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ASSESSMENT OF HEAT WAVE EVENTS IN A CHANGING CLIMATE OVER NIGERIA

Elijah Adesanya ADEFISAN[1*] & Sani AHMAD[2]
[*]Department of Meteorology and Climate Change, Federal University of Technology, Akure, Nigeria.
Central Forecasting Office, Nigerian Meteorological Agency, Abuja, Nigeria

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Abstract
Heat waves have attracted increasing attention in recent years due to their frequent occurrence. The present study investigated the heat wave frequency, duration and magnitude in Nigeria using daily maximum, minimum and mean temperatures over thirty-six weather stations from 1986 to 2015. The excess heat factor (EFF) index was applied in the work to investigate the heat wave characteristics. The index is based on a three-day-averaged daily mean temperature (DMT), and is intended to capture heatwave characteristics as they apply to human health outcomes, although its usefulness is likely to be much broader and with potential for international applicability. It is found that the heat wave frequency, duration and intensity show a sandwich distribution across Nigeria, with high occurrence rates in northern part of the country, where the maximum frequency and duration exceeded 2 times and 9 days per year respectively. The high-value zones of heat wave frequency, duration, and intensity in 1986-2015 were basically concentrated in the middle and northern Nigeria. The strongest heat waves were found in extreme north of the country with the highest frequency. The inter-decadal variation of heat wave frequency, days, and intensity are similar. Decreasing trends were all found from around 1986 to around 2003, and significant increasing trends were observed from around 2007 to 2015. The three years with the highest heat wave intensity and maximum heat wave days all appeared in the last decade, indicating that the heat wave intensity, duration and frequency are increasing in Nigeria.

Introduction
There is now a strong scientific consensus that climate change is happening, and that it is largely attributable to human emissions of greenhouse gases (GHGs) (IPCC 2007d). The Intergovernmental Panel on Climate Change (IPCC) has concluded that, warming of the climate system is unequivocal, as it is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (IPCC 2007d). In the last 100 years, global average temperatures have risen approximately 0.75°C and sea levels have risen over 4 centimeters (IPCC 2007c). Climate change is likely to be further exacerbated by increasing GHG emissions (Rogelj *et al.*, 2011). There is much evidence that with current climate change mitigation policies and related sustainable development practices, yet global GHG emissions will continue to grow (IPCC 2007c). Because timely mitigation requires concerted action nationally and internationally, but may be impeded by a lack of political commitment and technical limits (IPCC 2007b; Stern 2007). Even if GHG emissions are drastically reduced, climate change will continue into the next few decades at least due to the time scales associated with climate processes and feedbacks (IPCC 2007a). Continued GHG emissions at or above current rates will cause further warming and induce many changes in the global climate systems during the 21st century that would very likely be larger than those observed during the 20th century (IPCC 2007c).

Climate change endangers human health, both globally and domestically (Haines *et al.*, 2006; McMichael *et al.*, 2012; Patz *et al.*, 2005; WHO 2008). Therefore, public health adaptation has become an important issue on the climate change agenda (Campbell-Lendrum *et al.*, 2007; Ebi and Burton 2008; Hess *et al.*, 2012). Actually, climate adaptation is not an entirely new concept to public health (Frumkin *et al.*, 2008; McMichael *et al.*,2012). Because of the importance of the climate in relation to human health, there are well documented historical observations of human adaptation to the climate. Throughout human history, people adjusted their behavioral patterns, technologies and socio-economic systems to adapt themselves to a range of climatic variations, from arctic cold to desert heat (Burton *et al.*, 2006). However, climate change creates new challenges which may be beyond our past experiences. The fast rate of warming expected in the next few decades means it is unclear how successful future adaptation will be compared to the past. Extreme and unusual weather events could become regular features. Therefore, the current systems, infrastructure, practices and strategies that are well-adapted to the present climate will become increasingly inappropriate and maladapted (Leary *et al.*, 2008; McMichael and Lindgren 2011; Menne and Ebi 2006). While public health adaptation is increasingly regarded as an inevitable part of the response to climate change, a number of studies show that there are constraints and barriers to adaptation (Ebi *et al.*, 2009; O'Neill and Ebi 2009; Wolf *et al.*, 2010). Despite significant investment in adaptive capacity and increased attention to adaptation actions, extreme weather events continue to result in many deaths and injuries (Handmer *et al.*, 2010; Mills 2009; WHO 2009). To date, few studies have evaluated the likely barriers to public health adaptation to climate change. Therefore, it is important to better understand these barriers in order to improve the planning and implementing of public health.

Africa is likely to pay a heavy price for global warming, despite having contributed little to its cause. It is one of the most vulnerable continents due to its high exposure and low adaptive capacity (IPCC 2014). In the past three decades Africa suffered 27% of the world's reported fatalities from natural catastrophes (614 250 people) and experienced 1560 weather-related catastrophes, such as drought, heatwaves, storms and floods (Munich Re 2011). Near surface temperatures have increased by 0.5 °C or more during the last 50–100 years over most parts of Africa (Hulme *et al.*, 2001; Jones and Moberg 2003; Kruger and Shongwe 2004; Schreck and Semazzi 2004; New *et al.*, 2006; IPCC 2007; Rosenzweig *et al.*, 2007; Trenberth *et al.*, 2007; Christy *et al.*, 2009; Collins 2011; Grab and Craparo 2011; Hoffman *et al.*, 2011; Mohamed 2011; Stern *et al.*, 2011; Funk *et al.*, 2012; Nicholson *et al.*, 2013). In northern Africa the northwestern Sahara experienced 40–50 hot days per year in the period 1989–2009 (Vizy and Cook 2012). In the last 15 years in South Africa, the probability of austral summer heat waves has increased with respect to the period 1961–1980. This is associated with deficient rainfall conditions that tend to occur during El Niño events (Lyon 2009). In analogy, in northern Africa there is a projected increase in number of hot days in the coming decades (Patricola and Cook, 2010; Vizy and Cook, 2012). In a future warmer climate with increasing mean temperatures, African heat waves will not only become more frequent; their duration and intensity are very likely to increase as well (Min *et al.*, 2011; Coumou and Rahmstorf, 2012; IPCC 2012), strongly challenging the adaptive capacity and resilience of the population. Longer, hotter and more frequent heat waves are very likely to have a strong impact on mortality, occurrence of wild fires and crop failure. All of us will be affected by climate change, but some people and places will be more vulnerable (Hess *et al.*, 2008; Mirza 2003; WHO 2008). Vulnerability to climate change has been defined by the IPCC as, the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2007a). Vulnerability is comprised of three components: exposure, sensitivity, and adaptive capacity. Exposure is the degree to which a system is exposed to changed climatic conditions; sensitivity is the degree to which systems will respond to a changing climate; and adaptive capacity is the ability of a system to manage the impacts of climate change (Adger, 2006; Fussel, 2007). Understanding who is vulnerable and why, can help us to prevent, cope with, and adapt to the adverse effects of climate change.

The Earth's climate system has undergone tremendous changes since the early days of industrialization, some of which were due to human activities. As a result, the global climate has changed significantly, characterized by the warming of the surface air temperature over the last 100 years or so, with an approximate increase of 0.85°C in global average combined land and ocean temperatures during the period 1880–2012 (Stocker *et al.*,2013). Particularly, it has been observed that the frequency, duration and intensity of heat waves have increased in some regions, leading to significantly adverse impacts on economy, agriculture and public health. Furthermore, scenario-based projection research indicates that global averaged surface temperature is projected to increase by 1.4°C to 5.8°C over 1990 to 2100 (White 2010.), which may increase future heat-related morbidity and mortality. As such, there is a need of frequent investigation and examination of the occurrence of warm spell (heat waves) in order to minimize morbidity and mortality, the risk on public health, economy and agriculture. Heatwave represent a significant natural hazard, arguably more hazardous to human life than bushfires, tropical cyclones and floods, but for many years, these other forms of natural disaster have received much greater public

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attention than Heatwave. Different researches were carried out in different parts of the world using different methodologies. In Nigeria, a similar research was done with same methodology by Balogun *et al.,* (2016) but the work was restricted to limited number of station (5 stations). There is a need to expand the study for a higher number of stations. Therefore, this particular piece of research was able to expand the study of up to 36 stations across the country, thereby, covering the whole country. This work aimed to assess the occurrence of heat wave events in Nigeria from 1986 to 2015 by examining the frequency, duration and magnitude of the events as they apply to human health outcome.

Data and Methodology

The study area is Nigeria, a country located in West Africa, it lies between latitude between 4ºN and 13ºN and between longitude between 3ºE and 14ºE. It is bounded from the north by Niger Republic, from the Northeast by Chad Republic, from the Southeast by Cameroon from the West by Benin republic and it is bounded from the South by the Atlantic Ocean. The study area with the locations of the stations used is in Figure 1

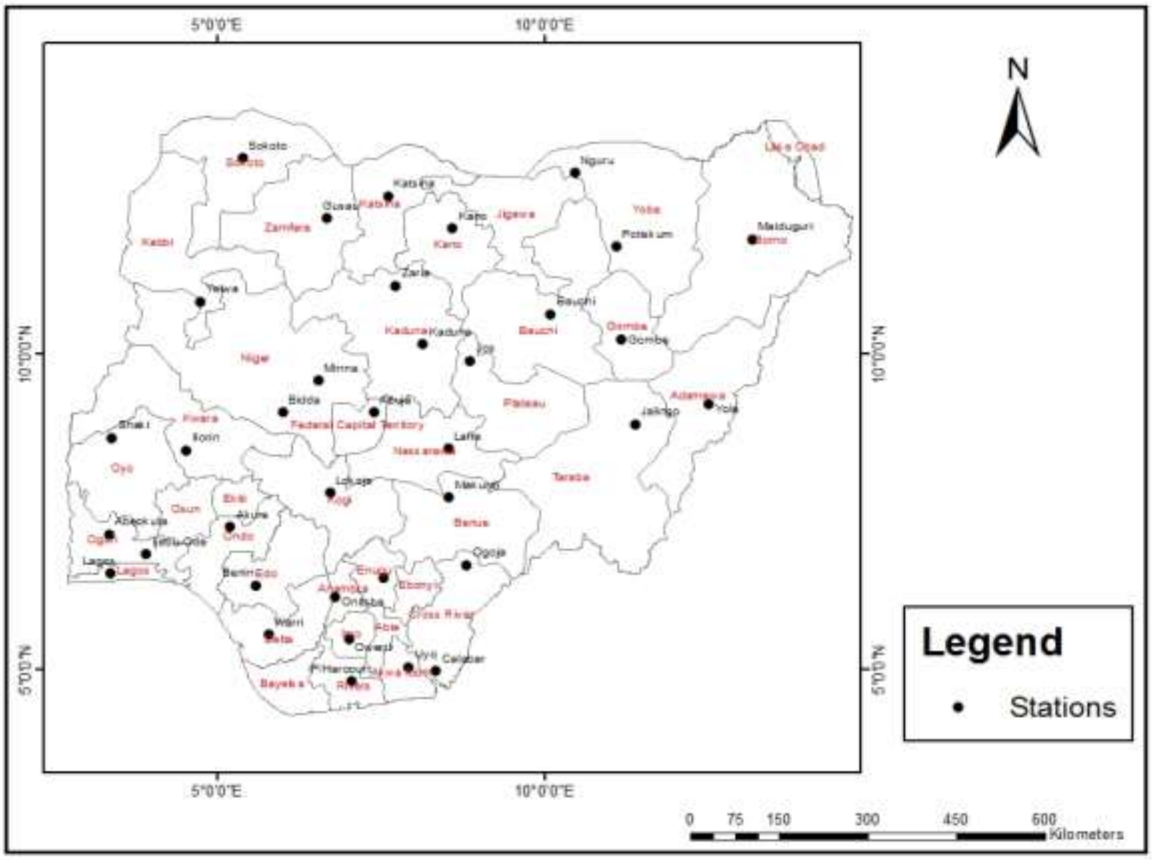

Figure 1:The study area showing the locations of the thirty six stations used.

The data used in this work was sourced from the archive of the Nigerian Meteorological Agency (NiMet) and comprising of daily maximum, minimum and mean temperatures of thirty-six stations for a period of thirty years spanning from 1986 to 2015.The method used in this study was originally introduced for use in monitoring and forecasting of occurrences of heat wave in Australia. The following concepts were developed in order to provide a platform for developing a heatwave definition that is applicable to any location. Indices are adopted that match these concepts as detailed by (Nairn *et al.*, 2015). Excess heat is high heat arising from a high daytime temperature that is not sufficiently discharged overnight due to unusually high overnight temperature. Maximum and subsequent minimum temperatures averaged over a three-day period are compared to a climate reference value to characterize this unusually high heat in an excess heat index. This is expressed as a long-term (climate-scale) temperature anomaly.

Excess heat index is calculated as follows:

$$EHI_{sig} = (T_i + T_{i+1} + T_{i+2})/3 - T_{95} \quad (1)$$

where T_{95} is the 95th percentile of daily temperature, and $T_i$is the mean temperature on day *i*.

Nairn *et al.,* 2015 used daily mean temperature (DMT)as the average of daily maximum and minimum temperatures because they did not have access to synoptic hourly temperatures. In this work,DMT was the average of the eight synoptic period observations made every day. $EHI_{sig}$is in effect an anomaly of three-day DMT with respect to climatological 95th percentile of the DMT. A three-day-averaged DMT is compared directly with the 95th percentile of DMT. If EHI_{sig} is positive, then the Three-Day Period (TDP) is unusually warm with respect to local annual climate. Conversely, if EHI_{sig} is negative or zero, then the TDP cannot be considered as unusually hot, and so for a heatwave to be present, we require EHI_{sig} to be positive.Heat Stressarises from a period where temperature is warmer, on average, than the recent past. Maximum and subsequent minimum temperatures averaged over a three-day period and the previous 30 days are compared to characterize this heat stress in a second index. This is expressed as a short-term (acclimatization) temperature anomaly. Heat Stress is quantified by the magnitude of the EHI_{accl}or the short-term temperature anomaly index, in contrast to the long-term temperature anomaly index of the previous section. It is expressed as:

$$EHI_{accl} = (T_i + T_{i+1} + T_{i+2})/3 - (T_{i-1} + \cdots + T_{i-30})/30 \quad (2)$$

This index can be applied to both biological and engineering systems. Heat regulation in biological systems requires an adaptive response by a range of interacting organs If EHI_{accl} is positive, then the three days are warmer (on average) than the recent past 30 days, and consequently there is lack of acclimatization on the warmer temperatures.The reason for the 30days is that Human physical adaptation to higher temperature may take between two (2) to six weeks. Excess Heat Factor (EHF) is the combined effect of Excess Heat and Heat Stress calculated as an index provides a comparative measure of intensity, load, duration and spatial distribution of a heatwave event. Heatwave conditions exist when EHF is positive.EHF is the product of the two indices. Implying that the Heatwave is present if EHF is positive (but not otherwise). The duration of the Heatwave comprises those days for which the significance index is positive.EHFis positive (denotes that a heatwave is in progress) when $EHI_{sig}$is positive (because the three-day period is hot in an absolute sense, being above the 95th percentile for DMT), but additionally EHFis large when the three-day period is substantially warmer than the preceding 30 days (EHI_{accl}> 1°C). The Excess Heat Factor is quantified by the magnitude of EHF, the combined index measure of long and short term temperature anomalies. Unless otherwise stated, the three-day periods represented by values of EHI_{sig}, and EHFwill be denoted by the first day of the three-day period.

In the case of a heatwave extending over more than one three-day period,the heatload of the event was defined as the sum of the consecutive positive EHFvalues. This definition has the benefit of simplicity, but it comes at the slight cost of down-weighting the DMT contributions from the first and last days of the multi-day (*n* > 3) period. The magnitude of the heat wave was computed by using 85th percentile of all the positive values of EHF obtained from equation (2) for each location. It is called severe (magnitude) threshold denoted asEHF_{85}. After calculating the 85th percentile of all the positiveEHF, each of the 85th percentile was multiplied by 3, then the $EHF_{85}$was computed with the positive EHF obtained earlier

WhenEHF $< 3 \times EHF_{85}$ the heat wave is normal while EHF $\geq 3 \times EHF_{85}$ the HW has become severe.

Results and Discussion

95thPercentile of Maximum Temperature

The climatic zone/region where a station is located determines the temperature of that particular station (i.e different temperature ranges determine the 95th percentile of each station). The 95th percentile for example say in Maiduguri located in the Sahel Climate or Tropical dry climate will definitely be much greater than that of Calabar which is located in the Tropical monsoon climate while the 95th percentile of stations in same climatic zone are not expected to have a wider gap. Even though, climate is not the only determinant of the threshold values. Some anthropogenic activities like urbanization, deforestation, industrialization etc. are among the determinant factors affecting the temperature and consequently affecting the threshold of a particular station

Table 1:The list of thirty-six stations used for the study with their respective longitudes, latitudes, altitudes and the 95th percentile temperatures from 1986 to 2015.

S/NO	Station	Latitude (°)	Longitude (°)	T_{95}(°c)	Altitude (m)
1	Abeokuta	7.1453	3.3590	34.3	67
2	Abuja	9.0765	7.3986	35.7	840
3	Akure	7.2571	5.2058	33.7	350
4	Bauchi	10.6371	10.0807	39.0	616
5	Benin	6.3350	5.6037	32.1	262
6	Bida	9.0797	6.0097	37.1	152
7	Calabar	4.9757	8.3417	29.0	32
8	Enugu	6.4584	7.5464	33.3	180
9	Gombe	10.2464	11.1617	39.4	454
10	Gusau	12.1628	6.6745	39.6	450
11	Ijebu-Ode	6.8300	3.9165	30.1	74
12	Ilorin	8.4799	4.5412	35.6	310
13	Jalingo	8.8929	11.3771	36.5	351
14	Jos	9.8965	8.8583	35.7	1217
15	Kaduna	10.1590	8.1339	36.2	626
16	Kano	12.0022	8.5920	40.0	488
17	Katsina	12.5139	7.6114	39.3	465
18	Lafia	8.5060	8.5227	36.1	290
19	Ikeja	6.5244	3.3792	30.1	41
20	Lokoja	7.8023	6.7333	34.8	113
21	Maiduguri	11.8311	13.1510	41.2	300
22	Makurdi	7.7322	8.5391	35.3	104
23	Minna	9.5836	6.5463	37.1	299
24	Nguru	12.8775	10.4565	41.2	348
25	Ogoja	6.6548	8.7977	33.7	252
26	Onitsha	6.1413	6.8029	33.0	215
27	Owerri	5.4851	7.0176	31.8	71
28	P/Harcourt	4.8156	7.0498	29.2	20
29	Potiskum	11.7072	11.0825	40.5	475
30	Shaki	8.6726	3.3943	35.5	230
31	Sokoto	13.1177	5.3940	41.4	285
32	Uyo	5.0377	7.9128	31.8	191
33	Warri	5.5544	5.7932	30.2	21
34	Yelwa	10.8370	4.7433	38.4	590
35	Yola	9.2035	12.4954	39.0	599
36	Zaria	11.0855	7.7199	37.3	644

The heat wave frequency (HWF)

The Heat wave frequency refers to as the number of heat wave events occurring in one year at a particular station. Here, the results presented indicated a total number of days in a year where the excess heat factor is greater than zero which is the criteria for heat wave event. However, in most areas, heat wave does not occur every year.Figure 2(a), shows that the decadal average frequency of heat waves in Nigeria for the period of 1986-1995 (first decade), the mean occurrence of heat wave events ranges from 0 and 3. Suggesting that the annual average frequencies of the heat waves in Nigeria is less than 1 in almost all the stations in Nigeria, suggesting that it occurs once or none in a year except in few stations like Akure which is greater than 2, saying that heat wave occurs more than twice in the station every year, and the entire south-west, but in areas around Kano, Zaria and Katsina also, the mean occurances was between 1 and 2 saying they were occurring either once or twice in the areas. Figure 2(b), shows that the entire country has a mean occurance of (0-1) heat wave event during the second decade (1996-2005) except stations like Akure, Gombe, Ptiskum, Maiduguri and Kaduna where there were (1-2) heat wave events. Comparing figure 3& 4.3, it is clearly seen that 2nd decade is cooler than the first decade and that the area around Akure exhibits more heat wave. The mean heat wave frequency suggests that, occurrences of the events is atmost once annually in almost the entire part of the country except Gombe, Potiskum, Kaduna and Maiduguri where the event occur once or twice every year within the second decade. Akure continues to exhibits high occurrences compare to the neighbouring station as observed in the first decade.

Mean spatial distribution of heat wave frequency for the third decade (2006-2015) is shown in figure 2(c), this decade shows a tremendous increase in heat wave frequency compared to the 1st and 2nd decades. While 1st and 2nd decades mostly exhibit heat wave frequency of between 0-2 in most part of the country. During the third decade, there are some very hot spots that were having the mean frequency of greater than 8. Those hot spots are: Nguru, Gusau, Sokoto and Yelwa. The entire middle and northern parts of the country exhibit high heat wave frequency having 4 or more occurrences. In general, during the study period (ie during the climatological period; from 1986 to 2015), the mean occurrences of heat wave divide the country in to two parts; having the entire coastal and inland regions observed the mean occurrence between 1 and 2 except areas around Akure and Shaki which had the mean occurrence of between 2 and 3 times. Also, the entire central and northern regions exhibit heat wave frequency between 2 and 3 except Makurdi, Lafia and Jos which exhibit the heat wave frequency between 1 and 2. Nguru is the hottest spot as shown in figure 2(d), which exhibits the heat wave frequency of more than 3 times mean occurrences.

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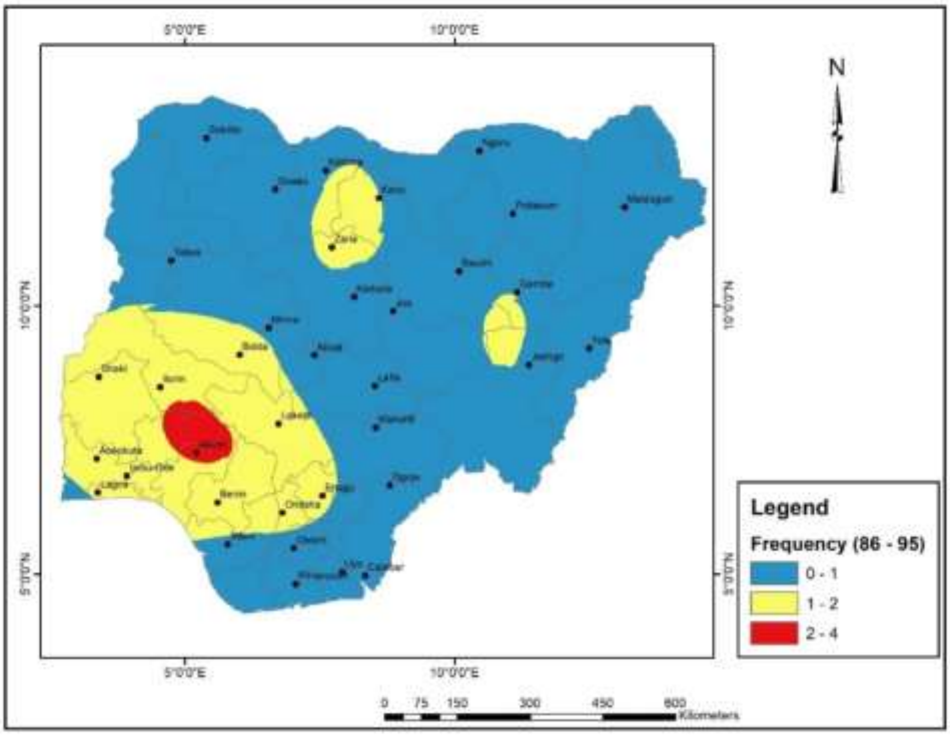

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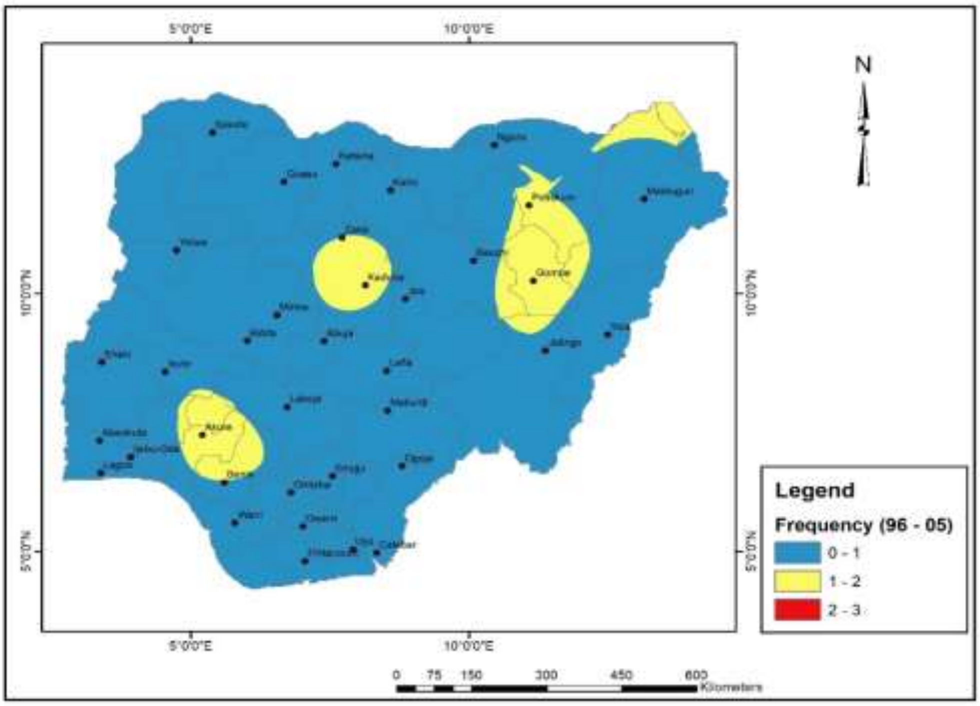

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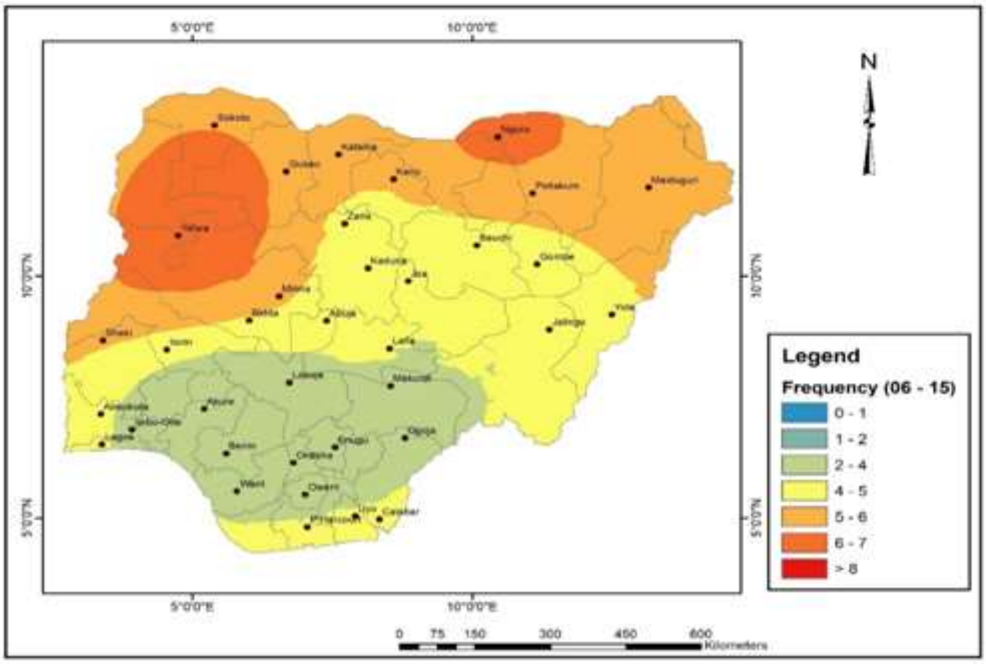
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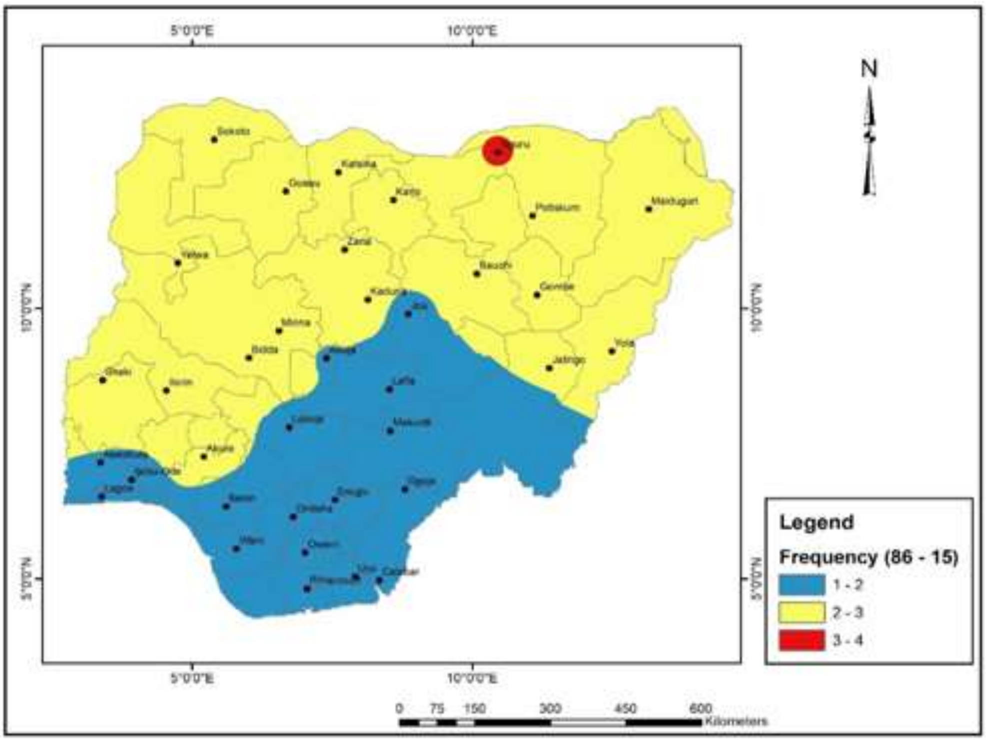
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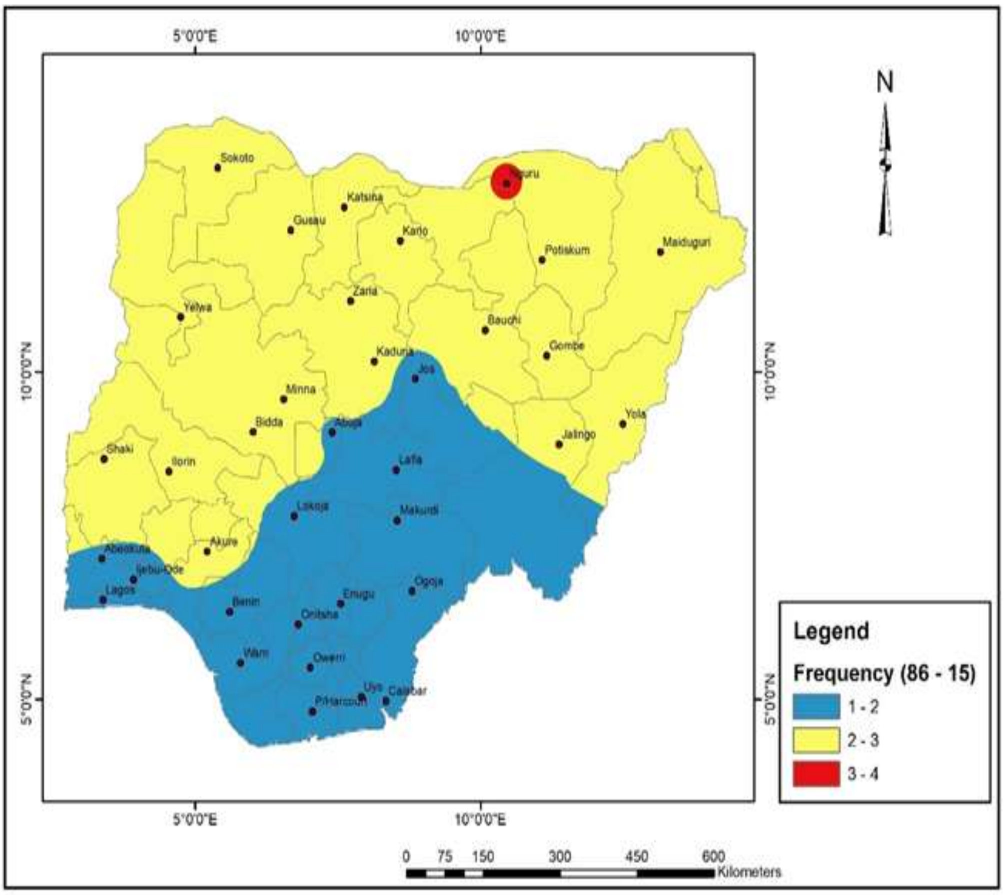


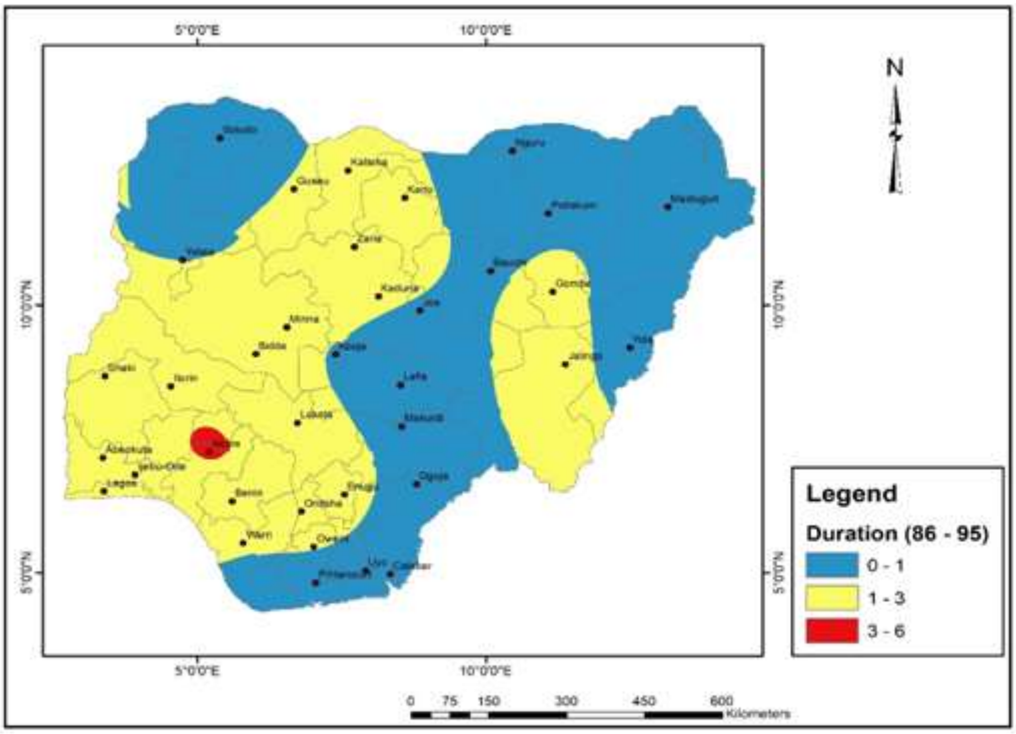
(d)

Figure 2: Spatial distribution of mean heat wave frequency for (a) first decade, 1986-1995; (b) second decade, 1996-2005; (c) third decade, 2006-2015; and (d) thirty years, 1986 – 2015.

The Heat Wave Duration

The mean spatial heat wave duration (HWD) depicted infigure 3(a) shows the distribution of decadal average HWD (in days) over Nigeria during the first decade (1986-1995). The temporal distribution of mean HWD shows that, the entire western part of the country had a mean duration of between 1 and 3 days except in Sokoto, Yelwa and Gusau which have less than a day annually during that period while on the other hand, the entire part of the east had mean duration of between 0 and 1 day per year except Gombe and Jalingo which observed a mean duration between 1 and 3 annually. Akure experienced the longest heat wave annually in the decade with mean duration of between 3 and 6 days yearly. Figure 3(b) shows that the entire country had a mean duration of heat wave events between 0 and 1during the second decade (1996-2005) except stations like Akure, Gombe, Kaduna and Zaria which have the mean duration between 1 and 3 days. It is obviously seen that the duration of heat wave event in the second decade are shorter when compared to the first decade which has station that experienced heat stress for more than 3 days. The entire country tends to have shorter events when compared to the first decade. Mean temporal distribution of heat wave duration for the third decade (2006-2015) which is shown in figure 3(c).

This decade displays a tremendous increase in mean heat wave duration compared to the firstand second decades. While first and second decades exhibit mean duration of between 0 and 3 days in most parts of the country, 3rd decade exhibits 3-6 days in limited number of stations like Akure, Benin, Warri, Onitsha and Ijebu-Ode while the remaining part showed the mean heat wave duration between 6 and 15 days except Sokoto, Yelwa, Katsina, Gusau and Niger which showed 15-20 days. The region around Yelwa exhibits more than 20 days and that is the longest mean heat wave duration recorded during the study period.The climatological mean of heat wave duration (1986-2015) shown in figure 3(d) shows that the entire country exhibits the mean duration between 3 and 6 days except in coastal region which has a mean duration of less than 3 days, and also in the arid region of Sokoto which exhibits the mean duration between 6 and 9 days. Which means the climatological period showed that the arid region of Sokoto experienced longest heat wave in average between 6 and 9 days annually for the thirty (30) years of study period. In contrast, the coastal region experienced just less than 3 days of excess heat annually for the study period. Meanwhile, the remaining part of the country which lies in between the two, has experienced between 3 and 6 days of excess heat in the study period.



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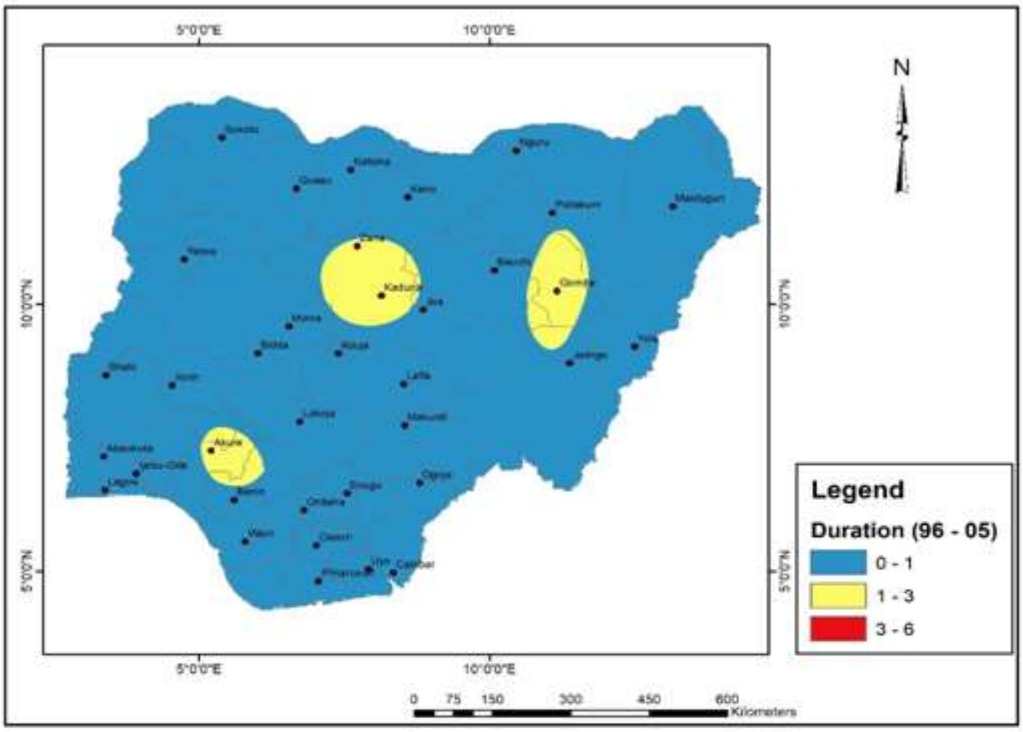
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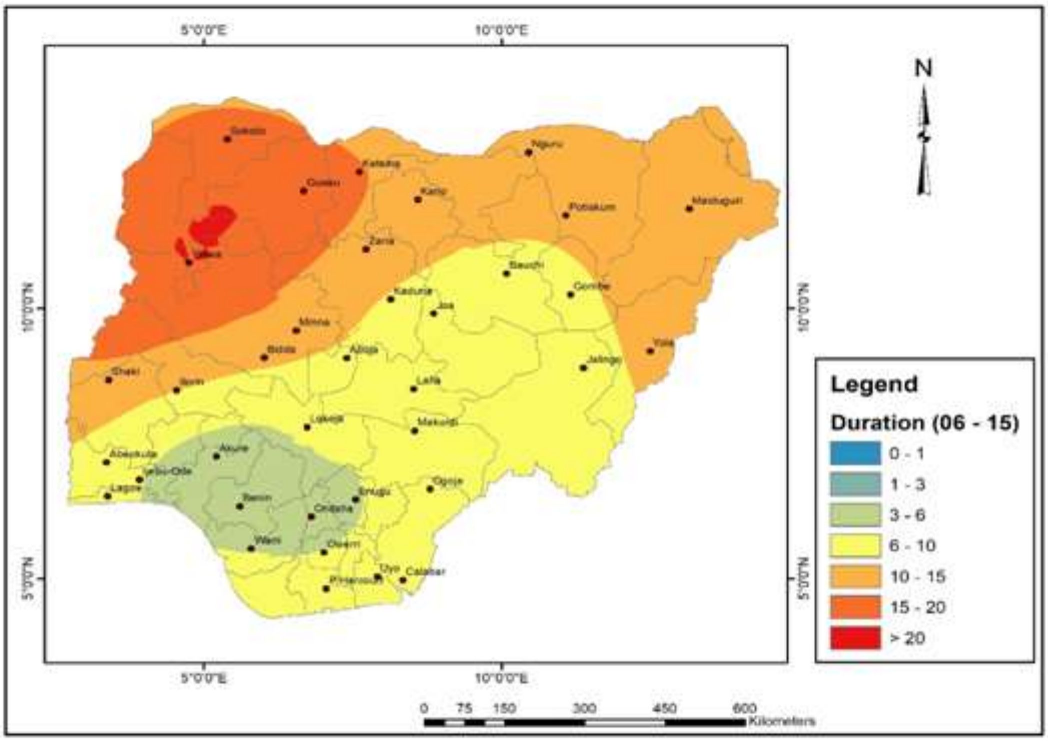
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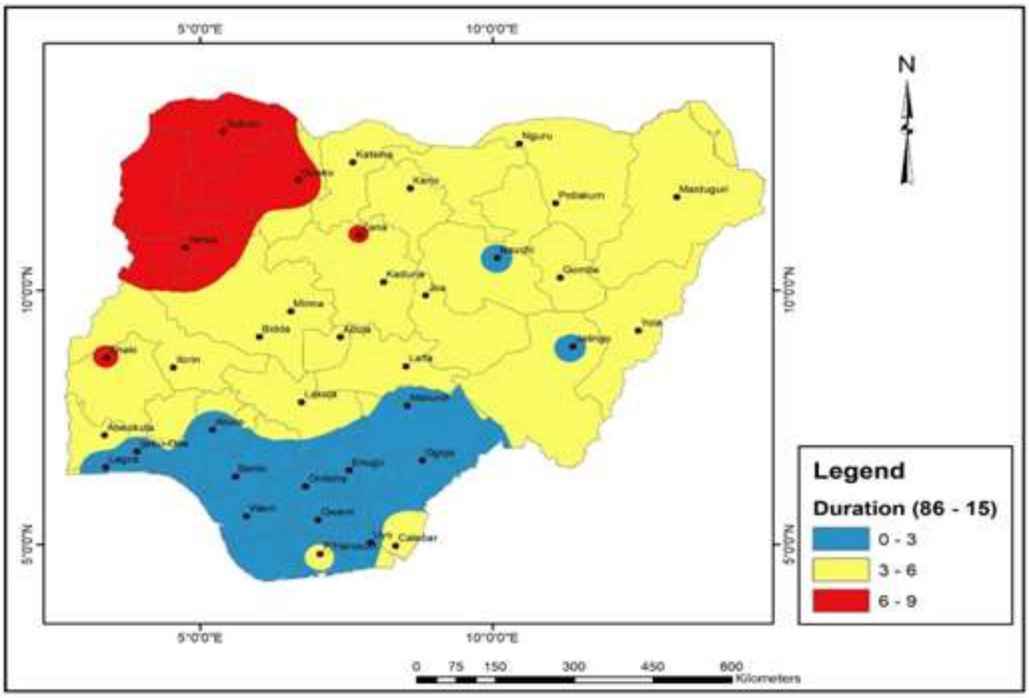


(d)

Figures 3: Same as figure 2 but for heat wave duration (HWD).

Heat Wave Magnitude (or intensity)

The Heat Wave Magnitude Index is defined as the maximum magnitude of the heat waves in a year. The heat waves mean magnitude takes the average daily magnitude across all heat waves event within the year. That is, the heat waves mean magnitude is the average taken on daily basis from the daily magnitude during all heat waves events within a given year.

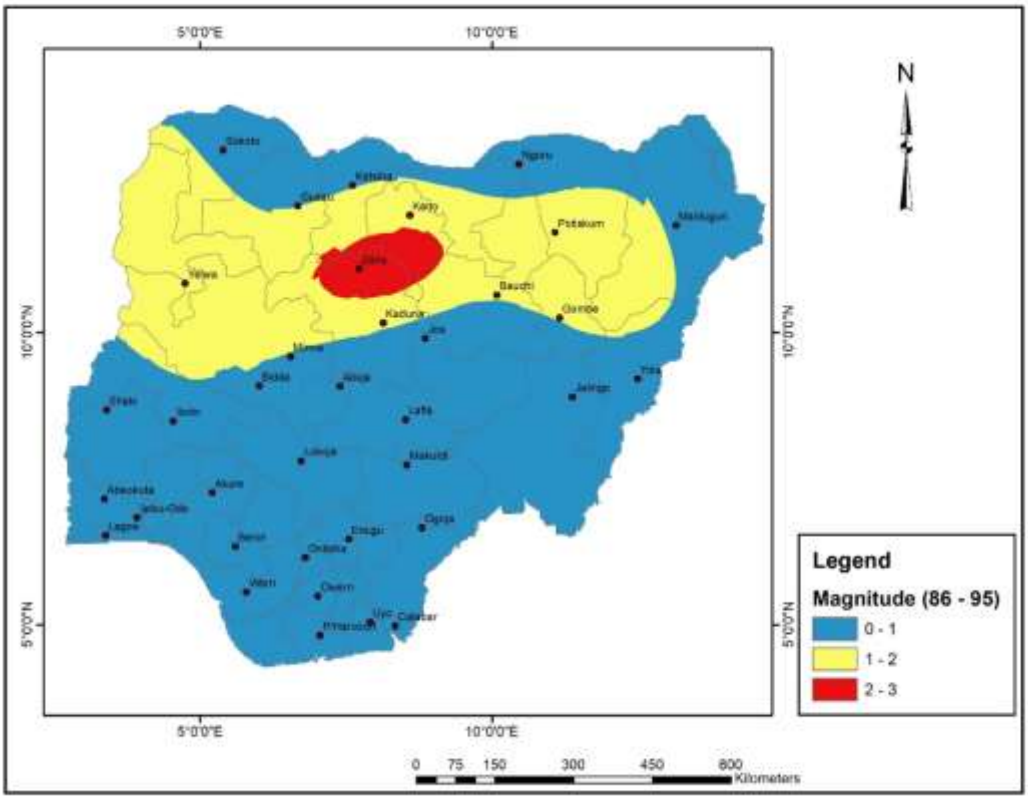
Table 2:Classification of heat wave magnitude levels (Russo et al., 2014).

	Normal	Moderate	Severe	Extreme Extreme	Very Extreme	Super Extreme	Ultra-Extreme

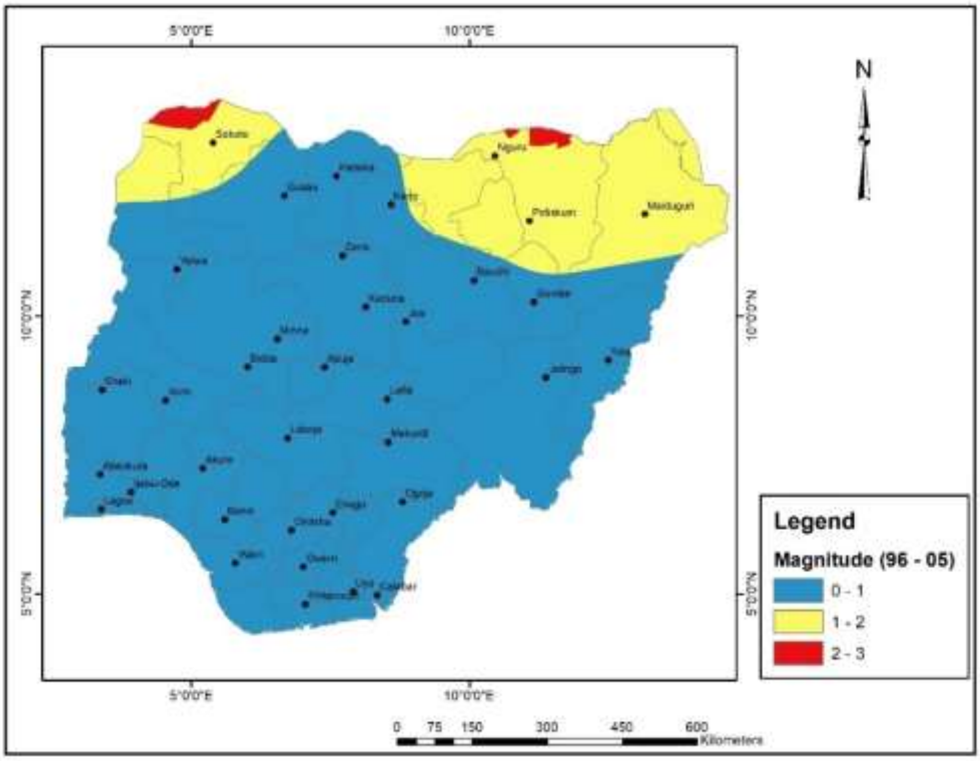
1 2 3 4 8 16 32

The mean heat waves magnitude observed in the period of 1986-1995 in Nigeria seems to be normal in almost the stations of the country. Figure 4(a), shows the magnitude of heat waves in Nigeria from 1986 to 1995 (first decade). The heat wave magnitude was observed to be normal in almost the entire country except in regions of Gombe, Potiskum, Bauchi, Yelwa, Gusau, Katsina, Zaria and Kaduna, which the observed mean magnitude was moderate. While in Zaria and Kano, the intensity heat wave was severe. In Akure, despite having more frequent and longer lasting heat waves in that decade, the events were observed to be mild (normal).

The heat wave mean magnitude in the second decade (1996-2005) was similar to that of the first decade, the entire country exhibits normal heat wave except in some areas of Maiduguri, Potiskum and Kano, where the mean magnitude was moderate while parts of Sokoto and Nguru were observed to have a severe heat wave. Figure 4(a and b) show that the intensity of heat wave events during the 1st and 2nd decade was almost same in Nigeria, having the magnitide in both decades ranging between normal and severe in the extreme north while having normal throughout the south. In the third decade as shown in figure 4(c), the normal heat wave that was experienced in the previous two decades over the south and central part of the country continue to prevail in the third decade except in Shaki, Minna, Bidda and Ilorin which observed moderate heat wave, but over the moderate heat wave was also observed over most part of the region except in Sokoto and Yelwa, and some part of Gombe, Bauchi and Potiskum which have severe heat wave. Extremely severe events were also observed over Nguru, Maiduguri and part of Sokoto which are the hottest spots in the study area during that decade. The 3rd decade is seen clearly hotter than the 1st and second decades as shown on figure 4(a,b and c). The climatological mean magnitude divides the country in to two parts as shown in figure 4(d); having the entire south and central parts to observed normal heat waves throughout the study period while the entire north experienced moderate heat wave in average except Potiskum and Maiduguri which exhibit a severe mean magnitude during the study period. The climatological mean magnitude shows that the southern and the central parts of the country are always cool and is favorable for human and animal while in the north there is a need to acclimatize from time to time. It is also shows that life in the northern region is more vulnerable to heat related diseases and problems.



(a)


5°0'0"E
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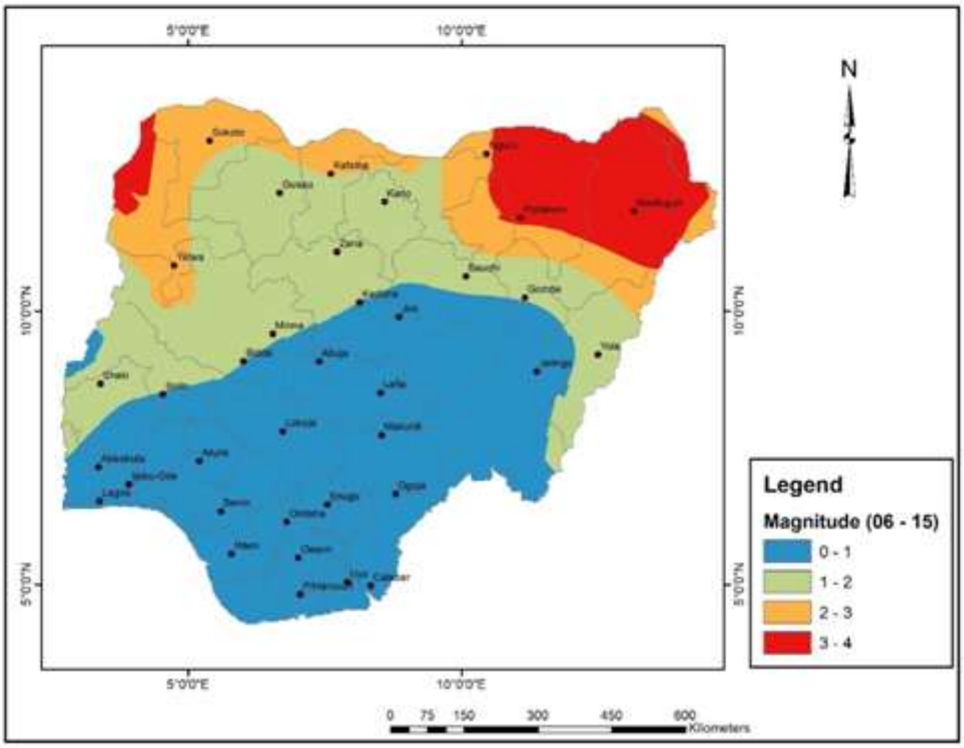
Legend
Magnitude (96 - 05)
0 - 1
1 - 2
2 - 3
0 75 150 300 450 600
Kilometers

(b)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Magnitude (06 - 15)
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Kilometers

(c)

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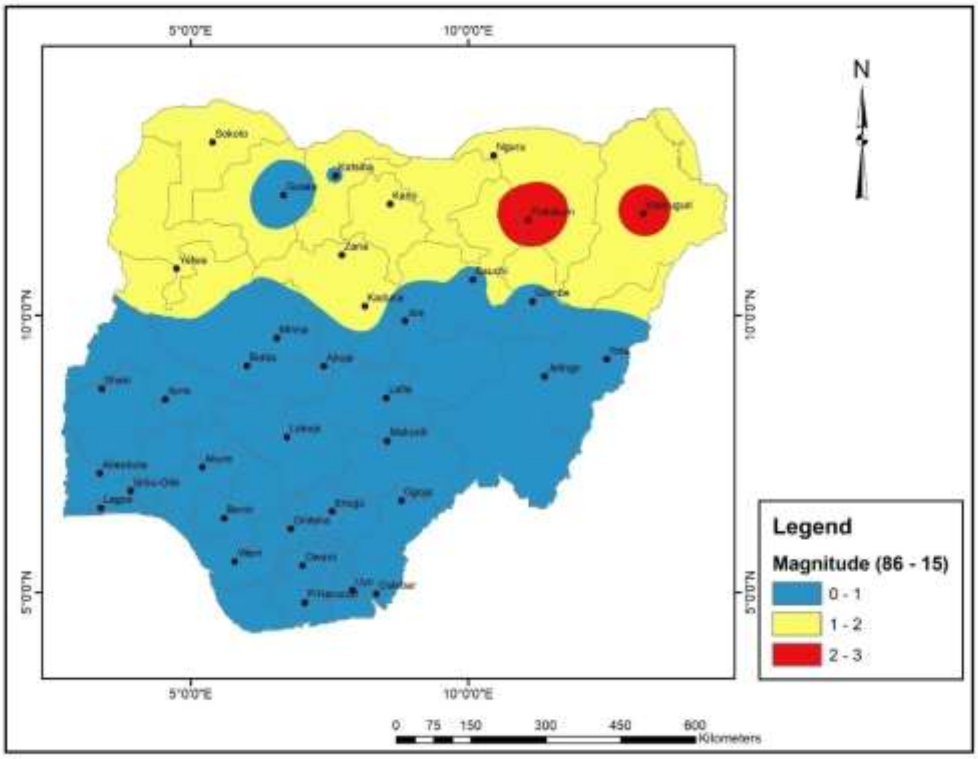

(d)

Figure 4: Same as figure 2 but mean heat wave magnitude.

The characteristics (frequency, duration and intensity) of heat wave were seeing to be influenced by some mechanisms such as atmospheric pressure, persistent atmospheric pressure pattern induced land-atmosphere feedback that lead to extreme temperature. During day time, heat was supplied by large scaled horizontal advection, warming of an increasingly desiccated land surface and enhanced entrainment of warm air into the atmospheric boundary layer. Overnight, the heat generated during the day was preserved in an anomalous kilometers deep atmospheric layer located several hundred meters above the surface, available to re-enter the atmospheric boundary layer during the next diurnal cycle. This resulted in progressive accumulation of heat over several days, which enhanced soil desiccation and led to further escalation in air temperatures. The combination of multi-day memory of the surface and the atmospheric boundary layer can be used to explain the extreme temperature. The Sahara Desert which is associated with atmospheric blocking patterns, is the requirement for the cause of high atmospheric pressure in the region and consequently resulting to high temperatures in the extreme northern part of the country.

Soil moisture is another factor that can influence heat wave,it can exacerbate hot conditions, in moisture-limited regions, when soil moisture is reduced (i.e. the Earth's surface is dry), the air temperature rises, and this can result in longer and more intense heatwaves (Seneviratne *et al.*,2010; Mueller and Seneviratne 2012). Soil moisture is reducing as one is moving from coastal region in to the country to the point that where there is no soil moisture in the extreme north. Therefore, causing longer and more intense heat wave. The longest heat wave was found at Potiskum where is located in a region where there is no soil moisture. In fact, in these regions, the level of soil moisture can determine whether an embryonic heatwave grows and intensifies, or whether it collapses. If there is enough water remaining in the soil, cooling associated with its evaporation could slow or dampen the severity of an oncoming heatwave, preventing the occurrence of very extreme heatwaves. In Akure, long lasting heat wave and more frequent were observed, while the station is located in a moister climate because the events might be preceded by a severe and prolonged dry period that significantly reduces the water content of normally moist soils.

Furthermore, cloud and aerosol reflect some incoming solar radiation (shortwaves) tending to cool the earth surface, but they trap some heat leaving the earth surface, causing warming to the surface. These effect is known as cloud radiative forcing, play a key role in temperature variations on earth's surface (Nigeria in particular). It was found that temperature increase with decreasing cloud cover. The cloud cover which usually forms as a result of condensation of water vapor which evaporate from water bodies and vegetation (evapotranspiration) in the atmosphere. The cloud cover is usually large usually broken (5-7 Oktas) in the southern part of the country (as a result of the proximity to the ocean and large vegetation cover), reflects some of the incoming solar radiations and stopping them from reaching the surface. Some radiations that get to the surface are absorbed and used by the vegetation to make their food. Therefore, the surface is always cool, because of the outgoing solar radiations that usually warm the surface are less. Aerosols which are formed by the oceans salt help also in reflecting the incoming solar radiation as they are scattered in the region. There is no heat stress in the region as surface temperatures are always conducive for human and animals. On the other hand, cloud rarely occur in the northern part of the country except during rainy season, which is usually shorter lasting season. The temperature goes high, since there is no mechanism that will prevent the incoming solar radiation from reaching the surface. The situation becomes worst during summer season because there is no cloud. The aerosols that do occur in the region is dust haze, which are drier. As such they don't reflect the incoming solar radiation, instead, they absorb it, get warmer and release the warm air to the surface. They also trap the outgoing radiation and reflect it back to the surface, acting as greenhouse gases making the surface becoming warmer and warmer. Consequently, the surface temperature will rise to the extreme. If the situation last longer it then become heat wave especially during summer.

Conclusion

A two-step process involving the calculation of heat wave characteristics, and involved the normalization of intensity (magnitude) via severity index scheme has allowed an assessment of the spatial and temporal characteristics of low-intensity, severe and extreme heatwaves.Heatwave frequency, duration and intensity have been calculated as the product of long term and short term daily mean temperature anomaly. Quality assured maximum, minimum and daily mean temperatures data present the opportunity to seamlessly assess how the characteristics of heatwave are changing for all locations. The high-value zones of heat wave frequency, duration, and intensity for the period of 1986-2015 were basically concentrated in the middle and northern Nigeria. The strongest heat waves are found in extreme north of the country province with the most frequency. The heat wave frequency, duration (days) and intensity illustrated large inter-annual variations. The highest frequency is more than 130 times in one decade, and the longest duration is more than 120 days. The inter-decadal variation of heat wave frequency, days, and intensity are similar. Decreasing trends were all found from around 1986 to around 2003, and significant increasing trends were observed from around 2007 to 2015. The three years with the highest heat wave intensity and maximum heat wave days all appeared in the last decade, indicating that the heat wave intensity, duration and frequency are increasing in Nigeria. This increase of the events is a response to the global warming. Since the 1990s, in particular since the beginning of the third decade, the heat wave intensity, frequency and heat wave duration have shown a significant increasing trend. First, this is mainly related to global warming. Secondly, with the acceleration of urbanization, the reduction of vegetation, the urban expansion, and the increase of population density, the urban heat island effect becomes even more obvious. This no doubt increases the temperature in cities in summer.

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