

Impact of Climate Change on Water Availability in the Weyib River Basin, Southeastren Ethiopia

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ABSTRACT: This study meant to estimate the monthly, seasonal and annual water availability of the Weyib River basin under CMIP5 climate change scenarios for three future time slices until year 2100. The SDSM was used to generate future likely both temperatures and precipitation whereas the ArcSWAT model was used to generate future water availability in the basin. Results revealed that future predicted both temperatures, and precipitation revealed a statistically significant (at 5% significant level) increasing trend in the forthcoming periods as perceived by Mann-Kendall test. The annual mean daily total water availability revealed an increase, possibly, in the ranges 9.18-24.49% (RCP8.5), 3.98-20.40% (RCP4.5) and 11.82-12.68% (RCP2.6). In addition, annual potential evapotranspiration has been shown a decrease by 13.31% (RCP8.5), 14.48% (RCP4.5) and 15.20% (RCP2.6). Results also revealed that a decrease of water availability in all months on the dry season this might cause water shortage in the lowland region, and greater increase of water availability in intermediate and rainy seasons this might cause flooding to some flood prone region of the basin.

KEYWORDS: CMIP5 climate change scenarios; SDSM-ArcSWAT model; Water availability; Weyib river basin; Southeastren Ethiopia.

I. INTRODUCTION

According to [3], [15] and [19], impact of climate change on water availability will knock all the biotic and abiotic surrounding in general. This is assured in some field of areas. For example, agriculture reported by [23], healthy by [10], ecology by [7]. Rainfall variability is more in African continent and resulted variation in water availability. For example, decrease of water availability or streamflow by 2050s was reported by [4] and [3]. Nevertheless, increase of water availability was also stated by [11]. As seen by various literatures, no consensus on extent of drop or rise of water availability. In general, temperatures revealed an increasing trend as reported by various researchers, for example, by [14], [22] and [17] which tends to glacier to melt and sea level to rise; just to name a few. According to [13], global mean temperature will increased by the ranges 2.6-4.8°C (RCP8.5), 1.4-3.1°C (RCP6.0), 1.1-2.6°C (RCP4.5) and 0.3-1.7°C (RCP2.6) relative to baseline time. Magnitude of temperatures will rise, too, in Ethiopia [16] in the ranges 0.9-1.1°C, 1.7-2.1°C and 2.7-3.4°C in 2030s, 2050s and 2080s respectively.

The Weyib River Basin is a multi-purpose river upon which diverse water resources schemes are involved to the flow of the river. However, increase in temperature; change in rainfall magnitude and pattern affect the basin negatively. Present climate capriciousness is striking a considerable threat to Ethiopia by mainly disturbing water resources and agricultural sectors. Recent flooding incidences as well as the very common drought in Ethiopia could remain placed as tangible indications for these influences [16]. In this study, therefore, the statistically downscaled using SDSM, CMIP5

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CanESM2 model under three RCP scenarios were used to generate future daily precipitation and both temperatures (maximum and minimum) series for the study area. Analysis of future climatic variables as well as total water availability were carried out in a monthly, seasonal and annual basis for three time slice in the upcoming periods of 2020s (time series of 2011-2040), 2050s (time series of 2041-2070) and 2080s (time series of 2071-2100).

What is confident about study zone in general and study area of Weyib River Basin in particular is that, our climate is changing. So far, however there is no single study has been done in the zone about future water availability under CMIP5 climate change scenario, but this study tried. This threat accentuates the need for effective and sustainable water resource management through enhanced appreciative of the hydrologic execution in the catchment. Therefore this study, aimed mainly to (1) downscale the CMIP5 GCM output (obtain daily simulations of Weyib River Basin climate variable) and to develop climate change under RCP scenarios for three future time slices until year 2100 (2) estimate the monthly, seasonal and annual water availability of study area under three RCP scenarios for different future time slices up to year 2100.

II. MATERIALS AND METHODS

A. A Brief Explanation about Study Area (Weyib River Basin)

It (Fig 1) has an area of 4215.93 km² and situated between 6.50-7.50°N latitude and 39.50-41.00°E longitude. The altitude variation ranges around 4389 m (a.m.s.l) at the highest point to 898 m at the confluence point. Mean annual maximum and minimum temperature of the study area is 22.30°C and 7.60°C, respectively. The study area has 22.30°C average annual maximum temperature and 7.55°C minimum temperature. Average rainfall of the study area ranges 749.34 mm-1368.90 mm (mean of 1037.40mm) per annum. Study area experiences bimodal rainfall shapes of double peaking on the month of April and August. The Eutric Vertisol and Dystric Cambiso are the two main soil types and agriculture is a leading land use type. Roughly, 70.54% of the basin area is covered with 0-15% land slope. Mean annual total water availability (in the simulation period 1984-2004) has to be 553.46 mm of this contribution of surface runoff, subsurface soil flow and baseflow to the total water availability is 24%, 55% and 21% respectively. Larger portion (55%) of water available in the stream comes from subsurface soil flow.

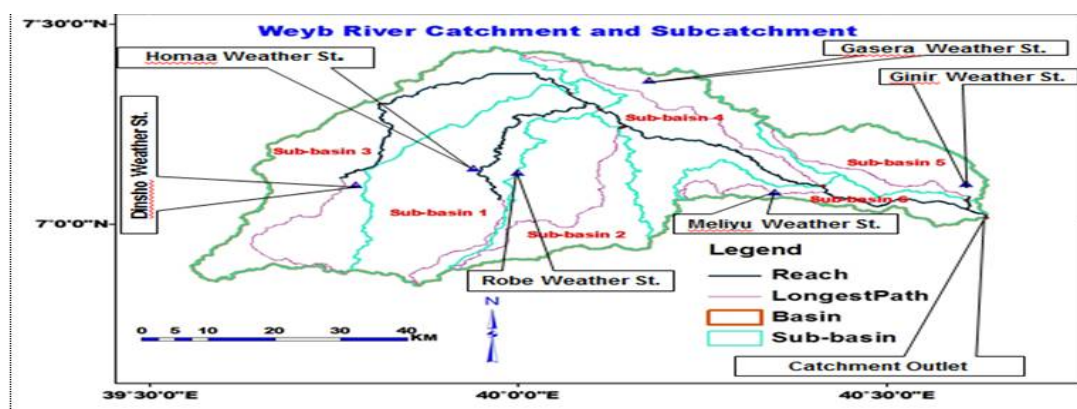


Fig 1 Study area: location map, reach, basin and subbasin delineation and selected weather stations of the weyib river basin

B. General Earth System Model (ESM) and RCP Scenarios

In this study, CMIP5-CanESM2 under three RCP scenarios has been used. Namely; (i) RCP2.6 in order to consider very low emission scenario, (ii) RCP4.5 to consider an intermediate emission scenario, and (iii) RCP8.5 to reflect the very high emission scenario have been utilized. CanESM2 has the 128x64 grid cells cover global domain according to T42 Gaussian grid. It has uniform horizontal resolution of 2.8° latitude x 2.8° longitude. The predictors associated with

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each grid cell are represented by corresponding folder named BOX_iiiX_jjY, where iii is longitudinal and jj is latitudinal index. The predictors are available for different regions in the world, so by providing latitude and longitude values the predictors that include the study area of Weyib River Basin has been downloaded through official website of Canadian Centre for Climate Modelling and Analysis. These predictors are found in zip file format as (i) CanESM2_historical_1961-2005, (ii) CanESM2_rcp26_2006-2100, (iii) CanESM2_rcp45_2006-2100, (iv) CanESM2_rcp85_2006-2100 and (v) NCEP-NCAR_1961-2005. The predictors organized this way are ready to be used as input in statistical downscaling model (SDSM). Therefore, in this study, a multiple regression based downscaling technique, using SDSM to downscale daily both temperatures and rainfall under future three RCP scenarios has been employed and finally future climate change scenario has been generated.

C. The ArcSWAT hydrologic model

In this study, considering the aim we are going to achieve, ArcSWAT model was used to simulate hydrological components of the watershed (Weyib River) Basin. Since sub-daily rainfall data was not available in study area that can be used for Green and Ampt infiltration method, modified Soil Conservation Service curve number equation (USDA 1972) has been used to estimate the surface runoff of the catchment. Penman Monteith method (Monteith 1965) was applied to estimate the PET.

Data necessary for this study comprises (i) daily weather data, (ii) spatial data (DEM, soil map and properties and LULC) and (iii) discharge/streamflow data. Daily weather data has been collected from National Meteorological Service Agency of Ethiopia (NMSA) for twelve weather stations that are established inside the basin and in nearby vicinity of the basin boundary of the Weyib River Basin. A 30 m resolution DEM obtained from ASTER official website was used for this study. Soil map as well as major soil physicochemical properties and LULC map was found from MoWE (Ministry of Water and Energy of Ethiopia). The streamflow, daily, data of the watershed at Alemkerem gaging station was found from Hydrology department of the MoWE. This data (discharge/streamflow) has been employed in ArcSWAT model sensitivity, testing and verification analysis. The standard procedure of ArcGis interface ArcSWAT hydrologic model was applied to delineate the watershed, determination of hydrological response units (HRUs), sensitivity analysis, model calibration and validation and sensitivity analysis. ArcSWAT hydrologic model was successfully calibrated and validated for the study area of Weyib River basin by [1].

D. Investigation of Future Climate Change Impact on Water Availability

The CMIP5-CanESM2 output, which was downscaled to the Weyib river catchment level, was used to generate the forthcoming water availability in the basin. The downscaled daily maximum and minimum temperature and rainfall using SDSM have been applied into ArcSWAT model as an input to generate future water availability under various RCP scenarios. Synthesis of the water availability was carried out in a monthly, seasonal and annual basis (Table 3) for three time slice in the upcoming periods of 2020s ('20s hereafter), 2050s ('50s hereafter) and 2080s ('80s hereafter). And then ArcSWAT model first ran for historic or baseline period (1984-2004) was re-run again subject to future period (2006-2100) climate variables which were downscaled as of CMIP5-CanESM2 outputs at station level. All other climatic and physiographic variables are supposed to be same in the upcoming imitation times.

III. RESULTS

In this section, the monthly, seasonal and annual changes related to climate scenarios are first described, followed by the simulation results of water availability in response to climate change.

A. Impact of Climate Change on Maximum Temperature

The predicted absolute change in monthly mean daily maximum temperature has larger extent of increase on Jun '80s 1.37°C (RCP8.5) and 0.80°C (RCP4.5) but on Jun in '50s time slice 0.58°C in case of RCP2.6 scenario then decline at the end of the century in all month and time slice because of history line of RCP2.6 (peak and decline scenario).

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Contrary, larger decrease on Dec '80s 0.75°C and 0.38°C occurred for RCP8.5 and RCP4.5 and larger decrease on Dec in '50s time slice by 0.32°C in case of RCP2.6 scenario (Fig 2a, b and c). Mostly, the absolute change in monthly mean daily maximum temperature for RCP8.5 scenario ranges -0.25°C to +0.48°C in '20s, -0.50°C to +0.91°C in '50s and -0.75°C to +1.37°C in '80s. In case of an intermediate emission scenario (RCP4.5), ranges -0.25°C to +0.47°C in '20s, -0.33°C to +0.70°C in '50s and -0.38°C to +1.37°C in '80s. The absolute change in monthly mean daily maximum temperature under RCP2.6 scenario ranges -0.12°C to +0.42°C in '20s, -0.32°C to +0.58°C in '50s and -0.28 to +0.55°C in '80s.

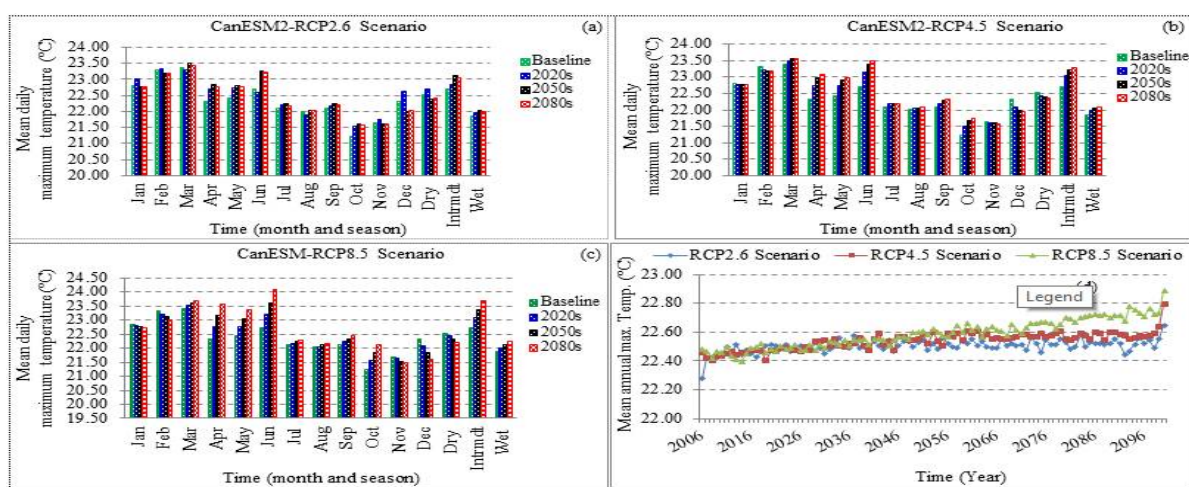


Fig 2a (upper left): Maximum temperature (monthly and seasonal mean daily) during baseline period (1981-2005) simulation and three future time slice for RCP2.6 scenario, **b** (upper right): same as **fig 2a** but for RCP4.5, **c** (bottom left): same as **fig 2a** but for RCP8.5, **d** (bottom right): future trend of mean annual maximum temperature

The future predicted seasonal mean daily maximum temperature shows a decreasing trend in dry season in all the three time slices for very low, an intermediate and very high emission scenario except in dry season of '20s time slice in case of very low emission scenario which is an increasing trend was observed. However, it has shown an increasing trend (Fig 2a, b and c) for both an intermediate and wet seasons in all the three time slices and in all the RCP scenarios. A rise of average annual maximum temperature was in the ranges 0.13 to 0.34°C (RCP8.5), 0.12-0.22°C (RCP4.5) and 0.14-0.17°C (RCP2.6). The deviation of maximum temperature is greater in case of high emission scenario than an intermediate and very low emission scenarios. Mann-Kendall test has shown a significantly (at 5% significant level) increasing trend of mean annual maximum temperature until year 2100 as seen in Fig 2d for RCP8.5 and RCP4.5 scenarios. Increasing trend but not significant (at 5% significant level) was observed for RCP2.6 scenario.

B. Impact of Climate Change on Minimum Temperature

The future predicted absolute change in monthly mean daily minimum temperature has larger extent of increase on Oct '80s 2.13°C (RCP8.5) and 1.24°C (RCP4.5) nonetheless on Oct in '50s time slice 0.95°C in case of RCP2.6 scenario then decline at the end of the century in all month and time slice. Contrary, the larger decrease on Feb '80s 0.51°C and 0.48°C ensued for RCP8.5 and RCP4.5 and larger decrease on Feb in '50s time slice by 0.36°C in case of RCP2.6 scenario (Fig 3a, b and c). Often time, the absolute change in monthly mean daily minimum temperature for RCP8.5 scenario ranges -0.30°C to +0.87°C in '20s, -0.41°C to +1.38°C '50s and -0.51°C to +2.13°C '80s. In case of an intermediate emission scenario (RCP4.5), ranges -0.32°C to +0.69°C in '20s, -0.42 degree centigrade to +1.12°C in '50s as well as -0.48°C to +1.24°C in '80s. The absolute change in monthly mean daily minimum temperature under RCP2.6 scenario ranges -0.30°C to +0.74°C in '20s, -0.31°C to +0.94°C in '50s and -0.36°C to +0.95°C in '80s. Relating with maximum temperature, the minimum temperature has revealed a greater tendency to rise.

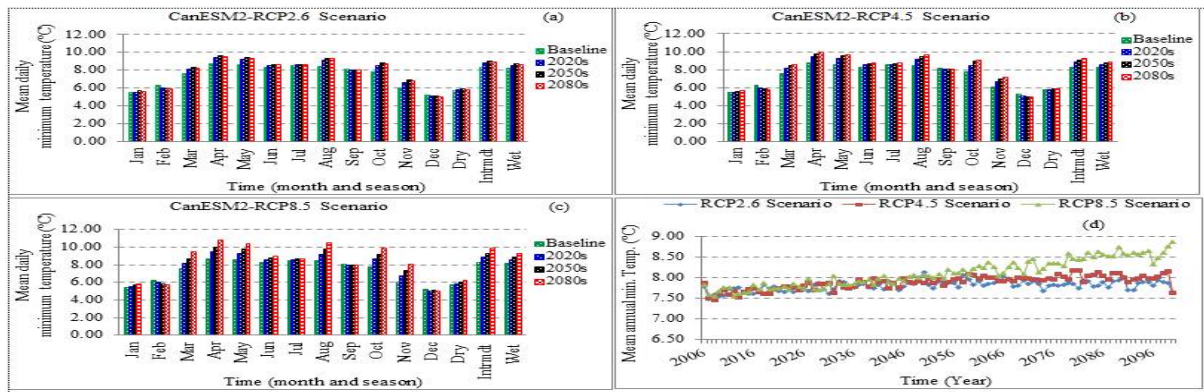


Fig 3a (upper left): Minimum temperature (monthly and seasonal mean daily) during baseline period (1981-2005) simulation and three future time slice for RCP2.6 scenario, **b** (upper right): same as **fig 3a** but for RCP4.5, **c** (bottom left): same as **fig 3a** but for RCP8.5, **d** (bottom right): future trend of mean annual minimum temperature

The future predicted seasonal mean daily minimum temperature has been revealed a rising tendency in all seasons, time slices and RCP scenarios (Figure 3a, b and c). A rise of average annual minimum temperature was in the ranges 0.34-1.04°C (RCP8.5), 0.31-0.57°C (RCP4.5) and 0.30-0.43°C (RCP2.6). Like in maximum temperature scenario, the deviation of minimum temperature is greater in case of high emission scenario than an intermediate and very low emission scenarios. Mann-Kendall test has shown a significantly (at 5% significant level) increasing trend of mean annual minimum temperature until the end of the century (Fig 3d) for RCP8.5 and RCP4.5 scenarios. Increasing trend but not significant (at 5% significant level) was observed for RCP2.6 scenario.

C. Impact of Climate Change on Rainfall

Predicted percentage change in monthly mean daily rainfall has larger extent of increase on Oct '80s 81.02% (RCP8.5) and 54.66% (RCP4.5) however on Oct in '50s time slice 42.77% in case of RCP2.6 scenario then decline at the end of the century in all month and time slice. Conversely, the larger decrease on Feb '20s 8.20% (RCP8.5), 10.35% (RCP4.5) and 10.80% (RCP2.6) (Figure 4a, b and c). Every so often, the percentage change in monthly mean daily rainfall for RCP8.5 scenario ranges -8.20% to +42.59% in '20s, -6.50% to +55.61% in '50s and +1.58% to +81.02% in '80s for the RCP8.5 scenario. In case of an intermediate emission scenario, varies -10.35% to +34.53% in '20s, -9.36% to +49.90% in '50s and -7.42% to +54.66% in '80s. The percentage change in monthly mean daily rainfall under RCP2.6 scenario ranges -10.80% to +35.41% in '20s, -8.59% to +42.55% in '50s and -9.37% +42.77% in '80s.

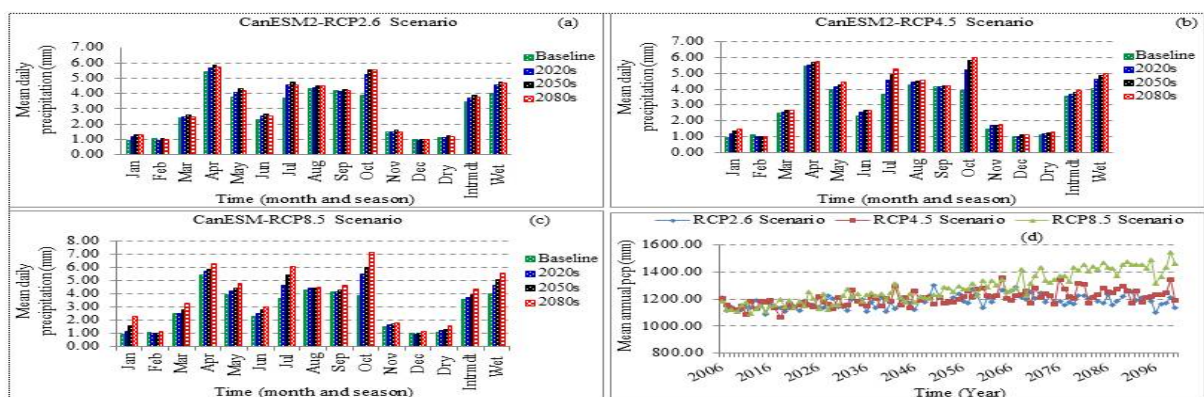


Fig 4a (upper left): Precipitation (monthly and seasonal mean daily) during baseline period (1981-2005) simulation and three future time slice for RCP2.6 scenario, **b** (upper right): same as **fig 4a** but for RCP4.5, **c** (bottom left): same as **fig 4a** but for RCP8.5, **d** (bottom right): future trend of mean annual precipitation

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The future predicted seasonal mean daily rainfall has been revealed a rising tendency in all seasons, time slices and RCP scenarios as can be seen in Figure 4a, b and c. An increase of precipitation relatively higher in the dry season 20.68% in '20s, 33.65% in '50s, and 53.74% in '80s under very high emission (RCP8.5) scenario which might have productive implication on lowland section of the Weyib as well as might implicate the upland parts adversely since the dry spell is explicitly foremost crop reaping period. A substantial increase of mean annual precipitation was found to be in the ranges 14.70-28.69% (RCP8.5), 9.54-16.94% (RCP4.5) and 8.68-13.00% (RCP2.6). The unevenness of rainfall is greater in case of high emission scenario than an intermediate and very low emission scenarios. Mann-Kendall test has shown a significantly (at 5% significant level) increasing trend of mean annual total precipitation upcoming period till year 2100 for RCP8.5 and RCP4.5 scenarios. Increasing trend but not significant (at 5% significant level) was observed for RCP2.6 scenario.

D. Impact of Climate Change on Water Availability

ArcSWAT hydrologic model was successfully calibrated and validated for the study area of Weyib River basin by [1]. They used two techniques that are widely used in models evaluating, namely quantitative statistics (four very common statistical indices) and graphical method (hydrograph analysis technique), were applied to estimate the performance of the ArcSWAT model to simulate historical water availability in the basin. Results of calibration and validation of the model at a daily time step furnished R^2 of 0.95, NSE of 0.92, RSR of 0.26 and Pbias of 1.31 for model calibration [1] while R^2 of 0.97, NSE of 0.95, RSR of 0.20 and Pbias of 2.48 for model validation period. After validated the performance of ArcSWAT model to simulate the historic water availability [1], the succeeding pace is to explore the influence of future temperatures and rainfall variation on water availability.

Regarding to particular months absolute shift in monthly mean daily total water availability amid the present as well as upcoming periods under RCP2.6 scenario has shown a decrease on months of Jan (in all the time slice), Oct ('50s and '80s time slice), Nov (in all the time slice) and Dec (in all the time slice) and an increase on the rest of the months and future time slices was observed (Fig 5a). The difference in monthly water availability was insignificant on the month of Feb and May in RCP2.6 scenario. While in case of RCP4.5 a decrease on the months of Jan (in all the time slice), Feb (at the '20s and '50s time slice), Oct (at the '80s time slice), Nov (at the '80s time slice) and Dec (in all the time slice) and an increment on the rest of the months and future time slices was observed (Fig 5b). The variance in monthly water availability was insignificant on the month of Feb (at the '80s time slice), Mar (at the '20s time slice), May (at the '80s time slice), and Nov (at the '20s and '50s time slice) in RCP4.5 scenario. In case of very high emission level (RCP8.5) there has been a decrease of total water availability on the months of Jan (at the '20s and '50s time slice) and Feb (at the '20s and '50s time slice and Dec (in all the time slice) and an increase on the rest of the months and future time slices was observed (Fig 5c). As compared to base period, the variance in monthly water availability was very minor on the month of Jan (at the '80s time slice), Feb (at the '80s time slice), Mar (at the '20s time slice), May (at the '80s time slice), Oct (at the '50s and '80s time slice) and Nov (in the entire time slice) in RCP8.5 scenario.

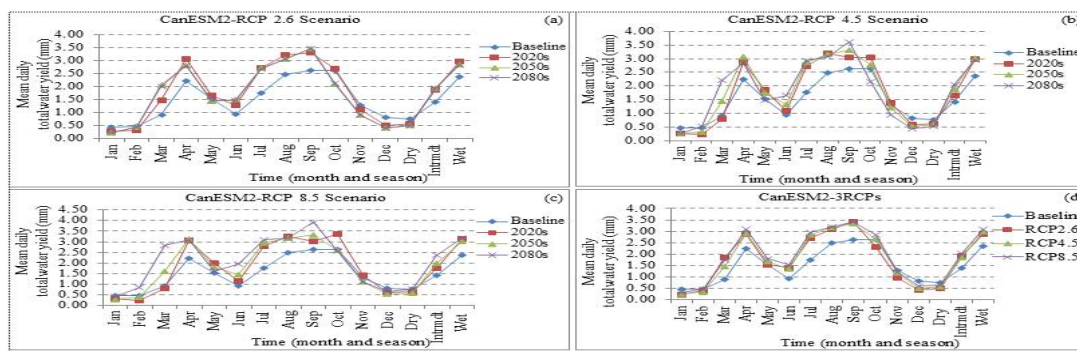


Fig 5a (upper left): Total water availability (monthly and seasonal mean daily) during baseline period (1984-2004) simulation and three future time slice for RCP2.6 scenario, **b** (upper right): same as **fig 5a** but for RCP4.5, **c** (bottom left): same as **fig 5a** but for RCP8.5, **d** (bottom right): same as **fig 5a** but without time slice for RCP2.6, RCP4.5 and RCP8.5 scenarios

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Table below revealed that the percentage change from base period on the months of Jan, Feb, Nov and Dec the generated total water availability decreases pointedly for all the three time slice and RCP scenarios with exceptions in time slice of '20s on Oct and '80s on Feb for both very high and an intermediate scenarios. The months March as well as July might practice a biggest increase of total water availability almost greater than 60% and 52% respectively for all time slice and for all RCP scenarios with exception of '20s time slice on the month of March for very high and an intermediate emission scenarios; future water availability may also rise, mainly, on the month of Jun, Apr, Aug and Sep. The highest decrease of monthly mean daily total water availability might be observed on the month Jan by 38.69%, 51.71%, 51.26%, and 42.66%, 44.03%, 45.11% and 35.73%, 37.07%, 18.02% (on Dec) in the time slice of '20s, '50s and '80s respectively for all RCP scenarios.

Table Percentage change in mean monthly, seasonal and annual total water availability in the three future time horizon from the base period simulation under three RCP scenarios

Month	RCP2.6 Scenario			RCP4.5 Scenario			RCP8.5 Scenario		
	2020s (%)	2050s (%)	2080s (%)	2020s (%)	2050s (%)	2080s (%)	2020s (%)	2050s (%)	2080s (%)
Jan	-38.69	-51.71	-51.26	-42.66	-44.03	-45.11	-35.73	-37.07	-9.10
Feb	-29.72	-3.72	-6.37	-53.22	-33.33	12.11	-51.95	-18.62	79.97
Mar	63.30	127.11	121.49	-13.44	60.23	143.32	-10.57	75.47	212.32
Apr	37.28	25.51	25.91	28.84	37.09	26.71	36.81	40.11	38.80
May	8.69	-5.47	-5.12	21.03	11.85	-4.82	28.05	17.44	5.08
Jun	37.66	59.81	56.73	15.32	43.06	76.36	23.64	55.62	110.54
Jul	54.97	54.61	52.96	54.24	63.48	66.79	59.98	68.83	77.06
Aug	29.36	23.70	23.33	28.96	27.56	24.50	31.79	27.76	28.11
Sep	26.26	31.86	31.84	16.32	26.66	37.97	15.92	26.35	49.56
Oct	2.66	-20.06	-18.25	16.15	5.91	-18.22	28.27	-0.26	-2.25
Nov	-13.98	-30.41	-29.33	6.38	-7.50	-28.66	9.47	-14.94	-14.19
Dec	-35.92	-49.39	-49.70	-30.19	-37.53	-46.18	-25.57	-33.78	-18.02
Dry	-29.58	-33.81	-34.17	-29.92	-30.60	-26.96	-25.94	-26.10	9.67
Intermediate	36.73	51.74	49.75	12.94	38.06	60.39	19.48	47.16	91.69
Wet	28.31	22.53	22.47	28.92	30.90	27.76	33.99	30.67	38.12
Annual	11.82	13.49	12.68	3.98	12.79	20.40	9.18	17.24	24.49

Future seasonal average daily total water availability might be decrease in dry season (for example, in the month of Nov, Dec, Jan and Feb) by 0.20mm (29.58%), 0.26mm (33.81%), and 0.26 mm (34.17%) (RCP2.6), and 0.15mm (29.92%), 0.19mm (30.60%), 0.22mm (26.96%) (RCP4.5) and 0.12mm (25.94%), 0.18mm (26.10%), 0.01mm (+9.67%) (RCP8.5) in '20s, '50s and '80s respectively, but increase an intermediate season (Mar, Apr, May and Jun) by 0.47mm (36.73%), 0.55mm (51.74%), 0.53mm (49.75%) (RCP2.6), and 0.25mm (12.94%), 0.49mm (38.06%), 0.63mm (60.39%) (RCP4.5) and 0.34mm (19.48%), 0.59mm (47.16%), 0.98mm (91.69%) (RCP8.5) in '20s, '50s and '80s respectively as well as increase in wet seasons (Jul, Aug, Sept and Oct) by 0.61mm (28.31%), 0.46mm (22.53%), 0.47mm (22.47%) (RCP2.6), and 0.63 mm (28.92%), 0.66mm (30.90%), 0.57mm (27.76%) (RCP4.5) and 0.75mm (33.99%), 0.64mm (30.67%), 0.82mm (38.12%) (RCP8.5) in '20s, '50s and '80s respectively as revealed in Fig 5a, b and c and Table, likewise the mean annual percentage change (Detailed in Table below) from base period of total water availability found to be increased by 11.82%, 13.49%, 12.68% (RCP2.6), and 3.98%, 12.79%, 20.40% (RCP4.5) and 9.18%, 17.24%, 24.49% (RCP8.5) in '20s, '50s and '80s respectively. As we can see from the results above that there has been high monthly and seasonal variation of water availability as compared to the annual variation for all the three

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RCP scenarios and upcoming time slices. However, the average annual water availability possibly increased in the ranges 9.18-24.49% (RCP8.5), 3.98-20.40% (RCP4.5) and 11.82-12.68% (RCP2.6). The results also point out that the annual potential evapotranspiration has been revealed a decrease by 13.31% (RCP8.5), 14.48% (RCP4.5) and 15.20% (RCP2.6).

IV. DISCUSSIONS AND CONCLUSION

A. Relating and Contrasting of this Study with the Literatures

The research article reported by [18] and found that there are significant variability exists across diverse environment situations. And also research findings reported by [5] and [2] found that the temperature prediction in the upcoming period will be in the range 2-4°C in Africa. The research has been conducted by [6] and they obtained that the temperature increase by the range of 2.2-4.1°C for most of Africa. Future climate prediction for Ethiopia have been reported by [16] and the results revealed that average temperature per annum rises between 0.9-1.1°C in 2030, ranges 1.7-2.1°C in 2050 and 2.7-3.4°C in 2080. Research study also reported by [13] and the results revealed that the rise in global mean temperature between 2.6-4.8°C (RCP8.5), 1.1-2.6°C (RCP4.5) and 0.3-1.7°C (RCP2.6) by the year 2100. We found, too, average temperature per annum will rises between 0.12-1.04°C (RCP8.5), 0.12-0.57°C (RCP4.5) and 0.14-0.44°C (RCP2.6). There has been observed slight variation of temperature increment in this study as compared to previous work reported: this might be due to types of GCMs and emission scenario used; method of downscaling, and spatial variation of temperature. The general increasing trend in rainfall has been observed by [22] in the tropics and East Africa. The greater spatial variability of precipitation (for example, decrease of 25-50% to an increase of 25-50%) was reported by [8]. Mean annual precipitation, in this study, substantially increased in the ranges 14.70-28.69% (RCP8.5), 9.54-16.94% (RCP4.5) and 8.68-13.00% (RCP2.6) and coincide with the various literatures.

Research reported by [9] stated that there have been rises in streamflow ranges 10-20%. In agreement with this study too, the mean annual water availability possibly increased in the ranges 9.18-24.49% (RCP8.5), 3.98-20.40% (RCP4.5) and 11.82-12.68% (RCP2.6). However, there have been greater monthly and seasonal variability. The larger monthly and seasonal variations in water availability (look at above Table) is discussed in this study and taken to be an advantage over the other studies which focused only annual basis. The monthly, seasonal and annual variation of the water availability under each RCP scenarios might be resulted from climate change effect in the Weyib River Basin and which, perhaps, will experience drought in lowland section (mainly in dry season) whereas there might be also flooding problems in highland section (mainly in monsoon season), this might harshly disturb the human livings as well as all locales involved to the flow of river

B. Impact of Variations in Rainfall, Water Availability, and Potential Evapotranspiration

An ultimate goal of this paper is to study upcoming climate change impact on the diverse hydrologic components of Weyib River Basin and compare the reliability with baseline simulation for the same. An extensive discussion has been made by [20] and states that the streamflow is profound to precipitation. Accurate for this findings too where an increase of annual rainfall (Fig.4d) in upcoming period tends in the direction of rising annual total water availability; the reason, probably, is that the annual potential evapotranspiration (PET) tends to decreases in all the three scenarios. As far as future projection in this study in general, the decrement of water availability in all months on the dry season might cause water shortage mainly in the lowland region, and greater increment of water availability in intermediate and rainy seasons might cause flooding to some flood prone region of the study area. Therefore, in order to alleviate these challenges (draught in some region and flooding in other corner) sustainable-integrated water resources management approach is paramount important.

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