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ORIGINAL ARTICLE

Test of Homogeneity of Variance among Regional Climatic Variables Using Stratification Process

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Abstract:

This paper examines the homogeneity of variance among the regional climatic variables using stratified process in computing the weighted mean and variance. It also determines effects of covariance on climate change using Gaussian-seidel method . Its measure the rate of change on average regional temperature and its effects on climate change in Nigeria. Our finding indicates that there are variations in average temperature in all the regions due to temporal and spatial variation associated to weather conditions, these influence the persist increase in average regional temperature in Nigeria. The Sahel and Guinea savannah contribute more to persistence in climate change due to extreme weather conditions associated to the two regions.

Keywords: Homogeneity, variance, regions, temperature, Gaussian- seidel

1. Introduction

All climate series data are heterogeneous in nature owing to climatic variation and other geographical factors which are responsible for spatial heterogeneity on average temperature in Nigeria. Kingsley and Israel(2020) cited the research work by Peterson and Easterling (1994) argue that heterogeneous climate series may contribute to deviation in computed statistic values obtained from each region. Therefore, this paper will stratify all the regional temperatures and then obtain the statistic value for homogeneity test on regional variance.

This study tends to estimate the coefficients of autocorrelation for regional climate change using a reference sites from each region that are randomly selected using hierarchical clustering to select the samples that has similarity on persistence level. The regional data can be clustered into homogeneous series. In this process cluster analysis with k-mean method will assist to determine the distance between two or more regional climatic variables before modelling the climate factors (Ukhurebor, and., Abiodun,2017b).

We seek to determine the basic assumptions on analysis of variance on past and current observations in stratified groups with unequal sample size. These observations were sampled from a normal distribution that is identical and independent. If these observations follow the preceding assumptions, then variance of each of these strata is referred to as homogeneity of variance, under the condition that these observations are influenced by the presence of heteroscedasticity. We observe that the presence of heteroscedasticity in time series data contribute to more persistence on climate change when measuring the rate of change in temperature of a given location. It also contributes to unequal mean levels of variance on each stratum

Statement of problem

The heterogeneity of climatic variables is a major constraint in studying climate change. The climate changes are influenced by unpredictable weather conditions known as random components and other man-made factors such as lack of update of measurement tools used to read average temperature and rainfall in each regional climatic variable. These variations contribute to persistence on climate change and it makes impossible to predict the likely weather condition at a particular time. This research intends to adopt stratified techniques to discover which of the regions experiences more heterogeneity in climatic variables and how that contributes to persistence on climate change in Nigeria.

2.0 Literature review

Modelling of climate factors will help us to measure the extent to which climate variability influences climate change. In other to achieve this, it will require high level of accuracy and reliability of all the observational data to be used in determining the persistence in the climate characteristics. Every research data must be produced with high quality. The instruments for collecting the data must be efficient, reliable and scientifically update. In case any of the instruments has any technical problem in measuring on observational data, it must be adjusted because it may influence the result obtained in the field.

The climatic variables are said to be homogeneous if the climatic variations are detected and removed using any of the statistical tools by mining the climatic data into K clustering before stratification process. A climatic variable is a continuous variable that is collected within a long period of time, it must possess qualities of homogeneous series and these qualities should not be influenced by the residual effects that occurred between the past and current changes on the observations. These residual values can be detected using the autocorrelation function to determine the shift between the past and the lag observations at a specific period of time. Also exponential weighted moving average (EWMA), moving average chart can be used to detect the large shift in climatologically data (Montgomery 2012). The quality control techniques help to detect the randomness in climatic variables and it can be used to obtain the homogenisation of climatic data. To detect changes in temperature and precipitation, CUSUM and EWMA chart will be helpful to measure at what point it changes to other points. Ukhurebor, and Azi, (2019) Mention Zhang (1998) he observed that amount of rainfall varies in season while the temperature changes are not uniform at each regional, owing to spatial and temporal variations that may exist between the different regions . Several research studies were carried out to determine the trends in temperature considering the spatial and temporal variations (UKhurebor, Azi; Abiodun,., and Enoyoze,2017c; Ogolo and Adeyemi, 2009). We observed that climate change in each region has a significant impact on agricultural production, management of water resources and overall economic growth. The food security is dependent on water availability to be supply plants and animals. The average temperature has negative impact on environmental degradation (Ukhurebor,., Batubo, Abiodun, and Enoyoze, 2017d; Joshua,2013). As of today, climate change has negative effects on human health, temperature, rainfall and humidity contribute to outbreak of infectious disasters such as malaria, cholera, etc. (Ukhurebor, and Nwankwo, 2020; Ogolo, 2009). The effects of change in regional climate are dependent on the location such as topography, wind pattern, altitude, precipitation, and temperature. The persistence in weather conditions depends on changes in climatic variables in each region (Enoyoze and Abutu 2012).

Ukhurebor,; Azi; Abiodun, and Ojiemudia,(2018) cited the work of Tuomenvirta and Alexanderson (1997) that recommended the use of standard Normal Homogeneity to define the homogeneity of climatic series. The procedures assume that there must be a significant difference between the observed and reference series before obtaining homogeneity series. The only approach used to obtain the difference is parametric method since it assumed that the series are from standard normal distribution. It involved the sequential segmentation of the series into two independent segments and the test statistic will be used to compare the mean for each of the two segments before and after the point of segmentations. Moreover, it can be used to identify a single shift at mean shift and double shift at mean with their mean and variance at series. However, these tests are expressed to identify the average run length and to evaluate abrupt changes in a series.

Ukhurebor and Nwankwo (2020) cited the work of Hoskling (1997) suggest the use of regression techniques to determine the homogeneity in temperature. The simple linear regression can be used to obtain the homogeneity temperature by obtaining the difference between the estimated values and the observed values and then compute the residual sum of squares. The steps to compute the residual sum of squares by increasing segmentation points, from fitted regression line the average run length and abrupt changes on line can be estimated. The fitted regression lines sometimes meet at the segmentation point. Any point within the segmentation points are seen as homogeneity. The homogeneity can be determined using likelihood ratio test to obtain the estimate mean from the sample drawn from population . This test involves the difference in the means between the two segments using student's test to ascertain the trend of homogeneous series even if the likelihood ratio is not found to be significant. The procedure will help to recognise numerous breaks in the trends of regression line. If the trend breaks then the non-parametric test will be used define multilevel effects based on fitted regression line.

Ukhurebor, Olayinka, Nwankwo, and Alhasan. (2019) cited the study of Vincent (1998) to advocates for the usage of regression models to detect the periods of homogeneity and heterogeneous in climatic variables by defining the abrupt changes in the trend of the observation and the probability that homogeneity will occurrence. The procedures of obtaining homogeneity series using simple linear regression is by computing with a reference series which as serve as independent variables and the series being examined will be dependent variable. The data series are considered to be homogeneous if the residuals from the regression line are independent, with zero mean and variance is one. The residual values can be detected using Durbin-Watson test to test for significance at lag one. If the autocorrelation exists, then it requires another regression to determine the linear trend. If autocorrelation in the residuals of this second model exist, then the model is discarded and a third model is examined. The first model with a step function are added to the third model and compute the sequential increases in the time at which it occur. The minimum residual sums of squares obtained from the regressions line will be identified as points of discontinuity. If autocorrelations occur in the residuals sum of square from the regression line go to the next step, the fourth model is considered and then move to the last regression line which is the trends before and after a step.

The regression analysis is most appropriate technique used to identify heterogeneous in climatic data, when there is variation. This method is used by researchers in many countries (Ukhurebor, and Umukoro,.2018).. They are aiming at detecting the behaviour patterns of heterogeneous and change in the average run length in the trend. To define the characteristics of a data series based on centred and smoothness of the trend, the heterogeneity of series influences the results obtain from an estimated regression line owing to variation in weather conditions. This research intends to observe the trend of climatic characteristics based on the variations from each stratum.

3.0 Methodology

Let y_{ji} be a homogeneous random sample drawn from heterogeneous population through a stratified process by dividing the observations into strata. Y_{hi} where h is number of stratum in the region and i observation from each region at strata i for all regional climate variables, then the distribution is said to be normal if $y_i \sim f(x_{ji}) \in N(\mu, \delta^2)$

Where y_i: Observation recorded by research of time i

x_{ji}:Observation assumed to be a reference series at time j and location i

X_t: The candidate series such as temperature or rainfall observed daily or average monthly climatic characteristics.

Y_t: The reference series observed from existing candidate series with minimum variance or standard error at a sequential pattern, by random selection

N: Number of observations from research area

N_h: Number of observations at each stratum in the location

n: Number of samples taken at all locations

n_h: Number of samples at strata in the location

e_{yx}: Correlation coefficient between the candidate and reference series

W_h: The weighted value i.e. $w_h = \frac{N_h}{N}$ where N_h

strata from each region of Nigeria while N population size of total observations taken at time (t).

Zt: The absolute difference between Yt and Xt at time (t)

$Z_t = Y_t - X_t$

$\mu_z = \frac{\sum W_j Z_t}{W_j}$ The weighted mean on stratified regional climatic variables

$\sigma_z^2 = \frac{\sum W_j^2 (Z_t - \mu_z)^2}{\sum W_j}$ The weighted variance on stratified regional climatic variable

Standardise normal homogeneity test for single shift on trend

Let y_1 - - - - - - - y_t be a set of series which are assumed to have a fixed mean level from y-series for a single shift and said to be normally distributed to reference series from different locations.

$$.f(y_{t;}\mu_{y,}\delta_y) = \frac{1}{\sqrt{2\pi\delta_y}} e^{-\frac{1}{2\delta_z}(y_t - \mu_y)^2}$$

$$Z = \int_a^b \left(\sigma_h^2 - \sigma_{Bh}^2\right)^2 f(y)\, dy,$$

Where $Z_t \sim$(a, b) are the minimum and maximum observations from points Z_t.

Compute the linear trend between the candidate and reference series using the following proposed model.

$C_t = w_j y_t + (1 - w_j) Z_{t-1}$ C_t: Cumulative series plot against time (t) to observe the trend of homogeneity series between the candidate and reference series.

Read off the maximum and minimum temperatures or precipitation

$$T_{Max}^t = Max\left(0,\ w_j y_t + (1 - w_j) Z_{t-1}\right) > R_h \quad \text{and} \quad T_{Min}^- = Min\left(0,\ w_j y_t + (1 - w_j) Z_{t-1}\right) < R_h$$

R_h; Rate of change in Temperature

Rate of Change on Regional Temperature in Nigeria

The rate of change on regional temperature assume an interval between $z_a \leq z \leq z_b$. These intervals are taken from Z_t series computed from the difference between observed and reference series. The intervals are obtained using a$\leq z_t \leq b$. The rate of change on temperature can be defined as $R_h = \int_a^b (\sigma_h^2 - \sigma_{Bh}^2)^2 f(y) dy$.

R_h: *Rate of change on temperature*

Computing the rate of change on average temperature we seek to use Jacobian transformation to generate new random variable. $R_h = \int_a^b (\sigma_h^2 - \sigma_{\beta h}^2)^2 \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}(y-\mu)^2} dy$.

Let $Z^2 = (\sigma_h^2 - \sigma_{Bh}^2)^2$. Differentiate with respect to Z . $R_h = \frac{\sqrt{2\pi}}{3.142}[-e^{z_t}]_a^b$

Discussion of Results

Analysis of Variance on Regional Climatic Variables Using Stratification Process

Strata	Region	Variation in Temperature	SS	DF	MS	F	F-value
S_h=1	Sahel savannah	Between Groups Within Groups Total	4.526 2.960 7.486	7 20 27	0.646 0.146	4.428	1.275
S_h=2	Guinea Savannah	Between Groups Within Groups Total	4.215 2.270 6.485	7 20 27	0.589 0.114	5.186	1.275
S_h=3	Rainforest region	Between Groups Within Groups Total	4.850 1.461 6.311	7 20 27	0.692 0.073	9.479	1.275
S_h=4	Coaster region	Between Groups Within Groups Total	1.253 1.539 2.792	7 20 27	0.179 0.086	2.081	1.275

H_0 : The variations in temperature for all the regions are the same at a given period of time t

H_1: The variations in temperature for all the regions are not the same at a given period of time t

The results from our findings indicate that the variations in temperatures for all the regions in Nigeria are not the same throughout the years, since the $F - tabulated\ values$ are greater than the p-values. The variations between and within the temperature in each region varies based on the region and the time of the year. We observed that the amount of deviation in temperature persists more in the Sahel and Guinea Savannah. This has contributed to continuous persistence on climate change in Nigeria owing to extreme temperatures experienced in the Northern region of Nigeria and its contributory effects on environmental degradation and socio-economic growth in Nigeria.

Combined Weighted Mean and Variance on Regional Climatic Variables

Table shows the weighted mean and variance observed and reference series on region in Nigeria

Regions	**Rainforest (RR)**	**Guinea Savannah (GS)**	**Coaster region (CR)**	**Sahel savannah(SS)**
μ_h	3.67	9.24	2.08	10.53
σ_h^2	7.99	8.94	2.56	10.68

The weighted mean and variance from each region are not equal owing to variation on climatic conditions. The Sahel savannah has the highest average temperature level of 10.53 with variance of 10.68. Also, the Guinea Savannah of Nigeria has the average weighted temperature of 9.24 and variance of 8.94. The finding shows that the average temperatures in Sahel and Guinea Savannah contribute to persistence in climate change owing to climatic conditions of the regions.

The Rainforest and Coaster region have the average weighted temperatures of 3.67 and 2.08 respectively. The minimum weighted variances of the regions are more precise than other regions where there are more extreme temperatures.

Akaike Information Criterion on Stratified Regional Climate Variables

Let Z_j be climatic variables selected from different regions at time (t).

The model is defined as $Y_t = \sum\sum\sum Z_j\, \alpha_j + \varepsilon_j$. $where\ Y_i = Years\ of\ time\ (t)$,

$Z_j =$ $the\ minimum\ and\ maximum\ temperatures.$
$\alpha_j\ =\ estimated\ parameters$

The estimated parameters can be selected from the model using AIC technique to evaluate the mean square error on climatic variable from each region. $(AIC)_h = T \ln \sigma_n + 2k$

Where AIC = Akaike information criterion

h = region of strata h

T = number of observations

k = parameters in the model minimum

α = the mean square error at strata h

Strata	**Region**	**AIC**	**K**	**MSE**	**T**
S_h =1	Rainforest region	31.99	2	2.82	325
S_h =2	Guinea Savannah	33.48	2	2.98	325
$S_{h=}$ 3	Coaster region	29.38	2	2.56	325
$S_{h=}$ 4	Sahel savannah	67.94	2	10.68	325

The Akaike information criterion on selection of sample of 325 observational data on climatic characteristics in Nigeria for both rainfall and average temperature indicates that the selected sample of 325 is suitable to fit a model on climate change associated with average temperature. The mean square error (MSE) on selected sample by stratification process indicates that minimum MSE for all regions and its value will take care of the expected error term that may likely correlate on past and current observations in each region. The sample selection process shows that it is suitable to fit the model using correlation matrix to evaluate the variations between and within the observations.

Use of Correlation Matrix to test homogeneity of variance between and within regional climatic variables

In this research, Gaussian-Seidel Method was used to determine the amount of variations between the observed and reference series from the computed correlation coefficients. An iterative method was used to evaluate the absolute climatic variability between climatic change associated with all the series between and within each region.

Correlation matrix are obtained from the four regions between 1990 to 2017 based on the average temperature observed on monthly bases as X_t and references series as Y_t.

Basic procedure:

- ✓ Compute the correlation matrix
- ✓ Compute the determinant matrix for each region
- ✓ Solve for Z_i and repeat until all the Z_i in each region are obtained
- ✓ Compute the absolute relative changes on the amount of variation accounted for at each region after each iteration are computed.

Let Z_{ij} represent a climatic variable as i^{th} temperature and j^{th} region which form a linear matrix $Y_t = \sum\sum\sum Z_{ij}\alpha_j + \varepsilon_j$, i = 1 ------- t, j = 1---------x

Y_t =**Reference Series**

	Y1	**Y2**	**Y3**	**Y4**
X1	$\rho_{x_1y_1}$	$\rho_{x_1y_2}$	$\rho_{x_1y_3}$	$\rho_{x_1y_4}$
X2	$\rho_{x_2y_1}$	$\rho_{x_2y_2}$	$\rho_{x_2y_3}$	$\rho_{x_2y_4}$
X3	$\rho_{x_3y_1}$	$\rho_{x_3y_2}$	$\rho_{x_3y_3}$	$\rho_{x_3y_4}$
X4	$\rho_{x_4y_1}$	$\rho_{x_4y_2}$	$\rho_{x_4y_3}$	$\rho_{x_4y_4}$

$$\rho_{x_iy_j} = \frac{cov(x_iy_j)}{S_{x_i}S_{y_i}} \quad where\ \rho_{x_iy_j}\ is\ correlation\ coefficient$$

The correlation matrix on average temperature in the four regions of Nigeria

$$\rho_R = \begin{bmatrix} Z & RR & GS & CR & SS \\ RR & 1.00 & -0.54 & 0.09 & 0.26 \\ GS & -0.54 & 1.00 & -0.24 & 0.18 \\ CR & 0.09 & -0.24 & 1.00 & 0.36 \\ SS & 0.26 & 0.18 & 0.36 & 1.00 \end{bmatrix}$$

Average temperature for each region is RR = 29.3, GS = 30.5 CR= 28.1, SS = 36.5

Let Z_1: Rainforest (RR)

Z_2 : Guinea Savannah (GS)

Z_3: Coastal Region (CR)

Z_4 : Sahel Savannah (SS)

Z_1 = 27.6, Z_2 = 30.4, Z_3 = 24.7, Z_4 = 35.6

RR = 29.3, GS = 30.5, CR = 27.6 and SS = 34.7

$Z_1 - 0.54Z_2 + 0.09Z_3 + 0.26Z_4 = 29.3$

$-0.54Z_1 + Z_2 - 0.24Z_3 + 0.18Z_4 = 30.5$

$0.09Z_1 - 0.24Z_2 + Z_3 + 0.36Z_4 = 27.6$

$0.26Z_1 + 0.18Z_2 + 0.36Z_3 + Z_4 = 34.7$

We seek to evaluate the amount of variation associated within the temperature in all the regional climatic variables using Gaussian-Seidel elimination method in the above equations.

Determine the absolute relative change in temperature $|T_R| = \left|\frac{Z_i - Z_i}{Z_i}\right| x\ 100$

The following values are obtained after the iterations

Iterations	**Z1**	$\|T_{RR}\|_1\%$	**Z2**	$\|T_{GS}\|_2\%$	**Z3**	$\|T_{CS}\|_3\%$	**Z4**	$\|T_{SS}\|_4\%$
1	34.2	23.9	48.5	37.5	27.6	71.8	-18.2	321.9

2	51.4	46.3	84.5	42.6	87.8	81.0	-11.3	27.4
3	73.5	30.3	48.1	75.6	48.5	2.6	-37.3	69.7
4	57.5	27.6	78.2	38.4	49.8	18.2	-44.4	15.9

The absolute relative change in temperature is 321.9% in the Sahel savannah Nigeria from 1990 to 2017. This change indicates that there is more persistence in climate change in the Sahel region owing to extreme increase in temperature and climatic conditions. The Guinea Savannah has a maximum relative change in temperature with 81% increase from 1990 to 2017. This change contributes to persistence on climate change.

Test for variability in regional temperature using the observed trend on the plotted point.

The trend can be defined as:

$T^{+}_{max} = \text{Max}\,(0, w_h y_t + (1- w_h) z_{t-1}) \geq R_h$

Where = $R_h = \frac{\sqrt{2}}{3.142}[e^{z_t}]_a^b$.

R_h rate of change in temperature

$T^{-}_{min} = \text{Min}(0, w_h y_t + (1- w_h) z_{t-1}) \leq R_h$

The global average temperature across the world in 20th century Nigeria Meteorological Centre Bulletin (2017) observed that the rate of change in temperature with a relatively hemisphere in the Northern and Southern regions of Nigeria are given next.

Regions Relative Change in Hemisphere	**Temperature**
Sahel Savannah	1.58 – 2.84
Guinea Savannah	0.89 – 1.60
Rainforest Region	1.08 – 1.94
Coastal Region	0.69 – 1.24

The rate of change in temperature can be computed using **a < Z_t < b.** Where **a** is minimum suspected increase and **b is the** maximum suspected increase.

The time plot shows the cumulative series on average temperature in Rainforest Region Nigeria

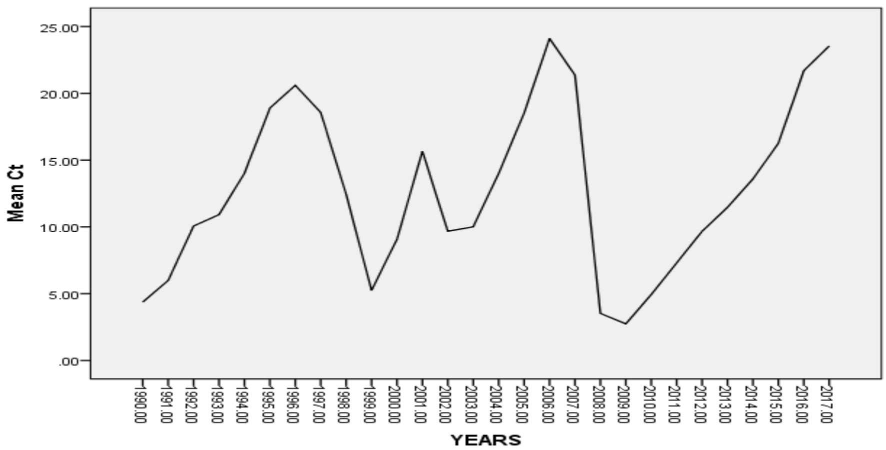

Fig. 1

Rainforest : $0.69<Z_t< 1.24 = \frac{2.506}{3.142}[-e^{1.24} + e^{0.69}] = 0.78$

In Fig. 1, the cumulative points on observed temperatures indicate nine points plotted are above the anomaly rate of change on temperature in Rainforest at $R_h = 0.78$ $T^{t}_{max} = \text{Max}\,(0, W_h y_t + (1-W_h) \geq 0.78$. These changes describe the homogeneity on average temperature which increase at point 2.0 in the year (1992), 7(1996), 7(2000), 9(2002), 10(2003), 11(2008), 11(2011), 15(2011), 9(2012), 10(2013) and 12(2017). These observed points show that temperature level contributes to environmental degradation.

The time plot shows the cumulative series on average temperature in Guinea Savannah Nigeria

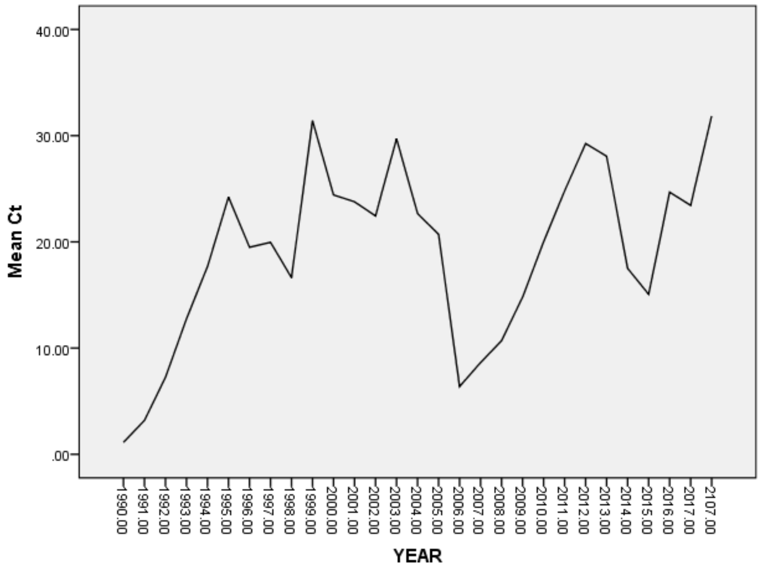

Figure 2

Guinea Savannah

$1.08 < Z_t < 1.94 = \frac{2.506}{3.142} [-e^{1.94} + e^{1.58}] = 1.37.$

In Figure 2, all plotted points in the graph shows that there are maximum temperature at $R_h = 1.37$ i.e $T^t_{max} = \text{Max}\ (0, W_h y_t + (1-W_h) \geq 1.37$. These points were two in (1990), 22(1992), 18(1994), 19(1995), 17(1998), 28(1999), 21(2000), 19(2001), 27(2002), 19(2003), 17(2004), 7(2005), 8(2008), 26(2011), 25(2012), 11(2013), 8(2015), 16(2017) and 28(2017). These points indicate the randomness in the average temperature experienced in the region owing to climate variations in time and season which persists on climate change in the region.

The time plot shows the cumulative series on average temperature in Coastal Region Nigeria

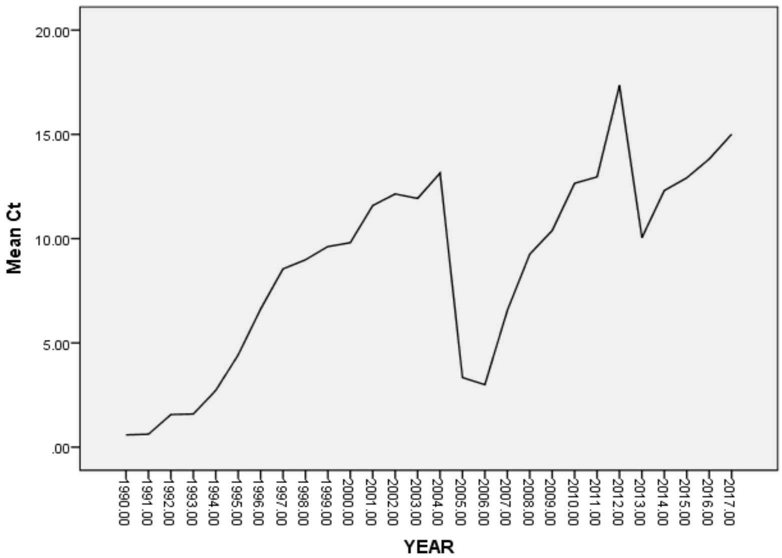

Figure 3

Coastal Region

$0.89 < Z_t < 1.60 = \frac{2.506}{3.142} [-e^{1.60} + e^{0.89}] = 0.87.$ In Figure 3, all points show the maximum rate of change in temperature at $R_h = 0.87$ i.e $T^t_{max} = \text{Max}\ (0, W_h y_t + (1-W_h) Z_{t-1}) \geq 0.87$. These points show that temperature contribute more to persistence in climate change owing to variation in climatic condition in the region.

The time plot shows the cumulative series on average temperature in Sahel Savannah Nigeria

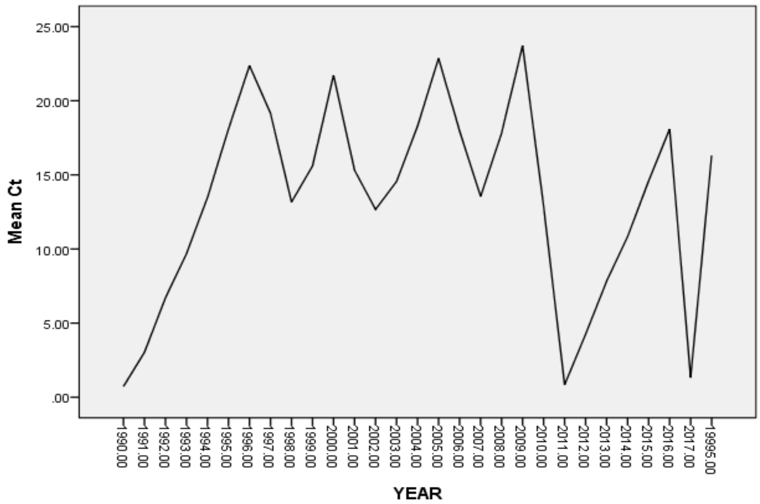

Figure 4

Sahel Savannah

$1.58 < Z_t < 2.58$ $R_h = -\frac{2.506}{3.142}[-e^{2.84} + e^{1.58}] = 1.30$

In Fig.4, we have nine points that are above the anomaly rate of change on temperature in Sahel savannah $R_h = 1.30$ i.e. These points are 22 at the year (1994) $T^{+}_{max} = Max\ (0, w_h y_t + (1- w_h) z_{t-1}) \geq 1.30$ 11 at (1996), 20 at (1999), 11 at (2002), 20 at (2004), 11 (2006), 21 (2009), 16 (2014) and 14 (2017). These points describe the persistence on climate change owing to high temperature experienced in the Sahel savannah.

Conclusion

The anomalies in all the four regions reveal that there is relationship in intensities of temperature between Sahel and Guinea Savannah; Rainforest and Coastal Region. These intensities in average temperature contribute to persistence in all the four regions but its effect in climate change varies in time and space in each region. The magnitude between the units of increase or decreases in average temperature depends on the time and space its persistence in the two regions but based on the conditional probability that the weather conditions are similar.

In general, modelling the climate change and its persistence is based on the time and space in each region based on their magnitude and consistent of the estimated coefficients from the proposal model. The magnitude describes the distance between the regional cluster with similarly and dissimilarly units.

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