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RESEARCH ARTICLE

ASSESSMENT OF FUTURE TEMPERATURE CHANGE SCENARIO BY STATISTICAL DOWNSCALING MODEL (CANESM2) IN ABAYA CHAMO SUB BASIN, ETHIOPIA

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ABSTRACT

Temperature change isn't a new phenomenon in the world history. In developing countries like Ethiopia, climate hazards are high due to low adaptation capability. This study predicts future temperature change scenario by using statistical downscaling model (SDSM) and the second generation Canadian Earth System Model (CanESM2) General Circulation Model (GCM) output. For SDSM calibration and validation, the baseline period was divided into two: 1988-2003 and 2004-2016 respectively. The validation and calibration result of coefficient of determination for all meteorological stations are between 0.53-0.83 and 0.55-0.86 for maximum temperature and minimum temperature respectively. This result showed that the SDSM model was performed well. Maximum temperature downscaled by RCP-2.6, RCP-4.5 and RCP-8.5 scenario showed an increasing projection in all months. The mean monthly increasing temperature up to the end of 2099 will be from 0.3°C to 3.4°C. Minimum temperature downscaled by RCP-2.6 and RCP-8.5 scenario showed a decreasing projection in March and April but by RCP-4.5 decreasing in April. The increase in temperature due to climate change might have a negative impact on the future natural resources of the study area.

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INTRODUCTION

Climate change is linked to global warming caused by carbon dioxide and other radioactive trace gases concentration rise in the atmosphere. This was the main topic of scientific investigations due to the fact that climate change has significant impacts on environment, ecosystems, water resources and every feature of human existence (Gulacha and Mulungu 2017). Since 1861 the world average surface temperature has increased. The increase over the 20th century has been between 0.2°c to 0.6°c. The minimum air temperature of night time from 1950 to 1993 has increased by 0.2°c per decade. It is about two times of maximum temperature (IPCC 2001). Africa is a negligible contributor of global greenhouse gas and methane emission. The percentage of contribution of the world total is only 3.2% in 1992 and 7.7% in 1991 respectively (Davidson 1998) but the temperature by the end of 21st century projected faster than the rest of the world (Adhikari et al. 2015; IPCC 2014). The latest projection of an increase temperature in Ethiopia by the end of the century indicates between 0.5°C-4.0°C (IPCC 2013).

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In Ethiopia the rise of temperature perhaps will increase water stress and crop yield (Adhikari et al. 2015; Thornton et al. 2009). Rift Valley Basin, Ethiopia is an area of significant climate change, ecological and environmental interest through the lakes system and the wild life. Its total area covers approximately 53,121.3 km^2. The most significant and direct effects of global warming would be the change of water accessibility. Ethiopian Rift valley Basin is exposed to climate change since Ethiopia economy mainly depends on agriculture, which is very responsive to climate change and variability (Setegn et al. 2011a; Setegn et al. 2011b). In Abaya Chamo Sub Basin the increase in population growth, urbanization and economic development together with climate change is expected to reduce the overall quantity of water resources demand accessibility for different functions (Awulachew 2007). Lakes which are found in the Main Ethiopian Rift are subjected to climatic factors, such as maximum and minimum temperature change, seasonal rainfall variability, which may change on a provincial or worldwide scale (Goerner et al. 2009). Lake Abaya and Chamo are one among, since the 1970 dramatic population growth, has been undertaking tremendous natural and man-made changes. Changes in climate, land-ownership and clearing of forests caused the change of the Lake Abaya and Chamo water level (Brigitta et al. 2003).

In the past half century the Global mean temperature have been increasing, and warming trends has hastened in recent decades. When the temperature level reaches very high from its normal condition it has negative impact on living things and natural resources (Li et al. 2013). In the sub basin there are many natural resources like lakes, natural forest, springs and national park (Nechisar National park). These natural resources are tourism sectors for the country. The national park covers by different vegetation types, including various species of birds, endemic birds, crocodiles and mammals (Biressu 2009). The springs obtainable in the natural forest are the main water sources of Arba Minch Town. It is important to predict the future temperature scenario because it has significant impact on local community, natural resources, agriculture and tourism income. In developing countries like Ethiopia climate hazards are high due to low adaptation capability (Gulacha and Mulungu 2017). This study predicts future temperature change scenario by using statistical downscaling model (SDSM) and the second generation Canadian Earth System Model (CanESM2) General Circulation Model (GCM) output, which is significant for assessment of temperature change impact of the sub basin. CanESM2 experiment has built-in simulation driven with for each representative concentration pathways (RCP-2.6, RCP-4.5 and RCP-8.5) (Hua et al. 2015). Thus, the study is backed up with observed data, online sources from website and suitable methodologies to obtain the future climate scenarios.

MATERIALS AND METHODS

Study Area: The southern part of Ethiopian Rift valley (ERV) system is characterized by two adjoining lakes, Lake Abaya and Lake Chamo, separated by a small naturally created ridge called "God's Bridge". Abaya Chamo sub basin extends from 5°51.5'N to 8°8'N latitude and 37°16.3'E to 38°39.3'E longitude (Awulachew 2007). The climatic condition of the sub basin is moderate tropical semi-arid and the rainfall distribution is bimodal (Wagesho et al. 2012). Lake Abaya and Chamo are located in southern Nations, Nationalities, and Peoples' Region (SNNPR). It is part of the ERV system, placed the town of Arba Minch with 1108m.a.s.l (Ayele 2017).

Data Used: The observed temperature and spatial data of Abaya Chamo Sub Basin are acquired from various organizations and online sources. Observed daily maximum and minimum temperature data are obtained from Ethiopian Natural Metrological Agency (NMA), South National Nationalist People's Region Meteorological Agency and Global Weather Data for SWAT via online sources (https://globalweather.tamu.edu/request/view/56626). Spatial data obtained from Ethiopian Ministry of Water, Irrigation and Energy (MoWIE). In the study area observed temperature data are not 100% recorded, there are missing data. The following table shows the list of stations and the percentage of missed data.

Methods

Estimation of missing data: For climate change analysis sufficient long record of meteorological data is required. The continuity of maximum and minimum temperature record may be broken with missing data due to absence of recorder or break or failure of instruments (Raghunath 2006). Stations with missed data were filled by the techniques of within station, between station and regression methods (Allen and Gaetano 2001; Kemp et al. 1983). To fill the missing data of Abaya Chamo sub basin meteorological stations within station and between station methods are used. Within station method is used to estimate the missing data between adjacent recorded days at the same station by using moving average and linear interpolation techniques. The estimated maximum or minimum temperature is given by (Kemp et al. 1983):

$$T_{ijkn} = \frac{\left[T_{i-1jkn} + T_{i+1jkn}\right]}{2} \quad (1)$$

$$T_{ijkn} = \frac{\left[T_{i-2jkn} + T_{i-1jkn} + T_{i+1jkn} + T_{i+2jkn}\right]}{4} \quad (2)$$

Where: T_{ijkn} is the estimated missing data; i, j and k are day, month and year and n is metrological station. Between station methods technique used to estimate the missing data by using the observed data of neighboring stations. The assumption of this method is the difference between monthly average and daily temperatures are equal between neighboring stations and the estimated maximum and minimum temperature is given by (Kemp et al. 1983).

$$T_{ijkn} = \sum_{\substack{J \le m \le M \\ m \ne n}} \left[\frac{T_{ijkm} + \overline{T}_{jkm} - \overline{T}_{jkn}}{M-1}\right] \quad (3)$$

Where: m and n are meteorological stations; M is total meteorological station number

Analysis of Trend Test: The characteristics of climate condition fluctuation can be identified by using various statistical methods. These methods are parametric and non parametric methods, and both are widely used for trend test study (Jhajharia and Singh 2011; Wagesho et al. 2012). The trend test of maximum and minimum temperature tested by Mann-Kendall (MK) trend analysis it is a non parametric test and suitable for the data including missing value (Jhajharia and Singh 2011; Wagesho et al. 2012). MK trend analysis is usually used for hydrological and meteorological trend test study (Dinpashoh et al. 2011; Douglas et al. 2000; Jhajharia et al. 2009; Jhajharia and Singh 2011; Kahya and Kalay 2004; Partal and Kahya 2006; Singh et al. 2008; Tebakari et al. 2005; Wagesho et al. 2012; Xu et al. 2003). The test computed for n time series values $\left(x_1, x_2, x_3, ..., x_n\right)$ as:

$$S = \sum_{i=1}^{n-1}\left[\sum_{j=i+1}^{n} \operatorname{sgn}\left(x_i - x_j\right)\right] \quad (4)$$

Where

$$\operatorname{sgn}\left(x_i - x_j\right) = \begin{cases} 1 for x_i - x_j > 0 \\ 0 for x_i - x_j = 1 \\ -1 for x_i - x_j < 0 \end{cases} \quad (5)$$

x_i and x_j are annual values, $i > j$ and n is the number of data points. If the null hypothesis $\left(H_o\right)$ is true, then S is approximately distributed with:

$$E(S) = 0 \quad (6)$$

$$Var(S) = \frac{n(n-1)(2n+5)}{18} \quad (7)$$

The variance of standard deviation is corrected for tied elements when $n \geq 10$ as:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i+1}^{m} t_i (i-1)(2i+5)}{18} \quad (8)$$

$$Z = Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} if S > 0 \\ 0 if S = 1 \\ \frac{S+1}{\sqrt{Var(S)}} if S < 1 \end{cases} \quad (9)$$

Where $E(S)$ is the expected value, $Var(S)$ is the variance of standard deviation, m is the number of tied elements, t_i is the number of tied data points of extent i and Z is the standard normal deviate. If $-1.96 < Z < 1.96$, the null hypothesis is significance at the 95% level (Singh et al. 2008). (H_o) of that the factors are identically and independent distributed is rejected if $|Z| > Z_{1-\alpha/2}$ at α -level of significance (Wagesho et al. 2012).

Predictors for Statistical Downscaling Model: Canadian Center for Climate Modeling and Analysis (CCCma) developed CanESM2. CanESM2 has advanced from CanESM1 (Arora and Boer 2010; Arora and Matthews 2009; Arora et al. 2011; Brovkin et al. 2013; Christian et al. 2010). The predictors which are used for SDSM input downloaded from the website of Canadian Centre for Climate Modeling and Analysis (http://climate-scenarios.canada.ca/?page=pred-canesm2). The predictors are found in grid basis 2.8125°*2.8125°for different regions in the world and in zip file format. The major data set categories used as input data to calibrate, validate and generate future scenarios of maximum and minimum temperature are observed daily maximum and minimum temperature (1988-2016), Predictor variables of the National Center of Environmental Prediction (NCEP) (1961-2005) and CanESM2 predictor variables (2006-2100) for RCP-2.6, RCP-4.5 and RCP-8.5 scenarios. The basic steps for future climate change scenario assessment in SDSM are quality control, screen variables (to select predictor variables), calibrate model, weather generator and scenario generator (Singh et al. 2015; Wilby and Dawson 2013). There are 26 CanESM2 predictors used for screening process.

RESULT AND ANALYSIS

Mann-Kendall trend test: Seasonal maximum and minimum temperature trend during baseline period time (1988-2016) has been assessed by using MK trend test. The positive and negative value of the standard normal deviate shows increasing and decreasing trend respectively (Jhajharia et al. 2009; Wagesho et al. 2012) . Four meteorological sites, namely Alaba Kulito, Boditi, Fiseha Genet and Haisawita significant increasing trend observed in all seasons for both maximum and minimum temperature. The classification of the four seasons used by (Jhajharia et al. 2009).

Maximum Temperature and Minimum Temperature

Model Calibration and validation: Screening predictors in SDSM is the key step to obtain a good result for model calibration. The predictor variables are varying from station to station (Saraf and Regulwar 2016; Wilby et al. 2002). The three supportive tasks to select appropriate predictors variables are analyse, correlation matrix and scatter plot (Saraf and Regulwar 2016; Wilby and Dawson 2007). For temperature unconditional sub model process was selected to consider predictor-predictand relationships and to test the significance level of predictor-predictand correlation the default value $p < 5\%$and partial correlation of$r \pm 1$. The numbers of maximum predictors' variables chosen are twelve (Wilby and Dawson 2007). The selected appropriate predictors for maximum and minimum temperature for all stations are mslp, *_f, *_u, *_v, p500, p850, temp and shum. After predictor variable chosen the next step is model calibration with a set of chosen predictor variables based on multiple regression equations (Wilby and Dawson 2007). In Abaya Chamo sub basin the observed data from 1988-2016 year divided in to two for model calibration (1988-2003) and model validation (2004-2016). The model performance in simulating observed maximum or minimum temperature was evaluated during calibration and validation by coefficient of determination (R2). R2 describes the performance of the model. The monthly average difference between observed and simulated maximum and minimum temperature for all station is between -0.1°C to 0.1°C.

Monthly maximum temperature scenario: In SDSM temperature scenario generator process generates troupes of synthetic daily weather series given daily atmospheric predictor variables provided by a CanESM2. The CanESM2 predictor variables must be standardized concerning a reference period and obtainable for all variables used in model adjustment (Wilby and Dawson 2007). Maximum and minimum temperature scenario generation processed from 2017 to 2099. In Abaya Chamo sub basin mean monthly maximum temperature projection is increased by all scenarios. The highest mean maximum temperature increase occurs in Jun, July and August and the minimum in December. The increase in maximum temperature will be from 0.3°C to 3.2°C, 0.4°C to 3.3°C and 0.4°C to 3.4°C by the end of 2099 for RCP-2.6, RCP-4.5 and RCP-8.5 respectively. The percentage change of future scenario with respect to the base line period shows that the mean maximum temperature trend is increasing from 0.2%-4.2%, 0.2%-8.5% and 0.9%-11.5% in 2002s, 2040s and 2080s respectively.

Monthly minimum temperature scenario: The mean monthly minimum temperature projection is decreased from March to April by RCP-2.6 and RCP-8.5 scenarios and April by RCP-4.5 scenario. The projected change in mean monthly minimum temperature will be from -0.5 to 1.6, -0.3 to 1.9 and -0.2 to 2.1 by the end of 2099 for RCP-2.6, RCP-4.5 and RCP-8.5 respectively.

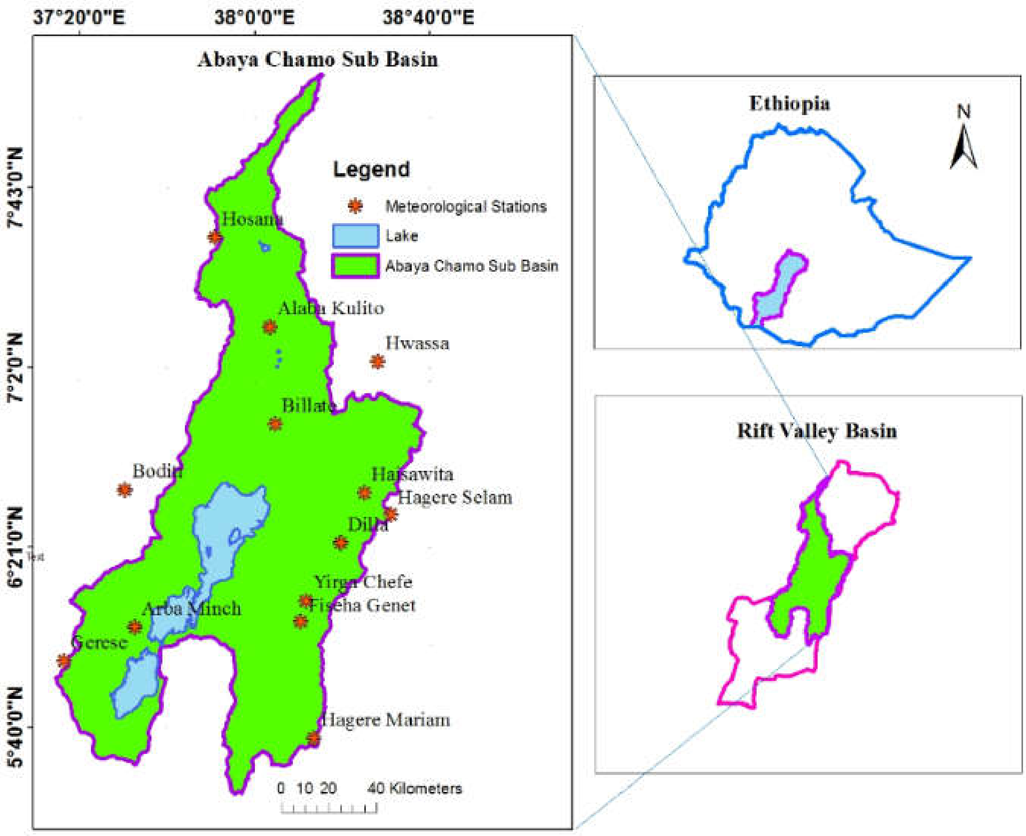


Figure 1. Study area location map

Table 1. List of meteorological stations with percentage of missed data

S.No	Station Name	Lat	Long	Maximum Temperature		Minimum Temperature		Station Type (Class)	Percentage of Missed data	
				Start Year	End Year	Start Year	End Year		Max.Tem	Min.Tem
1	Alaba Kulito	7.19	38.06	1988	2008	1988	2008	3	10.81	8.83
2	Arba Minch	6.05	37.55	1987	2016	1987	2016	1	3.34	4.12
3	Bilate	6.82	38.08	1985	2016	1985	2016	1	11.45	10.27
4	Boditi	6.57	37.51	1988	2008	1988	2008	3	2.88	12.52
5	Dilla	6.37	38.33	1988	2016	1988	2016	1	22.65	14.83
6	Fiseha Genet	6.07	38.18	1987	2016	1987	2016	3	11.24	12.39
7	Gerese	5.92	37.28	1988	2013	1988	2011	3	20.38	23.14
8	Hagere Mariam	5.63	38.23	1975	2016	1975	2016	3	19.96	16.61
9	Hagere Selam	6.48	38.52	1988	2016	1988	2016	3	10.68	24.91
10	Haisawita	6.56	38.42	1978	2016	1978	2016	3	5.00	5.04
11	Hawassa	7.06	38.47	1973	2016	1973	2016	1	2.50	2.55
12	Hossaena	7.53	37.85	1978	2016	1978	2016	1	17.47	14.25
13	Yirga Chefe	6.15	38.2	1966	2016	1966	2016	3	3.39	4.25

Note: Station Type Class 1 means the station records all parameters and Station Type Class 3 means the station records Maximum and minimum temperature and rain fall.

Table 2. List of predictors variables used by SDSM (Source: http://climate-scenarios.canada.ca/?page=pred-help) and (Guo et al. 2013; Saraf and Regulwar 2016; Wilby and Dawson 2013)

S.No	Predictors	Symbol	S.No	Predictors	Symbol
1	Mean sea level pressure	mslp	14	500 hpa divergence	p5zh
2	Surface airflow strength	p1_f	15	850 hpa airflow strength	P8_f
3	Surface zonal velocity	p1_u	16	850 hpa zonal velocity	P8_u
4	Surface meridional velocity	p1_v	17	850 hpa meridional velocity	P8_v
5	Surface vorticity	p1_z	18	850 hpa vorticity	P8_z
6	Surface wind direction	p1_th	19	850 hpa geopotential height	p850
7	Surface divergence	p1_zh	20	850 hpa wind direction	p8th
8	500 hpa airflow strength	p5_f	21	850 hpa divergence	p8zh
9	500 hpa zonal velocity	p5_u	22	Near surface relative humidity	rhum
10	500 hpa meridional velocity	p5_v	23	Specific humidity at 500 hpa height	s500
11	500 hpa vorticity	p5_z	24	Specific humidity at 850 hpa height	s850
12	500 hpa geopotential height	p500	25	Near surface specific humidity	shum
13	500 hpa wind direction	p5th	26	Mean temperature at 2m	temp

Table 3.Trend analysis of Maximum temperature by Mann-Kendall test

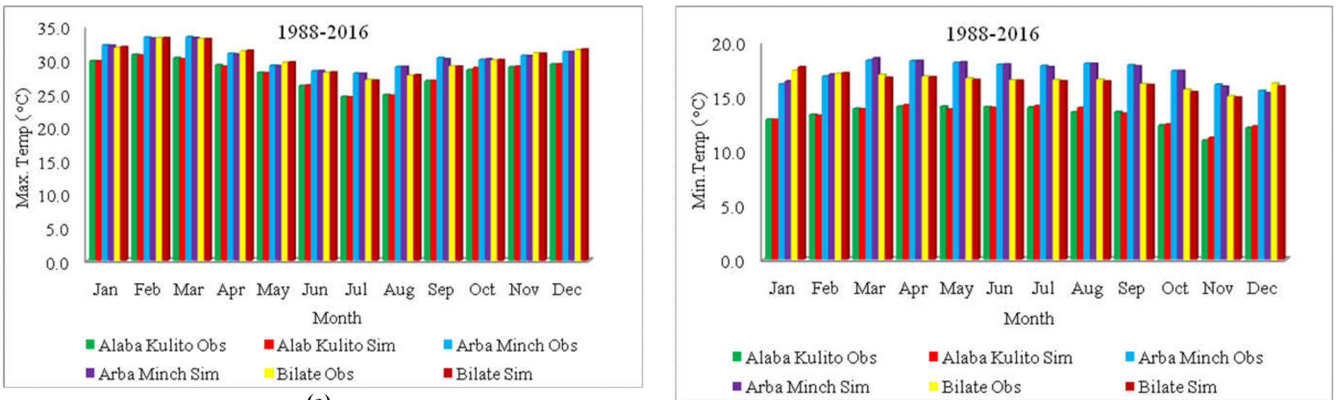
Meteorological Station	Mann-Kendall Test							
	S_1	Trend @α=0.05	S_2	Trend @α=0.05	S_3	Trend @α=0.05	S_4	Trend @α=0.05
Alaba Kulito	4.80	IT	4.52	IT	3.16	IT	4.42	IT
Arba Minch	1.86	NSST	1.67	NSST	2.04	IT	0.26	NSST
Bilate	1.54	NSST	0.81	NSST	1.82	NSST	0.75	NSST
Boditi	3.06	IT	3.43	IT	2.57	IT	2.70	IT
Dilla	0.22	NSST	1.16	NSST	0.58	NSST	0.36	NSST
Fiseha Genet	4.71	IT	4.75	IT	4.84	IT	4.18	IT
Gerese	-1.88	NSST	-0.56	NSST	0.15	NSST	-0.24	NSST
Hagere Mariam	4.19	IT	3.28	IT	3.08	IT	3.71	IT
Hagere Selam	3.00	IT	4.86	IT	4.82	IT	3.21	IT
Haisawita	2.63	IT	2.83	IT	3.81	IT	1.97	IT
Hawassa	1.93	NSST	1.78	NSST	3.30	IT	-0.17	NSST
Hossaena	1.37	NSST	2.16	IT	3.41	IT	2.91	IT
Yirga Chefe	1.11	NSST	0.00	NSST	0.21	NSST	-0.82	NSST

Table 4. Trend analysis of Minimum temperature by Mann-Kendall test

Meteorological Station	Mann-Kendall Test							
	S_1	Trend @α=0.05	S_2	Trend @α=0.05	S_3	Trend @α=0.05	S_4	Trend @α=0.05
Alaba Kulito	3.67	IT	3.58	IT	4.21	IT	3.16	IT
Arba Minch	-0.62	NSST	-0.39	NSST	0.21	NSST	1.41	NSST
Bilate	3.83	IT	4.35	IT	3.83	IT	4.54	IT
Boditi	4.28	IT	5.49	IT	5.36	IT	4.86	IT
Dilla	0.92	NSST	1.59	NSST	2.63	IT	2.18	IT
Fiseha Genet	4.05	IT	4.07	IT	3.19	IT	3.04	IT
Gerese	-1.65	NSST	0.67	NSST	3.53	IT	1.63	NSST
Hagere Mariam	-1.69	NSST	-0.97	NSST	-1.01	NSST	-2.07	DT
Hagere Selam	-1.89	NSST	-2.03	DT	-2.19	DT	-2.08	DT
Haisawita	3.24	IT	3.66	IT	4.07	IT	3.68	IT
Hawassa	1.58	NSST	3.09	IT	4.73	IT	3.68	IT
Hossaena	-0.45	NSST	1.18	NSST	2.87	IT	0.79	NSST
Yirga Chefe	3.04	IT	1.63	NSST	-0.28	NSST	2.66	IT

Table 5. Calibration and validation result of (R^2) for maximum temperature and minimum temperature

S.No	Stations	R^2			
		Maximum Temperature		Minimum Temperature	
		Calibration	Validation	Calibration	Validation
1	Alaba Kulito	0.62	0.65	0.76	0.80
2	Arba Minch	0.55	0.60	0.65	0.68
3	Bilate	0.58	0.62	0.61	0.63
4	Boditi	0.63	0.62	0.66	0.68
5	Dilla	0.59	0.60	0.65	0.67
6	Fiseha Genet	0.81	0.85	0.64	0.72
7	Gerese	0.82	0.82	0.81	0.82
8	Hagere Mariam	0.53	0.55	0.71	0.73
9	Hagere Selam	0.68	0.71	0.86	0.86
10	Haisawita	0.57	0.59	0.55	0.58
11	Hawassa	0.62	0.64	0.66	0.71
12	Hossaena	0.65	0.66	0.66	0.68
13	Yirga Chefe	0.81	0.83	0.61	0.65



(a) (b)

Figure3 a) Monthly mean observed and simulated maximum temperature and b) Monthly mean observed and simulated minimum temperature

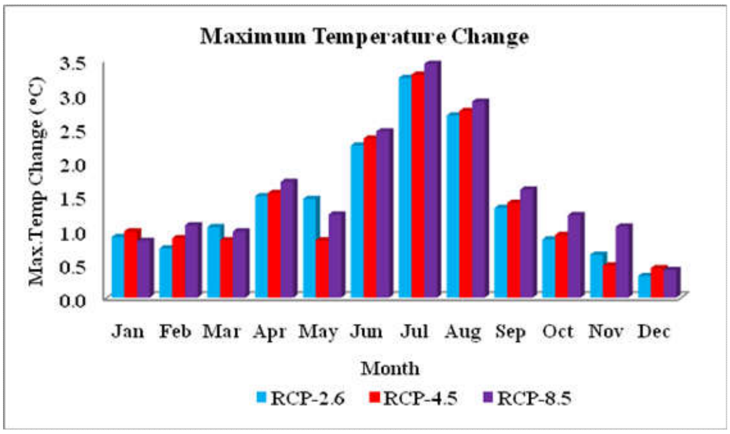


Figure 4. Mean monthly maximum temperature change

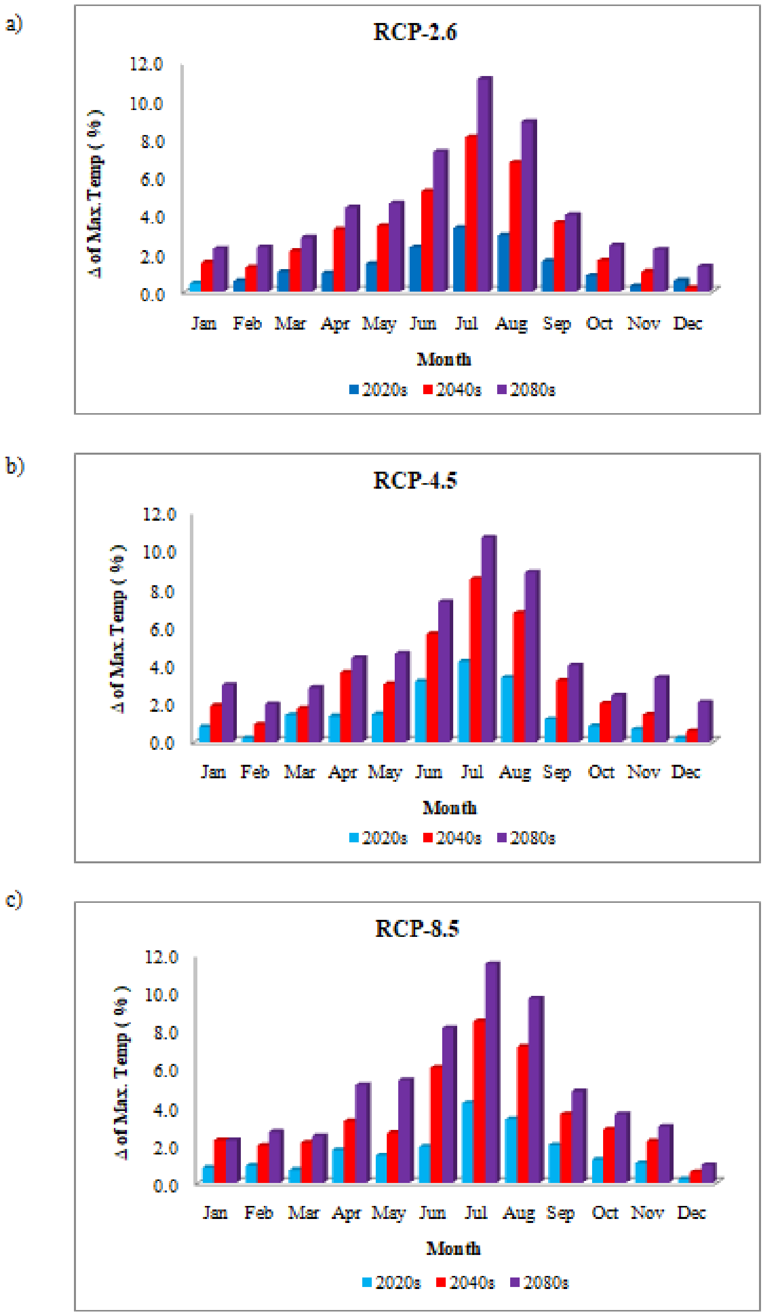


Figure 5. Percentage change of Maximum Temperature a, b and c

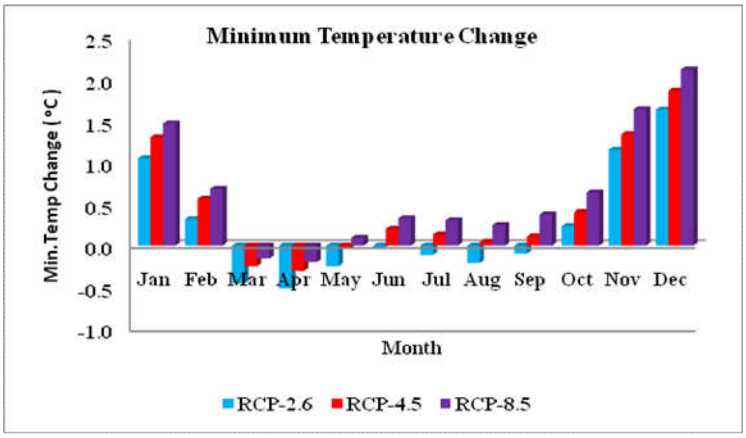


Figure 6. Mean monthly minimum temperature change

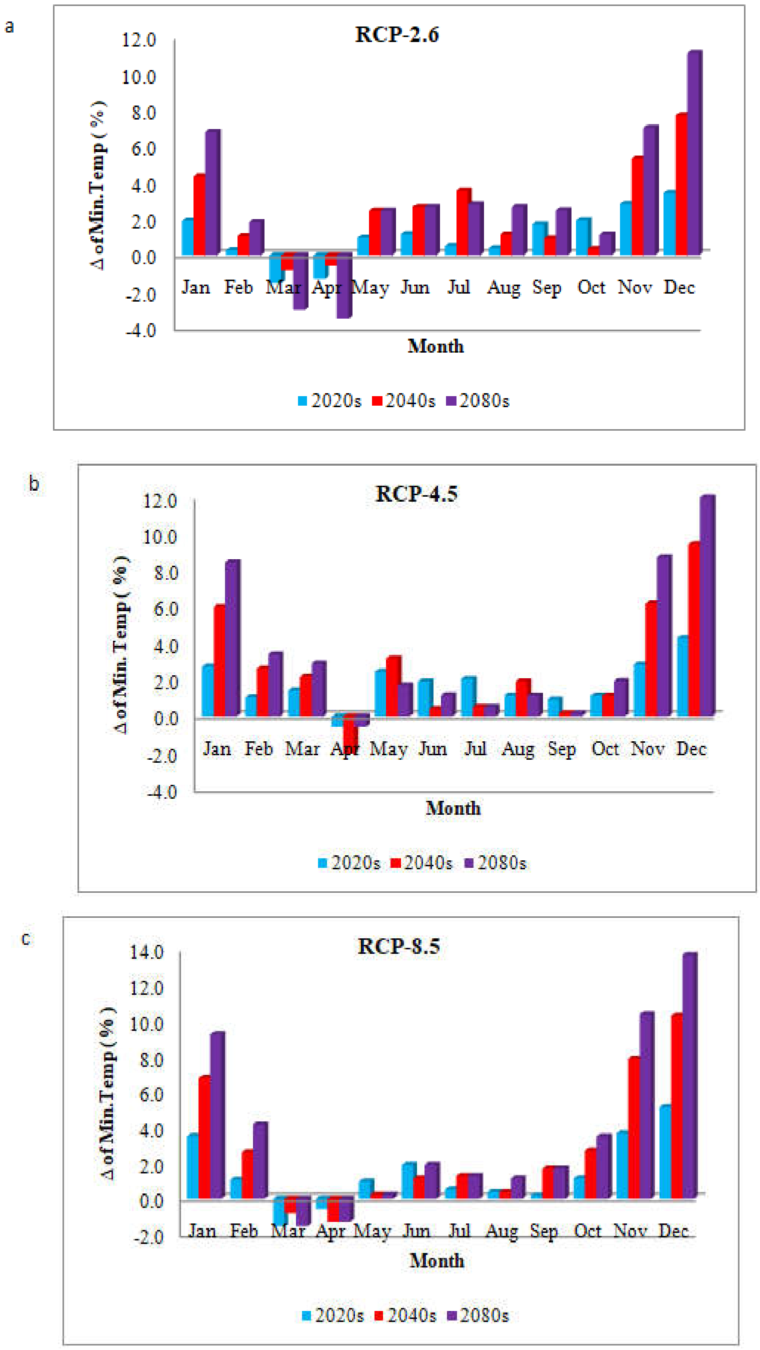


Figure 7. Percentage change of Minimum Temperature a, b and c

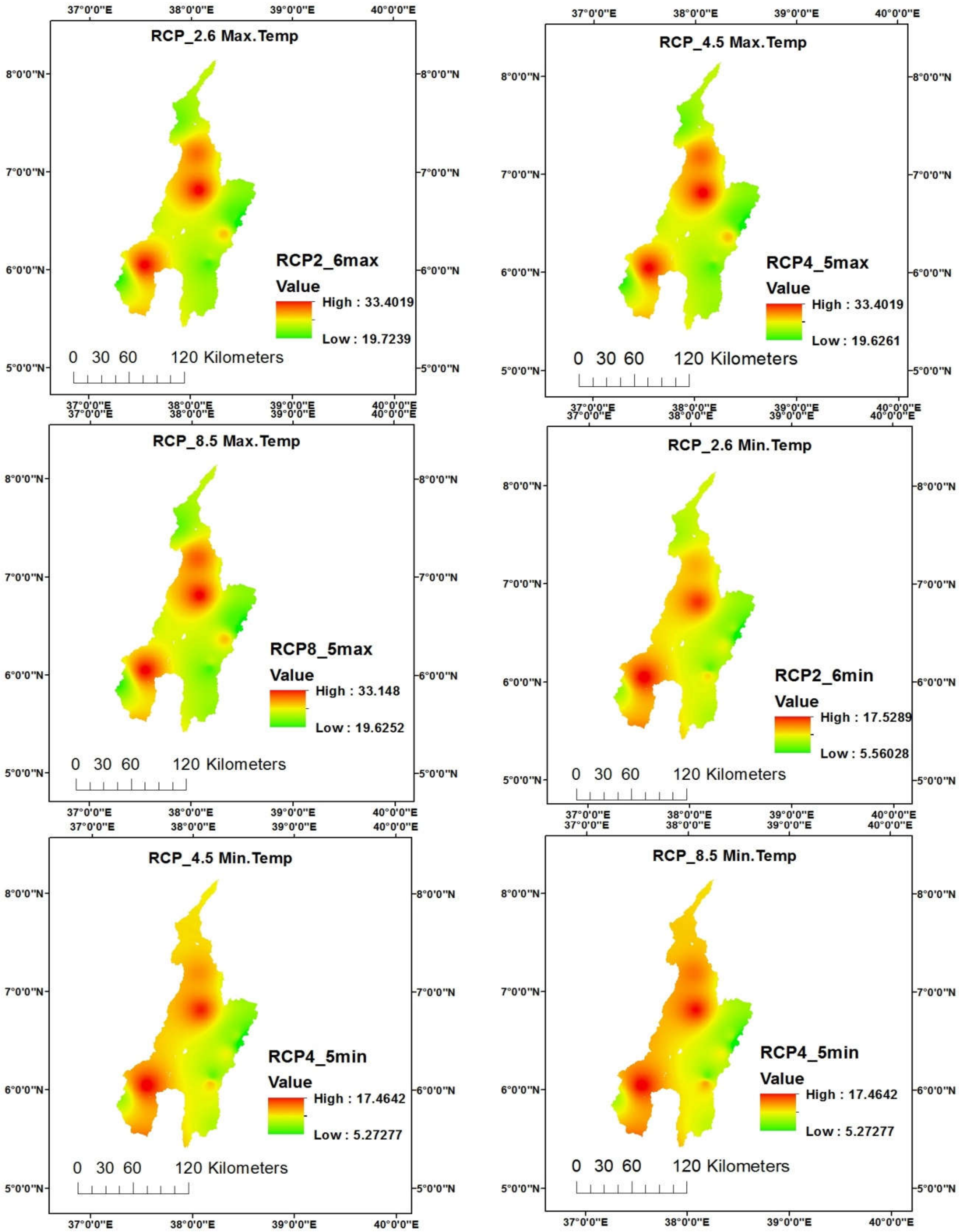


Figure 8. Spatial distribution of mean maximum and minimum temperature future scenario at the end of this century

The percentage change of future scenario with respect to the base line period shows that the mean minimum temperature trend is increasing from 0.2%-5.2%, 0.2%-10.3% and 0.3%-13.7% in 2002s, 2040s and 2080s respectively, and decreasing from0.6%-1.5%, 0.6%-2.0% and 0.6%-3.5% in 2002s, 2040s and 2080s respectively. In Abaya Chamo Sub Basin the highest mean monthly temperature recorded between November and April.

Both observed and future scenario results shows the mean monthly maximum temperature recorded in low lands of the sub basin rift valley area in March and minimum temperature in high lands in July. The mean monthly trend analysis of the study area for both scenarios indicated that there will be an increase temperature up to the end of the century. Therefore in the future adaptation and mitigation measures will be necessary to handle the temperature change effects.

Conclusion

Temperature occasions of various extents are subjected to short and long-term time reliance analysis to investigate for conceivable fluctuations in climate variables. Statistical Downscaling Model is used to downscale and generate future temperature scenarios from CanESM2 model predictors in Abaya Chamo sub basin. Seasonal temperature events are characterized by Mann-Kendall trend test. Increasing trends are observed in all seasons for both maximum and minimum temperature at four meteorological sites, namely Alaba Kulito, Boditi, Fiseha Genet and Haisawita. The simulated maximum and minimum temperature data during validation and calibration of SDSM showed that the model was performed well. The validation and calibration result of coefficient of determination (R^2) for all meteorological stations are between 0.53-0.83 and 0.55-0.86 for maximum temperature and minimum temperature respectively. Maximum temperature downscaled by RCP-2.6, RCP-4.5 and RCP-8.5 scenario showed an increasing projection in all months. The mean monthly increasing temperature up to the end of 2099 will be from 0.3°C to 3.4°C. Minimum temperature downscaled by RCP-2.6 and RCP-8.5 scenario showed a decreasing projection in March and April but by RCP-4.5 decreasing in April. The mean monthly change of minimum temperature up to the end of 2099 will be from -0.5°C to 2.1°C. The future scenario projections of temperature in this study are based on sensible scenarios. The substantial vulnerabilities are combined with the quantitative assessments on the grounds that the anticipated temperature acquired uncertainties because of uncertainties related with CanESM2 models and restrictions of the SDSM in downscaling of temperature. Notwithstanding, downscaled temperature from predictors of canESM2 models have shown good statistical agreement with observed. In this manner, it can be concluded that SDSM has performed well in downscaling of maximum and minimum temperature from predictors of CanESM2 models in Abaya Chamo Sub Basin, Ethiopia.

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REFERENCES

Adhikari U., Nejadhashemi A., Woznicki S. 2015. Climate change and eastern Africa: a review of impact on major crops. *Food and Energy Security*, 4: 110-132.

Allen R., Gaetano A. 2001. Estimating Missing Daily Tempertaure Extremes Using An Optimized Regression Approach. *International Journal of Climatology*, 21: 1305-1319.

Arora V. K., Boer G. J. 2010. Uncertainties in the 20th century carbon budget associated with land use change. *Global Change Biology*, 16: 3327–3348.

Arora V. K., Matthews H. D. 2009. Characterizing uncertainty in modeling primary terrestrial ecosystem processes. *Global Biogeochmical Cycles*, 23 1-14.

Arora V. K. et al. 2011. Carbon emission limits required to satisfy future representative concentration pathways of greenhouse gases. *Geophysical Ressearch Letters*, 38: 1-6.

Awulachew S. 2007. Abaya-Chamo Lakes Physical and Water Resources Characteristics, including Scenarios and Impacts. Paper presented at the Lake Abaya-Chamo Research Symposium. Arba Minch University.

Ayele E. 2017. Impact of climate change on Lake Chamo water balance, Ethiopia. *International Journal of Water Resources and Environmental Engineering*, 9: 86-95.

Biressu A. 2009. Resettlement and Local Livelihoods in Nechsar National Park, Southern Ethiopia. University of Tromsø.

Brigitta S., Gerd F., Stefan T., Bernd W. 2003. Modern Water Level Changes of Lake Abaya, South Ethiopia. Paper presented at the Human-environment Interactions. USA.

Brovkin V. et al. 2013. Effect of Anthropogenic Land-Use and Land-Cover Changes on Climate and Land Carbon Storage in CMIP5 Projections for the Twenty-First Century. *American Meteorological Society*, 26: 6859-6881.

Christian J. R. et al. 2010. The global carbon cycle in the Canadian Earth System Model (CanESM1) Preindustrial control simulation. *Journal of Geophysical Research*, 115: 1-20.

Davidson O. "Climate change mitigation in Africa. In: Mackenzie G, Turkson J, Davidson O (eds) Proceedings of International Conference on Climate Change Mitigation in Africa, Zimbabwe, 1998Risø National Laboratory UNEP Collaborating Centre on Energy and Environment, Roskilde, pp 29-38.

Dinpashoh Y., Jhajharia D., Fakheri-Fard A., Singh V., Kahya E. 2011. Trends in reference crop evapotranspiration over Iran. *Journal of Hydrology* 399: 422-433.

Douglas E., Vogel R., Kroll C. 2000. Trends in floods and low flows in the United States: Impact of spatial correlation. *Journal of Hydrology* 240: 90-105.

Goerner A., Jolie E., Gloaguen R. 2009. Non-climatic growth of the saline Lake Beseka, Main Ethiopian Rift. *Journal of Arid Environments* 73: 287-295.

Gulacha M., Mulungu D. 2017. Generation of climate change scenarios for precipitation and temperature at local scales using SDSM in Wami-Ruvu River Basin Tanzania. *Physics and Chemistry of the Earth* 100: 62-72.

Guo J., Guo S., Li Y., Chen H., Li T. 2013. Spatial and temporal variation of extreme precipitation indices in the Yangtze River basin, China. *Stochastic Environmental Research and Risk Assessment*, 27: 459–475.

Hua W., Chen H., Sun S., Zhou L. 2015. Assessing climatic impacts of future land use and land cover change projected with the CanESM2 model. *International Journal of Climatology*, 35: 3661-3675.

IPCC 2001. International Panel on Climate Change, Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton J, Ding Y, Griggs D, Noguer M, Van der Linden P, Dai X, Maskell K and Johnson C (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC 2013, Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC 2014. Climate Change 2014-Impacts, Adaptation and Vulnerability:Part B: Regional Aspects. Press CU, Cambridge.

Jhajharia D., Shrivastava S. K., Sarkar D., Sarkar S. 2009. Temporal characteristics of pan evaporation trends under the humid conditions of northeast India. *Agricultural and Forest Meteorology*, 149: 763-770.

Jhajharia D., Singh V. 2011. Trends in temperature, diurnal temperature range and sunshine duration in Northeast India. *International Journal of Climatology*, 31: 1353-1367.

Kahya E., Kalay S. 2004. Trend analysis of streamflow in Turkey. *Journal of Hydrology* 289: 128-144.

Kemp W., Burnell D., Everson D., Thomson A. 1983. Estimating of Missing Daily Maximum and Minimum Temperature. *Journal of Climate and Applied Meteorology*, 22: 1587-1593.

Li T., Horton R., Kinney P. 2013. Future projections of seasonal patterns in temperature-related deaths for Manhattan. *Nature Climate Change*, 3: 717-721.

Partal T., Kahya E. 2006. Trend analysis in Turkish precipitation data. *Hydrological Processes*, 20: 2011-2026.

Raghunath H. (2006) Hydrology Principles Analysis Design. Second edn, New Age International (P) Ltd., Publisher, New Delhi

Saraf V., Regulwar D. 2016. Assessment of Climate Change for Precipitation and Temperature Using Statistical Downscaling Methods in Upper Godavari River Basin, India. *Journal of Water Resource and Protection*, 8: 31-45.

Setegn S., Rayner D., Melesse A., Dargahi B., Srinivasan R. 2011a. Impact of climate change on the hydroclimatologyof Lake Tana Basin, Ethiopia *Water Resources Research* 47: 1-13.

Setegn S. et al. 2011b. Climate Change Impact on Agricultural Water Resources Variability in the Northern Highlands of Ethiopia. *Springer, Dordrecht*: 241-265.

Singh D., Jain S. K., Gupta R. D. 2015. Statistical downscaling and projection of future temperature and precipitation change in middle catchment of Sutlej River Basin, India. *J Earth Syst Sci* 124: 843-860.

Singh P., Kumar V., Thomas T., Arora M. 2008. Basin-wide assessment of temperature trends in northwest and central India. *Hydrological Sciences Journal*, 53: 421-433.

Tebakari T., Yoshitani J., Suvanpimol C. 2005. Time-space trend analysis in pan evaporation over Kingdom of Thailand. *Journal of Hydrologic Engineering*, 10: 205-215.

Thornton P., Jones P., Alagarswamy G., Andresen J. 2009. Spatial variation of crop yield response to climate change in East Africa. *Global Environmental Change* 19: 54-65.

Wagesho N., Goel N., Jain M. 2012. Investigation of non-stationarity in hydro-climatic variables at Rift Valley lakes basin of Ethiopia. *Journal of Hydrology*: 444-445, 113-133.

Wilby R., Dawson C. 2007. Statistical Downscaling Model (SDSM), Version 4.2. Department of Geography, Lancaster University, UK.,

Wilby R., Dawson C. 2013. The Statistical DownScaling Model: insights from one decade of application. *International Journal of Climatology*, 33: 1707-1719.

Wilby R., Dawson C., Barrow E. 2002. sdsm-a decision support tool for the assessment of regional climate change impacts. *Environmental Modelling and Software* 17: 145-157.

Xu Z., Takeuchi K., Ishidaira H. 2003. Monotonic trend and step changes in Japanese precipitation. *Journal of Hydrology*, 279: 144-150.

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