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# Downscaling Future Temperature and Precipitation Values in Kombolcha Town, South Wollo in Ethiopia

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## Abstract

Whilst climate change is already manifesting in Ethiopia through changes in temperature and rainfall, its magnitude is poorly studied at regional levels. Therefore, the main aim of this study was statistically downscale of future daily maximum temperature, daily minimum temperature, and precipitation value in Kombolcha Town, South Wollo, in Ethiopia. For this the long term historical climatic data were collected from Ethiopian National Meteorological Agency for Kombolcha station and the GCM data were downloaded from the global circulation models of, the Canadian Second Generation Earth System Model from the link (http://climate scenarios.canada.ca/?page=dstsdi). For future climate data generation among the different downscaling techniques, the statistical down scaling method, a type of regression model was used and the variations of temperature (maximum and minimum) and precipitation in the town for annually and seasonally condition were analysis based on the base of the 2020s, 2050s and 2080s. In the future, relative to the observed mean value of annual rainfall in Kombolcha town, mean value of annual rainfall will decrease 1.36% - 7.03% for RCP4.5and 5.37% -13.8% for RCP8.5 emission scenarios in the last 21 century. Both maximum and minimum temperature of the town will be increased in the future time interval for both RCP4.5 and RCP8.5 emission scenarios. The rise in temperature will exacerbate the town maximum heat effects in warm seasons and decrease in precipitation is expected along with a possible risk of water supply scarcity due to a low level of water supply access and a high rate of urbanization.

**Keywords:** Downscaling • Kombolcha • Precipitation and temperature • Emission scenarios.

## Introduction

Global climate has changed over the last century mainly, due to anthropogenic factors [1]. Climate change is described as the most universal and irreversible environmental problem facing the planet Earth [2] and becoming one of the most threatening issues for the world today in terms of its global context and its response to environmental and socioeconomic drivers [3]. The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report observed an increase of 0.74 ± 0.18°C in mean annual global temperature [1]. According to [4] most scholars have agreed that the global annual average temperature is likely to be 2°C above pre-industrial levels by 2050. This may makes the world more intense rainfall, frequent and intense droughts, floods, heat waves, and other extreme weather events.

Africa is considered as the most vulnerable continent to climate change in the world [5]. According to AR4, it is very likely that all of Africa will warm up during this century and that, throughout Africa and in all seasons, the warming will be larger than the global annual mean warming [6]. According to future projections, precipitation and temperature will increase over Eastern Africa in the coming century [7]. It is predicted that the temperature in Africa continent will rise by 2 to 6°C over the next 100 years [8].

Regionally, in East Africa, studies indicate that in countries like Burundi, Kenya, Sudan, and Tanzania people are badly hit by the impacts of climate chang [9,10]. Temperature projections in the region indicates that, the median near-surface temperature in the 2080 to 2099 period will increase by 3°C to 4°C when it compared to the 1980 to 1999 period. It has to be underlined that this increase is about 1.5 times the projected global mean response [6]. Because of significant dependence on the agricultural sector for production, employment, and export revenues, Ethiopia is seriously threatened by climate change, which contributes to frequent drought, flooding, and rising average temperatures [11]. In the country, the daily temperature observations show significantly increasing trends in the frequency of hot days, are much larger increasing trends in the frequency of hot nights. The average number of 'hot' days per year increased by 73 (an additional 20% of days) between 1960 and 2003 [12]. In the country related with precipitation, consistent models' ensemble of different model, indicating increases in total precipitation occurring in 'heavy' events, and increases in the magnitude of one-day maxima and five-day maxima rainfall [13].

Whilst climate change is already manifesting in Ethiopia through changes in temperature and rainfall, its magnitude is poorly studied at regional levels [2]. This is because of that, the results of the temperature and precipitation data that obtained from meteorological observation of some regions are missing and limits the downscaling of future weather values from general circulation models. Now a time we can determine the consequences of climate change earlier and our self for necessary adaptation measures by simulate changes in climatic elements of the present and future from global general circulation models (GCMs) [12]. However, due to, coarse resolution of the GCM output it is difficult to apply the raw data of GCMs at a local scale, such as the watershed scale or points of emphasis of this study urban climate change without downscaling [14]. Therefore, in order to use the results of general circulation model to study the impact of climate change on a local scale, it is common to downscale and bring the results into the finest resolution. This can be done through the development of tools for downscaling GCM predictions of climate change to regional and local or station scales [15].

The Statistical Downscaling Model (SDSM) is a freely available tool that produces high resolution climate change scenarios result from GCMS for local scale climate change study [16]. The SDSM provides reasonably good results after calibration with NCEP predictor variables [1] and establish a relationship between past local climate and past GCM outputs and extend this relationship into the future, to generate future local climate series from future GCM output [17]. The projection of future climate value is critical information that is needed to assess the impact of potential climate change on human beings and on the natural environment [18]. It is also helpful for long-term planning development at both regional and national levels for mitigation and adaptation strategies of future climate change as, it gives opens space for a set of potential responses [19].

In Ethiopia, studies like, statistical downscaling for daily temperature and rainfall in South Wollo [20], the study of future changes in climate parameters in Amhara Regional State [2], future climate studies in northwestern Ethiopia for assessing the hydrological response of the Gilgel Abay River to climate change

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in the Lake Tana Basin [12], climate change impact on the Geba Catchment in Northern Ethiopia [21], GIS based quantification and mapping of climate change vulnerability hotspots in Addis Ababa [14], Impacts of Climate Change Under CMIP5 RCP Scenarios on the Hydrology of Lake Ziway Catchment [22], Impact of Climate Change on Hydrology of the Upper Awash River Basin [23], Impact of Climate Change on Evapotranspiration and Runoff in Awash basin [24] and Climate Change Impact on Water Resources in the Awash Basin [25] were conducted by using downscaling applications in different time intervals throughout all direction of the country to detect climate change impacts in agricultural and hydrological applications. But, applications of statistical downscaling of general circulation models for future time temperature and precipitation value estimation for industrial town of Kombolicha, South Wollo in Ethiopia has not been undertaken.

It is important to some large cities of East and North African [26,27] and Addis Ababa city in Ethiopia [14,18] use of downscaled results from GCMs to assess future projections and to identify adaptation measures were explored recently. Only a few studies are available for Kombolcha town, which differ in method and temporal scale from these studies [28] and [29]. So, in order to fill the above listed limitation by establish a relationship between past local climate and past GCM outputs and extend this relationship into the future time interval required scientific evidence on statistically downscaling of future temperature and precipitation values since, it is vital for policymakers, researcher, planner to formulate the adaptation and mitigation options of future temporal and spatial variation in the study area. Therefore, the main aim of this study was statistically downscale of future daily maximum temperature, daily minimum temperature, and precipitation value in Kombolcha Town, South Wollo, in Ethiopia.

# Materials and Methods

## Description of the study area

The study was conducted in Kombolcha town, which is found to the North East of Ethiopia in Amhara regional state of South Wollo Zone. The town is located in a range of altitudes and longitude between11°1'30"- 11°15'0" N latitude and 39°40'30" - 39 ° 49'30" E longitudes. It is one of the industrial towns in Amhara regional state of Ethiopia. Based on the 2007 national census conducted by the central statistical agency of Ethiopia (CSA), Kombolcha has a total population of 85,367 of whom 41,968 are men and 43,399 women; 58,667 or 68.72% are urban inhabitants living in town of Kombolcha, the rest of the population is living at rural Kebles around the town (Figure 1).

The town is a plain land with altitudes difference of 1,500 m - 1,840 m above sea level and surrounded by hills. It is crossed by Borkena River and numerous small streams. The Borkena valley and the gullies formed by the streams from the surrounding hills have made the configuration of the town undulating. The average annual maximum temperature for Kombolcha over the last 30 years (1976-2005) was 26.3°C and the average annual minimum temperature was 12.69°C. Also in the last 30 years the average annual rain fall for the town was 1021.6 mm. The monthly rainfall distribution of town indicates that July and August are the wettest months of the year in the past time (1976-2005) (Figure 2); they get more than 250 mm of average monthly rainfall. Also, as shown in Figure 2, there is high variation between the daily maximum and minimum temperature of the town in the time interval of 1976-2005.

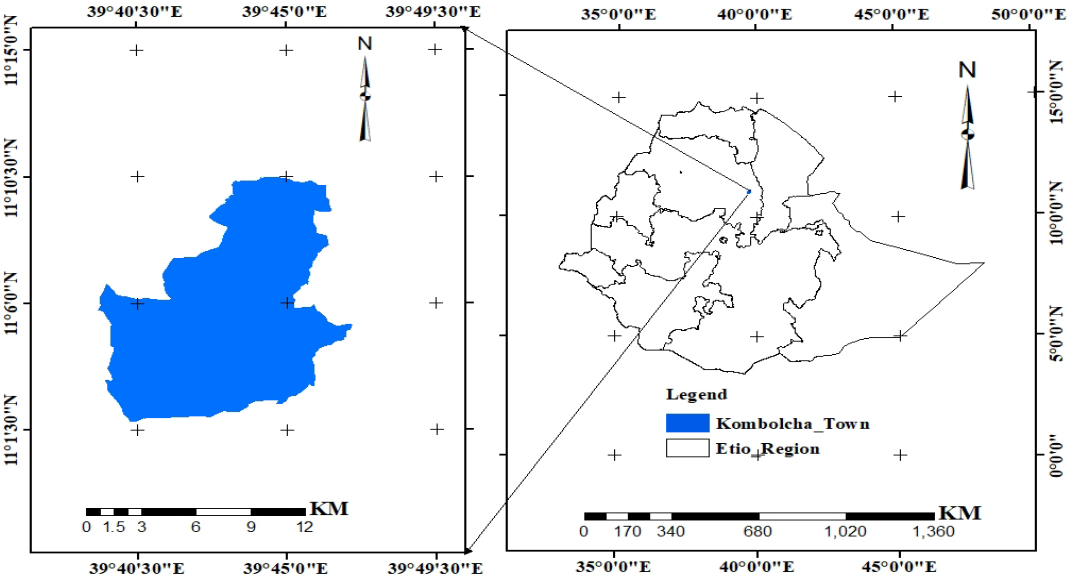

**Figure 1.** Map of the study area (Source: Arc GIS 10.7).

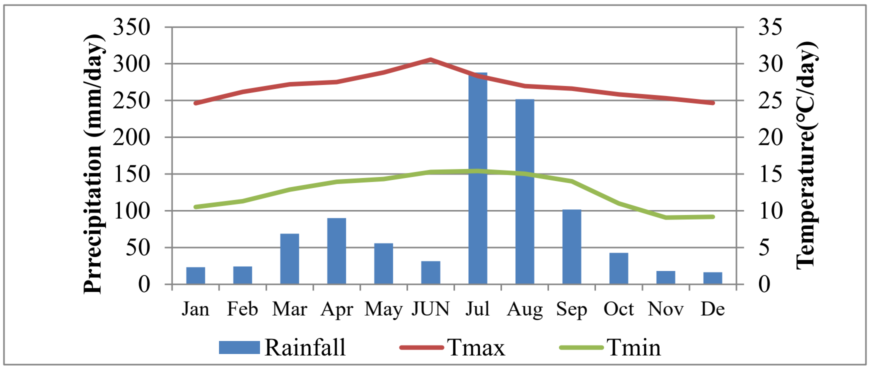

**Figure 2.** Observed monthly mean rainfalls, Tmax and Tmin of the study area (1976-2005).

# Materials, Software and Models to be used

## Different materials, softwares and models were used in this research.

Software like: Arc GISversion 10.7.1 to locate the study area, PCP INSTAT to covert the long term daily data in to monthly and annual base time interval XLSTAT for homogeneity and outlier data test for the observed meteorological data, Mendeley Desktop application for reference citation from different sources.

Models like: Climate model (canESM2) to generate the base time and future time climate scenario data for RCP4.5 and RCP8.5 emission scenario.

## Data description

Historical meteorological variables such as rainfall, maximum and minimum temperature were required as predicant to downscale the respective global GCM data statistically to the local climate variables. So, the long term (1976-2005) historical climatic data were collected from the Ethiopian National Meteorological Agency (NMA) only for Kombolcha station. Because, in the town there is no other meteorological stations with temperature and precipitation records. From the 30 years data of the station (1976-2005), 20 years data (1976–1995) were used for model calibration and the remaining 10 years data (1996–2005) were used for model validation.

The GCM Data which were required to project and quantify the future value of rainfall and temperatures in the study area and to calculate the relative change of these climate variables variables between the current and the future time horizon was downloaded from the global circulation models of, the Canadian Second Generation Earth System Model (canEMS2) from the link (http://climate scenarios.canada.ca/?page=dstsdi) which is freely available for the African window. From this GCM (CanEMS2) future scenario weather data for the ground stations were generated by using statistical downscaling method (SDSM) for the two emission scenarios (RCP 4.5 and RCP8.5) from 2006 -2100 based on the means of the 20 ensembles of SDSM. The base time scenario for both RCP4.5 and RCP8.5 emission scenarios also generate for the evaluation of the model performance by comparing the mean value of observed and base time weather parameter in monthly and annual base.

## Data preparation

The climate data that were collected from their respective source for model input were first captured with Microsoft excel 2007 spreadsheet following the day of the year entry formula; second the data were checked for the missing value, outlier, consistency, homogeneity and finally, by using INSTAT plus software, the daily data were summarized into annual, monthly and seasonal time scale based on the objective this study.

Statistical check about the outlier value determination of meteorological data was conducted using Grubbs outlier data test in statistical software of XLSTAT. The data in the time interval were tested and the presence of outlier in the data set was determined when p-value of the test was greater than significant level of 0.05. In addition to this, Z-score was also used to dictate the outlier data by displayed the Z-score value in bold weather it is maximum or minimum. After this data was arranged in normal data level by optimized this outlier data sets, because most statisticians would agree that outliers should not be removed automatically rather than they should be carefully studied [30].

Standard Normal Homogeneity Test (SNHT) from XLSTA statistical software was used for homogeneity test of meteorological data. Because, SNHT is one of the most popular homogeneity tests in climate studies and the test supposes that tested values are independent and identically normally distributed (null hypothesis) and alternative hypothesis assumes that the series has a jump-like shift or break [30] and results was determined by the compaction of the significance level of alpha value (0.05 or 0.01) with the computed p-value with the null hypothesis (Ho) and alternative hypothesis (Ha);When the computed p-value greater than the alpha valve the data is homogenous [31].

## Downscaling Method

Climate scenarios data from a global climate model (GCM) are usually at a large scale, for this mater, downscaling is mandatory for impact and adaptation studies as they require detailed local data. Among the different downscaling techniques, the SDSM a type of regression model was used in this study. Because a number of studies indicate that the SDSM yields reliable estimates of extreme temperatures, seasonal precipitation, totals and inter site precipitation behaviors for a given study area [14,21] in addition to this SDSM is widely applied in many regions of the world over a range of different climatic condition and permits the spatial downscaling of daily predictor–predictand relationships using multiple linear regression techniques (Yihun et al., 2013).

SDSM used SDSM4.2.9a decision support tool which was downloaded from https://www.sdsm.org.uk/for the assessment of regional climate change impacts. This decision support tool was developed by [16] and used to downscale large predictors. The SDSM software reduces the task of statistically downscaling daily weather series into, quality control, data transformation, screening of predictor variables, model calibration, weather generation (using observed predictors), statistical analyses, graphing model output, and scenario generation (using climate model predictors).

## Selection of predictors

Selecting a predictor is an important step in the downscaling process. It is an iterative procedure consisting of a rough screening of the possible settings and predictors, which is repeated until an objective function is optimized [32]. In this, screen variable operation was done after a quality control check and transformation of rainfall data by fourth root. Identifying the best predictors was conducted on the relationships which were drawn between a suite of global scale predictors and local scale predictand, based on linear correlation analysis and scatter plots; and finally the predictors with the highest correlation were selected.

From Canadian climate change scenario group website (http://climate scenarios.canada.ca/?page=dstsdi) for the African window, the National Centers for Environmental Predictions (NCEP 1961–2005) reanalysis data and canESM2 predictor variables for RCP4.5 and RCP 8.5 are obtained on a grid by grid-box basis from a resolution of 2.8° latitude and 2.8° longitude. So, the required predictor data that represent the town were down loaded from Kombolcha station and the determination of empirical relationships between gridded predictors (such as mean sea-level pressure) and single-site predictands (such as station precipitation) was performed for all parameters (rainfall, maximum temperature and minimum temperature). The predictor data files downloaded from the grid of interest (station of the study area) consists of the following three directories [16].

(a) NCEP_1961-2005: This directory contains 45 years of daily observed predictor data, derived from the NCEP reanalysis, normalized over the complete 1961-1990 period.

(b) RCP4. _2006-2100: This directory contains 95 years of daily GCM predictor data, derived from the canESM2 experiment, normalized over the 1961-1990 period.

(c) RCP8.5_2006-2100: This directory contains 95 years of daily GCM predictor data, derived from the canESM2 experiment, normalized over the 1961-1990 period.

Large-scale predictor variable information from National Center for Environmental Prediction (NCEP_1961-2005) reanalysis data set is used for the calibration and validation of SDSM with the observed precipitation, maximum and minimum temperature data of this study; and also RCP 4.5 and RCP8.5 _1961-2100 data were used for the baseline and future time climate scenario generation of the station by using linear correlation and scatter plot partial correlation analysis for appropriate downscaling predictor variables selection through the screen variable option of SDSM. This statistic identifies the amount of explanatory power of the predictor to explain the predictand [16]. For this, first, all the predictors Table 1 from historical records were correlated with the past observed (1976-2005) maximum temperature,

**Table 1.** Twenty-six Predictor variables derived from African window for the study area.

| Predictor Variable | Description | Predictor Variable | Description |
|---|---|---|---|
| Ncepmslpgl.dat | Mean sea level pressure | Ncepp5zhgl.dat | 500hpa divergence |
| Ncepp1_fgl.dat | Surface air flow strength | Ncepp_fgl.dat | 850 hpa air flow strength |
| Ncepp1_ugl.dat | Surface zonal velocity | Ncepp_ugl.dat | 850 hpa zonal velocity |
| Ncepp1_vgl.dat | Surface Meridians velocity | Ncepp_vgl.dat | 850 hpa meridians velocity |
| Ncepp1_zgl.dat | Surface velocity | Ncepp_zgl.dat | 850 hpa vortices |
| Ncepp1thgl.dat | Surface wind direction | Ncepp850gl.dat | 850 hpa geo potential height |
| Ncepp1zhgl.dat | Surface divergence | Ncepp8thgl.dat | 850 hpa wind direction |
| Ncepp5_fgl.dat | 500hpa air flow strength | Ncepp8zhgl.dat | 850 hpa divergence |
| Ncepp5_ugl. Dat | 500 hpa zonal velocity | Nceprcpgl.dat | Relative humidity at 500 hpa |
| Ncepp5_vgl.dat | 500 hpa meridians velocity | Nceps500gl.dat | Specific humidity at 500hpa |
| Ncepp5_zgl. Dat | 500 hpa vortices | Nceps850gl.dat | Specific humidity at 850 hpa |
| Ncepp500gl. Dat | 500hpa geo potential height | Ncepshumgl.dat | Surface specific humidity |
| Ncepp5thgl.dat | 500hpa wind direction | Nceptempgl.dat | Mean temperature at 2m |

minimum temperature, and precipitation. Then, the predictors with the highest correlation(r) and zero p-values were selected for each weather parameters. Finally, for the selection of the best predictor variables for each predictand (rainfall, maximum and minimum temperature) scatter plot was carried out in screen variable option of SDSM software.

### Calibration and weather Generation of SDSM

The SDSM was calibrated for each parameters for the first 20 years (1976-1995) of observed data and predictor variables of NCEP reanalysis data sets and the last 10 years (1996-2005) of observed data from Kombolcha station were used for evaluation (weather generation) of the calibration data. Similar to calibration of the model, weather generation was carried out from predictors of NCEP reanalysis datasets using independent observed data in a time series (observed data which was not used for calibration).

Statistical Downscaling Model (SDSM) can be simulated on monthly, seasonal and annual basis, but, for this study, the model was simulated at monthly level by the process of conditional for rainfall parameter and unconditional for temperature parameter in order to see the monthly variation of precipitation, maximum and minimum temperature values. According to [1], during calibration and validation of SDSM, direct link are established between predictors and predictands under unconditional model process and in conditional models there is an intermediate process between regional forcing and local weather. As a result, in conditional process the observed data were transformed by the fourth root before calibration and validations were done, but for unconditional process the observed data were used directly for model calibration and validation without transforming the data.

The performance of the model during model calibration and validation was measured by using statistics like mean, variance, sum, minimum and maximum values of simulated and observed data by summary statistics analysis operation of SDSM software before scenario generation. This was used to select an appropriate event threshold value, variance inflation and bias correction of the model. In addition to the above listed statistics, coefficient of determination (R2) for simulated and observed data was used for performance measure of the model. However, for discussion coefficient of determination (R2) and mean of observed and simulated data comparison of all parameters were selected and the condition for each predictand (rainfall, maximum and minimum temperature) was presented in the following section.

### Climate projection for future period

Based on the objective of this study, to see the future temperature and precipitation values for Kombolcha town, the future data of these climate variables were downloaded from CanESM2 for Kombolcha meteorological station. The future data were also generated for RCP 4.5 and RCP 8.5 emission scenarios by SDSM method based on the average of 20 ensembles. The variations of temperature (maximum and minimum) and precipitation in the town for annually and seasonally condition were analysis based on the base of the 2020s, 2050s and 2080s.

## Results and Discussion

### Input data quality control

The meteorological data sets (rainfall, maximum and minimum temperature) in the study area contend a total of 0.3-0.5% missing data from the whole observed data of rainfall and temperature, which were used in this study. Since the missing data are too small, the values were filled by averaging of previous and following days of records [33,34].

Homogeneity of meteorological data was tested by Standard Normal Homogeneity Test (SNHT) XLSTA of statistical software. Since p-values of the test were greater than the alpha value for both significance levels (0.01 and 0.05), the data were considered as homogeneous in the time series of observed data. The homogeneity test result for Kombolacha meteorological station indicated in Table 2.

### Selection of downscaling predictor variables

The number of selected predictors for all weather parameters (rainfall, maximum and minimum temperature) varies from four to five in the study area (Table 2). The correlation (R) statistics and p-values were used to explain the strength of the relationship between the predictor and predicted. So, in this study, Predictor variables which have a high correlation value(R) and zero p-values were selected. Even there were common predictors for all weather parameter; in most cases the valve of correlation (R) was different from parameter to parameter. The results also show a strong association between mean temperatures at 2m (Nceptempgl.dat) for all weather parameters in most case. In addition to this, as the results provide in Table 3 the amount of explanatory power (partial correlation R valve)for each predictor is unique.

In the town, the selected predictors have better chance of the association with all predicand as the values of p is zero and Predictor like 500hpa geo potential height (Ncep500gl.dat) with maximum temperature, mean temperature at 2m (Nceptempgl.dat) with minimum temperature and 850 hpa geo potential height (Ncepp850gl.dat) with rainfall has higher positive association. On the other hand, surface air flow strength (Ncepp1-fgl.dat) predictor has higher negative association with both maximum and minimum temperature and there is no, any predictor which has negative association with rain fall in the town (Table 3).

### Model calibration, weather generation and its performance

Before future scenario generation the results of the observed data for maximum temperature, Minimum temperature and precipitation are correlated with the modeled data during the calibration and validation periods using the coefficients of determination. SDSM was calibrated for each parameters separately for the first 20 years (1976-1995) of observed data and predictor variables of NCEP reanalysis data sets, weather generation was done for the last 10 years (1996 - 2005) of observed data set; the mean result of simulated

**Table 2.** SNHT for meteorological data of Kombolcha station.

| Parameters | Minimum | Maximum | Mean | SD | Alpha($\alpha$) | |
|---|---|---|---|---|---|---|
| | | | | | **0.05pvalue** | **0.01pvalue** |
| Rainfall | 749.1 | 1319.3 | 1021.6 | 148.13 | 0.325 | 0.333 |
| Maxi T | 25.44 | 27.6 | 26.3 | 0.529 | 0.775 | 0.775 |
| Min T | 11.75 | 13.54 | 12.659 | 0.497 | 0.105 | 0.109 |

**Table 3**. Selected predictor variables in Kombolcha town.

| Predictor | Predictand | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | MaxT | $R^2$ | P | Tmin | $R^2$ | P | Rainfall | $R^2$ | P |
| Ncepp1-fgl.dat | | -0.277 | 0 | | -0.353 | 0 | | 0.077 | 0 |
| Ncepp1-vgl.dat | | -0.118 | 0 | | | | | | |
| Ncep500gl.dat | | 0.295 | 0 | | 0.203 | 0 | | 0.072 | 0 |
| Nceps500gl.dat | | | | | | | | 0.086 | 0 |
| Ncepp8thgl.dat | | -0.212 | 0 | | | | | | |
| Ncepp850gl.dat | | | | | -0.11 | 0 | | 0.249 | 0 |
| Ncepshumgl.dat | | | | | 0.369 | 0 | | 0.096 | 0 |
| Nceptempgl.dat | | | | | 0.568 | 0 | | | |

and observed data of all predictand data variations were determined. Figure 3a shows the mean of simulated and observed precipitation data of the study area from Kombolcha meteorological station. All most all months of the year have underestimated simulated results for precipitation. In the model, even the above variation was observed, in related with a mean of observed and mean of simulated rainfall data at the monthly level but, the value of coefficient of determination (R2) which shows the overall association of observed and simulated data was 0.929 for the study area. So, the overall agreements of the observed and simulated mean results were very good with, related to the coefficient of determination (R2). Figure 3b shows R2 value of Kombolcha station in the study area. This show high variation and good agreement of observed data and simulated data from SDSM. The mean of observed and simulated maximum temperatures in the study area show a little variation in monthly levels. As shown in Figure 4a, the simulated maximum temperature mean graph superimposed on observed maximum mean temperature graph, this may be due the condition that the simulated and observed mean maximum temperature have all most equal means. In addition to this point, R2 values show good relationship between the observed and simulated data Figure 4b.

The minimum temperatures of the town have almost equal mean result for observed and simulated conditions at the baseline time throughout all month of the years as indicated in Figure 5a. As a result of this graph of simulated and observed minimum mean temperature in the baseline period are superimposed each other in all months of the year. At the same time, R2 value shows the presence of great conformity between the observed and simulated mean minimum temperature as indicated in Figure 5b. In this study from the three weather parameters (rainfall, maximum and minimum tempera), the SDSM model simulation result shows good performance for maximum temperature next to the minimum temperature when it evaluates by coefficient of determination.

## Future temperature and precipitation

**Future precipitation:** The mean results of future precipitation, which was downscaled from canESM2 GCM by using NCEP-NCAR predictors show significant variation when it compared with the reference period (1976-2005) mean rainfall of the town for all rainfall season (annual, Kiremt and Belg).

The mean value of rainfall for the Belge rain season for all three future time horizons of this study Table 4 will indicate a higher value than the base time mean value of Belg season rainfall for RCP4.5 emission scenario. However, for RCP8.5 emission scenario the mean value of Belg rainfall will indict lower value as compared to observed time mean Belg rainfall value. The maximum increasing and decreasing mean value of Belg rainfall will occur in 2020s for RCP4.5 and RCP8.5 respectively (Table 4). Maximum increase and decrease will occur by 2020s, for both RCP4.5 and RCP8.5 respectively 2020s = 2006 -2035, 2050s = 2036 – 2065 and 2080s = 2066 – 2095.

In the future, relative to the observed mean value of Kiremt rainfall in Kombolcha town, mean value of Kiremt rainfall will decrease for both RCP4.5 and RCP8.5 emission scenarios in all three-time horizons (Table 5). The maximum decreasing rate will occur in 2050s for both RCP4.5 (16.75%) and RCP8.5 (26.7%). The decreasing rate of mean Kiremt season rainfall is higher for RCP8.5 relative to RCP4.5 in respective future time interval of this study. As cited by Belay et al.(2013), Arndt et al. (2011) indicate that the future projections Kiremt rainfall will decline by 20% in Ethiopia and also indicated that seasonally maximum precipitation reduction is projected during the Ethiopian local rainy season of Kiremt in the future time horizons.

Future expected mean annual rainfall in 2080s in Kombolcha town will show maximum decreased (13.8%) mean annual rainfall value relative to observed mean annual rainfall (Table 6). In the town RCP4.5 shows 7.03% and 1.36% decrement in the 2020s and 2050s respectively; RCP 8.5 also shows 5.47% and 7.22% decrement in the same respective time. This result is found in the same line with Asore et al. (2010), all models and scenarios show a decrease in mean annual precipitation and consequently, a decrease in runoff in lower Awash River Basin, where the area of this study found; The Projection of future mean annual rainfall conditions suggest that the annual mean rainfall in the Central Rift Valley area is most likely to decrease (Belayet al., 2013), the generated future scenarios results show decreasing trend for mean annual precipitation in upper Awash Sub-basin, of Ethiopia [4] and also as cited by [21], Monireh et al. (2013) was also indicated up to 25% decline of mean annual precipitation in Ethiopia for the future time interval.

**Future temperature:** Mean maximum temperature value which expected in the future three-time horizons (2020s, 250s and 2080s) for the two emission scenarios (RCP4.5 and RCP8.5) in Kombolcha town for Belg, Kiremt and annual season are given in Table 7. In the town throughout the three-time horizons mean maxim temperature of the three seasons (Belg, Kiremit and annul) for both RCP4.5 and RCP8.5 emission scenarios indicates increment value when it compares with the base time mean maximum temperature.

In the town the maximum increment of Belg season mean maximum temperature will be occurred in 2050s for both RCP4.5 and RCP8.5 with a value of 1.88ºC and 1.77ºC respactively. For Kiremt season this will be occurred in 2020s for both RCP4.5 (1.52ºC) and RCP8.5 (1.48ºC). In annual base even the increment will be occurred in 2020s for both RCP4.5 and RCP8.5, the value is small when it compares with the Belg and Kiremt season increment values.

The mean annual, Kiremt and Belg minimum temperature value of Kombolcha town for the time of the 2020s, 2050s and 2080s are indicated in Table 8. The expected mean annual, Kiremt and Belg season minimum temperature of the town show increment values when it compares to base time value of respective seasons.

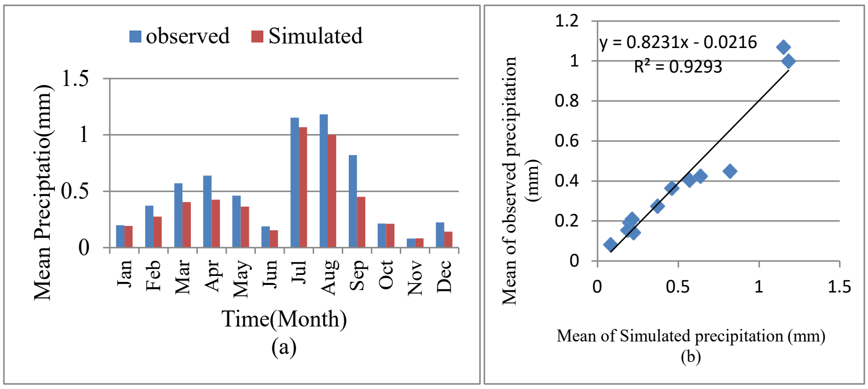

**Figure 3.** Simulated and observed mean daily precipitation (a) and ($R^2$) in studyarea.

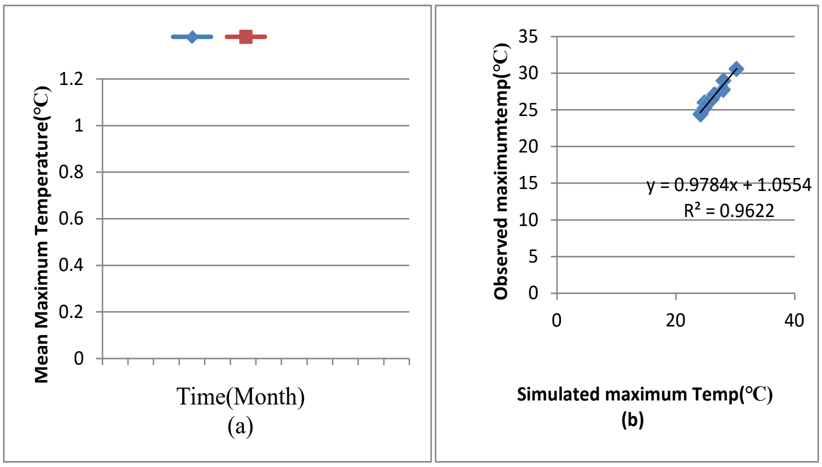

**Figure 4.** Simulated and observed mean daily maximum temperature (a) and $R^2$ (b) in the study area.

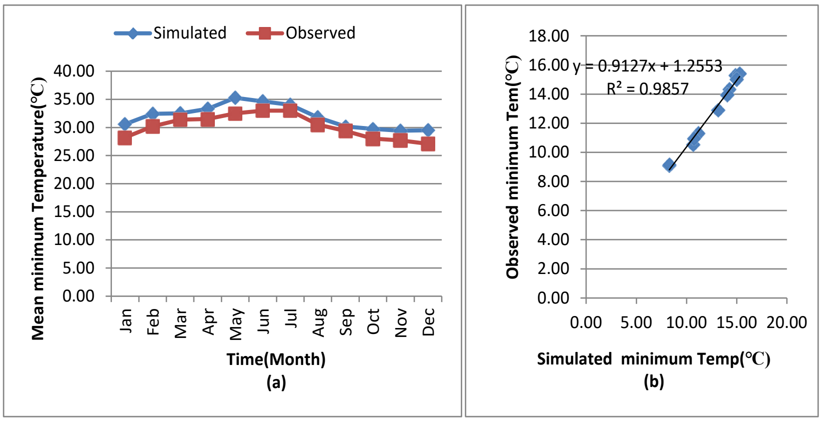

**Figure 5.** Simulated and observed mean daily minimum temperature (a) and $R^2$ (b) of the study area.

**Table 4.** Mean of future Belg season rainfall relative to the base period.

| **Observation** | **Projected *Belg* rainfall(mm)** | | | | | |
|---|---|---|---|---|---|---|
| | **RCP4.5** | | | **RCP8.5** | | |
| Base period | 2020s | 2050s | 2080s | 2020s | 2050s | 2080s |
| 215.69 | 231.9 | 221.6 | 221 | 195.1 | 198.4 | 198.9 |
| Increase/Decrease (%) | 7.5* | 2.75 | 2.59 | -9.57* | -8.04 | -7.78 |

**Table 5**. Futures mean Kiremt rainfall change relative to the base period rainfall.

| **Observation** | **Projected Annual rainfall(mm)** | | | | | |
|---|---|---|---|---|---|---|
| | **RCP4.5** | | | **RCP8.5** | | |
| Base period | 2020s | 2050s | 2080s | 2020s | 2050s | 2080s |
| 1023.43 | 951.5 | 1009.5 | 968.5 | 967.5 | 949.5 | 882.2 |
| Increase/Decrease (%) | -7.03 | -1.36 | -5.37 | -5.47 | -7.22 | -13.8 |

**Table 6.** Future annual rain fall change relative the base time.

| **Observation** | **Projected Annual rainfall(mm)** | | | | | |
|---|---|---|---|---|---|---|
| | **RCP4.5** | | | **RCP8.5** | | |
| Base period | 2020s | 2050s | 2080s | 2020s | 2050s | 2080s |
| 1023.43 | 951.5 | 1009.5 | 968.5 | 967.5 | 949.5 | 882.2 |
| Increase/Decrease (%) | -7.03 | -1.36 | -5.37 | -5.47 | -7.22 | -13.8 |

**Table 7.** Future annual, Kiremt and Belg season mean maximum temperature.

| **Observation** | **Maximum Temperature** (°C) | | | | | |
|---|---|---|---|---|---|---|
| | **RCP4.5** | | | **RCP8.5** | | |
| Base period | 2020s | 2050s | 2080s | 2020s | 2050s | 2080s |
| *Belg*(27.87°C) | 27.93 | 29.75 | 28.19 | 27.93 | 29.64 | 28.26 |
| Difference | 0.06 | 1.88* | 0.32 | 0.05 | 1.77* | 0.39 |
| *Kiremt*(28.10°C) | 29.62 | 29.2 | 28.67 | 29.58 | 29.29 | 28.26 |
| Annual (26.86°C) | 26.97 | 26.86 | 26.94 | 26.97 | 26.9 | 27.12 |
| Difference | 0.11 | 0 | 0.08 | 0.11 | 0.04 | 0.26 |

**Table 8.** Future annual, Kiremt and Belg season mean minimum temperature.

| **Observation** | **Minimum Temperature** | | | | | |
|---|---|---|---|---|---|---|
| | **RCP4.5** | | | **RCP8.5** | | |
| Base period | 2020s | 2050s | 2080s | 2020s | 2050s | 2080s |
| *Belg*(13.72°C) | 14.03 | 13.87 | 14.23 | 14.71 | 14.54 | 15.06 |
| Difference | 0.61* | 0.15 | 0.51 | 0.99 | 0.82 | 1.34* |
| *Kiremt*(14.90°C) | 15.55 | 15.29 | 16.51 | 16.19 | 15.07 | 15.63 |
| Difference | 0.65 | 0.39 | 1.61* | 1.29* | 0.17 | 0.73 |
| Annual (12.63°C) | 12.76 | 12.96 | 13.89 | 14.48 | 13.82 | 14 |
| Difference | 0.13 | 0.33 | 1.35* | 1.85* | 1.19 | 1.37 |

The future mean annual minimum temperature of the town will be increased by 1.35ºC for RCP4.5 and 1.37ºC for RCP8.5 in 2080s when it compared to the historical mean annual minimum temperature of the town. This is the maximum increment values in the future three-time horizon. Similar nature with future mean annual minimum temperature in2080s, Belge and Kiremt season mean minimum temperature in the 2080s expected by the increment value for both RCP4.5 and RCP8.5 emission scenarios. In Belge the increment value for RCP8.5 (1.34ºC) will be higher than that of RCP4.5 (0.51ºC); the condition will be reverse in Kiremt when the mean minimum temperature will be increased by 1.61ºC and 0.73ºC for RCP4.5 and RCP8.5 respectively.

In the future three-time horizons of this study the maximum Belg season mean minimum temperature increment will be occurred in 2020s for RCP4.5 and in 2080s for RCP8.5. For Kiremt season mean minimum temperature with contradiction of Belg season mean minimum temperature, the increment will be occurred in 2080s for RCP4.5 and in 2020s for RCP8.5.

## Conclusion

Africa is considered as the most vulnerable continent to climate change in the world. Regionally, in east Africa countries like Burundi, Kenya, Sudan, and Tanzania people are badly hit by the impacts of climate change. Because of its significant dependence on the agricultural sector for production, employment, and export revenues, Ethiopia also seriously threatened by climate change, which contributes to frequent drought, flooding, and rising average temperatures.

Whilst climate change is already manifesting in Ethiopia through changes in temperature and rainfall, its magnitude poorly studied at regional levels. This is because of that, the results of the temperature and precipitation data that obtained from meteorological observation of some regions are missing and limits the downscaling of future weather values from 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.

In Ethiopia, various downscaling applications and their potential to detect climate change impacts in agricultural and hydrological applications were conducted in different time intervals throughout all direction of the country. But, applications of statistical downscaling of general circulation models for future time temperature and precipitation value estimation for industrial town of Kombolicha, South Wollo in Ethiopia has not been undertaken. So, in order to fill the limitation by establish a relationship between past local climate and past GCM outputs and extend this relationship into the future time interval required scientific evidence on statistically downscaling of future temperature and precipitation values since, it is vital for policymakers, researcher, planner to formulate the adaptation and mitigation options of future temporal and spatial variation in the study area. Therefore, the main aim of this study was statistically downscale of future daily maximum temperature, daily minimum temperature, and precipitation value in Kombolcha Town, South Wollo, in Ethiopia.

The mean value of rainfall for the Belge rain season for all three future time horizons of this study will indicate a higher value than the base time mean value of Belg season rainfall for RCP4.5 emission scenario. In the future, relative to the observed mean value of Kiremt rainfall in Kombolcha town, the mean value of Kiremt rainfall will decrease for both RCP4.5and RCP8.5 emission scenarios in all three-time horizons. Also, in the town both RCP4.5 and RCP8.5 scenarios show a decrease in mean annual precipitation values throughout the three future time interval of this study. In the town throughout the three-time horizons both mean maxim and minimum temperature of the three seasons (Belg, Kiremit and annul) for both RCP4.5 and RCP8.5 emission scenarios indicates increment value when it compares with the base time mean maximum temperature. The rise in temperature will intensify the town maximum heat effects in warm seasons and decrease in precipitation is expected along with a possible risk of water supply scarcity due to a low level of water supply access and a high rate of urbanization in the town.

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