Developing Climate Change Projections using Different Representative Concentration Pathways of Emission Scenario: Case of Lower Awash River Basin

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Abstract

With experimental proof, it is scientifically well known that the cause of climate change is related to anthropogenic green-house gas emissions. And, to test the occurrence and the effect of climate change, Global(GCM) and Regional(RCM) climate change scenario models have been developed and used in practice for more than a couple of decades. Then, several study results have evidently shown that the entire globe has dramatically experienced climate change, in a rapidly trend, due to recent emissions are the highest in history. One way of demonstrating the indication of this climate change possibility over localities is by dealing with GCM and RCM climate change scenario models through statistical or dynamical downscaling method. Thus the objective of this research is to develop climate change scenario for lower Awash River basin under high, medium and low representative carbon concentration path ways (RCPs: Rcp2.6, Rcp4.5 and Rcp8.5). And, our aim is to investigate and deliver comprehensive and remarkable information to concerned bodies and communities about climate change possibilities and impact over lower Awash River Basins of Ethiopia. The method engaged to generate climate change scenario for each RCPs is Statistical Downscaling Method (SDSM Version 4.2.9), using CanESM2 coupled general circulation model. Besides, statistical regression analyses such as Nash Sutcliffe Model Efficiency and R2 are manipulated in order to evaluate model performance. Then, the results in this study showed that regarding model evaluation, almost all the three climate stations in common, except on very few months, the model demonstrated good to excellent efficiency with calibration value (R2>0.95) and validation strength value (R2>0.90) in case of maximum and minimum temperature; whereas the value is relatively less during model evaluation in replicating and simulating the precipitation. While, regarding the results of climate change scenario projections, on most of the climate stations and over Lower Awash River Basins in aggregate, on some months and seasons a change in temperate ranges from a very minor rise (0.3 d0c) and from a very minor decrease (-0.2 d0c) to a large and significant increase (3.5 d0c) on some other months under low, medium and high Rcps in ascending order. Especially, significant changes are observed on the periods 2050s and 2080s than 2020s under each Rcps. The same is happened in a case of precipitation, in all periods (2020s, 2050s and 2080s) and under each Rcps. Further, similar to other's study findings, the rise in minimum temperature (2.5 d0c) is anticipated to be larger than the maximum temperature (2.0 d0c), on temporal average under medium and high Rcps. When season wise change in minimum and maximum temperature prospect is considered, the Summer season is anticipated to experience the maximum or peak deviation; and Winter and Spring come next in order of magnitude. However, in case of precipitation, under each Rcps the reverse is likely to happen opposite to the order of temperature-peak-change related to seasons. In general, the study revealed indications of extreme weather events which result in introducing increased climate variability on monthly, seasonal and inter-annual outlook, especially in precipitation (one time very dry with probability of drought occurrence and the other time very wet with high probability of flood incidence) and one time extremely hot the other time extremely cold. However, more or less, an increasing trend is observed for both precipitation and temperatures starting from 2020s to 2080s in all cases of Rcps and time frames (monthly, seasonal and annual). In addition, seasonal shift in precipitation patterns like changes in onset and cessation of rainy seasons, shortened or shrink of rainy season and changes in mode of seasonal rain fall pattern (bimodal to mono-modal and vice versa) are observed to occur in the anticipated future climate change scenario. The other important finding observed in this study is that the climax or peak effect of the Climate Change is pronounced over lowlands than mid-land and highlands (Mille, Diredawa and Cheffa).

Conclusion: The climate models used in downscaling from global and regional level to local level have their own limitations associated in. So, by considering this fact the results achieved with CanEsm2 model is generalized and concluded as the following. In general, projected changes in temperature and precipitation extremes are likely to have moderate to significant negative impacts on various socioeconomic activities over the communities and natural ecosystems over Lower Awash River Basins.

Recommendation: Based on this study result we recommend that areas over Lower Awash River Basins require close monitoring. So, planning, developing and implementing effective climate change adaptation and mitigation strategies; and strengthening early warning and disaster prevention and response mechanisms shall exhaustively sustain against climate change impacts. And, another recommendation in account of this study result is that prioritizing climate change adaptation and mitigation to those low land areas which are going to be affected highly likely. In general, effective and efficient utilization of water resource are recommended for actualizing climate smart agriculture and lessen the negative impact of drought, flooding and reservoirs sedimentation.

Keywords: Downscaling climate models • Climate change scenarios • Climate extremes • Environmental impacts

Introduction

Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen. The globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85 (0.65°C to 1.06°C), over the period 1880 to 2012, for which multiple independently produced datasets exist. The total increase between the average of the 1850-1900 period and the 2003-2012 period is 0.78 (0.72°C to 0.85°C), based on the single longest dataset available. For the longest period when calculation of regional trends is sufficiently complete (1901 to 2012), almost the entire globe has experienced surface warming IPCC, Climate Change 2014 Synthesis Report .

Nevertheless the definition of climate change becomes difficult to generalize in a single short word, climate change can be defined as a change in the state of the climate that can be identified by changes in the average and/or the variability of its properties, and persist for an extended period of time, normally a decade or longer stated .The impact of changing climate, such as rising global average temperatures and increases in frequency and severity of extreme events, droughts and floods, are already affecting human being, biodiversity and ecosystems, economies and societies worldwide . Seasons are shifting, temperatures are climbing and sea levels are rising around the globe. Meanwhile, our planet must still supply us and all living things with air, water, food and safe places to live .

General circulation models

One of the recent advances in climate science research is the development of global General Circulation Models (GCMs) to simulate changes in climatic elements of the present and future, which helps us to determine consequences earlier and prepare for necessary adaptation measures General Circulation Models (GCMs), which are widely used nowadays to simulate future climate scenarios. There are different techniques for down scaling large scale GCM outputs to small scale resolutions to use in other models. All the available techniques and rationale of downscaling are categorized under two broad groups, namely dynamic downscaling and statistical downscaling [1-3]. The dynamic downscaling is performed by Regional Climate Models (RCMs) or Limited Area Models (LAMs) at 0.5° x 0.5° or an even higher resolution that parameterizes the atmospheric processes. The RCMs utilize large scale and lateral boundary conditions from GCMs to produce higher resolution outputs that demands high competition time [4].

The statistical downscaling techniques involve developing quantitative relationships between large scale atmospheric variables (the predictors) and local surface variables (the predictands). The second generation of Earth System Model CanESM2 is the fourth generation coupled global climate model developed by the Canadian Centre for Climate Modelling and Analysis (CCCma) of Environment Canada [5]. SDSM permits the spatial downscaling of daily predictor-predictand relationships using multiple linear regression techniques. The predictor variables provide daily information concerning the large-scale state of the atmosphere, whilst the predictand describes conditions at the site scale [6].

Some meaningful statistical Terms in climate study

Standard deviation looks at how spread out a group of numbers is from the mean, by looking at the square root of the variance. The variance measures the average degree to which each point differs from the mean- the average of all data points (e.g, temperature and precipitation records). The other meaningful statistical computations are spatial and temporal mean of precipitation, temporal mean of temperature and daily average temperature (the average of daily maximum and minimum temperature).

Seasons: A single month or a combination of two or more consecutive months can make up a season characterized by defined climate for a given place .For example, the climate season classifications over majority parts of Ethiopian Agro-ecological zones are categorized as:

Winter/Bega: Cold and dry season, comprises months starting from October, November, December and January (ONDJ).

Spring/Belg: Hot and moderately wet season comprises months starting from February, March, April and May (FMAM).

Summer/kiremt: Cold and wet season, comprises months starting from June, July, August and September (FMAM).

Objectives

General Objective: The general objective of this research is to develop climate change scenario for lower Awash River basin under high, medium and low Representative Concentration Path Ways (RCPs) [7].

Specific Objectives:

- Determine Climate Model calibration and validation used in this study (coupled general circulation model, CanESM2) using Statistical Downscaling Model (SDSM).
- Model performance evaluation using Nash Sutcliffe model Efficiency coefficient, R2 , R and absolute model error.
- To generated climate change scenario under different RCPs and question the prospective impact over lower Awash River basin.

Methods and Study Area Description

Study area

Awash River basin is one of the nine basins in Ethiopia; and it is unique from the others in that it does not have cross boundary flow [8]. The lower Awash basin, the area under consideration in this study, covers most of the lowest areas in dimension of altitudes. And, three weather stations are represented to this site which is near to the water shade in lower Awash catchment area. These are Diredawa, Mille and Cheffa with 42.533 m, 9.9667 m and 1180 m longitude, latitude and altitude values, 40.76 m, 11.43 m, 488 m and 39.81219 m,10.84426 m, 1466m, respectively. With these stations, the catchment elevation in average ranges from 488 m to 1466 m above mean sea level [9].

Data sets

The primary data source for this study is station data obtained from National Meteorology Agency of Ethiopia; and missing climate data high resolution satellite grid data (4 km by 4 km) merged with in-situ data have been used. And, climate parameters comprised in this study are daily precipitation, maximum and minimum temperature records starting from the year 1987 G.C to 2016 G.C. The material used to carry of the analysis is SDSM (software developed for Statistical downscaling of climate change scenario)[10].

Details of methods

SDSM Description: The SDSM software reduces the task of statistically downscaling daily weather series into seven discrete steps: Quality control and data transformation; Screening of predictor variables; Model calibration; Weather generation (using observed predictors); Statistical analyses; Scenario generation [11].Process of SDSM According to Moges Molla 2020 and Zhao F F and Xu Z X 2008, SDSM includes five important parts:

- Select the atmospheric predictors of large scale, that is to filtrate the predictor variables;
- Select and calibrate the statistical downscaling pattern;
- Test the pattern using independent observational data;
- Apply the statistical pattern to GCM, and produces future climate scenarios;
- Diagnosis and analyse the future climate scenarios, including Statistical analysis of output data, model output, mapping and so on (Figures 1 and 2).

The first step before model calibration was quality control using SDSM through identification of gross data errors, missing data codes and outliers to get the appropriate quality data [12]. The screening Predictor variables will be done by trial and error procedure for model calibration. Using the partial correlations statistics, predictors which showed the strongest association with the predictand will be selected. Assembly and calibration of statistical downscaling model(s) the large-scale predictor variables identified are used in the determination of multiple linear regression relationships between these variables and the local station data. Then SDSM manual procedure will be followed to generate climate scenario for the basins. Data source observed daily precipitation and maximum and minimum temperatures data will be obtained from weather stations located in or near the watershed. GCM-derived predictors will be generated form global data base. Screening of Potential Downscaling Variables Screening of the potential predictors for the selected predict and (i.e. observed precipitation, minimum and maximum temperature) were used to select the appropriate downscaling predictors for model calibration and the most crucial and decisive part in statistical downscaling model. This is done by identifying an appropriate large-scale gridded predictor's result in good correlation between observed and downscaled climate variables

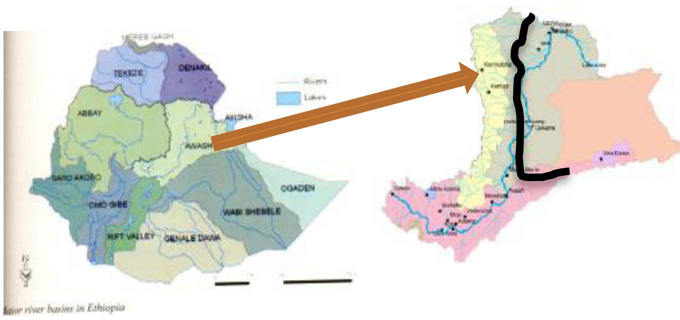


Figure 1. Map description of the study area for lover awash river basin.

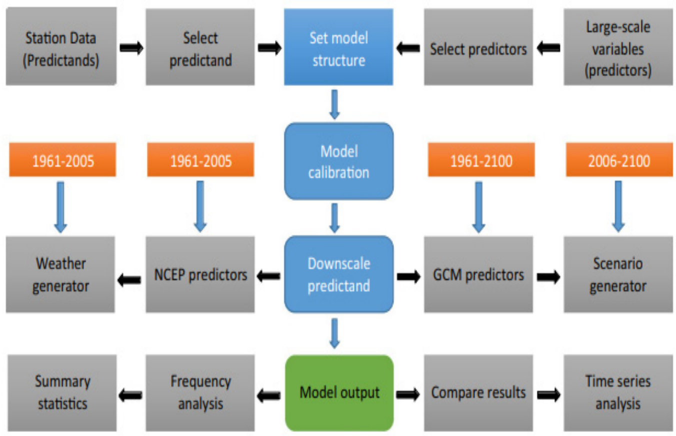


Figure 2. Schematic diagram of the Statistical Down Scaling Model (SDSM)

during model calibration and scenario generation[13]. The recommended methods for screening the potential predictors is starting the processes by selecting seven or eight predictor at a time and analyze their explained variance, then select those predictor which has higher explained variance. The significance level which tests the significance of predictor-predictand correlation was set to the default P<0.05 and drop the rest. For the selected predictor analyze or calculate their correlation matrix with the observed predictand. This procedure is repeated by holding those predictors which passé the above criteria and add new predictors from the reset of available predictors[14]. So, in general, in this paper all these steps are carried out in same procedures and design similar.The other methods used in analysis are statistical regression models used to evaluate model performance are Nash Sutcliffe formula which is strong to determine the model efficiency compared to observed data and r-squared (R^2) value [15]. This statistics identify the amount of explanatory power of the predictor to explain the predictand and finally the scatter plot or bar graph is carried out in order to identify the nature of the association (linear, non–linear, etc.)

Result and Discussion

Model performance evaluation of climate change projection for calibration and validation over lower awash river basin

Before generating climate change scenarios, calibration and validation are essential processes in adjusting climate data simulation with SDSM model, which is used in this study. So, to compare and relate the strength of the model to simulate observed historical data, different correlation approaches analyzed by regression models (such R^2 and Nash Sutcliffe model Efficiency coefficient) are manipulated. R^2 tells us tells how well the regression model fits the observed data while Nash Sutcliffe model tells the model efficiency in simulating the data [16].

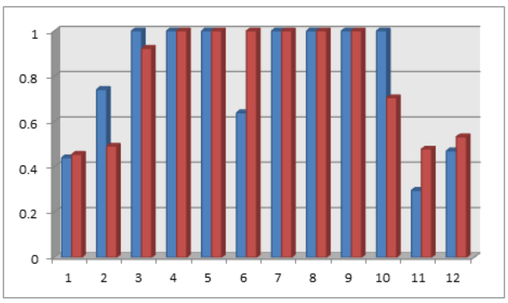
Model calibration and validation for Precipitation records

In each case positive value close to 1 indicates good relation and high model efficiency in simulating the data by the model which is deployed for climate data calibration and validation [17]. While, negative values indicate opposite relation of the data set and poor model efficiency. In general, value greater than 0.5 is considered as good coefficient of determination and efficiency. The blue bars represent observed data and those with red are calibrated/validity by SDSM climate model. In the above Figure 1, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Cheffa climate station R2 and Nash model computed to be 0.7 and 0.7 respectively, on annual precipitation level. And, each regression models have a value very close to 1 for nine months [18].

In the above Figure 3, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Mille climate station R2 and Nash model computed to be 0.51 and 0.44 respectively, on annual precipitation level. And, each regression models have a value very close to 1 for nine months [19].

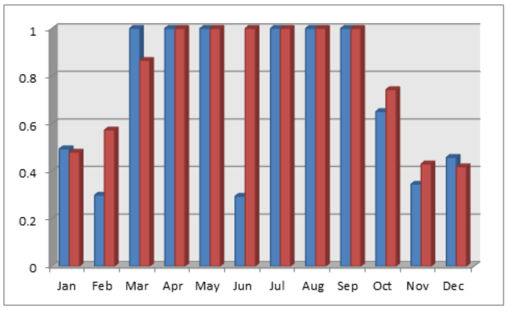
In validation process, for Cheffa climate station R2 and Nash model computed to be 0.65 and 0.66 respectively, on annual precipitation level. This implies, as indicated in Figure 4, for few months the model overestimates while for the most months the model exhibited good validation efficiency.

In validation process, for Mille climate station R2 and Nash model computed to be 0.42 and 0.41 respectively, on annual precipitation level. This implies, as indicated in Figure 5, for few months the model



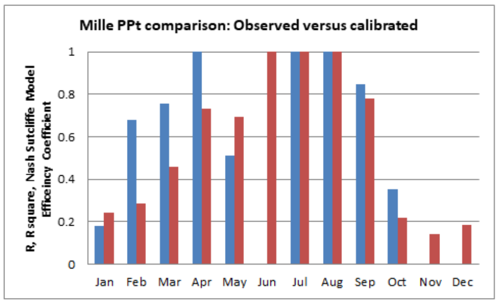
R2	Nash Sutcliffe model Efficiency coefficient
0.7	0.7

Figure 3. Precipitation over Cheffa: Observed versus calibrated averaged over 12 months for the period 1983-1999



R2	Nash Sutcliffe model Efficiency coefficient
0.65	0.66

Figure 4. Precipitation over Cheffa: Observed versus validated averaged over 12 months for the period 2000-2016.



R2	Nash Sutcliffe model Efficiency coefficient
0.51	0.44

Figure 5. Precipitation over Mille: Observed versus calibrated averaged over 12 months for the period 1983-1999.

overestimates while for the most months the model exhibited good validation efficiency.

In the above Figure 6, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Dire climate station R2 and Nash model computed to be 0.55 and 0.50 respectively, on annual precipitation level. And, both regression models have a value very close to 1 for nine months[20].

In validation process, for Dire climate station R2 and Nash model computed to be 0.50 and 0.41 respectively, on annual precipitation level [21]. This implies, as indicated in Figure 7, for few months the model overestimates while for the most months the model exhibited good validation efficiency.

In the above Figure 8, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Cheffa climate station R2 and Nash model computed to be 0.86 and 0.98 respectively, on annual precipitation level and, each regression models have a value very close to 1 for nine months [22].

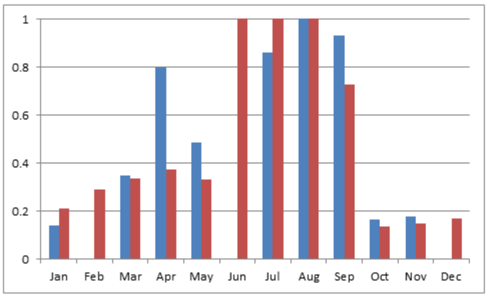
Model calibration and validation for Maximum Temperature records

In validation process, for Cheffa climate station R2 and Nash model computed to be 0.72 and 0.98 respectively, on annual precipitation level. This implies, as indicated in Figure 9, for few months the model overestimates while for the most months the model exhibited good validation efficiency [23].

In the above Figure 10, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Mille climate station R^2 and Nash model computed to be 0.93 and 0.88 respectively, on annual precipitation level [24]. And, each regression models have a value very close to 1 for nine months.

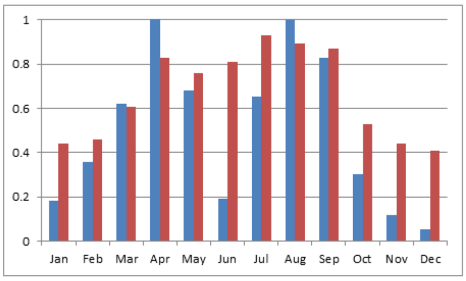
In validation process, for Mille climate station R2 and Nash model computed to be 0.91 and 0.84 respectively, on annual precipitation level. This implies, as indicated in Figure 11, for few months the model overestimates while for the most months the model exhibited good validation efficiency.

In the above Figure 12, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Diredawa climate station R^2 and Nash model computed to be 0.88 and 0.85



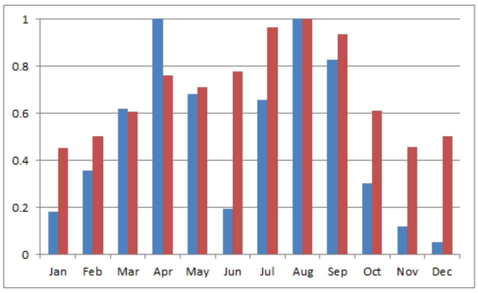
R2	Nash Sutcliffe model Efficiency coefficient
0.42	0.41

Figure 6. Precipitation over Mille: Observed versus validated averaged over 12 months for the period 2000-2016.



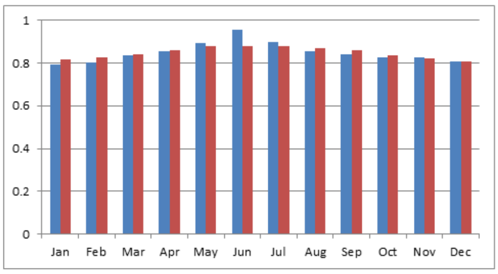
R2	Nash Sutcliffe model Efficiency coefficient
0.55	0.50

Figure 7. Precipitation over Diredawa: Observed versus calibrated averaged over 12 months for the period 1983-1999.



R2	Nash Sutcliffe model Efficiency coefficient
0.50	0.41

Figure 8. Precipitation over Diredawa: Observed versus validated averaged over 12 months for the period 2000-2016.



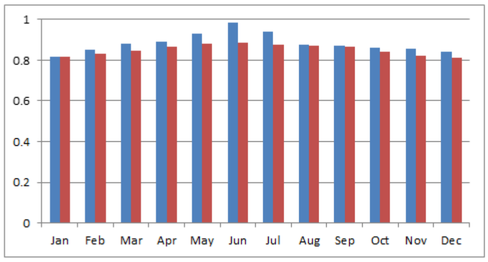
R2	Nash Sutcliffe model Efficiency coefficient
0.86	0.98

Figure 9. Maximum Temperature over Cheffa: Observed versus validated averaged over 12 months (2000-2016).

respectively, on annual precipitation level and, each regression models have a value very close to 1 for nine months[25].

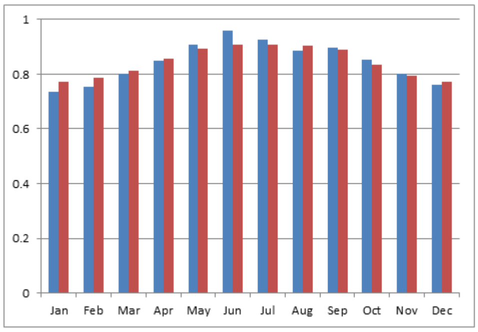
In validation process, for Diredawa climate station R2 and Nash model computed to be 0.90 and 0.80 respectively, on annual precipitation level. This implies, as indicated in Figure 13, for few months the model overestimates while for the most months the model exhibited good validation efficiency.

In validation process, for Diredawa climate station R2 and Nash model computed to be 0.90 and 0.80 respectively, on annual precipitation level. This implies, as indicated in Figure 14, for few months the model overestimates while for the most months the model exhibited good validation efficiency.



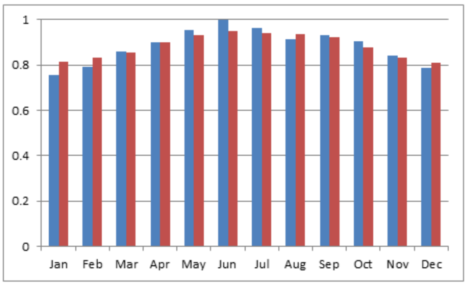
R2	Nash Sutcliffe model Efficiency coefficient
0.72	0.98

Figure 10. Maximum Temperature over Mille: Observed versus calibrated averaged over 12 months (2000-2016)



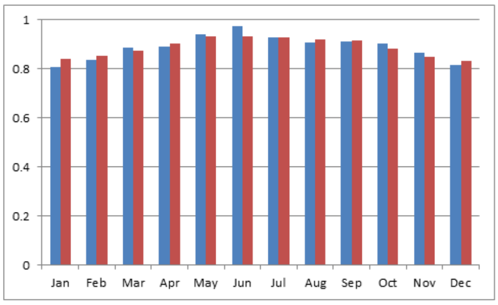
R2	Nash Sutcliffe model Efficiency coefficient
0.93	0.88

Figure 11: Maximum Temperature over Mille: Observed versus validated averaged over 12 months (2000-2016)



R2	Nash Sutcliffe model Efficiency coefficient
0.91	0.84

Figure 12. Maximum Temperature over Diredawa: Observed versus calibrated averaged over 12 months (2000-2016)



R2	Nash Sutcliffe model Efficiency coefficient
0.88	0.85

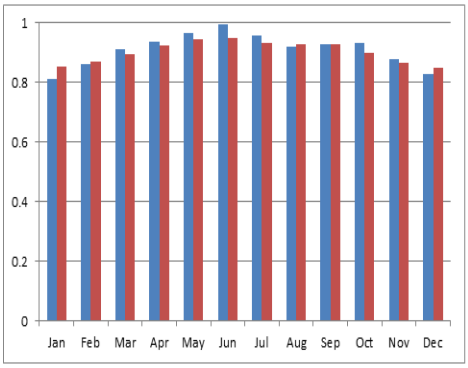
Figure 13. Maximum Temperature over Diredawa: Observed versus validated averaged over 12 months (2000-2016)

Model calibration and validation efficiency for minimum temperature records

In Figure 15, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Cheffa climate station R2 and Nash model computed to be 0.96 and 0.93 respectively, on annual precipitation level. And, both regression models have a value very close to 1 for nine months[26].

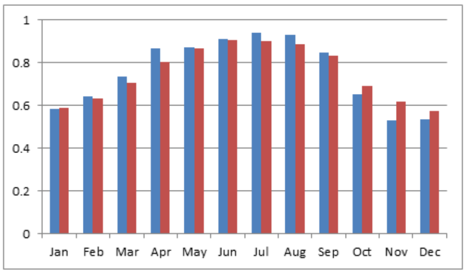
In validation process, for Cheffa climate station R2 and Nash model computed to be 0.97 and 0.96 respectively, on annual precipitation level. This implies, as indicated in Figure 16, for few months the model overestimates while for the most months the model exhibited good validation efficiency.

In the above Figure 17, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Mille climate station R2 and Nash model computed to be 0.98 and 0.93 respectively, on annual precipitation level [27]. And, each regression models have a value very close to 1 for nine months.



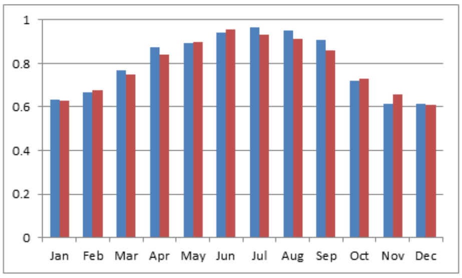
R2	Nash Sutcliffe model Efficiency coefficient
0.90	0.8

Figure 14. Maximum Temperature over Diredawa: Observed versus validated averaged over 12 months (2000-2016)



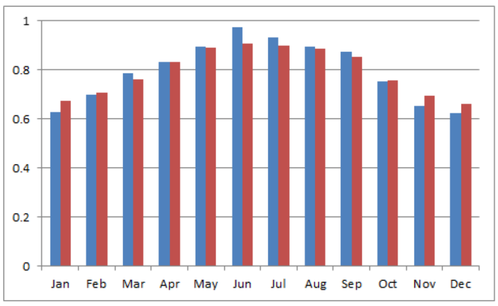
R2	Nash Sutcliffe model Efficiency coefficient
0.96	0.93

Figure 15. Minimum Temperature over Cheffa: Observed versus calibrated averaged over 12 months (1983-1999)



R2	Nash Sutcliffe model Efficiency coefficient
0.97	0.96

Figure 16. Minimum Temperature over Cheffa: Observed versus validated averaged over 12 months (2000-2016)



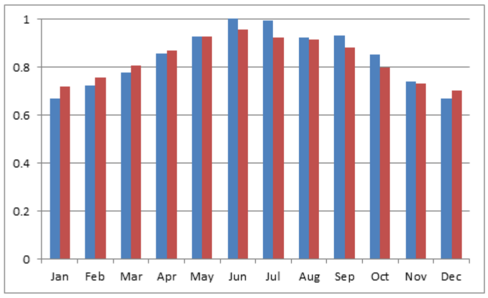
R2	Nash Sutcliffe model Efficiency coefficient
0.98	0.93

Figure 17. Minimum Temperature over Mille: Observed versus calibrated averaged over 12 months (1983-1999)

In the above Figure 18, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Mille climate station R2 and Nash model computed to be 0.93 and 0.88 respectively, on annual precipitation level [28]. And, each regression models have a value very close to 1 for nine months.

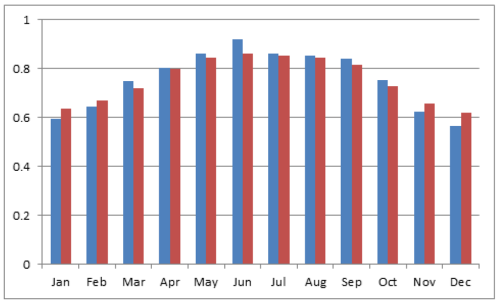
In the above Figure 19, months run from 1 to 12 on the X-axis and 0 to 1 on Y-axis. Between the observed and calibrated data, for Diredawa climate station R2 and Nash model computed to be 0.97 and 0.93 respectively, on annual precipitation level. And, each regression models have a value very close to 1 for nine months.

In validation process, for Diredawa climate station R2 and Nash model computed to be 0.96 and 0.84 respectively, on annual precipitation level. This implies, as indicated in Figure 20, for few months the model overestimates while for the most months the model exhibited good validation efficiency[29].



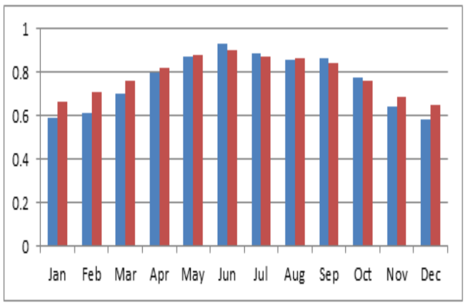
R2	Nash Sutcliffe model Efficiency coefficient
0.93	0.88

Figure 18. Minimum Temperature over Mille: Observed versus validated averaged over 12 months (2000-2016)



R2	Nash Sutcliffe model Efficiency coefficient
0.97	0.93

Figure 19. Minimum Temperature over Diredawa: Observed versus calibrated averaged over 12 months (1983-1999)



R2	Nash Sutcliffe model Efficiency coefficient
0.96	0.84

Figure 20. Minimum Temperature over Diredawa: Observed versus calibrated averaged over 12 months (1983-1999)

Table 1. Summary of Climate change scenario model calibration and validation over Lower Awash River Basin.

Stations		Cheffa			Mille			Diredawa			Average over Lower Awash River Basin		
Climate Parameters		Precipitation	Max. Temp	Min. Temp	Precipitation	Max. Temp	Min. Temp	Precipitation	Max. Temp	Min. Temp	Precipitation	Max. Temp	Min. Temp
R^2	Calibration	0.7	0.73	0.96	0.51	0.93	0.98	0.55	0.88	0.97	0.59	0.85	0.97
	Validation	0.65	0.72	0.97	0.42	0.91	0.93	0.5	0.9	0.96	0.52	0.84	0.95
Nash model Efficiency	Calibration	0.7	0.98	0.93	0.44	0.88	0.93	0.5	0.85	0.93	0.55	0.9	0.93
	Validation	0.66	0.98	0.96	0.41	0.84	0.88	0.41	0.8	0.84	0.5	0.87	0.89

Summary I

The following summary table provides the model strength during calibration and validation. As shown on the tabular data below, the model relatively could capture strongly in replicating the data in calibration periods in the case of all parameters, being the validation value nearly equal.

Compared to the minimum and maximum temperature, the precipitation could not be able to replicate the observed data (Table 1). This is due to high variability associated to nature of precipitation and the current climate models could not fully capture spatial and temporal variability of precipitation. Analogous to similar studies, in this study rainfall prediction exhibited a larger degree of uncertainty than that of temperature. In case of maximum and minimum temperature, all the three climate stations, in common, except on June the calibration strength demonstrated good to excellent with corresponding validation value; but on other months the result varies station to station [30]. In general, with this condition, the model could exhibit the maximum efficiency value in replicating the observed data and simulating climate generation over each station and/or over Lower Awash River basins in combined effect.

Climate change scenario generation over each climate stations in lower awash river basin

Under this section, climate change anticipation is compared with the baseline period in terms of precipitation and temperature anomaly (normalized standardized deviation). The anomaly is computed based on Rcp2.6, Rcp4.5 and Rcp8.5 carbon dioxide concentration pathways for each climate change scenario period: 2020, 2050 and 2080 [31].

Precipitation scenario

Figure 21 shows that based on Rcp2.6 concentration pathway on 2020s, for Cheffa climate station, the precipitation exhibited a decrease up to 10% from the mean on some months, an increase on few months and very minimal change on most of the months. In season wise and annual outlook, the model output showed a slight decrease in Rainfall amount (<5%) on Winter, a slight increase (around 5%) on Spring and insignificant (or virtually no change) on Summer and annual mean [32]. While, for the period 2050s and 2080s the model projected an increase more than 10% from the mean for several months, but no anticipation is exhibited by the model in Rainfall amount decline. Comprehensively, for these two periods the result revealed more or less above 20% increase on Winter and Spring as compared to seasonal average; however on Summer and annual level the possibility in precipitation is found to be moderate rise (<10%).

Figure 22 shows that based on Rcp4.5 concentration pathway on 2020s, for Cheffa climate station, the precipitation exhibited a decrease below 10% from the mean on months of January, February and March, a slight increase on the remaining. In season wise and annual outlook, the model output showed a slight increase in Rainfall amount (about 5%) on Winter, a slight increase (around 5%) on Spring and insignificant (or virtually no change) on Summer and annual mean. While, for all months, seasons and annual case the model projected an increase more than 10% and 20% from the mean for the period 2050s and 2080s, respectively. But, on both periods the deviation on Winter and Spring is very pronounced compared to Summer and annual mean[33]. Unlike Rcp2.6 the model simulation demonstrated a higher deviation in Rainfall amount on 2080s than 2050s.

Figure 23 shows that based on Rcp8.5 concentration pathway on 2020s, for Cheffa climate station, the precipitation exhibited a decrease (below 10%) from the mean for some months, an increase on few months and very minimal or insignificant change on other months [34]. Similar to Rcp4.5, the model output showed a slight increase in Rainfall amount (about 5%) on Winter, a slight decrease (around 5%) on Spring and insignificant (or virtually no change) on Summer and annual mean. Likewise, for all months, seasons and annual case the model projected, on average, an increase more than 10% and 20% from the mean for the period 2050s and 2080s, respectively [35]. Again, on both periods the deviation on Winter and Spring is very pronounced compared to Summer and annual mean.

Figure 24 shows that based on Rcp2.6 concentration pathway on 2020s, for Diredawa climate station, the precipitation exhibited a decrease (below 5%) from the mean on few months, up to 5% increment on the of the months, seasons and annual base. While, on average, the model projected an increase more than 10% from the mean for several months and a Rainfall amount decline up to 10% on few months for the period 2050s and 2080s, respectively. Analogues to Cheffa climate station, the period 2050s relatively showed a higher rainfall deviation possibility than 2080s for most of the months based on Rcp2.6 carbon dioxide concentration pathway [36].

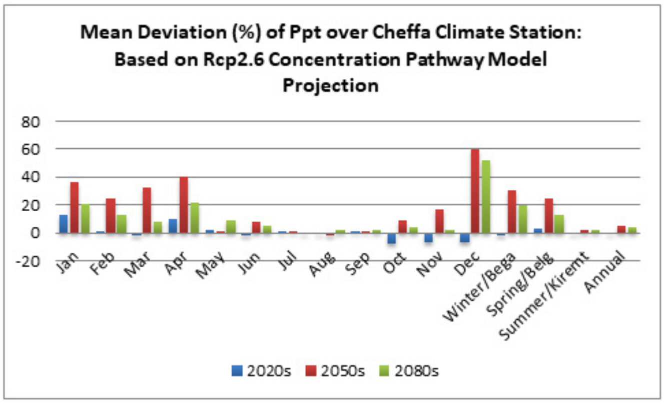


Figure 21. Mean Deviation (%) of precipitation over cheffa climate station: Rcp2.6 Concentration Pathway

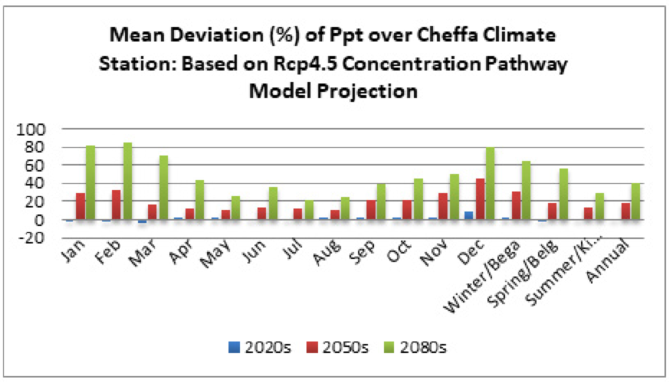


Figure 22. Mean Deviation (%) of precipitation over cheffa climate station: Rcp4.5 Concentration Pathway

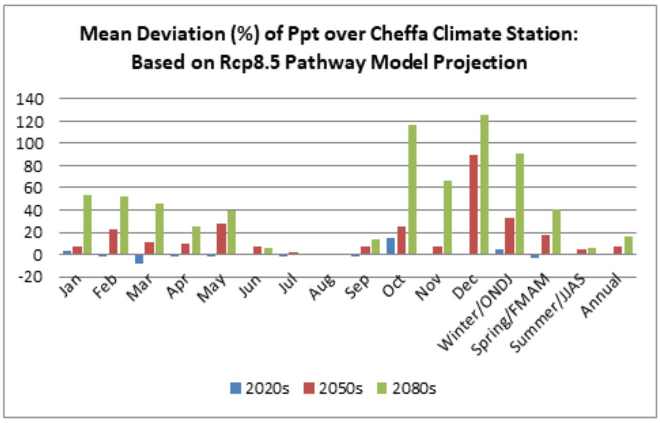


Figure 23. Mean deviation (%) of precipitation over cheffa climate station: Rcp8.5 concentration pathway

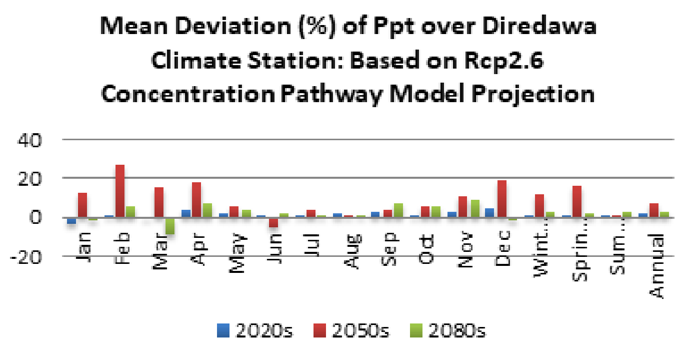


Figure 24. Mean deviation (%) of precipitation over diredawa station: Based on Rcp2.6 concentration pathway.

Figure 25 shows that based on Rcp4.5 concentration pathway on 2020s, for Diredawa climate station, the precipitation projected to decrease about 5% from the mean only on January; but there is anticipation that a slight increase to exist, in amount, on the remaining months, seasons and annual level. On other hand, for all months, seasons and annual case, on average, the model projected an increase up to 10% and beyond compared to the baseline for the period 2050s and 2080s, respectively [37]. Except Winter, on both periods the deviation on the rest of the seasons and annual average is almost equivalent. Again over this climate station also, unlike Rcp2.6 the model simulation demonstrated a higher deviation in Rainfall amount on 2080s than 2050s, on all months and seasons.

Figure 26 shows that based on Rcp8.5 concentration pathway on 2020s, for Cheffa climate station, the precipitation exhibited a decrease (below 10%) from the mean on months like January, February and March, an increase on few months and very minimal or insignificant change on other months[38]. On this period, similar to Rcp4.5, the model output showed a slight increase in Rainfall amount (about 5%) on Winter, a slight decrease (nearly 5%) on Spring and insignificant (or virtually no change) on Summer and annual mean[39]. Whereas, for all months, seasons and annual case the model projected, on average, an increase more than 10% and 20% from the mean for the period 2050s and 2080s, respectively. Based on Rcp8.5, the modeled precipitation, all in all, showed very parallel simulation result compared to Cheffa climate station, in case of both: all periods (2020s, 2050s and 2080s) and months, seasons and annual condition.

Figure 27 shows that based on Rcp2.6 concentration pathway on 2020s, for Mille climate station, the precipitation exhibited a decrease up to 5% from the mean on some months, an increase on few months and very minimal change on most of the months. In season wise and annual outlook, the model output showed a slight decrease in Rainfall amount (below<5%) on Winter and Summer and a slight increase (around 5%) on Spring and insignificant (or nearly no change) on annual mean. While, for the period 2050s and 2080s the model projected an increase more than 5% from the mean for several months a slight decrease on few months; but for 2050s no anticipation is exhibited by the model in Rainfall amount decline. Moreover, on all seasons the model projection demonstrated there is a chance of rise in precipitation for these two periods [40]. On Winter and Spring seasons the deviation was higher in 2050s than in 2080s although the reverse happened on Summer and annual level. The last these two

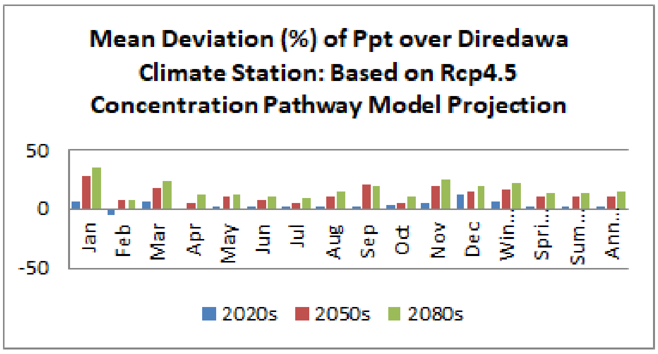


Figure 25. Mean deviation (%) of precipitation over diredawa station: based on rcp4.5 concentration pathway.

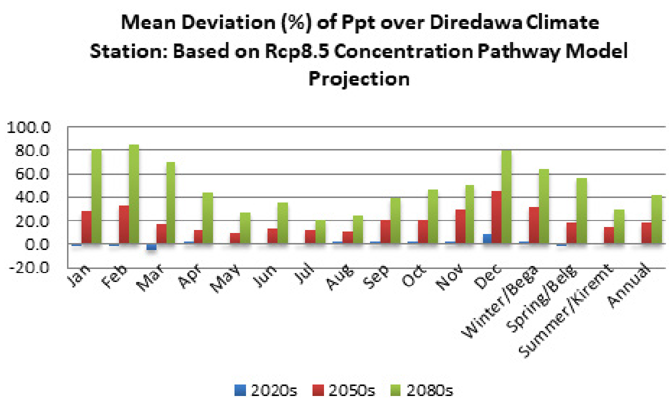


Figure 26. Mean Deviation (%) of precipitation over Diredawa station: Based on Rcp8.5 concentration pathway.

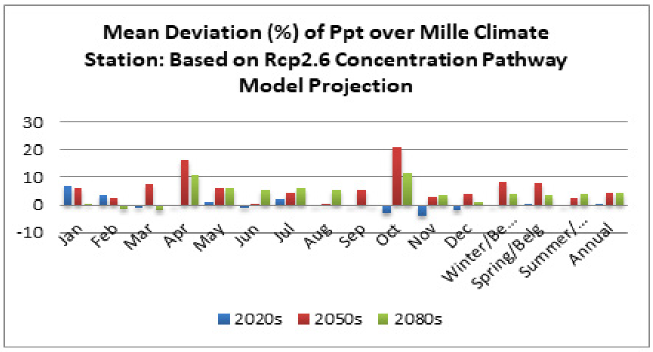


Figure 27. Mean Deviation (%) of precipitation over Mille Station: Based on Rcp2.6 Concentration Pathway.

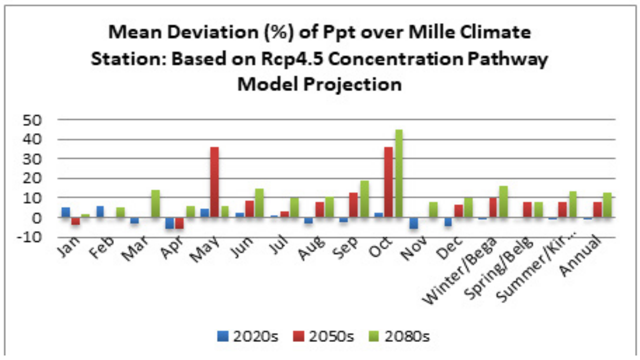


Figure 28. Mean Deviation (%) of precipitation over Mille station: Based on Rcp4.5 concentration pathway

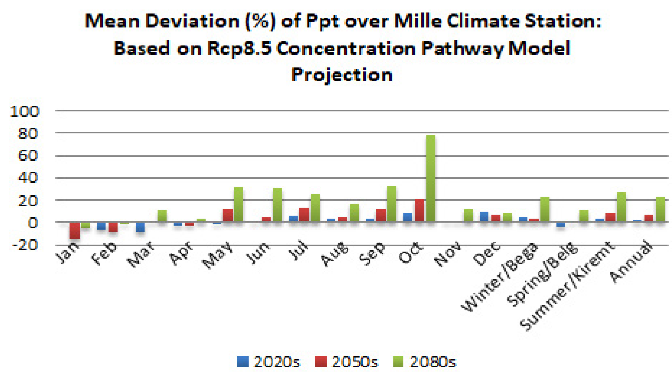


Figure 29. Mean Deviation (%) of precipitation over Mille station: Based on Rcp8.5 concentration pathway

facts go almost in parallel with the result stated for Cheffa and Diredawa climate stations based on Rcp2.6 weather generation.

Figure 28 shows that based on Rcp4.5 concentration pathway on 2020s, for Mille climate station, the precipitation exhibited a decrease below 10% from the mean on some months, increase on the others. On all seasons, there is insignificant up to a very slight increase in precipitation amount as observed from the model output [41]. Except few months in 2050s, the Rainfall is expected to increase, on average on most of months and all seasons, more or less above 5% and 10% in 2050s and 2080s, respectively. Also over this climate station alike to Cheffa and Diredawa, the deviation is observed to be relatively greater in 2080s than 2050s on most of the months and seasons. This fact is based on the result obtained with Rcp4.5 differing from Rcp2.6 climate change projection scenario.

Figure 29 shows that based on Rcp2.6 concentration pathway on 2020s, for Mille climate station, the precipitation exhibited an increase and a decrease up to 10% from the mean on different months and very minimal or insignificant change on few months. Except a decrease on Spring, a slight increase was observed on the remaining seasons and annual case. In 2050s, there is up to 20% expectation in precipitation decline for few months and 20% rise from the mean on the rest of the months. While, in 2080s the precipitation anomaly took similar pattern to 2050s deviation from the monthly mean except that the magnitude in rise of Rainfall amount was beyond 20% on average in the former period [42]. In case of seasons, there was no observation in decline on all seasons and the rise in precipitation, analyzed with SDSM climate change projection model, evaluated to be around 10% and 20% on average in 2050s and 2080s, respectively. When comparing amongst periods, also over this climate station, 2080s found to experience the highest precipitation change (an increase in most of the months and seasons from the mean and a decrease on certain times). However, this fact is verified for all the stations with Rcp8.5 and Rcp4.5 unlike Rcp2.6 which let the highest change in precipitation to be anticipated in 2050s.

Maximum temperature scenario

Figure 30 shows that based on Rcp2.6 concentration pathway on 2020s, for Cheffa climate station, the maximum temperature, except a decrease on January and June, exhibited a slight rise on the rest of the months and seasons. While, for the period 2050s and 2080s the model projected an increase in maximum temperature on all months and seasons[43]. Similar to precipitation scenario, the period 2050s expected to experience the highest difference/anomaly (normalized standard deviation) in maximum temperature based on Rcp2.6 carbon dioxide concentration pathway.

Figure 31 shows that based on Rcp4.5 concentration pathway, for Cheffa climate station, the maximum temperature exhibited a slight to moderate rise in 2020s, 2050s and 2080s on all months and seasons. But, with Rcp4.5, unlike to Rcp2.6 the period 2080s estimated to experience the maximum rise in daily maximum temperature record [44]. This result is analogous to the precipitation change scenario projection over all the three stations, as discussed in starting from Figure 19 to 28.

Figure 32 shows that based on Rcp8.5 concentration pathway on 2020s, for Cheffa climate station, the maximum temperature, except a minimal decrease on March, exhibited a slight rise on the rest of the months and seasons[45]. While, for the period 2050s and 2080s the model projected an increase in maximum temperature on all months and seasons. Here again, similar to Rcp4.5 the period 2050s expected to experience the highest temperature difference/anomaly in daily maximum temperature records.

Figure 33 shows that based on Rcp4.5 concentration pathway, for

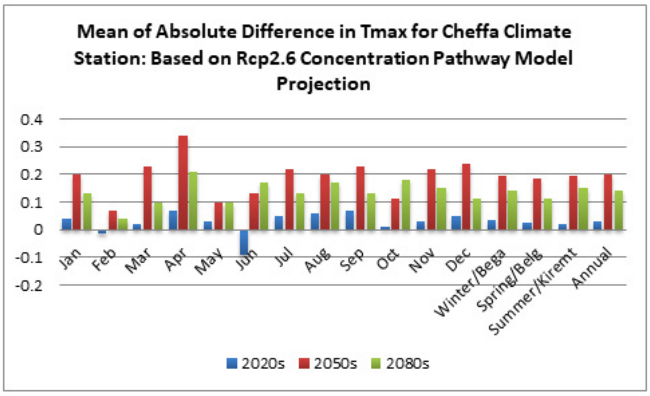


Figure 30. Mean of absolute difference in maximum temperature for Cheffa:Rcp2.6 concentration pathway

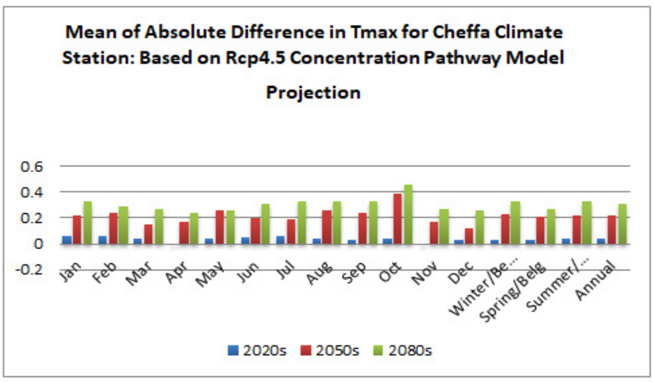


Figure 31. Mean of absolute difference in maximum temperature for Cheffa: Rcp4.5 concentration pathway

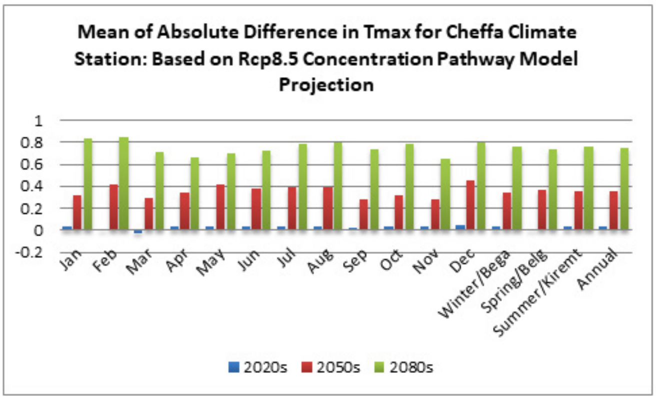


Figure 32. Mean of absolute difference in maximum temperature for Cheffa: Rcp8.5 concentration pathway

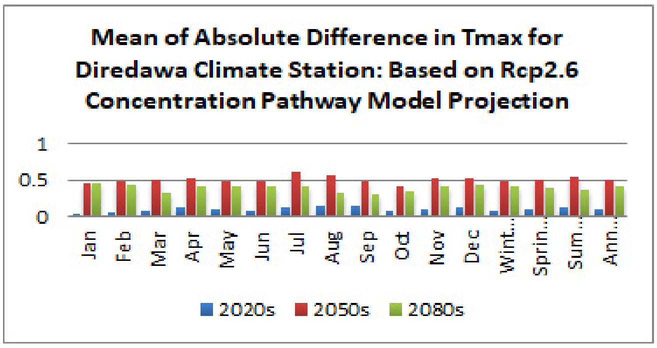


Figure 33. Mean of absolute difference in maximum temperature for Dire: Rcp2.6 concentration pathway

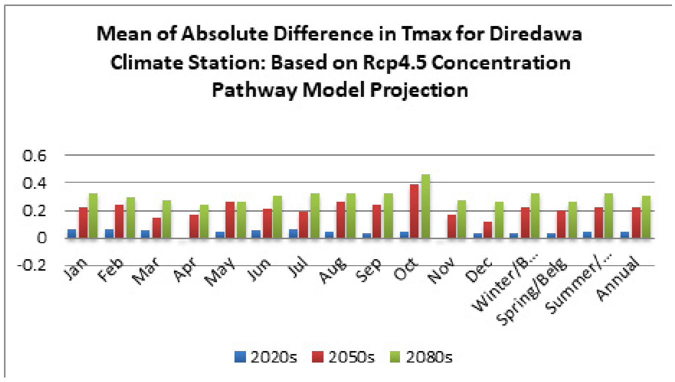


Figure 34. Mean of absolute difference in maximum temperature for Dire: Rcp4.5 concentration pathway

Diredawa climate station, the maximum temperature exhibited a slight to moderate rise in 2020s, 2050s and 2080s on all months and seasons. But, with Rcp2.6, the period 2080s estimated to experience the maximum rise in daily maximum temperature record. This result is analogous to the precipitation change scenario projection over all the three stations, as discussed in starting from (Figures 28 to 36).

Figure 34 shows that based on Rcp4.5 concentration pathway, for Diredawa climate station, the maximum temperature exhibited a slight to moderate rise in 2020s, 2050s and 2080s on all months and seasons. But, unlike to Rcp2.6 the period 2080s estimated to experience the maximum rise in daily maximum temperature record [46]. This result, except magnitude of the difference, is parallel to the change in maximum temperature prospect observed over Cheffa climate station under Rcp4.5.

Figure 35 shows that based on Rcp8.5 concentration pathway, for Diredawa climate station the maximum temperature, exhibited a slight to high rise in 2020s, 2050s and 2080s on all of the months and seasons[47]. But, the difference is notable in 2080s under Rcp8.5, over this station (on average increase about 2.5°C) compared to Cheffa climate station (on average increase up to 0.8°C).

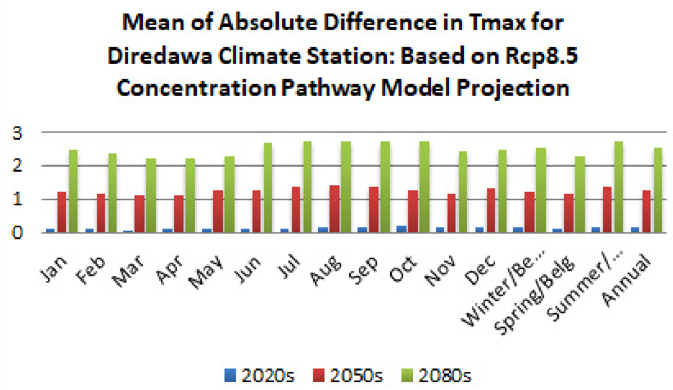


Figure 35. Mean of absolute difference in maximum temperature for Dire: Rcp8.5 Concentration Pathway

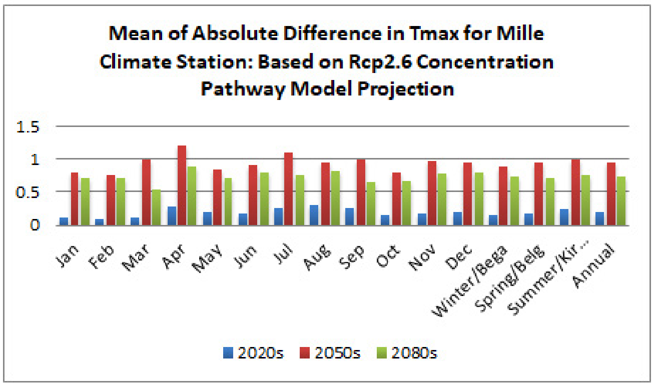


Figure 36. Mean of absolute difference in maximum temperature for Mille: Rcp2.6 concentration pathway

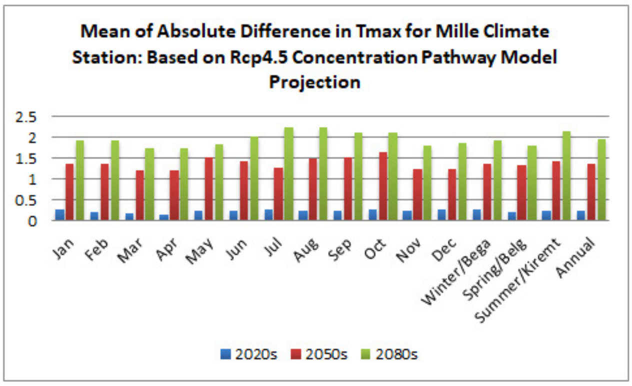


Figure 37. Mean of absolute difference in maximum temperature for Mille: Rcp4.5 concentration pathway.

Figure 36 shows that based on Rcp4.5 concentration pathway, for Mille climate station the maximum temperature exhibited a slight to moderate rise in 2020s, 2050s and 2080s on all months and seasons. Likewise to Cheffa and Diredawa, under Rcp2.6, the period 2080s estimated to experience the maximum rise in daily maximum temperature record[48].

Figure 37 shows that based on Rcp8.5 concentration pathway, for Mille climate station the maximum temperature, exhibited a slight to high rise in 2020s, 2050s and 2080s on all of the months and seasons. Almost equivalent to the situation observed over Diredawa under Rcp8.5, the difference is notable in 2080s under Rcp4.5 over this station (on average increase about 2.0°C).

Figure 38 shows that based on Rcp8.5 concentration pathway, for Mille climate station the maximum temperature, exhibited a slight to high rise in 2020s, 2050s and 2080s on all of the months and seasons. Over this station also, under Rcp8.5 model projection, the difference in daily maximum temperature observed to reach, on average, about 4.0°C and 2.0°C in 2080s and 2050s, respectively [48].

When season wise change in maximum temperature prospect is considered, the Summer is anticipated to experience in the maximum

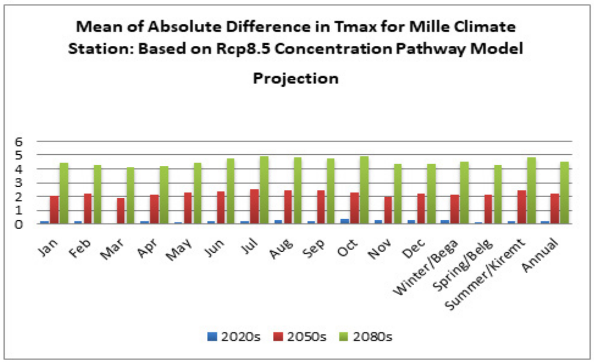


Figure 38. Mean of absolute difference in maximum temperature for Mille: Rcp8.5 concentration pathway.

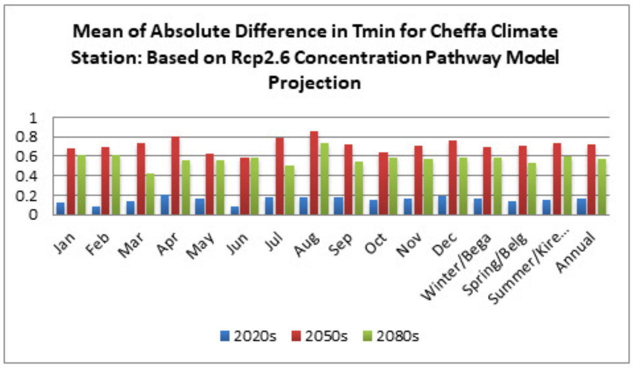


Figure 39. Mean of absolute difference in minimum temperature for Cheffa: Rcp2.6 concentration pathway

deviation (rise in most cases) in daily maximum temperature, and Winter and Spring come next in order of magnitude. This condition is observed more or less the same over all the three stations, in allperiods (2020s, 2050s and 2080s) and under Rcp2.6, Rcp4.5 and Rcp8.5 [49].

Minimum temperature scenario

Figure 39 shows that, under Rcp2.6, for Cheffa climate station the daily minimum temperature exhibited a slight to moderate rise in 2020s, 2050s and 2080s on all of the months and seasons[50]. Analogous to precipitation and maximum temperature, the prospect in the change of daily minimum temperature is greater in 2050s under Rcp2.6, relatively than the other two periods.

Figure 40 shows Mean of Absolute Difference in minimum temperature for Cheffa: Rcp4.5 Concentration Pathway ows that, under Rcp4.5, for Cheffa climate station the daily minimum temperature exhibited a slight to moderate rise in 2020s, 2050s and 2080s on all of the months and seasons. But the magnitude of the deviation is greater than the result observed under Rcp2.6. On other hand the maximum variance is observed to become in 2080.

Figure 41 shows that, under Rcp8.5, for Cheffa climate station the daily minimum temperature exhibited a slight to high rise in 2020s, 2050s and 2080s on all of the months and seasons. But in this case the magnitude of the deviation almost doubles (around 2.0°C and 4.0°C) in 2050s and 2080s, respectively [51].

Figure 42 shows that, under Rcp2.6, for Diredawa climate station the daily minimum temperature exhibited a slight to moderate rise in 2020s, 2050s and 2080s on all of the months and seasons. Under Rcp2.6, this result is observed in the same manner and equivalent to the condition expected over Cheffa climate station.

Figure 43 shows that, under Rcp4.5, for Diredawa climate station the daily minimum temperature exhibited a slight to high rise in 2020s, 2050s and 2080s on all of the months and seasons. Alike Cheffa Climate station, the magnitude of the deviation is greater than the result observed under Rcp2.6; and the maximum variance is observed to become in 2080s.

Figure 44 shows that, under Rcp8.5, for Diredawa climate station the daily minimum temperature exhibited a slight to high rise in 2020s, 2050s and 2080s on all of the months and seasons. Like to Cheffa, in this case the magnitude of the deviation on average doubles (around 2.0°C and 4.0°C) in 2050s and 2080s, respectively.

Figure 45 shows that, under Rcp2.6, for Mille climate station the daily minimum temperature exhibited a slight to moderate rise in 2020s, 2050s and 2080s on all of the months and seasons. Under Rcp2.6, this result is observed in the same manner and equivalent to the condition expected over Cheffa and Diredawa climate station.

Figure 46 shows that, under Rcp4.5, for Mille climate station the daily minimum temperature exhibited a slight to high rise in 2020s, 2050s and 2080s on all of the months and seasons. Alike Cheffa and Diredawa Climate station, the magnitude of the deviation is greater than the result observed under Rcp2.6; and the maximum variance is observed to become in 2080s.

Figure 47 shows that, under Rcp8.5, for Mille climate station the daily minimum temperature exhibited a slight to high rise in 2020s, 2050s and 2080s on all of the months and seasons. Like to Diredawa, in this case the magnitude of the deviation on average doubles (around 2.0°C and 4.0°C) in 2050s and 2080s, respectively.

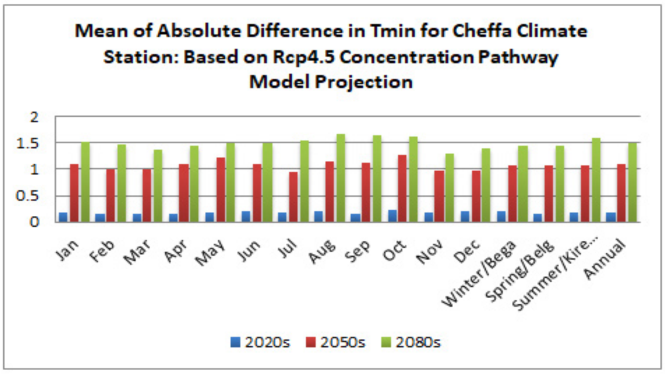


Figure 40. Mean of absolute difference in minimum temperature for Cheffa: Rcp4.5 concentration pathway

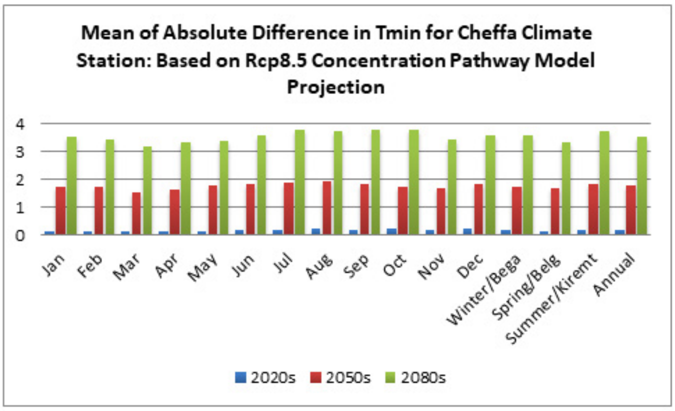


Figure 41. Mean of absolute difference in minimum temperature for Cheffa: Rcp8.5 concentration pathway.

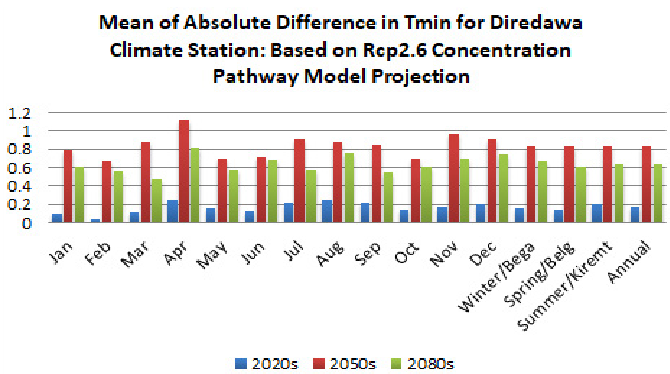


Figure 42. Mean of Absolute Difference in minimum temperature for Dire: Rcp2.6 Concentration Pathway

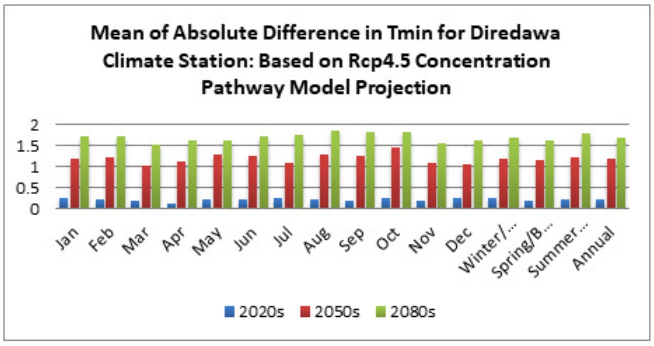


Figure 43. Mean of absolute difference in minimum temperature for Dire: Rcp4.5 concentration pathway

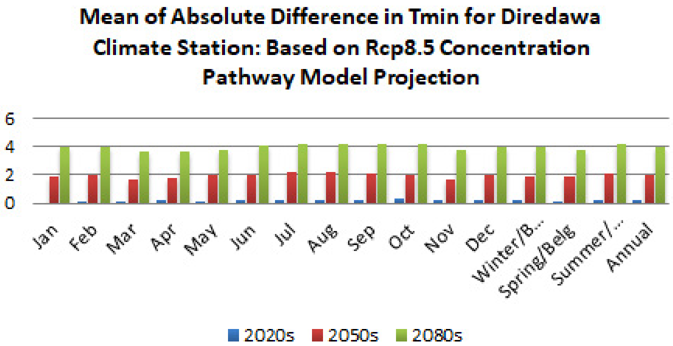


Figure 44. Mean of Absolute Difference in minimum temperature for Dire: Rcp8.5 Concentration Pathway

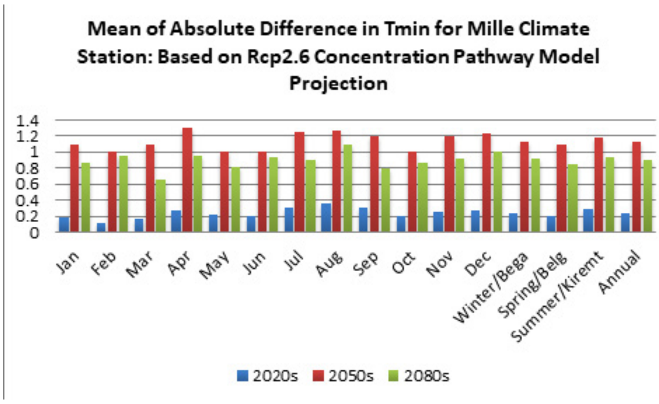


Figure 45. Mean of absolute difference in minimum temperature for Mille: Rcp2.6 concentration pathway.

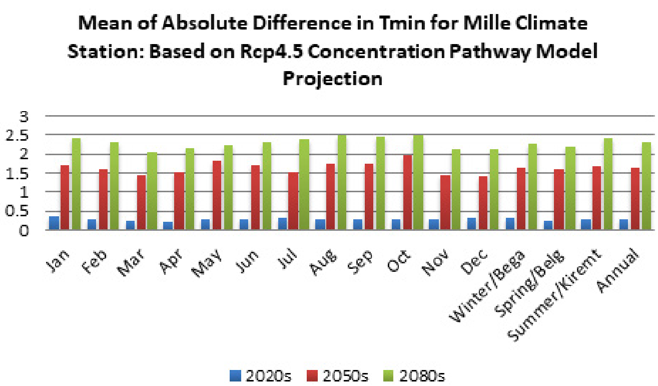


Figure 46. Mean of Absolute Difference in minimum temperature for Mille: Rcp4.5 Concentration Pathway.

When season wise change in minimum temperature prospect is considered, alike daily maximum temperature, the Summer season is anticipated to experience in the maximum deviation (rise in most cases) in daily minimum temperature, and Winter and Spring come next in order

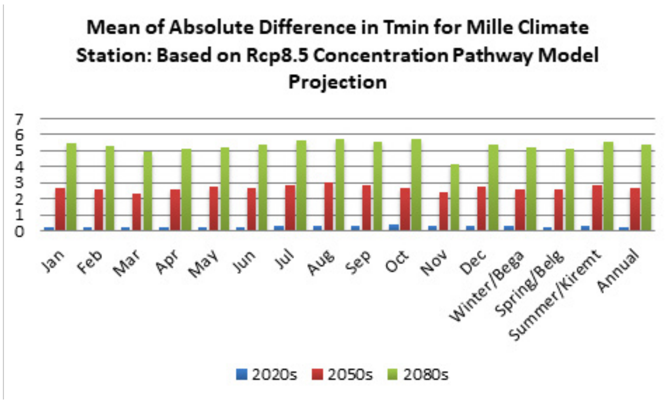


Figure 47. Mean of absolute difference in minimum temperature for Mille: Rcp8.5 concentration pathway

of magnitude. This also means that in Summer season the number of hot nights is likely increase, as the model presented the result in the downscaling climate change scenario treated in (dealt within) this study[52]. This condition is observed more or less the same over all the three stations, in all periods (2020s, 2050s and 2080s) and under Rcp2.6, Rcp4.5 and Rcp8.5.

Climate change scenario generation in lower awash river basin averaged over the three Stations: Based on Rcp2.6, Rcp4.5 and Rcp8.5

Precipitation outlook over lower awash river basin: To provide summarized information about precipitation scenario over Lower Awash River basin, the condition over the three climate stations is averaged. And, it is with this data that meaningful information about the precipitation discharge in to Lower Awash River basin could be forwarded after performing climate change scenario downscaling analysis by the model applied throughout this study[53]. Thus, this data in aggregate of climate stations over Lower Awash River basin could adequately answer the effect of climate change that it is expected to potentially affect sectors like water resources (surface runoff and underground), agriculture and so on.

Figure 48 shows that based on Rcp2.6 concentration pathway on 2020s, for Lower Awash River basin, the precipitation exhibited a decrease up to 5% from the mean on some months, an increase on few months and minimal/slight change on most of the months. In season wise and annual outlook, the model output showed a slight decrease in Rainfall amount on Winter, a slight increase on Spring and insignificant (or virtually no change) on Summer and annual mean [54]. While, for the period 2050s and 2080s the model projected an increase more than 10% (being the highest 25% on December) and 5% (being the highest 15% on the same month) from the mean for several months, respectively. But no significant anticipation is exhibited by the model in Rainfall amount decline. Further, for these two periods the result revealed an increase above 20% in 2050s and above 5% increase in 2080s on Winter and Spring, respectively as compared to seasonal average. However on Summer and annual level the rising possibility of precipitation is found to be moderate rise (up to 5% in 2050s and below that in 2080s)[55]. The result which was observed over each climate station is also displayed over Lower Awash River basin in cumulative average; that is under Rcp2.6 the period 2050s is anticipated to get the major change in precipitation scenario on most of the months, seasons and annual case.

Figure 49 shows that based on Rcp4.5 concentration pathway on 2020s for Lower Awash River basin the precipitation, except few months (March and April) exhibited an increase up to 5% on the rest of the months, compared to historical mean (baseline). In season wise and annual outlook, the model output showed a slight increase in Rainfall amount on all seasons and annual total. While, for the period 2050s and 2080s the model projected an increase more than 10% (being the highest above 20% on December) and 15% (being the highest 35% on December and January) compared to the mean for several months, respectively. Like in the case of Rcp2.6, for these two periods the result revealed an increase above 10% in 2050s and above 25% increase in 2080s on all seasons and annual case. Unlike to Rcp2.6 the magnitude of the change in precipitation is evaluated to be the maximum in the period 2080s. This result, seen over Lower Awash River basin in cumulative average, is found to be analogues with the ones achieved over each climate station[56].

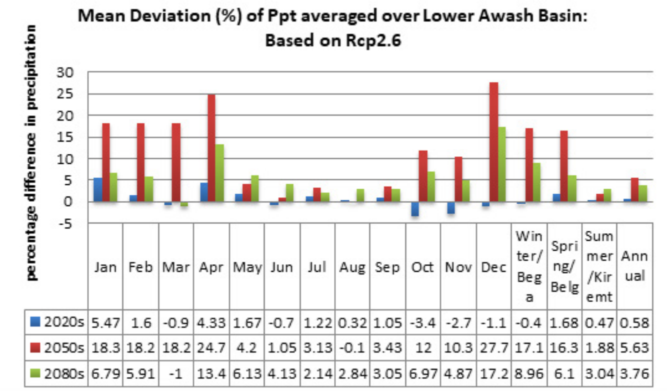


Figure 48. Mean Deviation (%) of precipitation averaged over three stations in Lower Awash Basin: Rcp2.6.

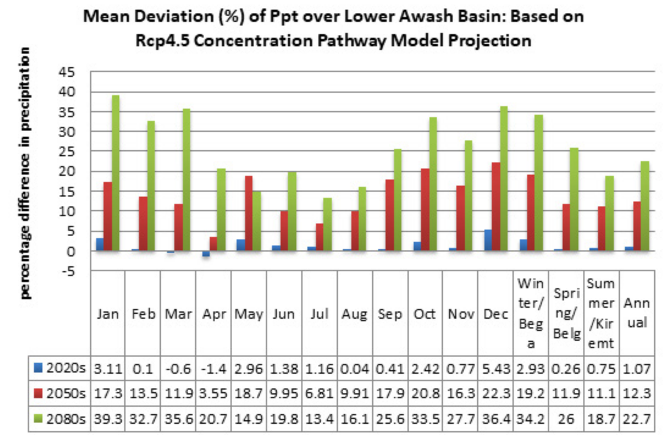


Figure 49. Mean Deviation (%) of precipitation averaged over three stations in Lower Awash Basin: Rcp4.5

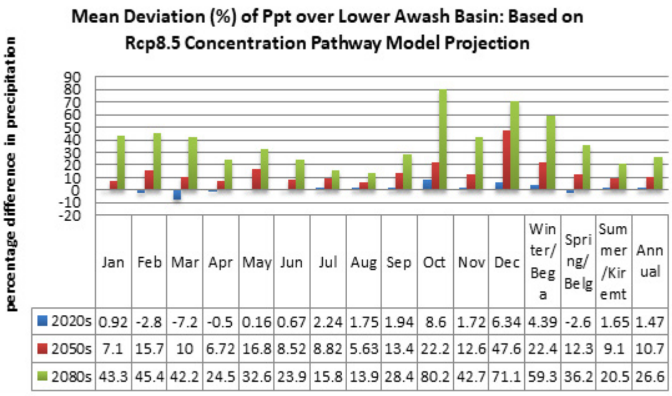


Figure 50. Mean Deviation (%) of precipitation averaged over three stations in Lower Awash Basin: Rcp8.5

Figure 50 shows that based on Rcp8.5 concentration pathway on 2020s for Lower Awash River basin the precipitation, except a minor (decrease in Spring) difference, scenario result is similar to the case under Rcp4.5. Again, with the exception of higher magnitude estimated on October, December and several corresponding months and seasons, for the period 2050s and 2080s the model presented same output as in the case of Rcp4.5.

Summary II

A. What is observed, in general, among Climate Change Scenario Periods versus Rcps?

- Over each climate station, based on Rcp8.5 and Rcp4.5, the model simulation demonstrated a higher deviation in Rainfall amount on 2080s than 2050s and 2020s, on all months and seasons. But, unlike the previous Rcp2.6, the period 2050s relatively showed a higher rainfall deviation possibility than

2080s and 2020s for most of the months based on Rcp2.6 carbon dioxide concentration pathway. In both the above cases, the same is observed over Lower Awash River basin catchment areas in aggregate.

- The same is observed for maximum and minimum temperature scenario with the aforementioned two statements (refer to point 1 under this summary).

B. What is expected in Precipitation Projection Scenario?

- With this fact, on monthly and annual base minimal (insignificant) to high deviation is anticipated on 2020s, 2050s and 2080s in case of the three climate parameters, except under Rcp2.6. And, an increase in precipitation scenario is found to be up to 40% over Diredawa and Cheffa climate stations on annual case.
- In addition, in the precipitation scenario case, most of the months exhibited an increase (+5% to +100%) and few months a decrease (less than 5%). And, the situation (increase or decrease) considerably varies month to month among the three climate stations under consideration; this indicated that, similar to observed historical records, the nature of temporal and spatial Rain fall variability is also high in future climate change scenarios.

C. What is expected in Maximum and Minimum Temperature Projection Scenario?

- While, in case of maximum temperature, the model output demonstrated up to 4.0°C, 2.5°C and 0.8°C increase for over Mille, Diredawa and Cheffa on annual base, respectively [57]. In similar condition, the model output for minimum temperature demonstrated up to 5.0°C, 4.0°C and 3.5°C increase for over Mille, Diredawa and Cheffa, on annual base, respectively. In comparison, the minimum temperature showed an exceeding value in rise than the maximum temperature, almost in all scenario periods (2080s, 2050s and 2020s). This, finding a special summary can be drawn that the changes from the mean are peak/magnified over lowlands than high lands (Mille 488 m; Diredawa 1188 m and Cheffa 1466 m altitude) in descending order magnitude. This is true for minimum temperature and precipitation also.
- Unlike to precipitation scenario, for maximum and minimum temperature the model result in the projected deviation showed almost parallel and similar pattern among the three climate stations, on monthly mean. Here also indicated that, similar to observed historical records, the nature of temporal in maximum and minimum temperature is also low in future climate change scenarios.
- When season wise change in maximum temperature prospect is considered, the Summer is anticipated to experience in the maximum deviation (rise in most cases) in daily maximum temperature, and Winter and Spring come next in order of magnitude [58]. This condition is observed more or less the same over all the three stations, in all periods (2020s, 2050s and 2080s) and under Rcp2.6, Rcp4.5 and Rcp8.5.
- When season wise change in minimum temperature prospect is considered, alike daily maximum temperature, the Summer season is anticipated to experience in the maximum deviation (rise in most cases) in daily minimum temperature, and Winter and Spring come next in order of magnitude. This also means that in Summer season the number of hot nights is likely increase, as the model presented the result in the downscaling climate change scenario treated in (dealt within) this study. This condition is observed more or less the same over all the three stations, in all periods (2020s, 2050s and 2080s) and under Rcp2.6, Rcp4.5 and Rcp8.5.

D. What is expected over Lower Awash River Basins: Precipitation Outlook?

1. Precipitation Scenario with Rcp2.6:

- Monthly Prospects:- With Rcp2.6 concentration pathway on 2020s, for Lower Awash River basin in areal average, the precipitation exhibited a decrease up to 5% from the mean on some months, an increase on few months and minimal/slight change on most of the months. While, for the period 2050s and 2080s the model projected an increase more than 10% (being the highest 25% on December) and 5% (being the highest 15% on the same month) compared to the mean for several months, respectively. But no significant anticipation is exhibited by the model in Rainfall amount decline.
- Seasonal and Annual Prospects:- With Rcp2.6 concentration pathway for lower Awash River basin in aggregate, on the period 2020s, the model output showed a slight decrease in Rainfall amount on Winter, a slight increase on Spring and insignificant on Summer and annual mean. Further, with Rcp8.5, for the next two periods the result revealed an increase above 10% in 2050s and above 5% increase in 2080s on Winter and Spring, respectively as compared to seasonal average,. However on Summer (20%) and annual level the rising possibility of precipitation is found to be moderate (above 20%).

2. Precipitation Scenario with Rcp4.5 & Rcp8.5:

- Monthly Prospects:- With Rcp4.5 concentration pathway on 2020s for Lower Awash River basin the precipitation, except few months (March and April) exhibited an increase up to 5% on the rest of the months, compared to historical mean (baseline). While, for the period 2050s and 2080s the model projected an increase more than 10% (being the highest above 20% on December) and 15% (being the highest 35% on December and January) compared to the mean for several months, respectively.
- Seasonal and Annual Prospects:- Based on Rcp4.5, in season wise and annual outlook, on the period 2020s, the model output showed a slight increase in Rainfall amount on all seasons and annual total. On the remaining two periods the result revealed an increase above 10% in 2050s and above 25% in 2080s on all seasons and annual case.
- Seasonal and Annual Prospects:- Based on Rcp8.5 concentration pathway on 2020s for Lower Awash River basin the precipitation, except a minor (decrease in Spring) difference, scenario result is observed similar to the case under Rcp4.5. Again, with the exception of higher magnitude estimated on October, December and several corresponding months and seasons, for the period 2050s and 2080s, the model presented same output as in the case of Rcp4.5.
- Generally, the result which was observed over each climate station is also displayed over Lower Awash River basin in cumulative average; that is under Rcp2.6 the period 2050s is anticipated to get the major change in precipitation scenario on most of the months, seasons and annual case.

Conclusion

Regarding model calibration and validation evaluation, in case of maximum and minimum temperature, almost all the nine climate stations, in common, except on very few months the model calibration strength demonstrated good to excellent efficiency with corresponding validation value. This implies, with this condition, the model could exhibit the maximum efficiency value in replicating the observed maximum & minimum data; and in simulating the climate change scenario generation over each station and/or over Awash River basins, in combination. Compared to the minimum and maximum temperature, the model could not be able to replicate the observed precipitation data. This is due to high variability and uncertainty associated to a nature of precipitation and the current climate models could not fully capture spatial and temporal variability of precipitation.

While dealing with climate change prospects, on some months and seasons a change in temperate ranges from a very minor rise/decrease to a large and significant increase in Rcp2.6, Rcp4.5 and Rcp8.5 in ascending order. Especially, significant change is observed on periods 2050s and 2080s. The same is happened in a case of precipitation. And, seasonal shifts in precipitation also observed on some climate stations. The preceding conditions are exhibited almost in all stations more or less with a little difference in magnitude or amount, as compared within station to station. When season wise change in minimum and maximum temperature prospect is considered, the Summer (cold and wet) season is anticipated to experience in the maximum or peak deviation (rise in most cases); and Winter(Bega: cold and dry) and Spring(Belg: hot and wet) come next in order of magnitude. This also means that in Summer season the number of hot nights and days are likely increase. Further, the rise in minimum temperature is anticipated to be larger than the maximum temperature. This condition is observed more or less the same over all the three stations, in all periods (2020s, 2050s and 2080s) and under each Rcp2.6, Rcp4.5 and Rcp8.5. However, in case of precipitation, under each Rcps the reverse is likely to happen; that means the result revealed an increase above 59% in 2050s and above 36% increase in 2080s on Winter and Spring, respectively as compared to seasonal average; and on Summer (20%) and annual level the rising possibility of precipitation is found to be moderate.

The other important finding observed in this study is that the climax or peak effect of the Climate Change is pronounced over lowlands than mid-land and highlands (Mille, Diredawa and Cheffa).

In general, the study revealed indications of extreme weather events which result in introducing increased climate variability on monthly, seasonal and inter-annual outlook, especially in precipitation (one time very dry and the other time very wet) and one time extremely hot the other time extremely cold. However, more or less, an increasing trend is observed for both precipitation and temperatures starting from 2020s to 2080s in all cases of Rcps and time frames (monthly, seasonal and annual). Further seasonal shift in precipitation patterns like changes in onset and cessation of rainy seasons, shortened or shrink of rainy season and changes in mode of seasonal rain fall pattern (bimodal to mono-modal and vice versa) are observed to occur in the anticipated future climate scenario.

What are the implications associated to the possible events and impacts followed to these investigated climate change Scenarios?

- Extreme weather events which result in introducing increased climate variability, especially in precipitation (one time very dry the other time very wet conditions).
- This increased variability in precipitation is associated to impacts followed then; e.g, frequent and intensified (elongated) droughts and frequent and intensified flood occurrence than ever, followed by damage and reservoirs sedimentation.
- Increased number of hot days and nights which result in discomfort weather and high evapotranspiration rate, increased rate of wild fires are other events & the associated impacts of the anticipated climate change scenario on the described periods.
- Another event anticipated to occur is seasonal shift in precipitation like: changes in onset and cessation rainy seasons; shortened/shrink of rainy season followed by elongated dry season; elongated rainy seasons followed by unseasonal rain; and changes in mode of seasonal rain fall pattern (bimodal to mono-modal and vice versa) are highly probable/likely.
- So, crop damages, pest and disease incidence & existence conducive condition for locust & malaria out break are other impacts of Climate change which are caused by unseasonal rain/ seasonal shifts in general.

The climate models used in downscaling from global and regional level to local level have their own limitations associated in. So, by considering this fact the results achieved with CanEsm2 model is generalized and concluded as the following.

In general, projected changes in temperature and precipitation extremes are likely to have moderate to significant negative impacts on various socioeconomic activities over the communities and natural ecosystems including animals existing over Lower Awash River Basin.

Recommendations

So, what are recommendations and suggestions to stand against the anticipated climate change effects are indicated below?

- Primarily, early warning & disaster response systems to climate change related impacts should be strengthened further in accordance and agreement to the climate change degree of extent.
- Thus, adjustment in socio-economic development like agricultural and agroforestry sectors, water & energy sectors and health care shall better take in to account.
- So, wise utilization and management practices in natural resource conservation and management shall be sustained through the following courses: apply effective and climate friendly practice in agriculture and energy development; deal and investigate additional choice of sustainable clean/renewable energy application and technologies; amend climate change, environmental change, Energy and Industrial related policies as appropriate and commit to actualize it.
- Therefore, enhancing and implementing suitable and innovative adaptation and mitigation options practices are advised to lessen the impacts of Climate change.

Thoroughly, areas over Lower Awash River Basins require close monitoring, planning and developing effective adaptation and mitigation strategies and preparing disaster prevention and response mechanisms against climate change impacts. Therefore, implementing the available adaptations and mitigations choices and dealing and investigating additional options are further required efforts to make them substantial and suitable throughout the socio-economic and development sectors like agricultural, water and health sectors. And, another recommendation in account of this study result is that prioritizing those low land areas which are going to be affected highly likely. So, early warning information about onset and cessation of rainy seasons and flood occurrence shall be strengthen and delivered to concerned bodies and communities, timely. In general, mitigation and adaptation of climate smart agriculture and effective and efficient utilization of water resource are recommended to lessen the impact of drought, flooding and reservoirs sedimentation.

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