International Journal of Scientific Research in Multidisciplinary Studies
Vol.5, Issue.12, pp.56-65, December (2019)

Research Paper
E-ISSN: 2454-9312
P-ISSN: 2454-6143

Spatial and Temporal Variability in Temperature and Rainfall over Mecha area, Ethiopia

Z. Meseret[1*], **S. Belay**[2]

[1,2]Center for Environment and Development, Addis Ababa University, Addis Ababa, Ethiopia

**Corresponding author: meseretzewdu903@gmail.com Phone number: +251967297189*

Available online at: www.isroset.org

Received: 10/Dec/2019, Accepted: 16/Dec/2019, Online: 31/Dec/2019

Abstract—Variability of temperature and rainfall and climatic hazards like droughts, floods, and windstorms affect agricultural activities. In the study area, the main livelihood of the people depends on rain-fed agriculture that would be affecting by the variation of rainfall and temperature. The study aims to analyze the recent spatiotemporal variability and trends of rainfall and temperature at seasonal and annual timescales over Mecha area where detail analysis of the two climate indicators does not exist, to inform development planners and improve the effectiveness of agricultural activities. In this study, we analyzed gridded monthly temperature and rainfall data from 1983 to 2014. The data were constructed to 154 points at a 10×10 km resolution and input into Geographic Information Systems (GIS) to model the spatial relationship of rainfall and temperature. Linear regression, standardized anomalies used to analyze temporal variation. Findings reveal that annual minimum and maximum temperature significantly increased at a rate of 0.11^{O}C and 0.08^{O}C per decade respectively. Seasonal warming trends for maximum temperature were significant in the winter and spring seasons ($p = 0.05$) whereas ($p = 0.01$) in winter and autumn for minimum temperature. Adjusted R-square values of the OLS method resulted in spatial relationships for annual rainfall, minimum and maximum temperature are 0.41, 0.44 and 0.68 respectively. The mean annual and seasonal rainfall distribution shows statistically non-significant increasing trends. These results call a need to develop local level and context-specific climate change adaptation strategies.

Keywords: trend, spatial variability, temporal variability, climate factors

I. INTRODUCTION

In low-income countries like Ethiopia, climate is the primary determinant of agricultural productivity. Since Ethiopia is dependent on rain-fed agriculture and has limited resources to adapt to climate changes [1], long-term changes in temperature and rainfall decrease net revenues from agricultural production with corresponding negative effects on food security [2], [3], [4]. Variations in climatic factors such as temperature and precipitation and the frequency and severity of extreme events like droughts, floods, and windstorms affect the productions of crop [5]. Temperature and rainfall patterns also impact the availability of water for agricultural activities, including irrigation [6].

The average annual minimum and maximum temperature over Ethiopia has been increasing by about 0.25^{o}C and 0.1^{o}C, respectively, every 10 years [7]. In the Amhara regional state of Ethiopia, climate-related hazards affect the rural households that are largely dependent on weather-sensitive crop and livestock production systems. A study shows that crop-pest, livestock epidemic, hailstorm, drought, and flood are the most frequently occurring climate-related hazards in the region [8]. Flooding affected approximately 42,850 people; displaced 12,571 in five zones, including the study area; and damaged a total of 20,300 hectares of crop land.

The main livelihood of the people in the study area depends on agricultural activities including irrigation that are the most vulnerable activities to climate change impacts because of its dependence on temperature and rainfall [9], [10]. The spatial and temporal variation of rainfall and temperature would impact the activities of the farm households [11]. Therefore, this study aims to analyze spatial and temporal variability and trends of rainfall and temperature in *Mecha* area detail spatiotemporal analysis of the two climate indicators does not exist. Further, the study is valuable for local adaptation to future climate change and variability; for development planners and water resource managers to decide on the irrigation practices.

II. RELATED WORK

Previous studies on rainfall reported high variability of annual and seasonal rainfall. Gebreselassie [12] examined the spatio-temporal variability of seasonal and annual rainfall totals over Tekeze river basin in Ethiopia using coefficient of variability and ordinary kirging interpolation technique. The result revealed that the annual and kiremt (June to September) season rainfall distribution are highest at the southwest part of the river basin and decrease to other directions. Ayalew [13] also analyzed the spatial and temporal rainfall characteristics of Amhara Region, Ethiopia; using standard rainfall statistical descriptors. Variations of rainfall were found in every month in all stations. The spatial distribution of annual rainfall was varied from 850 to 1485 mm. Changes in daily rainfall indices in the wettest part of Ethiopia were examined over the period 1978–2007. A complex picture of rainfall variability emerges from the analysis: increasing and decreasing trends [14].

Studies on the temperature, in contrast, mengistu [15] observed a significant warming trend of temperature over most parts of the Blue Nile river basin in all seasons. At annual time scale, maximum and minimum temperatures increased in over 33% of the Basin at a rate of 0.1 and 0.15^{o}C per decade, respectively; however, the western part (12%) of the Basin experienced declining trends in annual and seasonal time scales. Further, Alemayehu [16] evaluates spatiotemporal variability and trends of temperature in the central highlands of Ethiopia utilizing linear regression and F-distribution test. Significant spatiotemporal variability in the maximum and minimum temperatures was observed across the study area.

III. MTHODOLOGY

A. Description of the study area

The study was conducted in the Mecha area, Amhara National, Regional State, Ethiopia (Figure 1). Mecha area is situated at 500 km northwest of Addis Ababa, the capital of Ethiopia and 35km to the west of Bahir Dar, the capital of the Amhara region. The study area lies between the coordinates 110 24’ 62’’ N latitude and 37º 08’ 97’’ E longitudes. It is situated at an altitude ranging from 1795 to 3268 meters above sea level and has an area coverage of 156 027 ha. The total population of Mecha area is 375,716: 323,315 in rural areas and 52401 in urban areas. Land use of the area is dominated by traditional, rain-fed, subsistence peasant farming on individual holdings. The overall farming system is strongly oriented towards grain production. The population generally keeps different livestock for the production of milk by-products and as transferable assets. Crop residue and extensive grazing in the low lying areas are the major contributors to livestock feed resources [17].

In response to increasing demand for food and contrastingly declining agricultural production in the study area, the Ethiopian government constructed a Koga dam in the Mecha area to irrigate 7,000 ha land. The Koga irrigation project where this study was undertaken is found between 1892-2043 masl altitude with UTM coordinates of N 1,255,000, N 1,270,000, E 290,000 and E 300,000. The project area covers a total size of about 10,000 hectare.

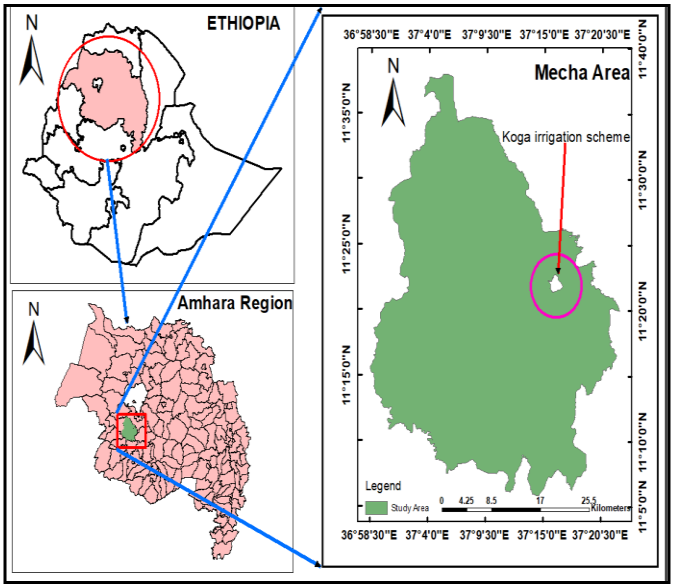


Figure 1: Location map of the study area (source: constructed by authors)

B. Data and Analysis

In this study, we analyzed the spatial and temporal variability and trends of rainfall; and maximum and minimum temperatures at seasonal and annual time scales in the Mecha area. Gridded monthly rainfall, minimum and maximum temperature data were constructed to 154 points on 10×10km resolution for the period from1983 to 2014.

We analyzed the data temporally and spatially using different methods below. Based on [18], [19], there are three rainfall seasons in Ethiopia: *Kiremt* from June–September, *Belg* from March-May and *Bega* from October- February, therefore, we analyzed rainfall based on these three seasons. For temperature: winter from December–February, spring from March-May, autumn from September–November, and summer from June-August [20].

The gridded data were input into Geographic Information Systems (GIS) as point data to model the spatial relationship of rainfall and temperature data. This study used Geo-statistical techniques using an Inverse Distance Weighted (IDW) to predict the map of the spatial distribution of the two climate data sets based on the assumption that things close to one another are more alike than those that are farther apart [21], [22]. Global interpolator spatial statistics tool _Ordinary Least Squares (OLS) _ was used to model spatial relationships, i.e. dependent variable’s relationships of explanatory variables associated with geographic features such as latitude, longitude, and altitude; and to measure how strong those relationships are. Before the OLS regression application, we constructed a scatter plot matrix between variables to see the relationship strength of dependent and independent variables. We used Robust Probabilities (Robust Pr) to determine coefficient significance, and the Joint F and Wald Statistic determine overall model significance. R-square values are used to assess model performance, with the values for r^2 range from 0.0 to 1.0 [23].

We applied the following regression equation to the independent variables to best predict the dependent variables, similar to studies by [24], [25].

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 \pm - - -\beta nXn + \mathcal{E} - - - \quad (1)$$

Where Y is dependent variable, the Xs are explanatory variables, β is regression coefficients and Ɛ is a random error term or residuals.

For temporal trend analysis of rainfall and minimum and maximum temperature, linear regression was employed to each of 154 points using the equation (2) below. The standard Z score was used to calculate anomalies of rainfall and temperature (equation 3). The same equations (2 & 3) were utilized by [26], [27], [28].

$$Y = mx + b - - - - - - - - - \quad (2)$$

Where Y is the dependent variable, m is the slope, x is the independent variable and b is the intercept.

$$Z = \frac{X - \mu}{\delta} - - - - - - - - - - \quad (3)$$

Where Z is a standardized anomaly; x is the value of a particular year; μ is long term mean annual record over a period of observation and δ is the standard deviation of annual rainfall over the period of observation.

IV. RESULTS AND DISCUSSION

A. Temporal and Spatial Variation of Maximum Temperature

Table 1 pointed out the temporal variation of maximum temperature at annual and seasonal time scale over the study area for the period 1983-2014. The finding showed that an average annual maximum temperature of the study area is 26.5°C and significantly increased by 0.08°C per decade. Monthly mean value varies from 23.1°C in July to 29.9°C in March.

Table 1: Trends of annual and seasonal maximum temperature from 1983 to 2014

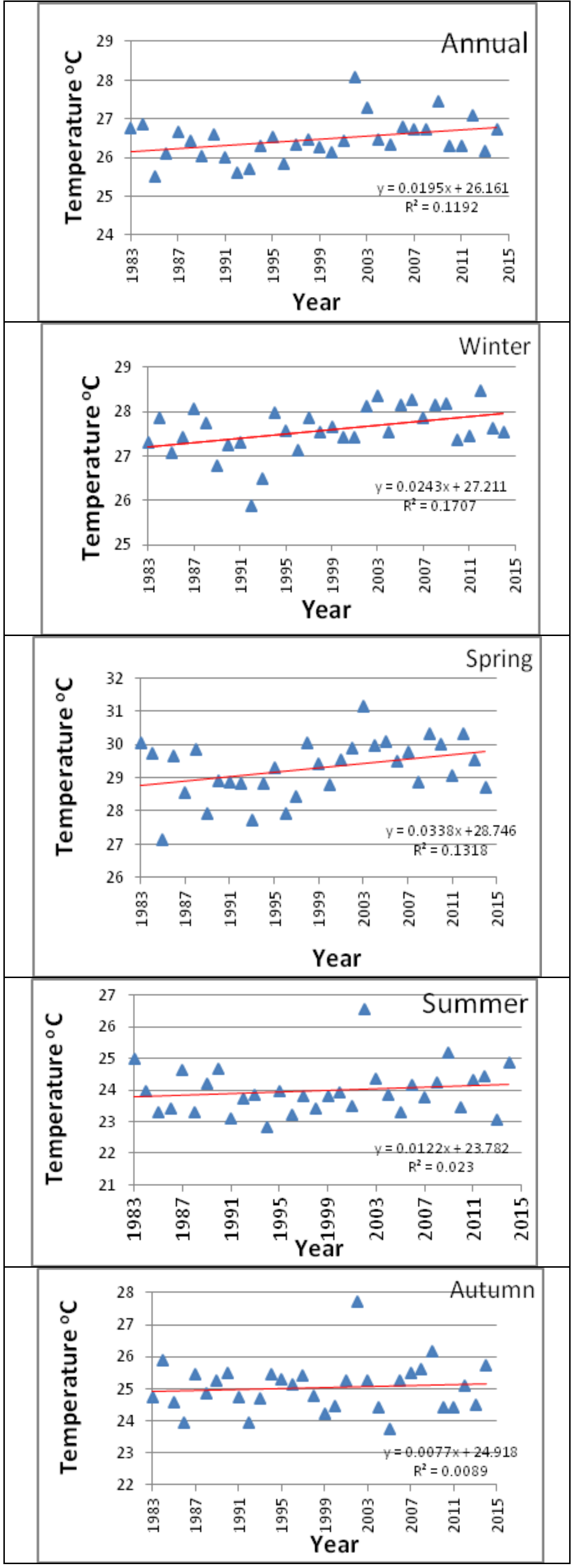
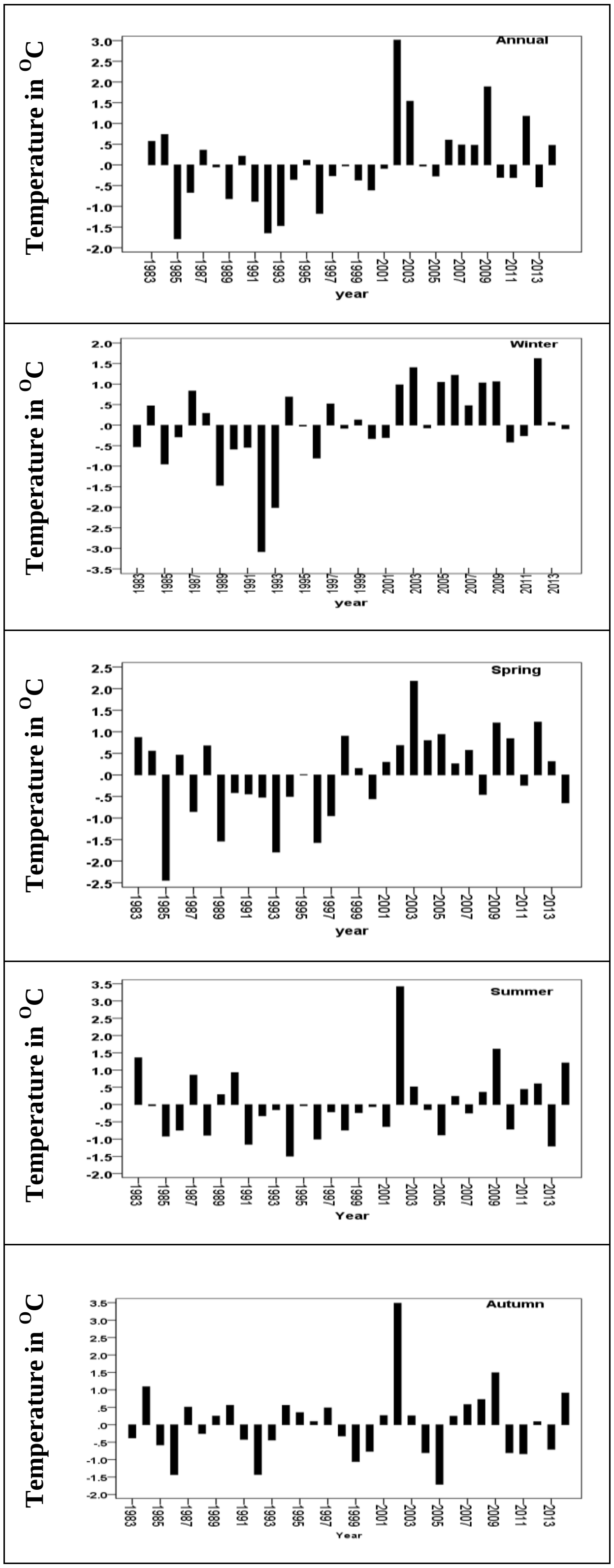


Table 2: Annual and seasonal maximum temperature anomalies from 1983 to 2014



The warming trends in the winter and spring seasons were significant (p=.05). Other studies of climate variability in Ethiopia for instance, [29] in Addis Ababa, [30] in the upper Blue Nile basin, [31] in Weleka sub-basin, [32] in the central Highlands of Ethiopia, and [33] and [34] for the whole country reported similar warming trends of maximum temperature with substantial variation at different spatial scales and period. Comparable warming trends [35] also reported in the horn of Africa from 1961 to 2010.

The inter-annual variability of maximum temperature (Table 2) showed that the existence of hot, moderate and cold years from 1983 to 2014. Inter-annual variation of annual maximum temperature showed negative anomalies for most of the years from 1985 to 2001. This result coincides with a study by [36] in the annual maximum temperature of Efratana Gidim. The last decade is warmer than the first two decades in the annual winter and spring maximum temperatures, whereas great anomalies observed in summer and autumn. Analogous maximum temperature anomalies reported in other studies by [37], [38], [39].

The result presented in Figure 2 showed that the mean annual maximum temperature varies spatially from 23°C in the south-eastern parts of the study area to 27.5°C in the north and north-western parts during 1983-2014. OLS results, for annual data, point out that the coefficient of variation is significant (p< 0.01) and the adjusted R2 value is 0.68. Seasonally, it varies spatially from 23.3 to 28.9°C; 25.7 to 30.6°C; 20.4 to 25.2°C; and 21.6 to 26°C for winter, spring, summer and autumn respectively.

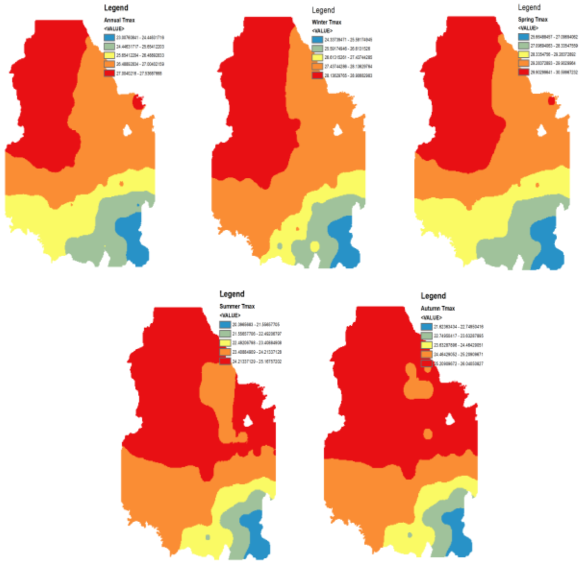


Figure 2: Annual and seasonal spatial map of maximum temperature from 1983 to 2014

The area has experienced similar spatial warmer and cooler trends with annual maximum temperatures during winter and spring. Warmer areas observed during summer and autumn in the north half of the area, and cooler areas located similarly with the annual and the other two seasons for the recorded period. Based on spatial statistics, OLS results, the coefficient of variation is significant for all seasons ($p<0.010$; and adjusted R2 values are 0.69, 0.55, 0.52 0.49 for winter, spring, summer, and autumn, respectively.

3.2. Temporal and Spatial Variation of Minimum Temperature

Table 3 presents the annual and seasonal temporal variation of the minimum temperature in the study area. The study revealed that the average annual minimum temperature of the study area is 10.5^{o}C and significantly increased by 0.11^{o}C per decade. The monthly mean value varies from 6.7^{o}C in January to 12.7^{o}C in May. The result shows significant warming trends of annual minimum temperature ($p = 0.01$). Seasonally, the warming trends of winter and autumn are significant ($p=0.01$) whereas spring and summer are significant at 0.05 levels. Other researchers reported similar warming trends in minimum temperature in different places and periods. In Addis Ababa, [45] reported increased trends in annual minimum temperature of 0.4^{o}C per decade from 1951 to 2002. In the upper Blue Nile basin, [40] also found that minimum temperatures increased at a higher rate than the maximum temperatures during winter, summer, autumn and the annual time scale. Other studies also found increasing trends of minimum temperature: [41], [42], [43]. The inter-annual variation of minimum temperature (Table 4) shows that the area has experienced both warm and cold years in the observed period. Inter-annual variation of annual minimum temperature shows positive anomalies from 2002 to 2014. In winter, we observed negative anomalies in the 1980s and 1990s, except in 1994 and 1995. The last decade is warmer than the first two decades for the recorded period consistently. Other studies_ [44], [45], [46], [47], [48]_ also reported similar minimum temperature anomalies with different spatial scale and temporal variation.

Figure 3 shows annual and seasonal spatial variation of minimum temperature in the area based on IDW interpolator technique for the period 1983 to 2014. Mean annual minimum temperature varies spatially from the 8.5^{o}C, the cold temperate area in the southeastern to 11.2^{o}C the hot temperate area in the north parts of the area. OLS results showed that the coefficient of variation is significant: $p < 0.01$ and the adjusted R^{2} value is 0.44. We observe considerable seasonal spatial variation of minimum temperature compared to the maximum temperature. It varies from 6.2 to 7.9^{o}C; 9.7 to 12.1^{o}C; 9.9 to 13.4^{o}C; and 8.4 to 11.7^{o}C for winter, spring, summer and autumn, respectively.

Table 3: Trends of annual and seasonal minimum temperature from 1983 to 2014

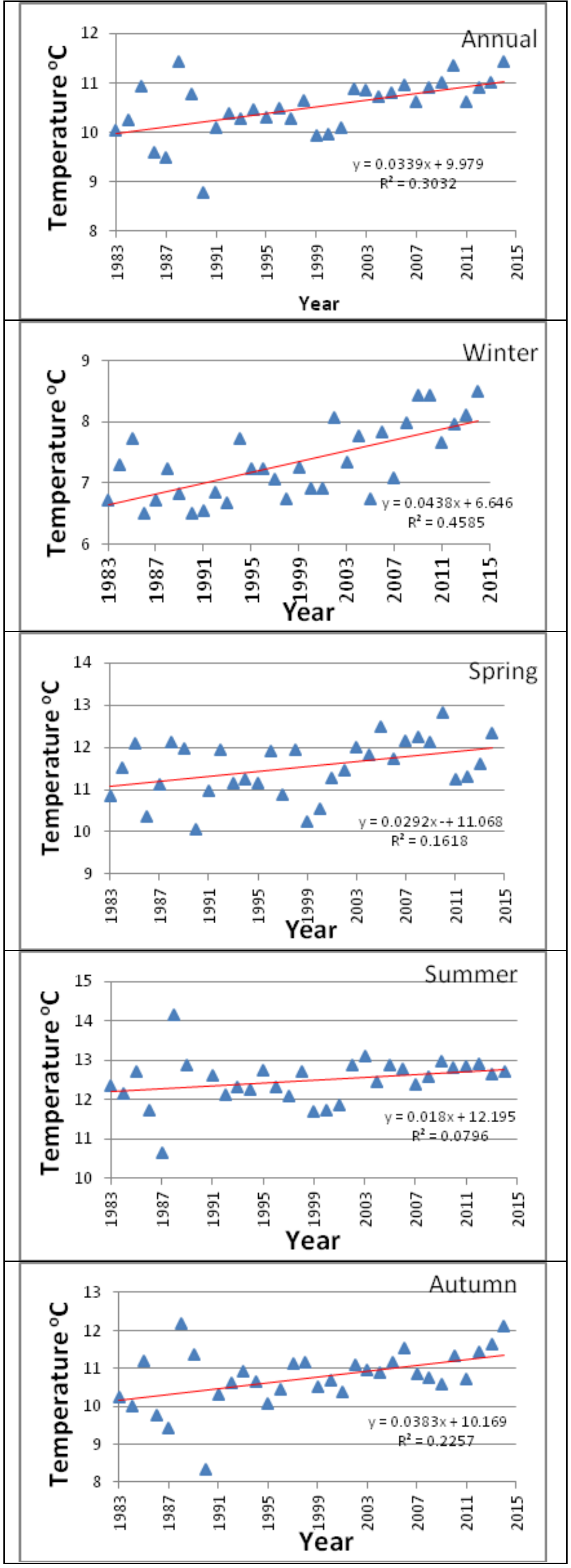
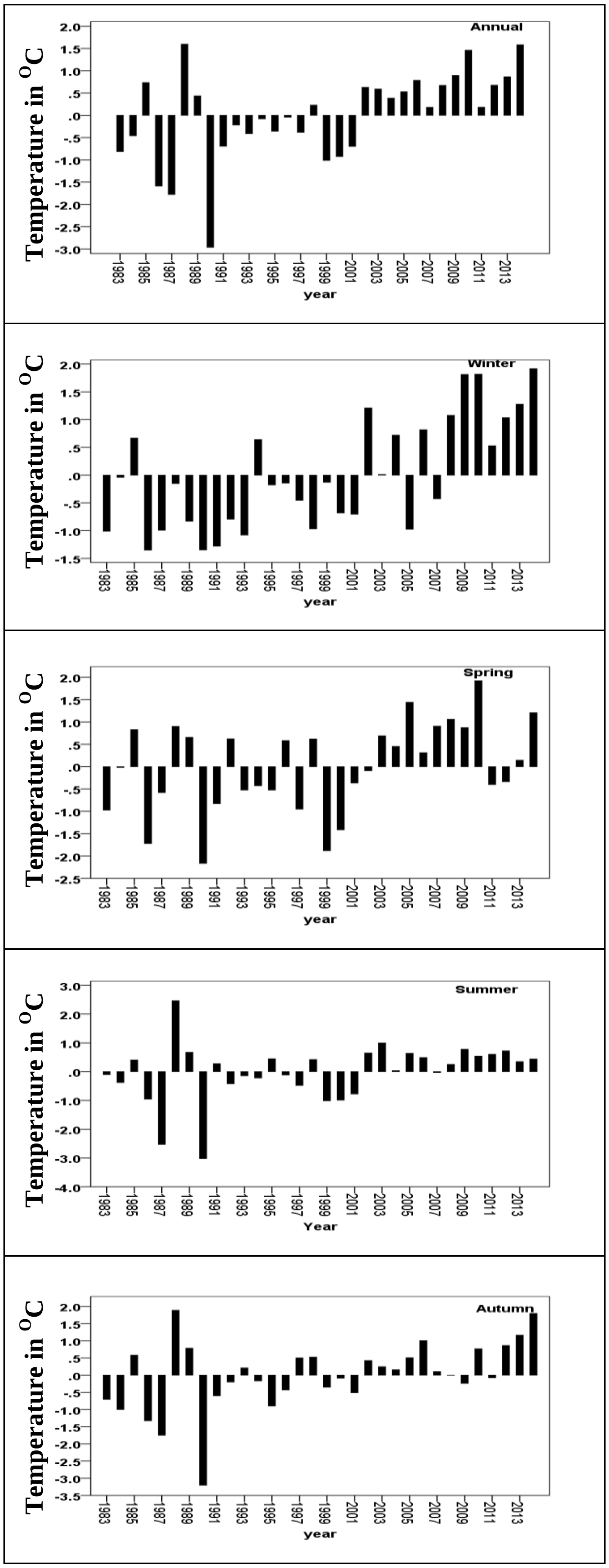


Table 4: Annual and seasonal minimum temperature anomalies from 1983 to 2014



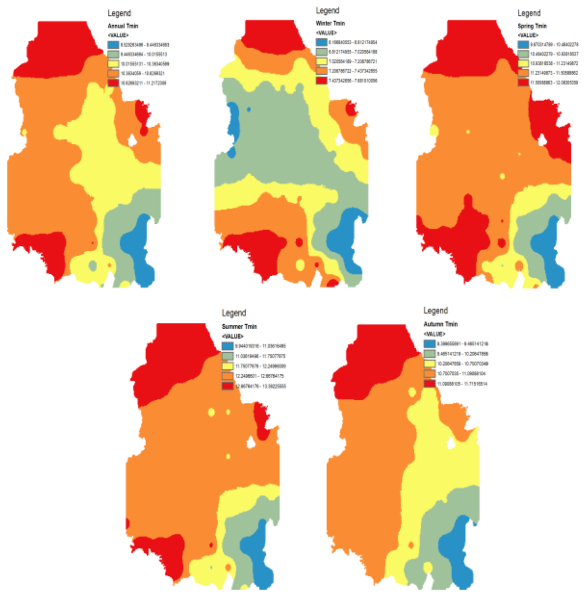


Figure 3: Annual and seasonal variation map of minimum temperature from 1983 to 2014

The area has experienced consistent hotter temperate in the north and colder temperate in the southeastern parts in all seasons during the recorded period. The spatial statistical results revealed a significant coefficient of variation p<0.01 in all seasons; and adjusted R^2 values for winter, spring, summer and autumn are 0.36, 0.27, 0.39 and 0.45 respectively (see Figure 3).

3.3. Temporal and Spatial Variation of Rainfall

The total annual rainfall distribution presented in Table 5 varies from 1319.8- 1939.7mm for the recorded period. Seasonal total rainfall varies from 1054.8-1597.3mm in *kiremt*; 30.4-405.6mm in *Belg*; 30.7-265.5mm in *Bega*. The annual and seasonal rainfall shows statistically non-significant increasing trends. Similar results were reported by [49] except a decline rainfall trend for spring in the Blue Nile river basin; [50] found a statistically non-significant increasing trends of Kiremt rainfall in Efratana Gidim and significant increasing trend in Menz Gera Meder, central highlands of Ethiopia. Similar non significant increasing trend [51] reported in Gatira, southwestern Ethiopia. Gedefaw et al. An increasing trend of annual rainfall [52] observed in Amhara region specifically in Gondar, Bahir Dar and Motta.

Inter-annual variation of annual rainfall in Table 6 indicates negative anomalies for most of the 1980s. Seasonal rainfall variability has shown negative and positive anomalies in the 1990's for Kiremit (June-September) and Belg (March-May) seasons, respectively. The driest and wettest years are 2009 and 2006, respectively. The area has experienced both wet and dry years with moderate inter-annual rainfall variation.

The results are consistent with [53] in the central highlands of Ethiopia; [54] and [55] in the Amhara region.

Table 5: Trends of annual and seasonal rainfall from 1983 to 2014

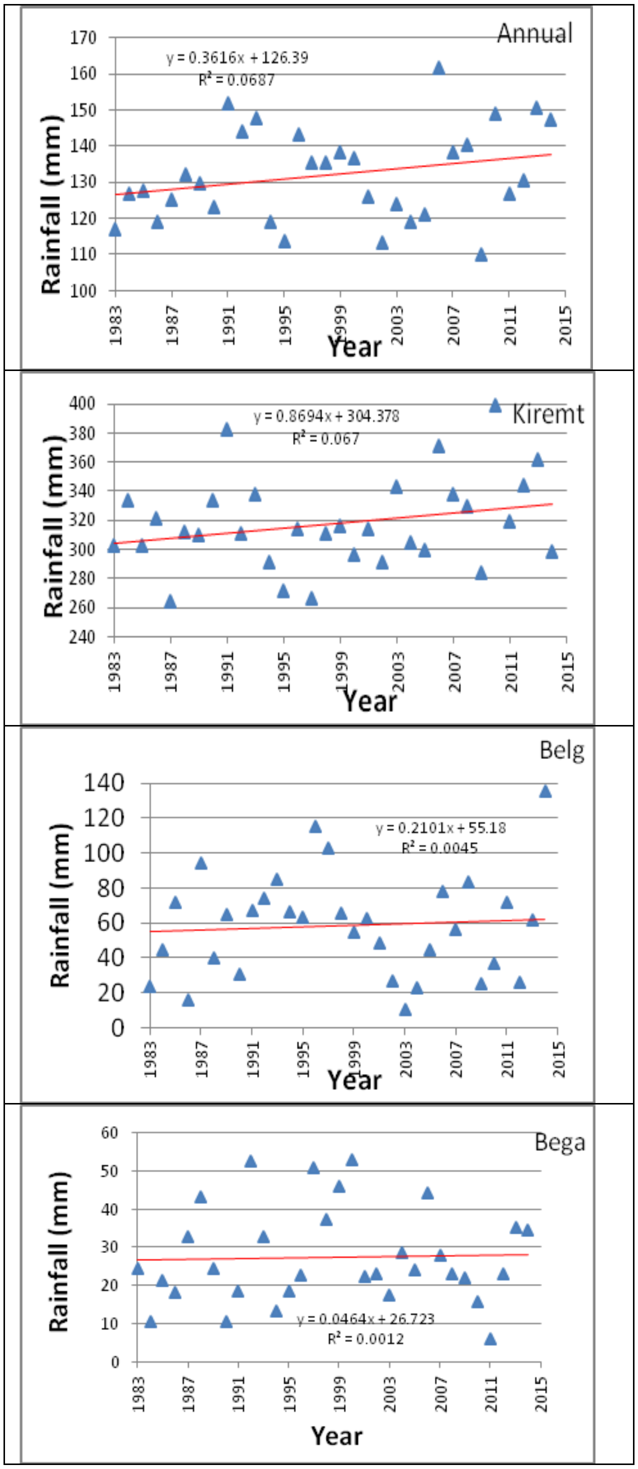
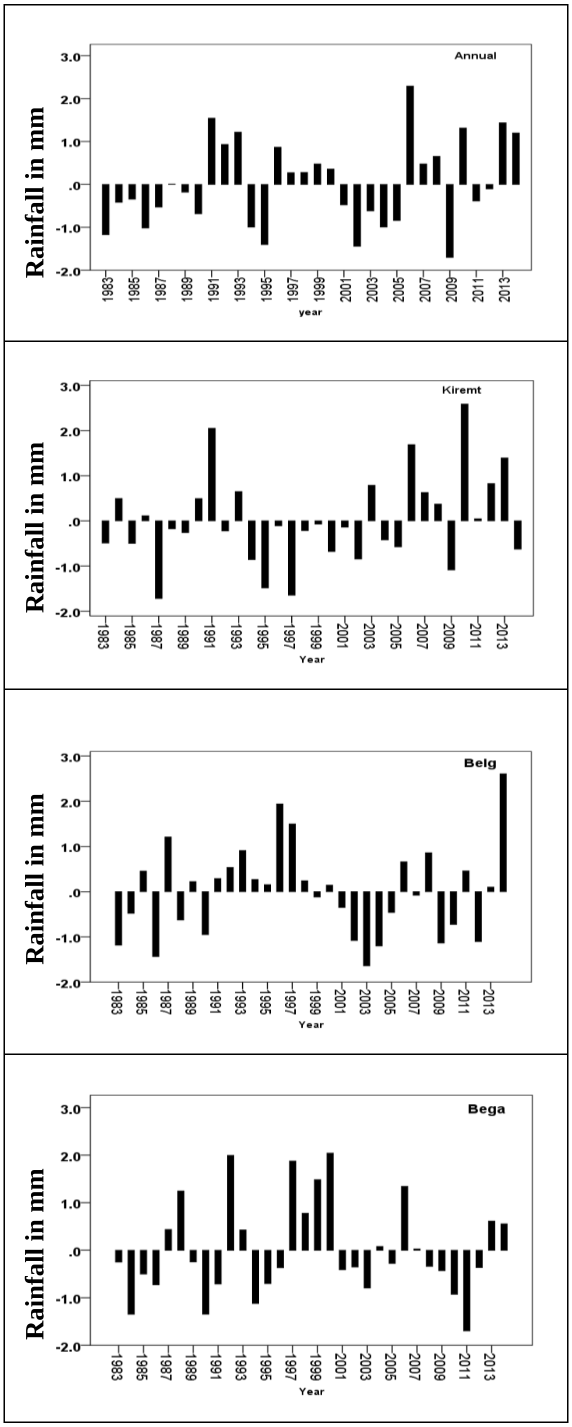


Table 6: Annual and seasonal rainfall anomalies from 1983 to 2014



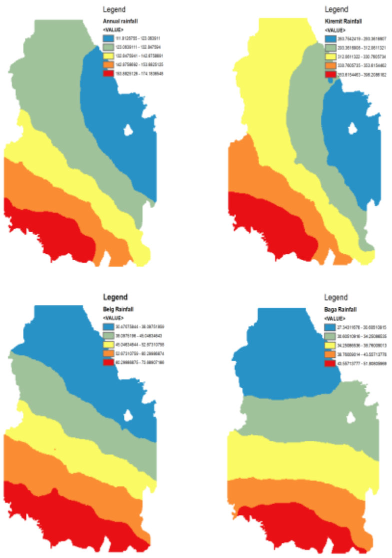


Figure 4: Annual and seasonal spatial variation map of rainfall from 1983 to 2014

The spatial distribution (Figure 4) of mean annual rainfall varies from 111.81mm in the eastern part of the area to174. 18 mm in the southwestern part. The spatial statistics showed that robust pr is significant ($p<0.01$) with the adjusted R-square values (R^2 is 0.41). Seasonal and spatial mean rainfall distribution varies from 263.75-396.21mm in Kermit, similar location with an annual rainfall; 40.22 mm in the north and northeastern areas to 95.94 in south and southwestern areas; and 27.34mm in the north to 51.81mm in the south parts of the area. The spatial statistical result showed that robust pr is significant $p<0.0$ in Kiremt and Belg seasons with R^2 values of 0.32 and 0.17 respectively.

V. CONCLUSION

In countries like Ethiopia that are heavily dependent on rain fed agriculture, assessment of the spatial and temporal distribution of rainfall and temperature and observing their trends are vital input for sustainable agricultural production. Based on the analysis using different statistical methods, the study area experienced significant warming trends of maximum temperature in winter and spring seasons and non significant warming trends for annual time frame, summer and autumn seasons. North and North-western parts of the area have experienced warmer temperatures compared with the southeastern, the cooler area. The last decade of the observed period for minimum temperature was warmer than the first two decades in annual and all seasons. We observed consistent spatial warmer and cooler trends in the north and southeastern parts of the area, respectively, at annual and seasonal time scales. Statistically non-significant increasing trends with moderate inter-annual rainfall variability were observed at annual and seasonal time scales over the study area. The area has experienced the highest rainfall distributions in the annual time scale and the kiremt season in the southwest; and in Belg and Bega seasons in the south. The results call a need for planning of local adaptation strategies to prevent negative impacts of temperature and rainfall on agriculture.

ACKNOWLEDGEMENT

The authors gratefully acknowledge Ethiopian National Meteorological Service Agency for providing the monthly rainfall, minimum and maximum temperature data.

REFERENCES

[1] T. G. Apata, K. D.Samuel, A. O. Adeola, “*Analysis of climate change perception and adaptation among arable food crop farmers in South Western Nigeria*” In International Association of Agricultural Economists’ 2009 Conference, Beijing, China, pp. 16-22, 2009.

[2] W. Bewket, “*Rainfall variability and crop production in Ethiopia: Case study in the Amhara region*”, In Proceedings of the 16th International Conference of Ethiopian Studies, Vol. 3, pp. 823-836, 2009.

[3] T. Deresa, R. Hassan, C. Ringler, “*Perceptions of Adaptation to Climate Change by Farmers in the Nile Basin of Ethiopia*” Journal of Agricultural Science, Vol.149 No.1, pp. 23-31, 2010..

[4] A. Alemayehu, W. Bewket, “*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*”, Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[5] R. Masika, ‘*Gender, Development and Climate Change*”, Oxfam Publishing 2002.

[6] P. Döll "*Impact of climate change and variability on irrigation requirements: a global perspective*." Climatic change, Vol. 54, No. 3 pp. 269-293, 2002.

[7] NMSA (National Meteorological Services Agency), “*Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change*” (UNFCCC), Report 2001.

[8] T. Misganaw, A. Enyew, T. Temesgen, “*Investigating the determinants of adaptation measures to climate change: a case of Batii district, Amhara region, Ethiopia*”, International journal of agricultural research, Vol. 9, No. 4, pp. 169-186, 2014.

[9] P. Döll "*Impact of climate change and variability on irrigation requirements: a global perspective*", Climatic change, Vol. 54, No. 3 pp. 269-293, 2002.

[10] O. Deschênes, M. Greenstone, “*The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather*”, American Economic Review, Vol. 97, No. 1, pp. 354-385, 2007.

[11] J. L. Lee, W. C. Huang, “*Impact of climate change on the irrigation water requirement in Northern Taiwan*”, Water, Vol. 6 No.11, pp. 3339-3361, 2014.

[12] M. G. Gebreselassie, S. A. Moges, “*Spatial and Temporal Variability of Rainfall at Seasonal and Annual Time Scales at Tekeze River Basin, Ethiopia*”, Journal of Natural Sciences Research, Vol.5, No. 19, pp. 27-32, 2015.

[13] D. Ayalew, K. Tesfaye, G. Mamo, B. Yitaferu, W. Bayu, “*Variability of rainfall and its current trend in Amhara region, Ethiopia*”, African Journal of Agricultural Research, Vol. 7, No. 10, pp. 1475-1486, 2012.

[14] G. Kebede, W. Bewket, "*Variations in Rainfall and Extreme Event Indices in the Wettest Part of Ethiopia*", SINET: Ethiop. J. Sci., 32(2): 129-140, 2009.

[15] D. Mengistu, W. Bewket, R. Lal, "*Recent spatiotemporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia*", International Journal of Climatology, Vol. 34, No.7, pp. 2278-2292, 2014.

[16] A. Alemayehu, W. Bewket, "*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*", Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[17] T. Mekonen, F. Kebede, "*Suitability of Koga Watershed for Irrigated sugarcane and onion production in the Blue Nile Basin, Ethiopia*", Journal of the dry lands, Vol.4, No. 2, pp. 325-332, 2011

[18] W. Bewket, D. Conway, "*A note on the temporal and spatial variability of rainfall in the drought‐ prone Amhara region of Ethiopia*", International Journal of Climatology: A Journal of the Royal Meteorological Society, Vol. 27 No. 11, pp. 1467-1477, 2007.

[19] A. Alemayehu, W. Bewket, "*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*", Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[20] D. Mengistu, W.Bewket, R. Lal, "*Recent spatiotemporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia*". International Journal of Climatology, Vol. 34, No.7, pp. 2278-2292, 2014.

[21] P. A.Bostan, Z. Akyürek, "*Spatio-temporal analysis of precipitation and temperature distribution over Turkey*", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 38, No. 2 pp 92-97, 2009.

[22] Environmental Systems Research Institute (Esri), "*GIS 10.4 Desktop help: Interpreting OLS results*", Berkley, California, 1995-2016.

[23] Environmental Systems Research Institute (Esri), "GIS 10.4 Desktop help: *Interpreting OLS results",* Berkley, California, 1995-2016.

[24] P. A. Bostan, Z. Akyürek, "*Spatio-temporal analysis of precipitation and temperature distribution over Turkey*", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 38, No. 2 pp 92-97, 2009.

[25] S. M. Vicente-Serrano, M. A. Saz-Sánchez, J. M. Cuadrat, "*Comparative analysis of interpolation methods in the middle Ebro Valley (Spain): application to annual precipitation and temperature*", Climate research, Vol. 24, No. 2, pp. 161-180, 2003.

[26] W. Bewket, D. Conway, "*A note on the temporal and spatial variability of rainfall in the drought‐ prone Amhara region of Ethiopia*", International Journal of Climatology: A Journal of the Royal Meteorological Society, Vol. 27 No. 11, pp. 1467-1477, 2007.

[27] D. Mengistu, W.Bewket, R. Lal, "*Recent spatiotemporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia*". International Journal of Climatology, Vol. 34, No.7, pp. 2278-2292, 2014.

[28] A. Alemayehu, W. Bewket, "*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*", Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[29] D.Conway, C. Mould, W. Bewket, "*Over one century of rainfall and temperature observations in Addis Ababa, Ethiopia*", International Journal of Climatology: A Journal of the Royal Meteorological Society, Vol. 24 No. 1, pp. 77-91, 2004.

[30] D. Mengistu, W.Bewket, R. Lal, "*Recent spatiotemporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia*". International Journal of Climatology, Vol. 34, No.7, pp. 2278-2292, 2014.

[31] A. Asfaw, B.Simane, A. Hassen, A. Bantider, "*Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin*", Weather and Climate Extremes, Vol. 19, pp. 29-41, 2018.

[32] A. Alemayehu, W. Bewket, "*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*", Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[33] NMSA (National Meteorological Services), "*Climate Change National Adaptation Program of Action (NAPA) of Ethiopia",* National Metrology Service, Addis Ababa, Ethiopia, 2007.

[34] M. R. Jury, C. Funk, "*Climatic trends over Ethiopia: regional signals and drivers*", International Journal of Climatology, Vol.33 No. 8, pp. 1924-1935, 2013.

[35] P. A. Omondi, J. L. Awange, E. Forootan, L. A. Ogallo, R. Barakiza, G. B.Girmaw, M.Kilavi, et al. "*Changes in temperature and precipitation extremes over the Greater Horn of Africa region from 1961 to 2010*", International Journal of Climatology, Vol. 34, No. 4, pp. 1262-1277, 2014.

[36] A. Alemayehu, W. Bewket, "*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*", Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[37] M. Taye, F. Zewdu, "*Spatio-temporal variability and trend of rainfall and temperature in Western Amhara, Ethiopia: a GIS approach*", Glo Adv Res J Geogr Reg Plann. Vol. 1, No.4, pp.65–82, 2012.

[38] G. Tesso, B. Emana, M. Ketema, "*A time series analysis of climate variability and its impacts on food production in North Shewa zone in Ethiopia*", African Crop Science Journal, Vol. 20, No.2, 261-274, 2012.

[39] D. Mengistu, W.Bewket, R. Lal, "*Recent spatiotemporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia*". International Journal of Climatology, Vol. 34, No.7, pp. 2278-2292, 2014.

[40] D. Conway, C. Mould, W. Bewket, "*Over one century of rainfall and temperature observations in Addis Ababa, Ethiopia",* International Journal of Climatology: A Journal of the Royal Meteorological Society, Vol. 24 No. 1, pp. 77-91, 2004.

[41] D. Mengistu, W.Bewket, R. Lal, "*Recent spatiotemporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia*". International Journal of Climatology, Vol. 34, No.7, pp. 2278-2292, 2014.

[42] A. Alemayehu, W. Bewket, "*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*", Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[43] G. Eshetu, T. Johansson, W. Garedew, "*Rainfall trend and variability analysis in Setema-Gatira area of Jimma, Southwestern Ethiopia*", African Journal of Agricultural Research, Vol.11, No 32, pp. 3037-3045, 2016.

[44] M. Gedefaw, D. Yan, H. Wang, T. Qin, , A. Girma, A. Abiyu, D. Batsuren, "*Innovative Trend Analysis of Annual and Seasonal Rainfall Variability in Amhara Regional State, Ethiopia*" Atmosphere, Vol.9 No. 9, pp. 326, 2018.

[45] M. Taye, F. Zewdu, "*Spatio-temporal variability and trend of rainfall and temperature in Western Amhara, Ethiopia: a GIS approach*", Glo Adv Res J Geogr Reg Plann. Vol. 1, No.4, pp.65–82, 2012.

[46] A. Alemayehu, W. Bewket, "*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*", Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[47] G. Tesso, B. Emana, M. Ketema, "*A time series analysis of climate variability and its impacts on food production in North Shewa zone in Ethiopia*", African Crop Science Journal, Vol. 20, No.2, 261-274, 2012.

[48] D. Mengistu, W.Bewket, R. Lal, "*Recent spatiotemporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia*". International Journal of Climatology, Vol. 34, No.7, pp. 2278-2292, 2014.

[49] D. Mengistu, W.Bewket, R. Lal, "*Recent spatiotemporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia*". International Journal of Climatology, Vol. 34, No.7, pp. 2278-2292, 2014.

[50] A. Alemayehu, W. Bewket, "*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*", Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[51] G. Eshetu, T. Johansson, W. Garedew, "*Rainfall trend and variability analysis in Setema-Gatira area of Jimma, Southwestern Ethiopia*", African Journal of Agricultural Research, Vol.11, No 32, pp. 3037-3045, 2016.

[52] M. Gedefaw, D. Yan, H. Wang, T. Qin, A. Girma, A. Abiyu, D. Batsuren, "*Innovative Trend Analysis of Annual and Seasonal Rainfall Variability in Amhara Regional State, Ethiopia*" Atmosphere, Vol.9 No. 9, pp. 326, 2018.

[53] A. Alemayehu, W. Bewket, "*Local spatiotemporal variability and trends in rainfall and temperature in the central highlands of Ethiopia*", Geografiska Annaler: Series A, Physical Geography, Vol. 99 No.2, pp. 85-101, 2017.

[54] W. Bewket, D. Conway, "*A note on the temporal and spatial variability of rainfall in the drought- prone Amhara region of Ethiopia*", International Journal of Climatology: A Journal of the Royal Meteorological Society, Vol. 27 No. 11, pp. 1467-1477, 2007.

[55] D. Ayalew, K. Tesfaye, G. Mamo, B. Yitaferu, W. Bayu, "*Variability of rainfall and its current trend in Amhara region, Ethiopia*", African Journal of Agricultural Research, Vol. 7, No. 10, pp. 1475-1486, 2012.

AUTHORS PROFILE

Mrs. **Meseret Zewdu** is currently a PhD candidate in Environment and Development at College of Development Studies, Addis Ababa University. Her area of research interest is on Gender, climate change, and natural resource management. She has 2 years teaching experience in University of Gondar, North-west Ethiopia

Dr. **Belay Simane** is an associate Professor of Environment and Development Studies at Addis Ababa University (AAU). He served in different institutions: head of the Centre for Environment and Development at college of Development studies, AAU, Director of Research Centre of Haremaya University and Research Advisor of the Sida/ANRS Rural Development Project. He has published extensively in reputable journals in areas related to climate change, environmental management, rural development, agronomy, and crop physiology. He is an associate editor of Journal of Natural Sciences and Journal of Crop Sciences. He is actively participating in local, regional and national scientific and development programs.