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ANALYSIS OF TREND AND VARIABILITY OF CLIMATE OF HAWASSA BASED ON SURFACE OBSERVATIONS

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ABSTRACT

Precipitation and temperature are the main determinants of climate change and variability of one's area. Their change can be disruptive to the normal hydrological processes which plays an important role in agricultural and non-agricultural operations activities. This study is to determine climatology, trends, onset and retreat of rainy seasons and variation in temperature and precipitation by statistical and Mann Kendall test methods at Hawassa station for the period of 1973-2018. The increasing trend of minimum and maximum temperature were detected to be 0.05 and 0.04°C with high coefficient of determination (R^2 = 0.63 and 0.66), respectively. Besides, annual rainfall showed a coefficient of variation 15.2% with mean and standard deviation 965.3mm and 146.5, respectively. Seasonally, Belg season showed higher variability with statistical significant an increasing trend. And also the mean onset Belg season was identified as in the 1st decade of March and cessation date was in the 2nd decade of May, and Kiremt season mean onset was after 1st decade of June and cessation in the 2nd decade of September. The observed warming temperature and fluctuation of rainfall are impacts of global climate change during the last decades in the area.

Contribution/Originality: This study is my original work to contribute in the existing knowledge of climate and increase the understanding of the seasonal cycle of rainfall for the benefit of local social-economic activities.

1. INTRODUCTION

Long term Precipitation and temperature variations are one of the main determinants of climate change and variability of one's area. This change in climate causes a significant impact on the water resource by disturbing the normal hydrological processes and also which plays an important role in many of the agricultural and non-agricultural operations [1]. In Ethiopia, Climate variability, particularly rainfall variability and the recurrent associated droughts have been major causes of food insecurity and famine, due to its great reliance on climate-sensitive industries, particularly agriculture and affect the lives of millions of people [2, 3]. It is also recognized that rainfall is one of the key climatic variables that affect both the spatial and temporal patterns on water availability [4]. According to Miro, et al. [5] the occurrence of hydro-climatic events such as droughts and floods increase in many parts of the country, causing severe socio-economic impacts that include food insecurity, famine, deaths, epidemic diseases, pests and economic losses among others. Therefore, Climate variability plays a great role in agricultural production having a direct impact from the start of land preparation to the final harvest. It also influences crop and livestock production, hydrologic balances, input supplies and other components of agricultural systems. This study was conducted because of climate variability and change, to understand the climatology and strengthen the capacity of Regional Meteorological Service to produce and disseminate more localized weather information to the regions. Rainfall and temperature are the most important and sensitive climatic elements in tropical regions and information about their characteristics, especially the extremes are critical in the planning and management of most socio-economic activities. An increasing the risks of heat waves and rainfall variability is associated with drought. Some national and regional analysis was undertaken to the trend indices showed significant increases and decreases in seasonal and annual precipitation and temperature [6, 7]. The findings shall contribute to the knowledge of local on climate and rainfall variability in the study area in particular and relevant to the water resources management and rainfall-related risk managements operations. Therefore, the objectives of this study are to determine the trends and variability of climatic variables, and identify onset and retreat of rainfall and to contribute to the knowledge of local on climate and rainfall variability in the study area.

2. DATA AND METHODOLOGY

2.1. Description Study Area

The study was conducted, based on Hawassa synoptic station observations, in southern region of Ethiopia. It is located 273 km south of Addis Ababa. The city serves as the capital of the Southern Nations, Nationalities, and Peoples' Region. It has a latitude and longitude of 7°3′N, 38°28′E and an elevation of 1708 meters above sea level Figure 1. The study area is characterized by a tropical high land climate with heavy rain fall, warm temperature and long wet period. It is the parts of the country experience a bimodal rainfall pattern. Fishing is a major local industry.

Figure-1. Study Area locations.

2.2. Methods

To address these objectives, data of precipitation and temperature were obtained from SNNPR regional meteorological office. The trends of monthly, seasonal and annual climate data were analyzed by linear regression and Mann Kendall trend test was used to detect the significance of the trends. The Mann Kendall trend test will be calculated by trend software XLSTAT2014. Statistical computations of onset and cessation of rainy season have been performed with *INSTAT 3.37*.

2.3. Mann Kendall Trend Analysis

The Mann–Kendall (MK) test is based on time data ranking, i.e. each data point is compared with all data points that follow in time. Non-parametric methods (Mann-Kendall test and Sen's slope estimator) were used to detect trends using XLSTAT software. The statistics is given as:

$$S = \sum_{i-1}^{n-1} \sum_{j=i+1}^{n} sgn(xj - xi) \tag{1}$$

,where, S is the Mann-Kendall's test; xi and xj are the sequential rainfall values in the year i and j (j>i), and n is the length of the time series. The Sgn (xj −xi) is equal to +1, 0, −1 if *z* is greater than, equal to, or less than zero, respectively Equation 1. The null hypothesis is that the data are independently and identically randomly distributed, i.e. no trend exists in the data set. For the MK statistic holds $E(s) = 0$. The variance (Var(s)) of S-statistics in the x values, is given by: $var\ (s) = \frac{1}{18}(n(n-1)(2n+5)| - \sum_{i=1}^{m} ti(ti-1)(2ti+5)$.

Where m is the number of tied groups in the data set and it is the number of data points in the ith tied group. For the sample size n≥10, the standard test Z_{mk} is calculated as:

$$Zmk = \begin{cases} \frac{s-1}{\sqrt{Var(s)}} if s > 0 \\ 0 if s = 0 \\ \frac{s+1}{\sqrt{var(s)}} if s < 0 \end{cases} \tag{2}$$

In Equation 2, Z_{mk} is used to evaluate the trend. Positive Z_{MK} indicate increasing trends, negative Z_{MK} values reflect decreasing trends. The presence of a statistically significant trend is evaluated using the Z_{MK} value. $Z_{1-\alpha/2}$ is the critical value of Z_{MK}. For 5% and 10% significance level, the value of Z1-α/2 is 1.96 and 1.64 respectively Equation 2. It is not affected by missing data, insensitivity to extreme values and better performance even for normally distributed data. Then, the slope (change per unit time) was calculated as:

$$Q = \frac{Xj - Xi}{i - j}, i \neq j \tag{3}$$

Where, X_i and X_j are data values at times i and j (j>i), respectively Equation 3. The median of these n values of Q is Sen's estimator of slope [8].

3. RESULT AND DISCUSSION

3.1. Rainfall Climatology

3.1.1. Monthly Climatology and Annual Rainfall Trend

The monthly climatology and annual trends of Hawassa meteorological station was analyzed of its 45 years (1973-2018) precipitation data. The annual ranging from 668.0 (2015) mm to 1226.3mm (1977), mean rainfall is 965.2 mm and bimodal type Figure 2. Kiremt season is main rainy season receiving 48.8% of annual rainfall and 35.4% in Belg seasons, respectively Table 1. The maximum monthly precipitation occurs in May in belg sea and, in July and August in Kiremt season. Statistically, an insignificant increasing linear trend (0.92mm/45 years) was detected for precipitation on annual basis at 95 % confidence limit during the period of study Figure 2.

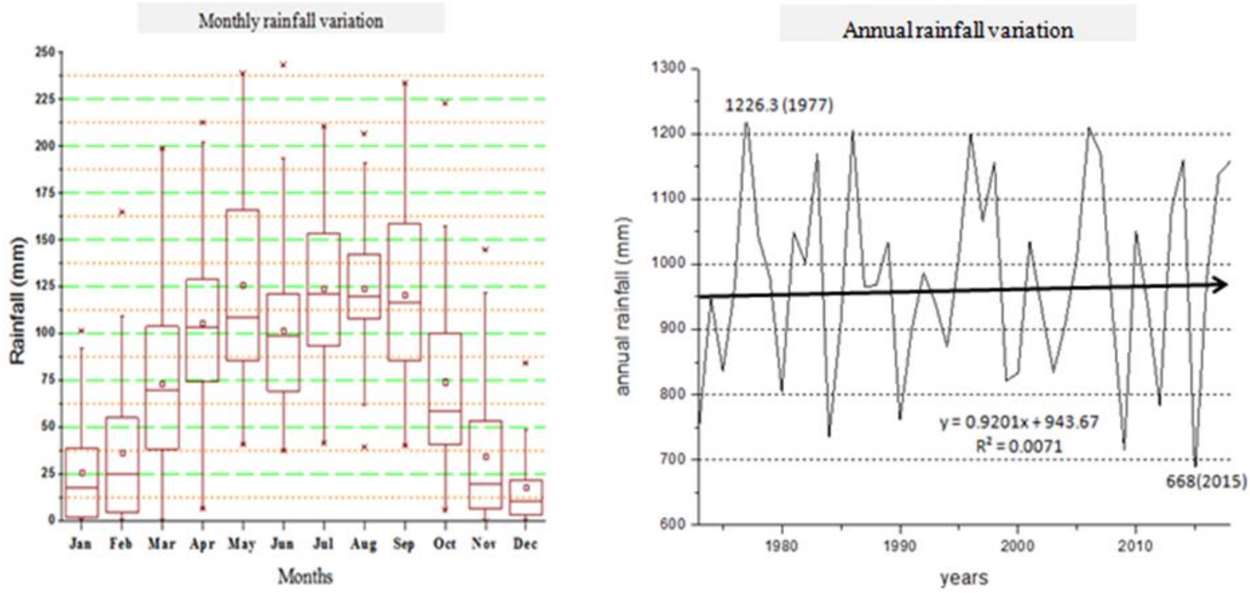

Figure-2. Monthly climatology (Boxplot (Box=25 to75%, whiskers line=up to 10 to 90% and Dots= min & max)) and annual trend of rainfall for Hawassa station (1973-2018).

3.1.2. Climatologically Mean Decadal and Cumulative Rainfall

The mean rain per day and mean rain per Decade varies in time and have maximum values in the peak months rainy seasons. The maximum values observed are 8.59 mm/Decades and 44.22 mm/decades in the peak months (May) Belg rainy seasons and 47.71mm/decade (July) kiermt season Figure 3.

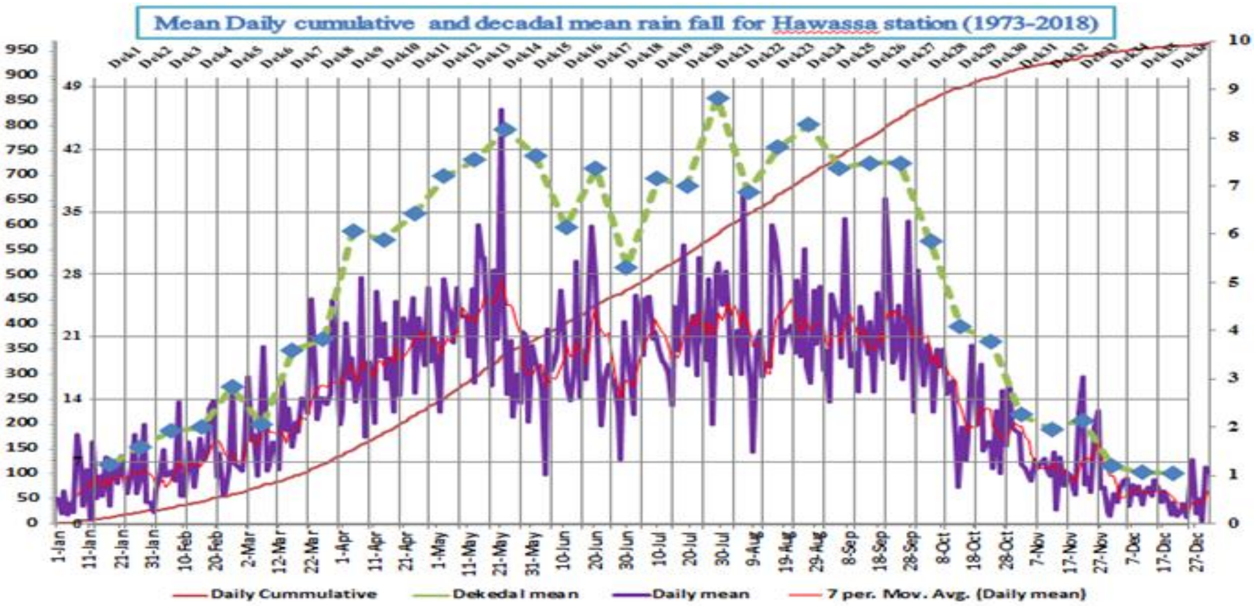

Figure-3. Daily mean cumulative and decadal rainfall for Hawassa station from 1973-2018.

3.1.3. Descriptive Statistical Summary of Monthly, Seasonal and Annual Precipitation

The amount and distribution of annual and seasonal total rainfall are critical rainfall features that indicate useful information on temporal rainfall variability over an area. The seasonal total rainfall ranged from 126.3 to 529.9 mm in Belg (FMAM) and 281.0 to 712.7 mm in Kiremt(JJAS) season, respectively Table 1. The CV is much higher for Belg season rainfall total than Kiremt rainfall, which indicates higher temporal variability of the Belg seasonal rainfall Table 1. This is similar with NMA [6]; Conway, et al. [9]; Suryabhagavan [10] findings. The annual total rainfall also showed high interannual variability and ranged from 668.0 to 1226.3 mm Table 1. The

MK-trend for all temporal scale showed both increasing (Belg & Bega season) significant trend was found during the Belg season and decreasing (Kiremt) insignificant trend Table 1.

Table-1. Statistical summary, linear and Mann-Kendall trend tests of monthly, seasonal and annual precipitation for Hawassa station (1973-2018).

Time	Descriptive Statistics					Mann-Kendall trend	
	Minimum	Maximum	RF & POC	STD	CV%	MK-test	Sen's Slope
Jan	0.0	101.6	26(2.7)	28.5	109.8	-0.09	0.0
Feb	0.0	164.9	36.8(3.8)	39.6	107.5	-0.98	-0.33
Mar	0.0	198.7	73.1(7.6)	43.2	59.1	1.48	0.77
Apr	6.8	212.4	105.7(10.7)	51.4	48.7	0.85	0.54
May	40.7	238.8	126.3(13.1)	55.6	44.0	0.42	0.39
Jun	37.6	243.3	101.9(10.6)	45.4	44.6	0.06	0.11
Jul	41.7	210.6	124.1(12.9)	40.8	32.9	-0.52	-0.29
Aug	39.5	206.6	123.9(12.8)	35.5	28.7	-1.10	-0.33
Sep	40.2	233.9	120.8(12.5)	44.6	36.9	-0.46	-0.31
Oct	5.8	222.9	74.4(7.7)	46.6	62.6	-0.68	-0.28
Nov	0.0	144.8	34.7(3.6)	38.6	111.5	1.52	0.36
Dec	0.0	84.3	18.1(1.9)	21.0	115.9	0.18	0.0
Annual	668.0	1226.3	965.3	146.5	15.2	0.66	1.39
Belg	126.3	529.4	341.8 (35.4)	93.4	27.3	**1.75**	**1.85**
Kiremt	281.0	712.7	470.6(48.8)	102.3	21.7	-0.89	-0.91
Bega	48.5	444.1	153.1 (15.8)	79.9	52.2	0.91	0.88

Note: RF =Rainfall, POC= Percent of contribution, STD= standard deviation & CV= coefficient of variation, Significance level: 10(%).

3.2. Temperature Analysis

3.2.1. Monthly Temperature Climatology

The minimum and maximum temperature has recorded in the station. The highest levels of maximum temperature were recorded in the months of March exceeding 29.7 °C whereas the lowest levels of maximum temperature were recorded during months of July and not exceeding 24.2 °C Figure 4. Furthermore, January, February and December were the months of high variations of monthly temperature recorded. Besides, May was the month of high deviation of temperature occurrence the lowest levels of minimum temperature were recorded during months of December and January less than 10.0°C were recorded.

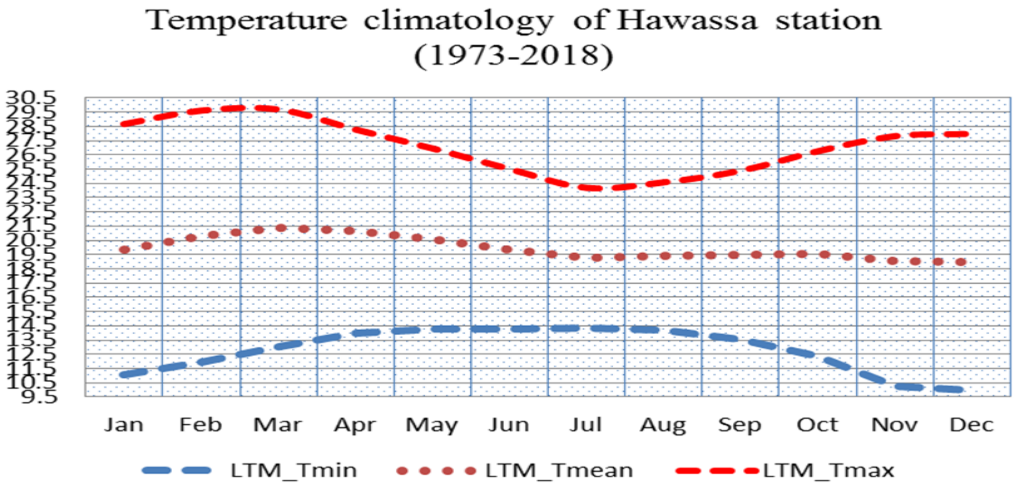

Figure-4. The minimum and maximum temperature climatology for Hawassa station (1973-2018).

3.2.2. Annually Temperature Trends

Regarding temperature, significant trends are found for minimum and maximum temperature data on annual and monthly basis while negative trends are detected for minimum temperature for the period of observed from 1973-2018 Table 1. In general, annual minimum and maximum temperature trend showed a warming trend and also both results are statistically significant at 95 % confidence limit during the period of study. These findings are consistent with previous studies concerning the variations of temperature trends [6] and Suryabhagavan [10].

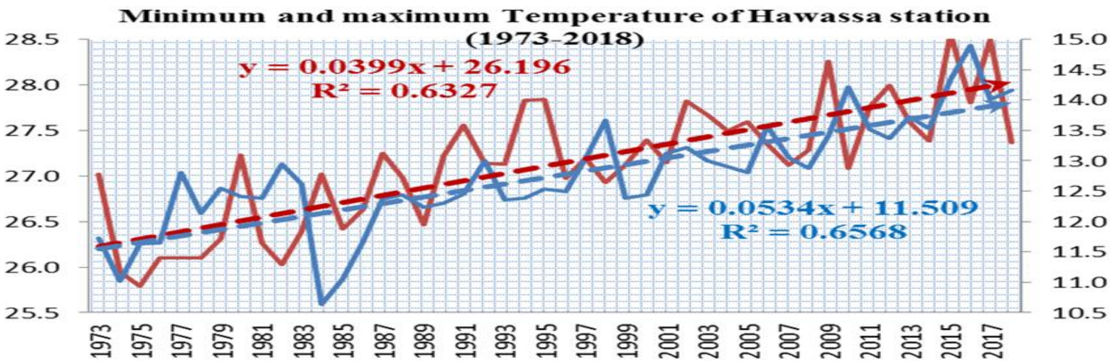

Figure-5. Trends of maximum and minimum temperature for Hawassa station (1973-2018).

3.3. Onset And Cessation of Rainy Seasons

Several models have been proposed for determining the dates of onset and end of the rainy season and the length of growing season as a tool for rainfall water resources assessment. The start of the rainy seasons was identified based on Muchiri [11] simple soil water balance model which suggested that a growing period starts when a decadal (ten-days) rainfall amount is equal or greater than half of the reference evapotranspiration (ETo) and 7-day total greater than 25mm and includes at least 4rainy days during the beginning of the rainy seasons. Accordingly the end of the rainy seasons was set when the decadal rainfall of amount during the end of season.

3.3.1. Onset and Cessation of Belg Rainy Season

The average onset date was in the 1st decade of March and cessation date was in the 2nd decade of May during the Belg (FMAM) season in the study area for the period. Figure 6 shows the high variability of onset than offset date of rainfall. Therefore, the mean onset date (03 March) could be taken as a reference for early land preparation and dependable planting date for long growing crops at and around Hawassa. On the other hand, the Belg rainy season offset after 1st decade of May therefore, decisions related to harvesting of short growing crop could be made more easily Figure 6.

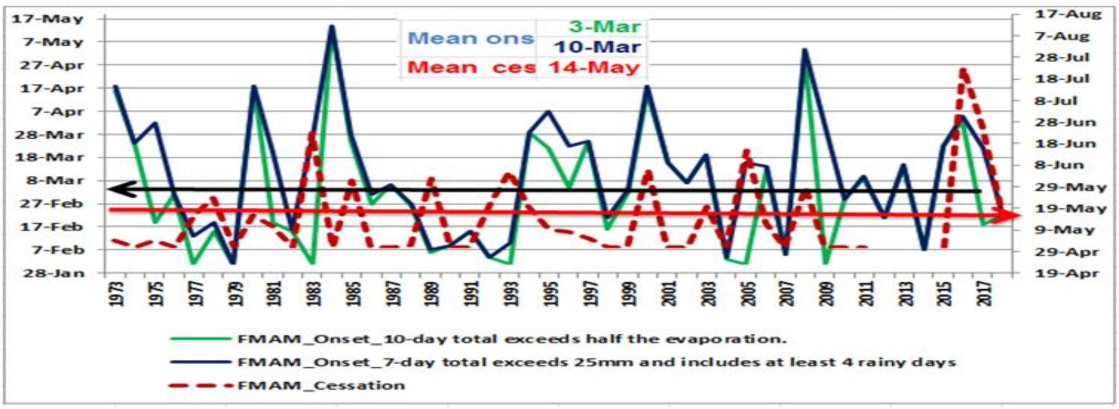

Figure-6. Onset and cessation of Belg rainy season for Hawassa station (1973-2018).

3.3.2. Onset and Cessation of Kiremt Rainy Season

The average onset date and offset date was in the 1st decade of June and by other method cessation date was in the 2nd decade of June during the *Kiremt (JJAS)* season in the study area for the period. On the other hand, the Kiremt rainy season cessation in the 2nd decade of September therefore, decisions related to harvesting and post harvesting activities like storage could be made more easily Figure 7. General seasonal mean onset and cessation date of the belg and kiremt rainy season more or less similar with NMA, 2017 and Abebe, 2006.

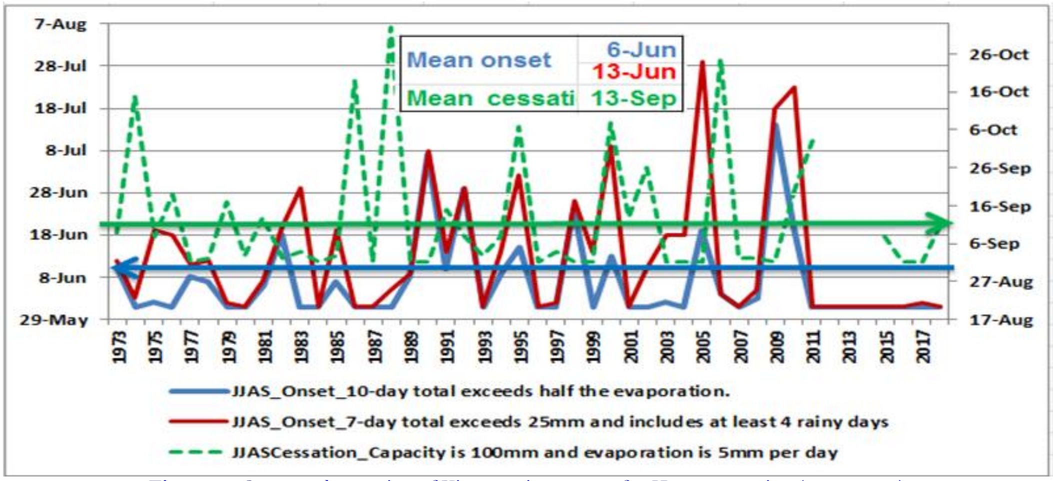

Figure-7. Onset and cessation of Kiremt rainy season for Hawassa station (1973-2018).

4. CONCLUSION AND RECOMMENDATIONS

The precipitation and temperature were analyzed *for Hawassa station (1973-2018)*. The study detected an increasing rainfall trend (for annual, Belg & Bega season) of which significant in Belg season, and insignificantly decreasing Kiremt seasonal trend was noticed. The coefficient of variation (CV) indicated more variability for Belg seasonal rainfall than Kiremt, which is an indicator of less predictability, and more prone to both wet and dry extremes of seasonal climate than kiremt. Kiremt season is main rainy season with Seasonal contribution of 48.8%, and Belg season is small rainy season with Seasonal contribution of 35.4% of annual rainfall. As far as trends of temperature concerned, the MK-test on the annual mean maximum and minimum temperatures exhibited statistical significant increasing trend. The MK-trend for all seasonal scale showed either increasing or decreasing statistical insignificant trend but significant trend was detected during the Belg season. The mean onset date of Belg season was in the 1st decade of March and cessation date was in the 2nd decade of May, and for *Kiremt* season mean onset was after 1st decade of June and cessation in the 2nd decade of September. The result of the study showed that there are variability of the rainfall in amount and timing and consistently increasing of temperature in the area. The detected significantly an increasing Belg season rainfall trend has implication of flooding in the city. Therefore, Hawassa city and around areas should use climate information for adjust hydro agricultural operations practices and flood risk management to avert the risk of climate change and variability.

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