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MICRO-CLIMATE AND HUMAN THERMAL COMFORT AT MAIDUGURI AND YOLA IN NORTH-EASTERN NIGERIA

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ABSTRACT
Heat index describes the combined effects of Temperature and Relative Humidity on the body. The Heat Index provides an apparent temperature felt by human body that cools slower at higher values of relative humidity due to reduction in the rate of evaporation. This paper examines the Thermal Comfort Index of Maiduguri and Yola using two (2) different models; namely Temperature-Humidity Index and Humidex. Thirty years (1988 to 2018) temperature and relative humidity data obtained from the archives of the Nigerian Meteorological Agency were used for the study. These were subjected to some descriptive and inferential statistical analyses. Values for the two models (Temperature Humidity Index and Humidex) were also computed for each station. The temporal (monthly, seasonal and annual) variation of the thermal indices and meteorological variables were also assessed. The result indicated a peak for Temperature-Humidity Index at Maiduguri in May, while that of Yola occurred in April. On the other hand, Humidex had its maximum value in May for both Maiduguri and Yola. Furthermore, both the Temperature Humidity Index as well as Humidex have their lowest heat index values in January at the two study locations. Additionally, inter-annual characteristics of the two heat comfort models for both Maiduguri and Yola showed an upward trend during the study period (1998 – 2018). So also, the temperature anomaly manifested an impression of continuous and regular increase in temperature across the study areas and this was determined due the straight line obtained from the simple regression. Hence, it can be stated categorically that in evaluating the impact of heat index on outdoor comfort, it must be emphasized that changes in surface air temperature is not the only reason but instead changes in humidity also play a significant role.
Keywords: Micro-climate, Human index, thermal, comfort, temperature

INTRODUCTION

Man has always tried to create a thermally comfortable environment for himself. This is reflected in building traditions around the world. Today, creating a thermally comfortable environment is still one of the most important parameters to be considered when designing buildings. Thermal Comfort, in general terms, is that condition of mind which expresses satisfaction with the thermal environment (ISO, 1994). Thermal comfort was defined as a state in which there are no driving impulses to correct the environment by the behavior (Farooq, 2020). It is a subjective psychological perception of people based on physiological thermoregulation mechanisms when the human body is exposed to a combination of various environmental factors including air temperature, air humidity, wind speed, and radiation conditions (Tung *et al*, 2014).

Human thermal comfort can also be described as the absence of thermal discomfort or conditions in which 80% to 90% of the people do not express discomfort. Variables of the thermal comfort are the air temperature, radiant temperature, relative humidity, air velocity, activity and clothing (ASHRAE, 2004). More general Definitions of comfort include a sense of relaxation and freedom from worry or pain. People feel uncomfortable when they are too hot or too cold, or when the air is odorous and stale. The feeling of comfort—or, more accurately, discomfort—is based on a network of sense organs: the eyes, ears, nose, tactile sensors, heat sensors, and brain.

Today, thermal discomfort arises due to the modification of the local climate. Local climate gets modified as radical changes occur in the nature of the surface and atmospheric properties of a region. These result in the transformation of radiation, thermal, moisture, and aero dynamics characteristics and there by dislocate the natural solar and hydrological cascades. Reduction of the natural vegetation in an area, lessen the possibilities for evapo-transpiration processes and thereby possibly reduces the natural cooling effect in areas where vegetation is scarce. It is well known that the discomfort that is felt in hot weather depends to a significant degree on the humidity of the air as well as the actual air temperature. Numerous attempts have been made to quantify this effect.Thermal comfort has been studied since the start of 20th century, and improvements in building techniques, as well as discoveries in central heating and air conditioning systems have led to improved comfort in indoors, even in the hottest and coldest climates (Brager and de Dear, 1998). Several investigators have also shown that variation in the heat indices, especially temperature, have significant relations with human mortality (Kalkstein and Smoyer, 1993; Alcamo *et al.*, 2007). The health impacts of climate, particularly temperature and humidity, have been of interest for centuries. One area of growing concern is the health effects of heat waves, especially given the likely increased frequency and intensity of extreme temperature events under human-induced climate change (Perkins *et al.*, 2012).

Relative Humidity (RH) also measures water vapour, but relative to the temperature of the air. In other words, it is a measure of the actual amount of water vapour in the air compared to the total amount of vapour that can exist in the air at its current temperature (Louisville, 2021). The combination of heat and high humidity may cause personal discomfort, health may strongly be affected. Because humidity affects the body's ability to cool itself, bio meteorologist and scientists who study the relationship between weather and life have looked for ways in which to combine the air temperature and humidity. Man has a very effective temperature regulatory system, which ensures that the body's core temperature is kept at approximately 37°C.The ability of a human body to release heat through evaporation is restrained by increase in relative humidity in the atmosphere resulting in discomfort and stress. Allen and Segal-Gidan (2007) proposed that excessive heat could result in a range of adverse health impacts, including heat cramps, heat edema, heat exhaustion and life- threatening heat stroke.

The heat index (HI) or heat stress index (HSI) is an index that combines air temperature and relative humidity, in an attempt to determine the human perceived equivalent temperature. The result is known as the "felt air temperature "or "apparent temperature" Climate change and increased heat stress in cities has led to serious interest in the assessment of thermal comfort. This has led to the development of various discomfort indices. But there have been relatively small numbers of studies on thermal comfort for outdoor environment (Spangnolo & de Dear, 2003). However, the impact of urban environments on human health has become a critical issue facing the global society as the number and percentage of humans living in urban areas continues to grow (Changnon, 1992).

Research has shown that the encroachment of urbanization leads to higher temperatures at night, presenting a contribution to some of the climate change issues (Arnfield, 2003). A better understanding of the interaction between air temperature, relative humidity and urban growth is essential in advancing micro-climate studies and those studies related to climatic change and urban ecosystems in a tropical environment (Ifatimehin *et al*, 2010).Over the course of time, the events of climate change coupled with the level of urbanization has given rise to urban heat island within the urban cities (Balogun *et al.,* 2012) as many regions are striving to carry out one or two projects in order to cater for the yearning of the masses. The rising in urban heat island has led to discomfort index in some areas while the areas that have vegetation can still be seen to be comfortable for the people. Outdoor public spaces have become the heart of civic life in the city where people carry out their activities and leisure, it is well known that improving the quality of life in urban centers does require not only efficient buildings, but also climatically sensitive urban public spaces that can enhance and enrich urban life (Grifoni *et al.*, 2013). The study aimed at assessing the impact of micro-climate on human thermal comfort and suggest the proper respond to the dynamic nature of micro-climate of the area.

MATERIALS AND METHODS

Study Area

Figure 1 locates the study area. Two cites in North-eastern Nigeria were used for the study: Maiduguri in Borno State and Yola in Adamawa State. Maiduguri, being the Capital of Borno State is a major city in North-eastern Nigerian, Yola is also the capital of Adamawa State and the largest city.

While Maiduguri is located within latitudes 11°04'N to 11°44'N, and longitudes 13°04'E to 13°44'E. covering a total land area of 543 km^2; Yola is located on latitude 09.20^{o}N and Longitude 12.49^{o}E.(Daura, 2002). In terms of climate, Maiduguri is characterized by low annual precipitation (650 mm), high evaporation and negative water balance. The rainy season starts in June and ends in October. Highest rainfall is normally received in August. Generally however the rains are concentrated in the months of July, August and September. There are four identified seasons in the area which include the *Rainy Season*, (June to September) *Harvest Season* (September to November), *Harmattan or Cool Season* (December to February) and *Hot Season* (March to May). Generally the mean monthly temperature is always above 20°C but the daily extremes vary in a wide range reaching up to 47°C in April. Daily temperature may occasionally exceed 40°C, while the night temperatures are high but lowered in the early morning hours. The climate of the area is affected by the North East trade winds and the South West monsoons originating from the Sahara and the Atlantic Ocean respectively (Daura, 2002; Waziri, 2009; Mohammed *et al.*, 2016).

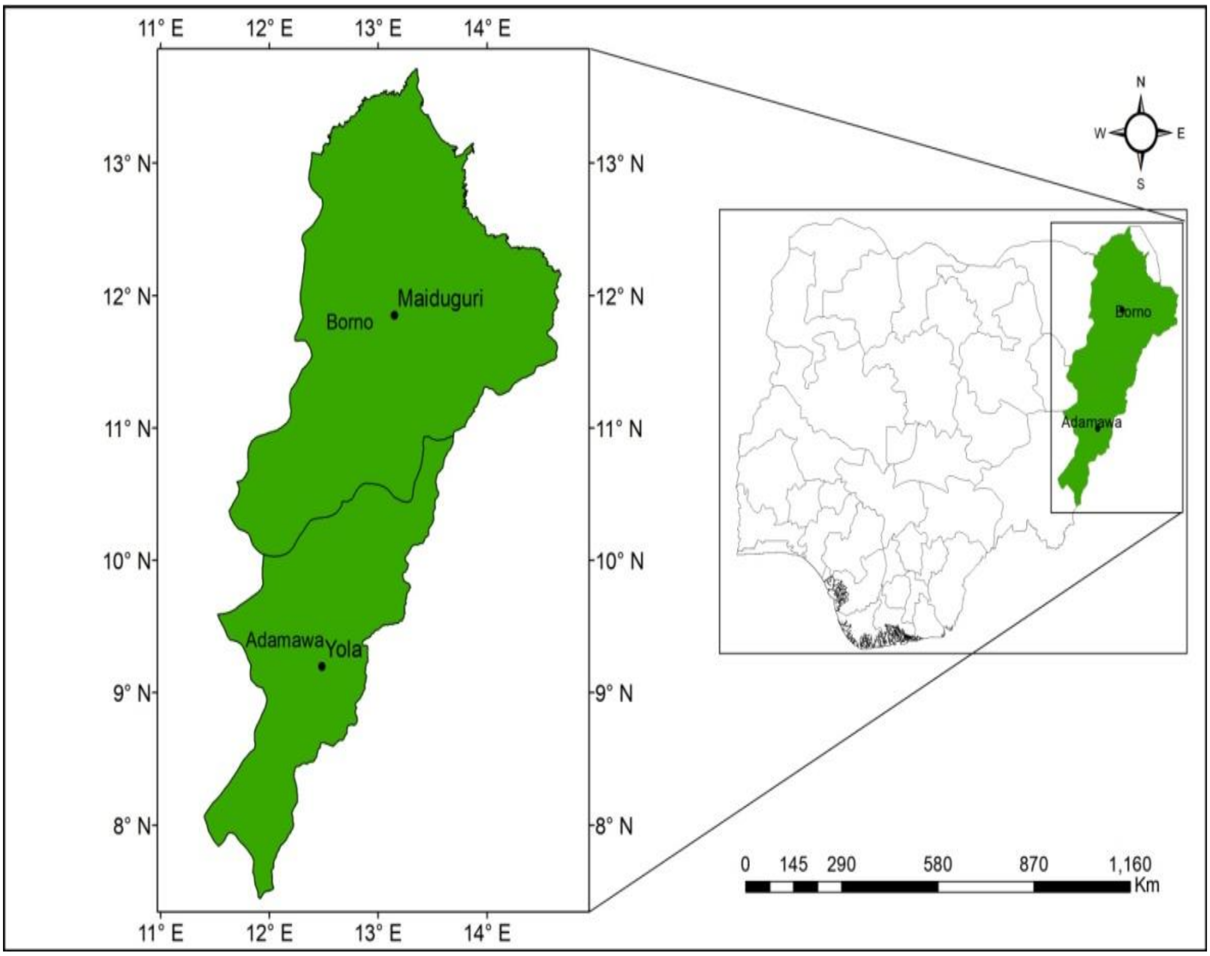

Figure 1: Location of the Study Area

Yola on the other hand, has an annual rainfall ranging from 1000 to 1500mm with double maxima, which has an average Relative Humidity of 60%. The air temperature in the state as a whole is a typical West African Savannah Climate with a mean annual temperature of 27^{0}C. Temperatu is generally high throughout the year. Yola has a seasonal change in temperature, from January – April; the temperature increase is because of the clearer sky view which permits the receipt of high insolation. There is usually a drop in temperature at the onset of rains due to the effects of cloud cover. The temperature decreases at the beginning of the raining season to the end which is as a result of the cloud effect. The temperature again increases after the cessation of the rains (October to November) before the arrival of the harmattan which leads to further drop in temperature (Adebayo, 1999).

Methods

Monthly temperature and relative humidity data for thirty years (1988 to 2018), were used the study. These were obtained from the Archives of the Nigerian Meteorological Agency (NIMET). The data were analysed using relevant descriptive and inferential statistics. Two empirical models for estimating human comfort were also employed. Temperature and relative humidity values were collected; arranged from January to December across the specified years and cities into Microsoft Excel Statistical Package. In computing for seasonal variations, two seasons (rainy and dry) were accounted for, June to October was taken as the rainy season while November to May depicts the dry season. Meteorological parameters and thermal conditions during rainy season were obtained by computing their average values from June to October for 30years (1988 - 2018). Also, during the dry season, weather variables and thermal conditions were obtained by computing their average value from November to May for the period of 30years (1988 - 2018). Heat index has been used in many studies for temperature impact assessment in human morbidity, heat waves and urban heat island effect (Hartz *et al*., J. Golden, C. Sister, W.-C. Chuang and A. Brazel 2003-2006). Monthly average of recorded temperature and relative humidity over the study period was calculated using the equation 1.

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} \quad 1.$$

Where $\bar{X}$ is the calculated average of the weather variable, X_i = Monthly value of temperature or relative humidity for a particular year, n is Number of years. Temperature anomaly time series were constructed in order to assess inter-annual fluctuation in the two cites (Maiduguri and Yola).

The Anomaly was computed using the relationship, Anomaly = $\frac{\text{(Observed−Mean)}}{\text{Standard Deviation}}$.

Temperature and Humidity Index (THI) was estimated with the algorithm modified by Nieuwolt, (1977) stated as equation 2.

$$\boldsymbol{THI = 0.8t} + \frac{RH \times t}{5000} \quad 2.$$

Where; t *is* Air Temperature. , RH = Relative Humidity. Mean values of the estimated Temperature and Relative humidity values were worked out with the aid of Microsoft Excel software. The estimated THI values were then classified into different categories of thermal perceptions based on the scale provided by Table 1.

Table 1: Thermal perceptions with corresponding THI threshold for Nigeria

THI Classes for Nigeria (*°C*)	Thermal Perception	Level of Thermal Stress
<14	Very cold	Extreme cold stress
14 – 17	Cold	Strong cold stress
18 – 19.5	Cool	Moderate cold stress
20 – 22	Slightly cool	Slight cold stress
23 – 24.6	Neutral	No thermal stress
24.7 – 27	Slightly warm	Slight heat stress
28 – 30	Warm	Moderate heat stress
31 – 34	Hot	Strong heat stress
>34	Very hot	Extreme heat stress

Adapted from and modified Omonijo and Matzarakis (2011).

Humidex Index (*H)* was estimated with the algorithm modified by the Canada Environment Meteorologist (2000) which is expressed in equation 3.

$$\text{HI} = T_{air} + 0.5555\left[6.11e^{5417.7530\left(\frac{1}{273.16}-\frac{1}{T_{dev}}\right)} - 10\right] \quad 3.$$

Where; T_{air} = Air Temperature, T_{dew} = Dew point Temperature

The dew point temperature, $Tdew$ was estimated using the equation 4.

$$\boldsymbol{T_{dew}} = T - \frac{(100-RH)}{5} \quad 4.$$

Where; RH = Relative Humidity, T = Temperature

Estimation of the mean values of Humidex and dew point temperature were worked out with the aid of Microsoft Excel software. The estimated Humidex values were then classified into different categories of thermal perceptions as contained in Table 2.

Table 2: Thermal perception with Humidex index

Degree of Comfort	Humidex Range
Comfortable	20-29
Noticeable discomfort	30-39
Intense discomfort	40-45
Dangerous discomfort	45-53
Heat stroke possible	Above 54

Adapted from Canada Meteorologist (2000).

Correlation analyses (Equation 5) were carried out at the first instance to measure the degree or strength of association between the weather parameters and the estimated indices by the relation.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{x})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2(y_i-\bar{x})^2}} \quad 5.$$

Where: x is the independent variable (weather variable) , y is the dependent variables (estimated indices), 'n' is the number of pairs of data, $\bar{x}$ and $\bar{y}$ are the respective mean. The values of r is such that $-1 \leq r \leq +1$, the closer the r coefficient approaches ±1, regardless of the direction the stronger the existing association, when r = 0 indicates that no association exist between the measured variables (Taylor, 1997). A positive correlation implies a direct relationship while a negative correlation shows a negative relationship between the measured variables.

Coefficient of determination was computed to determine the degree of influence of each weather variable on the estimated indices using coefficient of determinant.

RESULTS AND DISCUSSION

Monthly Temperature and Relative Humidity Characteristics

Figure 2 presents the temperature characteristics for Maiduguri and Yola. High temperatures are experienced at the two locations in the months of March, April and May. The high temperatures can be attributed to high solar radiation intensity received when the atmosphere is clean and clear as a result of little or no cloud and low relative humidity in both locations during the dry season. Furthermore, The highest values of temperature for Yola and Maiduguri stations were 33.50ºC in the month of April and 33.20ºC in the month of May respectively while their least temperature values were Yola and Maiduguri are 25.60ºC, and 22.20ºC respectively both in the month of January. However Yola has the highest mean value of temperature recorded while Maiduguri has the lowest mean value of temperature. Therefore, temperature values were observed to be lower in the wet months (June-October) than in the dry months (November- May).

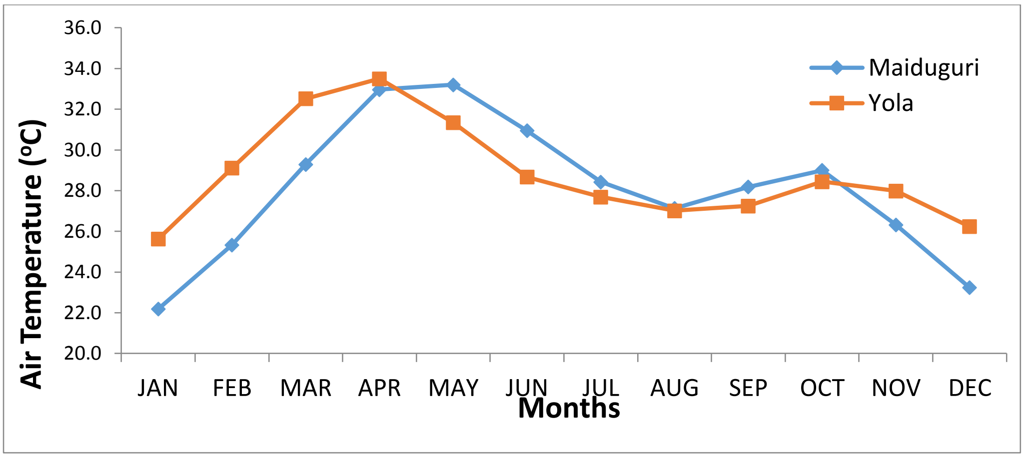

Figure 2: Monthly Air Temperature Distribution

Meanwhile, the lowest values of temperature were observed in January for both stations. This agrees with Ifatimehin *et al.* (2013), who found a similar situation in Lokoja. Furthermore, Umoh (2000) opined that Nigeria experiences high temperature all the year round and that the highest temperature is normally in April in Northern Nigeria and a little earlier in the south, while minimum temperature on the other hand decreases northward. The result also agrees with that of Buba and Ibrahim (2017).

Figure 3 is the representation of the monthly values for relative humidity, it is clear that the lowest mean values of relative humidity for Yola occurred in February while that of Maiduguri occurred in March. Similarities were observed in the highest mean values of relative humidity for Yola and Maiduguri, with both stations having their highest values in August. The lowest mean values recorded for relative humidity for Yola in the Guinea savanna was 25% while Maiduguri in the Sahel savanna part recorded its least relative humidity value of 17% around March. These can be associated (attributed) with the transition from dry season (which is dominated with dry and cold North east trade wind) to rainy season (dominated with warm and moist air from the southwest monsoon flow). The highest mean values for Yola and Maiduguri were 80%, and 77% respectively. Relative humidity mean values were recorded to be high in wet months (June - October) and low mean values in dry months (November - May), Maiduguri station has the lowest mean value of relative humidity.

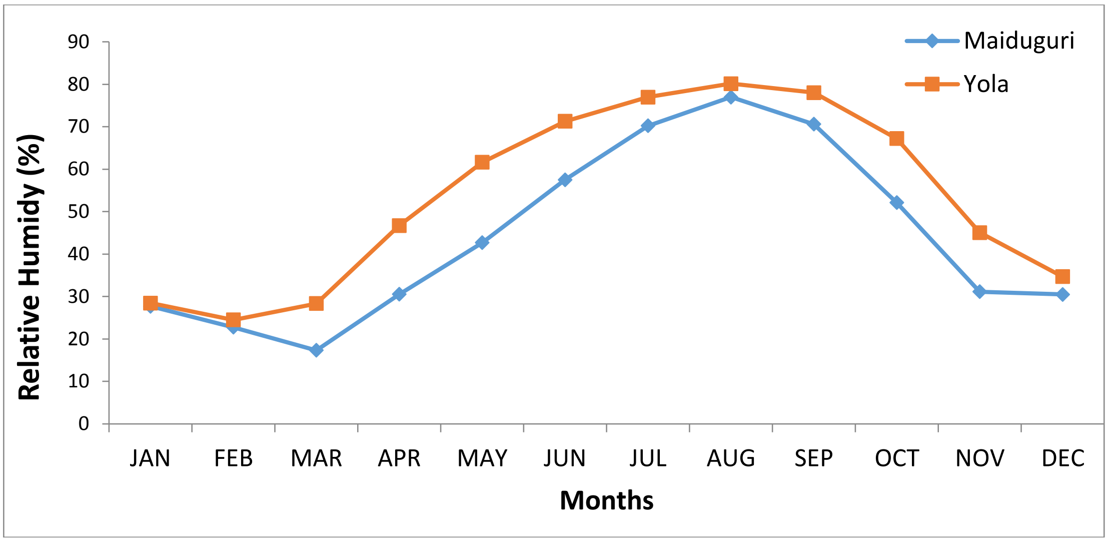

Figure 3: Monthly Relative Humidity

Ifatimehin *et al.* (2013) also ascertained that in Lokoja, the highest mean monthly relative humidity data was recorded in the month August while the lowest mean relative humidity was recorded in the month of November and this was totally different from what was obtained in the lowest mean monthly relative humidity value in Yola and Maiduguri which were both observed during the dry season. Sawa and Buhari, (2011) similarly reported that during the dry season are characterized by a period of low temperature with harmattan season around December-February; and the hot dry season between March-April with temperatures as high as 32ºC. Relative Humidity is high only during the raining season, but drops during the dry season.

Monthly Characteristics of Thermal Indices

Figures 4 presents the monthly distribution of Temperature Humidity Index (THI) estimates for the study area. With increasing temperature and less availability of moisture in the atmosphere during the dry season, THI increases. The highest value of THI within this period for Yola and Maiduguri are 29.92 ºC in the month of April and 29.40 ºC in the month of May respectively, while their respective lowest THI values are 21.90 for Yola and 19.0^{0}C for Maiduguri both in the month of January. It was observed that the months of April and May in the period studied for both Yola and Maiduguri were had values that fall within the warm (moderate heat stress) categories of thermal stress level. This means that thermal conditions deteriorated between the months of April and May in both stations.

THI estimates for the months November, December, January February and March shows that thermal conditions are more tolerable. This finding relates to that of Musari *et al.* (2014) where the months of November, December, January February and March are mostly observed to bring comfortable sensation for Bauchi and Maiduguri.

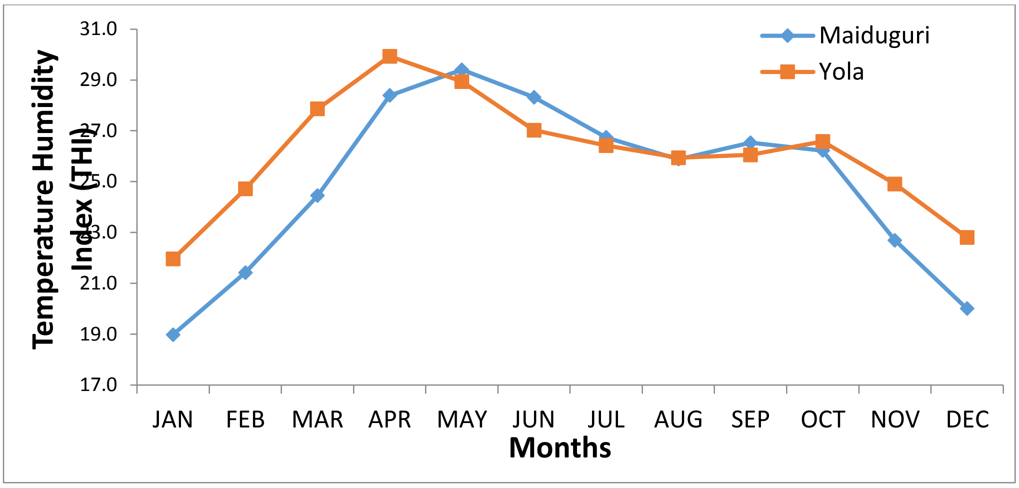

Figure 4: Seasonal THI Distribution

Figur 5 presents the monthly distribution of Humidex values over the study area. While Yola had Humidex estimates of 42.10^{0}C and 41.90^{0}C for the months of April and May respectively, which implies intense discomfort level, Maiduguri had 40.20 ^{0}C for both the months of May and June which also signifies intense discomfort levels. Humidex estimates also show that in the month of November, December, January, February and March, thermal conditions were at a more tolerable level in both cities. Humidex value for Yola was 25.4 ^{0}C and that of Maiduguri 20.8 ^{0}C for the month of January, which falls within the comfortable zone.

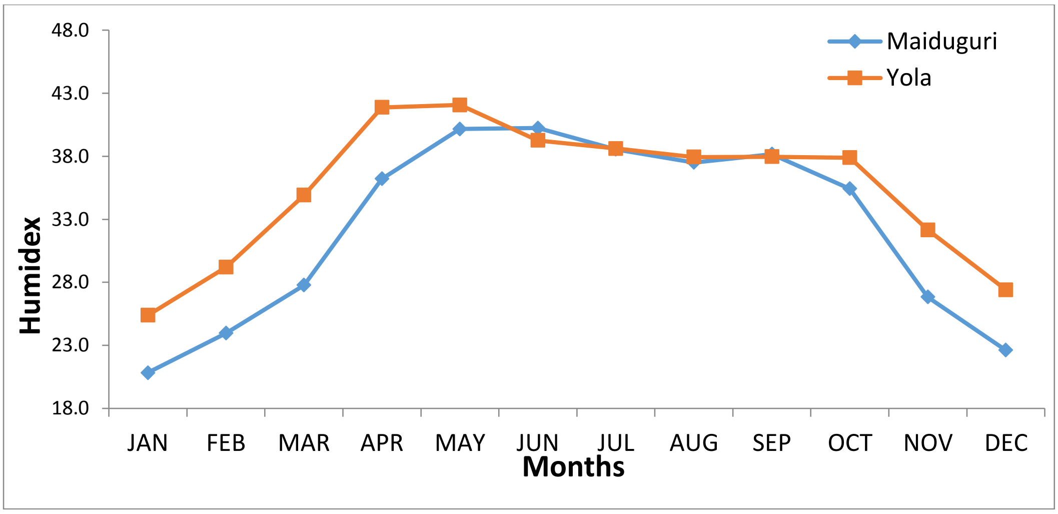

Figure 5: Seasonal Humidex Distibution

In summary, monthly variation of thermal conditions represented in figures 4 and 5) are quite similar but differ a little bit, THI and Humidex estimates shows that within the months of April and May thermal condition deteriorate to its peak except in the case of Maiduguri whose Humidex value had its peak in the months of May as well as June, while in January thermal conditions are at the most comfortable conditions for both Yola and Maiduguri. However, decreasing thermal discomfort was observed in November, December, January and February can be attributed to harmattan which is characterized by the dry and dusty northeasterly trade wind, of the same name, which blows from the Sahara Desert over West Africa into the Gulf of Guinea as reported by Buba and Ibrahim (2017).

Relationship between thermal Comfort Indices and Weather Variables

THI was found to strongly correlate (r= 0.9440) with Air Temperature in Maiduguri, with a coefficient of determination of 89%, suggesting that temperature has a strong influence on THI. THI and Relative humidity has a positive correlation of 0.5207 in Maiduguri, it shows that THI increase with the increase in relative humidity and also decreases with the decrease in relative humidity. But the strength of association between THI and Air temperature is stronger than that between THI and relative Humidity. The contribution of relative humidity is far less than that of air temperature on THI relative humidity has a contribution of 27% according to the coefficient of determinant in table 4.1 above. Air temperature and relative humidity has a contribution of 89% and 27% respectively, this shows that air temperature has more contribution and effect on THI than relative humidity.

Humidex and air temperature has strong positive correlation (r = 0.88) with 0.1 less than that between THI and air temperature. The strong positive correlation suggests that Humidex increase with the increase in air temperature in Maiduguri. The same scenario happen in the contribution, Air temperature has stronger effect on THI than on Humidex; this is seen in the high value of correlation coefficient of THI versus air temperature compared to Humidex versus air temperature.

Relative humidity on the other has more effect on Humidex than it has on THI. There is a difference of about 0.22 in the correlation between Humidex with relative humidity and THI with relative humidity. Humidex and relative humidity has a strong and positive correlation of 0.7461 with a percentage contribution of 55%. This statistical value shows that Humidex increase with the increase in relative humidity, it also shows that air temperature has more contribution on Humidex than relative humidity in Maiduguri. The results reveal that there is no significance difference in the effect of the weather variables on THI and Humidex in Maiduguri and Yola despite the fact that Maiduguri is situated in the Sahelian zone while Yola is situated in the Guinea Savanna. As in the case of Maiduguri, air temperature has a strong and positive correlation of 0.8586 with THI in Yola, which implies that THI increases with an increase in air temperature, it also account for 74 percentage of the relationship..

Relatively air temperature has higher effect on THI in Maiduguri than in Yola. Relative humidity as a measure of water content in the air has a positive correlation (r = 0.4156) with THI and 17 percentage contribution. The influence temperature and relative humidity are more on THI in Maiduguri than in Yola. Air temperature has stronger effect on THI than on Humidex; this view is supported by the high value of correlation coefficient of THI versus air temperature compared to Humidex versus air temperature. Humidex and air temperature have positive correlation of r = 0.56 with percentage contribution of 31%. Humidex and relative humidity have a strong and positive correlation of r = 0.72 with a percentage contribution of 51%. These results show that Humidex increases with the increase in relative humidity.

CONCLUSION

The results presented show that the months of April and May are characterised by high levels of thermal discomfort, while January was observed to have the lowest thermal discomfort. Thermal conditions were found to be more tolerable in the wet season which is characterised by lower temperatures. Furthermore, variation in the heat indices values may be associated with two factors namely, day time temperature and relative humidity. Evaluating the impact of heat index on outdoor comfort, it must be emphasized that changes in surface air temperature is not the only reason but that changes in humidity also play a significant role. To this end, it can be suggested that the Humidex model can be used in the absence of Thermo-humidity index because of the similarity in seasonal patterns they both exhibited.

REFERENCES

Alcamo, J., Moreno, J. M., Nov´aky, B., Bindi, M., Corobov, R., Devoy, R. J. N. (2007). Giannakopoulos C, Martin E, Olesen JE, Shvidenko A.. Europe, climate change: impacts, adaptation and vulnerability. In Contribution of Working Group II to the Fourth Assessment Reportof the Intergovernmental Panel on Climate Change, Parry ML, Canziani OF, Palutikof JP, der Linden PJ V, Hanson CE (eds). University Press: Cambridge, UK, 541–580.

Allen, A & Segal-Gidan, Freddi. (2007). Heat-related illness in the elderly. Clinical Geriatrics. 15. 37-45.

Arnfield, A. J. (2003). Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. *Int J Climatol*, 23: 1-26.

ASHRAE, (2004). Thermal environmental conditions for human occupancy. ANSI/AmericaSociety of Heating, Refrigerating, and Air-Conditioning Engineering Standards. *Atlanta,35pp.ASHVE fiansactions,* **53:** 307-309.

Balogun, I.A., Balogun, A.A. and Adeyewa, Z.D. (2012). Observed urban heat island characteristic in Akure, Nigeria. *African journal of Environmental Sciences and Technology.* Vol. 6(1), pp 1-8.

Brager, G. S. and de Dear, R. J. (1998). "Thermal adaptation in the built environment: a literature review". *Energy and Buildings.* ***27*** *(1):83–96. doi:10.1016/S0378-7788(97)00053-4. ISSN 0378-7788.*

Buba, L. F. & Ibrahim, A M. (2017). Temperature variations as evidence of climate change in northern Nigeria. Bayero Journal of Pure and Applied Sciences. 10. 99. 10.4314/bajopas.v10i2.17.

Changnon, S. A. (1992). Inadvertent weather modification in urban areas: lessons for global climate change. Bulletin of the American Meteorology Society, 73(5):619-627.

Daura, M. M. (2002). "Maiduguri" Atlas of Nigeria in Africa Atlasses. Bietlot, Belgium, 148 - 149.

Grifoni C.R, Passerini .G, and Pierantozzi.M., (2013). Assessment of outdoor thermal comfort and its relation to urban geometry. School of Architecture and Design, Camerino University, Italy Department of Energetics, Marche Politechnic University, Italy. WIT Transactions on Ecology and The Environment, Vol 173.

Ifatimehin, O.O., Adeyemi, J.O. and Salisu, A.O. (2013). Impact of Urban micro-climate on Human comfort in Lokoja Area, Nigeria. Katsina Journal of Natural and Applied sciences, Vol.3.No:2.

Ifatimehin, O.O., Ishaya, S. and Ujoh, F. (2010). An analysis of temperature variations using remote sensing approach in Lokoja Area, Nigeria. Production Agricultural Technology Journal, 6(2):63-70.

Farooq A.S., (2020). Fundamentals, materials and strategies for personal thermal management by next generation textiles, Journal for applied science and manufacturing, Vol 142.

Kalkstein L.S., Smoyer K.E. (1993). The impact of climate change on human health: Some international implications. Experientia. 1993;49:969–979. doi: 10.1007/BF02125644. - DOI - PubMed.

Mohammed, A. J., Abbas B., and Abel A. A. (2016). "Spatial Distribution Pattern and Terrain Analysis of Urban Flash Floods and Inundated Areas in Maiduguri Metropolis, Borno State, Northeast, Nigeria" *Journal of Geographic Information System,* 8, 108-120. http://dx.doi.org/10.4236/jgis.2016.81011

Musari, A.A, Ajayi, M.A., Abatan, O.A. (2014). Discomfort Index in Northeastern, Nigeria.Department of Science Laboratory Technology, Mashood Abiola Polytechnic Abeokuta, Nigeria. *IOSR. Journal of Applied physics:2278-486.Vol 6.*.

Louisville, K.Y (2021). National Weather service, forescast-ofiice. (https://www.weather.gov/lmk/humidity)

Perkins, S.E., Alexander, L.V., Nairn, J.R., 2012. Increasing frequency, intensity and duration of observed global heatwaves and warm spells. Geophys. Res. Lett. 39 (20), L20714. http://dx.doi.org/10.1029/2012GL053361.

Sawa, B. and Buhari, B. (2011). Temperature Variability and Outbreak of Meningitis and Measles in Zaria, Northern Nigeria. Research Journal of Applied Sciences, Engineering and Technology, 3, 399-402.

Spangnolo, J. and de Dear. R (2003). A field study of thermal comfort and outdoor and semi Outdoor environment in subtropical Sydney Australia. *Building and Environment,* 38: 721-730.

Taylor, John R. (1997). "An introduction to Error Analysis: The Study of Uncertainties in Physical measurements (2nd ed.). Sausalito, CA: University Science Books. Page.217.

Technology, Haifa, Israel. 85 pp.Theor. Appl. Clim. 38, 43-49.

Tung, CH., Chen, CP., Tsai, KT. (2014). Outdoor thermal comfort characteristics in the hot and humid region from a gender perspective. *Int J Biometeorol* **58,** 1927–1939. https://doi.org/10.1007/s00484-014-0795-7

Waziri, M. (2009). Spatial Pattern of Maiduguri City: Researchers' Guide. Adamu Joji Publishers, Kano City.