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RESEARCH PAPER

Spatiotemporal Attribution and Trends of Climate Variables in Iluababora Zone, Oromia National Regional State, Ethiopia

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Abstract

The environmental diversity associated climatic variables in the micro environments are anticipated to change over times. This study aimed to examine precipitation concentration and anomaly indices, and trends of climatic variables over micro-environments of Iluabbabora zone. Climatic data were obtained from NASA's dataset, recorded from 1981–2018. Precipitation concentration indices were estimated and interpolated using an inverse distance weighting. The frequency and percentile of drier and wetter periods was analyzed using standardized precipitation anomaly index model. The Mann Kendall trend test was used to determine trends of seasonal and annual temperature and precipitation. Results show that both seasonal and annual precipitation concentrations were inconsistently distributed among the seasons and neighboring locations. A strong concentration index (23) was observed in Meko during summer season. Standardized precipitation anomaly indices Analyses indicated that the frequency and percentiles of the driest years were more pronounced than wettest periods in all locations. The higher percentage (55.41%) drier period above the normal was observed in Bedele followed by Birbisa (54.05%). Trends analyses of seasonal mean temperature and precipitation were inconsistently changed with respect to the seasons and locations. The spring minimum temperature of Bedele, winter minimum temperature of all locations and annual minimum temperature of Gore were significantly warmed (P>0.05). Similarly, the spring season of Birbisa, and Gore, winter summer seasons and annual maximum temperature of Bedele and Gore locations were significantly increased (P<0.05) whereas the spring and summer seasons of Bedele, annual and summer season precipitation of Gore were significantly decreased (P<0.05). Therefore, the study confirmed that variability and change of climatic variables in different micro environments were rapidly and indifferently tracked toward severe climatic shocks, and suggesting that sound implementations of existing forest protection and soil water conservations in the study area.

Keywords: *precipitation concentration, standardized anomaly index, trend analysis*

Introduction

Climate is changing more rapidly than ever before. Changes in temperature and precipitation are one of the most critical factors determining the overall change in climate. The local, regional or global change in the long-long term average temperature, precipitation and related weather variables are robust since industrial revolution (IPCC, 2014). The rising global temperature is resulting from the increase in carbon dioxide and other greenhouse gases accumulation in the atmosphere. Since the last 20th century, global surface temperatures have risen by approximately 1°C and a further increase of 2- 4 °C will be expected by the end of the 21th century (IPPC, 2013). However, change in rainfall at global scales is complex due to large regional differences, gaps in spatial coverage of vegetation and lack of long term data (Abdul Haris et al., 2010). Like other African states, Ethiopia has become warmer over the past century and the human induced climate change will bring further warming over the next century at unprecedented rates (EPA, 2011). As results of study reported by (Kebede & Adane, 2011) the seasonal temperature is increasing most rapidly from July to September by 0.32°C per decade in Ethiopia.

In view of the above, a number of studies have attempted to investigate trend of climatic variables regional and national levels. However, present study also examined the attributions and trends of temperature and precipitation variables, which are critical for supplying hydrological demands of agriculture, water and energy sectors in Ethiopia (EPA, 2011). whilst, the consequences of changes in precipitation patterns and rising temperature are best explained by these sectors through increasing the risks of both droughts and floods (IPCC, 2014). The change in temperature and precipitation also shortened growth period results in early flowering, seed bearing and physiological maturity and alters incidence of pests and diseases (Karmakar et al., 2016), followed by declining agricultural production, relative to the rising population (Pathak et al., 2018).

Like in the others parts of the country, Ilu Abbabora Zone is characterized by environmental diversity ranging from low lands to highlands. Associated with this environmental diversity, climatic variables in the study area are anticipated to change over time and also vary across eco-environments. However, scientific evidences on the changes of temperature and precipitation are not generated and hence, the local communities lack information about their environment with respect to their low adaptive capacity resulting from low level of socioeconomic development, high population growth, inadequate infrastructure, lack of institutional capacity, high dependence on climate sensitive natural resource-based activities, poor technologies and development (Wold Bank, 2015).

In Iluababora zone, the analysis of drought trends was performed by an index estimating the proportion of agricultural drought (SPEI-3) in cropping season showed a remarkable increasing trend (Benti and Achalu, 2019). Moreover, the change in climatic variables is more intensified over the moist-cool region of the Iluabbaora zone and this indicated that the zone is rapidly tracked toward severe climatic shocks since 1981. However, the result of the study was aggregated as the study restricted to only one district which could not represent the entire micro-environments of a given zone. Therefore, these facts were concerned to assess seasonal and annual the precipitation concentration indices, the precipitation Anomaly indices, trends and percentage change of temperature and precipitation in microclimate of Iluabbabora zone.

Methodology

Description of the Study Area

The study was conducted in four representative rainfall localities; namely, Bedele, Birbisa, Gore and Meko in Ilubbabora zone, Oromia National Regional State, Ethiopia. Ilu Abba Bora zone is located between 7.285°-9°N latitude and 35° - 37° E longitude with an average elevation of 1803 meters a.s.l. The average annual temperature and rainfall of the Zone is 20℃ and 2080 mm, respectively. Considering precipitation, temperature and elevation factors , Ilu Ababora Zone is categorized under moist cool zone and known as Semi humid Zone (Zerga & Mengesha, 2018). It has three hydrological seasons locally known as Belg (spring), Kiremt (summer) and Bega (winter). The Belg is the shorter rainy season that extends from February to May. Summer is the main rainy season (June–September), also known as the agricultural season corresponding with this rainfall is locally referred to as Meher. The dry season which is extended from October–January is referred as Bega season.

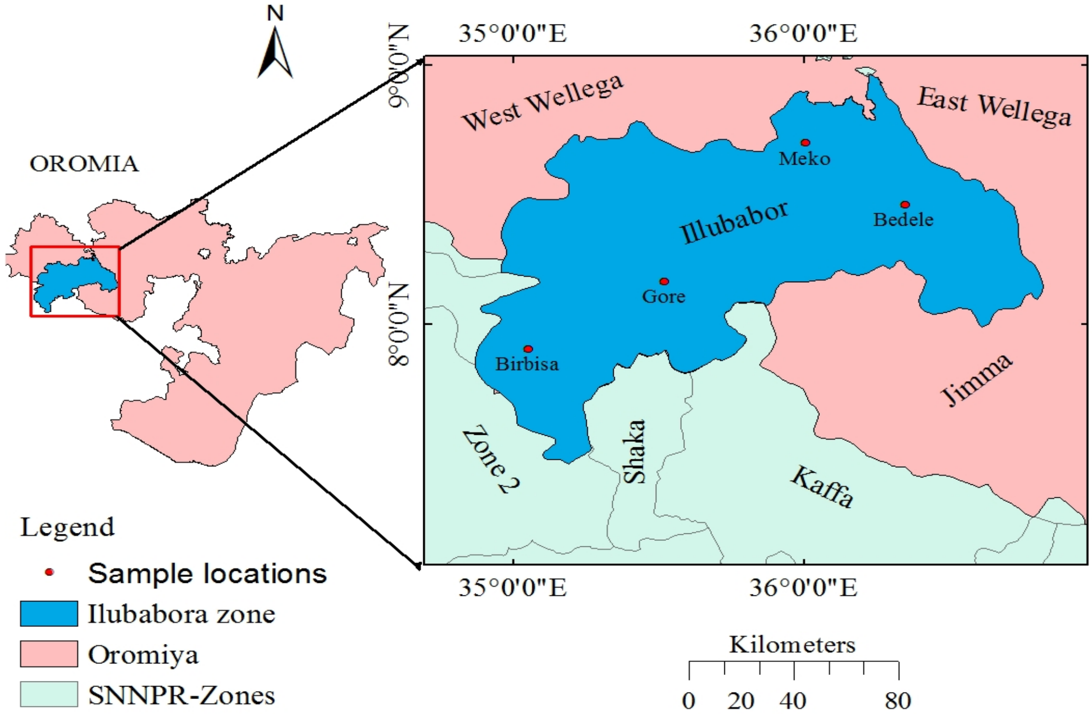

Figure 1: Location Map of the Study Areas

Data Collection and Analyses

Historical data of precipitation, maximum and minimum temperatures on record from 1981-to-2018 in four rainfall locations (Birbisa, Gore, Bedele and Meko) were obtained from NASA Langley Research Center (LaRC) data products, which are available via the web page https://power.larc.nasa.gov/data-access-viewer/. It is gridded data, by 0.5x0.5 degree resolutions. The missing data, outliers, and autocorrelation were detected before data analyses to avoid internal variation that could affect the absolute values of average, standard deviation and moving average.

Data Analyses

Precipitation Concentration Index (PCI)

Standardized Precipitation Concentration Index (SPCI) was analyzed using formula proposed by (Oliver, 1980), which best estimates the precipitation distribution patterns and erosivity. SPCI is a powerful indicator of the temporal distribution of precipitation, traditionally, applied at annual scales. Moreover, it is calculated to understand the features of annual precipitation concentration variations. The more variation in precipitation, the more is precipitation concentrated indices. Therefore, SPCI of both seasonal and annual scales was calculated for each selected locality in the study area (Equation 1).

$$PCI_{Annual} = \frac{\sum_{i=1}^{12} \rho_i{}^2}{(\sum_{i=1}^{12} \rho_i)^2} * 100 \ldots\ldots\ldots\ldots equ.1$$

For seasonal precipitation, the annual scale precipitation concentration index was modified to be suitable for the seasonal classification of the study area. Subsequently, seasonal scale precipitation concentration indices of the three seasons were separately calculated for Belg (Feb-Mar-Apr-May), Kiremt (Jun-Jul-Aug-Sept) and Bega (Oct-Nov-Dec-Jan) as used in methods of Al-shamarti (2016).

$$PIC_{seasonal} = \frac{\sum_{i=1}^{4} \rho_i{}^2}{(\sum_{i=1}^{4} \rho)^2} * 33 \ldots\ldots\ldots\ldots equ.2$$

Where; p_i is the monthly precipitation in month i.

- ✓ PCI < 10 indicates uniform precipitation distribution patter (low precipitation concentration).
- ✓ PCI >11 and <15 indicates moderate precipitation concentration.

- ✓ PCI >16 and < 20 indicates irregular distribution.
- ✓ PCI > 20 indicates a strong irregularity (i.e., high precipitation concentration).

Standardized Anomaly Indices (SPAI)

Annual standardized precipitation anomaly indices were also analyzed for each selected localities in order to examine year to year fluctuation of precipitation using Standardized Anomaly Index (SAI) which is a commonly used for local, national and regional climate change analyses (Babatolu & Akinnubi, 2013). Standard precipitation anomaly index is expressed as a standardized departure of total precipitation in i^{th} time minus long term mean and divided by standard division, calculated using equation 3.

$$SAI = \frac{x_i - \overline{X}}{\delta} \text{.............................equ. 3}$$

Where: SAI is standardized Anomaly Indices, X is the total precipitation in year i, $\overline{X}$ is the long-term average, and δ is the standard deviation. A period is considered as drier when rainfall below the long-term average dominates and wetter, when rainfall above long-term average is persistent.

Precipitation percentile; percentile rank of each precipitation value was estimated using the climatological distributions during 1981–2018. Percentiles were calculated separately for seasonal and annual of rainfall for each location. Target precipitation values were converted to a corresponding percentile values using equation 4.

$$\rho = \left(\frac{C_1 + 0.5 f_i}{N}\right) * 100 \text{.....................equ. 4}$$

Where; C_l is the number of times that annual precipitation values for a given period of time were below or above the normal precipitation values, f_i is the frequency with which the target precipitation value appears in the expected (climatological) distribution, and N is the total number of years included in the analysis. Finally, the rainfall location data were interpolated using the deterministic Inverse Distance Weighted (IDW) to identify areas experiencing continuous moisture stress

Temperature and Precipitation Trend Analyses

Pre-whitening was used to detect trend of seasonal and annual precipitation in a time series in presence of autocorrelation as described in (Burn et al., 2004). Both seasonal and annual trends of precipitation and temperature were analyzed using the Mann Kendall trend test. Mann-Kendall provides that the strength of the trends, which is directly proportional to the magnitude of the Mann Kendall statistic value (S-score). In this case, the term describes the internal strength of climate system to change the climatic variables (temperature and rainfall). S is defined as the sum of the number of positive differences minus the sum of the number of negative differences, given by:

$$S = \sum_{k=1}^{n-1} \sum_{J=k+n}^{n} \text{sgn}(Y_j - Y_k) \text{.............equ. 5}$$

Sign ($Y_j - Y_k$) is an indicator function that results in the values 1, 0, or −1 according to the significance of $Y_j - Y_k$, where j =2, 3, 4…and k=1, 2, 3… then the function is calculated as follows:

$$\text{Sgn}(\theta) = \begin{cases} 1 \text{ if } \theta > 0 \\ 0 \text{ if } \theta = 0 \\ -1 \text{ if } \theta < 0 \end{cases}$$ **Where**; sign (θ) = sign (Y_j - Y_k)

A positive value of S connotes "upward trend, while a negative value of S showing downward trends. In addition, the probability (normalization) associated with S and the sample size N test is important to quantify the significance of the trend (Sheng et al., 2002). Therefore, a normalized test statistic (Z-score) was computed to check the statistical significance of the increasing or decreasing trends or non-significance. When Z-values $< +1.96$ or $Z > -1.96$), it is non-significant, $Z -$ values between $+ 1.96$ and $+ 2.57$ or bteween $- 1.96$ and $- 2.57$) , significant at 0.05 and highly significant at 0.01 when Z-values above or equal to 2.58 or less or equals to -2.58.

Furthermore, If a significant trend is found, the rate of change can be calculated using the Sen's median Slope estimator as works of Khambhammettu (2005).

$$\beta = \text{Median}\left(\frac{Y_j - Y_i}{X_j - X_i}\right) \text{.........................equ.6}$$

Where; β is describes Sen's median slope estimator. for all i < j and i = 1, 2, …, n-1 and j = 2, 3,…, n; in other words, computing the slope for all pairs of data that were used to compute S. Some trends may not be evaluated to be statistically significant although they might be of practical interest, and vice versa. For the present study, percentage change was computed as an extension of trend analyses by approximating it with a linear trend followed the works of Yue & Hashino (2003).

$$Pc = \frac{\beta * \tau}{\mu} \text{..equ.7}$$

Where; Pc is percentage change, β is median slope, τ is period length and μ is the corresponding mean

Finally, trends of seasonal and annual temperature and precipitation were interpolated using an Inverse Distance Weighting (IDW) with a power parameter1 ArcGIS.

Results and discussions

Precipitation Concentration Index (PCIs)

Seasonal Precipitation Concentration Index (PCI_S); the seasonal and annual time courses of precipitation concentration indices are illustrated in figure 2. The results indicate that the seasonal precipitation concentration indices (PCI) of localities were inconsistently distributed over time series. Belg season precipitation concentration indices of the localities were observed uniform (PCIs < 10) in Gore, moderate (11< PCI <15) in Bedele and Birbisa, and irregular (16 <PCI< 20) in Meko as shown in figure 2a. However, Kiremt season precipitation concentration indices were identified a uniform precipitation distribution patterns (PCI < 10) over the whole localities (Figure 2b). Similarly, Bega season precipitation concentration indices were detected uniform (PCIs < 10) in Bedele, Birbisa and Gore, and strongly irregular (PCI >20) in Meko locality (Figure 2c).

Annual Precipitation Concentration Indices (PCI_A); alike to seasonal precipitation concentration indices, results of annual precipitation concentration indices show a uniform precipitation distribution patterns (PCI < 10) in Birbisa and Gore and moderate (10< PCI <16) in Bedele and Meko as shown in the figure 2d. Deforestation might be the major reasons for higher of the irregularity of precipitation concentration (high precipitation concentration). Although precipitation variability had not caused serious problems over the last thirty eight years, now it is reached warning time to establish planning and management of the most essential natural resource.

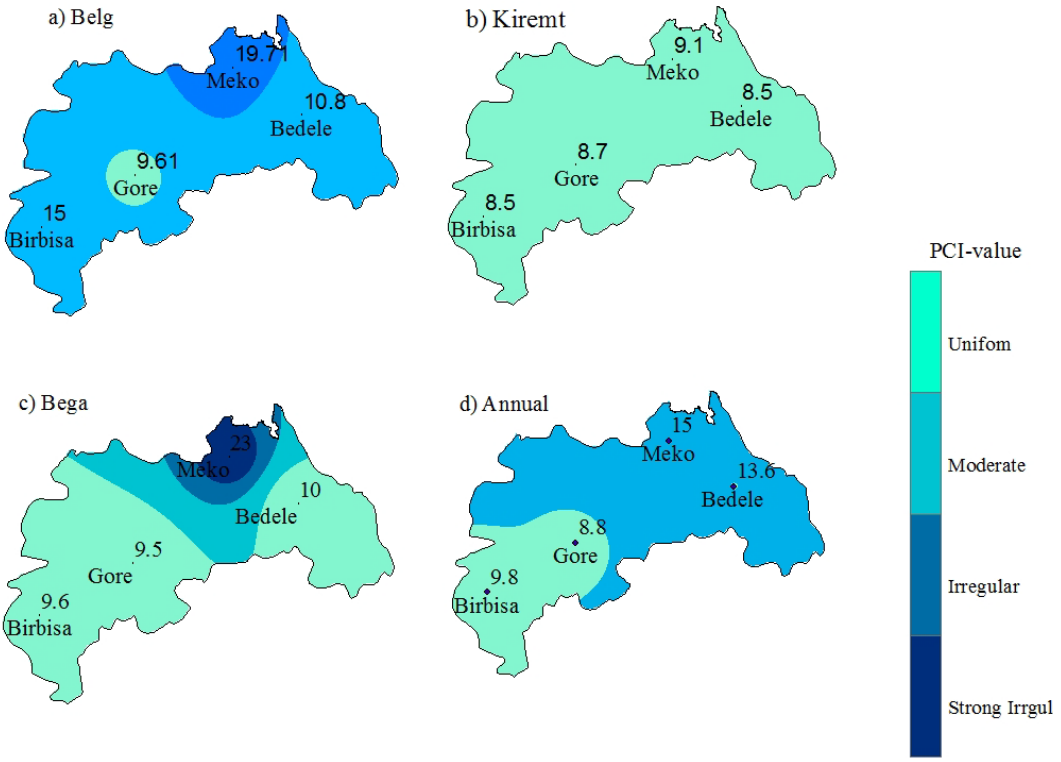

Figure 2.Seasonal and annual precipitation concentration indices during the periods 1981-2018

Standardized Precipitation Anomaly Index (SPAI)

The annual standardized precipitation anomaly indices of the localities were experienced in fluctuation during the 1981-2018 as it illustrated in the figure 3.

Analyses of standardized precipitation anomaly indices showed that localities have been experienced in various dimensions of precipitation extremes (dry, normal wet periods). The negative values of SAI (figure 3) beneath the normal precipitation distribution indices (SAI ≤-1) in the entire locations were greater than the positive values of SAI above the normal (SAI ≥1). This indicated that the frequencies of drier period were more than the wetter period over normal and these higher frequencies of drier and the lower wetter periods were more manifested in Bedele and followed by Birbisa sample locations. The percent values of dry years in the different locations, during the given time were 55.41, 54.05, 52.70 and 51.35 for Bedele, Birbissa and Gore, and Meko rainfall locations, respectively (Table 1). The average negative value of standardized anomaly indices below the normal was found to be about 53.47% drier (SAI <-0.99) and the positive anomaly (SAI > 0.99) was 46.53% wetter above the normal during the given time courses. This might be related to the decrease of rainy months where the time series of thee precipitation under stepped in its long-term mean and an increase of rainless day where it's long-term means less than the average rainfall of different years (see Table 1).

Table 1.The frequency and weights of wetter and drier periods in the rainfall locations during 1981-2018

Locations	Frequency of drier years than normal	Frequency of wetter years than normal	% of Drier year	% of wetter year
Bedele	7	3	55.41	44.59
Birbisa	7	4	54.05	45.95
Gore	7	5	52.70	47.30
Meko	6	5	51.35	48.65
Average	6.75	4.25	53.47	46.53

The time period from 2000-2005 and 2011 were the longest drier time courses for most of sample locations in the study area. Furthermore, the year of 1984 was the drier year for the Meko and Gore locations. . On the other hand, higher range of wetter periods manifested in the years of 1996 and 2015-2017 were the longest wetter period for the Birbisa, Meko and Gore s. Similarly, the 1987 in Bedele and 1988 in Gore and Meko locations were another additional wetter (Figure 3).

Therefore, these fluctuations of precipitation extremes (drier and wetter) might have affected water and agricultural sectors, especially dry and/ or wet anxious crops during the given time courses. However, it is very important to understand that the increasing precipitation would not necessarily lead to a greater availability of soil moisture or water resources as temperature might be affected by the availability of the resources through evapo-transpiration, and evaporation or the more intense precipitation event might be run to be greater runoff as reported by Keenan et al.,(2015). Furthermore, the heavier wetter events might be caused soil water erosion, which selectively removes the soil organic matter, and other essential soil nutrients from the soils(Karmakar et al., 2016).

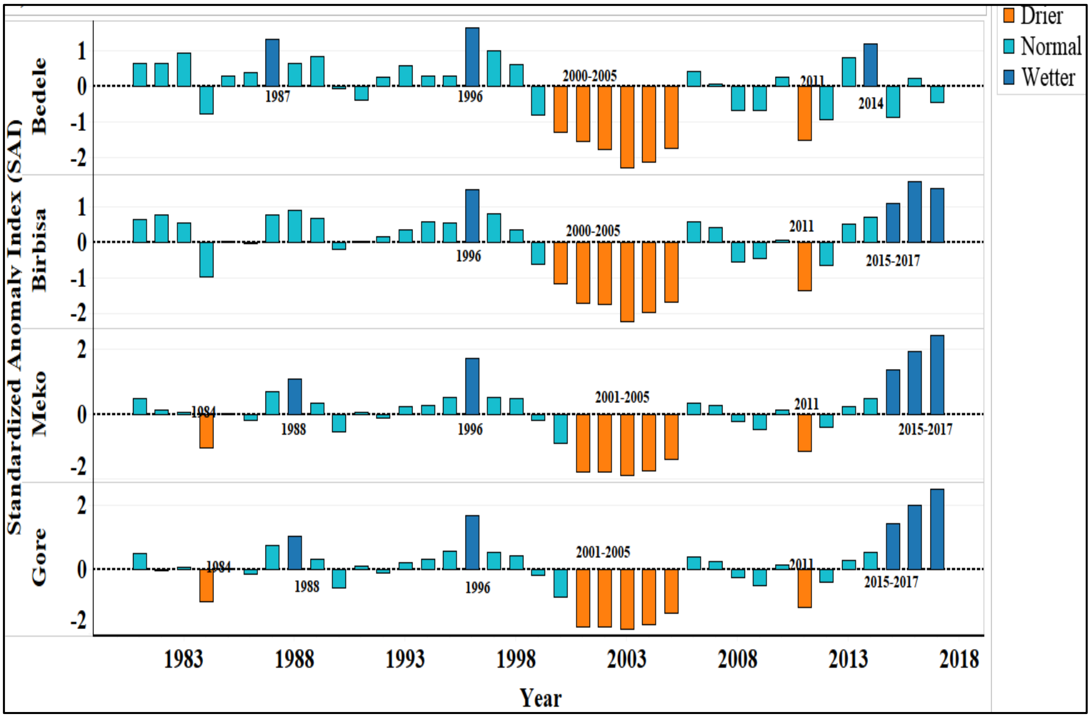

Figure 3. Time series precipitation extremes of the different locations in Ilu Abbabora Zone

Therefore, the time series precipitation anomaly indices explicitly indicated how the localities were shocked by dry and excess of water while fluctuation of the precipitation. This explains why so much research has been conducted on this topic over the different countries. Even if past precipitation experiences are not indicative of future tendencies, the present study results will be valuable for future agricultural activities and water management planning since the implications of described changes might have a strong influence on natural processes such as soil erosion, modifying fluvial regimes, groundwater recharge and water availability, and production of hydroelectricity as explained in Luis et al (2011).

Trends of Seasonal and Annual Climatic Variables

The long-term seasonal and annual increasing or decreasing trends, mean, and rate of changes percentage are illustrated in Table 2. *Seasonal minimum temperatures*; trend analyses results, illustrated in figure 4 show that there were significant warming trends of average seasonal minimum and annual minimum temperature during the period 1981-2018. Belg season's average minimum temperature was significantly increased (P<0.05%) at rate of 0.02°C/year in Bedele. Bega season's average minimum temperatures was highly significant increased (P<0.01) at the rate 0.02°C/year in Birbisa and significantly increased (P<0.05) at equal rate of 0.02 °C /year for Bedele, Gore and Meko localities (Figure 4c). However, no significant trend of the minimum temperature was noticed in Kiremt season in all localities (Figure 4b).

Annual minimum temperature; a substantial warming trend of annual average minimum temperature, was detected raised in Gore, which was raised at rate of 0.02 °C/year (Table 2) whereas none significant trend was detected in the rest of the locations (Figure 4d).

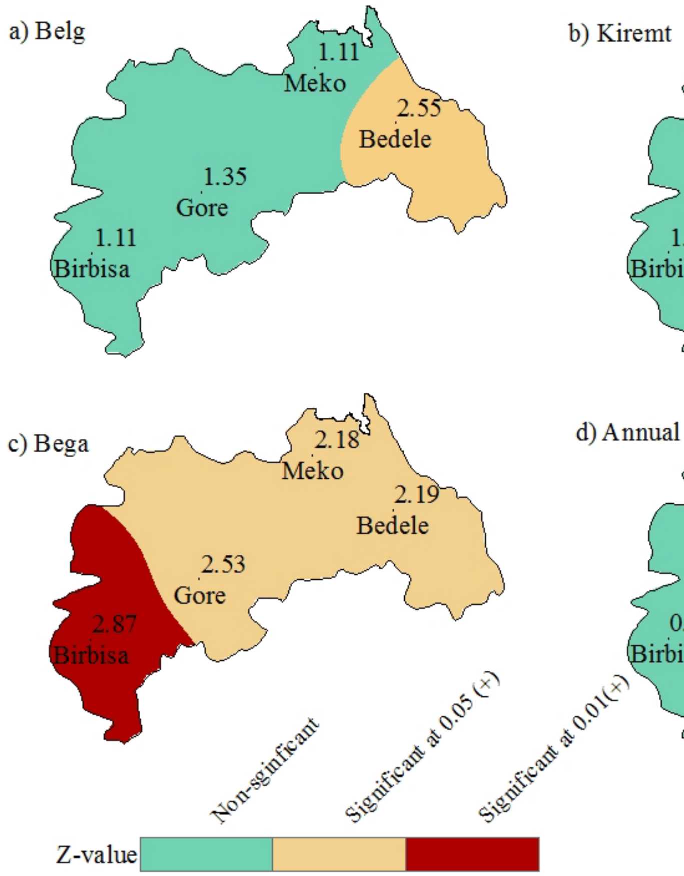

Figure 4. Spatiotemporal trends of seasonal and annual minimum temperatures over Ilubabora Zone. The red color indicates highly significant, slight yellow, significant trend and slight green, non-significant increasing trends.

Table 2.Trends of Seasonal and Annual minimum, Maximum Temperatures and Rainfall during 1981-2018-2018

Location	Parameter	Seasons									Annual		
		Belg (FMAM)			Kiremt(JJAS)			Bega (ONDJ)					
		TMIN	TMAX	PRCP	TMIN	TMAX	PRCP	TMIN	TMAX	PRCP	TMIN	TMAX	PRCP
Bedele	μ	13.80	25.27	7.17	13.32	20.76	8.00	11.21	22.47	2.6	12.76	22.83	5.83
	S	204	112	-264	110	205	199	175	198	-30	94	206	-138
	β	0.02	0.10	-0.06	0.01	0.04	-0.08	0.02	0.05	-0.02	0.02	0.06	-0.04
	Δ	0.06	0.15	-0.32	0.03	0.08	-0.35	0.05	0.08	-0.28	0.04	0.09	-0.24
Birbisa	μ	17.49	27.97	7.39	15.96	22.93	8.25	15.16	25.77	3.11	16.20	25.56	6.65
	S	86	206	-20	94	140	-126	229	68	-25	96	64	26
	β	0.02	0.03	-0.08	0.01	0.02	-0.04	0.02	0.03	-0.01	0.02	0.04	-0.06
	Δ	0.04	0.08	-0.4	0.03	0.04	-0.18	0.04	0.04	-0.06	0.04	0.06	0.33
Gore	μ	14.91	26.40	6.16	14.02	21.37	8.11	12.13	23.90	2.35	13.68	23.89	5.54
	S	104	212	- 46	130	179	-204	202	160	- 135	94	143	- 166
	β	0.02	0.07	-0.03	0.01	0.13	-0.07	0.02	0.04	0.01	0.02	0.08	-0.02
	Δ	0.05	0.1	-0.18	0.03	0.22	-0.32	0.05	0.06	0.16	0.06	0.13	-0.13
Meko	μ	15.27	27.51	3.9	14.63	22.11	8.87	12.25	24.32	2.48	14.05	24.63	5.08
	S	86	96	-96	130	144	24	174	44	-20	97	66	-30
	β	0.02	0.06	-0.01	0.01	0.022	0.18	0.02	0.025	-0.05	0.02	0.037	0.08
	Δ	0.05	0.08	-0.09	0.03	0.04	0.75	0.06	0.04	-0.75	0.05	0.06	0.58

Note; μ indicates Mean, S ~ Mann Kendall statistical score, β ~ Sen.'s slope, represents rate of change, Δ ~ change of variable during the given time courses(°C), MAM~ February, March, April and May, JJAS~ June, July, August and September, ONDJ~ October, November, December and January, TMIN ~Minimum Temperature, TMAX~ Maximum Temperature, PRCP~ Precipitation

Seasonal maximum temperature: Mann Kendall trend analyses results also depicted that the long-term trend of average maximum temperature was observed inconsistently increasing across the study localities. Belg season average maximum temperatures detected a higher significant warming trend of (P<0.01) in Gore at rate of 0.07°C/year. Similarly, Kiremt and Beaga seasons' average maximum temperatures were characterized by higher significantly warming (P<0.01) at rates 0.04 and 0.05°C/year respectively in Bedele locality (Table 2). Apparently, Belg season's average maximum temperature was significantly increased (P<0.05) at rate of 0.03°C/year in Birbsa locality (Figure 5a, b and c). *Annual maximum temperature;* a significant increase of annual average temperature of the localities are illustrated in table 2 and figure 5d. A higher significant warming trend of annual average maximum temperature (P<01) was detected at rate of 0.06°C/year in Gore and significant warming trends (P<0.05) was detected at rate of 0.13°C/year in Bedele locality.

According to Khambhammettu (2005), the monotonically increasing trends of minimum temperature, maximum and annual climatic variables indicate the uncertainty of climate system to keep a given variable inconsistency. The increase of summer seasons maximum temperature might be related to the summer equinox occurrence when the sun passes directly above the equator because of the tilt of the Earth (Cnossen et al., 2012). Moreover, a higher significant change of seasonal temperatures might be primarily due to the increase in greenhouse gas concentration in the atmosphere and the diverse topography and relief features of the areas of the study. The higher human activities at the highlands area might be another that escalating temperature as the results of emission from agricultural activity, deforestation and forest degradations. Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels (IPCC, 2014). In line with the current finding, previous studies conducted by Mekasha et al (2014) in north part of the country reported that maximum temperature in the neighboring stations were independently increasing. Asfaw et al (2018) also reported that maximum and minimum temperature tended significantly increasing in all over the Ethiopia for period 1901- 2014.

The implications of warming temperature on crop plant were and analyzed by(Hatfield and Prueger, 2015). As the author's reports, warmer temperatures expected with climate change and the potential for more extreme temperature events will impact plant productivity. It is primarily affecting the rate of plant development and then, affecting phenolgical stages. Pollination, which is one of the most sensitive phenological stages to temperature extremes across all species, would be greatly affected (Hatfield and Prueger, 2015).

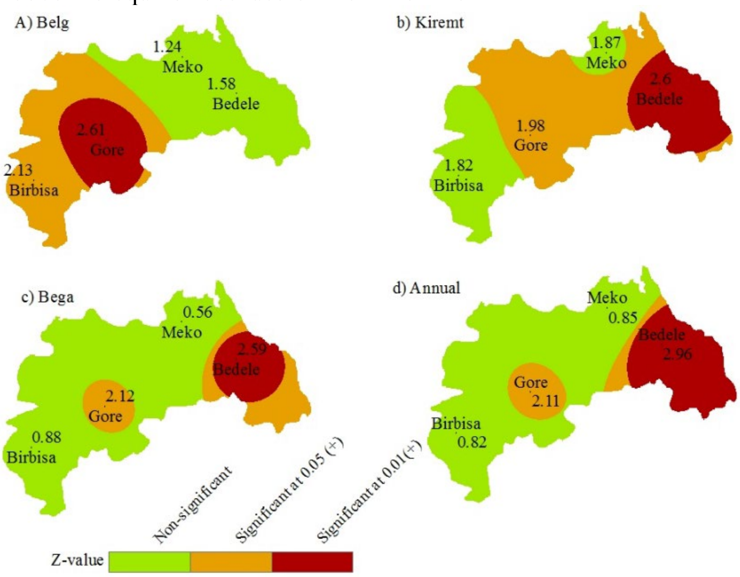

Figure 5. Spatiotemporal trends of seasonal and annual maximum temperature in four different localities. The extended yellow areas represent significant warming trends of maximum temperature while areas with slight green color represent a non-significant change of the given climatic variable

Seasonal and Annual Precipitation Trends

Seasonal precipitation trends; The Mann Kendall trend test indicated that the seasonal and annual precipitation were characterized by decreasing trend in almost all localities which are depending upon geographical features with respect of forest coverage and water bodies and maintains. However, the meaningful change of precipitation observed merely in two locations (Bedele and Gore). The Belg season's precipitation was detected decreasing trend at higher level of significance (P<0.01), with of 0.06 mm annual rate of decrement in Bedele locality. Karemt season's precipitation was detected a significant decreasing trend (P<0.05) with 0.08 and 0.07 mm annual rates of decrement for Bedele and Gore localities, respectively. Whilst non-significant trends of Bega season precipitation was detected (Figure 6c and Table 2).

Annual precipitation trend; annual of precipitation was noticed significantly decreasing trend (P<0.05) at rate of 0.02 mm/year in Gore locality (Table 2) whereas non-appreciable increasing trends were observed in Birbisa and Meko localities (Figure 6d). The reductions of seasonal and annual precipitation might be related to global warming and the variability of ENSO. Bathiany, et al (2010) reported that decadal and global warming and variability of ENSO significantly enhance drying trends in east Africa. This observation suggested that a 1°C increase in El Niño-3.4 SSTs produces a 79 mm decrease in East Africa's rainfall. Deforestation results a strong reduction of precipitation as the hydrological cycling has been interrupted when forest land has been lost (Manatsa et al., 2008). The previous studies on variability and trends of precipitation in tropical areas apparently reported the reduction of precipitation since 1970s and the adverse effects of these climatic variables on land features (Getachew et al., 2018; Nogherotto et al., 2013). Reduction in precipitation increases the incidence of drought and the warming temperature, increase evapotranspiration and hence, increasing the risks of heat waves associated with drought(Lee et al., 2017)

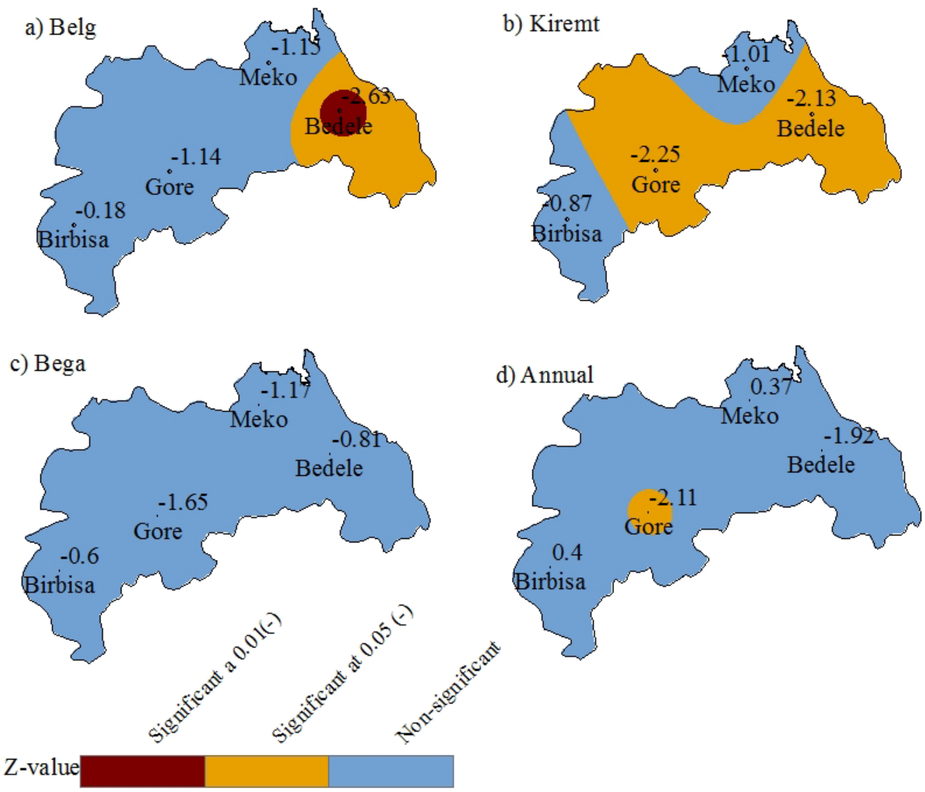

Figure 5.Trends of seasonal and annual precipitation in the four different locations during 1981-2018

Conclusion

In this paper, it was attempted to determine the seasonal and annual variability of precipitation pattern using PCI, and its' extreme events using SAI as well as the trends of seasonal and annual temperature and precipitation of the locations in the Ilubabora zone. The results presented in this study have shown that the precipitation concentration indices of the different locations were in different ranges from uniform to strong irregular precipitation distribution pattern during the different seasons. The Meko area, north parts of the Ilubabora zone is characterized by the higher precipitation concentration index, during spring and winter seasons than other three locations. This might be implications of the monsoon winds from Indian Ocean more influenced Meko area than the three locations. Apparently, the results of standardized anomaly precipitation indices show that the locations were differentiated by aggregated precipitation extremes during the period 1981-2018. The Bedele location was characterized by the higher percentage of drier and the lower wetter years than the rest, and followed by Birbisa sample location. With regard to the seasonal and annual trends of the variables, the minimum and maximum temperatures were independently increasing among the sample locations while precipitation was detected decreasing. The strong significant increasing trends of minimum temperature were more detected in Birbisa during spring season and for maximum temperature, in Bedele and Gore during the whole time courses. Therefore, these results are very important input, to be used as guidance for planning and management of soil and water conservation, decision for cropping seasons and disaster preparedness. Suggesting that there should be sound implementations of existing forest protection and soil water conservation at Ilubabora zone to minimize climate induced risks.

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