Hydrological Response to Climate Change Impacts and Adaptation Strategies for Upper Awash Sub-basin, in the Awash Basin, Ethiopia

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Introduction

Climate change is likely to exacerbate water availability and quality, which will have wide range of implications for business (IPCC 2007). Water resource is now changing around the world, being redistributed more erratically due to the impact of climate change (Arnell 1999; Gleick 2000). Climate change will have a profound impact on natural resources, of which water is one of the most important. With climate change the amount of rainfall in many parts of Africa is expected to decline while variability may increase dramatically (IPCC 2007). With climate change and increases in climate variability, the need for managing water resources requires immediate action or attention. Climate change has the potential to reduce water resource availability in the Nile basin countries in the forthcoming decades (Setegn et al. 2011). Because of fast growing population rates, increasing resources and industrial development, water is becoming a very scarce and valuable resource (Chekol 2007).

Upper Awash sub-basin is normally endowed with land features that are characterized by large intensive downstream irrigable lands, high head hydropower plant and several towns, including the capital, Addis Ababa and industrial enterprises lie within the basin. Since downstream irrigation and industrial enterprises in the area has been expanding from time to time there is an increasing demand for water which leads to competition for water among different sectors. Unless the available water resources are utilized with the balanced approach between supply and demand and with a careful consideration of sustainability, satisfying the needs of the future will remain point of concern.

Therefore, assessing the impacts of climate change on surface water availability, essentially involves taking projections of climatic at a global scale, downscaling these global-scale climatic variables to local-scale hydrologic variables, and computing hydrological impact is crucial for the future water resources planning and management. The objective of this study is to assess the impacts of climate change on Surface water resource availability of upper Awash River basin by using the Regional climate model and Soil and Water Assessment Tool (SWAT) hydrology model.

Materials and Methods

In order to obtain the objectives outlined a conceptual SWAT model was applied to a number of catchments throughout the basin. Dynamically downscaled data from a suite of GCM, run using a range of emissions scenarios is incorporated to force the SWAT model for three future time periods, the 2020s, 2050s and 2080s. The historical climate data and stream flow data have been collected from National Metrological Agency (NMA) and Ministry of Water Resources (MoWR) that used to calibrate and validate SWAT model. Changes in sub-basin hydrology as a result of climate change are assessed for sub-basin, with the uncertainty in future impacts derived from different GCM, emission scenarios and the SWAT model employed highlighted.

The procedures consist of using climatic output data from General Circulation Models (GCM) to retrieve climate scenarios. The weather generator was then used to produce daily temperature and rainfall data to serve as input data for the hydrological model to simulate stream flow.

The general procedure to evaluate climate change impacts on the water resources are presented below:

1. Precipitation, and temperature, is extracted at the grid nodes from a long time period of General Circulation Model simulations.
2. GCM downscaled to RCM . Bias corrected downscaled RCM with historical met data.
3. Using meteorological data and observed stream flows, a Hydrological model (SWAT) is calibrated and validated, and it is forced with downscaled GCM scenarios to produce stream flows sequences for different climates GCM scenarios.
4. With the stream flow sequences produced, a water resource simulation model is used to assess the climate scenarios and their impact on hydrology and the water resources system.
5. Finally, evaluate some water management policies in order to mitigate the impacts on water resources system.

Results

Bias correction RCM for base period (1981-2010): Since the output of RCM is not directly used for climate change impact assessment on water resource, bias corrections have been done for the base period using the measured weather data of selected stations. Fig. 1a, b shows the comparison of observed, RCM and bias corrected monthly mean precipitation data (1981-2010). (Fig. 1a, b) show that there is considerable discrepancy between the RCM data and observe data. Therefore, to adjust and minimize the variation in estimated precipitation a bias correction is necessary.

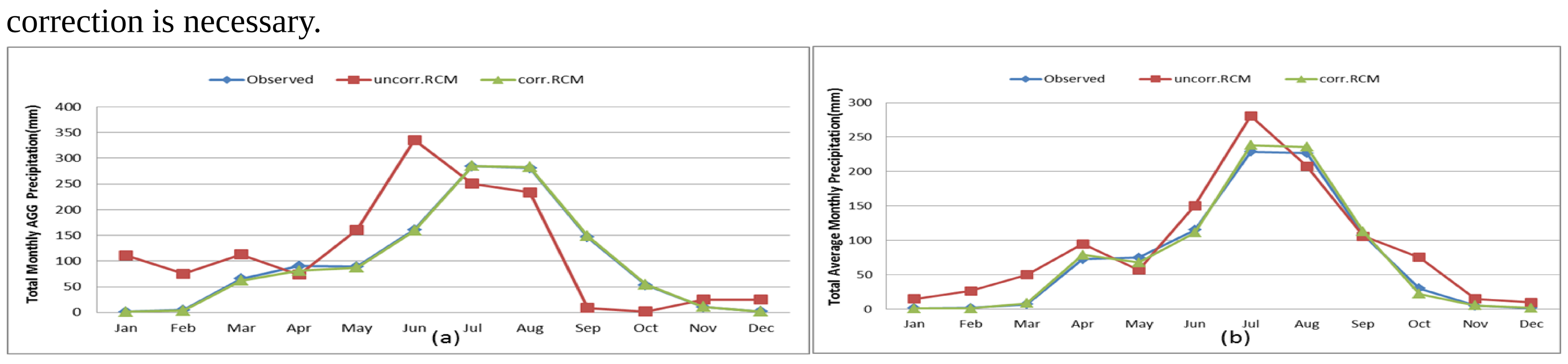

Figure 1: Bias corrected precipitation for base period (1981-2010) at (a) Addis Ababa and (b) Debrazeit

Bias correction for minimum and maximum temperature:Temperature cannot be corrected using a similar power law as was used for correcting precipitation, because temperature is known to be approximately normally distributed and therefore, linear bias correction was applied As shown in the (Fig. 2a,b) and Fig. 3a,b), the estimated maximum and minimum temperature at selected station was over estimated for all months and need to apply a bias correction to minimize the variation with the observed.

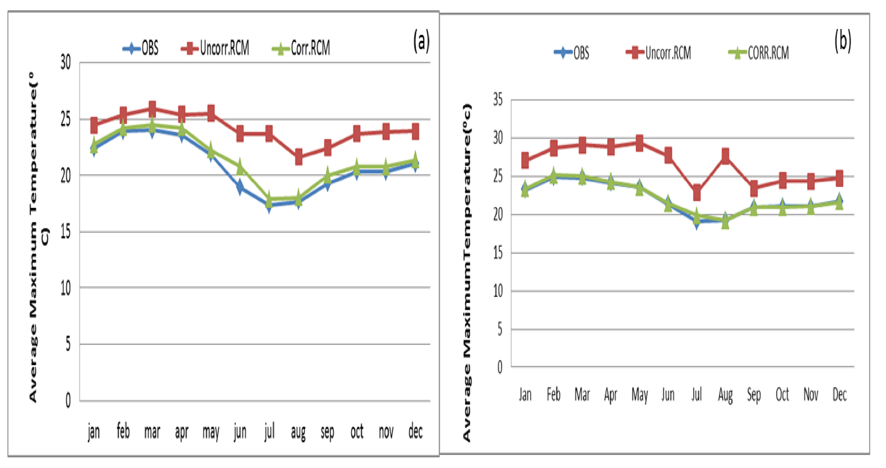

Figure 2: Bias corrected maximum temperature for base period (1981-2010) at (a) Addis Ababa and at (b) Debrezeit.

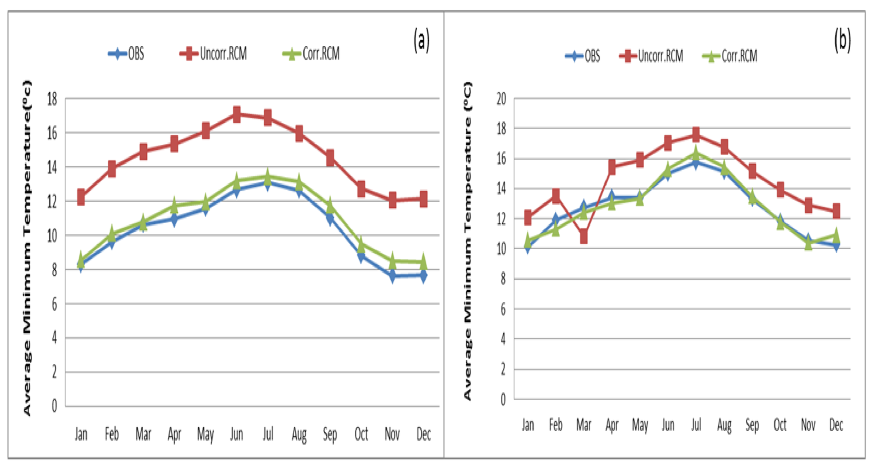

Figure 3: Bias corrected minimum temperature for base period (1981-2010) at (a) Addis Ababa and at (b) Debrezeit

Results

Scenarios Developed for the Future Time Series (2011-2100): The generated future scenarios for the three climate variables (precipitation, maximum temperature, and minimum temperature) are graphically plotted in order to observe the trend. The generated future scenarios results show an increasing trend for average minimum and maximum temperature (Fig. 4b) and decreasing trend for total annual precipitation (Fig. 4a).

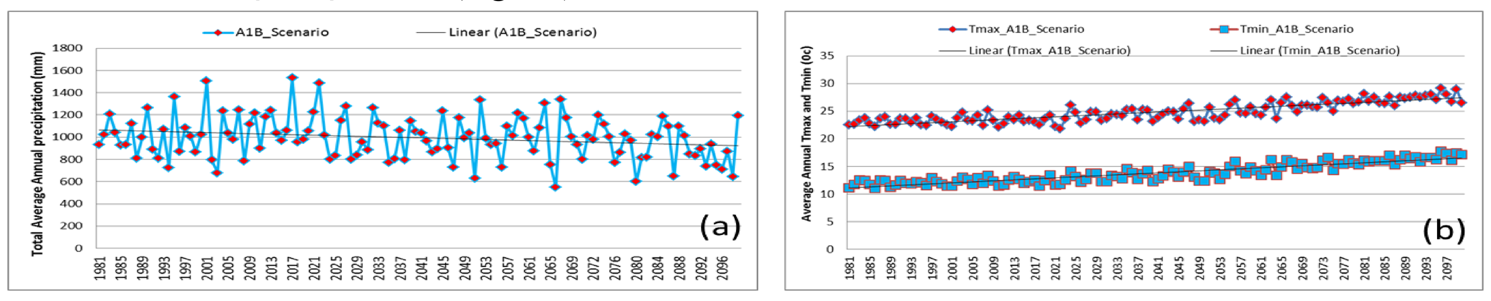

Figure 4: Future trend of (a) total annual mean precipitation, and (b) annual mean maximum and minimum temperatures of Upper Awash sub-basin.

Changes in Temperature and Rainfall: Average annual maximum temperature changes for the sub-basin were 2020s: 0.53°C, 2050s:1.18°C, and 2080s:1.87°C relative to the historical climate data 1981-2010. Average annual minimum temperature change for the three bench mark were 0.58°C, 0.82°C and 2.14°C in 2020s, 2050s and 2080s respectively. Basin-average annual rainfall based on the ECHAM5 downscaling were increased by 2.40% in 2020s while reduced by -2.14 and -10.11 % for future periods of 2050s and 2080s respectively

SWAT Model Calibration and Validation

The results of the model calibration and validation showed reliable estimates of monthly stream flow with R2 = 0.85 and ENS = 0.80 during the calibration period and R2 = 0.83 and ENS = 0.78 during the validation period (Figure 5).

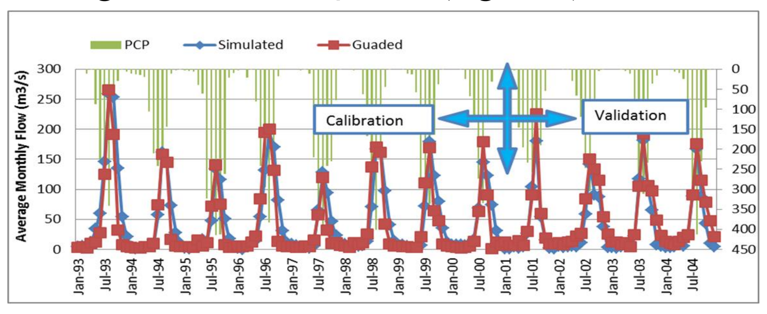

Figure 5: Calibration and validation results of average monthly simulated and gauged flows.

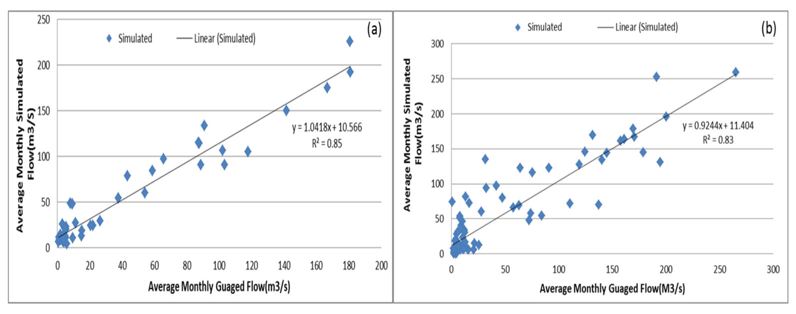

Figure 5: Scatter plot of monthly simulated versus gauged flow (a) calibration and (b) validation periods

Seasonal and annual impacts of Climate Change on Stream Flow and Surface runoff

The annual stream flow of Upper Awash sub-basin is reduced by 2.46% and 18.14% in 2050s and 2080s respectively, while the stream flow increased in 2020s by 4.90% for A1B scenario (Fig. 6). The simulated flow at: 2050s and 2080s with A1B scenario from RCM shows reduction of runoff by 1.52% and 3.50% in the sub-basin and it is directly related to the reduction in precipitation, while the annual runoff increase in 2020s by 8% (Fig. 7).

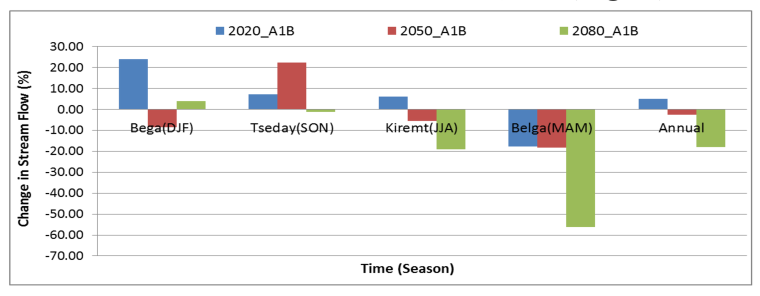

Figure 6: Change in seasonal and annual stream flow

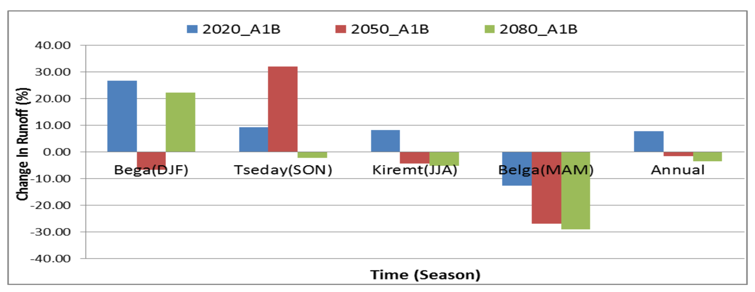

Figure 7: change in projected mean annual and seasonal runoff.

Adaptation Strategies: In general, adaptation to climate change problems causing reduction in the water availability includes: Development of watershed based integrated water resource management, introducing new farming techniques, crop calendar shift, constructing water storage structures to store excess water flowing during rainy, growing drought-tolerant crops, irrigation farming, awareness creating among the community of the future climate change in the watershed area.

Discussion and Conclusions

The SWAT model is able to capture daily and patterns which can be proven by the regression coefficient and the Nash-Sutcliffe simulation efficiency values obtained during calibration and validation periods. The result of climatic projections of bias corrected results revealed that the climatic variables generally follow the same trend with the observed meteorological data. . For all time period, the projected minimum and maximum temperature increases in all time periods for A1B emission scenario. The climate models predicted an increase in precipitation for the 2020s, while reduces for the time period of 2050s and 2080s. Generally, the analyses carried out in this study revealed that climate change would have a significant impact on the Surface runoff and stream flow, and other hydrological parameter causing a possible reduction on the total water availability in the upper awash sub-basin.

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