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Potential Impacts of Climate Change on the Hydrology and Water resources Availability of Didessa Catchment, Blue Nile River Basin, Ethiopia

Sintayehu Legesse Gebre[1]*, Kassa Tadele[2] and Bogale G Mariam[3]

[1]*Department of Natural Resources Management, Jimma University, P.o.box 307, Ethiopia*
[2]*Department of Water Resources and Irrigation Engineering, Arbaminch University, P.o.box 21, Ethiopia*
[3]*Department of Water Resources and Hydraulic Engineering, Arbaminch University, P.o.box 21, Ethiopia*

Abstract

This study was carried out in Didessa catchment, which is situated in the south-west part of Blue Nile River Basin. This part of the basin is very important due to the location of the place where different water resources development are undertaking, like the Grand Renaissance dam and other development projects, So it was crucial to study and evaluate the potential impacts of climate change on the hydrology and water resources availability. Future Climate change scenarios of precipitation, temperature and potential evaporation were developed using output of dynamically downscaled data of ECHAM5 (GCM) 50 Kms resolution under A1B emission scenario for 2030's (2031-2040) and 2090's (2091-2100). The future projection of the GCM model of climate variables showed an increasing trend as compared to the base line period (1991-2000). At 2030's and 2090's average annual precipitation may increases by +33.22% and+8.40% respectively over the Didessa catchment.

The climate changes variables used as input in to HBV hydrological model to simulate the future runoff at the out let of gauging station of Near Arjo town. The impact of climate change on future runoff resulted a positive magnitude change in average runoff flow at the outlet of the catchment. The increase in average runoff is associated with the increase in precipitation projection over the catchment. During the main rainy season of summer, at 2030's and 2090's average seasonal runoff percentage change may increase up to+157% and+136% respectively as compared to the base line period. Hence, more likely in the future the water resources availability may increases in the catchment. This may create an opportunity for small scale farmers to harness enough amount of water during rainy season for later use.

Introduction

Climate change refers to 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 persists for an extended period, typically decade or more. Climate change may be due to internal process and/or external forcing. Some external influences, such as changes in solar radiation and volcanism, occur naturally and contribute to the natural variability of climate system. Other external changes, such as the change in the composition of the atmosphere that began with the industrial revolution, are the result of human activity [1].

The temperature of Earth is determined by the balance between the incoming solar radiation and the outgoing terrestrial radiation. The energy coming in from the sun can pass through atmosphere and therefore heats the surface of the Earth. But the radiation emitted from the surface of the Earth is partially absorbed by some gases in the atmosphere' and some of it re-emitted downwards [2]. The effect of this is warming the surface of the Earth and the lower part of the atmosphere. Without this natural greenhouse effect, the temperature of the Earth would be about 30°C cooler than it is, and it would not be habitable. However, this important function of atmosphere is being treated by the rapidly increasing concentrations of greenhouse gases well above the natural level while also new greenhouse gases such as CFCs and CFC replacement is added to the atmosphere as a result of human activates (for example, CO_2 from fossil-fuel burning). This will add further global warming which could threaten sustainability of Earth [3].

Nowadays there is strong scientific evidence that average temperature of Earth surface is increasing due to greenhouse gas emission [4]. For instance, the average global temperature has increased by about 0.6°C since the late 19th century. Also the latest IPCC, 2007, Intergovernmental panel on climate change scenarios project temperature rises of 1.4-5.8°C, and sea level rise of 9-99 cm by 2100.

Precipitation is expected to vary considerably from region to region. Change in climate (changes in frequency and intensity of extreme weather events) is likely to have major impacts on natural and human systems [5]. With respect to hydrology, climate change can cause significant impacts on water resource by resulting changes in hydrological cycle. For instance, the changes in temperature and precipitation can have a direct consequence on evapotranspiration and on both quality and quantity of the runoff components of the water balance [6].

Consequently, the spatial and temporal variability of water resource, or in general the water balance, can be significantly which in turn affects agriculture, industry and urban development. Climate change is expected to have adverse impacts on socio economic development globally; the degree of the impact will vary across nations [7].

*Corresponding author: Gebre SL, Department of Natural Resources Management, Jimma University, P.o.box 307, Ethiopia, Tel: +31687227932; E-mail: sintayehulegesse@gmail.com

The IPCC findings indicate that developing countries, such as Ethiopia, will be more vulnerable to climate change. It may have far reaching implications to Ethiopia for various reasons, mainly as its economy largely depends on agriculture and low adoptive coping. A large part of the country is arid and semiarid, and is highly prone to drought and desertification. Climate change and its impacts are, therefore, a case for concern to Ethiopia. Hence, assessing vulnerability to climate change impact mapping and preparing adaptation options as part of the national program is very crucial for the country [8].

Despite the fact that the impact of different climate change scenarios is projected at a global scale, the exact type, and magnitude of the impact at a catchment scale is not investigated in most parts of the world. Hence, identifying local impact of climate change at a watershed level is quite important [9]. Didessa catchment is one of the biggest tributaries of the Blue Nile and its water resources is a great input for the different water development projects and the lively hood support of the dwellers in the area. Currently two main multipurpose water resources development structures are proposed in the Didessa valley. The site is also identified as a high potential area for extension large irrigation scheme. Some of the water development projects are underway of implementation. It is very critical determining the potential impacts of climate change for the sustainability of the project impacts and looking for the possible mitigation measures otherwise all the cost indebted will be lost in failing to meet the objectives.

In this study, the dynamically downscaled data of General Circulation Model (GCM) of the ECHAM5 A1B scenario using nested RegCM3 of the future climate output under assumed green gas emission scenario was used. Then the data was used as input to the hydrological model (HBV-96) to simulate the effect of climate on the hydrology and the surface water resources availability of the catchment. This gives an opportunity to define the degree of vulnerability of local water resources and the sustainability of the water development projects and plan appropriate adaptation measures that must be taken ahead of time. Moreover this will give enough room to consider possible future risks in all phases of water resource development projects.

Description of the study area

Didessa river catchment

The Didessa River is the largest tributary of the Blue Nile River in terms of volume of water, contributing roughly a quarter of the total flow as measured at the Sudan border [10]. Draining an area of nearly 34,000 square kilometers, the Didessa River originates in the Mt. Vennio and Mt. Wache ranges, flowing in an easterly direction for about 75 kilometers, and then turning rather sharply to the north until it reaches the Blue Nile River. The major tributaries of the Didessa River are the Wama entering from the east, the Dabana from the west, and the Anger from the east. Didessa catchment is situated in the southwest part of Blue Nile River Basin. The catchment area at a gauging station near Arjo town is 9,981 km². In this study taking the out let at gauging station near Arjo town, the catchment delineated and studied (Figure 1).

Materials and Methods

General description of the methodology

Figure 2 shows Conceptual frame work of the methodology.

Materials

Meteorological data: Observed meteorological data (precipitation,

maximum temeperature,minimum temperature and wind speed) of seven stations (Arjo, Bedelle, Chira, Dembi, Jimma, Nekemte and Sibusire) obtained from the National Meteorology Services Agency (NMSA), Ethiopia. For this study climate data from 1991-2000 were used. The criterions for the selection of the meteorological data were based on the availability of data, the data quality and possibly whether the station is within the watershed or not. The data were used as input to the hydrological model development.

Areal rainfall determination: To determine the mean areal rainfall, the rainfall amount of each station was multiplied by the area of its polygon and the sum of these products was divided by the total area of the catchment. If P1, P2….Pn are the rainfall magnitudes recorded by the stations 1, 2….n respectively, then the average rainfall over the catchment P is given by:

$$Pave = \frac{P1A1 + P2A2 + P3A3 + ... + PnAn}{A1 + A2 + A3 + ... + An} \tag{1}$$

$$Pave = \sum_{i=1}^{m} Pi\frac{Ai}{A} \tag{2}$$

Where: m is the number of stations and the ratio A_i/A is called the weighting factor for each station.

In this study, the proximity investigation was carried out using spatial analyst tool in Arc_GIS environment to decide the contribution of each station for the areal rainfall of the catchment. The percentage contributions of each rainfall stations for the rainfall share received by each sub catchment calculated. The areal rainfall for each sub-catchment was then determined by multiplying the time serious rainfall of each station which contributes to a particular sub-catchment by the respective weights obtained through the above analysis. However, the total areal rainfall is computed from the summation of weighted rainfall of the contributing stations.

Hydrological and spatial data: The stream flow data of the Didessa watershed was required for calibrating and validating the model. Therefore, daily stream flow data (1991-2000) and remote sensing data were collected from the Hydrology Department of Ministry of Water resources and Energy, Ethiopia. A 90 m by 90 m resolution grid SRTM covering the entire watershed was processed by Global mapper to change into digital elavation model (DEM). The terrain preprocessing is carried out using Arc_GIS 9.2 as a series of steps to derive the draiange networks.

Potential Evapotranspiration (PET): There are a number of methods to estimate potential evapotranspiration. However, the methods vary based on climatic variables required for calculation. The temperature based method uses only temperature and day length; the radiation based method uses net radiation and air temperature and some other formula like Penman, requires a combination of the above net radiation, air temperature, wind speed, and relative humidity.

The FAO Penman_Monteith method is recommended as the sole ET_0 method for determining reference evapotranspiration when the standard meteorological variables including air temperature, relative humidity and sunshine hours are available [11].

$$ET_0 = \frac{0.408\Delta[R_n - G]}{\Delta + \gamma(1 + 0.34u_2)} + \frac{\gamma}{\Delta + \gamma(1 + 0.34u_2)} \times \frac{900U_2(e_s - e_a)}{(T + 273)} \tag{3}$$

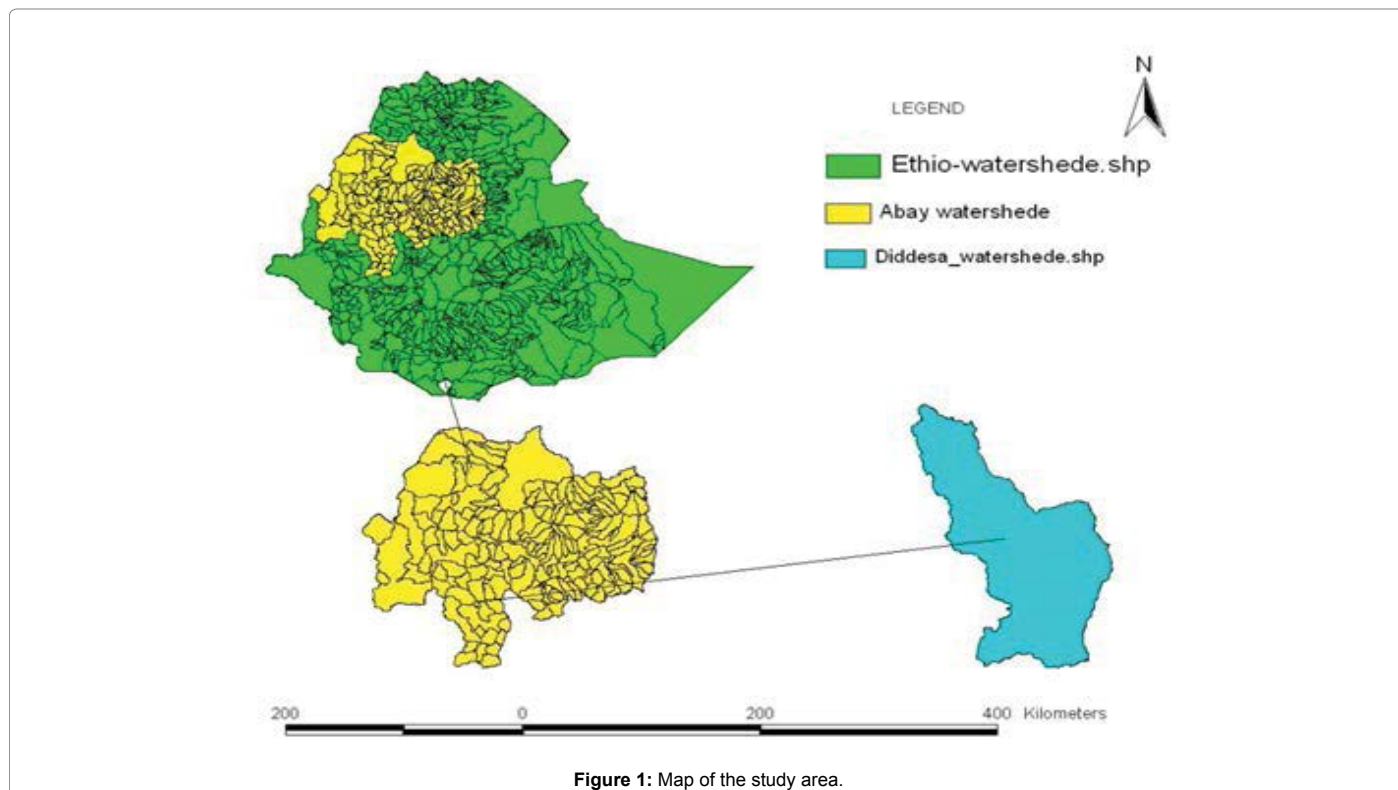Where,

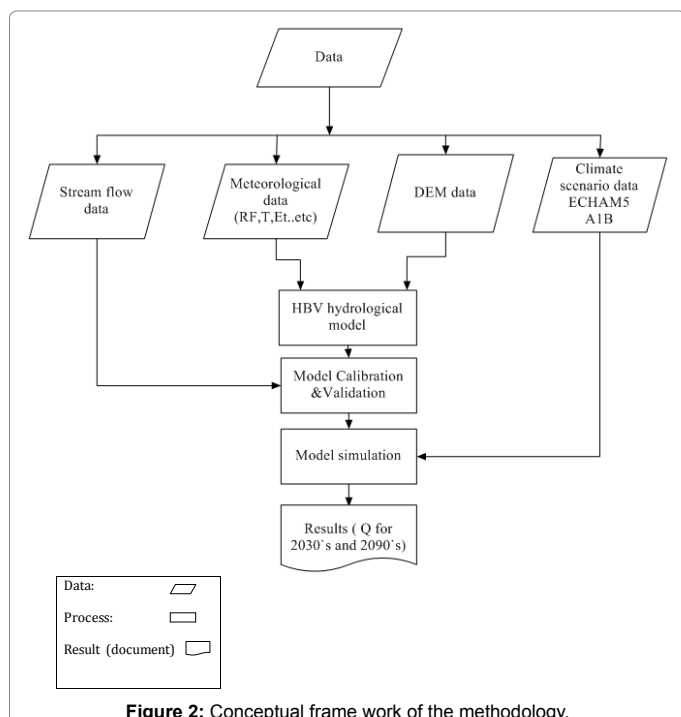ET_0 = Reference Evapotranspiration, mm/day,

Figure 1: Map of the study area.

Figure 2: Conceptual frame work of the methodology.

Rn = Net radiation, MJm^{-2} day^{-1}

G = Soil heat flux, MJm^{-2} day^{-1}

e_s = Saturated vapor pressure, KPa,

e_a = Actual vapor pressure, KPa,

e_s-e_a = Saturated vapor pressure deficit, KPa,

Δ = Slope of the saturation vapor pressure temperature relationship, KPa°C^{-1}

γ = Psychometric constant, KPa°C^{-1}

U_2 = wind speed, ms^{-1} and

T   =Mean daily air temperature at 2 m height (°C)

In this study the potential evapotranspiration for the study area was computed by FAO (Food and Agricultural Organization) Penman-Monteith method. The long term monthly potential evapotranspiration was computed for the study area to be used as input for the conceptual hydrological model.

General Circulation Model (GCM): The climate model is a mathematical description of the Earth's climate system, broken into a number of grid boxes and levels in the atmosphere, ocean and land. At each of these grid points, equations are solved which describe the large-scale balances of the momentum, heat and moisture. Based on this, a wide range of climate models are developed [12]. The modeling approach and the resolution of the model vary from model to model. In this study the fifth-generation atmospheric general circulation model (ECHAM5) developed at the Max Planck Institute for Meteorology, (MPIM), German is the most recent version in a series of ECHAM models evolving originally from the spectral weather prediction model of the European Centre for Medium Range Weather Forecasts (ECMWF) therefore, the first part of its name: EC) and a comprehensive parameterization package developed at Hamburg (therefore the abbreviation HAM) [13]. The part describing the dynamics of ECHAM is based on the ECMWF documentation, which has been modified to describe the newly implemented features and the changes necessary for climate experiments. Since the release of the previous version, ECHAM4, the whole source code has been extensively redesigned in the major infrastructure and transferred to Fortran 95. ECHAM is now

fully portable and runs on all major high performance platforms. The restart mechanism is implemented on top of net CDF (Common Data Form) and because of that absolutely independent on the underlying architecture [14].

The ECHAM model (version 5) it has a hybrid sigma-pressure vertical coordinate. In the ensemble members used in these experiments, ECHAM has a horizontal T42 spectral resolution (2.8 latitude–longitudes) and has 19 vertical levels, with the top extending to 10 hPa. The model's prognostic variables are vorticity, divergence, surface pressure, temperature, specific humidity, and the mixing ratio of total cloud water. The mass flux scheme is employed for both deep and shallow convection [13].

RegCM3 model: The Regional Climate Model (RegCM) Version 3 [9] is a limited area model built around the hydrostatic dynamical component of the National Center for Atmospheric Research (NCAR)/ Pennsylvania State University Mesoscale Model version 5.0 (MM5) [15]. The model is compressible, based on primitive equations, and employs a terrain following r-vertical coordinate. The model includes parameterizations of surface, boundary layer and moist processes which account for the physical exchanges between the land surface, boundary layer and free atmosphere. The model's vertical resolution is composed of 18 levels, with seven levels below 800 hPa. A vertical interpolation is performed to account for differences in vertical resolution and topography between RegCM and the driving fields [16].

Emission scenario: In 1996, the IPCC began the development of new set of emission scenarios, effectively to update and replace the well-known IS92 scenarios. The approved new set of scenarios is described in the IPCC special report on emission scenarios (SRES). Four different narrative storylines where developed to describe consistently the relationship between the forces driving emission and their evaluation and to add context for the scenario quantification. The resulting set of 40 scenarios cover the wide range of the main demographic, economic and technological driving forces of the future greenhouse gas and sulpher emission. Each scenario represents the specific quantification of one of the four storylines. All the scenarios based on the same storyline constitute a scenario "family" which briefly describe the main characteristics of the four SRES storylines and scenario family. There are four main story lines, A1, A2, B1 and B2 .The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in the mid-century and decline thereafter, and the rapid introduction of few and more efficient technologies. Major underling themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capital income. The A1 scenario family develops into three groups that describe alternative directions of technological change in energy system. The three A1 groups are distinguished by their technological emphasis: fossil; initiative (A1FI), non-fossil energy source (A1T), or a balanced across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy sources, on the assumption that similar improvement rates apply to all energy supply and end use technologies) [17].

In this study the output of the ECHAM5 global circulation model (GCM) of the A1B scenario was used to force the regional climate model RegCM3, as initial and lateral boundary conditions. The output of the regional climate model (RCM) 50 kilometers by 50 kilometers resolution used. This includes daily precipitation, temperature, relative humidity and wind speed.

HBV-96 hydrological model: The HBV model is a semi-distributed conceptual hydrologic model developed by the Swedish Metrological and Hydrologic Institute (SHMI) in 1970s. The HBV model is a standard forecasting tool in nearly 200 basins throughout Scandinavia, and has applied in more than 40 countries including Ethiopia. The model is design to run in on a daily time step (shorter time steps are available as option) and to simulate river runoff in river basins of various sizes. The basin can be disaggregated in to sub-basin, elevation zone, and land cover types. Input data includes precipitation, air temperature, long term average monthly estimates of evapotranspiration, runoff (for calibration) and basin geographical information. The model consistence of subroutine for snow accumulation and melt, a soil moisture accounting procedure, routines for runoff generation and a simple routine procedure. The treatment of snow accumulation and melt in HBV is based on a simple accounting (degree-day) algorithm [18]. A simple model based on bucket theory is used to represent soil moisture dynamics [19].

There is a provision for channel routing of runoff from tributary basins, using a modified Muskingum method. It also simulates the out flow from reservoirs or lakes by specifying the stage-discharge rating curve or providing reservoir regulation policy. The reservoir regulation policy has priority than stage-discharge curve for calculating the out flow from reservoir.

HBV model input: The model input requirements for the HBV model are daily rainfall, temperature, estimates of potential Evapotranspiration, and catchments characteristics of the area.

Since the HBV-96 model works as semi-distributed model, the catchments area was divided into different sub basins and the sub basins further be divided into different elevation and vegetation zones.

In order to simulate the future runoff the downscaled climate data as input. The grid points (50 km by 50 km) resolution overlaid on the study catchment and only grid center points which have a contribution for the runoff selected and used. The weight of each grid center points was computed by the Thiessen polygon and their areal precipitation calculated.

HBV model performance: Finally the model performance was evaluated for both calibration and validation period. By using visually inspection of the hydrograph and Nash-Sutcliffe efficiency. The Nash-Sutcliffe efficiencies criterion often used to asses HBV model simulation performance [20].

Nash-Sutcliffe efficiencies (E_{NS}) [21].

$$E_{NS} = 1 - \frac{\sum(Q_{obs} - Q_{sim})^2}{\sum(Q_{obs} - \overline{Q}_{obs})} * 100 \qquad (4)$$

Where:

Q_{obs} = observed discharge

Q_{sim} = simulated discharge

$\overline{Q}_{obs}$ = mean of observed discharge

$\overline{Q}_{sim}$ = mean of simulated discharge

Nash-Sutcliffe efficiencies can range from $-\infty$ to 1. An efficiency of NS=1 corresponds to a perfect match of modeled discharge to the observed data. An efficiency of NS=0 indicates that the model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero ($-\infty < R^2 < 0$) occurs when the observed mean is a better predictor than the model. The closer the model efficiency

is to 1, the more accurate the model is. NS values between 0.6 to 0.8 indicates model performs from fair to good, when NS values become between 0.8 and 0.9, the model performance is very good [22].

Result and Discussion

Base period climate projection (1991-2000)

The output of the dynamically downscaled ECHAM5 (GCM) using nested RegCM3 under A1B scenario condition for the study area was used. Generally, the comparison of the generated projection with respect to the base period analyzed, average mean daily projected precipitation, and evapotranspiration resulted in producing a similar pattern with the observed climate data of the Didessa catchment. The coefficient of determination R^2 is 0.97 and 0.89 respectively (Figure 3).

From this, we clearly understand that the GCM output simulated the reality of the observed precipitation and evpotranspiration in a good manner with a little bit over estimation and underestimation discrepancies in values over the catchment. The study done by [23] indicated that ECHAM GCM average climate projection output resembled the observed climate variables for base period over Blue Nile River basin.

Future climate change projection for 2030's (2031-2040) and 2090's (2091-2100)

Precipitation projectionL: Generally, average monthly precipitation showed an increasing trend except during the month of January, March and May as compared to the base line period. At 2030's the projected average seasonal precipitation percentage change varied ranging from -12.24 to +62.8%. Maximum precipitation change projected in winter and spring than summer season. At 2090's average seasonal precipitation showed an increase in percentage change in all seasons except in spring, which decreased by 10% as compared to the base period. Generally from -10% to +25% average seasonal precipitation change expected. The results presented in this research are within the range of projection presented in other study over the upper Blue Nile basin, the difference is they used HadCM3 GCM output and SWAT hydrological model [24] (Figure 4).

Temperature

Minimum temperature: The minimum temperature showed an increasing trend in both future time horizons. The minimum relative change of temperature is observed in January in both climate periods. During January, average minimum temperature may change by +0.56°C and by +3.59°C at 2030's and at 2090' respectively. Maximum relative increment change projected in February by +1.72°C and in December by +4.59°C at 2030's and 2090's respectively (Figure 5).

Maximum temperature: Average maximum temperature also showed an increasing trend. At 2030's the projected average monthly maximum temperature increases ranging from +0.40°C to +1.86°C. Maximum change in April and minimum change in February exhibited. At 2090's, average maximum temperature increases ranging from +1.96°C to +4.91°C. The projected minimum and maximum temperature in both future time horizons is within the range projected by IPCC, average temperature increases ranging from 1.4°C to 5.8°C towards the end of century. The temperature change projection for the catchment is in line with the range produced in by other researcher over the Blue Nile River basin [25] (Figure 6).

Potential evapotranspiration

In Figure 7, projected percentage change in average monthly

potential evapotranspiration ranges from -8% to 12% and from -5% to 27% for 2030's and 2090's respectively as compared to the base line period. At 2030's negative percentage change is observed only in the months of February and May. At 2090's the projected average monthly potentialevapotranspiration increases in all months except in october. Generally, a postive potential evaporation change resulted both seasonaly and annually for both future time horizons as compared to the base line period.

HBV hydrological model calibration and validation results

The model is calibrated and validated for ten years period, taking one year for warming up of the model for better performance and, from 1992-1997 for calibration and from 1998-2000 for testing validation. Calibration was done manually by optimizing the model parameters in each subroutine that have significant effect on the performance of the model. Based on this, several runs were made to select the most optimum parameter set in order to match the observed discharge with simulate discharge. The Nash and Sutcliffe effieciency critrion which was commonly considered as the main model performance indicator in the HBV model resulted 0.601 for calibration and 0.61 for validation period. The model performance in terms of replicating the observed hydrograph with E_{NS} greater than 0.5 in this study considered as satisfactory [22].

Future impacts of climate change on runoff

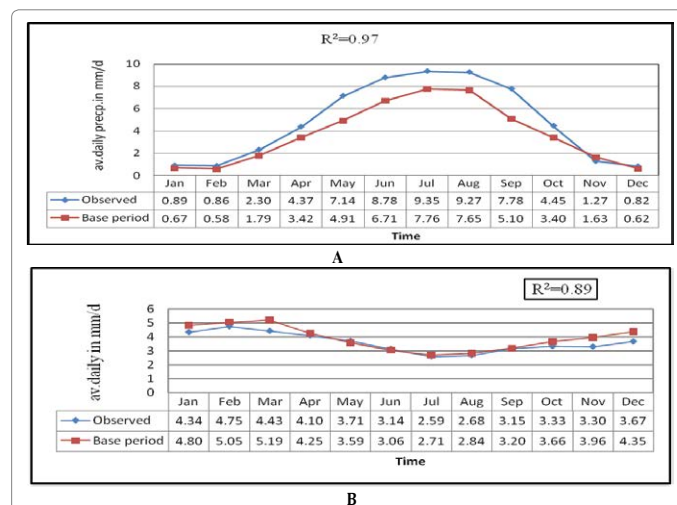**Impacts of climate change on mean monthly runoff flow:** In

Figure 3: Comparison of average daily observed and projected precipitation and evapotranspiration during base period (1991-2000) at Didessa catchment. A, precipitation in mm and B, evpotranspiration in mm.
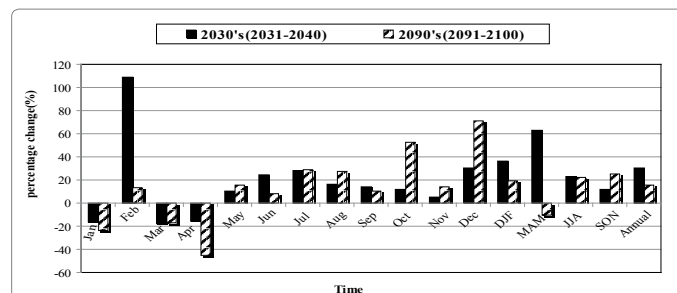

Figure 4: Precrecentage change of projected average Precipitation at 2030's (2031-2040) and at 2090's (2091-2100) with respect to the base period (1991-2000) at Didessa catchment under ECHAM5 (GCM) A1B scenario.
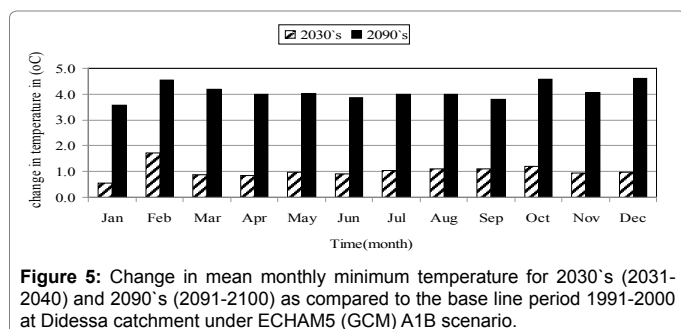
Figure 5: Change in mean monthly minimum temperature for 2030`s (2031-2040) and 2090`s (2091-2100) as compared to the base line period 1991-2000 at Didessa catchment under ECHAM5 (GCM) A1B scenario.
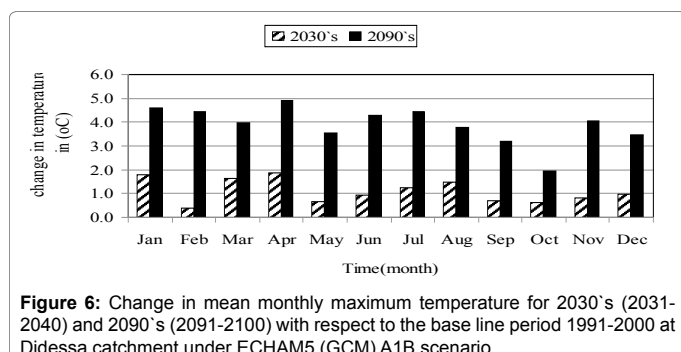

Figure 6: Change in mean monthly maximum temperature for 2030`s (2031-2040) and 2090`s (2091-2100) with respect to the base line period 1991-2000 at Didessa catchment under ECHAM5 (GCM) A1B scenario.

Figure 8, projected average monthly runoff increases ranging from +28% to +178%, and from -12% to +188% at 2030`s and 2090`s respectively as compared to the base period (1991-2000). The increases in runoff resulted due to the increases in precipitation. Even if,the potential evpotranspiration increases,this has been compensated by large projected percentage change in precipitation over Didessa catchment.

Comparison of projected future average seasonal and annual runoff

Future average seasonal and annual runoff comparison showed that, runoff increases in magnitude in both future periods as compared to the base period (1991-2000). High amount of increase in average seasonal runoff exhibited during summer season (Figures 9 and 10)

At 2030`s and 2090`s,average seasonal and annual runoff projection result showed that, runoff increases during all seasons, maximum increases exhibited in summer (Kiremt) and autumn (Maher) as compared to the base line period (1991-2000). Over all in the future the average seasonal and annual runoff volume increases over the Blue Nile basin. A study conducted by [25] indicated that, future average sesaonal and annual runoff increases over the Blue Nile River basin,the projected changes are in line with the range projected in this study.

Conclusion and Recommendation

This study assessed the impacts of climate change on water resources availability and the hydrology regime of Didessa catchment, for 2030`s and 2090`s under ECHAM5 (GCM) A1B climate scenario using HBV hydrological model to simulate runoff. The projected climate output of precipitation and evpotranspiration resembled the observed climate data for the base period with R^2 correlation greater than 0.9. In other study, using ECHAM5 (GCM) of RCM over Blue Nile River was able to reproduce the precipitation pattern over the basin [23]. Therefore, the result obtained in this study assured that it is possible to use ECHAM 5 GCM output for climate projection for Blue Nile River basin.

Future projection of temperature and evapotranspiration results showed an increase trend in both future periods. At 2030`s and 2090`s average seasonal and annual precipitation increases over the catchment as compared to the base period. Maximum precipitation percentage change projected during summer season.

A change in temperature and precipitation due to climate change has significant impacts on the amount of runoff. Generally, average monthly and seasonal runoff projection showed that runoff increases in most of the months, especially during summer seasons. Average annual runoff may increases by +131% and by +124% at 2030`s and 2090`s respectively. The projected increase of runoff associated with the increase in precipitation over the catchment in both future periods. The results shown in this research were similar to the output presented using different GCM out puts including ECHAM GCM ,the only difference is they used at River basin scale where as we used at catchment scale [26]. From this study the future water resources availability in the catchment will not be under stressed by the climate change in meeting the water resources development. Hence, the surrounding community in the future will be more secured under climate change. This will lead the
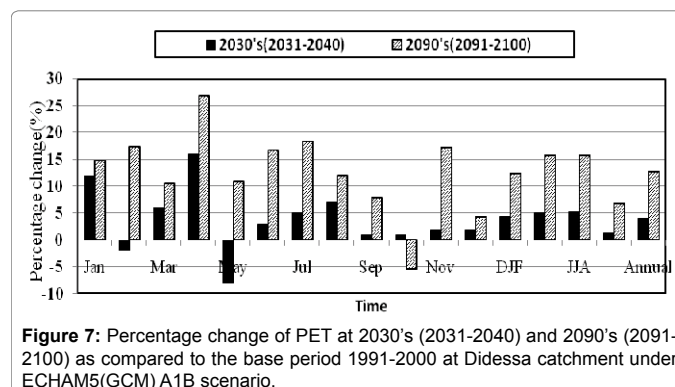

Figure 7: Percentage change of PET at 2030's (2031-2040) and 2090's (2091-2100) as compared to the base period 1991-2000 at Didessa catchment under ECHAM5(GCM) A1B scenario.
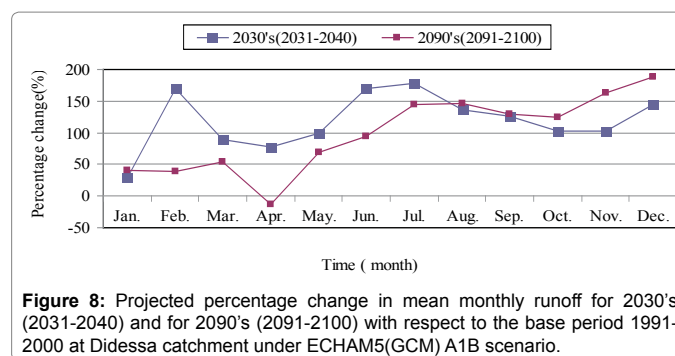

Figure 8: Projected percentage change in mean monthly runoff for 2030's (2031-2040) and for 2090's (2091-2100) with respect to the base period 1991-2000 at Didessa catchment under ECHAM5(GCM) A1B scenario.
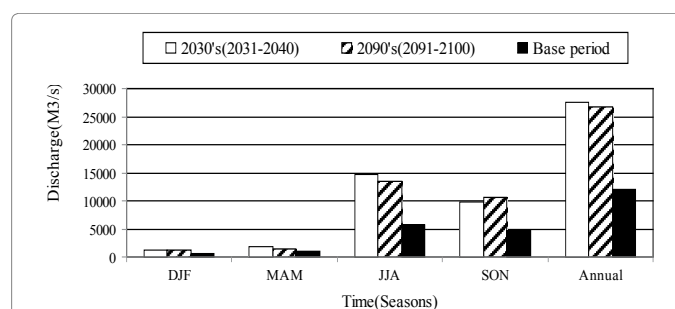

Figure 9: Comparison of projected mean seasonal and annual runoff for 2030`s (2031-2040) and 2090`s (2091-2100) as compared to the base period 1991-2000 at Didessa catchment under ECHAM5 (GCM) A1B scenario.
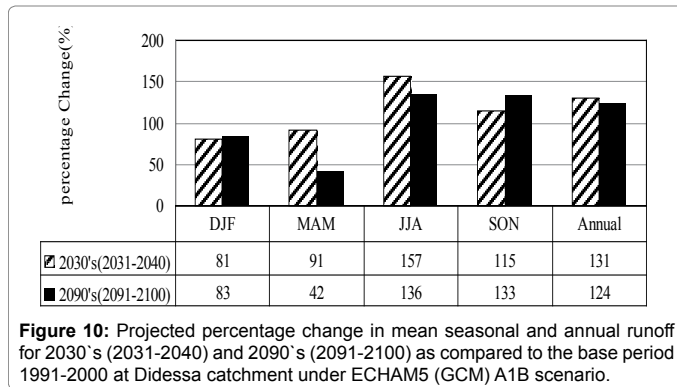
Figure 10: Projected percentage change in mean seasonal and annual runoff for 2030`s (2031-2040) and 2090`s (2091-2100) as compared to the base period 1991-2000 at Didessa catchment under ECHAM5 (GCM) A1B scenario.

	DJF	MAM	JJA	SON	Annual
2030's(2031-2040)	81	91	157	115	131
2090's(2091-2100)	83	42	136	133	124

overall economy of the country to move further one step in enhancing the sustainable food security. Especially small scale rain dependent farmers can harness water during rainy season for later use.

However, there are many sources of uncertainty in climate and in hydrological models. Hence, the results of this study should be taken with care and be considered as indicative of the likely future rather than accurate predictions. The hydrological model simulations have not considered land use changes explicitly; it is likely that changes in land use may interact with climate leading to different projections of future hydrological conditions. Therefore; future studies on climate change impacts should include land use and different GCM out puts.

Acknowledgement

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