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Bioclimatic Conditions of Urban Residents through Deteriorating Ecosystem Practices in an Emerging City of Nigeria

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Abstract The increase in impervious and non evaporative surfaces, emission of heat and greenhouse gases at the detriment of rapid vegetation decline results in the significant thermal differences in urban environment. However, Anyigba town is seriously witnessing this trend in its landscape like any other urban area. Therefore, In situ temperature and humidity data from the year 2000 to 2013, Landuse types and Land surface temperature data of 2006 and 2012 were collected from published works. Monthly and Yearly Heat indexes for Anyigba town were calculated using the Bioclimatic Heat Index Calculator. The heat index chart placed Anyigba town in two different thermal discomfort zones - Extreme caution and Danger. From the months of November to march falls within the extreme caution zones while the months of April to October falls within the danger zones. The years 2003, 2010, 2011, 2012 and 2013 all falls within the danger zones this is as a result of unprecedented increase in urbanization and conversion of land uses from vegetation and green spaces to built up and vacant lands. The built up area increases at the rate of 2.44km^2/yr and the LST at 0.73°C/yr while green spaces within the city and at the periphery are depleted at the rate of 0.55km^2/yr and 2.165km^2/yr respectively. Anyigba town is becoming hotter daily as the ecosystem is undergoing modification daily. The discomfort levels can be reduce if the ecosystem can be improve upon though increase in green space per capita, enforcement of planning laws and proper documentation of vulnerable assets.

Keywords Green spaces, Vacant land, Discomfort, Heat index, Built up, Land surface temperature

1. Introduction

In this era of rapid urbanization and emergence of cities in both developed and developing countries, a lot of environmental resources are consumed and depleted unsustainably. The economic opportunities, prevailing lifestyles and consumption pattern in cities had greatly impacted negatively on the environment [1]. The combined effects of land use conversion (loss in vegetal covers, increase in impervious and non evaporative surfaces) and emission of heat and Green House Gases (GHG) from anthropogenic activities (Cooking, Cooling, industry, electricity and vehicular) contributes significantly to thermal differences between the urban and rural environment, where the urban is more warmer than the rural and giving the cities it microclimate as Urban Heat Island (UHI) manifest [1].

The UHI effects as it relates to high surface temperature in the night time is also witnessed during the daytime [2]. The associated high temperatures in cities have negative consequences to human health and well-being [3-5], and also attributed the quality of urban outdoor spaces to public health, psychology and economy as the urban residents are exposed to this thermally stressful outdoor environments when performing their economic and recreational activities [6]. The higher the level of discomfort among the urban residents, the higher the activities of the proponents hindering the effective benefits derived from green spaces in the city [7, 8]. The urban thermal comfort is one of the sub-indicators of Ecological conservation in measuring the level of impact of urban development through Micro-level Urban-ecosystem Sustainability Indicator Composite (MUSIC) [9] and also as urban microclimate analysis tool for sustainable urban development (Wong et al., 2012).The elevated levels of temperature and moisture (humidity) among others can be used in measuring the Heat index values of urban environment [10].

The main objective of the paper is to ascertain the change in microclimatic conditions and the resulting thermal discomfort associated with the change.

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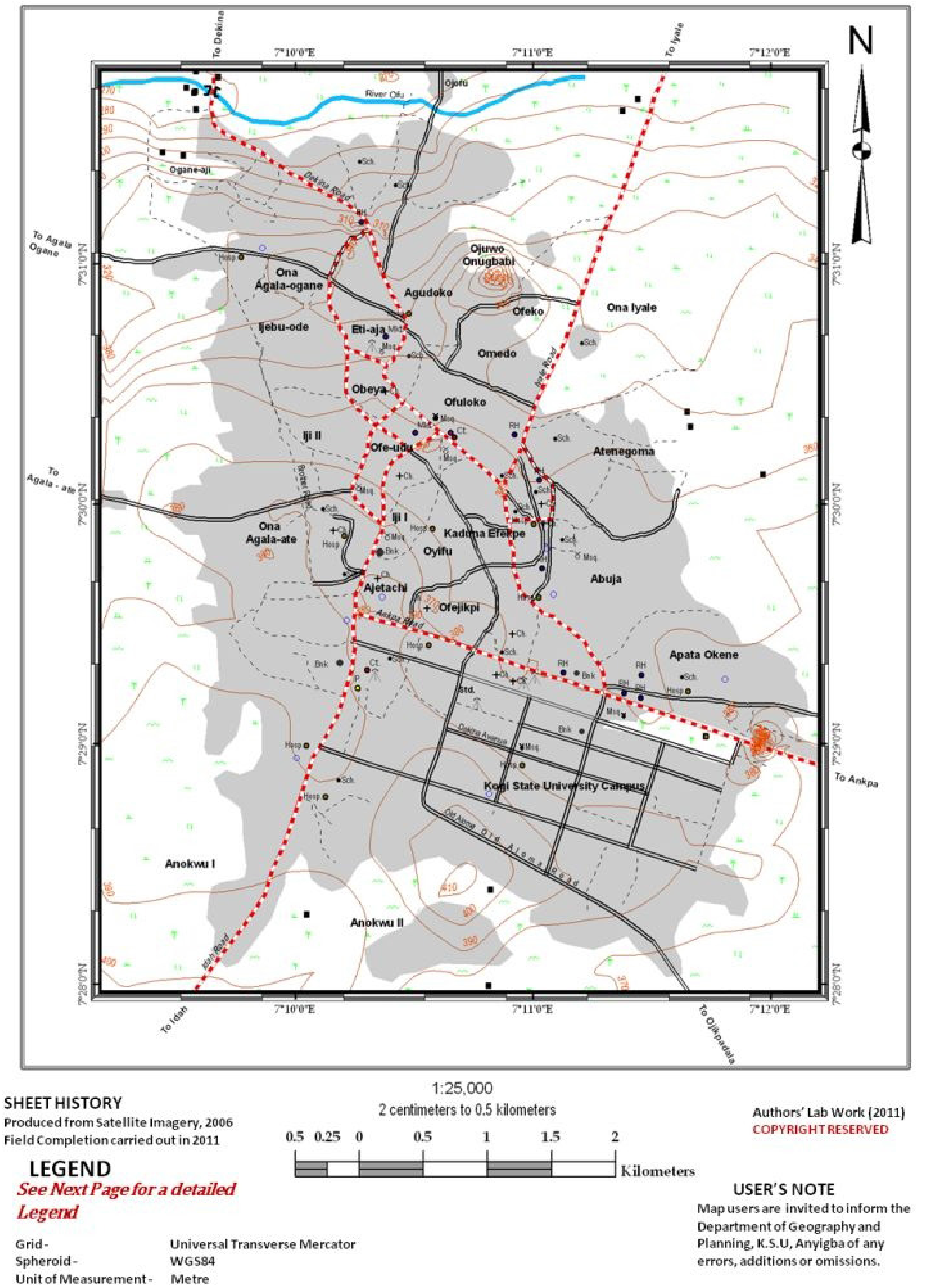
2. Methodology

2.1. Study Area

Anyigba, a University town in Nigeria located on latitude 7°15' – 7°29'N and longitude 7°11'–7°32' E. The university town has attracted commence, knowledge, innovation and physical development to its surrounding and responsible for rapid growth of its population from 44,271 in 2000 to 172,468 in 2012 [11, 12]. The University town falls within the tropical wet and dry (Aw) climatic region and the guinea savanna.



Source: Ifatimehin et al., 2014

Figure 1. Anyigba

2.2. Materials and Methods

In situ temperature and humidity data from the year 2000 to 2013 were collected from the University Weather Station and the Centre for Lower Atmospheric Research in Anyigba, Kogi State. Published data on Landuse types and Land surface temperature of 2006 and 2012 were also sourced. The Bioclimatic Heat Index Calculator with the formulae expressed below was used in calculating the monthly and yearly heat index (HI) using the temperature and humidity data. The Heat Index chart was used for the interpretation of the calculated heat Index

$$HI = -42.379 + 2.04901523T + 10.14333127R - 0.22475541TR - 6.83783x10^{-3}T^2 - 5.481717x10^{-2}R^2 + 1.22874x10^{-3}T^2R + 8.5282x10^{-4}TR^2 - 1.99x10^{-6}T^2R^2 \quad (1)$$

where T = ambient dry bulb temperature (°F) R = relative humidity (integer percentage)

Table 1. Heat Index Chart

Classification	Heat Index	Effect on the body
Caution	80°F - 90°F	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution	90°F - 103°F	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
Danger	103°F - 124°F	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger	125°F or higher	Heat stroke highly likely

Source: http://www.srh.noaa.gov/images/ffc/pdf/ta_htindx.PDF

3. Results and Discussion

The Land use of types of Anyigba had really transformed from 2006 to 2012 as built up had increased with about 14.63km^2 while green spaces (within the town and at the periphery) depreciated at about 16.28 km^2 (Table 2). This indicated a high level of transformation of green spaces land use to other land uses especially to built upand vacant land.

This transformation suggest an increase in impervious and non-evaporative land use types and decrease in evaporative land use types which can adversely affected the radiation and absorption of heat. Table 3 showed that the land surface temperature of the land use types studied had increased (Built up, +4.4°C; Open land, +4.1°C, Green Spaces [Within the city, +2.0°C; At the periphery, +1.1°C])

The thermal discomfort levels in the town as indicated by the Heat index suggest that a large percentage of the population is exposes to two different conditions as shown in both tables 4 and 5. The two levels of discomfort are classified as Extreme caution and Danger. From the months of November to March, the heat index ranges between 90 to 98 and falls within the Extreme caution where heat stroke, heat cramps, or heat exhaustion is possible with prolonged exposure. While from the months of April to October falls within the Danger zones (104-113), where heat stroke is possible with prolong exposure. In a similar study in cities of Pakistan, the Danger zones where within the months of May to September [10].

The annual trend of discomfort shows a double peak in the years 2003 and 2011. However, the years 2010, 2012 and 2013 all falls within the same zones of discomfort (Danger) with 2003 and 2011, whereas from the year 2000 there was a steady rise 2002 of the index from 98 to 102 and then 98 in 2004 to 101 in 2009.

Table 2. Land Use Types of Anyigba in the year 2006 and 2012

Land use type	2006		2012		Change in land uses between 2006 to 2012 (Km^2)
	Area (Km^2)	%	Area (Km^2)	%	
Built up	12.55	29.84	27.18	64.62	14.63
Open (Vacant) Land	2.15	5.11	3.8	9.04	1.65
Green Spaces					
a. Within the town	4.67	11.10	1.38	3.28	-3.29
b. at the periphery	22.69	53.95	9.70	23.06	-12.99
Total	42.06	100	42.06	100	

Source: Adapted [12, 13]

Table 3. Land use types and their respective Land Surface temperature (LSTs)

	Built up	Open Land	Green spaces	
			Within the City	At the periphery
Min & Max LST (2006)	27.7-28.8°C	28.9-30.0°C	24.7-26.6°C	23.00-25.4°C
Min & max LST (2013)	28.6-32.4°C	29.3 - 33.7°C	25.8 - 27.5°C	23.4 - 26.1°C
Change in LST	+4.4°C	+4.1°C	+2.0°C	+1.1°C

Source: Adapted [12, 14, 15]

Table 4. Annual Heat Index from 2000 to 2013

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp (°C)	29.88	30.84	31.76	33.01	33.36	32.14	32.06	32.27	32.29	32.8	32.09	30.53
Humidity (%)	59.93	61.21	59.79	61.78	70.21	74.07	73.5	79.21	74.93	64.71	56.56	52.07
Heat Index (HI)	91	95	98	104	113	108	107	113	110	105	97	90

The increase in heat index during the 2010 to 2013 and its seasonal increase too in the summer period depicts that this a significant increase temperatures as built up area increases 2.44km^2/yr with complementing increase too in LST at 0.73°C/yr. This implies that at every 2.44 km^2 increase in built up environment, there is a 0.73°C increase in LST. The rapid expansion of the built up area witnessed are done indiscriminately and haphazardly without conforming with the planning laws and this is responsible for most of the degradation found [12]. It was Musa et al., (2011) and Ifatimehin et al (2014) reported that the controlled expansion of the built environment of Anyigba, is the major contributing factor to its vulnerability to the increasing flood events at every down poor and the breeding of plasmodium infected mosquitoes in the town [12, 14].

Table 5. Monthly Heat Index from 2000 to 2013

Year	Temp (°C)	Humidity (%)	Heat Index (HI)
2000	30.85	68.75	98
2001	31.13	66.75	99
2002	32.08	64.83	102
2003	32.6	65.67	105
2004	31.3	64	98
2005	31.29	65.75	99
2006	32.02	65.25	102
2007	32.18	64.17	102
2008	32.05	64.33	101
2009	32.03	64.33	101
2010	32.23	66.67	104
2011	32.66	66	105
2012	32.32	66.33	104
2013	32.13	66.5	103

A lot of urban activities that emits both GHG and Heat are also on the increase. Among these activities are vehicular activities (4, 3 and 2 wheeled), use of cooling devices, and power generators during the day time for commercial purposes and during the night by households accounts for 0.05mt of carbon is emitted daily from vehicular activities [16]. The green spaces found within the town and at the periphery is to provide regulating services to the environment in terms of regulating the climate through absorption of carbon and the heat emitted, is fast been depleted at a rate that surpasses its regeneration capacity. The green spaces within the town is to check the build-up of urban Heat Island, but it is been depleted at the rate of 0.55km^2/yr and LST is increasing simultaneously at the rate of 0.33°C/yr. The Green spaces at the Periphery which is to stabilize the heat from within the city by providing cooling effects through the wind is also undergoing the degradation as it reduces at faster than Green spaces within the city at 2.165km^2/yr while its LST at 0.18°C/yr.

Table 6. Rate of Change of land use and Land Surface temperature between 2006 and 2012

	Built Up Area	Open (vacant) spaces	Green spaces	
			Within the city	At the periphery
Rate of LST Change in 6 years (°C/yr)	+0.73	+0.68	+0.33	+0.18
Rate of Land use change in 6 years (Km^2/yr)	+2.44	+0.275	-0.55	-2.165

It was equally observed that green space per capita in the studied area is 160m^2 which is far above what is obtained in many cities of the world and also above set standards by many urban centres in mitigating climate change impacts [17]. This implied that Anyigba is an emerging urban centres in which the ecological benefits of green space can be explored and sustainably maintained to avert future disaster.

4. Conclusions and Recommendations

The implication of the above scenario is on the well-being of the residents as valuable assets of the town are unsustainably depleted. if allow to continue in this manner (Business As Usual) for a targeted year in time, Urban heat island effect will surely takes its toll on the residents. Therefore, there is the need to employ strategic action plan and sustainable approaches to restoring green spaces. The impact of However, the following are recommended:

1. Increase in Green spaces per capita should be encourage;
2. Enforcement of planning laws;
3. Increase in trees per capita should also be encourage;
4. A proper documentation of the vulnerable assets as a result of the impended hazards of flood and heat waves should be done.
5. Sidewalks and bicycles should be encourage to reduce the increasing dependent on a two wheeled motorised cycles for intra urban movements.
6. An alternative source of energy be encourage so that the use of generators by majority of the households will be reduced.

The immediate solution to these impending double tragedy from both thermal discomfort and flood is to scale down on and prioritised actions/strategies that are have both adaptive and resilience capabilities at this micro level.

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