42°c	5.25°c

4.4 Climate Change Impacts on Hydrology

The hydrological change under the projected change future temperature and precipitation under two representative concentration pathways (RCP 4.5 and RCP 8.5) were simulated using the calibrated and validated SWAT_CUP model and analyzed at annual as well as seasonal scales. The hydrological components considered were evapotranspiration (Et) and surface runoff (Qs). Due to a lack of observed data for all the water balance components the downscaled baseline climate data output of SWAT was used for the current hydrology to evaluate changes in the hydrological components for the projected future scenarios.

From the result table below, the annual surface flow has been decreased under RCPs with varying magnitude on the contrary the annual evapotranspiration was increased in two-time frames with different magnitudes under RCPs. The annual decreasing change in surface runoff was 21.45% and 30.66% in MC and EC under RCP 4.5 scenario respectively, similarly under RCP8.5 the 22.43%, and 30.0% in MC and EC.But evapotranspiration was detected to decrease throughout the simulated periods. For the intermediate scenario the annual mean evapotranspiration was increased by 1.02% and 0.53% and under RCP 8.5 the evapotranspiration was increased by 1.04 and 0.61 in MC and EC respectively. According to Gebremicael, et al. (2017), in semiarid watersheds, generally, there is a growing tendency in water abstractions, which can further reduce stream flows. Climate change is one of the factors that have a great influence on surface runoff decrease (Abebe, 2014; Tesfaye, 2017). The climate change scenario simulation analysis shows that the change in runoff is positively correlated with the change in precipitation (Xingxing et al., 2019). Therefore the decrease in rainfall has a direct impact on the decrease of runoff. This is proved and verified further from the result obtained in this study as shown below the graph.

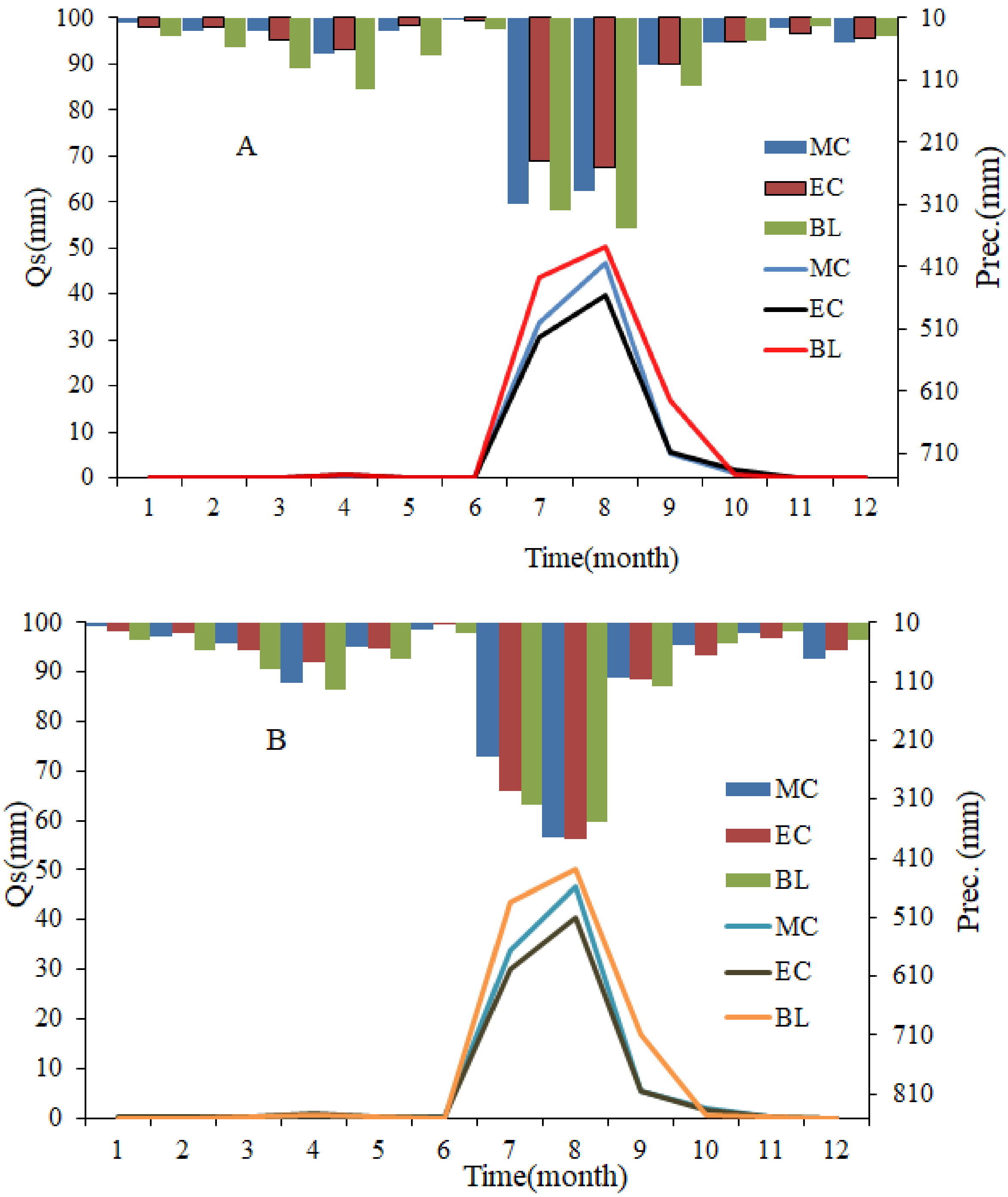
Table 4.8: Annual Hydrological Components Using 1994 LULC

Scenario	Comp.	BL	MC	EC	MC (%)	EC (%)
RCP 4.5	ET	636.96	643.44	640.32	1.02	0.53
.	QS	113.54	89.19	78.73	-21.45	-30.66
RCP8.5	ET	636.96	643.44	640.85	1.02	0.61
.	QS	113.54	88.08	79.48	-22.43	-30.00

[a] values are in %

[b] comp =components

On monthly scale, most climate models under RCP4.5 and RCP8.5 project a decrease in ET during the dry season and an increase during the wet



A= Uder RCP4.5; B =Under RCP8.5 scenarios

Figure 4.9: Mean Monthly Qs of Climate change Impact

seasons. At seasonal scale, under two scenarios for two-time frames the evapotranspiration shows decreasing in the low rainy seasons and increased in the rest two seasons. This is due to the fact that the maximum decrease of rainfall and increase of temperature was observed in the low season in projected climate data of the study area. Simulated surface runoff (Qs) is expected to decrease in all seasons under both scenarios on both time frames. The overall increase in temperature and decrease in rainfall results in a reduction in the hydrological components in the study area. Shiferaw et al. (2018) found surface runoff decreases ranged from 1.75 to 0.74% in RCP4.5 and from 0.76 to 0.36% in RCP8.5. According to the authors, a general increase in temperature will result in decreased surface runoff in the Ila watershed. As the surface runoff increase, base flow will also decrease over the analyzed periods.

4.5 Combined Impact on catchment hydrology

To evaluate the change of hydrological response under both land use and climate change in the study area, the simulated hydrological components under 2018 LULC and future climate change scenarios for the future period are considered and compared with the baseline. The analysis was done based on annually, monthly and seasonal scale. From the result tabulated below the change of hydrological components are similar to that of the impact of climate change only with a varying magnitude as compared to the baseline. In the intermediate emission scenario the surface runoff has decreased by 2.1% and 12.08% in MC and EC respectively. Similarly for high emission scenarios the annual surface runoff has been decreased by 3.02% and 13.85% respectively. On the contrary, the annual evapotranspiration indicates alleviated under combined LULC and CC scenarios compared to under climate change scenarios alone in the watershed. From the table below the maximum decreasing change of annual Et was 6.09% and 5.77% in both RCPs and time frames in intermediate emission scenarios and for high emission scenarios 5.74 and 5.62.

Table 4.9: Annual Average of Hydrological Components Using LULC 2018 and Future Climate

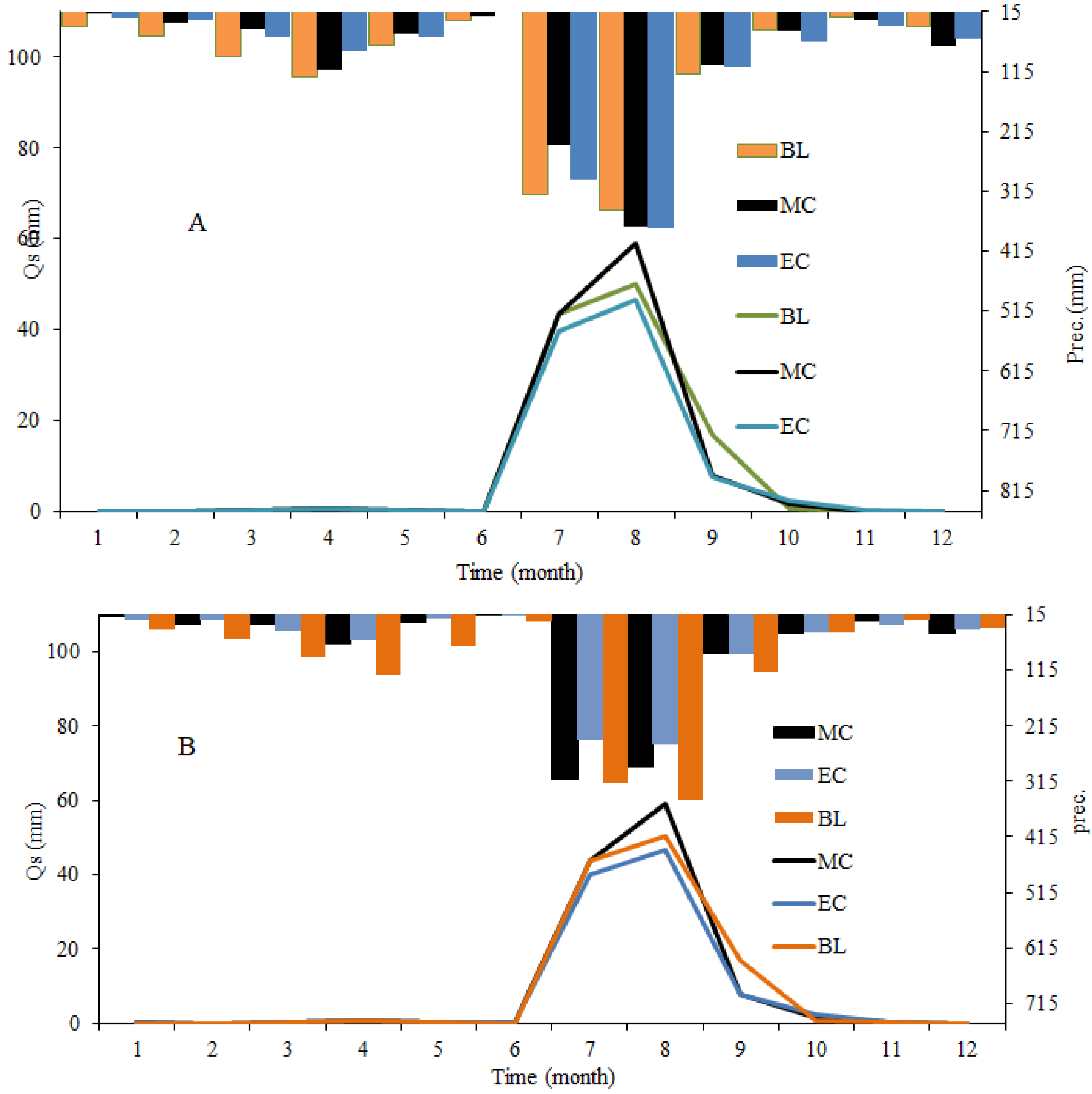
Scenario	Components	BL	MC	EC	MC (%)	EC(%)
RCP 4.5	ET	636.96	600.38	600.18	-6.09	-5.77
.	QS	113.54	111.20	99.80	-2.10	-12.08
RCP8.5	ET	636.96	602.38	601.18	-5.74	-5.62
.	QS	113.54	110.20	97.81	-3.02	-13.85

Seasonal simulated changes hydrological components due to the combined impacts of land use and climate changes were also evaluated to verify the change of hydrological components in the study area. From the result below Comparing to the baseline period surface runoff is projected to significantly increase in all seasons under both RCPs in all time frames. The maximum percentage change of surface flow (Qs) under RCP4.5 was simulated as 37.67% in the LRS season of mid-century and 34.32 % under RCP 8.5 in the dry season of the end-century.

But Evapotranspiration (Et) under RCP4.5 was simulated as increased in LRS season and for the rest seasons of the year decreasing of change has expected in both RCPs.

Generally the maximum increments of the Et were expected in the low rainy seasons and for rest times decrement changes were expected in both RCPs under both time frames.

In terms of combined impact, the magnitude of percentage change of hydrological components are relatively different climate change alone (LU1994 and 2041-2070/2071-2100 climate). This implied that the changes are intensified by LULC change or agricultural expansion and urban expansion.



A= Uder RCP4.5; B =Under RCP8.5 scenarios

Figure 4.10: Mean Monthly Qs vs Preciptation in Combined Impact

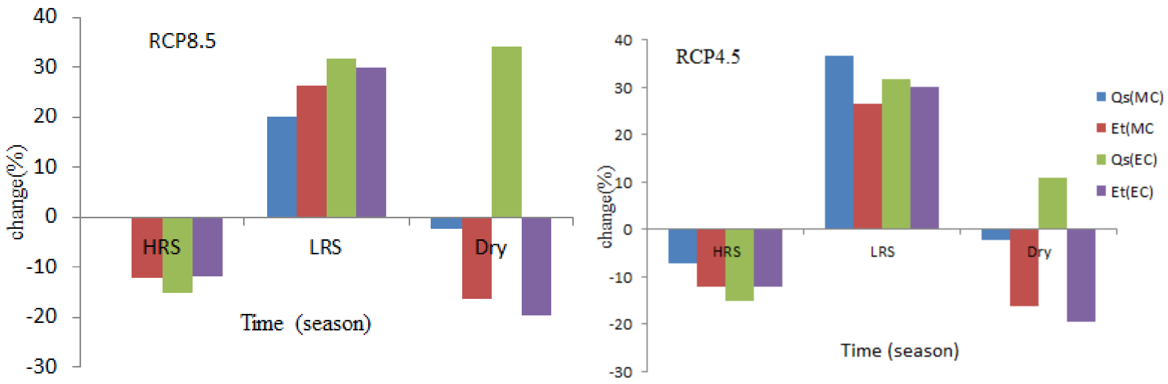


Figure 4.11: Seasonal Surface Runoff Under Combined Impact

4.6 Land Use/Cover Change Impact on Hydrology

In comparison to the baseline conditions (1974-2005), simulations under land-use change scenarios indicated a decrease in the mean annual ET and an increase in the mean annual Qs.

Two land use maps (1994 and 2018) were used to assess the effect of land use change on streamflow and hydrological components. To determine the impact of LULC change alone, the impact of climate change alone was used as a baseline and compared to the impact of combined LULC and climate change. Since the response of the hydrological components for the combined land use and climate change (2018LU and MC/EC) are either aggravated (strengthen) or alleviated (soften) compared to that under only climate change. Therefore, the analysis was made by considering the change between the two simulations as the impact of LULC change only. The land use land cover changes (LULC 2018 and MC/EC climate) impacts on long term annual and seasonal average hydrological components including surface runoff and evapotranspiration as characteristics of the hydrological process of the watershed were evaluated. Simulation outputs indicated that the annual average values of surface hydrological components are affected by LULC change. The percentage change in annual average due to the impact of land use/cover change with respect to climate change presented in the table below.

Table 4.10: Annual Change of Hydrological Components Under LULC Change

Scenario	Com.	MC(1994)	EC(1994)	MC(2018)	EC(2018)	MC(%)	EC(%)
RCP4.5	ET	643.44	640.32	600.38	600.18	-6.69	-6.26
.	QS	89.19	78.73	111.20	99.80	24.67	26.76
RCP8.5	ET	643.44	640.85	602.38	601.18	-6.38	-6.19
.	QS	88.08	79.48	110.20	97.81	25.11	23.06

1. Surface runoff (Qs)

From the table above the result indicates that the mean annual surface runoff was increased by 24.68% and 26.76% from 1994 to 2018 in mid and end century under RCP 4.5. Similarly surface runoff was increased by 25.12% and 23.06% in the mid and end century under RCP 8.5. This is due to the fact that the increase in agriculture and settlement has a direct impact on surface flow. As a result, high runoff was generated during this period. Generally, during the study period, Borkena watershed showed that an increase in surface runoff.

2. Evapotranspiration

The mean annual Et was decreased from time to time. As a result, the actual mean annual Et simulated by the SWAT model was at the baseline was decreased by 6.69% and 6.25% in the years from 1994 to 2018 in mid-century and end century under RCP 4.5. For RCP 8.5 annual mean evapotranspiration was decreased by 6.38% and 6.19% in the mid and end century respectively. The decrease of the evapotranspiration could due to the simultaneous expansion of cultivated land and the shrinkage in forest coverage in the 2018 map, relative to the 1994 baseline. Furthermore, this deforestation may reduce the canopy's interception of the rainfall, decrease soil infiltration by increasing raindrop impacts, and reducing plant transpiration, which can significantly increase surface runoff, reducing Et.

At seasonal scale the maximum Qs and Et were expected to increase under both scenarios in LRS, and have a mixed change of these components in the rest seasons under RCPs. Surface runoff has been increased in all seasons and the maximum change was expected in the dry seasons with 29.7% under low rainy season under RCP 4.5 in the end-century and similarly it was increased by 32.77% in the LRS season under RCP 8.5 in the mid-century. From the result the maximum decrease and increase of evapotranspiration were expected in mid-century in LRS and dry season respectively under both scenarios.

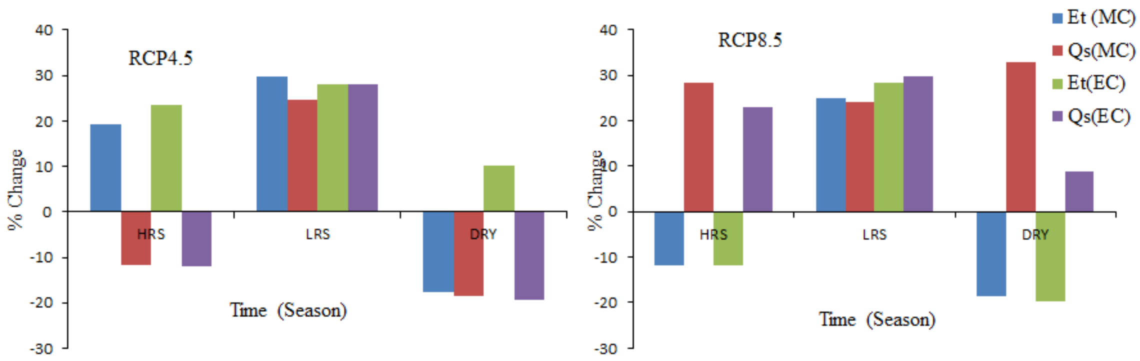


Figure 4.12: Seasonal Change of Hydrological Components Under LULC Change

In general, the decrease in forest cover, shrubland grassland, and the increase in urbanization and agriculture in the study area leads to increase in surface runoff and decrease evapotranspiration. Intensive agricultural activities can reduce the surface roughness and canopy ability to intercept precipitation (Baker, 2013) . A similar study conducted by (Gebremicael et al., 2017), has reported that the expansion of agricultural and grazing land at the expense of natural vegetation has increased surface runoff at Geba catchment between the 1970s to 1990s.

4.7 Inspect the most sensetive change

To investigate the impact of these land use land cover and climate change on Borkena watershed, the statistical analysis was done using two way ANNOVA taking the surface runoff has more effect on the change from hydrological components. From the two RCPs and BL surface runoff has been statistical evalueted. The result of p-value for LULC change is

0.03 and for climate 0.042 with considered significance level, the result indicates that with significance level of 5%, the impact of climate change over the study area is expected lower than that of LULC change for this analysis.

4.8 Limitations and Uncertainties

This study couples climate change models and hydrological models, whereby each model can be a source of uncertainty affecting the results. It is challenging to project climate change accurately into the future, especially in terms of precipitation. The uncertainty can be attributed to uncertainty linked to several GCMs uncertainty associated with each representative concentration pathways (RCPs), uncertainty to downscaling and bias correction methods, and uncertainty of hydrological models (Chen et al., 2012).

Two major data used in this study are current land use and future climate change scenarios. As a result systematic bias is found in derived climate data compared to observed data from weather stations from 1987 to 2005. The land use land cover scenarios are simplified compared to climate scenarios, without considering the factors affecting land use change like land use policy, economic development, and natural environment. It was set up based on the assumption current land use is the same for future land use. This might not be similar to actual land use trends in the study area in the future.

For the hydrological model, sources of uncertainty can present due to the model structure (model assumptions and equations) as well as data inputs (e.g. lack of relevant spatial and temporal variability of rainfall, land uses, soils and topography). It should be noted that in this study the SWAT model was mainly calibrated and validated for stream flow and not specifically for other water balance components such as evapotranspiration and surface runoff. Furthermore, all model parameters are considered homogeneous throughout the watershed. However, future land use and climate changes may change these parameters (Vaze et al., 2010).

All of the aforementioned limitations might reduce the accuracy of the model results. Thus, the results of the analysis regarding these water balance components should be interpreted taking into account the uncertainty.

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The present study assessed the impacts of land use land cover and climate change on hydrological components of Borkena watershed in Awash basin, Ethiopia. From the result, the following was concluded.

The change in LUL covers in the study period from 1994 to 2018, significant change have been expected. From the result the urban/settlement and agriculture have been significantly increased from time to time with an increasing rate of 0.19% and 3.2% for agriculture and 2.7% and 5.71% for settlement from 1994 - 2007 and 2007 -2018 respectively. With the same period significantly decreasing change were expected on forest, shrubland, and grassland with a decreasing rate of 3.73%, 1.41%, and 0.2% from 1994-2007 with similar trend these components have decreased from 7.4%, 1.76%, and 10.3% from 2007-2018. The maximum losses were expected forest land and shrub land and the maximum gain was observed in the setlement within 25 years of study periods.

The SWAT hydrological model was used to simulate present and future changes in surface hydrological components. The sensitive parameter and adjusted parameters were found using SWAT CUP from observed streamflow down near the outlet of the catchment and performance of the model were found (ENS= 0.667 and R2=0.67 for calibration) and (ENS = 0.69 and R2=0.71 for validation). From results, the SWAT model has good performance to use it for further analysis in Borkena watershed.

The projected annual precipitations of RCP 4.5 in the mid-century and the end-century would decrease by 14.56% and 16.51% respectively, and in the RCP8.5 scenario would be decreased by 24.53% and 31.66% for the mid-century and the end-century, respectively. During the evaluation of the climate change impact on the surface hydrological components, hydrological components are expected to change over time in both RCPs.

The change is pronounced in mean annual surface runoff and evapotranspiration are predicted to decrease and increase respectively.

The annual and seasonal surface runoff has been improved with combined LULC and climate change response while compared its climate change impact alone. On the other hand; evapotranspiration was reduced due to the expansion of agricultural land use an expense of vegetation. The hydrological components are found more sensitive to LULC change than to climate changes, even though changes in land use have far-reaching impacts on streamflow and water balance components.

Generally, from the overall results of the study it can be concluded that the effects of LULC and climate change potentially change the hydrological regimes of the whole watershed. Therefore, understanding the potential impact is important for sustainable water resources management. The findings of this study can be useful for decision-makers and planners to design adaptive measures to land use land cover and climate changes. This study also has valuable implications for informing watershed modeling in the region. However, this study cannot generalize that only the mentioned hydrological components are representative of the whole hydrological components.

5.2 Recommendations

During this study it was tried to identify and come across various problems, which is not all could be answered in this study, but need to be addressed in future research. The following list shows the most important issues:

The impact of land use land cover was set up based on the assumption current land use is the same for future land use. This might not be similar to actual land use trends in the study area in the future. Future might apply land use modeling to estimate future land use changes, which can produce more reasonable land use data because many land use change models can estimate the land use changes influenced by different socio-economic and biophysical driving forces under conditions of different scenarios.

The land use land cover maps were assumed all row crops and cultivated cropland as agriculture land without any distinction between the crop types. Various crop types and rotations should be considered for future assessment on the hydrologic impact of land use change.

Field sampling and laboratory-based soil mapping is good for result accuracy giving the exact conclusions of the findings. This study was presented due to developed a large scale soil map found from the ministry of water irrigation and electricity. Therefore further study field investigation is recommended to include in-situ soil infiltration tests, hydraulic conductivity tests, and soil compactness, and soil laboratory.

It is known that different soil and water conservation measures have a certain impact on rainfall-runoff relationships. The research presented not fully consider soil conservation measures. It should be addressed for future research.

Borkena watershed experiences losses of vegetation especially in the forest and expansion of agriculture and settlement this increases the surface runoff and decreases the evapotranspiration. To mitigate it land and water management practices by increasing afforestation which increases water retention and reduces surface runoff.

This study focused on surface hydrology which didn't include other hydrological components for the future it is better to study other hydrological components for a better understanding of water resources in the watershed.

Finally, this study involved several models and model outputs each including a certain level of uncertainty. However, it is believed that the results of this study give an indication and increase awareness of the changes in land use/land cover and future risks of climate change. Hence, such studies should continue on different basins considering the wide range of uncertainties associated with models and try to reduce the uncertainties by the use of different GCM outputs, downscaling techniques, and emission scenarios as well as different hydrological models.

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APPENDIX

A. Historical Hydro-climate Data

A.1 mean maximum and minimum monthly temprature

Months	Guguftu	Harbu	Majete	Comb
Jan	23.79	29.02	26.29	26.28
Feb	25.17	30.00	27.61	27.56
Mar	25.88	31.09	28.56	28.55
Apr	26.57	31.68	29.33	29.27
May	27.93	33.08	31.05	30.99
Jun	29.27	34.29	32.74	32.73
Jul	27.24	32.32	29.99	30.11
Aug	26.04	31.22	28.69	28.69
Sep	25.99	30.84	28.40	28.43
Oct	25.56	30.42	27.87	27.88
Nov	24.80	29.97	27.09	27.12
Dec	23.85	29.25	26.10	26.12

Months	Guguftu	Harbu	Majete	Comb
Jan	7.92	11.52	10.50	10.86
Feb	8.90	12.60	11.65	11.84
Mar	10.88	14.27	12.97	13.04
Apr	11.99	15.38	14.01	13.85
May	12.01	15.55	14.37	14.18
Jun	12.44	16.63	15.23	14.79
Jul	13.65	16.43	15.35	14.76
Aug	13.39	15.86	14.91	14.45
Sep	12.25	14.72	13.89	13.32
Oct	8.90	12.33	10.80	11.44
Nov	7.19	10.68	9.21	10.16
Dec	7.09	10.30	8.81	9.95

A.2 Mean annual monthly flow

year/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	4.47	3.26	5.85	0.28	2.09	0.10	34.47	99.08	40.29	12.33	2.18	0.59
1999	3.47	0.80	1.01	1.10	0.18	0.11	60.24	88.38	43.09	34.42	4.54	1.95
2000	1.49	0.42	0.03	0.03	2.19	0.03	23.39	107.78	32.02	7.84	6.78	3.76
2001	1.43	0.66	5.35	2.00	0.59	0.01	18.28	110.54	35.78	4.31	1.24	0.89
2002	1.46	0.54	2.69	1.01	3.40	0.20	13.68	102.23	10.51	2.97	0.31	1.99
2003	1.15	1.03	1.48	2.87	2.93	0.21	6.11	50.55	27.93	7.62	0.75	1.62
2004	0.85	1.53	0.26	4.72	0.99	0.19	8.27	87.77	9.71	5.31	0.54	0.43
2005	0.22	0.22	3.12	1.60	9.81	0.58	24.65	53.67	20.36	5.39	1.05	0.52
2006	0.47	0.33	0.42	9.36	3.82	0.47	15.59	63.15	14.78	5.71	1.29	0.63
2007	0.80	0.79	1.19	3.84	3.64	0.42	13.69	60.63	17.41	5.65	2.30	1.34
2008	1.32	0.85	0.65	0.65	0.65	0.65	13.85	48.02	14.29	6.41	2.28	0.93
2009	0.70	0.55	1.34	3.86	4.48	0.83	17.54	43.58	26.29	1.97	1.02	4.86
2010	0.82	0.63	0.90	4.43	3.15	0.74	31.87	50.74	16.36	2.00	2.14	1.94
2011	1.52	1.30	1.75	1.56	2.22	2.01	3.12	42.38	6.08	2.04	1.36	1.12
2012	1.10	0.90	0.66	2.40	1.68	1.25	19.16	48.88	14.58	2.03	1.42	0.42
2013	0.06	0.06	0.06	0.08	0.12	0.06	26.37	62.88	28.79	6.91	2.79	1.80
2014	1.36	1.07	0.69	1.28	1.54	0.42	24.11	58.85	29.10	21.58	2.19	1.42
2015	1.05	0.86	1.01	1.33	0.56	0.93	18.19	53.25	19.64	8.14	1.94	1.19

A.3 Mean Annual monthly rainfall of the rcoreded stations

Year	GUGUFTU	HARBU	BORUMEDA	MAJETE	COMBOLCHA
1987	1044.06	1036.80	1062.15	1224.90	800.20
1988	1702.60	1140.03	1267.63	1174.20	1194.70
1989	1139.74	1066.55	1384.02	1018.60	1149.20
1990	1096.92	594.27	884.90	972.70	892.80
1991	968.78	1640.40	1016.17	1112.80	777.67
1992	1073.85	1082.15	1225.02	1141.37	1040.10
1993	1254.89	1160.17	1340.95	941.50	1280.00
1994	1396.60	1080.31	1278.53	1352.30	1185.10
1995	1520.40	1086.27	1203.80	1344.90	1096.00
1996	1362.12	1187.44	1201.14	1256.10	1127.50
1997	1652.11	1073.36	1110.50	1495.20	1031.93
1998	1327.80	987.23	1404.98	1555.20	1319.30
1999	1633.50	1137.89	1213.60	1248.30	1053.40
2000	1395.50	1212.42	1254.80	1120.60	1211.50
2001	1215.60	1126.19	1262.75	1177.90	983.40
2002	1284.90	1297.26	1099.20	1079.20	898.10
2003	1384.80	1149.20	1268.70	1060.00	991.40
2004	1420.50	820.90	1154.99	1148.80	908.20
2005	1306.40	1031.30	1270.61	1295.00	975.10
2006	916.24	1023.00	1260.95	1243.30	1117.92
2007	988.60	934.00	1277.55	916.00	911.10
2008	988.20	814.50	1220.60	1044.20	821.30
2009	1202.62	1022.49	1154.25	1065.50	961.30
2010	1190.70	1210.70	1344.56	887.47	895.20
2011	1175.19	800.40	1344.26	1070.83	1008.50
2012	1301.79	1200.00	1085.36	1173.67	969.70
2013	1495.60	1055.29	975.40	1306.80	1010.00
2014	919.80	680.10	1536.40	-186.42	1108.00
2015	1544.70	502.90	962.40	1681.41	749.10
2016	1610.70	789.40	905.46	1111.91	1144.80
2017	2074.40	1385.10	862.80	1387.50	1270.66
2018	1126.80	1100.30	824.40	1387.50	1107.90

A.4 WGNoutput for weather generated

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmp_Max_Ave	26.2	27.7	28.9	29.2	31.2	32.6	30.1	28.9	28.6	28.0	27.3	26.1
Tmp_Min_Ave	13.5	13.6	13.9	13.8	13.9	14.1	13.9	13.9	13.8	13.9	13.8	13.7
Tmp_Max_Sd	2.1	2.2	1.9	2.4	1.7	1.8	2.1	1.6	1.4	1.3	1.4	1.5
Tmp_Min_Sd	1.2	1.2	0.8	1.1	0.8	0.6	0.9	0.7	1.0	0.9	1.0	1.0
Pcp_Ave	17.4	9.6	50.5	88.5	51.4	22.1	289.4	262.3	99.6	46.5	20.7	6.3
Pcp_Sd	2.1	1.3	5.5	6.0	4.8	2.4	13.0	10.5	6.9	5.7	3.8	1.1
Pcp_Skew	6.2	4.8	4.8	3.1	4.6	4.9	2.3	1.8	3.3	6.2	7.6	8.7
Wet_Dry	0.1	0.1	0.2	0.2	0.2	0.1	0.8	0.6	0.4	0.1	0.1	0.1
Wet_Wet	0.5	0.5	0.5	0.7	0.5	0.5	0.8	0.8	0.6	0.5	0.5	0.3
Pcp_Days	5.3	3.3	7.5	13.4	8.6	6.3	24.2	24.1	15.2	6.0	2.7	2.8
Pcp_Hhr	2.9	1.2	7.3	6.7	6.1	3.5	18.0	14.2	8.5	7.9	4.2	0.9
Slr_Ave	18.8	20.5	20.8	20.1	21.4	19.3	17.6	18.3	18.7	19.7	20.2	19.3
Dew_Ave	0.6	0.4	0.5	0.5	0.4	0.5	0.8	0.7	0.6	0.5	0.5	0.5
Wnd_Ave	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.6	0.5	0.6	0.5	0.5

B. Land Use and Land Cover

B.1 Accuracy assesment for 2007

Table 5.1: Accuracy Assessment Result for 2018 LULC Map

	Reference												
class	Bar	wat	Wet	For	Gr	Shr	Agr	Setl	Totals	er.o.	Pr.ac	er. C.	us.ac.
Bare	15	0	0	0	0	0	3	1	19	0	100	21.1	79
wat	0	3	1	0	0	0	0	0	4	0	100	25	75
Wet	0	0	6	0	0	0	0	0	6	25	85.7	0	100
For	0	0	0	24	0	3	0	0	27	13.6	88.9	11.1	88.9
Gr	0	0	0	0	11	3	0	0	14	22.2	92.3	21.4	77
Shr	0	0	0	3	1	21	3	0	28	16.7	82.1	25	75
Agr	0	0	0	0	1	1	27	0	29	21.6	81.8	6.9	93.1
Setl	0	0	0	0	0	0	0	8	8	20	88.9	0	100
totals	15	3	7	27	13	28	33	9	135	_	_	_	_

[a] Abreviation is the same in table 4.2

B.2 Accuracy assesment for 1994

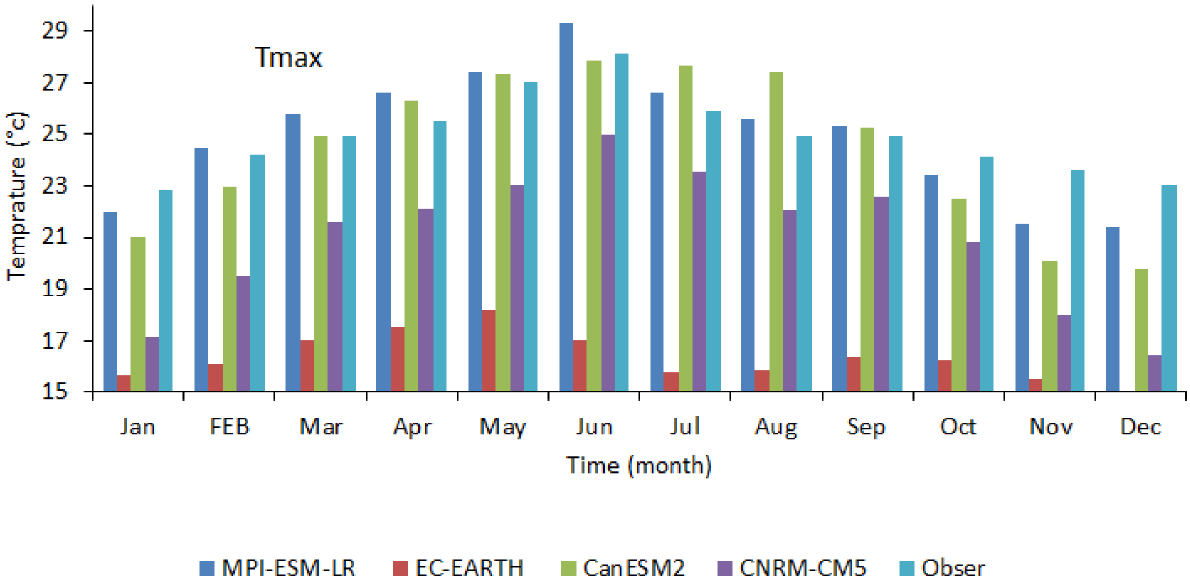
Table 5.2: Accuracy Assessment Result for 2018 LULC Map

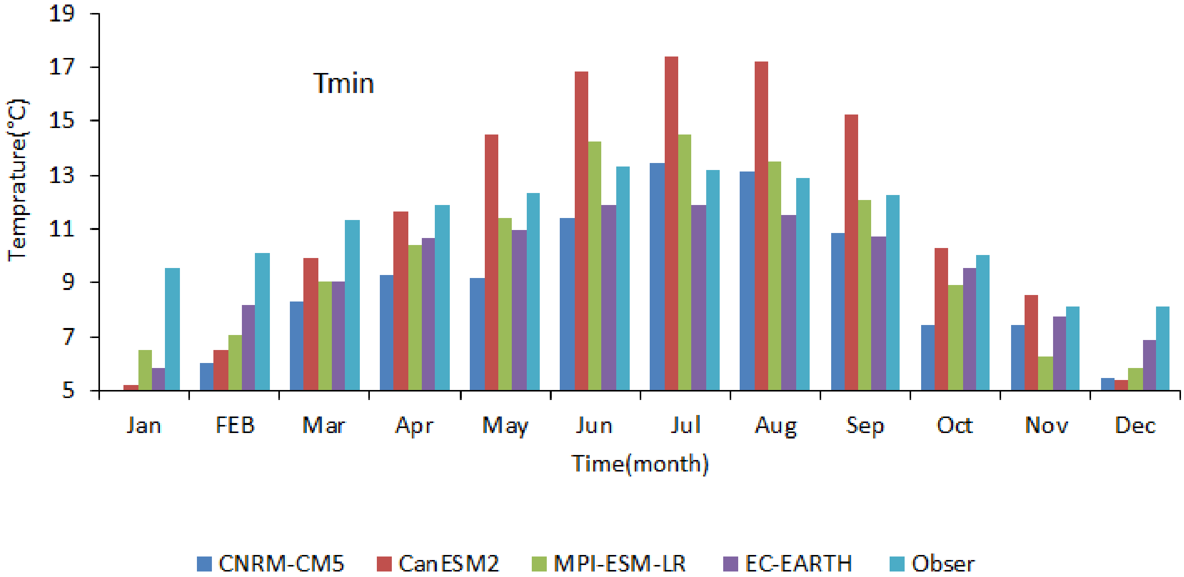
	Referece												
Classs	Bar	Wat	Wet	For	Gr	Shr	Agr	Setl	Totals	Er.o.	Pr.Ac	Er.C	U. Ac.
Bare	8	0	0	0	1	0	3	1	13	0	100	38.5	61.5
Wat	0	2	1	0	0	0	0	0	3	0	100	33.4	66.8
Wet	0	0	3	0	0	0	0	0	3	14.3	75	0	100
For	0	0	0	20	0	2	0	0	22	11.1	86.4	9.1	90.9
Gr	0	0	0	0	14	3	1	1	19	7.7	77.8	26.3	73.7
Shr	0	0	0	2	2	25	3	0	32	17.7	83.3	21.8	78.2
Agr	0	0	0	0	1	0	30	0	31	18.2	78.8	3.2	96.8
Setl	0	0	0	0	0	0	0	8	8	11.1	80	0	100
Totals	8	2	4	22	18	30	37	10	131	.	.	.	.

[a] Abreviation is the same in table 4.2

C. Simulated Climate Data

C.1 Maximum and minimum temprature before correction





C.2 Maximum and minimum temprature after correction