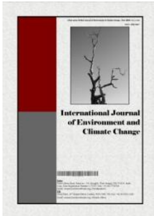

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Green to Grey: An Urban Heat Assessment of Kumasi, Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. Author CK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BS and DNT managed the analyses of the study. Author BS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The current study assessed the city of Kumasi, Ghana to find out the extent of urban heat and the views of the populace about their climate. Both the subjective and objective approaches were utilized in the study. Secondary data from the Meteorological Survey Department in Kumasi covering temperature and relative humidity values for a 42- year period (1976 - 2018) was retrieved and used in the analysis to find the trend of urban heat phenomenon. Alongside, a developed questionnaire had a response from 2,083 people. The findings reveal among other things that there's a 2ºC rise in mean annual temperature from 1976 to 2018. Additionally, the data shows that the past 4 years have had high mean temperature values. Subjectively, 1, 271 residence representing 61% voted in the "slightly warm-hot" range on the thermal sensation scale. Majority of the respondents across all the ages indicated how uncomfortable their outdoor spaces have become in recent times. 36% of the respondents attributed this discomfort to the lack of greenery with over 95% across all ages indicating that Kumasi city has lost its greenery and green

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spaces to buildings and other infrastructural activities. Whiles climate change and global warming have both become a global menace, the onus lies on individual countries and for that matter, various city authorities to make a conscious effort in planning our cities with greenery to alleviate the menace we already find ourselves. A conscious effort to retrieve and restore encroached green spaces must be undertaken by the city authorities while the parks and gardens division ought to be efficiently resourced to manage our green spaces.

Keywords: Urban heat island; thermal comfort; Kumasi; urbanization; climate change.

1. INTRODUCTION

With the absence of services, facilities and infrastructure across the length and breadth of any country, people will always move to areas where these provisions are available, populating these places in the process. According to a report by UN-Habitat [1], close to half of the world's population lives in urbanized settings and this is expected to increase to 80-90% in forty years. The report further indicated that with regards to future trends in population growth, 93% of the urban growth would happen in Asia and Africa, and to a lesser extent in Latin America and the Caribbean.

The concept of urbanization in recent times has been a major cause of alarm especially with the introduction of the urban heat island (UHI) effect. Urban growth is always related to UHI effect. According to Voogt and Oke [2], UHI refers to the phenomenon that apparent higher temperatures are found in urban areas when compared to surrounding rural areas, mainly due to atmospheric and surface modifications associated with urbanization". By 2030, it is estimated that urban land cover will nearly triple, increasing by 1.2 million km^2 [3] and most of the world's population will be exposed to anthropogenic climate change in urban areas (Intergovernmental Panel on Climate Change (IPCC), [4]). IPCC [5] has further predicted that Global mean temperature change for the period of 2016–2035 is predicted to be in the range of 0.3–0.7ºC.

Ghana as a country has experienced great population growth and rapid urbanization since the mid-1980s. According to the World Bank Group Report [6], as Ghana's total population more than doubled between 1984 and 2013, urban population outpaced rural population growth (4.4 percent annually), and the urbanization rate rose from 31% to 51%. Over this period, Ghana's urban population more than tripled, rising from under 4 million to nearly 14 million people. Population growth consequently, comes with the burden of the provision of housing and commerce. Most often than not, urban vegetation is sacrificed for these amenities. Eventually, the city is plagued with unbearable pollution which UHI effect is one borne from the recent wave of global warming and climate change. The paper therefore sought to find the thermal environmental conditions from the residents whilst assessing documented climatic factors to find out how temperature values have changed over the years.

2. LITERATURE REVIEW

Literature for the study covered areas such as the Urban Heat Island effect and outdoor thermal comfort.

2.1 Urban Heat Island

UHI is seen as one of the major complications for humans' ever-growing population in the twenty-first century as a result of urbanization and industrialization [7,8]. According to Zhang et al. [9], analysis of the association of UHI and urbanization indicated that the UHI increased with the expansion of population and rapid increase of gross domestic product. The authors further argued that the continuous increase of power consumption and area of paved road and decrease of area of cropland caused the growth of UHI intensity. Green land had a positive effect on mitigation of heat island based on an inversed U-shaped curve with UHI intensity. One of the major phenomenon associated with climate change is the urban heat island, in which surface air temperature in the urban area is higher than in the surrounding suburban and rural areas [10]. In fact, temperature increases have been found to be a global issue now with the advent of climate change and global warming. In 2007, the Intergovernmental Panel on Climate Change (IPCC) were of the view that increases in temperature was widespread globally and that average global surface temperature had increased about 0.74ºC in the past century.

Rizwan et al. [7] and Oke [10] all attribute the causes of UHI as the large amount of heat generated from urban structures, as it absorbs and reradiate solar radiation, and from anthropogenic heat sources. Related studies on UHI have led to the documentation of several results. Zhang et al. [9] opined that since 1980s, there has been several studies investigating the UHI in Shanghai, China. Zhou and Zhang [11], Zhou and Wu [12] and Zhou and Shu [13] pointed out that the UHI was rather obviously caused by the rapid development of the economy. By comparing the annual mean temperature (1961–1980) of Xujiahui (an urban station) and Chongming (a rural station), Zhou [14] found that the UHI intensity between urban and rural areas had increased about 0.3–0.4°C in those two decades. Deng et al. [15] analyzed the characteristics of the UHI in Shanghai with six Davis automatic stations in urban and suburban areas in 1998–1999. The results showed that UHI occurrence frequency was 87.8% and the monthly mean UHI intensity was greater than 0.8ºC; the mean intensity was stronger at night and in autumn/winter than during the day and in summer. Using data from ten meteorological stations, Zhao et al. [16] found that the difference in mean annual temperature between four urban stations (Xujiahui, Minhang, Jiading, Baoshan) and six rural stations (Nanhui, Fengxian, Songjiang, Jinshan, Qingpu, Chongming) increased from 0.1ºC in the late 1970s to 0.7ºC in the early 2000s, with an increase of 0.24ºC per decade. The results of Cui et al. [17] showed that the UHI intensity between one urban station (Xujiahui) and six rural stations (Nanhui, Fengxian, Songjiang, Jinshan, Qingpu, Chongming) increased at a rate of 0.21ºC per decade from 1959 to 2005. These studies imply that the UHI intensity has increased significantly with the rapid expansion of Shanghai.

Furthermore, Boonjawat et al. [18] found an increase of 1.23ºC in lowest air temperature values in the UHI of Bangkok for the last 50 years. The authors posited that the peak temperature of metropolitan cities such as Bangkok can be higher than the surroundings by 3.5ºC during clear and clam nights in the dry season. Increased temperatures due to the UHI effect may increase water consumption and energy use in urban areas and lead to alterations to biotic communities [19]. Kiattiporn et al. [20] found and documented that an increase in 1ºC of the temperature will result in an increase of 6.79% electricity consumption in Bangkok Metropolitan Area. Excess heat may also affect the comfort of urban dwellers and lead to greater health risks [21].

2.2 Outdoor Thermal Comfort Conditions

Thermal comfort which according to Pino et al. [22] is defined as the “physical and psychological wellness of an individual when temperature, humidity, and air movement conditions are favourable for the activity that must be developed” is largely influenced by microclimate and as such, most urban cities are hard hit. This arises when trees and other vegetation cover that could harmonise the environment are destroyed to give way to the construction of low, mid and high-rise city infrastructures. Wong et al. [23] theorised that solar energy has been deemed the largest contributor to the UHI effect. This is true especially when urbanisation clears the land of its vegetation cover acting as shade from solar radiation. In fact, there are claims that outdoor spaces in cities which are thermally comfortable have an increasing social and economic benefit as they attract residents, vendors, office workers, students, etc., and ultimately assists in monetary outcome as well as social interaction (Sharmin et al., 2012; [24]. Since indoor comfort is directly affected by outdoor conditions in the adaptive model, it becomes paramount that the outdoor is comfortable. Chen and Ng [25] asserted that outdoor thermal comfort is an important implication for city development because urban outdoors and daily activities contribute to urban livability and vitality. Aljawabra and Nikolopoulou [26] also argued that solar radiation influences visitors and activity in these spaces. A study of Chennai, India, by Rose [27] assessed the impact of urbanization on thermal comfort. Conclusions drawn included a significant decrease in the thermal comfort conditions due to urbanization and increasing discomfort in daytime temperatures over years. Hirashima et al. [28] also surveyed the two squares located in the city of Belo Horizonte, Brazil, to assess their thermal comfort using Physiological Equivalent Temperature (PET) index over summer and winter seasons. The study suggested the incorporation of design strategies such as shading, exposure to the wind and providing increased environmental diversity to improve urban environments.

Dalman and Salleh (2011) in their study said that the three types of built form in Bandar Abbas urban area: high rise towers, mid- rise blocks and low-rise compact courtyard houses have strong effects on the urban microclimate and consequently, on thermal comfort. Similar studies resulted in the knowledge that “Those alter the solar radiation, air movements as well as temperature and shading effects” in reference to the built forms (Thapar, 2008). According to Tobi et al. (2014), trees, as a form of vegetation foster microclimatic control and thermal comfort. In the studies of Irmak et al. [29], Armson et al. [30] and Shashua-Bar et al. [31], the conclusion was that indeed trees and greens in general leads to cooler and more comfortable outdoor spaces. This knowledge is buttressed by Shashua-bar et al. [31], that tree shading reduced the duration of thermal discomfort by over half and limited the severity of heat from solar radiation.

3. MATERIALS AND METHODS

3.1 The Study Area

According to Adabor [32], Kumasi, the capital city of the Ashanti Region of Ghana as a Metropolis lies 270 km north of the national capital. It is between latitude 6.35°- 6.40°and longitude 1.30°-1.35° with an elevation of between 250 –300 m above sea level. The city lies within an area of about 254 square kilometres. It is located in the transitional forest zone, a zone characterized by

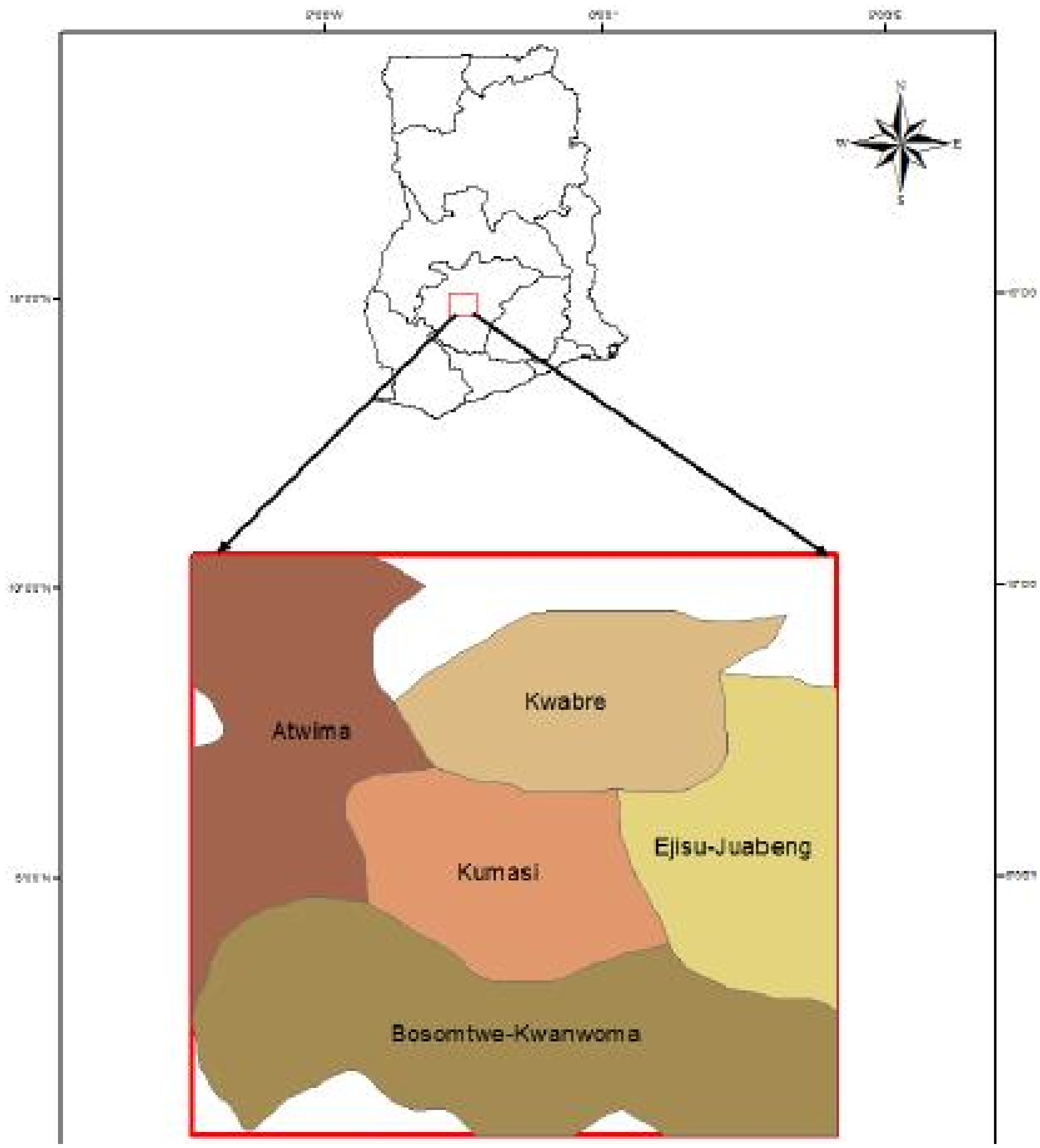

Fig. 1. Map of Ghana showing Ashanti Region and Kumasi in relation to the other towns

heavy and intense rainfall in the months of June and September (Double Maxima Regime). Fig. 1 illustrates the position of Kumasi in Ashanti Region and Ghana as a whole. It is the second largest Metropolitan city after Accra, the capital of the country. The population of Kumasi is estimated to be about 2 million people.

The climatic condition of Kumasi is categorized as sub-equatorial, with a daily average minimum and maximum temperature around 21.5ºC and 30.7ºC respectively [33]. According to Thrift [34], Kumasi experiences much higher rainfalls than northern part of the country, and has average total rainfall and mean number of rain days are 107.9 mm and 9.9 days respectively. The Kumasi Metropolitan Assembly [35] as cited in [33] has stated that Kumasi has an average humidity range of 60% to 84% depending on the season. Kumasi has ten districts for development and growth purposes as indicated in Fig. 2. History has it that Kumasi was named the "Garden City" by the Queen of England in the nineties. Afrane and Amoako [36] postulate that Kumasi has recently (2000-2010) increased at an unprecedented pace with an estimated annual population growth rate of 5.4%. This figure according to the Ghana Statistical Service [37], is known to have increased from 5.2% per annum between the 1984 and 2000 inter-censual years. These growth figures have all been about twice the national growth rates of 2.7% (1984-2000) and 2.4% per annum recorded between the year 2000 and 2010 (GSS, 2010) as cited by Afrane and Amoako [36].

As an economic magnet, Kumasi's population is continually increasing through in-migration. Residents from six suburbs/districts of Kumasi [Asokwa, Subin, Kwadaso, Manhyia (Fanti New Town/Ash Town), Bantama and Oforikrom] were selected for the subjective study. Satellite imagery (Fig. 3) indicates that these areas have lost their green spaces hence their selection.

3.2 Data Collection Procedure

Both objective and subjective strategies were used in the study. Secondary data from the Ghana Metrological Service covering temperature and relative humidity values for a 42-year period (1976 - 2018) in Kumasi was retrieved and used in the analysis to find the trend of urban heat phenomenon. On the other hand, a survey on how the residents perceived urban heat, their thermal comfort conditions as

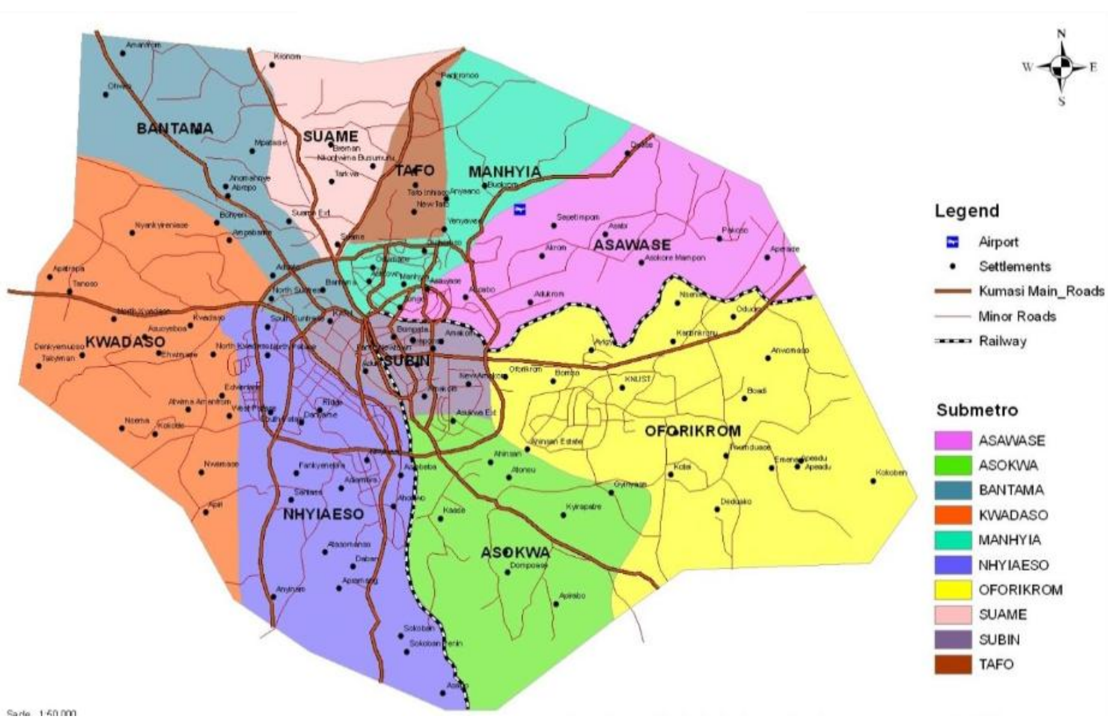

Fig. 2. Administrative Map of Kumasi (Source: KMA, 2011)

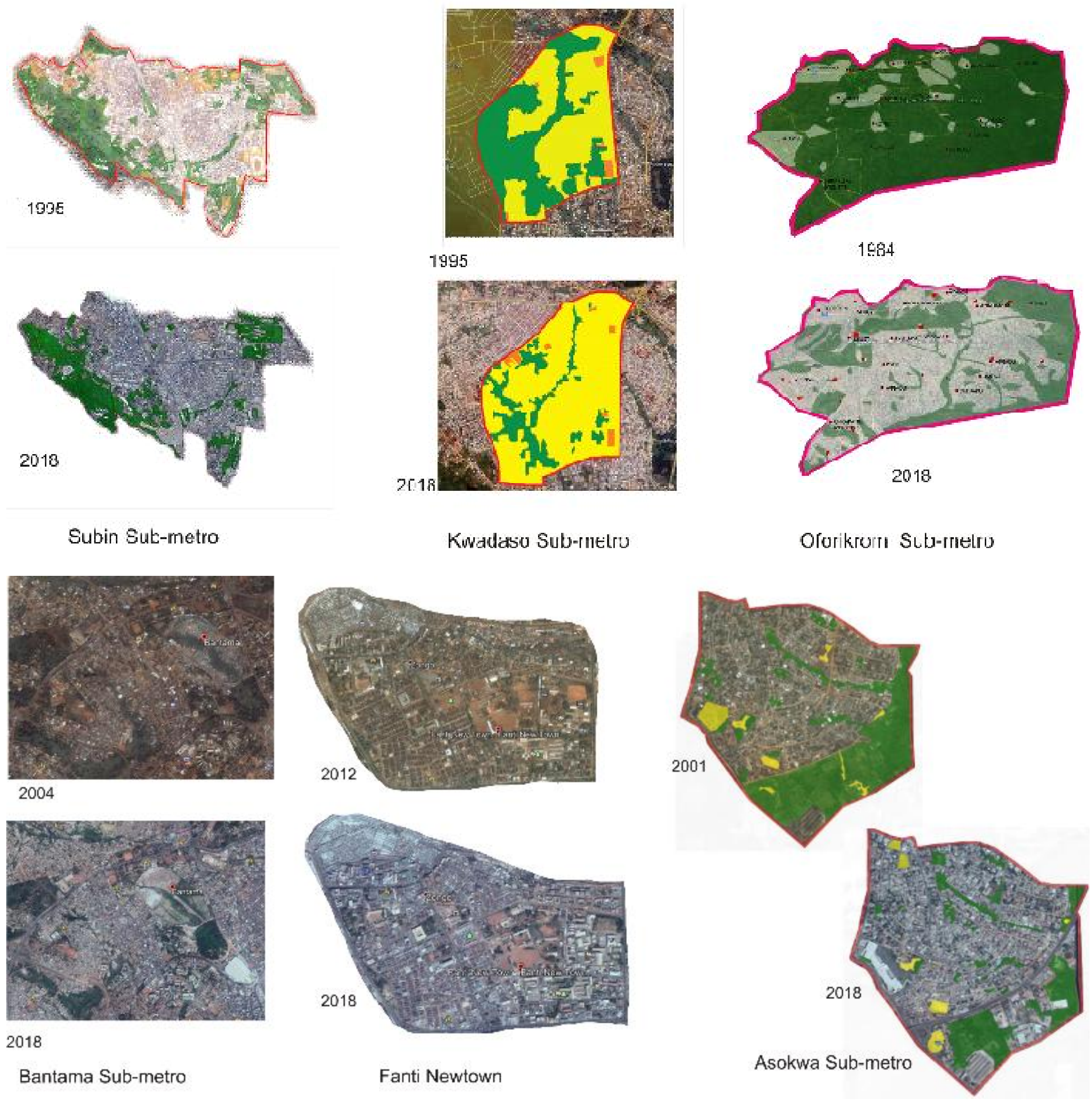

Fig. 3. Satellite imagery of selected suburbs in Kumasi

well as opinions of the usefulness of green spaces and its impact on Urban Heat Island was undertaken. The questionnaire was made up of the following sections:

- Demographic data of respondents;
- Ownership type (accommodation) and duration of stay in Kumasi;
- Perception on the usefulness of Green Spaces;
- Perception on Kumasi's available greenery today;
- Perception on outdoor space usage;
- Perception of Urban Heat in Kumasi; and
- The commitment of City authorities on urban greenery.

3.3 Sampling

A representative sample of residents in Asokwa, Subin, Kwadaso, Manhyia (Fante New-Town), Bantama and Oforikrom, all suburbs in Kumasi were used for the study. Views concerning the above areas were solicited from respondents who had lived in the various neighborhoods for at least 20 years. Since the population sizes of these residential areas were large, the mathematical model below was used to determine the sample size necessary for the study [38].

$$N = \frac{(Z_{2}^{\alpha})^2 \sigma^2}{e^2} \quad (1)$$

Where $(Z_{2}^{\alpha})^2$ is the confidence interval, σ^2 is the standard deviation from the population, and e^2 is the margin of error.

From this model, a confidence level of 95%, 0.5 standard deviation and a margin of error +/-5% was used. Z- Score = 1.96.

Therefore, 384 respondents were selected randomly in each suburb giving a total of 2,304 people.

4. RESULTS AND DISCUSSION

4.1 Objective Data

Secondary data from the Ghana Meteorological Service analyzed shows the following results for Kumasi. Only the maximum temperature values for the years under review for Kumasi was considered since intense heat causes thermal discomfort.

Mean annual temperature values (Fig. 4) shows a fluctuating trend from 1976 to 2018. However, from 2015 to 2018, there is a gradual increase from 31.9ºC to 32.0ºC. In 1976, however, mean annual temperature recorded was 30ºC. Examining Fig. 2 again, it is evident that maximum temperature values over the years have increased steadily. The difference between the mean temperature values of 1976 and 2018 is 2°C. This difference is quite alarming given the predictions by the Environmental Protection Agency (EPA) of Ghana based on the years 1961 to 2000. The agency estimated that annual mean temperature values will see increases of 0.6ºC, 2.0ºC and 3.9ºC by the years 2020, 2050 and 2080 respectively (EPA (2011)).

The results indeed indicate that as population increases (presently 2 million with a 5.4% annual increment) and for that matter urbanization becomes widespread, temperature values also increases. Related studies show similar results. Zhao et al. [16] found an increase from 0.1ºC in the late 1970s to 0.7ºC in the early 2000s, with an increase of 0.24ºC per decade. Boonjawat et al. [18] found an increase of 1.23°C in lowest air temperature values in the UHI of Bangkok for the last 50 years. The authors posited that the peak temperature of metropolitan cities such as Bangkok can be higher than the surroundings by 3.5ºC. Chen et al. [39] postulated that UHI effect of Szeged and New York are 3.1ºC and 8.0ºC respectively. Yang et al. [40] and Tran et al. [41]

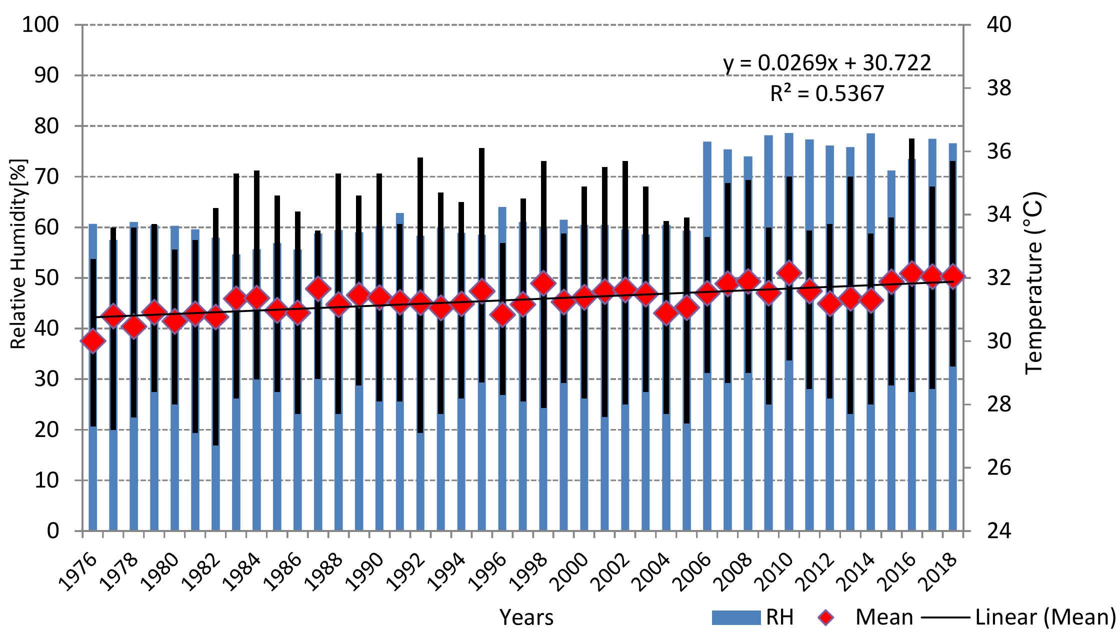

Fig. 4. Temperature and relative humidity values for a 42-year period

found severe UHI effect in many modern cities, especially, the average temperature difference on the outskirt of Beijing reaches 3.3ºC from 1961 to 2000, and UHI effect of Shanghai reaches 7.4ºC. In Ghana, temperature values are high from the months of January reaching a peak in February then gradually reduces from March through May with the lowest in July (Fig. 5). From August, there is a gradual increase until it reaches a peak in November/ December.

4.2 Subjective Responses

2,194 questionnaires were returned out of which 2,083 were correctly answered and therefore found useful for the study. This represent a 90.4% response rate. Table 1 shows the demographic data of the respondents. The Table shows a large number (61%) of respondents renting various apartments/houses within the various neighborhoods. This observation influences the findings as without the concern of the landlords/ ladies, the tenants are not able to plant any greenery within their compounds.

The distribution of thermal sensation votes is presented in Fig. 6. 18% of the residence voted "neutral" with the percentage of warm sensation voting (61%) being significantly higher than cool sensation voting (20.6%). When residence were

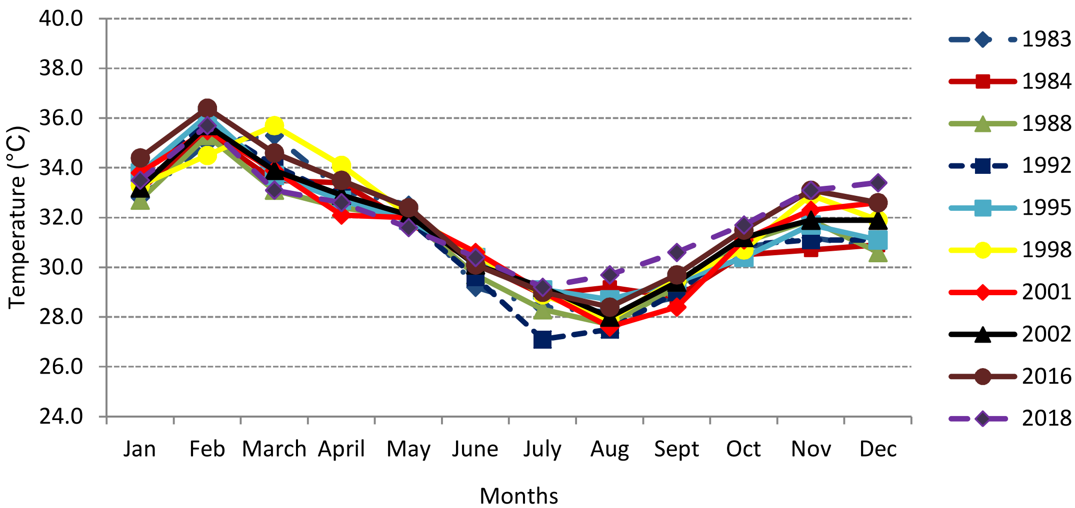

Fig. 5. Ten hardest hint years of high temperature values

Table 1. Demographic data of respondents

Variables		Frequency	Percentages
Gender	Male	1189	57%
	Female	894	43%
Age (years)	20-30	672	32%
	31-40	817	39%
	41-50	442	21%
	50 and Above	152	7%
Educational Level	Basic	497	24%
	Secondary	826	40%
	Tertiary	587	28%
	Dropout	173	8%
Ownership type of Accommodation	Rented	1,271	61%
	Family house	146	7%
	Own apartment	646	31%
	Other	21	1%
Duration of stay in current neighborhood (years)	20-30	375	18%
	31-40	729	35%
	41-50	708	34%
	Above 50	271	13%

asked about their perception of outdoor comfort as compared to 10-30 years ago, the following illustrate the responses (Fig. 7). 38% of the inhabitants aged 20-30 years indicated that the city's outdoor today is comfortable. This might be due to their relatively young age which might not have permitted them to have observed any difference between then and now. However, the adult respondents expressed their discomfort in modern times as compared to 20-30 years ago. The objective data from the Meteorological survey department is therefore justified looking at the 2ºC increase in temperature values from 1976 to 2018.

36% of the residence who took part in the study attributed their outdoor discomfort to the apparent lack of greenery all over the vicinity (Fig. 8) whilst 26% argued that it was because of lots of hard landscape. These factors are all ostensibly due to urbanization. Afrane and Amoako [36] made similar observations when they reported that the green spaces available today in Kumasi has been replaced with hard impervious surfaces due to urbanization. This observation is alarming since researchers such as Quagraine [42] and Nowak [43] have all outlined the importance of greenery to the human species.

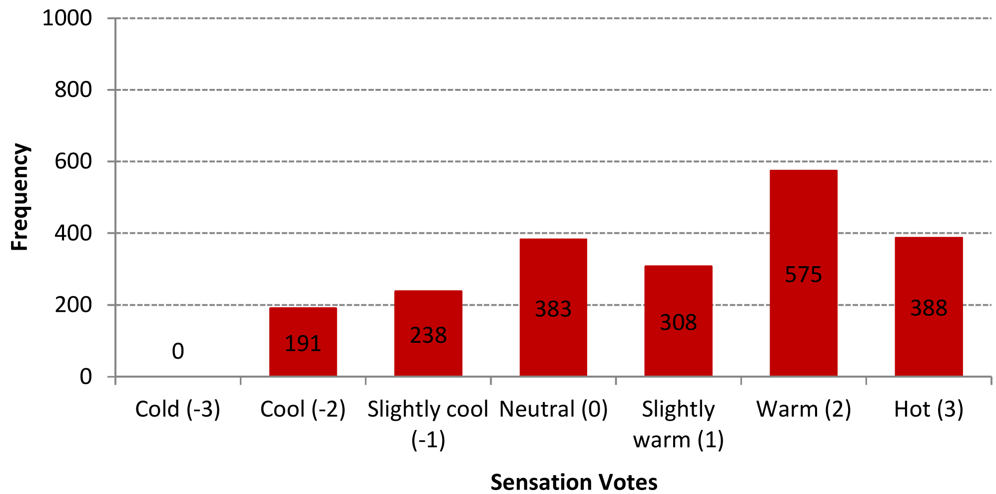

Fig. 6. Distribution of thermal sensation votes

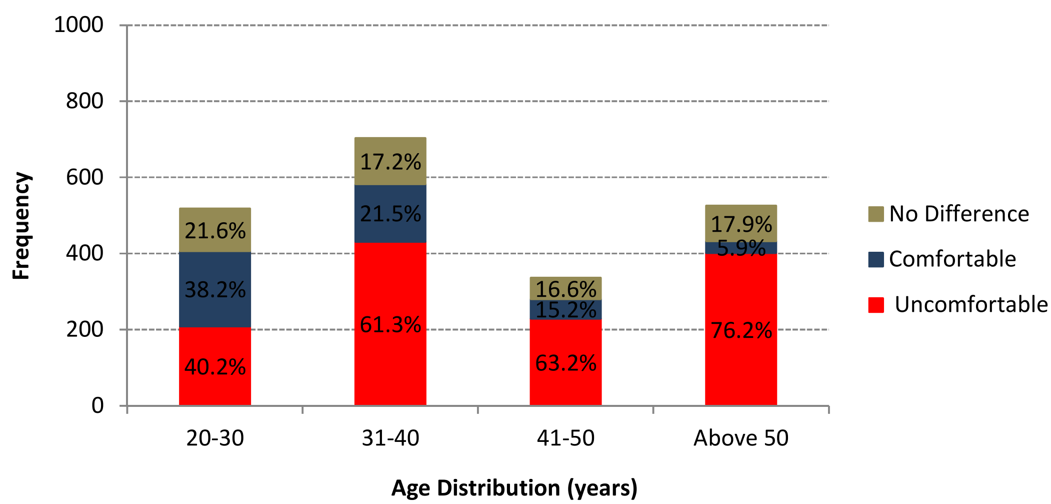

Fig. 7. Respondents' perception of outdoor comfort in recent times

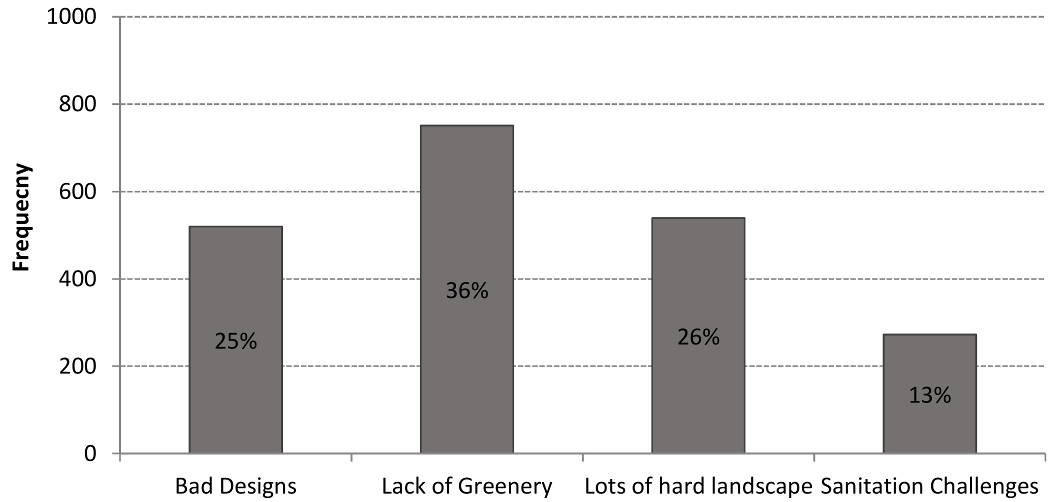

Fig. 8. Causes of outdoor discomfort

The consensus concerning the city's available greenery is that losing its greenery and/or has lost its green spaces to buildings and other infrastructural works (Fig. 9) is the main worry. According to Collins (2014), when the city was planned in 1945, a large proportion was earmarked for landscape green spaces. Today, all the beautiful gardens such as the Adehyeman gardens, Parks and Gardens at Patasi, Abbey's park, lawns and shrubs at the city centers have been encroached upon due to rapid urbanization. Pragmatic measures therefore must be taken to address the diminution of green spaces in the Metropolis by city authorities lest the city risk becoming ecologically dysfunctional just like the cities of Easter Island and Norse Greenland in the past [42].

More than 95% of the respondents (from age 20-50 years) ascribed the loss of Kumasi's greenery to the fact that the masses are unaware of the eminent dangers of climate change (Fig. 10). The issue of climate change and global warming has taken Africa and the world at large by storm, and

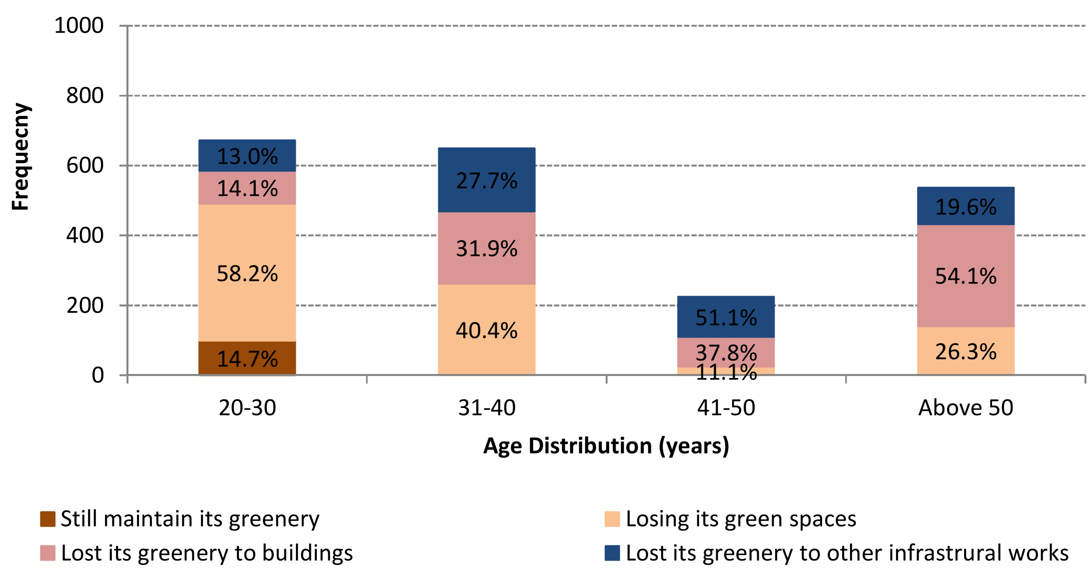

Fig. 9. Perception on Kumasi's available greenery in recent times

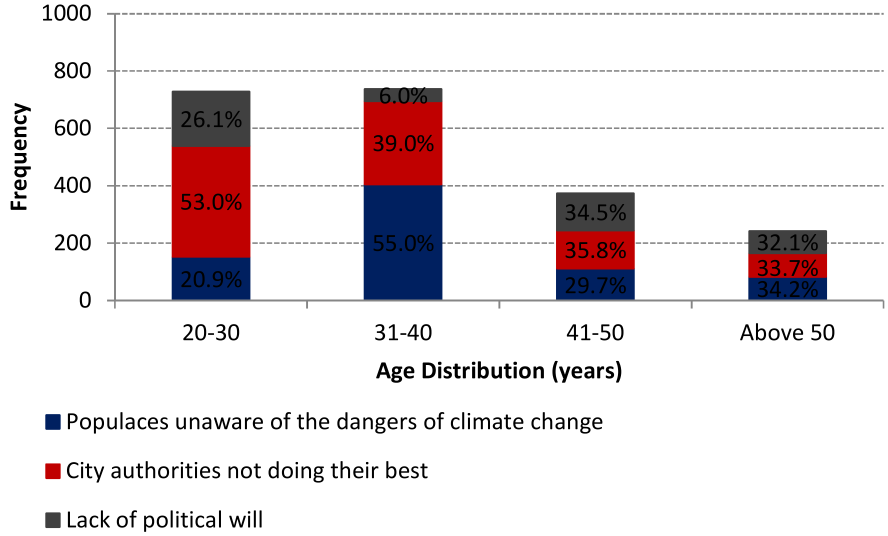

Fig. 10. Probable causes on the loss of green spaces in Kumasi

desperate efforts should be made to address it the sooner than later. It's been noted that while Africa is responsible for only 4% of global greenhouse-gas emissions, 65% of the African population is directly impacted by climate change [44].

5. CONCLUSION AND RECOMMENDATIONS

The study presented outcomes on the assessment of urban heat in Kumasi using both objective and subjective strategies. Secondary data from the Meteorological survey department in Kumasi was collected and analyzed for a 42-year period. Subsequently, a section of the populace in 6 suburbs of the city was sampled to respond to a questionnaire. The following are the conclusions:

The secondary data analyzed shows a steady rise in air temperature of 2ºC. With a $P \leq 0.05$, this difference in temperature is statistically significant and environmentally distressing. The effect of climate change and global warming can be associated with respondents (about 60% on average) account of how the climate in contemporary times have become very unbearable, an indication of the dangers of replacing greenery and green space with hard landscape.

Given the predictions of the EPA of Ghana (annual mean temperature values to see increases of 0.6°C, 2.0°C and 3.9°C by the years 2020, 2050 and 2080), this figure shows that the pace of climate change is doubling. In fact, it is only a matter of time before outdoor and by extension, indoor conditions become fatal if nothing is done now.

By this, city authorities should be cautious of how it expands infrastructural projects to the detriment of urban green areas. Practical actions therefore must be taken to address the diminution of green spaces in the Metropolis by city authorities lest the once 'garden city of Kumasi', risk becoming ecologically dysfunctional. Measures are to be focused on the restoration and preservation of the lost green spaces.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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