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Investigation of Population and Urban Warming of Minna City and Environs: Implication for Sustainable Human Health

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Abstract

Rise in population, industrialization and urbanization have intensified health risks resulting to heat stress, respiratory diseases and vector-borne illnesses. Thus, this study has investigated population and urban warming of Minna city and environs for sustainable human health. The study utilized thermometer instrument to generate air temperatures from both rural and urban land uses on daily and weekly basis from January to December at three different times of morning (7-8am), afternoon (12-1pm) and evening (4-5pm) in the year 2024. The heat index was derived when air temperature and dew point temperatures of the locations were corresponded in the heat index chart or data logger calculator. A mathematical model was utilized to forecast the urban warming based on population data from the National Population Census (NPC) projected from 2024 to 2050. The results revealed that from 2024 to 2050, Minna town and environs had mean urban warming of 4.2^{0}C. Whereas the population of 2022 recorded 315,355 people and urban warming of 4.0℃. When projected to 2026, the population revealed 361,805 dwellers and showed urban warming of 4.1^{o}C; 2035 had population of 493,098 (4.2^{o}C), 2043 had projected pollution of 671,804 (4.3^{o}C) respectively. Also, 39.3% of the study area was within heat index caution level (27-32°C), 48.8% (32-41°C) under extreme caution level, 19.7% (41-54°C) under danger level and 1.2% (> 54^{o}C) was under extreme danger threshold, indicating that heat cramps, heat exhaustion and heat stroke were possible. The study has among others recommended urban greening and tree planting as the management framework to cushion the effects of urban warming in Minna city, Niger State, Nigeria.

Keywords: *Environs, Health, Population, Sustainability, Urban, Warming*

Introduction

Rapid urbanization and environmental changes have become increasingly significant issues affecting human health on a global scale. Minna City, located in Nigeria's Niger State, serves as a critical case study for understanding the implications of population density and temperature variations on sustainable human health outcomes. The city's rapid population, alongside anthropogenic activities, contributes to urban heat islands (UHI), which exacerbate health risks related to heat stress, respiratory diseases, and vector-borne illnesses [1]. The relationship between population dynamics and environmental conditions is critical for informing healthcare policies and urban planning strategies aimed at promoting sustainability and health equity.

Understanding the demographic trends in Minna City is essential for recognizing the correlations between population growth, resource allocation, and public health challenges. According to the National Population Commission of Nigeria, the population of Minna is projected to increase significantly over the next decade, which will put additional pressure on already strained infrastructure and health services [2]. The influx of people into urban centers often leads to overpopulation, inadequate sanitation, and increased vulnerability to environmental stressors, thereby highlighting the necessity of examining population and heat bias as integral to public health planning.

The influence of urban heat islands is particularly pronounced in Minna, where inadequate vegetation cover and expansive urban development contribute to rising temperatures. Research has shown that urban areas can experience temperatures that are several degrees higher than surrounding rural locations, leading to health challenges such as heat-related illnesses [3]. These heat variations pose a particularly severe risk for vulnerable populations, including the elderly, children, and those with pre-existing health conditions, making it imperative to explore the implications of heat bias in the context of sustainable human health in Minna.

Several studies have underscored the importance of incorporating climate and demographic factors into health assessments. For instance, a systematic review by [4] found strong associations between high urban temperatures and the prevalence of heat-related ailments in Nigeria. Furthermore, understanding how population growth exacerbates these conditions can guide health interventions, enhance resilience, and ultimately support sustainable urban living. By investigating the intricate dynamics of population growth and heat bias in Minna City, this study aims to contribute to the growing body of knowledge on climate-health interactions, with the potential to influence policy and planning efforts.

This investigation seeks to clarify if and how population increases and UHI effects in Minna City influence human health outcomes. By analyzing empirical data and integrating health indicators with demographic and climatic variables, this research will provide valuable insights into the implications of current trends for sustainable health in the city [5]. The findings will not only contribute to academic discourse but also serve as a resource for policymakers, urban planners, and public health professionals aiming to build healthier, more sustainable communities in the face of rapid urbanization and climate change.

Methodology

Minna city and environs is located within between latitudes 9°32’0’’N and 9°42’0’’N, and longitudes 6°26’0’’E to 6°28’0’’E along the Greenwich Meridian. The city is divided into two Local Government Areas: Chanchaga and Bosso (Figures 1).

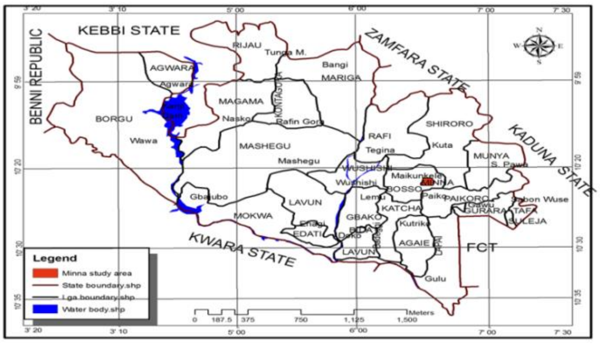

Figure 1: Minna Study Area Map

To analyze the air temperature data and urban heat island (UHI) pattern in Minna town and its surroundings, a Handheld Digital Thermometer ST9269 model, produced by MEXTECH, was utilized. This thermometer has a resolution of 0.1°C (0.2°F) and a measuring range of -50°C to 300°C (-58°F to 572°F) for model St-9283B, and -50°C to 200°C (-58°F to 392°F) for model St-9269B. It has an accuracy of ±1.0°C within the range of -50°C to 150°C (±2.0°F within -22°F to 302°F), and readings were found to be error-free.

Temperature readings in rural areas were taken from plots along the Minna-Paiko Road, characterized by deciduous low vegetation and moderate to tall grasses, with the device mounted on an average wooden pole or held by hand. In urban settings, data were collected from various land use types, including areas with minimal or no tree cover, at a height of approximately 1.5 meters above the ground within the canopy layer. The urban land uses included pavements made of stone, tile, brick, concrete, and other construction materials across different districts of Minna, such as administrative, residential, commercial, industrial, educational, and recreational sites.

Air temperatures from both rural and urban land uses were recorded daily and weekly from January to December at three different times: morning (7-8am), afternoon (12-1pm), and evening (4-5pm). Simultaneous temperature readings were taken at designated rural and urban sampling locations. The average daily, weekly, and monthly temperatures were computed, analyzed, and documented, assisted by field helpers, private residences, and commercial areas that provided concurrent measurements. To obtain the UHI results, the highest temperature reading from urban areas was subtracted from the lowest reading in rural locations to determine the UHI scores, using the formula: ΔT(u-r), where ΔT represents the temperature difference, (u) is the urban reading, and (r) is the rural reading.

Heat index was derived when air temperature and dew point temperature of the locations were corresponded in the heat index chart or data logger calculator. Heat index can also be derived by computing air temperature and relative humidity using the heat index chart or data logger calculator. The computation of heat index is obtained by multiple regression analysis programmed in the calculator and the data logger [6].

The dew point temperature (Td) was derived using the dew point calculator, by keying the temperature data, the dew point calculator associates and estimates temperature for which air must be cool at a given temperature reading [7] [8]. Dew point is closely related with relative humidity, one of them can be used along with air temperature to estimate heat index of an area [9]. Also, temperature in degree Celsius (^{0}C) was converted to degree Fahrenheit (^{0}F) [(0^0C x 9/5) + 32 = 32^0C] and applied in the Heat Index (HI) chart (Table 1). Temperature effects of heat index were corresponded to the various temperature readings of caution, extreme caution, danger and extreme danger in the analysis (Table 2).

Table 1: Heat Island Index Chart using Air Temperature and Dew Point Temperature Data

DEW POINT TEMPERATURE (°F) / AIR TEMPERATURE (°F)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
60	81	83	85	87	89	91	93	95	97	99	102	104	106	108	111	113	115	117	119	121	123
62	82	83	85	87	89	92	94	96	98	101	103	105	107	110	112	114	116	119	121	123	125
64	82	84	86	88	90	93	95	97	99	102	104	107	109	111	113	116	118	120	122	124	127
66	83	85	87	89	91	94	96	98	101	103	106	108	110	113	115	117	120	122	124	126	128
68	83	85	88	90	92	95	97	100	102	105	107	110	112	115	117	119	122	124	126	128	130
70	84	86	89	91	94	96	99	101	104	107	109	112	114	116	119	121	124	126	128	130	132
72	85	87	90	93	95	98	101	103	106	109	111	114	116	119	121	123	126	128	130	133	135
74	86	88	91	94	97	100	102	105	108	111	113	116	119	121	124	126	128	131	133	135	137
76	87	90	93	96	99	102	105	108	110	113	116	119	121	124	126	129	131	133	136	138	140
78	89	92	95	98	101	104	107	110	113	116	119	121	124	127	129	132	134	137	139	141	143
80	90	94	97	100	103	107	110	113	116	119	122	125	127	130	133	135	138	140	142	144	147
82		96	99	103	106	110	113	116	119	122	125	128	131	134	136	139	141	144	146	148	150
84			103	106	110	113	117	120	123	126	129	132	135	138	140	143	145	148	150	152	155
86				110	114	117	121	124	127	131	134	137	140	142	145	148	150	152	155	157	159
88					118	122	125	129	132	136	139	142	145	147	150	153	155	157	160	162	164
90						127	131	134	138	141	144	147	150	153	156	158	161	163	165	167	169

Source: Wendell, 2015

Table 2: Effects of Various Heat Island Index Scores

Celsius	Fahrenheit	Notes
27-32°C	80-90°F	Caution: fatigue is possible with prolonged exposure and activity. Continuing activity could result in heat cramps.
32-41°C	90-105°F	Extreme caution: heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke.
41-54°C	105-130°F	Danger: heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity.
Over 54°C	Over 130°F	Extreme danger: heat stroke is imminent.

Source: Wendell, 2015

In this context [10] created a formula to estimate the population of a location. The researcher analyzed the relationship between population and temperature changes in any given geographic area. This formula acts as a climate prediction model for urban heat, measured in degrees Celsius (°C) and represented as:
UHI = 0.73 log10 Pop
Where: Pop signifies the population.

Consequently, this mathematical model was utilized to forecast the Urban Heat Island (UHI) effect for Minna town and its surrounding areas, based on population data from the National Population Census (NPC) projected from 2022 to 2050, having a growth rate of 3.5%.

Results and Discussion

Adopting the above formula with population prediction of 3.5% in progress [11], population of 2022 registered 315,355 people and heat bias of 4.0℃. When projected to 2026, the population revealed 361,805 dwellers and showed warming bias of 4.1°C; 2035 had population of 493,098 (4.2°C), 2043 had projected pollution of 671,804 (4.3°C) respectively (Table 3). This identifies UHI variation of 4.0-4.3°C within twenty-eight (28) years interval across Minna town and environs. From 2022 to 2050, Minna town and environs had mean warming bias of 4.2°C. This is contrary to the findings of [12] in their growth prediction report noted that surface warming ranges from 0.09 to 0.27°C in decadal interval. The core LGAs in Minna town (Chanchaga and Bosso) occupy the heart of built-up area with warming bias of 4.3°C (825,816 persons) in 2050.

[13] verified the method with 10 persons and exposed warming bias of 1.46°C. Also, a town with 1000 persons received warming bias of 2.2°C. Another big city with one million people attracted warming bias of 4.4°C and variation of 5.5°C. These findings corroborate with the findings of [14] for Benin City which had 1,147,188 persons and 4.4°C warming bias. [15] viewed that human comfort is preferred at temperature threshold of 27°C. [16] in their studies in Paris suggested UHI values of +0.5°C-2.5°C as comfortable threshold for city dwellers. Contrarily, [17] recognized UHI strength of Kuala Lumpur in Malaysia at 1.5°C as satisfactory value for psychological comfort and sustainable existence of people living in towns. Rise in Minna urban warming is attributed to influx of people, expansion of pavement surfaces, farming activities, deforestation due to fuel wood exploitation, urban morphology, energy consumption and automobile emissions across different LULC.

Population and pavement materials in a geographical space are active parameters of urban heat bias. The capacity of cities to generate UHI is now a well-accepted fact. According to [18] urbanization has modified the surrounding of man, placing new urban surfaces interfacing with atmospheric changes. [19] declared that half of world population in 2009 was resident in cities and 70 percent would migrate to urban sites, determined by urbanization conditions.

Table 3: Projected Population and UHI of Minna Town and Environs from 2022 to 2050

YEAR	PROJECTED POPULATION (3.5% GROWTH RATE)	UHI = 0.73 $\log_{10}$ Pop (WARMING BIAS)
2022	315,355	4.0
2023	326,329	4.0
2024	337,750	4.0
2025	349,571	4.0
2026	361,805	4.1
2027	374,468	4.1
2028	387,574	4.1
2029	401,139	4.1
2030	415,178	4.1
2031	429,709	4.1
2032	444,748	4.1
2033	460,314	4.1
2034	476,424	4.1
2035	493,098	4.2
2036	510,356	4.2
2037	528,218	4.2
2038	546,705	4.2
2039	565,839	4.2
2040	585,440	4.2
2041	605,930	4.2
2042	627,137	4.2
2043	649,086	4.2
2044	671,804	4.3
2045	695,317	4.3

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2046	719,653	4.3
2047	744,840	4.3
2048	770,909	4.3
2049	797,890	4.3
2050	825,816	4.3
	Mean UHI	**4.2**

Table 4 showed Heat Index (Temperature in ^{0}F) from January to December 2024. Thus, 39.3% of the period was within heat index caution level (27-32°C), 48.8% (32-41°C) under extreme caution level, 19.7% (41-54°C) under danger level and 1.2% (> 54^{o}C) was under extreme danger threshold indicating that heat cramps, heat exhaustion and heat stroke were possible. However, the period showed that continuing activities could result to heat stroke especially those located in mixed administration, residential, commercial, industrial and educational sites. On the average, all land use types were under caution level heat index during the period. Residents in rural and educational sites experienced some form of comfort. But people in commercial site had to experience intense heat stroke as extreme danger zone. Also, February, March and April had the most dangerous heat index indicating people were vulnerable to having heat stroke during these months. From May to January had mild heat index values showing that Minna residents would have possible fatigue, heat cramps and heat exhaustion with prolonged exposure and activity. Generally, the period under study exceeded the comfort threshold for residents of Minna town and environs.

During the year under study the mean analysis showed that caution and extreme caution heat index levels were paramount indicating that residents of Minna city and environs had exceeded the heat comfort threshold where fatigue, heat cramps, exhaustion and heat stroke were common health hazards prevalent in the area especially those residing in sites mixed with both resident houses and commercial building. The analysis indicated that the population of 128,247 persons were under cautionary category, 159,248 (extreme caution), 64,286 (danger) and 3,915 (extreme danger).

Heat index of extreme danger (over 54.4°C) could result to heat waves. The city and its environs have attained heat index danger level (41-54°C) of possible heat stroke. Young children are generally in more danger due to factors of 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 [20] [21 [22].

Table 4: Heat Index (Temperature in ^{0}F) from January to December 2024

Month /Land Use Type	Rural	Admn.	Resi.	Comer.	Indus.	Educt.	Recreat.
Jan	83	85	92	101	99	96	83
Feb	91	85	91	99	108	95	85
March	95	105	108	131	119	105	101
April	92	105	119	110	113	103	101
May	83	101	95	103	99	95	92
June	81	92	92	89	95	89	88
July	81	89	90	92	88	86	83
August	81	91	90	92	91	83	83
Sept	81	83	85	86	83	83	83
Oct	81	83	91	89	91	89	85
Nov	84	92	96	99	95	92	89
Dec	83	91	92	96	99	95	91
	Caution 39.3%		**Extreme Caution 48.8%**		**Danger 19.7%**		**Extreme Danger 1.2%**
Vulnerable Population	**128,247**		**159,248**		**64,286**		**3,915**

Conclusion

This study investigated population and urban warming of Minna city and environs and its implication for sustainable human health. Rise in Minna urban heat island is due to influx of people, expansion of pavement surfaces, farming activities, deforestation due to fuel wood exploitation, urban morphology, energy consumption and automobile emissions. The population of Minna City and modification of the urban surfaces have caused severe urban warming. From 2022 to 2050, Minna town and environs has mean warming bias of 4.2^{0}C. The town shows UHI variation of 4.0-4.3^{o}C within twenty-eight (28) years interval. This is an indication that Minna City needs urgent intervention to militate the dangerous impact of heat disasters. The month of March has revealed greater potential of extreme danger capable of causing heat stroke especially to the elderly in the society. Extreme caution level has the highest population of 159,248 showing that residents of Minna city and environs have exceeded the heat comfort threshold where fatigue, heat cramps, exhaustion and heat stroke are common health hazards prevalent in the area especially those residing in sites mixed with both resident houses and commercial building. To address the peculiarity of urban warming, it is recommended that green infrastructure should be implemented such as urban

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greening, creation of parks to enable natural cooling of the city. Also, there should be urban planning that will reduce urban pavement surfaces to promote reflective and cool roofing materials. Additionally, it is pertinent to control urban expansion, regulate emissions from transportation and promote energy efficiency. Public awareness campaign and alert systems to manage extreme heats especially in the month of March and the establishment of cooling centers as well as health services for vulnerable population are crucial to protect residents from heat-related health hazards.

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