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ANALYSIS OF TEMPERATURE TREND AS AN INDICATOR OF CLIMATE CHANGE USING LAND SURFACE TEMPERATURE (LST) AND METEOROLOGICAL DATA IN AKURE, SOUTHWEST NIGERIA

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ABSTRACT

The study aims to examine the Temperature trend as a determinant of climate change in Southwest Nigeria. Monthly Climatic Data for the study was retrieved from the Nigeria Meteorological Agency (NIMET) and Landsat Satellite imageries obtained from United State Geological Survey (USGS). This study presented a descriptive and inferential analysis of temperature in Akure, Nigeria for a period of 31–year (1990 to 2020). The data were subjected to statistical analysis using mean, standardized temperature, decadal and time series. The result revealed increase in observed temperature above the standardized temperature (1981 to 2010). At the end of the first decade (2000), the temperature rose above normal by 1.0°C, while at the end of second decade (2010) and third decades (2020), the temperature increased by 1.9°C and 1.6°C respectively. The findings also revealed that the maximum and minimum temperature of the Satellite Land Surface Temperature increases with decades. In the same vein, the average LST increases from the base year (1990) (26.4°C), to 27.2°C, 27.3°C, and 28.3°C in the year 2000,2010 and 2020 respectively. The decadal increase was 0.8°C (3.0%) between 1990 and 2000; 0.1°C (0.4%) between 2000 and 2010; and 0.1°C (3.6%). The time series showed a trend variation while the time plot showed irregular pattern in the data series. Minimum and maximum temperature series for Akure attained stationarity since p-value (0.001) for the series are less than 5% level of significance. Temperature values is predicted to be in its highest every February of the forecasted years in Akure with February 2022 having the highest forecasted temperature of 34.7^{0}C. The indication of these finding is attestation to climate change and to prepare the stake holders to be well prepare to avert the danger of global warming. Further study can be conducted on rainfall variation in the study area.

Keywords: Decadal temperature, stationarity, seasonality, climate change

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INTRODUCTION

Climate is commonly defined as the synthesis of weather averaged over a long period. It is the statistically appreciable variations of weather parameters that stay for a long period, which could be decades or longer. This is the frequency and magnitude shift of sporadic weather events as well as the slow continuous rise in global mean surface temperature. The purpose of the use of climate data differs but the standard averaging period is 30 years (World Meteorological Organization (WMO), 2017) The anomaly of climate parameters degenerates to climate change which is one of the greatest environmental, social, and economic threats facing our world today (Chomitz*et. al.,* 2006). Climate change occurs because of changes to Earth's environment, like changes in its orbit around the sun or human modification of the atmosphere. There is nothing inherently wrong with climate change. It has happened in the past and will happen again. The current concern stems from the rate of change – how quickly changes are happening that is beyond human provision for adaptation. Scientists have found that the current rate of temperature increase is higher than any previously seen in the last 800,000 years. The most meteorological variables used in climatic trend studies are rainfall and temperature (Ferrari*et al* 2018; Medori*et a*l.2012). Globally, the symptoms of the climate change problem are manifesting through, flora and fauna, melting glaciers, and decreasing mountain snow caps. For example, the mosquito belt has considerably expanded to higher elevations due to the temperature increase, frequency, and droughts. From the aggregate of the past events of the earth, climate (global, regional, and local) has never been static. The non-static natures are in various magnitudes ranging from variability through fluctuation, trends, and abrupt to gradual changes (Ayoade, 2003).Evidence of global climate change in the past 100 years are shown in the empirical observations and climate models and will likely change more rapidly in the future (Adeleke *et al*., 2018). There is a term ″climate normal″. The World Meteorological Organization (WMO)describes climate normal as lubber line used by the Climatologists to relate current climate trends to that of the past (Normal) so as to predict for the future. Scientists traditionally define it as an average over a recent 30- year period(World Meteorological Organization (WMO) (2017). Increase in temperature; rainfall variation; rise in sea level and flooding; drought and desertification; loss of biodiversity; frequent extreme weather events occurrence has been the evidences of changing climate in Nigeria (Elisha *et. al* 2017; Akande *et al* 2017). It is widely projected that as the planet warms, climate and weather variability will increase. Changes in the frequency and severity of extreme climate events and in the variability of weather patterns will have significant consequences for human and natural systems. Increasing frequencies of heat stress, drought and flooding events are projected for the rest of this century, and these are expected to have many adverse effects over and above the impacts due to changes in mean variables alone (IPCC, 2012).

There is no gainsaying in the fact that the earth is warming. Detailed observations of surface temperature assembled and analyzed by several different research groups showed that the planet's average surface temperature was 1.4°F (0.8°C) warmer during the first decade of the 21st century than during the first decade of the 20th century, with the most pronounced warming over the past three decades (Hood, 2019; Herrig and Lindsey, 2020).Since 1980s, temperature has increased significantly (Federal Ministry of Environment, 2014). Also, weather events in different ecological zones revealed that temperature will continue to increase in the foreseeable future (Akande *et al* 2017). There have been records of farmlands reduction, poor crop yields and lower agricultural productivity, because of higher temperatures, lower rainfall, drought and desertification (Ogbuabor and Egwuchukwu, 2017).

Report from research carried out by Building Nigeria's Response to Climate Change (BNRCC, 2011) on National Adaptation Strategy and Action Plan on Climate Change for Nigeria (NASPA-CCN) on the premise of analysis of climate spread across the ecological zones of Nigeria. In the project, trends of past climate over Nigeria were analyzed using historical climate records from 40 NIMET stations for 30 years (1971-2000) to predict future occurrence of climatic phenomena.Two future climatic projection from nine Global Climate Models were downscaled. The two future climate projections were based on two scenarios known as A2 and B1. A2 containing higher greenhouse gas emission (GHG) and B1 lower GHG emissions. The A2 was selected as the strongest. This scenario suggested a warmer climate in future. The result was significant at 95% confidence level positively with 0.014°C per year for maximum temperature and 0.025°C per year for minimumtemperature. For the study period (30 years) record of temperature increase was revealed for maximum (0.4°C) and minimum (0.8°C).

Research study on Spatio-Statistical Analysis of Rainfall and Temperature Distribution, Anomaly and Trend in Nigeria was carried out to examine the variability of rainfall and temperature based on spatio-statistical Data retrieved from Nigeria Meteorological Agency (NIMET). The findings concluded that the area was experiencing significant increase in temperature with mean temperature (28C) and mean sunshine (4.7) hours. Temperature anomaly ranged between -2.31C and 1.73C. The correlation coefficient revealed average temperature (0.867) was significantly related to minimum temperature, sunshine hours (-0.389) and average temperature (-0.749) was significantly related to maximum temperature (Adeleke and Orebayo, 2020).

Most of the warming over the last several decades can be attributed to human activities that release carbon dioxide (CO_2) and other heat-trapping greenhouse gases (GHGs) into the atmosphere. The burning of fossil fuels—coal, oil, and natural gas—for energy is the single largest human driver of climate change. While agriculture, cattle grazing, forest clearing, and certain industrial activities also make significant contributions in Southwest Nigeria.

MATERIALS AND METHODS

The Study Area

Akure is one of the major cities in Ondo State of Nigeria. According to Köppen and Geiger, this climate is classified as Aw (Tropical wet). It is located in tropical rainforest, with Coordinates of between longitude 5°06‟E to 5°38‟E and between latitude 7°07‟N to 7°37‟N. It has Climate Normal (CN) average annual rainfall of 1546mm, average annual temperature of 25.9°C and humidity of 77%. It is bounded by Akure North and Ifedore Local Government Area in the North and Owo Local Government Area in the East. Ile-Oluji/Oke-igbo, Local Government Area in the west and Idanre Local Government Area in the South. The climate condition of Akure follows the pattern of Southwest that is influenced mainly by Southwest monsoon wind (rain-bearing) which brings moisture from the Atlantic Ocean as rain. It is also influenced by wind from the North East called North-east dry wind that takes its source from Sahara Desert. Akure experiences a warm humid tropical climate with two distinct seasons, the rainy and dry seasons. The rainy season lasts for seven months, April-October.

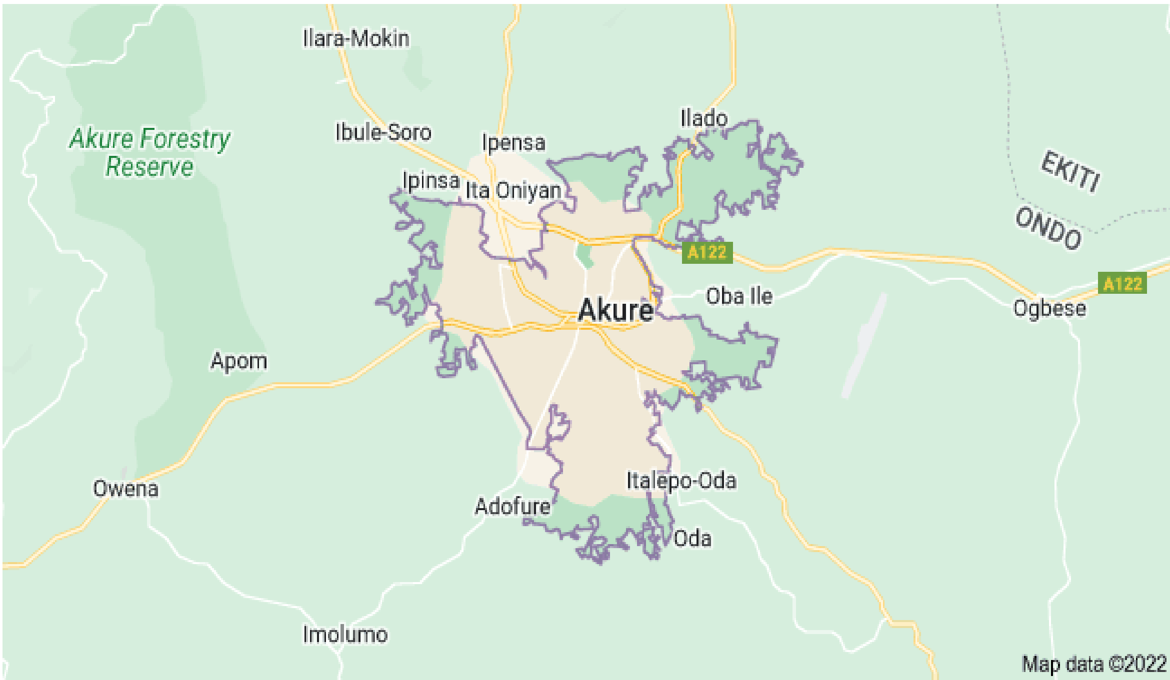


Figure 1: Akure and the surrounding villages.
Source: ResearchGate .net

Figure 2: Ondo State showing Akure
Source: Researchgate.net

Experimental Methods

The Study utilized secondary data from Nigeria Meteorological Agency (NIMET) (climatic data) and Landsat Satellite Imageries obtained from the United State Geological Survey (USGS).This study focused on the temperature characteristics for the period of 31 years. Land cover maps were utilized to quantify land cover change in the periods[6] under investigation. The Landsat satellite images was downloaded from the official website of US Geological Survey as standard products, i.e., geometrically corrected. and used in order to achieve the research objectives. The study area was located in the Landsat path 191 and row 55. The pixel sizes of the images were 30m x 30m with the exception for the thermal infra-red (IR) bands (band 6) and (10-11) respectively, which has 100-m resolution bands. All the images were obtained in the same season (winter). The obtained Landsat data (Level 1 Terrain Corrected (L1T) product) have been pre-georeferenced to Universal Transverse Mercator (UTM) zone 31 North projection using World Geodetic System (WGS-84) datum. The other necessary corrections were performed in this study. Table 1 presents the specifications of Landsat TM, ETM+ and OLI images which are the three-medium resolution Landsat Imageries in assessing land use land cover pattern of the study area. The time interval selected were based on available data.

Table 1: Satellite Images

Satellite Sensor	Spatial resolution	Acquisition years	Path	Row	Source	Category
Landsat 5, 7 (TM & ETM+)	30m x 30m	1990, 2000, 2010	190/191	55	GLCF	Secondary
Landsat 8 (OLI)	30m x 30m	2020	190/191	55	GLOVIS	Secondary
High resolution Image	Google Earth	2020				Secondary

Source: Satellite Images, 2021

Monthly temperature (^{0}C) was sourced from Nigeria Meteorological Agency (NIMET), Abuja. NIMET has been the only agency responsible for the collection and compilation of reliable weather data in every part of the nation. Time series analysis of climatic variables in form of trends analysis and seasonality index were examined in the analysis. The standardized anomalies of seasonal values of temperature were calculated for each site by using the means and standard deviations calculated for the reference period (1981-2010). Also, regression analysis was employed to examine the change in temperature images.

Climatic Derivations

Monthly temperature data collected for the study areas was used to derive the Temperature Effectiveness Indices (TEI): average temperature, optimum temperature, maximum temperature and minimum temperature.

Time Plot

This is the graph of observation Xt against time t. It is the first step to take in time series analysis. It depicts some characteristics of interest that are present in the series like the trend and the seasonal variation.

Estimation and Isolation of Component of Time Series

A time series is a collection of observation made sequential at equal interval of time. This is denoted by X_t, where X_t is the observed value at time t. Time Series Analysis (TSA) involves the investigation of the degree and the pattern of dependent observation X_t. Time series observation can be discrete or continuous in nature.

Discrete time series data is a single point value for time series frequency (daily, weekly, monthly, quarterly, and annually).

Continuous time series is given as interval value and continuous time series can be converted at discrete time series by measuring its constant interval.

Deterministic Time Series Model

In the analysis of a time series; either of the following two (2) models could be assumed.

1. The multiplicative model i.e.

$$X_t = T_t.S_t.C_t.I_t \ldots\ldots\ldots (1)$$

2. The addictive model

$$X_t = T_t + S_t + C_t + I_t \ldots\ldots. (2)$$

Where:

X_t - The value of the variable at a particular time

T_t - Trend

S_t -Seasonal variation

C_t - Cyclical variation

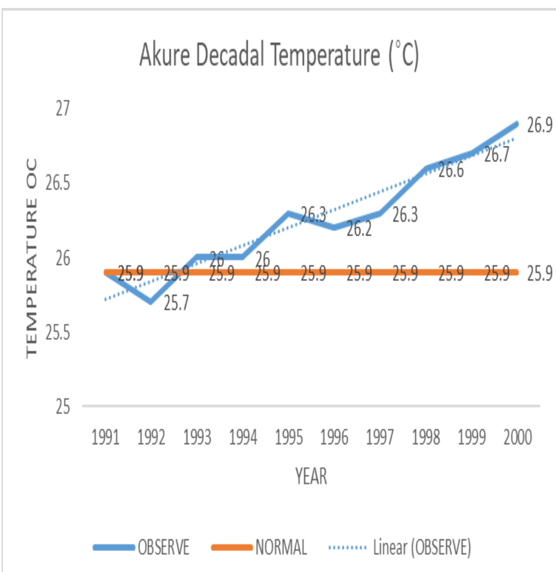
I_t -Irregular variation

The objective of time series analysis is to isolate individual components on the original composite series such that each component can be measured and analyzed independently of the other.

RESULTS

Decadal Presentation of Temperature Over Three Decades (1991-2000; 2001-2010; 2011-2020).

The decadal trend in figures 3 to 5 for Akure showed an upward trend in the first (1991-2000), Second (2001-2010) and third (2011-2020) decades. It is observed that the trends in all the decades are above the expected Temperature. The trend in the first decade is very sharp while the remaining trends are gentle in nature. In the first decade, there was a drop in temperature from normal by 0.2°C in year 1993, then started rising until year 2000 by 1.0°C. In the second decade, the rising was cyclical but at the end of the decade there was a sharp increase in temperature above normal (25.9°C) by 1.9°C in the year 2010. The third decade showed a spike in the year 2019 by 2.3°C rise in temperature above normal, but fairly constant in the year 2011 to 2018.



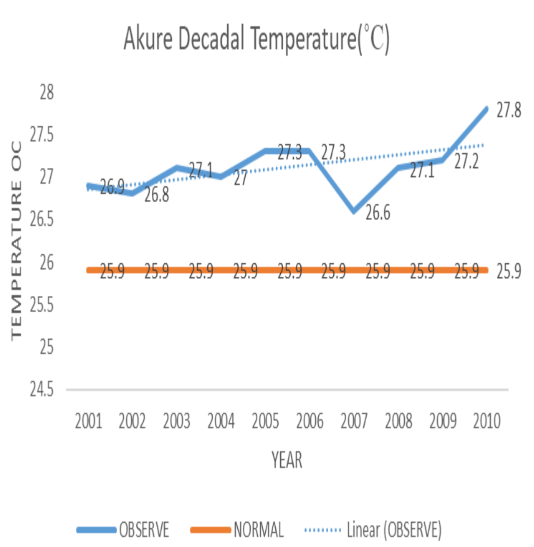


Figure 3 Decadal Temperature (1991-2000) Figure. 4 Decadal Temperature (2001-2010)

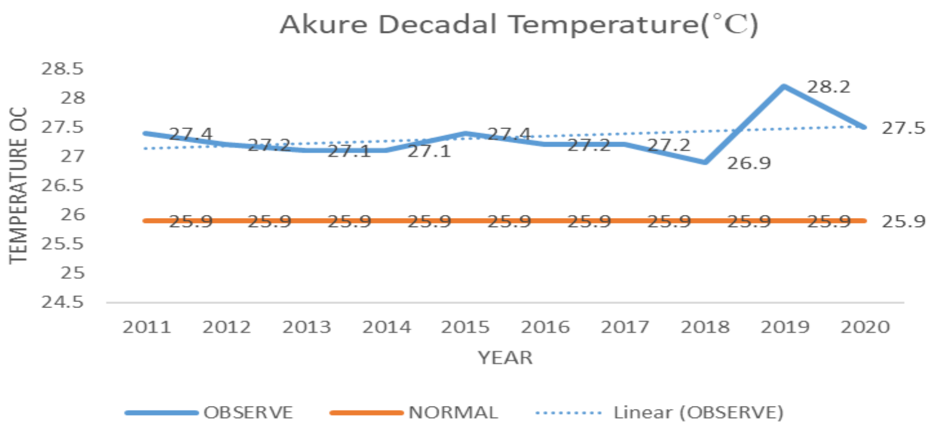


Figure 5 Decadal Temperature (2011-2020)

Figures 3-5 Observed and Expected Decadal Average Temperature for Akure and the Trend (1991-2000; 2001-2010; 2011-2020)

Time Series Analysis of Temperature in Akure

Figures 6 and 7 show the time plot of the monthly maximum temperature, and minimum temperature series for Akure from 1990 to 2020**.** The figure revealed that there is an irregular pattern in the data series. The mean is not constant throughout the series as it assumes a fairly stable mean, the data series has a trend variation. The figure also shows that the data series are stationary, therefore there is need to carry out a unit root test. Since decomposition procedures are used in time series to describe the trend and seasonal factors in a time series, hence, in this study, only trend and seasonal decompositions is considered.

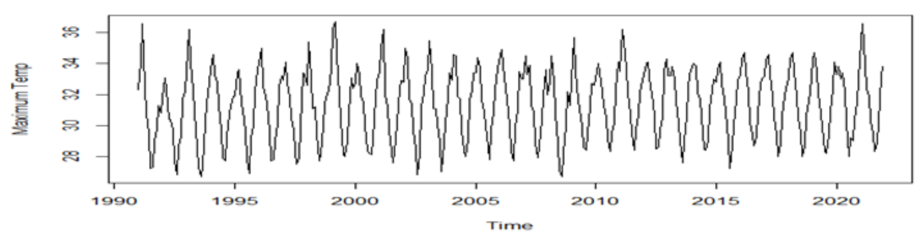


Figure 6:Time plot for monthly maximum temperature series for Akure

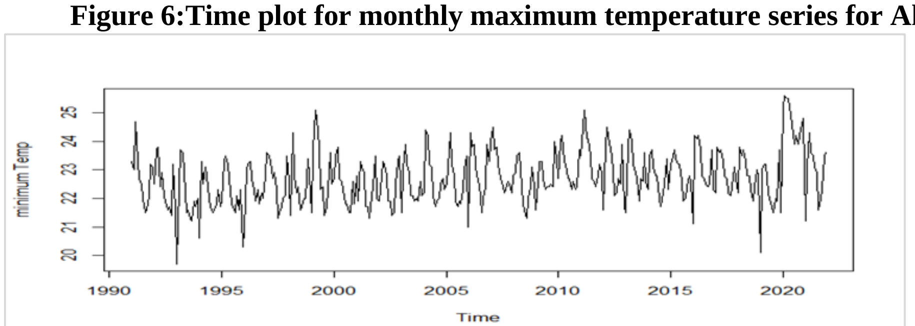


Figure 7: Time plot for monthly minimum temperature series for Akure

Figures 8 and 9 show the additive time series decomposition of the series into random, seasonal, trend and observed variation. The plot shows the observed series, the smoothed trend line, the seasonal pattern and the random part of the high and low temperature series for the study location.

Since trend, season, and cycle are the most common variations in data recorded through time, then, each of these patterns might affect the time series in different ways. So, choosing a forecasting model is premised on identifying patterns like trend and season to understand how each one behaves in the series. The decomposition procedure (Figures 6 and 7) analyzes the trend and seasonal components of the temperature series in separate plots: A time series plot of the original data. Detrend values are the data with the trend component removed. The detrend values are either the differences between the observed values and the trend values (additive model). Since the plot of the detrend data looks different from the original data, this means that a trend component exists in the data.Seasonally adjusted values are the data with the seasonal component removed. The seasonally adjusted values are either the differences between the observed values and the seasonal values (additive model). Also, since the plot of the seasonally adjusted data looks like the original data, then it is safe to conclude that seasonal component does exist in the data. This is shown in Figures 6 and 7. The seasonally adjusted and detrend values are also called residuals. The residuals are the differences between the observed values and the predicted values.

Observing these 4 Level graphs closely justified that data satisfies all the assumptions of SARIMA modeling, mainly, stationarity and seasonality. Next, we need to remove non-stationary part for ARIMA. To achieve stationarity: difference the data – compute the differences betweenconsecutive observations; log or square root the series data to stabilize non-constant variance; if the data contains a trend, fit some type of curve to the data and then model the residuals from that fit. These were the procedures used in modeling. Unit root test was then used to find out that first difference or regression which should be used on the trending data to make it stationary. In Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, small p-values suggest differencing is required.

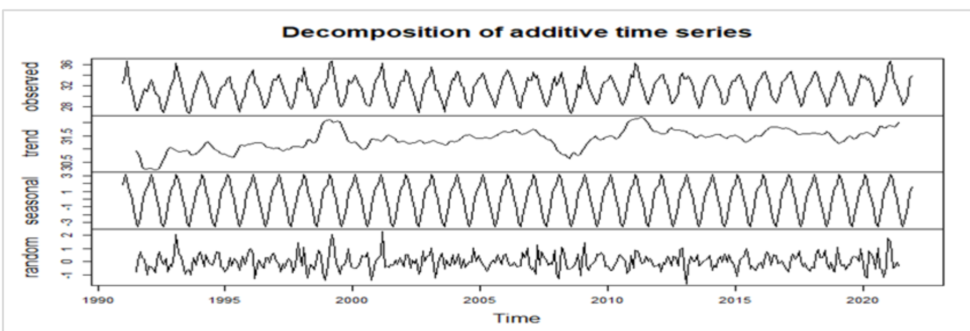


Figure 8: Decomposition of monthly maximum temperature series for Akure (random, seasonal, trend and observed)

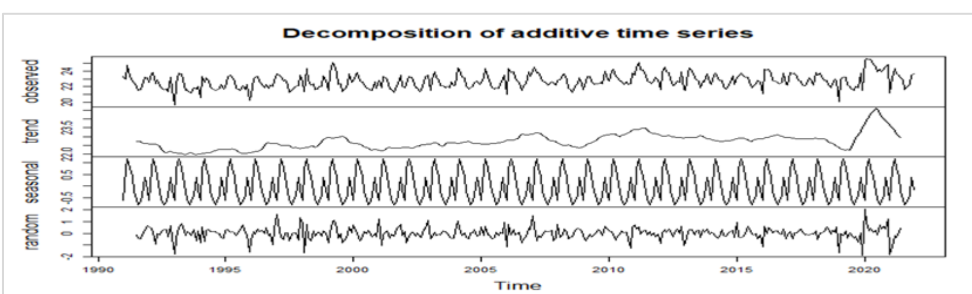


Figure 9: Decomposition of monthly minimum temperature series for Akure (random, seasonal, trend and observed)

Unit Root Test

Augmented Dickey Fuller Test was carried out to test for the stationary in the data set. Table 2 suggests that the maximum temperature and minimum temperature series for Akure attained stationarity since the p-value (0.01) for the series are less than 5% level of significance. Hegy test and Canova-Hansen test was carried out to determine seasonality and order at which the seasonal variation is stationary in the series. It is confirmed that the stationarity is stable as shown in the table with order 1

Table 2 Augmented Dickey Fuller Test for the series for Akure

Locations	Parameters	DF statistic	Lag-order	p-value	Seasonality	
					Decision	Order
	Max. Temp.	-11.412	7	0.01	Yes	1
	Min. Temp	-7.8386	7	0.01	Yes	1

Model Identification

The Autocorrelation Function (ACF) was used to identify the probability time series models that best describes the series for Akure. Figures 10 and 11 show the ACF plot of the series for monthly maximum temperature and minimum temperature for Akure. The plots suggests that the highest attainable order for the Autoregressive Model (AR) and Moving Average (MA) are between 0 and 9. The number of attainable orders is determined by the number of significant spikes.

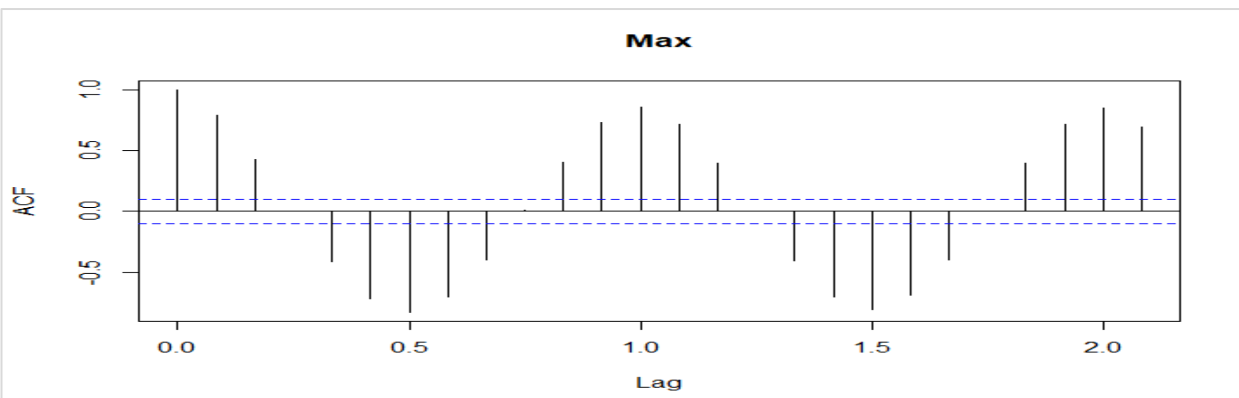


Figure 10: ACF plot of monthly maximum temperature series for Akure

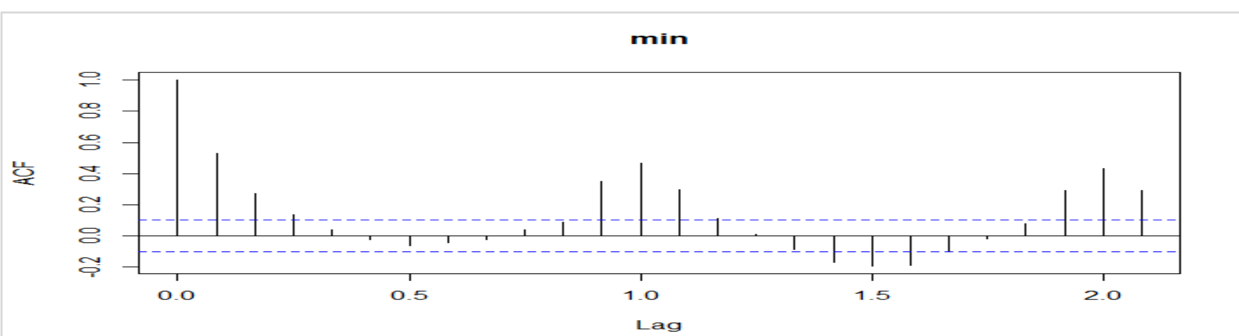


Figure 11: ACF plot of monthly minimum temperature series for Akure

Parameter Estimation

After the stationary of the data have been attained and the ACF and PACF have been examined, it was concluded that the data series follows Seasonal Autoregressive Integrated Moving Average (SARIMA) model. Tables 3 and 4 show the parameter estimation for the model that best describe the monthly maximum temperature and minimum temperature series for Akure.

Table 3: Model Estimation of monthly Maximum Temperature series for Akure SARIMA (0, 0, 1) (2, 1, 2)$_{12}$

Model	**MA1**	**SAR1**	**SAR2**	**SMA1**	**SMA2**		
Estimate	0.4229	-0.0803	0.0546	-0.8459	-0.0211		
S. E	0.0462	0.6018	0.0789	0.6002	0.5133		
Performance	R2	AIC	Log-likelihood	ME	RMSE	MAE	MASE
Criteria	0.4583	765.13	-376.56	0.1183	0.6613	0.4923	0.6601

Table 4: Model Estimation of monthly Minimum Temperature series for Akure SARIMA (2, 0, 2) (0, 1, 2)$_{12}$ with drift

Model	**AR1**	**AR2**	**MA1**	**MA2**	**SMA1**	**SMA2**	Drift
Estimate	0.73	0.0693	-0.4588	0.0074	-0.7355	-0.5218	0.0021
S. E	0.332	0.2945	0.3338	0.2058	0.0526	0.0673	0.035
Performance criteria	R2	AIC	Log-likelihood	ME	RMSE	MAE	MASE
	0.43	737.74	-360.87	-0.0014	0.639	0.4426	0.6853

ARIMA is a model that can be fitted to time series data to predict future points in the series. MA(q) stands for moving average model, the q is the number of lagged forecast error terms in the prediction equation. SARIMA is seasonal ARIMA and it is used with time series with seasonality

The AR stands for autoregressive and refers to using lagged values of our target variable to make our prediction. For example, we might use today's, yesterday's, and the day before yesterday's sales numbers to forecast tomorrow's sales. That would be an AR (3) model as it uses 3 lagged values to make its prediction. The I stand for integrated. It means that instead of taking the raw target values, we are differencing them.

Model Diagonistic

The MA stands for moving average. A moving average model takes the lagged prediction errors as inputs. It's not a directly observable parameter unlike the others (and it's not fixed as it changes along with the models in others parameters). At a high level, feeding the model's errors back to itself serves to push it somewhat towards the correct value (the actual Y values).

Figures 12 and 13 present the diagnostic plots of the residual generated from the time series model. It contains the residual plots, Autocorrelation Function plot and histogram to show the normality of the residual generated from the time series analysis. The entire residual plot showed that the error is normal with the histogram displaying normality of the residual structure thereby suggestive of a good prediction from the time series models obtained.

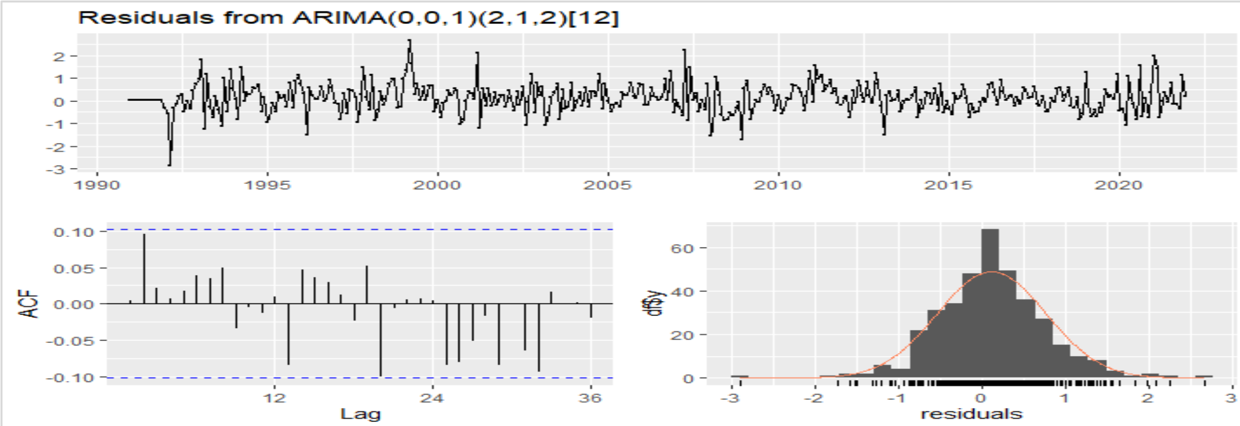


Figure 12: Residual diagnostic for Maximum Temperature in Akure

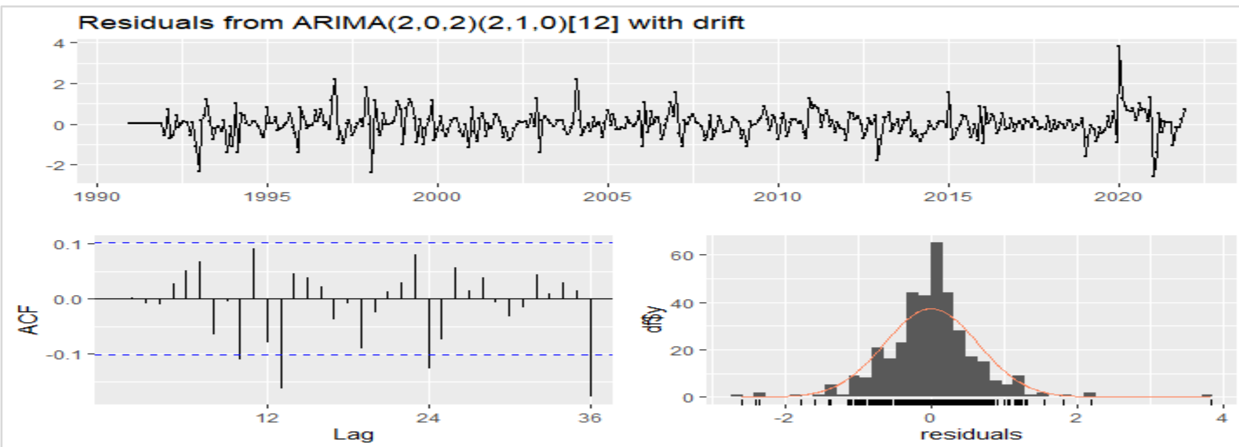


Figure 13: Residual diagnostic for Minimum Temperature in Akure

Temperature Forecast for the Study Area

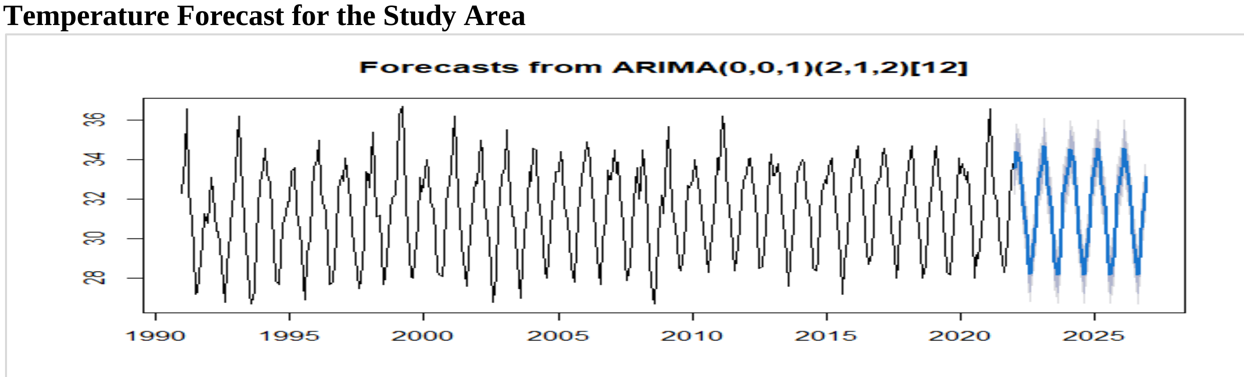


Figure 14: Five (5) years forecast plot for maximum temperature in Akure

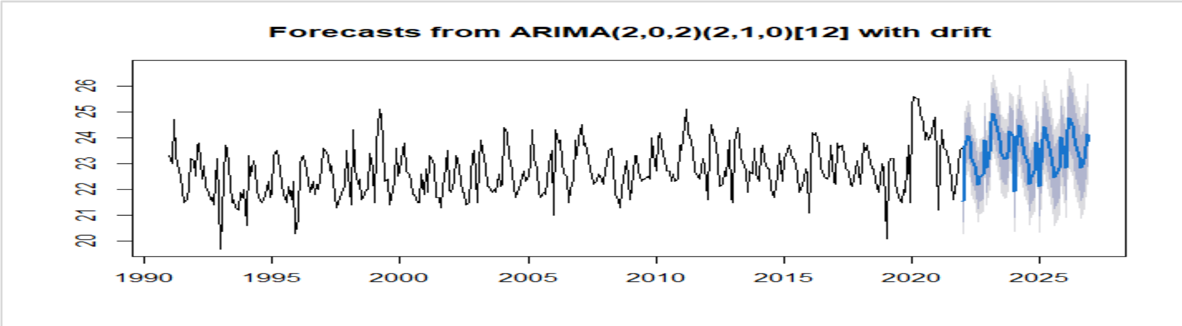
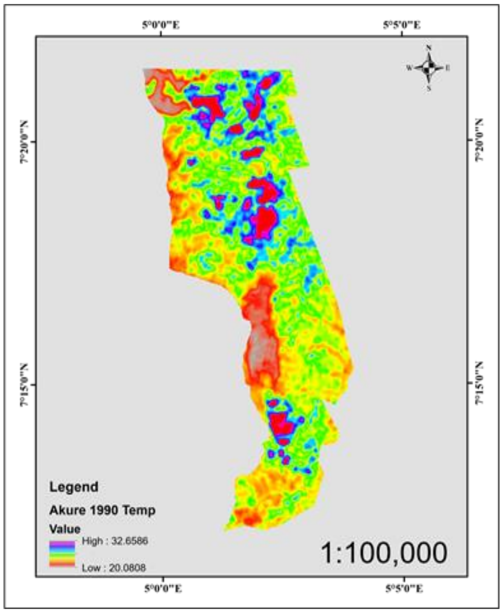


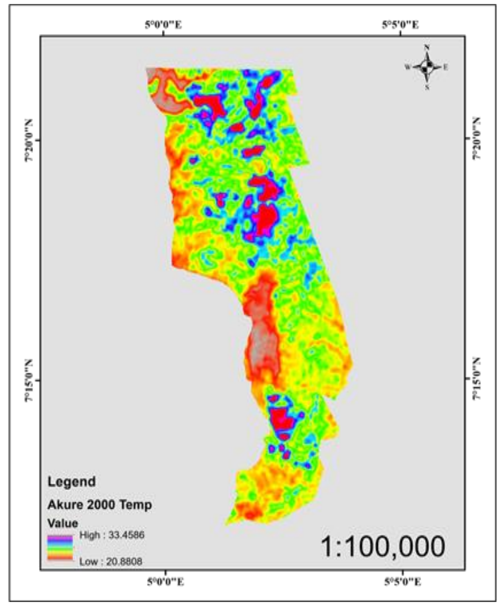
Figure 15: Five (5) years forecast plot for minimum temperature in Akure

Here the forecasts for 2021-2025 are plotted as a blue line, and the 95% prediction interval as a gray shaded area. The ‘forecast errors’ are calculated as the observed values minus predicted values, for each time point. We were able to calculate the forecast errors for the time period covered by our original time series, which is 1990-2020 for the temperature data. As mentioned above, one measure of the accuracy of the predictive model is the sum-of-squared-errors (SSE) for the in-sample forecast errors as stated in Tables 3and 4. The in-sample forecast errors are stored in the named element “residuals” of the list variable returned by forecast. If the predictive model cannot be improved upon, there should be no correlations between forecast errors for successive predictions. In other words, if there are correlations between forecast errors for successive predictions, it is likely that the simple exponential smoothing forecasts could be improved upon by another forecasting technique.

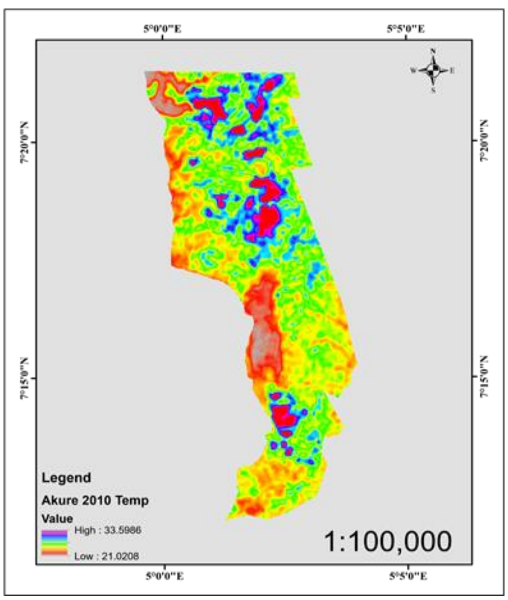
Table 5 showed a steady rise in temperatures across the decades which is an indication of intensified Land use Land Cover such as farming activities, illegal grazing, fuelwood, illegal logging, urbanization, firewood gathering etc as gathered from the field.



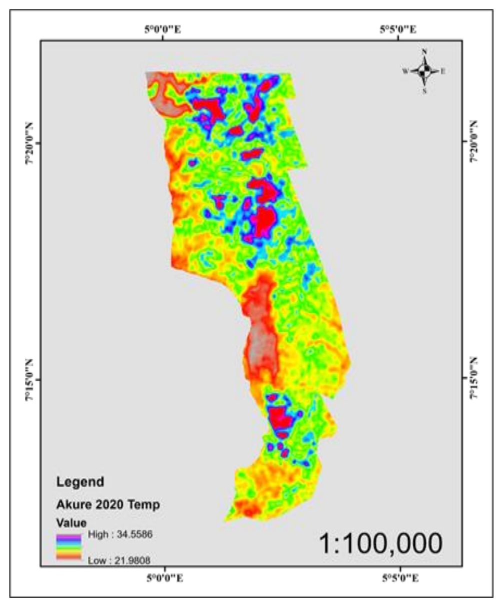
1990



2000



2010



2020

Figure 16: Changes in Temperature at Akure Forest reserve between 1990 and 2020

Table 5: Akure Retrieved Satellite Temperature in ^{0}c

	1990	**2000**	**2010**	**2020**
Low	20.0	20.8	21.0	22.0
High	32.7	33.5	33.6	34.6
Average	26.4	27.2	27.3	28.3

Source: Satellite Data 2021.

Temporally, in Akure forest reserve, there was positive increase in temperature within the decades between 1990-2000 (3.0%), 2000-2010 (0.4%) and 2010-2020 (3.6%). The nature of increase in temperature is cyclical as shown in Table 5. Table 6 presents the temperature variations retrieved from the Landsat imageries in four different period (1990, 2000, 2010 and 2020).Temperatures forecast derived from Seasonal Auto Regressive Integrated Moving Average (SARIMA).Table 7 shows the average, high and low temperature forecast for five years (2021,2022,2023,2024 and 2025). It is realized that the temperatures have the tendency to increase till the end of forecast period. This portends that evidence of persistence climate change with the chains of havoc on socio-economic activities.

Table 6:Satellite Average Land Surface Temperature Changes for the Study Area (°C)

Location	1990	2000	Difference	% Increase	2010	Difference	% Increase	2020	Difference	% Increase
Akure	26.4	27.2	+0.8	+3.0	27.3	+0.1	+0.4	28.3	+0.1	+3.6

% -Percentage

Source: Land Surface Temperature Retrieval from Satellite Imagery, 2021.

Table 7: Forecast Value for Parameters in Akure

	Maximum Temperature			Minimum Temperature		
Date	**Forecast**	**Lo 95**	**Hi 95**	**Forecast**	**Lo 95**	**Hi 95**
Jan-21	33.55	32.22	34.88	21.56	20.27	22.84
Feb-21	34.42	32.98	35.86	23.69	22.36	25.02
Mar-21	33.93	32.49	35.37	24.08	22.70	25.46
Apr-21	32.81	31.36	34.25	23.89	22.48	25.29
May-21	31.70	30.26	33.14	23.20	21.78	24.63
Jun-21	30.25	28.81	31.69	22.93	21.49	24.36
Jul-21	28.72	27.28	30.16	22.56	21.12	24.01
Aug-21	28.23	26.79	29.67	22.17	20.72	23.63
Sep-21	29.05	27.61	30.49	22.47	21.02	23.93
Oct-21	30.55	29.11	31.99	22.56	21.11	24.02
Nov-21	32.19	30.75	33.63	23.90	22.45	25.36
Dec-21	33.09	31.65	34.53	22.82	21.36	24.28
Jan-22	33.71	32.26	35.15	23.44	21.93	24.95
Feb-22	34.70	33.25	36.14	24.62	23.11	26.14
Mar-22	33.98	32.54	35.43	24.93	23.41	26.45
Apr-22	32.72	31.28	34.17	24.73	23.20	26.25
May-22	31.69	30.25	33.14	24.21	22.69	25.74
Jun-22	30.26	28.81	31.70	23.89	22.37	25.42
Jul-22	28.85	27.41	30.29	23.39	21.86	24.92
Aug-22	28.18	26.73	29.62	23.17	21.64	24.69
Sep-22	29.04	27.59	30.48	23.17	21.65	24.70
Oct-22	30.52	29.08	31.97	23.42	21.89	24.95
Nov-22	32.34	30.90	33.78	24.24	22.71	25.77
Dec-22	33.18	31.73	34.62	24.08	22.55	25.61
Jan-23	33.59	32.12	35.05	21.93	20.35	23.50
Feb-23	34.56	33.09	36.03	23.69	22.11	25.27
Mar-23	33.98	32.51	35.45	24.48	22.89	26.06
Apr-23	32.75	31.29	34.22	24.02	22.43	25.60
May-23	31.68	30.21	33.15	23.68	22.09	25.27
Jun-23	30.25	28.78	31.72	23.33	21.74	24.92
Jul-23	28.80	27.33	30.27	23.01	21.42	24.60
Aug-23	28.18	26.71	29.65	22.19	20.60	23.78
Sep-23	29.05	27.58	30.52	22.47	20.88	24.06
Oct-23	30.54	29.07	32.01	22.71	21.12	24.30

Nov-23	32.27	30.80	33.74	23.84	22.25	25.43
Dec-23	33.13	31.66	34.60	23.62	22.03	25.21
Jan-24	33.60	32.13	35.08	22.11	20.31	23.92
Feb-24	34.58	33.11	36.06	23.95	22.12	25.77
Mar-24	33.98	32.51	35.46	24.42	22.58	26.26
Apr-24	32.75	31.27	34.23	24.16	22.31	26.00
May-24	31.68	30.20	33.16	23.60	21.75	25.46
Jun-24	30.25	28.77	31.73	23.30	21.44	25.15
Jul-24	28.81	27.33	30.29	22.91	21.05	24.78
Aug-24	28.18	26.70	29.65	22.45	20.58	24.31
Sep-24	29.05	27.57	30.52	22.68	20.81	24.54
Oct-24	30.54	29.06	32.02	22.84	20.98	24.71
Nov-24	32.29	30.81	33.76	24.01	22.15	25.88
Dec-24	33.14	31.66	34.62	23.36	21.49	25.22
Jan-25	33.60	32.11	35.09	22.82	20.89	24.76
Feb-25	34.57	33.08	36.06	24.30	22.36	26.24
Mar-25	33.98	32.49	35.47	24.75	22.81	26.70
Apr-25	32.75	31.26	34.24	24.48	22.53	26.43
May-25	31.68	30.19	33.17	23.99	22.04	25.94
Jun-25	30.25	28.76	31.74	23.67	21.72	25.62
Jul-25	28.81	27.31	30.30	23.24	21.29	25.19
Aug-25	28.18	26.68	29.67	22.82	20.87	24.78
Sep-25	29.05	27.56	30.54	22.95	20.99	24.90
Oct-25	30.54	29.05	32.03	23.17	21.21	25.13
Nov-25	32.28	30.79	33.77	24.15	22.19	26.11
Dec-25	33.14	31.65	34.63	23.84	21.89	25.80

In most of the forecasted years presented, there are increase in temperature above the temperature normal. The cause of this can be attached to anthropogenic activities (Table 8). (IPCC, 2013). Table 8 presents the monthly standardized Temperature and Forecasted temperature derived from NIMET Data. This revealed that the forecast temperature (maximum and minimum) is higher than the expected temperature every month using year 2023 as a case study.

Table 8: Monthly Maximum and Minimum Temperature for Normal and Forecast (2023) as an Indication for Increase in Temperature.

Month	Maximum Temperature (Normal)	Maximum Temperature (Forecast) 2023	Minimum Temperature (Normal)	Minimum Temperature (Forecast)2023
January	31.9	33.6	20.6	21.9
February	32.8	34.6	21.4	23.7
March	32.9	34.0	22.6	24.5
April	32.1	32.8	22.6	24.0
May	31	31.7	21.8	23.7
June	29.3	30.3	21.6	23.3
July	27.5	28.8	20.8	23.0
August	27.7	28.2	20.6	22.2
September	28.1	29.1	21.2	22.5
October	29.4	30.5	21.3	22.7
November	31.7	32.3	21.7	23.8
December	32.5	33.1	20.7	23.6

Source: Extracted from WMO Data and Data Prediction

DISCUSSION

The increase in temperature is an indication of climate change with the resultant effect as global warming. When temperature increases throughout the year, there is the tendency for it to affect human-wellbeing, plants, crop production, income, increase in diseases, drought occurrence, among others.The temperature throughout the study years was above normal and there is the tendency for persistent rising in temperature as shown in all the decades. This can affect the water balance with the effect on plant, human and animals.This confirmed the work of Ogunrayi et al, (2016) which revealed that temperature of Akure was increasing; causing a warmer environment, with consequences on human health, amongst others. From all indications, temperature values is predicted to be in its highest every February of the forecasted years in Akure with February 2022 having the highest temperature of 34.7°C.This follows the finding of Allison *et al*., (2009) that the solar output experienced in 2000s resulted in an unusual deep solar radiation minimum between 2007 and 2009 and this was responsible for unabated increase in surface temperature. Nicholls and Collins (2006) agreed with the estimate global temperature changes of 0.6±0.2°C over 100 years, was due to the increase in GHG concentration for CO_2 from 282ppm by 1800 to 365ppm by 2000. All the methods, observed meteorological data and satellite imagery, for confirming existence of climate change through temperature, proof positive.From the result, the tendency for the increase in temperature is very high in the next decades.Temperature is a determinant of the amount of precipitation available in the soil. The period when soil is moist enough for plant growth depends on prevailing temperature. This study provides a starting point and a useful guide on climate variability and change in Akure and its environment.

CONCLUSIONS

This study examined the temperature trends as an indication of climate change in Akure, Ondo State, Nigeria. The results showed a slow increase in temperature over the period of study. Thisis majorly due to anthropogenic activities that has added to greenhouse gases in form of carbon dioxide. This has led to increase in the amount of energy striking the earth surface from the sun that is being trapped and not being able to be re-radiated back to the space. The results showed increase observed temperature above the expected both monthly and seasonally. The satellite Land Surface Temperature also revealed a steady increase in temperature throughout the study period (1990-2020).Furthermore, the forecasted period showed higher temperature above the expected temperature.Therefore, temperature is the yardstick to justify the evidence of climate change. It is hereby recommended that data on temperature changes should be made available to farmers, foresters, etc. for proper forecasting so as to ameliorate the effect of global warming on humans. Also, there is likelihood that the temperature will continue to increase in the nearest future because of the uncertainty in the provision of alternative to the drivers of climate change.

REFERENCES

Ayoade, J. O. (2003) Climate Change: A Synthesis of its Nature, Causes, Effects, and Management Vantage Publisher, Ibadan .https://www.scirp.org/(S(lz5mqp453edsnp55rrgjct55.))/reference/referencespapers.aspx?referenceid=1308883

Adeleke Elisha Ademola and Orebayo Eniola Aminat (2020). Spatio-Statistical Analysis of Rainfall and Temperature Distribution, Anomaly and Trend in Rainfall, 5(2) (2020); GEOSFERA INDONESIA. pp.1-11

Adeleke, M.L Al-Kenawy, D. Nasr-Allah, A.M. Murphy, S. El-Naggar, G.O. Dickson M. (2018). ″Fish farmers' perceptions, impacts and adaptation on/of/to climate change in Africa (the case of Egypt and Nigeria) Theory and Practice of Climate Adaptation″, Springer, Cham: 269-295.

Akande, A. Costa, A.C. Jorge Mateus, J. and Henrique, R. (2017) ″Geospatial Analysis of Extreme Weather Events in

Nigeria (1985–2015) ″ Using Self-Organizing Maps. Advances in Meteorology.Volume 2017 | Article ID 8576150 | https://doi.org/10.1155/2017/8576150

Allison I, Bindoff N. L, Bindschadler R. A, PM Cox N, de Noblet M. H, England J. E, Francis N, Gruber A. M, Hayw ood D. J, Karoly G, Kaser C, Le Quéré T.M, Lenton M.E, Mann B. I, McNeil A. J Pitman S, Rahmstorf E, RignotH.. J, Schellnhuber, S. H, Schneider S. C, Sherw ood R.C.J, Somerville K Steffen E. J, Steig M, Visbeck, Weaver A. J (2009). The Copenhagen Diagnoses: Updating the World on the Latest Climate Science. Sydney, Australia: UNSW Climate Change Research Centre 60 p.

Building Nigeria's Response to Climate Change, BNRCC. (2011). National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN). Climate Adaptation Strategy Technical Reports, Ibadan, Nigeria.

Chomitz, K.M. Buys, P DeLuca, G., Thomas, T. S Wertz-Kanounnikoff, S(2006). ″At Loggerheads? Agricultural expansion, poverty reduction, and the environment in the tropics″. (The World Bank, Washington 2006),Book p. 308. ISBN: 9780821367353

Ennio Ferrari; Roberto Coscarelli; and Beniamino Sirangelo: (2018). ″Correlation Analysis of seasonal Temperature and Precipitation in a Region of Southern Italy″. *Article geosciences*, 8, 160, pp.1.

Elisha, I., Sawa B.A., Lawrence Ejeh (2017). ″Evidence of climate change and adaptation strategies among grain farmers in Sokoto State, Nigeria″. IOSR *Journal of Environmental Science, Toxicology and Food Technology (*IOSR-JESTFT),11(3), 1-7.

Federal Ministry of Environment (2014). United Nations Climate Change Nigeria. National Communication (NC). NC 2. 2014. https://unfccc.int/sites/default/files/resource/nganc2.pdf

IPCC (2012). Managing the risks of extreme events and disasters to advance climate change adaptation. In: CB Field V Barros, TF Stocker, et al., editors. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge, NY, USA: Cambridge University Press; 2012.

IPCC (2013). The fifth Intergovernmental Panel on Climate Change. Climate change2013.org.

Marlowe Hood (2019) ″ Earth warming more quickly than thought″, new climate model shows PHYS ORG. 2019.

Herrig, D and Lindsey, R ″what evidence exist that Earth is warming and that humans are the main causes″?2020. Climate. Gov.science and information. A climate Smart Nation https://www.climate .gov.

Medori, M, Michlini, L Nogues, I Loreto, F., Calfapietra, C.″The impact of root temperature in photosynthesis and isoprene emission in three plants species″, *Science World Journal*.2012.

Nicholls, N., Della-Marta, P., and Collins, D. (2004). 20th century changes in temperature and rainfall in New South Wales. Aust. Met. Mag., 53, 263–268.

Ogbuabor, J. E. and Egwuchukwu, E. I. (2017). The impact of climate change on the Nigerian economy. International Journal of Energy Economics and Policy, 7(2), 217-223. https://dergipark.org.tr/en/download/article-file/361739

Olujumoke A. Ogunrayi, Folorunso M. Akinseye, Valerie Goldberg and Christian Bernhofer (2016). Descriptive analysis of rainfall and temperature trends over Akure, Nigeria. *Journal of Geography and Regional Planning*,9(11):195-202

World Meteorological Organization (WMO) Guidelines on the calculation of climate normal 2017 edition. WMO - No. 1203.