AN EVALUATION OF THE INFLUENCE OF LAND-USE/LAND-COVER CHANGE ON THE SURFACE TEMPERATURE OF FEDERAL CAPITAL CITY (ABUJA) USING REMOTE SENSING AND GIS

BY

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DECLARATION

I declare that the work in this project thesis entitled *an evaluation of the influence of land-use/land-cover change on the surface temperature of Federal Capital City (Abuja) using remote sensing and GIS* has been carried out by me in the department of geography. The information derived from the literature has been dully acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

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Usman I. Joy Date

CERTIFICATION

This project thesis titled **an evaluation of the influence of land-use/land-cover change on the surface temperature of Federal Capital City (Abuja) using remote sensing and GIS** by **Joy Isoyiza Usman** meets the regulations governing the award of the degree of MSC Climatology of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to God Almighty; my source of existence

ACKNOWLEDGEMENT

Starting this journey was a miracle and bringing it to a conclusion with this project is even a greater miracle. I am eternally grateful to the Almighty God for *this* miracle. I'm particularly thankful for journey mercies to and fro and for the strength to carry on even when it seemed so difficult.

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ABSTARCT

As cities rapidly develop to accommodate the growing urban population, a transformation in city landscape becomes inevitable leading to changes in land use and land cover, this has environmental and ecological consequences one of which is the changes observed in the micro climate of major cities. This study employed remote sensing and GIS in evaluating the influence of land use/land cover (LULC) change in the Federal Capital City (FCC) Abuja on surface temperature. A nineteen year study period was chosen with specific objectives to examine land use land cover changes within the set period, assess the growth of urban FCC and examine the effect of this growth on surface temperature and subsequently, urban heat island (UHI) development. Three Landsat TM and ETM^{+} images of the study area (1987, 2001 and 2006), all acquired in the dry season (September to December) were used to complete the study; Land use/ land cover analysis was carried out using IDRISI 17.0 and Land surface temperature of the various land uses for all three years was extracted from thermal band (6). LULC was found to increase (18.57%) in areal extent for built up between 1987 and 2001 while by 2006, a 2.31% decrease for built up is recorded, showing changes in urban growth and consequently, on surface temperature. correlation analysis was carried out and the degree to which UHI was present in the city established.

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CHAPTER ONE

INTRODUCTION

1.1 Background Of The Study

The climate in cities and other built up areas is altered most by the modifications humans make to the surface of the Earth during urbanization (Streutker, 2002). City surfaces are typically rougher and often drier as naturally vegetated surfaces are replaced by buildings and paved streets. Buildings along streets form urban street canyons that cause the urban surface to take on a distinctly three-dimensional character. These changes affect the absorption of solar radiation, evaporation rates, storage of heat, the turbulence and wind pattern of cities and the surface temperature (Voogt, 2004). With increasing urban population, human activities in cities also produce emissions of heat, water vapour and pollutants that directly impact the temperature in the atmosphere above cities; in fact, urbanization alters just about every element of climate and weather in the atmosphere above an urban area.

An urban area is an area with an increased density of human created structures in comparison to the areas surrounding it (John, 2009). These areas may be cities or towns, created and further developed by the process of urbanization. Urban areas are highly dynamic and are continually undergoing rapid changes, one of which is changes observed in land-use/land-cover (LULC) also known as land change. The knowledge of land use/land cover change is important to understanding certain occurrences in the earth's biophysical composition. It entails a conversion of natural types of land to uses associated with growth of population and economy, transforming the landscape from its natural form to impervious urban lands termed cities and towns. According to Detwyler and Marcus cited in Griffith (1976), "cities are

expressed as the nodes of man's greatest impact on nature, the places where he has most altered the essentially reserved resources such as land, air, water and even organisms. A city is the quintessence of man's capacity to induce and control changes in his habitat. Through urbanization, man has created new ecosystems within which the interactions of man, his works and nature are examples". This goes to say that urbanization as a necessary process that leads to the formation of what we now have as urban areas is not without its consequences, one of which is the modification of land surface and atmospheric boundary conditions that lead to a modified thermal climate which leaves the cities warmer than surrounding non urbanized areas.

Research from previous works (Adebayo and Zemba, 2002; Karl *et al*, 1998; Ifatimehin, 2007) has shown that urban areas differ substantially in their micro-climate. These differences are caused by the alteration of the earth's surface by human activities such as construction: which causes concrete, asphalt and glass to replace natural vegetation. The vertical surfaces of buildings added to the normally flat rural landscape and the release of artificially created energy into the environment from factories, industries and refineries also form a part.

As a result of all these activities, Changes occur in local weather and climate, one of the most familiar being the urban heat island (UHI) phenomenon (Landsberg, 1981). This is defined as the characteristic warmth of both the atmosphere and surfaces in cities (urban areas) compared to their non-urbanized surroundings (Voogt, 2004). The heat island is an example of unintentional climate adjustment when urbanization changes the characteristics of the Earth's surface and atmosphere. Though heat islands may form on any rural or urban area, and at any spatial scale, cities are most favored since their surfaces are prone to release large quantities of heat (lower evapo-transpiration due to paved surfaces). The urban heat island

effect is usually strongest at the city centre where population densities are highest and industrial activity is at a maximum, here, urban surfaces generally have a lower albedo (defined as the ratio of reflected radiation from the surface to incident radiation upon it), greater heat conduction and more heat storage than the surfaces they replaced.

Investigations concerning the thermal environment as demonstrated by Vasquez *et al*, 2009, require area-wide temperature information and satellite data is useful in providing such information. With the development of satellite remote sensing in 1960, great improvement in environmental sciences has been recorded (Sarka, 2004). The quality of tools and technology build up has led to radical changes observed in the field and one such technology is remote sensing. Remote sensing can be defined as the activities of perceiving, observing and recording (sensing) objects or events at far away (remote) places; it is the technology of acquiring information about the earth's surface (land and ocean) and atmosphere using sensors (e.g aircraft, balloons, space shuttle and satellites) onboard platforms (www.crisp.nus.edu.sg).

The data produced by this system can be analyzed for different purposes using one or both methods of image interpretation/analysis and the quality of these data sets lie in their resolution of which there are four types; spatial, spectral, temporal and radiometric resolutions. Sabins (1997) defines spatial resolution as the ability to distinguish between two closely spaced objects on an image. He stated that spatial resolution is affected by shape, size, arrangement and contrast ratio. Spectral resolution is defined as the sharpness of wavelength which is used to record object more clearly (Sutanto, 1995), while temporal resolution of a sensor system refers to how often it records imagery of a particular area and radiometric resolution defines the sensitivity of a detector to different strength as it records the radiant flux reflected or emitted from the terrain or target of interest (Jensen, 1996).

Geographic information system (GIS) is a powerful management tool used for capturing, modeling, analyzing and displaying spatial data (Worboys, 1995). It represents an amalgamation of database technology with computer assisted cartography (Bernherdson, 1992). Analysis is achieved across data layers in an object oriented programming environment, allowing spatial variables to be statistically compared and thus producing new spatial datasets beneficial to a range of applications such as applied sciences like climatology.

High resolution satellite images developed recently has brought remarkable improvement in the analysis of surface temperature. Detailed examination of surface layer heat island can now be conducted where brightness temperature information from satellite data together with satellite land use/cover data is extracted and becomes very useful to understanding surface conditions of urban areas. Thermal infrared remotely sensed data in the bandwidth of 10.4-12.5 μm, available from Landsat 4 and 5 Thematic Mapper and Enhanced Thematic Mapper (TM and ETM+), which have 60m resolution in the thermal region are widely used assess urban heat islands (Rahman, 2007).

1.2 Statement of the Research Problem

A reality facing the human race in this era is that majority of the world's population live in urban areas for the first time in history causing an unprecedented expansion of urban areas. For example, In Nigeria, the years 1980 to 2000 saw a 5% growth rate in urban population while total population growth was 30% (Knox and McCarthy, 2005 cited in Akpu and Anger, 2010), the FCT is not left out as it has been reported that some areas around Abuja have been growing at 20% to 30% per year causing Squatter settlements and towns to spread rapidly in and outside the city limits (www.fct.gov.ng/fcta) implying a high urban growth rate. This makes the demand for standardized land use and land cover data to increase as we seek to assess and manage areas of critical concern for environmental control such as flood plains

and wetlands, energy resource development and production areas, wildlife habitat, recreational lands, and areas such as major residential and industrial development sites.

Whereas urbanization has had positive impacts on the quality of life in many societies, the problems created in some regions such as Africa could easily prevent and undermine the accomplished or potential gains. Africa's rate and levels of urbanization are by far exceeding her absorptive capacity in terms of labour, shelter, sanitation, infrastructure, public health and environmental sustainability.

Thermal comfort, a projection of the overall temperature condition in a surrounding, defined as the condition of mind that expresses satisfaction with the thermal environment (ASHRAE, 1996 cited in Wong and Chen, 2009) is a necessary facet to a balanced human physiology. This comfort is farfetched in tropical Africa due to the extreme hot climates in the region. Acquiring thermal comfort means there should be a balance between human body temperature, which has to be maintained at a constant level internally and the environment. A constant heat exchange between the human body and environment gives the stable condition which in turn gives natural ventilation. Now, it is noticed that the high unpleasant temperature and relative humidity in the tropics interferes with this process and puts the region at a disadvantage, causing thermal discomfort which can slow the tempo of life of the inhabitants because increased temperature and humidity reduces the rate of evaporation of moisture from the human body especially in areas where there is little air movement. With this insight, the importance of the present study even in application to human health cannot be undermined.

Urban heat island is considered as one of the major problems in the 21st century posed to human beings as a result of human civilization (Liu *et al*, 2007). Accurate observation of surface temperature provides much information about surface climate thereby inputting to the

general database of urban heat island studies. However, the complexity of urban surfaces (buildings, roads, drainage, roof tops, farms, play grounds, gardens e.t.c), means that it is exceedingly difficult to obtain representative measurements of surface temperature because of the number of surfaces that need to be sampled. To get around this problem, remote measurements of surface temperature using instruments such as radiometers that measure the radiation coming from the surface are used. These instruments may be mounted on satellites, aircraft, tall towers, or on the ground. When corrections are made for atmospheric effects on the transmission of radiation to the instrument and also, on the reflectivity of the surface for radiation, radiometers provide images of the surface temperature (Gallo and Owen, 1999).

Several studies have been carried out to investigate the relative warmth of cities by measuring air temperature (also known as ambient temperature) through land based observations. For example; Nduka, 2011 used thermochron i-Button data-loggers to assess the urban canopy heat island variation and land use/land cover in Onitsha metropolis in the hot and dry season. His work was able to establish a significant variation in both spatial and temporal distribution of UHI in the metropolis. Abdulhameed, 2011 also conducted a similar study but in a different location (Kano) and over a different time frame (one year period). He used the same method and obtained similar results, which is significant spatio-temporal UHI variation for the location under study. Other works include those by Efe, 2004, which checked the impact of the urban landscape on rain water quality in Warri using thermo-hygrographs. The same instruments were used in the study by Adegoke, 2002, Aina, 1989 and ojo, 1981.

The method employed in these previous works can be both costly and time consuming while at the same time, is limited in its representation since it only reflects temperature surrounding a particular location at a given time (air temperature). It is important to note that air temperature data, obtained from meteorological archival records are inadequate for urban climate studies. This is especially true in the case of Nigeria where nearly all meteorological

stations in the country are usually located at airports, often cited on the periphery of cities. These locations could serve as 'rural' sites but the problem of obtaining climatic data representative of the urban site still arises because of the heterogeneous nature of urban surfaces. The present study intends to breach this gap by using remote sensing technology to obtain surface temperature data which is more representative of the urban area under study. Also, a gap is left open by paucity of climate information on the nation's capital Abuja. This requires momentous attention, hence, the present study which will contribute its quota to the national data base.

1.3 Study Aim and Objectives

The aim of this study is to evaluate the effect of land-use/land cover changes on surface temperature in the Federal Capital City using remote sensing and GIS

This aim will be achieved through the following objectives which are to:

i. examine land-use/land cover changes within the study period.

ii. examine the rate of urban growth in the area.

iii. assess the urban surface temperature intensities of the various land use categories of the study area through the study period.

iv. examine the impact of urban growth on surface temperature and urban heat island phenomenon.

1.4 Justification of the Study

Cities in Africa are rapidly expanding. More than 50% of the populations in many African countries live in urban areas (US census bureau, 2009). In response to this development, Abuja, a sub-Saharan African capital has in the last three decades, doubled in urban land-use extent, giving rise to a change in land cover.

The emergence of urban heat islands in tropical cities cause's higher temperatures which in turn, not only causes thermal discomfort but also, water pollution and even air pollution. Atmospheric pollution can be aggravated by accumulation of smog which is a combination of high temperature and air pollutants (NRDC, 2007). The level of suspended particulate matter (SPM) in cities of tropical areas is usually always exceeded with guidelines by a factor of two while the level of concentration of SPM exceeds by four (Wong and Chen, 2009). Unlike temperate cities where the effects can be positive, the tropics suffer negative impacts most times, especially as the level of energy consumption is affected. The main consumer of energy in tropical cities is air conditioning systems. As affluence is increasing in societies, the use of air conditioners (AC) has become prevalent and this increases the demand in electricity consumption. In a commercial building in a tropical urban area, air conditioning system will consume up to 50% of the total energy consumption in the building. This is shown in a study conducted in Singapore; where it was discovered that electricity consumption increased from 25,858Gwh in 1998 to 41,017Gwh in 2007; this represents an annual increase o f 5.3%. These, coupled with so many other adverse effects highlighted in the cause of this work necessitate the study of surface temperature for urban related issues.

The information produced from this analysis will go a long way in adding value to the database of the FCT metropolitan planners when issues regarding human comfort, health and city geometry need to be addressed and if adequately updated, the result may be a baseline data to them for monitoring temperature variation, pollution and impact of development.

1.5 Scope of Study

Several factors influence urban heat island development in cities but this study is focusing on land use land cover change and its influence on urban temperature in the FCC. It will span through the four corners of Abuja municipal area council (Garki, Maitama, Wuse and

Asokoro).. The period of study is from 1987 to 2006 with available Landsat images as primary source of data for the area. Remote sensing/GIS technology and geo-statistical analysis constitute the method used for derivations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This research focuses on surface temperature (surface urban heat island), as it is an important quantity that plays a role in many environmental processes; it also serves to measure urban heat islands (UHI). The study intends to fill the void left open by previous studies in the use of remote sensing/GIS as conventional methods of carrying out urban climate studies. It will determine the influence of urban development in Abuja on its local climate over the years by looking at the development of surface urban heat island (SUHI), as locally altered urban climates that have existed for many years, provide us with some insight into how to respond to large scale climate change, therefore making the study of urban climates increasingly important.

This chapter centers on surface temperature and subsequently, the urban heat island phenomenon. An appraisal of the many different works that have been done on urban heat in the past from different areas across the globe also forms a part. It starts by defining significant requisites related to surface urban heat islands and proceeds to relate all terms. There are several factors contributing to the development of UHI (solar reflectance, thermal emissivity, heat capacity of materials and urban geometry), surface cover; ie, land use/ land cover change is the factor considered here. The reason for this choice being that it's the one factor that relates directly to and affects communities and which they also to a large extent, can control with available technologies. The review also takes on the different types of UHI, methods for identifying them and factors that contribute to their development.

2.2 Land use/Land Cover Change and Urbanization

There are many different sources of information on existing land use and land cover and on changes that are occurring. Most planning agencies make use of detailed information generated during ground surveys which involves enumeration and observation. Interpretation of large-scale aerial photographs have been used widely for the purpose and satellite imagery also offers another source of getting accurate information on land use/ land cover and on detecting changes that occur (Anderson *et al,* 1976).Land use affects land cover and changes in land cover may or may not translate into urbanization. Land in very simple terms can be defined as a primary input and factor of production which is not consumed but without which no production is possible (www.businessdictionary.com), it is said to be a resource that has no cost of production and though its usage can be switched from a less to more profitable one, its supply cannot be increased.

By its availability for and as a factor of production, land must be put to use to make meaning, hence land use being defined as the human use of land; it involves the management and modification of natural environment into artificial environment such as fields, pasture and settlement. It has also been defined as the activities and inputs that people undertake in a certain land cover type to produce, change or maintain it (FAO, 1997). Defining land use in this way establishes a direct link between people's actions in the environment and land cover and examples of land use include urban development, agriculture, forestry, recreation and mining. In difference to this, land cover refers to the observed biophysical cover of the earth surface, in broad terms, it describes vegetation and man-made features (FAO, 2003), meaning that areas with features as bare rock or soil and water bodies will be describing land itself rather than land cover. However, science in practice usually describes those aspects under the term "land cover", which is the case in the course of this work.

According to Gabe (2009), a major effect of land use on land cover in times past was deforestation, especially in temperate regions, more recent significant effects of land use include, soil erosion, soil degradation, salinization, desertification and urban growth which is the focus in this research. Basically, land use/ cover can be altered by either of two forces; Natural such as weather, climate fluctuations and eco system dynamics and anthropogenic which largely points at human influence. An alteration in land use produces a change in land cover hence the term land use/ land cover change, this can be detected principally by the use of field survey and analysis of remote sensing imagery with a foremost result of the change being urbanization

The loss of marginal land around cities in most regions of the world as a result of urbanization has become a topic of global attention (Zemba, 2008). Researchers such as Wu and Jennerete (2001), , Longely *et al* (2001), Weng and Lu (2004) all carried out extensive studies in an attempt to bring further attention to the situation by focusing on the social and eco-system implications associated with urbanization.

Urbanization which involves changes in land use and land cover is one of the dominant demographic trends of our time; in 1900, 150 million people lived in cities, by the year 2000, it was 2.9 billion people, a 19-fold increase and according to IAUC (2006), the year 2020 will see more than half of the world's people living in cities,making us for the first time, an urban species.Taking a cursory look at the situation in Nigeria, approximately 50% of Nigerians are urban dwellers with at least 24 cities having populations of more than 100,000 (US Census Bureau, 2006).

The whole concept of urbanization has reached an important milestone in recent times: Even when it seems that majority of the Sub-Saharan population still live in rural areas, the average annual urban growth rate of 4.58 % between 1980 and 1993 has been more rapid in these

areas than in any part of the world and is cause for great alarm (World Bank, 1995a). Globally, the estimated annual urban population growth rate of 1.78% is nearly twice as fast as that of the global population and if this trend continues, 5 billion people out of a total world population of 8.1 billion will reside in cities by 2030 (Van de Voorde *et al*, 2008).

With this much increase in population density, the cities have had to expand both in size and features bringing about a total change in morphology; agricultural land is converted to industrial layouts, open spaces are built on, forests diminish as more land is needed for housing/shelter to accommodate people and property, and vegetation (e.g. grassland for grazing, park land etc) goes extinct in some cases. It is no surprise then, that these urban areas are conflict zones between economic growth, society and the environment. Cities suffer from many environmental problems: ranging from higher temperatures in the form of heat islands to air pollution, traffic jams and high levels of ambient noise, empty houses and derelict lands all which undermine the quality of life of city dwellers and imprint a negative view of urban life.

2.3 Land Use/Land Cover Classification Systems

Classification is an abstract representation of the situation on the field using well defined diagnostic criteria known as classifiers. It is the ordering or arrangement of objects into groups or sets on the basis of their relationship (Sokal, 1974). A classification describes a systematic framework with the names of the classes and the criteria used to distinguish them and the relations between the classes, it therefore involves definition of class boundaries that should be clear, precise, and possibly quantitative, based upon objective criteria.

Analyzing and mapping land use/land cover involves to a large extent the process of developing a classification system suitable to the purpose of the researcher since in practice, the most useful classes are those that match the informational needs of the map user. Usually,

the land use scheme is adopted from one of the standard schemes available or carved out and tailored to suit the needs of the research work in progress.

A few of the land use/land cover (LULC) classification systems that will be extensively assessed in this chapter include; traditional (qualitative) system, parametric (quantitative) method and the Andersons classification scheme.

- **Traditional systems:** Often qualitative assessments depending largely on experience and intuitive judgment; they are real empirical Systems that involves classifying the parcel of land under investigation based on observation and experiment (Rosa and Van diepen, 2002), Qualitative land evaluations may be as simple as narrative statements of land suitability for particular uses, or they may group the land in a subjective way into a small number of categories or suitability classes. This assumes a thorough knowledge of the optimum land conditions and of the consequences of the deviations from this optimum. These relatively simple systems of land evaluation depend largely on experience and intuitive judgment and are therefore, real empirical systems. Traditional method is best used in suitability assessment of land for agricultural purposes or for natural resource evaluation as has been used widely by the USDA, with its adaptations used by British Land Use Capability Classification, the Canadian Land Capability Scheme, and the Dutch system (Rosa and Van Diepen, 2002) .
- **Quantitative (parametric) method:** It involves following a priori reference to spatial dynamics, it considers the available datasets for classification and the necessity to define coarse generic classes in order to derive generic response functions to be investigated and parameterized for case study regions (Wolfgang et al, 2008). Morphology, typology and development dynamics are key indices to this classification scheme. Parametric systems allocate a numerical value on the most

significant land characteristics, the account for interactions between such significant factors are expressed through a simple multiplication or an addition of single-factor indices, in this case, correlation and multiple-regression analyses are used to investigate the relative contributions of the selected land characteristics on land classes (Rosa and Van diepen, 2002). Multiplying systems assign separate ratings to each one of several land characteristics and then take the product of all factor ratings as the final rating index. One advantage of this system is that any important productivity factor controls the rating while a second is that the overall rating cannot be a negative number. The system is not without its limitation which is that the overall final rating may be considerably lower than the ratings of each one of the individual factors, thereby making it appear conflicting.

- **Andersons classification scheme:** It is the most widely used in the United States and elsewhere especially since most of the other classification systems can only be used effectively if the researcher has gained some experience in the practice of land survey. Generally, it is regarded as impractical to rely on any other method of data collection for wide area coverage except the use of aerial photo and other remote sensing imagery. Remote sensing has been employed severally in land use and land cover analysis since the origin of aerial photographs. Large volume of data have been turned out from different parts of the world both at local and state levels using aerial photos acquired by earth orbiting satellites at varying time intervals. In 1970, the United States geological survey (USGS) began a program for mapping land use/land cover in the United States using aerial photography with a process that included producing a land use/cover system.

  A modification of this system devised for the USGS program has become one of the most widely used classification system for land use maps prepared by the

interpretation of remotely sensed imagery (Anderson et.al, 1976) and it is called the Andersons classification scheme which is prepared from high resolution remotely sensed imageries. Remotely sensed images lend themselves to accurate land cover and land use mapping in part because land cover information can be visually interpreted more or less directly from evidence visible on aerial images and objects can be seen in context of the neighboring features (Lunneta and Elvidge, 1998). In land use classification, it is important to use systems that are compatible with others that have been used in the past, an important factor if maps and data are to be compared over time (i.e change detection).

The Andersons scheme provides one of the best and most widely applicable outlines for structuring classification; it has more general categories that can be used as a frame work in the production of the succeeding categories, it also has a hierarchical structure that lends itself to use with images of differing resolution and scales ranging from 1:12,500 and larger to 1:250,000 and smaller. It is divided into three categories; level 1, tailored for use with broad scale, coarse resolution imagery (e.glandsat imagery) with examples as urban, agricultural land, water, barren land and others. Levels II and III are composed of more detailed classes that can be interpreted from large scale, fine resolution images with the level three mostly left for the analyst to specify as required by the study. Level II category are usually a sub-division of level I and examples are industrial lands, residential high and low, cropland and pastures, beaches, playgrounds and so on while level III categories are most times devised by the researcher in local studies which need thorough detail. Within the scope of this study, Level I category, adopted from Andersons scheme is applied.

Other land use/land cover classification systems, like the enumeration technique and statistical technique (an interplay between qualitative and quantitative techniques) exist but they can only be listed here as they are not so relevant to the study.

2.4 Land Use/Land Cover Change Detection

Remote sensing can be used to detect locations of change related to land use/cover. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Ridd and Liu, 1998 in Zemba, 2003). Land cover change is one of the most immediate impacts of the human use of land, with significant environmental consequences; natural habitats are distorted, resources are modified, and exchanges between the land and atmosphere are altered in ways that can potentially have impacts over extensive regions (Eastman *et al*, 2005). Although land use and land cover change has long been a focus of geographers like Von Thunen and Ricardo, it is only recently that remote sensing and GIS have become a critical ingredient to the understanding of land cover change.

According to Singh (1989), methods for remote sensing land-use change detection can be divided broadly into two categories; Post-classification change detection which refers to techniques where two or more predefined land-cover/use classifications exist from different points in time, and where the changes are detected, usually by subtraction of the datasets (image differencing). The technique is straightforward but also, very sensitive to inconsistencies in interpretation and classification of the land categories, Pre-classification change detection which is the second refers to a more sophisticated and biophysical approach to change detection. Differences between spectral response data from two or more points in time are compared by statistical methods and these differences are used to provide information on land-cover/use changes. This approach is less sensitive to interpretation inconsistencies and can detect much more subtle changes than the post-classification approaches, but is less straightforward and requires access to the original remote sensing

data. A study conducted by Shaoqing and Lu (2008) using ERDAS IMAGIN made a detailed comparative study of three different methods (image differencing, image ratio and post classification) of remote sensing change detection; panchromatic image of Beijing (2001 and 2002) were used for image subtraction method while a composite of three bands of the image of Wuhan (1995 and 2000) are the data used in the post classification method. They were able to outline the principle underlying each method while also comparing the advantages and disadvantages of all three methods discussed.

A post classification change detection method (image differencing and cross tabulation) is employed in this study since it appears to be the most widely applied change detection algorithm for a variety of geographical environments given the constraint of data availability in the original form. It involves subtracting one date of imagery from a second date that has been precisely registered to the first (Zemba, 2003), it has been used previously with successful results by Yang (2002), Yuan et.al (2005), Lu and Weng (2005),Weng et.al (2006), and Ikesumoran (2009).

2.5 Surface Temperature in Urban Areas

The surface temperature of a place is a measure of the state of energy exchange at the surface. It combines the influence of a number of processes that occur such as radiative exchange, subsurface heat storage, evaporation and turbulent heat fluxes. These are all factors that are derivatives of surface cover types and interactions.

The knowledge of surface temperature is important for urban climatology and human health. With rapid industrialization and growth in the sub-urban areas, there is a general warming and change in weather conditions, measuring surface temperature is very important not only to obtain boundary conditions of the atmosphere but also to understand the environmental conditions necessary for human beings, for example, an estimation of the night-time thermal

environment is very valuable in agriculture to prevent cold damage and to forecast crop yield (Yates et al. 1984)

Urban areas are always intercepting and absorbing radiation on their vertical surfaces making Surface temperature an important parameter in the characterization of energy exchange between the ground surface and the atmosphere (Voogt, 2004). The ground surface here means the materials on ground or land cover which marks out or delineates the area under focus as urban or rural. In difference to air temperature which is measured at the canopy and boundary layer of the atmosphere in cities thereby giving the temperature of the urban atmosphere, surface temperature refers to the relative warmth of urban surfaces, it is a measure of the energy emitted or reflected from the various land surfaces, a basic reason why it is also termed land surface temperature (LST).

Land surface temperature is an essential factor in the field of atmospheric science as it combines the result of all surface-atmosphere interaction and energy fluxes between the ground and the atmosphere making it a good indicator of the energy balance at the Earth's surface (Wan and Snyder, 1996). LST controls the surface heat and water exchange within the atmosphere and it influences the overall weather and climate patterns which is why efforts are being made to study its development. Estimation of LST from satellite infrared radiometers has proven useful and most studies have focused on the use of polar orbiting satellite systems because of their high spatial resolution (Sun *et al*., 2004). Some previous work done by Brown (1974); Kawashima (1986); Asrar *et al*. (1988); Holbo and Luvall(1989) used thermal-infrared images derived from aerial multispectral scanner data. Heat Capacity Mapping Mission satellite data was used in each of these cases; Price (1980); Carlson et al. (1981); Gurney and Hall 1983, while NOAA AVHRR data was used by Carlson *et al.* (1977); Matson *et al*. (1978); Price (1984); Kidder and Wu (1987); Balling and Brazel(1988); Roth *et al*. (1989); Ottle and Vidal-Madjar(1992); Platt and Prata(1993);

Johnson *et al*. (1993), and Landsat TM data was applied in Tokyo by Honjo and Takakura(1987); Kawashima (1991).

2.6 Thermal Remote Sensing of Urban Areas

All objects with temperature above absolute zero emit thermal radiation and thermal remote sensing has become increasingly important because it conveys information not easily derived from other forms of remote sensing (Campbell, 2002). Remote sensing in the mid and far infrared (7-18um) uses imaging devices which are different from cameras and films used in the visible and near infrared, this is because the interactions of the mid and far infrared with the atmosphere is different from that of the shorter wavelengths, also different is the kind of information sort and acquired. Variations in emitted energy in the far regions of the spectrum provide information on surface temperature and thermal property of different surfaces such as soil, rock, vegetation and man-made structures (Campbell, 2002). The most widely used imaging sensors for thermal remote sensing are called thermal scanners; they are designed to sense radiation from features beneath the flight path of the aircraft or satellite and produce digital images of the terrain in perspective.

An example of a satellite system that carries the thermal scanner is the Landsat thematic mapper (TM) which has an additional band 6 often designated as TM band 6, effective in detecting surface temperature and is sensitive in the region 10.4-12.5um, it has lower radiometric sensitivity and a coarser spatial resolution (120m x 120m) when compared to other TM bands (30m x 30m), this spatial resolution is advantageous for broad scale classifications as proposed in this work. The Landsat TM band 6 responds to varying temperatures and emissivity on the ground, it produces images that show the relative differences in emitted thermal energy that correlate in part with the effects of solar heating on surfaces of varying composition and orientation. Landsat TM thermal imagery (despite its

lower spatial resolution) both supplements reflected radiation images and stands alone as an information source (Short 1996, Roy et al. 1997).The relevance of satellite derived surface temperature values for studies of urban climate depends largely on the relationship between temperature of the various surface materials (land cover) and their emissivity. Satellite derived temperatures correspond to surface temperature and in an urban area, this means the temperature just below the urban canopy layer.

Land surface temperature is a function of four surface properties; albedo, emissivity, thermal property of urban construction materials and the composition and structure of the urban canopy (Adebayo and Zemba, 2003). All four properties display different characteristics in their relation to radiation. The albedo of a body, whether object or surface is the fraction of incident light that it reflects, this falls between 0 and 1. The lower the albedo of a surface, the darker it is and vice-versa, dark surfaces like asphalt on pavement and roads absorb most of the radiant energy that falls on it which is why they show as dark, meaning albedo in this case is closer to 0 than 1, while a surface like snow will have an albedo much greater than 0 and closer to 1 thereby giving it the colour perceived visibly. A perfectly black object always has albedo equal to 0. This defines what is called a 'black body' which is a hypothetical object said to absorb all the radiation that falls on it (www.ICT international.au).

Emissivity (e) on the other hand refers to the relative ability of a surface to emit energy by radiation; it is the ratio of energy radiated by a particular material to energy radiated by a black body at the same temperature (www.sciencedirect.com). A true black body would have an emissivity equal to 1 while other objects would have emissivity less than 1. In general, the duller and blacker a material is, the closer its emissivity is to 1. The more reflective a material is, the lower its emissivity. Though black body is a theoretical object that acts as a perfect absorber and emitter of radiation, it is useful in describing the thermal behavior of actual objects (surfaces). Both black body temperature as generated from band 6 of Landsat and

emissivity of the various land cover identified in this work are correlated and act as input variables to generating land surface temperature.

Recent studies indicate that satellite remote sensing is one of the promising technologies inherently studied for understanding the relationship between land-cover change and changes in surface temperature (Bekele, 2002, cited in Xian and Crane, 2006). Climatological phenomena are naturally spatially variable and hence GIS represents a useful solution to the management of vast spatial climate datasets for a wide number of applications (Chapmann and Thorne, 2002).

Another advantage of remote sensing as method used is that Satellite remote sensing collects multispectral, multi-resolution and multi-temporal data, and turns them into information valuable for understanding and monitoring urban land processes and for building urban land cover datasets.

2.7 Urban Heat Islands

As urban areas develop, changes occur in the landscape. Surfaces that were once permeable and moist become impermeable and dry as a result of infrastructural development which causes concrete to replace most of the open land and vegetation. This condition leads to the formation of what scientists call urban heat islands (UHI). Oke, 1982; 1987; Goldreich, 1985 and Bornstein, 1987 defined urban heat island as higher temperature in urban areas when compared to the surrounding non urbanized (rural) areas. A more in-depth definition is given by Voogt, 2000 which describes heat island as closed isotherms indicating an area of the surface that is relatively warm. He noted that the most commonly associated are areas of human disturbance such as towns and cities. Other scholars that have defined the concept are: Oguntoyibo, 1984; Aina, 1989; Adebayo, 1990 and AbdulHamed, 2011.

The annual mean air temperature of a city with one million or more people can be 1 to 3^0 C warmer than its surroundings and on a clear calm night, this temperature difference can be as much as 12^0 C (www.urbanheatislandbasics.com). No matter how small a city is, as long as it has all the features of modernization, it will produce heat islands, though the effect often decreases as city size decreases.

2.7.1 Urban Heat Island Types

Broadly speaking, two main categories of urban heat islands have been identified; atmospheric urban heat island (AUHI) and surface urban heat islands (SUHI). These two heat island types differ in the way they are formed, the techniques used to identify and measure them, their impacts, and to some extent, the methods of mitigation (www.urbanheatislandbasics.com).

The atmospheric urban heat island is often further divided into two by experts; canopy layer urban heat island (CLUHI) and boundary layer urban heat island (BLUHI). A summary of the basic characteristics, which also gives the differences between both heat island types, is given in table 2.1.

Table 2.1 Basic Characteristics of Surface and Atmospheric Urban Heat Islands

Feature	**Surface UHI**	**Atmospheric UHI**
Temporal development	• Present at all times of the day and night. • Most intense during the day and in the summer.	• May be smaller or non-existent during the day. • Most intense at night or predawn and in the winter.
Peak Intensity (most intense UHI conditions	• More spatial and temporal variation: - Day: 18 to 27^0F (10 to 15^0C) - Night: 9 to 18^0F (5 to 10^0C)	• Less variation: - Day: -1.8 to 5.4^0F (-1 to 3^0C) - Night: 12.6 to 21.6^0F (7 to 12^0C)
Typical Identification Method	• Indirect measurement: - Remote sensing	• Direct measurement: - Fixed weather stations - Mobile traverses
Typical Depiction	• Thermal image	• Isotherm map • Temperature graph

Source: Urban Heat Island Basics

In the identification of Urban Heat Islands, scientists use direct method and indirect methods and numerical modeling and estimates based on empirical models. Researchers on the other hand often use remote sensing, an indirect measurement technique to estimate surface temperatures. The data collected is often used to produce thermal images, from which the heat intensity emitted from the surface can be assessed relative to the factor considered.

2.7.2 Factors Influencing UHI Development

The urban heat island is a combined effect of land surface and atmosphere interactions (Dupont and Mestayer, 2000). The major factors that lead to and favour the presence of heat islands are:

- **Reduced vegetation in urban areas:** In the country side, vegetation and open land dominate the land surface. Normally, trees and vegetation provide shade which serves to not only lower surface temperatures but also, air temperature through evapotranspiration. In such instances, plants release water to the surrounding air thereby dispelling ambient heat. The case is different in an urban area where most part of the surfaces is dry and impervious due to the presence of building, roofs, roads and others. Development, which is an intrinsic feature of every city, is continuous and as this is so, more vegetation is lost and more surfaces become paved. This change in land cover results in less shade and moisture to keep urban areas cool and this contributes to elevated surface and air temperatures (www.epa.gov/heatisland).

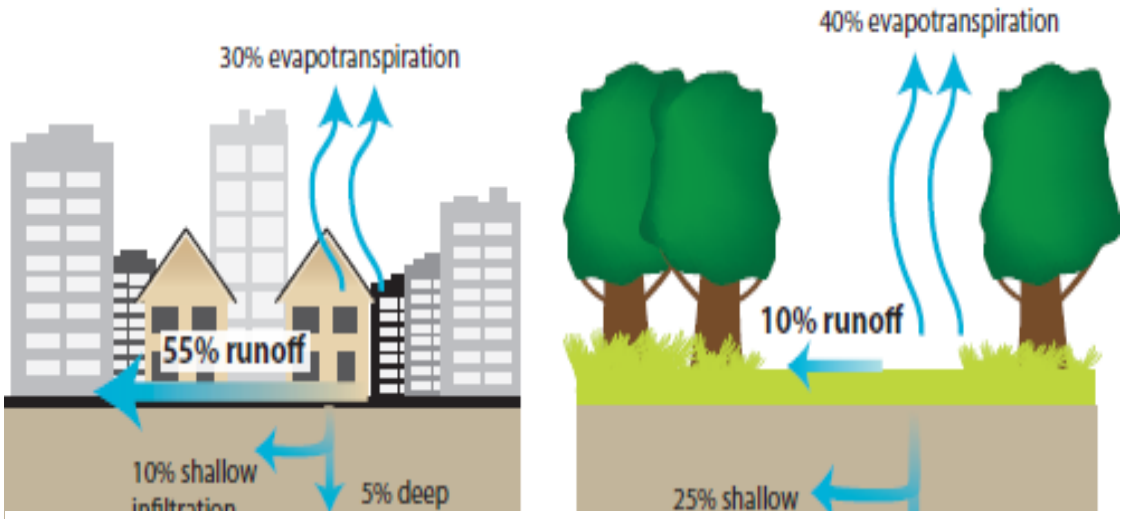


Figure 2.1 Impervious surfaces and reduced evapotranspiration

Source: www.epa.gov

A characteristic that contributes to higher surface and air temperatures is depicted in figure 1; highly developed urban areas (on the right) characterized by 75-100% impervious surfaces are shown. They have less surface moisture available for evapotranspiration as compared with natural ground cover (left) which has less than 10% impervious cover.

- **Properties of urban materials:** the properties of urban materials, particularly, solar reflectance, thermal emissivity and heat capacity greatly influence heat island development since they are determinants of how incident solar radiation is reflected, emitted and absorbed. Energy from the sun is composed of ultra-violet (UV) rays, visible light and infra-red energy, each reaching the earth in different percentages (5% in the UV spectrum, 43% visible light and 52% infra-red) and at different wavelengths. Energy in the UV spectrum includes that which causes sunburn while visible light energy comes in colours ranging from violet to red. The infra red which is most important to thermal remote sensing consists of energy felt as heat. Energy across these different wavelengths contributes to the formation of heat islands.
- Solar reflectance (albedo), is correlated with a materials colour. Albedo is the percentage of energy reflected by a given surface. Cities and towns often have their surfaces covered in concrete and asphalt and these materials have a lower albedo than those found in rural areas. Due to this fact, urbanized areas will reflect less and absorb (trap) more of the suns energy thereby inducing heat island formation (Voogt, 2000). Although solar reflectance is the main determinant of a material's surface temperature, emissivity and heat capacity also plays a role. Thermal emittance (emissivity) is a measure of a surface's ability to shed heat, or emit long-wave (infrared) radiation while heat capacity is the measure of a materials ability to store heat. Surfaces with high emittance values will stay cooler, because they will release

heat more readily while surfaces with (www.epa.gov).high heat capacity, like most city building materials will store solar energy more readily.

- **Urban geometry:** An additional factor that influences urban heat island development, particularly at night, is urban geometry. This refers to the dimensions and spacing of buildings within a city. Urban geometry influences wind flow, energy absorption, and a given surface's ability to emit long-wave radiation back to space (www.epa.gov). the more developed regions have a way of obstructing surfaces and structures with objects. These obstructions which can be in the form of a neighboring building causes the city surfaces to become large thermal masses that cannot release their heat very readily. Urban geometry is the major influence on night time heat island development because of the canyon effect which depicts a narrow street lined by tall buildings. The tall buildings create shade, thereby reducing both surface and air temperature.

  An aspect of urban geometry that has great dealing with the temperature in urban areas and therefore needs to be understood is the urban surface energy budget: An energy budget provides an equation that quantifies the balance of incoming and outgoing energy flows, or fluxes (www.epa.gov). The surface energy budgets of urban areas and their more rural surroundings differ because of differences in land cover, surface characteristics, and level of human activity. Such differences can affect the generation and transfer of heat, which can lead to different surface and air temperatures in urban areas. The elements of the energy budget include: short wave radiation, thermal storage, long wave radiation, sensible heat, evapotranspiration and anthropogenic heat. Figure 2 gives a holistic view of the process involved.

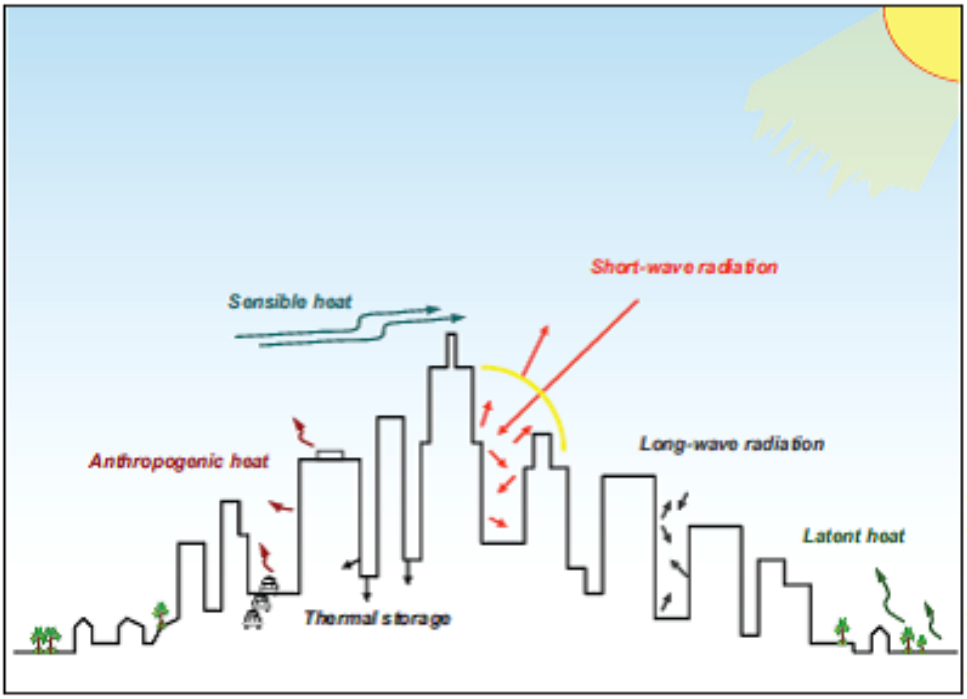


Figure 2.2 Urban Surface Energy Budget

Source: www.epa.gov

- **Anthropogenic heat:** this refers to heat produced by human activities. It comes from different sources (air conditioning, cars, industrial facilities) and is estimated by totaling all energy used for heating and cooling, running appliances, transportation and industrial processes. Its effect is felt more in winter especially in dense urban areas that have more energy intensive buildings and transportation.
- **Weather/ geographic location:** though communities hardly have control over these two factors, their contribution to UHI development cannot be ignored. Two weather characteristics affect the development of heat islands, these are wind and cloud cover. Calm winds and clear skies favor the formation of UHI because this condition maximizes the amount of solar energy reaching urban surfaces and minimizes the amount of heat loss by convection. On the contrary, areas prone to strong winds and cloud cover have lower temperatures because UHI development is suppressed by these factors. Similarly, a cities natural location determines its climate and topography

which in turn, influence UHI. For example, a city located close to a large body of water will have a moderate temperature because of the effect of strong wind from the ocean which takes the heat away by convection. Also, mountain ranges can either block wind from reaching a city or create a pattern that passes through the city.

2.8 Surface Urban Heat Islands (SUHI)

During summer, solar energy reaching the earth can heat dry exposed urban surfaces like roofs and pavement, to temperatures 50 to 90°F (27 to 50°C) hotter than the air. The situation is often different in rural areas where temperatures remain close to air temperature because the surfaces are shaded and moist (www.urbanheatislandbasics.com). Though surface urban heat islands are present day and night, it tends to be strongest during the day when the sun is shining.

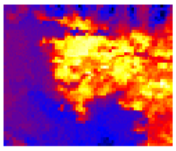
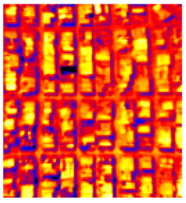
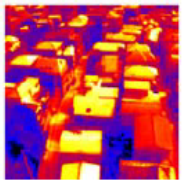
The magnitude of surface urban heat islands varies with seasons, due to changes in the sun's intensity as well as ground cover and weather (www.epa.gov). As a result of such variation, surface urban heat islands are largest in the summer, with the effect felt more in tropical regions where daily average temperature can be as high as 38°C.

2.8.1 Measuring Surface Urban Heat Island

Heat islands are not a newly-discovered phenomenon. In fact, for two centuries, weather watchers noticed that cities tend to be warmer than rural areas by using simple mercury thermometers. Similarly, researchers have long noticed that the magnitude of heat islands can vary significantly between cities but accurate comparisons have long eluded scientists because ground-based air temperature sensors tend to be unevenly distributed and prone to local bias (www.nasa.gov). The lack of quantifiable definitions for urban versus non-urban areas also hindered comparisons.

Remote sensing offers a uniform view of urban heat island and its the tool for surface urban heat island measurement. Remote sensors use none contact instruments that sense long wave or thermal infrared radiation to estimate surface temperature Voogt and Oke (1997). A definition of the urban morphology is important in remote sensing of UHI. The sensors see the surface directly at a particular swath width, depending on the satellite system used. The three basic platforms with their characteristics, from which sensors view the Earth are given in table 2.2.

Table 2.2 Platforms for SUHI measurement.

Platform	Sample Image	Comments
Satellite		Extensive spatial coverage; temporal coverage may be limited. Impacted by weather and atmosphere. Spatial resolution may be limited.
Aircraft		Higher resolution, more detail of urban features. High cost, irregular coverage. Non-standardized product.
Ground-based		May provide unique perspective of some urban features. Possibility of high temporal resolution, can avoid corrections due to atmospheric influence.

Source: Voogt and Oke (1997)

After viewing the Earth, these sensors produce images of the area under scrutiny. The image contains all the details of the area and depending on what is being examined, analysis is carried out. Figure 2.3 gives an example of an image showing heat island.

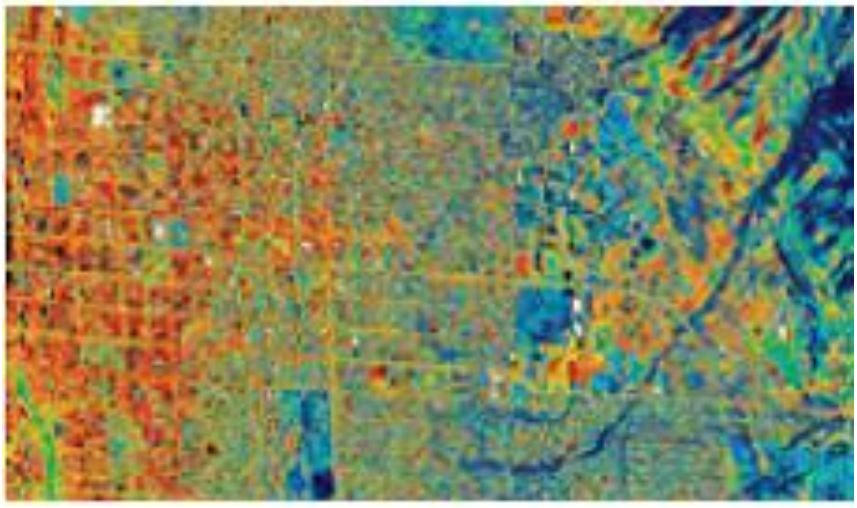


Figure 2.3 Thermal Image Depicting a Surface Heat Island

Source: Urban Heat Island Basics

White areas on the image reflect temperature around 70°C, while the dark blue areas are near 30°C. The left side of the image in red shows the warmer urban surface temperature, and then the cooler surfaces are around the foothills to the right.

2.9 Case Studies: Surface Cover, Surface Temperature and Urban Heat Islands

Although cities form a very small fraction of the Earth's surface area, the world's population has become increasingly urbanized and is now affected by urban climates. With around half of the world's human population living in urban areas, future predictions and estimates are that by 2030, the global rate of urbanization will increase by 70% of the present world urban population (EPA, 2008), this makes cities important sites for greenhouse gas emissions because of the high energy demands and activities by urban residents. These emissions have an indirect influence on city climate with their cumulative effect being the development of urban heat islands (UHI). Urban heat islands develop even in the smallest cities in the world and it has been extensively studied over the past few decades.

The relationship between surface cover and surface temperature has been examined by a number of authors; Karl et al (1988) estimated urbanization effects on the United States climate by using climate records and population data, their results showed that areas with high population was warmer than those less populated, Carlson et al (1997) were able to prove that warmer than surrounding thermal features are associated with urban land use and could be identified from infrared radiative surface temperature observed from satellite data. Xian and Crane (2006) used Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper plus (ETM+) data to analyse the influence of urbanization on surface temperature in Tampa Bay Florida. In the study, measurements of percent Impervious Surface Area (ISA) was used to determine urban extent while a 50 year temperature record of the city was utilized to study temperature trends in the watershed and subsequently, to assess the effect of urbanization on local climate. Adebayo and Zemba (2002) used remote sensing/GIS to study and examine the impact of urban growth and urban bio-physical structures on the development of UHI; four remote sensing imageries were used to derive information on land-use/cover and its changes through time, the infra- red band of three of the imageries was used to generate land surface temperature maps from which urban heat island patterns of the city was examined. Others are; Adinna et al (2009), Vasquez et al (2009), Ifatimehin et al (2010) and Streutker (2003).

The modifications to a city's climate in contrast to its rural surroundings, known as the Urban Heat Island (UHI) phenomenon, has not been extensively studied in tropical areas where sub Saharan Africa and subsequently, Nigeria falls. Early work in these areas occurred only in the late 1960s and even at that, the study of the UHI phenomenon in Nigeria lags far behind that of other tropical countries. The first ever comprehensive study of the UHI phenomenon in the cities across the country was completed in 1970 by Oguntoyibo. In contrast to this, the

developed world has carried out quite a number of researches both empirically and with the use of remotely sensed information to detect thermal characteristics of urban surfaces.

In the united states, Matson et al (1978) used NOAA 5 satellite night-time thermal infrared imagery to obtain maximum urban-rural temperature differences ranging from 2.6 to 6.5 degree Celsius for more than 50 selected cities and from NewYork, Price (1979) was able to demonstrate that for many large cities, satellite sensed temperatures were 10 to 15 degrees warmer than surrounding rural areas while

Though Africa is amongst the fastest growing and urbanizing continents in the world; with sub-Saharan Africa having the highest projected growth rates during the coming 25 year period (Growth rates, just over 2.5 % per annum since the mid-80's, are expected to remain above 2 %through 2020), not much has been done with regards to the impending problem of the urban heat island effect as is the case in other parts of the developing world. For example: Emmanuel (2003) assessed the impact of land cover changes on urban bio-climate of Colombo. He correlated the land cover changes in and around the three first order weather stations with the bioclimatic trends in the region during the last 30 years. In Malaysia, Hashim and Ahmad used remote sensing and GIS to evaluate urban growth and land surface temperature relationship. They used surface temperature information from thermal infrared band of Landsat imagery to determine urban heat island, similar studies was carried out in China by Weng (2001) and Tran *et al* (2004). All of which concentrated on the use of remote sensing and GIS to determine urban expansion and its impact on surface temperature.

Sarkar (2004) in India went a step further by using two indices in his evaluation; land cover and population density. He was able to establish that both factors have a direct relationship with the development of urban heat island in tropical cities. Remote sensing was used for land cover analysis while a GIS data base system was used for population density. His study

demonstrated the efficacy of remote sensing and GIS in synchronizing both climate and demographic data in one.

In Nigeria as stated before, the earliest documented research in the field was done by Oguntoyinbo (1970) in which he studied the albedo and reflection fluxes of urban and rural surfaces in Ibadan. His findings indicated a mean albedo of 12% for urban surfaces and 6% for rural surfaces. Oguntoyinbo (1973) further examined the impact of urbanization on the climate of Ibadan, he used thermo- hygrographs and whirling hygrometer to measure temperature and relative humidity data across the city. Since the pioneering works by Oguntoyinbo, other urban climate studies were undertaken largely on the issue of the urban heat island phenomenon using ground based measuring instruments: Ojo, 1981; Adebayo,1985;Omogbai, 1985; Aina,1989; and Oniarah,1990, a common characteristic of all the studies being their empirical nature.

Other works in urban climate studies in Nigeria include those byAdegoke (2002) who checked the variations of carbon monoxide with thermal comfort in Ibadan; Efe(2004) examined the effect of the urban landscape on precipitation and rainwater quality in Warri. Abdulhamed (2011), then Nduka (2011) both conducted similar studies; the first in Kano, assessed the spatio-temporal variation of urban canopy heat island , while the latter assessed the urban canopy heat island variation and land use/land cover in Onitsha metropolis, they both used digital temperature loggers (i-buttons) in assessing the spatial and temporal distribution of the urban canopy layer heat island in the study areas of interest.

There has been frequent mention of assessing urban heat island effect using remote sensing and GIS outside Nigeria, but work done at home were mostly done using land based observations and in- situ field measurements. Worthy of note also is the fact that most of the works on urban climate in the country is concentrated in the south-eastern/Western part of Nigeria, not much as yet is known of the trend of development of UHI in the north/ north

central parts where temperature ranges highest in the country, especially so is that not one documented research has been carried out on the climate conditions of Abuja city and as such, this work intends to contribute its quota in that vein. For a holistic data base, more in-depth studies on Nigeria's climate from every region, particularly the causes for its bioclimatic changes are needed to advance the knowledge base. Such an advanced knowledge is essential because on the one hand, an unprecedented acceleration of urbanization is currently underway in cities like Abuja. From a steady rate of approximately 22% urbanization in the decades leading up to the 1980s, Abuja has now entered a rapid phase of urbanization whereby the 2020 urban levels are expected to top 50% of the present population(US Census Bureau, 2006).

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1Introduction

The area under study is the Federal Capital City (FCC), the central part of Abuja Municipal Area Council. The intention in this chapter is to emphasize on the major physiographic features of the city that is useful to the present study. The description will run through from the physical to climatic and then to its human/economic activities. Another aspect to chapter three is the methodology which accounts for the paths taken to arrive at and the resources put together to generate the results presented in the study. Included within this scope are; data required for the study, data characteristics, method of data collection and data analysis while at the same time, more light is shed on its general characteristics..

3.2 Description of Study Area

3.2.1 Location and Areal Extent

Abuja, the Federal Capital Territory (FCT), lies between latitude 9°4′North of the equator and longitude 7°29′East of the Greenwich Meridian. It is a planned city in the centre of the country bordered to the north by Kaduna state, to the east by Nassarawa state, to the south-west by Kogi state and to the west by Niger state. The Federal Capital City (FCC) which is the study area is located at the north eastern part of the FCT on lat 09.00^0 – lat 09.12^0N and long 07.26^0 – long 07.32^0E. It covers about 52.9sqkm of the total land area of the FCT. The area is considered the most ideal and conducive for human habitation and settlement development within the FCT (Mabogunje, 1976). The FCC is rich in infrastructure such as expanding road network, drainage and sewage systems, pipe borne water, electricity, and communication networks. Due to its central location and accessibility, people from all parts of the country crowd into the city in search of better living.

Figure 3.1 shows a map of the federal capital city (FCC) and its position in the federal capital territory (FCT). The five district areas of the FCC can be located on the map, also displayed are some selected areas of greenery, buildings and roads.



Figure 3.1 Map of Abuja Showing Study Area with Districts

Source: Author. 2012

3.2.2 Climate

Abuja under Koppen climate classification features a tropical wet and dry climate. The FCT experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season. In between the two, there is a brief interlude of harmattan (northeast trade wind) with the main feature of dust haze, intensified coldness and dryness (www.secureafrica2012.org).

Weather conditions in Abuja are influenced by its location within the Niger ¬Benue trough on the windward side of the Jos Plateau and at the climate transition zone between the very humid south and the sub-humid north of the country. The climatic dictates of the FCT are from the south west to the North West due to the rising elevation from the Gurara valley in the south west, to the Bwari-Aso hills and the Agwa ¬Karu hills to the north east. The high temperatures and the relative humidity in the Niger ¬Benue trough give the Federal Capital Territory a heating effect but the increasing elevation towards the north east reduces the heat in areas like the Gwagwa plains where the Federal Capital City (FCC) is sited than on the Iku-Gurara plains to the west. There are two distinct seasons; the rainy season and the dry season. Although, a brief harmattan season, occasioned by the north east trade wind and the attendant dust haze with increased cold and dryness is experienced within these seasons.

The rainy season begins from April and ends in October peaking in September, during which abundant rainfall is received in the form of heavy downpours. At this time, daytime temperatures reach 28 °C (82.4 °F) to 30 °C (86.0 °F) and nighttime lows hover around 22 °C (71.6 °F) to 23 °C (73.4 °F). In the dry season, daytime temperatures can soar as high as 40 °C (104.0 °F) and nighttime temperatures can dip to 12 °C (53.6 °F). Even the chilliest nights can be followed by daytime temperatures well above 30 °C (86.0 °F). The high altitudes and undulating terrain of the FCT act as a moderating influence on the weather of the territory. Rainfall in the FCT reflects the territory's location on the windward side of the Jos Plateau and the zone of rising air masses. Due to the hilly and mountainous nature of Abuja city, Orographic activities bring heavy and frequent rainfall of about 1,500 mm (59.1 in) during the rainy season. Annual rainfall is highest within the FCC, about 1,631.7m (www.secureafrica2012.org).

The federal capital territory records relative humidity in the dry season which goes as high as 20% in the afternoons at the northern high elevations and about 30% in the extreme south.

The low relative humidity coupled with the high afternoon temperatures gives rise to the desiccating effect of the dry season and during the rainy season, relative humidity rises as much as 50% which gives the area a heat trap effect experienced more in the southern part making this place uncomfortably hot. For maximum human comfort, the northern parts, particularly the north-east where the FCC is located is better. One noteworthy phenomenon of weather in the territory is the frequent occurrence of disturbance or line squalls, this describes a weather condition brought on by dense dark cumulonimbus clouds with thunder and lightning, followed by strong winds and rainfall of very high intensity, the rain may last some minutes and then followed by drizzles of several hours. A few days of bright clear skies replaces this weather, a phenomenon associated with high convective activity aided by relief effects. The presence of isolated hills (inselbergs) brings about another type of weather condition experienced in the FCT. These inselbergs trigger off convectional activities giving rise to intense relief rain in their immediate surroundings.

3.2.3 Relief/Geology/Soil

The Federal Capital City is in tune with nature with abundant hills and highlands that makes it a site to behold (plate 3.1a). It is characterized by a hilly dissected terrain and is the highest part of the FCT with several peaks that are 760m above sea level (Balogun, 2001). Hills in the FCC occur either as clusters or form long ranges, the most prominent being the Gwagwa range in the northeast. Gurfata range southwest of Suleja, Bwari-Aso range also in the northeast, the Idon-Kasa range northwest of Kuje and the Wuna range north of Gwagwalada are all surrounding highlands to the city while the low lands lie to the extreme south-west, around the flood plain of river Guraja, an elevation of 70m above sea level. Some parts of the city have many roundish isolated hills called inselbergs. Between these are extensive plains covering some portion of the land area, the most are the Gwagwa plains selected as location

for the Federal Capital City. This relief pattern in the FCC constitutes to the modification of the overall city climate, hence, the likely presence of heat island.

The geology of the area is underlain by basement complex rocks and the soil is basically alluvial and luvisols making it a fertile ground for agriculture and vegetation growth. This is more so the case in the Gwagwa plains where the FCC is located; the most fertile soil for agriculture is found here, although the high sand content also makes it prone to high level of erosion. One major advantage of the type of rocks and soils found in the FCC is that they constitute good construction materials in the form of building stones, quartz and pistolytic gravel, building sands and earth for use as foundation materials (www.secureafrica2012.0rg). With the many buildings and construction works going on, these soils are excavated for use leaving eroded surfaces in its wake as is shown in plate 3.1b.



Plate 3.1a Aso Rock, an example of a highland in Asokoro district. (Field work 2012)



Plate 3.1b Eroded Surface in Central Area (FCC). (Field work 2012)

3.2.4 Vegetation

The FCT falls within the Guinean forest-savanna mosaic zone of the West African sub-region. Patches of rain forest, however, occur in the Gwagwa plains, especially in the rugged terrain to the southeastern parts of the territory where a landscape of gullies and rough terrain is found. These areas of the Federal Capital Territory (FCT) form one of the few surviving occurrences of the mature forest vegetation in Nigeria, (www.fct.gov.ng/fcta). As for the Federal Capital City, the vegetation around most part can only be found in the many parks that abound within the city, the largest and most popular of these is the millennium park, located in Maitama district. Rich mountain, savanna (3.2b), deciduous and rainforest (3.2a) vegetation of Nigeria are preserved in their natural form in one part of the park while brushwood and beautiful flowers accentuate the paths along each route.



Plate 3.2a Riparian (dense) vegetation, Millennium Park, Maitama. (Field work 2012)



3.2b Sparse vegetation, Millennium park, Maitama. (Field Work, 2012).

Most of this type of natural cover can only be found in the parks in the city. Around the residential and commercial areas, what are basically available are flowers and small shrubs, planted for aesthetical purposes as is captured in figures 3.3a and 3.3b.



Plate 3.3a Planned Urban Vegetation, New Market Area. (Field Work, 2012).



3.3b Planned Urban Vegetation, Central Area. (Field Work, 2012).

3.2.5 Land-Use/Cover in the FCC

Abuja being the Federal Capital Territory is home to both the indigenous Gbagyi people and others who relocate from every part of the country in search of greener pastures. This has led to a diversification in human activities which defines the use to which land is put to in the

city. Regional and city master plans were prepared to guide the development of the new capital territory on its inception, but this soon ran into problems especially in the areas of provision of infrastructure and city management (Abuja development control, 2007).

Broadly speaking, land use in the Federal Capital City Garki; numbered 1-11, Wuse; numbered 1-8, Maitama and Asokoro) is of two categories; Built up and others. Such categorization can be made based on the fact that most of the land surface is covered with buildings ranging from commercial centers to multinational companies and offices, markets, shopping malls, hotels and residential layouts. Notable among these is the general post office, Abuja international conference center all on Herbert Macauley way Garki, Wuse market, Wuse general hospital, Sheraton hotel and towers, foreign affairs ministry headquarters still in Wuse, Transcorp Hilton hotel (Maitama), British high commission along Agui-Ironsi way (Maitama), ECOWAS secretariat and the presidential palace (Aso rock) both in Asokoro. One of these is shown in plate 3.4.



Plate 3.4 Transcorp Hilton Hotel, Central Area. (Field work 2012).

Transportation as a function of land use is grouped along with built up areas in the course of this study. This is because they comprise the same materials of which the basic is concrete (impervious). Several roads abound such as the ring road which divides all four parts of the FCC into district, that could not be captured here but some others are shown in plate 3.5a and b. figure 3.5a captures a little of the sidewalks which are all concrete too.



Plate 3.5a High Traffic road at Maitama.

Source: Field work 2012



3.5b Cross Road at New Market Area, Wuse.

Other land use/ land cover identified are flowered gardens shown in plate 3.6a, bare/open surfaces in plate 3.6b and water in plates 3.6c. Very few farmlands are found within the municipal as most of the land is built up to accommodate the bursting population.



Plate 3.6a Flowers in Millennium Park, Central Area. (Field Work 2012)



3.6b Open Ground, Central Area. (Field work 2012).



Plate 3.6c Water body at Royal Falls, Zone 7, Garki. (Field work 2012).

In the course of this research, the major land uses identified and classified are; paved surfaces (comprising all impervious surfaces such as roads, buildings, roof tops (plate 3.8a), drainages, bridges (plate 3.8b), walkway (plate 3.9), parking lots and rock outcrop), Riparian vegetation (includes all trees and wild plants growing along river parts), sparse vegetation (includes plants tendered in gardens, flowers, grasses and bushes) bare surface (includes all

untarred roads and foot paths, play grounds and open spaces), and water body (comprising lakes and marshland water).



Plate 3.7a Rooftops, Central Area.



3.7b Bridge, Central Area (Field Work, 2012)



Plate 3.7c.Walkway in Central Area.

Source: Field work 2012.

3.2.6 Ecology

Abuja, no longer a natural environment but a developed one faces a lot of ecological problems due to an imbalance in all that makes up the society which is mainly caused by the continuous movement of people into the city. This has been on the increase yearly with the greatest challenge faced in areas with the highest population influx like the FCC. Apart from overstretching of social amenities, this kind of concentration usually increasing the intensity of human activities with enormous consequence on the environment some of which are:

De-vegetation: To prepare lands for both cultivation and urban development, a lot of the greenery in the territory especially those in the municipal area have been cleared and destroyed regardless of the inherent role vegetation plays in sustaining the ecosystem, sometimes game chasers even set fire on vegetation to enable them gain access to wild animals. Naturally, vegetation acts as heat sink often appreciated more on excessively hot days but with most of it gone, high thermal condition is recorded in the city leaving much to be desired as far as human comfort is concerned.

Urban Pollution: The Nigerian Environmental Society has revealed that the federal capital city (FCC) is polluted (Leadership paper, 19/07/12), this statement is made based on research findings from environmental risk assessment exercise carried out by the above mentioned body. The research shows that there is an eight hourly emission of carbon-monoxide (CO), Oxygen (O2) and low explosive limit gases (LEL) for wet and dry season which goes above world health organization and Nigerian air Control Standards. The result of the assessment highlighted industrialization and developmental activities as the primary precursor to changes in the environment giving rise to several health implications such as low birth weight and congenital anomalies by mothers exposed to air pollution. Another severe implication is on climate change which has influenced the geographic range, seasonality, and incidence rate of

various infectious diseases such as malaria, diarrhea and cholera (Leadership paper, 19/07/12).

Soil Erosion and Gullying: Human activities like urban growth, vegetation clearance and cultivation have pushed land use activities towards highly fragile areas. Today there are several areas of heavily eroded 'badlands', surfaces and numerous gullies of varying dimensions, some of which covers up to 0.1sq.km in areal extent, as can be seen in plate 3.8.



Plate 3.8 Eroded Surface in Central Area.

Source: Field work 2012.

3.3 Methodology

3.3.1 Data Requirements and Data Sources

The variables to be investigated and derived in this research includes; surface cover, surface temperature and subsequently, urban heat island. To get around these, the following data were collected:

i. Land use/Land cover (LULC) data

ii. Land surface temperature data (LST)

iii. Impervious surface area (ISA)

The main data source of the present study is: Remotely sensed imageries (Landsat) of 1987, 2001 and 2006. Other materials and tools employed include;

1. Computer unit with necessary properties (hardware and software) for image processing.
2. Remote sensing/ GIS softwares; IDRISI 17.0 (selva version), ERDAS IMAGINE 9.2 and ArcGIS 9.3.
3. A germine 12 global positioning system (GPS) for taking geo-coordinates and field check.
4. Topographic and administrative map of the study area to aid in ground truthing and image classification/ interpretation.
5. An 8.0 mega pixel digital camera for photo shots of city surface cover to serve as Ancillary data.
6. A canon calculator for proper statistical computations and numeric analysis.
7. Digital map/guide of study area obtained from 2010 Google Earth edition to aid pre-field point selection and direction on field.

3.3.2 Data Characteristics

Research using remote sensing and geographic information system is often associated with the use of imageries containing details of the area under study. In this study, images from the Landsat satellite series form the main data source.

3.3.2.1 Landsat Image Characteristics

The Landsat system provides global coverage between 81ºN latitude and 81ºS latitude. Landsat satellites have been continuously acquiring Earth observation imagery since 1972. Seven Landsat satellites have been built, and six have been successfully launched and operated in orbit. Two remain operational, one of which is Landsat-5 which was launched in 1984 and has remained operational since then. The second is Landsat 4, the fourth satellite of the Landsat program, it was launched on July 16th 1982 and ended operation in 1993. Both these satellites have a primary goal of providing a global archive of satellite imagery. They orbit at 705 km in a sun-synchronous orbit, with an equatorial crossing time of approximately 10:00 a.m. The repeat cycle is 16 days so users benefit by having Landsat images. Landsat 4 and 5 generated the data used in this work.

The instrument onboard both satellites (landsat 4 & 5) called the thematic mapper (TM)) is an advanced, multispectral scanning, Earth resources sensor designed to achieve higher image resolution. The thematic mapper possesses sharper spectral separation, improved geometric fidelity and greater radiometric accuracy and resolution than the multispectral scanner (MSS) sensor. TM data are sensed in seven spectral bands simultaneously, band 6 senses thermal (heat) infrared radiation. All TM scenes have an Instantaneous Field Of View (IFOV) of 30m x 30m in bands 1-5 and 7 while band 6 has an IFOV of 120m x 120m on the ground.

Landsat satellites were designed to be of use to a variety of fields like forestry, agriculture, geology, and land-use planning, the choice of spectral bands for the Landsat satellites was also geared towards discriminating different types and amounts of vegetation. Landsat's

strengths are generally seen to be its regular acquisition schedule (revisits each spot on the earth every 16 days), long-term data archive (image with comparable specifications is available from 1982), and relatively rich spectral information, with the Landsat series, data continuity is assured. Landsat has the deepest archive of systematic satellite images of any sensor orbiting the earth, a fact that is invaluable for studying global change (Gillan, 2009). Landsat5 TM provides a link to the next generation. The spectral bands, wavelength and sensor (TM) on both satellites are briefly described in table 3.1.

Table 3.1 Landsat band description

BAND	RESOLUTION	WAVELENGTH (um)	DESCRIPTION
1	30m	0.45-0.52	Blue
2	30m	0.53-0.61	Green
3	30m	0.63-0.69	Red
4	30m	0.78-0.90	Near Infrared
5	30m	1.55-1.75	Short-wave Infrared
6	60m	10.4-12.5	Thermal Infrared
7	70m	2.09-2.35	Short-wave Infrared

Source: Gillan, 2009.

Figure 3.2 below shows how the thematic mapper sensor (TM) onboard Landsat interacts with various wavelengths of energy in the different parts (Visible, infrared, near infrared and radio) of the electromagnetic spectrum.

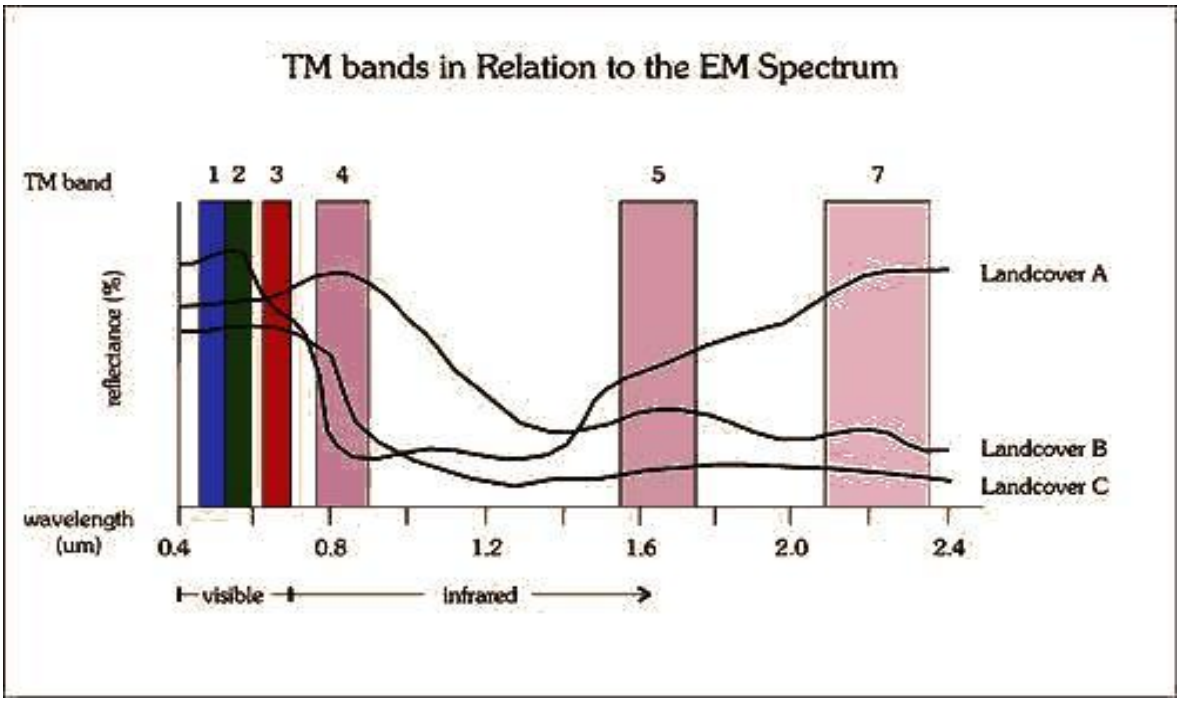


Figure 3.2 Relationship between TM bands and the electromagnetic spectrum.

Source: www.satelliteimpressions.com

3.3.2.2 Ancillary Data

The ancillary data used in this work includes topographic map sheet, population data, administrative map of the FCC gotten from the FCDA archives, information on the physical and socio-economic variables of the city obtained from library sources from the University of Abuja and historical records gotten mostly from web sources. Pictures of important urban features and surface cover also served as ancillary data. Lastly, A high resolution imagery of NIGSAT 2 (2011), available from the National Space Research and Development Agency (NASRDA) was used along with image of study area on Google Earth for proper field validation and confirmation of training sites selected during image interpretation and analyses since a good part of the interpretation process was visual (VIP).

3.3.3 Method of Data Collection

3.3.3.1 Reconnaissance survey

A reconnaissance survey involves an examination of all or part of an area accomplished in sufficient detail to make generalizations about the types and distributions of properties present (www.palmettohistory.org). In remote sensing, adequate field knowledge is necessary in the interpretation process, it aids the researcher especially in visual image interpretation (VIP). It is imperative that the researcher gain adequate knowledge of the study area in order to get around gathering data correctly, as information regarding the presence or absence of surface properties is important.

During the exercise which was carried out in June 2012, a global positioning system and an 8.0 megapixel camera was used. The GPS aided in the collection of the right coordinates (longitude, latitude and elevation) for points identified on the study area image during pre-field check. Pictures of specific land marks were taken alongside. A confirmation of certain historical facts about the city was obtained from talking with relevant sources on field.

3.3.3.2 Site Selection and Ground Truthing

The images analyzed were studied carefully. This aspect involved the selection of training fields (sites) from which generalizations were made. First of all on a Google Earth image of the location under study, important land marks representing various land uses were identified to represent different classes of land cover observed in the study area. Such locations were verified and marked on ground with a GPS during field check. This is shown in table 3.2. Ground truthing becomes a necessary part of site selection because some of the points taken on the image from Google Earth differed by a few degrees in actual location.

Table 3.2 GPS Selected Sites for Ground Truthing

Land Mark	Location	Area
Millennium Park	09° 04′20.4″N – 07°29.48′4″E	Central Area
Wuse market	09°04′05.7″N – 7°27′56.69″E	Wuse
Ninety-nine Steps Garden	09°27′30″N – 07°2726′.39″E	Zone 6, Garki
National Arboretum	09^0 04′20.00″N -$07^0$31.04′70″E	Asokoro
IBB Golf Club	$09^0$04.55′39″N – $07^0$30′20.83″E	Asokoro
Aso Rock	$09^0$04′11.36″N – $07^0$31′15″E	Asokoro

Source: Field Work, 2012

3..3.3.3 Data Acquisition

The main data used in this work were landsat images gotten from the global land cover facility (GLCF) site. The data collection of interest were chosen, in which case it is IMAGERY for this purpose, and then the LANDSAT header was selected from where an OVERVIEW page comes up. At this stage, the researcher looked through the archives for images available for the years of interest. Data (images) was downloaded to the C –drive of the computer in use, this was done through the Earth Science Data Interface (ESDI). All data were downloaded with projection from UTM-32 and they include the thermal band 6. Table 3 shows the data obtained for the work.

Table 3.3 Image Data Acquired

Data	Year	Sensor	Date acquired	Path rows	Columns
Landsat (4)	1987	Thematic Mapper (TM)	Dec 12th	189/054	225-534
Landsat (5)	2001	Enhanced Thematic Mapper Plus (ETM^+)	Dec 27th	189/054	225-534
Landsat (5)	2006	Enhanced Thematic Mapper Plus (ETM^+)	Sept 12th	189/054	225-534

Source: Authors download from GLCF,

The next stage after getting the image to computer is to get them to the environment where they will be processed, used and analyzed to get results. This means importing them (various bands (1-8) of the images for all three years) to IDRISI, the software to be used. The process is given below.

- **Importing Image:** The path is as follows

File→Import→Govt/data provider format→Landsat ETM (NLAPS/FAST/GEOTIFF/HDF).

This introduces the next stage which is subsetting.

- **Image Subset or Carving:** Satellite data image usually covers more areas than users are actually interested in, so a subset gives the section or portion of interest. This was equally carried out on IDRISI by using the X, Y co-ordinates of the study area which is 09.00^0 -09.12^0N and 07.26^0 – 07.32^0E. An appropriate output file name is entered (AOI in this case), then the display window shows the carved area.

- **Band combination:** This is also called image compositing, an enhancement technique aimed at improving both visual and digital interpretability of an image by increasing the apparent distinction between the features in the scene. Bands 2 (blue), 3 (green) and 4 (red) of 1987 image are combined through the following path:

Image processing → Enhancement → Composite → Histogram equalization → Output image. The same is done for all the remaining years so that at the end, 1987A, 2001A and 2006A are formed as output images. Histogram equalization is chosen as compared with simple linear or linear with saturation points because of clarity and precision.

3.3.4 Data Analysis

3.3.4.1 Description of Variable

The main variables to be investigated in this work include: Land use/land cover; which involves classifying the heterogeneous surface cover on the imageries into different homogeneous groups using an existing classification scheme. Land surface temperature; this includes temperature values (in degree Celsius) gotten from the different LULC classes as generated from the thermal band on image; Impervious surface area (ISA) which is a measure of those surfaces that water cannot infiltrate (Bauer and Loffelhoz, 2007), this will be estimated using the classified image of all three years

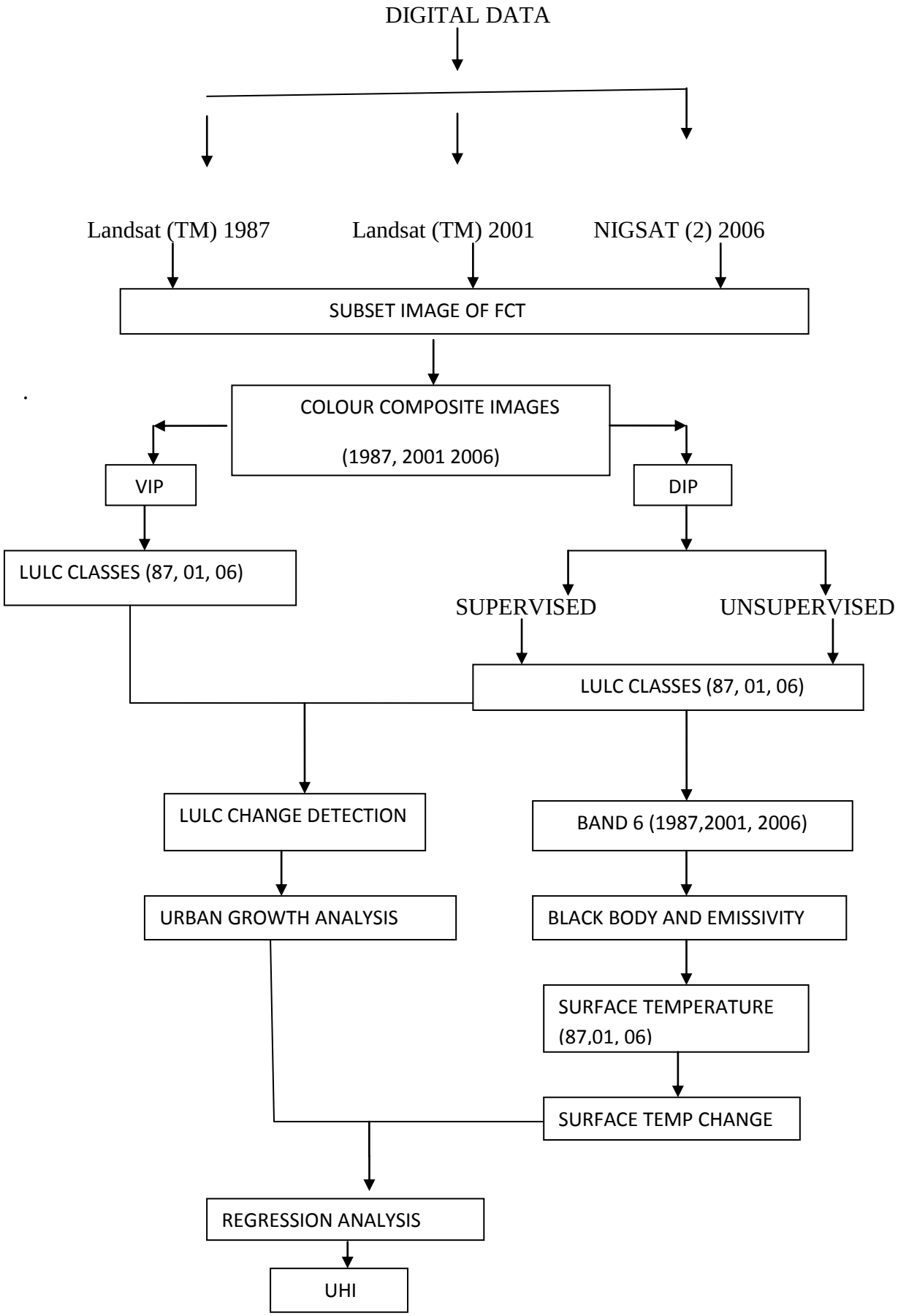


Figure 3.3 Data Analysis Tree. (Source: Author, adopted from Campbell, 2002).

A design of the paths followed in the analysis is given in figure 3.3 on page 57; this was adopted by the researcher from the sample guide given by Campbell (2002). Every stage is coined out of the proposed steps outlined therein for accurate analysis of remote sensing data.

3.3.4.2 Image Pre-Processing

Remotely sensed data is not free from internal and external errors such as radiometric and geometric distortion. Many of these errors are systematic and are most times removed from the data before they get to the end user as the case is with the images used in this work. The only thing particularly carried out in the form of correction here is the conversion of all the bands to a similar spatial resolution. This was done by an operation on IDRISI termed resampling. The original pixel sizes of 120m for TM band 6 which is different from the rest was resampled to 30m using the nearest neighbour algorithm so that it matches with the pixel size of the other spectral bands.

3.3.4.3 Digital Land Use/Cover Classification

Classifying land use/land cover digitally involves using the Anderson scheme which is developed using IDRISI 17.0. The images which serve as input data are segmented into a mosaic of parcels with each parcel assigned to a land-use class. There are two broads of digital classification procedures: supervised classification and unsupervised classification. The supervised classification is the essential tool used for extracting quantitative information from remotely sensed image data (Richards, 1993). Using this method, the analyst has available sufficient known pixels to generate representative parameters for each class of interest. This step is called training. Once trained, the classifier is then used to attach labels to all the image pixels according to the trained parameters. The most commonly used supervised classification is maximum likelihood classification (MLC), which assumes that each spectral

class can be described by a multivariate normal distribution. Therefore, MLC takes advantage of both the mean vectors and the multivariate spreads of each class, and can identify those elongated classes. However, the effectiveness of maximum likelihood classification depends on reasonably accurate estimation of the mean vector and the covariance matrix for each spectral class data (Richards, 1993). Again, it assumes that the classes are distributed un-imodal in multivariate space. When the classes are multimodal distributed, we cannot get accurate results.

Another broad type of classification is unsupervised classification. It doesn't require humans to have the foreknowledge of the classes, and mainly using some clustering algorithm to classify an image data (Richards, 1993). These procedures can be used to determine the number and location of the un-imodal spectral classes. One of the most commonly used unsupervised classifications is the migrating means clustering classifier (MMC). This method is based on labeling each pixel to unknown cluster centers and then moving from one cluster center to another in a way that the measure of the preceding section is reduced data (Richards, 1993).

In this research, a supervised classification, with a maximum likelihood algorithm is conducted. Image combination is done using three bands of green (2), red (3) and near-infrared (4). Training sample sets are then collected based on ground truth data gathered during field checks as specified before, on completion they are run on mosaic.

3.3.4.4 Land-Use/Cover Classification

Classification: This is the first step which is where the sample points, 50 training sites for each class except for water body that is limited, were taken for the different land use classes that have already been designed by the researcher. The 17^{th} icon on the IDRISI panel is used for this purpose and it all goes as follows.

Name of layer (eg, 1987 classes)⟶Class 1 = Background ⟶ Digitize. Subsequently, the classes are changed with the completion of one class selection, for example, class 1 which is background value is replaced with class 2, paved surface and selection begins for class 2. The selection process over, the 19th icon is then picked to save all data. From here, both vector and raster images of the selected sites are made available for signature development and the following classes formed as shown in table 3.4

Table 3.4 Land use/land cover classes

Class	Land Use	Description	Examples
1	Background	Image background with 0 pixel values	—
2	Paved Surface	Includes all surfaces that cannot be infiltrated by water.	Roads/Bridges, Buildings (industrial, commercial or residential), roof tops, rock outcrop, tiled pathways and drainages.
3	Bare Surface	Includes all open grounds that are neither vegetated nor built-up, untarred roads and footpaths.	Playgrounds and derelict lands.
4	Sparse Vegetation	Includes all light vegetation along streets and residential areas.	Small grasses along foot paths and streets, shrubs, small home gardens, and small house farms and flowers.
5	Riparian vegetation	This includes plants along water paths, denser than the former.	Mixed woodland, broad leaved trees, scrubs, trees planted for afforestation.
6	Water	Every form of surface water present is included.	Lakes, water in drainage, small rivers and streams.

Source: Adopted from Anderson (1976)

The next stage which is signature making and development registers each sample representation of a class as is shown in the appendix (1),these now served as input data to the formation of land-use maps choosing maximum likelihood algorithm over parallel piped or minimum distance algorithm(s) in the path below:

Image processing ⟶ Hard classifiers ⟶ MAXLIKE ⟶ Output image (map).

3.3.4.5 Land Use Change Analysis

Having developed land use maps for all the years under study, the next step is to assess the changes over year 1(time (t_1)), year 2 (time (t_2)) and year 3 (time (t_3)). Two methods were used here for the purpose of accuracy; cross tabulation and image differencing methods, all obtainable in IDRISI. The paths followed are:

- **Cross Tabulation**

  GIS Analysis ⟶ Data Base Query ⟶ Cross Tab ⟶ Input Image (1&2) ⟶ Output Image (map).

- **Image Differencing**

Data base query ⟶ Change/ Time Series ⟶ IMAGEDIFF ⟶ Input Image (latter – earlier) ⟶ Output Image (map). A similar path is taken to get percentage difference map image for the area, the mathematical operation involved is:

Latter image – earlier image/ earlier image * 100. Statistical analysis; chi square and graphs are used to better derive changes that have occurred.

3.3.4.6 Surface Temperature Analysis

Thermal emission from the landscape including the top of the canopy for vegetated surfaces as well as other surfaces (such as bare soils, water, paved) is to be investigated. The present study will generate land surface temperature from the thermal bands of landsat TM and ETM by using the temperature to emissivity relationship as proposed by Planck and summarized in the equation below

Emissivity (e) = $E_y/B_y(T)$ where $E_y$is the emitted radiance at wavelength (y) and $B_y(T)$ is the blackbody emission at wavelength (y) and temperature T, which can be calculated from the Planck function. IDRISI 17.0 offers the possibility of this variable to be generated as is documented in this research.

The first step taken towards achieving this goal was to convert the thermal band 6 of each year chosen to blackbody temperature through the path stated below:

Image Processing ⟶ Transformation ⟶ Thermal ⟶ output image (blackbody). This was done for all the years concerned. Emissivity for each land class is generated by using an existing look up table of emissivity values; the one employed here (table 5) is adopted from Lilesand and Keifer (1994) with values for each class as thus:

Table 3.5 Emissivity of classified land surfaces

MATERIAL	WAVELENGHT (um)	TEMPERATURE (^{0}c)	EMISSIVITY
Paved surface	-----	0 - 100	0.94
Bare surface	-----	20	0.95
Sparse vegetation	-----	----	0.88–0.94 AV= 0.91
Dense (riparian) Veg	-----	----	0.96–0.99 AV= 0.98
Water body	8-14	38	0.98

Source: Adopted from Lilesand and Keifer (1994)

The emissivity values are then substituted in for the various land use categories by re-classing, an operation in IDRISI that allows you to assign new values or reclassify the pixel values stored in images, the feature ID values of vector files or the second column values of

attribute values files into new integer categories. Classification or reclassification is by equal intervals division of the data range, or by the application of user-defined limits.

The user defined limit is taken to be substituted with the emissivity values in table above. The path followed in this conversion is:

Image processing ⟶ data base querry ⟶ Reclass. The input file here is the classified image, while an output file name is chosen for the new image which becomes the emissivity image of each year as performed. Since the temperature output by THERMAL in the IDRISI environment is blackbody temperatures, a process is defined to estimate real surface temperatures. The values given by the emissivity of the land cover types present is multiplied by the blackbody temperature, this is done by choosing to multiply first image by the second in the OVERLAY module, to get the resultant image which is the surface temperature map of the study area for the various years. A cross tabulation is run to ascertain the changes in surface temperature, the result is produced in the form of maps, charts and statistical calculations (chi square) for determination of surface heat intensity of each land use and subsequently, urban heat island evaluation.

3.3.4.7 Impervious Surface Area Measurement (ISA)

Urban areas are heterogeneous and most Landsat pixels consist of a mixture of different surfaces; water, bare surface, vegetation, buildings and a lot of others. Measuring impervious surface helps in estimating urban land-use/cover and also, it tells the extent to which an area is becoming urban. Due to unavailability of high resolution imagery for all three years under study, the sub-pixel change detection method could not be employed but the researcher used landsat images in estimating the portion of each land that is paved by comparing the growth of built up in all three years, this made it possible for objective three to be achieved.

3.3.4.8 Statistical Analysis

Pearson's Correlation analysis is carried out between land use change and surface temperature using statistical software SPSS. The results indicate the relationship between land use/land cover change and surface temperature which is +0.336. This led to the determination of the impact of urban growth on surface temperature and urban heat island.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the results generated through the whole study. The results and statistics derived from the classified satellite images of the study area indicate various changes in the LULC of the FCC. Attention is focused on the extent to which urban development, directly expressed in terms of change in land use/ land cover, has affected the surface temperature within the FCC.

Remote sensing images, one of 1987, the second of 2001 and a third of 2006 were subjected to land use classification with an intent to mapping the various land use/ land cover types identified in the region and also, identifying the nature of changes that have occurred. The information gotten from the land use/land cover analysis was further used to evaluate the city surface temperature. Land use maps for each year under study, tables, graphs and charts are contained here in this chapter.

4.2 Land Use/Land Cover

4.2.1 Land Use/Land Cover 1987/2001

The algorithm for classification used is maximum likelihood algorithm; the different parcels of land are represented by the colours in the legend. Each class carries its own colour; the background with 0 values is represented in red and is considered negligible in this work, paved surface in cream, bare surface in leaf green, forest vegetation in brown, riparian in purple and water body in cyan, this goes the same for each year under review. The year 1987 obviously had a lot of the land surface covered with vegetation (together both forest and riparian vegetation accounts for about 30.64km^2 of land use). This forms a large portion of the total land area which is 53.00km^2.

The land use maps and table compares the portion of land area occupied by each land use, their differences which signify gain or loss, thereby accounting for change and the percentage difference of each as derived by the formula specified in methodology.

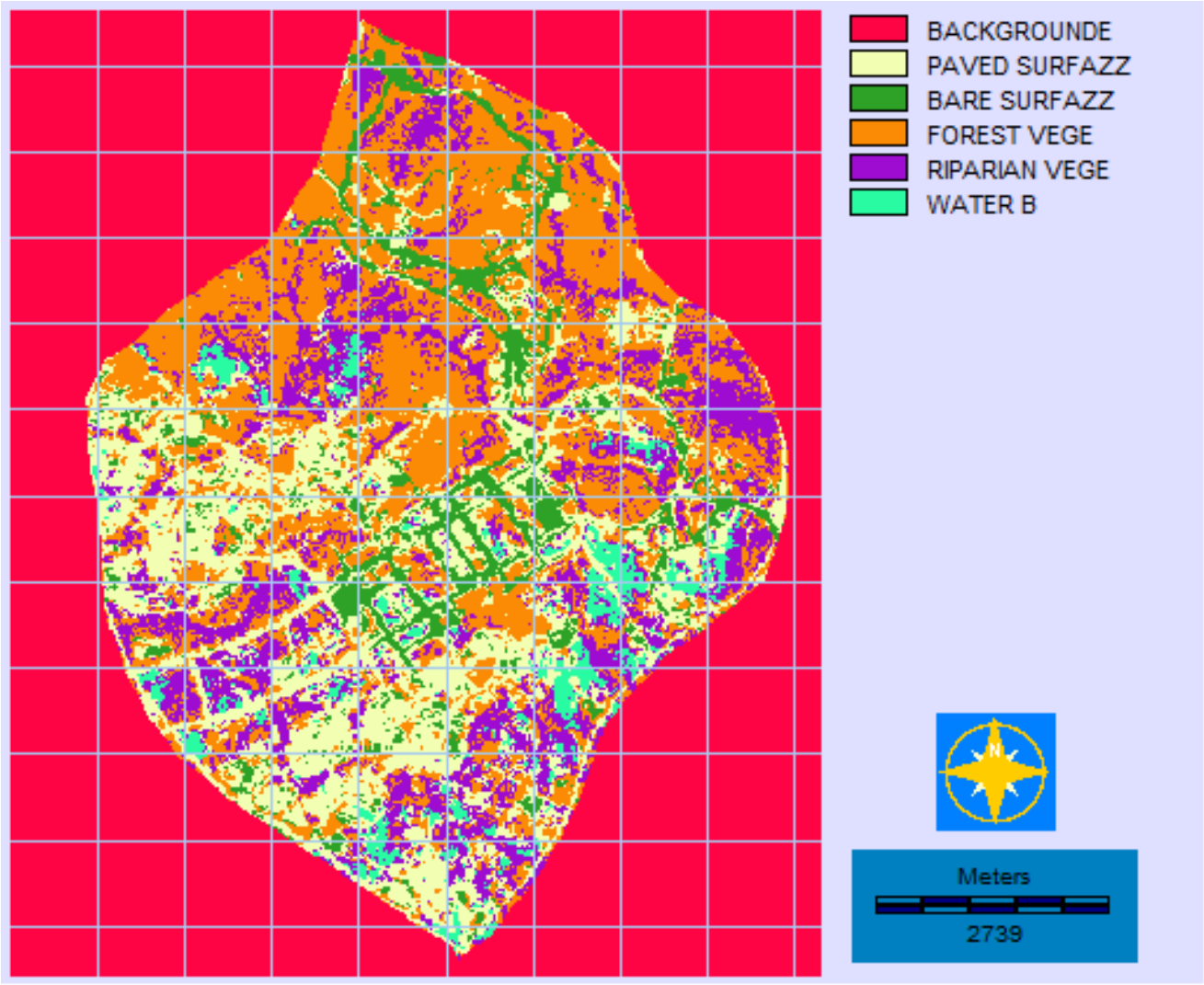


Figure 4.1 Land use/land cover map 1987

source: Authors analysis, 2012.

Figure 4.1 is the land use/cover map of 1987 and it shows the result of LULC classification of the study site for 1987, six classes are here identified with the background given a 0.00 value which makes it negligible in the course of the work. The main LULC identified are displayed and can be identified using the map legend. Figure 4.2 which is the LULC map for 2001 follows below for comparison. Table 4.1 is presented for further comprehension.

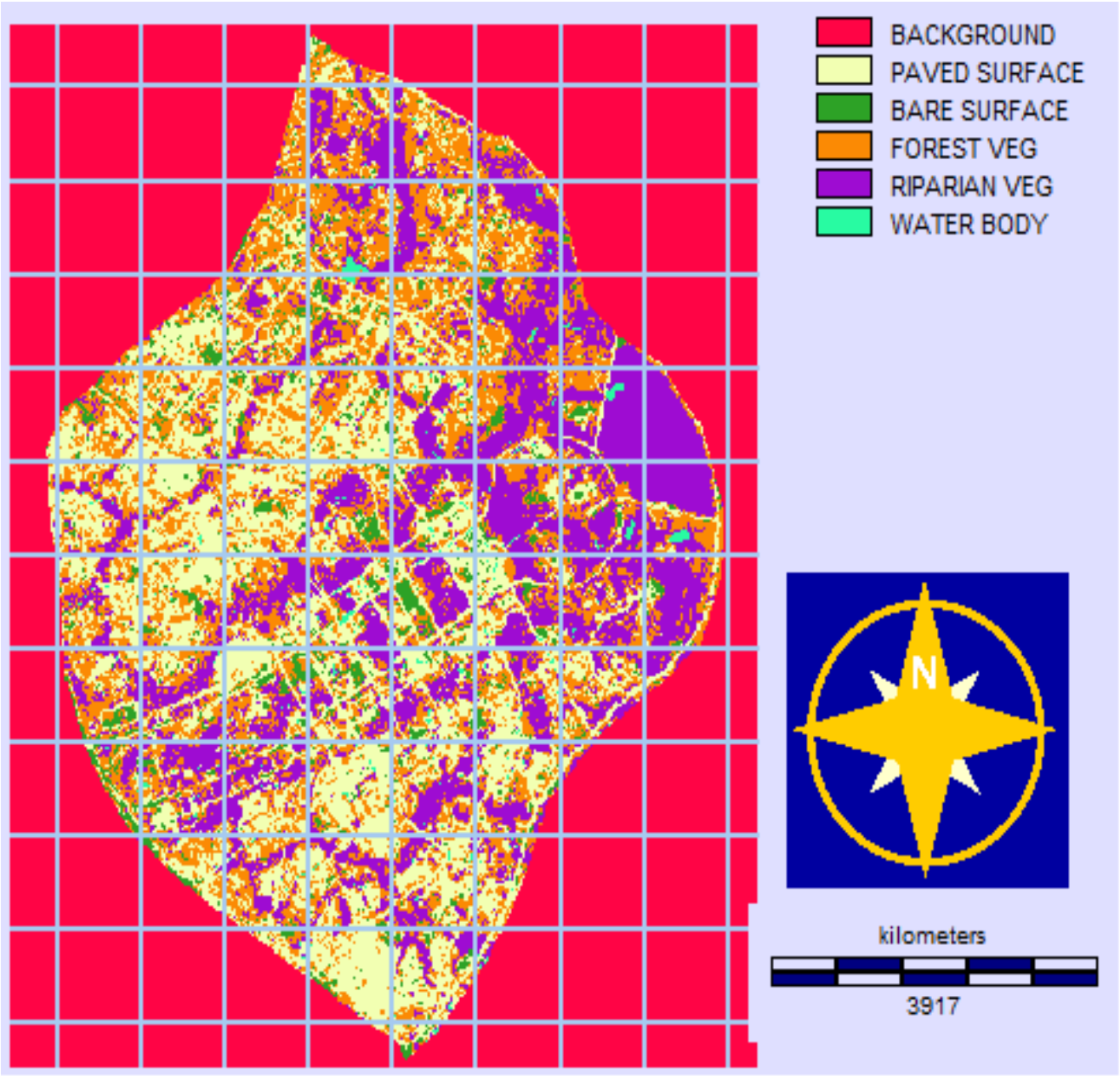


Figure 4.2 Land use/land cover map 2001

Source: Authors analysis, 2012.

Table 4.1 Land use/land cover proportion; 1987/2001

	Area in 1987(km^2)	Area in 2001 (km^2)	Difference (change)	Percentage Difference
Land cover class				
Background (BG)	51.37	51..37	+0.00	+0.00
Paved surface (PS)	14.97	17.75	+2.78	+18.57
Bare surface (BS)	4.98	2.68	-2.3	-46.18
Sparse veg. (SV)	19.96	17.56	-2.4	-12.11
Riparian veg. (RV)	10.68	14.94	+4.26	+39.00
Water body (WB)	2.34	0.46	-1.88	-80.34

Source: Authors GIS analysis (2012)

The negative values in table 4.1 indicate that land classes in the former image, figure 9 (1987) for such group are greater than the same class in the latter image, Figure 10 (2001). This means that in the comparison of the year 1987/2001, bare surface was more in 1987 than 2001 (%) difference of -46.18), implying that by the year 2001, such surface had significantly converted to other land cover as the change map in figure 4.3 coming up latter will indicate. In the same vein, sparse vegetation by 2001 converted to other land cover as the percentage difference shows (-12.11%), similarly some water body too changed (-80.34%) probably owing to seasonal changes in weather (period which image was acquired). These changes are not uncommon and can be explained by the fact that the FCT was officially made Nigeria's state capital only within the time (1991), development until this time was stunted so most of the land was used by the locals for agriculture while most other parts, even within the present

FCC was forested. By the year 2001, paved surfaces had increased (18.57%) and the riparian vegetation too increased.

4.2.2 Land Use/Land Cover Change Analysis; 1987/2001.

Land use change by cross tabulation: Figure 4.3 is the cross tabulation map. It is also the change map because it was able to show the changes that occured over 14 years between 1987 and 2001. The legend shows two rows of numbers, the first year (1987) representing year A is in the column while the second year (2001) representing year B is in the row.

The various colours in the boxes against the numbers represent each layer that has changed, for example, the first box which has figure 1/1 means that there has been no change from class one in 1987(A) to class one in year (B). looking at the area where the colour comes up on the image shows this is true, i.e the background class remains the same for year (A) and year (B).

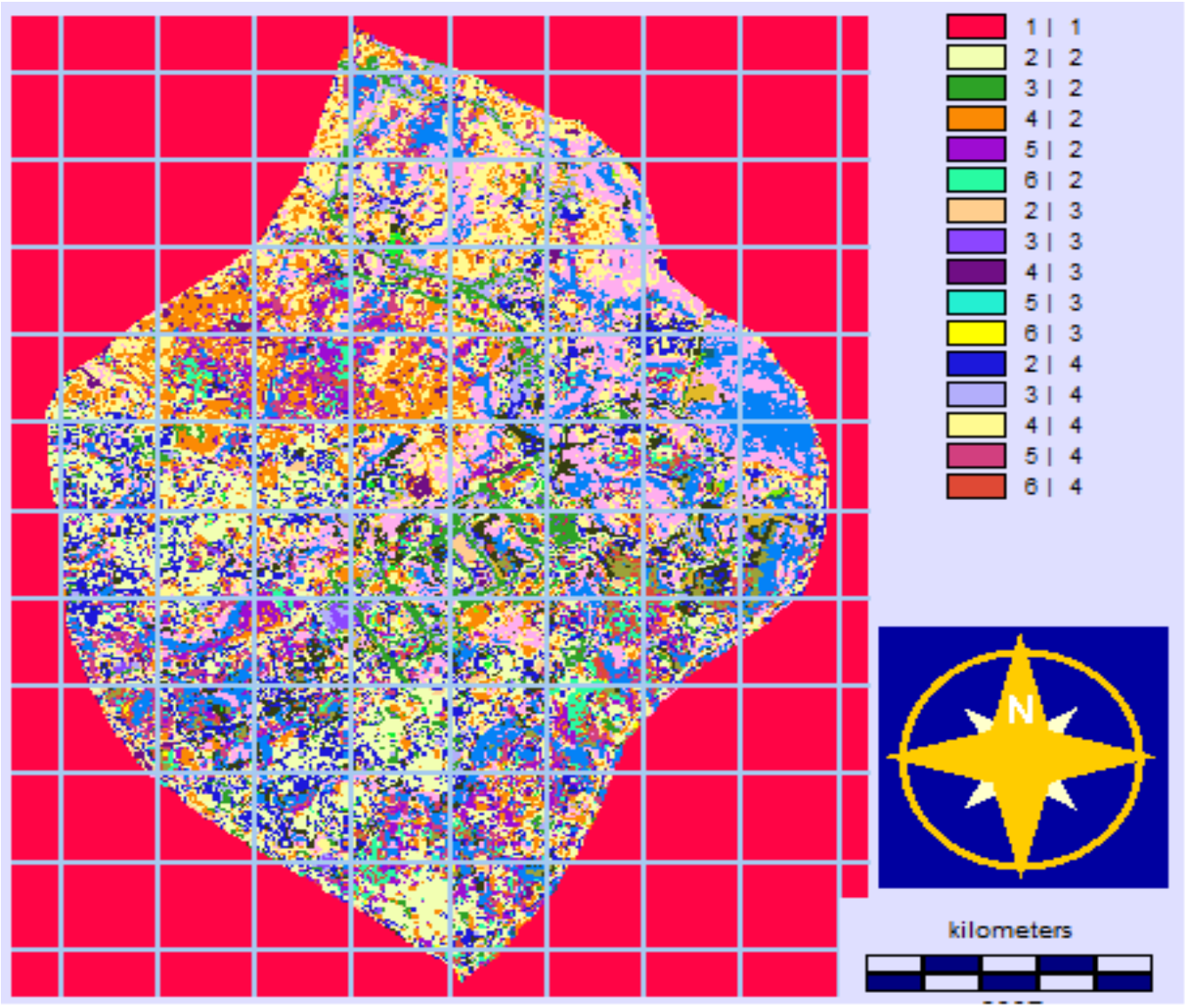


Figure 4.3 Land use/ Land Cover Change Map (1987/2001).

Authors GIS Analysis, 2012.

The second shows 2/2, this means built-up remained the same in the white region for both years. The third shows 3/2, now, here we have a variation displayed, meaning that areas with the green colour changed from bare surface (class 3) in 1987 to built-up (class 2) in 2001. this can be interpreted for all other parts of the legend. The Built environment, which is the main interest class in this study changed at one time to bare surface and at another to sparse vegetation which is possible as bare surface can be constructed on while vegetation can be cleared for buildings.

4.2.3 Land Use Land Cover 2001/2006

A period of five years exists between the two years being compared here. At this stage, development was at a steady rate in the FCC. As at 2006, urban planning was an issue that could not be compromised, a fact that manifested in the city's morphology. A land use map for 2001 has already been presented for reference, leaving that of 2006 which is displayed in figure 4.4.

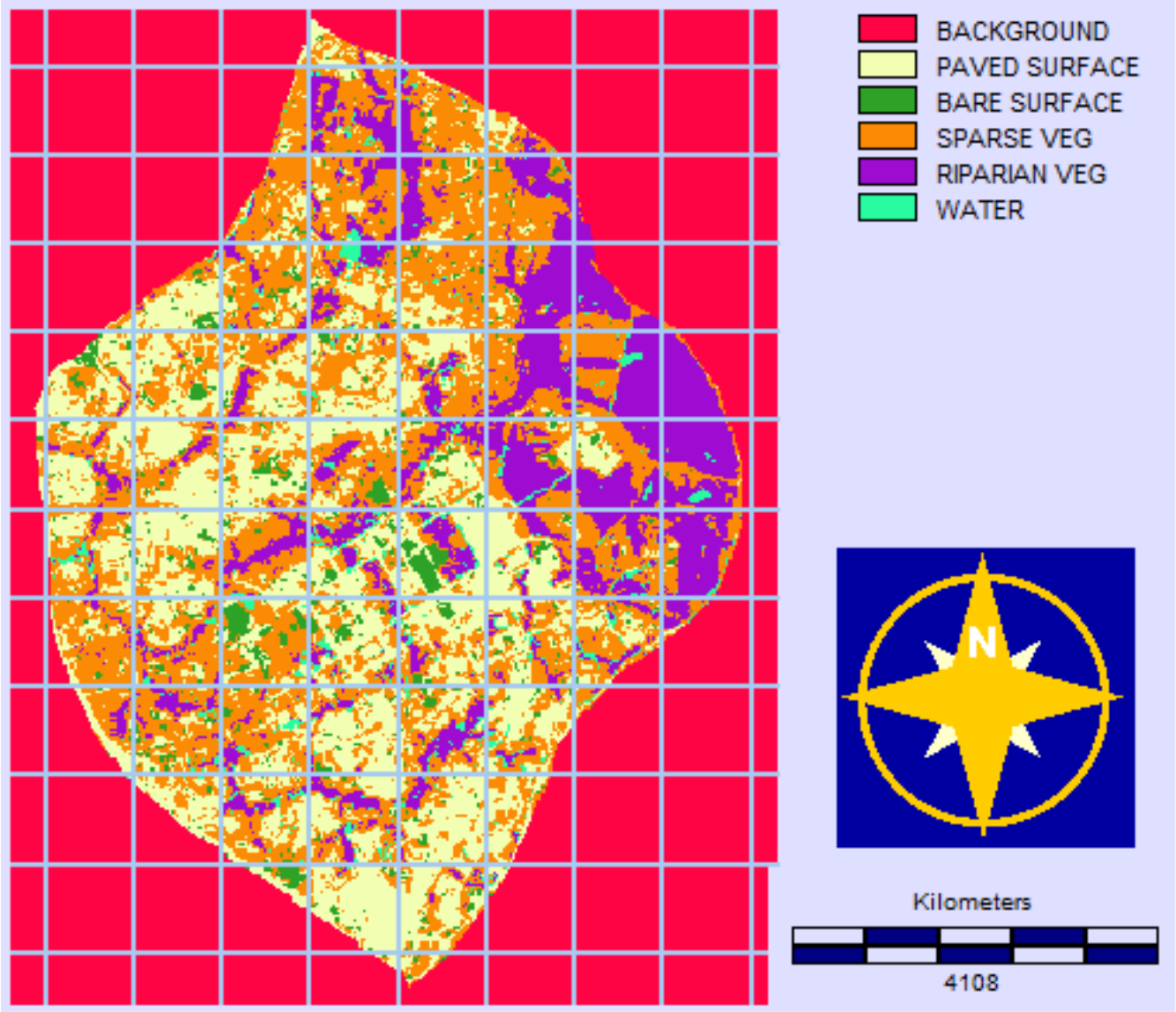


Figure 4.4 Land use/Land Cover Map 2006

Source: Authors GIS Analysis, 2012

The classified 2006 image produced the map on page 72; the classes remain the same as before for this year so that the changes can be assessed accurately.

A comparison of the above map with that of 2001 already displayed shows the changes though not as pronounced like it was between the first two years, the extent to which it changed is as shown in figure 4.5 and table 4.2.

4.2.4 Land Use/Land Cover Change 2001/2006

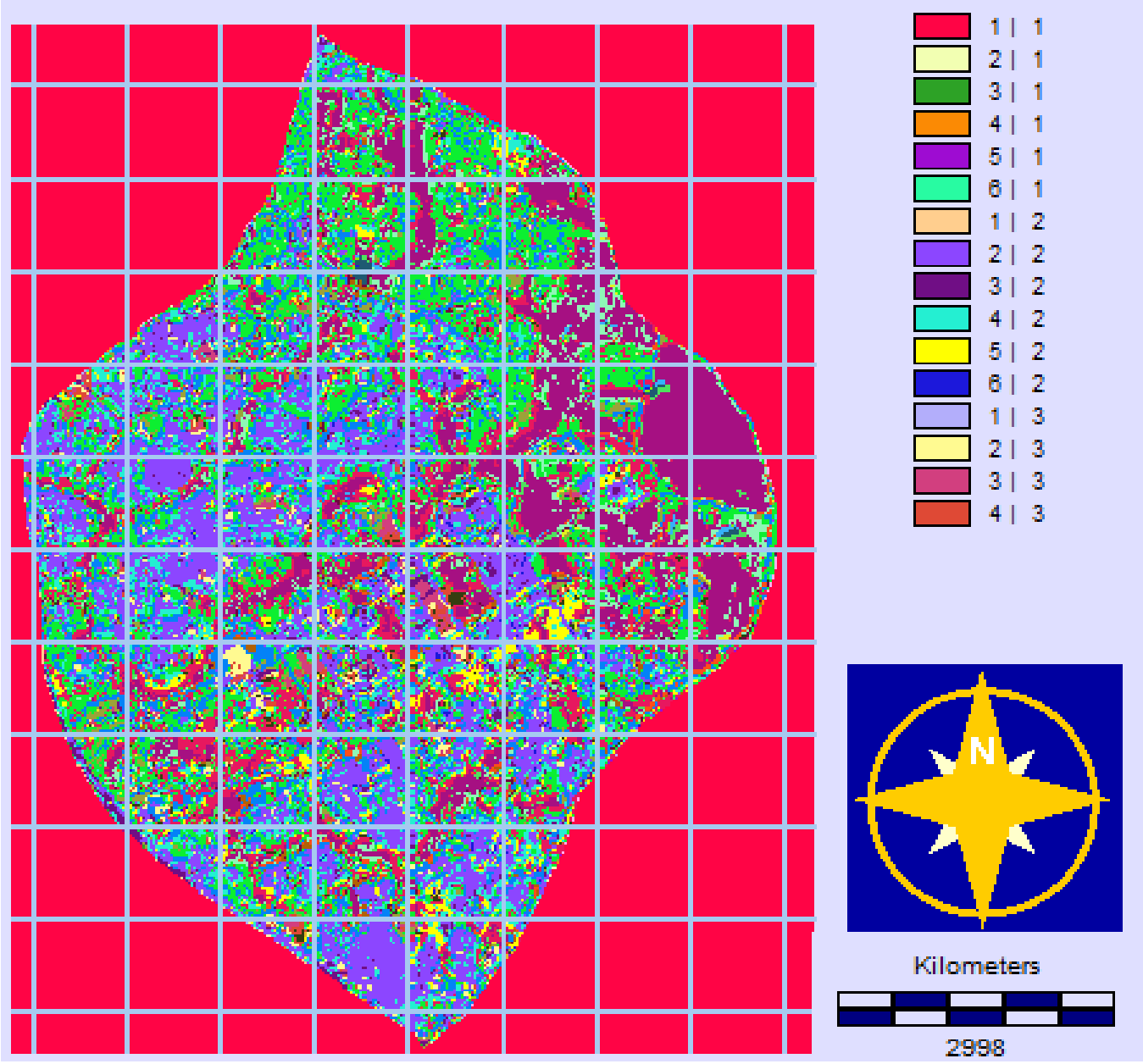


Figure 4.5 Land Use/Land Cover Change Map 2001/2006

Source: Authors GIS Analysis, 2012.

The different colours in the legend as before show the various changes that have occurred. two land classes though remained the same through both years at some point; class 2 (paved surface) and class 3 (bare surface). Table 4.2 compares the area occupied by each land use for both years. The difference and percentage difference between each year is also given so that changes are made more obvious on a first glance**.**

Table 4.2 Land use/land cover proportion; 2001/2006

	Area in 2001(km^2)	Area in 2006 (km^2)	Difference (change)	Percentage Difference
Land Cover Class				
Background (BG)	51..37	51.37	+0.00	+0.00
Paved surface (PS)	17.75	17.18	-0.57	-3.21
Bare surface (BS)	2.68	2.19	-0.49	-18.28
Forest vegetation (FV)	17.56	22.43	+4.87	+27.77
Riparian vegetat. (RV)	14.94	9.83	-5.11	-34.20
Water body (WB)	0.46	1.33	0.87	189.13

Source: Authors GIS Analysis 2001/2006.

The period between 2001 and 2006 (5 years) did not see much increment in the urban land extent, in fact, a decrease of -0,57% is recorded and the change map indicates areas where this has happened. This can be accounted for by the demolition exercise which took place within the stated period. The implementation of the Abuja master plan was seriously being carried out by the FCT ministers' the peak of which was experienced between 2005 and 2006. Then, areas with scattered unplanned buildings were brought down and replaced with

structured buildings possessing the right landscaping which may include trees and flower planting, examples of these are the gardens found in central area and Wuse, with manmade lakes within some (e.g royal garden at zone 7), field checks, coupled with digital analysis was able to confirm this information.

A bar chart (figure 4.6) is used to further give a pictorial view of the changes in the years of study.

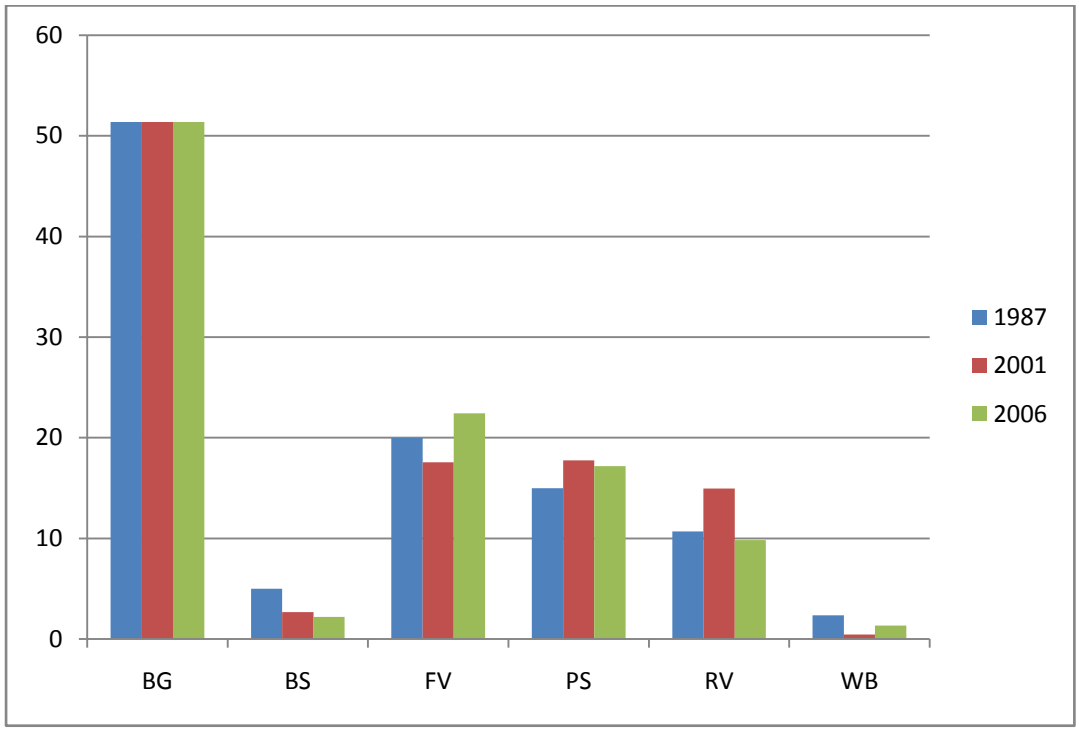


Figure 4.6 Bar-chart showing land use/ cover for all three years (1987, 2001 and 2006)
Source: Authors data generated and developed on excel.

4.3 Surface Temperature

Surface temperature has been established as a major indicator of the presence of urban heat island in cities and urban areas typically impinge on the environment in different ways. Many studies have been conducted using in-situ measurements of surface temperature with climate data (Aina, 1989; Adebayo, 1985; Ojo, 1981; Abdulhamed, 2011; Nduka, 2011) to show the relationship between and effect of urban areas on their micro climate. Several others have

also been conducted using remote sensing and GIS (Ifatimehin et al, 2010; Ifatimehin et al, 2007; Onyeuwoaoma et al, 2011) as is done below.

4.3.1 Surface Temperature, 1987

The temperature map shows that temperature ranges for the year 1987. The range is from a little below 16^0c to 26^0c in extreme cases. Emissivity of the various land use classes and black body temperature from band 6) generated this surface temperature. It can be said that 1987 was a relatively cool year with the highest temperature range at 26 degree Celsius, the effect of the green areas dominant at that time is evident. Figure 4.7 shows this clearly.

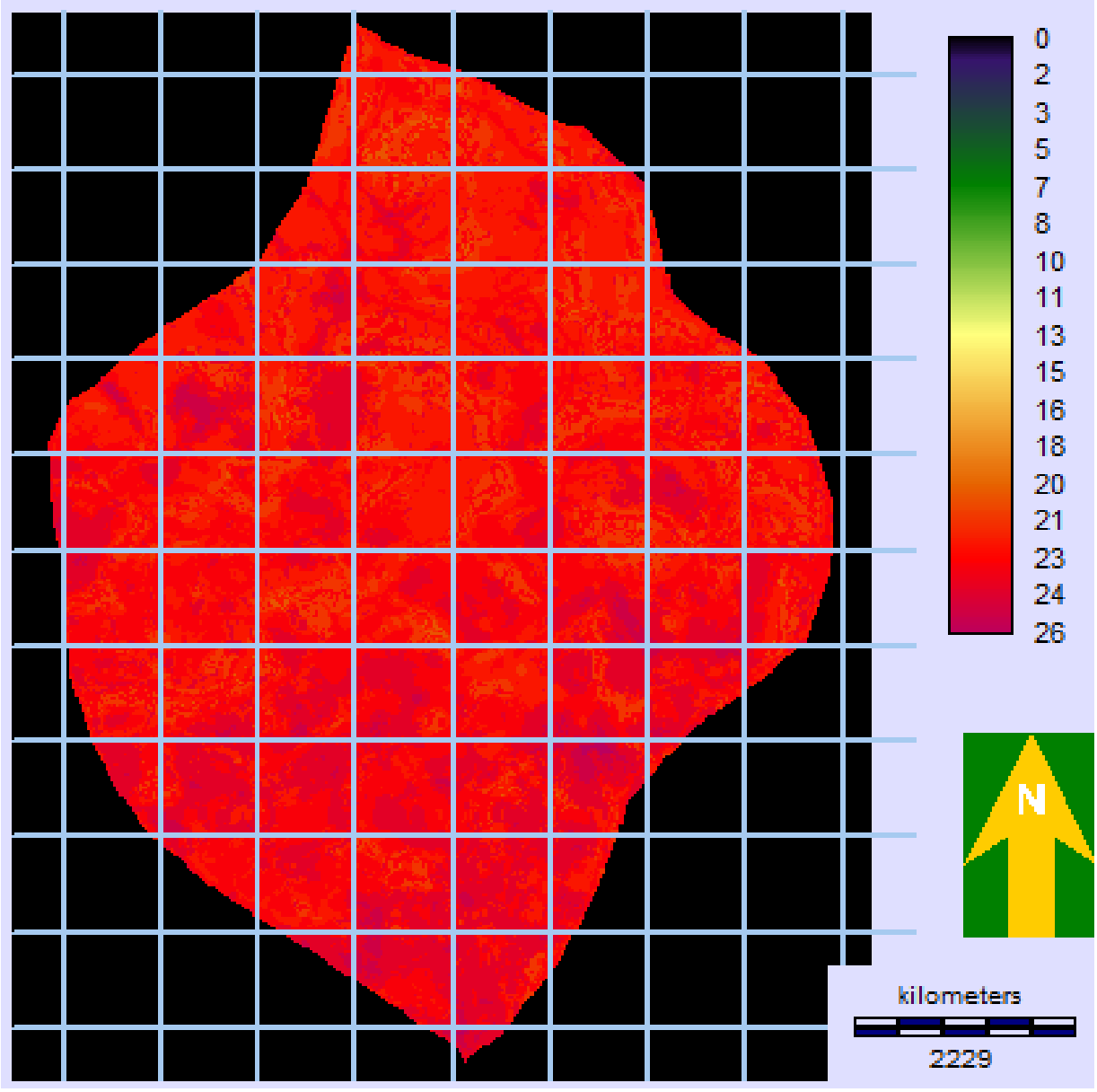


Figure 4.7 Surface Temperature Map 1987 (Source: Authors GIS Analysis)

The series of land uses which have their individual emissivity, display these variations which can be interpreted visually with the aid of the legend when compared with the land use map for the same year displayed above. The purple colour, falling within 24^0c– 26^0c indicates the highest temperature for that year and this shows more in the built up areas while the range from 21^0c - 23^0c is the next highest and still falls within the paved areas, the range from 16^0c – 22^0c is the lowest temperature record for the region and it is noticed that the riparian vegetation and other vegetation reflect this amount.

4.3.2 Surface Temperature, 2001

The 2001 map (figure 4.8) gives a clear picture of the sharp rise in temperature as a result of anthropogenic changes in the FCC. It is interesting to note the changes in surface reflectance in the landscape. The temperature range for 2001 is between 28^0c and 48^0c which is quite alarming as compared to previous year (16^0c to 26^0c). The vegetated areas, especially the dense riparian around the National Arboretum on lat has the lowest surface reflectance between 28^0c and 32^0c, another range between 33^0c and 39^0c is observed and this covers the built-up and other paved surfaces. A third range, falling from 40^0c to 45^0c covers the densely built areas and a final range 46^0c - 480c comes mainly from the roads which are also paved. The highest range of temperature for 2001 which is between 53^0c and 55^0c is hardly observed on any land cover except for a small portion of built-up in central area and as such is considered negligible.

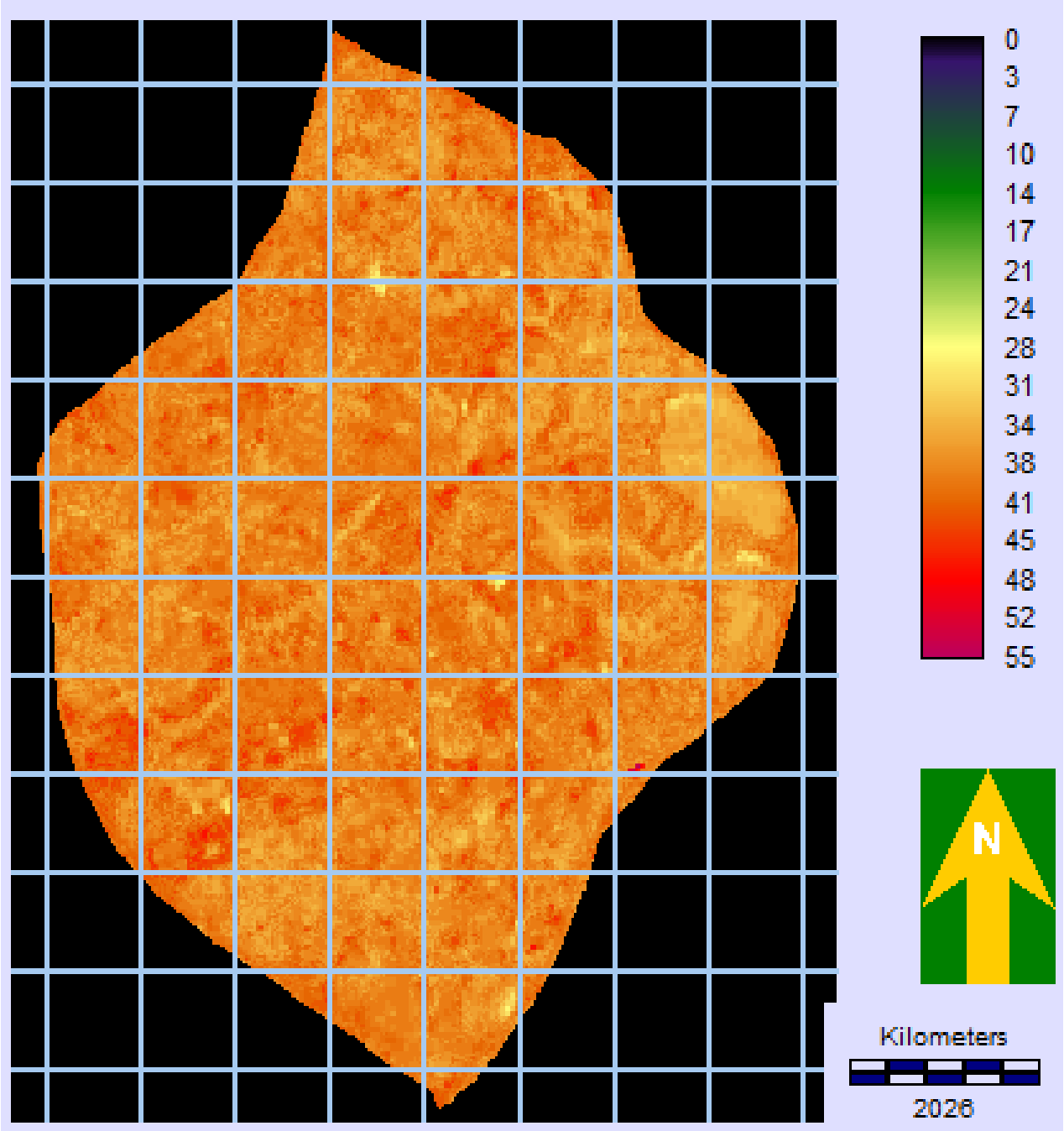


Figure 4.8 Surface Temperature Map 2001

Source: Authors GIS analysis

4.3.3 Surface Temperature, 2006

The year 2006 saw a decrease in temperature range (0^0c- 43^0c) as compared with the previous year (0^0c-55^0c). This shows the direction of change as a result of the careful urban planning being implemented within this period as noted before. The temperature map is displayed as figure 4.9.

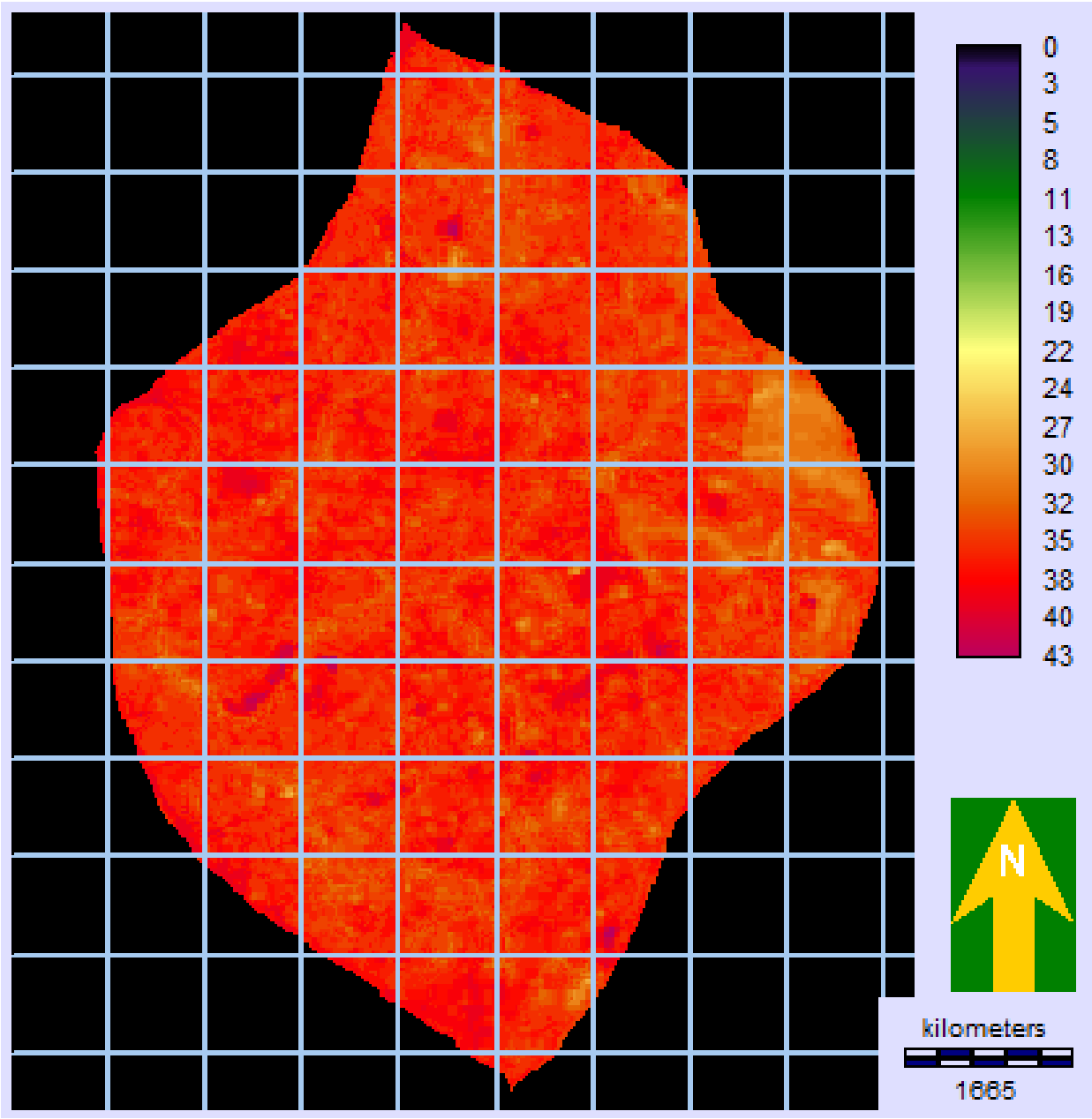


Figure 4.9 Surface Temperature Map 2006

Source: Authors GIS analysis

4.3.4 Surface Temperature for Various LULC

The different types of paved surfaces; roofs, buildings, asphalt (roads), all have high but vsaried reflectance since they are all made from different materials and colours, and these affect the level to which each surface react to radiation. The general range of reflectance for all paved surface is summarized and an average value chosen for this work. Same goes for all other land uses in all the years.

4.3.4.1 Year 1987/2001

Table 4.3 gives a picture of what each land use class for 1987 and 2001 respectively generated in terms of surface temperature. It also gives the differences between both.

Table 4.3 Surface Temperature for LULC and their differences 1987/2001

Land Use/ Land Cover Class	Average Temp (^{0}c) for 1987	Average Temp (^{0}c) for 2001	Diff (0c)
Background	0.00	0.00	0.00
Paved Surface	24.50	41.80	17.30
Bare Surface	22.00	36.00	14.00
Sparse Veg	21.00	36.00	15.00
Riparian Veg	18.00	30.00	12.00
Water Body	17.00	28.00	11.00

Source: Authors Image Interpretation Results 1987/2001

A summary of the various surface temperature reflected by each LULC identified in the study area for 1987 and 2001 is displayed. It is presented this way so that instant comparison can be made. As usual, background values remain 0.00. Just like sharp changes could be observed between both years for land use and land cover, so also is the variation of LULC with temperature. Paved surface gives a 24.50^{0}c reflectance for 1987 while by 2001, the same land use class reflects 41.80^{0}c giving a temperature difference of 17.30^{0}c between both years which is alarming. All other land use/land cover classes also recorded increased temperature in 2001 showing that the temperature over the city in that year was generally higher than was obtained in the former year.

4.3.4.2 Year 2001/2002

The different surface reflectance by the various land use classes in 2001 and 2006 and their differences is given in table 10 below.

Table 4.4 Surface temperature for the different LULC and their differences 2001/2006

Land Use/ Land Cover Class	Average Temp (^{0}c) for 2001	Average Temp (^{0}c) for 2006	Diff (0c)
Background	0.00	0.00	0.00
Paved Surface	41.80	39.50	-2.30
Bare Surface	36.00	35.00	-1.00
Sparse Veg	36.00	34.50	-1.50
Riparian Veg	30.00	27.00	-3.00
Water Body	28.00	22.50	-5.50

Source: Authors Image Interpretation Results 2001/ 2006

The general decrease in built up area between the years 2001 and 2006 and the increase observed in vegetation cover accounts for the decrease observed in the temperature for 2006. There was a 3.21% decrease in paved surfaces in 2006 which yielded a difference of -2.30^{0}c, bare surface also decreased, producing a difference of -1.00^{0}c. sparse vegetation, with a percentage difference of 27.77% yielded a difference of -1.50^{0}c, while riparian vegetation also recorded difference of -3.00 to a percentage change in land cover of -34.20%. Water body records a difference in temperature of -5.50^{0}c to a percentage change in land cover of -77.36%.

From the records arrived at, the year 2006 has a lower built up area as compared to 2006, the observed difference in land area can be explained by the presence of reconstruction work goin on in the FCC within this period. The then Minister embarked on serious demolition exercise in the FCT which affected some parts of the FCC as well. Some buildings that were not properly located such as those that were built on sewage pipes (areas around Wuse, central Area and Asokoro) were brought down, local reports attest that this action was most felt from mid 2005 into the year 2006.

4.4 Urban Heat Island Development

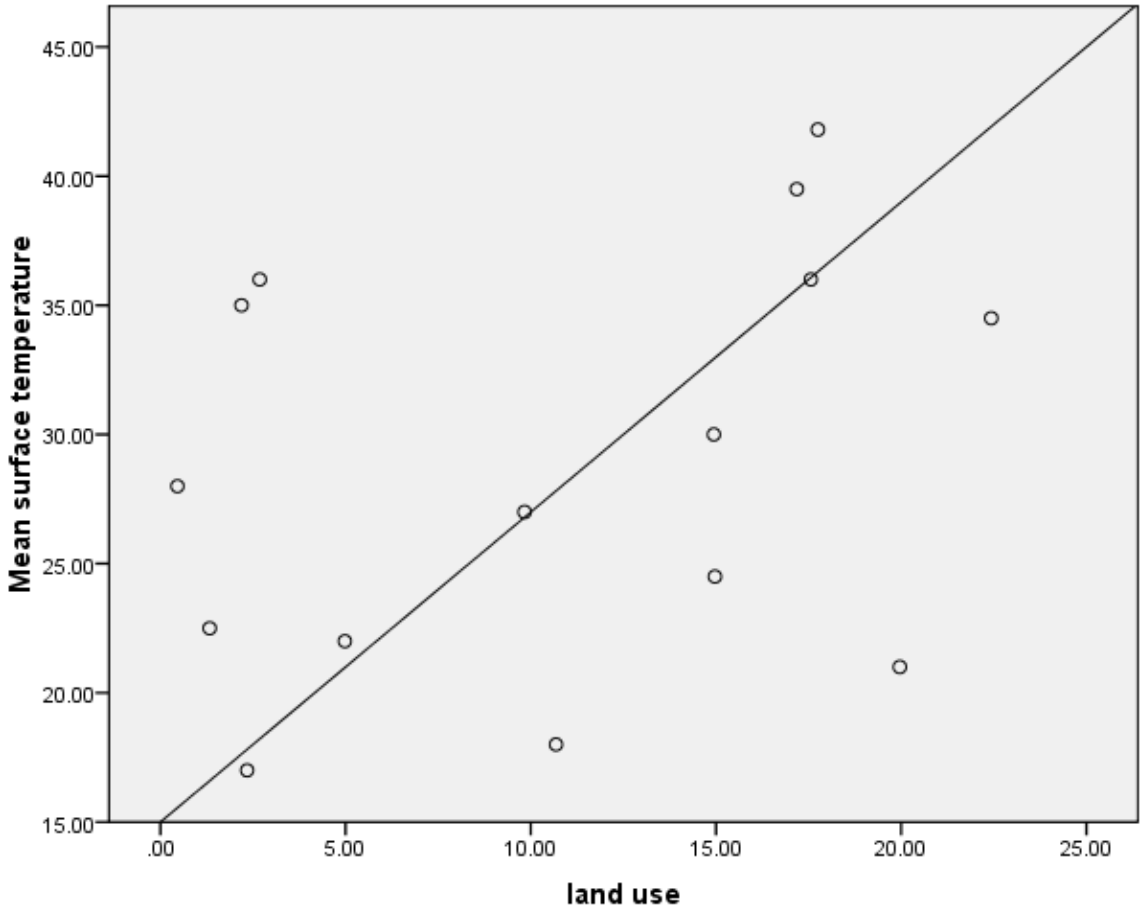


Figure 4.10 LULC and Surface Temperature Relationship.

Source: Authors Statistical Analysis on SPSS

Figure 4.10 is a scatter graph of surface temperature against land use/land cover for the period of study. From the analysis, there exists a +0.336 correlation coefficient. This being

positive means we can conclude there is a relationship between LULC change and surface temperature. But since a perfect relationship exists from +0.5 to +1, then it means the present study is able to draw a +0.336 relationship only which is not so strong.

Therefore, the statistical analysis together with the image analysis for all years points at the fact that surface urban heat island, defined as the relative warmth of air close to the surface (Oke, 1982) exists in the city of Abuja. The 18.57% change in paved surfaces from 1987 to 2001 had an adverse effect on temperature (17.30^0c), this is a course for concern because the little reduction in paved surfaces by 2006 (0.42%) had just as much little impact on the temperature for that year (2.30^0c). On the other hand, the reduction of sparse vegetation from 1987 to 2001 by 12.11% increased surface temperature by 15.00^0c, and by 2006 when the vegetation increased by 27.77%, a 1.50^0c decrease in temperature was recorded. Riparian vegetation throughout the three years recorded very low temperatures, meaning this land cover class, serves to cool the environment and thereby, reduces whatever chances there is of urban heat island developing. Water and bare surface class occupy very little portions of the total land area and as such have very little influence on the overall city temperature.

The weak relationship noted is so because of the inconsistent trend in the changes taking place from the first year to the last. The most contradictory of all the LULC classes in all three years is seen in paved surface and riparian vegetation which both increased between the first two years (1987/2001) and decreased in the last two years (2001/2006).

CHAPTER FIVE

SUMMARY/CONCLUSION/RECOMMENDATION

5.1 SUMMARY

The aim of the study was to assess urban temperature dynamics by establishing a link between the apparent changes in temperature and the level of urbanization which shows in land conversions for different purposes in the federal capital city, Abuja. Surface temperature is a major prediction variable for air temperature, and with the current issues concerning climate change across the globe, it has become imperative that researches such as was completed here is carried out from time to time to monitor the activities going on in the climate environment, all contributing factors must be monitored and their rate of influence checked so that solutions will be easier reached. This research assessed urban temperature dynamics by the use of remote sensing techniques and geographic information system. It was able to achieve this by analyzing three remote sensing imageries of the FCC (Abuja) for 1987, 2001 and 2006.

Variations in urban land use was greatly observed between the years 1987 and 2001, this impacted adversely on the surface temperature record of the later year with temperature rise ranging from 28^0 - 36^0 and 38^0- 48^0in extreme cases (accounting for very negligible portion of the surface) in 2001 as compared to the tolerable and comfortable temperature range of 16^0- 21^0 and extreme of 22^0- 26^0 in 1987. The year 2006 proposed an interesting submission to the study as a decline in paved surfaces by 2006 and increased vegetation was recorded. This may be as a result of the governments consciousness towards implementing the master plan of Abuja city within this periods, several buildings and land cover were demolished in the process and some of these areas were converted to gardens and other aesthetical features often natural vegetation in the form of special trees and flowers along pavements, roads and

built-up environments. The temperature records for 2006 is between 22^0- 32^0 normal and 33^0 - 43^0 in extreme cases, this compared with the record in 2001 shows the variation recorded for both years. Pearson's correolation analysis was able to establish that a relationship exists between land use/land cover and surface temperature and subsequently, urban heat island in the city, a phenomenon very much studied recently in many great cities in the world.

5.2 CONCLUSION

The pace of urbanization in the tropics over the last 60 years has been much faster than that of the developed world which took about 200 years (Wong and Chen, 2009) putting the tropical region above comfort zone because of extreme climatic conditions.

The long exercises conceded here have been geared towards establishing that a relationship exists between land-use/land-cover changes (depicted as urbanization), surface temperature and urban heat island.

In Nigeria, Africa's most populous country, there are more cities with over a million people than any other nation on the continent. The Federal Capital City, a part of the nation's capital continues to be indicative of urbanization, integrating the area into the urban system. With this trend, government and planners need an efficient system for monitoring spatial growth of urban settlements for reasons that are very obvious, given that this growth leads to a reduction in natural land covers as was recorded here between 1987 and 2001. Though the year 2006 recorded an increase in natural cover, it should be duly noted that this could only be achieved when the government made a conscious effort towards greenery.

Conventional monitoring techniques (involving field checks, surveys etc) are time and cost intensive in comparison to the spatial extent of some urban areas thus, an efficient, cost effective, fast and reliable method of monitoring and picking out changes is required to map

and guard the ever expanding urban landscape which is where remote sensing and GIS have, as demonstrated in this research, proven useful.

5.3 RECOMMENDATIONS

Having highlighted the importance of the present research severally, it goes without saying that a problem identified only becomes a reference point when efforts are made to resolve and asphyxiate its impact. This research will therefore not be complete without an attempt at proffering solutions and making recommendations of importance to urban climate issues felt in the FCC. Givoni (1994) suggests that it is possible to improve urban climate through urban planning and design, city planning should be given great attention in the tropics. Some recommendations are stated below:

- City planning; location of the cities in a region, its layout and orientation, street network, density of built up area, types of buildings and green area should be carefully planned.
- Neighborhoods should be well orientated to avoid bad solar orientations but welcoming prevailing wind. Priority should be given to achieving good cross ventilation when there is conflict between solar and wind orientation.
- Light colour (low absorption and high reflectance) facades should be encouraged in a built environment to mitigate urban heat island.
- Vegetation should be introduced extensively and carefully, this will help to provide shading at residential level and building facades or roofs. Though blockage of air movement should be avoided.
- Self shading and shading from near buildings should be well utilized within sites.
- Raising the first floor off the ground while building foundation should be encourage to allow cool air circulation beneath, it has been found to help in places where this is

practiced. Also, Arched, doomed and pitched roofs are better than flat ones in terms of heat gain/loss. Large roof overhangs are also encouraged to protect walls and openings in case of mitigating excessive solar radiation.

- Plants should be introduced to building in their roofs, facades and surrounding to provide thermal comfort. This is also called roof top gardening; wall climbing plants should be planted too. In Europe and America where temperatures are not even as high, this is a very common practice. Nigerian architecture can learn to be inclusive of that to help maintain a relatively cool micro-climate through all seasons.
- Preserving and replicating greenery is very important in the context of city planning as has been noticed in this work.
- The use of traditional building materials even in our cities such as timber and bamboo should be promoted. This can help alleviate the effects from the sun, the advantages are that they are light weight, have low thermal capacity which reduces solar heating accumulation during day time and long wave heat release at night. Thatch can be used for roofing since it is commonly found, cheap and durable, it also helps cool the buildings. These among others are some of the reasons why rural areas are proven to be always cooler than the cities.

Recommendation for Further Studies and Research

- Urban Heat Island Mitigation: Both high-albedo surfaces and increased vegetation help reduce urban air temperatures by replacing the strong heat sources with lesser ones. Thus, they do not mitigate the heat island by cooling the air, but by warming the air less. The effectiveness of a surface in reducing daytime urban air temperatures depends on the amount of heating avoided by using that surface. By examining the energy balance at each surface, one can compare the effectiveness of a high-albedo and a vegetated surface in mitigating the urban heat island.

- Due to unavailability of climate data, time and space, this research could not go the mile to compare the results generated using remote sensing with that gotten from in-situ measurements of air temperature, this can be a topic for the next research.
- Also, the next researcher can take the present study onwards by projecting into the future (prediction) to see the situation of surface temperature with continued urban development.

Though a lot has been done over the last few decades, many more needs to be done to ensure data generation and continuity in the field of urban climatology so that more discoveries are made particularly in the aspect of mitigation strategies.

REFERENCES

Abdulhamed, A. I. (2011). Assessment of Spatial Variation of the Urban Canopy Heat Island (UCHI) in Kano Metropolis. Unpublished PhD thesis. Ahmadu Bello University, Zaria, Nigeria.

Adebayo, Y. R. (1985). The Microclimatic Characteristics within the Urban Canopy of Ibadan. Unpublished PhD thesis. University of Ibadan, Nigeria.

Adebayo, A. A. and Zemba, A.A (2003) "Analysis of micro-climatic variations in Jimeta-Yola, Nigeria".*Global Journal of social sciences 2: 79 – 88.*

Adinna, E. N.I., Enete, I. C and Okolie, T. (2009) "Assessment of urban heat island and possible adaptations in Enugu urban using landsat-ETM".*Journal of Geography and Regional Planning*, 2(2): 030-036.

Ahmad, A. and Hashim, N. (2006). "Remote Sensing of Land surface Temperature Using Landsat TM Thermal Infrared Band".*Proceedings of The Asia GIS 2006 International Conference, UTM Johor, Malaysia, 9-10 March 2006.*

Ahmadi, F.S and Hames, A.S. (2008).Comparison of Four Classification Methods to Extract Land use and Land cover from raw Satellite Images for Some Remote and Arid Areas, Kingdom of Saudi Arabia. *JKAU;Journal of Earth Science* 20: 167 – 191

Anderson, J.R., Hardy, E.E., Roach, J.T. & Witmer, R.E. (1976). *A land use and land cover classification system for use with remote sensor data.* U.S. Geological Survey Professional Paper, No. 964.USGS, Washington, D.C.

Akpu, B. and Anger, T. R (2010). The impact of Spatial Distribution of Solid waste Dumps on Infrastructures in Samaru, Zaria Using Geographic Information. A seminar presentation at the Department of Geography, ABU, Zaria.

Arnfield A.J. (2003) Two decades of urban climate research: A review of turbulence, exchanges of energy and water, and the urban heat island. *International journal of Climatology*, 23: 1-26.

Balogun, A. A., Balogun I. A., Adefisan, A. E. and Abatan, A. A (2006) "Observed characteristics of the urban heat island during the harmattan and monsoon in Akure, Nigeria".*89th Annual AMS meeting and Eight Symposium on the Urban Environment (11th – 16th January, 2006) Phoenix, AZ, USA.*

Bauer, M. E and Loffelhoz, B. C (2007). *Estimating and Mapping Impervious Surface Area by Regression Analysis of Landsat Imagery*. CRC Press, Boca Raton, FL.

Bauer, M.E., Loffelholz, C.B., Sauyer, E.K and Yuan, F (2005).Land Cover Classification and Change Analysis of the Twin Cities (Minnesota) Metropolitan Area by Multi-temporal Landsat Remote Sensing. Journal of Remote Sensing of Environment. Pp 317-328.

Beker, F. (1987). The Impact of Spectral Emissivity on the Measurement of Land Surface Temperature from a Satellite. *International Journal of Remote Sensing*, 8(10): 1509-1522.

Campbell, J. (2002). *Introduction to Remote Sensing*. Guildford press, New York.

Carlton, M.A. (1992). *Satellite Remote Sensing in Climatology*. CBS ltd press, New Delhi, India.

De la Rosa, D. and Van Diepen, C. A. (2002). *Qualitative and Quantitative Land Evaluation*. Encyclopedia of Life Support System (EOLSS-UNESCO), UK: Oxford University Press.

Douset, B. and Goumelon, F. (2003).Satellite Multi-Sensor Data Analysis of Urban Surface Temperature and Land cover. *Journal of Applied Photogrametry and Remote Sensing*, 58 (1-2): 43-54.

Driessen, P.M and Konijin, N.T (1992). *Landuse Sysytems Analysis*. ISRIC Library (Netherlands).

Dror, R.O., Adelson E.H and Wilsky, A.S. (2001). Estimating Surface Reflectance Properties from Images Under Unknown Illumination. Proceedings of the SPIE 4299: Human Vission and Electronic Imaging IV. San Jose, California.

Dupont, S. and Mestayer, P.G. (2006). Parameterization Of The Urban Energy Budget With The Submesoscale Soil Model. *Journal Of Applied Meteorology And Climatology*, 45: 1744-1765.

FAO 1995. Planning for sustainable use of land resources; Towards a new approach. Rome.

Gabe , P. W. (2009). Identifying Land Use/Land Cover (LULC) Using National Agricultural Imagery Program (NAIP) data as a hydrologic input for local flood plain management. Research project available online: http://ecommons.txstate.edu/arp/296.

Gallo, K.P and Owen, T.W, (1999). Satellite Based Adjustments For the Urban Island Temperature Bias. *Journal Of Applied Meteorology*, 38: 806-813.

Gallo, K.P., McNab, A.L., Karl, T.R. and Brown, J.J. (1993). The Use Of Vegetation Index for Assessing Urban Heat Island Effect. *International Journal of Remote Sensing*. 14(11): 2223-2230.

Gillan, J. (2009). The Landscape Tool Box: tools and methods for effective rangeland management.Retrieved 20/08/12 from http://wiki.landscapetoolbox.org.

Gregorio, D. and Jansen, L.J.M. (2000). Land Cover Classification System (LCCS). Classification Concepts and User Manual for software version 1.0.FAO, Rome.

Griffiths, J.F. (1976). *Applied Climatology- An Introduction*. Oxford University Press.

González, J.E., Luvall, J.C., Rickman, D.L., Comarazamy, D. and Picón, A.J. (2007). Urban heat island identification and climatological anlaysis in a coastal, tropical city: San Juan, Puerto Rico. In *Urban Remote Sensing*. Q. Weng and D.A. Quattrochi. CRC Press, Florida, 223 – 225.

Goodchild, M.F., Batty, M., and Maguire, D. J. (2005).GIS. *Spatial Analysis and Modelling*. ESRI press, California.

Heywood, I., Cornelius, S., and Carver, S. (1998). *An Introduction to GIS*. Pearson Education Press.

Ibidun O. A. (2005). Country Report: Urban climate research in Nigeria, IAUC Newsletter.

Ifatimehin, O.O (2007). An Assessment of Urban Heat Island of Lokoja Town And Surrounding Using Landsat ETM Data.

Ikesumoran, M. (2009). Land use and Land cover change Detection in the Kainji Lake Basin Nigeria Using Remote sensing and GIS Approach. *Bayero Journal of Pure and Applied Sciences, 2:* 83-90.

Ifatimehin, O.O., Ishaya, S and Fanan, U (2010). An Analysis of Temperature Variations Using Remote Sensing Approach in Lokoja Area. Nigeria Production Agriculture and Technology. ISSN: 0794-5213.

IPCC Special Report on Land Use, Land Use Change and Forestry, 2.2.1.1.

Jensen, J.R (1996). Introductory digital image processing: a remote sensing perspective, 2nd edition. Prentice hall, USA.

Jiao, L and Liu, Y (2012).Analyzing the Shape Characteristics of Land use Classesin Remote Sensing Imagery. *Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 1-7.

Karl, T. R., Diaz, H.E. and Kukla G. (1988) Urbanization, its effects and detection on the United States climate record. *Journal of climatology*. (1): 1099-1123.

Kim, H. H. (1992). Urban Heat Island.*International Journal of Remote Sensing*. Vol. 13, Issue 12, pp 2319-2336.

Landsberg, H.E (1981). The Urban Climate.Accademic Press, Newyork, pg6.

Landsat Technical Guide. Retrieved October 2010 from http://landsat.gsfc.nasa.gov
Lilesand, T., Keifer, W. R., and Chipman, J. (1994).Remote Sensing and Image Interpretation, third edition. John Willey and Sons inc.

Liang, S and Jin, M (2006).An Improved Land Surface Emissivity Parameter for Land Surface Models Using Global Remote Sensing Observations. *American Meteorological Society*.Vol 19, pp 2867 – 2881.

Lunetta, R. S and Elvidge, C. D (1998) Environmental monitoring methods and applications.Ann Arbor press.

Lo, C.P., Quattrochi, D.A. and Luvall, J.C. (1997). Application of high Resolution Thermal Infrared remote Sensing and GIS to Assess The Urban Heat Island Effect. *Journal of Remote Sensing*. Vol. 18, Issue 2, pp 287-304.

Mabogunje, A. L (1976). Cities and African Development (Studies of African Resources). Available online at www.amazon.com

NRDC, (2007).Climate change threatens health: Air Pollution.

Nduka, I.C (2011). Assessment Of Urban Canopy Heat Island (UCHI) Variation In Onitsha Metropolis, Anambra State, Nigeria. Unpublished M.Sc thesis, Ahmadu Bello University, Zaria.

Nichol, J. E. (1996). High Resolution Surface Temperature Patterns Related to Urban Morphology in a Tropical city: a satellite based study. *Journal of applied Meteorology and Climatology*, 35(1).

National Aeronautics and Space Administration.The Landsat Program, retrieved 20/08/12 from http://landsat.gsfc.nasa.gov/about/landsat4.html.

Norris, J.R and Peppin, N.C (2005). An Examination of the Differences Between Surface and Free-air Temperature Trend at High Elevation Sites: Relationship with Cloud cover, snow Cover and Wind.*Journal of Geographical Research*, 110.

Oke, T.R (1982). The Energetic Basis of The Urban Heat Island.*Quarterly Journal of The Royal Meteorological society*, vol 108 pp 1-24.

Onokerohoraye, A. (1977). *Urban Land Use in Nigeria: Problems and Implications for Policy The Town Planning Review*, 48(1): 59-72. University Press, Liverpool:.

Onyeuwaoma, N.D., Mohammed, S.O., Eguaroje, E., Ogbole, J.O.,Ozah, A.P.,Adagbasa, G.E.,Ajileye, O.O., Omolere, O.S. and Dike V.N. (2008). Effects of Land-Cover Changes on Land Surface Temperature of Ibadan and Environs Nigeria, Using Remote Sensing Approach. Proceedings of the International Conference of the Nigerian Meteorological Society, Climate Change Impacts: Risks and Opportunities.

Owen. T.W., Carlson, T.N. and Gillies, R.R. (1998). An assessment of satellite remotely – sensed land cover parameters in quantitatively describing the climatic effect of urbanization. *International Journal of Remote Sensing,*19(9): 1663 – 1681.

Richards, J.A. (1993). Remote Sensing Digital Image Analysis: an introduction. 2nd edition.

Roth, M., Oke, T.R. and Emery, W.J. (1989).A satellite Derived Urban Heat Island From Three Coastal Cities And The Utilizing Of Such Data in Urban Climatology. *International Journal Of Remote Sensing*, 10(11): 1699-1720.

Sabins,F.F (1997). Remote sensing: Principles and Interpretations, Third edition. W.H. Freeman and Company.

Sabrino, J. A, Jimenez-Munoz, J. C. and Paolini, L. (2004).Land Surface Temperature Retrieval From Landsat TM5. *International Journal of Remote Sensing*, 90(4): 434-440.

Sarkar, H."Study of Landcover and Population Density Influences on Urban Heat Island in Tropical Cities by Using Remote Sensing and GIS:A Methodological Consideration".Access From internet http//:geo.wvu/geog655/spring2002/01/project.htm. Jan 2004.

Streuker, D. R. (2002).A Remote Sensing Study of The Urban Heat Island of Houston. *International Journal of Remote Sensing*, 22(13): 2595-2608.

Singh, A. (1989). Digital change Detection Techniques Using Remotely Sensed Data. *International Journal of Remote Sensing*. 989-1003.

Southworth, J (2004). An assessment of Landsat TM Band 6 Data for Analyzing Land cover in Tropical Dry Forest Regions. *International Journal of Remote Sensing*, 25: 689 – 706.

Snyder, C.W., Wan, Z., Zhang, Y and Feng, Y. (2005). Classification Based Emissivity for Land Surface Temperature Measurement from Space.

Mikon Instrument Company Inc. Table of Emissivity of Various Surfaces for Infra-red Thermometry.

UNESCO.(1973). International Classification and Mapping of Vegetation.Paris.

UN Report on Climate Change.Retrieved 25 June 2010 (from web archive).

Ujoh, F., Kwabe, J.D and Ifatimehin, O.O (2010).Understanding Urban Sprawl in the

Federal Capital City, Abuja: Towards Sustainable Urbanization in Nigeria.*Journal of Geography and Regional Planning.*Vol, 35, pp 106 – 113.

VanDiepen, C.A and De la Rosa, D (2002).Qualitative and Quantitative Land Evaluation. In 1.5 Land Cover and Land use.in Encyclopedia of Life Support System (EOLSS-UNESCO) Oxford, UK.

Voogt, J.A. and Oke, T.R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment*,86: 370 – 384.

Voogt, J.A. (2004). Urban Heat Island: hotter cities. Retrieved from www.actionbioscience.org

Voogt, J.A. and Oke T.R. (1998). Effects of Urban Surface Geometry On Remotely Sensed Surface Temperature. *International Journal of Remote Sensing*, 19(5): 895-920.

Voogt, J. A. (2000). How Researchers Measure Urban Heat Islands.

Voogt, J.A andOke, T.R. (1997). Complete Urban Surface Temperatures. *Journal of Applied Meteorology*, 36: 1117 – 1132.

Warner, T. A. and Campagna, J.D. (2009). Remote Sensing with Idrisi Taiga: a beginners guide.Geocarto International Center (HongKong).

Weng, Q (2001). "A Remote Sensing–GIS Evaluation of Urban Expansion And Its ImpactOn Surface Temperature In The Zhujiang Delta, China". *International Journal of Remote Sensing*, 22(10):1999–2014.

Weng, Q., Dengsheng, L., and Jacquelyn, S. (2004). Estimation of Land Surface Temperture and Vegetation Aboundance Relationship for Urnab Heat Island Studies.*Remote Sensing of Environment*, 89(4): 483-464.

Wong, N. H. And Chen, Y. (2009) Tropical Urban Heat Islands: climate, buildings and greenery. (London: Taylor and Francis).

Wolfgang, L., Kostl, M., and Steinocher, K. (2008).Quantitative Classification Of The Major European Rural-Urban Regions. Available online at plural.net.

Wu, B., Wang, X., Shen, H., and Zhou, X. (2012).Feature Selection Based on Max-Min-associated Indices for Classification of Remotely Sensed Imagery. *International Journal of Remote sensing*, 33(17-18): 5492-5512.

www.urbanheatislands.com. The Urban Heat Island Effect (UHI).Retrieved Aug 2011.

Xian, G and Crane, M. (2006) “Evaluation of Urbanization Influence On Urban Climate With Remote Sensing And Climate Observations”. National CentreFor Earth Resources Observation And Science, Sioux Falls, SD 57198.

Xian, G., Crane, M. and McMahon, C. (2008).Quantifying Multi-temporal Urban Development Characteristics In Las Vegas from Landsat and Aster Data. *Journal of Photogrammetric Engineering and Remote Sensing*, 74: 473 – 481.

Yuan, F. and Bauer, M. E.(2007). Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery. *Remote Sensing of Environment*, 106: 375 - 386.

Yuan, L.C and Deou Yang, K (2009).Unsupervised Classification of Remote Sensing Imagery with Non-negative Matrix Factorization.

WEB SOURCES

http://www.crisp.nus.edu.sg .retrieved May 2010

http://www.electro-optical.com. Retrieved Aug 2012.

http://en.wikipedia.org. retrieved Jan 2012.

http://glcf.umlacs.umd.edu. Retrieved Aug 2012

http://landsat.gsfc.nasa.gov. Retrieved May 2010

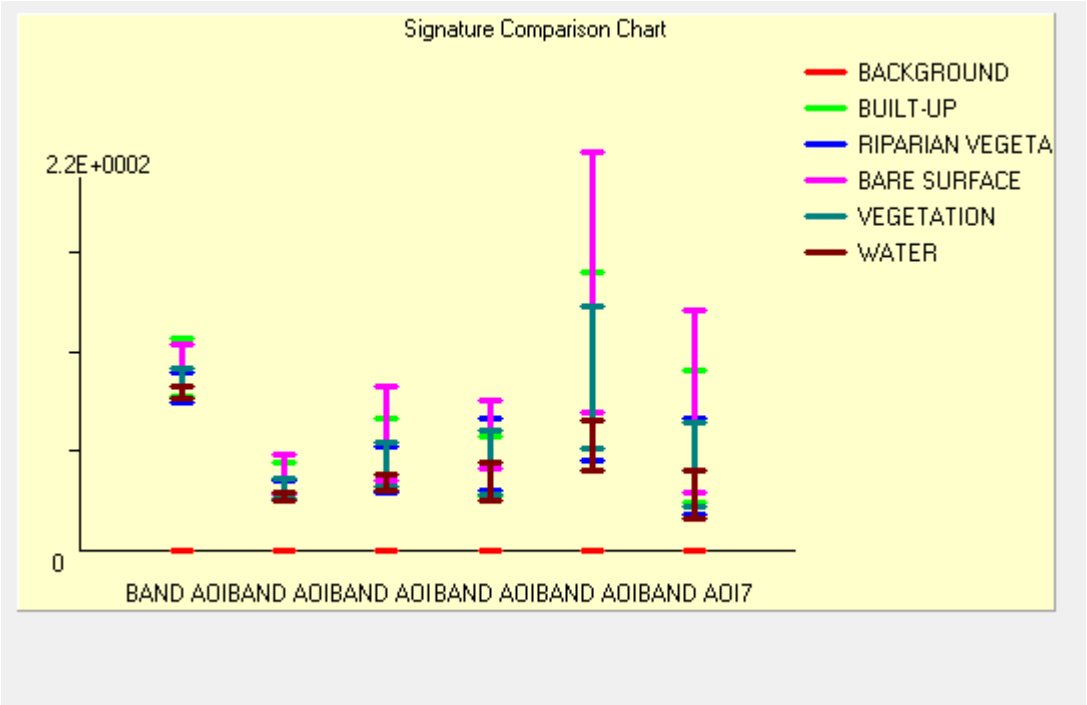
http://www.urbanheatislandbasics.com. Retrieved Nov 2012

http://www.epa.gov. Retrieved Nov 2012

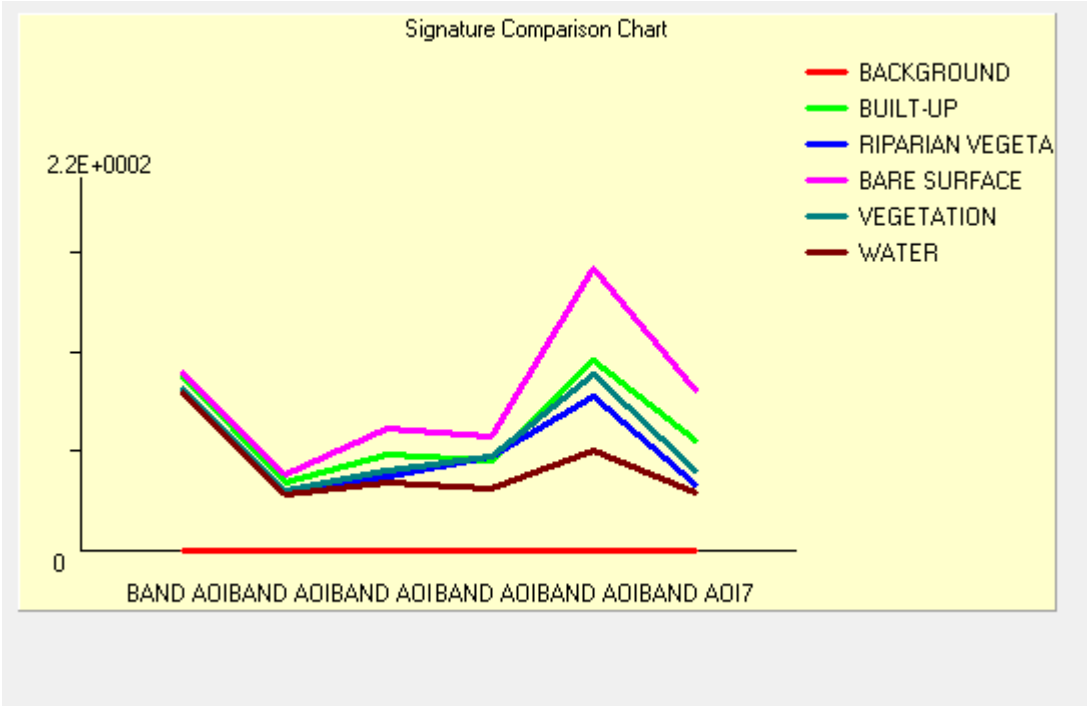
APPENDICES

Appendix I: Signature Files Developed from LULC Classification

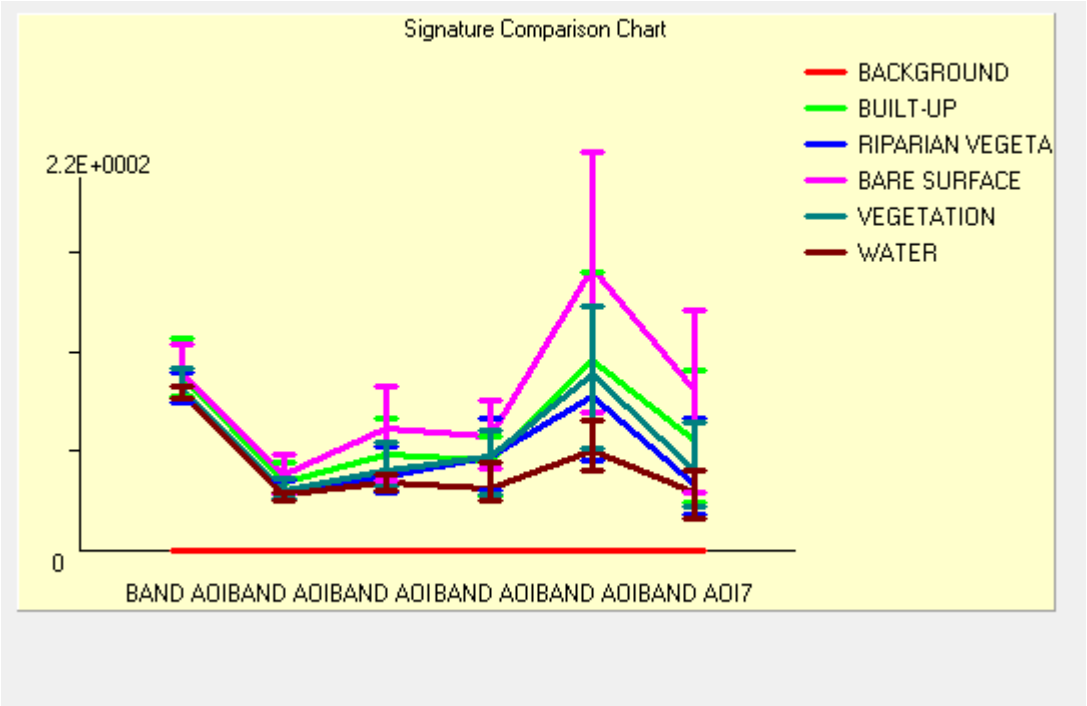
Signature Development from Bands1, 2, 3,4,5,6 and 7. Landsat (Tm) 1987



a. Minimum and Maximum

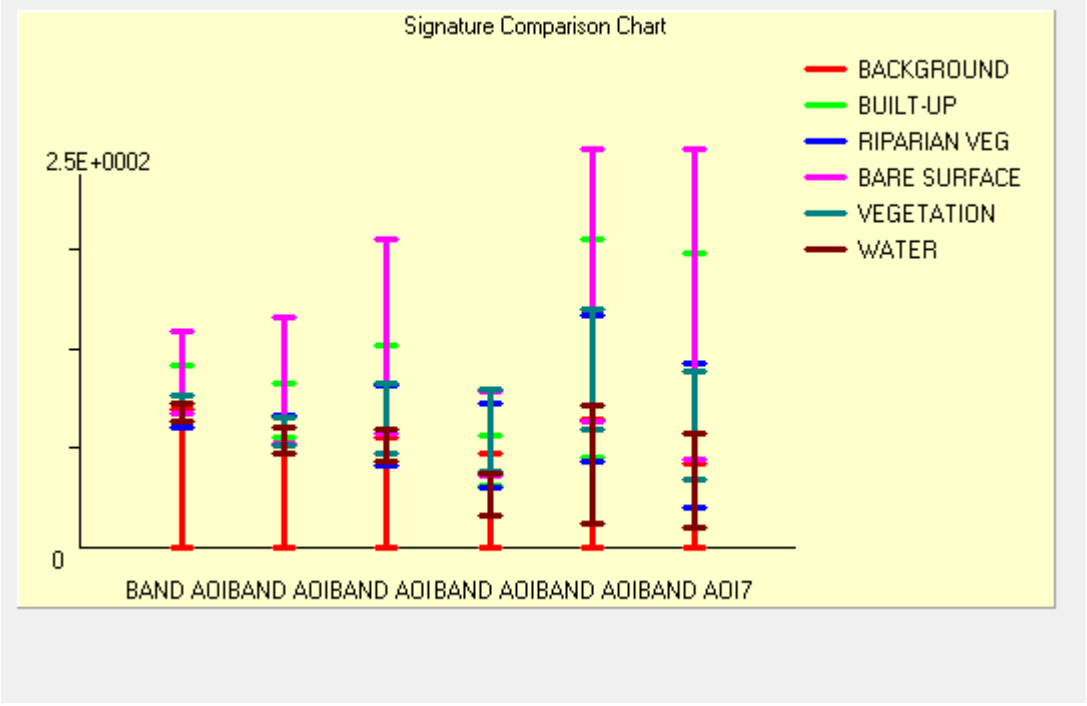


b. Mean

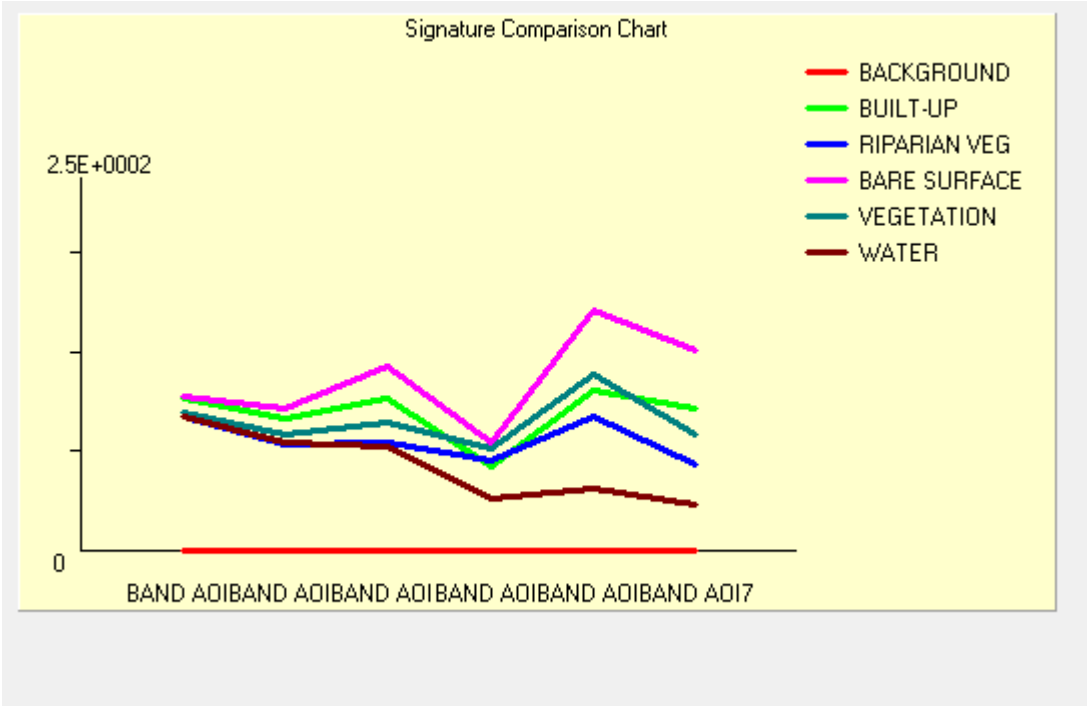


c. Minimum, Maximum and Mean

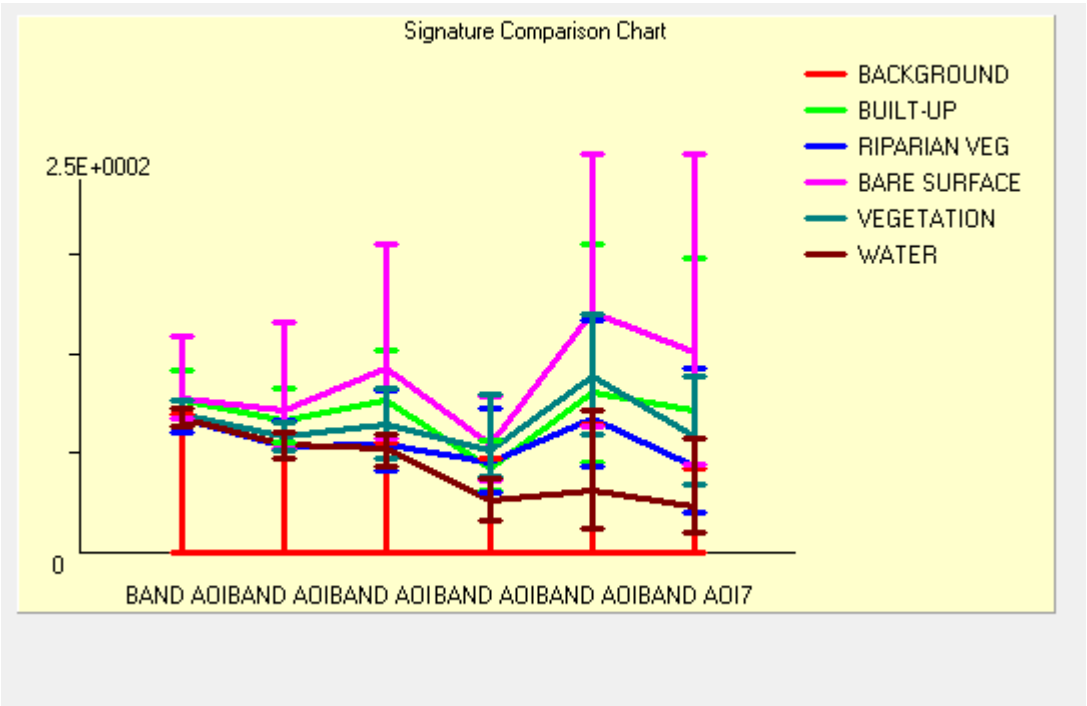
Signature Development from Bands1, 2, 3,4,5,6 and 7. Landsat (ETM) 2001



a. Minimum and Maximum

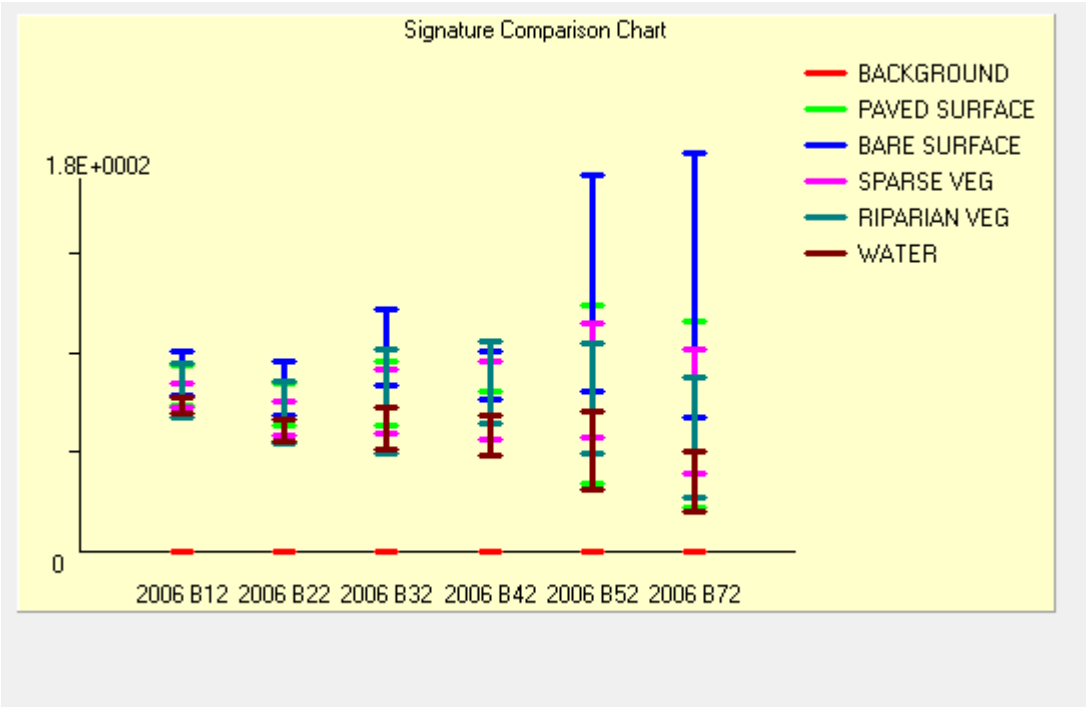


b. Mean

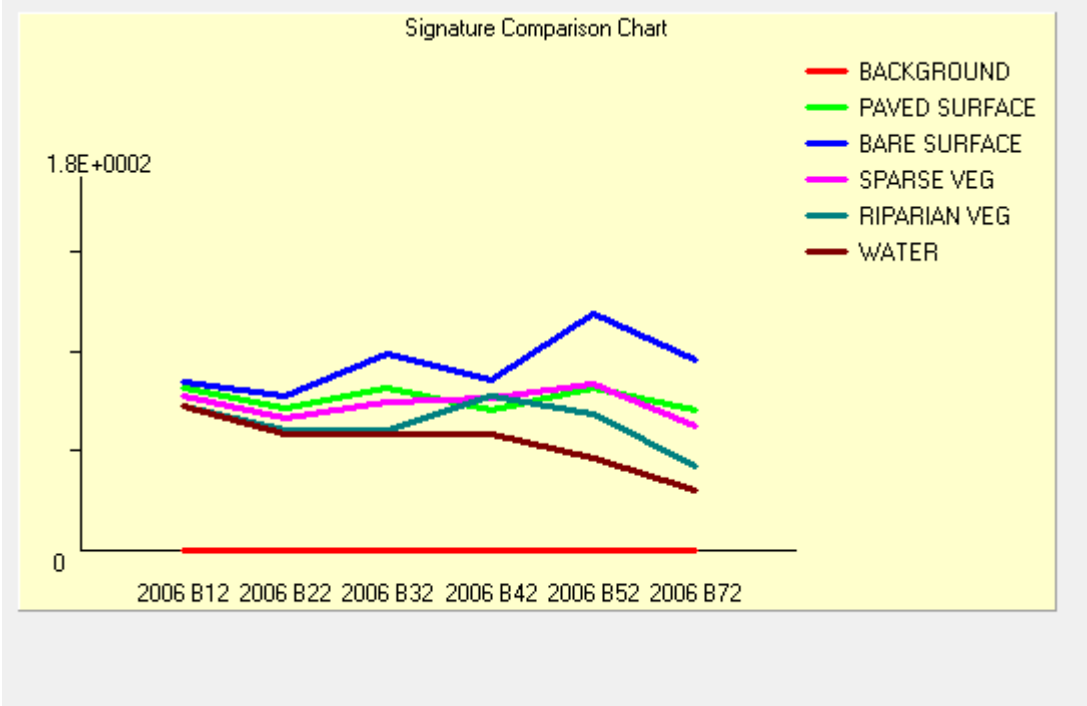


c. Minimum, Maximum and Mean

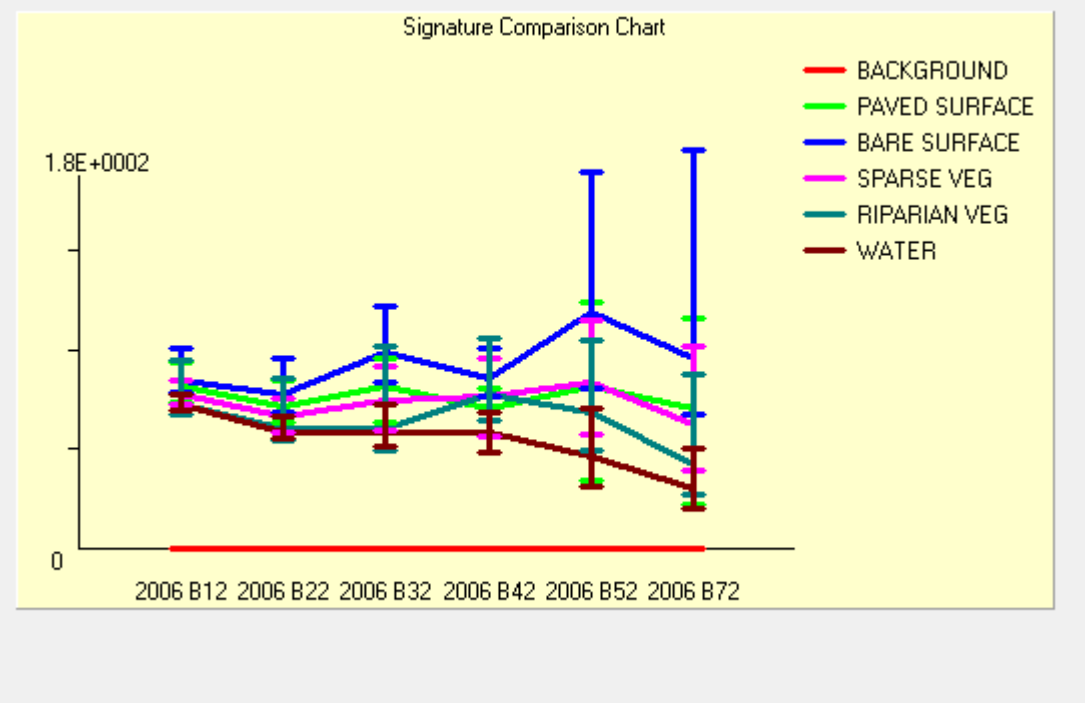
Signature Development from Bands1, 2, 3,4,5,6 and 7. Landsat (ETM) 2006



a. Minimum and maximum



b. Mean



c. Minimum, maximum and mean

APENDIX II: Cross Tabulation (LULC Change) Statistics

CROSS TAB FOR 2001 AND 2006

Cross-tabulation of MAXI LIK 01A (columns) against MAXI-LIK 2006 (rows)

	1	2	3	4	5	6	Total
1	63636	43	16	41	16	3	63755
2	52	12037	1316	5880	1870	165	21320
3	6	985	537	869	306	20	2723
4	57	7620	1293	12058	6652	159	27839
5	8	701	106	2359	8904	128	12206
6	2	470	35	406	640	96	1649
Total	63761	21856	3303	21613	18388	571	129492

Chi Square = 173208.20313
df = 25
P-Level = 0.0000
Cramer's V = 0.5172

Proportional Crosstabulation

	1	2	3	4	5	6	Total
1	0.4914	0.0003	0.0001	0.0003	0.0001	0.0000	0.4923
2	0.0004	0.0930	0.0102	0.0454	0.0144	0.0013	0.1646
3	0.0000	0.0076	0.0041	0.0067	0.0024	0.0002	0.0210
4	0.0004	0.0588	0.0100	0.0931	0.0514	0.0012	0.2150
5	0.0001	0.0054	0.0008	0.0182	0.0688	0.0010	0.0943
6	0.0000	0.0036	0.0003	0.0031	0.0049	0.0007	0.0127
Total	0.4924	0.1688	0.0255	0.1669	0.1420	0.0044	1.0000

Overall Kappa 0.6340

APENDIX III: PEARSONS CORRELATION

		VAR00004	VAR00005
VAR00004	Pearson Correlation	1	.336
	Sig. (2-tailed)		.221
	N	15	15
VAR00005	Pearson Correlation	.336	1
	Sig. (2-tailed)	.221	
	N	15	15

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