EFFECT OF URBANISATION ON THE LOCAL CLIMATE, FEDERAL CAPITAL TERRITORY; ABUJA

BY

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BEING A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF POSTGRADUATE DIPLOMA IN ENVIRONMENTAL MANAGEMENT.

DECLARATION

I hereby declare that this research work titled, "Effect of urbanization on the local climate: A case study of Federal Capital Territory, Abuja", was purely a record of my own research work. All information used in this work were obtained from personal research while due acknowledgement were given to those materials used through appropriate referencing.

Sign: ________________________________

Name: ________________________________

Date: ________________________________

CERTIFICATION

This thesis titled: 'Effect of Urbanization on the Local Climate, Federal Capital Territory; Abuja' by Osoba Benahi (PGD/GEO/2005/334) meets the regulations governing the award of Post – Graduate Diploma (PGD) of the Federal University of Technology, Minna and is approved for its contributions to scientific knowledge and literal presentation.

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DEDICATION

To the jewel of my heart, Master Joshua Osayi Osarense Boluwatife Enesi, thanks for adding colour to my life.

ACKNOWLEGDEMENT

To God, the father of all creations, who is the author and owner of my life, my profound thanks for seeing me through another phase of my life.

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ABSTRACT

Modification of the earth's surface through urbanization can have a dramatic impact on the local climate. An Urban Heat Island (UHI) is formed in a metropolitan area as vegetation is replaced by asphalt and concrete for roads, buildings and other structures necessary to accommodate growing population. The asphalt and concrete surfaces absorb rather than reflect the sun's heat, causing surface temperature and overall ambient temperature to rise. This makes the temperature in the affected area to be significantly higher than the surrounding areas.

This project is aimed at verifying if activities associated with urbanization have had adverse effects on the local climate of the study area. This will be achieved by comparing the change in the land use cover as seen via satellite images between 1983-1987 and 2000-2004, which represents pre- and post-urbanization periods, respectively, with meteorological parameter (temperature and rainfall) readings of the same period.

From the analysis done it was seen that as vegetation cover and agricultural land were cleared and converted to developed areas, there was a noticeable increase in the temperature and rainfall readings. Since urbanization is a major sign of development there is need for sustainable development. This can be achieved by changing dark surfaces to light reflective surfaces and by planting trees.

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CHAPTER ONE

1.0 INTRODUCTION:

Urbanization has been a dominant demographic trend, not only in Nigeria, but also in the rest of the world, during the last century. With the high pace of social and economic development in Nigeria and the resultant growth of city and town populations, lack of infrastructure, environmental degradation and housing shortage have become the major issues faced by cities and towns in their sustainable development.

The implications of rapid urban growth include increased unemployment, inadequate urban services, over-burdening of existing infrastructure and lack of access to land, finance and adequate shelter, increased violent crime and sexually transmitted diseases and environmental degradation. Even as national output is rising, a decline in the quality of life for a majority of population that offsets the benefits of national economic growth is often witnessed in over-populated areas. Urbanization thus imposes significant burden on sustainable development.

It should be noted, however, that urban growth has a number of positive impacts on the environment and on human capital costs of providing energy, health care, infrastructure and services. Urbanization has historically been associated with declining birth rates, which reduces population pressure on land

and natural resources. Despite all these positive impacts, almost all major cities of the world are increasingly plagued by environmental problems.

Urbanization does not have only local environmental impacts but results also in a large so-called "ecological foot prints" beyond their immediate vicinity. Intensive and extensive exploitation of natural resources to support urban economy includes excessive extraction of energy resources (including fuel wood), quarrying and excavation of sand, gravel and building materials at large scales and over extraction of water. These all contribute to the degradation of the natural support systems and result in irreversible loss of critical ecosystem functions, such as the hydrological cycle, carbon cycle and biological diversity, in addition to conflicts with rural uses of such limited resources.

1.1 BACKGROUND OF THE STUDY

Urban land use change has been and will continue to be one of the biggest human impacts on the terrestrial environment. At the start of the 1990s, there were only sixteen cities with population over 1 million. However, by the year 2000, there were 417 with populations of over 1 million (UNCHS, 2002). Building cities on previously vegetated surfaces modifies the exchange of heat, water, trace gases, aerosols, and momentum between the land surface and overlying atmosphere (Crutzen, 2004). In addition, the composition of the atmosphere over urban areas differs from undeveloped area (Pataki, et al 2003). These changes imply that urbanization can affect, regional, and possibly global climate at diurnal, seasonal, and long-term scales (Zhou et al 2004; Zhang et al 2005).

1.2 STATEMENT OF THE PROBLEM

Development, which is a very essential factor in any country or place, takes its toll on the environment and eventually on the very people who "need it". Urbanization, which is one of the major components and factors of development, has been said in the above introduction to have both positive and negative impacts on the environment. In order to create an urbanized area, a natural environment must be destroyed through deforestation and the creation of impervious surfaces. These and other human activities within an urban system produce many destructive and irreversible changes, such as loss of habitat, increased flooding magnitude and air pollution.

Urbanization has been known to alter the local climate as a result of the activities and changes that take place within the local environment. The days tend to be hotter and nights warmer than they originally were before the advent of urbanization. The warm nights are due to what has been called the Urban Heat Island (UHI) effect, which is the result of two main features of urban areas. First, buildings, roads, and paved surfaces store heat during the day, which is then released slowly over the evening. This is due to the thermal properties of the surface materials and the building geometry which traps the heat stored during the day. The second contributing factor to the UHI is the artificial heat released into the urban atmosphere by combustive processes from vehicles, industrial activities and the heat that escapes from commercial and domestic air conditioning.

This increased temperature causes discomfort for everyone. The study area is known to have become very uncomfortable to its residents due to the increase in temperature especially between January and April, which is known to be the peak of the hot season. As a result almost every building in the study area has a cooling device which in turn contributes to the problem.

The loss of forest or vegetation cover which naturally acts as regulator of the local climate is one of the main reasons for the change in temperature. Areas with lots of trees are known to be cooler than areas with more pavements. In the study area, only 32.5% of the available land has been allocated to open space and recreational facilities or green area, but this has been heavily encroached upon by buildings. The few hectares that remain lack adequate amount of trees needed to help cool the local environment.

The streets are heavily paved; the roads are new and therefore, still very dark; the buildings are of concrete structures and in some areas closely built. These, to mention but a few all contribute to the urban heat process.

1.3 AIMS AND OBJECTIVE

This study aims to verify if activities associated with urbanization have adverse effects on the local climate. This will achieved by:

(a) Reviewing the land use map of the study area

(b) Land use and land cover classification to determine which area is used for commercial, residential, industrial and institutional purposes.

(c) Reviewing temperature and rainfall records of the study area of the pre-urbanization (1982-1986) and post-urbanization (2000-2005) periods obtained from the Nigeria Meteorological Agency (NIMET) located in the study area.

(d) Reviewing satellite images of the pre-urbanization and post-urbanization periods of the study area which were gotten from a Julius Berger publication (Abuja at 30) and the Abuja Geographical Information System (AGIS), respectively.

(e) Analyzing and correlating the change in the land use with the meteorological parameters.

1.4 SCOPE AND LIMITATIONS OF THE STUDY

This study is limited to determining the effect of urbanization on the local climate. It will look into the different possible factors contributing to the change and recommend possible mitigating methods.

The limitations encountered during this research work included the following:

(a) The financial cost of acquiring the satellite images.

(b) The procedure and time taken in obtaining data on temperature, rainfall amount and relative humidity of the study area from the NIMET.

(c) Inability to acquire temperature records of the nearest rural area, which would have made comparison between the temperature records of the two different settlements possible.

(d) Incomplete record of meteorological parameters available in NIMET.

1.5 JUSTIFICATION FOR THE STUDY

The Federal Capital Territory is hotter now than eleven years ago. And very little is known by policy makers and residents about the reasons for the change. Everyone seems eager to want a piece of the available land for construction in order to be economically empowered without realizing the negative impact such activity has on the environment. If the master plan of the local environment is not strictly adhered to in its development, the residents will complain about warmer weather in due course and there will be chaotic traffic as more and more automobiles will be on the road than originally envisaged. Natural forests are being destroyed in order to plant gardens with very few trees.

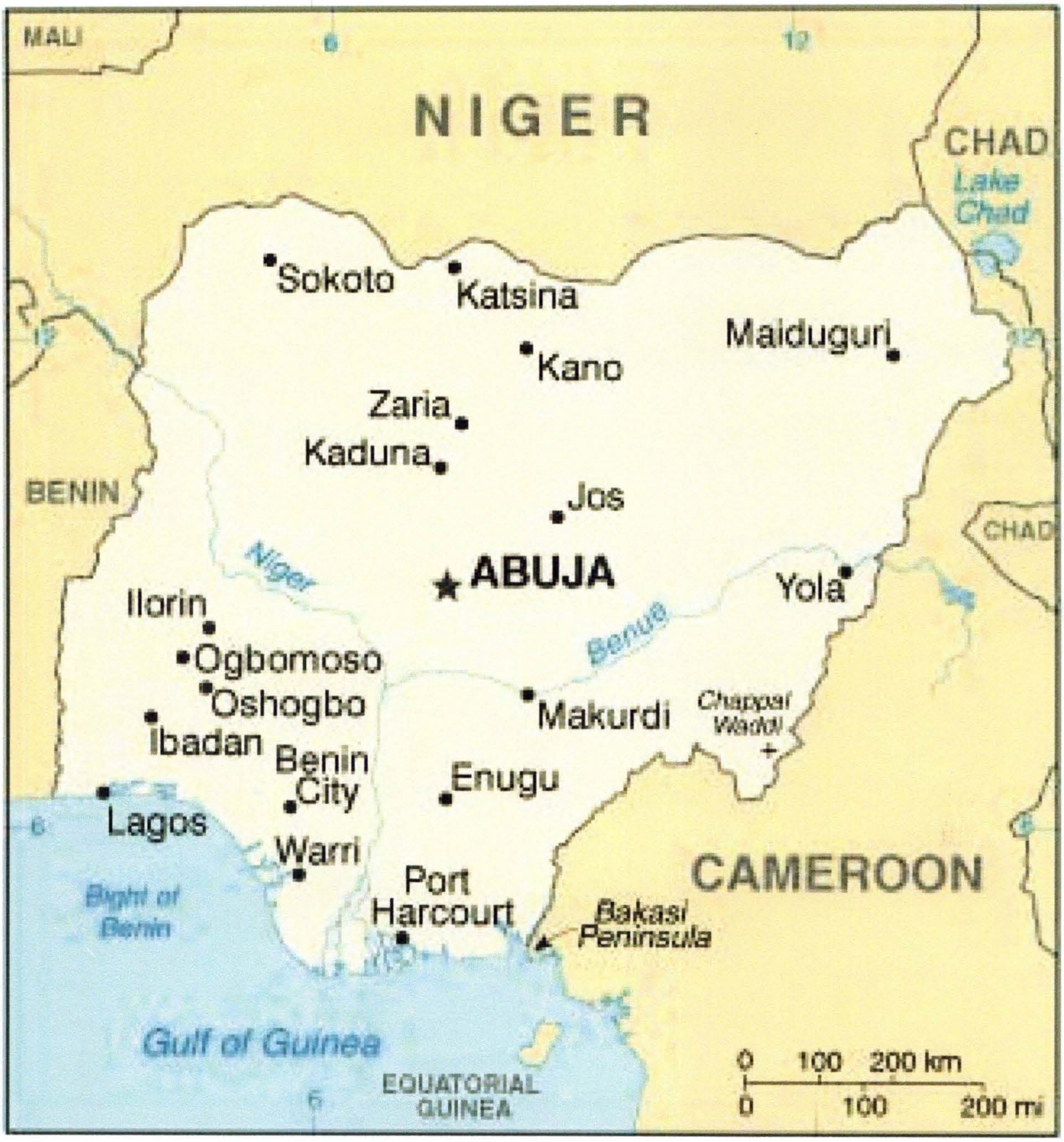
The aim of this study is to draw the attention of policy makers and the general public of the Federal Capital Territory to the effect of urbanization on the local climate and to suggest some mitigating factors. It is possible to have an "urbanized cool" area if only the right mechanism are put in place.

1.6 THE STUDY AREA

1.6.1 HISTORY, LOCATION AND PLAN

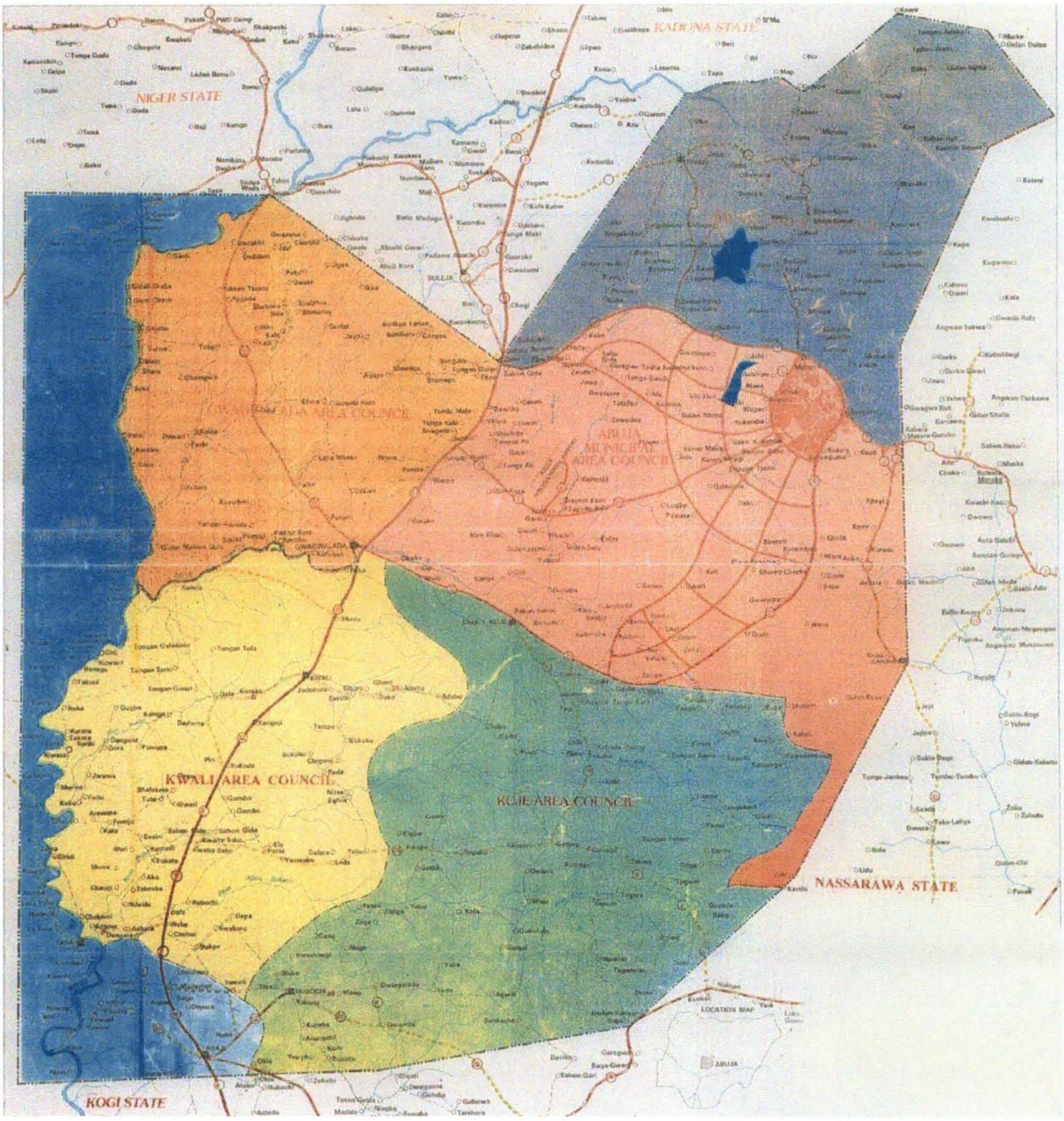
The Federal Capital Territory is located in the geographical center of Nigeria with a land area of 8,000 square kilometers. It is bounded on the north by Kaduna State, the west by Niger State, the east and southeast by Nasarawa State and southwest by Kogi State. It falls within latitudes 7^{o} 20^{I} North of the equator and longitudes 6^{o} 45^{I} and 7^{o} 39^{I}. Figure 1.1 shows the map of Nigeria indicating the study area. The study area lies almost in the heart of the county, making it easily accessible. Figure 1.2 shows the map of the study area indicating all the area councils, including Bwari, Gwagwalada, Abuaj Municipal, Kwali and Kuje while figure 1.3 shows the land use plan for phase one of the study area indicating the different districts, areas designated for vegetation cover and residential and commercial activities.

Fig 1.1: Map of Nigeria Indicating the Study Area



Source: Encarta 2007

Fig 1.2: Map of the Study Area



Source: Abuja Geographic Information System (AGIS)

Fig 1.3: The Land Use Plan for Phase One of the Study Area

Source: Abuja Geographic Information System (AGIS)

The new capital was developed and built on the Chukuku hills during the 1980's. Prior to its creation, Nigeria was administered from Lagos as its capital, which was constitutionally recognized and empowered to function as a state. This was due to the fact that the main seaport, industrial and commercial activities were all centered in Lagos. This resulted into perennial cases of traffic jams, intolerable congestions at the ports, inadequate infrastructure and social amenities as well as lack of land for further expansion. These put together rendered the city ineffective as seat of government.

The choice of Abuja by the panel head by Justice Akinola Aguda in 1975 was determined by factors such as centrality of location, easy accessibility from all parts of the country, healthy climatic conditions, low population density, availability of land for future expansion, physical planning convenience and ethnic accord.

The Abuja Master Plan covers about 250 square kilometers. Its design provides for a four-phased development, with the city divided into sectors and further subdivided into districts. It was projected that each sector would accommodate between 100,000 to 250,000 people. Thus, the city would have a total population of 3.1 million people at the end of phases one and two. Table 1.1 below shows the amount of land allocated by the government for the different land use.

Table 1.1: FCT LAND USE ANALYSIS

S/N	CATEGORY OF LAND USE	LAND BUDGET	% OF TOTAL
1	Government activity	500,000ha	1.96
2	Services activity	891.00ha	3.49
3	Residential	12,480ha	48.97
4	Light industries	920.00ha	3.61
5	Infrastructure	1840.00ha	7.22
6	Commercial	561.00ha	2.2
7	Open space and Recreational Facilities	8,300ha	32.5
Total		**25,498.00**	**100**

Source: FCDA, Abuja.

The above table shows that 67.5% was allocated for development of structures while 32.5% was allocated to vegetation cover and recreational facilities. But this has been seriously distorted during the course of development.

The whole of Abuja has been designed to be an urban settlement. It is undergoing fast development both in terms of infrastructure and population. Buildings are sprouting in different places, deforestation/degradation is going on at a high rate and more service roads are being constructed to accommodate the dramatic increase in the population of humans and automobiles. All these are taking their toll on the environment, especially the local climate which in turn affects the very same people who are responsible for its degradation.

The Federal Capital Territory, which is the first planned city to be built in Nigeria, is divided into two zones:

- The central zone with the national Assembly, the city hall, national Cultural institutions, government related offices that include the administrative headquarters of all Federal Government ministries and parastatals and major private sector organizations and foreign missions.
- The second zone provide for housing, shopping facilities and other urban amenities

1.6.2 RELIEF

The lowest elevation in the Federal Capital Territory is located in the extreme south-west where the flood plain of the River Gurara is at an elevation of about 70m above sea level. From there, the land rises irregularly eastwards, northwards and north-west wards. The highest part of the territory is in the northeast with the existence of many peaks over 760m above sea level. Hills occur either as clusters or long ranges. The most prominent ones include the Gawa Range in the northeast, the Gurtata Range in the southwest of Suleja, the Bwari–Aso Range in the northeast, the Idon Kasa Range in the northwest of Kuje and the Wuna Range in the north of Gwagwalada. There are many roundish isolated hills called inselbergs in other areas. Extensive plains are found in between the major hills, most important are the Gwagwa plains, the Iku-Gurara plains, the Robo plains and the Robochi plain. Indeed, about fifty two percent of the federal capital territory consists of plains

1.7.2 CLIMATE

As in the tropics, the FCT experiences two weather conditions annually. These are the rainy season (the equivalent of winter in the temperate region) and the dry season (the equivalent of summer in the temperate climate).

The high altitude and undulating terrain of the area regulates the weather. During the day, the temperature varies between 30^{o}c in the northwest to about 37^{o}c in the southwest. This period is characterized by high diurnal range which may be as high as 17^{o}c. Temperatures drop considerably during the rainy season resulting from the dense cloud cover. The diurnal range also drop to about 7^{o}c especially between July and August. The relative humidity in the dry season is about 20 percent in the afternoon at higher elevations and at more in northern locations but about 30 percent in the extreme south. This low relative humidity, coupled with the high afternoon temperatures, account for the desiccating effect of the dry season, also marked by the presence of the harmattan haze. During the rainy season, the afternoon relative humidity rises to above fifty percent everywhere. For maximum human comfort, the northern locations are better, especially the northwest, while the extreme south is uncomfortably hot.

Rainfall in the FCT starts from about March in the southern most part of the territory and about April in the northern limits. The rainfall for Abuja shows very high seasonal fluctuation. The annual range is in the order of 1,100mm to 1,600mm. The rain ends around October in the Northern parts and extends to around November in the extreme south.

One important weather feature in the territory is the frequent occurrence of disturbance in line squalls. This is a weather condition characterized by the occurrence of dense, dark, cumulonimbus clouds with thunder and lighting, followed by strong winds and rainfall of very high intensity which may last for up to half an hour and then followed by drizzle for several hours. The weather condition is then replaced by a few days of bright, clear skies. This phenomenon is associated with high convective activity aided by relief effects. It is most common in the late afternoons at the beginning and end of rainy seasons and often causes serious damage to buildings.

1.7.3 SOILS AND VEGETATION

The soils of Abuja are generally shallow and sandy in nature especially in the major plains of Iku – Gurara, Robo and Rubochi. This is basically because the area is regarded as a basement complex. The high sand content makes the soils to be highly erodable.

Those on the Gwagwa plains are, however, deep and clayed perhaps due to the influence of the parent materials like gabbro and fine to medium textured biotitic granite. As a result, the soils of Gwagwa plains are the most fertile and productive. They are also more ideal for urban development due to their being more or less from exposed interfluves summits. The area falls within the savannah zone vegetation of the West African sub-region. Patches of rain forest, however, occur in the Gwagwa plains, especially in the gulled terrain to the south and the rugged south-eastern parts of the territory. These areas of the FCT form one of the surviving occurrences of the maluire forest vegetation in Nigeria.

The dominant vegetation of the Federal Capital Territory is however, classified into three savannah types.

1. The park or grassy savannah: This is about 53 percent (i.e. 4,231 square km) of the total area of the FCT. Vegetation occurs annually and tree species found include albizia, zygia,

butyrospernum paradoxum, anniellia, oliveri and parkios clapperloniani.

2. The savannah wood land: this region covers 12:8 percent or 1,026 square km of the territory. It occurs mostly on the Gurara, Robo and Rubachi plains and surrounding hills. Common trees found in this region include afzelia, africana anogeissus, Leiocapus, Butyroscapus paradoxim, daniella oliveri, khaya senegalensis, prosopis africana, vapaca togensis, albizia, zygia, vitex doniant, bombox costatum and ptrecapus erinacesu.

3. The shrub savannah: This class of vegetation occurs extensively in rough terrain close to hills and ridges in all parts of the territory. It covers about 12.9 percent or 1,031 square km of the land area. Tree species found in include Antiaris Africana, anthocleista nobils, ceiba pentandra, cola gigantean, celtis spp, chorophora excels, (Iroko), Khaya grandifolia (Benin mahogany), terminalia superb (afara), triplochiton scleroxylon and dracacna arborea. Certain tree species normally associated with other parts of the rain forest in the south of Nigeria are also found in some of the forest patches, (ekki) and terminalia worensis (idigbo).

Apart from the rain forest elements, some dominant tree species of the savannah wood lands yield high quality timber, e.g Anogeissus leiocapus, danieilla oliveri khaya senegalensis and plerocrpus avenaceous.

1.7.4 POPULATION

Based on the 2006 population census report (provisional figures), the population Of FCT was 1,405,201 as against 378,671 in 1991. The report showed that the study area has an annual exponential population growth rate of 9.3%.

1.8 ORGANISATION OF THE THESIS

This thesis is organized in chapters. Chapter One covers the introduction, statement of the problem, aims and objectives, scope, limitation and justification of the study and also a brief literature of the study area. Chapter Two covers the concepts used in the study and also literature reviews of previous similar works.

Chapter Three and Four covers the methodology and analysis, respectively, while Chapter Five summarizes findings, highlights possible solutions and recommendations.

CHAPTER TWO

CONCEPTS

Urban heat islands (UHIS) are of interest primarily because they affect so many people. According to estimates by the United Nations, nearly half of the world's population currently lives in urban areas. Within Western Nations, this number can approach 75%. The impact of UHIS on the world's populace has the potential to be large and far-reaching. UHIS have the potential to directly influence the health and welfare of urban residents. Within the United States alone, an average of 1000 people die each year due to extreme heat. (Changnon et al. 1996).

Another consequence of UHIS is the increased energy required for air conditioning and refrigeration in cities that are in comparatively hot climates.

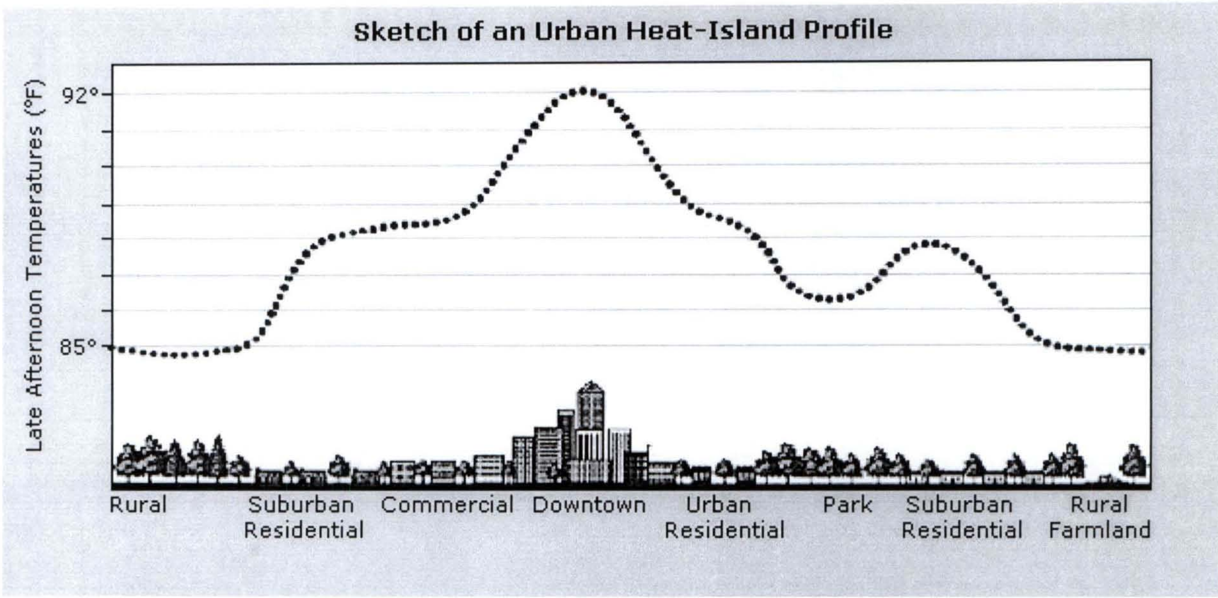
Aside from the obvious effect on temperature, UHIS can produce secondary effects on local meteorology, including the altering of wind patterns, the development of clouds and fog, the number of lightning strikes and the rates of precipitation.

2, 1.1 WHAT IS A HEAT ISLAND?

The term "heat island" refers to urban air and surface temperatures that are higher than nearby rural areas.

An "urban heat island" is therefore a metropolitan area which is significantly warmer than its surroundings. As population centers grow in size, they tend to have a corresponding increase in average temperature.

Fig. 2.1: Urban Heat Island Profile



Source: Heat Island Group

The heat island sketch (fig 2.1) here shows a city's heat island profile. It demonstrates how urban temperatures are typically lower at the urban-rural border than in dense downtown area. The graphic also shows how parks, open land and bodies of water can create cooler areas.

2.1.2 HOW "HEAT ISLAND" IS FORMED

The reason the city is warmer than the countryside comes down to a difference between the energy gains and losses of each region. There are a number of factors that contribute to the relative warmth of cities:

(a) During the day in rural areas, the solar energy absorbed near the ground evaporates water from the vegetation and soil. Thus, while there is a net solar energy gain, this is compensated for by some degree by evaporative cooling. In the cities where there is less vegetation, the buildings, streets and side walks absorb the majority of solar energy input.

(b) Because the city has less water, runoff is greater in the cities because the pavements are largely nonporous (except by the pot holes). Thus, evaporative cooling is less which contributes to the higher air temperatures.

(c) Waste heat from city buildings, cars and trains is another factor contributing to the warm cities. Heat generated by these objects eventually makes its way into the atmosphere. This heat contribution can be as much as one-third of that received from solar energy.

(d) The thermal properties of buildings add heat to the air by conduction. Tar, asphalt, brick and concrete are better conductors of heat than the vegetation of the rural area.

(e) The canyon structure that tall buildings create, enhances the warming. During the day, solar energy is trapped by multiple reflections off the buildings while the infrared heat losses are reduced by absorption.

(f) Introduction of anthropogenic heat sources from heating and ventilation systems, industrial processes and internal combustion engines. In general energy consumption will generate heat as a by-product. Since more energy is stored in the urban environment, these modifiers result in relatively slower nocturnal cooling rates in urbanized environment.

2.1.3 WHEN HEAT ISLAND IS FORMED

Heat Islands can occur year round during the day or night. Urban-rural temperature differences are often largest during calm, clear evening. This is because rural areas cool off faster at night than cities, which retain much of the heat stored in roads, buildings and other structures.

As a result, the largest urban-rural temperature differences, or maximum heat Island effect, are often three to five hours after sunset.

2.1.4 RELATIONSHIP BETWEEN HEAT ISLANDS AND GLOBAL WARMING

There is no controversy about cities generally tending to be warmer than their surroundings. What is controversial about these heat islands is whether and if so how much, this additional warmth affects trends in global temperature record.

Heat islands describe local-scale temperature differences, generally between urban and rural areas. In contrast, global warming refers to a gradual rise of the earth's surface temperature.

While they are distinct phenomena, summertime heat islands may contribute to global warming by increasing demand for air conditioning, which results in additional power plant emission of heat-trapping greenhouse grasses. Strategies to reduce heat islands, therefore, can also reduce the emissions that contribute to global warming

The current state of the science is that the effect on the global temperature trend is small to negligence: the International Panel on Climate Change (IPCC) says urban islands effects are real but local, and have a negligence influence (less than 0.006^{0}C per decade over land and zero over the oceans) (Camilloni and Barros, 1997).

2.1.5 CAUSAL FACTORS BEHIND URBANISATION

(a) RURAL-URBAN, URBAN-URBAN MIGRATION

The primary driving forces of rural-urban, urban-urban migration include the opportunities and services offered in urban areas – especially jobs and education, while in some cases, conflict, land degradation and exhaustion of natural resources in rural areas are responsible.

The problem of this migration may be city specific, among other things, changes in the city economic base, labour market and age structure. They also reflect social, economic and political changes within the region and nation and are greatly influenced by economic factors in the surrounding and distant rural areas.

For Migrants from the rural areas most evidence suggest that increasing the income and level of education of rural population accelerates migration and this phenomenon, coupled with the greater access to urban areas, has led to an inevitable increase in rural population seeking employment opportunities in urban areas. While for migrants from the urban areas, evidence suggests that a decline in social amenities, job opportunities, infrastructure and economic and social security has lead to the migration of people to other urban areas where things are still far preferable

(b) MISMANAGEMENT

It is often pointed out that many urban environmental problems are the result of poor management, poor planning and absence of coherent urban policies rather than of urbanization itself.

The problem of urbanization has significantly been exacerbated by inappropriate incentive systems, such as the 'growth-first' strategy adopted by the government of many countries in the regions, especially in developing countries.

The 'land mark' factors that accounted for exacerbating urbanization problems include inappropriate regulation, lack of security, inadequate infrastructure capacity, inadequate information, inadequate pricing and taxation, weak institutions and poorly coordinated actors in the land market. All these factors necessitate significant improvement in overall urban governance to effectively reduce and bypass the urbanization problems.

(c) LINKS TO GLOBALISATION

The steady increase in the level of urbanization reflects the fact that the size of the world's economy has grown many times and has changed from one dominated by relatively closed national economies or trading blocs to one where most countries have more open economic and where production and services it needs including financial services, are increasingly integrated internationally. These trends appear to be strengthening, reinforced especially by the free and faster flows of information and knowledge under the impact of new information technologies. Technology has increased the already dominant economic role and importance of urban area worldwide, indicating the growing importance of cities in the global economy.

2.2.0 LITERATURE REVIEW

The influences of cities on local climates can be studied using a historical analysis of climate measurements that are continually recorded in an area in which urban land cover is increasing. Urban effects on climate can then be assessed by comparing present to earlier pre-urban conditions (Lowry, 1977). Statistical tools, remote sensing or both can be used to determine whether significant differences exit between the two periods. For example, Zhou, et al (2004), adopted the method of Kalnay and Cai (2003) to estimate the impact of urbanization and other land-use changes on climate in China.

They used observed monthly mean daily maximum and minimum land surface air temperatures at 671 meteorological stations of the Chinese network for the period from January 1979 to December 1998 which were collected and processed by the National Meteorological Center of the China Meteorological Administration. The result from the analysis showed that on the average, the observed maximum and minimum temperatures increased by 0.352° C and 0.548° C per decade, respectively.

Also Kaufmann,et al 2004, established the effect of urbanization on precipitation in the Pearl River Delta, China, with data from an annual land-use map (1988—1996) derived from Landsat images and monthly climate data from sixteen local meteorological stations. A statistical analysis of the relationship between climate and urban land-use in concentric buffers around the stations indicated that there is a causal relationship from temporal and spatial patterns of urbanization to temporal and spatial patterns of precipitation during the dry season. Results suggest an urban precipitation deficit in which urbanization reduces local precipitation.

However, Balling, *et al.* (1990), analyzed records of daily maximum, minimum, and mean temperatures collected in July and August from 1948 to 1988 at the National Weather Service Forecast Office in the Phoenix Sky Harbor Airport, located in the center of the city. The 40-year period record corresponded to the period during which both the population and urban land cover of the Phoenix metropolitan area tripled. They concluded that average summer temperatures in Phoenix were rising at a rate of 0.072K (0.13°F) per year, with a 0.10K (0.18°F) per year increase in average minimum temperatures and a 0.04K (0.07°F) per year increase in average maximum temperatures. Based on an analysis of the frequency of extreme temperature maxima or minima, the authors cautioned against predicting extreme temperatures from rises in average temperatures due to the change in the distributions of daily maximum or minimum temperatures over time

A similar analysis was conducted using temperature and atmospheric moisture records from the National Weather Service site at the Municipal Airport, 12 km south of the center of Tucson's central business district. During the period of record (1948 - 1985), the population of Tucson increased tenfold. The analysis found no significant trends in the data over the 37-year period of record. Yet, over the most recent 18-year period, afternoon temperatures increased significantly by 0.02K (0.04°F) per year. The authors noted that because the airport is located some distance from the center of Tucson and because urban land cover is replacing dry desert land, the effects of urban development on the local climate is less than those observed in Phoenix (Balling and Brazel, 1987a).

Cayan and Douglas (1984) analyzed records of near-surface temperatures at Los Angeles Civic Center as part of a study of urban influences on temperatures in several southwestern cities. The authors found that annual mean temperatures rose with a linear trend rate of 0.03K (0.054°F) per year (1.4K or 2.6°F total) between 1932 and 1980. The temperature rise was more pronounced in summer months, as linear trends for monthly mean temperatures rose over the same period by 0.7K (1.2°F) in January and by 2.3K (4.1°F) in July. They also compared monthly mean maximum and minimum temperatures averaged over the period 1941 - 1970 with those averaged over 1969 - 1980. The increase in mean temperatures in January was largely due to an increase in minimum temperatures, while the increase in July seemed to be caused by rises in both maximum and minimum temperatures.

The same temperature record was examined by Akbari ,*et al.* (1990), in a work focusing on energy and air pollution costs of heat islands and the potential for heat island mitigation. Yearly highs between 1880 and 1985 decreased from an average of 38.3°C to 37.2°C (101°F to 99°F) between 1880 and 1930. Thereafter, yearly highs rose to 41.1K (106°F) by 1985, an average increase of 0.07K (0.13°F) per year. Temperature increases were also apparent in monthly average temperatures during the summer months, as shown in Table 2.1.

	Rate of Increase	
Month	K/year	°F/year
June	0.07 ± 0.02	0.13 ± 0.03
July	0.06 ± 0.01	0.11 ± 0.02
August	0.07 ± 0.01	0.12 ± 0.02
September	0.06 ± 0.02	0.11 ± 0.03

Table 2.1: Rates of increase in monthly average temperatures for summer months in the L.A. Civic Center climate data record (Akbari et al. *1990).*

Both analyses rely solely on the climate record at the Civic Center and thus are susceptible to bias caused by natural temperature trends, changes in documented station location and elevation, and undocumented sources of bias.

The use of a single urban climate record for heat island analysis, however, may be inadequate. If large differences in climate conditions are detected, it may be improper to attribute them exclusively to urban development since natural oscillations in temperature may bias the climate record. For example, abnormally high summertime temperatures and consecutive drought years characterized California weather during the 1980's. Using a single station, an analysis of urban climate data in California ending in the 1980's may overestimate temperature trends due to urbanization.

This weather bias can be partly removed by considering climate records from at least two locations and observing trends in differences between concurrent measurements. If one climate record is chosen from an urban area and another from a nearby rural location and if the period covered by the record encompasses the entire period of urban growth, the comparison of the two may reveal the entire climate effect of urban development.

Karl, *et al* (1988), used such approach in an attempt to assess the effect of urbanization in climate records used to detect global warming signals in the United States. Pairs of stations were selected from among the United States Historical Climatological Network (HCN) in which a rural station was located in a community with less than 2000 residents in 1980 and an urban station was located between 30 and 100 km away in a larger town. They related the rate of change of these differences to a measure of urbanization at the urban station. This method detected clear increases in urban daily minimum temperatures in cities of all sizes but found no tendency toward increasing urban maximum temperatures

Pon, et al (2006), examined monthly averages of daily maximum and minimum temperatures for linear trends at the eleven stations selected. A t-statistic was used to assess the significance of the trends. The three stations at which large, statistically significant trends were found in yearly temperature maxima -- Burbank, Culver City, and the Civic Center -- and UCLA show June rates between 0.05 and 0.09K (0.09 and 0.16°F) per year. Milder increases were observed in March and September averages. These increases suggested that the daytime warming is becoming more important over time at these stations during the summer months. However, whether this rise in daily maxima is caused by local-scale heat island effects or simply by changes in microclimate below canopy height is uncertain. Other significant increases in daily maximum temperatures were detected at Pasadena (June, 0.04 ± 0.01K per year), Pomona (December, 0.01 ± 0.01K per year), and Torrance (June, 0.05 ± 0.02°F per year). The analysis confirmed the presence of historical increases in daytime and nighttime temperatures at Burbank, Culver City, the Civic Center, and UCLA. These four stations are all located within areas of dense urban development, and the findings are consistent with the presence of strong heat island effects.

Balling and Brazel (1987b) analyzed long-term temperature records from the cooperative network in Phoenix. Twelve stations were selected, all of which experienced location changes of less than a kilometer and elevation changes of less than 30m over their period of operation. Averages of daily temperature maxima and minima for the summer months of June, July, and August were examined for trends over the period 1949-1985. The significance of observed trends was tested using the Mann-Kendall Rank Statistic (Mann, 1945, Mitchell *et al.* 1966). Climate records at the three stations located in the center of greater Phoenix (Mesa Experiment Farm, Phoenix WSFO, and Tempe) all showed significant increases in both maximum and minimum temperatures, indicative of heat island effects. In the same work, the authors examined daily maximum and minimum temperatures recorded between 1980 and 1985 at 35 sites. Amateur weather observers performed measurements at 29 of these sites. These sites are predominantly located in residential areas and supplement data from the other six sites, all operated by the National Weather Service. Contour maps using this data reveal average heat island profiles over the Phoenix areas with high values 1 - 2K (2 - 4°F) for daily maxima and 3 - 4.5K (6 - 8°F) for minima. Distances as large as 3 km in the urban area and 15 - 30 km in the surrounding areas separate the measurement locations. This makes an interpretation of the linear contour maps presented by the authors problematic since the city environs, which were used to characterize synoptic weather characteristics and thus define the magnitude of the heat island, were insufficiently characterized.

Fractal analysis can also be used to detect urban heat island. This method makes use of satellites which are able to show the difference in thermal properties of various land cover. Studies on the UHI phenomenon using satellite remote sensing data have been conducted primarily using NOAA AVHRR data (Kidder and Wu, 1987; Balling and Brazell, 1988; Roth *et al.,* 1989; Gallo *et al.,* 1993). The 1.1-km spatial resolution of these data is found suitable only for small-scale urban temperature mapping. The 120-m spatial resolution Landsat TM thermal infrared (TIR) data have also been utilized to derive surface temperature. Carnahan and Larson (1990) and Larson and Carnahan (1997) used TM TIR data to observe meso-scale temperature differences between the urban area and the rural area in Indianapolis, Indiana. Kim (1992) studied the phenomenon of urban heat islands in metropolitan Washington, D.C., and pinpointed the significance of soil albedo and moisture availability to surface energy balance. Nichol (1994) carried out a detailed study using TM thermal data to monitor microclimate for housing estates in Singapore. Weng (2001) examined the surface temperature pattern and its relationship with land cover in urban clusters in the Zhujiang Delta, China. More recently, researchers have used very high spatial resolution (10-m) ATLAS data (specifically, channel 13:

9.60 to 10.2 *m*m) to assess the UHI effect during daytime and nighttime in several cities and found it effective (Quattrochi and Ridd, 1994; Lo *et al.,* 1997; Quattrochi and Luvall, 1999). Quattrochi and Ridd (1998) applied 5-meter resolution TIMS (Thermal Infrared Multispectral Scanner) to study thermal energy responses for two broad classes (i.e. natural grass and urban/residential trees) and ten subclasses of vegetation in Salt Lake City, Utah. It is concluded that thermal responses for vegetation can be highly varied depending on the biophysical properties of the vegetation and other factors, and trees have a great effect on doming or mitigating the thermal radiation upwelling into the atmosphere. Satellite derived surface temperatures are believed to correspond more closely with the canopy layer heat islands, although a precise transfer function between the ground surface temperature and the near ground air temperature is not yet available (Nichol, 1994). Byrne (1979) observed a difference of as much as 20°C between the air temperature and the warmer surface temperature of dry ground.

Fractals have two basic characteristics suitable for modeling the topography and other spatial surfaces in the earth's surface: self-similarity and randomness. Self similarity refers to the well-known observation that the Earth's morphology appears similar across a range of scales (Malinverno, 1995). The concept of self-similarity also contains randomness, because the resemblance of the Earth's Morphology at different scales is not exact but statistical (Malinverno, 1995).

Weng (2001) used Surface radiant temperatures derived from Landsat TM Thermal infrared images of 13 December, 1989, 03 March, in Guangzhou, China. To examine the spatial distribution of surface radiant temperatures, transects were drawn and analyzed from each temperature image. Moreover, the fractals dimensions of these transect were computed using the divider method, so that the spatial variability of surface radiant temperatures caused by the thermal behavior of different land-cover types and landscape pattern characteristics could be better understood. The effect of urban development on the geographical distribution of surface radiant temperatures and thus on the UHI was also investigated. A choropleth map was produced to show the spatial distribution of the surface radiant temperatures based on the classification scheme of standard deviation. It was clear from the map that all the urban or built-up areas had a relatively high temperature, ranging from 21.17°C to 25.23°C.

Xiao et al (2006) in their analysis got their data from different sources: topography, Beijing census of 2000 and Landsat 5 TM scene. The following data processing methods were used.

Geometric correction: Geometric image correction was performed using corresponding ground control points in the GIS layer. The nearest-neighbour method of resampling was employed, resulting in a root mean square value of less than 1 pixel. The geometrically corrected image was used as "master" for the geometric correction of all other data sets.

Calculation of SRT and NDVI: Surface radiance temperature (SRT) was derived from the corrected TM TIR band (10.4~12.5 μm). The following equation was used to convert the digital numbers into absolute radiation luminance (Li, 1998)

$$R_{Tm\,6}\,(R_{max}\text{-}\,R_{min})\;255\;{}^*DN+\,R_{min} \qquad (1)$$

Where, R_{TM6} is the spectral radiation luminance, R_{max}=1.869 (mW*cm^{-2}*sr), R_{min}=0.153 4(mW*cmP^{-2}*sr);

The radiance luminance per unit spectral range:

$$R_b = R_{TM6}/b, \qquad (2)$$

where b is effective spectral range (sensor's response ≥50%), b=1.239μm. R_b was converted into effective at-satellite temperatures T by:

$T = K_1/\ln(K_2 / R_b + 1)$ (3)

where K_1, K_2 are calibration constants. For Landsat 5 TM the

constants $K_1 = 60{,}776$ mW*cm^{-2}*sr^{-1}*µm^{-1} and $K_2 = 1260.56$

Temperatures were converted from degree Kelvin into degree Celsius for simpler handling. Normalized Vegetation Index (NDVI) is one of vegetation indices which depicts the amount and nature of vegetation cover. It was retrained for each pixel in the composite product according to the following equation:

$$NDVI = \frac{ir - r}{ir + r}$$

Where, *ir* is the pixel value in the infrared band and *r* is the pixel value in the red band.

On the base of Beijing 2000 Population Census and Beijing township boundary, using zonal attributes in ERDAS Images, each township was calculated the mean temperature, mean land use/cover ratio and mean NDVI. The results were stored in a data base which was the basis for all statistical and spatial visualizations. The result of the analysis showed that the shape of the UHI pattern was almost concentric and the temperature values increased from outskirts towards the inner urban areas. In the center of Beijing within second ring road, the mean SRT was highest (23.28), but it was only 19.72 in the exurb area.

Basara et al (2007) in their analysis of the Oklahoma City urban heat islands utilized two main datasets collected prior to and during Joint Urban 2003. The former included temperature values collected from several PWIDS (Portable Weather and Information Display Systems) stations deployed within Oklahoma City on traffic poles and observations from six Oklahoma Mesonet sites for the period spanning 1 July 2002 until 30 April 2003. The second dataset focused on the Joint Urban 2003 (Allwine, et al, 2004) period and included PWIDS and Oklahoma Mesonet data as well as observations collected from 37 HOBO temperature data loggers installed across Oklahoma City at a height of 2 meters. The results from this study demonstrated a mean UHI of 1-2 Celsius at the 9-meter height which persisted regardless of time of year. However, the observations collected at 2 meters during JU2003 revealed a strong UHI signal during the overnight period and a weak urban cool island (UCI) signal during the daylight period.

Akinbode et al(2007) in their work 'impact of urbanization on soe atmospheric variables in akure,Ondo state, Nigeria' used temperature and relative humidity data from 1992 to 2001 which were obtained from three meteorological stations and daily measurements taken along primary roads for

2 weeks. The result showed that the city characterized annual mean temperature, which ranged between 26.2^{o}c and 30.4^{o}c, and minimum and maximum temperature that varied from 12.3^{o}c to 26^{o}c and 22.5^{o}c to 39.6^{o}c, respectively.the relative humidity ranged between 27.5% and 98.2%.The study showed that urban hat island was intense around the central business district.

CHAPTER 3: RESEARCH METHODOLOGY

3.0 Introduction

Urban development usually gives rise to a dramatic change of the Earth's surface, as natural vegetation is removed and replaced by non-evaporating and non-transpiring surfaces such as metal, asphalt, and concrete. This alteration will inevitably result in the redistribution of incoming solar radiation, and induce the urban-rural contrast in surface radiance and air temperatures. The difference in ambient air temperature between an urban area and its surrounding rural area is known as the effect of urban heat island (UHI). Given the relationship between air temperature, surface radiant temperature, and the texture of land cover, the impact of urban development on the UHI can be examined.

Urbanization which is one of the major components and a factor of development has its effect on the environment, but the magnitude of this effect largely depends on the way in which it is carried out.

The destruction of the natural environment by human activities such as deforestation and devegetation, creation of impervious surface such as roads, pavements, buildings, etc., results in irreversible changes, loss of habitat, increased flooding magnitude, etc.

One of the problems of urbanization is the change in the local climate, the days are hotter and nights warmer than they originally were before the advent of urbanization. This phenomenon has been called the urban heat island (UHI) effect which is the result of two main features of urban area

First, buildings, roads, paved surfaces store heat during the day, which is then released slowly over the evening due to the thermal properties of the surface materials and the building geometry which traps the heat stored during the day. The second contributing factor to the UHI is due to the artificial heat released into the urban atmosphere by combustive processes from vehicles, industrial activity and the heat that is released from commercial and domestic air conditioning. These lead to an increase in the temperature which in turn causes discomfort to the residents living in the affected area.

The aim of this study therefore is to verify how the activities of urbanization affect local climates. This will be done by:

(a) Reviewing the land use map of the study area

(b) Land use and land cover classification, to determine which area is used for commercial, residential, industrial and institutional purposes.

(c) Reviewing temperature and rainfall records of the study area during the pre-urbanization (1983-1987) and post-urbanization (2000-2004) period from the Nigeria Meteorological Agency (NIMET) located in the study area.

(d) Reviewing satellite images of the pre- and post- urbanization periods of the study area which are in the custody of the Abuja Geographical Information Systems (AGIS).

(e) Analyzing and correlating the change in the land use with the temperature records.

The study aims to create awareness of the adverse on the effect of urbanization on the local climate and to suggest the best possible way to reverse such trends. It is possible to have an "urbanized cool" area if only the right mechanisms are put in place.

Allied to this goal is the prospect that the results from this research can be applied by urban planners, environmental managers and other decision-makers, when determining how urbanization impacts the local climate and the overall environment of the FCT area. It is our intent to make the results of this study available to the appropriate authorities in order to help facilitate measures that can be applied to mitigate climatological or air quality degradation and in the design of alternate measures to sustain or improve the overall urban environment.

3.1.0 DATA COLLECTION

The data for the study were collected via meteorological parameters, satellite images and ground truthing

3.1.0.1 METEROLOGICAL PARAMETERS

Meteorological parameters such as the surface air temperature, rainfall amount and relative humidity of the study area between (1983-1987) and (2000-2004) which represent pre-urbanization and post-urbanization, respectively, were acquired from the Nigerian Meteorological Agency (NIMET).

The data were analyzed in order to determine if there has been any changes in these parameters and if so, to know the extent to which urbanization has affected them. The values of the rainfall amount were collected from NIMET while the average mean of the temperature was calculated from data obtained from NIMET.

3.1.0.2 SATELITE IMAGES

Satellite images from ikonos with resolution of 1 meter of the study area before and after urbanization showing Phase 1 which comprises of Wuse 1 and 2, Garki 1 and 2, Asokoro and Maitama were acquired from the Abuja Geographical Information System (AGIS).

The acquired satellite images enabled us to know the extent of development over the years and also the amount of vegetation cover and exposed soil that were available at the time of data collection.

3.1.0.3 GROUND TRUTHING

The essence of this was to confirm the satellite information with what is on ground.

3.2 METHOD OF DATA ANALYSIS

The meteorological data colleted from NIMET were plotted on a graph showing the mean monthly and yearly readings of the various data colleted, which enabled us to see the changes between the two periods. These were then related with the satellite images collected from AGIS for the different periods so as to analyze the surface changes that have taken place which might be responsible for changes in the local climate.

3.3 PROBLEMS ENCOUNTERED IN DATA COLLECTION

Apart from the limitations stated earlier in Chapter One, other problems encountered during the acquisition of the data include:

(a) The satellite images of the study area only show the Phase 1, also called Abuja Municipal Area which comprises of Wuse 1 and 2, Garki 1 and 2, Asokoro and Maitama. This incapacitated efforts to know the full extent of development occurring in the area.

(b) The temperature and relative humidity data from NIMET are incomplete. As a result, the mean value is higher than they ought to be, which would make comparison between the data from the 80's and 2000's highly unreliable since that of the 80's would appear to be higher.

The readings of the 80's were only that of day time, while that of the 00's were both day and night. Therefore only the day time readings were used in this project which would make it difficult to know the full degree of 'heat island' in the study area since heat island is known to be at its peak after and before sunset.

(c) The unavailability of data from 1980-1981 due to the fact that NIMET was not established as at that time, resulting in the use of only data from 1983-1987 and 2000-2004.

CHAPTER 4

4.0 DATA ANALYSIS

One of the effects of urbanization is the change in the local climate as the days are hotter and nights warmer than they originally were before the advent of urbanization. Urbanization gives rise to dramatic change on the earth's surface when natural vegetation is removed and replaced by non-evaporating and non-transpiring surfaces such as metal, asphalt and concrete.

The difference in ambient air temperature between an urban area and its surrounding rural area is known as the effect of urban heat island (UHI). As a result of the relationship between air temperature, surface radiant temperature and the texture of land cover, the impact of urban development on the UHI can be examined.

The data collected from the Nigeria Meteorological Agency were grouped into two periods: the pre-urbanization period\era (1983-1987) and the post-urbanization period\era (2000-2004). These years were chosen as a result of the rate of development that took place during those periods and the availability of data relating to those developments.

4.1 ANALYSIS OF METEOROLOGICAL DATA

4.1.1. RAINFALL DATA

Tables 4.1 and 4.2 show the mean monthly rainfall from 1983-1987 and 2000-2004, with the highest monthly amount of rainfall in the pre-urbanization period of 399mm recorded in August 1987 while the highest rainfall of 488mm in the post-urbanization period recorded in August 2002. This shows an increase of 22.3% of rainfall in the post-urbanization period over the pre-urbanization period. The mean monthly rainfalls for the pre-urbanization and post-urbanization periods are shown in Fig. 4.1 and 4.2, respectively.

The mean yearly rainfall readings (Table 4.3) shows that the amount of rainfall dropped from approximately 119mm in 1983 to approximately to 104mm in 1984, but there was an increase in 1985 and 1986 with readings of 127mm and 130mm, respectively. The amount then dropped with about 4mm in 1987, which had an annual rainfall record of 125.78.

During he post-urbanization era, there was an increase in the amount of rainfall between 2000/2001and 2001/2002 with records of 23mm and 35mm, respectively. However, there was a decrease in 2003 of about 14mm and again in 2004 of about 19mm. The fluctuation in the amount of rainfall during the post-urbanization period could be attributable to the stage of development in the study area. The rate and intensity of activities such as construction of buildings, roads, parks, could influence local environmental changes.

From fig. 4.3 it is seen that the highest amount of rainfall in the pre-urbanization period was 130mm while it was 162mm in the post-urbanization period, showing an increase of about 22.6%.

Table 4.1; Rainfall readings of the study area

RAINFALL READINGS OF THE STUDY AREA FROM 1983-1987

Month	1983	1984	1985	1986	1987
	RAINFALL	RAINFALL	RAINFALL	RAINFALL	RAINFALL
January	0.0	0.0	0.0	0.0	TR
February	N.R	0.0	0.0	0.0	7.40
March	1.30	10.20	58.70	79.60	9.40
April	7.40	68.10	37.10	117.90	22.60
May	142.50	104.50	184.80	155.10	66.00
June	190.90	204.90	251.20	139.70	202.90
July	262.30	240.50	219.30	235.50	159.50
August	312.80	221.50	355.30	338.30	399.40
September	335.20	279.60	386.70	288.60	347.50
October	53.20	112.60	28.30	180.70	168.90
November	3.30	0.0	0.0	23.20	0.0
December	0.0	3.40	0.0	0.0	0.0

Source: NIMET Agency Abuja. N.R (No Reading)

Table 4.2; Rainfall readings of the study area

RAINFALL READINGS OF THE STUDY AREA FROM 2000-2004

Month	2000	2001	2002	2003	2004
January	0	0	0	0	0
February	0	TR	0	23.7	11.5
March	TR	0.5	70.5	19.3	0
April	58.3	96	NR	82	64.3
May	138.1	105.5	82	167.7	222
June	143.8	152.6	227.7	340.9	310.7
July	276.6	354.2	450.3	482.7	255.5
August	214.8	333.4	487.8	257.6	302.6
September	255.2	245.9	353.1	249.5	164.9
October	110.1	101.6	263.3	82.2	202.7
November	0	0	6.9	63.3	5.9
December	0	0	0	0	0

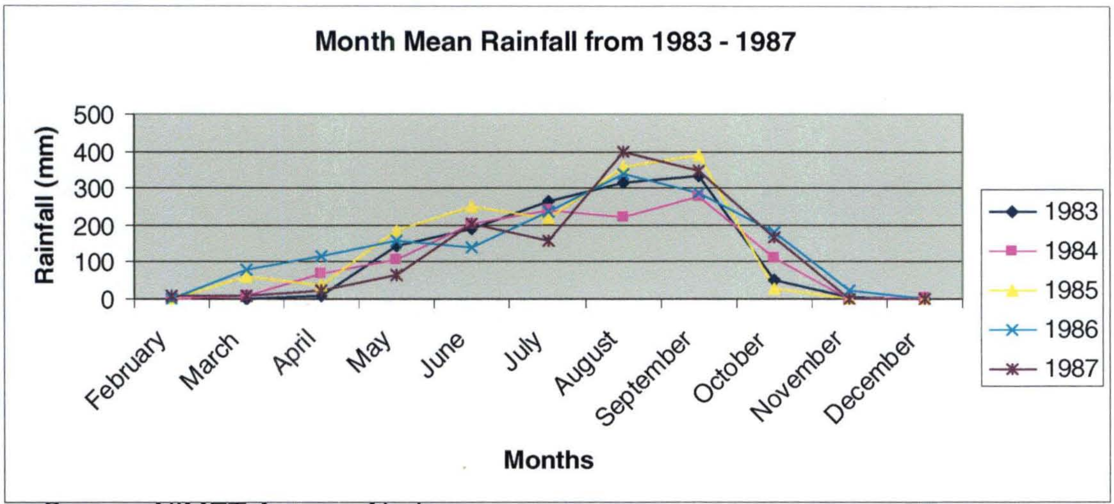
Source; NIMET Agency Abuja. NR (NO READINGS)

Table 4.3 YEARLY MEAN RAINFALLS FROM 1983-1987 AND 2000-2004

pre-urbanization		post-urbanization	
year	mean rainfall	year	Mean rainfall
1983	118.99	2000	103.51
1984	103.78	2001	126.34
1985	126.78	2002	161.8
1986	129.88	2003	147.41
19887	125.78	2004	128.34

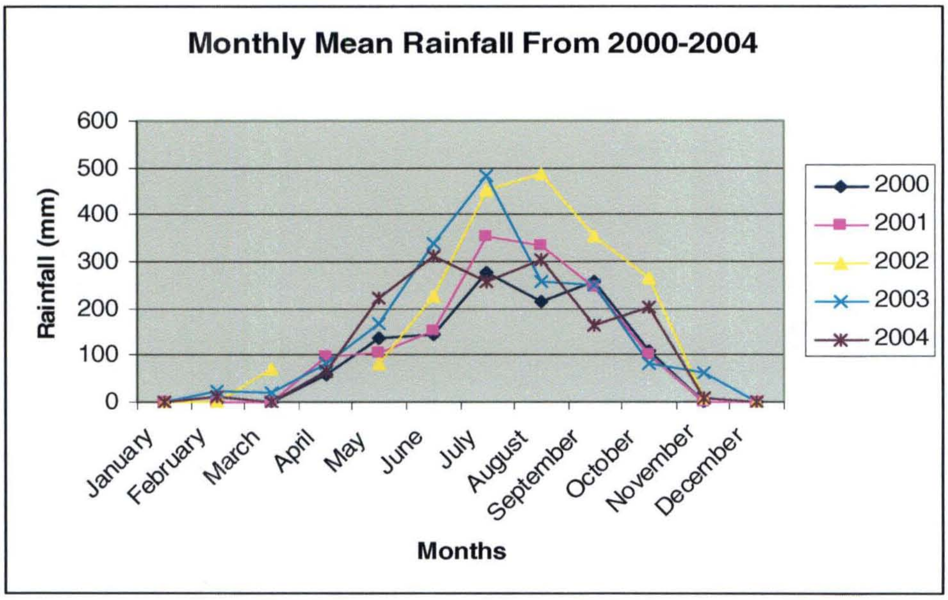
Source: NIMET Agency Abuja

Figure 4.1:Monthly mean rainfall of the study area from 1983-1987



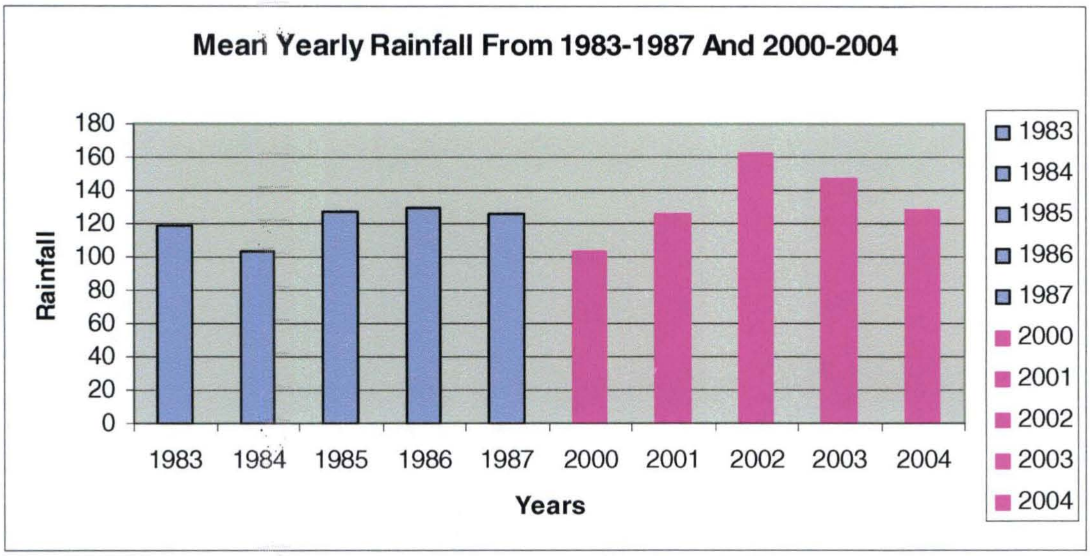
Source: NIMET Agency Abuja

Figure 4.2: Monthly mean rainfall of the study area from 2000-2004



Source: NIMET Agency Abuja

Figure 4.3: Yearly mean rainfall of the study area from 1983-1987 and 2000-2004



Source: NIMET Agency Abuja

4.1.2. TEMPERATURE DATA

The temperature data used in this study was the day time maximum surface temperature of the study area gotten from NIMET agency. Only the day-time readings could be used as a result of incomplete data (night readings) during the pre-urbanization period.

Form the available data (Tables 4.4 and 4.5), it is shown that the highest monthly temperature readings for the pre-urbanized period was 31.8^{o}c in March 1983 while that of the post-urbanized period was 33.6^{o}c in March 2004, showing an increase of 5.7%.

Table 4.6 shows the mean yearly temperature reading in 1987 of 28.5°c exceeded that of 2003 which had the highest record in the post-urbanization era with 0.1°c although it was seen that on the average the temperature readings of the post-urbanization period were higher than those of the pre-urbanization period with 0.18°c, showing an increase of about 0.6%

Table 4.4; Temperature reading of the study area from 1983-1987

TEMPERATURE READINGS OF THE STUDY AREA FROM 1983-1987

Month	1983 TEMPERATURE	1984 TEMPERATURE	1985 TEMPERATURE	1986 TEMPERATURE	1987 TEMPERATURE
January	26.80	28.20	29.20	28.20	28.40
February	N/R	30.60	30.00	30.50	30.60
March	31.80	31.30	30.40	29.50	30.70
April	30.40	30.10	29.50	29.40	31.90
May	29.80	27.70	28.30	28.20	31.50
June	26.50	27.50	26.20	26.90	27.00
July	25.30	26.20	25.00	25.10	26.40
August	25.30	26.40	25.60	25.20	25.70
September	25.80	25.80	25.50	25.60	26.00
October	27.00	27.30	27.20	26.70	26.90
November	28.90	28.50	29.10	27.20	28.20
December	28.20	27.30	27.30	27.00	28.20

Source: NIMET Agency Abuja

Table 4.5; Temperature reading of the study area from 2000-2004

	2000	2001	2002	2003	2004
Month	TEMPERATURE	TEMPERATURE	TEMPERATURE	TEMPERATURE	TEMPERATURE
January	29.62	28.18	28.26	29.32	28.7
February	29.7	24.34	31.3	31.38	31.24
March	32.3	32.2	31.74	32.34	33.68
April	30.66	30.58	30.2	30.42	30.38
May	29.24	24.8	29.74	29.84	27.78
June	26.76	26.82	27.38	26.46	26.78
July	25.4	25.42	26.02	26.14	25.8
August	25.38	24.92	25.28	25.26	25.44
September	24.46	25.66	25.7	25.78	20.4
October	27.22	28.22	26.9	27.22	27.5
November	29.28	29.74	28.66	28.48	28.34
December	28.32	29.64	28.7	28.24	28.72

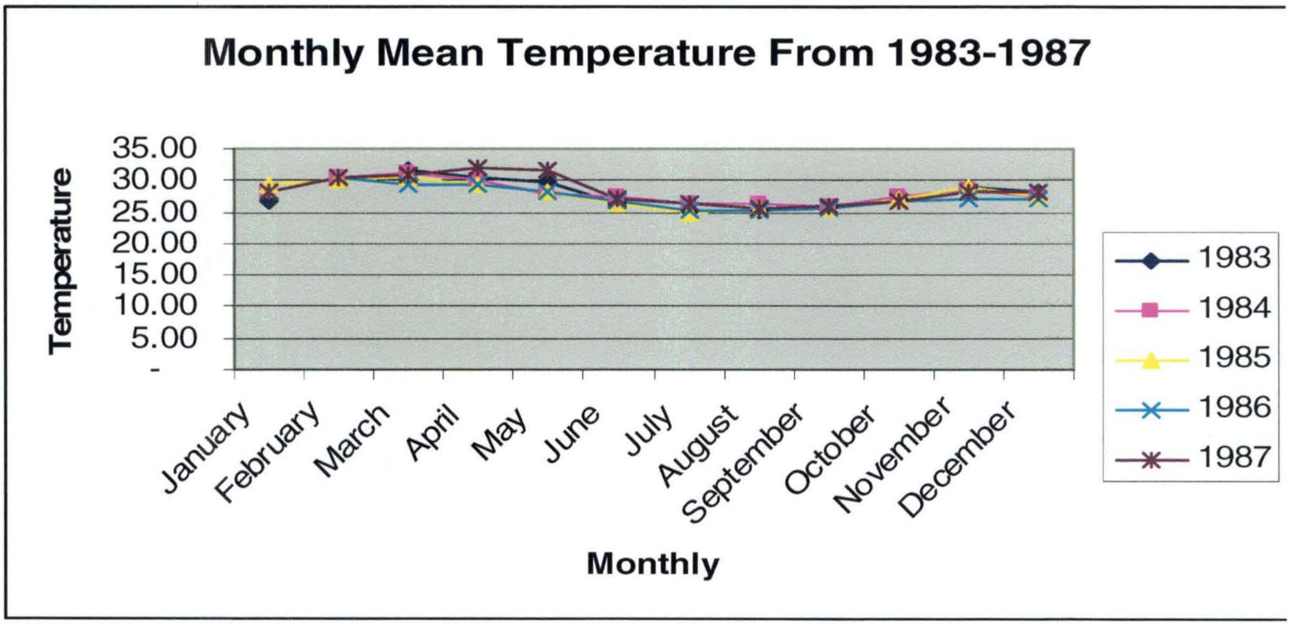
Source; NIMET Agency Abuja

Table 4.6; Yearly Mean Temperature Of the study area from 1983-1987 and 2000-2004

pre-urbanization		post-urbanization	
year	mean temperature	year	mean temperature
1983	27.8	2000	28.2
1984	28.1	2001	27.8
1985	27.8	2002	28.3
1986	27.5	2003	28.4
19887	28.5	2004	27.9

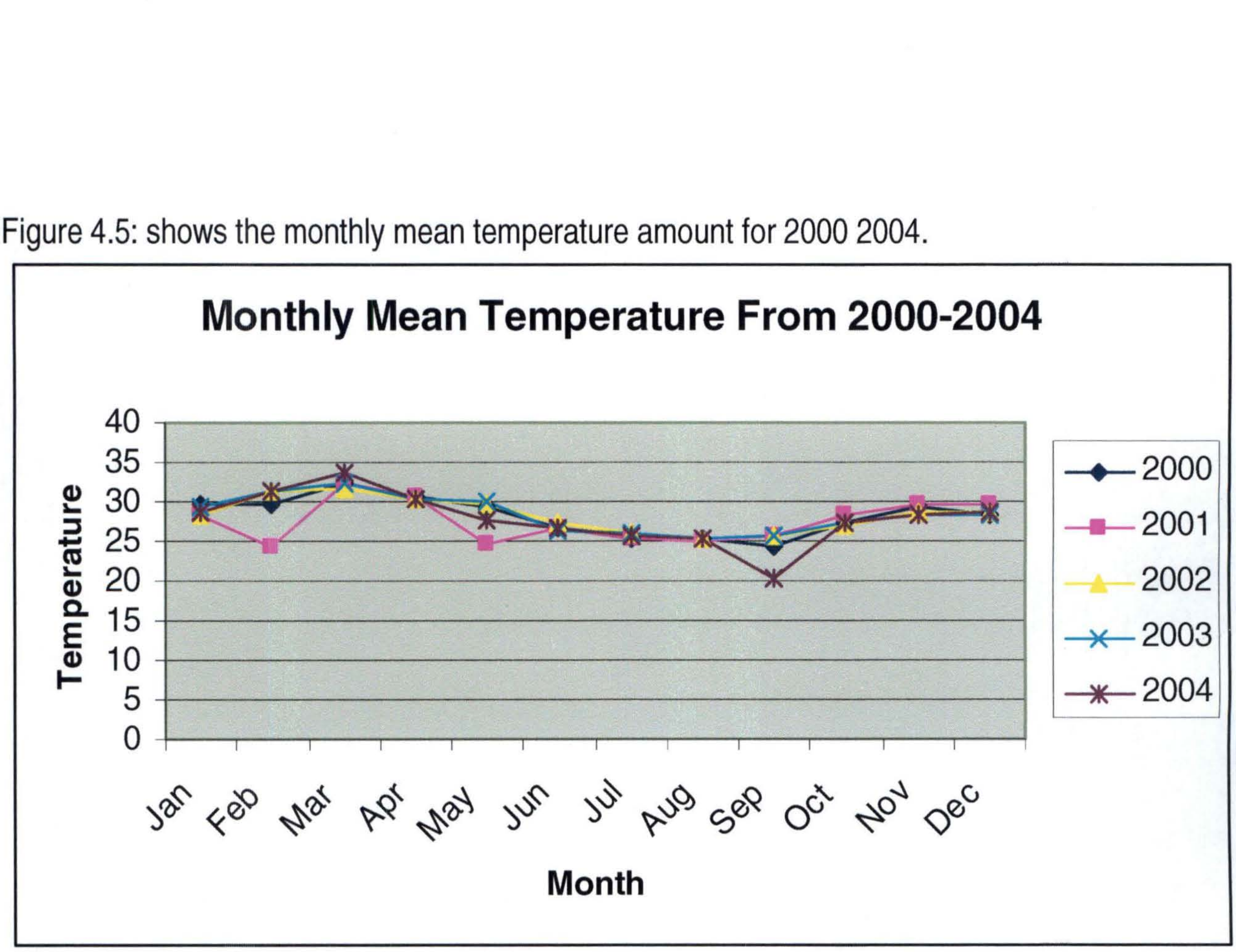
Source; NIMET Agency Abuja

Figure 4.4: shows the monthly mean temperature from 1983-1987



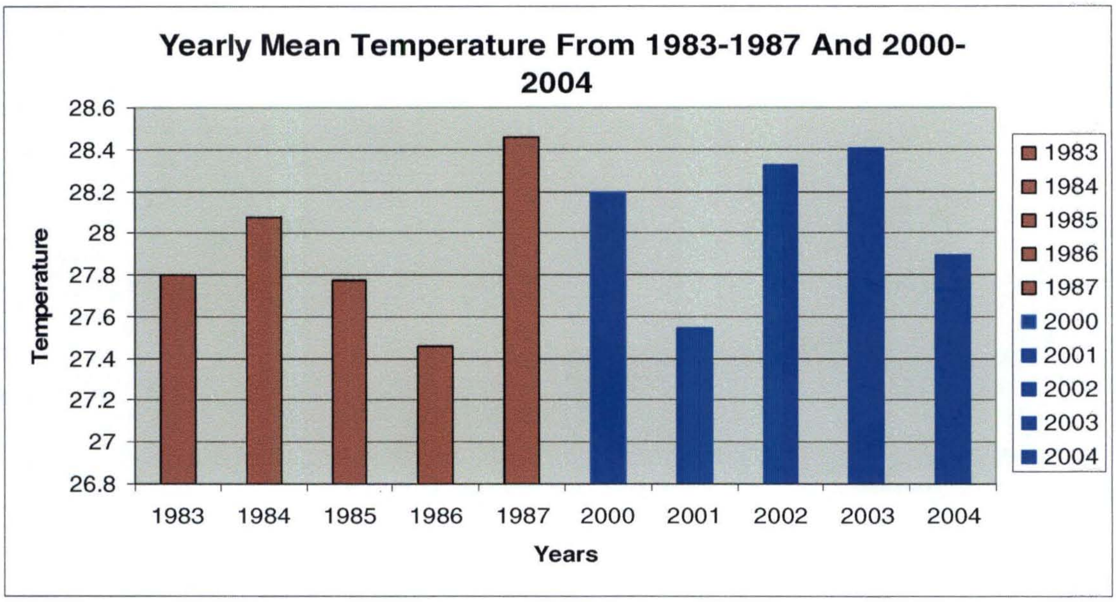
Source; NIMET Agency Abuja

Figure 4.5: shows the monthly mean temperature amount for 2000 2004.



Source; NIMET Agency Abuja

Figure 4.6: Yearly mean temperature of the study area from 19983-1987 and 2000-2004



Source; NIMET Agency Abuja

4.2 SATELLITE DATA

From the Ikonos satellite images obtained from a Julius Berger publication for the pre-urbanization period (Figures 4.7 and 4.8, respectively) it can be seen that less than 50% of the land in the study area had been tampered with for development, with about 10% of the study area shown in the satellite images as bare ground with little or no development. A comparison of the image for 1983 with that of 1987 showed that there were more exposed land surfaces in image of 1987 than that of 1983, which were signs of on-going development.

When satellite images of the pre-urbanization era are compared with those of the post-urbanization era the land use cover can be seen to have drastically changed from natural vegetation to developed structures. Fig 4.9 shows how closely built some of these areas were, with the percentage of natural vegetation cover reduced to barely 10% of the area covered by the image. Although areas such as the parks and gardens could be considered as green area, they are seen to have very few trees. Trees are needed to help control or regulate surface temperature.

At a closer resolution, the types of roofing materials can be seen, the most common being the asphalt shingle and aluminum roofs. The asphalt shingle had a predominant colour of black and the aluminum roofs were predominantly red and green colours. These roof colours have been known to have solar reflectivity (albedo) of less than 60% and with temperature rise greater than 30% (heat island group). These materials absorb and retain more heat in buildings due to their composition, resulting in the need for cooling devices.

It can also be seen from the post-urbanization image that there were a lot of road networks, probably partly resulting from the high congestion rate of traffic due to population growth in the study area. As a result, there are lots of dark new asphalt surfaces in the study area.

In an experiment conducted by Mel Pomerantz and Hashem Akbari in the Heat Island Group, the temperature of different pavement outside were measured at the same time of the day. It was revealed that dark, fresh asphalt had an albedo of 0.05 and a temperature of 51°c while the lighter, aged asphalt had an albedo of 0.15 and a temperature of 46°c. Following the conclusions reached by the Heat Island Group, it can be said that as a result of the newness of the roads in the study area, they were likely to absorb more heat and contribute to the UHI effect.

In comparing Fig 4.9 with that of the land use plan (Fig.1.3), there were indications that development had encroached into areas designated for vegetation cover, these areas as indicated in Fig.4.10.

If the satellite data are compared with meteorological data, it would be seen that as development increased and more land were converted into developed areas there was incremental rise in the meteorological parameter readings.

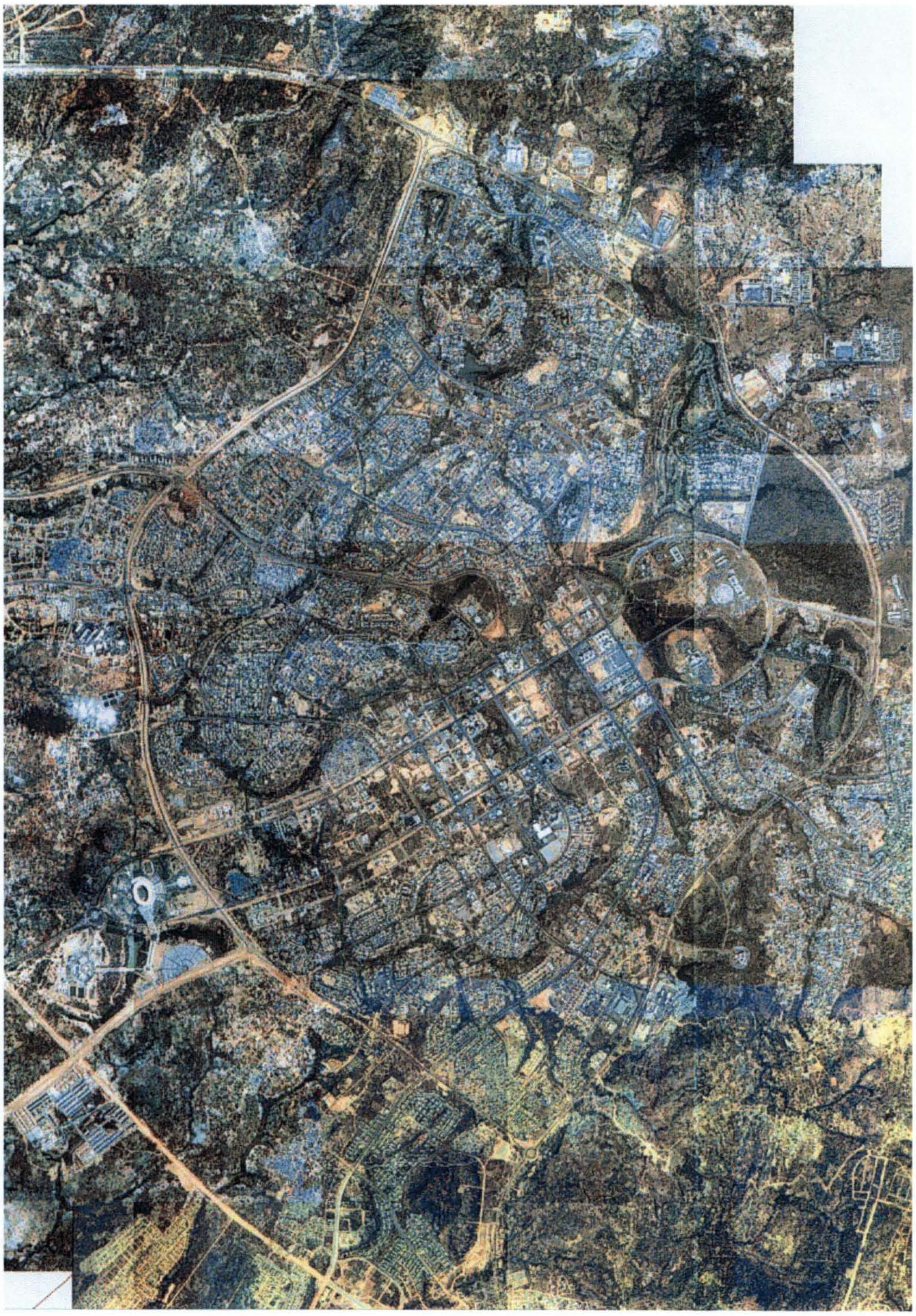
Fig 4.7: 1983 Satellite Image of the Study Area

Source: Julius Berger Journal, 2006

Fig 4.8: 1987 Satellite Image of the Study Area

Source: Julius Berge Journal, 2006

Fig 4.9: Satellite Image of the Study Area During Post-Urbanization Period



Source: Abuja Geographic information System (AGIS)

Fig 4.10: Map Indicating Areas Encroached by Development

Source: Abuja Geographic Information System (AGIS)

CHAPTER 5

5.1 SUMMARY

The change in urban land use for a long time has been and will continue to be one of the biggest human impacts on the terrestrial environment. At the start of the 1990s, there were only sixteen cities with population over 1 million; by 2000, there were 417(UNCHS, 2002). Building cities on previously vegetated surfaces modifies the exchange of heat, water, trace gases, aerosols, and momentum between the land surface and overlying atmosphere (Crutzen, 2004). In addition, the composition of the atmosphere over urban areas differs from undeveloped area (Pataki, et al 2003).

Urbanization has been known to alter the local climate as a result of the activities and changes that take place within the local environment. The days tend to be hotter and nights warmer than they originally were before the advent of urbanization. The warm nights are due to what has been called the Urban Heat Island (UHI) effect, the principal reason for the night-time warming is (comparatively warm) buildings blocking the view to the (relatively cold) night sky. Two other reasons that UHIs occur are changes in the thermal properties of surface materials and lack of evapo-transpiration in urban areas. Materials commonly used in urban areas, such as concrete and asphalt, have significantly different thermal bulk properties than the surrounding rural areas. This initiates a change in the energy balance of the urban area, often causing it to reach higher temperature (measured both on the surface and in the air) than its surroundings. The energy balance is also affected by the lack of vegetation and standing water in urban areas, which inhibits cooling by evapo-transpiration.

Other causes of a UHI are due to geometric effects. The tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. Another effect of buildings is the blocking of wind, which also inhibits cooling by convection.

As urban areas are often inhabited by large numbers of people, heat generation by human activity also contributes to the UHI. Such activities include the operation of automobiles, air conditioning units, and various forms of industry.

This project work aims to verify if activities associated with urbanization have had adverse effect on the local climate. This was achieved by reviewing the land use map of the study area, the land use and land cover classification to determine which area is used for commercial, residential, industrial and institutional purposes. Also the temperature and rainfall records of the study area during the pre-urbanization (1983-1987) and post-urbanization (2000-2004) period obtained from the Nigeria Meteorological Agency (NIMET) located in the study area were reviewed. The satellite images for the pre-urbanization and post- urbanization periods of the study area were collected from a publication by Julius Berger Nigeria Plc (Abuja at 30) and the Abuja

Geographical Information System (AGIS), respectively, were also reviewed. The changes in the land use were then compared with the meteorological parameters.

Data collected included, temperature and rainfall reading of the study area from 1983-1987 and 2000-2004, satellite images for the same period from a Julius Berger Nigeria Plc publication as well as from AGIS. The maps of the study area indicating the land use plan, and vegetation cover were obtained and a ground truthing was also done to confirm the satellite information with what was on ground.

The meteorological data were then plotted into graphs so as to easily see the trend of change. These were then compared with the ikonos satellite images to determine the rate of land use change which could have contributed to the changes seen in the meteorological data.

From the above analysis it was found that there has been an increase in the meteorological parameters over the last 20 years. The highest rainfall reading in the pre-urbanization period was 399mm in August 1987 while the post-urbanization peak rainfall was 488mm in August 2002. This showed an increase of 22.3% of rainfall in the post-urbanization over the pre-urbanization period. Similarly, the mean yearly rainfall in 1986 was 130mm while in 2002, it was 162mm, or an increase of 24.6%.

The highest daytime temperature of 31.8^{o}c during the pre-urbanization period was recorded in March 1983 while that of the post-urbanization period of 33.6^{o}c was recorded in March 2004, showing an increase of 5.7%

Comparing the satellite images and the meteorological parameter readings of the two periods, it is incontrovertible to state that as the vegetation cover and agricultural land were cleared and converted to developed areas, there was a noticeable increase in the meteorological parameter reading. To a large extent the conversion of land use can be said to have induced some increase in the local climate.

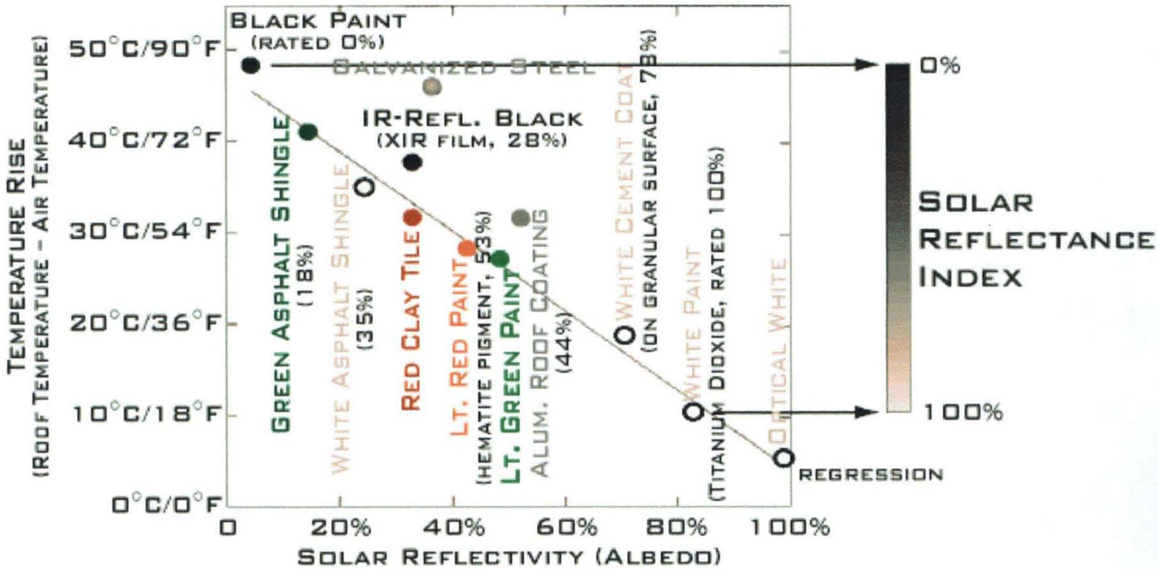
5.2 RECOMMENDATIONS

It is the view of this study that sustainable development can be achieved within the framework of urbanization within the study area. Sustainable development is described as an environment where development takes place with little or no impact on the local environment.

Sustainable development can be achieved by changing dark surfaces to light reflective surfaces and by planting trees. Dark surfaces such as black roofs on buildings absorb more heat than light surfaces, which reflect sunlight. Black surfaces in the sun can become up to 70°F (40°C) hotter than the most reflective white surfaces (urban heat island) and that excess heat is transferred to the building itself, creating an increased need for cooling. By using light coloured roofs, buildings can use 40% less energy (urban heat island group).

In an experiment conducted by the heat Island group (see Fig 5.1), it was found that different roofing materials had different solar reflectivity.

Fig.5.1 solar reflectivity of different roofing material



Source: Heat Island Group

Outdoor measurement on the 12 samples in Fig 5.1 above shows how the temperature rise in the full sun is inversely correlated with the solar reflectance values measured. Materials with emittance of approximately 0.9 fall near the straight line. Materials with lower emittance, particularly galvanized steel fall above the line, due to their limited ability to emit thermal radiation (Berdah and Bretz, 1997). As a result of this finding, Berdah and Bretz (1997) recommended the use of white cement coat on granular surface. The authors advised that the use of concrete, which is a common material used for roof tops, should be discourage

Berdah and Bretz (1997) also concluded that roads and parking lots frequently paved with black asphalt concrete (commonly called "asphalt") and other dark materials absorb most of the sunlight that falls on them. The energy of the sunlight is then converted into thermal energy which makes the pavements hot; thus, heating the air around them and contributing greatly to the heat Island effect. They recommended that materials which do not absorb so much heat should therefore be used for making pavement. Such materials reflect sunlight and last longer because they are not easily made thread-bare due to excessive heat.

Planting trees not only helps to shade cities from incoming radiation, they also increase evapo-transpiration, which decreases the air temperature. Trees can reduce energy loss by 10%-20% (urban heat island). It is therefore recommended that more trees should be planted in green areas and around buildings. This will greatly help to provide a cooler environment in the study area. In addition, government should ensure that green areas encroached by development are fully recovered and future reoccurrences of such practice prevented. It is also recommended that fences around residential and commercial buildings should be lowered and maybe supported by iron railings in order to increase the rate of wind flow which will in turn help to reduce the air temperature around those structures. Also high rise residential buildings should be approved by the appropriate authority so as to reduce the space occupied by buildings there by making room for vegetation cover.

5.3 CONCLUSION AND NEXT STEP

Urbanization, which is one of the major components and factors of development, has been said in the above introduction to have both positive and negative impacts on the environment. In order to create an urbanized area, a natural environment must be destroyed through deforestation and the creation of impervious surfaces. These and other human activities within an urban system produce many destructive and irreversible changes.

This study has established that an urban heat island has been created in the FCT as a result of urbanization. Detailed analysis of the effects of these changes on inhabitants of the study area may be the subject of future studies.

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