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Research Article

The Recent and Future Trend Analysis of Inter-Seasonal to Seasonal Rainfall and Temperature to Climate Change and Variability in Dire Dawa City Administration, Ethiopia

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ABSTRACT

The trend analysis has been employed to inspect the change of rainfall and temperature in Dire Dawa city administration, using gauged monthly precipitation and temperature data obtained from National Meteorological Agency of Ethiopia from 1980 to 2014 and the future climate data of GCM used by the Intergovernmental Panel on Climate Change fifth generation CMIP5 and World Clim obtained from Agricultural Model Inter-Comparison and Improvement Project (AgMIP) website. Two models such as HadGEM2-ES and MRI-CGCM3 under rcp4.5 and 8.5 have been considered to generate rainfall, maximum and minimum temperature data using AgMIP R script of "run_agmip_simple_delta R" in R software 3.5.3 version. Recent and future rainfall variability CV, Standard deviation and rainfall Anomaly have been computed using excel spread sheet for variability analysis and the Mann-Kendall test was used to detect the time series trend of inter-seasonal to seasonal temperature and rainfall using R software version 3.5.3. The inter-seasonal to seasonal observed and projected rainfall data shown highly variable while the annual rainfall variability shown in moderate range of variability. The declining trend for belg and inclining trend of kiremt mean observed and HadGEM2-ES (CMIP5) under rcp8.5 model rainfall were found to be statistically significant while that of annual and other monthly trend were not significant except July in observed data but the other projected model for future rainfall trend shown no statistical significant. Therefore, the concerned bodies should take in to consideration climate change adaptation strategy and finally, it is recommended to extend farther study with Ensemble GCM model and RCM.

Keywords: Climate change; Mann-Kendall test; Seasonal rainfall; Trend analysis

INTRODUCTION

Warming of our planet due to the emission of Greenhouse Gases (GHGs) is now undeniable; and over the last century, atmospheric concentration of CO_2 has increased significantly which induced the average global temperature to increase by 0.74°C as compared with the preindustrial era [1]. The other scientific Researches have shown that surface air temperature increased by 0.2°C to 0.6°C in 20th centuries [2] and Global climate has undergone significant and unprecedented changes during the past 100 years [3] and warming will continue beyond 2100 under all RCP scenarios except RCP 2.6 [4]. According to IPCC (2014), report state that, if no additional efforts are taken to mitigate the effects of climate change CO_2 eq concentration are likely to increase to approximately about 450 ppm by 2030 and between 750 ppm to 1300 ppm by 2100. If this occurs, by 2100 the earth may experience global mean surface temperature increase of 3.7°C to 7.8°C compared to pre-industrial era. So, there is increasing evidence that global warming has resulted in an increase in the frequency and severity of precipitation and drought events [5].

Surface precipitation is an important component of the global climate and one of the most important variables in the global hydrological cycle [6] as well as an important indicator in evaluation of water resources [7]. Rainfall and temperature are the two of the most important variables in the field of climate sciences and hydrology frequently used to trace extent and magnitude of climate change and variability [8]. Uncertainty of rainfall and uneven temporal and spatial distribution in one hand, creating flooding and of the other hand longer dry spells evoking drought conditions. Increase in precipitation trends can also result in an increase in the frequency of floods occurrence. On the other hand,

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a decrease in rainfall trend could imply an increase in instances of drought. Climate change studies are mainly focused on the probable changes in the climatic parameter such as rainfall or temperature. Several climate change models (physical models) are being used to study the long term changes in climate parameters on temporal and spatial scale [9-11]. Temporal and spatial variability of climatic parameters can also be studied using statistical approach through the analysis of long term climatic data [12]. Analysis of rainfall trend on different spatial and temporal scales is needed to construct the climate scenarios comprehensively [13]. Using these scenarios on specific location can solve the problems associated with flood and drought as well as the availability of water can be handled accordingly.

In Africa, precipitation amounts are likely to decrease for most parts of Sub-Saharan Africa (SSA) while rainfall variability is expected to increase [4] and World Bank (2010) argued that Africa is expected to experience mainly negative climate change impacts, in terms of an increase in the already high temperatures and a decrease in the largely erratic rainfall in its context of widespread poverty and low development [14].

A marked note that is worthy to be noted is that of the increase in the number of heavy precipitation events, which can also be found even in areas experiencing reduction in total precipitation amount. Thus, study on precipitation has received much attention [15] over the past few decades as understanding rainfall patterns is necessary for assessment of climatic change, managing agricultural issues and also water resources management. Most of the scientists have shown that by 2100, parts of the Sahara are likely to be the most vulnerable with frequently occurrence of extreme climate events will make the region under stress and adverse impacts will be felt in associated with climate change [16].

The long-term climatic change related to changes in precipitation patterns, rainfall variability, and temperature is most likely to increase the frequency of droughts and floods in Ethiopia [17]. Current climate variability is already imposing a significant challenge to Ethiopia by deterring the struggle to reduce poverty and sustainable development efforts [17]. World Bank (2010) has ranked Ethiopia among the most vulnerable countries in the world to the adverse effects of climate change; mainly due to its high dependence on rain fed agriculture, low adaptive capacity and a higher reliance on natural resources base for livelihood, among others [14,17,18]. The impact of climate change on precipitation in Ethiopia is more on its distribution and timing than the total amount [17,19,20].

Trend analysis studies conducted so far in Ethiopia are not conclusive and some are conducted at macro scale; which needs further research. The spatial rainfall distribution in Ethiopia is too much variable from place to place, due to variation in local feature like topography. Thus, the study of climate in specific location is important to identify the trend of climate change on rainfall and temperature variables. Dire Dawa City Administration is found in Eastern Ethiopia, which is frequently influenced by flood and drought. Though trend analysis of meteorological variables is not new in Ethiopia, no prior comprehensive study was conducted in the study area, which is a drought-prone area of the country, needs more attention to analysis the trends of climatic variables for adaptation. The variation in rainfall and increase in temperature due to climate change and variability may causes to lack of water availability and heat stress. In view of above, this study was undertaken to detect the temporal trends in the inter-seasonal to seasonal time series of rainfall and temperature analysis which will be helpful for detecting climate related events and in devising climate change and variability state.

This study incorporates both variability investigation, trend analysis based on historical data of (1980-2014) years and considering two GCM models such as HadGEM2-ES and MRI-CGCM3 for future projection climate scenarios under RCP 4.5 and RCP 8.5 for inter-seasonal to seasonal as well as annual rainfall trend and variability analysis using descriptive statistics and trend test for rainfall, maximum and minimum temperature on the climate change induced variability in Dire Dawa City. This information is helpful in quantifying the magnitude of risks posed by climate change and variability to guide prioritization risk management by directing appropriate measures. Therefore, understanding the temporal patterns of climate change and variability is a key step towards designing and targeting appropriate adaptation strategies. Therefore the study hypothesis that, understanding past and future climate change and variability for decision supporting in appropriate adaptive measures.

Therefore, the general objective is to analysis trends of rainfall and temperature, on various time-scales, and rainfall variability analysis indicating the occurrence of extreme events in order to investigate the influence of climate change and variability in Dire Dawa City Administration is

- To analysis the recent and future temporal variability of rainfall
- To analysis occurrence of climate change and variability trends of the recent and future rainfall and temperature data in Dire Dawa City administration

MATERIALS AND METHODS

Familiarizing the study area

Dire Dawa lies in Eastern Ethiopia (Figure 1) having an altitude of about 1200 m.a.s.l. It receives 638.2 mm average annual rainfall and experiences frequent droughts, dry spell and floods. The mean annual maximum temperature of the area is 32.1°C while its mean annual minimum temperature of 19.1°C. The rainfall type of Dire Dawa is a bimodal type characterized by two rainy seasons and one dry season, namely belg a small rainy period ranges from the months of half of February to May, and kiremt, second rainy season occurring from June to September. The distribution of rainfall mostly occurs from mid-June to mid-September (second rainy season), locally known as kiremt, and mid-February to May is the first rainy season, which is locally known as belg [21-23].

However, the rainfall is highly characterized by inter-annual and inters- seasonal variation. In general, the Major rain bearing systems during the belg season are the development of thermal low over South Sudan, generation and propagation of disturbances over the Mediterranean Sea, sometimes coupled with easterly waves, development of high pressure over the Arabian Sea, the interaction between mid-latitude depressions and tropical systems accompanied by troughs and the subtropical jet and occasional development of the Red Sea Convergence Zone (RSCZ) [24]. While, the Major rain producing systems during kiremt, on the other hand, include Northward migration of ITCZ, development and persistence of the Arabian and South Sudan thermal low along 20°N latitude, development of quasi-permanent high pressure systems over South Atlantic and South Indian Oceans, development of tropical easterly jet and the generation of low level Somali jet that enhance low level south westerly flow [24].

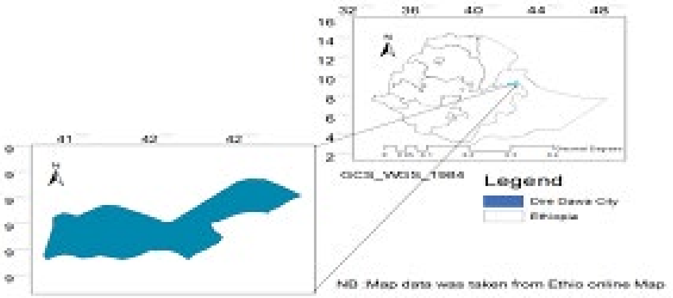

Figure 1: Map of the study area of Dire Dawa City.

Research design

Data type and sources: Daily observations of surface temperature and precipitation for the period 1980-2014 were taken from the National Meteorological Agency (NMA) and the future climate data of GCM used by the Intergovernmental Panel on Climate Change (IPCC) fifth generation CMIP5 and WorldClim data have been obtained from AgMIP format as described in the AgMIP website [25].

Generating future daily weather data: Since each climate model has its own uncertainty, more than one climate model will be better for dealing with the accurate projection problem. Based on this recommendation this study considered two GCM models such as HadGEM2-ES and MRI-CGCM3 under rcp 4.5 scenarios to generate rainfall, T_{max} and T_{min} data of 2010 to 2100, in range of near, medium and end century separately and under RCP 8.5 for medium and end century has been used to generate future climate data. The climate data of five GCMs namely: CCSM4, GFDL- ESM2M, HadGEM2-ES, MIROC5, and MPI-ESM-MR were recommended for monsoon benefited regions. Because these GCMs subset were selected due to their long history of development and evaluation, a preference for higher resolution, and established performance in monsoon regions [25]. According to Thornton and Yang (2014 and 2015) recommendation for East African climate study, Had GEM2-ES and MRI-CGCM3 model have been proposed for East African climate study based on its spatial resolution for atmospheric and there are highly applicable a new feature of the updated tool out of the 20 combination models found in GCM [20,22,26]. HadGEM2-ES, and MPI-ESM-MR, were separately analysed for mean changes in projected climate compared with baseline (1980-2010) and the two models were considered in this study for Future climate projections of Dire Dawa meteorological station (Table. 1).

Table 1: GCM model selected for generation of climate data.

Model Name	Resolution, Lat. × Lon.	Institution
HadGEM2-ES	1.2414 × 1.875	Met Office Hadley Centre
MRI-CGCM3	1.125 × 1.125	Meteorological Research Institute

RCPs usually refer to the portion of the concentration pathway extending up to 2100, for which Integrated Assessment Models have produced corresponding to emission scenarios [3]. The RCP 8.5 is a high emissions scenario, corresponding to projections of high human population (12 billion by 2100), high rates of urbanization and limited rates of technological change, all resulting in emissions approaching 30 Gt of carbon by 2100 compared with 8 Gt in 2000 [27]. The RCP 4.5 scenario is an intermediate mitigation scenario characterized by continuously increasing human population but at a rate lower than in the RCP 8.5 scenario, intermediate levels of economic development and less rapid and more diverse technological change [28]. Therefore, Representative Concentration Pathways (RCP) proposed contains a range of low, moderate and high emissions pathways. According to AR5 report, the highest estimated RCP in the year of 2100 is RCP 8.5 and lower is RCP of 2.6 W/m^2. Based on those emissions scenario, RCP (4.5) medium lower and RCP (8.5) upper maximum have been selected for future mid and end century in climate projection in this study. The tools to generate the future weather data for Dire Dawa meteorological station was AgMIP R script of "run_agmip_simple_delta R" in R sofware 3.5.3 version.

Data analysis techniques: A number of techniques have been developed for the analysis of rainfall and temperature, which generally fall into variability and trend analysis categories. Variability analysis involves the use of Coefficient of Variation (CV), rainfall anomaly, monthly and seasonal contribution to annual rainfall, departure of model output rainfall data from the observed mean and other basic statistical analysis have been applied to this study. Additionally trend detection and analysis are performed through parametric and non-parametric tests using Mann-Kendall test and sense slope estimator. As a result, Mann-Kendall (MK) test is widely used to detect trends of meteorological variables [29-32]. MK test is a nonparametric test, which tests for a trend in a time series without specifying whether the trend is linear or non-linear [33].

Inter-seasonal to seasonal climate variability analysis: The seasonal rainfall data from 1980 to 2014 of Dire Dawa meteorological station and projected future model data were taken to analysis inter-seasonal to seasonal rainfall coefficient of variation of seasonal rainfall variability of a given station. The temporal variation was derived by calculating Coefficient of Variation (CV) for interested period of time period. In this study, rainfall variability CV and Standard deviation have been computed using excel spread sheet. A higher value of CV is the indicator of larger variability, and vice versa. The coefficient of variation of inter-seasonal to seasonal rainfall variability of observed and projected rainfall data has been analysed by:

$$CV = \left(\frac{\delta}{\mu}\right) \times 100 \quad Where\ \mu = \frac{\sum Xi}{N} \quad and\ \delta = \frac{\sqrt{(Xi-\mu)^2}}{N-1} \qquad \text{(Equation 1)}$$

Where CV is the coefficient of variation; Xi is rainfall of each year, N is number of rainfall observation, δ is standard deviation and μ is the mean of precipitation. According to Hare (2003), justification, CV is used to classify the degree of variability of rainfall events is less (CV<20), moderate (20 ≤ CV<30), and high (CV ≥ 30) [1].

Seasonal rainfall anomaly analysis: The Rainfall Anomaly Index (RAI), designed by Van Rooy (1965), considers rainfall anomaly index values to calculate positive and negative precipitation anomalies [34]. Based on his suggestion, the seasonal rainfall performance of each rainy season was obtained by making the rainfall anomaly of the study area using excel spreadsheet. The variability is the difference between total rainfall for each year/ season and the LTM was divided by standard deviation to derive the annual rainfall anomalies. The anomalies indicate the departure from LTM with negative values below -0.5 representing periods of below normal rains while positive values above +0.5 reveal above normal rains. The rainfall anomaly index can gives a representation of abnormal wetness and dryness of a given season.

$$RAI = \frac{Xi - \overline{X}}{\delta} \quad \text{(Equation 2)}$$

Where, RAI is standardized rainfall anomaly; Xi is the seasonal rainfall of a particular year; X is long term mean annual rainfall over a period of observation and δ is the standard deviation of seasonal and annual rainfall over the period of observation and projection period.

The analysis of inter-seasonal to seasonal contribution of Rainfall was undertaken by:

$$Contribution = \frac{\overline{X}}{Annual\ RF} \times 100\% \quad \text{(Equation 3)}$$

Where X is monthly or seasonal long year mean and Annual RF is annual long year mean of rainfall of the study area.

Trend analysis of recent and future climate: Increasing or decreasing trend of all the independent weather parameters (e.g. annual and seasonal temperature, rainfalls etc.) were statistically examined in two phases. First one is the using of non-parametric Mann-Kendall test and second one is the nonparametric Sen's slope estimator. MK test is non-parametric test, which tests for a trend in a time series without specifying whether the trend is linear or non-linear. The increasing or decreasing trend was tested based on normalized test statistics (Z) value. When Z is positive, trend is said to be increasing and when Z is negative, it is said to be decreasing. The trend's slope gives the annual rate and direction of change [35]. Several researchers have widely used this method for different hydro-meteorological parameters [15,36]. Analysis of rainfall trend on different spatial scales is needed to construct the climate scenarios comprehensively [13]. Using these scenarios, problems associated with flood, drought and the availability of water can be handled accordingly.

Therefore, MK test has been used to detect the presence of monotonic (increasing or decreasing) trends in the study area to analysis whether the trend is statistically significant or not. Trend analysis has been carried out on annual bases, inter-seasonal and seasonal with observed and projected rainfall and temperature data. Since the study area gets first rainy season from half of Feb to May and its second rainy season is kiremt rainfall from half of June to September, monthly trends test of recent and future rainfall and temperature data have been analysed separately. The trend analysis considered rainfall amount, T_{max} and T_{min} of Dire Dawa meteorological station have been analysed in base line years (1980 to 2010) and future climate scenarios 2010 to 2100 with two GCM model data. The Software used for performing the Mann Kendall and trend statistical test was R software Kendall, plotly and trend package.

The Mann–Kendall statistical test has been frequently used to quantify the significance of trends in climatic parameters time series. The Mann-Kendall test Tau statistic is calculated as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sgn}(x_j - x_i), \quad \text{(Equation 4)}$$

$$\text{sgn}(x_j - x_i) = \begin{cases} +1, & x_j - x_i > 0, \\ 0, & x_j - x_i = 0, \\ -1, & x_j - x_i < 0, \end{cases} \quad \text{(Equation 5)}$$

Where n is the length of the time series $(x_1, x_2, x_3, \ldots\ldots x_n)$, x_i and x_j are the data values in the time series i and j (j > i), respectively, and $\text{sgn}(x_j - x_i)$ is the sign function.

The variance V(S) of statistics S is computed as:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{p} t_i(t_i - 1)(2t_i + 5)}{18} \quad \text{(Equation 6)}$$

t_i is the number of ties of extent i.

Where n is the number of data points, p is the number of tied groups, the summation sign (Σ) indicates the summation over all tied groups ti the number of data values in path group. If there are no tied groups, this summation process can be ignored. A tied group is a set of sample data that have the same value. In cases where the sample size n > 30, the standard normal tests statistical Zs is computed as follows:

$$Z_S = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & if\ S > 0 \\ 0, & if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & if\ S < 0 \end{cases} \quad \text{(Equation 7)}$$

Positive values of Z_S indicate increasing trends, while negative Z_S values show decreasing trends. Testing trends is performed at the specific α significance level. When $|Z_S| > |Z1 - \alpha/2|$, the null hypothesis is rejected, indicating that a significant trend exists in the time series. $|Z1 - \alpha/2|$ is obtained from the standard normal distribution table. MK test is used to detect if a trend in annual and seasonal precipitation series is statistically significant. The significance level of Mann-Kendall test has proven to be useful in determining the possible existence of statistically significant trends assuming a 95% probability level [37] which is p value ≤ 0.05. At the 5% significance level, the null hypothesis of no trend is rejected if, $|Z_S| > 1.96$.

Sen's Slope estimation test computes both the slope (i.e. the linear rate of change) and intercept according to Sen's method. The magnitude of the trend is predicted by Theil (1950) and Sen (1968) slope estimator methods. A positive value of β indicates an 'upward trend' (increasing values with time), while a negative value of β indicates a downward trend [38,39]. Here, the slope (Ti) of all data pairs is computed as (Sen, 1968). Teil-Sen's estimator is used to quantify the magnitude of trends and has been widely used in analyzing hydrological time series data [40]. The magnitude of the trend is estimated by Sen's slope method (Sen, 1968) which is proceeds by calculating the slope as a change in measurement per change in time,

$$Q = \frac{x_j - x_i}{j - i}, \quad i < j, \quad \text{(Equation 8)}$$

Where Xj and Xi i[th] and j[th] data point in time series (j>i), respectively. Teil-Sen's estimator's main advantage lies in the global median used, which makes it more resistant to the effect of extreme values in the time series [13] and Q is the slope between data points Xj and Xi , Sen's slope estimator is simply given by the median slope,

$$\beta = \begin{cases} Q'_{\frac{N+1}{2}}, & N \text{ is odd} \\ \frac{1}{2}\left[Q'_{\frac{N}{2}} + Q'_{\frac{N+2}{2}}\right], & N \text{ is even} \end{cases} \quad \text{(Equation 9)}$$

Where, N is the number of calculated slopes. A positive value of ***β*** indicates an increasing trend and a negative value indicates a decreasing trend in the time series. Finally, this paper used linear regression, quadratic and cubic line to assess trends in these extreme indicators for each season and model.

RESULT AND DISCUSSION

Descriptive statistics and rainfall variability analysis

The mean annual rainfall of the area during the study period was 638.2 mm with 158.1 mm standard deviation and 24.8% CV. The annual minimum and maximum ever recorded rainfalls were 379.4 mm (in 1980-the driest year) and 1012.7 mm (in 2010-the wettest year) per year respectively. And the kiremt Seasonal minimum and maximum ever recorded rainfalls were 97 mm (in 1987-the driest seasonal) and 521.8 mm (in 2010-the wettest season) per kiremt seasonal rainfall respectively, while 47.4 mm (in 2000-the driest seasonal) and 615.5 mm (in 1987-the wettest season) per belg seasonal rainfall respectively (Table 2). The result showed on table 2 is that a time series of percentage contributions of each rainfall month to the total seasonal rainfall since records began.

As depicted in Table 2, the kiremt and belg seasonal rainfall contribution have shown almost similar contribution rain season in the study area contributes about 46.3% of the total rainfall (where nearly 41.6% comes only in belg season which clearly revealed that relatively presence of more concentration of rainfall. While ONDJ contributes only 12%: monthly maximum contribution were 18.1% and 17.4% in August and April respectively while minimum monthly contribution were about 3.1%, 3.8% and 3.8% in January, February and June rainfall respectively). It is easy to understand that June monthly rainfall has less contribution to kiremt rainfall for the study area.

Table 2: Basic statistical analysis of rainfall in Dire Dawa Meteorological station (1980-2014).

Month	Min	Max	Mean	Contribution%
January	0	128.2	19.7	3.1
February	0	135.2	24.2	3.8
March	1.3	222	75.8	11.9
April	22	249.9	110.8	17.4
May	0	243.5	55.2	8.7
June	0	75	23.9	3.8
July	2.3	206.9	83.9	13.1
August	51.6	241.5	115.3	18.1
September	16.2	215.2	72.1	11.3
October	0	266.9	31.9	5
Nov	0	82.1	13.6	2.1
Dec	0	129.8	11.9	1.9
FMAM	47.4	615.5	265.8	41.6
JJAS	97	521.8	295.3	46.3
ONDJ	0.2	381.6	77.1	12.1
Annual	379.4	1012.7	638.2	100

Analysis of climate variability

Inter-Seasonal to seasonal climate variability of monthly and seasonal time scale of rainfall mean and coefficient variation of Dire Dawa meteorological station were analysed. The result reveals that the rainfall either in monthly or seasonal time scales is highly variable (Tables 3 and 4). The rainfall anomalies also witnessed for the presence of seasonal variability and the trend being below the long-term average become more pronounced (Figures 2 and 3). The kiremt seasonal rainfall anomalies indicated in (Figure 2) revealed that the study area received above normal rainfall in 1983, 1992, 1994, 1996, 1998, 2001, 2007 and 2010,whiel with the latter being the most severe and Widespread droughts (below normal rainfall) were experienced in1980, 1981, 1984, 1987, 1989, 1990, 1991, 1993 and 2009 of kiremt seasons in the study area (Figure2). Similarly, belg seasonal extreme drought years were experienced in 1980, 1984, 1992, 2000, 2002, 2003, 2004, 2009, 2011 and 2012 and extremely wet belg season were in 1981, 1983, 1986, 1987, 1989, 1990, 1991, 1996 and 2010 (Figure 3). While very low values of rainfall anomaly correspond to severe belg seasonal drought periods-1.7 in 2000 and-1.6 in 2009 (Figure 3).

Historical kiremt seasonal droughts in Ethiopia had been linked with ENSO events in the past [17,30,41-43]. Recent documented kiremt seasonal droughts of 1984, 1987, 1991-1992,1993-1994, 2002, 2009, and 2012, were either coincide or follow El Nino events shortly. As depicted (Figure 2); the rainfall anomaly for these drought years were found to be very low (Figures 2 and 3).

The descriptive statistics of inter-seasonal precipitation such as the Coefficient of Variation (CV) has been discussed in (Table 2). So from the analysis it is observed that the monthly precipitation coefficient of variation ranging from 51.6 in month of July and 223.9% in the month of December (Table 3). According to Hare (2003), CV is used to classify the degree of variability of rainfall events as less (CV<20), moderate (20<CV<30), high (CV>30), very high CV>40% and CV>70% indicate extremely high inter-annual variability of rainfall [1]. Based on this classification, the observed rainfall data in all the months, belg and kiremt season had above 30% coefficient of variation (CV) highlighting the high variability of precipitation over the study area while the annual rainfall shown that moderate variability (Table 3). The rainfall CV of belg (46.4%) is higher than that of kiremt CV (33.1%) which implies more inter-annual variability of belg rainfall is higher than that of kiremt one (Table 3). The result of seasonal rainfall variability agrees with the findings of Yilma and Zanke (2004), Aklilu (2006), Viste (2013) and Arragaw and Woldeamlak (2017) where more variability in belg rainfall than the kiremt rainfall in most parts of Ethiopia [29,42,44,45].

Table 3: Basic statistical analysis of rainfall in Dire Dawa Meteorological station during observed period and (CMIP5) underrcp 4.5 future model data.

Period	Observed Rainfall data (1980-2010)			MRI-CGCM3(CMIP5) rcp 4.5 Rainfall data (2010-2100)				HadGEM2-ES (CMIP5) rcp 4.5 Rainfall Data (2010-2100)			
	δ	μ1	CV	δ	μ2	CV	Δμ	δ	μ3	CV	Δμ
January	30.1	19.7	152.8	22.6	17	132.9	-2.7	34.6	25.9	133.4	6.2
February	34.2	24.2	141.1	55.6	26.3	211.5	2.1	71.3	47.4	150.5	23.2
March	57.7	75.8	76.1	74.5	88.2	84.6	12.4	27.1	35.4	76.5	-40.4
April	66.3	110.8	59.8	77.2	117.7	65.6	6.9	73.9	123.1	60	12.3
May	51.2	55.2	92.7	57.2	61.3	93.3	6.1	37.9	41.2	92	-14
June	23.2	23.9	96.6	22.8	23	99.4	-0.9	19.9	20.1	98.9	-3.8
July	43.3	83.9	51.6	48.9	87.7	55.7	3.8	47	83.4	56.3	-0.5
August	45.9	115.3	39.8	41.5	91.6	45.3	-23.7	52.7	121.5	43.4	6.2
September	39.4	72.1	54.7	41.7	74.7	55.8	2.6	35.1	64.7	54.3	-7.4
October	48.5	31.9	152.1	55.9	37.6	148.6	5.7	59.6	39.8	149.7	7.9
Nov	19.9	13.6	145.8	19.7	13.3	148.5	-0.3	23.8	17	139.9	3.4
Dec	26.8	11.9	223.9	68.1	33	206.4	21.1	38.2	18.8	202.9	6.9
ONDJ	73.3	77.1	95	95.3	100.9	94.5	23.8	92.7	101.5	91.3	24.4
FMAM	123.4	265.8	46.4	149.2	293.5	50.8	27.7	126.2	247.1	51.1	-18.7
JJAS	97.7	295.3	33.1	98.4	276.9	35.5	-18.4	100.1	289.6	34.5	-5.7
Annual	158.1	638.2	24.8	167.4	671.3	24.9	33.1	159.7	638.3	25	0.1

Table 4: Basic statistical analysis of rainfall in Dire Dawa Meteorological station during observed period and (CMIP5) under rcp 8.5 future model data.

Period	Observed Rainfall data (1980-2010)			MRI-CGCM3(CMIP5) rcp 8.5 Rainfall data (2040-2100)				HadGEM2-ES (CMIP5) rcp 8.5 Rainfall Data (2040-2100)			
	δ	μ1	CV	δ	μ2	CV	Δμ	δ	μ3	CV	Δμ
January	30.1	19.7	152.8	41.5	31.9	130.2	12.2	28.9	21.2	136.1	1.5
February	34.2	24.2	141.1	57.2	39.5	144.8	15.3	30.7	21.1	145.4	-3.1
March	57.7	75.8	76.1	60	78.7	76.2	2.9	148.8	181.7	81.9	105.9
April	66.3	110.8	59.8	133.1	221.4	60.1	110.6	100.1	160.3	62.4	49.5
May	51.2	55.2	92.7	46.6	49.4	94.4	-5.8	69.5	72.8	95.5	17.6
June	23.2	23.9	96.6	26.2	26.7	98	2.8	24.1	24.4	98.9	0.5
July	43.3	83.9	51.6	57.5	101.5	56.7	17.6	45.4	79.3	57.2	-4.6
August	45.9	115.3	39.8	60.8	135	45	19.7	30.5	61.6	49.5	-53.7
September	39.4	72.1	54.7	28	51	55	-21.1	33.5	59.6	56.2	-12.5
October	48.5	31.9	152.1	60.8	40.1	151.7	8.2	60.5	39.6	153	7.7
Nov	19.9	13.6	145.8	24.1	17	141.8	3.4	26.6	17	156.8	3.4
Dec	26.8	11.9	223.9	53.8	26.2	205.5	14.3	52.2	25.3	206.4	13.4
ONDJ	73.3	77.1	95	100.1	115.2	86.9	38.1	91.6	103	88.9	25.9
FMAM	123.4	265.8	46.4	188.6	389	48.5	123.2	230.7	436	52.9	170.2
JJAS	97.7	295.3	33.1	111.3	314.1	35.4	18.8	88.6	224.9	39.4	-70.4
Annual	158.1	638.2	24.8	211	818.3	25.8	180.1	216	763.9	28.3	125.7

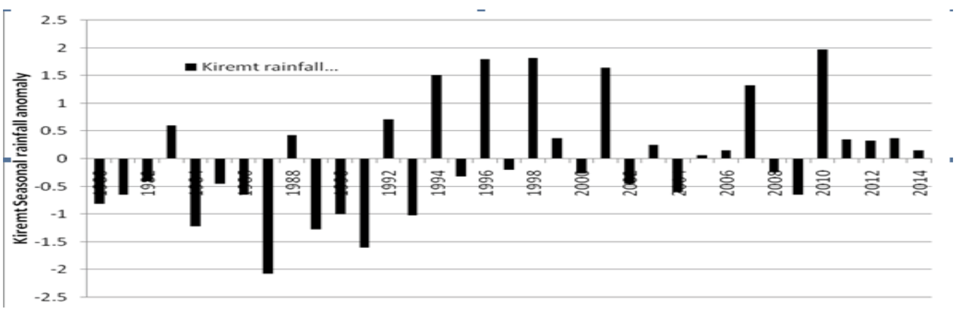

Figure 2: Kiremt seasonal rainfall variability in Dire Dawa rainfall station.

When the rainfall amount of the recent (1980-2014) is compared with the near, mid and end of the 21st centuries under RCP 4.5 of model MRI-CGCM3 CMIP5 and HadGEM2-ES (CMIP5), a reduction in kiremt mean rainfall and annual mean has shown slight increment within both considered model while ONDJ has shown an increment of mean rainfall within both model. On the other hand FMAM mean rainfall in MRI-CGCM3 (CMIP5) under rcp 4.5 has shown an increment while decrement in HadGEM2-ES (CMIP5) model data (Table 3), while annual rainfall variability in MRI-CGCM3 (CMIP5) under rcp 4.5 is about 24.9% and HadGEM2-ES (CMIP5) under rcp 4.5 is 25.0%. Based on Hare (2003), CV of rainfall classification, the annual rainfall variability of Dire Dawa station has shown moderate rainfall variability in both model under rcp 4.5, while inter-seasonal and seasonal rainfall variability have shown that highly variable in observed and future model data (Table 3).

When the rainfall amount of the recent (1980-2014) is compared with the mid and end of the 21st centuries under RCP 8.5 of model HadGEM2-ES (CMIP5), a has shown that reduction in kiremt rainfall mean while annual mean, ONDJ and FMAM mean were shown a slight increment within both considered MRI-CGCM3 CMIP5 and HadGEM2-ES (CMIP5 model but rainfall variability will be expected to increase. According to Hare (2003), CV classification of Dire Dawa meteorological station in observed as well mid and end century of both considered model, rainfall variability indicated that 24.8% in observed 25.8 in MRI-CGCM3 (CMIP5) and 28.3% in HadGEM2-ES(CMIP5) under rcp 8.5, which is categorized under moderate rainfall variability (Table 4) [1].

Rainfall and temperature trend analysis

The Inter-seasonal and seasonal mean of time series data of climatic parameters, particularly temperature (maximum and minimum) and precipitation were analysed using MK test for Dire Dawa Meteorological station with observed data from (1980 to 2014) and GCM model data from (2010 to 2100). MK statistics and p-values derived at 5% level of significances were considered in this study. In the MK test, parameters like Kendall's Z statistic, p-Value, Sen's Slope were considered to identify the increasing or decreasing trend in the time series of climatic parameters. The test results are discussed in detail separately for each parameter in (Tables 5 to 9). The observed rainfall trend based on monthly and seasonal time

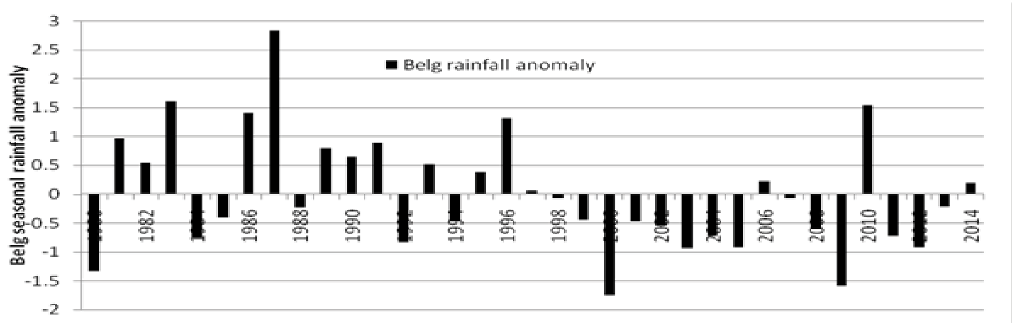

Figure 3: Belg seasonal rainfall variability in Dire Dawa rainfall station.

Table 5: Monthly Mann-Kendall results of precipitation and temperature for Dire Dawa station

Time series	Rainfall (1980-2014) N=35				T_{max} (1980-2014) N=35				T_{min} (1980-2014) N=35			
	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope
Jan	1.167	0.243		0	4.21	0.00003	***	0.06	-0.54	0.589		-0.012
Feb	-1.4	0.1699		-0.0579	3.73	0.0002	***	0.076	-1.15	0.25		-0.025
Mar	-0.7	0.4954		-0.5	3.02	0.0026	**	0.069	-2.18	0.029	*	-0.029
April	-1.5	0.1251		-1.6444	4.04	0.00005	***	0.129	2.74	0.0062	**	0.033
May	-0.23	0.8203		-0.1125	4.25	0.00002	***	0.104	2.06	0.039	*	0.036
June	1.52	0.1286		0.4238	4.7	2.00E-06	***	0.079	0.47	0.638		0.004
July	3.09	0.0019	**	1.8388	2.68	0.0072	***	0.039	-1.81	0.071		-0.0214
Aug	1.42	0.1556		1.1571	1.79	0.074		0.025	-1.45	0.1458		-0.0192
Sept	0.16	0.8759		0.1111	3.32	0.0009	***	0.054	-0.87	0.3834		-0.008
Oct	0.06	0.9547		0	3.64	0.0003	***	0.062	-0.09	0.9319		0
Nov	1.13	0.2575		0	3.98	0.00007	***	0.056	0.36	0.7219		0.004
Dec	0.96	0.3353		0	4.27	0.00002	***	0.0533	-0.71	0.4767		-0.0111
ONDJ	0.45	0.645		0.25	5.3	1.00E-06	***	0.06	-0.83	0.4067		-0.005
FMAM	-2.1	0.0355	*	-4.7	4.8	2.00E-06	***	0.108	0.527	0.5981		0.0051
JJAS	2.27	0.0231	*	3.547	4.4	9.00E-06	***	0.05	-1.4	0.162		0.009
Annual	-0.23	0.8203		-0.55	6.4	0	***	0.072	-0.63	0.5291		0

*significant; ** more significant; ***highly significant

Table 6: Inter-seasonal to seasonal Mann-Kendall test results of precipitation and temperature for Dire Dawa station within HadGEM2-ES (CMIP5) model data under RCP 4.5.

Time series	HadGEM2-ES(CMIP5)rcp4.5 Rainfall Model Data (2010-2100), N=91				HadGEM2-ES(CMIP5) rcp4.5 T_{max} Model Data (2010-2100), N=91				HadGEM2-ES(CMIP5) rcp4.5T_{min} Model Data (2010-2100), N=91			
	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope
Jan	-0.34	0.732		0	8.31	0	***	0.033	4.93	0	***	0.028
Feb	-0.1	0.924		0	6.4	0	***	0.039	4.01	0.00005	***	0.026
Mar	-0.984	0.325		-0.082	6.1	0	***	0.033	5.8	0	***	0.033
April	-1.89	0.058		-0.533	5.6	0	***	0.045	8.8	0	***	0.038
May	-0.16	0.875		-0.121	5.9	0	***	0.038	8.1	0	***	0.041
June	1.1	0.283		0.042	8.4	0	***	0.042	6.6	0	***	0.032
July	2.48	0.013		0.344	6.8	0	***	0.026	4.7	0	***	0.022
Aug	1.7	0.089		0.283	6.5	0	***	0.03	5.4	0	***	0.025
Sept	-0.79	0.426		-0.098	8.4	0	***	0.044	6.3	0	***	0.03
Oct	0.74	0.459		0.059	6.4	0	***	0.031	7.8	0	***	0.041
Nov	0.78	0.431		0	7.8	0	***	0.032	7.1	0	***	0.033
Dec	0.68	0.497		0	9.9	0	***	0.038	4.5	0	***	0.024
ONDJ	1.16	0.247		0.311	10.1	0	***	0.033	8.3	0	***	0.031
FMAM	-1.54	0.124		-0.822	7.3	0	***	0.039	8.1	0	***	0.035
JJAS	1.5	0.137		0.559	9.1	0	***	0.036	5.7	0	***	0.026
Annual	0.082	0.934		0.064	10.4	0	***	0.037	7.9	0	***	0.031

*significant; ** more significant; ***highly significant

Table 7: Monthly Mann-Kendall results of precipitation and temperature for Dire Dawa station within MRI-CGCM3 (CMIP5) model data under RCP 4.5.

Time series	MRI-CGCM3 (CMIP5) rcp4.5 Rainfall Model Data (2010-2100), N=91				MRI-CGCM3 (CMIP5) rcp4.5 T_{max} Model Data (2010-2100), N=91				MRI-CGCM3 (CMIP5) rcp4.5 T_{min} Model Data (2010-2100), N=91			
	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope
Jan	0.09	0.9268		0	6.7	0	***	0.023	4.8	0	***	0.027
Feb	1.02	0.3062		0	3.9	0	***	0.022	3.9	0	***	0.026
Mar	-3.25	0.0012	**	-0.743	5.3	0	***	0.029	4.9	0	***	0.021
April	0.94	0.3475		0.267	3.8	0.0002	***	0.0312	7.5	0	***	0.025
May	-0.98	0.3268		-0.129	3.9	0	***	0.027	4.7	0	***	0.18
June	1.313	0.1891		0.066	4.8	0	***	0.0212	5.5	0	***	0.016
July	1.8	0.798		0.248	3.1	0.002	**	1.84	3.7	0.0002	***	0.011
Aug	-1.1	0.2848		-0.168	5.8	0	***	0.0242	4.4	0	***	0.0133
Sept	-0.45	0.651		-0.061	6.7	0	***	0.029	5.8	0	***	0.021
Oct	1.3	0.2045		0.092	0.87	0.382		0.004	5.3	0	***	0.018
Nov	1.1	0.2673		0	4.1	0.00003	***	0.016	5.1	0	***	0.017
Dec	1.1	0.292		0	6.4	0	***	0.019	3.8	0.0001	***	0.02
ONDJ	2	0.0431	*	0.467	6.1	0	***	0.016	7.6	0	***	0.02
FMAM	-0.75	0.4528		-0.444	5.4	0	***	0.028	7	0	***	0.023
JJAS	0.1	0.9235		0.048	7.5	0	***	0.023	5.9	0	***	0.015
Annual	0.7	0.4822		0.567	7.5	0	***	0.0233	7.9	0	***	0.019

*significant; ** more significant; ***highly significant

series have shown that month of July and JJAS seasonal rainfall were shown an inclined trend at 5% statistical significant level, while FMAM (belg) seasonal rainfall has shown declining at 5% statically significant level. Other time period considered in this study has no statistical significant (Figure 5 and Table 5). Similarly, the observed maximum temperature trend shown that an inclining trend at 5% statistical significant level while minimum temperature change is not statistically significant at 5% level except declining in March and incline in April and May (Figures 4 and 5, Table 5). The mean maximum temperature changes were more significant than the mean minimum temperature change. Figure 4 shows that the annual maximum temperature was increased significantly through time series 1980-2014 as per indicated by the trend line.

Table 8: Monthly Mann-Kendall results of precipitation and temperature for Dire Dawa station within HadGEM2-ES (CMIP5) model data under RCP 8.5.

Time series	HadGEM2-ES (CMIP5) rcp8.5 Rainfall Model Data (2040-2100), N=61				HadGEM2-ES (CMIP5) rcp8.5 T_{max} Model Data (2040-2100), N=61				HadGEM2-ES (CMIP5) rcp8.5 T_{min} Model Data (2040-2100), N=61			
	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope
Jan	-0.6	0.5472		0	7.8	0	***	0.086	4.7	0	***	0.054
Feb	-0.73	0.4654		0	6.8	0	***	0.087	4.2	0.00003	***	0.0553
Mar	0.77	0.4403		0.293	6.3	0	***	0.082	3.9	0.00009	***	0.054
April	0.16	0.8764		0.135	5.9	0	***	0.089	6.7	0	***	0.055
May	-0.18	0.8568		-0.033	6.2	0	***	0.077	6.3	0	***	0.0575
June	1.78	0.075		0.175	8	0	***	0.09	4.8	0	***	0.038
July	3.5	0.00047	***	1.103	6.4	0	***	0.048	3.1	0.002	**	0.026
Aug	2.6	0.0105	*	0.98	5.3	0	***	0.041	3.9	0.00008	***	0.028
Sept	-0.67	0.5015		-0.13	7.5	0	***	0.085	5.4	0	***	0.0444
Oct	0.55	0.5839		0.069	6.65	0	***	0.067	6.1	0	***	0.062
Nov	1.3	0.1944		0	7.8	0	***	0.069	4.9	0	***	0.064
Dec	1.3	0.2087		0	8.4	0	***	0.069	5.1	0	***	0.0634
ONDJ	1.2	0.2297		0.662	9.1	0	***	0.072	5.9	0	***	0.0576
FMAM	-0.068	0.9454		-0.077	7.6	0	***	0.086	6.1	0	***	0.057
JJAS	3.1	0.002	**	2.32	8.2	0	***	0.067	4.1	0.00005	***	0.032
Annual	-0.227	0.8203		-0.55	9.9	0	***	0.075	5.3	0	***	0.048

*significant; ** more significant; ***highly significant

Table 9: Monthly Mann-Kendall results of precipitation and temperature for Dire Dawa station within MRI-CGCM3 (CMIP5) model data under RCP 8.5.

Time series	MRI-CGCM3 (CMIP5) rcp8.5 Rainfall Model Data (2010-2100), N=91				MRI-CGCM3 (CMIP5) rcp8.5 T_{max} Model Data (2010-2100), N=91				MRI-CGCM3 (CMIP5) rcp8.5 T_{min} Model Data (2010-2100), N=91			
	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope	MKZ	p value	Sig	Sen's Slope
Jan	-1.1	0.2763		0	7.3	0	***	0.0585	4.9	0	***	0.0576
Feb	-0.39	0.6914		0	5.2	0	***	0.0567	3.1	0.002	**	0.0378
Mar	1.7	0.0917		1.56	4.5	0	***	0.047	3.6	0.0003	**	0.039
April	0.7	0.4858		0.453	2.7	0.00654	**	0.038	5.7	0	***	0.0365
May	-0.1	0.9256		-0.267	2.5	0.014	*	0.0306	4.7	0	***	0.0345
June	1	0.3224		0.0965	6.5	0	***	0.0552	4.7	0	***	0.0342
July	0.17	0.8666		0.0242	6.3	0	***	0.047	2.7	0.008	**	0.0193
Aug	-2.65	0.0082	**	-0.543	6.1	0	***	0.0502	3.8	0.0001	***	0.0264
Sept	-1.44	0.1506		-0.289	7	0	***	0.0665	4.9	0	***	0.035
Oct	-0.17	0.8665		-0.102	6.7	0	***	0.0693	5.8	0	***	0.049
Nov	1.8	0.0716		0	5.4	0	***	0.067	4.7	0	***	0.0422
Dec	1.3	0.1943		0	7.8	0	***	0.052	4.7	0	***	0.054
ONDJ	1.11	0.2653		0.567	8.8	0	***	0.054	5.9	0	***	0.0489
FMAM	0.98	0.3224		1.6	4.7	0	***	0.044	5.7	0	***	0.0394
JJAS	-1.1	0.2873		-0.663	7.9	0	***	0.0557	4	0	***	0.0276
Annual	1.04	0.2987		1.67	8.8	0	***	0.052	5.3	0	***	0.0369

*significant; ** more significant; ***highly significant

There were many climate trend related studies have been conducted in different parts Ethiopia with different results. In this study as depicted in (Table 5), though the declining trend of belg rainfall and inclining in kiremt season and particularly July monthly rainfall shown an inclining trend statistical significance (Table 5). In this study, there is statistical significant decreasing trend of belg rain through time was obtained which coincides with Rosell and Holmer (2007) in the eastern part of South Wollo (Ethiopia) had found a slight decrease in rainfall during the short belg season while the long rainy season (kiremt) had shown an

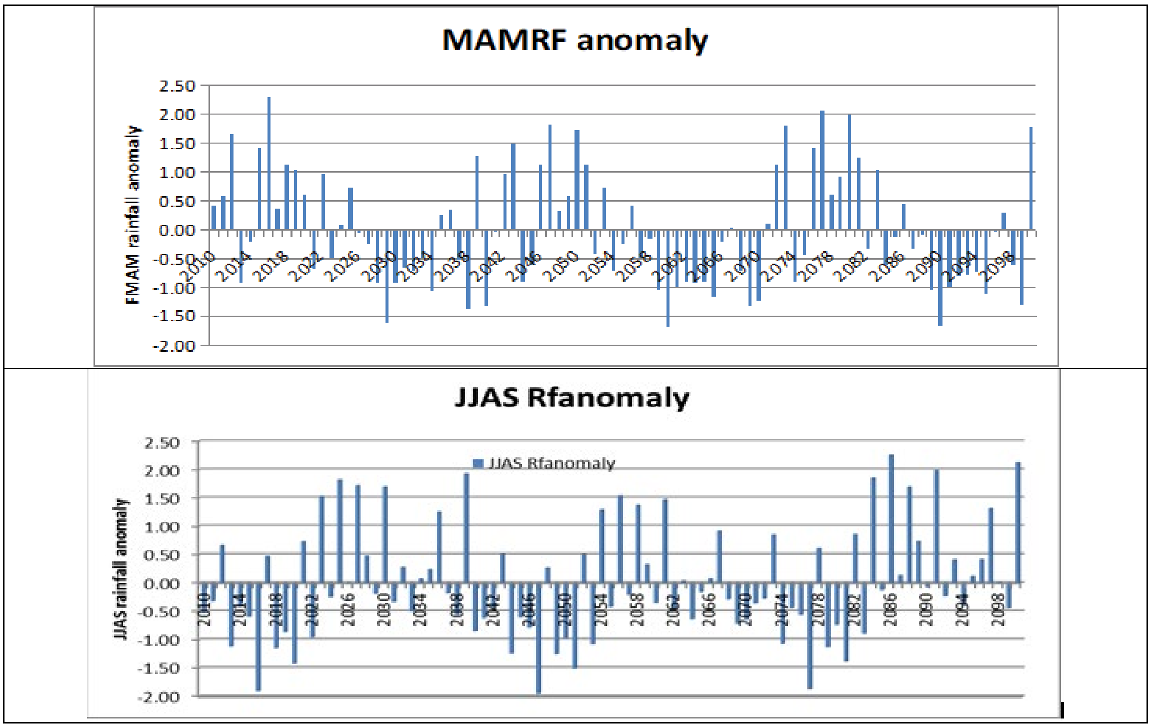

Figure 4: Seasonal rainfall anomaly with HadGEM2-ES model under rcp 4.5.

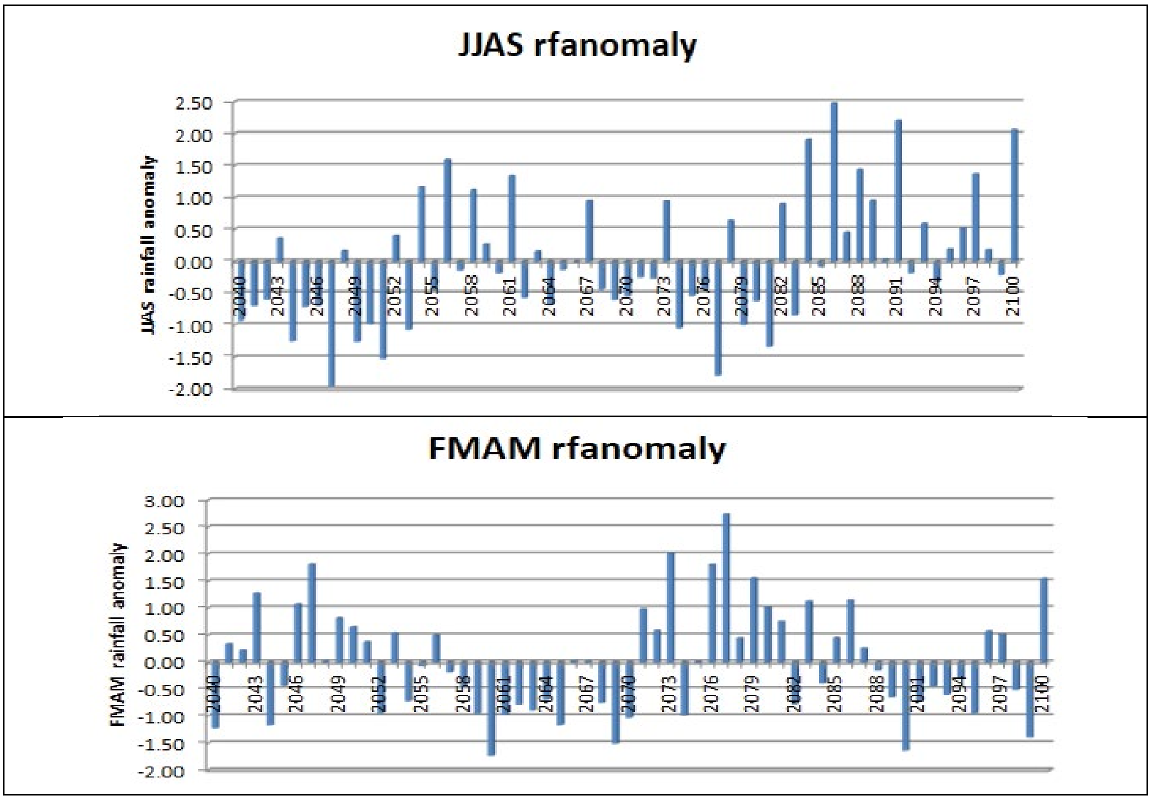

Figure 5: Seasonal rainfall anomaly with HadGEM2-ES model under rcp 8.5.

increasing trend through time and Arragaw and Woldeamlak (2017) where belg rainfall showed a significant decreasing trend and on other hand, the results are different from the findings of Yilma and Zanke (2004) disclosed a significant decline in the annual and kiremt rainfalls for the eastern, southern and south-western stations since about 1982 [29,45,46]. And also Negash (2013) had investigated the spatiotemporal variability of annual and seasonal rainfall over Ethiopia and reported decreasing trends of kiremt and annual rainfall in northern, north western and western parts of the country [47]; while an increasing trend in annual rainfall was observed in a few grid points in eastern parts of the country. Daniel (2014) in his study where statistically non-significant increasing trend was recorded in all seasons (including annual time scale) and Seifu and Abdulkarim (2006) where no significant trend of belg rainfall totals while kiremt rainfall exhibited a significant decreasing trend [30,44].

Based on HadGEM2-E and MRI-CGCM3 (CMIP5) Model under rcp 4.5 future generated data of Dire Dawa station from

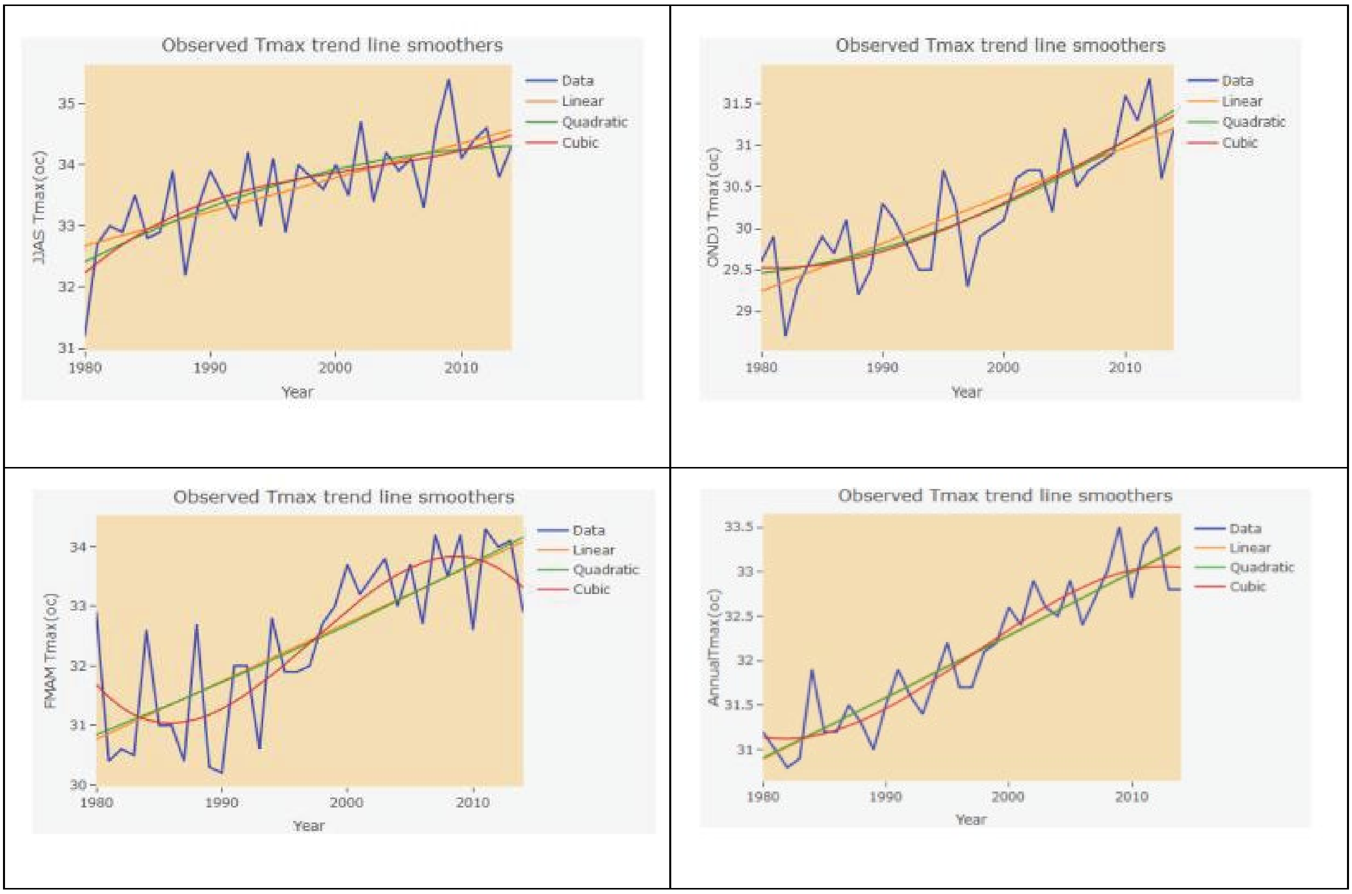

Figure 6: Seasonal and annual observed T_{max} trend analysis for the period 1980-2014.

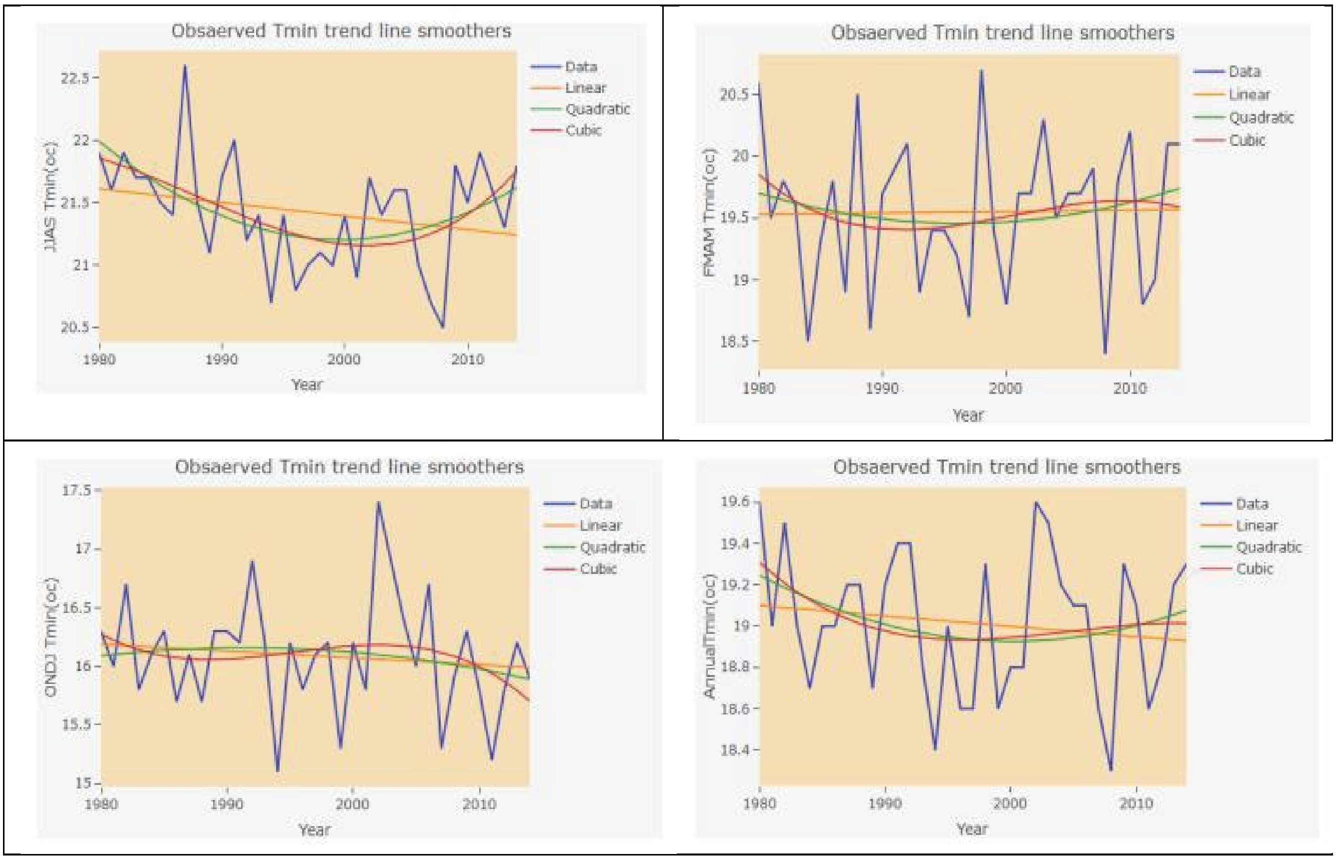

Figure 7: Seasonal and annual observed T_{min} trend analysis for the period 1980-2014.

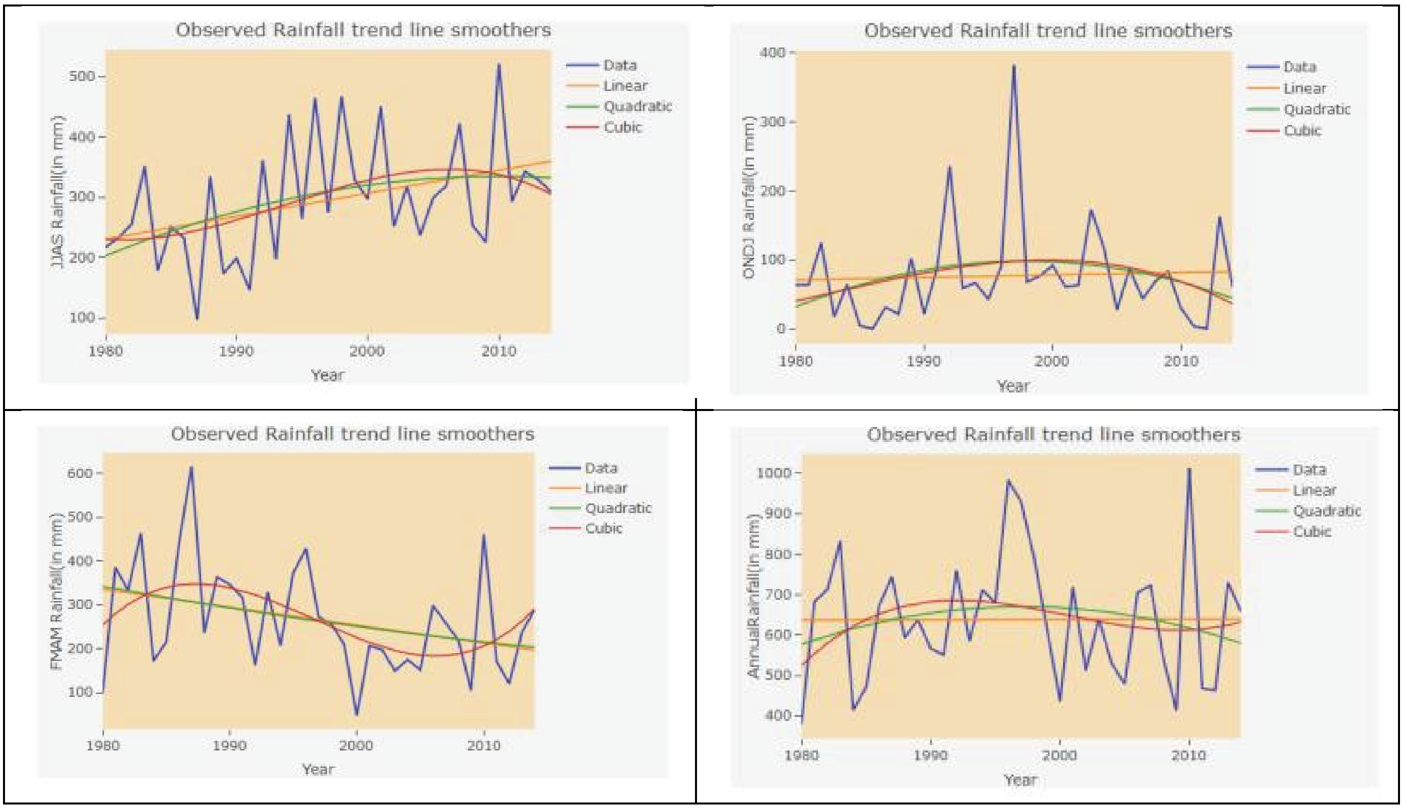

Figure 8: Seasonal and annual observed RF trend analysis for the period 1980-2014 of Dire Dawa.

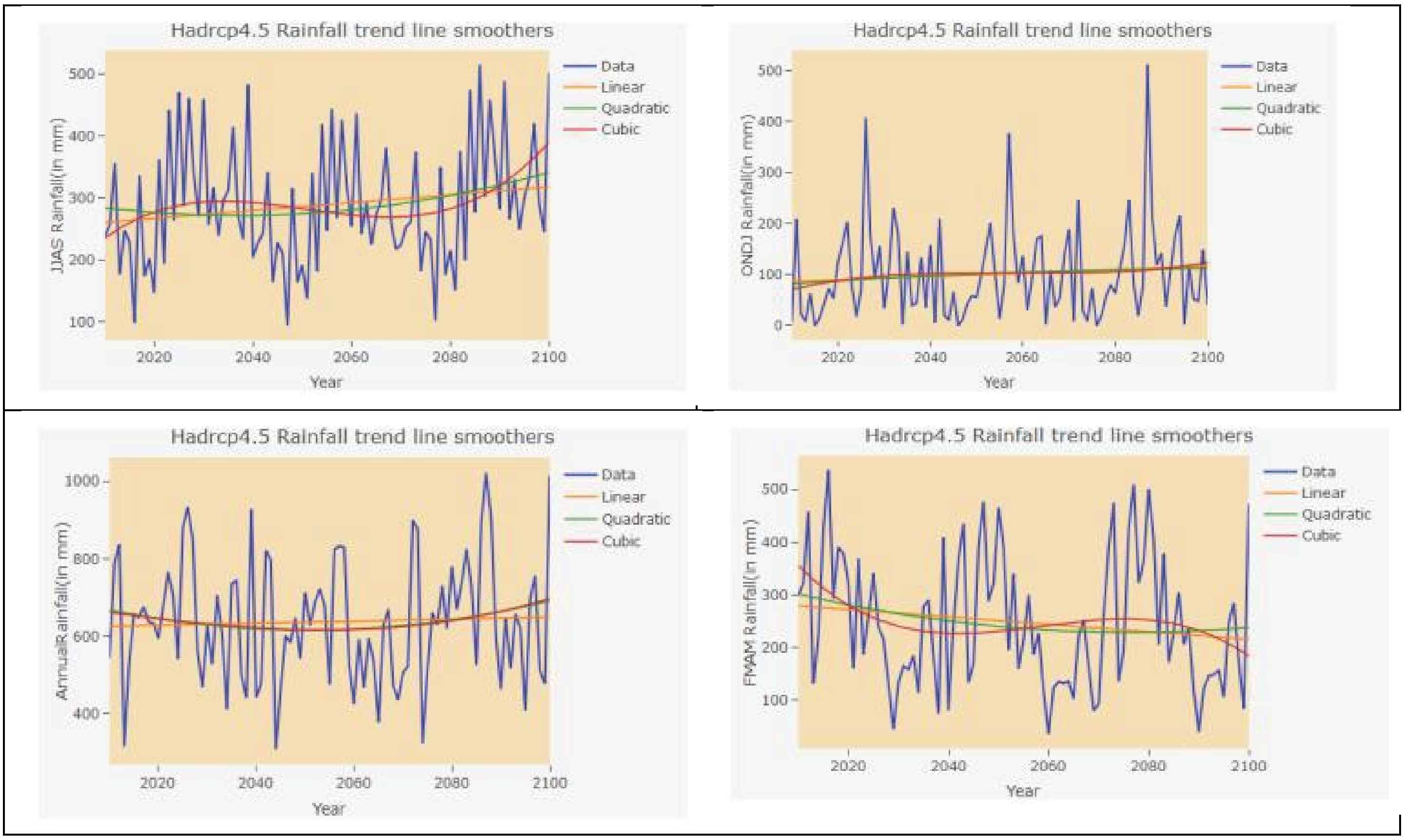

Figure 9: Had (CMIP5) model under rcp4.5 RF trend for the period 2010-2100 of Dire Dawa.

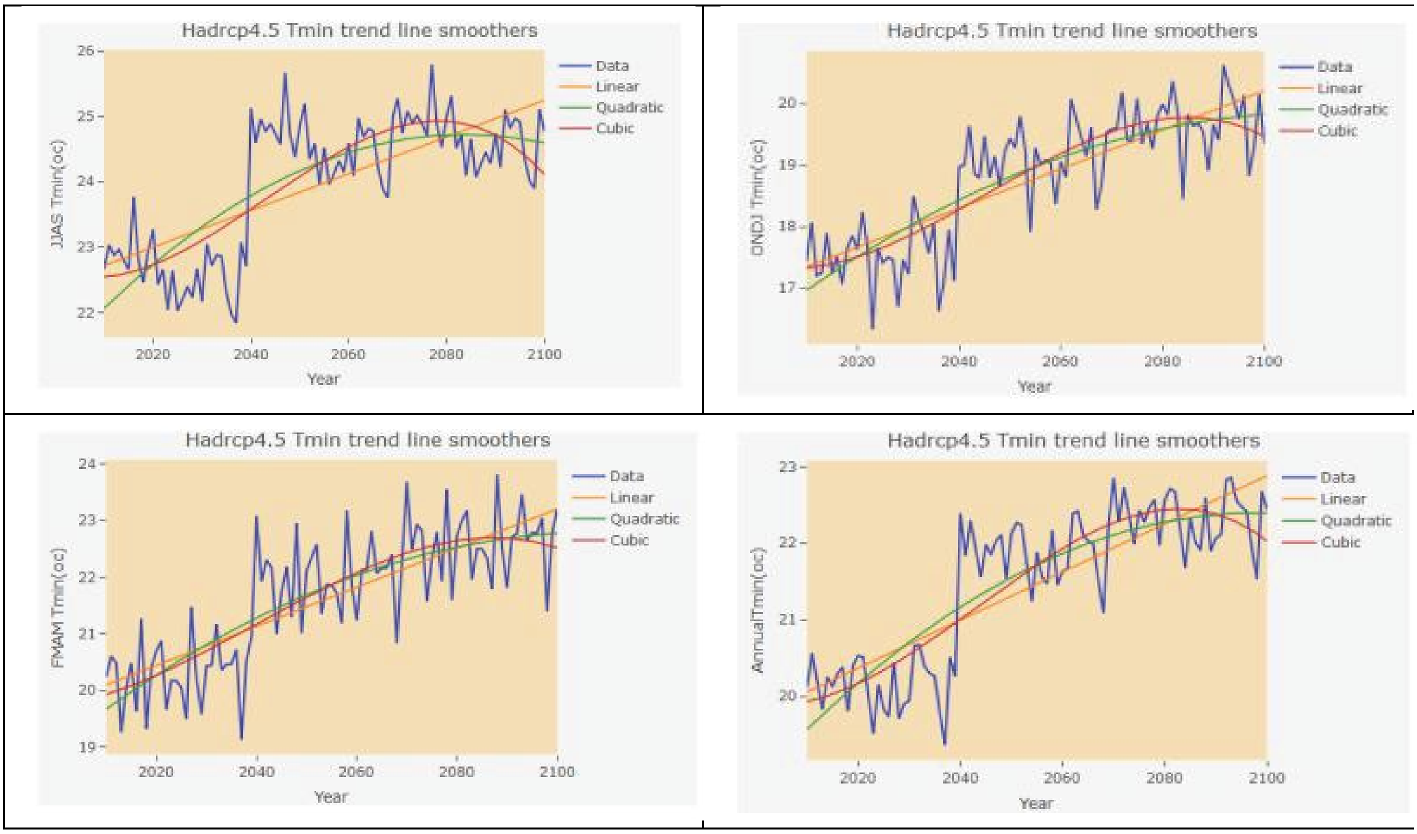

Figure 10: Had (CMIP5) model under rcp4.5 Tmin trend for the period 2010-2100 of Dire Dawa.

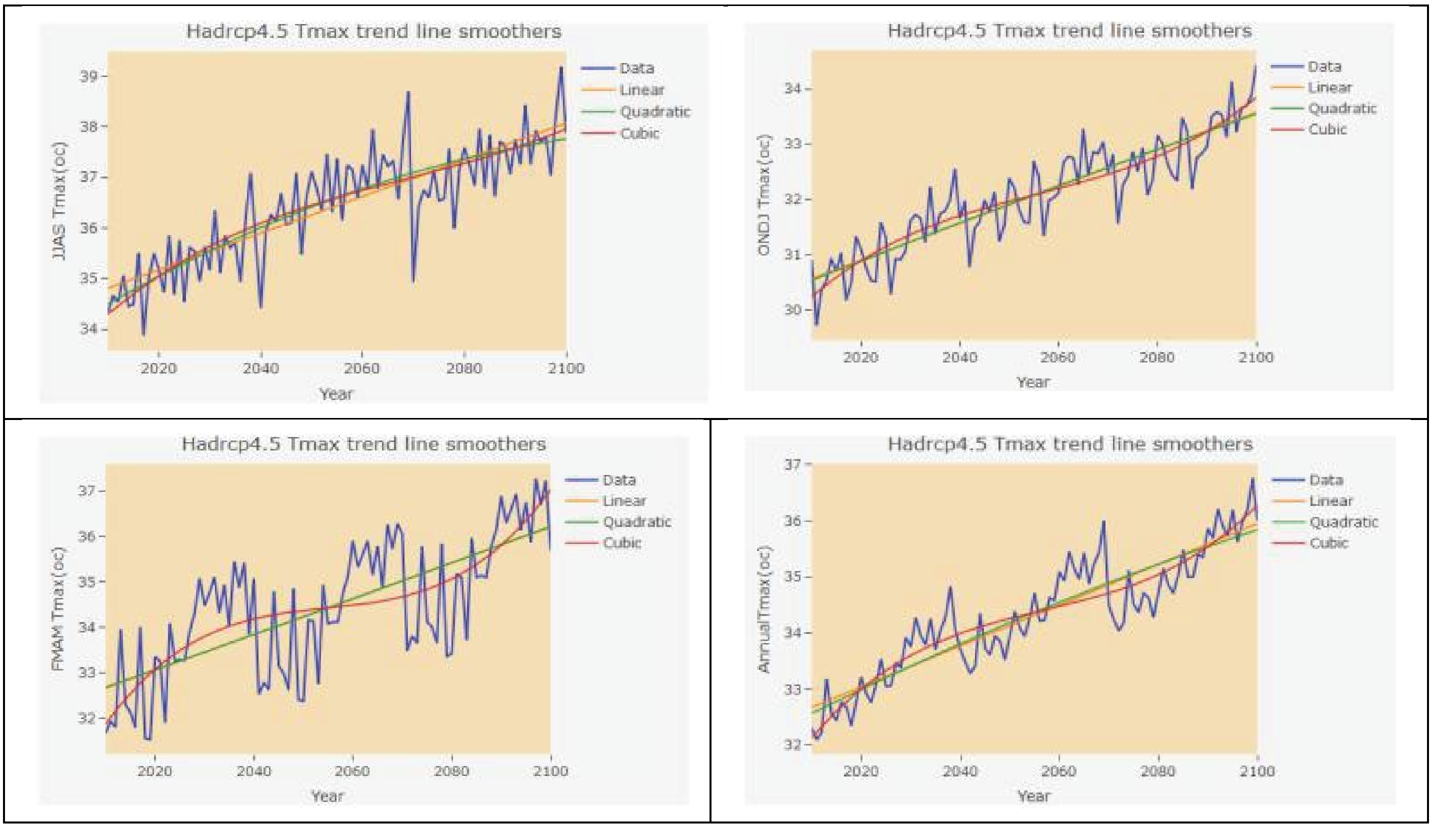

Figure 11: Had (CMIP5) model under rcp4.5 Tmax trend for the period 2010-2100 of Dire Dawa.

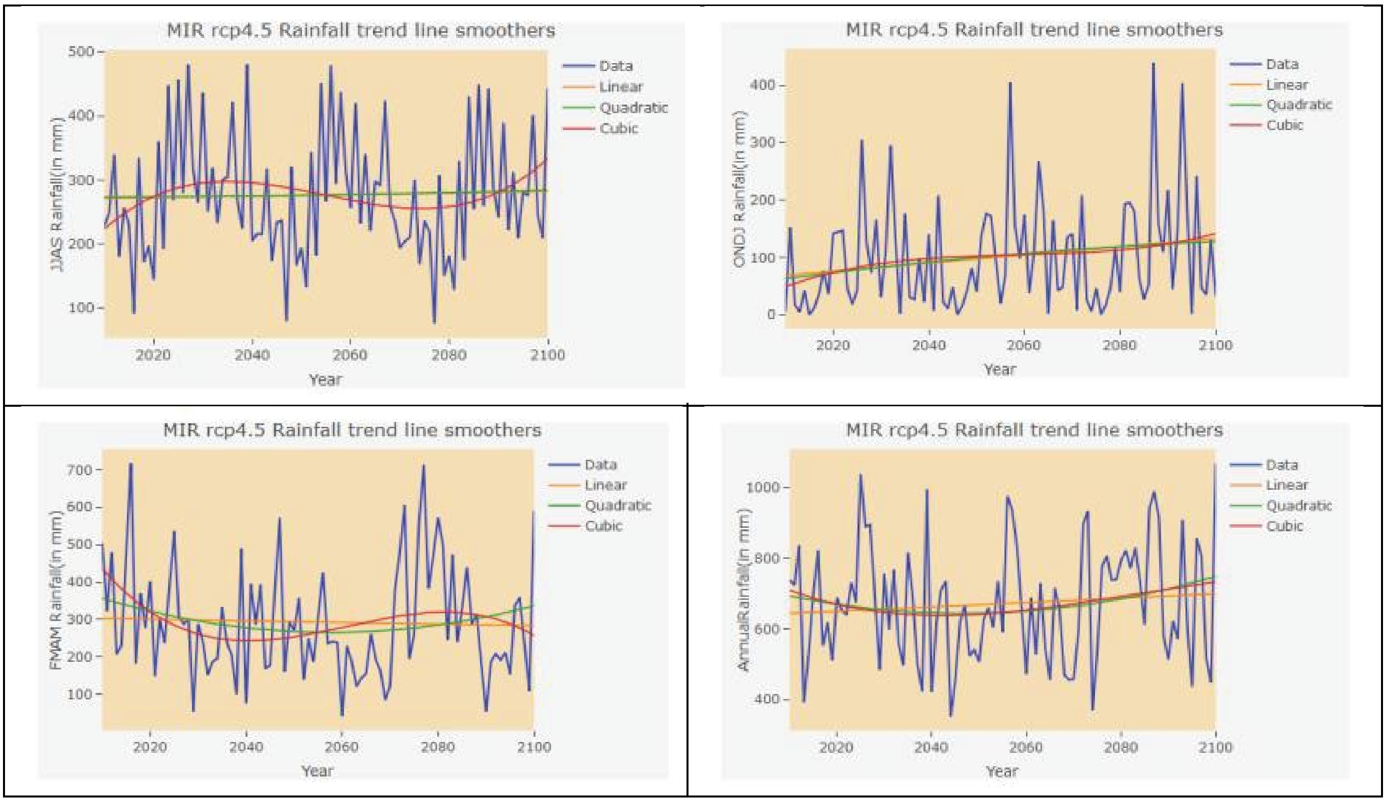

Figure 12: MIR (CMIP5) model under rcp4.5 RF trend for the period 2010-2100 of Dire Dawa.

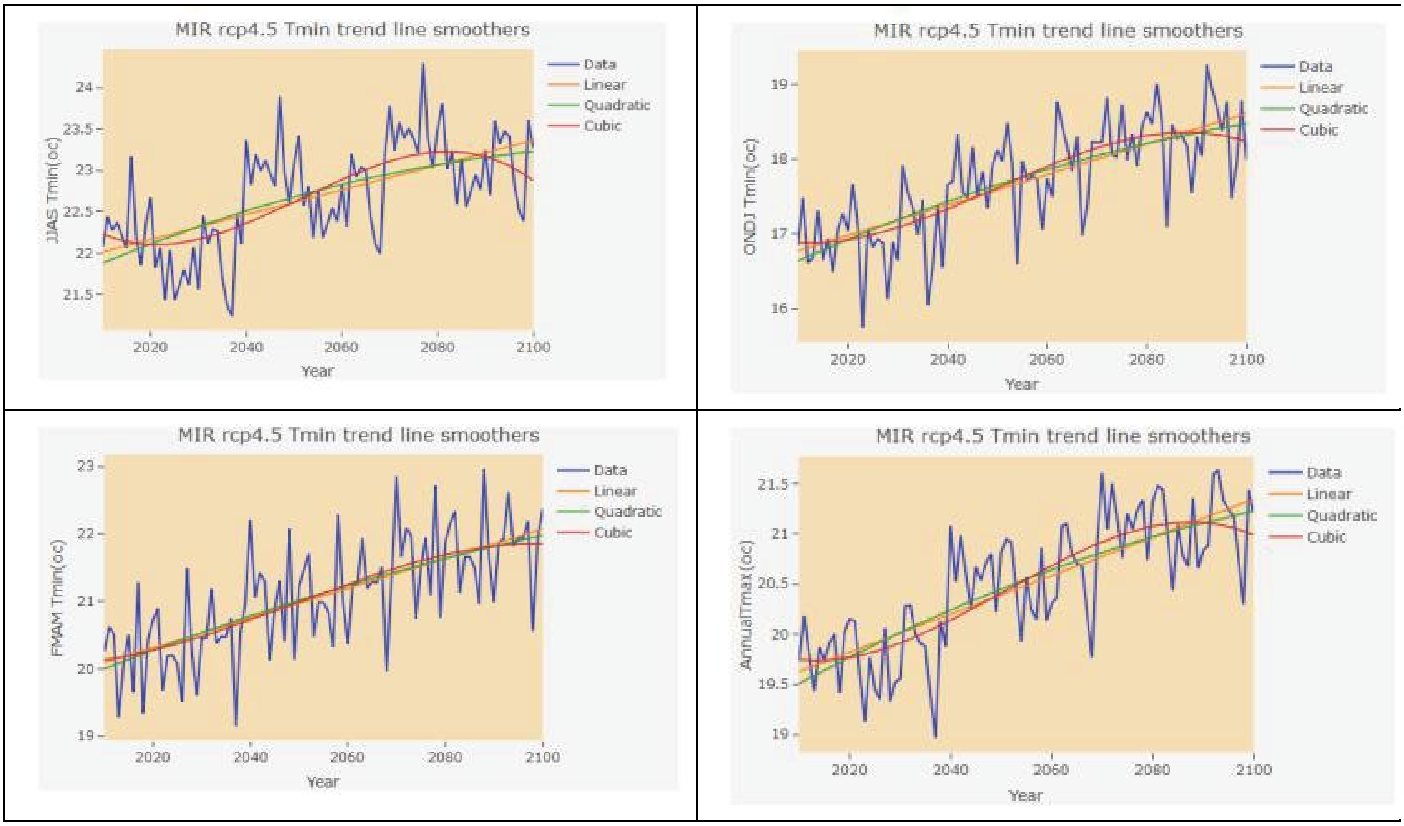

Figure 13: MIR (CMIP5) model under rcp4.5 Tmin trend for the period 2010-2100 of Dire Dawa.

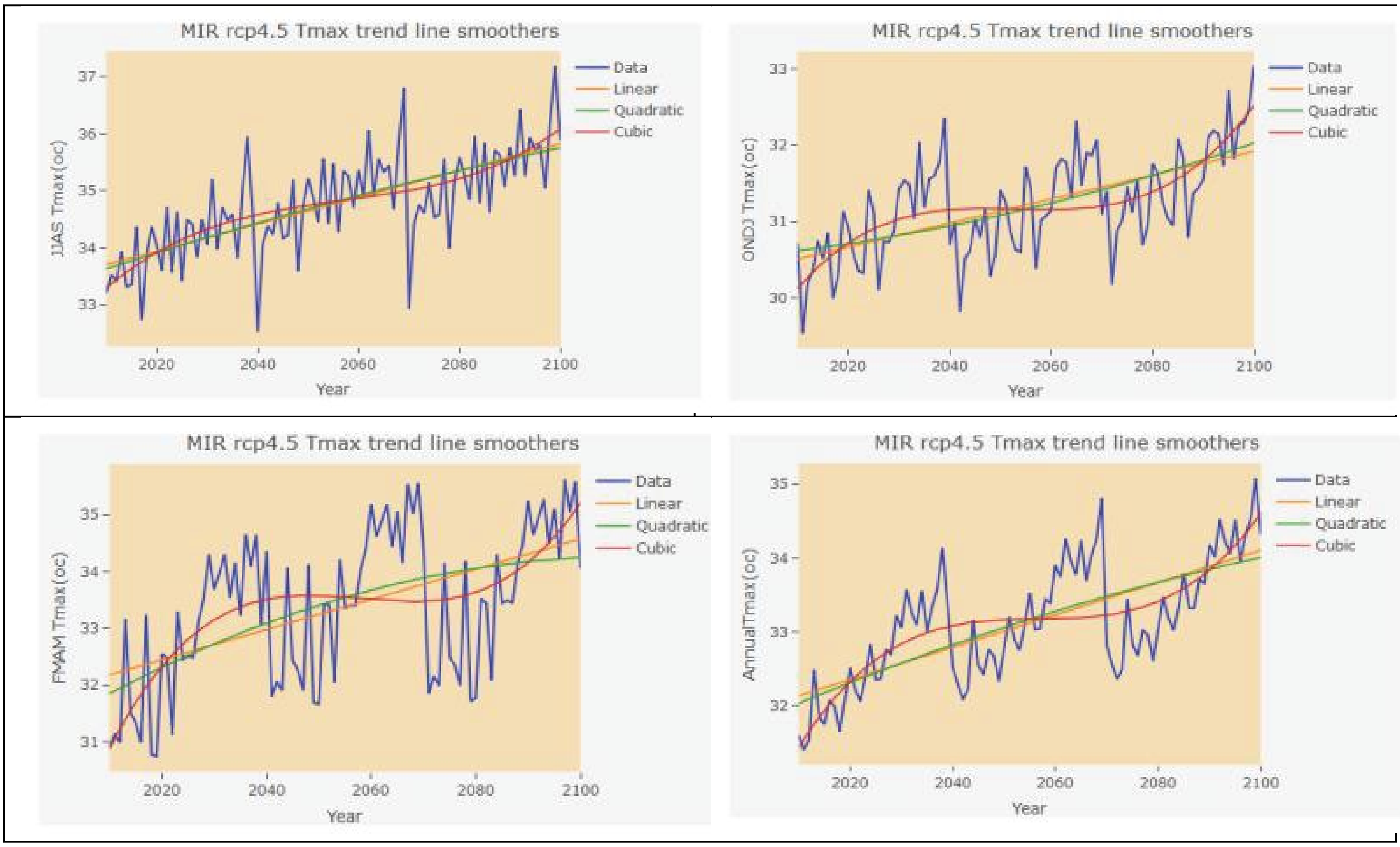

Figure 14: MIR (CMIP5) model under rcp4.5 Tmax trend for the period 2010-2100 of Dire Dawa.

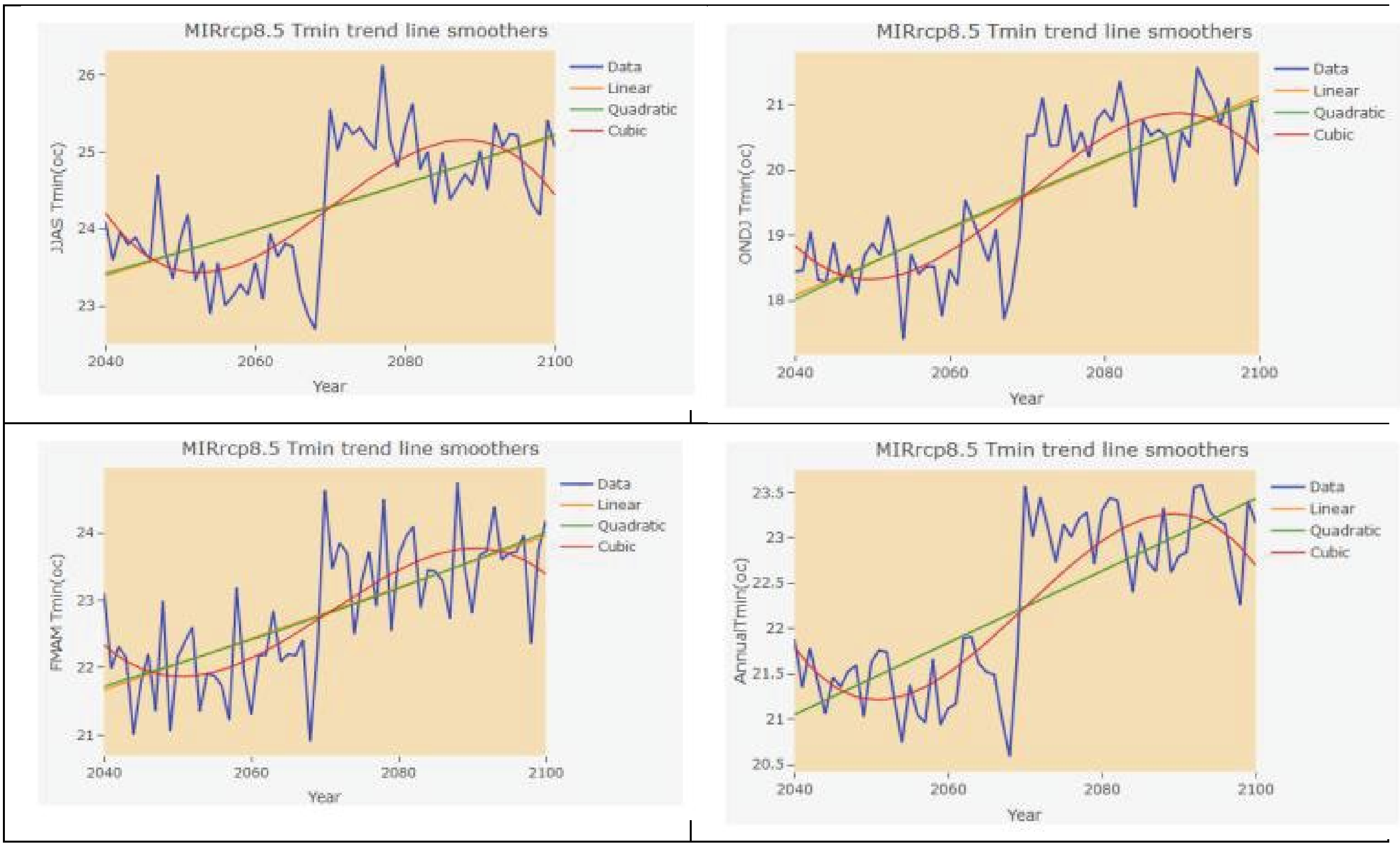

Figure 15: MIR (CMIP5) model under rcp8.5T_{min} trend for the period 2010-2100 of Dire Dawa.

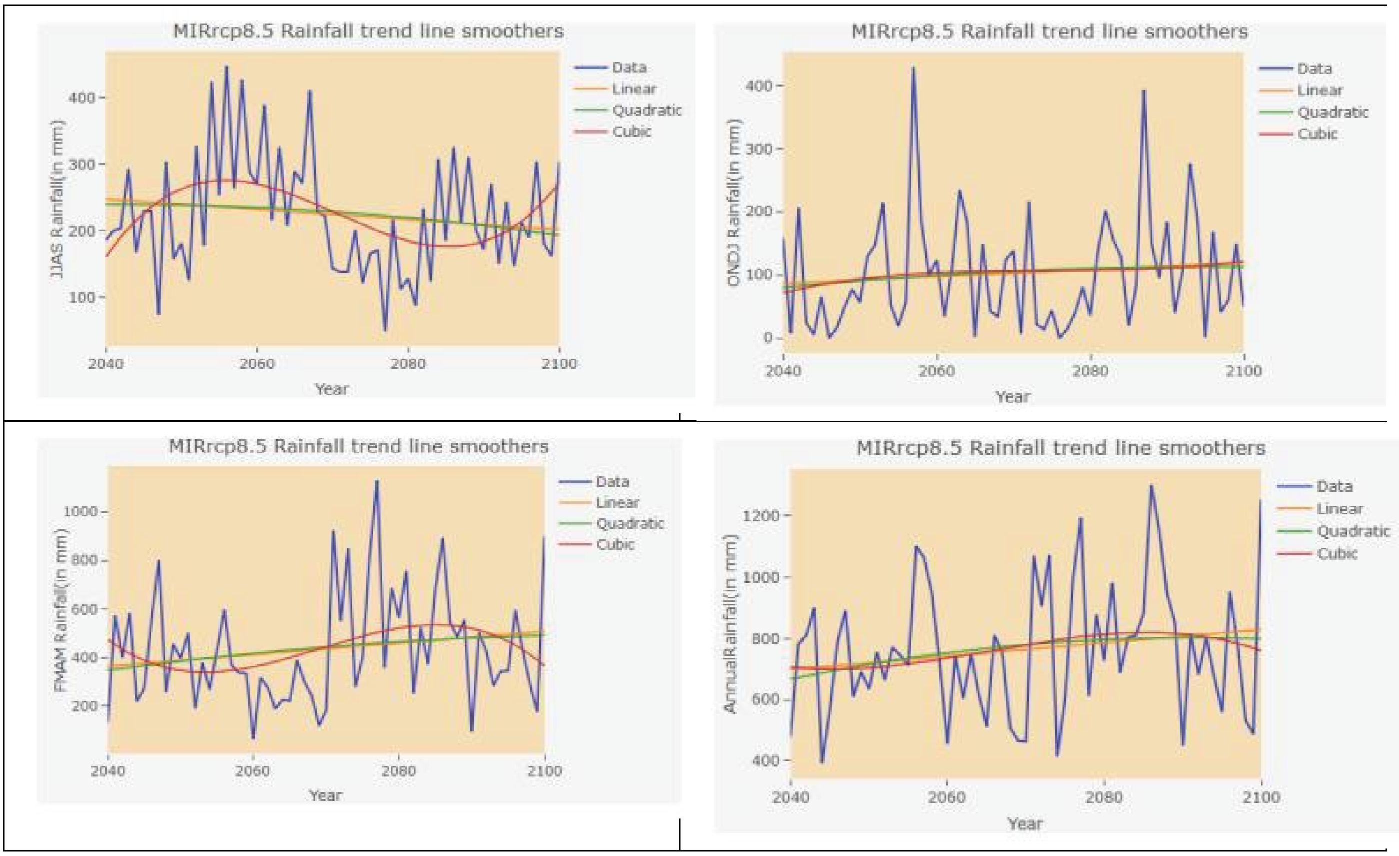

Figure 16: MIR (CMIP5) model under rcp8.5 RF trend for the period 2010-2100 of Dire Dawa.

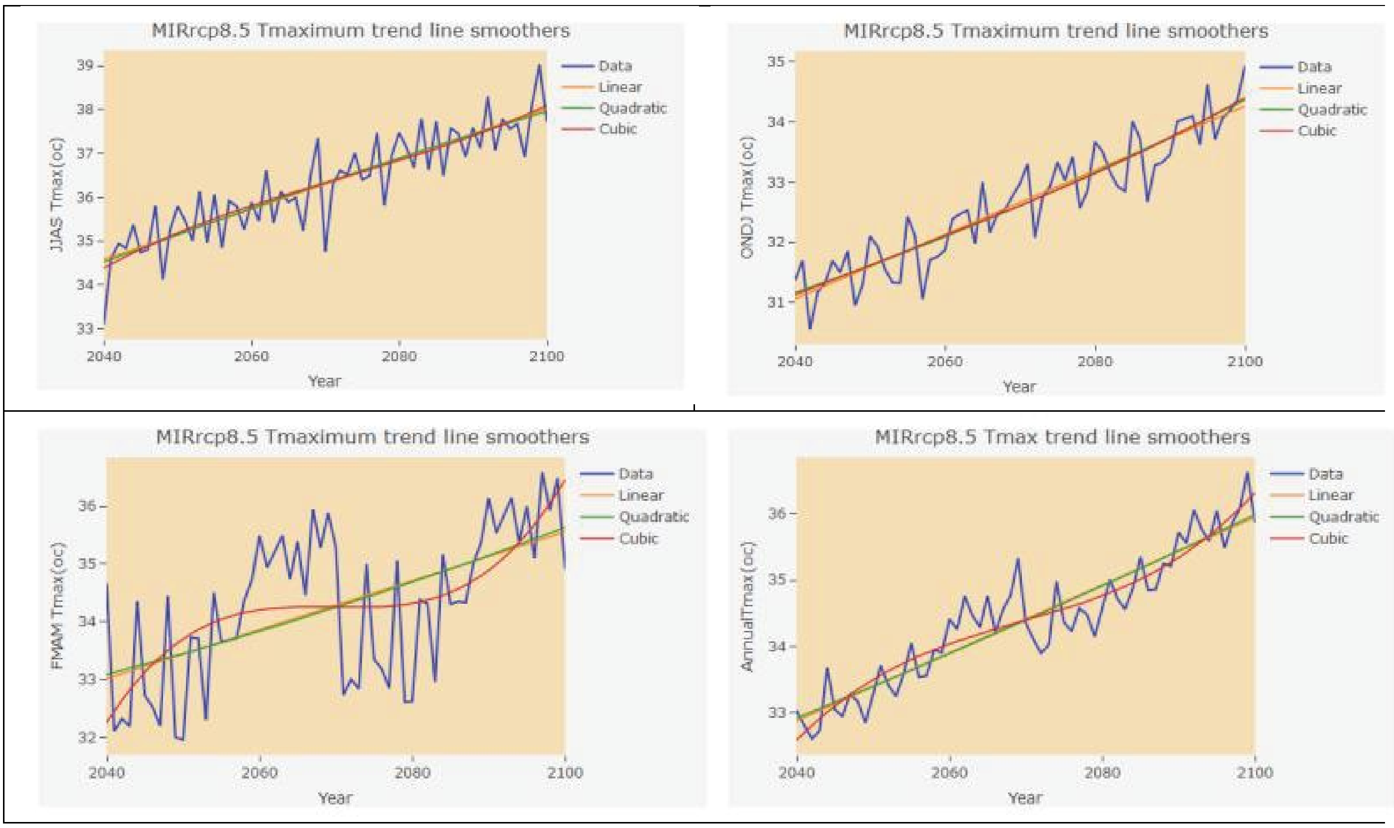

Figure 17: MIR (CMIP5) model underrcp8.5 T_{max} trend for the period 2010-2100 of Dire Dawa.

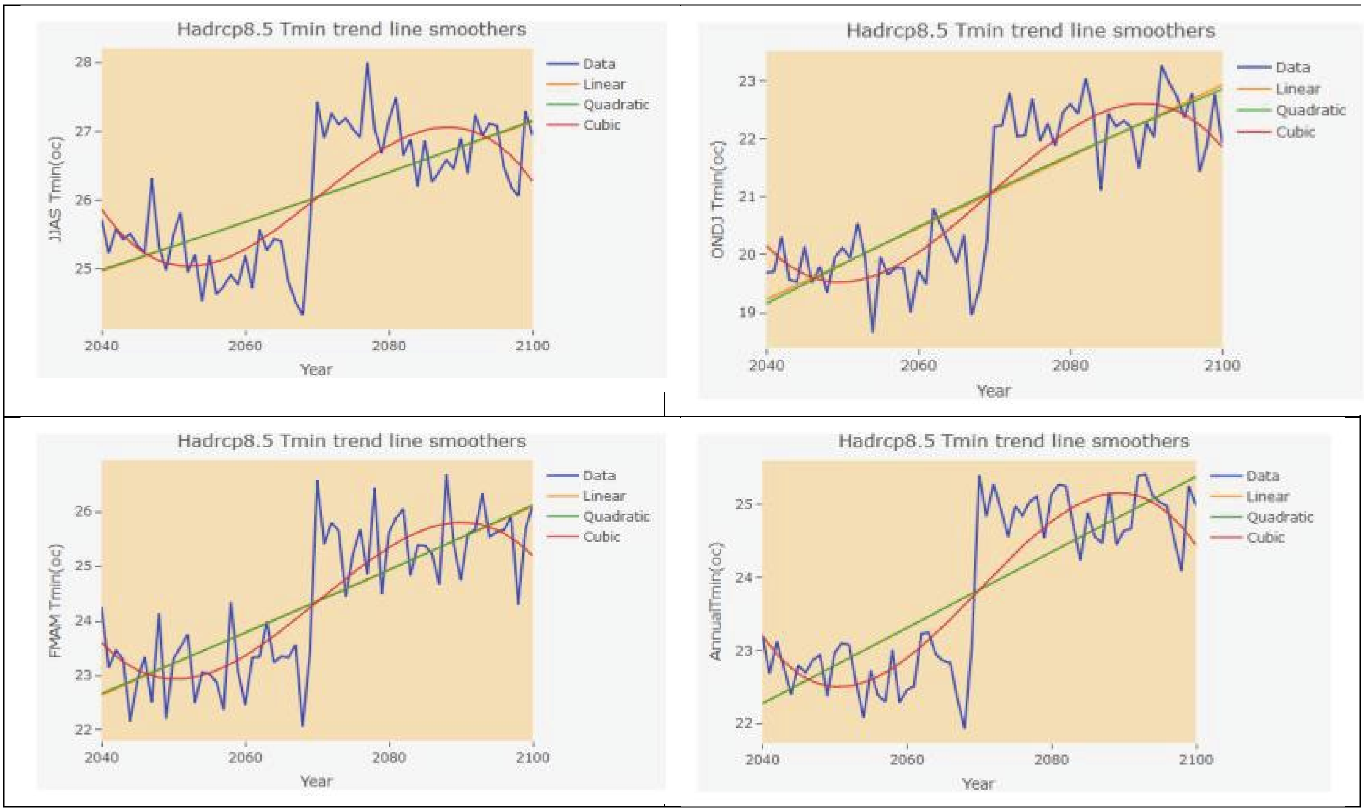

Figure 18: Had (CMIP5) model under rcp8.5 T_{min} trend for the period 2010-2100 of Dire Dawa.

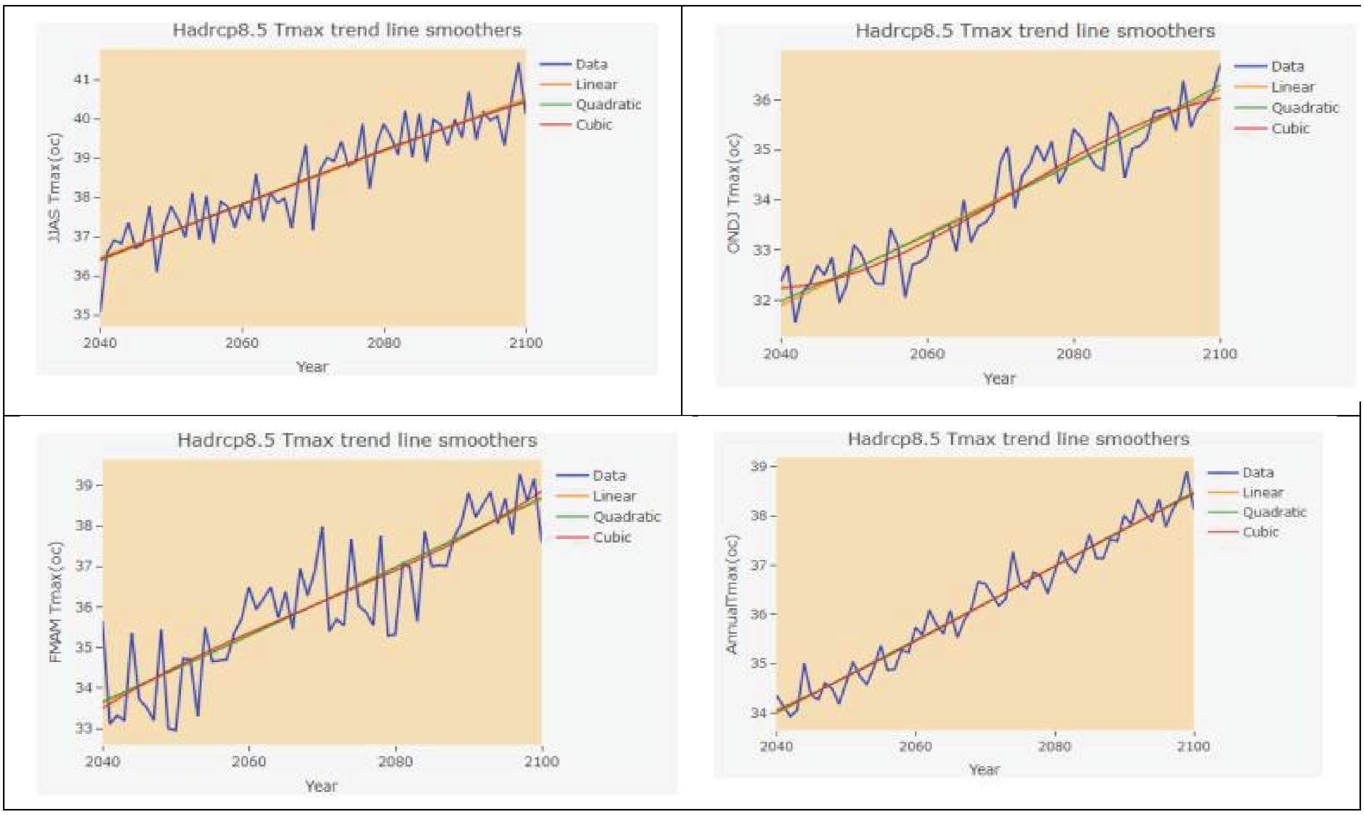

Figure 19: Had (CMIP5) model under rcp8.5 T_{max} trend for the period 2040-2100 of Dire Dawa.

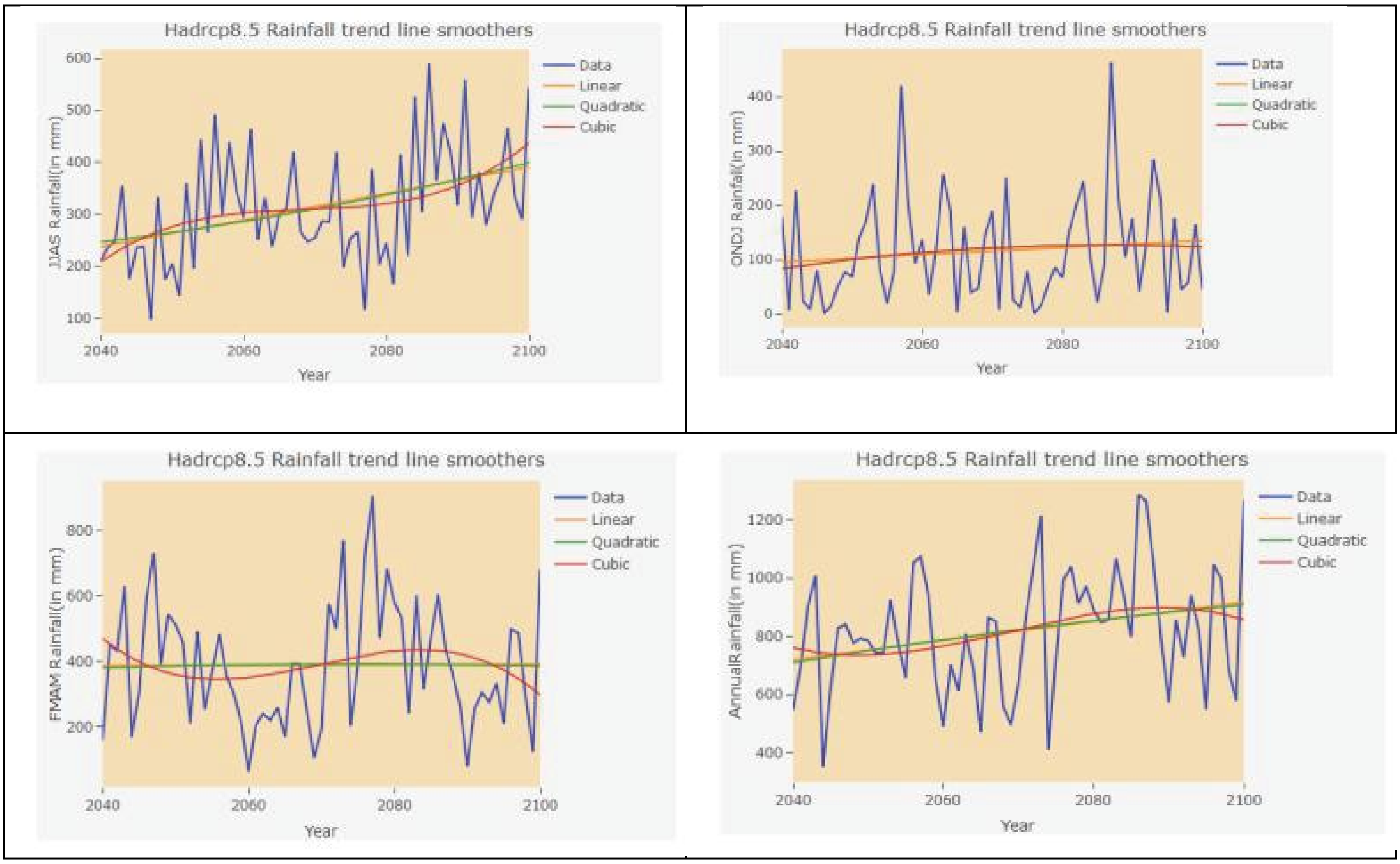

Figure 20: Had (CMIP5) model under rcp8.5 RF trend for the period 2040-2100 of Dire Dawa.

(2010 to 2100) trend analysis of climate parameters, the result of HadGEM2-ES (CMIP5) under rcp 4.5 shown that rainfall has no statistical significant at 5% significance level at each time period taken (Figure 7 and Table 6). And the result of MRI-CGCM3 (CMIP5) model data under rcp 4.5 of rainfall trend shown that no significant trend at a given significance level except month of March which has shown declining trend and ONDJ has shown inclining trend (Table7). Similarly, the two considered model under rcp 8.5 have shown different rainfall trend results. i.e the HadGEM2-ES(CMIP5) under rcp 8.5 analysis result revealed that inclining trend in kiremt seasonal rainfall and inclining trend in July and August monthly time period while the other monthly and seasonal rainfall trend has no statistical significance of trend at a given statistical level (Table 8). And MRI-CGCM3 (CMIP5) model data under rcp 8.5 analysis result of rainfall trend has no statistical significant except declining in the month of August (Table 9). It could be seen that different GCMs predicted different sets of values for rainfall increase (or decrease). In relation this, the analysis of both maximum and minimum temperature generated with both GCM model data under rcp 4.5 and 8.5 shown that an inclining trend in all time period (Tables 6-9).

Climate projections generated by UNDP for Ethiopia highlight the likelihood of mean temperature increases of 1°C in 2020s and up to 3.9°C to 2080s. Using a multi-model dataset the National Meteorological Agency of Ethiopia indicates that the mean annual temperature is likely to rise significantly when compared with the 1961-90 level by a maximum of 1.1°C by 2030, 2.1°C by 2050 and 3.4°C by 2080.

The following figures (Figure 6-20) shown that, the trend graph of Rainfall, T_{max} and T_{min} in different season and annual within observed and two model data under rcp 4.5 and rcp 8.5.

SUMMARY AND CONCLUSION

This study analysed the temporal variability and monotonic trends in rainfall and temperature in Dire Dawa City Administration with observed (1980 to 2014) and future model data of (2010 to 2100). The study area is susceptible to climate change and variability, the monthly rainfall was highly variable in study area and moderate in annual time period with observed and future generated data. Annual rainfall anomalies revealed temporal distributions of extreme wet with above normal rains and extreme dry with below normal rainfall. Increased surface temperature has been observed and also warming will be continued. Analysis of the 35 years monthly precipitation data by taking a representative ground based Dire Dawa meteorological station showed a coefficient of variation ranging from 39.8% (July) to 223.9% (December) which is categorized in highly variable in inter-seasonal time period. While, seasonal and annual coefficient of variation of rainfall of Dire Dawa meteorological station during ONDJ, FMAM, JJAS and Annual were shown as 95.0%, 46.4%, 33.1% and 24.8% respectively, which indicated that highly seasonal variable and medium annual rainfall variability.

Though, recorded meteorological data analysis of maximum temperature and future maximum and minimum indicate that increasing trends detected, the minimum mean temperature recorded trend change is not significant except decline in March and inclining in April and May. While the future rainfall trend under both considered model and rcp 4.5 and rcp 8.5 have shown erratic trend and under both model output different trend has been observed. Regarding to the Mann-Kendall monotonic trend analysis test, the maximum temperature examination bring about in a general warming trend. Information generated in this paper could be used to inform targeting of appropriate adaptive measures across multiple sectors. The concerned bodies should take in to consideration of highly rainfall variability and inclining of temperature of the area in to their climate change adaptation strategy. Lastly, other GCM climate model are recommended to generating future climate data, which can decrease uncertainty of incorrect detection and interpretation compared with a little GCM model data in the study area.

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