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Descriptive analysis of rainfall and temperature trends over Akure, Nigeria

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Climate change is expected to alter rainfall and temperature regimes across the world, Nigeria inclusive. Climate projections indicate warming and changes in rainfall varied from one location to another. This study presents a descriptive analysis of rainfall and temperature in Akure, Nigeria for a period of 32-year (1980 to 2011) using monthly record from the Nigerian Meteorological Agency (NIMET) and the Climatic Research Unit (CRU). Descriptive and time series analyses were used to determine the rainfall and temperature regime of Akure. Climate diagram after Walter-Lieth was used, indicating significant difference between the rainy and dry season. The result showed that rainfall in the study site is characterized by alternating wet and dry periods with a tendency towards a wetter condition, which implies that rainy season length is becoming longer than dry season period. While temperature is increasing; causing a warmer environment, with consequences on human health, amongst others. This study provides a starting point and a useful guide on climate variability and change in Akure, Nigeria for further investigations, both at the local and national level with focus on more specific issues like public health, planning, adaptations and barriers.

Key words: Rainfall, temperature, walter-lieth, descriptive analysis.

INTRODUCTION

According to IPCC (2001) and Meehl et al. (2004), there is strong evidence that the global warming over the past 50 years has been essentially contributed by the increase in greenhouse gas concentrations. The report by Peterson and Baringer (2008) had shown that most of this warming began in the 1970s, with the 20 warmest years having occurred since 1981 and with all 10 of the warmest years occurring in the past 12 years. However, with the solar output declination experienced in 2000s resulting in an unusually deep solar radiation minimum between 2007 and 2009, surface temperatures continue to increase (Allison et al., 2009). The observed changes in global temperature are about 0.6 ± 0.2°C over 100 years as quoted by Folland *et. al.,* (2001); Nicholls and Collins (2006) agreed well with estimates due to the increase in GHG concentration for CO_2 from 282 ppm by

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1800 to 365 ppm by 2000. But present day knowledge of CO_2 revealed its concentration to be already around 400 ppm (Roségrant et al., 2002).

There is a growing consensus among several scientific literatures that over the coming decades, the increase in temperatures and precipitation variability levels caused by climate change will be unfavourable for crop growth and yield in many regions and countries (FAO, 2008; Yesuf et al., 2008). Patterns of precipitation and storm events are also likely to change while some regions may have less precipitation, and some may have little or no change. The intensity of rainfall events is likely to increase on the average (Meehl et al., 2007).

Nigeria like other countries in sub-Saharan Africa is highly vulnerable to the impacts of climate change and studies had showed that there is no 'one impact fits all', or silver-bullet adaptation for the region (Adiku et al., 2014). The historical climatic record of Nigeria has shown considerable signals of a changing climate. A report by Nigerian Meteorological agencies (NIMET, 2008) for both rainfall and temperature record over the period 1941 to 2000 indicate a shift from "early to normal" the onset of the rainy (wet) season between 1941 and 1970 (Figure 1a) with the Isolated places around Sokoto, Maiduguri, Owerri, Port Harcourt and Calabar had late onset of the rainy season. However, with the increasing late onset of the rainy season characterized the period from 1971 to 2000 implies a vast portion of the country is greatly affected by delay onset of the rains (Figure 1b). Furthermore, the report on cessation of the rainy season in the country indicated changes from "normal" between 1941 and 1970 (Figure 2a) to "early cessation" during the 1971 to 2000 period (Figure 2b) in most stations (NIMET, 2008)

Their results ascertained that the period of the rainy season in the country has decline from 1941 while the signals of late onset and early cessation of the rainy season set in. Thus, the length of the rainy season has remained shrinking; the annual total rainfall is almost the same, thereby giving rise to occasional flash floods and drought occurrences during growing period. Anuforom (2012) opined that yearly rainfall amounts all over the country were generally higher than long term mean values. Temperatures across the country showed an increasing trend from mid-20th century to date. The mean temperature anomaly (Figure 3) indicated warming in most locations in the country. Temperatures have increased from 0.2 to 0.5°C in the high ground areas of Jos, Yelwa and Ilorin in the north and Shaki, Iseyin and Ondo in the southwest to 0.9 to 1.9°C over the rest parts of the country.

Building Nigeria's Response to Climate Change (BNRCC, 2011) also reported on National Adaptation Strategy and Action Plan on Climate Change for Nigeria (NASPA-CCN) based on climate analysis and pilot projects spread throughout the ecological zones of the country. Their studied considered trends of past climate over Nigeria by analyzing the historical climate records from 40 NIMET stations for the period 1971 to 2000; and future climate change scenarios was generated by downscaling two future climate projections from nine Global Climate Models. The two future climate projections were based on two scenarios known as A2 and B1, with A2 incorporating higher greenhouse gas emissions (GHG), and B1 lower GHG emissions. The higher global GHG emissions scenario (the A2 scenario) was selected as the strongest. Overall, the scenarios suggest a warmer climate in the future. The historical record between 1971 and 2000 shows a trend in rising temperature in Nigeria. The positive trend, which is statistically significant at 95% confidence level, is approximately 0.014°C per year for maximum temperature and 0.025°C per year for minimum temperature. In total, over the thirty year period studied, the maximum and minimum temperatures have increased by 0.4^{o}C and 0.8^{o}C respectively. In addition, the incidence of heat waves (defined as continuous hot days) has increased by more than 20 days over the period (Abiodun et al., 2011).

Akure is a microcosm of the Nigeria nation situated in the high forest zone (or rainforest) in the south west region. The climate of the area consists of two peaks rainy season with short and long dry season. The rainy season begins from March to mid-July and late-August to Mid-November. Little/short dry season occurs between Mid-July and early-August, the long dry season begins from late-November to March (Akinseye, 2010; Akinseye et al., 2012). The temperature throughout the year ranges between 21 to 29°C while humidity is relatively high. The annual rainfall varies from 2,000mm in the southern areas to 1,150mm in the northern areas. The rainfall decreases in amount and distribution from the coast to the hinterland. Thus, the fact that Akure is located in a warm humid tropical climate of Nigeria and its rainfall is characterized by large inter-annual variability with increasing temperature, there is a need for continuous studying. This present study analyzes the rainfall trends and temperature patterns in the zone in order to determine the current climatic trends.

MATERIALS AND METHODS

Akure is the capital of Ondo State (Figure 4), Nigeria and the major dominating town of Akure South Local Government. It lies between longitude 5°06'E to 5°38'E and between latitude 7°07'N to 7°37'N in the Southwestern Nigeria (Ayeni, 2011). It is bounded by Owo Local Government Area in the east, Akure North and Ifedore Local Government Areas in the north, Ile-Oluji/Oke-Igbo Local Government Area in the west and Idanre Local Government Area in the south. The rapid growth of the city, particularly within the last 25 years, has made it one of the fastest growing metropolitan cities in the Southwestern Nigeria. Its population has more than tri-pled from 157,947 in 1990 to ~500,000 in 2006 (Balogun et al., 2011). The climatic condition of Akure follows the pattern of southwestern Nigeria where the climate is influenced mainly by the rain-bearing southwest monsoon winds from the ocean and the dry northwest

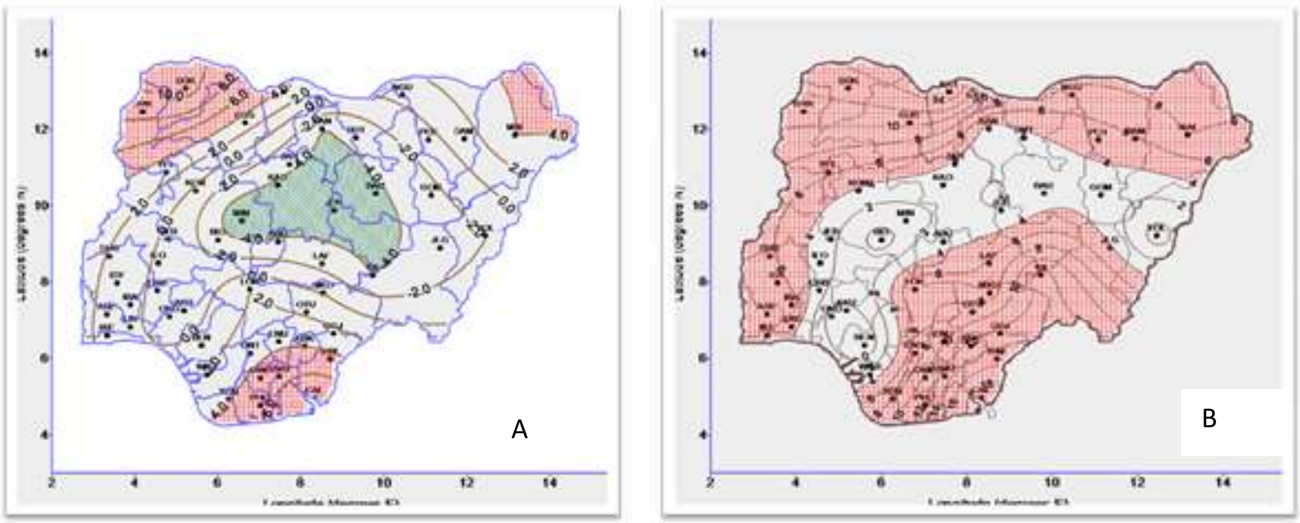


Figure 1. Onset dates anomaly (a) 1941 -1970; (b) 1971- 2000. (NIMET, 2008).

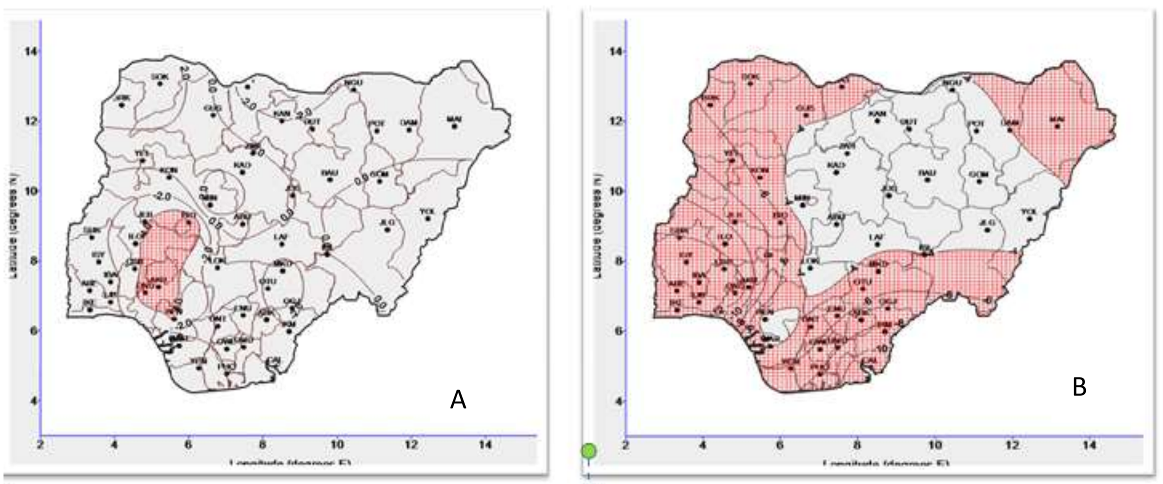


Figure 2. Cessation dates anomaly (a) 1941 -1970; (b) 1971- 2000. (NIMET, 2008).

winds from the Sahara Desert. Akure experiences a warm humid tropical climate, with two distinct seasons, the rainy and dry seasons. The rainy season lasts for about seven months, April to October.

Akure and its environs experience a frequent annual rainfall of over 1500 mm with a short August break. The average temperature is about 22°C during harmattan (December to February) and 32°C in March. The vegetation is tropical rainforest and drained by River Ala and its tributaries (Barbour et al., 1982; Uluocha and Ekop, 2002). Monthly rainfall and temperature data of 1980 to 2011 (32 years) and 1991 to 2011 (21years) were used for this study. The data were obtained from the Nigerian Meteorological Agency (NIMET), Akure. Satellite data for temperature, which covers 31years (1980 to 2010) were collected from the Climate Research Unit (CRU) published by European Centre for Research, Training and Development, UK (www.ea-journal.org). The monthly and annual values were calculated from the monthly rainfall and temperature amounts. Descriptive statistics analyses such as the mean, regression were computed from the climatic data. Also, a pictorial representation in the form of climatograph, after Walter-Lieth and control charts. Time series analysis of the monthly and annual rainfall and temperature values were used to illustrate the trend in rainfall and temperature behaviours and also in estimating seasonal variation.

RESULTS AND DISCUSSION

Figure 5 shows the climate diagram after Walter-Lieth. The temperature and precipitation scales were plotted in a ratio of 1:2. This serves to mark months with arid and

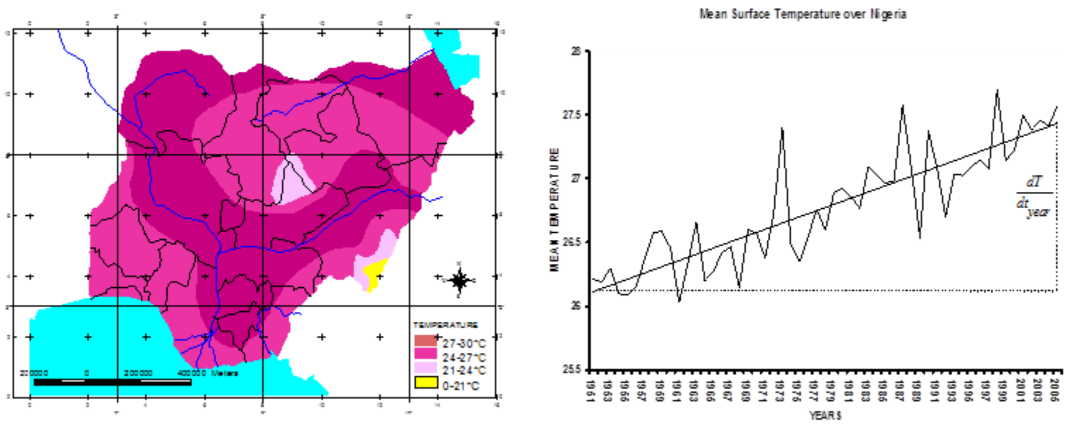


Figure 3. Spatial and temporal distribution of mean annual temperature in Nigeria (Adejuwo, 2004; NIMET, 2008.

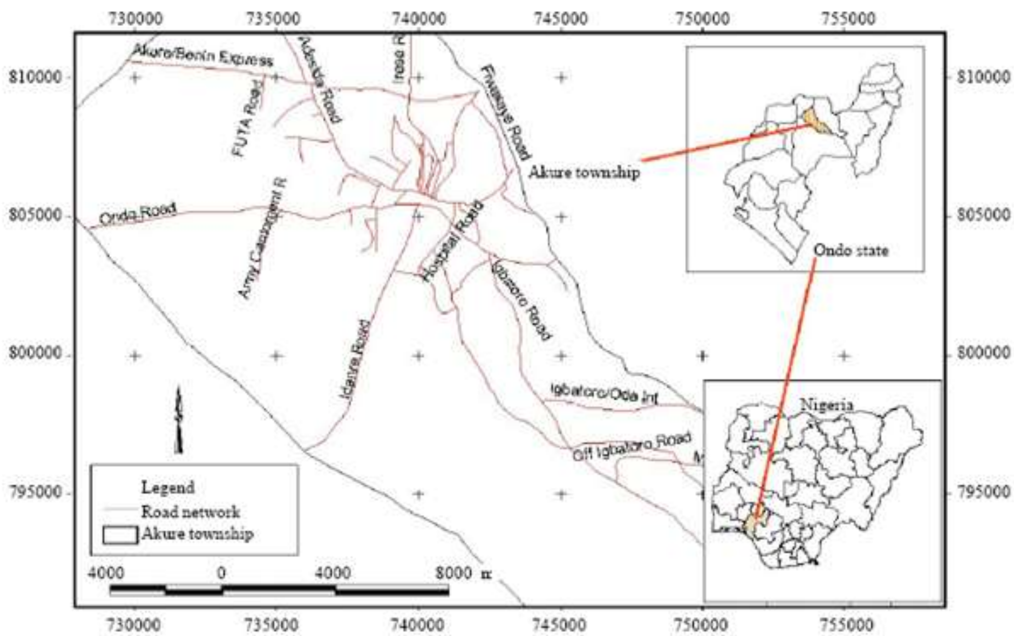
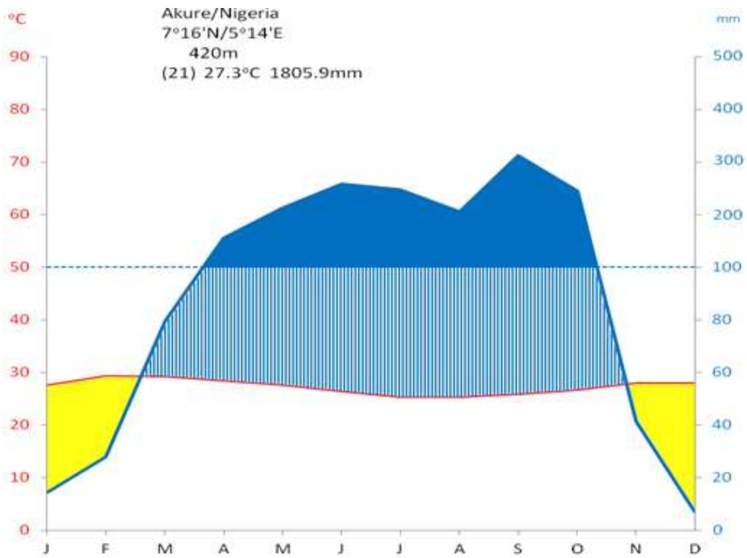


Figure 4. Akure township (Ayeni, 2011).

humid conditions. The curves represent annual cycle of monthly mean temperature in °C, and annual cycle of monthly precipitation in mm/month. At the top of the diagram are indicated the station name and altitude, the period of record, and the annual means. The data, in the form of monthly averages, were plotted as time series on the same graph. When the precipitation curve supersedes or lies above the temperature curve, a moisture surplus are indicated which implies the humid condition (wet season). On the other hand, when the precipitation curve undercuts the temperature curve, a moisture deficit is implied, indicating dry season.

From the Figure 5, it can be observed that the period from March to end of November is humid (blue areas); while in the other months arid conditions (light yellow areas) predominate. The months from April until October show high rainfall (a change in rainfall level of a factor of 10). Obviously, there is a significant difference between the rainy and dry season due to the fact that in the rainy season, the atmosphere is mostly dominated by high moisture depth of water vapour in the cloud which eventually increases humidity in the atmosphere compared to the dry season, which is characteristic of most tropical areas. The mean annual temperature is



Month	Temp (°C)	Rfall (mm)
JAN	27,6	14,4
FEB	29,4	27,8
MAR	29,2	79,4
APR	28,4	156,0
MAY	27,6	211,8
JUN	26,4	258,1
JUL	25,3	247,5
AUG	25,3	205,6
SEP	25,9	312,9
OCT	26,6	244,1
NOV	28,0	41,2
DEC	28,0	7,0
Annual Mean Temp.		
	27,3	
Annual Total Rainfall		
	1805,9	

Figure 5. Climate chart after Walter-Lieth for Akure, Nigeria. Temperature and precipitation scaled to 100mm equivalence of 50oC (ratio 1:2). This serves to mark months with arid (light yellow) and humid (blue) conditions. Monthly precipitation values above 100mm are shown in compressed form.

27.3°C; the annual total rainfall is 1805.9 mm.

Also, Figure 5 indicates that the rainy season usually begins in March and by April or early May, the rainy season covers everywhere throughout the area. The result showed a double rainfall maxima characterized by two peaks, with the first and second peaks occurring in June and September respectively. This implies that the first rainy season begins around March and last to the end of July with a peak in June. This rainy season is then followed by a dip in precipitation in August known as the 'August break', which is a reduction in monthly rainfall (short dry season) lasting for two to three weeks. Although rarely completely dry, this dip in rainfall can be useful agriculturally, because it allows a brief dry period for grain harvesting and also for preparing lands for second growing season (Gbuyiro and Adefisan, 2009). This break is broken by the short rainy season starting around early September and lasting to October with a peak period at the end of September. While months between March and November experience more than 100mm monthly rainfall. As it appears from the graph, September recorded the highest monthly rainfall (312.9mm) during the examined period. The increasing wetness of the September period was therefore triggered towards widespread flooding and erosion by the heavy rainfall such as that of 1999 (Adefolalu et al., 2001).

From the graph, it can be observed that temperature rises during the dry periods (November-March); and gradually cools at the approach of the wet season. This may be due to increase in rainfall observed. The shift in the onset and cessation of rainy season from March/April to October/November has significant implications for agriculture (Obot et al., 2011; Odjugo, 2010). This is due to the fact that early planting encouraged by false start of the rains was subsequently followed by rainfall cessation. In consequence, crops (like maize) already planted and beginning to germinate after the early rains was soon killed off by lack of moisture. When the crops do not fail, the vagaries of weather can still cause variation in yield (Olaniran, 2001). The annual variation in rainfall over Akure is displayed in Figure 5. There is a year to year variation in rainfall, which is evident in the graph. The trend suggests fluctuations, either increasing or decreasing. From the figures, the years 1980, 1991, 1995 and 2007 recorded high rainfall amounts while the least amount was recorded in 1984. It is evident that despite the fluctuations, rainfall is slightly on the increase. According to Olaniran (2001), the area is characterized by alternating wet and dry conditions with rainfall anomaly showing wetter than normal rainfall conditions. This finding is also in agreement with the observation made by (BNRCC, 2011)that this zone is now experiencing wetter conditions in recent years. These results agree with the work of (Ojo et al., 2008) that rainy period in a tropical location can fluctuate in length, time of occurrence, and severity.

However, Figure 6 shows how rainfall varies over time. A control chart is sometimes called shewhart or process-behaviour chart. It distinguishes between natural and special cause variation in a process, how far each data point is from the centre line-the mean. The upper control limit (UCL) and the lower control limit are usually placed 3 standard deviations from the mean. So there is a 99.73% probability that a data point will fall between the two limits. If the p-values (probability values), fall within the limits, the process is statistically 'in control' or predictable.

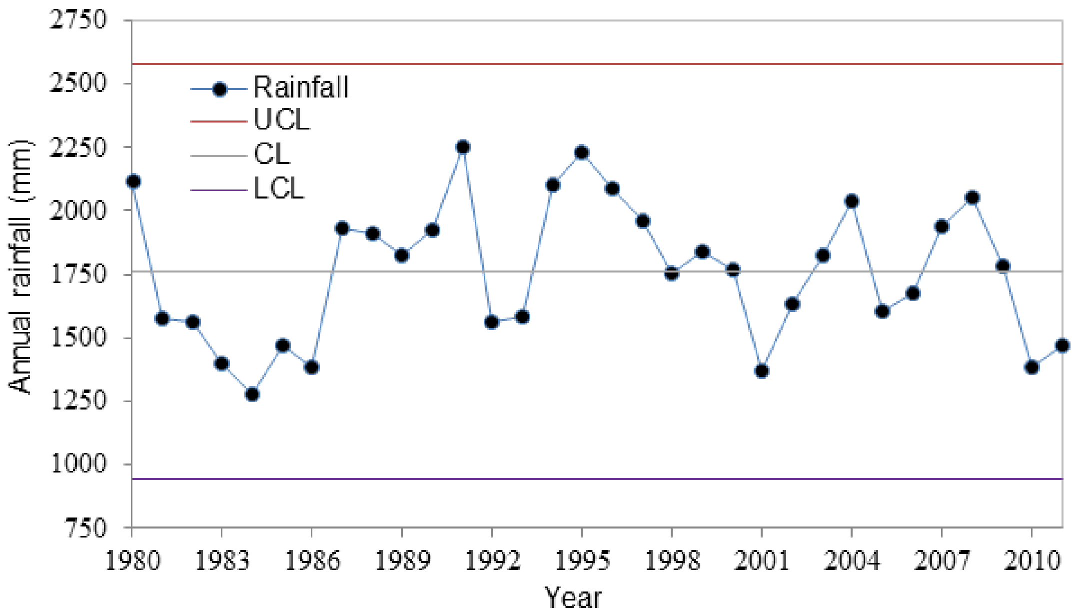


Figure 6. Annual rainfall variability over Akure between 1980 and 2011.

For p-values outside the limits, the process behaviour is unpredictable. The result shows that the rainfall observed over the years is in control; since the data points lie within the control limits. Also, the pattern observed over the years shows the trend is either increasing or decreasing. The advantage of this kind of a process is that it is predictable and can be extremely valuable as an early warning indicator.

Figure 7a displays the mean annual temperature distribution. The years observed indicate that temperature is fairly constant in the 80sand early 90s; but shows an increasing trend as the years go by. A significant increase is observed from the late 90s to the 20th century. The result is in agreement with the study conducted by NIMET that temperatures have shown a significant increase the area (NIMET, 2008). Recent findings have also shown that the 12 warmest years on record have all occurred since 1998 (Theguardian.com, 2014; UCS, 2013). In addition, Figure 7b illustrates the temperature deviations; 2001, 2003 to 2010 are years with above average temperature with 2010 showing the highest positive deviation. The list of hottest years on record is dominated by years from this millennium; 2010 topped the previous record set in the year of 1998 (NOAA, 2012). This finding is also in agreement with the observation made by BNRCC. Its' findings suggest a warmer climate in the future. For instance, the A2 scenario projects a temperature increase of 0.04°C per year from now until the 2046 to 2065 periods, rising to 0.08°C per year after 2050 (BNRCC, 2011).

Figure 8 shows the difference between the observed surface and CRU satellite data for temperature during the years under observation. The difference, which is denoted by ΔT, shows more coherence (r=0.757). As a result, the ΔT trends show reasonable consistency.

CONCLUSIONS

The study has examined trends and fluctuations in rainfall and temperature and, also significant changes in the rainfall pattern of Akure, Nigeria between 1980 and 2011. It is clear from the results that there is a fluctuating rainfall pattern across the observed years; this makes it difficult to forecast the rainfall for a future season. The study concluded that, at present, the climate of the region indicates a rainfall characterized by alternating wet and dry periods, and that the beginning of rainfall is becoming earlier which implies possible longer rainy season in the area. The temperature on the other hand, showed an increasing trend indicating warming throughout the year. Rainfall and temperatures are the leading climatic variables that influence human well-being, plant growth and crops production, amongst others. With the significant variation in rainfall patterns and rising temperatures, it might lead to unfavourable growing conditions. Also, the malaria risk will be greater due to more favourable conditions for the Anopheles mosquito. Findings have also shown that aside agriculture, weather and climate can influence host defences, vectors, pathogens and habitat. The rainfall positively correlated with malaria incidence. It is therefore recommend that qualitative climate data should be made available and accessible for easy analysis in order to improve climate

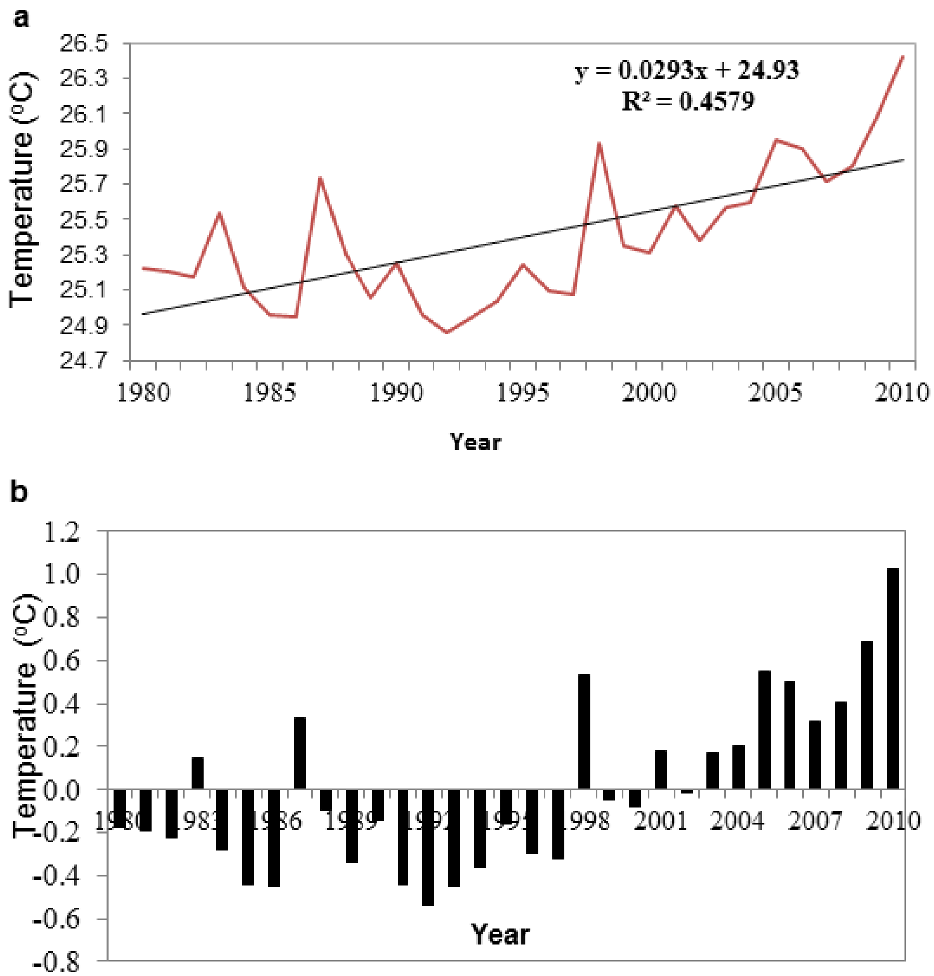


Figure 7. (a) Mean annual temperature variability; (b) Temperature anomaly over Akure between 1980 and 2010.

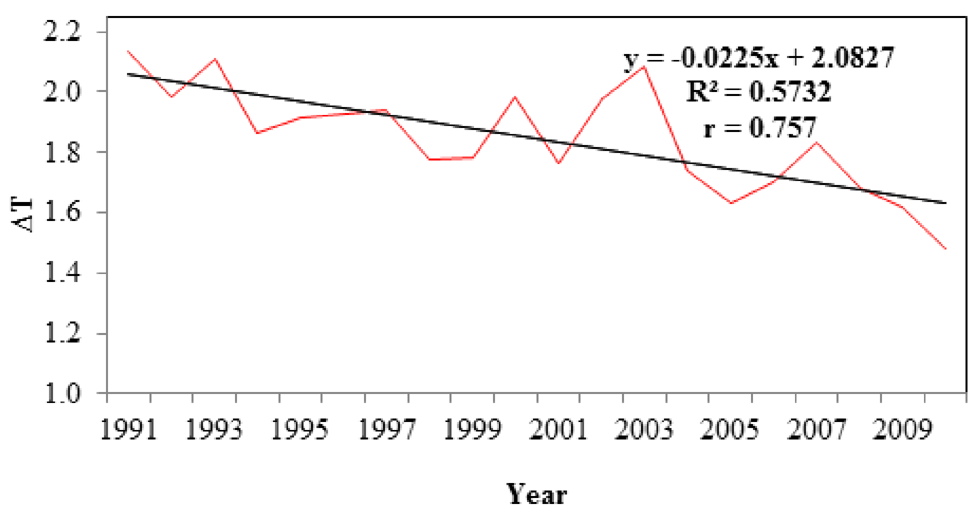


Figure 8. Difference between the observed surface and CRU satellite data for temperature over Akure between 1991 and 2010.

forecasting capacity.

Conflicts of Interests

The authors have not declared any conflict of interests.

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