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Discomfort Indices in North-Eastern Nigeria

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Abstract: *Meterological data for thirty years (1980-2009) from three whether stations which are Bauchi Yola and Maiduguri were analyzed to determine the comfort and discomfort period using Temperature humidity indices and wind chill index. Monthly variation of THI was shown to be a mirror image of WCI. No cold, bitter cold episodes were recorded throughout the investigation. The months with heat stress are April, May, June, July, August, September and October while the remaining months which are January, February, March, November and December mostly bring comfortable sensation for all the states investigated except Yola which records heat stress in the month of March. Bauchi and Yola record severe heat stress in the month of April and May where 100% of man and animal are not comfortable due to hot and humid weather. Percentage frequencies of the annual THI and WCI for the thirty years observed were also reported.*
Keywords: *Temperature-Humidity Index, Wind-Chill Index, Heat stress, Percentage Frequency*

I. Introduction

North-eastern region of Nigeria has climate which is characterized by high ambient temperature for a long period of time and one of the challenges to dairy producers and rabbit producers which are of majority in this region is heat stress. Heat stress is caused by a combination of environment factors (temperature, relative humidity, solar radiation air movement and precipitation). Many indices combining different environmental factors to measure the level of heat stress have been proposed. The majority of studies on heat stress have mainly focused mainly on temperature and relative humidity (Thom, 1959, Kibler 1964, Steadman 1979, NOAA 1976 e.t.c). Different researchers have also applied these indices to estimate thermal comfort in different stations (Venkitshwaran, Seaminathan 1967), to determine the effect of heat stress on the aged and those who suffered from malnutrition (Jauregul, 1984; Oke, 1982; Okpara, 1997) and to predict heat stress in dairy cows and their effect on milk production (Ballester et al., 1997; Basu and Samet 2002; Pauli and Rizzi, 2005)

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.

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, heat stress appear to be the critical factors affecting the break of crops, pests and diseases.

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-east geographical areas of Nigeria. There three urban cities each from three states in North-eastern Nigeria that were investigated due to the availability of their meteorological data and their results can also be used to predict the heat stress of some of their neighbouring environments. These three cities are Bauchi, the capital city of Bauchi states, Yola, capital city of Adamawa state and Maiduguri, the capital city of Borno 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 Bauchi Yola and Maiduguri stations.

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

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

Where T_a = average ambient monthly temperature in ^oC

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 ℃ .
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℃ .
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.
60-65	50% are partially comfortable.
<60	Almost 100% are comfortable due to cold and dry weather

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 THI was compared with NOAA (1979)'s discomfort Index 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 3 below showed the monthly variation of THI and WCI for all the three (3) urban towns chosen from three (3) states Bauchi, Yola and Maidiguri.

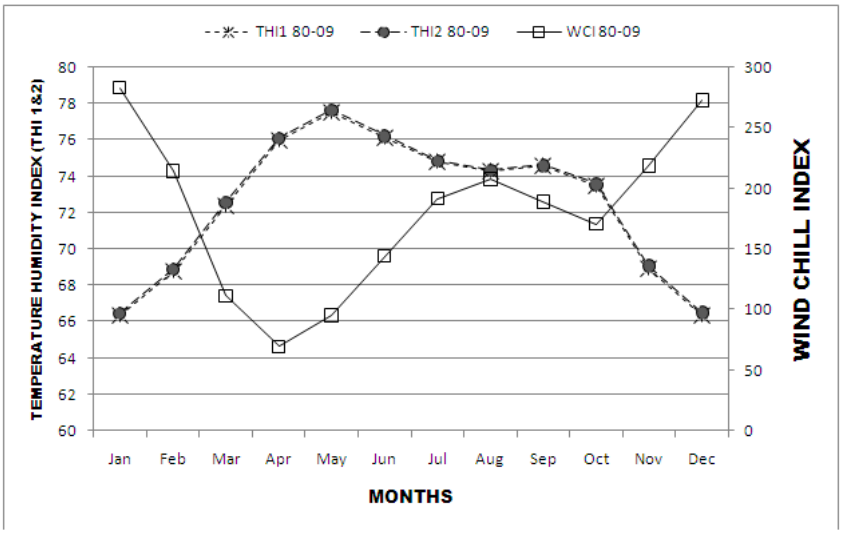

Fig 1: The Graph Of THI(1&2) And WCI in Bauchi From 1980-2009

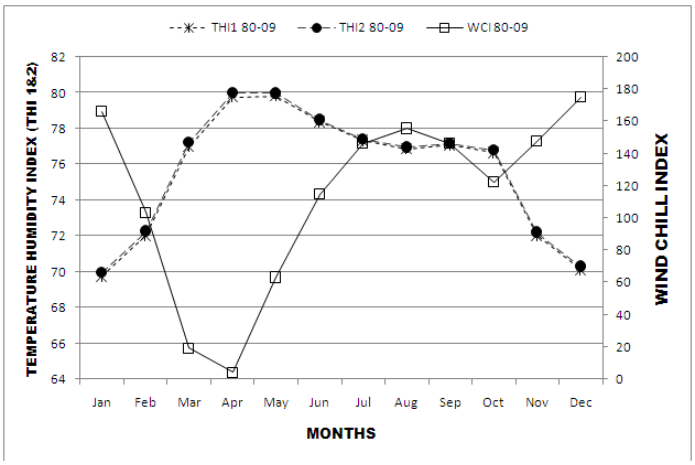

Fig 2: The Graph Of THI (1&2) And WCI From 1980-2009 In Yola

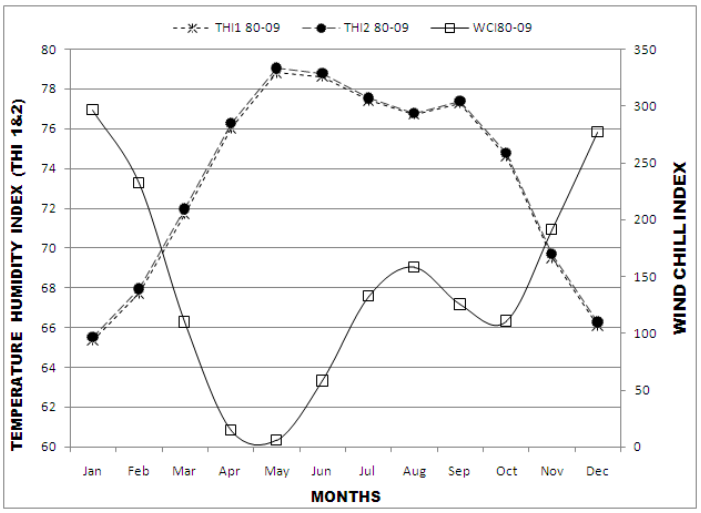

Fig 3: The Graph Of THI (1&2) And WCI in Maiduguri From 1980-2009

Monthly variation of Wind Chill index (WCI) is a mirror image of Temperature-Humidity Index (THI). It could be observed that cold, very cold and bitter cold episodes were not recorded throughout the period of investigation for all the three (3) states. Also THI and WCI values for January, February, November and December mostly give comfortable and pleasant feelings for all the three (3) urban towns investigated. March is also a month with cool and pleasant weather in Bauchi and Maiduguri but with moderate heat stress in Yola and severe heat stress occassionally. April and May values of THI and WCI reveal severe heat stress in Bauchi and Yola such that 100% of human and animals are not comfortable as a result of hot and humid weather while these months in Maiduguri has THI and WCI values which reveal moderate heat stress. The remaining months which are June, July, August September and October reveal moderate heat stress in all the three (3) urban towns investigated.

The percentage frequencies calculated reveal that for all the three urban towns investigated there are no records of 100% uncomfortability as a result of cold and dry weather. Although Bauchi according to table 2(a&b) records severe heat stress in April and May but with very little percentage frequency of 3.3% each while October is the month with minimum heat stress. Yola records severe heat stress in April and May according to table 3(a&b) with a high percentage frequencies of 40% and 56.7% respectively, severe heat stress was also observed in March, June and July with low percentage frequencies of 16.7%, 20% and 6.7% respectively while January February November and December are characterized with comfortable and pleasant weather, September, August and October are characterized with moderate heat stress where 50% are not comfortable due to hot and humid weather in descending order. Table 4(a&b) shows that the month of May and June are the months in Maiduguri with probable severe heat stress with percentage frequencies of 20% and 10% respectively, April July August September and October record moderate heat stresswhile the same month of October also records comfortable and pleasant weather of percentage frequency of 50% which implies that the probability of having hot or pleasant weather in the month of October is half $(1/2)$.

IV. Conclusions

The results showed that January, February, November and December are pleasant and comfortable months for all the three (3) urban towns investigated while Bauchi's hot season span through seven months which are May, April, June, July September August and October in descending order, but heat is experienced for a period of eight months in Yola which are May, April, June, March, July, September, August and October in descending order. Maiduguri's hot season are experienced for seven months like Yola and the months are May, June, July April September August and October in descending order. Generally for all the three (3) urban towns, each from three states Bauchi, Adamawa and Borno states investigated it can be concluded that these months characterized with heat stress has the highest heat stress in May while the least heat stress is experienced in October. Consequently, all the months are characterized with heat stress due to hot and humid weather which are not pleasant for both 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.

Table 2(a): Percentage Frequency of Annual Temperature Humidity Index (THI 1&2) in Bauchi from 1980 to 2009

THI 1&2	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Human/Animal and Plant Feeling(Weather)
>80	0	0	0	3.3	3.3	0	0	0	0	0	0	0	100% not Comfortable
75 - 80	0	0	10	70	96.7	93.3	66.7	43.3	46.7	16.7	0	0	50% not Comfortable due to hot & humid weather
65 - 75	86.7	100	90	26.7	0	6.7	33.3	56.7	53.3	83.3	100	93.3	100% are quite Comfortable
60 - 65	13.3	0	0	0	0	0	0	0	0	0	0	6.7	50% are partially Comfortable
<60	0	0	0	0	0	0	0	0	0	0	0	0	Almost 100% Uncomfortable due to Cold &Dry weather
Total	100	100	100	100	100	100	100	100	100	100	100	100	

Table 2(b): Percentage Frequency of Annual Wind Chill Index (WCI) in Bauchi from 1980 to 2009

WCI Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Human/Animal & Plant Feeling
<50	0	0	10	26.7	6.7	0	0	0	0	0	0	0	Hot
50 - 100	0	0	33.3	63.3	53.3	3.3	3.3	0	3.3	0	0	0	Warm
101 - 200	6.7	33.3	53.3	6.7	40	97.7	70	40	56.7	86.7	40	13.3	Pleasant
201 - 400	90	66.7	3.3	3.3	0	0	30	60	40	13.3	60	86.7	Cool
401 - 600	3.3	0	0	0	0	0	0	0	0	0	0	0	Very Cool
601 - 800	0	0	0	0	0	0	0	0	0	0	0	0	Cold
801 - 1000	0	0	0	0	0	0	0	0	0	0	0	0	Very Cold
>1000	0	0	0	0	0	0	0	0	0	0	0	0	Bitter Cold
Total	100	100	100	100	100	100	100	100	100	100	100	100	

Table 3(a): Percentage Frequency of Annual Temperature Humidity Index (THI 1&2) in Yola from 1980 to 2009

THI 1&2	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Human/Animal and Plant Feeling
>80	0	0	16.7	40	56.7	20	6.7	0	0	0	0	0	100% are not Comfortable
75 - 80	0	6.7	70	60	43.3	73.3	83.3	90	96.7	76.7	6.7	0	50% not Comfortable due to hot & humid weather
65 - 75	100	93.3	13.3	0	0	6.7	10	10	3.3	23.3	90	100	100% are quite Comfortable
60 - 65	0	10	0	0	0	0	0	0	0	0	3.3	0	50% are partially Comfortable
<60	0	0	0	0	0	0	0	0	0	0	0	0	Almost 100% Uncomfortable due to Cold &Dry weather
Total	100	100	100	100	100	100	100	100	100	100	100	100	

Table 3(b): Percentage Frequency of Annual Wind Chill Index (WCI) in Yola from 1980 to 2009

WCI Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Human/Animal and Plant Feeling
<50	0	10	86.7	90	36.7	3.3	3.3	0	0	0	0	0	Hot
50 - 100	6.7	30	13.3	10	50	20	3.3	0	0	30	16.7	0	Warm
101 - 200	76.7	60	0	0	13.3	76.7	83.3	96.7	100	70	76.7	73.3	Pleasant
201 - 400	16.7	0	0	0	0	0	10	3.3	0	0	6.7	26.7	Cool
401 - 600	0	0	0	0	0	0	0	0	0	0	0	0	Very Cool
601 - 800	0	0	0	0	0	0	0	0	0	0	0	0	Cold
801 - 1000	0	0	0	0	0	0	0	0	0	0	0	0	Very Cold
>1000	0	0	0	0	0	0	0	0	0	0	0	0	Bitter Cold
Total	100	100	100	100	100	100	100	100	100	100	100	100	

Table 4(a): Percentage Frequency of Annual Temperature Humidity Index (THI 1&2) in Maiduguri from 1980 to 2009

THI1 1&2	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Human/Animal and Plant Feeling
>80	0	0	0	0	20	10	0	0	0	0	0	0	100% are not Comfortable
75 - 80	0	0	3.3	86.7	76.7	83.3	96.7	100	100	50	0	0	50% not Comfortable due to hot & humid weather
65 - 75	66.7	96.7	96.7	13.3	3.3	6.7	3.3	0	0	50	100	90	100% are quite Comfortable
60 - 65	33.3	3.3	0	0	0	0	0	0	0	0	0	10	50% are partially Comfortable
<60	0	0	0	0	0	0	0	0	0	0	0	0	Almost 100% Uncomfortable due to Cold & Dry weather
Total	100	100	100	100	100	100	100	100	100	100	100	100	

Table 4(b): Percentage Frequency of Annual Wind Chill Index (WCI) in Maiduguri from 1980 to 2009

WCI Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Human/Animal and Plant Feeling
<50	0	0	6.7	90	90	46.7	0	0	0	0	0	0	Hot
50 - 100	0	0	40	10	10	50	13.3	0	16.7	40	0	0	Warm
101 - 200	0	30	46.7	0	0	3.3	83.3	100	83.3	60	63.3	3.3	Pleasant
201 - 400	96.7	70	6.7	0	0	0	3.3	0	0	0	36.7	96.7	Cool
401 - 600	3.3	0	0	0	0	0	0	0	0	0	0	0	Very Cool
601 - 800	0	0	0	0	0	0	0	0	0	0	0	0	Cold
801 - 1000	0	0	0	0	0	0	0	0	0	0	0	0	Very Cold
>1000	0	0	0	0	0	0	0	0	0	0	0	0	Bitter Cold
Total	100	100	100	100	100	100	100	100	100	100	100	100	

Table 5a: Summary Of Monthly Variation Of Temperature Humidity Index (Thi1&2) In Bauchi From 1980 – 2009

WCI Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Human/Animal and Plant Feeling
<50	0	0	6.7	90	90	46.7	0	0	0	0	0	0	Hot
50 - 100	0	0	40	10	10	50	13.3	0	16.7	40	0	0	Warm
101 - 200	0	30	46.7	0	0	3.3	83.3	100	83.3	60	63.3	3.3	Pleasant
201 - 400	96.7	70	6.7	0	0	0	3.3	0	0	0	36.7	96.7	Cool
401 - 600	3.3	0	0	0	0	0	0	0	0	0	0	0	Very Cool
601 - 800	0	0	0	0	0	0	0	0	0	0	0	0	Cold
801 - 1000	0	0	0	0	0	0	0	0	0	0	0	0	Very Cold
>1000	0	0	0	0	0	0	0	0	0	0	0	0	Bitter Cold
Total	100	100	100	100	100	100	100	100	100	100	100	100	

Table 5b: Summary Of Monthly Variation Of Wind-Chill Index In Bauchi From 1980 - 2009

THI1 VALUE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Yearly Average	66.33	68.72	72.36	75.94	77.51	76.14	74.81	74.28	74.55	73.46	68.94	66.36
Standard Deviation	1.89	1.63	1.59	1.72	1.35	1	0.99	0.93	1.13	1.26	1.46	1.24
Maximum value	70.48	72.37	75.58	80.77	82.54	78.54	76.81	76.37	78.33	76.34	72.79	69.39
Year of Maximum	2002	2006	1999	2002	2000	1999	2000	1997	2004	2000	2000	1995
Minimum Value	61.76	64.95	69.15	73.07	74.97	73.48	72.97	72.03	72.89	70.45	66.55	64.46
Year of Minimum	1983	1989	1990	2009	2004	2004	2008	2007	2007	1983	1982	1994

Table 6: Summary Of Monthly Variation Of Temperature Humidity Index (Thi1&2) In Yola From 1980 - 2009

THI 1 VALUE	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Yearly Average	65.71	67.87	72.57	75.2	75.23	73.89	72.92	72.44	72.61	72.26	67.89	66.02
Standard Deviation	1.49	1.87	2.49	2.04	1.62	1.88	2.09	1.28	1.02	1.88	2.09	1.09
Maximum Value	73.94	77.71	82.65	85.99	82.42	83.31	84.17	78.41	78.72	79.49	77.06	72.96
Year of Maximum	2003	2002	2004	2004	2000	1987	1990	1987	1997	1997	1990	1990
Minimum Value	66.95	69.02	72.85	76.59	76.41	73.76	73.29	72.99	73.84	73.36	64.93	68.49
Year of Minimum	1989	1989	1989	1992	1991	1992	1992	1991	1991	1991	2000	2009

Table 6b: Summary Of Monthly Variation Of Wind-Chill Index In Yola From 1980 - 2009

WCI VALUE	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Yearly Average	158.4	99.19	19.66	5.52	61.78	109.62	139.38	147.36	138.4	115.98	140.58	166.06
Standard Deviation	43.72	45.08	27.91	30.48	36.24	33.95	42.12	27.99	24.73	25.76	39.77	35.8
Maximum Value	251.8	177.2	74.06	72.23	145.05	144.73	230.51	212.29	179.4	177.22	231.78	247.48
Year of Maximum	1983	1989	1989	2008	1981	1981	1981	1981	2005	1986	1982	1980
Minimum Value	72.36	-10.59	-40.99	-40.52	-13.46	13.23	36.41	118.25	106.8	83.53	87.89	103.19
Year of Minimum	2003	2002	2004	1983	1987	1987	1990	1997	1997	1993	1997	1990

Table 7: Summary Of Monthly Variation Of Temperature Humidity Index (Thi1&2) In Maiduguri From 1980 – 2009

THI 1 VALUE	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Yearly Average	61.58	63.83	67.56	71.62	74.26	74.07	72.9	72.23	72.76	70.39	65.47	62.21
Standard Deviation	1.54	1.74	1.53	1.63	1.72	1.55	0.95	0.77	0.69	1.55	1.04	1.09
Maximum Value	67.75	71.39	75.55	79.22	82.18	81.3	79.53	78.4	78.24	78.15	71.39	69.34
Year of Maximum	1985	2005	2004	2004	1982	2002	2002	1981	1997	1997	1990	1990
Minimum Value	61.95	64.23	68.43	72.26	72.95	73.11	74.54	75.11	75.68	71.33	67.53	63.64
Year of Minimum	1989	1989	1989	1987	1983	1983	1980	1980	2003	1988	1996	1994

Table 7b: Summary Of Monthly Variation Of Wind-Chill Index In Maiduguri From 1980 – 2009

WCI VALUE	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Yearly Average	282.08	221.9	105.83	14.76	7.51	56.27	126.03	150.03	119.17	105.47	181.83	263.36
Standard Deviation	51.56	62.47	47.14	24.94	31.39	29.84	24.17	22.1	22.59	24.4	32.17	41.13
Maximum Value	428.07	368.78	212.07	82.98	89.4	160.47	206.96	191.08	168.71	169.72	251.19	363.55
Year of Maximum	1989	1989	1990	1987	1991	1980	1980	1980	1986	1988	1984	1994
Minimum Value	210.7	120.59	-3.74	-27.79	-54.79	19.93	91.09	101.81	81.94	71.13	127.66	186.52
Year of Minimum	2004	2004	2004	2002	1998	1990	1984	1984	2004	1993	1990	1990

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