

Research Article

Evaluating Variability and Characterization of Seasonal Rainfall Over East Shewa Zone, Oromia Region, Ethiopia

Gashawun Dereje Balcha^{1,*} , Abdisa Hirko Wami² , Asaminew Teshome Game³ 

¹Data and Climatology, Eastern and Central Oromia Meteorological Service Centre, Adama, Ethiopia

²Forecast and Early Warning, Eastern and Central Oromia Meteorological Service Centre, Adama, Ethiopia

³Forecast and Early Warning, Ethiopian Meteorology Institute, Addis Ababa, Ethiopia

Abstract

The objective of the research paper was classified as three main points. The first was to determine the seasonal and annual rainfall distribution of the zone. The second and the third was to evaluating seasonal rainfall variability and characterizing the seasonal rainfall of east Shewa zone in terms of onset and cessation date. Coefficient of Variation, Precipitation Concentration Index and Standardized Anomaly Index was the indicators used to assess the variability of seasonal rainfall of the zone for both main and second rainy season. Climatologically the zone received high amount of rainfall during June to September with peak value in July ranging from 300 to 660 averagely and during Belg with being peak in month of April with mean seasonal rainfall amount of 125 to 300. Bega is the dry period for the East Shewa zone as annual rainfall cycle result shown from the data of the year 1981 to 2020. Additionally 550 to 1060 mean annual rainfall observed during the study period. The result of coefficient of variation indicated that during the main rainy season its values ranged from 20 to 35% while from 30 to 50% during the second rainy season. It also indicated that high rainfall variability observed over Rift valley areas. The result stated that most parts of the zone are under moderate precipitation concentration during Kiremt and mostly irregular in the second rainy season. Standardized anomaly indicated that dry season dominated during second rainy period than the main rainy period. Characterization and identified variability of seasonal rainfall was important especially for rain-fed agriculture and hydrological advisory at zone level to support community.

Keywords

Characterization, Variability, Season, Onset, Cessation, Rainy Period

1. Introduction

1.1. Background of the Study

Rainfall recognized as a significant and crucial meteorological parameter. It is a major source for rain-fed agriculture. The economic sectors agriculture, hydro power and food

security mainly depend on availability of sufficient water [1, 2] and this was particularly linked to variability in inter-annual rainfall [3]. East African countries have marked spatial and temporal rainfall variability resulting in more frequent occurrence of catastrophic events, such as drought and floods

*Corresponding author: gashawunderege11@gmail.com (Gashawun Dereje Balcha)

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that have a negative impact on socioeconomic sectors in human and animal mortality [4]. In Ethiopia rainfall was the most important meteorological parameter since the agricultural sectors highly depend on it and it's the main source of water as estimated only 4 to 5% of the cultivated land irrigated which means that the significant amount of cultivated land not irrigated [5, 6].

In Eastern Africa the timing of growing period, onset and cessations are crucial for agricultural input because of the growth domestic products (GDP) of most countries in the region are climate sensitive and affected by rainfall variability in onset, cessation and length of growing periods. In Ethiopia rainfall varied spatially and temporally in amount and distribution and this variation was a result of topography, atmospheric circulation and seasonal migration of inter tropical convergence zone (ITCZ) [7, 8]. The amount, onset, cessations and the length of growing season as well as seasonal cycle of rainfall in the country used to describe the spatial variations whereas the direction and magnitude of the rainfall trend can vary temporally from days to decades and seasons [9].

Rainfall variability greatly affect agriculture in Ethiopia especially where the rainfall was scarce. Therefore understanding the spatial temporal rainfall variability was important for planning mitigation measures during high and low rainfall seasons [10]. Due to variation in altitude, mountains and atmospheric flows onset and cessations of rainy seasons vary in kilometers distance in the country [11].

There are three distinct seasons in Ethiopia. Locally these are referred to as Kiremt (June to September), bega (October to January), and Belg (February to May) based on rainfall patterns and their respective rainfall distribution. These classification does not include southern and southeastern lowlands of the country since they received rainfall in March to May and September to November. Additionally these classification also doesn't encompass the southwestern parts of the country because they received rainfall from February to November [12]. Kiremt was the main rainy season's counts for 85% to 90% of food production while Belg was the second rainy seasons for many parts of the country and highly variable in amount and time. East Shewa zone experienced bi-modal rainfall patterns. The study area get its main rain in Kiremt (June to September) and second rain in Belg (February to May). The main goal of the current work was to analysis seasonal rainfall variability of the two rainy season. Additionally it aimed at characterizing the season rainfall in terms of onset and cessations.

1.2. Objective

1.2.1. General Objective

The main objective of this study is to characterize and evaluate variability of seasonal of East Shewa Zone, Oromia region, Ethiopia.

1.2.2. Specific Objectives

The specific objectives of the research were:

1. To calculate seasonal and annual rainfall distribution over the zone.
2. To evaluate the variability of seasonal rainfall of the study area.
3. To characterize seasonal rainfall in terms of onset and cessation over the study area.

2. Data and Methodology

2.1. Description of Study Area

East Shewa zone located in the central part of Oromia region. Geographically East Shewa zone located at a longitude of 38° 50' to 40° 05' E longitude and 8° 12' to 9° 10' N latitude and altitude of the study area ranges from 865 to 2864 m above sea level. Based on moisture index climate classification east Shewa characterized by semi-arid and sub humid categories. The zone experienced two wet season. Kiremt (JJAS) was the main rainy season which extends from the month June to September. While considering long year average the area gets 300 mm to 660 mm during these seasons. On other hand Belg (FMAM) was the second rainy seasons. On average, the area gets 125 mm to 300 mm during the second rainy season. Annually East Shewa zone received 550 mm to 1060 mm of rain considering 40 years data.

2.2. Data Source

The observed daily station rainfall data (1981-2020) was obtained from Ethiopian meteorology institute (EMI). The quality of the data was checked using climate data tools (CDT) version 8.0. Under these station coordinates, outliers check for rainfall data, and homogeneity tested. Stations having missing data was addressed and filled using gridded data which was also obtained from EMI using python scripts.

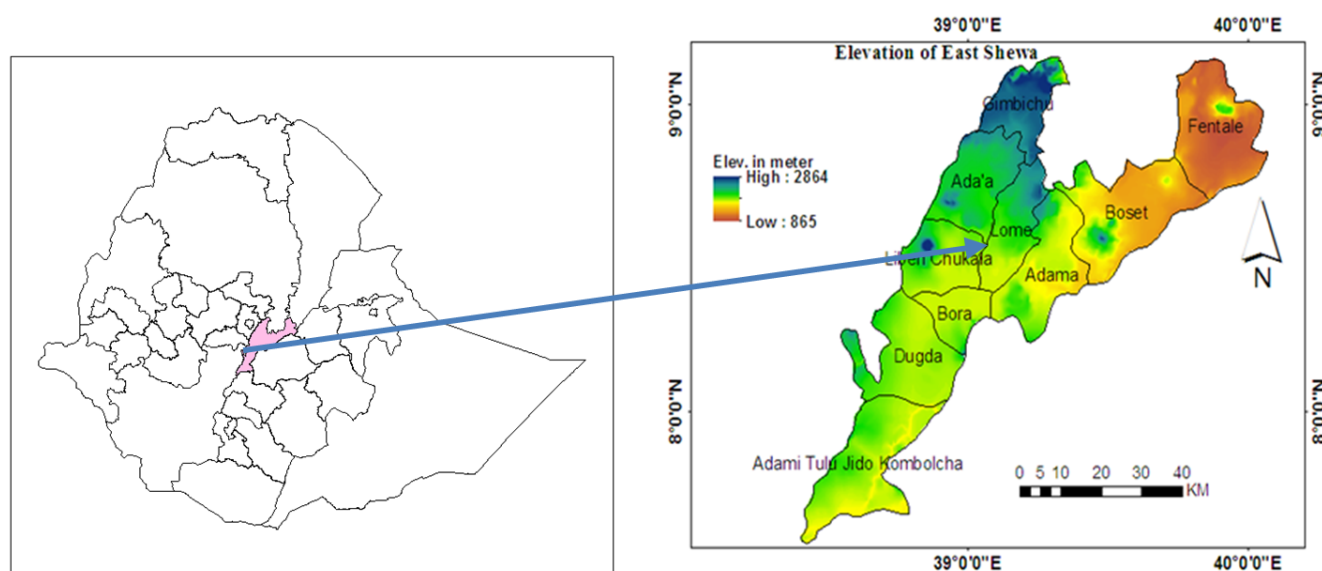


Figure 1. Description of the study area.

2.3. Method of Evaluation

The seasonal rainfall variability was evaluated using coefficient of variation (CV), Precipitation Concentration Index (PCI) and Standard Anomaly Index (SAI). On other hand characterization was evaluated using onset and cessation dates.

Coefficient of variation (CV)

The seasonal spatial rainfall variability calculated using coefficient of variations for each stations found in the study area.

$$CV = SD/\mu \times 100 \quad (1)$$

Where CV stands for coefficient of variation, SD standard deviation and μ seasonal mean. The higher values of CV the higher seasonal rainfall variability. The values of CV categorized as very high $CV > 40$, high $CV > 30$, moderate between 20 and 30 and less variable $CV < 20$ [13].

Standard Anomaly Index (SAI)

Standard anomaly index was another method used to analyze seasonal rainfall variability. SAI used to detect the dry and wet years in a record and calculated as follows:

$$SAI = X - \mu/\alpha \quad (2)$$

Where SAI stands for standardized seasonal rainfall anomaly, X seasonal rainfall of a given year, μ is long term or population mean, and α was standard deviation of the observation of total years.

A negative values of SAI indicated below normal seasonal rainfall or drought while positive values of SAI shows above normal rainfall or flood [14].

Table 1. Classification and description of standardized rainfall anomaly index.

SAI-values	Description
Greater than 2.0	Extremely wet
Between 1.9 and 1.5	Very wet
Between 1.49 and 1.0	Moderately wet
Between 0.99 and -0.99	Near normal
Between -1.0 and -1.49	Moderately dry
Between -1.5 and -1.99	Severely dry
Less than -2.0	Extremely dry

Source: [15]

Precipitation Concentration Index (PCI)

Precipitation concentration index (PCI) was suggested by [16] and further build up by [17] was used to assess the distribution of monthly rainfall in a given season and calculated as follows:

$$SPCI = \frac{\sum_{i=1}^4 P_i^2}{(\sum_{i=1}^4 P_i)^2} \times 25 \quad (3)$$

Where SPCI stands for Seasonal Precipitation Concentration Index, P_i monthly rainfall amount of the i^{th} month. Based on the above formula the SPCI calculated for JJAS and FMAM Seasons.

Table 2. Classification and description of Precipitation Concentration Index.

Values	Classification
Below 10	Uniform precipitation concentration
11-15	Moderate concentration index
16-20	Irregular concentration index
Greater than 20	Strong irregularity in precipitation distribution

Source [18]

Season's percentage of contribution to the annual rainfall

As mentioned earlier, in the east Shewa zone there are three seasons. Namely, Kiremt (JJAS) the main rainy season, Belg (FMAM) secondary rainy season and Bega (ONDJ) the dry season. It's important to calculate the percentage of season rainfall contribution to the annual for each stations found in the study area and calculated as:

$$PC\% = \frac{\bar{X}}{\mu} * 100 \quad (4)$$

Where PC was percentage of contribution in percent, \bar{X} were long term seasonal rainfall of each station and μ was the long term annual mean rainfall.

2.4. Characterizing Seasonal Rainfall

Rainy days: Are defined as any day that received measurable rainfall of 0.1 mm or more [12].

Onset of rainy season: Defined as the dates that 20 mm or

more rainfall's amount accumulated at least in three consecutive rainy days as the first day of the years wet spells providing there no sequence of eight or more dry days (<0.1 mm) in the subsequent 30 days. Accordingly, the onset date determined based on two conditions.

1. length and rainfall amount of the onset wet-spell and
2. Length of the dry spell immediately after the onset wet days.

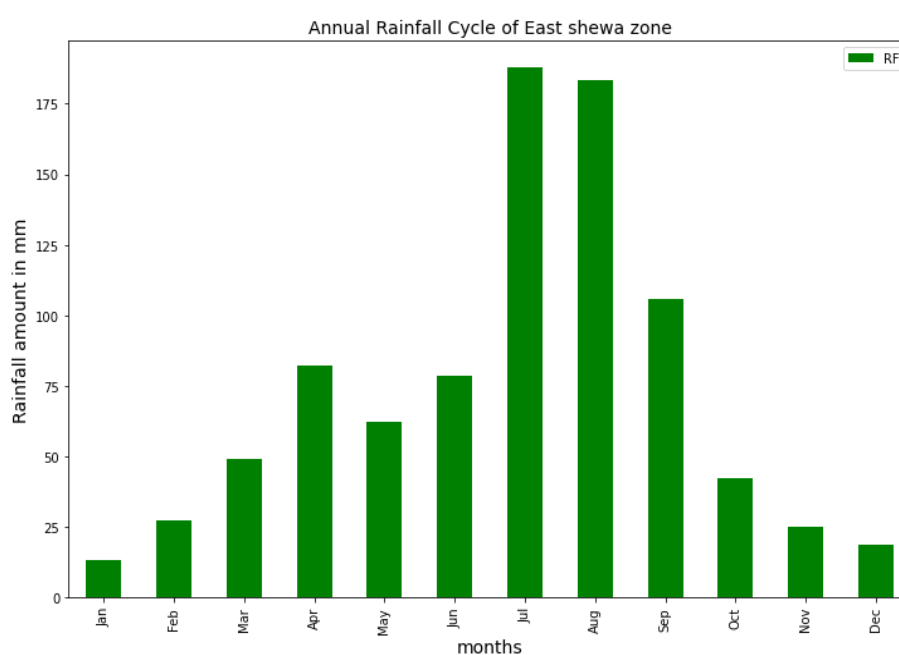
Cessation dates: defined as the first day of dry spell (<0.1 mm per day) of at least 20 days duration that occurred after onset and this definition was modified when 20 days of extended dry period occurred in the mid seasons, after which persistent rains returned [19].

3. Result**3.1. Rainfall Climatology and Its Distribution**

The annual rainfall cycle of the study area show bi-modal rainfall pattern when the peak of the year was July month for JJAS and for FMAM the peak was on April. The dry season is from October to January.

3.2. Mean Annual Rainfall Distribution

The below Figure 3 shows the spatial distribution of mean annual rainfall of east Shewa zone as calculated from the year 1981 to 2020. As a result, the area received 550 mm to 1060 mm annually. The highlands parts of the study area gets high amount of rainfall than lowland areas that only received rainfall amount up to 550 mm. Generally, from the map the northeastern parts of the study areas experienced less amount of rainfall while the northwest received greater annual rainfall.

**Figure 2.** Annual Rainfall Cycle of East Shewa Zone from 1981-2020.

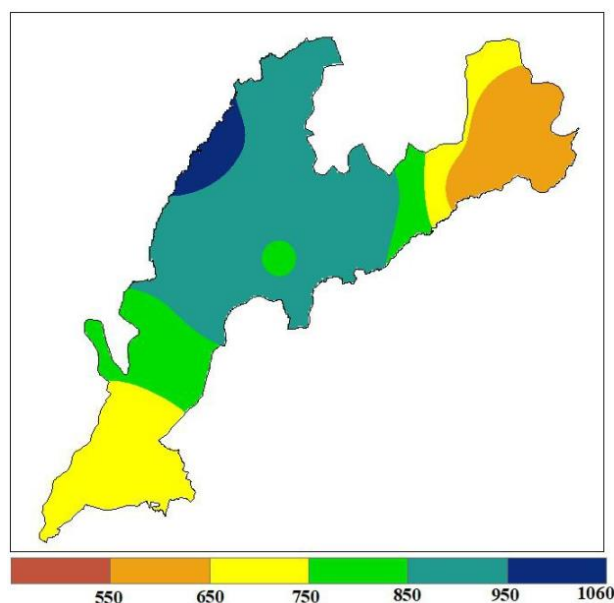


Figure 3. Spatial distribution of mean annual rainfall for the year 1981 to 2020.

3.3. Spatial Distribution of Mean Seasonal Rainfall

During JJAS, the area experienced mean seasonal rainfall amount of 300 mm over the northeast parts to 660 over the north-west parts of East Shewa zone. The result also clearly indicated that the highland parts of the study area received better rainfall than lowland and midland. Midland parts had better rainfall than lowland up to 475 mm during the season (figure 4a). On other hand in the FMAM season, the area obtained mean rainfall amount of 125 mm to 300 mm. The lowest amount observed over the Fentale (Northeast) (figure 4b).

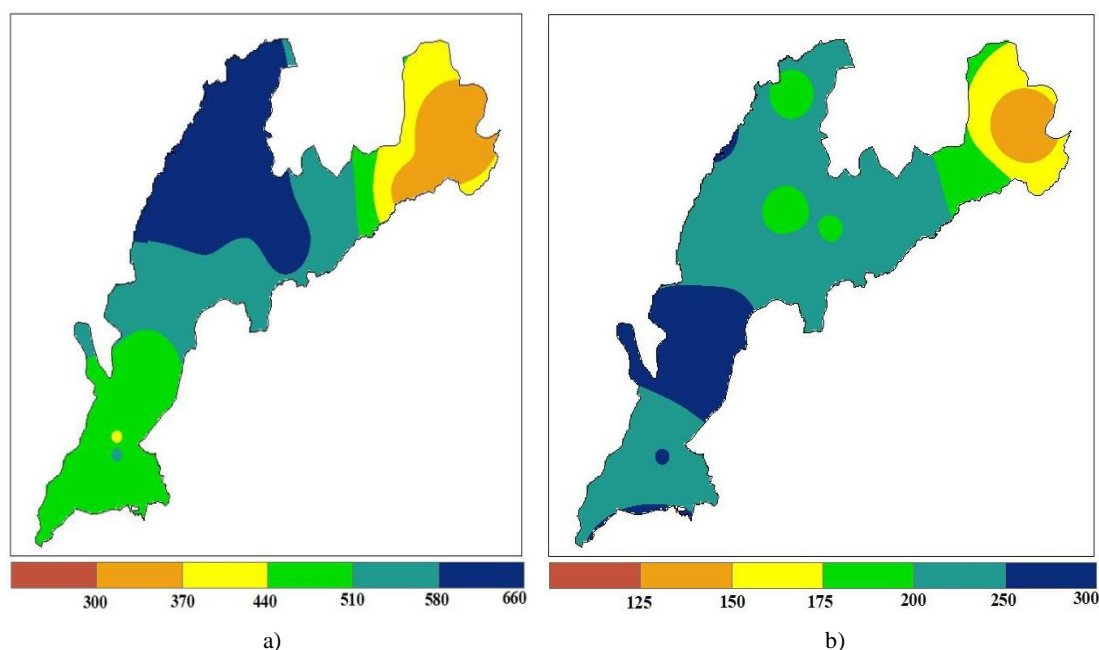


Figure 4. Spatial distribution of mean seasonal rainfall for the year 1981 to 2020 over the study area.

JJAS contribute 55 to 80% (figure 5a) and FMAM 20 to 40% (figure 5b) to the annual rainfall. During JJAS high contribution observed over southern parts while low contribution located over the northeastern parts (figure 5a). In the same way, low contribution observed over north and northeast while higher contribution observed over the southern areas during FMAM (5b).

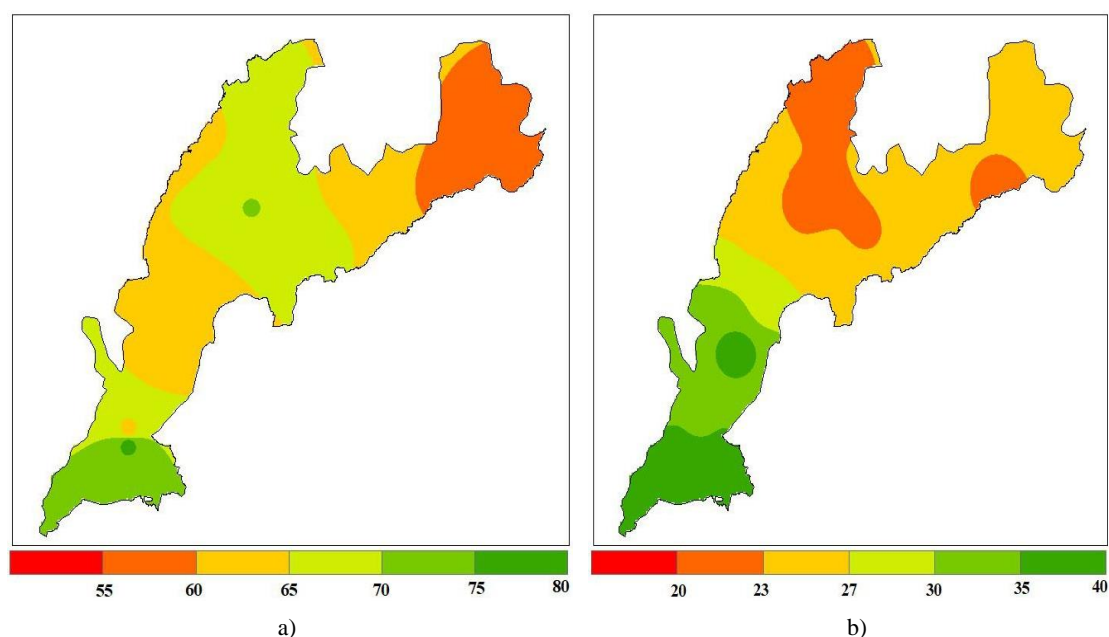


Figure 5. Spatial distribution of mean seasonal rainfall contribution to Annual rainfall.

3.4. Seasonal Rainfall Variability

In order to evaluate the seasonal rainfall variability of the study area coefficient of variation, precipitation concentration index and standardized anomaly index was applied.

3.5. Analysis of Coefficient of Variation (CV)

The following figure shows the spatial seasonal rainfall variability of East Shewa zone as calculated from the year 1981 to 2020 using coefficient of variation.

The JJAS season coefficient of variation ranged from 20 to 35%. Its values lower over northwest and pocket areas of central parts. High rainfall variability observed over the southern and pocket areas of northeast (figure 6a).

In other words, the seasonal rainfall coefficient of variation shown that during JJAS, it varies more over the northeast and south parts, where there is a strong CV. On other hands during FMAM the area experienced 30 to 50 coefficient of variation.

The variability was high over northeast and pocket areas of Central parts. During FMAM, variability dominated most parts, with a stronger CV value (figure 6b).

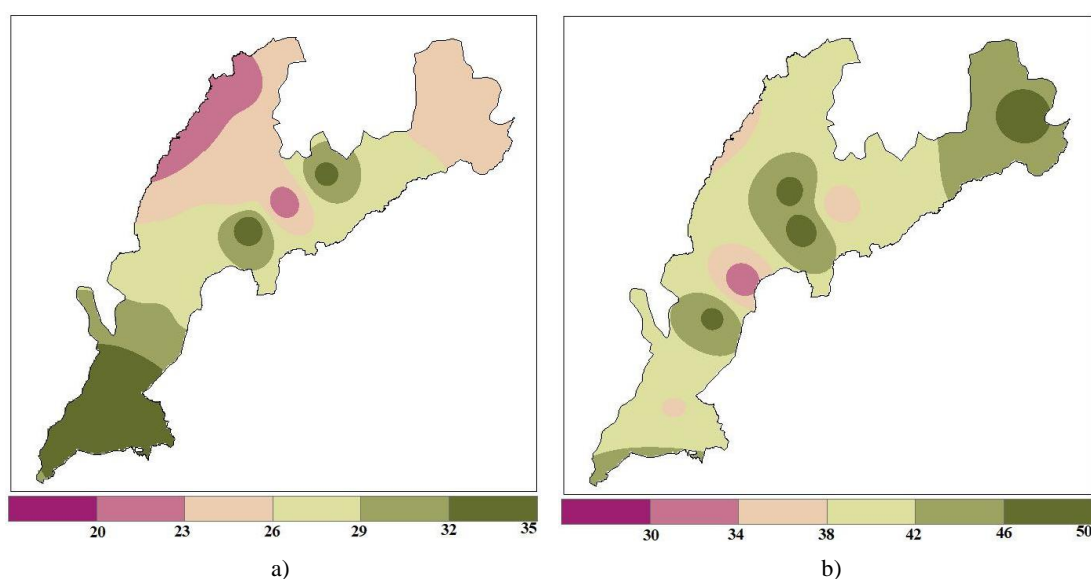


Figure 6. Spatial distribution of coefficient of variation for JJAS and FMAM.3.6. Analysis of Seasonal Precipitation Concentration Index (SPCI).

3.6. Analysis of Seasonal Precipitation Concentration Index (SPCI)

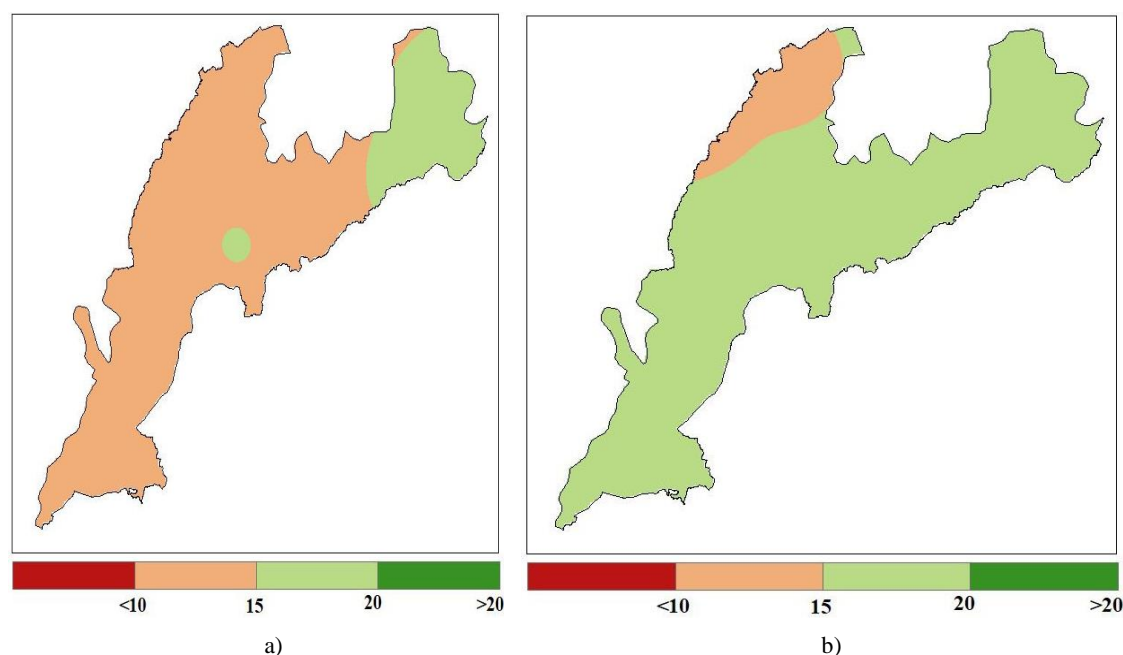


Figure 7. Spatial distribution of PCI for JJAS and FMAM.

Another important indicator of seasonal rainfall variability was SPCI. In the main rainy season (JJAS) most parts of the study area dominated by moderate precipitation concentration distribution while the Northern areas namely, Boset and Fentale experienced irregular seasonality in rainfall distribution (figure 7a). During the second rainy, season (FMAM) mostly east Shewa zone dominated by irregular seasonal rainfall distribution while areas of Gimbichu and Ada'a (northwest) parts of the study area are under moderate precipitation concentration distribution (figure 7b).

3.7. Standardized Anomaly Index (SAI)

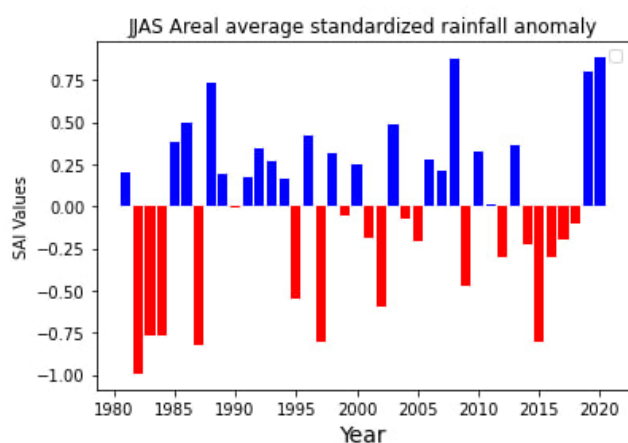


Figure 8. JJAS season mean standardized rainfall anomaly of the study area.

SAI used to evaluate the wettest and driest years in each season. In the zone both wet and dry years observed in both rainy season. During Kiremt season, 1988, 2001, 2010, 2019 and 2020 were the wettest while 1982, 1983, 1987, 1997, 2002 and 2015 were the driest year.

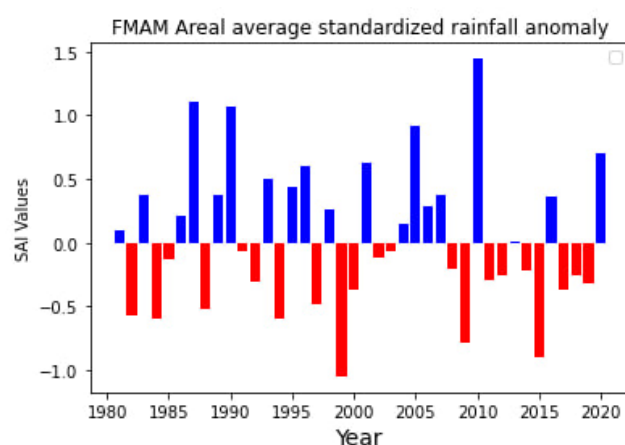


Figure 9. FMAM season mean standardized rainfall anomaly of the study area.

During Belg season 1999, 2009, 2012, and 2015 were driest while 1987, 1993, 1996, 2005 and 2010 were wettest. From the study, it was found that extreme dry years frequently observed in the recent decades, and the study area more exposed to dryness in Belg than Kiremt. In contrast to this, the wet

years experienced in the past than recent years and for both rainy period the last decade dominated by dryness rather than wetness. Therefore, the SAI of the study area indicated seasonal rainfall variation observed in the two rainy seasons (JJAS and FMAM).

3.8. Seasonal Rainfall Characteristics

The result shown distinct observed differences in the onset date but no significant variation in the cessation dates in both season. The onset of the Kiremt (JJAS) season begins earlier in the Northwest on June 20 to 25. However, averagely the onset date was from 05 to 09 July occurring over most parts of the study area (Figure 10). Almost the season ceases was around the end of 2nd decade of September. However, in comparison the later cessation date observed over Northwest part of the study area in relative to other parts of zone on September 28th (Figure 12).

During the second rainy season, the onset date starts averagely around March 2nd decade and lately at end of March 3rd decade to 1st decade of April (Figure 11). The season ceases was averagely on the 1st decade of May over the study area. In comparison the earlier onset date was on March 10 around Gimbichu and Ada'a woreda (northwest of the zone) and late over Fentale woreda on April 1st decade. In addition to these the earlier cessation date observed over Fentale on April 30th and late to 1st decade of May over most parts (Figure 13).

From the study, over the Rift valley area season starts lately and ceases early. In other word seasons onset was late over lowland and midland than highland areas. In similar way also highland areas experienced late cessation. In addition to these the parts that had earlier onset date resulted in later cessation in both season.

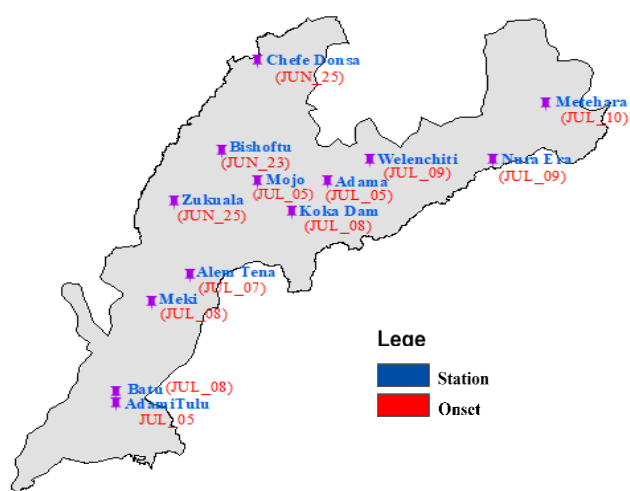


Figure 10. Spatial analysis of Kiremt season onset dates.

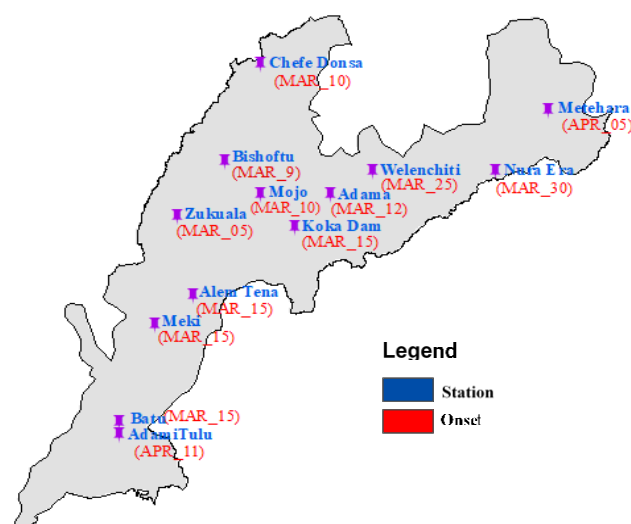


Figure 11. Spatial analysis of Belg season onset dates.

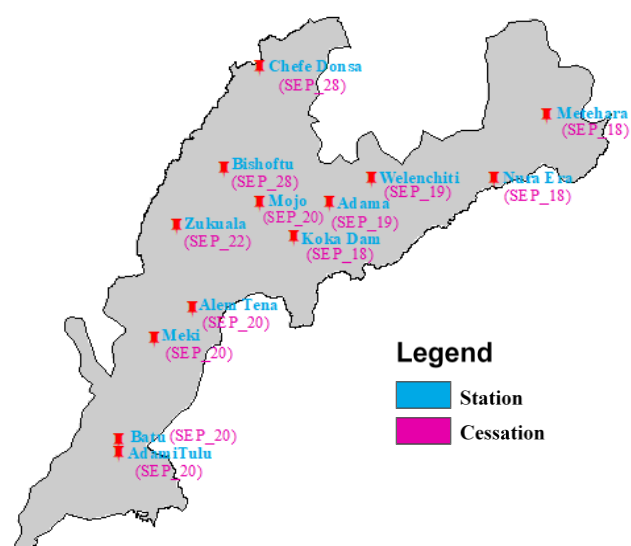


Figure 12. Spatial analysis of Kiremt season cessation dates.

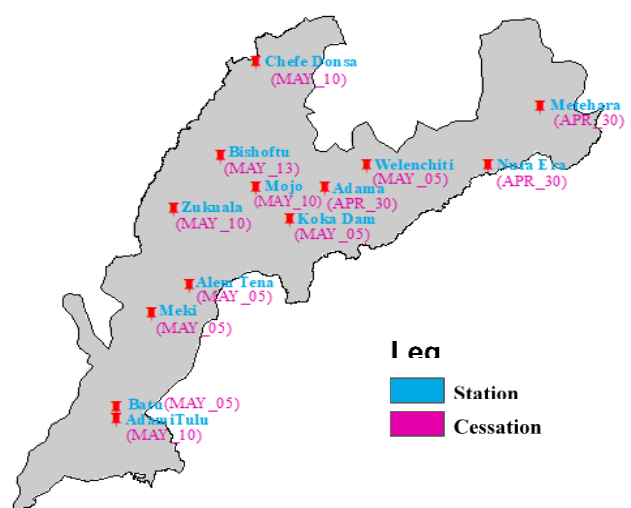


Figure 13. Spatial analysis of Belg season cessation dates.

4. Conclusion

East Shewa zone located in the central part of Oromia region, Ethiopia where all parts of the zone were included in the Great African Rift Valley. Climatologically, it is humid to dry area, where average annual rainfall amount of 550 mm to 1060 mm as rain gauge station data indicated. The zone experienced a bi-modal rainfall pattern. JJAS that is locally called Kiremt was the main rainy season. During this season the zone gets 300 mm-600 mm mean amount of rainfall that contributed 55 to 80% to the total annual rainfall. The second rainy season was FMAM that is known as Belg locally and mean seasonal rainfall of 125 mm to 300 mm observed that contributing 20 to 40% to the annual rainfall. ONDJ was dry season, which called Bega. During both rainy seasons, the highland parts of the zone had better rainfall than lowland or rift valley areas.

The value of CV ranged from 20 to 35% in main rainy season. The northwest had small value indicated low Kiremt season rainfall variability while the southern parts of the zone had high values of CV showing high Kiremt rainfall variability. During JJAS, almost all parts of the zone dominated by moderate PCI except the northeast which was dominated by irregular rainfall distribution. On the other hand Belg CV ranged from 30% to 50% which indicated high rainfall variability during the season. Most portions of the zone subjected to irregular rainfall distribution while northwest areas subjected to moderate precipitation concentration during the season. As obtained from the values of SAI East Shewa zone experienced both wettest and driest years during both rainy season. The years 1988, 2001, 2010, 2019 and 2020 was wettest years while 1982/83, 1987, 1997, 2002 and 2015 were the dry years during main rainy season. On other hand 1999, 2009, 2012 and 2015 was the dry years and 1987, 1993, 1996, 2005 and 2010 were the years taken as the wettest years in during the second rainy period for the study period. Those years are associated with known El Niño and La Nina phenomena. The onset date of JJAS was from 05-09 July averagely for most portion of the zone. The earlier onset is over northwest on June 20 to 25 and the cessation date was not significantly vary. During the FMAM onset dates was on the 2nd to 3rd decade of March as earlier and late to 1st decade of April over Boset and Fentale woreda while the cessation was on 1st decade of May and earlier cessation on 30th April over Fentale woreda.

Abbreviations

CDT	Climate Data Tools
CV	Coefficient of Variation
EMI	Ethiopian Meteorology Institute
FMAM	February to May
GDP	Growth Domestic Product
JJAS	June to September
ITCZ	Inter Tropical Convergence Zone
PC	Percent of Contribution

PCI	Precipitation Concentration Index
SAI	Standard Anomaly Index
SD	Standard Deviation
SPCI	Seasonal Precipitation Concentration Index

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Conflicts of Interest

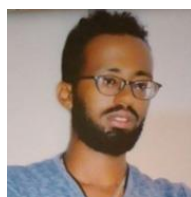
The authors declare no conflicts of interest.

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Biography



Gashawun Dereje Balcha is a Data and Climatology case team expert at Eastern and Central Oromia Meteorological Service Centre Adama Ethiopia. I completed My MSc in Meteorology science at Arba Minch Water Technology Institute Ethiopia and have BSc in Statistics from Dilla University. Additionally I had a post graduate diploma in Meteorology science from Ethiopian Meteorology Institute.