

# Investigation of Precipitation and Temperature Change Projections in Werii Watershed, Tekeze River Basin, Ethiopia; Application of Climate Downscaling Model

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## Abstract

Climate change is an overwhelming global issue. Everything, living or non-living in one or another way, have in contact with climate change. A statistical downscaling model (SDSM) was used to investigate future climate projections based on precipitation and temperature using (Regional climate Model) for A1B and B1 emission scenarios in Werii watershed (1797 Km<sup>2</sup>). Four meteorological stations, namely; Abyiadi, Adwa, Hawzen and Adigrat were selected based on proximity to the watershed and data availability. For A1B scenario, precipitation is likely to increase in each station by 11%, 34%, 31% and 20%, whereas for B1 scenario, precipitation will increase by 10%, 33%, 33% and 25% at Abyiadi, Adwa, Hawzen and Adigrat stations respectively by 2050. Change in maximum temperature shows increasing at Hawzen for A1B (0.16°C) and B1 (0.2°C) and smaller change at Adwa (0.06°C for A1B and -0.01°C for B1). The maximum temperature is expected to change in the range of -0.01°C to 0.2°C. Similarly, change in minimum temperature is expected to increase positively with maximum at Hawzen station for A1B (0.34°C) and B1 (0.29°C) and smaller change is likely at Adigrat station (0.07°C for A1B and 0.09°C for B1). Generally, future projection shows the change in precipitation and temperature is positive and will show an increasing trend in the period from 2015 to 2050. The REMO model and SDSM have simulated well in Werii watershed. Hence, REMO and SDSM model can be used in similar watersheds in the semi-arid regions.

**Keywords:** Climate change; Downscaling; Emission scenarios; REMO; SDSM; Werii watershed

## Introduction

Climate change is nowadays an overwhelming global issue. Everything, living or non-living in one or another way relates to the subject of climate change. It is because the global warming, an indicator of the climate change, is a common phenomenon unlike the past times [1]. Increase in temperature of the atmosphere, oceans, and landmasses of planet earth are the main symptoms of global warming. At present, the earth appears to be facing a rapid warming, which mostly believed as results of human-induced activities. The chief cause of this warming is thought to be the burning of fossil fuels, such as coal, oil and natural gas from which greenhouse gases are released into the atmosphere [2]. Climate change has varied devastating implications. It has influenced mainly the agriculture and water resources. It is inevitable that the hydrologic cycle systems will change as climate change occurs. The Fifth IPCC Assessment Report (AR5) (IPCC [2]) based on direct physical and biogeochemical measurements, remote sensing data and information derived from climatic archives revealed that climate systems have observed to provide a long-term changes in the atmosphere, the ocean, the cryosphere and at the land surface. This long-term climate system variability will create bad situations in the long run with the existence of human beings. It is difficult to blame global warming is caused by a specific hurricane or flood or drought or forest fire, it is a collective evidence that, it is due to a distinct anthropogenic influence [2-4]. It doesn't mean that the natural hazards are not contributing to the climate change, but human-induced climate changes are tremendously higher and complex. Anthropogenic impacts play an important role in these issues to occur as a result of unsustainable and unwise use of water resources especially in the past century. The situation of the future climate change that we will face is almost trouble and anxiety unless urgent mitigation measures are taken. Due to the impact of climate change, it is possible to say that the world will become worse and threatens the existence of life.

Most surprising is that the majority of this change of climate is due to human-induced problems through the releasing of greenhouse gases to the atmosphere, land use change emissions through forest fire and aerosols. Paeth et al. [5], Paeth and Thamm [6] studied a simulated future African climate change and outlined that the tropical parts of Africa may undergo dryer climate conditions by 2025, the land surface and lower-tropospheric temperature may increase up to more than 4°C explained with large variances occurs at summer monsoon season and reductions in vegetation cover and soil moisture. These have tremendous effects on the water cycle system of Africa. The effect of climate change is clearly observed in Ethiopia. There are variations in the occurrence and distribution of rainfall made drought a frequently recurring phenomenon. The spatial distribution and the frequency of drought occurrences in Ethiopia have increased in recent years [7]. Moreover, Gebrehiwot and Veen [8] indicated that the northern part of Ethiopia is warming faster than the national average temperature (0.25°C per decade). As a result, Ethiopia in general and Tigray in particular were suffering from a shortage of food due to erratic rainfall, unsustainable use of water resources and lack of scientific technologies and a continued total rain failure during the late 1980's [9,10]. This

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is experienced with unforeseen bad weather conditions and improper management of land and water resources in the region. This study is envisioned to investigate if there is a climate change due to precipitation and temperature change projections in Werii watershed of Tigray region, Northern Ethiopia. Precipitation and temperature history data recorded for the period (in between 1971-2000) was used as a baseline for downscaling future climate change projections occurred in the watershed for the next 35 years (2015-2050).

## Materials and Methods

### Area description

This study was conducted in Werii watershed (1797 km<sup>2</sup>) located in Tekeze the River Basin in Tigray Regional State, Northern Ethiopia (Figure 1). Werii watershed is found in the border between central and eastern administrative zones of Tigray region. The watershed touches five administrative districts of Ahferom, and Ganta-Afeshum at the upper stream catchment and Worie-Lekhe, Hawzen and Kola-Tembien at the downstream. The watershed has an average elevation of 1951 m.a.s.l. It is laid in between Kola and Wurch with majority falls at Woina-Dega agro ecological zones [11]. The area of the watershed is dominated by cropped land use type (41.4%) and silt clay loam soil type (49.5%).

### Climate scenarios

The SRES (Special Report for Emission Scenarios) are climate change projections developed by IPCC (Intergovernmental Panel for Climate Change) starting from 1990s [1,2]. These scenarios are due to emissions of greenhouse gases, aerosol precursor which produces global warming. The emission scenarios were developed based on population, economy, technology, energy and land used as driving forces.

According to IPCC [1,2] the emission scenarios are categorized into four families (A1, A2, B1 and B2) based on their unique characteristics for the twenty first century. This study, therefore, used the two storyline emission scenarios of the A1 (A1B) and B1. A1B and B1 are selected based on the balanced approach to economic development (A1B) and sustainable development (B1). Besides, Ethiopia is believed to have a balanced and sustainable economic development with corresponding emission and socioeconomic changes in the future. Although there are newly established next generation RCPs (Representative Concentration Pathways) scenarios [12]. The SRES emission scenarios are still functional and can be used in climate change studies. Hence, A1B and B1 emission scenarios were considered as an experimental treatment used as an indication for climate significances in the watershed from 2015-2050.

### REMO

REMO (Regional Model) is a regional climate model developed, to forecast climate changes, at the Max-Planck Institute for Meteorology (MPIM) in Hamburg, Germany [13]. The regional climate model REMO is based on the Europa Modell, the former numerical weather prediction model of the German Weather Service [14]. It is a hydrostatic limited area model that has been designed for applications at the synoptic scale [13]. The quality of the REMO simulation is achieved by using perfect boundaries which are considered as reality in local scale levels. The regional climate model is nested into the driving fields to harmonize the fields under consideration. Jacob and Podzun [14] have described the model as it is developed based on the fundamental scientific equations in terrain-following hybrid coordinate systems. The Model is therefore working based on the primitive equations related to temperature, surface pressure, horizontal wind components, water vapor content and cloud water content as prognostic variables [13]. The

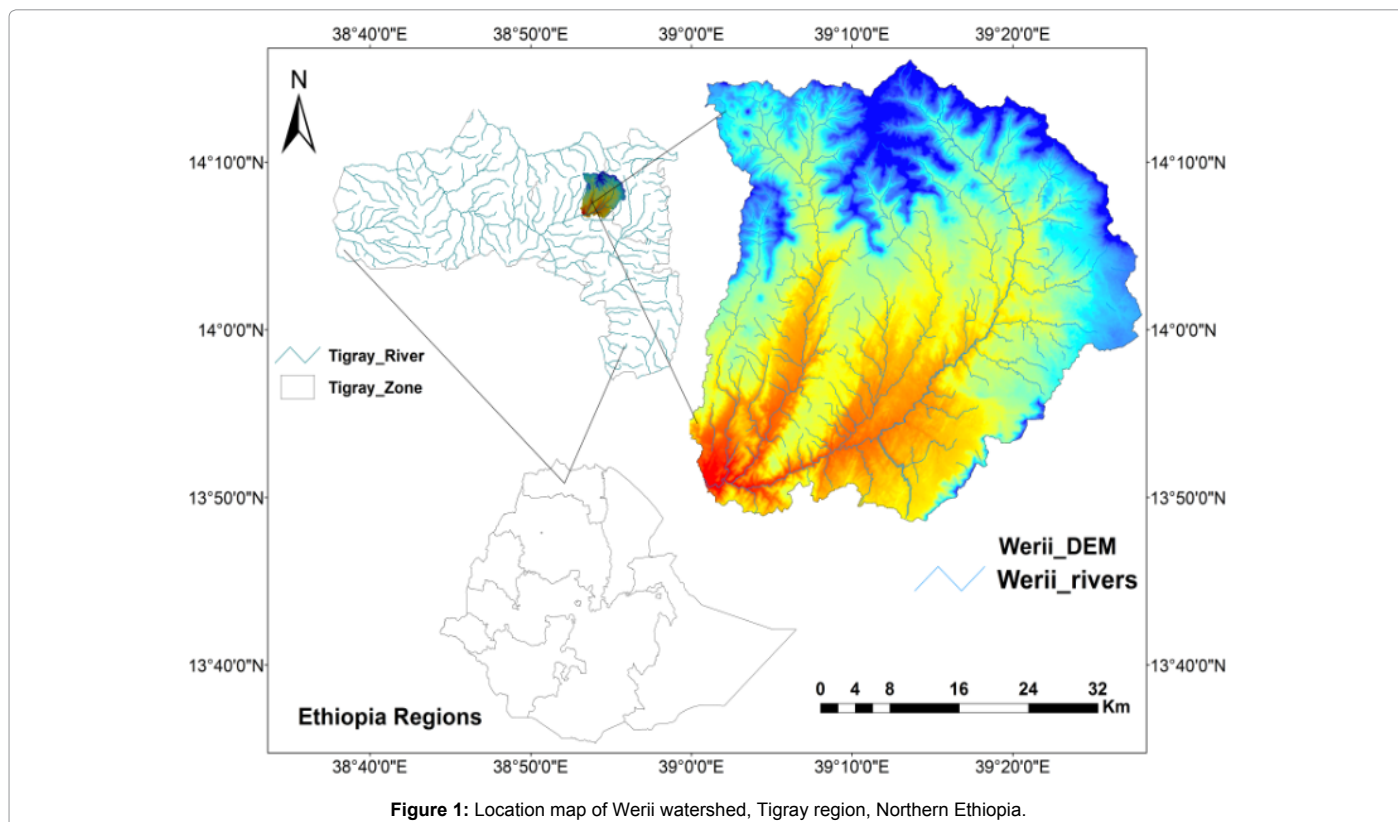


Figure 1: Location map of Werii watershed, Tigray region, Northern Ethiopia.

model equations are then transformed based on a geographical latitude/longitude grid with a terrain-following vertical coordinate during application. The model accommodates temperature, precipitation, evapotranspiration to be downscaled to the point scale/station scale for the application of future climate changes. The data necessary for the study were obtained from the REMO database [15] Climate data downscaled from REMO data sets are used in Western Africa [16], tropical and Northern Africa [16,17] and Ethiopia [18]. Observed data from meteorological stations and simulated data from REMO regional climate model ECHAM5/MPI-OM based boundary condition were downscaled through using Statistical Downscaling Model for A1B and B1 SRES emission scenarios [2]. In this study, all REMO simulations were driven from recent ECHAM5/MPI-OM global coupled climate model simulations.

### Climate downscaling

According to Wilby [19] and Wilby and Dawson [20] the downscaling of climate scenarios refers to a process of taking global information on climate response to changing atmospheric composition and translating it to a finer spatial scale that is more significant in the context of local and regional impacts. There are models available today for downscaling GCM (Global Climate Models) and RCM (Regional Climate Models) datasets and makes ready to use for future climate change predictions. SDSM (Statistical Downscaling Model) is used for downscaling large scale climate features available, statistically related to fine scale climate for the area of interest. It is a decision support tool which derives large scale climatic variables (predictors) to local/station variables (predictands) [19]. Statistical downscaling assures development of statistical relationships between local climate variables (predictands) and large scale climate variables (predictors) [19]. It also provides an application of predictands-predictor relationships to the output of GCM and RCM experiments simulate local climate characteristics. According to Wilby [19], Wilby and Dawson [20], Xu et al. [21] and Kebede et al. [18] statistical downscaling model provides a consistent estimate of temperature extremes and precipitations in seasonal and station level. The statistical downscaling model has advantages of ease of computation, can easily crafted and used for specific uses, direct regional incorporations of observational records as well as it uses basic standard statistical procedures [20,22]. The SDSM model has used in adverse environments and regions as it has been clearly briefed in Wilby and Dawson [22]. Therefore, the statistical downscaling model is used as a decision support tool as to which the historical climate data available and the downscaled climate data have relationships or not through calibration and validation of the model for the watershed. After having created the relationships the SDSM model simulates twenty ensembles for the precipitation and temperature and the average value of these ensembles were considered for the climate projection.

### Meteorological station data's (predictands)

Precipitation and temperature are the most vital elements of the climate system. Make use of these elements in the study of climate change is inevitable and takes use of time series data obtained from meteorological stations. In the Ethiopian context meteorological stations having longer historical data are found in urban and surrounding areas. These situations do not permit to study climate change impacts in remote rural areas through using long series baseline data. Since, recent years onwards, however, there are established meteorological stations in almost all representative areas in the country. These could not create a possibility to study climate change and variability impacts as climate study needs longer time series data (Table 1).

Although, Werii watershed is found in a relatively remote area, the meteorological stations selected to study existing and future rainfall and temperature change in the entire watershed are relatively found in and around the watershed. Fortunately, this creates a possibility to study such changes through using scientific methods by means of available data and models. The climate change study makes use of available meteorological data. There are several meteorological stations in and nearby of the watershed. Most of these stations are either established in recent times or have a lot of missing data to be selected for the study. There must be some mechanisms on how to choose which meteorological stations should be incorporated in the study. As a result, Stations; Hawzen, Abyiadi, Adwa and Adigrat are the carefully chosen meteorological stations based on data availability and proximity to the watershed. These stations have had relatively longer baseline data (Table 1). However, continuous and long term databases are hardly found in the study area as it was a site of instability during 1980s [10] and continued total rain failure over multiple years [9]. That is why; data were not recorded during the record periods of 1985-1989 in the stations.

### Station data's used for model calibration and validation

The meteorological data available from meteorological stations were used for calibration and validation of the statistical downscaling model. The historical database of rainfall and temperatures are observed variable and revealed different in each station. The non-continuous data recorded were used separately for calibration and validation purpose easily in the model. Time series data with longer periods were used for calibration and the lesser for validation of the model as depicted in Table 2.

### Identification of predictor variables

Rainfall and temperature data were stored at, and brought from the Ethiopian National Meteorological Agency (NMA) for research purposes. Local climate station data (predictands) were used to downscale the regional climate data produced from REMO. Each predictands parameter is downscaled with corresponding predictor variable's data obtained from REMO archives. Arc GIS software was used to investigate the REMO raster nodes surrounding each meteorological station. Accordingly, for down scaling the predictands, one REMO nodes were selected as a predictor variable, to each station data except for the Adigrat station. Two REMO nodes were used for the Adigrat station as it is laid in between two REMO nodes of equal distance. In principle, the predictands rain fall was downscaled by predictor variable rainfall from REMO and this works for all the remaining predictands variables. The

Stations	Elevation (m.a.s.l)	Latitude (degree)	Longitude (degree)	Meteorological data periods (years range)	Years with missed data
Abyiadi	1829	13.53	39.01	1971-2000	5
Adwa	1911	14.16	38.90	1971-2000	5
Hawzen	2242	13.98	39.43	1971-2000	5
Adigrat	2497	14.26	39.45	1971-2000	5

Table 1: Meteorological stations and data periods for Precipitation, Tmax and Tmin in the watershed.

Available Data	Abyiadi	Adwa	Hawzen	Adigrat
Calibration	1971-1985	1971-1985	1971-1985	1971-1985
Validation	1990-2000	1990-2000	1990-2000	1990-2000

Table 2: Data periods (years range) used for calibration and validation purposes for each station.

meteorological stations, REMO nodes and Werii watershed in Tekeze river basin and the Tigray regional map are explained in Figure 2.

### Model evaluation criteria

After having run the SDSM model, two methods of evaluation of performance of the model have done. In the first case, the model by itself has its own evaluation criteria. The coefficient of determination ( $R^2$ ) and explained variance (EV). Coefficient of determination ( $R^2$ ) is expressed as a squared ratio between the covariance and the multiplied standard deviations [23]. Explained variance (EV) is estimated as one minus the ratio of residual variance under the modelling and the residual variance under the null model [24]. However, these SDSM model evaluating criteria are not determinant model evaluating criteria for the sensitive parameters of variance inflation and model bias. Hence, the data outputs of the model were evaluated through using the standard deviation (STD) and mean absolute error (MAE). Mean absolute error is a quantity used to measure how close simulated forecasts are from the observed data [25].

$$\text{It is given by, } \text{MAE} = \frac{1}{n} \sum_{i=1}^n |f_i - y_i| \quad (1)$$

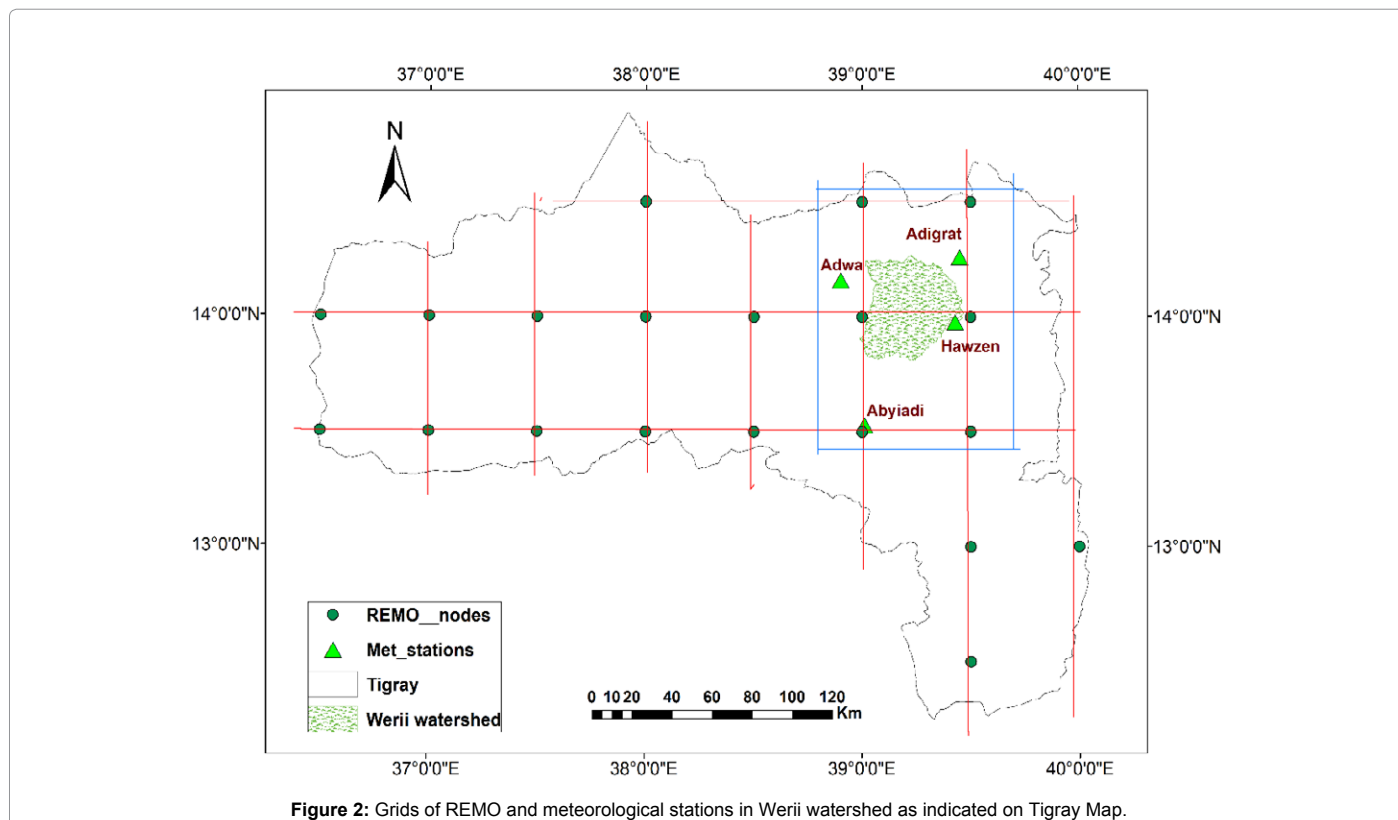
Where,  $f_i$  is the predicted value and  $y_i$  is the observed value. The optimum value for mean absolute error is 0.0. Hence, values closer to 0 are appropriate for calibration.

## Results and Discussion

### Observed and REMO data comparison before downscaling

The observed climatic data of the meteorological stations and corresponding REMO data considered to be downscaled are depicted

in Figure 3. The observed average monthly rainfall of the stations in both calibration and validations periods is highest during rainy seasons in the months of June and July (Figure 3). This situation explains the uni-modal rainfall distribution occurred in the entire watershed. The observed average monthly rainfall data ranges from zero during the dry season to a maximum of 13.2 mm during rainy season. Rainfall starts to rain during the month of June, continues up to late September (JJAS) and this season is considered as rain season in which cultivation of crops are possible. The observed average monthly temperatures were evaluated in minimum and maximum temperatures separately (Figure 3) in the calibration and validation periods. As a result, the minimum (4.9°C) and maximum (31°C) average monthly temperatures were obtained from Adigrat and Adwa stations respectively, among the meteorological stations. The average monthly temperatures were perceived lesser during the months of November, December and January. Meanwhile, higher mean monthly temperatures were recorded in the months of March to May and September to October. The data which are selected from the REMO data set grids for each of the meteorological stations are presented in Figure 3. The REMO data before downscaling are compared with observed station data. Both show similar trends for precipitation and temperature with a varied magnitude. Hence, down scaling the REMO data to the station variables has paramount importance. Moreover, the relationship among elevation and mean annual temperature of the meteorological stations were evaluated. The annual mean temperature was linearly regressed with elevation of the meteorological stations (Figure 4). It is clearly noted that the elevation is highly significant, but negatively correlated ( $R^2 = 0.95$ ) with a mean annual temperature. This indicates that as elevation increases temperature will decrease in all of the meteorological stations in the watershed.



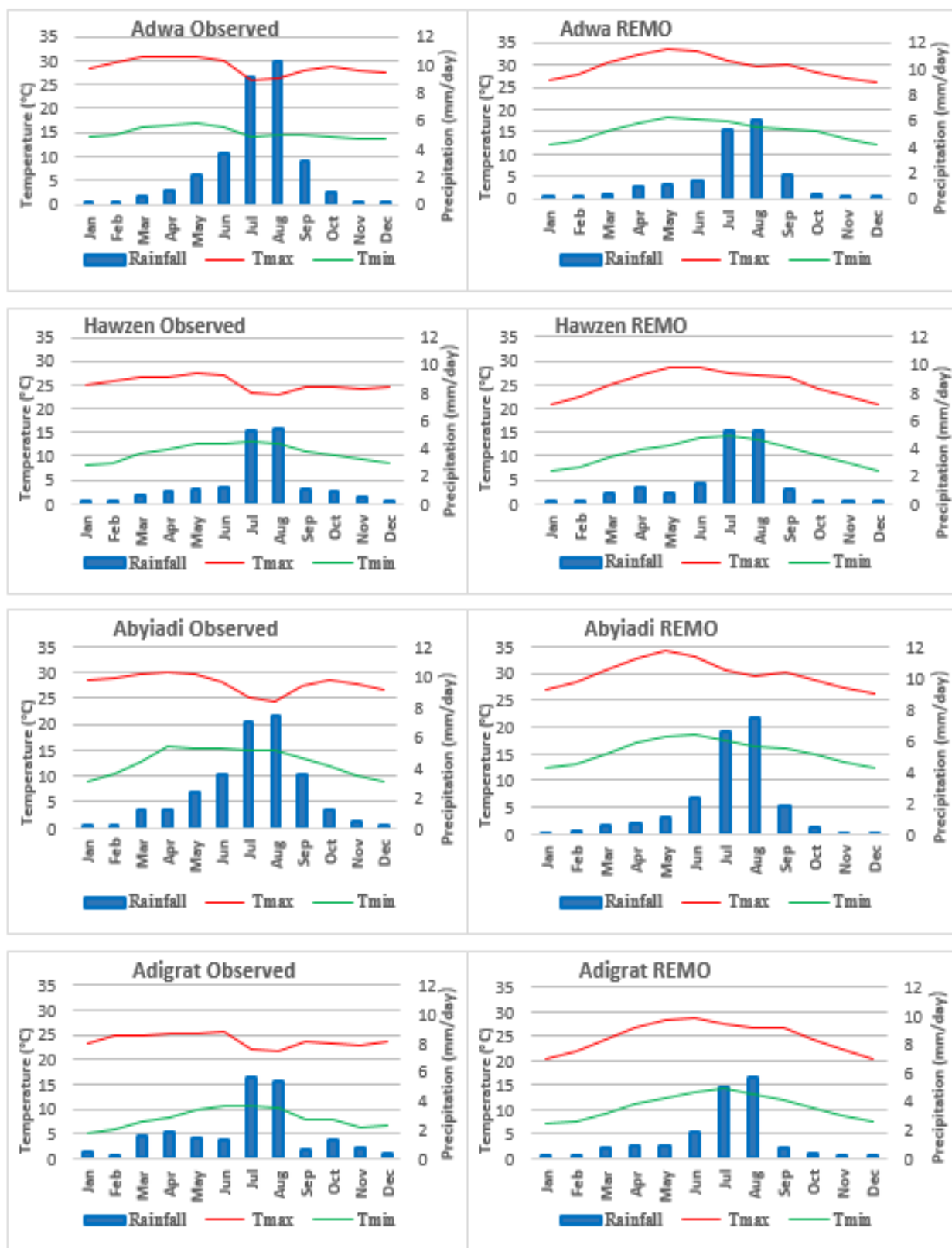


Figure 3: Observed average monthly rainfall, Tmax and Tmin of each meteorological station and corresponding REMOs before downscaling.

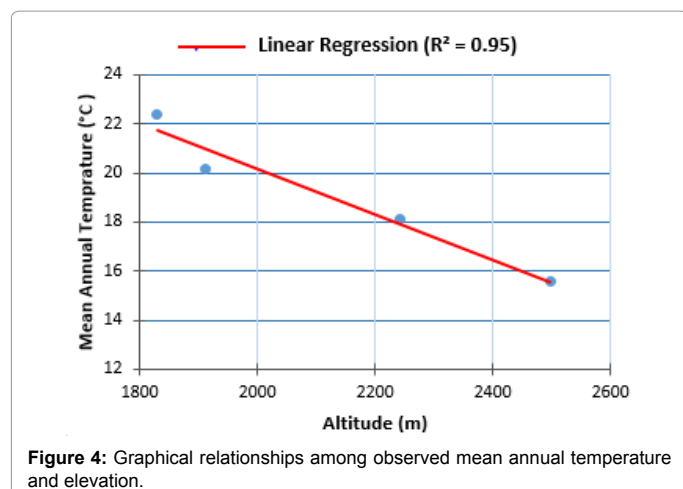


Figure 4: Graphical relationships among observed mean annual temperature and elevation.

### Model calibration results and likely future climate change projections

Calibration of a model is used to investigate a good agreement among the parameters in the model in this particular study. The calibration process was implemented based on an average of twenty ensembles simulated in the SDSM model. In this study, precipitation, maximum and minimum temperatures were calibrated and future likely impacts of climate change were downscaled based on the best agreement of calibration results between the predictands and predictors. Each meteorological station were generated a twenty synthetic ensemble for each of the A1B and B1 SRES emission scenarios on the daily time series basis for the period of 35 years (2015-2050). Hence, the averages of the simulated ensembles were taken for analysis of the climate variables. The following sections present the calibration results and future changes in climate for each meteorological station with corresponding changes for the annual climate variables (precipitation, maximum and minimum temperatures).

#### Precipitation

Precipitation is the most variable and a fundamental element in the climate system and its characteristics is not well manipulated in easy way. The diversity of rainfall patterns is inherent and naturally explained as erratic in this region. Before and after calibration results for rainfall of the stations considered in the watershed is explained in Figure 5. A manually, a trial and error method within the range of the parameters, was employed to find out the best fit agreements of the sensitive parameters of SDSM model. The values of the model evaluation criteria, i.e. the standard deviation (SD) and mean absolute error (MAE) are presented together with the precipitation values separately before and after downscaling of the precipitation (Figure 5). The annual rainfall was downscaled for the periods ranging from 2015-2050. As it has been depicted in Figure 6, the maximum change in annual rainfall in the period was observed in Adwa and Hawzen stations for the SRES emission scenarios, A1B (34% and 31% respectively) and B1 (both 33%). Minimum rainfall change was also observed at the Abiyadi station for A1B (11%) and B1 (10%). In the future climate system, negative change in rainfall is seldom in the watershed. Therefore, it is expected that rainfall is expected to increase in the course of the time and this trend is consistent with the IPCC report on climate change [2] and Nyenje and Batelaan [26]. Similarly, Kebede et al. [18] indicated that overall annual future rainfall trend will increase for both of the A1B and B1 SRES scenarios. Meanwhile, Kim et al. [27] reported that by the 2050, rainfall change will increase by

11% at the Upper Blue Nile River. The watershed is characterized with a definite summer (JJAS) for rainy season and winter (JFMAMOND) for the dry season. Hence, understanding of the monthly and seasonal changes in rainfall has practical implications. Here, both the seasonal and monthly rainfall changes, lack systematic trends. It has variable changes for each month and seasons and shows anomaly behavior. The monthly rainfall varies from minimum 4.2% change for B1 at Adwa station to a maximum of 129% for B1 at Abiyadi station. Similarly, seasonal change in rainfall occurs within the range of  $30\% \pm 17.3\%$  for the rainy season and  $58\% \pm 38\%$  in the dry period. The rainy season simulation is in line with in a similar study area [28]. Here, the monthly and seasonal changes in rainfall do not lead to drive a comprehensive conclusion. It is important to emphasis on the annual changes rather than either monthly or seasonal changes. Meanwhile, the SDSM model was produced possible rainy days and the amount of mean annual rainfall for each of the stations for the station data and REMO as explained in Table 3. The rainy days and mean annual rainfall were estimated from the observed station data and for the regional climate, REMO. In Ethiopia, a day with a minimum of 1 mm or more rainfall occurrence is considered as a rainy day [11]. Here, the possible rainy days are counted based on the above criterion.

#### Maximum temperature

Before and after calibration of the maximum temperature is presented in Figure 7. In order to exactly find the best fit values for each of the meteorological stations, a trial and error method was conducted for the sensitive parameters of variance inflation and bias correction in the SDSM model. The SD and MAE values of each of the meteorological stations (Tmax) maximum temperature for each of the before downscaling and after downscaling Tmax values are also inserted in Figure 7. After having calibrated the model, a future change in the annual maximum temperature is identified for both A1B and B1 SRES emission scenarios for each of the stations (Figure 8). As a result, the maximum will not show a systematic increase or decreasing trend, however, it coincides to be increased in the future as the majority of the stations revealed increasing even if it is not shown higher significance. Higher change in maximum temperature is observed in Hawzen station for A1B (0.16°C) and B1 (0.19°C). However, smaller change in maximum temperature is investigated at Adigart and Abiyadi stations. A negative change is also appeared at Adwa station for B1 (-0.01°C) emission scenario. Generally, the annual maximum temperature is expected to be in the range of -0.01°C to 0.19°C in the watershed in the future period (2015-2050) and this result is consistent [5,6,16,26,29].

#### Minimum temperature

Minimum temperature (Tmin) was also calibrated and downscaled in the SDSM model for this study. Downscaling (before and after) of the minimum temperature is explained in Figure 9 for each of the stations. A manual calibration method was conducted as usual to find out the best agreements among the parameters for each of the stations. Similarly, the SD and MAE are also embedded together with minimum temperature values (Figure 9). Future change in annual minimum temperature was also estimated based on the calibration results for the emission scenarios (Figure 10). As a result, the maximum change in annual minimum temperature is observed in Hawzen station for A1B (0.34°C) and B1 (0.29°C). Yet, smaller change was investigated in Adigart and Abiyadi stations for both emission scenarios. Negative change in minimum temperature will hardly found in the future range of the study time. Generally, minimum temperature will change increasingly and positively and this is in line with the findings [2,5,16,29]. So far the temperature is discussed separately as minimum

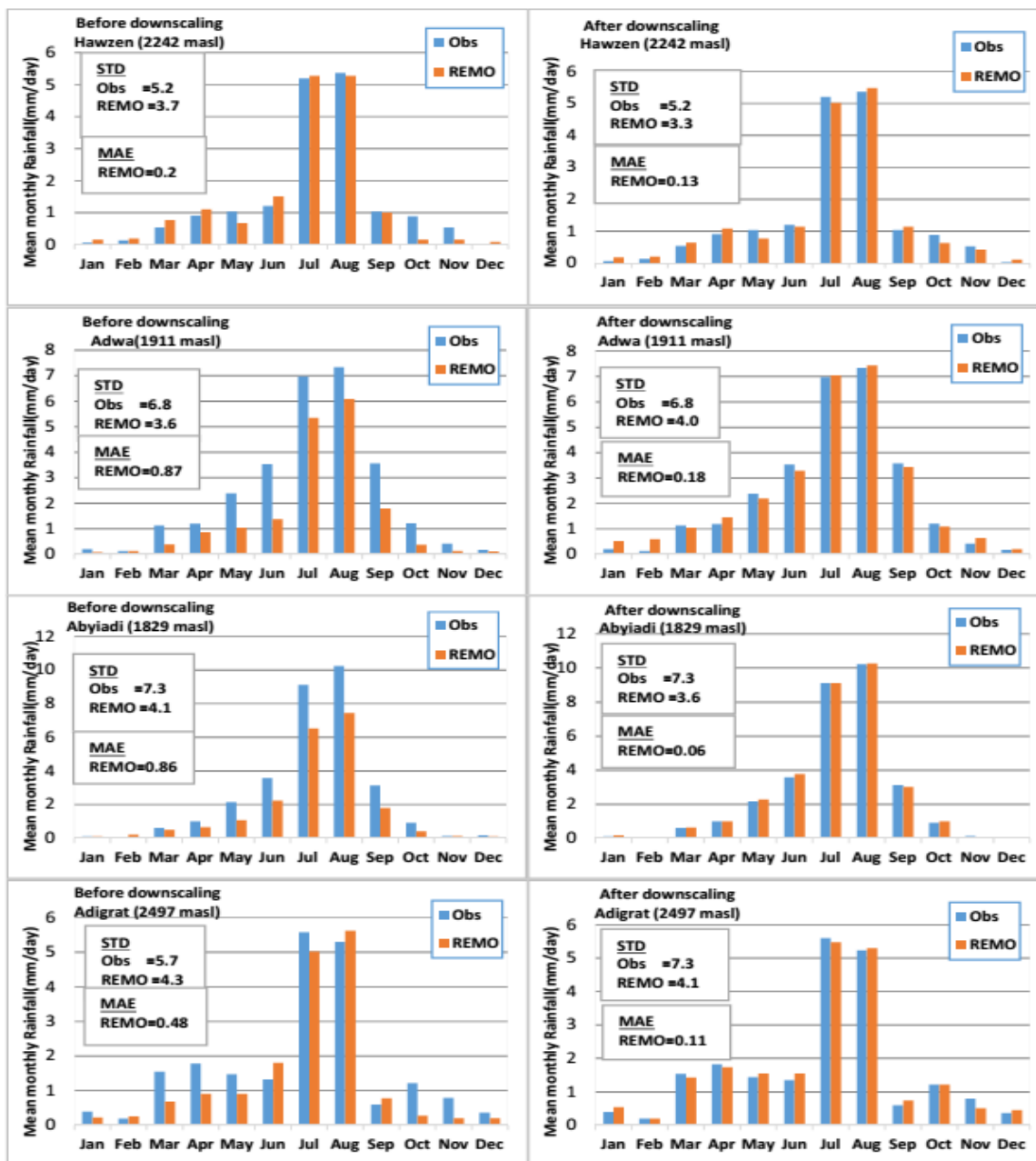


Figure 5: Before and after downscaling of each meteorological station's observed and REMO precipitation data. STD = Standard deviation, MAE = Mean absolute error.

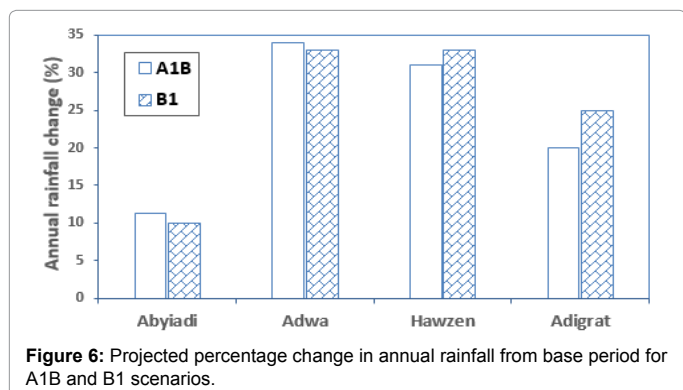


Figure 6: Projected percentage change in annual rainfall from base period for A1B and B1 scenarios.

Stations	Model run	Mean annual rainfall (mm)	Rainy days (days/year)
Abyiadi	Observation	956	81
	REMO	985	79
Adwa	Observation	867	94
	REMO	830	77
Hawzen	Observation	521	57
	REMO	507	46
Adigrat	Observation	632	73
	REMO	619	57

Table 3: Comparison of base period (observed and downscaled) annual rainfall and rainy days values for all stations.

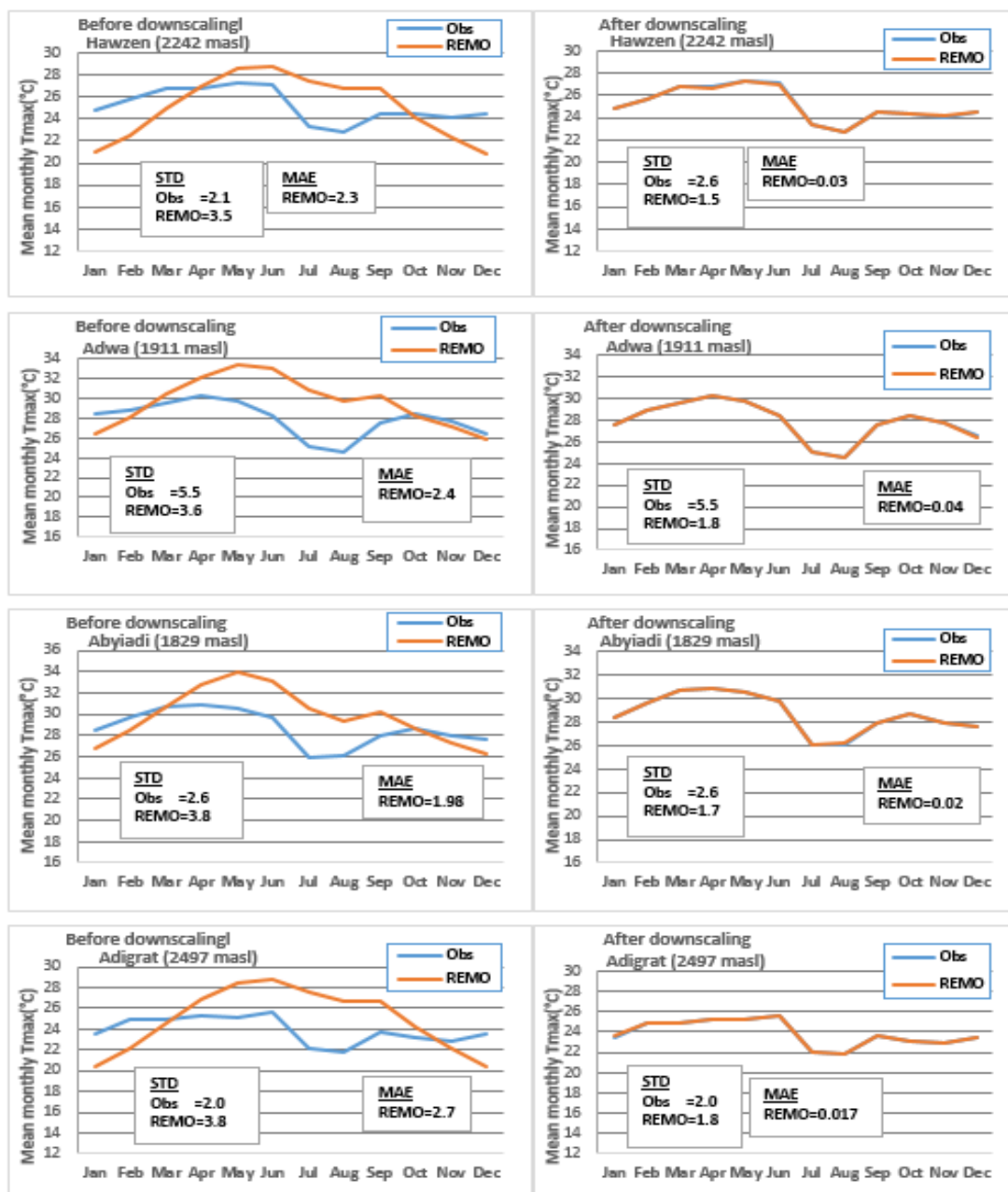


Figure 7: Before and after downscaling of each meteorological station's observed and REMO maximum temperature data. STD = Standard deviation, MAE = Mean absolute error.

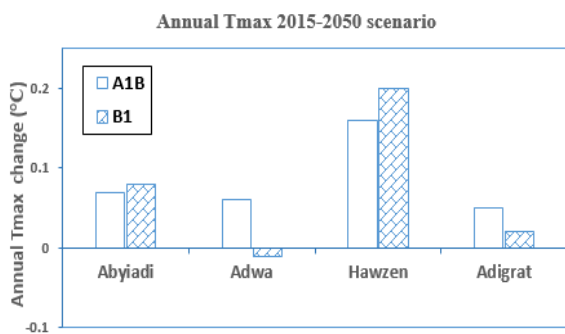


Figure 8: Projected Change in annual maximum temperature from base period.

and maximum temperatures and derived indicative results. The average increase in annual minimum temperature is higher and faster than the maximum temperature. This implies warming nights were occurring over the years [8,28]. It is important to drive a combined average result for temperature based on the separately obtained results. Hence, the annual temperature trend is increasing in general with greater change in minimum temperature for each station and scenarios used in this study. This is consistent with the results obtained [5,6,8,16,26]. However, the projected mean annual temperature is lower than the IPCC's projected 2°C to 4°C over the next 100 years [2,30]. Generally, the future likely climate projections for each of the annual precipitation, maximum and minimum temperatures for each of the meteorological stations for A1B and B1 SRES emission scenarios of Werii watershed is summarized in Table 4. The meteorological stations don't show



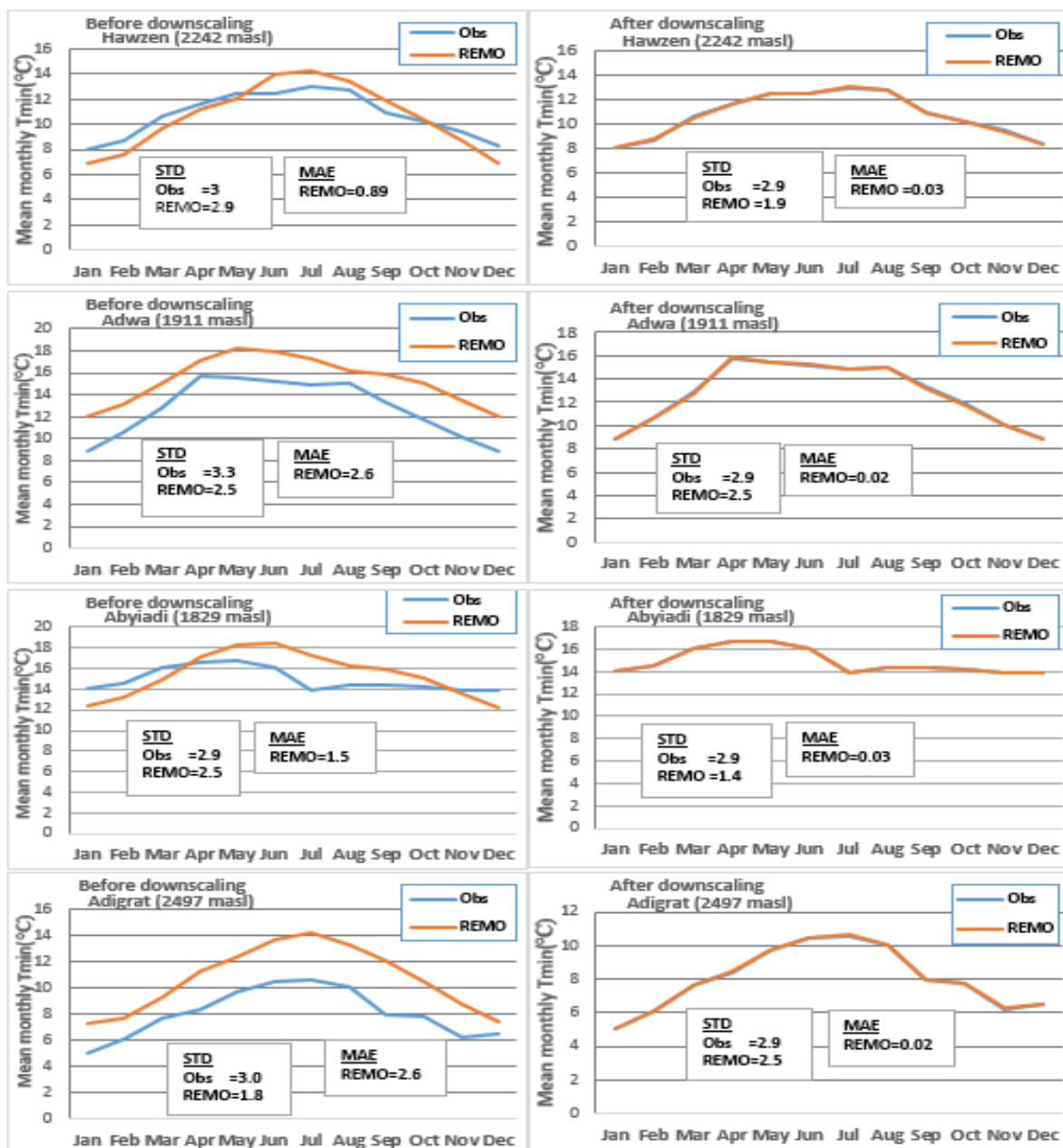


Figure 9: Before and after downscaling of each meteorological station's observed and REMO minimum temperature data. STD = Standard deviation, MAE = Mean absolute error.

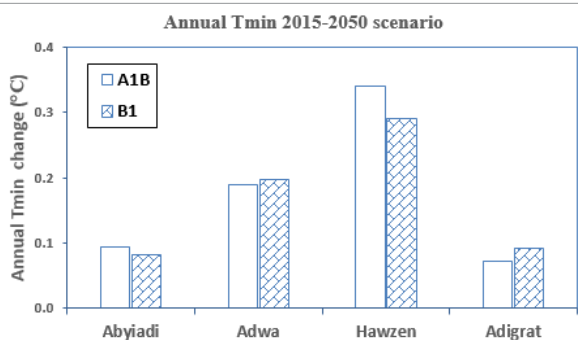


Figure 10: Projected Change in annual minimum temperature from base period.

identical trends for precipitation and temperature for both scenarios at the same time. Hence, relationships in future trends for these climate parameters are hardly found.

### Conclusions

The main focus of downscaling climate data is investigation of present climate situations and future climate change impacts due to greenhouse gas emissions through converting coarse resolution climate data from REMO to point or watershed level. Hence, based on the local climate variables (predictands) and a regional climate model REMO outputs were downscaled as predictor variables. The rainfall and temperature changes that will likely occur due to changes in climate for the period 2015 to 2050 were estimated. Hence rainfall and

Stations	Precipitation (%)		Maximum temperature (°C)		Minimum temperature (°C)	
	A1B	B1	A1B	B1	A1B	B1
Abyiadi	11	10	0.07	0.08	0.09	0.08
Adwa	34	33	0.06	-0.01	0.19	0.20
Hawzen	31	33	0.16	0.2	0.34	0.29
Adigrat	20	25	0.05	0.02	0.07	0.09

**Table 4:** Summarized future climate projections (2015-2050) for A1B and B1 SRES scenarios in Werii watershed.

temperature change projections were forecasted based on the emission scenarios considered as indicator treatments.

The future likely changes in precipitation for each of the meteorological stations, maximum change was observed in Adwa station, 34% for A1B and 33% for B1 and Hawzen station 31% for A1B and 33% for B1. Minimum rainfall change was also observed at the Abyiadi station for A1B (11%) and B1 (10%). The analysis shows future negative change in rainfall is seldom, but expected to increase in the future from 2015 to 2050. As per the analysis change in maximum temperature will also likely. As a result, the maximum change in maximum temperature is observed in Hawzen station for A1B (0.16°C) and B1 (0.2°C). The smallest change in maximum temperature, however, is investigated at Adigrat and Abyiadi stations. A negative change is also appeared at Adwa station for B1 (-0.01°C) emission scenario. Generally, maximum temperature is expected to be in the range of -0.01°C to 0.2°C in the watershed. Future change in minimum temperature was also estimated based on the calibration results for the emission scenarios. As a result, the maximum change in minimum temperature is observed in Hawzen station for A1B (0.34°C) and B1 (0.29°C). Nevertheless, smaller change was investigated in Adigrat and Abyiadi stations for both emission scenarios. Negative change in minimum temperature will hardly found in the future. Minimum temperature will change increasingly and positively. Generally, the future likely changes in precipitation and temperature are positive and will increase in the period from 2015 to 2050. However, climate change projections due to precipitation are higher and significant than that of insignificant temperature change. As a consequence of the expected changes in precipitation possible climate change adaptation options must be undertaken in the watershed. The REMO data sets and SDSM have produced and simulated well in Werii watershed. The REMO data set and the SDSM model can be used in similar watersheds in the semi-arid regions. These findings are important as to which beneficiaries can use it as an initial indication of climate change projections in Werii watershed. It is also possible to use the results obtained in this work for further study through including the remaining climate parameters.

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