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ASSESSMENT OF THERMAL COMFORT LEVEL OVER A SOLAR CYCLE IN BENUE STATE

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ABSTRACT

This study assessed thermal comfort levels in Benue State, Nigeria, focusing on temperature and humidity patterns and their combined effects as measured by the Temperature-Humidity Index (THI). The research methodology includes collection of Temperature and humidity data from NIMET Makurdi station. By analyzing temperature and humidity data over a solar cycle, the research reveals significant fluctuations in thermal comfort, particularly during solar maxima, when higher solar radiation leads to elevated temperatures and discomfort. During solar minimum periods, cooler temperatures and more favorable Temperature-Humidity Index (THI) values improve comfort levels. The study further highlights the implications of these climatic variations for urban planning, agricultural practices, and public health. High THI values during solar maxima increase heat stress, requiring adaptive measures in building design and crop management, while solar minima offer temporary respite for residents and farmers. The findings underscore the need for continuous monitoring of climatic variables to mitigate the effects of climate variability and enhance resilience in the region. This research contributes valuable insights into how solar activity influences local climate, providing a basis for informed decision-making in improving thermal comfort and sustainability in Benue State.

Keywords: Thermal comfort, Solar cycle, Benue State, Climate variability

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INTRODUCTION

Thermal comfort, a state of mind that expresses satisfaction with the surrounding environment, is a crucial aspect of human well-being. It significantly influences productivity, health, and overall quality of life. The factors contributing to thermal comfort include air temperature, humidity, air movement, and radiant temperature, among others. Overarching these factors are the broader climatic variations that occur due to natural phenomena, including the solar cycle. The solar cycle, an approximately 11-year cycle of solar activity, plays a pivotal role in influencing the Earth's climate. Understanding how the assessment of thermal comfort level varies over a solar cycle is essential for designing sustainable living environments and for adapting to climatic changes.

The solar cycle, characterized by periodic changes in the Sun's activity, including variations in the number of sunspots, solar flares, and other solar emissions, has significant implications for Earth's climate. During periods of high solar activity (solar maxima), increased solar radiation can lead to higher atmospheric temperatures. Conversely, during periods of low solar activity (solar minima), reduced solar radiation can result in cooler temperatures. The impact of the solar cycle on Earth's climate is complex and can be influenced by various feedback mechanisms in the Earth's atmosphere and oceans (Lean, 2010).

The solar cycle's influence on global temperatures is relatively modest compared to other factors such as greenhouse gas emissions. However, it can still lead to noticeable changes in regional climates and weather patterns. These variations can, in turn, affect thermal comfort levels in different regions. For instance, higher solar activity can exacerbate heatwaves, while lower activity might contribute to cooler winters (Haigh, 2007).

Thermal comfort is influenced by several environmental and personal factors. The primary environmental factors include air temperature, radiant temperature, humidity, and air velocity. Personal factors include clothing insulation and metabolic heat production. The Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) indices are commonly used to quantify thermal comfort levels. These indices consider both environmental and personal factors to predict the average thermal sensation and the percentage of people likely to be dissatisfied with the thermal environment (Fanger, 1970).
Changes in climate patterns due to the solar cycle can alter these environmental factors. For example, an increase in solar activity can lead to higher temperatures and possibly lower humidity levels, affecting the PMV and PPD indices. Additionally, seasonal variations in solar radiation can influence the heating and cooling needs of buildings, impacting energy consumption and thermal comfort (ISO 7730, 2005).

Future research should continue to explore the relationships between the solar cycle, climate, and thermal comfort. Advanced climate models that integrate solar activity data can provide more accurate predictions of how thermal comfort levels will evolve over time. Interdisciplinary approaches combining climate science, building engineering and human physiology can enhance our understanding of thermal comfort levels. By integrating these fields, researchers can develop comprehensive strategies for designing resilient and sustainable built environments that adapt to both short-term weather fluctuations and long-term climatic trends driven by the solar cycle.

METHODOLOGY

The Study Area

The study area used for this research work is Benue state. The state is located in the sub-tropics within latitude 6.5 to 8.5 ^{0}N; and longitude 7.47 to 10 ^{0}E. Benue State experiences two distinct seasons, the wet/rainy season and the dry/summer season. The rainy season lasts from April to October with annual rainfall in the range of 100-200mm. The dry season begins in November and ends in March. Temperatures fluctuate between 23 – 37 degrees Celsius during the year. The south-eastern part of the state adjoining the Obudu-Cameroun mountain range, however, has a cooler climate similar to that of the Jos Plateau. The vegetation of the State consists of rain forests which have tall trees, tall grasses and oil palm trees that occupy the state's western and southern fringes while the Guinea savannah is found in the eastern and northern parts with mixed grasses and trees that are generally of average height. Benue's topography is mainly undulating plains with occasional elevations of between 1,500m and 3,000m above sea level. The state's main geological formations are sandy-loam shelf basement complex and alluvial plains. These together with its location in the transition belt between the north and south ecologies and a favorable rainfall pattern account for its support for a wide variety of crops.

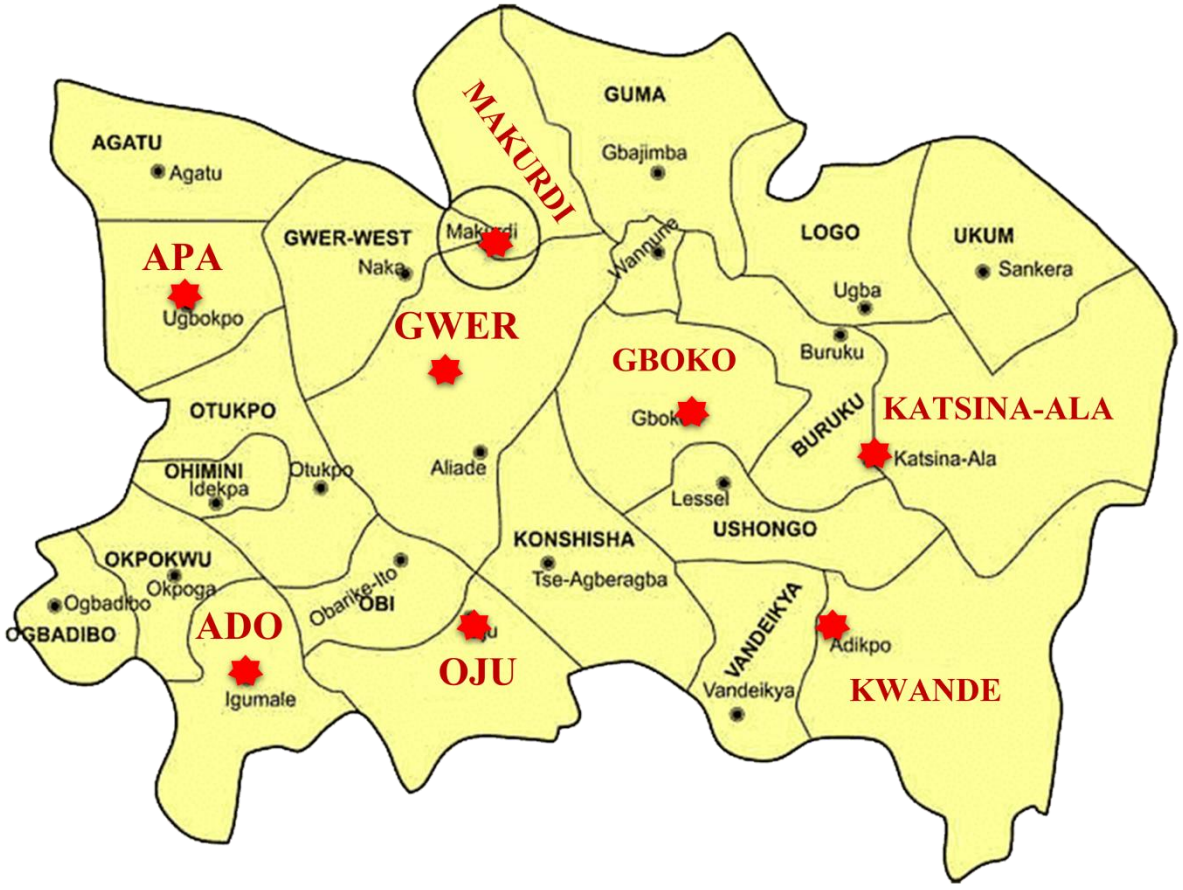


Figure 1: Map of the Study Area

Methods

Data, such as temperature and relative humidity were collected from Makurdi to ascertain the index of human comfort. In line with this, the comfort level was determined by using the Temperature Humidity Index (THI), as shown in the equation below:

$$THI = T - (0.55 - 0.0055Rh)(T - 14.5) \quad (1)$$

The index uses seven comfort classes ranging from THI value of >17.0 to <28.0 in determining human comfort levels. When the THI ranges from 19.0-26.9, the thermal condition shows a comfort zone when people feel relatively comfortable. The THI from <18.9 to >27.0 gives discomfort cold and hot respectively. Consequently, the data collected were analyzed using statistical methods to identify patterns and trends in thermal comfort levels over the solar cycle 24.

RESULT AND DISCUSSION

Temperature

Figures 1 - 12 show temperature trend of Makurdi over a solar cycle. The region experiences notable temperature variations, influenced by both natural and anthropogenic activities. The data revealed a gradual increase in average temperatures, particularly during the dry season. This trend is not unique to Makurdi; however, its specific implications for the region's ecosystem and its inhabitants necessitate focused observation. By delving into monthly and seasonal averages, one can identify peaks and troughs in temperature that coincide with specific solar cycles. For instance, the interplay between solar radiation and local weather patterns as observed in these figures often leads to pronounced warm spells during the months of February to April, where temperatures soar above the historical averages. Conversely, the rainy season, stretching from May to October, tends to moderate temperatures but can also introduce humidity levels that exacerbate heat discomfort during transition periods.

Relative Humidity

Figures 13 – 24 shows the humidity pattern of Makurdi over a Solar Cycle. Examining these patterns reveals a complex interplay between the local climate and seasonal variations that significantly influence the Temperature-Humidity Index (THI). Humidity, defined as the amount of water vapor present in the air, can greatly affect thermal comfort and overall weather conditions.In Makurdi, the humidity levels fluctuate throughout the year, exhibiting distinct patterns that correlate with the rainy and dry seasons as shown in Figure 13 - 24. Typically, during the rainy season, which spans from April to October, humidity levels rise dramatically. The abundant rainfall saturates the atmosphere, often pushing relative humidity percentages above 80%. This high moisture content can create a muggy environment, leading to discomfort among residents and impacting agricultural practices.Conversely, during the dry season, particularly from November to March, humidity levels drop significantly in Makurdi. The harmattan winds, which sweep across the region from the Sahara Desert, bring dry air that can cause relative humidity to fall below 30%. This drop in humidity not only affects personal comfort but also has implications for water bodies and local vegetation, which may struggle under these arid conditions.

Examining daily and seasonal humidity patterns in Makurdi also reveals interesting trends. Data collected over the years indicates that early mornings often experience peak humidity levels, as cooler temperatures at dusk allow moisture to condense in the air. As the day progresses and

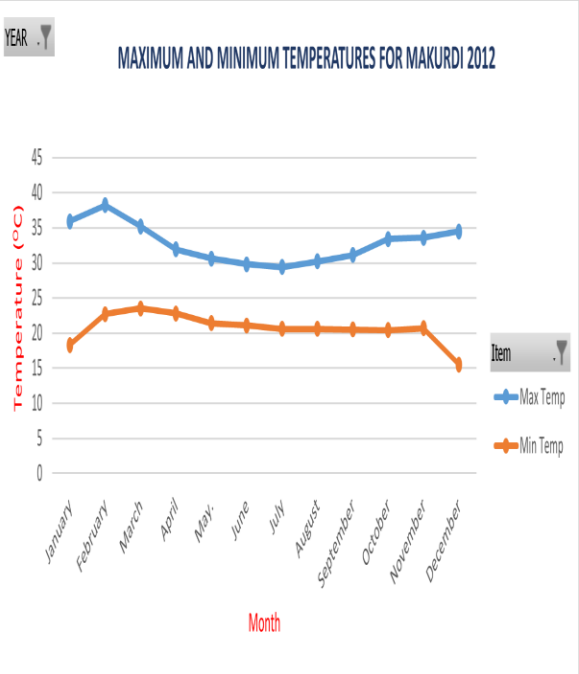
temperatures rise, humidity typically decreases, creating a cycle that is critical for understanding the local climate.This examination of humidity patterns is essential, not just for meteorological studies, but for informing agricultural practices and urban planning in Makurdi. By understanding how humidity interacts with temperature and the solar cycle, community planners and farmers can make informed decisions that enhance resilience to climate variability and improve the quality of life in the region.

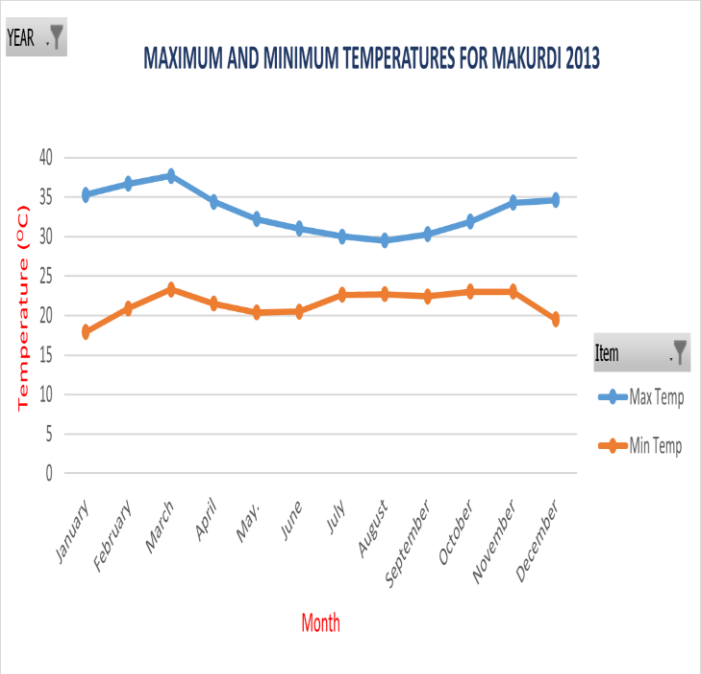
Correlation between Solar Cycleand THI in Benue State

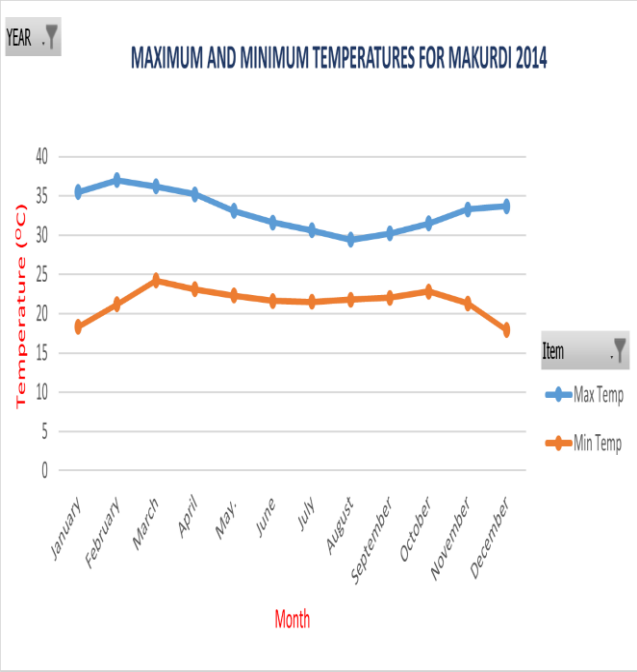
Figures 25 –36 shows the Annual Variation of THI over a solar cycle in Makurdi. This reveals intriguing patterns that has enhanced our understanding of local climate dynamics and agricultural practices. Solar cycles, which typically span approximately 11 years, involve fluctuations in solar radiation and activity levels, influencing weather patterns across the globe. In Makurdi, a region characterized by its distinct wet and dry seasons, these solar cycles can have a significant impact on temperature and humidity levels, ultimately affecting the THI. As analyzed in this research, it was observed that periods of heightened solar activity often correspond with increased temperatures and varying humidity levels in Makurdi. This relationship can be attributed to the intensified solar radiation during solar maximum phases, which results in higher daytime temperatures. Conversely, during solar minimums, the reduction in solar energy can lead to cooler temperatures and potentially altered humidity levels.

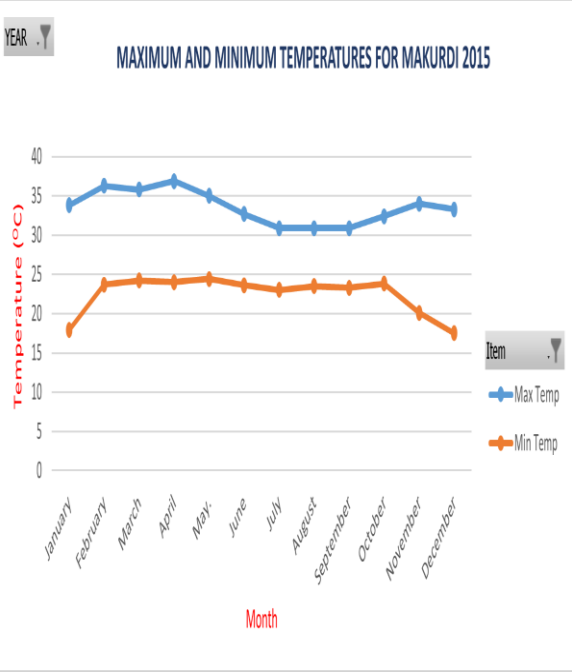
Therefore, understanding this correlation is particularly crucial for farmers in the region, as THI is a key indicator of livestock comfort and plant health. During solar maximum periods, higher THI values may indicate increased discomfort for animals and greater water loss for crops, prompting the need for adaptive strategies such as improved irrigation techniques or shaded enclosures for livestock. On the other hand, the cooler and potentially more humid conditions during solar minimums might offer a respite, allowing for more favorable growing conditions and less stress on animals. Additionally, the implications of this correlation extend beyond agriculture. By recognizing the cyclical patterns of solar activity and their effects on THI, urban planners and public health officials in Makurdi can better prepare for potential heat waves or humidity-related health issues. This foresight can lead to more effective resource allocation, infrastructure development, and community awareness programs aimed at mitigating the impacts of extreme weather conditions.

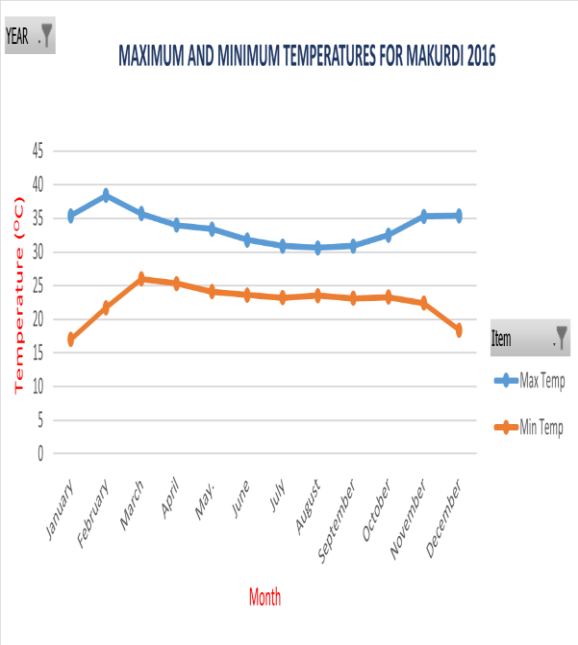
Conversely, case studies from solar minima - such as the one recorded in Solar Cycle 24 demonstrated a significant decrease in THI values. During this period, Makurdi experienced cooler temperatures and higher humidity levels, resulting in a THI that was consistently lower than average. This shift provided a temporary respite from the heat, allowing for more comfortable living conditions, and was particularly beneficial for agricultural practices, as crops thrived in the moderate climate. By analyzing these historical THI data points in conjunction with solar activity, we can better understand the intricate relationship between solar cycles and local climate variations. This knowledge is not only crucial for meteorological studies but also for agricultural planning, public health initiatives, and overall community resilience in adapting to climatic changes.

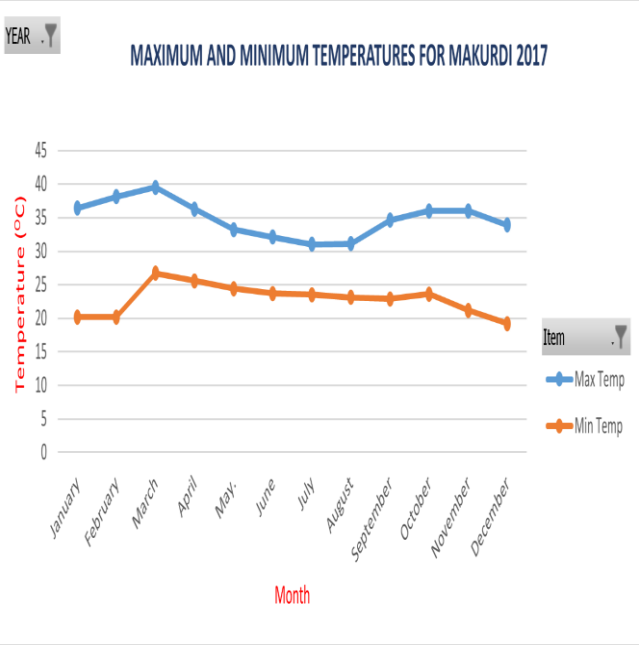

YEAR
MAXIMUM AND MINIMUM TEMPERATURES FOR MAKURDI 2012
Temperature (°C)
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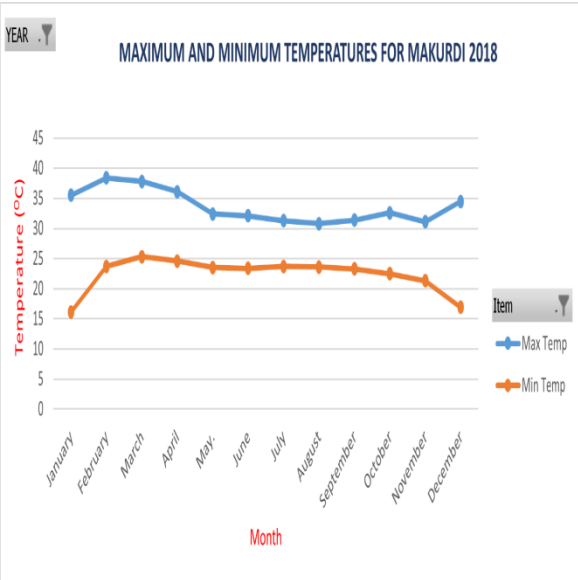

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MAXIMUM AND MINIMUM TEMPERATURES FOR MAKURDI 2013
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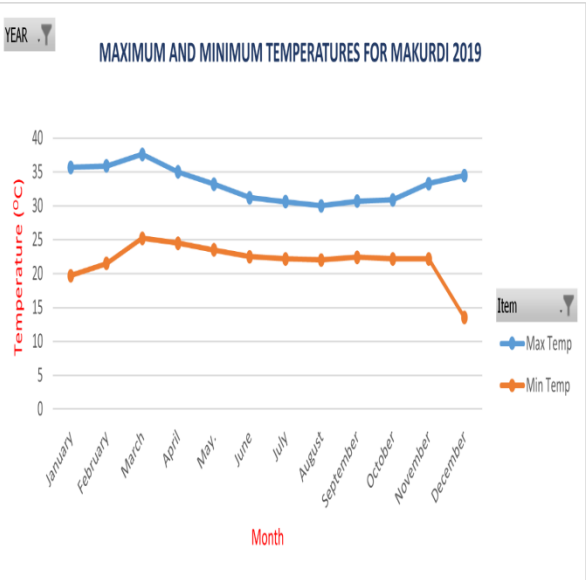

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MAXIMUM AND MINIMUM TEMPERATURES FOR MAKURDI 2014
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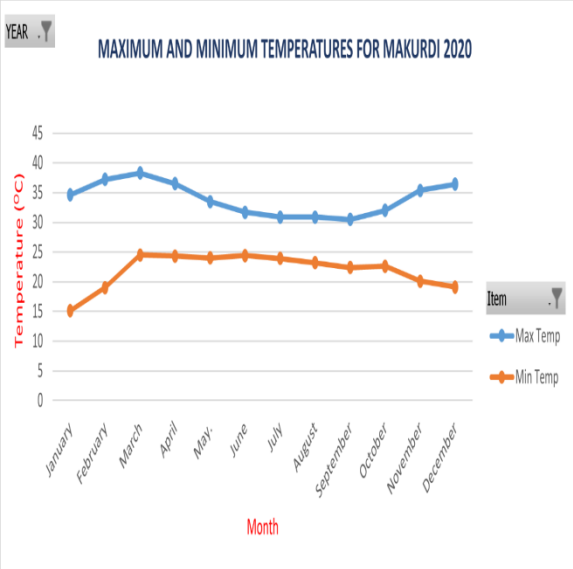

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MAXIMUM AND MINIMUM TEMPERATURES FOR MAKURDI 2015
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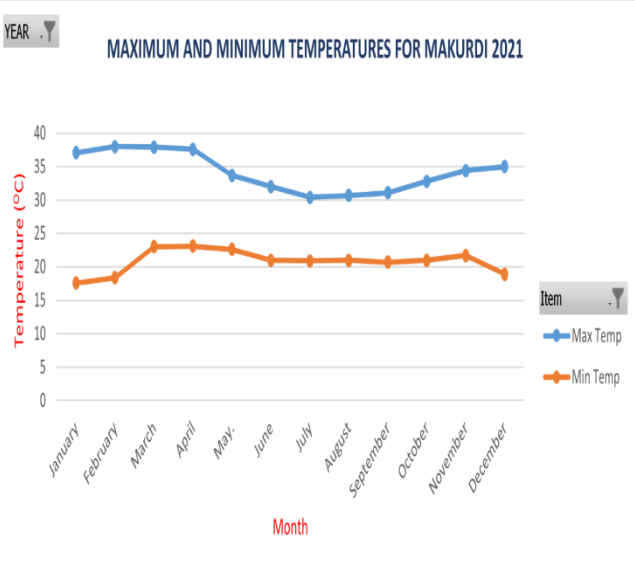

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MAXIMUM AND MINIMUM TEMPERATURES FOR MAKURDI 2016
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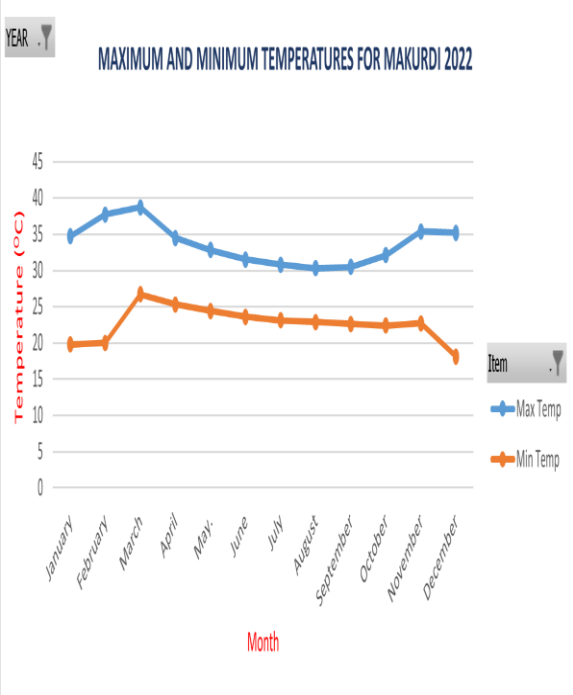

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MAXIMUM AND MINIMUM TEMPERATURES FOR MAKURDI 2017
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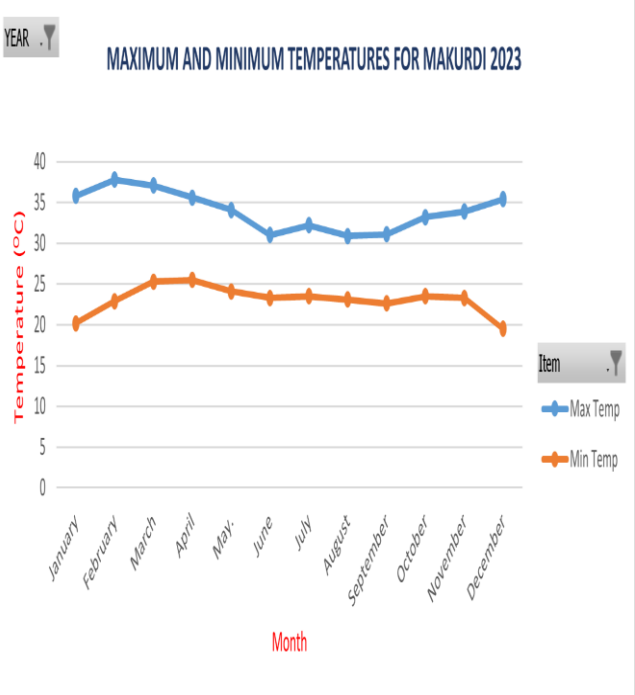

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MAXIMUM AND MINIMUM TEMPERATURES FOR MAKURDI 2018
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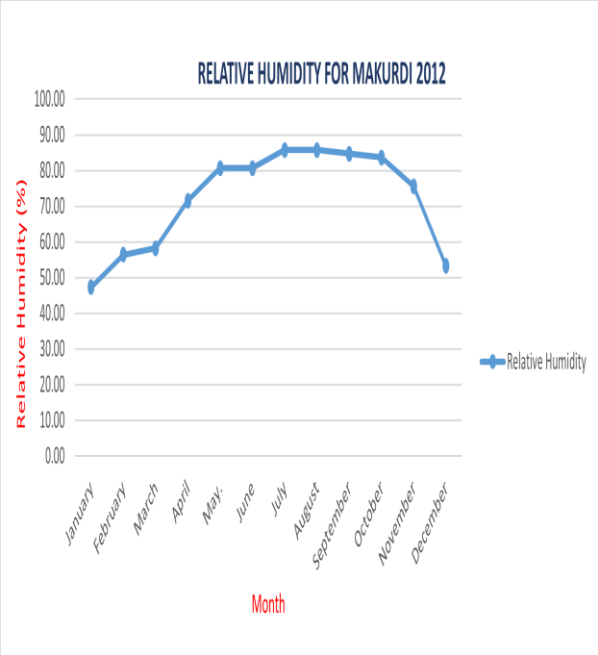

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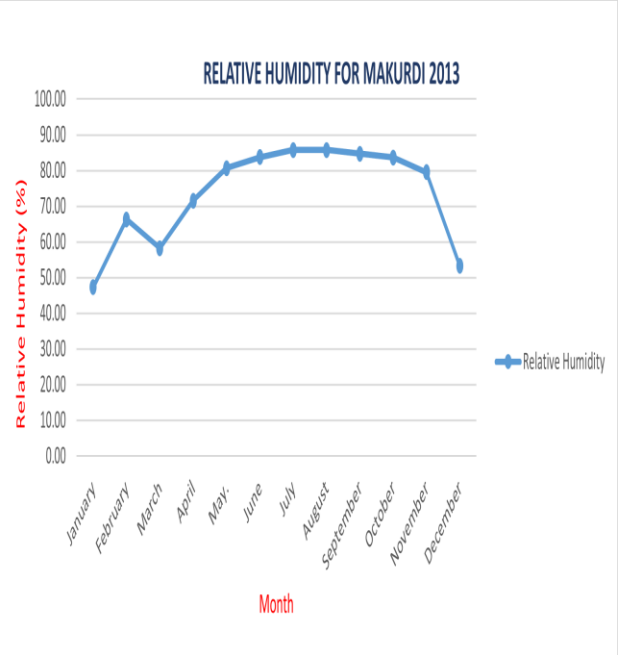

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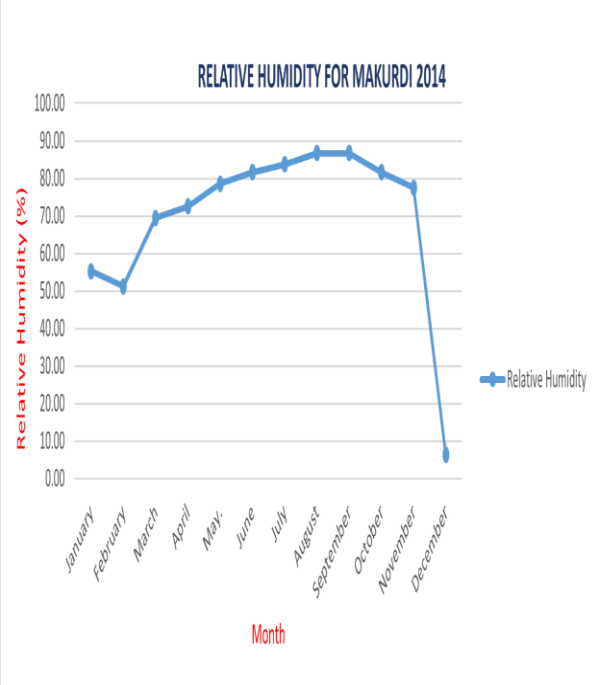

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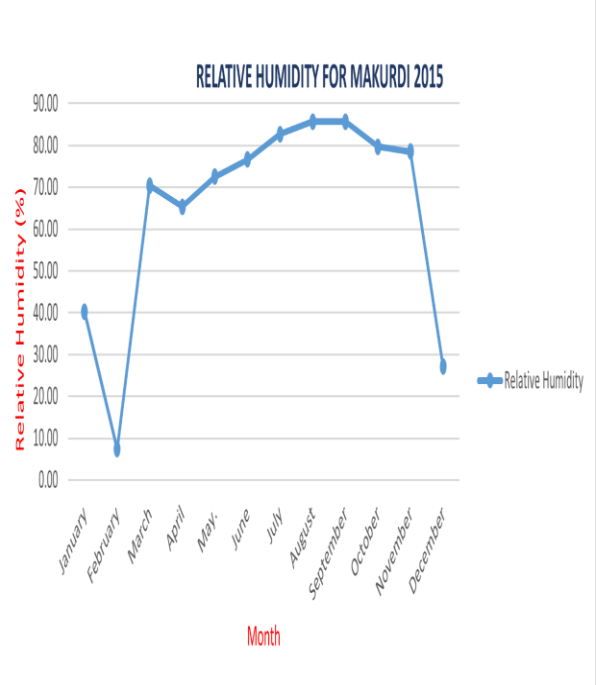

YEAR
MAXIMUM AND MINIMUM TEMPERATURES FOR MAKURDI 2022
Temperature (°C)
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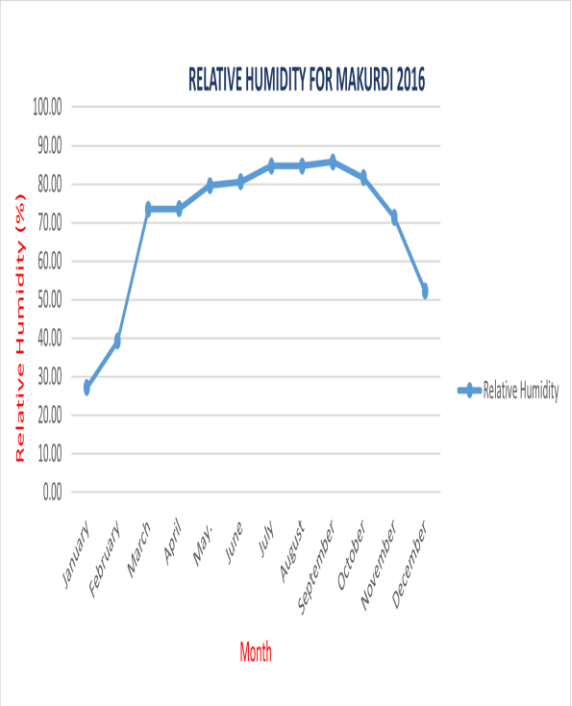

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MAXIMUM AND MINIMUM TEMPERATURES FOR MAKURDI 2023
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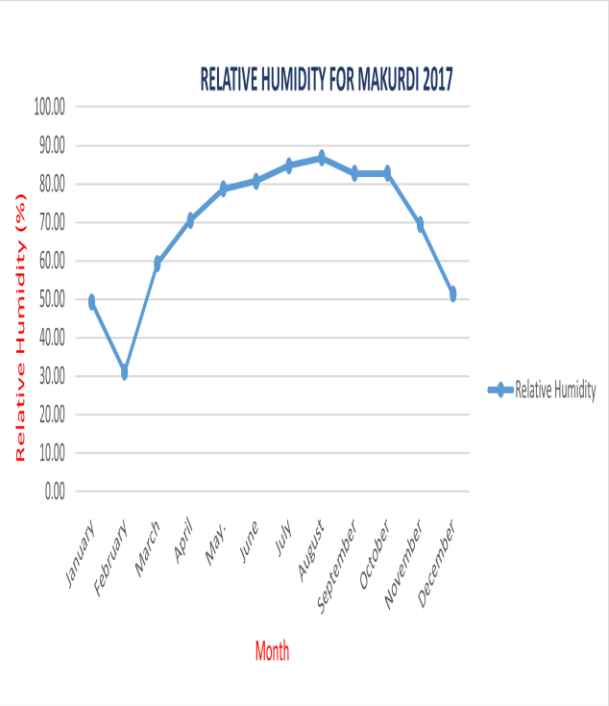

RELATIVE HUMIDITY FOR MAKURDI 2012
Relative Humidity (%)
100.00
90.00
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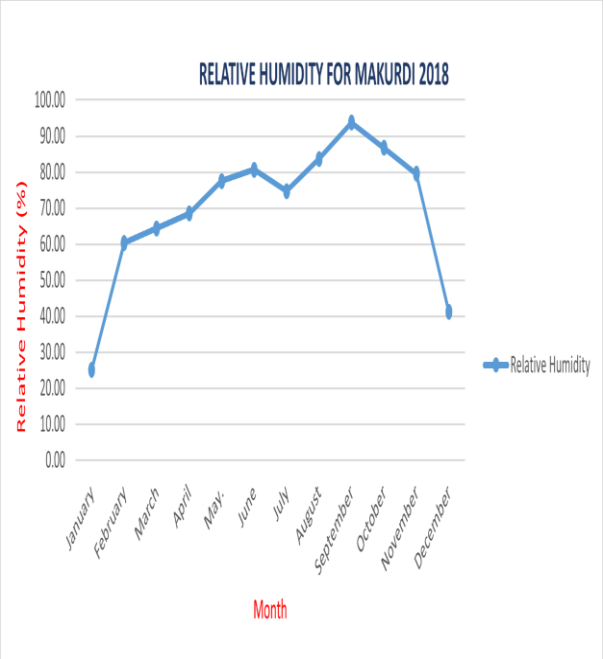

RELATIVE HUMIDITY FOR MAKURDI 2013
Relative Humidity (%)
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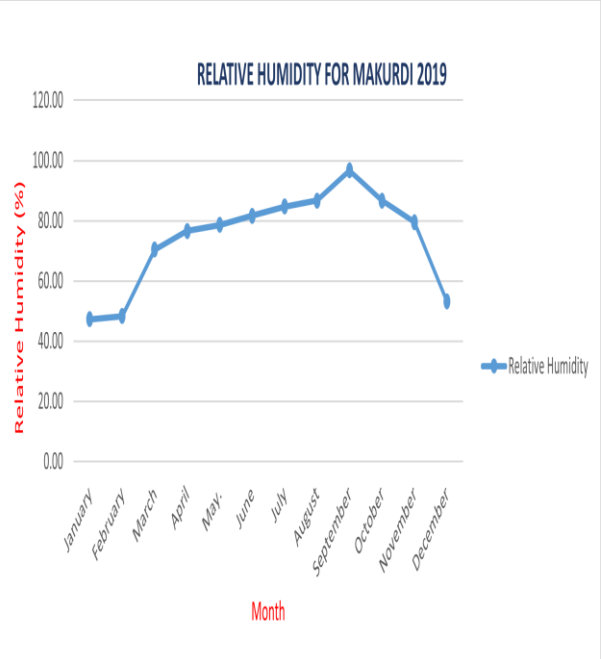

RELATIVE HUMIDITY FOR MAKURDI 2014
Relative Humidity (%)
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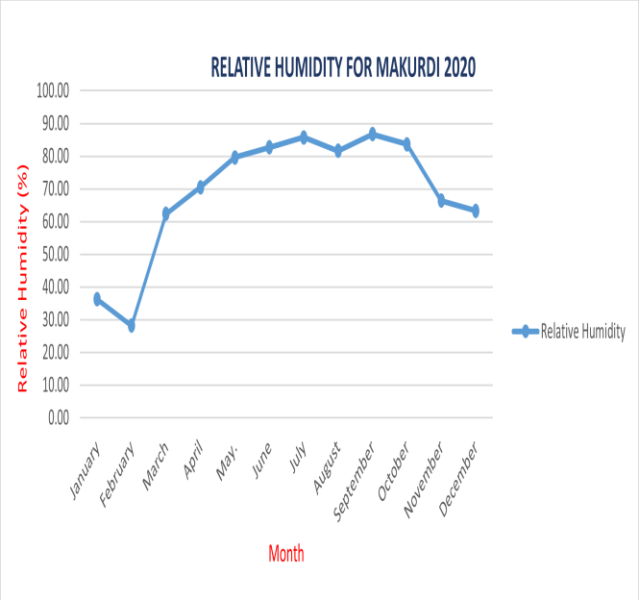

RELATIVE HUMIDITY FOR MAKURDI 2015
Relative Humidity (%)
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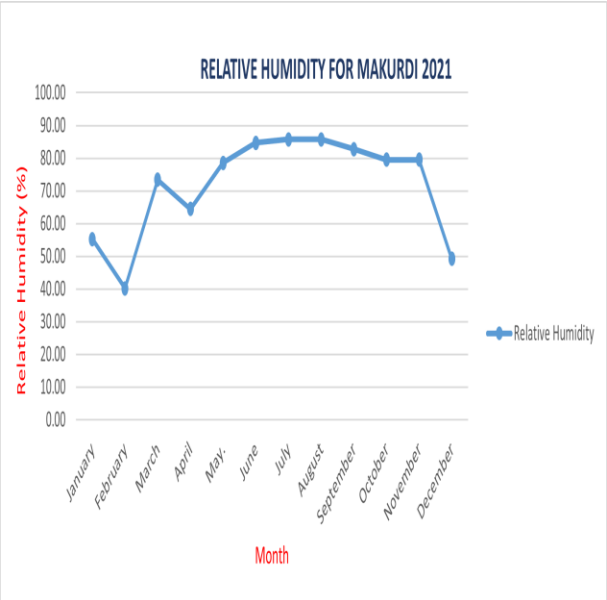

RELATIVE HUMIDITY FOR MAKURDI 2016
Relative Humidity (%)
100.00
90.00
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Relative Humidity

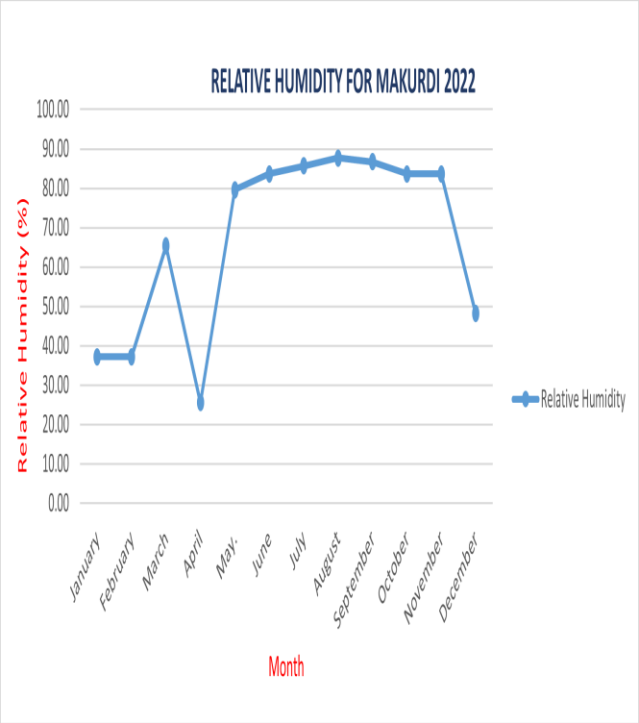

RELATIVE HUMIDITY FOR MAKURDI 2017
Relative Humidity (%)
100.00
90.00
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Relative Humidity

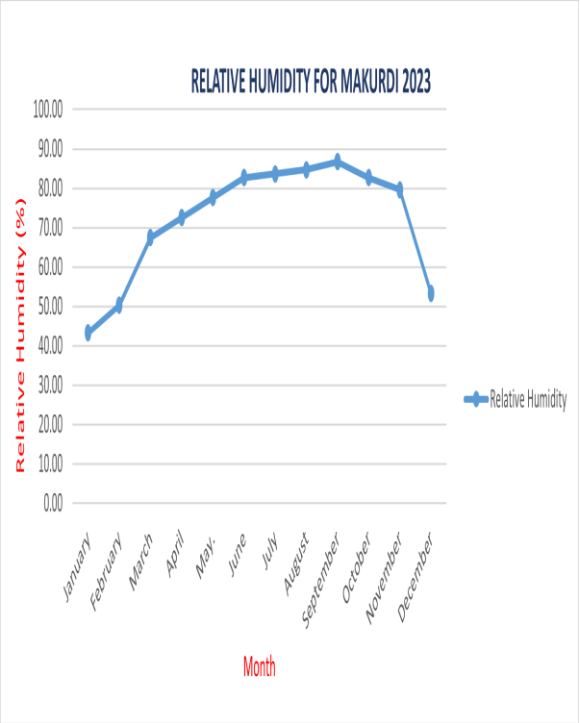

RELATIVE HUMIDITY FOR MAKURDI 2018
Relative Humidity (%)
100.00
90.00
80.00
70.00
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30.00
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10.00
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January
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Month
Relative Humidity

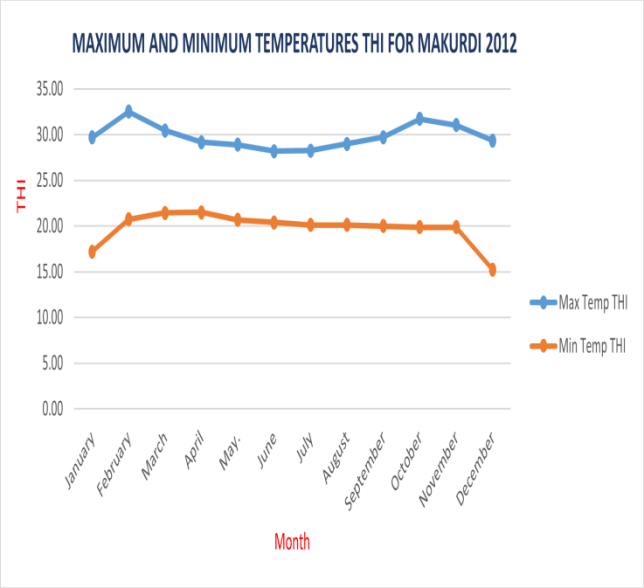

RELATIVE HUMIDITY FOR MAKURDI 2019
Relative Humidity (%)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Relative Humidity

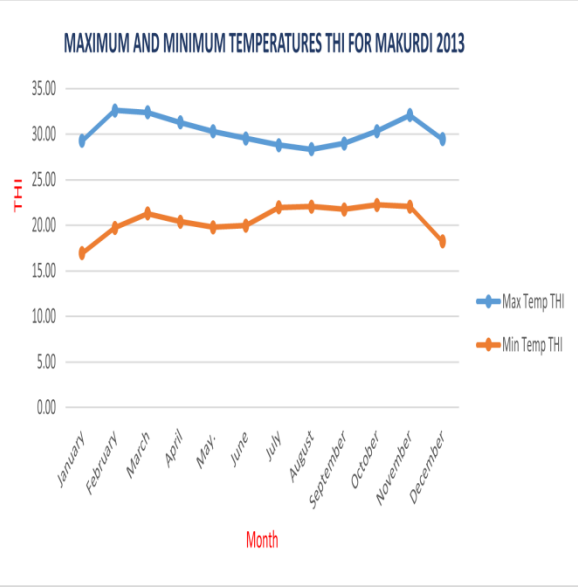

RELATIVE HUMIDITY FOR MAKURDI 2020
Relative Humidity (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Relative Humidity

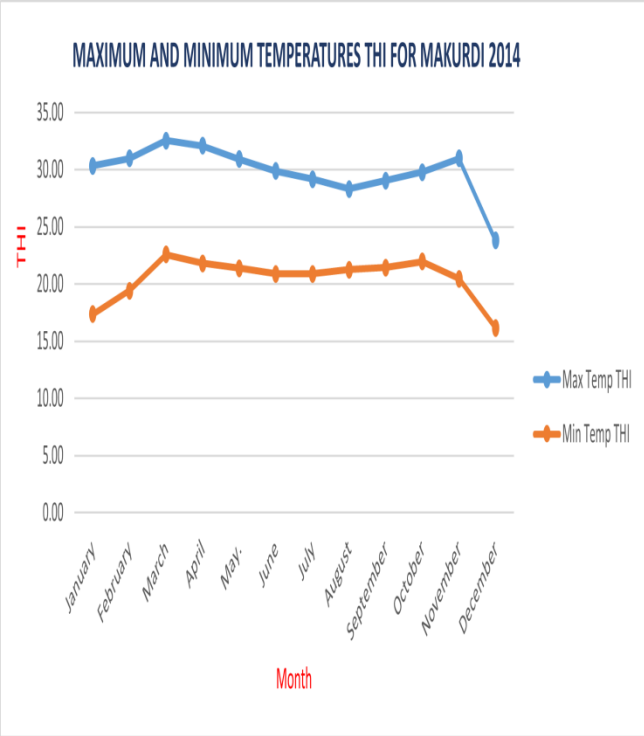

RELATIVE HUMIDITY FOR MAKURDI 2021
Relative Humidity (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Relative Humidity

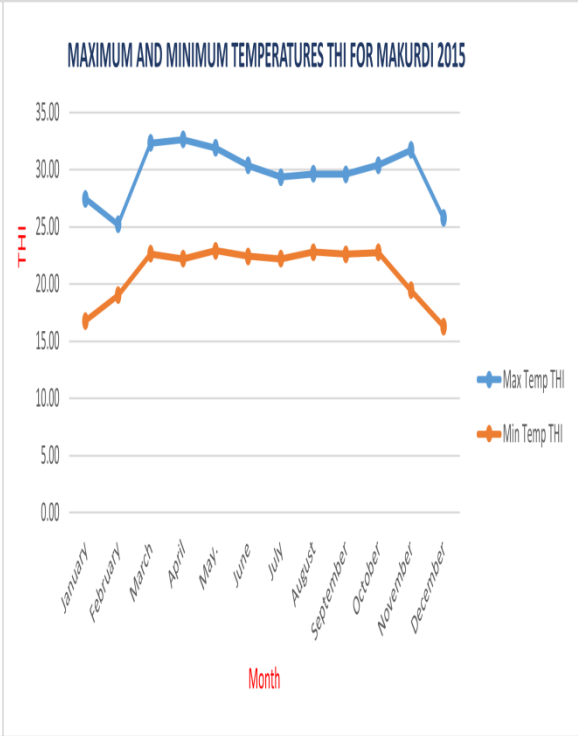

RELATIVE HUMIDITY FOR MAKURDI 2022
Relative Humidity (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Relative Humidity

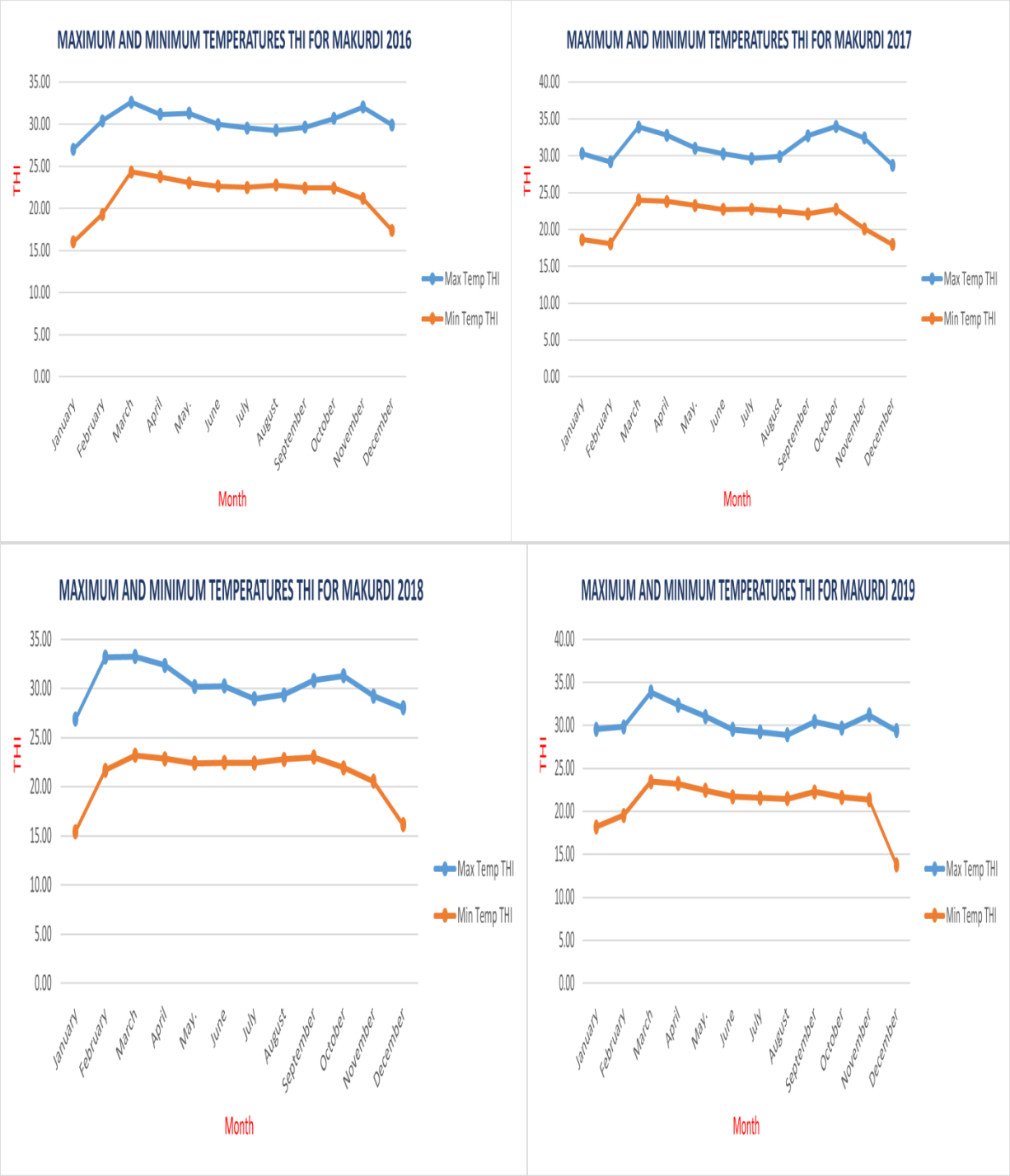

RELATIVE HUMIDITY FOR MAKURDI 2023
Relative Humidity (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Relative Humidity

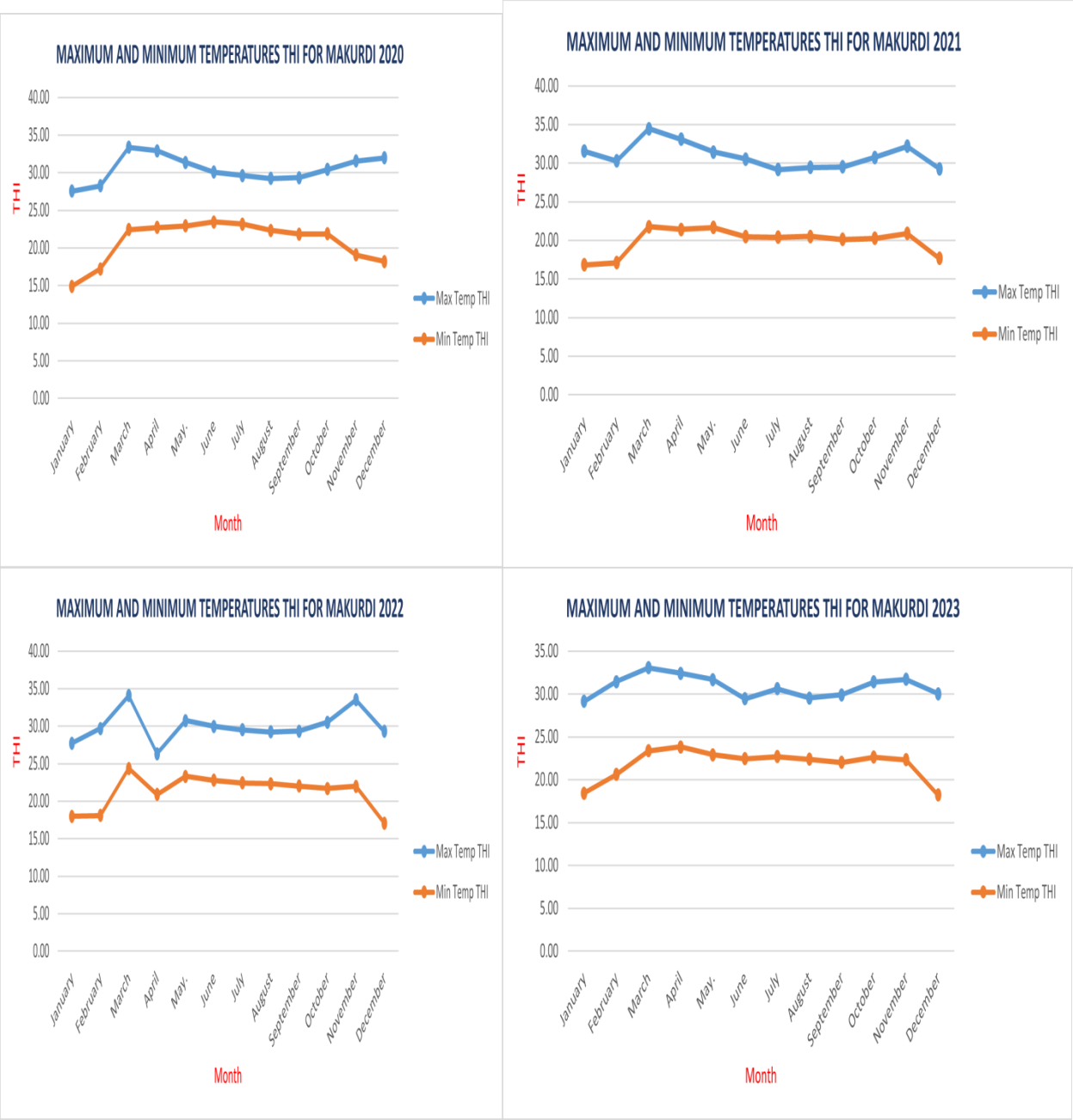

MAXIMUM AND MINIMUM TEMPERATURES THI FOR MAKURDI 2012
THI
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Max Temp THI
Min Temp THI


MAXIMUM AND MINIMUM TEMPERATURES THI FOR MAKURDI 2013
THI
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Max Temp THI
Min Temp THI


MAXIMUM AND MINIMUM TEMPERATURES THI FOR MAKURDI 2014
THI
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Max Temp THI
Min Temp THI


MAXIMUM AND MINIMUM TEMPERATURES THI FOR MAKURDI 2015
THI
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Max Temp THI
Min Temp THI


MAXIMUM AND MINIMUM TEMPERATURES THI FOR MAKURDI 2016
THI
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Max Temp THI
Min Temp THI
MAXIMUM AND MINIMUM TEMPERATURES THI FOR MAKURDI 2017
THI
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Max Temp THI
Min Temp THI
MAXIMUM AND MINIMUM TEMPERATURES THI FOR MAKURDI 2018
THI
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Max Temp THI
Min Temp THI
MAXIMUM AND MINIMUM TEMPERATURES THI FOR MAKURDI 2019
THI
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
January
February
March
April
May.
June
July
August
September
October
November
December
Month
Max Temp THI
Min Temp THI



CONCLUSION

The understanding of THI in Benue State is crucial for managing climate-related challenges faced in the region. The analysis highlights the intricate relationship between temperature and humidity, illustrating how they collectively influence human comfort, agricultural productivity, and public health. This study reveals that fluctuations in the THI can provide valuable insights into seasonal patterns and help predict extreme weather events, allowing residents and local authorities to prepare accordingly. Additionally, the importance of ongoing monitoring cannot be overstated. Regularly tracking THI changes equips stakeholders with the data needed to make

informed decisions concerning crop management, infrastructure planning, and health advisories. Therefore, by establishing a systematic approach to monitoring, we cannot only enhance our understanding of local climate trends but also empower the community to adapt to the realities of a changing environment.

Consequently, understanding the Temperature-Humidity Index (THI) over a solar cycle analysis for Makurdi offers valuable insights into the region's climatic patterns and their implications for both daily life and agriculture. By grasping the relationship between temperature, humidity, and solar activity, residents and decision-makers can make informed choices that enhance comfort and productivity.

REFERENCES

Akbari, H., Menon, S., & Rosenfeld, A. H. (2001). Global cooling: Increasing world-wide urban albedos to offset CO2. *Climate Change*, 94(3-4), 275-286.

ASHRAE. (2017). *ASHRAE Handbook—Fundamentals*. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASHRAE. (2017). *ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy*. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Baron, N., Cervero, R., Marshall, J., & Cohen, P. (2012). Climate change, extreme heat, and urban transportation: Strategies for mitigating heat islands and protecting health. *Journal of Planning Literature*, 27(1), 3-19.

Beatley, T., & Newman, P. (2013). *Biophilic Cities: Integrating Nature into Urban Design and Planning*.Island Press.

Brody, S. D., Zahran, S., Vedlitz, A., Grover, H., & Bernhardt, S. (2012). Social science research needs: Focus on vulnerable populations, forecasting, and interdisciplinary capacity. *Weather, Climate, and Society*, 4(2), 85-94.

Crawley, D. B., Lawrie, L. K., Winkelmann, F. C., Buhl, W. F., Huang, Y. J., Pedersen, C. O., ...& Strand, R. K. (2001). EnergyPlus: Creating a new-generation building energy simulation program. *Energy and Buildings*, 33(4), 319-331.

Dear, R., & Brager, G. (1998). Developing an adaptive model of thermal comfort and preference. *ASHRAE Transactions*, 104(1), 145-167.

Eddy, J. A. (1976). The Maunder Minimum. *Science*, 192(4245), 1189-1202.

Fanger, P. O. (1970). *Thermal Comfort: Analysis and Applications in Environmental Engineering*.McGraw-Hill.

Feldman, D., Tuller, S., & Diwekar, U. (2013). Solar radiation as a driver of thermal comfort: A review and critique. *Building and Environment*, 67, 124-137.

Givoni, B. (1998). *Climate Considerations in Building and Urban Design*. John Wiley & Sons.

Gray, L. J., Beer, J., Geller, M., Haigh, J. D., Lockwood, M., Matthes, K., ...& Cubasch, U. (2010). Solar influences on climate. *Reviews of Geophysics*, 48(4).

Haigh, J. D. (2007). The Sun and the Earth's Climate.*Living Reviews in Solar Physics*, 4(1).

ISO 7730. (2005). *Ergonomics of the Thermal Environment—Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria*.International Organization for Standardization.

Kwok, A. G., & Grondzik, W. T. (2013).*The Green Studio Handbook: Environmental Strategies for Schematic Design*.Routledge.

Lean, J. (2010). Cycles and trends in solar irradiance and climate.*WIREs Climate Change*, 1(1), 111-122.

Lean, J., & Rind, D. (2008). How natural and anthropogenic influences alter global and regional surface temperatures: 1889 to 2006. *Geophysical Research Letters*, 35(18).

Maunder, E. W. (1904). Note on the distribution of sun-spots in heliographic latitude, 1874-1902. *Monthly Notices of the Royal Astronomical Society*, 64(5), 747-761.

Meehl, G. A., Arblaster, J. M., Marsh, D. R., & van Loon, H. (2009). Mechanisms contributing to the warming hole and the consequent U.S. east–west differential of heat extremes. *Journal of Climate*, 22(6), 1544-1561.

Nicol, J. F., & Humphreys, M. A. (2002). Adaptive thermal comfort and sustainable thermal standards for buildings. *Energy and Buildings*, 34(6), 563-572.