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OCCURRENCE OF HEATWAVES IN KANO METROPOLIS, KANO STATE, NIGERIA

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ABSTRACT
The study analysed the occurrences of heatwaves in the metropolitan Kano between 1991 and 2010 to devise a mitigation protocol for this menace. Daily maximum temperature was taken at the synoptic hours (12 noon to 3:00 pm) during the period (March, April and May) of extreme heat (hot and dry). These temperature values were used to extract the period of heat waves using the 95th percentile thresholds. The maximum temperature data concerning heatwave occurrences were obtained from the International Institute for Tropical Agriculture (IITA) databases. The period from 2002 to 2009 experienced a high number of heatwave occurrences, with consecutive 26 days of 40.8 °C. Heatwaves typically occur in April and May. This implies that April and May were identified as the periods when the occurrence of heatwaves is intense in Kano. One of the key strategies to mitigate heatwaves is to enhance the early warning system for heatwaves, as this can help people take preventive measures, such as staying hydrated and avoiding outdoor activities during the hottest times of the day. Additionally, the government should invest in creating more cooling shelters and green spaces, particularly in urban areas, to provide relief during heat waves. Awareness campaigns about the risks of heatwaves and how to stay safe during such events are essential. This can include promoting lifestyle changes such as using light-coloured, loose-fitting clothing. Moreover, incorporating knowledge of the effects of heat waves into schools' curricula can help mitigate them. It will provide the general public with firsthand information on the dangers associated with heat waves and possible methods for mitigating them.

Keywords: Heatwave, Kano metropolis, Temporal, Temperature

INTRODUCTION
Heat waves are a ubiquitous feature during the warm seasons. An intense heat wave impacts public health, utility infrastructure, and human activities. The severity and frequency of heat wave events represent large-scale climate patterns and may be related to changing climate conditions (Hayhoe, Sheridan, Kalkstein, and Greene, 2010). Urban areas are perhaps the most complex of the Earth's surface due to the versatile nature of their artificial characteristics, as promoted by various human activities since the appearance of humankind (Montavez, Rodríguez, Jiménez, 2000; Ibrahim, 2011). The Earth's surface temperature has increased since the Industrial Revolution began in Europe (Brohan, 2006). The phenomenon was directly linked to the ample emission of greenhouse gases from anthropogenic activities. The increase in carbon dioxide (CO2), chlorofluorocarbons (CFCs), and methane (CH4) in the atmosphere has triggered the occurrence of global warming, which has emerged as a contemporary universal environmental challenge leading to many heat disorders (Intergovernmental Panel on Climate Change, 2007).

The increase in population in the metropolitan cities of most of the developed and developing countries which Kano is inclusive, probably might be the cause for the increase in the amount of greenhouse gases such as carbondioxide (CO_2), methane (CH_4), cloroflorocarbon (CFCs), and nitrous oxide (NO_2) from the large number of automobiles and electronic generators that emit such greenhouse gases with subsequent increase in the mean temperature of the area which may increase the spate of heat waves intensity. Increased heatwave intensity may also cause a lowering of water tables, leading to the emergence of recurrent droughts in the area, frequent bushfires, desertification, and decreased soil fertility, which leads to the loss of agricultural products and subsequently increases the risk of death and serious illness, especially in younger and older age groups and the urban poor who constituted a large sector of the population (Zaitchik, Macalady, Bonneau, and Smith 2006).

Major urban areas experiencing warm temperatures during a heatwave are further exacerbated by the urban heat island phenomenon, where air temperatures within cities are generally warmer than those in surrounding rural areas. (Fruh *et. al.,* 2011). The physical elements of an urban environment, such as asphalt and concrete, have a greater capacity for heat storage than surrounding rural areas and natural vegetation settings (Gallo et *al.,* 2011). During daytime heating, the buildings and roads absorb heat energy due to their low surface albedo. Urban structures retain heat energy effectively and have a significant net heat energy gain. (Gallo *et. al.,* 2011). That heat energy is slowly re-emitted through the latter part of the day and nighttime hours into the surrounding urban environment. Climate change in cities, resulting from overall global temperature increases combined with local climate change caused by urban development and the existing heat islands, intensifies urban heat stress (Fruh et *al.,* 2011).
However, despite the tremendous effects of heatwaves on human beings and their threat to survival, little information exists on the occurrence of heatwaves in Kano metropolis. Therefore, there is a need for the study to be conducted to analyse the spatial and temporal occurrences of heat waves in the Kano metropolis, Northwestern Nigeria.

Study Area

Metropolitan Kano encompasses all eight Local Government Areas: Dala, Fagge, Gwale, Municipal, Nassarawa, Tarauni, Kumbotso, and Ungogo. Figure 1 note. It lies between latitudes 11°52'N and 12°7'N and longitudes 8°22.5'E and 8°47'E, and is 500 metres above sea level. The total area covered is 499.95 Km^2 (Ahmed, 2010). The climate is of the tropical wet and dry type, classified as Aw according to the Köppen climate classification. Temperature is a critical element in this area. The temperature in this region ranges from 21 °C in the coldest months (December and January) to 31 °C in the hottest months (April and May). Four distinct seasons are experienced: dry and cool, dry and hot, wet and warm, and dry and warm (Olofin & Tanko, 2002).
The seasons are determined by the movement of two air masses, a moist, cool southerly mass known as south-westerlies and a hot and dry northern mass called the north-easterlies The moist southern air forms a wedge under the lighter dry air and the region where the two air masses meet is primarily an area of pronounced moisture gradient.
The humidity gradient is called the intertropical discontinuity (ITD). The annual motion of the ITD is northwards between February and August and southwards between September and January. The north-south movement of the ITD influences the weather patterns. Maximum rainfall is recorded in an area of considerable disturbance (air movement) 8 °C to 9 °C southwards of the ITD (Olofin & Tanko, 2002).

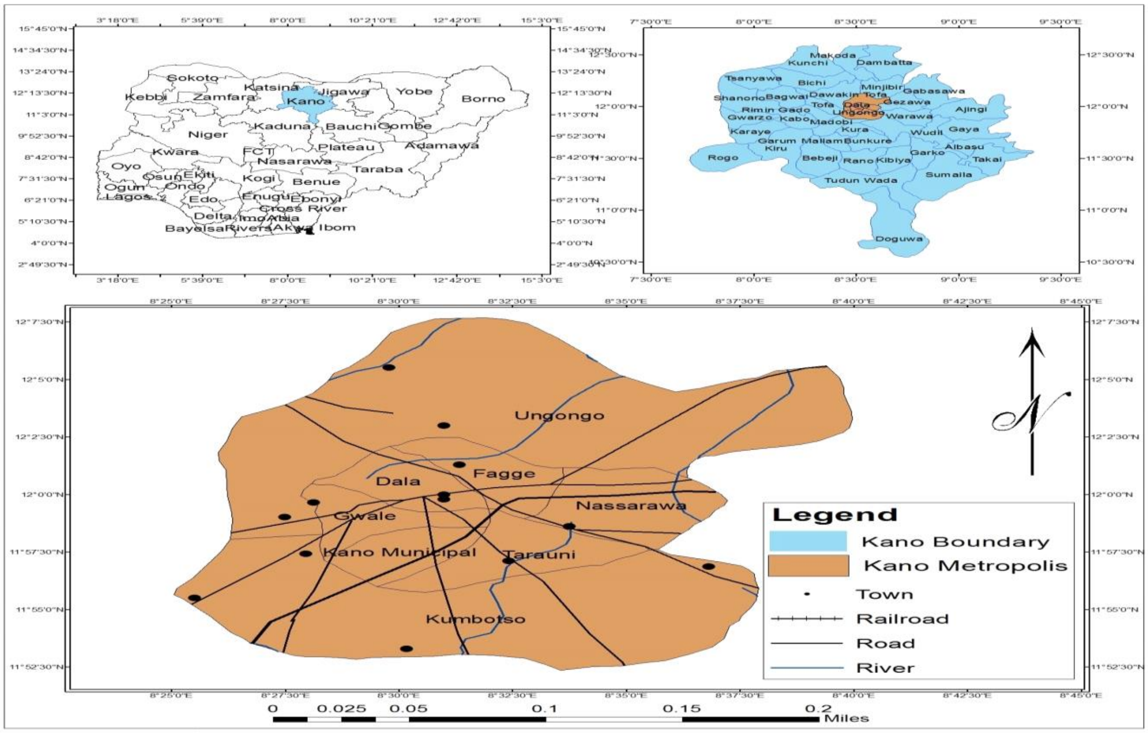

Fig. 1:

The ITD starts its southward movement in February and continues between March and May. It has no considerable influence in the region, and the weather is hot and dry during the rainy season. The mean temperature ranges from 280 °C to 300 °C, and this is the season when the "false" start of the rain is typically recorded in May. A few rainfall instances are recorded in May, and rainy days are separated by dry spells, with less than 1% of the annual rainfall recorded in May. (Olofin and Tanko, 2002). As a result of urbanisation and land use changes, the mean maximum temperature reaches up to 40 °C, which results in the occurrence of extreme heat events, such as heatwaves, in the Kano metropolis (Olofin & Tanko, 2002).

The ITD has, by now, made considerable advances northward, and rainfall is recorded in the region. Heavy rains are recorded mainly in the evenings, lasting one to three hours, with the highest intensity occurring within the first forty minutes of rainfall. Over 90% of the annual rainfall in the region is recorded in this season (Olofin & Tanko, 2002). This is the humid period when surface runoff is available for stream flow, and soil moisture is sufficient for plant growth. *Damina* is the crop-growing season when grains and legumes are cultivated. The temperature drops to an average of 240 °C to 290 °C, while evaporation is lower due to the higher relative humidity of the moist southwesterly air. This is why the runoff coefficient is highest during this season (Olofin & Tanko, 2002).

The ITD is now in its southward retreat, and only a few showers may be recorded in October (Olofin & Tanko, 2002), accounting for less than 8% of the annual rainfall. This is the harvest season between October and November, when farmers are busy harvesting crops and traders are buying what is offered. The average temperature is 280 °C to 290 °C, and this is a dry season, as evaporation exceeds rainfall. This is a season when soil moisture is depleted and stream flow recedes (Olofin & Tanko, 2002).

The ITD reaches its southern limit during this season, and the region is under the influence of northeasterly winds, which bring cool and dusty weather known as "Harmattan". From December to

February, the dry air from the north brings no rainfall, but transported harmattan dust is deposited to replenish soil nutrients. The depth of the windrift material varies from an average of 1m to 2m. This is the cool season, when the temperature ranges from 250 °C to 270 °C (Olofin & Tanko, 2002).

The average temperature is hot. Even during the cool Harmattan period, the minimum temperature rarely falls below 11°C, while the monthly average temperature remains consistently above 20 °C. During the hot season, typically from mid–March to mid-May, the maximum temperature reading may reach as high as 40 °C. The average temperature during these hot months may range between 30 °C and 32 °C. Annual rainfall is approximately 850– 870 mm (Olofin & Tanko, 2002).

The mean annual lower and upper thresholds for minimum and maximum temperatures were 14.5 °C and 23.2 °C for minimum temperature and 30.6 °C and 38.0 °C for maximum temperature. The region experiences a single rainfall peak, with the onset of rains between May and July and cessation between September and October (Camberlin & Diop, 2003). The monthly distribution of temperature has double peaks, that is, in April and another in October (Olofin & Tanko, 2002).

The population is presently estimated at 3.5 million. Kano is among the fastest-growing cities in Nigeria. With a population density of about 1000 inhabitants per km² within the Kano closed-settled zone, compared to the national average of 267 inhabitants per km², the increase in population in Kano metropolis has accelerated numerous anthropogenic activities. These activities may increase surface temperatures, thereby contributing to the occurrence of heat waves (Aminu, 2022).

Major urban areas experiencing warm temperatures during a heatwave are further exacerbated by the urban heat island phenomenon, where air temperatures within cities are generally warmer than those in surrounding rural areas. (Fruh *et. al.,* 2011). The physical elements of an urban environment, such as asphalt and concrete, have a greater capacity for heat storage than surrounding rural areas and natural vegetation settings (Gallo et *al.,* 2011). During daytime heating, the buildings and roads absorb heat energy due to their low surface albedo. Urban structures retain heat energy effectively and have a significant net heat energy gain. (Gallo *et. al.,* 2011). That heat energy is slowly re-emitted through the latter part of the day and nighttime hours into the surrounding urban environment. Climate change in cities, resulting from overall global temperature increases combined with local climate change caused by urban development and the existing heat islands, intensifies urban heat stress (Fruh et *al.,* 2011).

Materials and Methods

Twenty (20) years of daily maximum temperature data (1991 – 2010) for Kano Metropolis were used for this study. The mean monthly temperatures and Daily maximum temperatures data were obtained from the data archive of the International Institute for Tropical Agriculture (IITA) database. All the data were analysed to compute the 95th percentile values, which defined a threshold for maximum temperature. Values greater than the 95th percentile were extracted and counted for each day per year, and this process was repeated for each year over the 20 years. The values were then standardised to account for missing data. Plots were generated to show the 20-year variability of the extremes for each parameter. The data is set to between the range of ≥ 95th percentile values for the maximum temperature.

The data obtained were split into four seasons: Hot and Dry (March, April, and May), Warm and Wet (Nil), Warm and Dry (Nil), and Cool and Dry (Nil) in order to determine the period of heatwave occurrences in the study area. Percentiles were used in favour of maximum temperature values, as stated by Rensch and Cai (2012). Using the daily maximum temperature, the 95th percentile of temperature was found. A heat wave event occurred if it satisfied these criteria: maximum temperature ≥ 95th percentile of the maximum temperature for the month in which the heat wave begins, for a minimum of three (3) consecutive days.

Observations:

1. It is a calculated temperature tabulated on percentile values whereby the 95th percentile represents maximum temperature values greater than or equal to 350 °C.
2. The 95th percentile was used because the maximum temperature in the study area exceeds 350 °C.
3. Data from IITA and NIMET were used.
4. Two methods to determine the spatial occurrences of heatwaves in the study area were used (Landsat 5 Thermal Band Information and Landsat 7 EMT +)

Result and Discussion

Table 1 reveals that the number of heatwave occurrences between 1991 and 2000 was found in April 1993, 1994, 1995, 1998, 1999, and 2000, each lasting 5 days. No data were found in May 1996, 1997 and 1998. For the remaining months, no heatwaves were experienced. The occurrence of heatwaves from April 1993 to 1995 and from 1998 to 2000 may be attributed to the period when the population of Kano metropolis increased, and anthropogenic activities (Pollution, automobile emissions, and Land use changes) also increased atmospheric oxides of Carbon and sulfur, thereby increasing thermal invasion. This finding is in agreement with the study conducted by Alghamdi (2014), who reported the occurrence of heatwaves as thermal events in Saudi Arabia.

Table 1: Mean Monthly Maximum Temperature and Heatwave Occurrences from 1991-2000 in Kano (Threshold at 95th Percentile)

Mean Temperature	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
1991-2000	28.9	32.1	36.8	39.2	36.1	35.2	32.0	30.8	32.2	34.5	33.0	30.0	No. of heatwave
1991	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0
1992	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0
1993	Nil	Nil	Nil	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	5
1994	Nil	Nil	Nil	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	5
1995	Nil	Nil	Nil	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	5
1996	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0
1997	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0
1998	Nil	Nil	Nil	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	5
1999	Nil	Nil	Nil	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	5
2000	Nil	Nil	Nil	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	5
Total Decadal Heatwave Days													30

Source: IITA and Field Work, 2024

Table 2 indicates that the highest number of days with heatwave occurrences was found in April 2007, 2008, and 2009, with 10 days each. These were followed by March 2005, 2006, and May 2007, each with an 8-day duration. The least number of days in which a heatwave occurred during this decade were in April 2001, 2002, 2004, and 2006, followed by May 2002, 2003, 2004, 2005, 2006, and 2008. The remaining months did not experience heat waves. Thus, more heatwaves were experienced in April, followed by May and March. The duration of the heatwaves lasted between 5 and 10 days between 2002 and 2009. This conforms with the work of Balogun Ambore and Vincent (2016), who reported that the number of days in which heatwaves occurred in Kano in 2002 was 8 days. This implied that Kano, since 1993, had been experiencing longer heatwave scenarios than in past years due to the increasing duration of heatwaves.

Table 2: Mean Monthly Maximum Temperature and Heatwave Occurrences in Kano Metropolis 2001-2010 (Threshold at 95th Percentile)

Decade Mean Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2001-2010	28.8	32.2	36.7	39.2	36.7	35.7	32.7	30.8	31.9	34.2	33.5	30.3	No. of Heatwave
2001	Nil	Nil	Nil	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	5
2002	Nil	Nil	Nil	5days	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	10
2003	Nil	Nil	Nil	7days	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	12
2004	Nil	Nil	Nil	5days	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	10
2005	Nil	Nil	8days	6days	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	19
2006	Nil	Nil	8days	5days	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	18
2007	Nil	Nil	Nil	10days	8days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	18
2008	Nil	Nil	Nil	10days	5days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	15
2009	Nil	Nil	Nil	10days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	10
2010	Nil	Nil	Nil	9days	9days	Nil	Nil	Nil	Nil	Nil	Nil	Nil	18
No. of Heatwave days													135

Source: IITA and Field Work, 2024.

Figures 2 and 3 were generated using Landsat software. The Figures show the uneven distribution of the surface temperatures, indicating that the seasonal heatwaves increased from 1991 to 2010. The results obtained from measuring air/surface temperatures during the hot and dry seasons from 1991 to 2000 were also presented. The study area experienced a temperature range of 21 °C to 41 °C, with the lowest temperature recorded at 21 °C and the highest at 41 °C. Out of the total area of 499.95 km, only a tiny portion experienced temperatures ranging from 21 °C to 25.9 °C. Those were areas with green vegetation throughout the year. Temperatures ranging from 31 °C to 35.9 °C occupied some portions of water bodies. The temperature ranges of 36°C-40.9°C and 41°C-45.9°C covered at least 90% of the total area recognised as urbanised, where anthropogenic activities are more pronounced.

Spatial Distribution of Surface Temperature 1991-2000

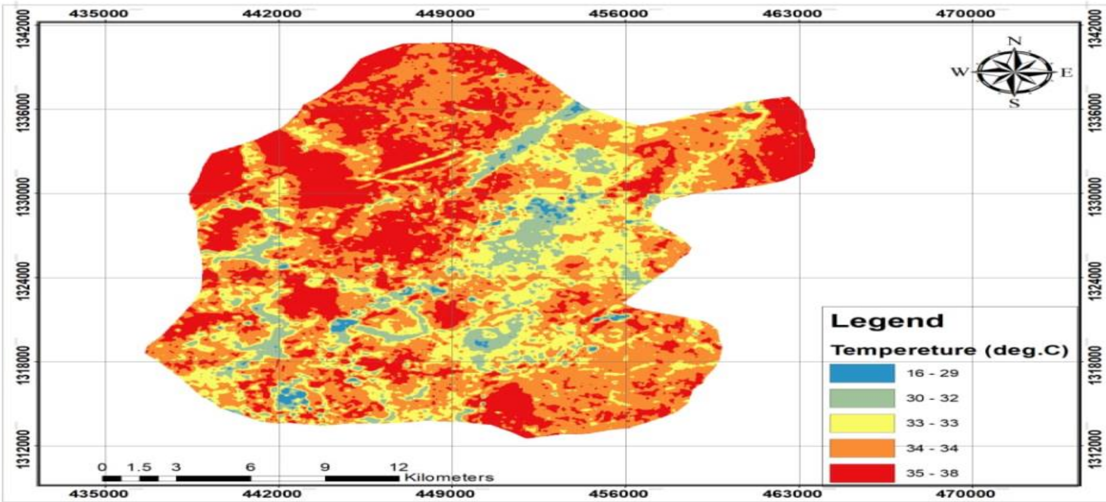

Figure. 2: Estimated Land Surface Temperature From Landsat 5 Thermal Band Information (April 18th, 1991, 18:50:31.896). The Image Spatial Resolution is 120 × 120 m.
Source: United States Geological Survey (USGS).

Spatial Distribution of Surface Temperature 2001-2010

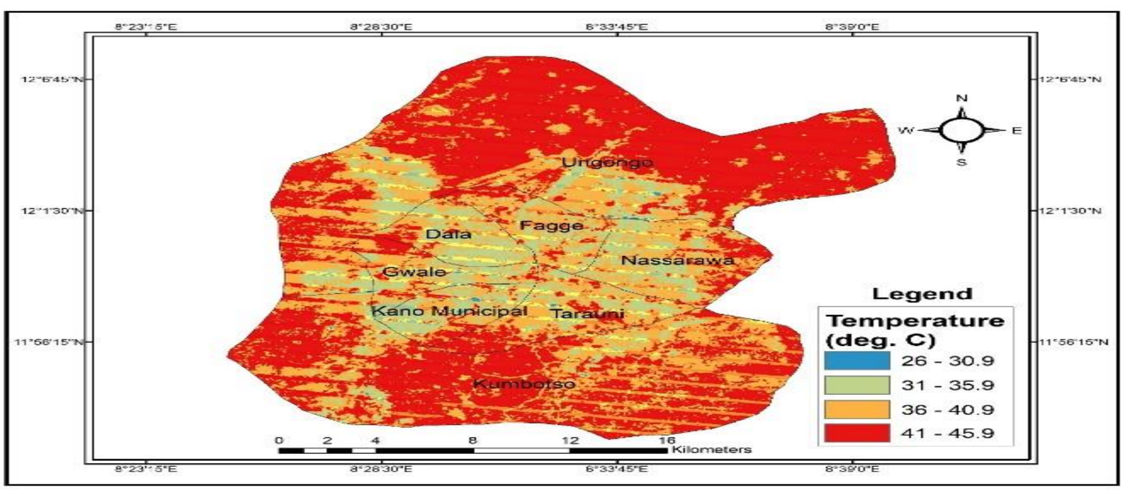

Figure 3: Estimated Land Surface Temperature From Landsat 7 ETM+ (April, 30 th 2010, 14:10:20.654).
The Image Spatial Resolution is 60 x 60m
Source: United States Geological Survey (USGS).

To mitigate the occurrence of heatwaves, greenhouse gas emissions should be minimised, and the transition to renewable energy should be achieved by shifting from the use of fossil fuel towards renewable resources like solar, wind and hydro power. Afforestation involves planting more trees to absorb carbon dioxide from the atmosphere. An early warning system for heatwaves can help people take preventive measures, such as staying hydrated and avoiding outdoor activities during the hottest times of the day. Additionally, the government should invest in creating more cooling shelters and green spaces, particularly in urban areas, to provide relief during heat waves. Awareness campaigns about the risks of heatwaves and how to stay safe during such events are essential. This can include promoting lifestyle changes such as the use of light-coloured, loose-fitting cl*othing.*

Conclusion and Recommendations

In conclusion, it is attested that a heatwave occurred in the Kano metropolis between April and May, with a peak of 21 consecutive days in 2016 and a maximum temperature of 40.8 °C. Therefore, it was recommended that the public be aware of the devastating impact of heatwaves via the media and organise sensitisation campaigns to prevent their future occurrence.

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