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Satellite-Based Air Temperature and Heat Index of Minna Town and Metropolis, Niger State, Nigeria

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Abstract

This study examined satellite-based air temperature and heat index of Minna town and metropolis, Niger state, Nigeria. Urban warming is capable of causing rise in water temperature, high energy consumption, increase in heat related ailments and death of aquatic organism. The investigation generated satellite air temperature data imageries and corresponded the records to heat index. The result showed that in 1990, air temperature concentrated all-round the surface of Minna city and environs having maximum range of 30^0C. In the year 2000, air temperature concentrated in the eastern segment of the city having maximum temperature of 29^0C 9. Also, in 2022, air temperature concentrated in the north and north-eastern part of Mnna city and environs recording temperature of 31^0C. It revealed that heat cramps and heat exhaustion were likely; heat stroke was probable with continued activity. The rise in air temperature and LST was due to increased human activities that devastate the vegetation cover of Minna surface area and rise in urban pavement materials that trap heat to the urban canopy and gradually release it to the environment. Therefore, it is recommended among others for the city dwellers and government to begin intensive tree planting and urban greeting in order to mitigate the impact of urban heat effects in the metropolis of Minna.

Keywords: Air Temperature, Heat Index, Metropolis, Satellite-Based

Introduction

Globally, air temperature from human activates and solar radiation has resulted to severe urban warming and heat index. Heat Index (HI) also known as humiture is an index that associates air temperature and dew point temperature or relative humidity of shaded areas to suggest human perceived corresponding temperature on how hot people would feel if the dew point temperature or humidity values vary in shaded areas [1]. Heat index can cause several heat related diseases such as stroke and dehydration.

On the other hand, air temperature is a measure of how hot or cold the air is at a given time; and relative humidity is a measure of the amount of water (moisture) in the air as compared to the maximum amount of water the air can absorb usually expressed in percentage. When air cannot absorb any more moisture, it is said to be fully saturated; it means that its relative humidity is 100 percent [2]. Thus, dew point is the temperature at which a given volume of air at certain atmospheric pressure is saturated with water vapor, causing condensation and the formation of dew, which is the condensed water seen on flowers and grasses early in the morning. Furthermore, the higher the relative humidity, the closer the dew point to the current air temperature. When dew point is below freezing (0°C or 32°F), the water vapor turns directly into frost rather than dew [3]. Dew point temperature and humidity are key variables that influence thermal comfort of a city; and they are prospective tools in weather forecast used to express the amount of moisture in the air.

Anthropogenic heat is the heat generated by man's activities. This heat is generated through material heating, air conditioning systems, vehicles. It can be generated through appliances, industrial and agricultural processes [4]. For example, some studies in Lodz, Poland, Switzerland, Basel, and some cities in the United States and Tokyo (Japan) confirmed that heat can be produced as high as $20W/m^2$, $32W/m^2$, $60W/m^2$ and $200W/m^2$ respectively in an urban environment [5].

It is obvious that when there is rise in city temperature, city dwellers will demand more electrical energy in order to remain comfortable. Demand for electricity will rise in the afternoon and in the night when there is high level of urban heat in the city. People will put on their Air Condition (AC) in

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order to remain cool during hot period. Also, electric bulbs and other heat appliances will propagate heat thereby concentrating heat in the city environment. However, demand for electricity will be raised by 1.5 to 2.0 percent for every 0.6°C rise in temperature [6].

Combustible fuels will exacerbate the effects of urban heat. Such pollutants such as sulfur dioxide, nitrogen oxides, particulate matter, carbon monoxide, and mercury can increase the effects of urban heat to the environment. The mixture of these pollutants with water droplets in the atmosphere can result to acid rain which is very common fall in the city area. Also, some power plants make use fossil fuel which can discharge harmful gases of carbon oxide that damage the ozone layer resulting to global warming [7]. However, raised air temperature can result to development of ozone at the ground level; and further reaction with nitrogen oxide and Volatile Organic Compounds (VOCs) with the aid of sunlight. Therefore, urban heat during hot weather condition in the presence of pollutants with slow wind can form ozone in a larger [8].

Intense urban heat will accelerate more pollutant formation and more harm to human health. The health of city dwellers will continues to deteriorate as the air is polluted and urban heat is rising at alarming rate. Health hazards such as respiratory ailments, heat rashes, and fatigue as well as death will be on the increase due to urban heat. Thus, on extreme cases the older and younger children are vulnerable to the danger of urban heat with resultant death effects [9].

Urban heat is a subtle pollutant very unnoticeable to the people. Heating of water bodies in a city can degrade the quality of water bodies. This heating can be contributed by some urban pavement materials and roofing sheets that can reach temperatures up to 27°C to 50°C which is transmitted to rivers and other water bodies [10]. In Arlington town of Virginia, the temperature of water was raised at 4°C within 40 minutes immediately after rainfall [11]. It is obvious that many aquatic organisms cannot survive high temperature. This may result to death of younger plants and animal species living in the water bodies. The increased heats will exacerbate the plant and animal body metabolism making them difficult to survive the heat and causing them their eventual death. Therefore, this study is to investigate air temperature and heat index of Minna town and metropolis, Niger State, Nigeria using satellite-based approach.

Materials and Methods

Minna study area is located approximately within longitude $6^0$30’50”E and $6^0$35’10”E and latitude $9^0$35’40”N and $9^0$40’0”N of the GMT (Figure 1). The location of Minna town is a hinterland location far away from the Atlantic Ocean. Therefore, the general atmospheric weather condition is influenced by the land breezes causing rise in temperature. Thus, Minna metropolis maintains temperature ranging between 25°C to 35°C, relative humidity of less than 85% per annum, and rainfall between 2000 to 2500mm per annum [12]. The months of April to September are known for higher rainy season which may extend beyond September in some years. Relative humidity gradually builds from April and gets to the peak during the months of July to September and declines in the months of January till March. Usually March use to have the highest temperature and lowest relative humidity. The performance of climatic variables influences the activities of people in the city on daily bases [13].

Generally, the Guinean Savanna zone which is far from the coast of Atlantic Ocean where Minna metropolis is located is an undulating area. Therefore, Minna metropolis is characterized by terrains that are low and plain with rough slope and natural flow of water channels during rainfall. This nature has enabled the area very prone to flooding which usually does not allow access to some roads especially during rainy season. The fringes of Minna metropolis are still occupied with trees and shrubs as well as badly accessible link roads [14]. At the riverside, are beachridge and saltwater zones. The drainage system is supplied by salt water inland, causing flooding and loss of biodiversity. The relief and drainage characteristics of Minna metropolis influence the spread and pattern of built-up and residential areas thereby affecting urban warming [15].

This study generated satellite remote data imageries using the Google Earth Engine (GEE) in the Geographic Information System (GIS) environment. The Landsat 5, 7 and 8 satellites carry thermal infrared radiometers, therefore their data were suitable for Air Temperature. A single channel algorithm was used for consistency among the estimated LSE, whereas the option of using air temperature from different sources provides flexibility for the algorithm’s implementation to any area of interest such as Minna town and metropolis. Also, algorithm for extracting LST from Landsat ETM+ data was applied in 2022 satellite data analysis where digital Number was converted to Spectral Radiance; and Spectral Radiance was adapted to at-sensor Temperature and Emissivity. Finally, Emissivity was used to establish brightness temperature value in the thermal band image of Landsat 8, band 10, and 11.

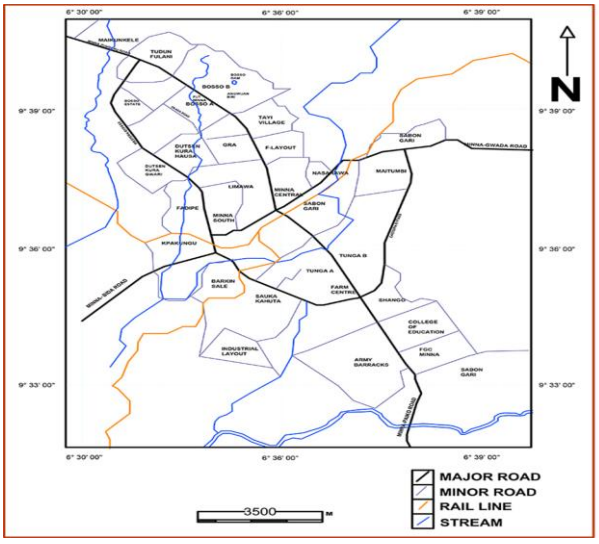

Figure 1: Minna Town and Metropolis

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Results and Discussion

Air temperature is a measure of how hot or cold the air is at a given period. It is the most commonly measured weather parameter and can influence the intensity of other weather parameters such as rainfall, wind speed, relative humidity and rate of evaporation. Therefore, the variability of ambient air temperature has the capacity to influence the urban heat of Minna city and environs.

In 1990, air temperature concentrated all-round the surface of Minna city and environs having maximum range of 30^0C (Figure 2). In the year 2000, air temperature concentrated in the eastern segment of the city having maximum temperature of 29^0C 9 (Figure 3). Also, in 2022, air temperature concentrated in the north and north-eastern part of Mnna city and environs recording temperature of 31^0C (Figure 4). This showed that there was increased trend of air temperature across the years of study. The direction in which air temperature concentrated was an indication of increased human activities and modification of urban surface area resulting to urban heat effect and attendant discomfort to the city dwellers.

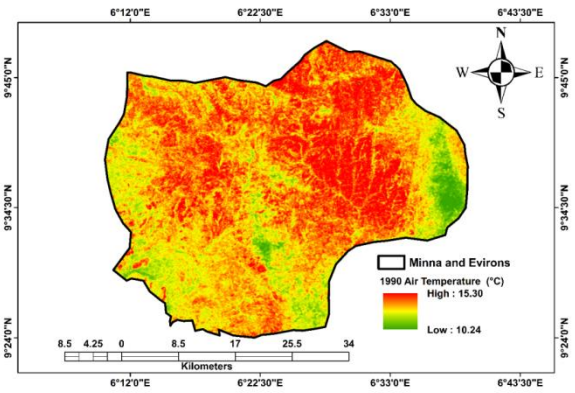

Figure 2: Air Temperature of Minna City and Environs (1990)

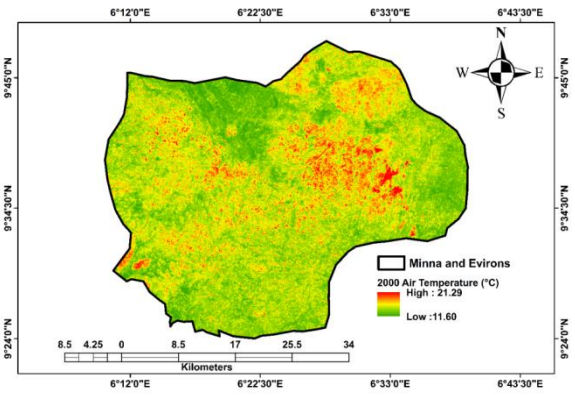

Figure 3: Air Temperature of Minna City and Environs (2000)

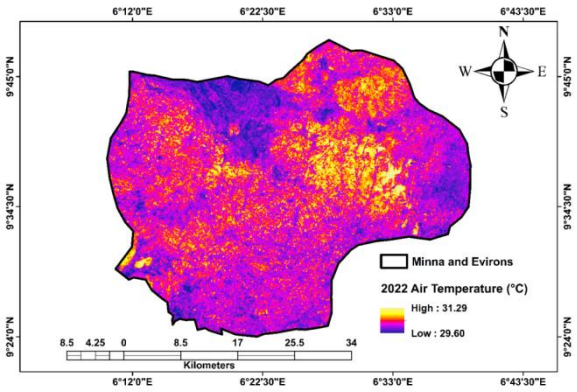

Figure 4: Air Temperature of Minna City and Environs (2022)

Heat index is the apparent temperature which measures how hot it really feels when dew point temperature or relative humidity is factored with the actual air temperature. This temperature is known to be the felt air temperature, apparent temperature and real feel of temperature of the environment. The heat index expresses the level of comfort or stress provided by a given area.

While perception varies between people and can acclimatize to higher dew points. Higher dew points are generally uncomfortable because the humidity inhibits proper evaporation of sweat, making it more difficult for a person's body to cool. Conversely, lower dew points can also be uncomfortable, causing skin irritation and cracking as well as drying out a person's airways. It is recommended that air temperatures be maintained between 68-76°F (20 -24.4°C) with relative humidity of 20-60% [16]. Below are heat index levels and their effects:

1. Caution (80-90°F/27-32°C) - fatigue is possible with prolonged exposure and activity. Continuing activity could result to heat cramps.
2. Extreme caution (90-105°F/32-41°C) - heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke.
3. Danger (105-130°F/41-54°C) - heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity.
4. Extreme danger (> 130°F/ 54°C) - heat stroke is imminent.

The heat index level as drawn from the maximum air temperature and Land Surface Temperature (LST) showed that Minna city dwellers were vulnerable to fatigue, heat cramps and imminent stroke (Table 1). In 1990, the maximum air temperature was 30^0C and maximum LST was 56^0C showing that fatigue was possible with prolonged exposure and activity. Continuing activity could result to heat cramps. It revealed that heat stroke was imminent. In 2000, the maximum air temperature was 29^0C and maximum LST was 40^0C indicating that fatigue was possible with prolonged exposure and activity. Continuing activity could result to heat cramps. It revealed that heat cramps and heat exhaustion were possible. Continuing activity could result in heat stroke. In 2022, the maximum air temperature was 31^0C and maximum LST was 45^0C showing that fatigue was possible with

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prolonged exposure and activity. Continuing activity could result to heat cramps. It revealed that heat cramps and heat exhaustion were likely; heat stroke was probable with continued activity. The rise in air temperature and LST was due to increased human activities that devastate the vegetation cover of Minna surface area and rise in urban pavement materials that trap heat to the urban canopy and gradually release it to the environment.

Table 4.1: Maximum Air Temperature, LST and their Heat Index Levels

Year	Maximum Air Temperature (^{0}C)	Maximum LST (^{0}C)	Heat Index Level and their Effects (^{0}C)
1990	30	56	Air Temperature showed that fatigue is possible with prolonged exposure and activity. Continuing activity could result to heat cramps. LST revealed that heat stroke is imminent.
2000	29	40	Air Temperature showed that fatigue is possible with prolonged exposure and activity. Continuing activity could result to heat cramps. LST revealed that heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke.
2022	31	45	Air Temperature showed that fatigue is possible with prolonged exposure and activity. Continuing activity could result to heat cramps. LST revealed that heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity.

The ambient air temperature is in line with the findings of [17] who carried generated temperatures from 23 locations at different times across Thrissur district using satellite approach. The finding showed that temperature differs across various locations of the disctrict's surface area. Temperature varied from 28^{0}C to 33.3^{0}C in different locations of the distric area. This is an indication that people will actually experience comfort in an area based on their location under the influence of ambient air temperature.

Urban heat index has critical health impact on people in the city. Young children are generally in more danger due to factors including larger skin surface relative to their small bodies, higher heat production as a result of exercise and typically sweating less than adults. Also, children are often less aware than adults of the need to rest and re-hydrate. Thirst is a late sign of dehydration, and it is important to remain hydrated, particularly before, during, and after outdoor activities, especially those involving heavy physical exertion. In addition to children, people with certain conditions including, the elderly, obesity, diabetes, heart disease, cystic fibrosis and mental retardation are at greater risk of overheating and dehydration [18] [19].

Conclusion

This study investigated the urban heat characteristics of Minna city and environs. Urban heat phenomenon occurs due to the alteration of the biophysical components of the city surface where the temperature of the inner city is higher than that of the peripheral sites; thereby propagating urban heat effects in the form of consumption of more energy, raise air pollutants and greenhouse gas, health disaster and impaired water quality. This study basically depended on data from satellite remote sensing used for analysis and findings. Currently, air temperature concentrated in the northern and north-eastern part of Mnna city and environs recording temperature of not less than 31^{0}C especially during the warm dry season. The appearance of urban heat across the surface area of Minna city shows that urban greening and tree planting is a serious challenge that has resulted to severe environmental degradation and critical health disasters. Therefore, there is need for proactive urban management framework, tree planting, green-roof intervention and proper city planning in order to cushion the effects of urban heat. There is need to conduct a special night-time urban heat study. It is necessary to carry out stringent study of climatological variables such as wind velocity, humidity, cloud density as well as characteristic of water bodies in the city area in other to understand their interactions as they influence urban heat phenomenon.

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