Analysis of Trend and Variability of Rainfall in South Eastern Amhara, Ethiopia

Demisew Getu*, Tsegaye Getachew and Belihu Nigatu

Debre Birhan Agricultural Research Center, Po. Box 112, Debre Birhan Ethiopia

***Correspondence**: demisewgetu@gmail.com

Abstract

The rainfall variability and trends over North Showa was analysed using gauge rainfall data from 1985 to 2018. The variability of rainfall in both annual and seasonal scales were evaluated using coefficient of variation (CV), standardized rainfall anomaly, precipitation concentration index (PCI), and standardized precipitation index. Mann-Kendall test and estimator were used to assess the rainfall trends. The rainfall in North Shewa was found to be highly variable both in space and time; i.e., irregular rainfall distribution was observed (PCI = 20%). The coefficient of variation showed moderate variation in both annual and Kiremt (June-September) rainfall as compared to the rainfall in Belg (February-May) and Bega (October-January) seasons. Mann-Kendall test resulted in a decreasing trend in Belg and Bega seasons and an increasing trend for annual and Kiremt rainfall. . The mean annual rainfall amount was 1107mm while Kiremt, Belg, and Bega received 786, 231, and 90 mm respectively. The mean onset and cessation dates were June 25th and October 7th, respectively while the mean duration of the Kiremt season was 77 days. The result showed that there was considerable temporal and spatial variation of rainfall over North Shewa. The coefficient of variation of the annual and Kiremt rainfall revealed moderate inter-annual and seasonal variability. However, much larger variation was observed during Belg and Bega season. Coefficient of variation showed low variability in the onset and cessation dates; whereas, the length of growing period was highly variable. Spatially, a general decrease of mean annual rainfall from east to west was observed. Annual and seasonal rainfall trends were for annual and Kiremt rainfall resulted in non-significant increasing trends.

Keywords: *Anomal, Dry spell, LGP, North Showa, SPI;*

Introduction

Climate change has adversely affected the livelihoods of people in developing countries where a large proportion of the population is heavily dependent on agriculture. Similarly, climate change has exacerbated poverty, food insecurity and vulnerability of agrarian communities in Sub-Saharan Africa (Akponikpe *et al*., 2010; Bryan *et al*., 2009). Ethiopia, a country located in the Horn of Africa, where the agricultural sector accounts for about 52 percent of the GDP and 85 percent of the foreign exchange earnings, and employs about 80 percent of the population (CSA Central Statistics Authority 2007) could be a typical example of the impact of climate change on the vulnerable rural communities in the developing world. CSA (2008) farm management practices survey, smallholders account for 96.3% of total area cultivated and 95% of total crop production. In Ethiopia, 5 of 11 till 2015 El Niño 1987, 1991, 2002, 2009 and 2015 coincided with intense and/or extended drought conditions from April to Nov, which encompassed the main Meher cropping season in all season (AKLDP 2015). Agriculture in Eastern Ethiopia practiced with a low use of external inputs and it is highly vulnerable to climate variability and change (Demeke *et al*., 2011, Kassie *et al*., 2013, Funk C, *et al*., 2012).

Rainfall is one of the most important climate elements for agricultural production throughout the world (Weldegerima *et al*., 2018). It is also the most important climate element for rainfed agriculture and the general socio-economic development of Ethiopia (Degefu MA, *et al*., 2016). Highly variable rainfalls with severe droughts have dev *et al*., 2013). When the uneven distribution of rainfall results in a mismatch between water availability and demand, irrigation structures are required to redistribute water concerning the requirements of a specific region (Warwade P, *et al*., 2018). Hence, for ecosystem resilience and sustainable agricultural activities, accurate estimation of the spatial and temporal distribution of rainfall is crucial, particularly for rain-fed agriculture (Ayalew D, *et al*., 2012, Wagesho N, *et al*., 2013). Various trend analysis of rainfall at different spatial (e.g., regional and national) and temporal (e.g., annual, seasonal, and monthly) scales have been studied which indicated changes in the spatial and temporal variability and trends. For example, according to Gamachu (Gamachu D, 1988) rainfall in Ethiopia has shown large variations across time and space, due to the complex topography and varying latitude of the country (Gamachu D, 1988). Spatially, the amount, seasonal cycle, onset and cessation times of rainfall as well as the length of growing period, have shown variability across the country (Gamachu D, 1988, Segele ZT and Lamb PJ 2005). Temporally, it varies from days to decades, with the magnitude and direction of historic rainfall trends varying from region to region and season to season (Wagaye B A., *et al*., 2020, Seleshi Y. and Zanke U., 2004 Cheung WH., *et al*., 2008, Jury MR. and Funk C 2012). Therefore, investigation of rainfall variability and trends at a local level (at a smaller area with higher resolution) has enormous advantage for a country like Ethiopia where the economy is mainly dependent on rain fed agriculture; it helps the decision-makers to take appropriate measures. Bekele F, *et al*., 2017 is probably the first to analyse rainfall variability and trends at Bale zone (south-eastern part of Ethiopia).

In contrast to the study by Bekele F, *et al*., 2017, in this study, the spatial variability and the temporal trend of rainfall using gauge as well as gridded rainfall data were investigated in a more detailed way for North Shewa (central part of Ethiopia). Consideration of the analysis of both the spatial variability and the temporal trend of the number of rainy days, onset, ending, and length of growing period (LGP) for the main rainy season (Kiremt). North Shewa received the highest rainfall amount during Kiremt season (75% of the annual rainfall). The area was chosen for the study because of recurrent drought and crop failures that are common in this part of Ethiopia (Gebrehiwot and van der Veen, 2013). As the farmers in this area have been experiencing drought frequently, their perceptions on drought are valuable and defined clearly for the ease of planning future mitigation measures.

In Amhara region, kiremt and Belg rainfall had contributed 55-85% and 8-24%, respectively to the annual rainfall totals (Bewketm & conway, 2007; Ayalew *et al*., 2012). Without including the impact of El Nino, since, 2013/2014, 2.5 million people in Amhara region was food insecure of which 80 % of it was happened in Eastern Amhara (BOA, 2014). Various trend analysis of rainfall at different spatial (e.g., regional and national) and temporal (e.g., annual, seasonal, and monthly) scales have been studied which indicated changes in the spatial and temporal variability and trends. Daily rainfall data obtained from each meteorological stations located in different agro-ecological zones were used to determine trends in annual and seasonal totals, onset and cessation dates, length of growing period (LGP) and dry spell length of the Eastern Amhara Region. The area was chosen for the study because of recurrent drought and crop failures that are common in this part of Ethiopia (Gebrehiwot and van der Veen, 2013). The study was conducted with the objectives of analysing trend and variability of rainfall in South Eastern Amhara, Ethiopia from 1985 to 2018.

Materials and Methods

Description of Study Area: The study area is located at 8° 42' 47" to 10° 44' 20" N latitude and 38° 39' 30" to 40° 05' 50" E longitude and about 2703 to 2909 m.a.s.l, at the joint of upper Blue Nile basin and middle Awash, in the central highland of Ethiopia (Figure 1). It is located in Amhara National Regional State to the northwest of Addis Abeba on the way to Desse. The study area is bounded on the south and west by the Oromia Region, on the north by South Wollo, on the northeast by the Oromia Zone, and on the east by the Afar Region. The highest point in the area is Mount Abuye Meda 4012 m.a.s.l, which is found in Gish Rabel woreda; other prominent peaks include Mount Megezez 3454 m.a.s.l. and the lowest point also Jeweha river which is found in Efratana gidem woreda 857 m.a.s.l. Based on the 2007 (CSA) Census, this Zone has a total population of 1,837,490. With an area of 15,936.13 Km^2, the population density of the area is 115.30 per Km^2. Among this 11.66% are urban inhabitants, and 0.01% are pastoralists.

The topography comprises uneven and rugged mountainous highlands in the northern and central parts of the zone, extensive plains and also deep gorges and cliffs in the periphery. The topographic feature of the administration is lower in the south, west and east peripheries and higher in the central part of the zone. The zone has four agro-ecological zones; namely, lowland: 500-1500m a.s.l, mid-latitude: 1500-2300m a.s.l, highland: 2300-3200m a.s.l, and above 3200m a.s.l. North Shewa is characterized by three distinct seasons with four months each, classified based on the climatology of rainfall and temperature. These seasons are locally known as (ONDJ), (FMAM), and

Bega is the dry season of the zone. The rain seasons have been inconsistent with respect to the onset, ending, distribution, and amount of rainfall. As a result of climate change, currently, the rain seasons (Kiremt and Belg) are becoming more inconsistent.

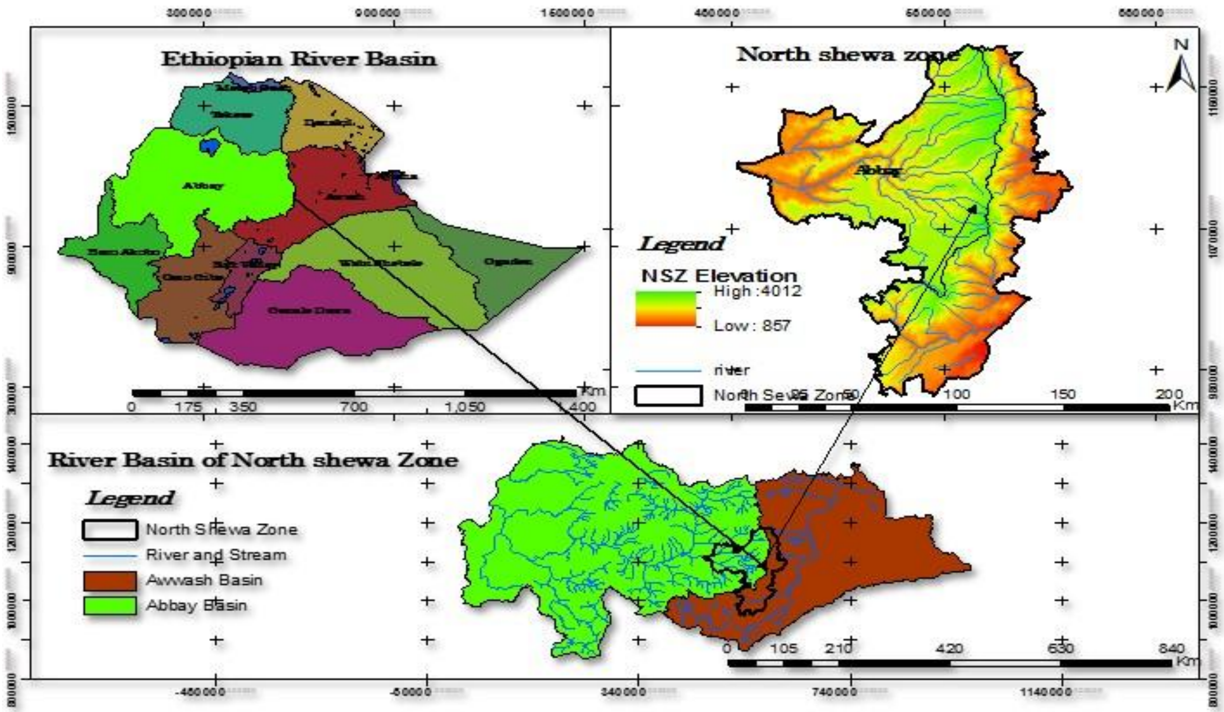

Figure 1. Geographical location of the study areas

Methodology: In this study, we employed R-INSTAT, XLSTAT, and MS Excel spreadsheet tools to analyses our data set. Graphs were mapped using ArcGIS software. Climate data from NMA and SRTM DEM extracted data from NASA SRTM website as an input to ArcGIS 10.5 tool for spatial analysis. The quality of data was controlled by outlier detector, Trend analysis and Homogeneity test of the annual rainfall data were tested by using RAINBOW software. The variability analysis was also done by standardized anomaly index, precipitation concentration index and coefficient of variation were used as descriptors of rainfall variability,

To determine onset and cessation date rainy season different authors use different threshold values to determine the onset of the rain. The criterion used in this study was a rainfall of 20 mm or more accumulated over three consecutive rainy days after a specified date (in this case July first) with no dry spell greater than 7 days in the next 30 days. Moreover, the end of the season was defined as the date when the available soil water content dropped to 10 mm m^{-1} of available water, the end of the growing season use a simple water balance equation, the evaporation was taken as 5mm per day and the storage limit as 100mm. Number of Rainy Days and Dry Spell Length also calculated by R-INSTAT software for each station.

Analysis of Rainfall Variability: Variability of rainfall has been computed using coefficient of variation (CV), standardized rainfall anomaly (SRA), precipitation concentration index (PCI), and standardized precipitation index (SPI). Contribution of seasonal rainfall to the total annual rainfall in percent (CT) for each station is also computed. For analysis, the monthly rainfall of all the stations was used to calculate an aerial average rainfall for North Showa using the equation of Nicholson $R\mathrm{j} = \frac{\sum_{k=1}^{\mathrm{j}} \mathrm{K_{ij}}}{I_{\mathrm{j}}}$ (Nicholson S 1985); where R_j is a real integrated rainfall for year j; X_{ij} is rainfall at station i for year j and I_j is the number of stations available for year j.

Analysis of Rainfall Trend: To estimate the sign and slope of long-term rainfall trends for the selected study sites, Mann-

presence of a statistically significant trend is evaluated using the ZMK value (Partal T, 2006 and Yenigun K, *et al.*, 2008). In a two-sided trend test, the null hypothesis *Ho* should be accepted if $|Z_{MK}$ $|$ < *Z1*- - s the critical value of ZMK from the standard normal table. E.g. for 5% significant level, the value of Z1-

study, a 5% significant level is used.

Results and Discussion

Data Inventory: Data inventory is a list of datasets with metadata that describes their contents, source, licensing and other useful information. A data inventory can be a useful tool for any organisation or project dealing with multiple types and sources of data. Creating a data inventory is also an important part of creating a data management plan for a research project. As show in figure 3.1 summarise the missing and available meteorological data in the respective meteorological data for further analysis.

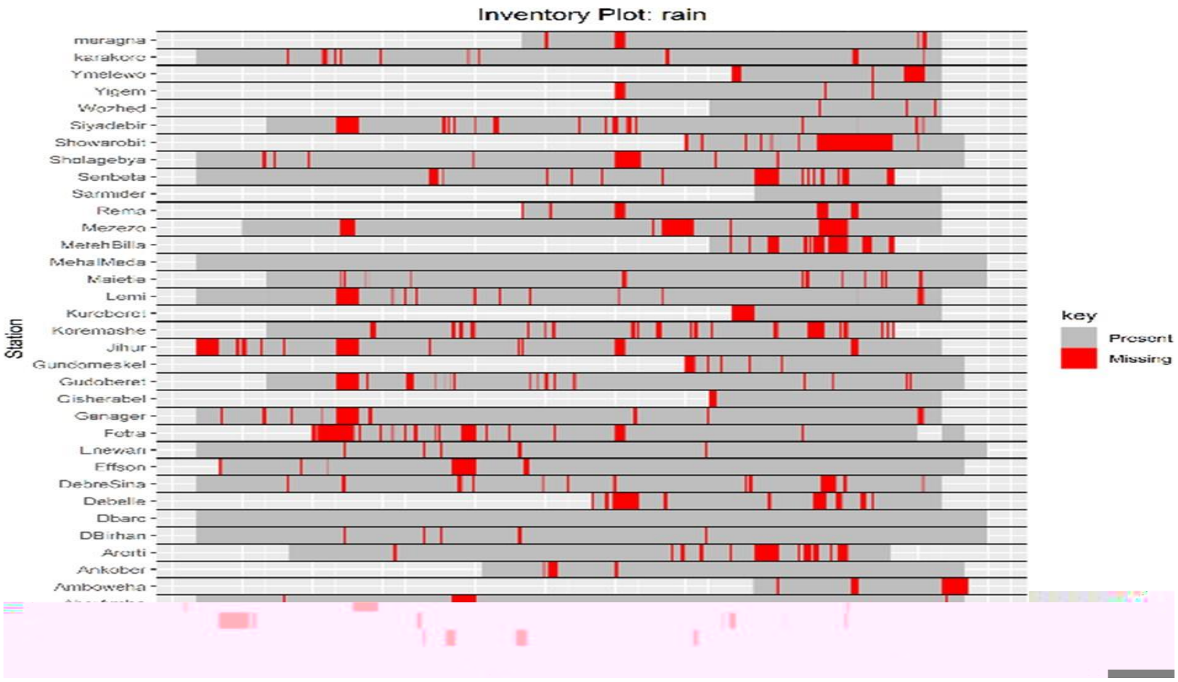

Figure 2. Data quality and Inventory

Spatial Distribution of Rainfall: Agro-climatic analysis of geo-referenced weather records needs to be conducted for all long-term stations in or near the region to develop maps of agro climatic patterns (Figure 3.2)

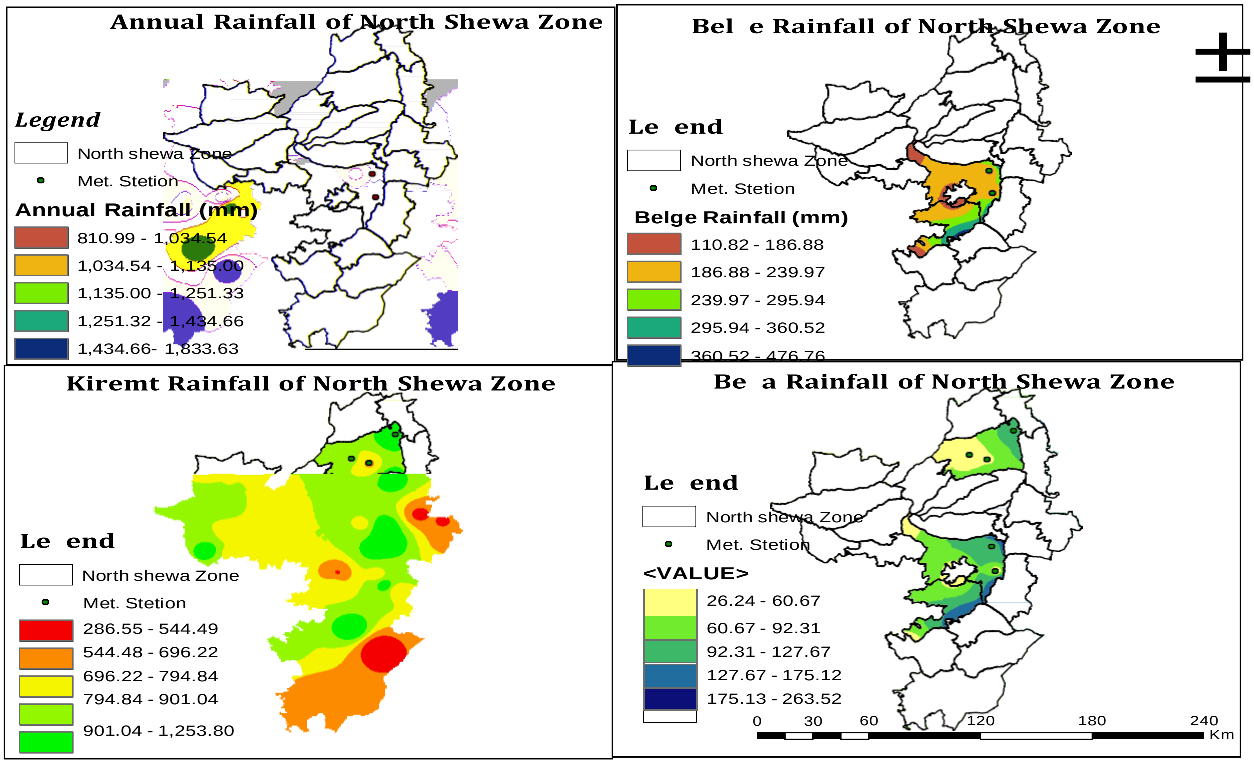

Figure 3. Annual and Seasonal Spatial Distribution of Rainfall.

As shown in Figure 3., spatial distribution showed a general decrease in annual mean rainfall from east to west. The corresponding seasonal rainfall distribution also shows similar spatial pattern.

Annual and Seasonal Rainfall Variability: Figure 3.3 showed the Mean annual and seasonal rainfall (mm), coefficient of variation (CV %), the contribution of seasonal rainfall to the annual rainfall (CT %) and precipitation concentration index (PCI %) for 18 meteorological stations. The study area received annual rainfall ranging from 850mm to 1796mm with a mean of 1137mm and CV of 24%; CV varied from 13-40%. At the seasonal level, Kiremt rainfall varied from 471-1255mm with mean of 804mm. For Kiremt, the mean CV was 30%; CV revealed high (CV=42%) and less (CV = 18%) variability. The mean total rainfall amount for Belg and Bega were 240 and 94 mm; they varied from 111-477mm and 27-2095mm, respectively. Bega rainfall was extremely variable (CV > 69%) for all stations.

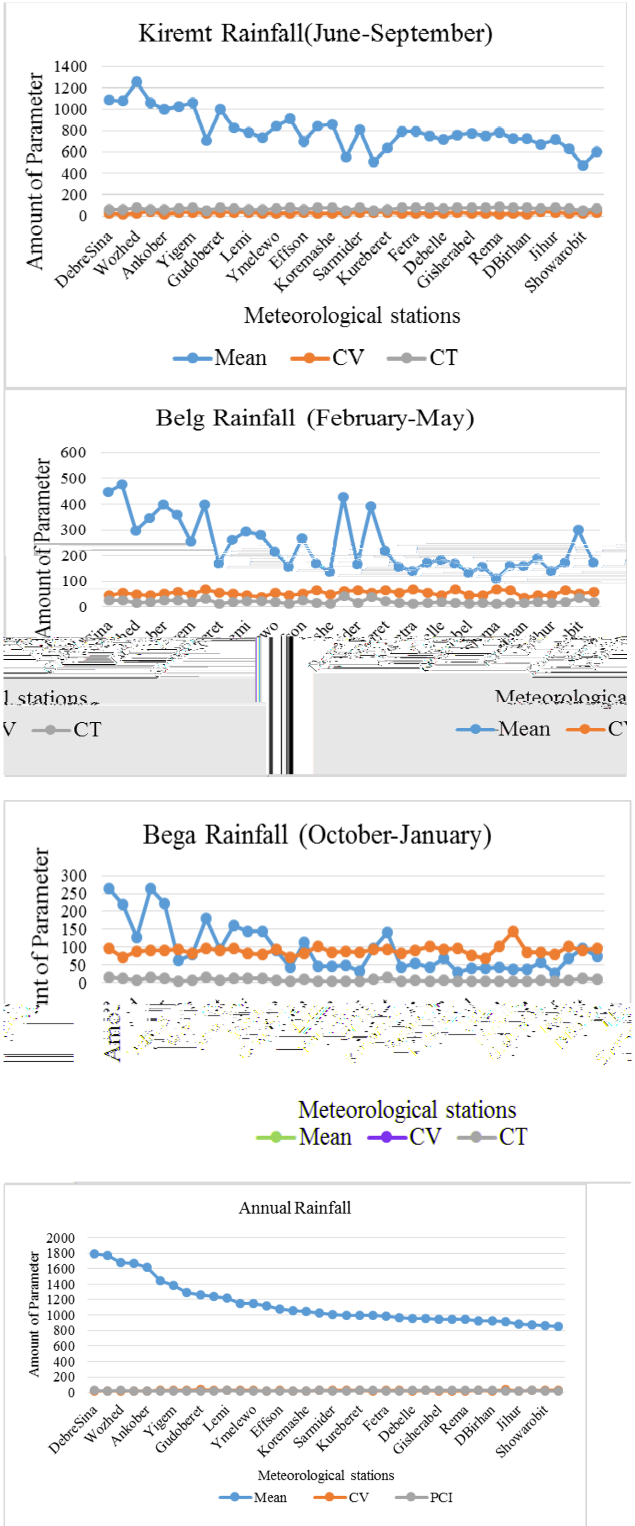

Figure 4: Spatial and seasonal rainfall variability.

As compared to Kiremt season, the Belg rainfall was more variable. For example, CV for Belg was 54%; it ranged from 37-69%. Thiranea(l)38(g 7(t)9)-229(i)38(t)-2(l)38(g( )-89(t)-21(h)20(38

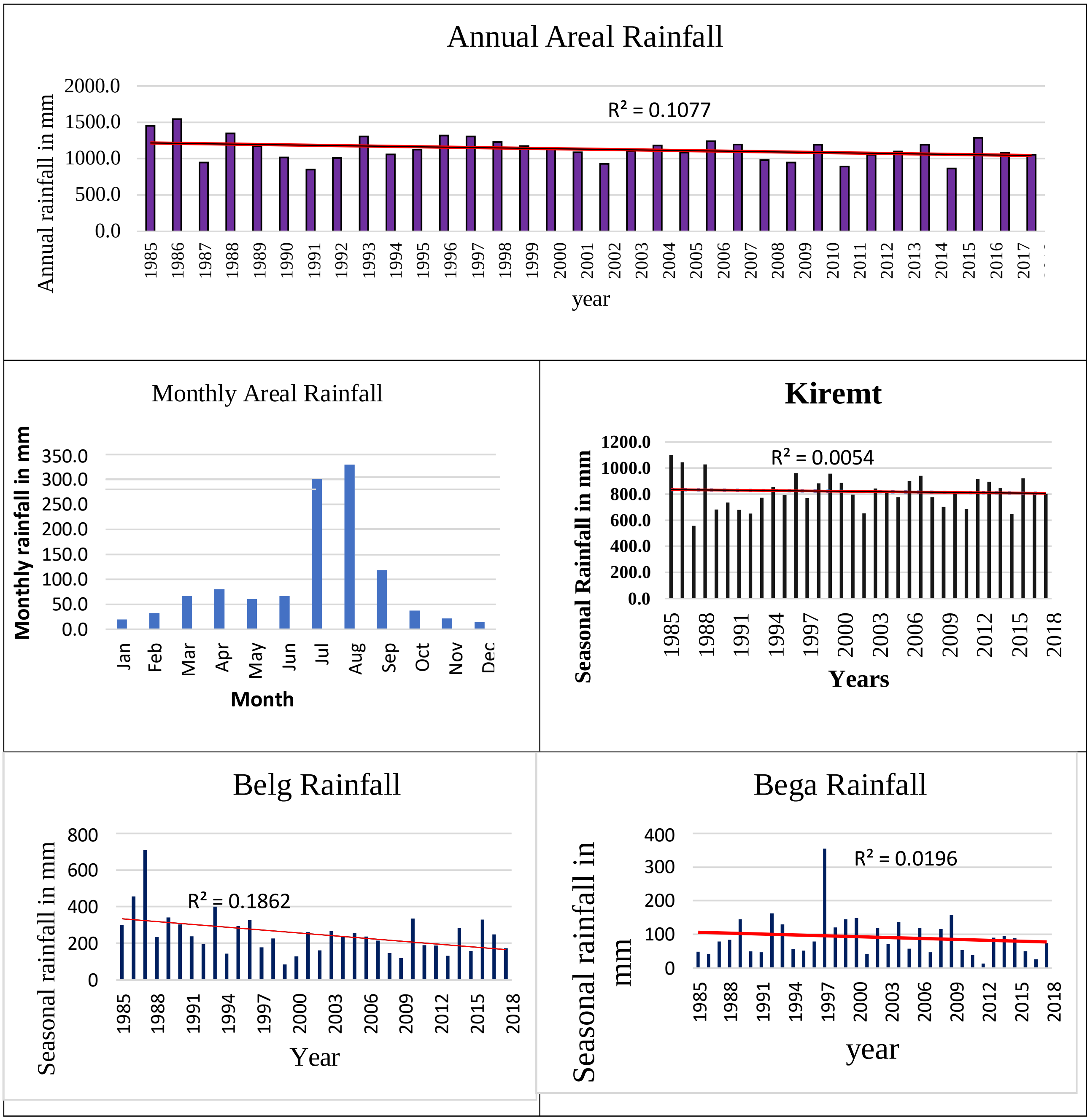

Figure 5. Temporal distribution Rainfall patterns over years

Figure 5 shows the temporal distribution of rainfall for the annual and seasonal time scales. Generally, the rainfall distribution showed a general decrease in annual mean rainfall from south to north. See Figure 3 for the corresponding seasonal rainfall distribution.

Number of Rainy Days and Dry Spell Length: Based on the definition of National Meteorological Service Agency of Ethiopia, a day is considered as a rainy day if it accumulates 1 mm or more rainfall (NMSA, 2001). Analysis of rainfall variability were analysed by Climate variability and changes detection attributes that will be made based on statistical analysis of current and past trends in the climatic parameters using INSTAT software. Degree Days (DD) is the accumulation of days from planting to maturity (Araya *et al*., 2011, McMaster & Wilhelm, 1997). Onset and cessation date: The criterion used in this study was a rainfall of 20 mm or more accumulated over three consecutive rainy days after a specified date with no dry spell greater than 7 days in the next 30 days (Araya *et al*., 2012). The end of rain can be set as the date when the available soil water content dropped to 10 mm m^{-1} of available water (Araya *et al*., 2012). Rainfall of on set and cessation is collected from local farmers using a semi-structured interview and adaptation options. Number of rainy days and dry spell length: Based on the definition of NMA ,2001, a day is considered as a rainy day if it accumulates 1 mm or more rainfall and maximum number of consecutive dry days (a day that accumulate rainfall <1 mm) can be counted to determine dry spell length in *kiremt* season.

Agro-climatic analysis of geo-referenced weather records needs to be conducted for all long-term stations in or near the region to develop maps of agro climatic patterns and Determine based on survey result about precipitation amounts and patterns (starting dates, ending dates, dry spells, length of the *belg* (short season) and *Meher* (long season) rainy seasons are changing over time.

Annual and Seasonal Rainfall Anomalies: Figure 3.4 shows the annual and seasonal rainfall anomalies. The result of Seasonal Rainfall anomalies (SRA) showed a 50% dry tendency and 50% wet tendency over the study area on annual basis. For Kiremt season 47% showed weak to strong negative departure from the long term mean rainfall and 53% recorded above the long-term average rainfall. Likewise, SRA during Belg and Bega season showed 50% and 59% dry tendency dominancy, respectively. According to the drought assessment method by Agnew and Chappel (1999), seven dry years: two extremes (1987 and 2018), two severe (1991 and 1992), and three moderate (1989, 1993 and 2015) dry years were identified. In contrast, 2007 and 2012 had experienced severe wet years; while that of 1998, 2003 and 2013 showed moderate wet years during Kiremt season.

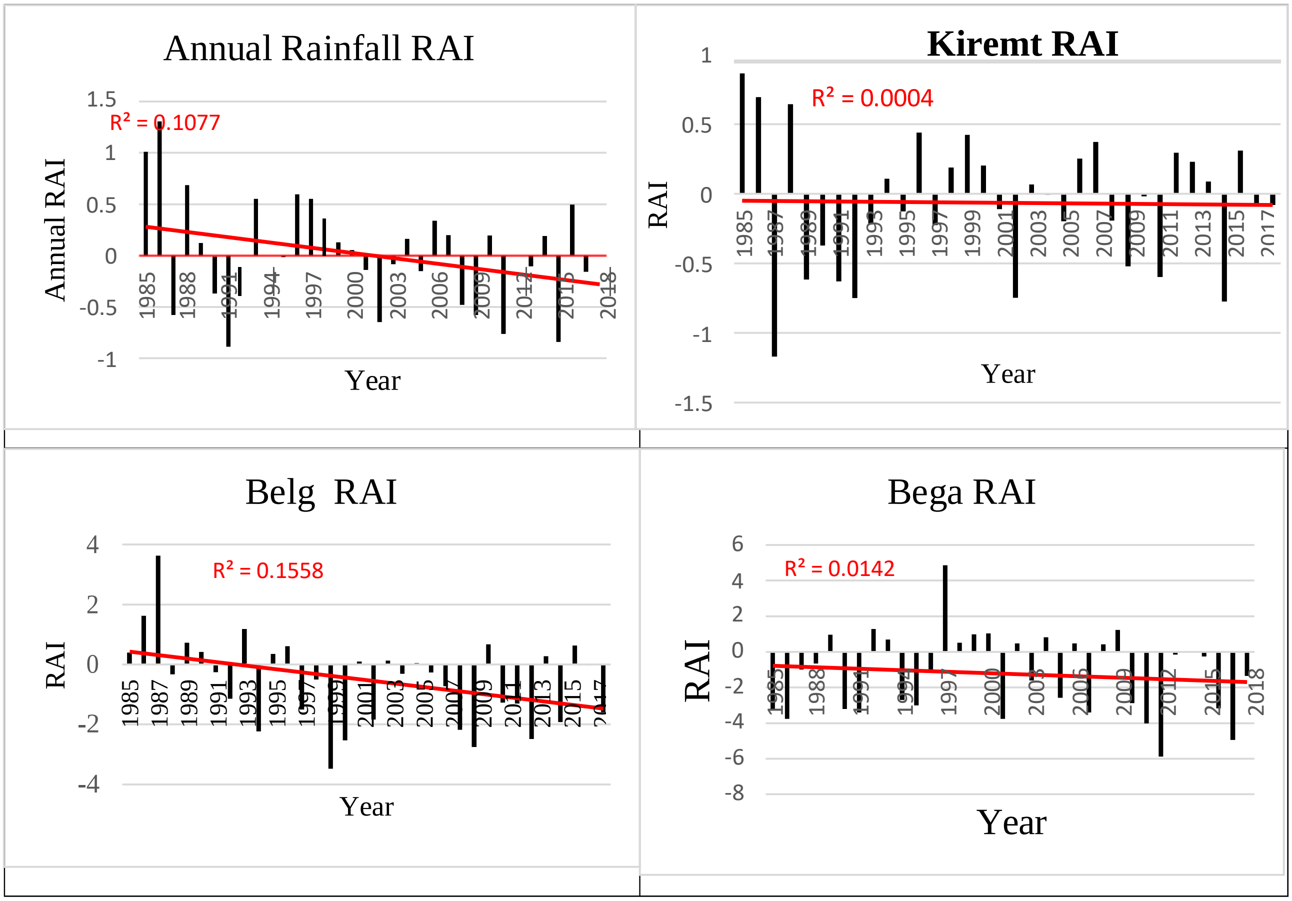

Figure 6. Annual and seasonal rainfall anomalies.

The average of 3-month SPI for a period of three years (2016-2018) and ten years (2009-2018) for Belg season. According to the 3-month SPI analysis, in both periods North Shewa

-

Comparatively, the three years (2016-2018) were a bit drier than the ten years (2009-2018). The areal average 3-month SPI for 1985-2018, 2009-2018, and 2016- 2018 was 0.14, 0.13, and 0.09, respectively which is in agreement with the trend of SRA for Belg season (Figure 6).

The Onset, Cessation, and Length of Growing Period of Kiremt Season

The lowest, highest, and mean LGP was 55, 138, and 78 days, respectively In a similar study conducted in Tigray region (northern Ethiopia) for the period 1980-2009, Hadgu *et al*., 2013 found the average LGP to vary from 66 to 85 days. The coefficient of variation (CV) of LGP ranged from 14-87%. Higher CV (> 13%) of LGP gives less confidence in crop selection based on the maturity period.

The inter-annual variability of the number of rainy days ranged from 13- 31% with an aerial mean of 19.7 days. The probability of dry spell occurrence for Belg (Feb, 1 to May, 31) and Kiremt (Jun, 2 to Aug, 14) seasons. During Belg season, the probability of the occurrence of dry spells for 5, 7, 10, and 15 dry spell days was above 40% in all stations. In the main rainy season (Kiremt), the probability of 7, 10, and 15 days dry spell occurrence in July and August was zero; whereas for 5 days dry spell it was more than 30% at all stations.

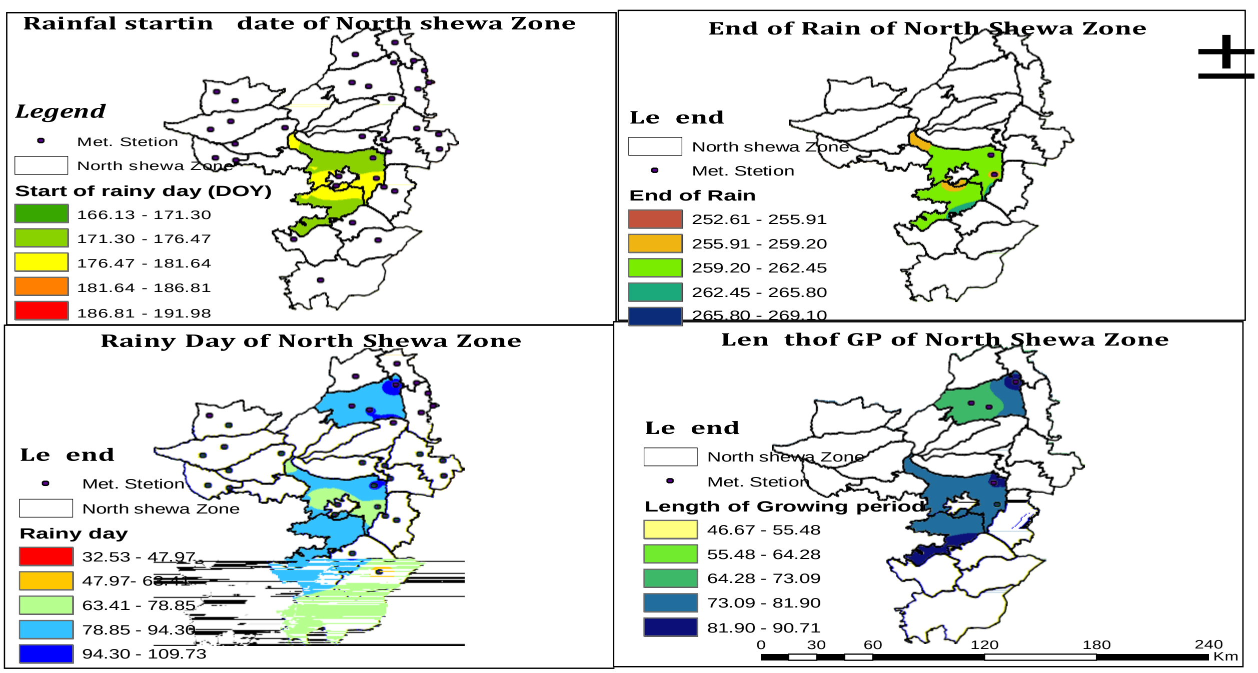

Figure 7. Onset, cession and length of growing period

Trends of Onset and Cessation Days of Rainfall for Kiremt Season

The Mann Kendall trend test showed a decreasing trend of annual rainfall at Alemketema, Alyuamba, Rema, Abayatir, kureberet and Shewarobit areas. At Abayatir, kureberet and Alyuamba station, the detected trends were significant at 5% significant level. The Mann-Kendall trend test on onset of Kiremt rainfall showed a decreasing trend in all stations except Abayatir, kureberet, Alyuamba and Meragna stations. The observed trends were statistically significant only at Gisherabel, Yigem and Gundomeskel stations while in the remaining stations the trends were not significant.

The cessation date of Kiremt rainfall showed an increasing trend in sixteen stations; in the four stations (Gudoberet, koremash, Mehalmeda and Rema), the trend was statistically significant. The length of the growing period (LGP) showed an increasing trend in sixteen stations; in seven stations the trend was statistically significant. The number of rainy days had shown increasing trends in all areas except at Ginager, Rema, kureberet, and Shewarobit areas. Generally, the number of rainy days had shown statistically significant increasing trends in the study area

Conclusion and Recommendation

Rainfall is the major climatic parameter that needs to be analyzed for its statistical characteristics in order to conduct successful rain-fed agriculture over central Ethiopia. Variation of rainfall in both time and space has a significant effect in the performance of agricultural productivity, particularly over central Ethiopia where agriculture heavily relies on seasonal rainfall. The mean annual rainfall amount was 1107mm while Kiremt, Belg, and Bega received 786, 231, and 90 mm respectively. The mean onset and cessation dates were June 25th and October 7th, respectively while the mean duration of the Kiremt season was 77 days. The result showed that there was considerable temporal and spatial variation of rainfall over North Shewa. The coefficient of variation of the annual and Kiremt rainfall revealed moderate inter-annual and seasonal variability. However, much larger variation was observed during Belg and Bega season.   On the other hand, the result of coefficient of variation showed low variability in the onset and cessation dates; whereas, the length of growing period was highly variable. Spatially, a general decrease of mean annual rainfall from east to west was observed. Annual and seasonal rainfall trends were for annual and Kiremt rainfall resulted in non-significant increasing trends. This study has offered useful information for a better understanding of the temporal trends and spatial distribution of rainfall in the study area, which is importance for water resources management particularly in securing sustainable agricultural production.

Acknowledgement

The authors are grateful to Debrebirhan Agricultural Research Center for allowing the first author to take part in the Graduate Study Program of Irrigation Engineering. The authors would also like to thank the National Meteorological Agency Combolcha Branch, for free data provisiona. Last but not least, we would like to extend our deepest gratitude to Mr. Ayele Desalgne for his encouragement and material support during the study.

References

and adaptation strategies in Sub-Saharan West-Africa. In: 2nd International Conference: Climate. Sustainability and Development in Semi-arid Regions, Fortaleza - Ceará, Brazil.

AKLDP, (2015). El Niño in Ethiopia Uncertainties, impacts and decision-making. Agriculture Knowledge, Learning Documentation and Policy (AKLDP) Project, Ethiopia.

Araya A. Stroosnijder L., Habtu S., Keesstra S.D., Berhe M. and Hadgu M. 2012. Risk assessment by sowing date for barley (Hordeum vulgare) in northern Ethiopia Agricultural and Forest Meteorology Volumes 154 155, 15 pp. 30-37

Ayalew D., Tesfaye K., Girma M., Birru Y., Wondimu B (2012). Variability of rainfall and its current trend in Amhara region, Ethiopia. African Journal of Agricultural Research 7(10): 1475-1486.

Ayalew, D., Tesfaye, K., Mamo, G. Yitaferu, B. Bayu, W. 2012. Variability of rainfall and its current trend in Amhara region, Ethiopia. Afr. J. Agric. Res. 7 (10): 1475-1486.

Bekele F., Mosisa N., Terefe D (2017). Analysis of current rainfall variability and trends over Bale-Zone., South Eastern highland of Ethiopia. Climate Change 3(12): 889-902

Bewket, W. and Conway, D. 2007. A note on the temporal and spatial variability of rainfall in the drought-prone Amhara region of Ethiopia. Int. J. Climatol. 27: 1467-477.

Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environ Sci Policy 12:413 426.

Cheung WH., Senay G., Singh A (2008). Trends and spatial distribution of annual and seasonal rainfall in Ethiopia. Int J Climatol 28(13): 1723- 1734.

CSA (Central Statistics Authority) (2004). The Federal Democratic Republic of Ethiopia Statistical abstract for 2003. CSA, Addis Abeba

CSA (Central Statistics Authority) (2007). The Federal Democratic Republic of Ethiopia Statistics. CSA, Addis Abeba

CSA (Central Statistics Authority) (2008). The Federal Democratic Republic of Ethiopia Statistics. CSA, Addis Abeba

Degefu MA., Rowell DP., Bewket W (2016). Teleconnections between Ethiopian rainfall variability and global SSTs: observations and methods for model evaluation. Meteorol Atmos Phys (2017) 129: 173- 186.

Demeke, A. B., Keil, A., and Zeller, M. 2011. Using panel data to estimate the effect of Ethiopia.

Climatic change vol. 108, no. 1-2, pp. 185-206.

Funk C, Rowland J, Eilerts G, Kebebe E, Biru N, White L, Galu G (2012) A climate trend analysis of Ethiopia. USAID; USGS; FEWS NET, Washington, D.C.

Gamachu D (1988). Some patterns of altitudinal variation of climatic elements in the mountainous regions of Ethiopia. MRD 8(2/3): 131- 138.

Gebrehiwot T. & Van der Veen A. 2013. Farm Level Adaptation to Climate Change: The

pp. 29 44.

Hadgu G, Tesfaye K, Mamo G, Kassa B (2013). Trend and variability of rainfall in Tigray, Northern, Ethiopia. Analysis of meteorological data and perception. Academically Journal Environmental Science 1(8): 159-171.

Jury MR., Funk C (2012). Climatic trends over Ethiopia: regional signals and drivers. Int J Climatol 33(8): 1924-1935.

Kassie B.T, Hengsdijk H, Rötter R, Kahiluoto H, Asseng S & Van Ittersum M. 2013. Adapting to Climate Variability and Change: Experiences from Cereal-Based Farming in the Central Rift and Kobo Valleys, Ethiopia. Environmental Management volume 52, pp. 1115 1131

McMaster, G.S. and Wilhelm, W.W. 1997. Growing Degree-Days: One Equation, Two Interpretations. Agricultural and Forest Meteorology, 87, 291-300.

Nicholson S (1985). Sub-Saharan Rainfall 1981-84. J Climate Appl Meteorolo 24: 1388-1391.

Partal T (2006). Trend analysis in Turkish precipitation data. Hydrological Process 20(9): 2011-2026.

Segele ZT., Lamb PJ (2005) Characterization and variability of Kiremt rainy season over Ethiopia. Meteorol Atmos Phys 89: 153-180.

Seleshi Y., Zanke U (2004). Recent changes in rainfall and rainy days in Ethiopia. Int J Climatol 24: 973-983.

Sen P (1968). Estimates of regression coefficients based on Ke
American Statistical Association 63(324): 1379- 1389.

Viste E., Korecha D., Sorteberg, A (2013). Recent drought and precipitation tendencies in Ethiopia. Theoretical and Applied Climatology 112: 535-551.

Wagaye B A., Antensay M. Rainfall Variability and Trends over Central Ethiopia. Int J Environ Sci Nat Res. 2020; 24(4): 556144.

Wagesho N., Goel NK., Jain MK (2013) Temporal and spatial variability of annual and seasonal rainfall over Ethiopia. Hydrological Sciences Journal 58(2): 354-373.

Warwade P., Tiwari S., Ranjan S., Chandniha SK. and Adamowski J. 2018. Spatio-temporal variation of rainfall over Bihar State, India. Journal of Water and Land Development 36(1): 183-197.

Weldegerima, T.M, Zeleke, T.T. Birhanu, B.S. Zaitchik, B.F. and Fetene, Z.A. 2018. Analysis of Rainfall Trends and Its Relationship with SST Signals in the Lake Tana Basin, Ethiopia. Hindawi Advances in Meteorology, pp. 10

Yenigun K, Gumus V, Bulut H (2008). Trends in streamflow of the Euphrates basin, Turkey. Proclamation Institute of Civil Engineering Water Management 161(4): 189-198.