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Spatio-Temporal Trends and Variability of Temperature Over Bale Zone, Ethiopia

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***Abstract:** Understanding of temperature trends and their spatiotemporal variability has great significances on making deep insight for planners, managers, professionals and decision makers of water resources and agriculture. Therefore, this research was set with aim to analyze spatiotemporal variability of temperature and their time series trends over Bale Zone. Statistical analysis: Parametric test with regression analysis on the anomalies like deviation from mean and Non-parametric test with Mann-Kendall test together with Sen's Slope Estimator & Zs statistics has been used for estimation of trends of a historical data series of monthly, seasonal and annually maximum and minimum temperature of selected meteorological stations in Bale Zone. Both tests relatively shows same results for monthly, seasonal and yearly temperature series. The coefficient of variation (CV) was used for variability analysis. Arc GIS 9.3 software was also used to investigate the spatial variability temperature (minimum and maximum) for the period under review. These methodology has shown a significant increasing and decreasing trends at 95% confidence level for certain time scale temperature series: temperature trends (i.e the mean maximum temperature series) showed a significant increasing trend in Robe (Annual, Spring, February, March, April, May, July, and October), Ginir (February, July, September, and December).Mean minimum temperature series showed a substantial increasing trend in Robe (May, July, September, and November) and Hunte (September). It is also observed that Mean seasonal and annually minimum temperature of the stations have shown higher variability than those mean seasonal and annual maximum temperature of the stations.*

***Keywords:** Bale Zone, Trends, temperature, Sen's Slope Estimator & coefficient of variation*

I. INTRODUCTION

A. *General*

Water resources are the most important resources that are the basis for survival and advancement of humanity. Wise use of these resources is important for continuity of living on earth, which embrace both quantities as well as quality. Climate change has major role in the decline of the water resources.

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Climate change commonly means any alteration in climate over the time initiated by naturally or anthropogenic response. In another word, climate change means the changing of climatic or meteorological parameters viz. precipitation, maximum temperature, minimum temperature etc. These meteorological parameters are the variables regularly measured around world's weather station on daily time scale. These are helpful to understanding and predicting weather and climate changes. According to recent report released by Intergovernmental panel on climate change (IPCC), the earth's temperature has increased by 0.74° C between 1906 and 2005 [1]. There is also a global trend for increased occurrence of droughts, as well as heavy rainfall events over the world. Cold days, cold nights and frost have become less common, while hot days, hot nights and heat waves have become more frequent. The IPCC has predicted that the temperature rise by the end of this century is likely to be in the range 1.5 to 4.0 °C. It is also likely that in future tropical cyclones will become stronger, with larger highest wind speeds and heavy rainfall.

Among the challenges posed by climate variability is ascertainment, identification, and quantification of trends in temperature and its implications on river flows in order to support in the formulation of adaptation measures through suitable strategies for water resources management [2]. For effective water resources planning, designing and management, trend analysis is the most important tool all over the world. Among main climatic variables Temperature affect both the spatial and temporal configurations of river water availability and agricultural production. Analysis of Temperature trends has the major parts of concentration to study its variability over the period. Investigating the long-term trends of temperature is important and necessary in studying long-term impacts upon the environment of an area for water resources project implementation starting from planning to construction [3]. Therefore, such studies provide important finding for water resources planner, designer, managers and other stakeholders.

Sen's slope, Mann-Kendall (MK) and Regression Analysis are the most commonly used statistical tests to identify trend and examine the consequence of trends in the climatic components.

Regression analysis is a parametric test conducted with temperature as the dependent variable and time as the independent variable. Regression analysis can be examined directly on the time sequence or on the anomalies (i.e. deviation from the mean).

Mann-Kendall (MK) test is a non-parametric test, broadly used for the investigation of the trend in climatologic [4] and in hydrologic time sequences [5].

Sen's slope estimation which used to determine the magnitude of the trend can complete non-parametric model such as Mann-Kendal (MK) test which determine the statistical significance trend of the variables.

These tests have the following two advantages: First, it is a non-parametric test and does not necessitate the data to be normally distributed. Second, the test has low sensitivity to unexpected breaks due to inhomogeneous time sequences [6].

Variablity and distribution of climatic elements can be analysed by the help of the coefficient of Variation and Spatial analysis tools in Arc GIS (Arc Geographical Information System) software respectively.The IDW (Inverse Distance Weighted) is spatial analysis tool in Arc GIS software, which is used to show the spatial pattern of temperature.

B. *Problem Statement*

In the past century analysis of temperature trends and variability on the basis of spatial and temporal time scale get great attention by researcher and other stakeholders due to global climate change [7].Among important requirements in climate change researches Analyzing and discovering historical changes in the climatic system is the major one [8]. The rising of world mean temperature has greater concern from communities working on climate change. However, climate fluctuates significantly on a provincial scale, can be predominantly damaging the availability of water and cause drought and flooding [1]. Since the livelihood of rural community relies on rain fed agriculture, any minor changes in temperature impose a severe challenge. Developing countries, such as Ethiopia is more susceptible to climate change due to less flexibility to regulate the economic structure and is mainly reliant on on rain fed farming.

Bale Zone the second largest zone in Oromia National Regional State practice an intensive rain-fed agricultural and as part of the world, it is affected by climatic variability which in turn has a great effect on agricultural productivity and hydrological responses. The climate highly varies both spatially and temporally. It is the immediate past that due to El Nino affect significant numbers of people were exposed to an agricultural drought. For such situation analyzing of the past observed data plays a central role to make the high flexible economic structure and to tackle such extreme events. Thus with the above rationale, this study will be conducted to analyze spatiotemporal variability of temperature and their trends using observed climate data from stations located in Bale Zone.

C. *Objective of the Study*

1) *General Objective*

The general aim of this research is to analyze spatiotemporal variability of temperature and their time series trends in Bale Zone.

2) *Specific Objective*

- To determine the spatio-temporal variability of temperature using Coefficient of Variation and spatial analysis tools in Arc GIS software.
- To ascertain trends and trend impact in temperature for the period under research using Regression analysis and Mann-Kendall and Sen's Slope.

To address study objectives, the research questions are:-

- How annually, seasonally and monthly temperature varies over space?
- How annually, seasonally and monthly temperature varies over a period of time?

II. METHODS AND METHODOLOGY

A. *Research Area description*

Bale Zone is the second largest zone among 17 Zones of the Oromia National Regional State. It is found 430 km far from capital city Addis Ababa and it falls between 5^0 11'03''N – 8^0 9' 27''N latitudes and $38^0$12'04''E – $42^0$12'47''E E longitudes having a total topographical area of 63,555 km^2. Bale Zone characterized by a wide variety of demographic and scopes. It shares about 17.50 % of the total land area of Oromia National Regional States (363,156 km2). Greater than 95 percent of the Zonal inhabitants depends on farming and 88% live in countryside.

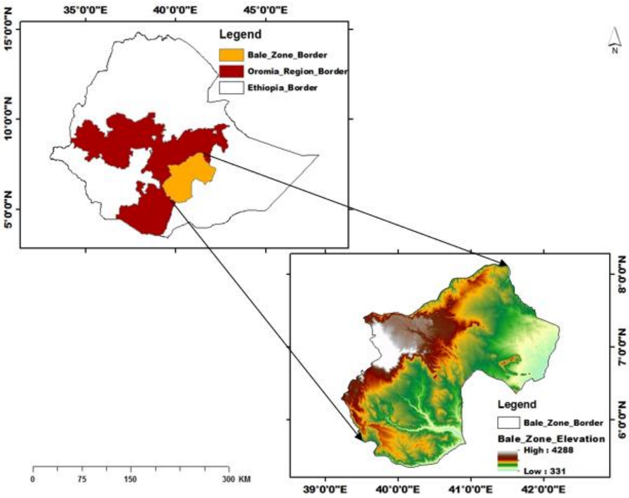

Fig.1 Research area map

B. *Availability of data*

Daily data of temperature (maximum and minimum) of four meteorological stations represent the weather pattern of the study area and fulfil the minimum criteria for climate change analysis were used as input data for purpose of spatiotemporal variability analysis. The daily data of aforementioned weather parameters for the period ranging from 1986-2015 were provided by the National Meteorological Agency (NMA), Addis Ababa, Ethiopia.

C. *Methodology*

1) *Statistical test analysis of trend*

Trend analysis of a time series consists of the magnitude of trend and its statistical significance. In general, the magnitude of a trend in a time series is determined either using regression analysis (parametric test) or using Sen's estimator method (non-parametric test) [9]. Both these tests assume a linear trend in the time series.

a) Parametric test

Regression analysis is accompanied with minimum and maximum temperature as the dependent variable and time as the independent variable.

Analysis of regression can be conducted directly on the time series or on the anomalies (i.e. deviation from the mean). In this study, anomalies (deviation from the mean) was used to determine the regression analysis.

b) Non- parametric test

Mann-Kendall (MK) test is the most frequently used non-parametric test for identifying trends in hydrologic variables. It is usually employed to distinguish monotonic trends in series of environmental data, climate data or hydrological data.
However, if autocorrelation exists in the data series the results of the test may contain an error. Pre-whitening procedure is performed to eliminate the autocorrelation in the time series to avoid such problem. If the autocorrelation is statistically significant and coefficient of autocorrelation is r then Mann-Kendall test is applied on "pre-whitened" series found as (x2 − rx1, x3 − rx2. . . xn − rxn − 1) where x1 , x2 , x3…xn represents data points of the series [13], [14].

$$R = \frac{\left(\frac{1}{n}-1\right)\sum_{t=1}^{n-1}\left[x_t - \overline{x_t}\right]\left[x_{t+1} - \overline{x_t}\right]}{\left(\frac{1}{n}\right)\sum_{t=1}^{n}\left[x_t - \overline{x}\right]^2} \quad (1)$$

Where:-

$$\frac{\{-1-1.645\sqrt{n-2}\}}{n-1} \le R \le \frac{\{-1+1.645\sqrt{n-2}\}}{n-1} \quad (2)$$

The statistical significance trend distinguished using Mann-Kendal (MK) test can be supplemented with Sen's slope estimation to determine the level of the trend.

For the analysis of the trend in climatologic and hydrologic time series Mann-Kendall test is a statistical test widely used methods [4], [5].
The significance of the trend is obtained using the Z test, where Z represents the standardized Z test statistic [10], and Var(S) is variance that can be approximated by (3) [11],[12].

$$Var_s = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k (t_k - 1)(2t_k + 5)}{18} \quad (3)$$

N represents sample size and k is number of tied groups

Sen's Slope Estimator Test:

Used to estimate the magnitude of the trend in the time series.

Here, the Slope (Ti) of all data pairs is calculated by (4) [9]

$$T_i = \frac{x_j - x_k}{j-k} \quad (4)$$

Where, X_j and X_k represent data values at time j and k (j>k) respectively for i=1, 2, 3…..N.

In this research, Regression analysis and Non-parametric method and daily temperature (minimum and maximum) records from weather stations of Bale Zone for the period ranging from 1986-2015 were adopted for analysis of temperature trend on the annual, seasonal and monthly timescale.

2) Statistical variability analysis (Coefficient of Variation)

In the present research, the coefficient of variation with spatial interpolation technique was employed to analyze the spatiotemporal variability temperature (minimum and maximum).

3) Spatial analysis tools

IDW (Inverse Distance Weighted) technique in Arc GIS software used to examine spatial pattern of minimum and maximum temperature.

III. RESULTS AND DISCUSSION

A. *Selected meteorological stations in Bale Zone*

To analyze spatial-temporal trends and variability of temperature over Bale Zone, four stations were used (Table -I).

Table-I: Selected meteorological stations in Bale Zone

Name of the station	Lat. (deg.)	Long. (deg)	Elev.(m)
Dinisho	7.10	39.77	3072
Ginir	7.13	40.70	1750
Hunte	7.05	39.40	2380
Robe	7.13	40.05	2480

B. *Minimum and Maximum Temperature Characteristics of Meteorological Stations in Bale Zone*

In this research, the spatio- temporal variability of minimum & maximum temperature over Bale Zone were analyzed using four meteorological stations found in the Bale Zone these are Dinisho, Ginir, Hunte, and Robe. In monthly scale scenario, in the month of February, Ginir meteorological station has experienced the peak mean monthly maximum temperature, 26.2 °C with standard deviation, 0.7 °C and coefficient of variation, 5.2 % and in the month of January Dinisho meteorological station has observed the lowest mean monthly minimum temperature of (2.0 °C) with standard deviation, 1.5 °C and coefficient of variation, 75.6 %. The mean annual minimum temperature of aforesaid stations are 3.76, 13.31, 6.61 and 8.18 °C which has standard deviation of 0.52, 0.29, 0.98 and 0.57 °C respectively. The coefficient of variation is 13.87 %, 2.19 %, 14.76 %, and 7.00 % respectively, these indicate slightly to the moderate variability of station's yearly minimum temperature. The mean annual maximum temperature of the stations are 17.22, 24.24, 23.96 and 21.89 °C which has standard deviation of 0.60, 0.50, 0.47 and 0.38 °C respectively. The coefficient of variation of the annual maximum temperature of aforementioned meteorological stations are 3.50 %, 2.08 %, 1.96 %, and 1.74 % respectively, these show the stations annual maximum temperature has less variability. Whereas lowest mean seasonal minimum temperature is observed in Dinisho meteorological station (2.33 °C) in the winter season and peak mean seasonal maximum temperature is observed in Hunte meteorological station (25.35 °C) in the spring season.

C. *Spatio-temporal Variability of Mean Annual and Seasonal Minimum and Maximum Temperature over Bale Zone*

Spatial Variations: Maps in Fig.2, Fig.3 and Fig.4 (a & b), shows the spatial variability of mean yearly and seasonal minimum and maximum temperature over Bale Zone. Somewhat similar spatial variability pattern of minimum temperature is observed in annual time series with the winter, autumn and spring seasons, having certain magnitude difference at their lower and upper limit temperature. The lowest mean annual, spring, autumn and winter minimum temperature is observed in Northwest parts of the Zone such as Kokosa, Dodola, Adaba, Nenesebo, Northwest Arena Buluk, West Goba, West Sinana Dinisho and most parts of Agarfa. The highest of minimum temperature is observed in Southeast Gololcha, West Seweyna, Northeast Goro and Northwest Rayitu and most parts of Ginir. In the summer season, the minima of minimum temperature are observed in East Adaba, West Sinana Dinisho, Northwest of Goba, Southwest, and Northwest of Agarfa with the magnitude of 4.64-7.33 ^{o}C (Fig.3c) with a coefficient of variation shown in Fig.3d. The maxima are observed in the same parts of the Zone with other seasons with the magnitude of 11.32-13.21^{o}C (Fig.3c), the coefficient of variation shown in Fig.3d.

Relatively, similar spatial variability pattern of maximum temperature is observed in the yearly, autumn and summer time series with certain magnitude difference in their lower and upper limit temperature (Fig.2c, Fig.5c, and Fig.6a). The highest maximum temperature is experienced in Southeast Gololcha, West Seweyna, Northeast Goro, Northwest Rayitu and most parts of Ginir for both seasons i.e. summer and autumn (Fig.2c, Fig.5c, and Fig.6a) with a coefficient of variation shown in Fig.2d, Fig.5d, and Fig.6b respectively. The lowest temperatures are experienced in West Sinana Dinisho, Southeast Agarfa, Northwest Goba and East Adaba (Fig.5c and Fig.6a) with a coefficient of variation shown in Fig.2d, Fig.5d, and Fig.6b. For spring the hottest maximum temperature is seen in West Adaba, Northeast Dodola, Northwest Goro, Southeast Seweyna, Northwest Rayitu and most parts of Ginir and the coolest maximum temperature is observed West Sinana Dinisho, Northwest Goba, East Adaba and most parts of Agarfa (Fig.5a). In winter season the lowest maximum temperature happens in west Sinana Dinisho, East Adaba and Southwest Agarfa and the highest maximum temperature happen in the same place with other seasons (Fig.6c).

Temporal Variations: the temporal classification of year wise maximum and minimum temperature distribution of the stations. Dinisho meteorological station, during the year of 1991 has received minima of minimum temperature with the magnitude of 2.83 ^{o}C, while during the year of 2006 the station has experienced the maxima of minimum temperature with the amount of 4.84 ^{o}C. During the remaining years, the station has received minimum temperature ranges between 3.17-4.65 ^{o}C. During the year of 1993, Dinisho meteorological station has received the maxima of maximum temperature with the magnitude of 18.63 ^{o}C, while during the year of 1986, the station has received minima of maximum temperature with the temperature of 16.10^{o}C. At Ginir meteorological station, during the year of 1995, the station has observed minima of minimum temperature with magnitude of 12.70 ^{o}C. whereas during the year of 1996 the station has experienced maxima of minimum temperature with value of 13.87 ^{o}C. During 1987, Ginir meteorological station has received the maxima of maximum temperature with magnitude of 24.98^{o} C. during the year of 1995, the station has observed the minima temperature of maximum temperature with magnitude of 23.28^{o} C.

Likewise at Robe meteorological station, during the year of 1985, the station has observed minima of minimum temperature with magnitude of 7.31 ^{o}C. whereas during the year of 2010 the station has experienced maxima of minimum temperature with value of 9.01^{o} C. During 2009, the station has received the maxima of maximum temperature with magnitude of 22.53^{o} C. during the year of 1985, the station has observed the minima of maximum temperature with magnitude of 21.21 ^{o}C. At Hunte meteorological station, during the year of 2010, the station has observed minima of minimum temperature with magnitude of 3.38 ^{o}C. whereas during the year of 1997 the station has experienced maxima of minimum temperature with value of 8.12^{o} C. During 2011, the station has received the maxima of maximum temperature with magnitude of 25.04^{o} C. during the year of 1992, the station has observed the minima of maximum temperature with magnitude of 23.07^{o} C.

D. *Mean Annual and Seasonal Minimum and Maximum Temperature Variability over Bale Zone*

It is observed that the mean annual minimum temperature ranges 3.76-13.31^{o} C as shown in Fig.2a, with a coefficient of variation 3-7 percent (Fig.2b). The highest variability of annual minimum temperature is observed in West Sinana Dinisho, East Adaba, Northwest Goba and most parts of Agarfa and the lowest variability is experienced in South Gololcha, Northeast Goro, Northwest Rayitu, Southwest Seweyna and most parts of Ginir. Mean annual maximum temperature varies from 17.23 to 24.24^{o}C as shown in (Fig.2c) with a coefficient of variation 1.74-3.50 % (Fig.2d). The highest variability of annual maximum temperature is observed in West Sinana Dinisho, South Agarfa and some parts of east Adaba. The lowest variability is experienced in South Gololcha, North Goro, Northwest Rayitu, Southwest Seweyna, South Gasera, Northeast Goba, Northeast Dodola, Northwest Adaba, East Sinana Dinisho and most parts of Ginir.

Seasonal scenario, Mean spring minimum temperature ranges between 4.41-14.22 ^{o}C (Fig.3a) with a coefficient of variation 4.32-18.90 percent (Fig. 5-3b). Mean summer minimum temperature ranges between 4.645-13.21 ^{o}C (Fig.3c) with a coefficient of variation 2.69-11.82 percent (Fig.3d).

Mean autumn minimum temperature ranges between 3.724-13.08 ^{o}C (Fig.3a) with a coefficient of variation 3.65-19.05 % (Fig.3b). Mean winter minimum temperature ranges between 2.33-12.7^{o}C (Fig.3c) with a coefficient of variation 5.30-47.40% (Fig.3d). In the entire seasons, the highest variability of minimum temperature is observed in Northwest parts of the Zone and the lowest in South Gololcha, Southwest Seweyna, Northeast Goro, and Northwest Rayitu and in most parts of Ginir.

Mean spring maximum temperature varies 17.69-25.35 °C (Fig.5a) with coefficient of variation 3.2-4.77% % (Fig.5b). Mean summer maximum temperature varies 17.34-23.87 °C (Fig.5c) with a coefficient of variation 2.18-3.52 %(Fig.5d). Mean autumn maximum temperature varies 16.36-23.59 ° C (Fig.6a) with a coefficient of variation 2.65-5.68 %(Fig.6b), and mean winter maximum temperature varies 17.51-25.01 ° C (Fig.6c) with a coefficient of variation 2.85-5.66% (Fig.6d). The place where the highest and the lowest variability of maximum temperature is observed for the entire seasons are shown in Fig.5 and Fig.6 (a-d). In general average seasonal and annual minimum temperature of the stations i.e. Ginir, Hunte, Dinisho, and Robe, have shown higher variability than those mean yearly and seasonal maximum temperature of the stations.

E. *Parametric and non-parametric trend analysis of mean annual, seasonal and monthly maximum & minimum temperature of meteorological stations in Bale Zone*

In this study, non-parametric and parametric trend analysis of minimum and maximum temperature of historical data series on the annual, seasonal and monthly scale of the stations in Bale Zone were also analyzed. The Sen's slope of maximum and minimum temperature indicated increasing, decreasing and no change level of slope in correspondence with the MK test values as Z statistics indicates the non-significance or significance of the current trend at 95 % confidence interval. Certain months indicate increasing trend & Z value of increasing slope, whereas some months shows decreasing or negative Sen's Slope and Z value and certain months, with no change in the Sen's Slope.

At Dinisho meteorological station the Sen's slope, the Mann-Kendall test of average monthly maximum temperature series for 26 years revealed that months of April, May, June, and August show no change in their magnitudes, this means no trends. In the remaining months, in spite of certain increasing and decreasing trends, none of the months has observed the significant trend and relatively analogous results were seen for both non-parametric and parametric tests as shown in Table-II.

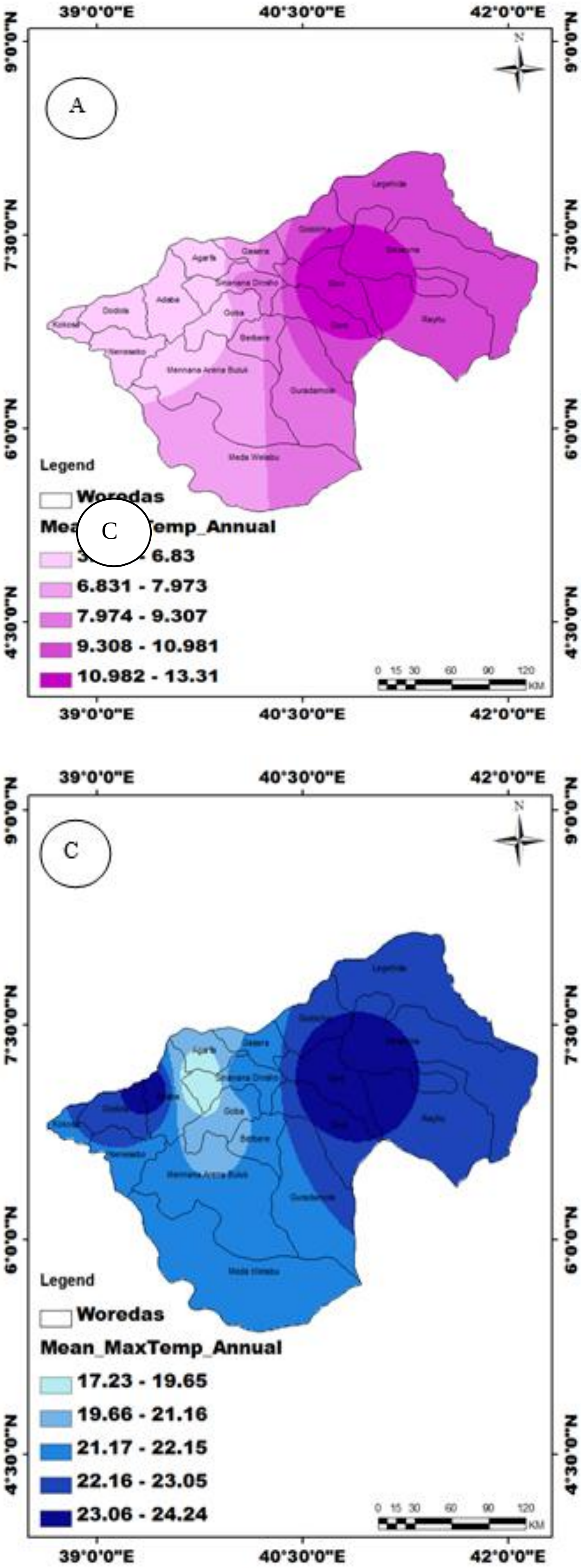

Fig.2(a-d): Bale Zone mean annual maximum and minimum temperature spatial variability

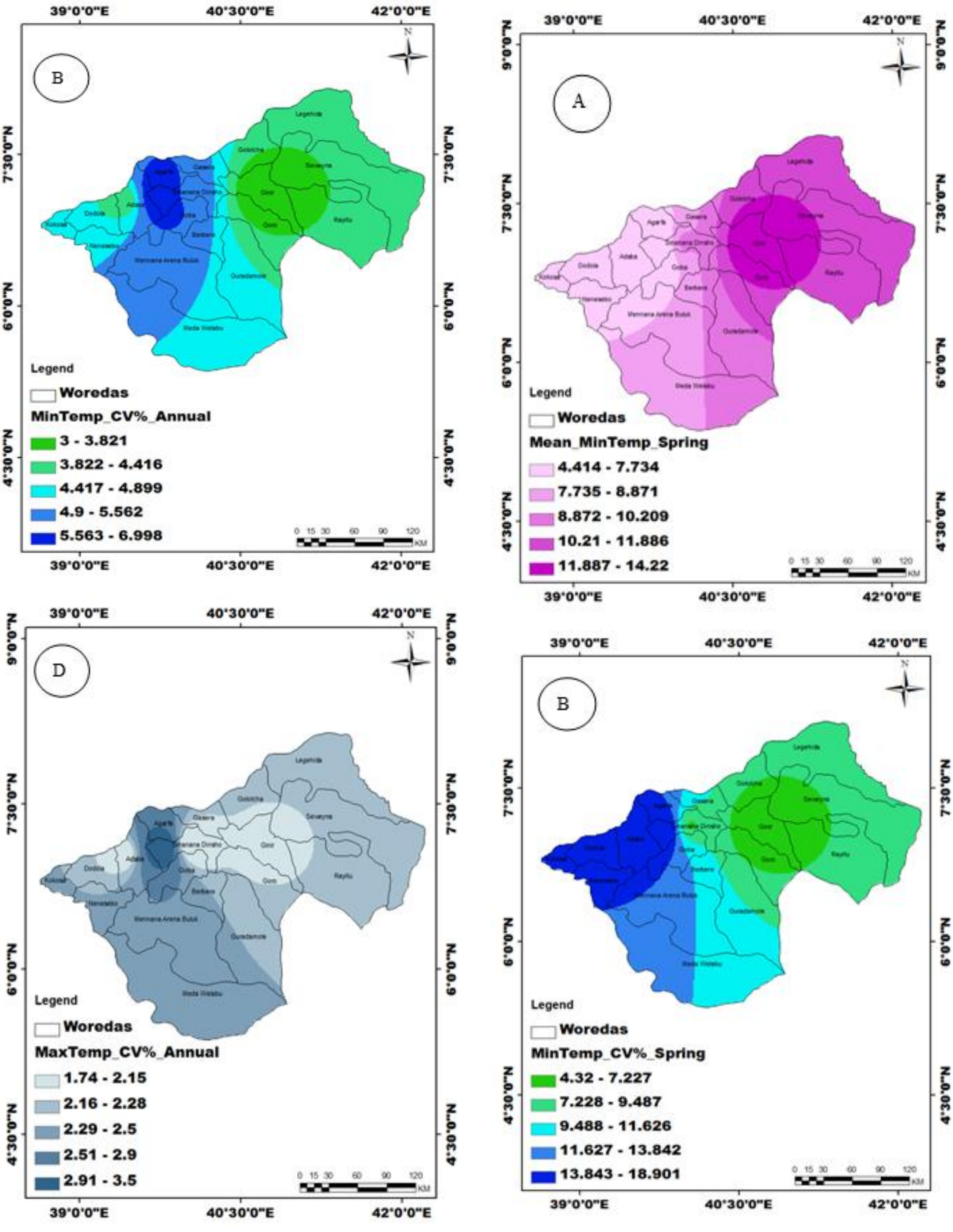

Fig.3 (a-d): Bale Zone mean spring & summer minimum temperature spatial variability

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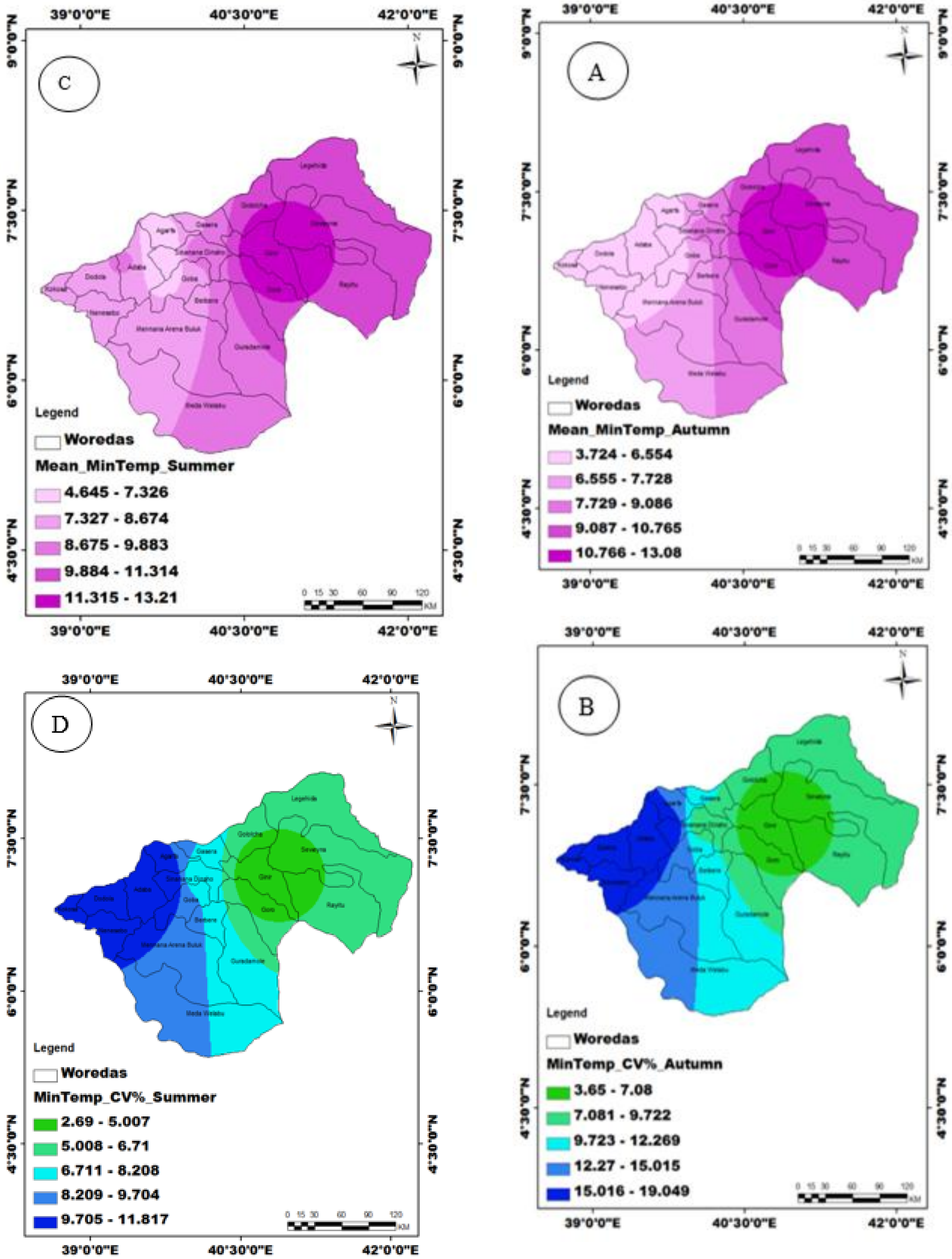


Fig.4(a-d): Bale Zone mean autumn & winter minimum temperature spatial variability

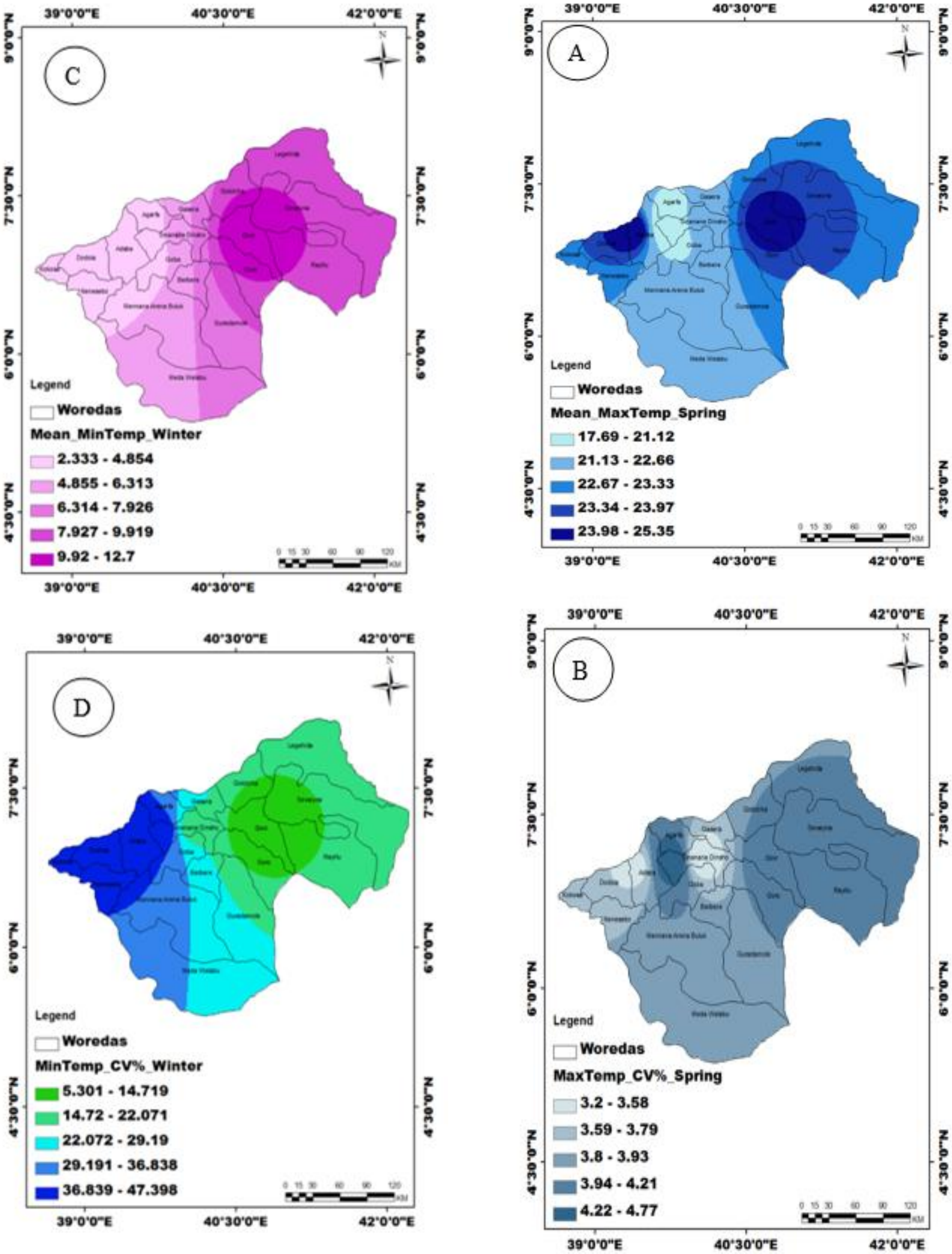


Fig.5 (a-d): Bale Zone mean spring & summer maximum temperature spatial variability

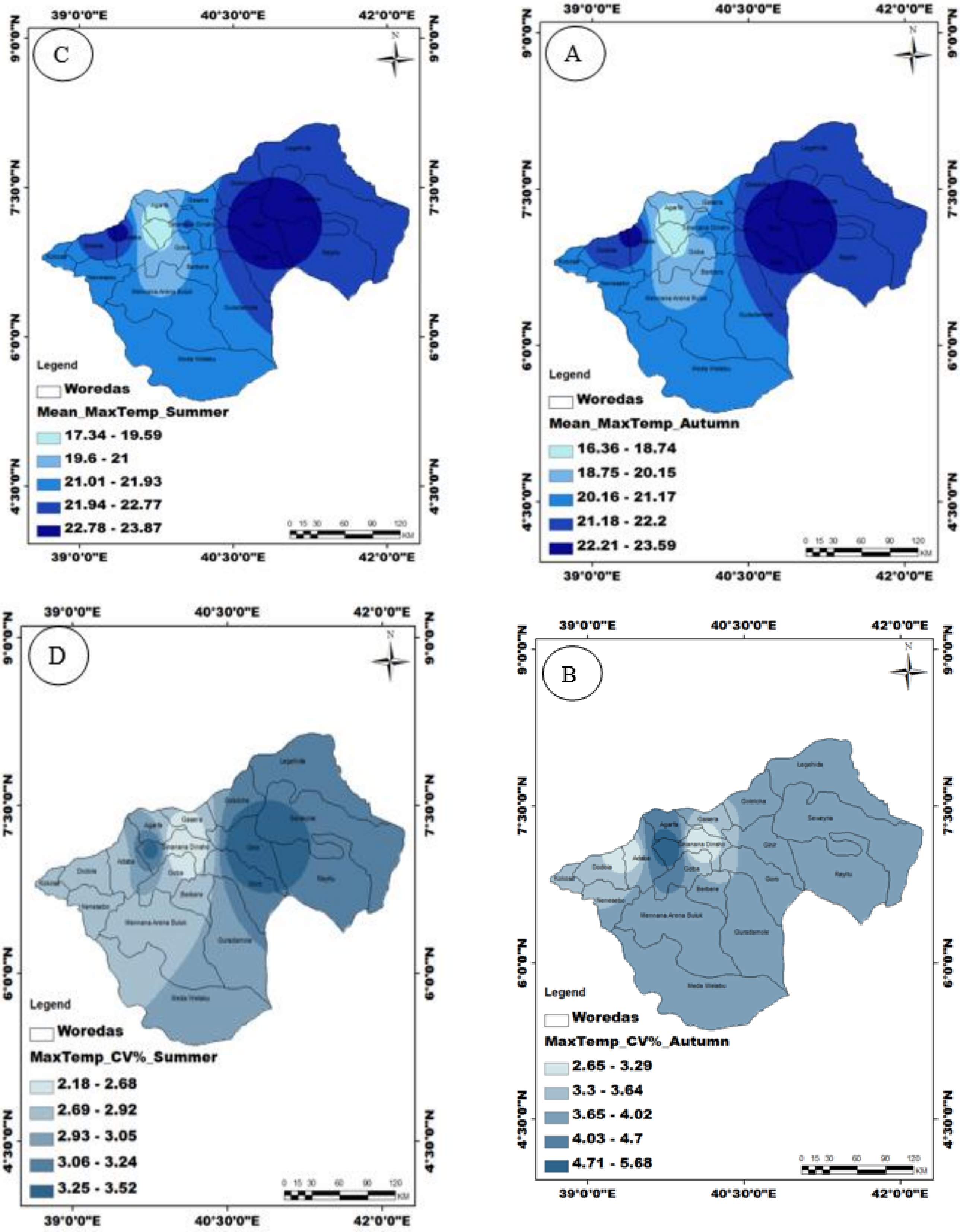
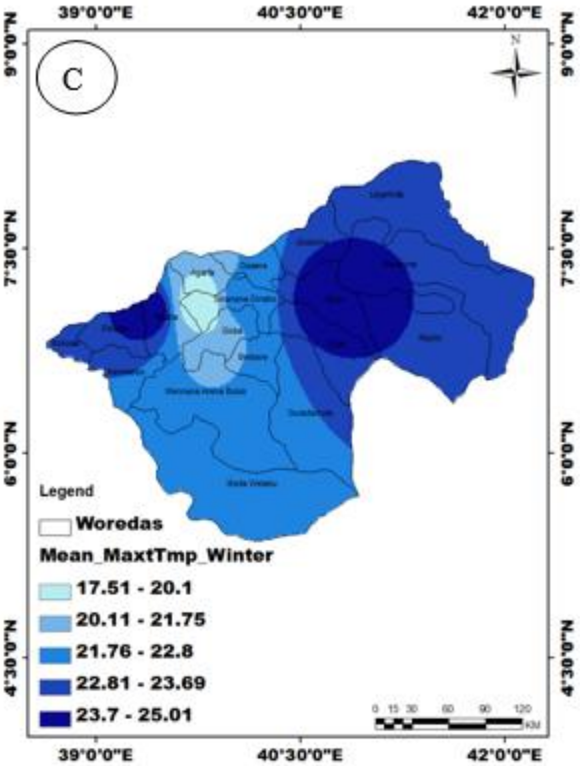
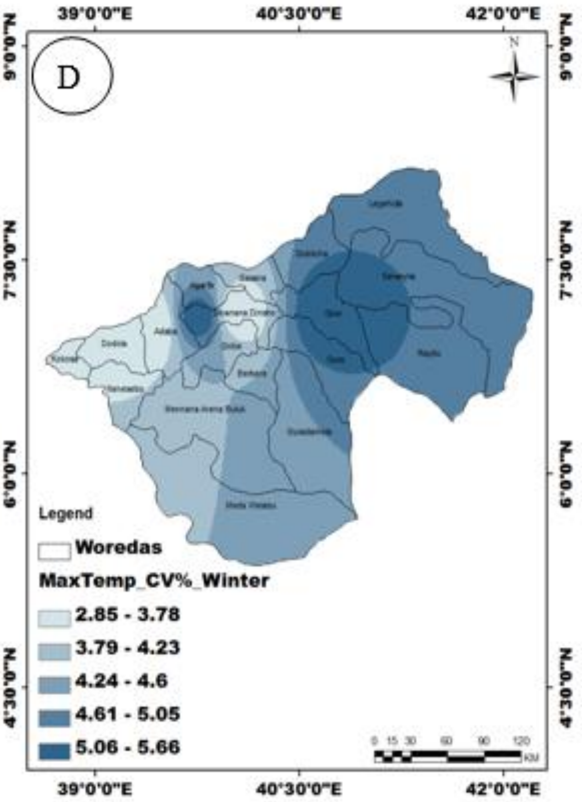


Fig.6 (a-d): Bale Zone mean autumn & winter maximum temperature spatial variability





Likewise, nonparametric test, the Sen's slope of average monthly minimum temperature indicated that months of December, November, May, April and February show no change in their values. While months like January, March, June, July, August, September & October experienced growing trend although a non-significant one. In addition, similar results were seen for both non-parametric and parametric tests as shown in Table-II.

At Ginir meteorological station the Sen's slope of maximum temperature series for 29 years has been estimated for 12 months presenting an increasing trend in the whole months (January to December). While months like December, September, July & February show a statistically significant increasing trend with a Sen's slope amount of 0.05, 0.03, 0.05 and 0.05 ^{o} C/year respectively. These results have a minor deviation from the parametric test results which are 0.07, 0.05, 0.03 and 0.03 °C/year respectively. Similarly, the Sen's slope value of minimum temperature is showing a negative trend at months of January (-0.02 ^{o} C per year), February (-0.02 ^{o}C per year), July (-0.01 ^{o}C per year) and December (-0.01 ^{o}C per year). While Sen's slope values for remaining months show a positive trend, however, none of the positive or negative trends showed a significant trend. The parametric test results, the regression slope of maximum temperature of Ginir meteorological station show increasing trends in the entire months except for decreasing trend in May(-0.01 ^{o}C per year). Likewise, regression slope of the minimum temperature of the station indicates increasing trends in April, May, June, September, and October and decreasing trend in the months of December, July, February & January. Months like November, August and March did not shows change in regression Slopes.

Table-II shows Sen's Slope of maximum temperature of Hunte meteorological station for months of January to December for 29 years. Except months of January and December among 12 months other months are showing either decreasing or increasing trend although a non-significant trend. Whereas the Sen's slope of minimum temperature of the station revealed trend of 0.07,-0.05, -0.03, 0.00, 0.01, 0.00, 0.00, 0.00, 0.06, -0.01, 0.02 and -0.02 ^{o} C/year for consecutive months of 29 years. For months like January, May, September, and November there is an indication of increasing trend whereas the significant increasing trend is experienced in September month (0.06 ^{o} C/year). Moreover, Sen's slope value is presenting a negative trend in December, October, March and February. In addition, the parametric test results of mean monthly minimum and maximum temperature of Hunte meteorological station are shown in Table-II and some increasing and decreasing regression slope magnitudes of the monthly time scale of minimum and maximum temperature of the station were seen.

At Robe meteorological station non-parametric test, the Sen's slope of maximum temperature indicated the trend of the series of 29 years for the 12 months. The entire months are presenting positive trend, while months like February, March, April, May, July & October are illustrating significant positive trend at Z value with Sen's slope magnitude, 0.04, 0.07, 0.04, 0.03, 0.03 0.06 ^{o} C/ year respectively and these results are relatively identical with parametric test, regression slope, 0.04, 0.07, 0.04, 0.03, 0.02 and 0.06 ^{o} C/ year respectively.

Whereas Sen's slope of minimum temperature revealed the trend of 29 years for every month. Entire months (January to December) showed increasing trend while months like November, September, July & May experienced significant increasing trend with Sen's slope magnitude, 0.06, 0.07, 0.06 and 0.06 ^{o}C/year respectively. The non-parametric test result showed the certain difference with a parametric test result of regression slope, 0.040, 0.030, 0.020 and 0.030 ^{o}C per year correspondingly. These results concise with the IPCC report [1] which states an increase in temperature because of increased radiative forcing, anthropogenic activity, and urbanization.

The Mann-Kendall Z-statistic and Parametric test results of the average seasonal and annual maximum and minimum temperature of entire meteorological stations are shown in Table-III. The average annual maximum temperature of Dinisho, Ginir, and Hunte meteorological stations observed increasing trends with Sen's slope magnitude of 0.002, 0.023 & 0.019 °C per year respectively, while the annual average maximum temperature of Robe station shows a statistically significant increasing trend as its Sen's slope value 0.03 °C per year.

Sen's slope of average spring, autumn and winter season's maximum temperature of Dinisho, Ginir, Hunte, and Robe meteorological stations revealed an increasing trend. Whereas, in the spring season, Robe meteorological station has experienced statistically significant growing trend with Sen's slope value of 0.056 °C per year. During summer season, Ginir, Hunte, and Robe meteorological stations have observed an increasing trend, with Sen's slope magnitude of 0.035, 0.04 and 0.022 °C/year although the non-significant one and decreasing trend in Dinisho meteorological station with Sen's slope value of -0.003 °C per year.

Sen's slope of average annual minimum temperature shows no change in Ginir station and an increasing trend in Dinisho, Hunte and Robe meteorological stations. Average autumn minimum temperature show an increasing trend in Dinisho, Ginir, Hunte and Robe meteorological stations with Sen's slope magnitude of 0.023, 0.02, 0.029 and 0.056 mm/year respectively. Whereas Sen's slope value of winter and summer seasons have experienced increasing trend at Dinisho & Robe stations and decreasing trend at Ginir and Hunte stations. Spring season shows decreasing trend at Hunte station and increasing trend at Dinisho, Hunte, and Robe stations. Table-III shows the corresponding Sen's slope.

Moreover, the parametric test results of mean seasonal and annual, minimum and maximum temperature of entire meteorological stations are shown in Table-III, an increasing and a decreasing regression slope magnitudes were observed.

IV. CONCLUSION AND RECOMMENDATIONS

These study have analyzed the behavior of annual, seasonal and monthly series of temperature of the selected stations over Bale Zone. Two techniques have been used to identify significant trends in temperature series: Parametric test which is regression analysis on the anomalies (i.e. deviation from mean) and Non-parametric test with Mann-Kendall test together with Sen's Slope Estimator and Zs statistics which shows the same results for annual, seasonal and monthly temperature series. Variability analysis was conducted using coefficient of variation (CV) and spatial variability was investigated by Arc GIS 9.3 software.

The results of mean maximum temperature trends showed a significant increasing trend at Robe (Annual, Spring, October, July, May, April, March and February), Ginir (February, July, September & December). Mean minimum temperature sequences indicated a significant increasing trend at Robe (May, July, September, and November) and Hunte (September). Mean annual and seasonal minimum temperature of the stations have shown higher variability than those mean annual and seasonal maximum temperature of the stations. Therefore, government office and other stakeholders working on the area of agriculture and water resource should use the result of this research for sustainability of their project to be implemented.

Finally, authors of this study would like to recommend the national and local meteorological authorities to make an effort on increasing the number of the meteorological stations in the region as well as on improving the existed meteorological stations so that adequate and reliable data can be available for the scientific community, monitor, prepare for and respond to extreme temperature event.

Table-II: Parametric test (Regression Analysis) and Non-parametric test (Sen's slope & Mann Kendall) result for mean monthly minimum & maximum temperature of meteorological stations in Bale Zone

Stations	Parameters	January	Febr.	Mar.	April	May	June	July	Augs.	Sept.	Octo.	Nove.	Dece.
TMax Dinisho (1981-2006)	Regr. Slope	-0.02	0.00	0.04	0.00	0.01	0.00	-0.02	0.00	0.02	0.01	0.01	0.02
	S	-32.00	27.00	-22.00	-7.00	11.00	9.00	-22.00	-10.00	0.00	26.00	8.00	36.00
	Z	-0.68	0.57	-0.46	-0.13	0.22	0.19	-0.49	-0.21	0.00	0.55	0.16	0.82
	Sen's Slope	-0.02	0.01	-0.01	0.000	0.000	0.000	-0.02	0.000	0.03	0.01	0.01	0.04
TMin Dinisho (1981-2006)	Regr. Slope	0.06	-0.01	0.02	0.00	0.00	0.01	0.03	0.01	0.03	0.04	0.00	0.02
	S	77.00	6.00	30.00	0.00	-1.00	46.00	74.00	33.00	67.00	78.00	-1.00	-3.00
	Z	1.68	0.11	0.64	0.00	0.00	1.00	1.61	0.71	1.46	1.80	0.00	-0.04
	Sen's Slope	0.07	0.000	0.03	0.000	0.000	0.01	0.03	0.01	0.02	0.04	0.000	0.000
TMax Ginir (1986–2013)	Regr. Slope	0.03	0.07	0.04	0.03	-0.01	0.02	0.05	0.03	0.03	0.02	0.01	0.03
	S	34.00	102.00	96.00	39.00	28.00	29.00	114.00	76.00	105.00	62.00	24.00	101.00
	Z	0.65	**2.00** [a]	1.88	0.75	0.53	0.55	**2.23** [a]	1.48	**2.06** [a]	1.21	0.45	**1.98** [a]
	Sen's Slope	0.02	0.05	0.07	0.02	0.01	0.01	0.05	0.03	0.03	0.03	0.01	0.05
TMin Ginir (1986–2013)	Regr. Slope	-0.02	-0.02	0.00	0.02	0.02	0.01	-0.02	0.00	0.01	0.01	0.00	-0.02
	S	-31.00	-57.00	37.00	27.00	74.00	35.00	-65.00	36.00	46.00	59.00	30.00	-15.00
	Z	-0.59	1.11	0.71	0.51	1.44	0.71	-1.27	0.69	0.89	1.15	0.57	-0.28
	Sen's Slope	-0.02	-0.02	0.01	0.01	0.02	0.000	-0.01	0.01	0.01	0.01	0.01	-0.01
TMax Hunte (1986-2013)	Regr. Slope	0.01	0.04	0.01	0.07	0.03	0.03	0.06	0.03	0.02	-0.02	-0.01	-0.01
	S	8.00	68.00	35.00	43.00	70.00	53.00	66.00	79.00	57.00	-16.00	-35.00	9.00
	Z	0.15	1.41	0.75	0.88	1.44	1.08	1.36	1.72	1.17	-0.31	-0.71	0.18
	Sen's Slope	0.000	0.03	0.01	0.02	0 .036	0 .020	0.03	0 .031	0.01	-0.01	-0.01	0.000
TMin Hunte (1986-2013)	Regr. Slope	-0.02	-0.07	-0.05	-0.08	-0.01	-0.05	-0.08	-0.05	0.02	-0.04	-0.02	-0.04
	S	59.00	-61.00	-27.00	4.00	10.00	13.00	-20.00	27.00	109.00	-22.00	48.00	-25.00
	Z	1.28	-1.32	-0.57	0.07	0.20	0.27	-0.42	0.58	**2.39** [a]	-0.46	1.04	-0.53
	Sen's Slope	0.07	-0.05	-0.03	0.000	0.01	0.000	0.000	0.000	0.06	-0.01	0.02	-0.02
TMax Robe (1985-2012)	Regr. Slope	0.01	0.04	0.04	0.07	0.04	0.02	0.03	0.01	0.02	0.02	0.03	0.01
	S	24.00	100.00	99.00	159.00	115.00	61.00	105.00	45.00	79.00	102.00	71.00	36.00
	Z	0.45	**1.96** [a]	1.94	**3.12** [a]	**2.25** [a]	1.19	**2.06** [a]	0.87	1.54	**2.00** [a]	1.38	0.69
	Sen's Slope	0.01	0.04	0.06	0.07	0.04	0.03	0.03	0.01	0.02	0.03	0.03	0.01
TMin Robe (1985-2012)	Regr. Slope	0.07	0.04	0.05	0.04	0.06	0.07	0.05	0.06	0.06	0.03	0.06	0.06
	S	77.00	75.00	90.00	93.00	97.00	83.00	109.00	81.00	107.00	65.00	141.00	86.00
	Z	1.58	1.46	1.76	1.92	**2.00** [a]	1.71	**2.25** [a]	1.67	**2.21** [a]	1.26	**2.77** [a]	1.68
	Sen's Slope	0.07	0.04	0.04	0.04	0.06	0.07	0.06	0.06	0.07	0.03	0.06	0.05

NB: [a] Statistically Significant trend of negative or positive sign at 0.05 level.

Table-III: Parametric test (Regression Analysis) and Non-parametric test (Sen's slope & Mann Kendall) result for mean seasonal & annual maximum &minimum temperature of meteorological stations in Bale Zone

Stations	Parameters	Spring	Summer	Autumn	Winter	Annual
TMax Dinisho (1981-2006)	Regression Slope	0.017	-0.0073	0.0128	0.00007	0.0057
	S	11	-8	-22	16	2
	Z	0.22	-0.16	-0.49	0.35	0.02
	Sen's Slope	0.005	-0.003	0.015	0.016	0.002
TMin Dinisho (1981-2006)	Regression Slope	0.0065	0.0165	0.0223	0.0182	0.0176
	S	32	58	78	56	56
	Z	0.72	1.26	1.8	1.21	1.28
	Sen's Slope	0.016	0.018	0.023	0.033	0.023
TMax Ginir (1986–2013)	Regression Slope	0.0209	0.0296	0.019	0.0211	0.0204
	S	42	84	81	73	53
	Z	0.81	1.64	1.58	1.42	1.08
	Sen's Slope	0.023	0.035	0.02	0.040	0.023
TMin Ginir (1986–2013)	Regression Slope	0.0117	-0.0037	0.0095	-0.0232	-0.0006
	S	50	-13	38	-65	2
	Z	0.97	-0.24	0.73	-1.26	0.02
	Sen's Slope	0.014	-0.002	0.007	-0.017	0
TMax Hunte (1986-2013)	Regression Slope	0.0344	0.0428	-0.0054	0.0098	0.0217
	S	79	105	5	22	80
	Z	1.63	2.17 a	0.08	0.44	1.65
	Sen's Slope	0.026	0.040	0.001	0.008	0.019
TMin Hunte (1986-2013)	Regression Slope	-0.054	-0.0609	-0.0094	-0.0463	-0.0398
	S	-32	-25	66	-39	-24
	Z	-0.72	-0.53	1.44	-0.84	-0.54
	Sen's Slope	-0.008	-0.005	0.029	-0.034	0.005
TMax Robe (1985-2012)	Regression Slope	0.0508	0.0221	0.0219	0.0274	0.0289
	S	157	90	97	98	168
	Z	3.08 a	1.76	1.9	1.92	3.3 a
	Sen's Slope	0.056	0.022	0.025	0.026	0.030
TMin Robe (1985-2012)	Regression Slope	0.0482	0.0605	0.0529	0.0425	0.0542
	S	59	73	85	87	25
	Z	1.21	1.5	1.75	1.7	0.5
	Sen's Slope	0.049	0.065	0.056	0.048	0.062

NB: [a] Statistically Significant trend of negative or positive sign at 0.05 level.

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