

An Estimate of Thermal Comfort in North-Central Region of Nigeria

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Abstract: Heat Index describes the combined effects of temperature and humidity on human body. The Heat index expresses an apparent temperature felt by human body that cools slower at higher values of the relative humidity due to the reduction in the rate of evaporation. This study aimed at describing the comfort and discomfort periods caused by heat stress in some selected urban towns in five states of the North central region in Nigeria. Monthly data of Temperature, Relative Humidity and Wind speed for thirty years (1980-2009) obtained from Nigerian Meteorological Agency were used to calculate the Temperature-Humidity indices (THI) and Wind-chill index (WCI) for the five urban towns in North central region investigated. The results showed that severe heat stress were experienced in the months of April, May and March in descending order for Abuja, Minna, Lokoja and Bida while moderate heat stress were recorded in June, October, July, September and August for all these four towns where 50% of human and animals are not comfortable due to hot and humid weather condition. Remarkable, pleasant and comfortable sensations were observed throughout the year in Jos with exception of November, December and January which shows that 50% of inhabitants are partially comfortable due to cold and humid weather. The percentage frequency charts for all the five towns investigated were also presented in this study.

Keywords: Temperature-Humidity Index, Wind-Chill Index, Heat stress, Percentage Frequency

I. Introduction

Nigeria is found in the tropics, where the climate is seasonally damp and very humid. The country experiences consistently high temperatures all year round. Since temperature varies only slightly, rainfall distribution over space and time becomes the single most important factor in differentiating the seasons and climatic regions. Nigeria has two major seasons, the dry and wet season, the lengths of which vary from north to south. The extent to which the thermal environment challenges the body's thermoregulatory mechanisms is referred to as the environment heat or thermal stress. The concept of the heat stress index as well as heat exposure assessment plays a fundamental role in integrating knowledge of human responses to the heat in a way which can be used to specify safe working conditions (Pourmahabadian et al 2008).

Atmospheric conditions which include relative humidity, temperature, wind, solar radiation, air pollution and precipitation greatly affect living creatures including human beings. There is always a certain limit beyond which these conditions are no longer tolerable by them (human beings, animals and plants). Whenever this limit is exceeded, disaster and stress is inevitable. Hospitals record increased admission during days with high temperature (Ballester et al., 1997; Basu and Samet 2002; Pauli and Rizzi, 2005). The physiological sensation of human and animal comfort is influenced by heat stress. In hot regions and seasons discomfort level is raised by heat stress as well as increase in mortality rate among the aged and those who constantly suffer from malnutrition (Jauregul, 1984; Oke, 1982; Okpara, 1997). The effect of heat stress is mostly felt in the urban areas. Temperature, relative humidity and wind speed being some of the meteorological parameters determine heat stress. Some of the comfort indices which can be computed from these meteorological parameters include Temperature-Humidity Index (THI), Discomfort Index (DI), Wind Chill Index (WCI) e.t.c.

A temperature-humidity index (THI) is a single value representing the combined effects of air temperature and humidity associated with the level of thermal stress. This index has been developed as a weather safety index to monitor and reduce heat stress related losses. Different animal species and human have different sensitivities to ambient temperature and the amount of moisture in the air.

Venkitshwaran and Seaminathan (1967) used Thom's Index to calculate human comfort for some selected stations in India during different hours. Prasad and Pawar (1982) investigated the diurnal variations of Thom's Index for different months of the year for Bombay. Hossain et al (1983) also used Thom's Index to calculate the human comfort for almost all the stations in Bangladesh for different months at 0600BST and 1800BST. They also utilized Siple and Passel (1945)'s Wind Chill Index to evaluate daily comfort during winter for Dhaka. Okpara (2002) evaluated the physiological sensation of human comfort or discomfort for Akure

using the Thom's formula. Adeniyi (2009) determined the heat stress in the tropical urban area of Ibadan, southwest Nigeria using THI and WCI.

The motivation for the research is that evaluation of temperature-humidity index (THI) provides industry with solution for tomorrow, it also serves as cow better predictors of body temperature, and heat stress appears to be the critical factors affecting the break of crops, pests and diseases. Heat stress varies from one geographic region to other both diurnally and intra-annually, anytime there is heat stress, the body's system of temperature regulations ceases to function normally and body temperature can increase to abnormal levels, imbalance in the body electrolyte may result when sweating rate is high and this ultimately would bring about reduced production and even death in both man and animal, heat stress has been shown to have negative effect on Human health (Jauregul, 1984; Oke, 1982; Okpara, 1997), reproduction of dairy cows (Ingrahamet, et. al., 1976, Du Preez et al. 1991) and also in the milk production of dairy cows (Salem, & Buoraoui, 2009).

The objectives of this research is to determine the monthly variation of THI and WCI for the purpose of database for the areas, to predict the discomfort period within the year and suggest potential management strategies available to reduce these effects in the environment and also to characterize the environmental conditions in the North-central geographical areas of Nigeria. Five (5) urban cities chosen from four (4) states in North-central Nigeria were investigated due to the availability of their Meteorological data like Minimum and Maximum Temperature, Minimum and Maximum Relative Humidity and Wind Speed for Abuja (federal capital territory of Nigeria), Bida, (a major city in Niger state), Jos (the state capital of Plateau state), Lokoja (state capital of Kogi state) and Minna (state capital of Niger state).

The results of these studies for the years 1980 to 2009 are presented in this work.

II. Materials And Methodology

The monthly temperature, relative humidity and wind speed data for thirty (30) years used in this investigation were procured from Nigeria Meteorological Agency stations in Abuja (federal capital territory of Nigeria), Bida, (a major city in Niger state), Jos (the state capital of Plateau state), Lokoja (state capital of Kogi state) and Minna (state capital of Niger state).

The Temperature-Humidity Index (THI) was calculated for each month using the formula developed by Kibler (1964):

$$THI1 = 1.8 \times T_a - (1 - RH)(T_a - 14.3) + 32$$

Where T_a = average ambient monthly temperature in °C

RH = average monthly relative humidity as a fraction of the unit.

The Wind Chill Index (WCI) was computed using the chill index of Sipple and Passel (1945) given by:

$$K = (10\sqrt{V} + 10.45 - V)(33 - T_a)$$

Where V is the wind speed in meters per second and T_a is the atmospheric temperature in °C .

The discomfort index was also calculated using the formula by NOAA (1979) as follows:

$$THI2 = (1.8 \times T_a + 32) - (0.55 - 0.55 \times RH) \times \{(1.8 \times T_a + 32) - 58\}$$

Where T_a = average ambient monthly temperature in°C .

RH = average monthly relative humidity.

Table 1(a) and (b) below (Adeniyi, 2009) respectively show the fundamental significance of temperature-humidity index (THI) and the Wind-Chill index (WCI).

Table 1(a): Significance of Temperature-Humidity Index (THI)

THI value	Human/animal and plant feeling
> 80	100% are not comfortable.
75-80	50% are not comfortable due to hot and humid weather.
65-75	100% are quite comfortable.
60-	50% are partially comfortable.
65	Almost 100% are comfortable due to cold and dry weather
<60	

Table 1(b): Significance of Wind-Chill Index (WCI).

WCI value	Human/animal and plant feeling
< 50	hot
50-100	warm
101-200	pleasant
201-400	cool
401-600	very cool
601-800	cold
801-1000	very cold
> 1000	bitter cold

III. Results And Discussion

In this work Kibler,(1964)'s THI1 was compared with NOAA (1979)'s THI2 and both were found to be almost the same. The correlation between them was 1 meaning that one could conveniently represent the other.

Fig 1 - Fig 5 below showed the monthly variation of THI and WCI for all the five (5) urban towns investigated.

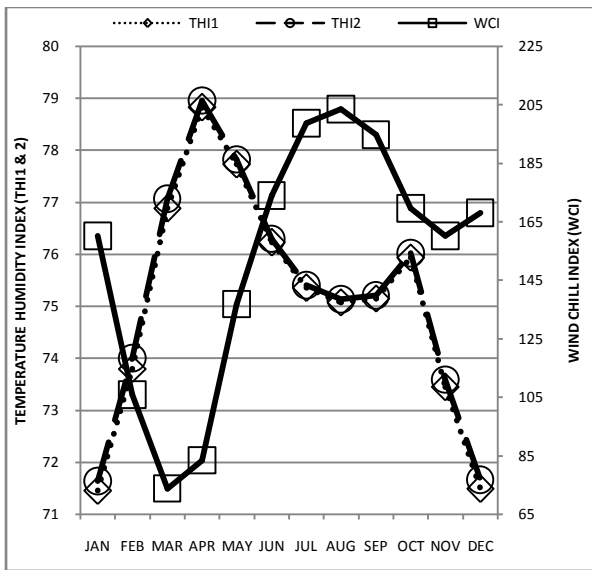


Fig 1: Monthly variation of THI1, THI2 and WCI for Abuja

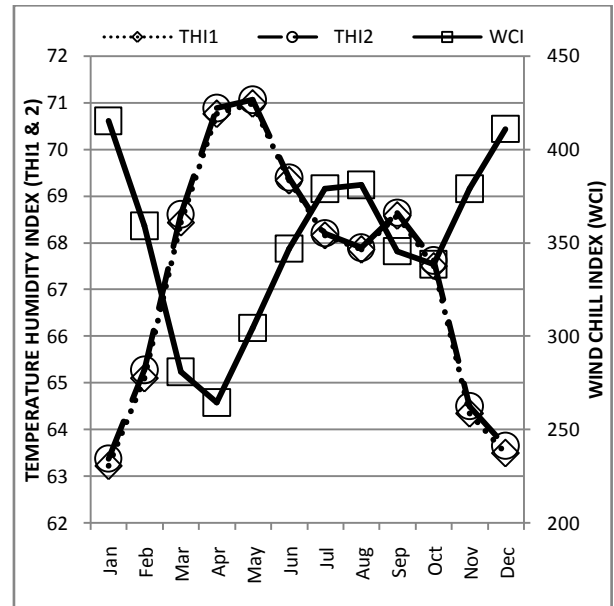


Fig 3: Monthly variation of THI1, THI2 and WCI for Jos

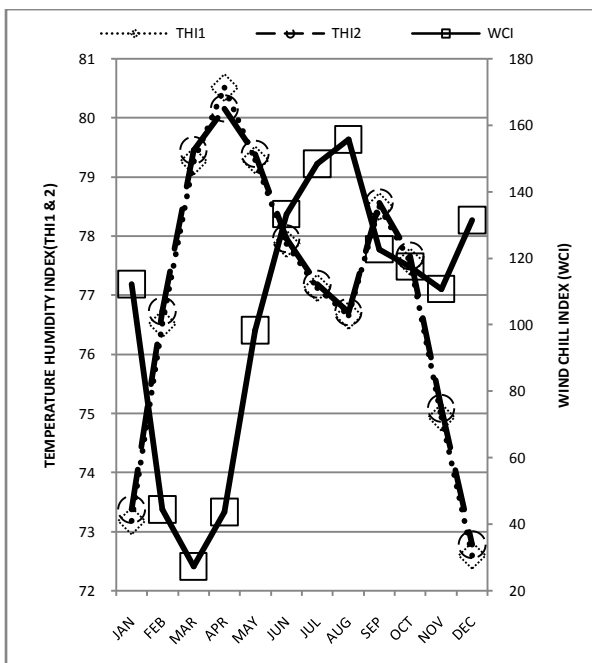


Fig 2: Monthly variation of THI1, THI2 and WCI for Bida

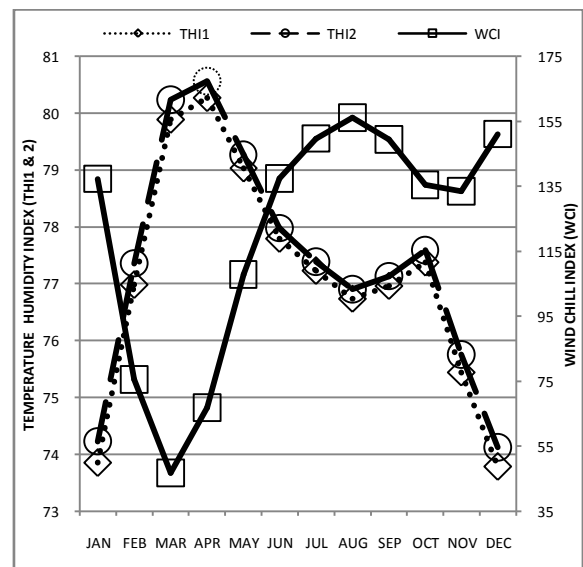


Fig 4: Monthly variation of THI1, THI2 and WCI for Lokoja

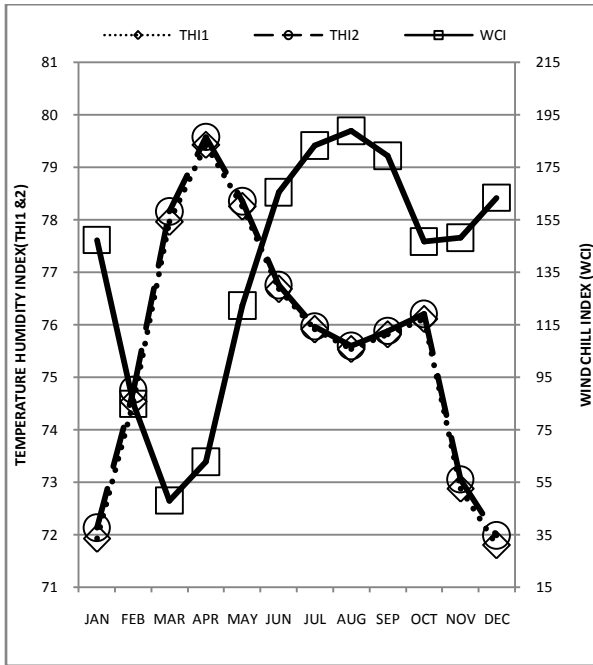


Fig 5: Monthly variation of THI1, THI2 and WCI for Minna

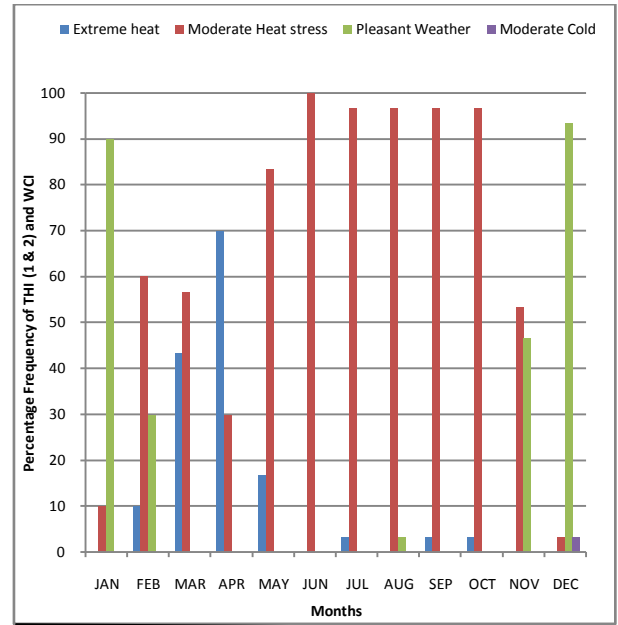


Fig 7: The Chart showing the Percentage frequency of THI 1 & 2 and WCI for Bida.

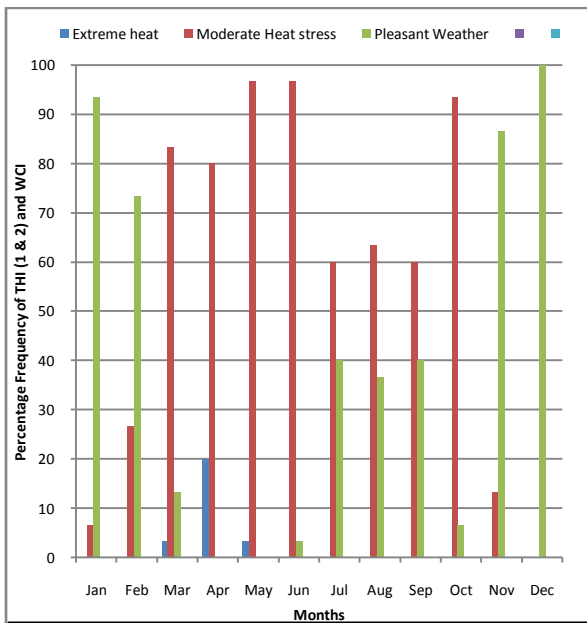


Fig 6: The Chart showing the Percentage frequency of THI 1 & 2 and WCI for Abuja.

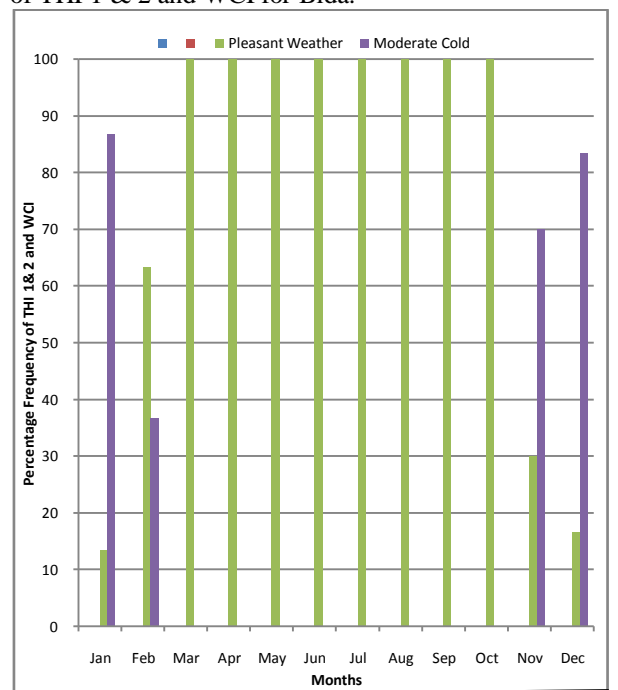


Fig 8: The Chart showing the Percentage frequency of THI 1 & 2 and WCI for Jos.

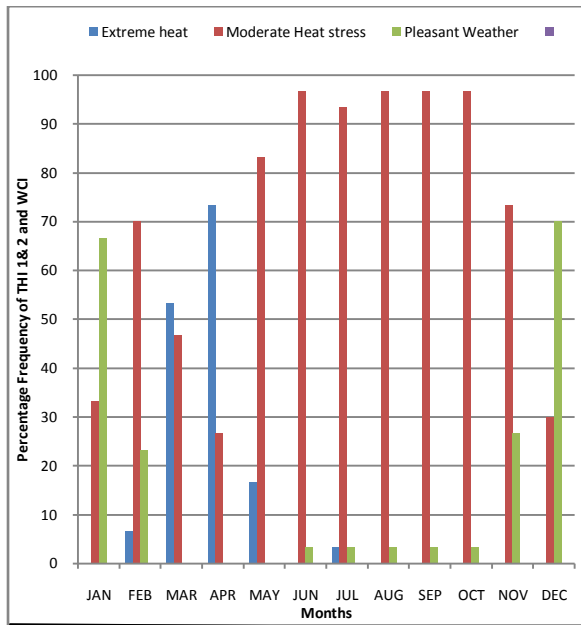


Fig 9: The Chart showing the Percentage frequency of THI 1 & 2 and WCI for Lokoja.

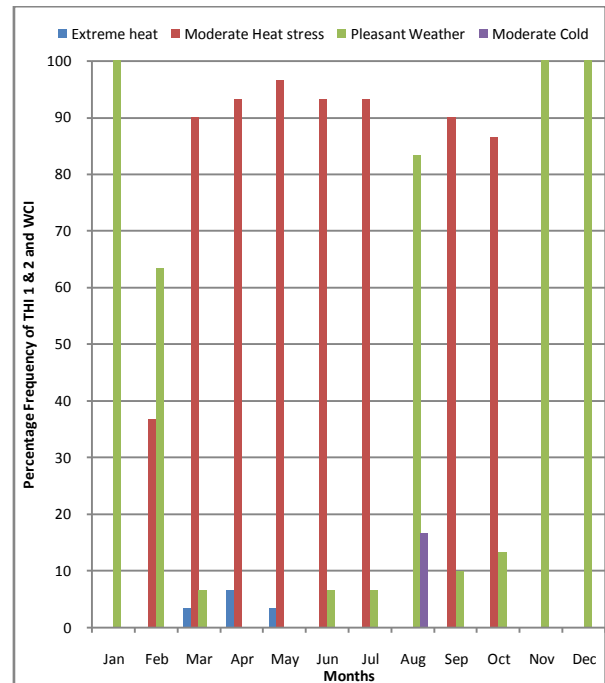


Fig 10: The Chart showing the Percentage frequency of THI 1 & 2 and WCI for Minna.

Fig 1 – Fig 5 above reveal that Monthly variation of Wind Chill index (WCI) is a mirror image of Temperature-Humidity Index (THI).

It could also be observed that cold, very cold and bitter cold episodes were not recorded throughout the period of investigation for all the Four (4) states. It could be observed that cold, very cold and bitter cold episodes were not recorded throughout the period of investigation for all the five urban towns. Pleasant and comfortable weather is experienced for four months which are January, February, November and December for Abuja, Bida, Lokoja and Minna while heat stress are experienced for eight months which are April, March, May, June, October, July, September and August in descending order for the four urban towns. Meanwhile, Jos records remarkable, pleasant and comfortable weather throughout the year except for the month of December, January and November in which the THI and WCI values reveal cold and humid weather in descending order. The charts showing the percentage frequency of the annual THI 1 & 2 and WCI for all the five urban towns investigated for 30 years (1980-2009) are presented above. The charts reveal that extreme heat stress is experienced mostly in April for all the urban towns except Jos with percentage frequency of 73% in Lokoja, 70% in Bida, 20% in Abuja and 6.7% in Minna. March and May also record extreme heat stress with highest % frequency of 53% in Lokoja 43% in Bida and 3.3% in Abuja and Minna.

Moderate heat stress is mostly experienced in May, June October March, April, August, September and July in descending order.

Jos records moderate cold and humid weather in January, December, November, February in descending order with Percentage frequency of 86%, 83%, 70% and 36% respectively while all other months reveal 100% comfortability.

In addition Jos values of THI and WCI reveal that It records relatively pleasant and comfortable weather throughout the year compared to any other towns in Nigeria, this is as a result of location of Jos at high level of elevation of about 1,238 meters or 4,062 feet high above sea level.

The tables below the summary of the Monthly variation for the thirty (30) years investigated (1980-2009)

Table 2: Summary of the Monthly Variation of THI 1& 2 for Abuja from 1980- 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Averages	71.46	73.80	76.89	78.83	77.73	76.23	75.36	75.08	75.15	75.94	73.45	71.49
Standard deviation	1.74	2.10	1.85	1.63	1.21	0.74	0.86	0.73	1.51	0.65	1.17	1.14
Maximum value	76.53	78.66	80.41	83.06	80.92	77.76	77.05	76.76	79.26	77.26	76.35	74.32
Minimum value	68.24	71.17	73.57	76.22	75.93	74.39	73.68	74.09	71.45	74.55	71.37	69.29
Year of Maximum	2006	2005	2005	1988	2006	1998	2006	2006	2004	2003	1993	1990
Year of Minimum	1989	2000	2004	1985	1985	2005	2009	1980	1988	1991	1996	1986

Table 3: Summary of the Monthly Variation of THI 1& 2 for Bida from 1980- 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Averages	73.18	76.52	79.26	80.51	79.29	77.87	77.13	76.66	78.50	77.57	74.93	72.60
Standard deviation	1.79	3.39	1.76	1.21	0.94	0.69	1.11	0.82	8.27	0.98	1.33	1.95
Maximum value	77.48	89.21	81.79	82.24	82.97	79.24	82.15	82.15	121.98	80.66	78.02	76.09
Minimum value	69.68	71.58	75.76	76.92	78.11	76.73	75.85	74.76	75.14	75.56	72.21	64.21
Year of Maximum	2006	2008	2005	1988	1988	2002	2005	2005	2007	2004	1993	1990
Year of Minimum	1989	2004	1983	2004	1999	2004	1997	2008	2008	2002	2003	1996

Table 4: Summary of the Monthly Variation of THI 1& 2 for Jos from 1980- 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Averages	63.23	65.10	68.44	70.76	70.98	69.33	68.16	67.86	68.58	67.51	64.34	63.49
Standard dev	1.36	1.60	1.38	1.46	1.37	1.30	1.25	0.94	0.94	1.00	0.81	1.16
Maximum value	66.19	69.18	70.68	70.68	75.03	73.14	71.94	70.42	72.10	69.40	66.45	66.93
Minimum value	59.64	66.02	64.68	64.68	67.15	66.63	66.24	66.03	67.49	65.77	63.15	61.51
Year of Maximum	2007	2007	2009	2009	2009	2008	2008	2008	2008	1997	2009	1993
Year of Minimum	1983	1986	1990	1990	1987	2007	1986	1988	1986	1988	1996	1986

Table 5: Summary of the Monthly Variation of THI 1& 2 for Lokoja from 1980- 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Average	73.85	76.98	79.89	80.27	79.03	77.79	77.23	76.74	76.96	77.38	75.44	73.78
Standard deviation	2.43	2.37	1.59	1.21	1.04	0.86	1.82	0.89	0.83	0.95	1.64	1.88
Maximum value	77.99	80.40	82.75	82.60	80.80	79.00	85.68	78.32	78.18	78.58	77.90	78.11
Minimum value	68.19	72.29	75.56	75.61	75.19	74.69	74.07	73.86	74.10	73.87	70.31	68.07
Year of Maximum	1985	1996	1996	1998	1987	1998	2001	1987	1987	1987	1999	1990
Year of Minimum	1988	1989	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988

Table 6: Summary of the Monthly Variation of THI 1& 2 for Minna from 1980- 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly averages	71.93	74.54	77.96	79.43	78.25	76.68	75.91	75.54	75.82	76.11	72.89	71.80
Standard deviation	1.33	1.65	1.72	1.01	1.46	0.84	0.79	0.69	0.94	0.87	0.90	1.30
Maximum value	74.16	78.11	80.83	81.25	82.31	77.99	78.05	77.30	79.89	78.26	74.57	75.36
Minimum value	68.76	72.40	74.22	77.20	75.58	74.77	73.37	73.80	74.80	74.09	70.94	69.94
Year of maximum	2000	1991	2002	2007	2003	2007	1987	1982	1982	1985	1990	1990
Year of minimum	1983	2000	1990	1987	1985	2004	2004	2003	2001	2002	1982	1980

IV. Conclusions

The results showed that severe heat stress were experienced in the months of April, May and March in descending order for Abuja, Minna, Lokoja and Bida while moderate heat stress were recorded in June, October, July, September and August for all these four towns where 50% of human and animals are not comfortable due to hot and humid weather condition. Remarkable, pleasant and comfortable sensations were observed throughout the year in Jos with exception of November, December and January which shows that 50% of inhabitants are partially comfortable due to cold and humid weather. Man and animals require active managerial intervention strategies like providing shade made of galvanized metal or aluminium roof to reduce the exposure to direct sunlight and possibility of sun-burn, installing sprinkler system that produce large droplet to wet the cow with as much water as can evaporate to reduce surface heat through conduction, avoiding transportation of animals on hot day during hottest part also prevent death rate of animals and in some cases the best option to ensure well being of animal will be to slaughter them.

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