ANALYSIS OF URBAN INFLUENCE ON RURAL SETTLEMENT GROWTH AND LAND USE \LAND COVER CHANGE IN THE FEDERAL CAPITAL TERRITORY OF NIGERIA USING REMOTE SENSING AND GIS DATA

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CERTIFICATION

This thesis titled: "Analysis of Urban Influence on Rural Settlement Growth and Land Use \Land Cover Change in the Federal Capital Territory of Nigeria Using Remote Sensing and GIS Data" by Mr. A.M Jinadu meets the requirement for the award of the degree of Doctor of Philosophy (Ph.D) of the Federal University of Technology, Minna and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to Almighty Allah and the entire Jinadu family of Baba Onilu Compound, Kisi, Oyo State.

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All praises be to Almighty Allah Who provided me the life, wisdom, health and the financial resources to complete this work. From Him we come and unto Him we shall return.

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ABSTRACT

The construction of the Federal Capital City (FCC) and the subsequent transfer of the Federal Capital of Nigeria from Lagos to Abuja between 1986 and 1991 generated substantial rural settlement growth and land use\land cover changes in the Federal Capital Territory (FCT). The continuous influx of migrants into the surrounding satellite settlements sets in motion the process of rural spatial disequilibria as evidenced in the mounting population pressure, settlement sprawl and development of slum enclaves with attendant social problems. In the past, one major constraint of studies, which used pure conventional survey approach, is the inability to capture the spatial manifestations of rural socio-economic transformations. This problem becomes surmountable with the development of remote sensing technology that has both synoptic and temporal data recording ability and which has facilitated settlement growth and change detection studies in both urban and rural settlements on a temporal basis.

This study examines the impact of the FCC on the growth of selected satellite settlements. It also identifies factors of rural settlement growth and the negative consequences associated with the observed growth. The study utilises the 1976 Landsat MSS, 1987 Landsat TM, 1994 SPOT XS and the 2001 Landsat ETM+ satellite images in conjunction with ground-based reference data to determine the amount of growth between 1976 and 2001, the quality of physical development and the factors of growth in the study area. The satellite images used were interpreted and mapped using the ERDAS IMAGINE, Arc\Info and Arc\View softwares to derive land use\land cover maps and settlement growth statistics of the area. The projection\modelling of future growth of the settlement areas was achieved using the ration method developed by Rao (1995) and regression analysis. The nature of spatial interaction and the socio-economic variables that explain settlement growth were identified using data collected through field survey conducted between August 2002 and June 2003. The information collected from the field were analysed using frequency tables, quadrat count analysis, correlation analysis and graphs.

The result of the analysis of spatial pattern of settlements shows that the settlements in the FCT are clustered in space. The mean interaction field of the FCC, as at the time of the study, covers 1,678.17 Km^2 with 128 interacting settlements and over 313,535 resident population. The daily interaction within the field is manifested in inter-settlement travels, which is dictated by the home-workplace relationship between the FCC and its satellite settlements. The result of urban growth monitored also shows that the built-up areas of the settlements increased from 1.22 km^2 in 1976 to 31.32 km^2 in 1987, 111.52 km^2 in 1994 and 119.5 km^2 in the year 2001. The selected satellite settlements were found to experience high growth rate (ranging from 22.3% to 330.9% in the 1987 – 1994 period and 12.9% to 228.8% in the 1994 – 2001 period) with more development impact felt in the post FCC period (1994 – 2001). Among others, nearness to Abuja and ease of commuting and population increases due to spill over from Abuja were found to be the most significant variables that explain 97.8% of the growth of the satellite settlements studied. The study estimated the growth of the settlements for the year 2008 and the analysis revealed that the expected future developments are still considerable. In view of this, proper development control and settlement improvement in the satellite settlements are recommended. Adequate provision of low-income housing within the context of Abuja Master Plan is also recommended to stem the tide of the population spill over effect, which is a major factor of counterurbanization in the area.

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CHAPTER ONE

1.0 INTRODUCTION, STATEMENT OF RESEARCH PROBLEM AND METHODOLOGY

1.1. Introduction

Settlements are a concrete expression of human occupation of the earth's surface and they form an essential element of the landscape (Hagerstrand, 1957). The earliest settlements evolved as campsites and later as temporary abode in the Palaeolithic period. However, as population grew, the advancement in agriculture and the production of surplus brought about sedentary living, which led to the emergence of more permanent settlements as far back as 10, 000 to 4000 BC (Onokerhoraye and Omuta, 1985; Encyclopaedia Britannica, 2001). From this initial simple form, settlements have developed through the centuries to become the permanent, more sophisticated spatial structures that now characterise the entire human landscape.

Settlements exhibit certain distribution pattern over space. Several evolution and distribution models advanced by Byhund (1960), Morrill (1962), Chisholm (1962), Hudson (1969) and Christaller (1933) help to explain how settlements have evolved over time and space as well as the principles behind their distribution pattern. The theoretical advancement of these models, coupled with the empirical findings of authors like Dacey (1962) and Rayner and Golledge (1972), establish three major settlement distribution patterns in the literature - regular, random and clustered. The emergence of any of these patterns is ascribed to both physical and human factors. Thus Money (1975) asserts that variations in relief and drainage conditions as well as customs and technological abilities of man strongly influence settlement pattern.

Generally, the human landscape exhibits a system of settlements of different sizes. The emergent scene is such that, "few great centres of metropolitan population stand out clearly while at the other extreme, the myriad of small rural communities lie at the extreme unit of our power of statistical discrimination" (Haggett et al, 1977). This settlement system(s) establish a set of relationship through continuous spatial interaction at the aggregate level. Thus, geographers have for long recognized that regions, possessing some kind of functional coherence and internal interdependence of their constituent elements, appear to characterize both physical and human landscapes, (Robinson, 1953).

The continuous spatial interaction and functional interrelationships between the urban and rural settlements generate certain processes, which result in settlement growth and land use change. Initially such changes were contemplated at the peri - urban areas as established by conventional studies of residential development at the city suburbs. However, more recent experiences, as shown in Pahl's (1966) study of rural urbanization in Britain, reveals that changes in the rural landscape occur far beyond the urban fringe. The British account, for instance, shows that increased affluence and the rising rate of car ownership has permitted the dispersal of the city into the countryside since the 1950s. As a result, "dispersed city was being created, composed of new towns, old towns, villages and hamlets beyond the built - up limits of central cities, but increasingly characterised by middle - class inhabitants with urban life styles and points of view" (Clout 1984). The nature of change occurring in distant rural communities is well captured by Glass (1962) who observed in Britain that, the countryside is overrun and festooned with ribbons of pseudo - rural habitations as most rural areas within 30 kilometres of sizeable towns experience increase in their resident population".

The effect of consistent population growth on the physical environment has renewed global interest on human dimension research. The study of the human dimensions of global environmental change encompasses analysis of human causes of global environmental transformations, the consequence of such changes for societies and economies, and the ways in which people and institutions respond to the changes (National research council (NRC), 1999). Efforts in this direction became formally linked with global change research in the late 1980s. In the United States, for instance, human dimension research became part of the U.S Global Change Research Program (USGCRP) in 1989 with a small National Science Foundation (NSF) program.

The outcomes of several researches on human dimensions of environmental change reveal that as the world population approached the 6 billion mark, human activities accelerated rapidly. Global statistics show that since 1700 human activity has converted 19% of the world's forest and woodland to cropland and pasture (NRC, 1999). The total energy consumption also increased from 188,000 petajoules[1] annually in 1970 to almost 3,000,000 petajoules in 1990, and per capita energy consumption increased from about 50 to 57 gigajoules[2] in the same period.

The increasing ecological transformations through deforestation and other anthropogenic land cover changes have severe implications for societies and economies of the world. The adverse consequences are expected to increase greatly in the new millennium. Consequently, social and applied scientists have devoted much effort at developing methods for assessing the nature of environmental change and the social and economic consequences they carry.

Notes: Joule is the unit of energy measurement. 1000 joules (10^3) = 1 Kilojoule; 10^6 = 1 Megajoule; 10^9 = 1 Gigajoule[2] while 10^{12} = 1 Petajoule[1]

Although interests in local and regional land use changes are long standing in the social sciences (NRC, 1999), the advent of modern remote sensing has increased human understanding of man - environment dynamics. The technology has shown a great potential for improving the knowledge base, for understanding and anticipating future environmental changes and for informing policies aimed at changing the future of our settlement environment. Arising from this, therefore, social scientists have begun to make greater use of orbital Earth - observing satellites with tremendous improvements in the ability to combine both the conventional reference data and remote sensing data for understanding, monitoring and modelling land use changes. Results obtained from this approach have shown great improvement over the conventional data method as they carry the advantage of real and short - term ability to monitor changes and update existing information.

One major area of remote sensing application is in the study of settlement development and planning. In this regard, specific areas of application include the study and mapping of the various elements of the urban and rural landscape, population estimation, land use and change detection as well as the monitoring of settlement growth as discussed in the literature review. Following from the utility and suitability of remote sensing data in these areas, this study uses remotely sensed data to analyse the influence of urban development on the growth of selected satellite settlements in the Nigerian Federal Capital Territory (FCT). It examined the level of urban development and rural settlement growth in the area and identified the explanatory variables as well as consequences of rapid counter-urbanization noticeable in the study area. The study also estimated future growth in the selected settlements and makes policy recommendations for managing the growth and expected consequences.

1.2 Statement of Research Problem

The increasing rate of man - environment interaction generates certain adverse consequences as we noted in the introductory section. The problems of urban influence on rural settlements are manifested in several forms. In the past, emphasis had been on rural depopulation and decline in productivity due to the urban pull - effect. In recent times however, attention is being focused on the counter force of rural urbanization and its associated problems.

The wave of urban influence, which is manifested in high population growth, rising demand for land and energy consumption, has resulted in changes in socio - economic and physical characteristics of the rural areas. In Nigeria, many rural settlements in the FCT are currently witnessing a rapid rate counterurbanization. This results from the intensive development of the Federal Capital City (FCC) beginning from 1985 and the subsequent transfer of government establishments to the city between 1986 and 1997.

As it were, the FCC was planned as the administrative capital of Nigeria. Consequently, emphasis had been on the provision of offices and residential accommodation for government employees to the neglect of the teeming supporting population. Even for the employees, there has been gross inadequacy of residential accommodation since the commencement of movement to the city. In 1986 for instance, statistics has it that only 2,918 housing units were completed in phases I and II to accommodate a total of 4,463 staff with an average family size of six persons (4,463 x 6 = 26,778 people). Also, by the end of 1990, seven ministries had moved to Abuja. According to the Ministry of Federal Capital Territory (MFCT) (1992), about 200,000 officials were expected to have moved to Abuja, but the Federal Capital Development Authority (FCDA) had built only 10,000 houses for allocation. Hence, with the problem of acute housing shortage in the FCC, most government workers and private business individuals find solace in the surrounding satellite settlements.

The continuous influx of population into the satellite settlements of the FCC has become a source of official worry. The issue of concern is that, the accelerated growth and land use transformation noticeable in these settlements have set in motion the process of rural spatial disequilibria. This is evident from the mounting population pressure, settlement growth and the development of slum enclaves and its associated problems noticeable in the area. All these have certain adverse socio-economic, health, infrastructure, security and physical planning implications for the FCC and the satellite communities themselves. Given the fact that man's organization of the natural environment may become paradoxically alien and possibly even self destructive (Toyne, 1974), it is realized that the emerging development in the FCT needs be empirically dimensioned, properly monitored and guided to forestall future problems. This study addressed this issue, using remote sensing data and tools for analysis.

1.3 Aim and Objectives

The aim of this study is to use remote sensing and GIS data to analyse the impact of the FCC on rural settlement growth and land use\land cover change with a view to understanding the nature and the variables of change as well as the direction of future growth in the selected satellite settlements.

The objectives are to:

(1) Examine the spatial pattern of rural settlements in the Federal Capital Territory.

(2) Delineate and map the urban mean field of the FCC in order to ascertain the settlements under the direct influence of the city and to understand the nature of interaction within the field.

(3) Examine the dynamics of relationships within the mean urban field with reference to development pattern; rate and direction of settlement growth and the nature of physical development in the area.

(4) Examine the factors responsible for rural settlement growth and land cover change as well as the implications of rapid growth in the area.

(5) Estimate future growth and the direction of growth in selected settlements with a view to making recommendations on how to manage the expected development.

1.4 Justification

As the traditional view that the countryside is changeless erodes, landscape feature changes become more dramatic and are more widely recognized than the fundamental economic, social and ecological changes they may reflect or conceal (Davidson and Wibberlgy, 1977). An intricate mechanism characterises man's decision within the environmental framework. This mechanism must be clearly appreciated and understood if we are to make future decisions with due regard to their full implications and repercussions and if the resulting system of landscape organisation is to function efficiently and effectively (Toyne, 1974).

Substantial efforts have been devoted to the study of settlement growth as well as related issues and problems. However, most researches have been urban biased. While few studies of urban growth with rural land use implications exist, (Mongkolsawat, 1991; Salem, 1995; Salami, 1997; Kelly, 1998 etc.) they have focused much more on the problems of agricultural land conversion. In his study of land use conversion in Philippines, for instance, Kelly (1998) observed a process of regionalized urbanization in which rural – urban relations are primarily constituted in the encroachment of urban land uses and employment into the rural setting. Even, the few existing studies of rural urbanization (Pahl, 1966; Clout, 1984;

Bracey, 1970; Wibberley, 1960; Spencer and Goodall, 1992, etc.) were focused on changes in socio - economic structure and functioning of the rural areas without capturing the physical manifestations or implications of such changes.

Perhaps, one of the constraints of earlier studies, which used pure conventional survey approach, is lack of adequate temporal data (e. g. base maps) to study the physical and environmental changes in the rural areas. This problem becomes surmountable with the development of remote sensing technology that has both synoptic and temporal data recording ability. In general, the remote sensing technique provides spatially consistent datasets with wide synoptic view, high detail and high temporal frequency, including historical time series (Martin et al., 2002). This new data methodology has facilitated settlement growth and change detection studies in both urban and rural settlements on a temporal basis.

Like their conventional counterparts, studies that utilized remote sensing methods have also shown greater inclination towards the urban centres. Most researches on land use - mapping and change detection (Silva, 1996; Fabiyi, 1999; Shan Yang et al., 2001; Shigenobu et al., 2002 etc.) have, for instance, focused much on the urban centres. It is also noted that other studies with rural dimensions (Henderson, 1975; Mongkolsawat, 1991; Leek and Solberg, 1995; Hamar et al., 1996 etc.) were also particularly more concerned with agriculture, vegetal cover change, forestry mapping and deforestation. Apparently, there is no sufficient research effort on the analyses of urban influence on rural settlement growth and land use change.

The inability of the conventional study approach to capture the physical manifestations of rural socio-economic transformations as well as the paucity of remote sensing studies on the linkages between urban development and rural settlement change constitute major gaps in knowledge. This study attempts to bridge these gaps, using remote sensing data method. It is hoped that the study will contribute to knowledge by extending the frontier of the areas of remote sensing application in settlement studies.

In addition to the above, research of this nature is further justified by the fact that there is no similar work on the rate and nature of rural settlement growth as well as the future implications of counterurbanization at the FCT. This assertion is confirmed in the Regional Development Plan of the FCT where it was observed that:

> "A strong impact was felt - both within the FCT and by all settlements in the surrounding States - immediately upon announcing the decision for the establishment of the Federal Capital, a higher order nucleus, in the middle of a previously undeveloped area. This Impact continues to be felt during the first phase of construction of the FCC... Information on the growth and changes witnessed in the total number of these settlements is very limited. Neither statistics nor studies on this dynamic evolution exist..."(Doxiadis Associates, 1983).

The study therefore not only presents empirical facts on the nature and dimension of growth in the area, it also provides the basis for intervention and a direction for the development of a sustainable settlement policy for the FCT.

1.5 Scope of the Study

The study is limited to the FCT of Nigeria, which is made up of six Area Councils, including Abuja Municipal, Bwari, Abaji, Kuje, Gwagwalada and Kwali Area Councils. The entire FCT is taken to consideration in the analysis of the spatial distribution of settlements and urban interaction field. Subsequently, the study is narrowed down to the mean interaction zone of the Federal Capital City (FCC) covering mainly the Municipal Area Council and zone of the Federal Capital City (FCC) covering mainly the Municipal Area Council and parts of, Bwari and Gwagwalada Area Councils (Figure 1.1). This area contains the main city (FCC) and its immediate satellite settlements. The area is characterized by high population influx, high population density and it accommodates over 80% of the population of FCT (Table 1). Besides, it is an area of major development where both the existing and new rural satellite settlements have shown a lot of changes since the construction of the FCC started in 1980.

FIGURE 1:1 THE F C T SHOWING THE STUDY AREA

Source : Adapted From Balogun, 2001

Table 1.1: The 1991 Population of FCT by Area Councils.

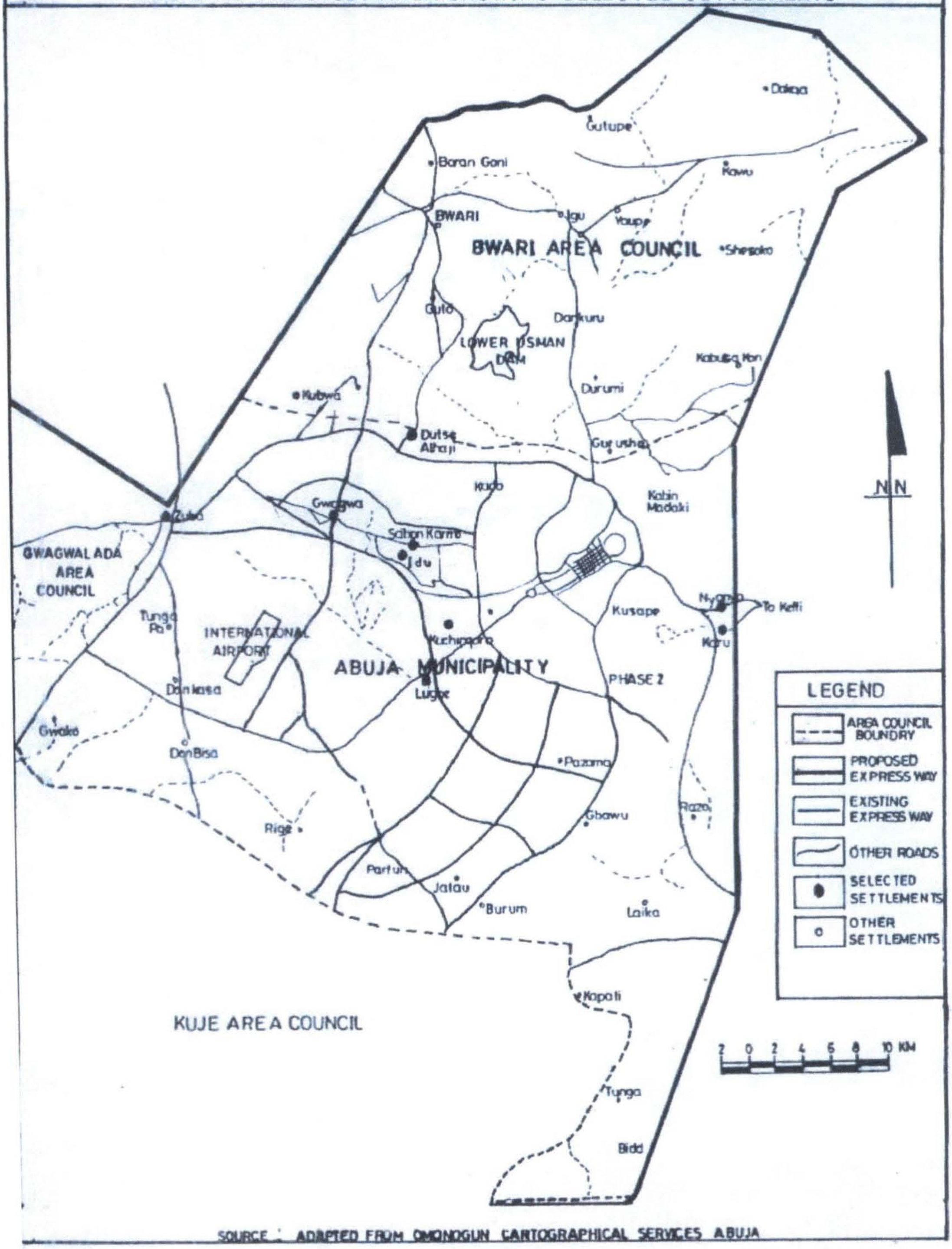
Area Councils	Male	Female	Total	Area (km^2)	Persons\ km^2
Municipal\ Bwari	122,388	97,561	226,949	2,561	106
Gwagwalada\ Kwali	42,656	36,650	79,306	2,086	25
Abaji	10,833	10,248	21,081	2,316	41
Kuje	22,422	21,916	44,338	1,037	25
FCT	205,299	166,375	371,674	8,000	56

Source: Compiled from National Population Commission, 1998 and Balogun, 2001.

Within the urban field, attention is further focused on ten rural settlements around the FCC. First, a reconnaissance survey was carried out to identify and list twenty settlements around the FCC that have shown evidence of rapid growth in the recent times. Among these, Karu, Yanyan, Idu, Sabon-Karmo, Gwagwa, Dutse Alhaji, Kubwa, Kuchigoro, Lugbe and Zuba, were randomly selected for study (figure 1.2). Although some other rural settlements within the interaction field of the FCC show varying degrees of changes, the study is focused on the selected settlements for effective coverage and ease of data collection.

Yanyan and Karu are located at about 9kms and 10kms, respectively away along the Abuja-Keffi road east of the FCC. They are built on the borderlands of the FCT with part of the settlements spilling over to the bordering lands of Nasarawa State. On the other hand, Kubwa and Zuba are situated in the northwest of the FCC at about 29kms and 39kms respectively away along the Abuja- Zuba dual carriageway. Sabon Karmo, Idu and Gwagwa are located at west central area at about 18kms, 19.5kms and 22kms respectively along the old Abuja-Suleja road while Kuchigoro and Lugbe are situated at about 9kms and 17kms respectively along the airport expressway. Altogether, these settlements form part of the system of satellite towns around the FCC and they are all linked to the city by motorable roads.

FIGURE 1:2 THE STUDY AREA SHOWING SELECTED SETTLEMENTS



SOURCE : ADAPTED FROM OMONOGUN CARTOGRAPHICAL SERVICES ABUJA

1.6 RESEARCH METHODOLOGY

1.6.1 Data Collected and Used in the Analysis

This study utilises data from multiple sources. The two main sets of data used are the remote sensing\Geographic Information System (GIS) data and reference data.

1.6.1.1 Remote Sensing\GIS Data.

Data in this category include raster - based satellite images and vector based digital data. The specific data used in the analysis and their attributes include the following.

i Landsat MSS Image of 1976

Satellite:	Landsat – 2
Sensor:	Multispectral Scanner (MSS)
Resolution:	80 Metres
Bands:	1 – 4
Projection:	Universal Transverse Mercator (UTM)
UTM Zone:	32
Ellipsoid:	Clarke 1880
Acquisition Date:	29th January 1976.

ii Landsat TM Image of 1987

Satellite:	Landsat – 5
Sensor:	Thematic Mapper (TM)
Resolution:	30 Metres
Bands:	1 – 7
Projection:	Universal Transverse Mercator (UTM)
UTM Zone:	32
Ellipsoid:	Clarke 1880
Acquisition Date:	January 1987.

iii SPOT XS Image of 1994

Satellite:	SPOT – 3
Sensor:	High Resolution Visible (HRV)
Resolution:	20 Metres
Bands:	1 – 3
Projection:	Universal Transverse Mercator (UTM)
UTM Zone:	32
Ellipsoid:	Clarke 1880
Acquisition Date:	3rd December 1994.

iv Landsat ETM+ Image of 2001

Satellite:	Landsat – 7
Sensor:	Enhanced Thematic Mapper plus (ETM+)
Resolution:	30 Metres
Bands:	1 – 3
Projection:	Universal Transverse Mercator (UTM)
UTM Zone:	32
Ellipsoid:	Clarke 1880
Acquisition Date:	27th December 2001.

These Satellite images were obtained from the Federal Department of Agriculture and Land Resources, Kaduna and National Remote Sensing Centre, Jos.

1.6.1.2. Reference Data

The reference data used in the study include conventional data such as maps, population data, public transport and commuting data, land and property value data, information on housing needs, infrastructure etc. These data came from both secondary and primary sources. Amongst others, specific secondary data collected include the following:

i. Political\infrastructure map of the FCT (1989) on Scale 1: 100,000

ii. Topographical Maps (Sheets 186 SE\1e, 1f, 3b, 3c, 3d, 4e and 4f; sheets 186 SW\ 4c and 4f; sheet 187 SW\3s; sheet 207 NE\1a, 1c and 2b) all on scale 1:10,000.

iii. Population estimates for 1980 and census figures for 1991.

iv. Land prices and Housing rent figures in Abuja and Kubwa.

The secondary data were obtained from the Department of Planning and Survey, FCDA; Federal Housing Authority; National Population Commission; Ministry of Federal Capital Territory; other government agencies and Nawa Properties Limited, Abuja. Other secondary information was derived from the Internet, books and journals, Abuja Master Plan 2000, Regional Development Plan for FCT and other published reports.

The primary data were collected directly from the field through personal observation, oral interviews and questionnaires. Two sets of questionnaire were used for field data collection. The first set (appendix 1) was designed to collect information on the different variables of settlement growth and land use change such as population increase, accessibility, land values, infrastructure, housing demand, proximity to place of work, employment etc. It was also used to collect information on respondents' place of abode vis-à-vis their work place, their perception of the nature, quality as well as consequences of rapid growth and land use changes in the area. The second set of questionnaire was structured to collect information for urban field delimitation using the public transport service and commuter range criteria (see appendix 2). It sought information on the major interaction routes, their distances from the city, number of buses per route and average daily return trip per bus. Interview on the physical development in the selected settlements was also conducted with officials of the Development Control Section of FCDA.

1.6.2 Questionnaire Administration.

The ten satellite settlements selected constitute the sampling unit while the household population in the settlements served as the elements, which the samples were drawn. Initially, ten per cent of the total household figure (18,713) in the ten settlements was sampled to derive the sample size of 1,873 questionnaires. The sample size was however reduced to 5 per cent of the universe due to uncooperative attitude of the respondents. It was found out in the course of the survey that the respondents were too sensitive to the questionnaire because of the large-scale illegal developments that characterise most of the satellite settlements. The residents of Zuba, Gwagwa, Idu, Sabon Karmo and Kuchigoro were particularly apathetic due to wide spread speculations of possible future eviction and demolition of illegal development and squatter settlements around the FCC. Thus only a total of 936 questionnaires were distributed in the area out of which 867 were recovered.

The questionnaire administration followed a two – stage (random- systematic) procedure. This was done using the existing road system as a guide. The samplings started from selected major roads and proceeded along all major streets in each settlement. The first 10 houses were sampled randomly (i.e picking among ten pieces of papers which conceal the identities of the houses) along each major road to determine the first sample member while subsequent members were selected according to fixed sample interval. The interval was determined by a simple formula:

CI = Th/Ss...(1.1)

Where:

CI = Class interval;

Th = Total number of households (18,713);

Ss = Sample size (1,873).

i.e 18,713 ÷ 1,873 = 9. 990

CI = 10 Approximately

Therefore if the starting number selected in a given settlement is 3, then other selected numbers will be 3 + 10 e.g 13, 23, 33, 43, 53, etc. The questionnaires were administered on one household head in each house based on first encounter. Only the valid responses were used in the final analysis as it was discovered that some respondents did not fully complete the questionnaire.

1.6.3 Data Analysis

The analysis was carried out to accomplish the following tasks.

(i) Analysis of settlement pattern in the FCT.

(ii) Delimitation of urban field of FCC and determination of the settlements within the mean interaction field.

(iii) Development of a classification scheme and interpretation key.

(iv) Map overlay, comparison and production of change map.

(vi) Determination of the rate and pattern of settlement growth.

(vii) Identification of the different variables of growth and their relative contribution.

(viii) Projection of growth or built - up area of the selected settlements for the year 2008, showing probable direction of growth.

The detail procedure used in achieving the tasks set up in this study are as itemised below.

i. Analysis of Settlement Pattern

Quadrat Count Analysis was used for settlement pattern analysis. The mean density of settlement points ($\bar{x}$) and the variance ($\Sigma(\chi - \bar{x})^2 \times f / n - 1$) were used in calculating the variance mean ratio (VMR), which gives an indication of the pattern of settlement distribution in the area. The Nearest Neighbour analysis was later used to determine the level of settlement dispersion in the area.

ii. Urban Field Delimitation

Several indices such as newspaper circulation, wholesale trade, commuting range, public bus service, banking service catchments area, employment, etc. have been used in urban field delimitation. This study used the public commuter bus service range in mapping the urban field of the FCC. This was done through field survey in the two major motor parks in Abuja to determine settlements serviced by direct route(s) from the city and from where people commute to Abuja respectively. Ten of the settlements with direct link with the FCC and their distances were used to delimit the mean interaction field.

iii. Classification Scheme and Image Interpretation Keys Used in the Study

The United States Geological Survey (USGS) classification system by Anderson et al. (1972) was used as a guide in image classification. Level 1 of the classification scheme was modified to suit the needs of the study. As seen in table 1.2 the classification scheme used contains five broad land use\land cover categories, which accommodate all the features seen on the images. The level 1 scheme is considered adequate for this study since the interest is on settlement growth and changes in broad land cover categories.

Table 1.2: Level 1 Classification Scheme Used for the Study

	Land use\Land cover Categories	Component Features
i.	Built – up area	Residential, commercial, industrial and other buildings, utilities and services, access roads and lanes
ii.	Roads	Expressways, trunk A and distributor roads.
iii.	Vegetation & agric. land	Forests, scrubs, rangeland, grassland, plantation, cropland and pasture, orchards, nurseries, grooves and vineyards.
iv.	Water bodies	Rivers, streams, canals, lakes ponds and reservoirs.
v.	Rock surfaces	Rock outcrops, quarries and gravel pits.

Source: Compiled by the Author, 2003.

A set of interpretation keys were also compiled using the various colour tones and patterns found on the images (table 1.3). The keys were used in image feature recognition and mapping.

Table1.3: Interpretation Key Used in the Study

Features	Pattern and Colour Tones
i. Settled (built-up) areas.	Polygon features. Light blue reflectance with roads linking them.
ii. Water bodies.	Polygon features. Sky-blue for shallow and polluted water. Deep blue or black for deep and pure water.
iii. Rock surfaces.	Polygon features, not often associated with roads. Navy blue colour.
iv. Vegetation & Cultivated land	Polygon features. Reddish patches for vegetation and whitish regular (e.g rectangular or square) patches for farmlands, particularly harvested ones. Other vegetated lands have light greenish colour due to the fact that the images were taken in Decembers and Januaries when the vegetation are less luxuriant or dry.
v. Roads.	Line features. Surfaced ones looking bluish and un-surfaced ones appear white in colour.
vi. Streams.	Line features. Identifiable through their meandering and tick reddish vegetation along their courses.

Source: Compiled by the Author, 2003.

iv. Ground Truthing Exercise

A ground truthing exercise was carried out in the study area on the 13th of January 2003. The purpose of the exercise was to check the image classification accuracy and to identify the selected settlements (and some others) on the images. The Garmin's Global Positioning

System (GPS) was used to pick the UTM coordinates of 23 points in different settlements and locations (table1.4). The coordinates were entered into the computer and used to generate points, which were dropped on the images. The display of the points on the images help to confirm the positions and names of settlements as well as other image features\landmarks such as rocky hills, Abuja National Stadium etc. picked on the ground. It further helped in picking some small, non-prominent settlements, which were not initially picked and thus improving on our interpretation of the images.

Table 1.4: Ground Positions and UTM Coordinates of Selected Points.

S\No.	Location	Point	X- Coordinate	Y-Coordinate	Elevation
1	Zuba	1	0303399	1005612	366.9
2	Zuba (hill)	2	0303047	1006047	395.2
3	Diedie	1	0308743	1007845	364.7
4	Gwagwa	1	0315055	1004944	387.1
5	Idu	1	0319017	1002767	404.5
6	Karmo	1	0320291	1002934	430.8
7	Kado	1	0323918	1002479	447.6
8	Life Camp	1	0323723	1003450	463.0
9	Jabi	1	0325731	1001660	435.9
10	Piwoyi	1	0323482	0995119	420.2
11	Lugbe	1	0320475	0992492	412.8
12	Lugbe (Village)	2	0320836	0992140	42101
13	Chika	1	0324355	0994086	432.4
14	Karonmajiji	1	0326778	0997797	435.5
15	Kuchigoro	1	0326528	0996854	441.8
16	Abuja Stadium	1	0329775	0999444	485.0
17	Karu (Site)	1	0342683	0996124	421.7
18	Karu (Village)	2	0343294	0996279	422.0
19	Nyanyan	1	0342832	0997540	425.8
20	Gwarinpa	1	0326439	1008218	495.0
21	Dutsen Alhaji	1	0321134	1010641	471.1
22	Kubwa (FHA)	1	0318284	1011444	422.0
23	Kubwa (village)	2	0315354	1011734	557.7

Source: Fieldwork, January 2003.

v. Analysis of Change Detection and settlement Growth

Change detection analysis and the production of change map were accomplished using the post classification comparison approach. Here, the results of classification for the different images were overlaid and compared to identify changes. The superimposition of new developments and earlier land cover images was carried out to analyse the pattern of change. The newly created settlement areas in settlement i ($\Delta s_{i\alpha}$) was calculated using a simple formula developed by Dimyati et al. (1996) as follows:

$$\Delta s_{i\alpha} = s_{i\alpha}(t) - s_{i\alpha}(o) \qquad \text{.....................................(1.2)}$$

Where:

Δ= difference between old and new land cover category;

s = settlement;

$_{\alpha}$ = land cover category;

t = a given year e. g. 1994; o = the base year e. g. 1976.

The growth rate of each settlement was determined by:

$$r = \frac{\Delta A}{nA_0} \times 100 \qquad \text{.......................................(1.3)}$$

Where:

r = growth rate

ΔA = change in area extent between 1976 and 1994

A_0 = Area extent of the base year (1976)

n = number of years.

Models 1.2 and 1.3 enable us calculate areas of new growth and the rate of growth in the study area. The models have been chosen for analysis not only because of their simplicity, but also because authors have used them successfully in the past (See Dimyati et al., 1996 and Salami, 1997)

The Pearson Product Moment Correlation analysis was used to establish the relationship between built up area and the growth variables. The analysis utilises a correlation formula in form of:

$$r = \frac{R = N \Sigma X_i Y_i - (\Sigma X_i)(\Sigma Y_i)}{\sqrt{\{N \Sigma X_i^2 - (\Sigma X_i)^2\}\{N \Sigma Y_i^2 - (\Sigma Y_i)^2\}}} \qquad (1.4)$$

Step-wise regression analysis was further used to model the relationship and to confirm the influence of the variable on settlement growth. Here, the built - up area (y) is considered, as the dependent variables while the factors responsible for land area growth ($x_1 \ldots\ldots x_n$) are the independent variables.

For the purpose of this study, the individual and joint explanation of the following variables were verified.

X_1 - Population increases due to spill over from Abuja

X_2 - Proximity to FCC and ease of commuting

X_3 - Availability of cheap accommodation in the satellite settlements

X_4 – Cheap land for development in the satellite settlements

X_5 – increased rate of car ownership

Assessment of future growth of settlement was carried out using the rating method developed by Rao (1995) and regression analysis. In the Rao (ibid) method (see detail in literature review), the built - up area of land activity (e.g shapes and area of settlements) was determined from the satellite imageries. The areas (M^2) and the circumferences of the FCC and the selected settlements were also determined form topographical maps and satellite images and the information derived were used in computing the influence rate (IR), the attraction potential rate (PR) and the growth potential of settlement (GP). The future built up area of each of the settlements was calculated using the formula:

FBA = (G. P x SA in present year + SA in present year). ....(1.5)

Where:

FBA = future built-up area.

G.P = growth potential rate of settlement

SA = settlement area in m^2

The regression method was used to model the future growth of the settlements using the settlement sizes as the criterion variable and the year as the predictor variable. The analysis uses the formula:

$y = a + bx + e$....................................(1.6)

Where:

y = criterion or dependent variable

x = predictor or independent variable

b = regression coefficients

a = y intercept when x = 0

e = error term of the prediction

The direction of future growth was determined by classifying study area into developable and un-developable lands using Landsat ETM+ of 2001. The visual distribution of developable land shows areas where future development activities are expected and are thus good indications of direction and pattern of future growth.

1.7 Tools for Analysis

The tools for analysis are both in hardware and software forms. The hardware includes A_0 digitizer, Garmin's GPS 76 Marine Navigator (2001 edition) with 15-metre accuracy, Kodak Digital Camera, Scan Prisa 640P (Scanner) and a Personal Computer with hard disk capability of 10.2 gigabytes. The major software for analysis includes ERDAS IMAGINE version 8.3.1, Arc\View version 3.2a, Arc\Info version 7.1.2, Ilwis 3.0 Academic and the Statistical Package for Social Services (SPSS) version 9.0.

CHAPTER TWO

2.0 GEOGRAPHY OF THE STUDY AREA

2.1 Introduction

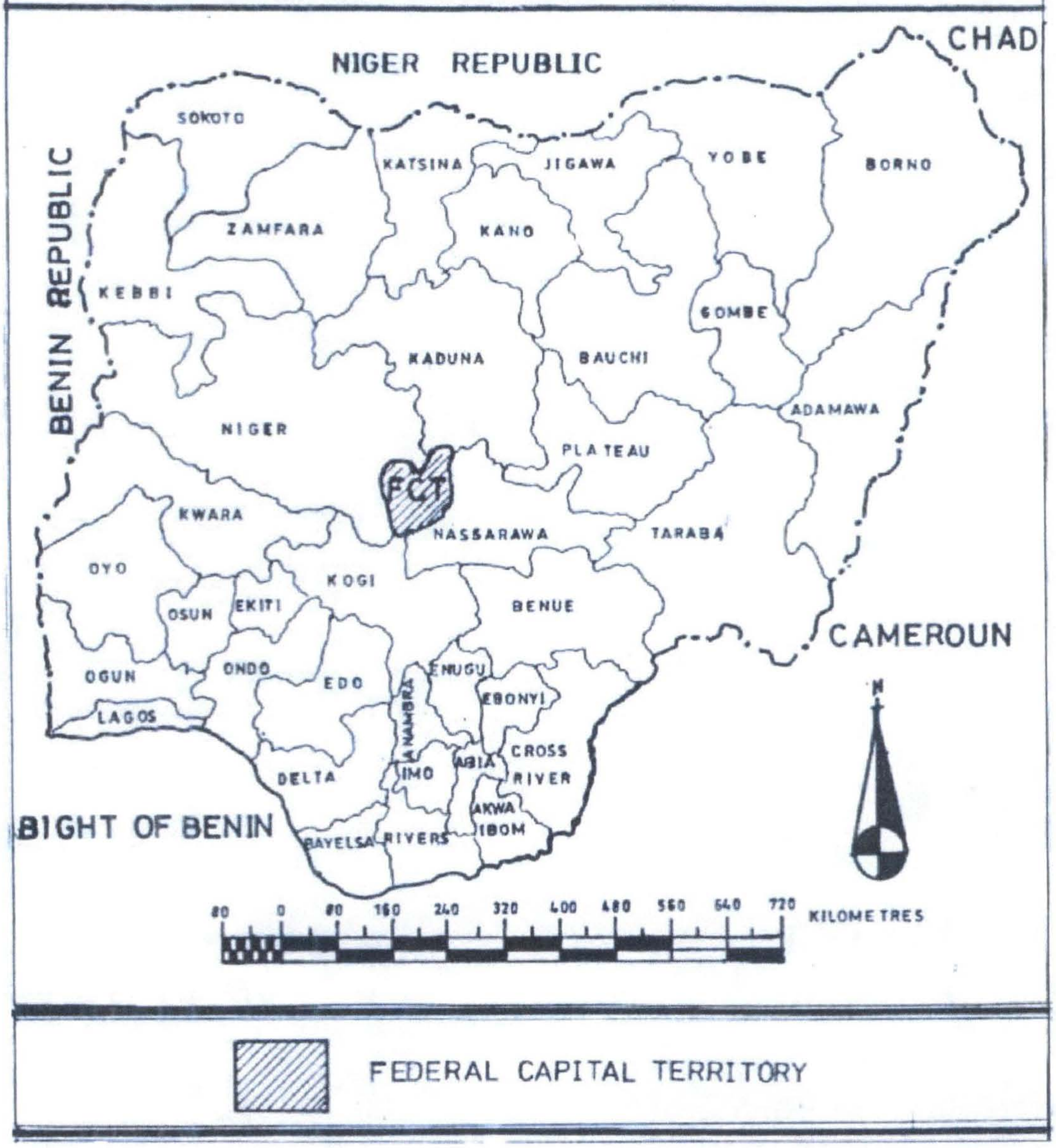
This chapter considers the geography of the FCT. It gives a vivid physical description of the study area with respect to size, location, climate, drainage and vegetation amongst others. It also considers the people of FCT with respect to ethnic composition and occupation. The chapter concludes with a brief history of the establishment and movement of the capital city of Nigeria to Abuja to give an understanding of how the city came into being.

2.2. Location and Physical Setting

The Federal Capital Territory (FCT) covers an area of 800km^2 (Abuja Master Plan, 1979). It is located at the heart of Nigeria, approximately between latitudes 7^0 25" - 9^0 20" north of the Equator and longitudes 6^0 45" - 7^0 39" east of the Greenwich meridian. It lies just above the hot humid lowlands of the Niger - Benue trough and it is bounded on the north by Kaduna state, on the west by Niger, on the east and southeast by Plateau and on the southwest by Kogi states (Figure 2.1).

The main city and its immediate surrounding settlements are located on the Gwagwa plain, which rises from an elevation of below 305m in the west to 760m above the sea level in the northeast. The lowest elevations occur in the extreme southwest in the Gurara floodplain with an elevation of as low as 70 metres above the sea level (Balogun, 2001). The Gwagwa plain is generally characterised by rocky knobs, inselbergs, escarpments and several ranges of low mountains including the Gawu, Gurfata, Idon-Kasa and Wasa- Sukuku. The major outcrops include the Abuja hills, Zuma, Aso and Bwari rocks and are made-up of granite masses with steep slopes (Abuja Master Plan, 1979). The general undulating terrain is interlaced by riverine depressions.

FIGURE 2.1: NIGERIA SHOWING THE FCT



Source: Adapted from F C D A, 2002 .

2.3 Climatic Setting

The FCT enjoys the hot, humid tropical continental climate typical of the central Nigeria. It records its highest temperatures during the dry season when there is little cloud. The maximum temperature ranges between 30.40° C and 35.1° C in the dry season while it ranges from 25.8 ° C and 30.2 ° C in the raining season (Balogun, 2001). The lower temperature in the raining season results in a low annual diurnal range of as slow as 7^0c in July and August.

Rainfall at the FCT occurs between March and October and lasts for between 190 days in the northern areas and 240 days in the southern part (Ministry for FCT, 1998). The annual total rainfall ranges from 1100mm to 1600mm and it is mainly characterised by a single peak with maximum rains occurring in the months of July, August and September. The rainfall is also characterised by frequent occurrence of squall lines, which begin with dense, dark cumulo-nimbus clouds. It is mainly orographic in nature and occurs in sort torrential down pours with strong wind, thunder and lightning.

Relative humidity in the FCT is generally high in the raining season. The mean monthly relative humidity calculated between1993 and 1997 is as high as 79.7% in the raining season, but falls to as low as 25.8% in the dry period (FCT Statistical Year Book, 1998). The mean annual potential evapotranspiration ranges between 1,797mm in the south and 1,277 in the north while the actual evapotranspiration is well over 1000mm.

Two major air masses dominate the climate of the FCT. These are the tropical maritime air mass and tropical continental air mass, both which bring about alternate wet and dry seasons. The moisture laden south west monsoon winds bring a lot of rains between April and October while the moisture thirsty north - east trade winds bring about dry, cold dust laden conditions (hamattan) between October to March. The hamattan is characterised by hazy condition in the morning hours of the day and it reduces visibility in the area.

2.4 Geology and Soils

The FCT is made up of two geological formations (Ministry of f FCT, 1998). These are the sedimentary belt occupying the southern and southwestern extremes and the pre-Cambrian Basement complex rocks, which underlie 80% of the territory. The sedimentary formation is part of the Nupe Sand Stone and it consists of grits, siltstone, gravel bed, sand and clay. The Basement complex on the other hand consists of the following three rock groups.

i. The igneous rock made up of biotite granites, rhyolite, syenite, gabbro and diorite.

ii. The metamorphic migmatites and gneiss complex which is made up of migmatites, granites, gneiss and porphynitic gneiss found on Gwagwa, Iku-Gurara and Robo plains.

iii. The schists, which consists of biotite\muscovite schists, muscovite and talc schists with quartzite intrusive are found in the eastern and southern parts of the territory.

The soils in the FCT are generally fertile, well drained and are of varying depth, depending on their texture, erodability and run-off potentials. The soils of the capital city are, generally deep, less stony types, which developed on the basement complex. The soils in the territory have been categorised into ten major complexes (See Abuja Master Plan, 1979).

The soils of the hill and rocky complexes occur on rock outcrops and are shallow, well drained with few outcrops of iron pan. The shallow soils of the Gumi, Gui and Panda complexes are found in the hilly areas to the east of the city and run through the Zuma - Bwari - Aso hills to the west of the city. They are generally characterised by stony to gravel sand with local sandy clay loams. The Takwa, Ageda, Wuse, Takwasharo and Kwali soil complexes are deep, well drained with moderate erodability and run- off potential. They are therefore regarded as the best soil associations in the area and are suitable for development.

2.5. Drainage and Vegetation

Two major rivers drain the entire FCT. These are the Gurara and the Usman Rivers. The Gurara River flows through the territory along its western edge with its watershed draining most of the territory into the River Niger. The Usman Rriver also flows westward from the northeast and emptied its water into the Gurara. These two rivers exhibit a dendritic pattern, with such tributaries as the Zangonkara, Afara, Bokwoi, Jabi, Wupa, Wuye, Robo, Mangol, Yewu, Itsu, Afara-Bokwoi and Rabba joining the major rivers at acute angles.

The streams are seasonal in nature. The wet seasons is characterised by high water volume, flash floods and rapid runoffs while most rivers are reduced to stagnant pools in the dry season. The few permanent streams experience extremely low flows in the dry period with water corridor limited to the trunk of Usman and Yewa Rivers. Aside from the streams the territory is doted by several other ponds and/or reservoirs prominent among which is the lower Usman dam.

The FCT is located at the savanna vegetation zone of the West-African sub-region. Its vegetation is characterised by extensive park savanna, shrubs thickets and high trees in riverine depressions and occasional patches of forests or wooded lands. The park savanna consists of stratified, discontinuous tree communities dominated by the savannah woodland flora species type such as albizia lebeck, butyrospermum, paradoxum, daniellia oliveri, afzelia africana and parkia clappertonia. It has a thick, tall grass layer consisting of

Andopogon and Hyparrhenia species and a shrub layer in which Terminalia, Piliostigma, Amona, Nauclea and Bombax are common (Abuja Master Plan, 1979). Woodland occurs in rugged areas especially in the Gurara, Robo and Rubochi plains as well as the surrounding hills. It covers approximately 1026 Km (12.8%) of the territory (Ministry for FCT, 1998).

The shrub savanna vegetation occurs on flatter plains and undulating terrain, covering about 1032 Km (12.9%) of the land area while the forestlands are scattered in several localities in the territory and they cover 293 Km (7.6%) of the land area. The forest types are mainly of rain and riparian forests. The riparian complexes occur in low lands along watercourse, mainly along the Wuye and Usman valleys. The common tree species in the forestland include antiaris africana, chlorophora excelsa (iroko), khaya grandifolia (mahogany), terminalia superba (afara), Afzeila africana, Allophyllus africana, Mitrgyna inermis, etc., and they are characterised by high forest, woodland, gallery forests and dense thickets. The forest vegetations are mainly found on interfluves, at the foot of hills and in deep river valleys. The general vegetation (savannas and forests) flourishes well during the rains but is less luxuriant in the dry period when most grass flora wither away.

2.6 The People of FCT

Historical facts and archaeological evidences indicate that the indigenes of the FCT were of the Kwa language group found around the Niger-Benue confluence. The Kanuris joined the original settlers during the Jihad period of the 19th century. Other groups in the area having deep affiliation with the Kwa language group include the Bassa, Gade, Gwari, Ebira-Koto, Gwandara, Koro and Ganagana (Ministry for FCT, 1998). However, the dominant groups are the Gwaris who accounted for 87.3% of the population, the Koros (6.6%) and the Gwandara (3.6%). Other tribes like Yoruba, Igbo, Hausa and Fulani constitute the remaining 2.5%. The indigenous people are predominantly farmers, with few artisans engaged in wood and craftwork, ironwork and weaving.

The initial dominance of the FCT by the indigenous cultures has reduced over the years due the large scale of development taking place and the subsequent influx of people into the area. Thus, the area has developed into a culturally complex region with the various cultures having very strong imprints on the landscape (Balogun, 2001).

2.7 Establishment and Relocation of the Federal Capital to Abuja

The thought of a new Federal Capital Territory arose from the problems of congestion, infrastructure inadequacy, and lack of adequate land for expansion in Lagos, the former capital of Nigeria. Thus, a seven-man committee headed by Justice Akinola Aguda was set up on August 9th, 1975 by the government of Late General Murtala Mohammed to examine the question of a new capital for Nigeria.

The designation of the FCT followed the acceptance of the report of Aguda Committee, which observed that Lagos could no long retain its dual role as Federal and State capitals. The alternative sites proposed for the new Federal Capital were evaluated based on thirteen predetermined criteria. Consequently, the site of the new FCT was selected based on centrality and multiple access possibilities, low population density, ethnic neutrality, conformability, healthiness and the possession of adequate land and natural resources for urban development.

Following the acceptance of the committee's choice, the Federal Government promulgated the Federal Capital Territory Decree on the 4th of February 1976 (Doxiadis Associates, 1983). The Decree vested the ownership, control and governance of the FCT in the hands of the Federal Government. It also established the Federal Capital Development Authority (FCDA) and charged it with the responsibility of planning, designing and developing the FCT.

Major construction work in the FCC started in 1980 during the administration of Alhaji Shehu Shagari (1979 - 1983). Successive governments later built Abuja and on the 12th of December 1991, the government of General Ibrahim Babangida formerly moved the seat of government from Lagos to Abuja. The relocation process occurred in phases from 1986 until 1997 when the remaining Federal ministries were moved to Abuja by the administration of late General Sanni Abacha.

CHAPTER THREE

3. 0 CONCEPTUAL BACKGROUND AND LITERATURE REVIEW

3.1 Introduction

This chapter considers some background concepts and reviews the relevant literature. The section on concepts and theoretical framework considers spatial processes, growth and organisation as well as models of settlement evolution, spread and interaction to serve as background\anchor for the study. The literature review examines the concept and development of remote sensing technology as well as its application in various fields of human endeavour. It places emphasis on remote sensing application to settlement studies and related issues, which are of relevance to this study.

3.2 Conceptual Backgrounds and Theoretical Framework

3.2.1 The Concepts of Process, Growth and Organisation

1. Process

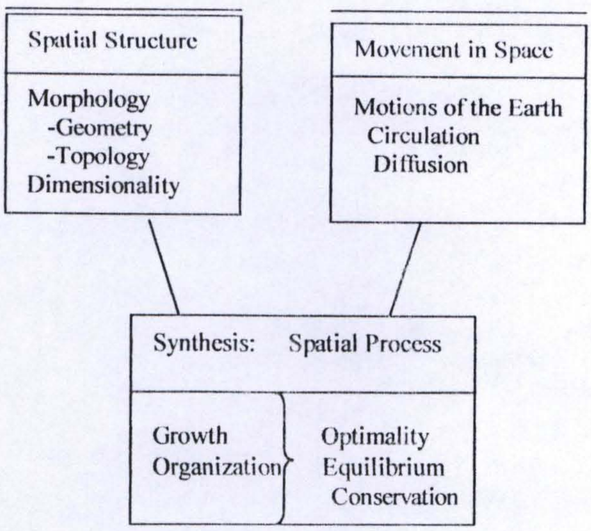
Interaction between settlements and other landscape elements takes place in space and time and could be better understood within the context of the process law. Process is defined as a continuous and regular succession of actions taking place or carried on in a definite manner and leading to the accomplishment of some results (Coffey, 1981). It is a sequence of events over time, which is connected by some mechanisms. The process law deals primarily with change over time (Harvey, 1969) and this affects the form of landscape elements.

Attempts have been made to distinguish between process and form in the literature. Schaefer (1953), for instance, established a form - process dichotomy within the discipline of geography. This dichotomy between the indigenous morphormetric postulates and derivative postulates is recognised by Harvey (1969) who, however, accepted a linkage between the process theories and theories of spatial form. This linkage is evidenced in Hagerstand's diffusion theory and Loch's central place theory that are models of interaction between process and spatial form.

Bunge's (1966) account presents a major attempt at reconciling the form - process dichotomy. He considered the two as dual expressions rather than contradictory ones. The author therefore designates the two as spatial process (movement over space) and spatial structure (the resulting distribution of phenomenon on the earth's surface). This conceptualisation according to Coffey (1981) is divisive and establishes yet another dichotomy between form and process. Coffey (ibid) considers "morphology as an intermediate and transitory state that is inexorably intertwined with changes over time and space in a spiral of cause and effect or, more exactly, circular and cumulative causation. According to him, process then may be viewed as of a feedback loop in which morphology is not only the result of changes, but to a large extent plays a causal role by setting the initial conditions or constraints for the processes.

The above presentations show that dichotomising spatial process and spatial form is arbitrary. Abler et al. (1973) have therefore pointed out that process and structure are circularly causal and are, in essence, the same thing. The authors viewed the concept of spatial structure as applicable to both static distributions and to process, which appear to us to be dynamic. This view is reinforced by Berry (1968) who asserts that, form can never be absolute and that to deal with fixed things is to deal with false imagination, for all phenomenal existence is seen to be transitory when the dimension of time is added. On this basis, Coffey (1981) considered the concept of spatial process as a synthetic one, integrating spatial structure and movement in space (figure 3.1). Thus, whether we see process or structure when we look at a spatial distribution depends on the time perspective that we adopt and the rapidity with which the process moves.

Figure 3.1: A General system paradigm.



Source: Coffey, 1981

2. Growth

Growth and organisation are two relative aspects of spatial process (figure 3.1) and the two are major aspects of change in the spatial characteristics of any system. As observed earlier, the process law deals with change over time. The resultant spatial and temporal change leads to growth or is, in itself, an element of growth.

Growth and process are often viewed as synonymous. According to Coffey (1981), one general process that may be identified is change and it occurs in time and space. Growth is therefore treated as spatial process with continuous changes in shapes and sizes of the object of interest. Generally, Boulding (1956) recognised three kinds of growth phenomena. These include simple growth, population growth and structural growth. The three kinds of growth are not mutually exclusive as the growth of any real phenomenon may involve all the three (Coffey, 1981).

Boulding's (1956) classification was further generalised to make distinction between absolute and relative growth. Both simple and population growth are forms of absolute growth as they deal with accretion or depletion of some quantity over time and they have direct spatial consequences (Coffey, 1981). Included in this category is expansion diffusion, plant dispersal, message diffusion, herding in animals and the growth of cities.

Unlike the absolute growth, relative growth involves time independent changes in the spatial relationships of elements of a system. It involves morphological development. Although it includes accretion or depletion of some quantity, the dominant characteristic of relative growth is both internal and external morphological differentiation. This form of growth deals with long -run developmental changes rather than the more ephemeral compensatory changes and it is evolutionary in nature (Coffey, 1981).

3. Organisation

The term organisation is a complex construct requiring a clarification of the different sense of its usage. Etymologically, organisation refers to the qualities that characterise a living organism (i. e connection and co-ordination of parts, a systematic and orderly structure, and functional interdependence) while morphologically; it refers to structure or arrangement that is orderly or systematic (Coffey, 1981). The latter sense of organisation is of interest to geographers and physical planners because it tended towards the production of an order or a territorial pattern, which gives a particular landscape its character.

System analysis appears to offer a productive conceptual framework for the study of the organisation of the complex structures that make up the rural landscape. By definition, a system consists of a "set of objects (or elements) linked together with the relationships between the objects and between their attributes" (Hall and Fagen, 1956).

The element of a system could be recognised at different resolution levels. At the aggregate level, regional landscapes may be considered as organised into systems consisting of series of elements (settlements) linked together with the relationships among the elements and among their attributes (e.g location, size, age, condition etc.). At the level of individual settlement however, the residential, commercial, industrial, transportation, etc. elements make up the system. All these elements have certain attributes, which give them their individual character. It is the relationships among the various attributes of these elements that constitute the morphological system of landscape organisation.

The functioning of any morphological system is determined by the nature and strength of the variousinputs and outputs among its elements. These inputs and outputs emanate from human decisions on the location and organisation of all economic activities. The decision making process thus constitutes the control system which gives the morphological structures of human landscape organisation its performance and dynamics (Toyne, 1974).

3.2.2 Settlement Pattern

Most occupied landscapes bear recognisable pattern of settlement. Pattern involves the specification of the spatial relations of discrete phenomena and it summarises their manner of distribution over space (Coffey, 1981). Generally, settlement pattern on an isotropic surface has been qualitatively and quantitatively established to proceed through a sequence of random to cluster (in their search for agglomeration benefits) and to regular (as they undergo competition for market area).

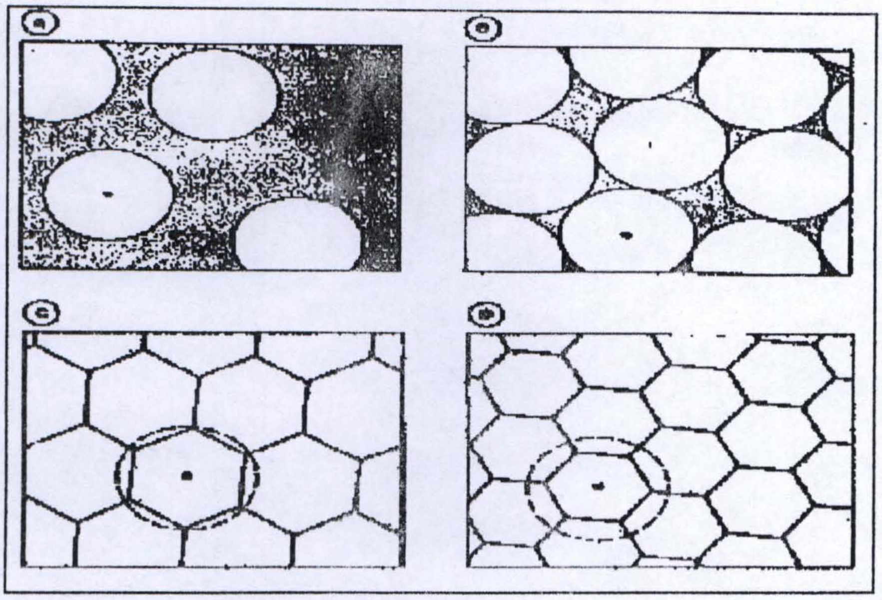
In simple terms, clustered and regular pattern treat settlements as points in space and provide information only on visual distribution without reference to settlement size and characteristics. They do not move pattern description beyond the simple disperse - nucleated dichotomy. The need to understand settlement pattern in terms of their location distribution as well as their size - function relationship or interdependence necessitate the consideration of other related theoretical advancements in the literature.

3.2.2.1 The Central Place Theory

The central place theory was postulated by Walter Christaller (1933) in his search for the order that underlie settlement spacing, sizes and function. Based on his assumption of an isotropic surface with equal ease of movement, uniform population distribution and resource endowment, Christaller (1933) postulated that settlements will spring up at evenly spaced points to serve tributary market areas with goods and services. According to the author, the settlements will be arranged in regular triangular lattices with each centre serving an hexagonal trade area.

The evolutionary trend of the hexagonal trade area was illustrated by Money (1975) who considered a group of simple rural settlement on a uniform plain. He observed that these settlements would be grouped so that each has an adequate tributary area to support them and will be spaced few miles from neighbouring settlements. There would be a maximum population that the resources of a tributary area can support before some residents migrate to colonise new territory. As more and more villages form, the most likely pattern would be such that each settlement holds land equally accessible from its centre, and the relative location of each is at the vertex of an equilateral triangle. This arrangement is regarded as sub optional as some land would not be taken up or serviced (Figure 3.2a and b).

Figure 3.2: Parking of Centres in the Colonization of a Plain to Give Hexagonal Territories



Source: Losch, 1954; Peter Haggett et al.; 1977

The eventual evolution of hexagonal pattern follows directly from five simplified assumptions given by Haggett (1975) viz.

(i) There must be unbounded isotropic plane with a homogeneous distribution of purchasing power.

(ii) Central goods must be purchased from the nearest central place.

(iii) All parts of the plane must be served by a central place, that is, the trade areas must completely fill the plane.

(iv) Consumer movement must be minimised

(v) No excess profit may be earned by any central place.

Based on assumption iii which states that the plane must be completely covered with trade areas, the circles of the different central place will overlap. However, since it is assumed

that consumers will shop at the closest central place, the areas of overlap will be bisected to give hexagonal tributary area, which allows the greatest density of settlements with shortest distances from each central place to the edge of its territory
(Figure 3.2c and d).

In establishing the functional relationship among the hexagonal central places, Chistaller (1933) demonstrated that the settlements are arranged in a hierarchical pattern in which each central place is a member of a functional order of centres. The town and cities constitute the higher - order centres and they provide specialist functions for their resident population and that of the lower - order, dependent centres e. g. hamlets and villages. In this hierarchical organisation of central places, the services areas of the lower - order centres are nested in the service area of the higher - order settlements next to their order to produce series of central places of that order and importance on the isotropic plane.

The major contribution of the central place theory to our theoretical framework requirement is in the development of a model for understanding the development of a regular settlement pattern. Besides the theory provides an insight into the functional relationship that exists among the system of settlements and establishes the influence of town and cities on the dependent rural settlements. It is therefore an ideal theoretical anchor for this study

3.2.3 The Concept of Counterurbanization

Counter-urbanization is a term applied to the fundamental reshaping of the geography of population and economic activity which has taken place over the last 30 years in most developed societies (Spenser and Goodall, 1992). It is defined as the reorganisation of urban living over a much-enlarged spatial scale. It involves the dispersal of population and economic activity to free - standing settlements in rural localities, and de-concentration, whereby the smallest settlements grow the most.

Counter-urbanization is not synonymous with sub-urbanisation and should not be treated as such. It occurred beyond the physical built up limit of towns or cities. According to Spenser and Goodall (1992), counter-urbanization may be simply referred to as metropolitan decline paralleled by rural growth. It is the spatial outcome of urban - rural shifts, which have brought expansion to medium and small sized towns.

3.2.4 Models of Settlement Evolution and Spread.

Generally settlements emerge as a result of the colonisation of open plain by men. Such founder settlements normally hive off their excess population to form secondary settlements. As more settlers arrive, the secondary settlements, in turn, hive off excess population in a circularly causal manner, making the countryside to become more and more occupied.

A number of deterministic and probabilistic models have been developed to explain settlement evolution and spread. The major models include, among others, those developed by Bylund (1960), Morrill (1962) and Hudson (1969b). Bylund's (1960) model places settlement expansion in a deterministic framework. In his study of settlement colonisation in central Lapland area of Sweden, Bylund (1960) considered the manner in which settlement waves propagate within an area and he produced four simple models of development (figure 3.3)

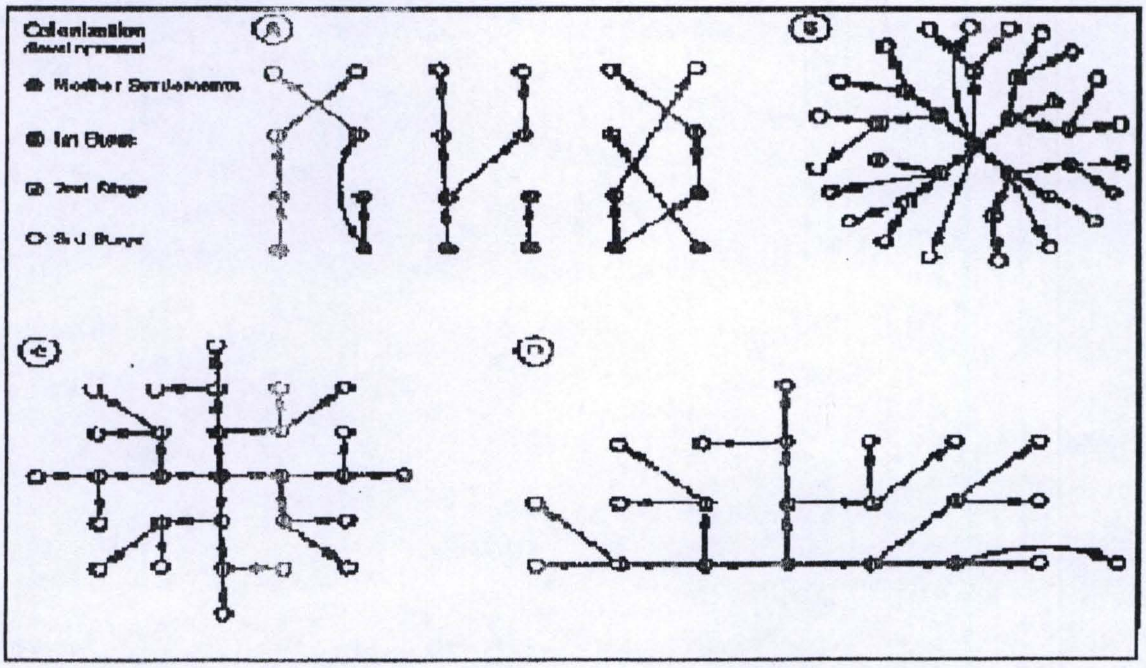
In developing those models, the author made two basic assumptions viz:

(i) that the physical conditions of the land are equal in all areas whether settled or unsettled, and

(ii) that further areas will not be settled until those close to the mother settlements have been occupied.

On the basis of these assumptions the author presented a three - stage colonisation development from the mother settlement, which proceed in a similar manner for all the models. The 'mother settlements' serve as the bases for other offsprings. However, the evolution and spread pattern differs on the basis of whether the mother settlements are located on a coast (models A and D) or in the hinterland (models B and C).

Figure 3.3: Hypothetical Models of Settlement Diffusion



Source: Bylund, 1960; Peter Haggett et al.; 1977

Hudson (1969) proposed a location theory, which provides more explanation for the rural settlement colonisation process suggested in Bylund's model. He identified the three main components of the evolution process including:

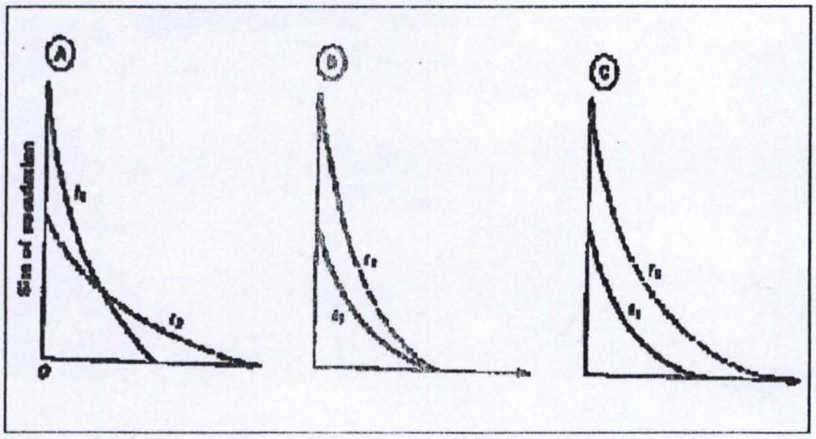
(i) colonisation - associated with the dispersal of settlement into new territory,

(ii) spread - associated with increasing population density in situ and a general tendency to short - distance infilling of gaps; and

(iii) competition - in which "owing to the limitation of the environment, weak individuals are forced out by their stronger neighbours, density tends to decrease, and pattern stabilises" (Hudson, 1969).

The relationship between colonisation and spread is shown in a one - dimensional situation in figure 3.4. Figure 3.4A shows colonisation alone while figure 3.4B shown spread alone. The third figure (3.4C) shows the two components combined. In all the three diagrams, the number of settlement varies inversely with distance from an optimal location (0) in the environment.

Figure 3.4: Relationship Between Colonisation and Spread Process. A- Colonisation alone; B- Infilling alone; C- Colonisation with infilling



Source: Hudson, 1969; Peter Haggett et al.; 1977

Under colonisation alone, the area available for occupation increases without changing the number of settlements thereby lowering density in order to expand settlement frontier. Under a pure spread process, the magnitude function is shifted upward and not outward, to produce an overall increase in density.

The models developed by Bylund (1960) and Hudson (1969) only accounted for hypothetical processes of settlement evolution and spread. The models are therefore incomplete, as they did not consider the causal factors or forces behind their propositions. The missing link in the theoretical postulates of the models is however supplied by Chisholm (1962) who suggested that the diffusion of new and smaller settlements around older ones might be linked to four major changes. These, according to the author, include:

(i) socio-economic changes in the land holding system;

(ii) removal of the need for defensive agglomeration;

(iii) elimination of such factors like disease, which inhibited earlier land settlement; and

(iv) technical improvement in water supply.

As it were, these explanatory variables combined well with the basic ideas of the models to enhance our understanding of the processes and factors of settlement evolution, colonisation and spread.

Morrill's (1962) model presents alternative approach to the evolution of settlement pattern using the framework of Monte Carlo simulation technique. The model conceptualises an initial settlement known as the "founder settlement" around which is a build-up of settlements hierarchy as governed by a sequence of random number. Morrill (1962) followed three basic rules in developing his model viz.

(i) In each time period or generation (t_o, t_1 ----t_T) every place generates at least one migrant in the order of its origin, with the total number of migrant from each place proportional to its size.

(ii) Any place may be settled more than once and enlarged in size provided it does not clash with the distance - comparability rule which restricts the size of a place according to its distance form the larger places (e. g. a settlement five cells from the origin, many increase to five and remain stagnant).

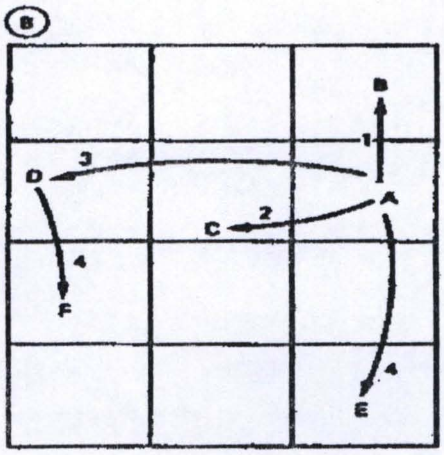
(iii) The distance and direction of each migrants move is governed by the members

in the probability matrix shown in figure 3.5A.

Figure 3.5: Simulation of Settlement Hierarchies. A - Distance and Direction Probability Matrix; B-Sample Simulation Sequence Using Monte Carlo Methods

(A)

1	2–3	4–7	8–9	10
11–12	13–18	19–28	29–34	35–36
37–40	41–50		51–60	61–64
65–66	67–72	73–82	83–88	89–90
91	92–93	94–97	98–99	100



Source: Morrill, 1962; Peter Haggett et al.; 1977

Through a sequential centring of the probability matrix on settlement A in a seaboard location, Morrills derived his generations of settlement. Using seven random numbers (10, 22, 24, 42, 37, 96 and 77) and the probability matrix, a hierarchy of six settlements was derived, with one large settlement (A), one medium settlement (D) and four smaller settlements (B, C, E, and F) as seen in figure 2.3B. By following the rules and re - centring the matrix over the settlement from which migrants are originating, a hierarchy can be slowly built up which stimulates a general pattern of settlements (Haggett et. al, 1977).

3.2.5 Spatial Interactions Models.

The various interaction models advanced by authors provide an ideal background for understating the relationships among settlements in a geographic region. Most of the models used by geographers to analyse spatial interaction draw on the physical analogies particularly on the Newtonian gravity theory (Haggett et. al, 1977). The Newton's Law of Universal Gravitation states that two bodies attract each other in proportion to the product of their masses and inversely as the square of the distance between them. The mathematical representation of the model is stated viz:

$$F = GM_1 M_2/d^2_{12} \qquad (3.1)$$

Where:

F = the force with which each mass pulls the other.

G = universal constant

M_i and M_2 = sizes of the two masses concerned

d_{12} =distance between them.

Based on Newton's law, Ravenstein (1885) used his empirical observation of migration in England and Wales and came up with a simple migration law, which states that:

> "Migration between an origin or source area and destination area was proportional to the product of their sizes and inversely proportional to the distance between raised to some power".

The law is represented as:

$T_{ij} = Ko_i D_j d_{ij}^{-\beta}$-------------------------------- (3.2)

Where

T_{ij} =migration between i and j

i and j = are origin and destination respectively

O_i and D_j = sizes of origin and destination

d_{ij} = Distance between origin and destination

K = constant

β= distance exponent.

Reilly (1929) who propounded a law of Retail Gravitation also applied the gravity model of spatial interaction viz:

> Two cities (i and j) attract retail trade from any intermediate town or city, in the vicinity of the break point, approximately in direct proportion to the population of the two cities and inversely proportional to the square of the distance from these two settlements to the intermediate town.

Reilly's breaking point formula has been applied to areas where retail trade is dominated by well spaced central spaces and is used to determine whether a given settlement will look up to city A or B as its dominant central place based on its breaking point along a main route.

Other variants of the gravity model are those which Stouffer (1940) used in traffic flow studies and that of Ullman (1957), which advanced the three relative concepts of complementarity, transferability and intervening opportunity as determinants of spatial interaction in geographic space. These and many other elementary models of spatial interaction offer simple and effective guides for estimating flows between areas (Heggett et al, 1977). However, the simplicity of these models constitutes a major limitation in their power to explain more complex spatial interaction and this has brought about certain conceptual refinement of the basic gravity model. The gravity models have particularly been criticised for assuming a common travel behaviour for different people without due cognisance of individual differences. One major attempt to rationalise the differences and to determine movement probability is the Huff's (1960) model. The model simply states that the probability (P) that a purchaser will buy something in his own town (1) rather than another is related to the number of shops in that town compared with those in the other towns and the comparative ease with which they can be reached. This model is expressed thus:

$$\frac{\text{Number of shops in centre 1 / Distance or time travel to reach them}}{\text{Total numbers of shops in whole study area/Total distance or time travel to reach them}} \quad \ldots.(3.3)$$

$$\text{i.e } P1 = \frac{N1/T1}{\Sigma N_i / \Sigma T_i}$$

The probability model of Huff (1960) is supported by Wilson's (1967) maximum entropy model. Entropy (the most likely state of a system) relates directly to the idea of probability and uncertainty and forms a directly measurable system property (Hagget et al 1977). The model introduced constraints into residence - work place interaction and agrees that individual's interaction in urban space is a function of the transport cost they can bear. The model ensures that flow patterns meet origin, destination and the overall cost constraints, while linking the likelihood of individual trip behaviour to the aggregate pattern of flow.

The entropy model and other elementary interaction models have generally been criticised for oversimplifying interactions as movements along one-dimensional line linking a pair of points. On the contrary, spatial interaction between points is multi- dimensional. This brings into focus the idea of interaction field, which establishes series of interaction link between a centre and its periphery or the surrounding settlements.

3.2.6 Concept of Urban Field

The urban field simply refers to the sphere of influence around a city. It defines an urban region, which include all the commuter villages and communities, which fall within the city's ambience. The term is often used interchangeably with hinterland, sphere of influence, tributary area, catchments area or the city region to refer to the area served by a town or city. The field is analogous to the magnetic field with the greatest degree of interaction at the centre (Daniel and Hopkinson, 1989). It is theoretically a continuous distribution with a very rapid fall - off near their centre and a very slow almost asymptotic fall - off at their outer ranges (Haggett et. al. 1977).

The continuous nature of urban field presents difficulty in its description in absolute term. This brought about the concept of mean(primary) field and maximum(secondary) field. The mean field is defined as a small trade area of a settlement, which records the highest intensity of interaction while the vast, peripheral areas of mild influence constitutes the maximum field. Two valid generalisations are often made with respect to the size of the mean field. These include:

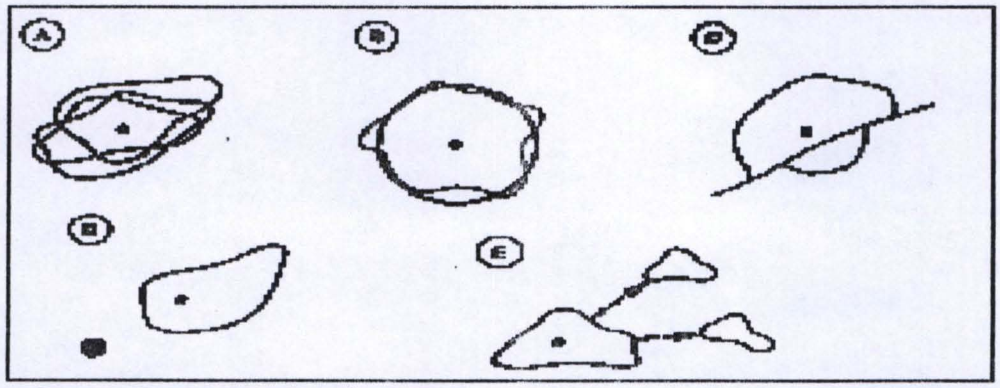
(i) The size of mean fields varies with the transferability of the item being moved. This assertion is established in the works of Ullman (1959) and Thunen (1862,1875), which relate ease of product movement to distance and relative movement cost.

(ii) The size of the mean fields varies over time. This results from the increasing mobility due to technical innovations, which have reduced the relative cost of distance.

These generalisations raise the question of the ideal shape of interaction fields. The general notion is that interaction field is conic in nature. Hence, an arbitrary line drawn round a centre delimits its field and is theoretically circular in shape (Haggett et. al., 1977). However, circular fields have not been empirically established by regional studies. Realities show that they approximate a circle and are rather irregular, amoeba - like in form. Some departures from these general shapes occur in form of truncated, distorted and fragmented fields (See figure 3.6 A-E).

Irrespective of its size and shape, the field gives context to spatial interaction. The concept therefore captures, adequately, the multiple and multi- dimensional nature of interaction among the elements (settlements) of human landscape.

Figure 3.6: Alternative Types of Movement Fields. A-Amoeba-like Field; B-Circular Field; C- Truncated Field; D- Distorted Field; E- Fragmented Field



Source: Peter Haggett et al.; 1977

3.3 LITERATURE REVIEW

3.3.1 Definitions and Principles of Remote Sensing

The field of remote sensing is an outgrowth of aerial photographic interpretation, which has grown rapidly since the term was first, coined by Evelyn Pruitt of the office of Naval Research in 1960 (Estes, 1974; Morain, 1998). Authors have variously defined the term. Lillesand and Kiefer (1994) define it as the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by device that is not in contact with the object, area or phenomenon under investigation. A similar definition given by the Kufoniyi et al. (2003) views remote sensing as the science of measuring the geometric and thematic properties of objects in the environment without coming in contact with such objects, using various devices carried in the air or space. Curran (1985) also defines the subject as the use of electromagnetic radiation sensors to record images of the environment, which can be interpreted to yield useful information.

These and other definitions provided by authors centre on information collection, analysis, storage and retrieval through the use of remote sensors and interpretation tools. Hence Robinson et al (1995) describe remote sensing as the process of collecting, storing and extracting environmental information from images of the ground acquired by devices not in direct physical contact with the features being studied.

The prime objective of remote sensing is to extract environmental and natural resources data related to our earth (Lo, 1986). The imaging principle of remote sensors (optical and active sensors) involves the detection and recording of energy in the selected portion of the electromagnetic spectrum (EMS) to form images of terrain features. The electromagnetic energy (EME) is a form of radiant energy that moves with the constant velocity of light (about $3x10^{10}$ cm\s in a harmonic wave pattern (Lillesand and Kiefa, 1994). The wave consists of both electric and magnetic fields, which are orthogonal to each other and the direction of wave propagation, which can be described in terms of wavelength (λ) or its frequency (f) as shown in the equation below:

$\lambda f = C$ or $f = c/\lambda$ ....(3.4)

All earth's surface features with absolute temperature above 0^{oc} reflect or emit radiant energy. This energy is detected by the sensor antenna and is processed to obtain information on earth's surface features. The basic principle of image formation, therefore involves a kind of energy-matter-environmental sensor interactions (Estes, 1974) to produce information on the spectral characteristic of the features of the target area.

3.3.2 Development and Geographic Uses of Remotely Sensed Data: A Time Dimensional Overview.

The evolution of remote sensing technology dates back to the beginning of the practise of photography in 1839. Gaspard Felix is recognised as the first person to photograph 'remotely' using balloon over Paris in 1859 (Morain, 1998). Subsequent advancement in photographic inventions which brought about the development of metal plate and calotype, dry plates, paper prints and flexible roll films between 1851 and 1900, paved way for remote sensing activities.

The historical development of remote sensing and geographical uses of its data have gone through at least five overlapping phases, four of which were concerned with aerial photos (Stone, 1974). The first phase (1860-1930) witnessed the first air photo taken in 1860 from a captive balloon at 1,200 feet high in Massachusetts, USA. The major events in this phase include the development of airplanes and subsequent improvements in camera and film. These developments made possible the taking of first photo from a plane on April 24, 1909 in Italy and facilitated more peacetime photography for mapping purposes.

The 1920-1950 period witnessed increased air photo coverage and short-lived experiments on the uses of air photo for mapping physical and cultural elements of the landscape. This period also witnessed a rapid wartime development of air photo interpretation as a sophisticated intelligence data gathering technique.

The military application of air photo extended to the third phase (1945-1960) during which emphasis later shifted to techniques rather than analytical uses of remote sensing results. The fourth phase (1955-1962) corrected this error by centring on the applied uses of air photo interpretation in geographic works. During this period, geographic applications of air photo data were specifically related to urban problems such as neighbourhood studies, transportation, land use-mapping etc. The development at this phase culminated into the last phase (1960 and beyond), which witnessed the development of new sensing system from remote heights. The introduction of TIROS (Television and Infrared Reflected Operational Satellite) in 1960 thus set the stage for the latest development in satellite remote sensing. Further development followed the launching of NIMBUS satellite with advanced television camera and a high-resolution infrared observational system, which produced the first day and night, picture of the earth in 1964.

The early years of the current phase witnessed efforts on general application as geographers became aware of the potentials of spacecraft data for both physical and cultural analysis. The 1966 period witnessed "tooling up" exercise to meet the challenges of remote sensing while by 1971, several geographers were already engrossed in the use of space imagery data for content analysis (Stone, 1974). Part of the tooling up exercise was the investigation and development of the cameral system, development of rural land-utilisation classifications and recognition techniques and the general automation of image interpretation techniques. All these prepared the stage for the modern day remote sensing.

3.3.3 TRENDS IN REMOTE SENSING DATA APPLICATION.

3.3.3.1 Introduction

One of the most perplexing problems facing urban planners, managers and analysts is the dearth of pertinent, timely and reliable information. Most researchers using conventional methods of data collection and analysis have incurred substantial time and financial costs and have experienced severe constraints in data void areas. However, the remote sensing data method offers a lot of opportunities and has generated immense data at less time and 'low' financial cost. According to Ruklanthi Silva (1996), remotely sensed data provide a cost effective means to obtain useful land use information for large area and the technique is good in obtaining required data efficiently and speedily in areas of difficult access. This and other advantages have combined to popularise remote sensing data application around the world. This section presents a general overview of remote sensing application areas and narrows down on detail issues on remote sensing application to settlement studies.

3.3.3.2 General Application of Remote Sensing Data

Available facts from the literature show a wide application of remote sensing methodology or data. Several authors including Lillesand and Kiefer (1994), Lo (1986) and Harris (1987) have, for instance, recognised the major application areas to include geologic and soil mapping, land use/land cover mapping, agriculture, forestry, hydrologic studies, meteorology, urban and regional planning, wetland mapping, wild life ecology, archaeology, environmental and land information management etc.

With regard to meteorology, Lo (1986) and Harris (1987) have discussed such major application issues as cloud classification and monitoring, earth's surface radiation characteristics, rainfall prediction and estimation, pressure pattern studies, wind direction and speed measurement, airflow estimation and general forecasting of weather systems such as tropical hurricane and storms. Important application studies carried out in meteorology include those of Smith and Kelly (1985) Susskind (1984), Epstein (1998), Janet Nichol et al. (2002), etc. For instance, the work of Nichol et al. (ibid) focuses on the use of Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) and Landsat ETM+ for microclimate study in Hong Kong. The images were used to compare the daytime and nighttime satellite- derived surface temperature in two densely built towns with high-rise buildings. The research established that both air and sea surface temperatures were 2^0 C cooler on 6^{th} October than on 17^{th} September and that the spatial variations were explained by differences in urban morphology.

The application of remote sensing to lithospheric environment has generally focused on the crust with a view to extracting geologic, geomorphologic and hydrologic information (Lo, 1986). Remote sensing data have been applied in lineament studies to detect different surface expressions, landform analysis and change detection, rock type identification and discrimination, mineral resource detection, thermal inertia mapping etc. Some of the numerous researches that utilised remotely sensed data in lithographic and geologic studies include those of Williams (1983), Lake et al. (1984), Mongkolsawat et al. (1991), etc.

Remote sensing data application to hydrologic studies has focused on a wide range of issues. These including ocean primary resources management, sea surface temperature, water colour and pollution, flooding, sea state local variation, sea ice detection, snows studies, ocean current and waves studies, coastal bathymetry, coastal sediments and land changes, ocean turbidity, underground water discharge, river channel changes, drainage pattern, river regime, lake eutrophication assessment, water chemical and suspended colloids etc. Several research works including those of Harries et al. (1983), El-Raey et al (1995), Ogunkoya et al (1997), Robert et al. (1999), Boggs et al. (2001), Serwan et al. (2003) and Jerry et al. (2003) have demonstrated the value of remote sensing data in the study of fluvial environments.

Quite a significant number of vegetation/forestry and soil studies have also utilised the remote sensing data methodology. Both aerial photograph and satellite image data have been applied to vegetation studies in the areas of forest resource inventory and species identification, geographic pattern, gross structure and physiognomy, tree-height measurement, estimation of tree volume and green leaf area index (LAI), timber resource estimation, deforestation, disease and fire damage estimation etc. Data from the two sources have also been applied to soil studies such as soil types and local variation, geomorphic characteristic, mineral component and organic matter content, soil moisture estimation etc. Relevant studies in these application areas include those carried out by Shoshany et al (1995), Laporte et al. (1995), Abubakar and Abdulkadir (1997), Kim Hwa Lim et al. (2000) and Edward et al. (2003). The work of Kim Hwa Lim et al. (ibid), for instance, focused on the use of SPOT-4 image of July 2000 in forest fire monitoring in Sumatra, India. The image was used to detect individual fires and their nature in terms of sizes of the smoke plumes. The temperature sensitive SWIR band of STOP-4's 432 was found to be more effective and efficient in forest fire monitoring.

The application areas of remote sensing to agriculture are varied and diverse. Lillesand and Kiefer (1994) and Lo (1986) have discussed extensively the application of aerial photo data to crop type classification, crop condition assessment and crop yield estimation. Harris (1987) has also discussed the Large Area Crop Inventory Experiment (LACIE) and the Agristars programs as being the two major case studies that demonstrate the application of remote sensing data to agriculture. The LACIE was jointly carried out by National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA) and the United States Department of Agriculture in 1974 to develop a testing method for wheat production estimation. The United States Agristars program has also revealed several areas of remote sensing application to include: improved commodity production forecast, land productivity estimates, agricultural land use classification and measurement, early famine warning and food security, crop disease detection, land capability and suitability study etc. Several other studies that established the utility of remote sensing data in agriculture include those of Leek and Solberg (1995), Hamar et al. (1996), Hutchinson (1998), Afzal and Ryosuke (2000), Paul Pinter et al. (2003), etc. While the work of Afzal and Ryosuke (ibid) considered crop growth response to climatic changes at the national level in Bangladesh, that of Paul Pinter et al. (ibid) assessed the role of remote sensing in yield prediction and demonstrated that remote sensing data can provide detailed spatial and temporal information on plant response to local environment.

The above overview reveals a wide area of remote sensing application. Details of application issues in these areas are presented in the works of the various authors cited. The remaining part of this review is therefore devoted to application issues in settlement studies and related issues.

3.3.3.3 Remote Sensing Application to Settlement Studies and Related Issues.

Remote sensing provides an opportunity to measure attributes of urban and suburban environments and records data in accurate digital maps, and files suitable for analysis with GIS. These data, together with those available from ground-based observations, can be used to monitor changes in space and time, to develop and validate dynamic models of urban development, and to forecast future land use pattern and changes in other urban attributes (Cowen and Jensen, 1998).

The early application of remote sensing data to settlement study dates back to the World War I period when some geographers associated with the military unit envisaged the peacetime civil use of the early military air photo coverage. According to Stone (1974), few of these geographers spoke of archaeological uses and detailed mapping of roads, buildings and fields, while others commented on mapping of physical features such as swamps and bedrock outcrops. From these initial thoughts, and subsequent to the development of remote sensing methods, the application of remotely sensed data to settlement studies have been intensified and extended to cover a wide range of issues.

Significant research efforts have revealed tremendous urban application of remotely sensed data. Lindgren (1974) has, for instance, recognised six major areas of application, which use both direct and indirect data types. These include urban land use mapping, transportation studies, engineering projects, municipal inspection, estimation of dwelling units and population as well as housing quality studies. Recent efforts to make remote sensing data

Table 3.1: Relationship Between Selected Urban/Suburban Attribute and the Remote Sensing Resolution Required to Provide Such Information

Application Areas	Minimum Resolution Required	
Land use/Land cover	**Temporal**	**Spatial**
L1-USGS Level I	5-10 years	20-100m
L2-USGS Level II	5-10 years	5-20m
L3-USGS Level III	3-5 years	1-5m
L4-USGS Level IV	1-3 years	0.3-1m
Building and Property Line Infrastructure		
B1- building perimeter, area, volume, height	1-2 years	0.3-0.5m
B2- cadastral mapping (Property Line)	1-6 months	0.3-0.5m
Transportation Infrastructure		
T1-general road centreline	1-5 years	1-30m
T2- precise road width	1-2 years	0.3-0.5m
T3-traffic count studies (car, airplanes, etc.)	5-10 min	0.3-0.5m
T4-parking studies	10-60 min	0.3-0.5m
Utility Infrastructure		
U1- general utility line mapping and routing	1-5 years	1-30m
U2- precise utility line width, right-of-way	1-2 years	0.3-0.6m
U3- location of poles, manholes, substations	1-2 years	0.3-0.6m
Digital Elevation Model (DEN) Creation		
D1- large scale DEM	5-10 years	0.3-0.5m
D2- large scale slope map	5-10 years	0.3-0.5m
Socio-economic Characteristics		
S1- local population estimation	5-7 years	0.3-0.5m
S2- regional/national population estimation	5-15 years	5-20m
S3- quality of life indicators	5-10 years	0.3-30m
Energy Demand and Conversion		
E1- energy demand and production potential	1-5 years	0.3-1m
E2- building insulation surveys	1-5 years	1-5m
Meteorological Data		
M1- daily weather prediction	30 min-12hr	1-8 km
M2- current temperature	30 min-1hr	1-8 km
M3- current precipitation	10-30 min	4km
M4- immediate severe storm warning	5-10min	4km
M5- monitoring urban heat island effect	12-24 hr	5-10m
Critical Environmental Area Assessment		
C1- stable sensitive environments	1-2 years	1-10m
C2- dynamic sensitive environments	1-6 months	0.3-2m
Disaster Emergency Response		
DE1- pre-emergency imagery	1-5 years	1-5m
DE2- post-emergency imagery	12hr-2 days	0.3-2m
DE3- damaged housing stock	1-2 days	0.3-1m
DE4- damaged transportation	1-2 days	0.3-1m
DE5- damaged utilities	1-2 days	0.3-1m

Source: Adapted from Cowen and Jensen, 1998 more socially relevant and useful by governments and remote sensing agencies have further extended the six major areas discussed by Lindgren (ibid). Hence, Cowen and Jensen (1998) have identified ten major urban/suburban attributes to which remote sensing data can be applied and the different temporal and spatial resolution of the data required (See table 3.1). These authors and many others have shown practical applications of remote sensing data, some of which are reviewed in the following sub-sections.

3.3.3.4 Application Issues and Models of Settlement Pattern and Growth

One major advantage of the remote sensing technique is its capacity to provide a synoptic view of earth's surface and to record the different physical and cultural elements of the human landscape. The synoptic view of the terrestrial environment provided by remote sensing data enables the mapping of spatial distribution of earth surface features. The potentials of remote sensing in mapping settlement distribution and landscape features is well summarised in the account of Rindfuss and Stern (1998) who observed that:

> "Remote sensing provides an additional means of gathering contextual data, particularly in describing the biophysical context within which people live, work and play. First of all, remotely sensed data provide an alternative representation of geographical context to that given by maps. Maps always include the map-maker's selection of what to represent........They (remotely sensed data) can therefore offer a check on what is in maps, additional information, and sometimes a useful alternative perspective"

Tobbler (1969) carried out a major pioneering on settlement distribution pattern. In his study of the relationship between population size and land area in the Nile Delta, Egypt, he demonstrated the use of satellite data in the mapping of settlement pattern. Using the Germini photograph, he identified individual settlements of varying sizes and noted the regularity of spacing of the smaller settlements in relation to larger ones to suggest the applicability of the central place theory. Based on the law of allometric growth, he applied an equation:

$$r = aP^b \quad (3.5).$$

Where r = radius of a circle of the same area of the settlement,

P = population; a = coefficient and b = an exponent,

and found out that the settlements in the Nile Delta area exhibited much higher a and b values than those for settlements in the USA and Europe. The author then divided all the settlement radii in the Nile Delta by four and obtained a computer aided proportional circle map of population distribution and the latitude-longitude positions of settlements at a scale of 1:50,000. The result compared favourably with the Gemini photograph, it validates the central place theory and reveals that the Nile Delta settlements are 16 times more compact than settlements in the USA. Lo (1984) also applied the methodology of Tobbler (ibid) to the study of settlement pattern in China. He made use of Shuttle Imaging Radar-A (SIR-A) data obtained with synthetic aperture radar (in L-band frequency) from space shuttle Columbia in November 1981 to test the validity of the central place theory. His result showed that settlements in China exhibited a mixed random-clustering pattern to reveal their non-conformity to the Christallerian structure of central places.

Beyond the mere location of settlements and the mapping of their distribution pattern, remote sensing data have been used to study morphological dynamics of rural and urban settlements. In the United Kingdom, for instance, the Department of Environment (DOE) investigated the use of Landsat MSS digital data to assist with the monitoring of urban growth (Carter, 1979; Carter and Stow, 1979). Also, Landsat MSS imagery for 1973 and 1978 and an RBV image for 1980 have been analysed to show change through time and to map urban development in Kuwait city from 1973 to 1980 (Harris, 1987). In line with this application direction, different authors have used different methods to study settlement growth. Lo (1986) has, for instance used a simple method of post classification comparison through temporal image matching to produce change map and measure the area of change. The author used aerial photograph at a scale of 1:12,000 to study land use change in Clarke County, Georgia between 1970 and 1983. His result noted an increase in the urban or built-up land category, particularly in residential, commercial and services and a decrease in the agricultural and forestland categories.

More recent studies have demonstrated the different facets of remote sensing application to urban growth. The work of Dimyati et al. (1996) examined the conversion of other land use types into new settlement areas. The authors employed a more rigorous maximum likelihood classification (MLC) approach to examine the pattern of land use/land cover change in suburban area of Yogyakarta, Indonesia. They used Landsat MSS images of May 1972 and October 1984 with thematic maps including road map from 1984 and 1990, sub-regency map of 1990 and land use map of 1990. The multi temporal Landsat images were registered with smallest pixel size of 100x100m while the thematic information data were digitised from map scale of 1:100,000. The satellite data were then registered into the UTM map projections and a MLC method was used to analyse land use/land cover from both images. The two images were later superimposed to produce image of spatial distribution of land use/Land cover change.

The analysis revealed that the pattern of change in the area was that of paddy coverage to open/barren land and to settlement. The authors found out that settlements grew rapidly in sub-urban areas where more space was available and that the annual growth ratio of new settlements to absorb paddy coverage, mixed vegetation and open/barren land were 16%, 20% and 64% respectively. The result also established a high correlation between settlement growth and accessibility as the highest settlement growth was distributed mostly in sub-urban areas between 200m and 400m from the secondary road.

Mehta and Sidhu (1991), Salem et al. (1995) and Shan Yang et al. (2001) have carried out a similar works, which focused on urban sprawl and the direction of settlement growth. Salem et al. (ibid) utilised Landsat TM data to detect rapid land transformation and the direction of urban sprawl between 1949 and 1990 in Egypt. Analysis of change in the relations between urban growth and agricultural land show an alarming rate (1.47% per annum) of loss of land to non-agricultural uses. They therefore concluded that if such rate continues, in the same pattern, all agricultural land in the area would be lost to urbanisation and other activities within less then 70years.

The study of Shan Yang et al. (ibid) considered the application of remote sensing and GIS in the monitoring of urban sprawl in Wuxi city, China. The authors examined the growth of Wuxi over a 32-year period (1966 – 1998) using information from topographic map and Landsat TM images. The study revealed that the built-up area of the city expanded more than ten fold (from 11.6 – 136.1 km^2) during the 32-year period. More expansion was recorded between 1977 and 1984 at a rate of 282.8 per cent.

In addition to the above, other studies that considered the dynamic aspects of urban settlement include those of Yu Cheng – Ming et al. (2002) which used Landsat images of 1972, 1981,1990 and 2000 to capture the trend of urbanization in Kaohsiung city, Taiwan and Anrong (2002) which used remote sensing and GIS data to analyse dynamic development of Beijin city, China. The studies established that development spread in the two cities has accelerated in the recent years.

In the last few years, models of land use change and urban growth have been expanded and have become innovative tools for city planners in making intelligent decisions for the sustainable settlement development. Martin et al. (2002) have evaluated and compared thirty-six of such growth models in terms of their data requirements and have applied the Clark's urban growth model (UGM) in the simulation of urban growth in Santa Barbara, USA. According to the authors, the models have shown their potential to support planning and management decisions in the understanding of the dynamics of urban systems, forecast of future changes or trends of development and in the assessment of the impacts of future developments.

The works of Rao (1995) and Cowen and Jensen (1998) present excellent examples of the ues of urban growth models. The authors have demonstrated how remotely sensed data could be used to analyse the past and present as well as future growth of settlements through predictive modelling. Rao (1995), displeased with the use of transportation modelling as a measure of future urban land use, proposed new methods of forecasting settlement growth in Tuni region of Andhra Pradesh, India. His objectives were to identify the growth of built-up land in shape and area, and to develop a relation between the built-up area and socio-economic condition.

Digital data for the study were obtained from the Indian Remote Sensing Satellite (IRS-1A-LISSI) on 3 April 1989. The filtering techniques and a P.C-based image processing system were used to develop a $90km^2$ image of the region. Data relating to the area of activity were extracted from the imagery while thematic information for 13 villages and towns was collected from the census department. From these data, basic information such as demographic details, land-use growth rate etc., were derived and three techniques were developed to estimate future land use in the area. Two of these techniques are as considered below.

The first technique developed by Rao (op cit) is the causal modelling technique. This technique identifies several factors that affect situations in a built-up area and develops a formula for forecasting future values. The basic form of the model is given as:

$$Y = a_o + a_1 x_1 + a_2 x_2 + \dots\dots\dots a_n x_n \quad \dots\dots\dots(3.6)$$

Where:

Y = dependent variable

X_1 , X_2 ......X_n = independent variables.

In this case, the built-up area is considered as the dependent variable while causes of land area growth like population increase, employment, non-agricultural land, literacy etc have been selected as independent variables. Each of the independent variables was modelled with a stepwise regression technique and their influence on the built-up area was confirmed. Multiple regressive equations were also developed for the variables and a few of them were statistically chosen for assessing future built-up area activity. On this basis, six models, which provide good estimate values with minor error of between 0.07-0.12, were developed. These models were used to predict built-up area for all the villages and towns in the Tuni region with the total built-up area estimated for the year 2001 to range between 890,000m^2 to 1014000m^2.

Another model used by Rao (1995) for future land use forecast is the rating method. This method uses geometrical parameters as the main tools for assessing future land activity growth. Here; the base year data extracted from imagery and census data form the basis for future forecast. The following formulas were then adopted to assess growth potential rate for each village.

$$\text{Influence rate of built-up area of village} = \frac{\text{Circumference of village}}{\text{Area of village.}} \quad \ldots\ldots(3.7)$$

$$\text{Attraction potential rate of town (P.R)} = \frac{\text{Circumference of town}}{\text{Area of town}} \quad \ldots\ldots\ldots(3.8)$$

Where the village built-up area is under influence of more than one town, the potential rate is calculated with the weighted index of area with distance as a parameter as shown below:

$$\text{Weighted index potential} = \frac{\Sigma\text{Area of potential x distance between village and Town}}{\Sigma\text{Distance between village and town.}} \quad \ldots.(3.9)$$

$$\text{The growth potential of village/pocket (GP.P)} = \frac{\text{Attraction potential rate}}{\text{Influence rate.}} \quad \ldots..(3.10)$$

If the village\pocket is under the influence of more them one town, the G.PP is given as:

$$\text{G.PP} = \frac{\text{Weighted index potential}}{\text{Influence rate.}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3.11)$$

In this case however, Tuni town is the only attraction potential in the region. Attraction potential rate (P.R) value is therefore the same for all villages in Tuni region. Hence the built-up areas were calculated as:

Future built-up land area = (G.P.P x area of village in present year + area of village in present year)............(3.12)

Using equations 3.7 – 3.12 above, data for 1971 were processed to estimate the 1981 built-up area. Similar exercises were done to derive the 1991 built-up area and the 1991 data were used to estimate future values for the year 2001, which was estimated at $85125m^2$. The different estimates derived were found close to actual data with an error of 0.12.

The methods developed by Rao (ibid) were found to provide comparative estimates for present and future built-up areas with minimum error. This demonstrates the value of remote sensing method for settlement studies. However, Fabiyi (1999) observed that the methods are deficient in that they do not show direction and pattern of growth. He also noted that the causal factors used to estimate the future growth of settlements might not be sufficient in adequately predicting the future change in the built-up area. Although these observations are correct, they do not however preclude the utility of the models. While future researches are expected to come up with more causal factors on area specific basis, the methods developed by Cowen and Jensen (1998) provide the missing link and could be used to complement Rao's models.

Cowen and Jensen (1998) reviewed the early urban growth models of Burgess (1925), Hoyst (1939) Harris and Ullman (1945), Alonso (1964) and Chapin and Weiss (1968) and found them inadequate. This is because the models treated the rate of expansion of city as a struggle between a series of centrifugal and centripetal forces, and modelled the diffusion process as a manifestation of random events as well. Unlike the assumptions of these models, the authors observed that it is likely that dynamic urban systems are not random, but deterministic in nature. They therefore advanced a time series model that capture and analyse a wide range of data sources to forecast the direction and pattern of future residential expansion in South Carolina.

Cowen and Jensen's (1998) model incorporated census data, land use/land cover data, raster based satellite imagery, building permit and postal code geography data. The first component of the model was the estimation of change in the amount of land available for development. The USGS land use/land cover polygons for 1976 and SPOTJ multispectral imagery for 1989 were used to determine urban land in 1976 and those converted to urban in 1989. The land use data provide a basis for determining where development can be expected to occur.

The SPOT Multispectral data at a resolution of 20x20m was further used to classify land in South Carolina into developable and undevelopable land. Developable land consisted of agricultural land, scrub/shrub, and forests while undevelopable land consisted of water bodies, wet lands and public lands such as parks, protected areas and military installations. This approach provided useful static view of potential areas of development throughout the state.

Once a measure of the amount of developable land had been determined, the average amount of land per housing unit was calculated for the model using the 1990 census figures of housing units at the block level. The average lot size was then adjusted on the basis of actual urban land use.

The final factor in the model was the estimation of the residential growth rate throughout the metropolitan area. The single-family building permits for an eleven-year period (1980-1990) were utilised to calculate residential growth rate. The permits were geo-coded and assigned to block groups to derive a time-series database for estimating the rate of land use conversion for small areas. Rather than fitting a generalised expansion model into the entire region, the authors summarised the temporal aspects of the permits data for each of the 393 blocks. A regression analysis was performed for each block to determine the relationship between the number of building permits and time. The parameters of the regression models (slope and intercept) actually became attributes of the polygons (land use classes). The Y intercept represented an estimate at the start of the study period while the regression coefficient provided a summary of the rate and direction of change through time.

By incorporating the availability of land and housing unit size into the model, it was possible to estimate the period when the developable land within a block group will become saturated. The authors used these models to forecast the number of housing units, the amount of available land, and the year of saturation from the 1992 to 2005 in South Carolina. A land use polygon showing the number of new houses forecast for the year 2005 and the pattern of growth was generated and displayed.

Thus far, accounts of the different authors considered in this sub-section reveal that remote sensing data combine favourably with other reference data in studies that seek the understanding of settlement pattern and growth. One basic fact emerging from this is that land use mapping and change detection are important preliminary exercises in the process of understanding and modelling settlement pattern and growth. This reveals other areas of remote sensing data application, some of which are considered below.

3.3.3.5 The Use of Remote Sensing Data for Land Use/Land Cover Mapping and Change Detection.

Land use and land cover data are most essential to planners who have to make decisions concerning infrastructure location, land allocation and general land resource management. The terms land use and land cover are sometimes used interchangeably in the literature. However, attempt has been made to distinguish the two. Clawson and Stewart (1965) define land use as man's activities on land, which are directly related to the land, while Burley (1961) describes land cover as the vegetation and artificial constructions covering the land surface. While land covers are directly visible from remotely sensed imagery, land use activities are inferred from land cover types.

Land use/land cover data are important in planning to overcome the problem of haphazard, uncontrolled development, deteriorating environmental quality as well as ecological degradation. One prime prerequisite for better use of land is therefore the knowledge of existing land use pattern and changes in land use through time (Anderson et al., 1976). Remote sensing has made a significant contribution in the area of land use/land cover data collection. Two major approaches appear to dominate land use applications of remote sensing (Nunnally, 1974). These are the comprehensive land use inventory, which determine the detail use of all land in an area and thematic land use mapping, which collects generalised land use data. The two approaches have been used in varying degrees by authors to demonstrate the application of remote sensing data as a comprehensive and less costly approach to land use mapping.

Many authors have attempted the evaluation of the applicability of satellite imagery for land use classification. The work of Henderson (1975) focused on rural land use mapping at a regional scale He used an AN/APQ-97 Real Aperture k-band SLAR imagery at an approximate scale of 1:180,000 to delineate landscape regions over the West and Midwest of USA (from Minnesota to North Utah). He was able to detect five major components of a land use region (surface configuration, natural vegetation, field pattern and size, settlement pattern and transportation and communications network), which were delineated on a transparent overlay and composited again to determine the boundaries of the level of the land use regions. A total of 14 land use regions were delineated and these were compared to the traditional land use map of Anderson (1970) and the land-resource region map of Austin (1965). It was thus found that the classification from radar imagery achieved 80% and 74% correct classification respectively in relation to the maps developed by the two authors. It was also noted that more detailed regions were created using radar imagery than using the traditional approach.

Mongkolsawat et al. (1991) have practically demonstrated the value of remote sensing data in agricultural land use classification and mapping. The authors used Landsat TM of December 1988 and August 1989 together with topographical map on scale 1: 50,000 for agricultural land capability mapping in the Udon Thani province of Northeast Thailand. Using the altitude parameters of elevation and slope gradient as well as soil type and current land cover, the study area was classified into capability classes with each parameter as a thematic input layer for GIS operation. The rasterized data were overlaid to derive land capability layer in map form. The mapping exercise gave rise to 14 land capability classes. The study revealed that land capability class 4 was the most widely distributed of the upper land types (85,487 ha) while class 9 was the most wide spread of the low land types (95,684 ha). The low fertility loamy soil (types S4 and S8 were found to have significant limiting effect on agricultural development in the area.

Unlike Henderson (op cit) and Mongkolsawat et al. (op cit) who focused on rural land classification, Kawka (1997) demonstrated the use of satellite imageries in the classification of urban land use in Maiduguri, Nigeria. Principal component analysis was used to process TM1-TM6 of the 1988 Landsat image of the area. An initial 25-class derived with the use of maximum likelihood algorithm was further aggregated to obtain nine urban land use classes in the area.

These and many more case studies have established the application of remote sensing data to both rural and urban land use/land cover mapping. However, researchers have noted the difficulty involved in the extraction of data from remotely sensed imageries, due to the complex pattern of urban land use. The two main problems often emphasised are those of classification and image resolution. However, the development of a standard classification scheme by the USGS and high resolution images (e.g SPOT and Ikonos with 10 – 30 and 1 – metre resolutions respectively) have enhanced the use of remotely sensed data for land use mapping in the recent times.

One major area of growing interest in land use/land cover researches is in land use monitoring and change detection. Throughout the history of man and the earth, the environment has evolved, placing stress on individuals and the earth's ecology. Although these changes are both natural and man-made (Aschmann and Bowden, 1974), recent advances in the study of human dimensions of global environmental change have produced useful hypothesis and models of how social forces drive changes in land use and land cover (NRC, 1999). The remote sensing platforms provide useful time-series data of good comparability that can be, and have been used, to monitor these changes. In the early period, several authors like Avery (1965), Falkner (1968), Richter (1969) and Wellar (1971) have considered land use dynamics and have advocated the development of special systems for recording land use change so that maps and data banks can be updated quickly. Consequently, the Geological Survey's Geographic Application Program (GAP) has executed research projects concerned with developing procedures for monitoring current land use changes using satellite and high-altitude aerial photography (Nunnally, 1974). From these initial efforts on system and procedural development in change detection, several studies have been conducted on change detection, some of which are considered below.

Many techniques have been established for deriving land use change statistics from remotely sensed raster images. Some of these methods include image overlay, image differencing, image rationing, principal component analysis, change vector analysis and post-classification comparison. (Mattikalli, 1995). Byrne et al. (1980) have used the principal component analysis (PCA) to monitor land cover change in Batemans Bay, New South Wales. They utilised two Landsat MSS scenes for 1972 and 1975 with four channels each. The two sets of four-channel data were then combined and treated as a single eight-dimensional data set-the first four dimensions being the four channels of the first image. PCA was performed on the variance-covariance matrix. The land cover changes identified by means of the black and white areas on the component image correlated with known changes in land cover identified in earlier works that utilise conventional methods. Amongst others, the result revealed changes, caused by forest clearing, intensive logging and urban developments.

Higgs and Bracken (1990) have also investigated land use changes in rural Mid-Wales and the effects of statutory designation on the changes observed. A multi-data approach combining information from the 1957 and 1985 aerial photographs, satellite images, existing secondary data and field survey was adopted. In the aerial photo interpretation, 100 x 100m raster cell surface maps for the land classes in 1957 and 1985 were created in run-coded format. The data were later transformed to pixel values using in-house software and were corrected for map projection and distortion by ERD image processing software.

The resulting data set were imported into the TYDAC spatial Analysis GIS (SPANS) and converted into its quadtree database structure for analysis and display of surface images for 1957 and 1985. Information on total areas of change, types and location of change were obtained using SPANS 2 map cross-tabulation function. The results revealed that during the 28-year period, the percentage of the Tywi catchment under forestry and agricultural production has increased from 21% in 1957 to 53% in 1985. Statutory designation was noted to be effective in controlling the extent of land use changes in the catchment as a whole. Thus it was discovered that of the total change in land use (152.2Km^2), only 6.9Km^2 (4.6%) took place within designated conservation areas.

Mattikalli (1995) has explored the integration of raster-based remotely sensed data and the vector-based GIS data format to analyse historical land use change in the river Glen catchment area in south Lincolnshire, England. Land use map for 1931, 1963 and 1971 derived from field mapping and aerial photograph as well as satellite images for 1984, 1987 and 1989 were used in the analysis. Using the vector-based GIS approach, the 1931, 1963 and 1971 data were scanned and digitised to input the data. The raster-to-vector conversion method was successfully used to integrate all the three satellite images and their classified products for the river Glen catchment.

Change detection method was later applied to analyse six land use categories - arable, grassland, woodland, water, bare soil and urban. Among others, a significant increase in arable land from 42% to 70% during the 1931-1971 periods was discovered. A decrease of grassland from 50% in 1931 to 36% in 1963 and to 20% in 1971 was also noted. The major form of changes noted in the study area is from grassland to arable land.

In addition to the above case studies, many other researches have used remotely sensed data to monitor changes in agricultural land use, coastal environment, river channel and surface configuration of reservoirs, vegetation and forestry etc. (See Cameron (1965), Lewin and Weir (1977),El-Raey et al. (1995) Laporte et al (1995), Hamar et al (1996) and Ogunkoya et al (1997). Aside from these, other studies of social relevance are being put forward to determine both the endogamous and exogenous variables of change. Mertens and Lambin (1997) have, for instance, used Landsat TM imagery and GIS analysis to identify six spatial patterns of land use and land cover change in eastern Cameroon that are indicative of market, subsistence, policy and urbanisation processes. Similarly, Amarsaikhan (2000) used SPOT Panchromatic of 1986 and 1990 together with SPOT Multispectral image of 1997 to detect changes which occurred in the central Ulaabaatar, Mongolia during the centralized and market economies and identified the socio-economic factors of change to include; increased income, movement to areas of good infrastructure and increased ownership of land parcels. Also, in a preliminary study of land use\land cover change in upper Magat watershed in Philippines, Bato (2002) used nine Landsat TM images of between 1988 and 1999 to classify the land cover of the area. The study isolated four major factors which affected land use to include; climatic conditions, human activities (through agriculture, deforestation and reforestation), natural disasters (like landslides from earthquakes) and soil erosion.

The use of remote sensing data in change detection was further demonstrated by Wemer Fricke and Anja WolfbeiB (1997) who demonstrated the relationship between population development and land use change in the Ture Hill- Kaltungo plain of the Gombe division of the former Bauchi State, Nigeria. First it was established from earlier studies that that the population of Tangale-Waja district in the area grew from 118,154 to 384,118 (about 224% increase) between the 1952 and 1991 census. The population of Ture was also observed to increase by 188% with density rising from 18 to 43 persons per squre kilometre while that of Kaltungo rose by 139% with an increase in density from 35 to 82 persons per square kilometre. The study also noted that the population density of Akko districts grew from 42 to 105 persons per square kilometres. The pressure of the population growth in these areas was found to lead to expansion of farmland. The land use of the area was monitored with the use of false colour SPOT image taken in 1991. The land use map derived reveals the extension of permanent farmland around Tulmi village and this was linked to the rapid population growth in the area. The indiscriminate extension of farmland and deforestation in the area was also noted to cause increase in erosion. Altogether, these studies show the current dimensions in the application of remote sensing data in land use mapping and change detection. They reveal that land use change is a dynamic spatial process, which involves complex interactions between many factors at various spatial extents. The complexity of this dynamic process makes the creation of a comprehensive model very challenging (Lay 2002).

Although the methodology for predicting and modelling land use change is relatively immature, efforts are being made to improve on land use change modelling. Aside from earlier models considered, Cellular Automata (CA) is one of the new models, which provides powerful tool for the dynamic modelling of land use change. Lay (2002) has successfully used the CA to study land use change in Tansui watershed, Taiwan. Using the

1971 and 1977 digital data, which were converted from Arc Info vector format to raster format, the author reclassified the original ninety-nine land use types into seven categories. The overlay was done with the Arcview's Tabulate Area function and the result showed about 4% (1,250 hectares) increase in settlement area. A computer programme was further coded to investigate the neighbourhood states of some target cells and this reveals that conversion was mostly from farmlands to settlement.

3.3.3.6 Remote Sensing Application to Settlement Quality Studies

An important derivation from the application of remote sensing data to settlement growth, land use mapping and change detection is the study of environmental quality. In the United States, George Marsh's "Man in Nature" published in 1864 perhaps, marks the earliest attempt at a comprehensive assessment of the problems of degradative changes in the environment (Aschmann and Bowden, 1974). With the development of remote sensing technology, application issues are increasingly showing its potentials in environmental quality study.

The use of aerial photograph for housing quality study has been demonstrated by Wellar (1968) who compared information extracted from multi-band aerial photograph directly with information contained in the American Public Health Association's (APHA) appraisal form. The aerial photograph data were found to correlate well with ground-truth data obtained from the APHA form. Large-scale photograph was also found capable of revealing a number of features associated with poverty (Lindgren, 1974). Such features include structural deterioration, debris, cluster, lack of vegetation, walls, paved streets and housing density. Housing density as an indicator was, for instance, used in the Lexington, Kentucky study. Information was extracted from a 1:6,000 scale black and white photograph. The map of urban poverty derived compared favourably with those compiled by the City County Planning Commission at 80% level of accuracy.

Adeniyi (1976) addressed the issue of urban quality in his study of Lagos, Nigeria. Residential density and accessibility indices were computed for five sampled areas. It was discovered that building density range from 3 residential houses per hectare in Ikoyi to about 47 in central Lagos. All buildings in Ikoyi were also found accessible while only 66% were accessible in central Lagos Island. Using other indices of slum such as evidence of structural deterioration and obsolescence, presence of garbage accumulation, lack of recreational, social and sanitary facilities etc; the author identified central Lagos island as a blighted area needing urban renewal.

The works of earlier authors considered above have been complemented by more recent studies. Ikhnoria (1988) for instance used aerial photograph to determine urban blight in Benin city, Nigeria and confirmed the potentials of remote sensing data in assessing neighbourhood quality and monitoring blighted environment. Fabiyi (1999) has also explored the relevance of remote sensing data and the use of GIS for monitoring and predicting urban quality levels in Ibadan, Nigeria. He used the 1975 and 1990 aerial photographs at scales 1:25,000 and 1:6,000 respectively and SPOT XS and SPOT P images taken in 1986 and 1994 respectively. The photographs were visually interpreted while the SPOT images were analysed with the use of IDRISI software. The results of the analyses were converted to vector data structure in form of maps and were used to estimate temporal changes of urban decay in the area. It was found out that quality classification for urban decay and good quality areas obtained from remotely sensed data were similar to those obtained from conventional questionnaire method. However, the result show dissimilarity in areas classified as deteriorating by the two methods. Hence, he concluded that remote sensing data complement the conventional data method with the added advantage of the capability to monitor urban quality over long period of time using the same parameters.

Pratima et al. (2002) have further demonstrated that the usefulness of remote sensing\GIS data and methods transcends mere slum monitoring and urban quality level prediction. The authors demonstrated how GIS can be used to locate, map and store information in Pune and Sangli slums at Maharashtra, India. They digitised the settlement maps of the two slums and developed a database, which were connected to the slum boundaries. Detailed map of each of the settlements showing the houses and other infrastructure were also developed with household data connected to each of the houses on the maps. The slum boundaries and the houses could therefore be queried to generate information of each of the slums for the purpose of planning and improvement exercises.

3.3.3.7 Application Issues in Housing and Population Estimation.

Studies on application of remotely sensed data to dwelling units and population estimation form the bulk of early efforts in aerial photo interpretation. A major pioneering work in dwelling units estimation was carried out in Birmingham, Alabama by Green (1956). The author used a black and white aerial photograph with scale 1:7,500 to examine 17 residential sub areas of Birmingham. Using such criteria as roof structure, yard and courts, driveways and entrance ways; and size, shape and height of structures, Green (1956) came up with five housing categories-single family, double-family, multifamily (3 to 5), multifamily (6-8) and multifamily (9 to 11). Although his results were fraught with underestimation and overestimation, his work demonstrated the potentials of remotely sensed data for dwelling unit estimation.

Adeniyi (1976) also estimated the number and characteristics of dwelling units in some selected residential districts of the urban region of Lagos, Nigeria. He made use of a large, uncontrolled mosaic made from the 1973, 880 panchromatic aerial photograph at a scale of 1:6,000. The photography was interpreted with a mirror stereoscope with magnifying ocular (3x). The result of his residential count from five sampled areas on the photograph (5,050) was obtained with 99.4% accuracy as it bears close relationship with ground survey count of 5,075 dwelling units.

Aside from studies that employ aerial photograph data, others have shown the application of satellite image data to the estimation of dwelling units. An illustrative example is that of Lo (1995) who used the GIS approach to estimate population and dwelling unit in metropolitan Kowlon, Hong Kong. Lo (1995) used SPOT HRV multispectral data in his study and came up with accurate estimation at the macro level but low or less accuracy at the micro level. The difficulty in discriminating residential use from non-residential use at the micro level explains the low accuracy recorded at this level.

Many studies use dwelling units estimation as a method for population count. This explains the applicability of remote sensing in generating population census figures, providing inter census population information or update and in resolving the problem of census undercount. Adeniyi (1976) has, for instance, explained how aerial photo data can be used in settlement identification and location, delimitation of enumeration areas (EAs) and population estimation using the knowledge of the number of dwelling houses, number of units in each dwelling house and room occupancy ratio. Generally, there are four different approaches to the use of remote sensing data for population estimation. According to Lo (1986, 1995) these approaches include estimation based on measured land areas, estimation based on counts of dwelling units, estimation based on measured land use areas and estimation based on spectral radiance characteristics by individual pixels. The choice of any of these approaches will depend on the type of population involved, data type and the technology available.

The most accurate remote sensing method for computing the population of a local area is to count individual dwelling units (Cowen and Jensen, 1998). This method was utilised by Hsu (1971) to estimate and map the 1963 population distribution of Atlanta area using an aerial photograph at the scale of 1:5,000. A transparent grid of one-quarter square mile size was constructed over the photographic area. By moving the transparent grid on the photograph and registering it with corresponding map grid, the number of dwelling units were counted and recorded. Using household census statistics and the estimated dwelling units, he computed a population density for each grid cell and derived a chloroplet map of population density of the Atlanta area in 1968 using the following formula.

$$\text{Population Density} = \frac{(\text{persons per household}) \times (\text{number of dwelling units})}{\text{Grid cell area}} \quad \ldots\ldots\ldots(3.13)$$

Unlike Hsu (1971) and other authors that utilised the dwelling count approach, Wellar (1969) and Lo and Welch (1977) employed the estimation by land area approach using the reversed allometric growth model in form of:

$$A = aP^b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.14)$$

Where:

A = built-up area; P = Population

a= a coefficient, and b= an exponent

Wellar (1969) has also measured the areas of ten settlements in Houston and San Antonio, Texas from Gemini XII photograph and input them individually in a model ($A = 0.00151\ p^{0.88}$) developed for the cities of USA. His result shows variations between actual and estimated population for several cities with close estimation for smaller settlement of below 10,000 and under-and-over estimation for population of large settlements.

Lo and Welch (1977) modified equation 3.14 above to $P = aA^b$ in their study of Chinese cities to overcome the problem encountered by Wellar (1969) and also introduced a linear regression ($P = a+bA$) to explain the more rapid growth of larger cities. The authors used the 1953 census data, the built-up areas of 124 cities as measured from maps at a scale of 1:250,000 produced in 1951-1956 and Landsat area measurement. The problem of over-and-under-estimation was resolved by grouping the cities according to regions and computing separate allometric growth model for each region. In this manner, model developed for north-east ($\log P = 4.8611 + 0.6312 \log A$ or $P = 72627A^{0.6312}$) and central China ($\log P = 4.9087 + 0.8071 \log A$ or $P = 81040\ A^{0.8071}$) were found, to improve the accuracy of population estimation.

Added to the two different approaches reviewed above are several other works which utilised other approaches and statistical models to general population estimates. For instance, Fahui Wang and Yanchun Meng (1999) used the polycentric model to explain spatial variation in population density distribution and change over time in Shenyang, China . Although these techniques provide statistical approximations that approach the values obtained in a regular Census (Cowen and Jensen, 1998), they have some limitations which necessitate the use of considerable ground reference data to calibrate the models.

3.3.4 Counterurbanization, Settlement Growth and Land use Change

As explained in section 2.6 Counterurbanization is the process of population and economic activity dispersal into freestanding rural localities, bringing about rural settlement growth. It is a process of decentralization in which people and employment move out of large settlement to smaller ones. Spencer and Goodall (1992) have identified three main causes of counter-urbanization. These include the shift in industrial investment to peripheral and other rural localities, the growth of rural service sector and the back to the land subculture of retirees or ex-urbanites. These factors have combined to increase rural population and economic activities.

According to Spencer and Goodall (1992) the far-reaching changes in the realm of production and service rendering have had demographic consequences. In their study of counterurbanization in south Oxfordshire England, the authors noted a population increase of 40,000 people (45% increase) in the area between 1961 and 1990 with the highest rate of increase found in Thames (142%) and Wallingford (72%). This tremendous population increase was said to warrant pressure on residential development. Consequently, the number of residential dwellings grew from 28,000 in 1961 to 53,000 in 1990, showing a 90% increase.

The increases in population and residential development brought about by counterurbanization have engendered social and physical changes in the rural settlements. With respect to social changes, Fielding (1989) asserts that in-migration of middle class or working class new comers distorts rural social structures. The assertion of Fielding (1989) confirms earlier observations of authors like Pahl (1966), Beegle (1964) and George (1964, 1965). Beegle (1964), for instance, reported that enormous social changes have already taken place amongst farmers in North America while George (1964, 1965) observed that the old social structure of rural areas has changed radically over the same period in France.

The account of Pahl (1966) presents a more illustrative case study. In his study of North London, the author noted that metropolitan villages consisted of group of residents including urban workers with limited income (the "reluctant commuters" forced out of the city by high property prices), rural working-class commuters and the traditional ruralites. With this composition, he found out that important social changes were taking place in the metropolitan villages around large cities, giving rise to "pseudo-rural settlements".

Physical changes in rural settlements as a result of counterurbanization manifest in form of settlement growth and environmental quality change. Growth is brought about by an upsurge in demand for land for development in and around specific settlements so that their character is altered. Such environmental change can subsequently affect people's wellbeing positively or negatively (Spencer and Goodall, 1992). The advantages of growth, according to the authors, may include more living space and better services and amenities. In contrast however, they observed that pressures and conflicts might threaten to erode the visual environmental qualities brought about by growth in the first place.

Researches on human dimensions of environmental change have established a positive relationship between aggregating human activities and land use/land cover transformations. The obvious hypothesis used to explain this observation is that human beings altered the land and use resources to meet the needs of a rapidly growing population and an expanding industrial economy (NRC, 1999). This hypothesis is confirmed by considerable progress already being made by researches that seek the understanding of land use/land cover change as a result of human population processes, e.g. counterurbanization.

Although human population growth is commonly seen as the major cause of land cover change and destruction of habitats, further research findings are isolating other factors of change. In his study of rural urbanisation in Zimbabwe, Wekwete (1990) noted that urbanisation is an inevitable consequence of economic development in most countries as reflected in governments' deliberate policy of decentralisation and rural development in the late 1960s and 1970s. According to the author, a survey carried out by the department of physical planning revealed that 36% of government designated rural centres became urban in 1987. Thus alongside other socio-economic factors, the decentralisation of government activities since1980 is seen as a major factor of rural urbanisation and change.

There has been a considerable global effort in the understanding of the multiple nature of the variables of rural change. In the Amazon River basin and Southeast Asia, for instance, global change research has made considerable progress in the understanding of the roles of social, political and economic institutions in land decisions; and the relationship between population and land cover change (NRC, 1999).

There is the need to understand the interactive nature of migration, economic and policy forces that shape the physical environment. To achieve this, research priorities for land use studies have been established internationally through the International Human Dimensions Programme (IHDP) and International Geosphere-Biosphere Programme (IGBP) core projects on land use/land cover change. These priorities have been set to address the following questions.

(i) What are the link among land use change, migration, political and economic changes,

cultural factors, and household decision making.

(ii) What are the interrelations between migration and environmental change?

(iii) What comparative case studies of land use and land cover change are useful for understanding and modelling land use change at regional and global scales?

According to the National Research Council (1999), research in these directions will include efforts to map land use and land cover to document changes over time, develop and validate classifications of land use and land cover, develop algorithms for making the classifications accurately from remotely sensed data and develop and test regional and global models of land use/land cover change. To achieve these will require improved data collection and analysis. Research progress will therefore depend on remotely sensed data, which can provide land cover information required at appropriate spatial and temporal resolutions.

3.3.5 Conclusion.

The foregoing review reveals the wide, almost inexhaustible areas of remote sensing data application. In recent years application focus is being extended to cover more socially relevant issues including environmental protection and disaster reduction, insurance, food security, telecommunication, human dimensions of environmental change, policy analysis and economic planning. In all of these areas, application issues have gone beyond mere data extraction from images and digital sources for research and planning to real time information services and monitoring. Although few constraints have been experienced in the past, the development of more powerful sensors, data handing techniques and human expertise have combined to make remote sensing a powerful tool in the study of earth's surface features.

CHAPTER FOUR

4.0 ANALYSIS OF SETTLEMENT PATTERN AND URBAN INTERACTION FIELD

4.1 Introduction

This chapter considers the pattern of settlement distribution in the FCT, urban interaction field delimitation and the nature of settlements interaction within the mean field. The pattern analysis is preceded by a brief discussion on settlement characteristics and development process. Section 4.3 is devoted to the delimitation of the interaction field of the FCC while the last section is devoted to the understanding of the nature of interaction within the field.

4.2 Analysis of Settlement Development Process, Characteristics and Distribution Pattern.

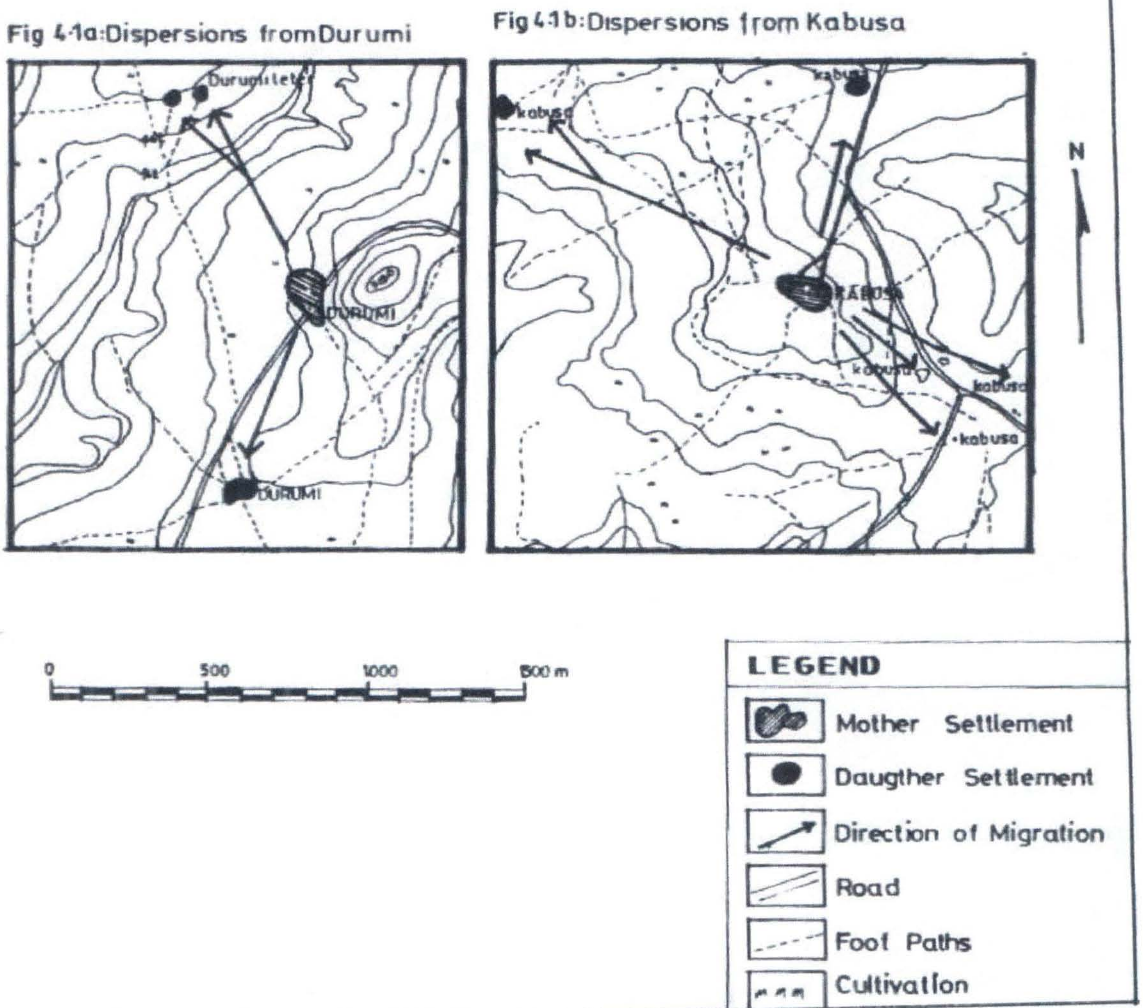
4.2.1 Settlement Development Process and Dynamics

The settlements of the FCT have undergone several development processes in form of disintegration, migration, amalgamation, displacement and relocation. At one time or the other, each of these development processes brought about settlement dynamism in form of birth, death, locational change as well as the reorganisation of the entire space economy. Historical facts on settlement development processes in the FCT presented by Balogun (2001) revealed that the process of settlement disintegration started in the pre-colonial period, which witnessed rampant inter-tribal wars and the Fulani Jihad operations. As a result, some of the war-affected settlements were ruined and deserted while others relocated to defensible areas. The subsequent relative peace brought about by colonial administration and missionary activities resulted in down hill migration of settlements. Generally, development at this period witnessed the movement of settlements away from barriers, hilly and inaccessible locations to areas of favourable economic conditions.

Settlement disintegration and migration also occur in form of the breaking and moving away of 'daughter' settlements from their 'mothers'. Nadel (1951) has empirically established the mother-daughter development process in the middle belt of Nigeria when he observed that, as in the Yoruba land, large settlements in the Nupeland had a number of daughter-settlements called tunga. In the FCT, the migration processes which give rise to daughter settlements were confirmed by Doxiadis and Associates (1983) who observed that settlement migration occurred both on plains with abundant farmlands and in hilly areas with limited farmlands. As it were, daughter settlement development process in the FCT began when few populations migrated afield for the purpose of farming. In the process, farm centres were created to reduce daily commuting to settlement of origin. Such farm centres were later transformed into hamlets and small permanent villages, which normally bear the name of the mother settlement or with the addition of the prefix *sabo* (new) or *Tunga* (area). Examples of such daughter settlements that have migrated from their mothers in the FCT include Kabusa, Durumi Jetere, Mailauni, Gaba, Pyakasa, Sabon Karmo, Sabon Lugbe, Tungan Ladan, Tungan Samu amongst others. Figure 4.1a and 4.1b illustrate examples of daughter settlements migration in the FCT. Figure 4.1a shows the case of Durumi where three daughter settlements migrated to the northwest and southwest with restrictions to the east due to hilly barriers while figure 4.1b shows the migration of five daughter settlements from mother Kabusa to the northwest, north and southeast directions without any barrier. The two examples show the nature of space colonization process in the FCT and they approximate the four models of Bylund's colonization theory described in the literature review.

The process of population displacement and relocation within the FCT has also brought about the death of some settlements and the creation of new ones. In line with the recommendations of the Abuja Master Plan, statistics given by the MFCT (1992) shows that of the Abuja Master Plan, statistics given by the MFCT (1992) shows that the Federal Capital Development Authority (FCDA) has displaced and relocated over 10, 000 people both within and outside the FCT. For instance, the construction of Abuja city has led to the demise of settlements like Garki, Maitama Tsoho, Maitama sabo, Durumi, Wuse, Asokoro, Kukuwaba and Jabi in which about 2,442 persons were displaced (FCDA, 1989). Likewise, the construction of the Lower Usman Dam led to the displacement of 1,200 persons from old Ushafa, Payi Jigo and Kwabara.

FIG 4.1a & b: PART OF TOPOGRAPHICAL SHEET 186 SE/4F & 207NE 12b SHOWING SETTLEMENT MIGRATION IN F.C.T



Source: Regional Development Plan for the FCT 2000 & Federal department of survey Abuja

The resettlement exercises, which followed series of displacements, saw to the birth of settlements like Kubwa, Ushafa, Dutse, Usuma town, Gosa and Giri within the FCT. Generally, displacement and resettlement exercise in the territory brought about migration and amalgamation of settlements. With respect to migration, the report of the Ministerial Committee on Physical Planning and Development Issues in the FCT noted, in 1999, that a total of 6,958 households were evacuated from the FCT and resettled at New Bwari, New Wuse and Gawun Babangida in Niger State as well as in New Karu, New Karshi, New Ukya, New Gwargwada and New Gudun Karya in Nasarawa State. Also, several other small, isolated settlements have amalgamated and transformed into larger ones. For instance, Payi, Jigo and Kwabara villages were brought together to form the Usuman resettlement town while Garki, Durumi, Maitama Tsoho, Maitama Sabo, Kukuwaba, Jabi I and Jabi II villages were brought under the Kubwa resettlement scheme (FCDA, 1989 and MFCT, 1999).

4.2.2 Structure and Characteristics of Settlements in the FCT

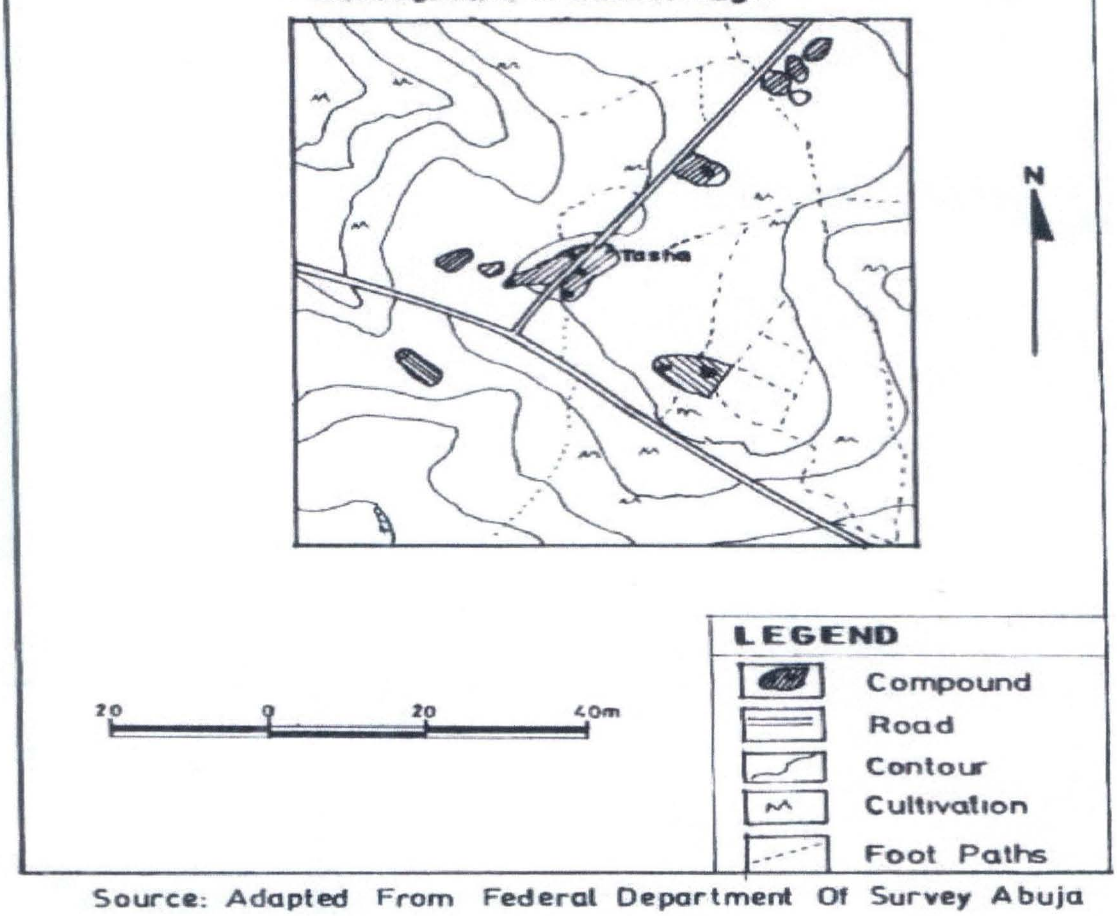
Whatever the process or the reason for their existence and location, the morphological structure of settlements in the entire FCT is mainly nucleated with few ribbon developments along route of communication. The nucleated type is found in all parts of the FCT and their spatial morphology is compact, circular or near rectangular in shape. The nucleated settlements normally have nuclei where development is focused and around which human socio-economic activities gravitate. Examples of nucleated settlements include, Karu, Sabon-Karmo, Gwagwa, Kubwa, Gwagwalada, Abaji, Kwali and Karshi amongst others. Plate I illustrates a typical nucleated development in Nyanyan with circular and compact housing development. The ribbon type of development occurs in areas of great accessibility such as the Zuba-Abaji and Zuba-Nyanyan axes. Structurally, these settlements are elongated in shape with houses close to the roads to take maximum advantage of the roads. Figure 4.2

shows a typical linear development in Tasha village where housing development occurs along the major roads.

Plate I: Nucleated Urban Development in Nyanyan

Source: Fieldwork, 2003

Figure 4-2 Part Of Topographical Sheet 186SE/3b Showing Linear Development in Tasha Village.



Source: Adapted From Federal Department Of Survey Abuja

Irrespective of their spatial morphology, the entire space economy of the FCT is characterised by settlements of various sizes. As at 1976, the 500 - 600 settlements within the territory were mostly villages and hamlets (Abuja Master Plan, 1979). Prior to the construction of the FCC, the area was entirely rural and was dominated by small, sparsely populated settlements, with about 85% of the settlements having a population of between 50-500 inhabitants (Gaza, 1990 as quoted in Balogun, 2001). A typical village settlement is made up of wards, which consist of a number of households. The settlements are normally closed up for security reasons with narrow passages as streets and a village square for festivals. They are characterised by limited facilities, poor access roads and predominantly primary production.

There was little urban development in the FCT in the early 1980s. According to Doxiadis and Associates (1983), only five settlements had a population of over 2000 while less than 100 persons inhabited 58.6% of the settlements (Table 4.1). The fairly large settlements at that time included Karu (4,384), Abaji (4,166), Izom (2,813), Gwagwalada (2,347) and Karshi (2,070) and they were regarded as small towns because of their numerical strength and the existence of relatively few services. This situation has however changed since the 1990s. The construction of the FCC, the transfer of the capital of Nigeria to Abuja in 1991 and the subsequent influx of people has brought about tremendous change. By 1996, some of the rural centres and small towns such as Gwagwalada (323,114), Abaji (11,785) and Karu (17,253) had grown in size while new population centres had emerged. Some of the new population centres include Abuja city (59,581), Sabon Karmo (10,166), Kubwa (18,668), Jiwa (14,244) and Nyanyan (24,864). These, together with the existing population centres now constitute the focal points for the organization of the space economy of the FCT.

Table 4.1: Distribution of Human Settlement in FCT by Population, 1980

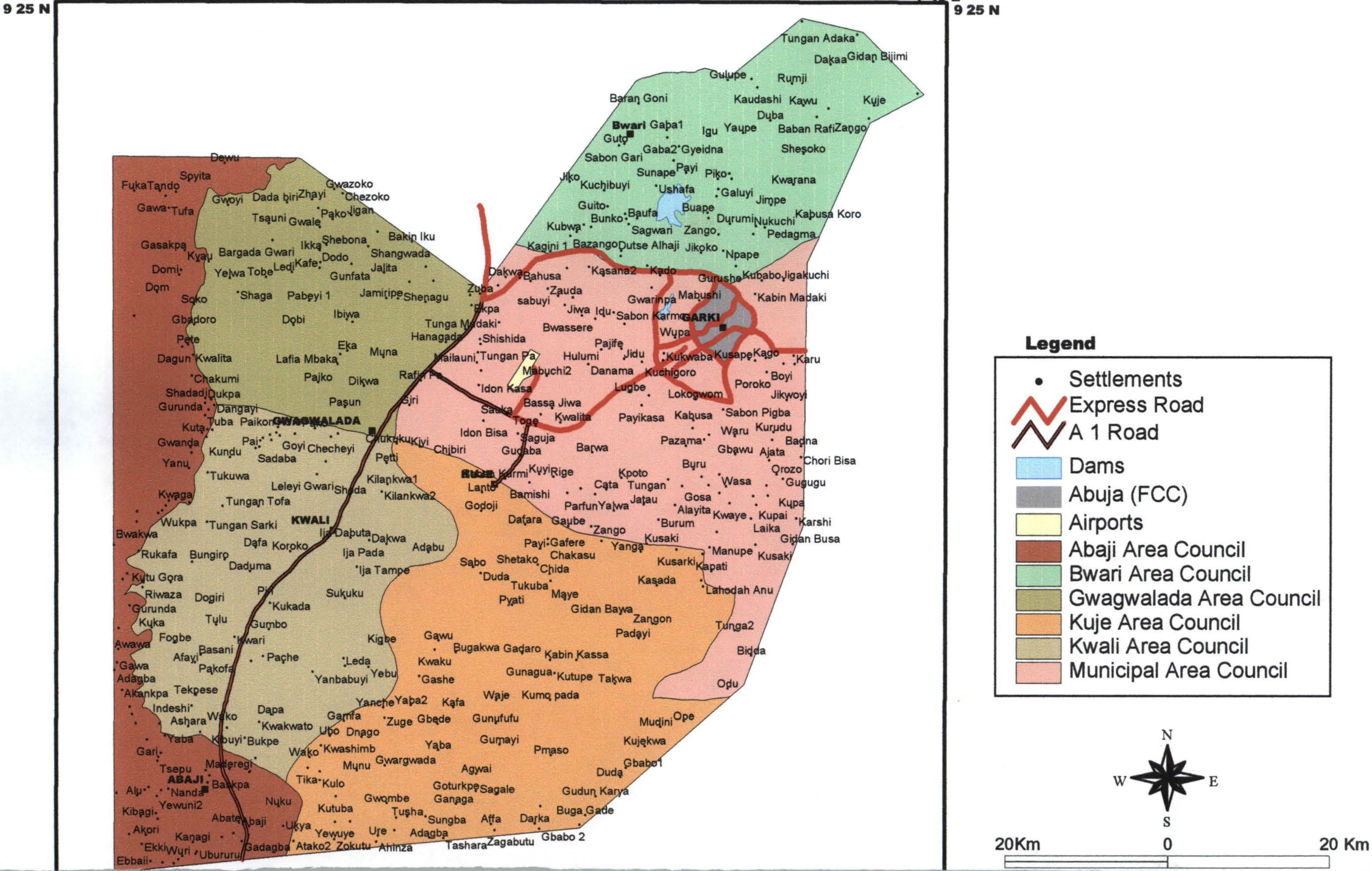
Population-Size Group	Number of Settlement	Percentage
0 - 100	455	58.6
101 - 200	153	19.7
201 - 300	66	8.5
301 - 400	31	4.0
401 - 500	22	2.8
501 - 600	12	1.6
601 - 700	9	1.2
701 - 800	4	0.5
801 - 900	4	0.5
901 – 1,000	3	0.4
1,001- 1,200	2	0.2
1,201 – 1,500	3	0.3
1,501 – 2,000	7	1.0
2,000 +	5	0.7
Total	776	100.0

Source: Adapted From Doxiadis Associates, 1983; Page 651

4.2.3 Analysis of Spatial Distribution of Settlement

The spatial pattern exhibited by the entire settlements was examined using the GIS data derived from the 1989 settlement and infrastructure map of the FCT produced by Omonogun Cartographic Services. In order to appreciate the spatial distribution of the settlements at a glance, the map was registered into the decimal degrees coordinate system and digitised with 0.049 error limit. The settlements were digitised as point features and saved in Arc\View with their corresponding identities (names) entered into the theme table. A map (figure 4.3) showing the spatial distribution of settlements in the FCT was composed in Arc\View. The figure reveals that the FCT has a dense population of settlements, which are spread all over the six Area Councils. The greatest number of settlements is found in the northeast, around the FCC and in the southwest corner of the territory, with heavy concentrations in the Municipal and Abaji Area Councils.

Figure 4.3: Spatial Distribution of Settlements in the FCT



A casual inspection of the spatial distribution of settlements in the FCT suggests a fairly even spread. The quadrat count statistical analysis was computed to determine the pattern of settlement distribution in the area. The number of settlements per unit area was determined by imposing $16km^2$ size quadrats on the settlement map of FCT (figure 4.4). The variance (σ) and the variance mean ratio (VMR) were calculated for the data (see table 4.2). The result yields a VMR value of 1.34. Since the calculated value is greater than 1.0, this shows that the distribution pattern is clustered in space.

Table 4.2: Calculation of Variance and Variance Mean Ratio

Settlement Per Quadrat (χ)	No. of Quadrat(f)	χf	Variance (σ) for No. of Settlement per Quadrat
0	214	0	$(0 - 0.9)^2 \times 214 = 173.3$
1	159	159	$(1 - 0.9)^2 \times 159 = 1.6$
2	75	150	$(2 - 0.9)^2 \times 75 = 90.8$
3	21	63	$(3 - 0.9)^2 \times 21 = 92.6$
4	15	60	$(4 - 0.9)^2 \times 15 = 144.2$
5	3	15	$(5 - 0.9)^2 \times 3 = 50.4$
6	0	0	$(6 - 0.9)^2 \times 0 = 0$
7	1	7	$(7 - 0.9)^2 \times 1 = 37.2$
Total	488	454	$\Sigma(\chi - \bar{x})^2 \times n = 590.1$

Source: Author's Analysis, 2003

Mean density ($\bar{x}$) $= \Sigma\chi f/\Sigma f = 454 \div 488 = 0.9$

Variance (σ) $= \Sigma(\chi - \bar{x})^2 \times f / n - 1 = 590.1 \div 488 - 1 = 1.21$

Variance Mean Ratio (VMR) $= \sigma/\bar{x} = 1.21 \div 0.9 = 1.34$ Approximately

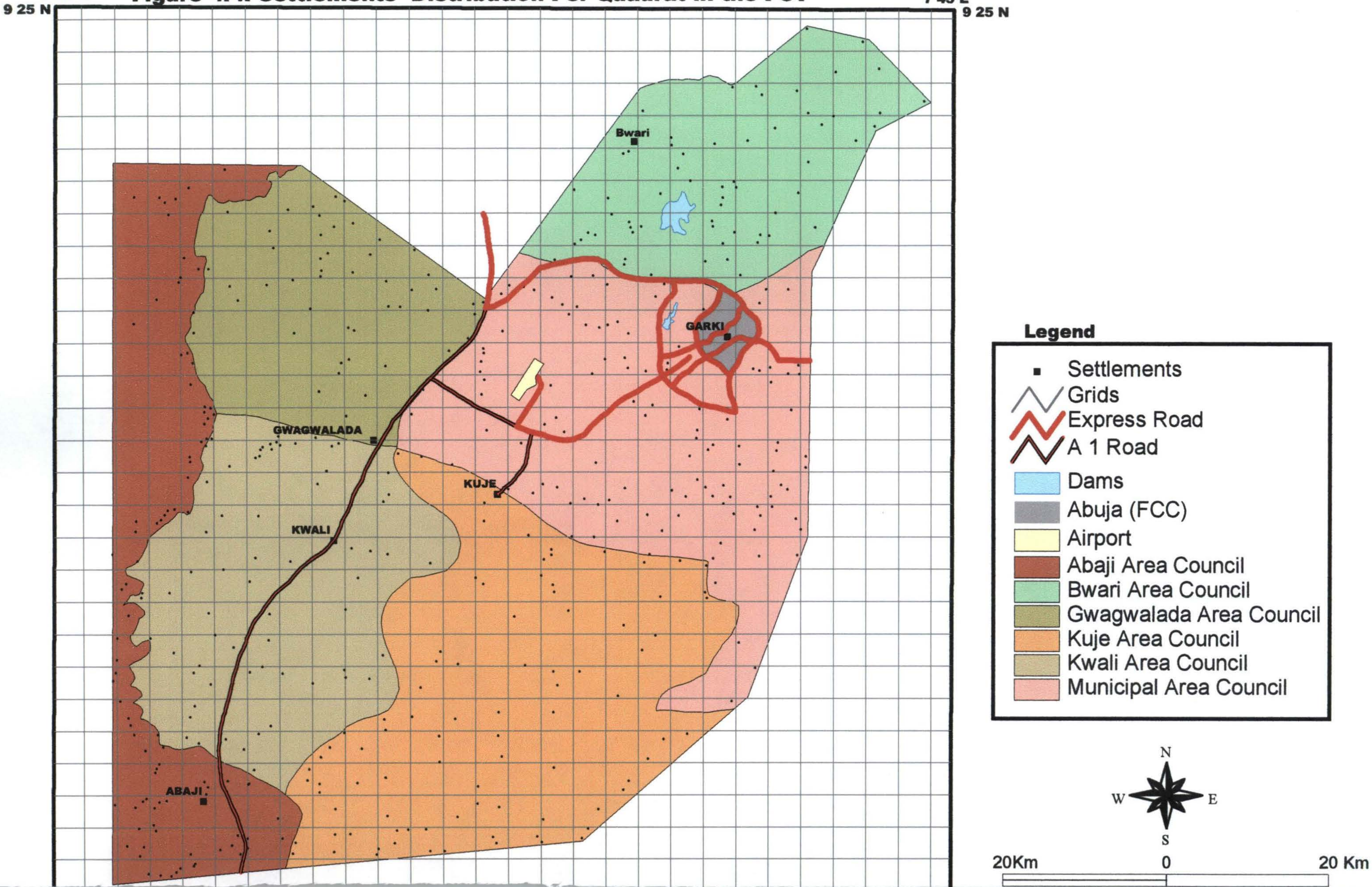
Quadrat Count Analysis Decision Rule

(i) If VMR is < 1.0, the distribution pattern is regular

(ii) If VMR is = 1.0, the distribution pattern is random

(iii) If VMR is > 1.0, the distribution pattern is clustered

Figure 4.4: Settlements Distribution Per Quadrat in the FCT



Although the spatial pattern of settlements in the FCT is generally clustered, settlement densities per square kilometre vary slightly over space with Kuje Area Council having the least settlement density (table 4.3). However, the goodness-of-fit test (Chi-Square analysis) performed for the observed and expected settlement point distribution in the Area Councils yielded a calculated X^2 value of 20.5 which is lower than the table value of 37.70 under 15 degree of freedom and 0.1 alpha level (See appendix 3). This shows that the difference in the level of clustering across the Area Councils is not significant.

Table 4.3: Settlement Densities by Area Councils

S\No.	Area Council	Area in Km^2	No. of Settlements	Density\Km^2
1	Municipal	1,600.33	108	0.07
2	Bwari	913.91	60	0.07
3	Abaji	935.01	85	0.09
4	Gwagwalada	835.16	54	0.07
5	Kuje	1,625.07	88	0.05
6	Kwali	1, 271.89	93	0.08
	Total	7, 181.37	488	0.43

Source: Author's Analysis, 2003

The quadrat count analysis performed enables us to statistically establish that the settlements in the FCT are clustered in space. However, the analysis did not provide information on the degree of closeness or dispersion amongst the settlements. This shows the limitation of the quadrat count method in pattern analysis. The Nearest Neighbour Analysis is a powerful measure of dispersion. In order to ascertain the degree of closeness and\or dispersion, the Nearest Neighbour Analysis (Rn statistics) was performed using figure 4.4 as the input point map. The point map data were imported from Arc\View to Ilwis 3.0 Academic software. Using the pattern analysis function of Ilwis, the Rn statistics was run to determine the probability of finding a given number of settlements within a given distance radius.

The result of the analysis is contained in the eight- column output table (appendix 4) in which the mean distances between reflexive nearest neighbours (RNN) were tested against the expected distances in a simulated complete spatial randomness (CSR). The first column of the table contains distance values from any point in the input point map. The Prob1pnt – Prob6pnt columns list the probabilities that, within certain distance of any settlement, at last one – six other settlements will be found. The probAllpnt values are the probabilities that, a randomly selected settlement pair from the point map has a separation of less than the corresponding distance in the distance column and it is determined by the addition of all probabilities (Prob1pnt + Prob2pnt +...+ Probn –1pnt) divided by (n – 1).

The distances in the output table are measured in meters and the values are multiplied by the map scale of 1:10,000 to get the ground distance. As shown in the output table, 51 per cent of all settlement pair has a separation of less than four kilometres, 63 per cent has a separation of less than five kilometres, 79 per cent has less than six kilometres while 97 per cent has a separation of less then nine kilometres. Also, for 100 per cent of the settlements in the point map, one to six nearest neighbours can be found within a radius of 1 kilometre. Considering the mean values calculated for the eight columns (table 4.4) it is found out that, for 80 per cent of all settlements in the point map, one nearest neighbour can be found within a radius of 2 kilometres. Also, for 68 per cent of the settlements, three nearest neighbours can be found while for 60 per cent of the settlements, six nearest neighbours can be found within a radius of 2 kilometres. The value in the probability of all points (ProbAllpnt) column (0.2390) indicates that, 23 per cent of all settlement pair has a separation of less than 2 kilometres. The calculated standard deviation values of between 0.3473 (1σ) – 0.4598 (2σ) establish 68 – 95 % confidence limit for the Nearest Neighbour statistics performed.

Table 4.4: Summary Statistics Calculated for the Nearest Neighbour Analysis

	Distance	ProbAllpnt	Prob1pnt	Prob2pnt	Prob3pnt	Prob4pnt	Prob5pnt	Prob6pnt
Min	0.0	0.0000	0.0211	0.0000	0.0000	0.0000	0.0000	0.0000
Max	1.3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Avg	0.2	0.2390	0.8041	0.7269	0.6831	0.6501	0.6240	0.6044
StD	0.3	0.3473	0.3183	0.3932	0.4219	0.4391	0.4513	0.4598
Sum	14.6	14.0996	47.4444	42.8844	40.3011	38.3538	36.8146	35.6569

Source: Author's Analysis, 2003.

The distance at which the probability of finding neighbours becomes 1 (i.e 100% probability) is determined by preparing a graph of the distance against the probability columns. As shown in figure 4.5 the probability of finding six neighbours becomes 1 at a distance of one kilometre. This indicates that, we are 100 per cent sure of finding 6 nearest neighbours within a distance of one kilometre radius on the map. For the ProbAllpnt, the probability becomes 1 at 11 kilometres (figure 4.6). This means, we are 100 per cent sure that a randomly selected settlement pair in the area will have a separation of less than 11 kilometres.

4.3 Settlement Interactions and Mapping of the Urban Field of the FCC.

4.3.1 Nature of Spatial Interaction in the Pre-FCC Period

Several theoretical postulations and empirical findings posit that functional specialization is the basis for interaction in a region where places or activity sub-areas are geographically separated. The separation of the different functional units and their complementarities therefore provides the basis and potential for spatial interaction (Abler et al., 1977).

Figure 4.5: Probability and Distance of Finding Six Neighbours

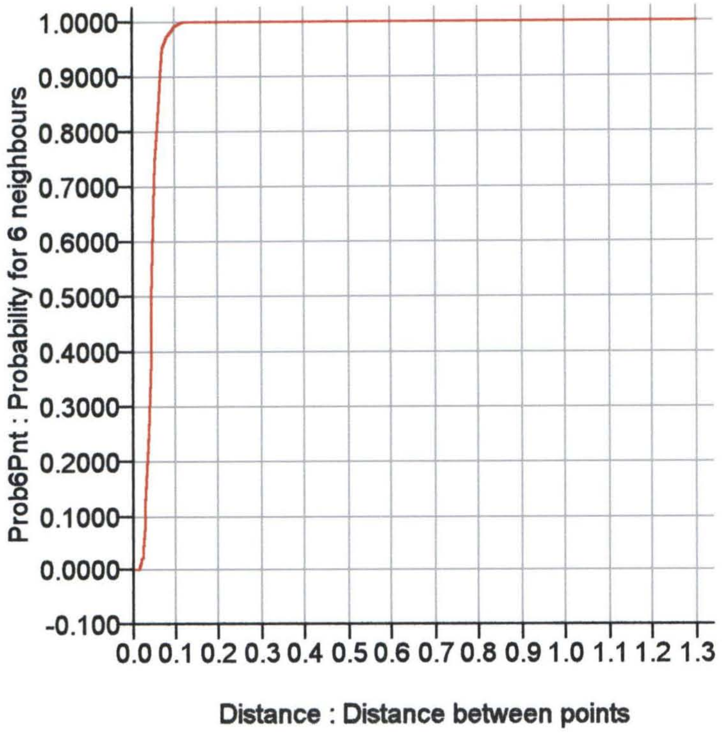
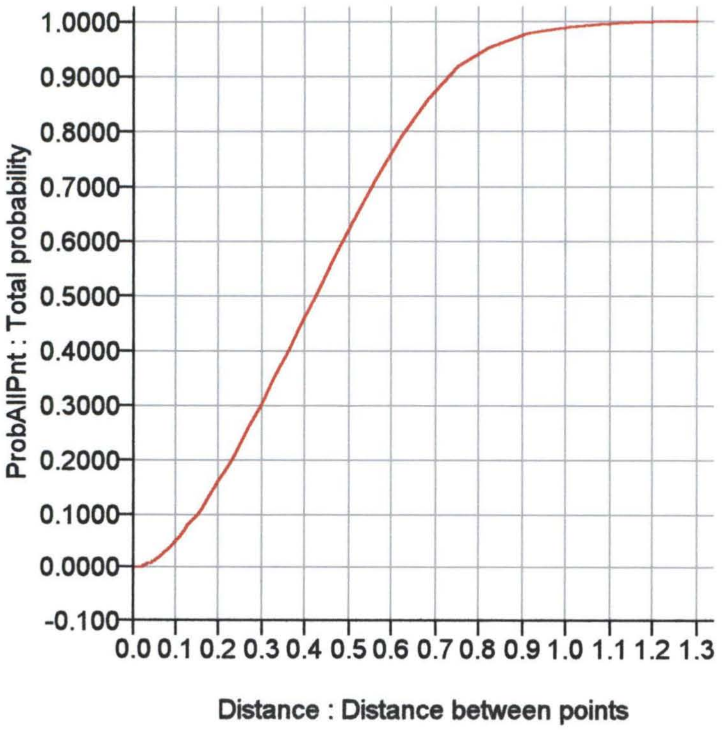


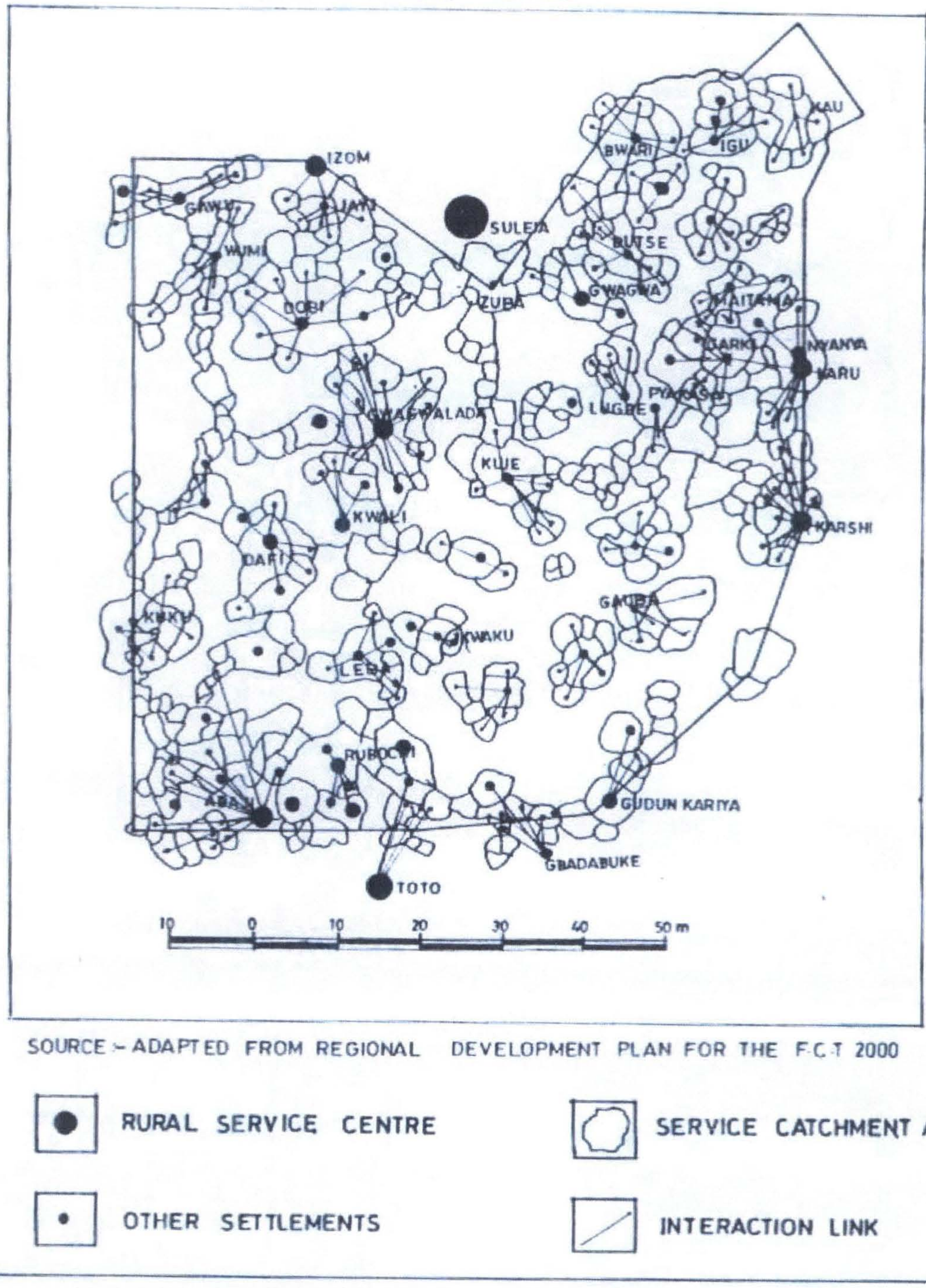
Figure 4.6: Probability and Distance of Finding Neighbours.



Spatial interaction is a permanent feature of human settlements since no settlement exists in isolation. Early studies have confirmed that the spatial organisation of settlements in the Nigerian middle belt region (including the FCT) is characterised by a network of central villages and market towns surrounded by dependent daughter settlements (Gana, 1983). The different hierarchies of settlements in the FCT exhibit a network of spatial interaction, which is facilitated by the existing road system. As it were, the small rural centres perform marketing, education, health and administrative functions for the smaller ones. The relationships and nature of interaction among the mother and daughter settlements was summed up by Nadel (1951), as cited in Gana (1983) who asserted that the village and its dependencies formed the interacting core of rural community life in which festivals, marriages, visits, meetings and other social functions were conducted.

Doxiadis Associates (1983) have also examined the nature of settlement interaction in the FCT and confirmed that the existing small towns formed the core of interaction prior to the construction and functioning of the FCC (between 1980 and 1991). The authors used the sizes and spatial distribution of settlements, the accessibility patterns and the distribution of the available central facilities in the FCT as basis for defining the interaction fields of the existing settlements. As illustrated in figure 4.7, it was established that the entire FCT exhibited clusters of settlements functioning as independent or semi-independent sub-systems. The nature of interaction at that time was such that the interaction fields of the sub-system were detached and independent from one another, with some of the sub-systems having their higher order centres outside the boundaries of FCT. Thus, the settlements in the FCT were loosely (if at all) interconnected and did not form a complete system of functionally interrelated communities (,Doxiadis Associates 1983).

FIG 4·7 EXISTING SETTLEMENT SUB SYSTEM & INTERACTION FIELD IN THE PRE–F.C.C PERIOD



SOURCE :- ADAPTED FROM REGIONAL DEVELOPMENT PLAN FOR THE F.C.T 2000

RURAL SERVICE CENTRE

SERVICE CATCHMENT AREA

OTHER SETTLEMENTS

INTERACTION LINK

The interacting sub-systems illustrated in figure 4.7 suggests no functional link among existing rural centres such as Karshi, Karu, Gwagwalada, Kuje, Kwali, Dafia, Rubochi and Abaji amongst others. This kind of relationship could not have existed bearing in mind that the 1981 consultant survey confirmed that there were limited central services such as health and secondary schools located in few centres in the FCT (See Doxiadis Associates, 1983; page 484). The restriction of some central facility to few centres is therefore a basis for interaction. Thus, the situation presented on the map rarely exist in the real sense of the world and it represents an over simplification of the nature of interaction that existed at that time.

Although there is an obvious limitation in the nature of spatial interaction reported by Doxiadis Associates (ibid), their work help establish the basic fact that interaction in the pre FCC period was characterised by numerous interaction foci (rural centres) with the absence of a single highest order settlement. This situation has, however, changed since the construction of the FCC. Balogun (2001) has demonstrated a structural change in the space economy of the FCT by classifying the settlements in the territory into six hierarchies – the city, urban centres, large towns, small towns, villages and hamlets. The author used the 1996 projected population figures for the size-class classification of all the settlements. Although this classification is incomprehensive for it did not incorporate the functional criterion, in arriving at the six hierarchies, it helps establish a basis for the understanding of the new dimensions of interaction in the FCT. For instance, the classification was able to recognise the FCC as the first-order settlement with complex administrative and central place functions. Thus, while the early centres such as Karu, Karshi, Kuje, Gwagwalada, Kwali, Rubochi and Abaji have grown in size and have continued to form foci of interaction for the villages and hamlets in their sub-systems, the FCC now forms the focus of interaction for all the lower-order settlements in the FCT. Section 4.3.2 considers the mapping of the urban field of the FCC as a prelude to the understanding of the current nature of settlement interaction in the area.

4.3.2 Mapping of the Urban Field of the FCC

The existence of spatial interaction among the different hierarchies of settlements in the FCT forms the basis for the delimitation of the urban field of the FCC in order to ascertain the settlements under its zone of influence. As the administrative capital of Nigeria, it is noted that the area of influence of Abuja covers the whole country and beyond. For the purpose of this study, however, the wider concept of urban field is substituted for the mean field. In this case, urban field consideration is, in the first place, limited to the administrative boundaries of the FCT and further, to the mean field (small trade area of the FCC, which records the highest intensity of interaction). This mean field is referred to as the zone of intensive and\or effective interaction in the FCT.

As noted under methodology, several indices are used in urban field mapping depending on the interest of the research. In our case, it is realised that the use of such indices as newspaper circulation, administrative, banking, hospital, postal, educational, and sporting stadium service catchments areas will produce the maximum field which may cover the entire country and beyond. Since our interest is on the mean field, the urban public bus service commuting range was used in delimiting the mean interaction field of the FCC. In order to achieve the mean field-mapping objective, traffic surveys were carried out in Berger Junction and Garki bus terminals in August 2002 to determine all settlements with direct bus service link to Abuja and from where people commute directly to the city. The survey revealed that major interactions take place along six major route axes. These are Abuja-

Zuba-Suleja, Abuja-Dutse-Bwari, Abuja-Nyanyan-Keffi, Abuja- Npape- Igu, Abuja-Kuje-Gwagwalada and Abuja-Karmo-Gwagwa. Table 4.5 shows the settlements along each axis and the maximum route distances. Daily bus passenger traffic on the major interaction routes is estimated at about 1,210 buses of various capacities, with about 5,190 return trips per day (table 4.6).

Table 4.5: Settlements and Distances Along Major Interaction Routes Axis.

Route Axes	Settlements with Direct Link from Abuja City	Max. Route. Distances (km)
Abuja-Zuba-Suleja	Mabushi, Jayi, Galadima, Gwarinpa, Dutse Alhaji, Kubwa, Kagini, Zuba,, Madala, Rafi Sanyi and Suleja.	45
Abuja-Dutse Alhaji-Bwari	Dutse Makaranta, Usuma quarters, Ushafa, Pei, Jigo, Pambara, Rogo and Bwari	42
Abuja-Nyanyan-Keffi,	Nyanyan, Karu, Maraba, Ado, New Yanyan, Masaka and Keffi.	50
Abuja-Kuje-Gwagwalada	Karomajiji, Kuchingoro, Chika, Aleita, Piwoyi, Lugbe, Sabon Lugbe, Gosa, Toge, Kuje, Gigi and Gwagwalada	57
Abuja- Karmo-Gwagwa	Utako, Ijabi, Life camp, Kado, Idu, Tasha, Karmo, Gwagwa, Jiwa, Sobaro and Rafin Daidayi .	30
Abuja- Npape- Igu	Katampe, Jikoko, Npape, Durumi, Baupe, Piko and Igu.	20

Source: Field Survey, August 2002.

Table: 4.6 Estimated Numbers of Buses and Volume of Daily Bus Passenger Traffic per Route

S\No	Routes	Estimated No. of buses per route	Average daily return trip per bus	Estimated volume of daily bus passenger traffic
1	Abuja-Zuba-Suleja	510	3	1,530
2	Abuja-Dutse Alhaji-Bwari	25	2	50
3	Abuja-Nyanyan-Keffi,	350	5	1,750
4	Abuja-Kuje-Gwagwalada	70	3	210
5	Abuja- Karmo-Gwagwa	215	6	1,290
6	Abuja- Npape- Igu	45	8	360
	Total	1,210	-	5,190

Source: Fieldwork, 2002.

Within the FCT, ten settlements (mainly terminal points along the major route axes) were selected for the mapping exercise (table 4.7). The identity (ID) numbers and the distances of the settlements from central Abuja (Garki) were fed into the computer to generate points around which a line of interacting zone was established. Figure 4.8 shows that the mean field of the FCC covers mainly nearby settlements in the Municipal and Bwari Area Councils. The total area coverage of the mean field was queried using the Arc\View analytical tool. The exercise revealed that the zone of intensive interaction of the FCC at the time of study covers a total of 1,678.17km^2 with 128 settlements (see appendix 5) located within the mean field. A projection of the 1991 census population figures compiled for some of the settlements in the appendix revealed that the mean field contains over 313, 535 people in the year 2003.

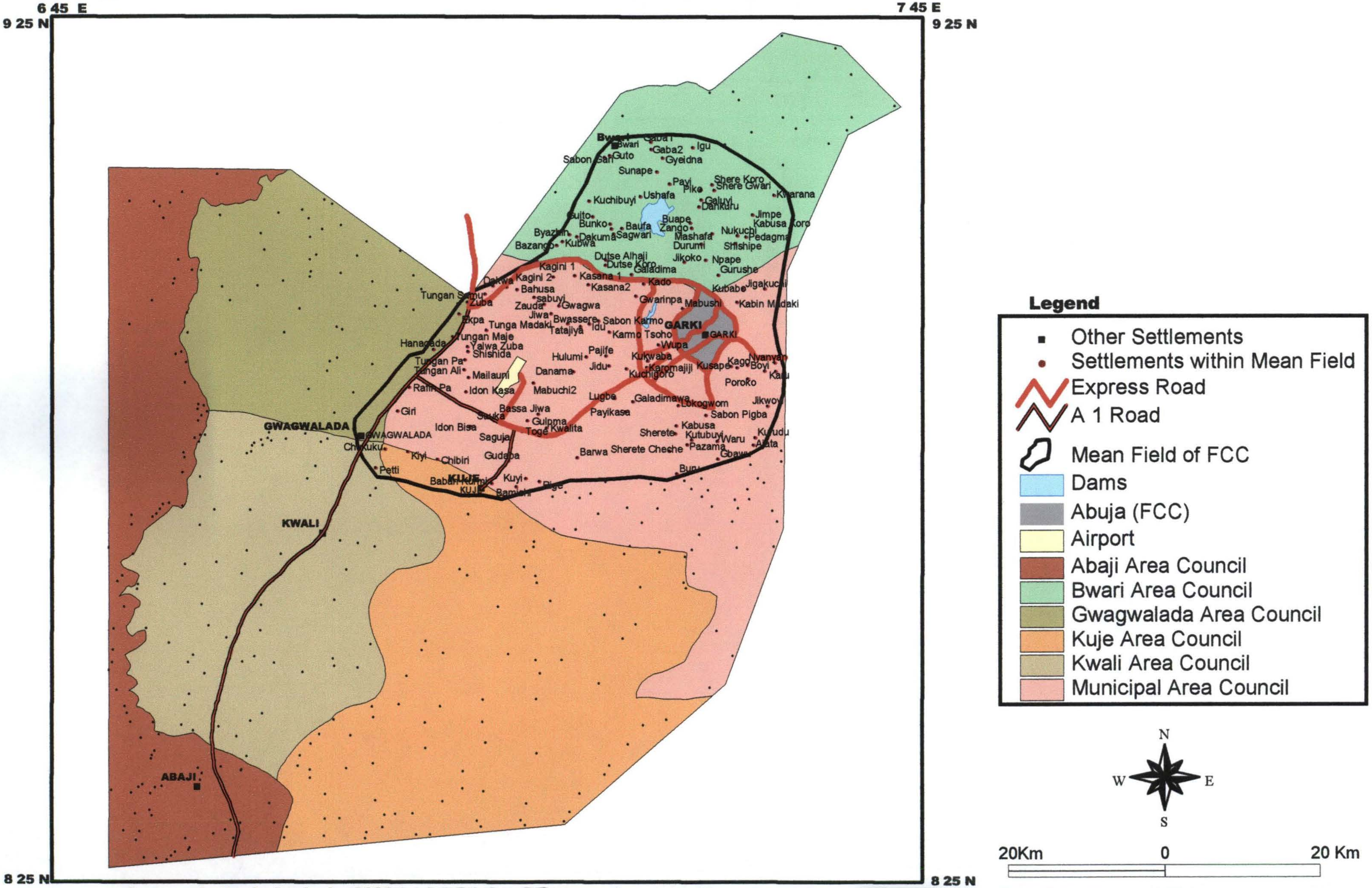
Table 4.7: Settlements Used in Urban Field Mapping.

S\No.	Settlement	ID Number	Distance from FCC (Km)
1	Gwagwalada	1	45.5
2	Kuje	2	34.5
3	Igu	19	24.2
4	Bwari	25	27.0
5	Kwarana	45	20.0
6	Kubwa	62	21.8
7	Zuba	67	30.4
8	Nyanyan	108	9.6
9	Karu	109	10.4
10	Kurudu	157	14.8

Source: Author's Analysis, 2003

Political\natural boundaries and physical barriers have been found to account for truncated urban field. Haggett et al. (1977) documented the works of Losch and Mackay, which demonstrated the effect of political boundary in creating truncated field along the United States-Mexican border and in Montreal respectively. As in the case of these examples, the

Figure 4.8: Mean Field of FCC and the Settlements Within the Field



FCC is also detached from other areas within its mean interaction field by political boundary. The mapping exercise was thus constrained by the non-representation of other settlements within the city's mean field but which fall outside the map of the FCT used. As a result, other settlements like Madalla, Sabon Wuse, Suleja, Dumez, Bakin-Iku, New Karu, New Nyanyan, Keffi amongst others which fall within the mean interaction field of the FCC could not be mapped. This limitation notwithstanding, the field presented in figure 4.8 serves the purpose of this research and it provides the basis for understanding the nature of interaction between Abuja and the settlements within its mean field.

4.3.3 Nature of Settlement Interaction Within the Mean Field of FCC

The FCC and the settlements within the mean field form a network of geographically separated activity places – the city being the work place and the satellite settlements being the home for the majority of the workers. As shown in figure 4.3, the workplace and the home are connected by different categories of road that facilitate interaction through traffic flows.

The nature of interaction between the city and other satellite settlements was investigated to ascertain the pattern of flow and travel behaviour of the commuters. A census of the trips attracted and generated by the FCC was taken along Abuja-Zuba-Suleja and Abuja-Kuje-Gwagwalada route axes on 16 May, 2003. The survey revealed that continuous interaction between the city and other settlements is facilitated through the use of both private and public vehicles and it occurs on minutes\ hourly and daily basis. The means of interaction documented include cars (both private and taxi cabs), Mini and Midi\big buses (including 10 – 14 sitter commuter buses, 36-sitter coaster buses and luxurious buses), Vans\lorries (pick-ups, 911 lorries, tippers and water tankers) and articulated vehicles (mainly trailers and construction vehicles). As shown in table 4.8, over 26,024 cars; 6,208 mini buses; 1,003 midi\big buses; 1,862 vans\lorries and 685 articulated vehicles facilitated daily interaction along the routes.

Table 4.8: Daily Traffic Attracted and Generated by the FCC Along Abuja-Zuba-Suleja and Abuja-Kuje-Gwagwalada Route Axes

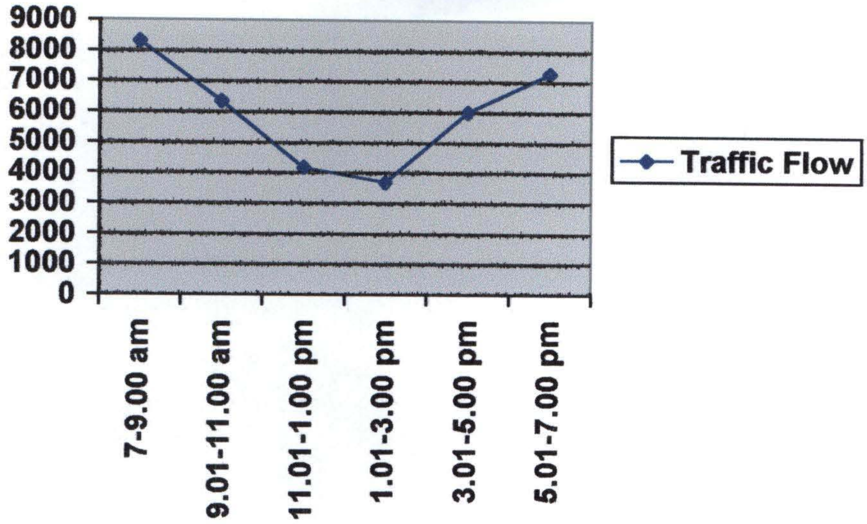
Period\Vehicles	Cars	Mini buses	Midi\big buses	Vans\lorries	Articulated
7 – 9.00 am	6213	1385	306	288	122
9.10 – 11.00 am	4730	1060	184	247	119
11.01 – 1.00 pm	2991	721	60	297	106
1.01 – 3.00 pm	2585	654	73	290	83
3.01 – 5.00 pm	4401	934	183	357	130
5.01 – 7.00 pm	5104	1454	197	383	125
Total	26,024	6,208	1,003	1,862	685

Source: Fieldwork, 2003

The interaction is manifested in the flow of people as well as goods and services. The commuters comprise people of diverse socio-economic background, who work in Government establishments, organised private and the informal sectors. The goods transported are mainly agricultural (food items) and construction materials, which find their way into the different shops\markets, homes and construction sites.

The flow characteristics observed is such that traffic started trickling into the city by 6.30 am and picks up by 7.00 am to reach the morning peak between 7.00 am and 9.00 am. As illustrated in figure 4.9, the intercity travel is low between 11.00 am and 1.00 pm. The flow reaches its lowest ebb between 1.00 pm and 3.00 pm from where it picks up to reach another peak in the evening hours (5.01 – 7.00 pm)

Figure 4.9: Pattern of Daily Traffic Flow Between Abuja and the Satellite Settlements



The intercity travel pattern is largely unidirectional with the bulk of the traffic attracted into the FCC in the morning hours (see table 4.9 and figure 4.10) while the evening hours witnessed the generation and dispersal of traffic into the satellite settlements (see table 4.10 and figure 4.11). It is therefore common to see a thick traffic flow into the FCC in the early hours of the day (between 7.00 – 11.00 am) and a reversed flow in the evening hours (between 3.00 – 7.00 pm) when people move en-masse out of the city to the different satellite settlements, thus creating a temporarily desolate city in the hours of the night.

Table 4.9: Traffic Flow Attracted into the FCC by Vehicle Mode

Period\Vehicles	Cars	Mini buses	Midi\big buses	Vans\lorries	Articulated
7 – 9.00 am	5270	969	276	205	82
9.10 – 11.00 am	3643	661	159	152	58
11.01 – 1.00 pm	1821	322	30	162	47
1.01 – 3.00 pm	913	263	20	111	30
3.01 – 5.00 pm	1195	387	39	156	52
5.01 – 7.00 pm	791	458	34	131	54
Total	13, 633	3, 060	917	259	320

Source: Fieldwork, 2003

Figure 4.10: Traffic Flow Attracted (Inflow) into the FCC by Vehicle Mode

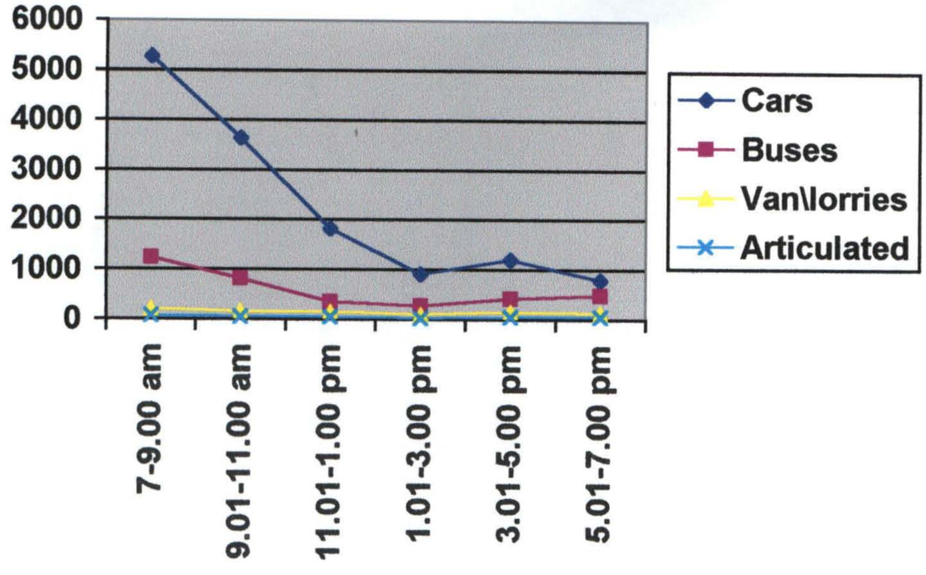
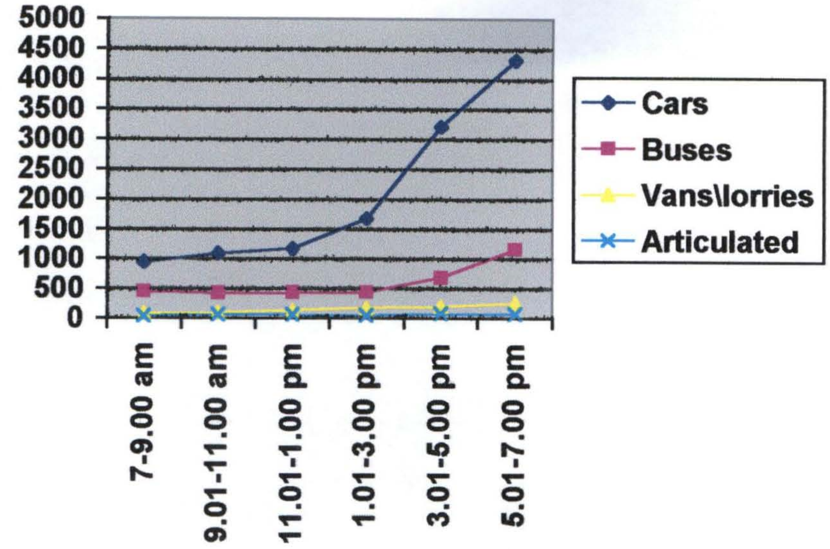


Table 4.10: Traffic Flow Generated by the FCC by Vehicle Mode

Period\Vehicles	Cars	Mini buses	Midi\big buses	Vans\lorries	Articulated
7 – 9.00 am	943	416	30	83	40
9.10 – 11.00 am	1087	399	25	95	61
11.01 – 1.00 pm	1170	429	30	135	59
1.01 – 3.00 pm	1672	444	53	179	53
3.01 – 5.00 pm	3206	547	144	201	78
5.01 – 7.00 pm	4313	996	163	252	71
Total	12, 391	3, 148	445	945	362

Source: Fieldwork, 2003

Figure 4.11: Traffic Flow Generated (Outflow) by the FCC by Vehicle Mode



The observed traffic flow pattern reveals that the work-day-length and the time-of-day effects condition the travel behaviour of the people. As we have seen, the peak periods correspond with the work-start and the closing hours while low traffic is associated with office\working and night hours. This finding conforms to that of Mehndiratta et al. (2001) who, in their study of time-of-the day effects in intercity business travels in California, USA, found out that individual's normal daily trip schedule is defined by the cycle of sleep, work and leisure.

The home - workplace relationship between the satellite settlements and the FCC and the consequent daily travels and\or interaction result in spatial and functional integration of the FCC and the settlements within its mean field. As it is now, Abuja city and the settlements exist and function more or less as a single spatial entity with most residents spending substantial part of their daily life in both the city (workplace) and the satellite settlements (home). The implication of the emerging trend is that, activities and developments in the surrounding settlements will have socio-economic and physical impact on the entire spatial surrounding settlements will have socio-economic and physical impact on the entire spatial economy. Therefore infrastructure planning and provision (e.g. water, electricity, housing, transport, education and other services) in Abuja has to be done in cognisance of the entire population of the FCC and settlements within its mean field.

4.4 Conclusion

The analysis and discussion in this chapter reveal that the space economy of the FCT accommodates about 488 settlements of various sizes, which have undergone series of development processes – disintegration, migration, amalgamation, displacement and relocation. Structurally, the settlements are mostly nucleated with few ribbon development in areas of great accessibility. The settlements are clustered in space and they interact with one another at the regional scale. However, 128 settlements are found to fall within the intensive interaction zone (mean field) of Abuja. These settlements and Abuja are found to function interdependently with daily and hourly flows of people, goods and services. Developments within the mean field are observed to have implications for the entire spatial entity and as such infrastructure provision and physical planning in Abuja should be done in cognisance or along with all the settlements within the urban field.

CHAPTER FIVE

5.0 ANALYSIS OF URBAN AND RURAL SETTLEMENT GROWTH

5.1 Introduction

This chapter presents the analysis of the general level of urban expansion in the study area and the growth of selected rural settlements between 1976 and 2001. The analysis was done using satellite image data from Landsat MSS of 1976, Landsat TM of 1987, SPOT XS of 1994 and Landsat ETM+ of 2001. First, image sub-sect was carried out and an area of 1,464.93 square kilometres was defined for the study (table 5.1). This area contains the FCC and most of the satellite settlements within its mean field. A time series analysis was then carried out to determine the level and pattern of urban growth between 1976 and year 2001 in the area. The chapter also monitors the growth of selected satellite settlements and concludes with the estimation of future growth of the settlements as well as the direction and pattern of future growth.

Table 5.1: Study Area Box

Coordinate Name	UTM Coordinate
Upper Left X (ULX)	301192.5370
Upper Left Y (ULY)	1019423.77330
Lower Right X (LRX)	349732.5370
Lower Right Y (LRY)	989243.77330

Source: Authors' Analysis, 2003.

5.2 Image Interpretation and Mapping

As noted under methodology, the entire image processing exercise was preceded by the development of a classification scheme (table 1.3) to guide image interpretation. Interpretation of the images used in the study was done through direct signature and pattern recognition approach. First, the images were spatially and spectrally enhanced to facilitate the recognition of the non-parametric signatures in the images' feature space. The interpretation key (table 1.4) was used in visual interpretation of the colour tones and pattern found on the images. Using the colour, texture, map and ground truth information, the images were visually scanned and familiar physical and cultural features were recognised on the images. Identification of such features as settlements, road networks, rivers and reservoirs, rock outcrops and the airport help put the images in proper perspective.

Mapping of the image features was done through the direct tracing approach using the on-screen digitisation function of the ERDAS IMAGINE software. The computer cursor was used to map outlines of features and lines were drawn around features of similar appearance to group them into the same land use\land cover category. This user defined lines and polygon method allows for a high degree of control and mapping accuracy even though it is tedious and time consuming. It allows the selection of image properties of interest for level one classification, leaving out the un-necessary details. The method therefore minimises classification error often associated with both the supervised and unsupervised Maximum Likelihood Classification (MLC) method since it involves the use of field data and human skill in image feature classification.

5.3.1 Level and Pattern of Urban Growth, 1976 - 1987

The FCT was designated as the new capital territory of Nigeria in 1976. Landsat MSS image of 1976 (appendix 6) with 80 metres spatial resolution was thus used as the base year data to establish the pre- FCC development situation in the study area. Interpretation of the 1976 data provided limited information on the surface features of the area due to poor resolution. Only the spectral signatures of rock outcrops, vegetation\agricultural land and streams were easily picked from the image and this necessitated additional information from other sources. Thus, information on settlement location and sizes was generated from Abuja Topographical Sheets on scale 1: 10,000, which were prepared from aerial photographs taken in 1976. Map data from nine topographical sheets were digitised in Arc\View, using decimal degrees with error limit of between 0.002 – 0.007. The data were converted into Arc\Info coverages and were corrected for digitisation error. The data were projected into the UTM coordinates (geo-referenced) and transferred to the Arc\view coverages of the image data for map composition. The land use\land cover map of the area (figure 5.1) was composed using the layout function of the Arc\view software.

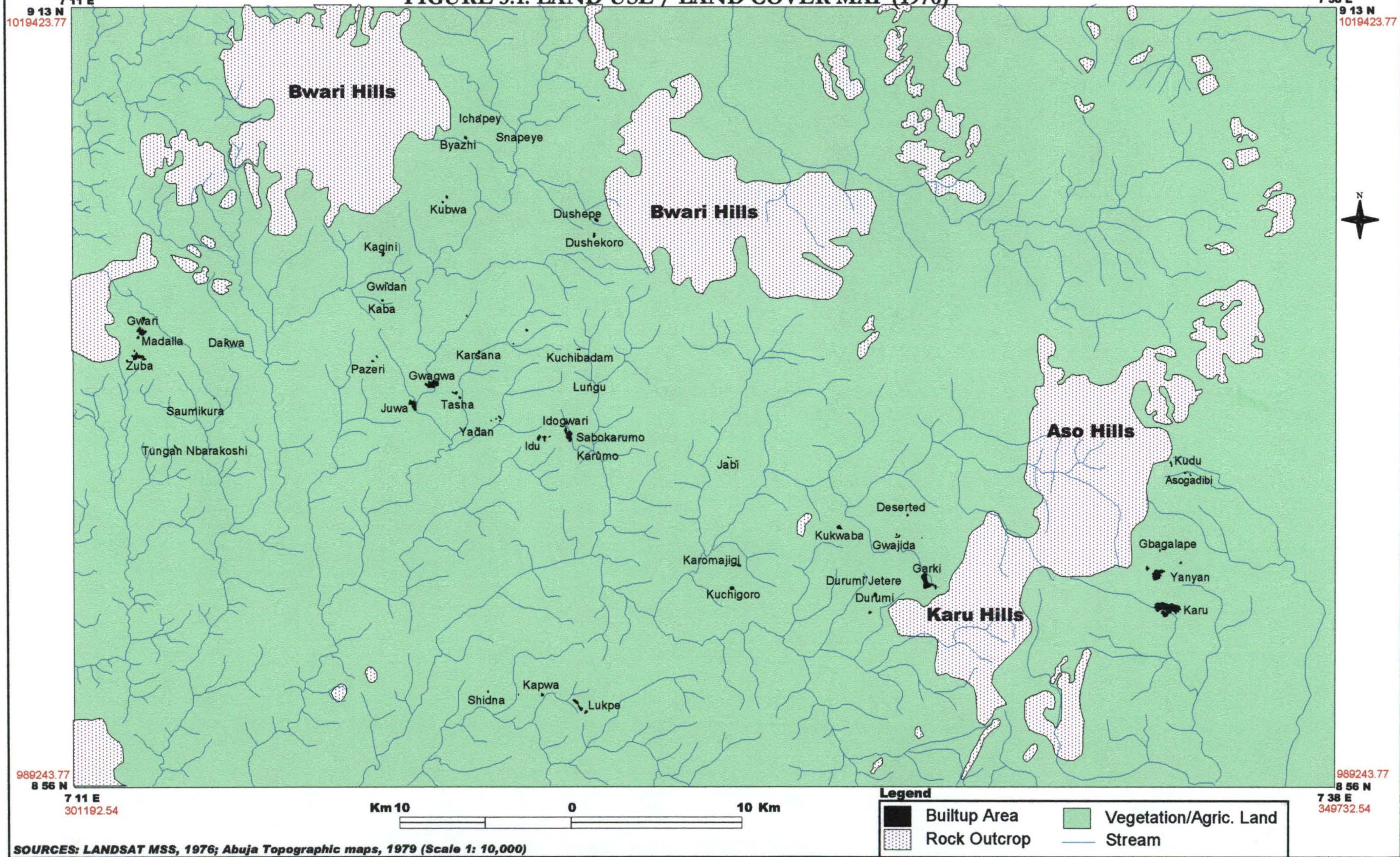
The 1976 land use\land cover map shows the preponderance of small-sized settlements and portrays the area in its rural setting. The map reveals that there was little or no urban settlement in the area in 1976. Map statistics generated using the statistical function of Arc\view show that the area was predominantly rural with 86.3 per cent of the land occupied by vegetation\agricultural land (table 5.2). At that time, rock outcrops (13.6%) featured more prominently than the built-up area as only 0.1 per cent of the area was occupied by settlements, which were mainly hamlets and villages. The entire area was traversed by 1,036.60 kilometres of streams and serviced by about 43.1 kilometre of regional road (A1), which ran through the FCT from Zuba in the west through to Karu and Nyanyan in the east. These findings help confirm earlier assertions and write-ups which established that the FCT was less developed, agrarian, with small rural settlements that cannot be described as urban (See Master Plan for Abuja, 1979; Mabogunje and Abumere, 1981; Doxiades Associates, 1983; Olusule, 1987 and Balogun, 2001).

Table 5.2: Land use\Land cover Statistics, 1976

S\No.	Land use\Land cover Class	Area (Km^2)	% of Total
1	Built-up area	1.22	0.1
2	Rock outcrops	199.40	13.6
3	Vegetation\Agricultural land	1, 264.31	86.3
4	Water body	-	-
	Total Area (Km^2)	1, 464.93	100

Source: Author's Analysis, 2003

FIGURE 5.1: LAND USE / LAND COVER MAP (1976)



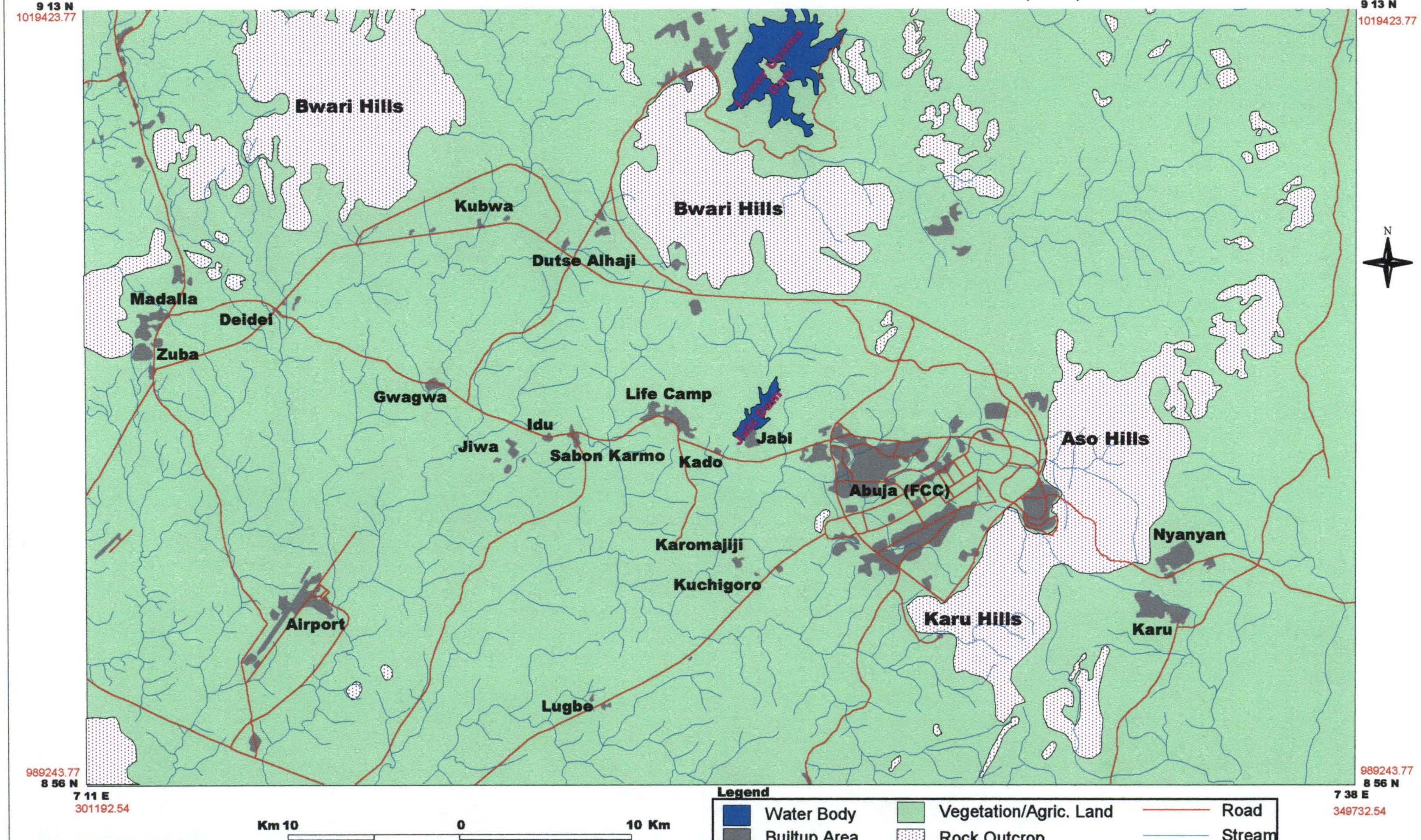
SOURCES: LANDSAT MSS, 1976; Abuja Topographic maps, 1979 (Scale 1: 10,000)

The situation in 1976 began to change in 1980 when the construction of the FCC and its region commenced. The gradual development activities in the early 1980s culminated into mass construction efforts between 1985 and 1987 under the military regime of General Ibrahim Babangida. The early development efforts include the construction of 51 primary schools and 3,000 housing units within the city proper and about 6,000 units in the nearby satellite settlements (FCDA, 1986).

In order to capture the level of urban growth in the formative years, Landsat TM image taken in 1987 (appendix 7) was used to assess the situation in the study area after seven years of construction activities. The image was interpreted and the spectral signatures of six major surface features were picked and digitised as polygons and lines. The data were saved as vector files and used to compose the land use\land cover map of the area (figure 5.2) using Arc\view software.

The land use\land cover map of 1987 reveals that both minor and major urban growth had occurred in the area. The map statistics (table 5.3) show that 31.32 Km^2 (2.1%) of the area was occupied by settlements which were serviced by 390.26 Km of major and minor roads. Water bodies covered an area of 11.8 Km^2 as a result of the construction of Jabi and Lower Usuma dams, rock outcrops covered another 199.40 Km^2 (13.6%)of land while vegetation\agricultural land occupied 1, 223.03 Km^2 (83.5%).

FIGURE 5.2: LAND USE / LAND COVER MAP (1987)



SOURCE: LANDSAT TM, 1987

Table 5.3: Land use\Land cover Statistics, 1987

S\No.	Land use\Land cover Class	Area (Km^2)	% of Total
1	Built-up area	31.32	2.1
2	Rock outcrops	199.40	13.6
3	Vegetation\Agricultural land	1,223.03	83.5
4	Water body	11.18	0.8
	Total Area (Km^2)	1,464.93	100

Source: Author's Analysis, 2003

An index of change between 1976 and 1987 was analysed by comparing the values in table 5.2 and 5.3. As shown in table 5.4, the built-up area increased by 30.1 Km^2 (96.1%) while the length of roads increased by 347.16 Km (89.0%) between 1976 and 1987. The increase in built-up area and the construction of Jabi and Lower Usuman dams (water bodies) resulted in a 41.28 Km^2 decrease in vegetation\agricultural land. However, the major change in the 1976–1987 period is from vegetation\agricultural land to settlement (built-up area).

Table5.4: Land use\land cover Change Statistics, 1976 – 1987

S\No.	Land use\Land cover Class	Area (Km^2)\length		Increase\ decrease	Percentage Change
		1976	1987		
1	Built-up area	1.22	31.32	+30.1	96.1
2	Rock outcrops	199.40	199.40	0.0	0.0
3	Water body	-	11.18	+11.18	100
4	Vegetation\Agricultural land	1264.31	1223.03	-41.28	3.27
5	Roads	43.1	390.26	+347.16	89.0
6	Streams	1,036.60	1,024.27	-12.33	1.2

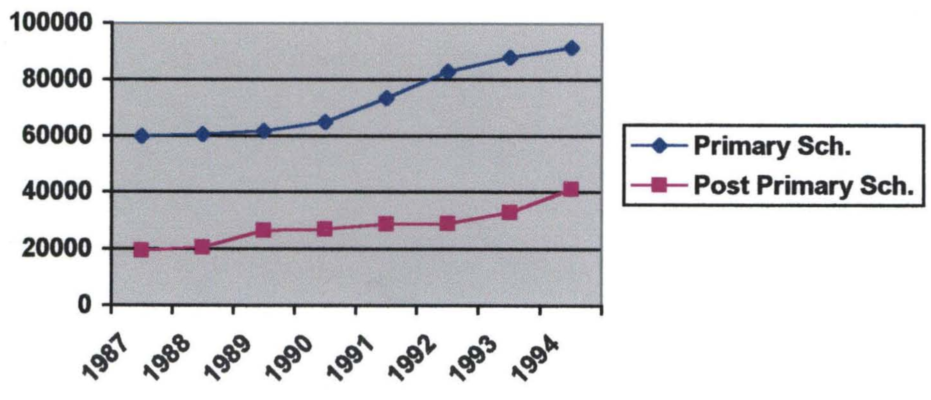
Source: Author's Analysis, 2003

Generally, major urban growth occurred in the central part of the study area covering the main land of the Municipal Area Council and parts of Bwari, Kuje and Gwagwalada Area Councils. Development pattern followed an east – west direction with many of the settlements occupying areas of least resistance as the rocky areas constituted development barriers.

5.3.2 Level and Pattern of Urban Growth, 1987 – 1994

The tempo of physical development in the FCC and its surroundings continued in the post 1987 period. The 1987 – 1994 period witnessed mass construction and population influx due to the movement of government's establishments from Lagos to Abuja between 1986 and 1990 and the eventual movement of the seat of the Federal government to Abuja in 1991. The influx of people into the FCC at this period is evidenced in the rise in primary and post-primary school enrolment figures that increased from 59,985 and 19,518 respectively in 1987 to 91,412 and 41,341 respectively in 1994. Figure 5.3 shows the rising trend in school enrolment in the FCT between 1987 and 1994. According to the record of the MFCT (1998), some physical developments that accompanied the population growth in this period include the construction of 39 secondary schools (35 of which were located in the satellite towns), 9 clinics and 2, 820 junior\intermediate housing units at Kubwa, amongst others.

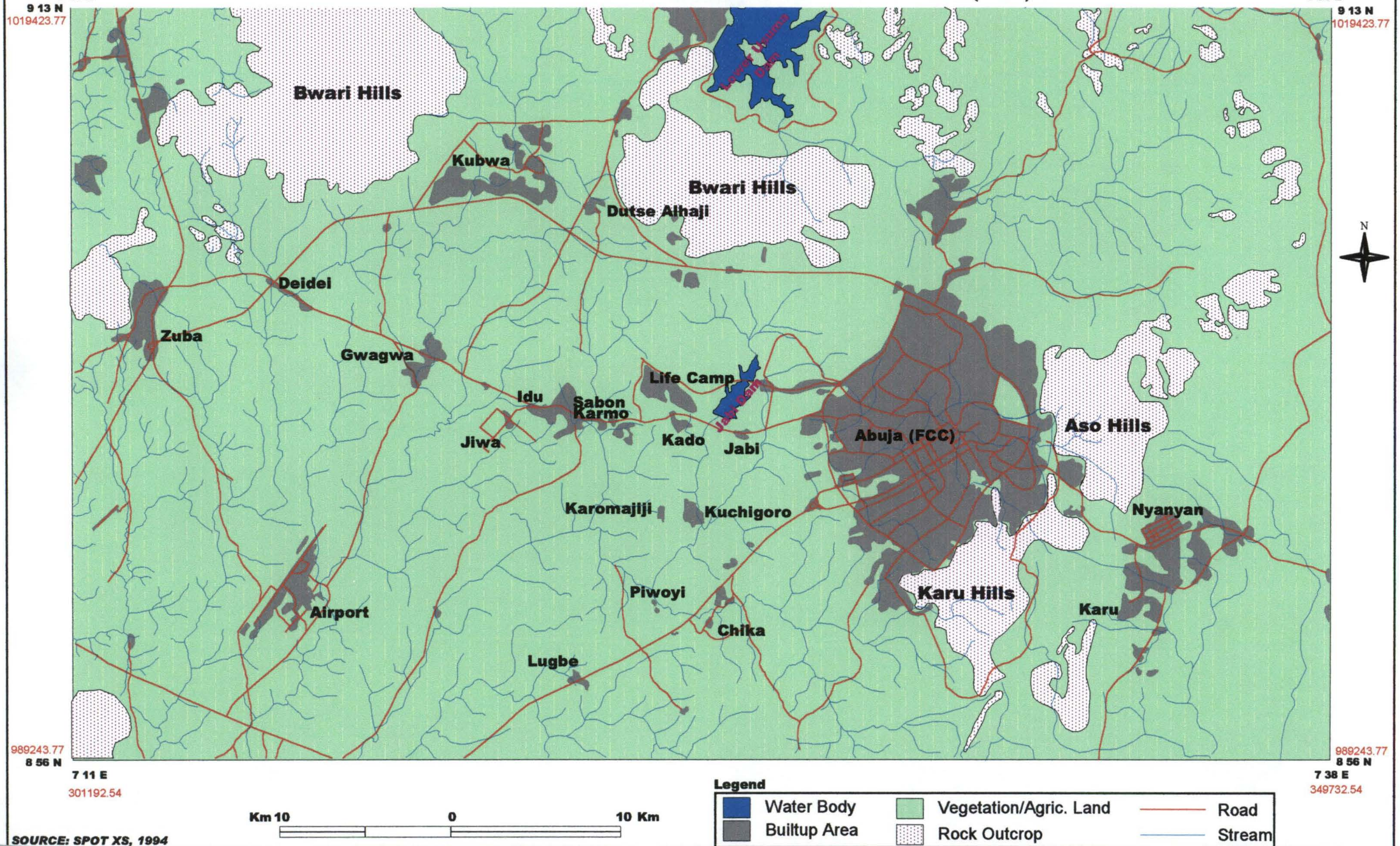
Figure 5.3: Trend in Primary and Post-Primary School Enrolment, 1987 - 1994



Source: Author's Analysis, 2003

The level of urban growth from 1987 – 1994 in the study area was investigated using SPOT XS image taken in 1994 (appendix 8). The image was processed and the land use\land cover map of the area (figure 5.4) was composed to show the level of urban expansion in 1994.

FIGURE 5.4: LAND USE / LAND COVER (1994)



It is evident from the map that the FCC and other satellite settlements such as Karu, Nyanyan, Sabon Karmo, Idu, Gwagwa, Kubwa and Zuba had assumed prominence with some of the settlements merging together. The land cover statistics in 1994 (table 5.5) shows that the built-up area covered 111.52 Km^2, rock outcrops and water body occupied 188.53 Km^2 and 10.88 Km^2 respectively while vegetation\agricultural land accounted for the remaining 1, 154.0 Km^2 of land.

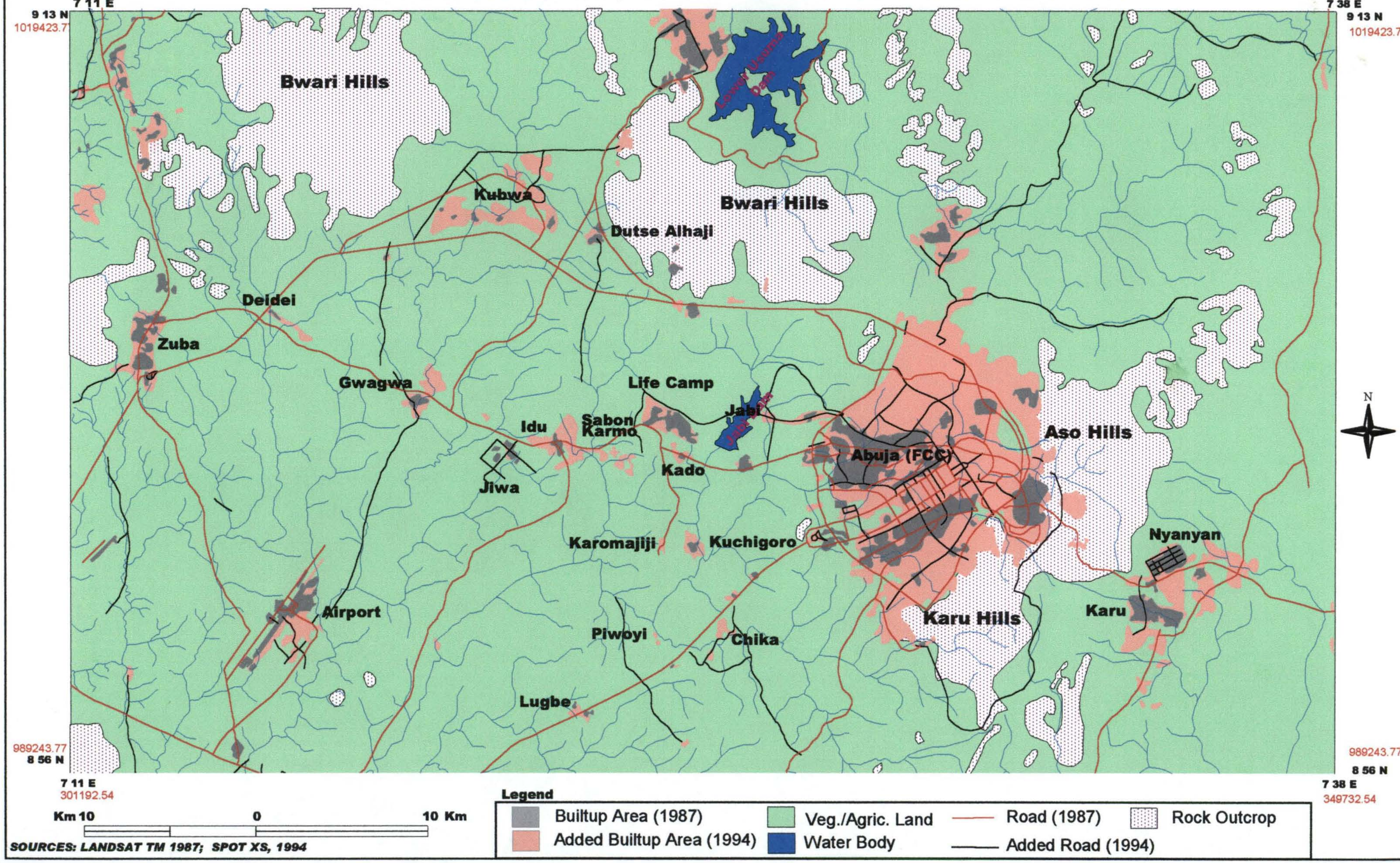
Table 5.5: Land use\land cover Statistics, 1994

S\No.	Land use\Land cover Class	Area (Km^2)	% of Total
1	Built-up area	111.52	7.6
2	Rock outcrops	188.53	12.9
3	Vegetation\Agricultural land	1,154.0	78.8
4	Water body	10.88	0.7
	Total Area (Km^2)	1, 464.93	100

Source: Author's Analysis, 2003

In order to analyse the spatial distribution of the land use\land cover change, the developments in 1987 (figure 5. 2) were superimposed on those of 1994 (figure 5. 4) to produce a composite map (figure 5.5). The change statistics as shown in table 5.6 reveal that the built-up area increased by 80.2 Km^2 (71.9%) while roads increased by 175.25 Km (31.0%) in 1994. Also, rock outcrops and vegetation\agricultural land have decreased by 10.87 (5.8%) and 69.03 (6.0%) respectively due to quarrying and construction of new settlement areas. The slight decrease (2.8%) in the size of water body could be attributed to dam siltation and vegetation re-growth.

FIGURE 5.5 : LAND USE / LAND COVER CHANGE MAP 1987 - 1994



SOURCES: LANDSAT TM 1987; SPOT XS, 1994

Table 5.6: Land use\land cover Change Statistics, 1987 – 1994

S\No.	Land use\land cover Class	Area (Km^2)\Length		Increase\ Decrease	Percentage Change
		1987	1994		
1	Built-up area	31.32	111.52	+80.2	71.9
2	Rock outcrops	199.40	188.53	-10.87	5.8
3	Water body	11.18	10.88	- 0.3	2.8
4	Vegetation\Agricultural land	1223.03	1,154.0	- 69.03	6.0
5	Roads	390.26	565.51	+175.25	31.0
6	Streams	1,024.27	1,027.18	+ 2.91	0.3

Source: Author's Analysis, 2003

5.3.3 Level and Pattern of Urban Growth, 1994 – 2001

The 1994 – 2001 period witnessed the progressive stabilization of the urban growth process in the FCC and its satellite settlements. The period was characterised by extension of infrastructure such as residential housing, schools, clinics, roads etc. by the government and private individuals. Available statistics show that by 1995, the total mileage of Federal, State and Local governments' roads had reached 630 kilometres (FCT Statistical Year Book, 1998) while the stock of government's houses had reached 22,378 (table 5.7) by 1998. Over twelve government hospitals have also been built by 1998 while the number of private clinics rose from 28 in 1993 to125 in 1997 (MFCT, 1998). In the aggregate, the number of health establishments in the FCT increased from 115 in 1994 to 208 in 1996. Other physical development carried out in this period include the construction of six new primary schools (five of which were located in the satellite settlements) and the expansion of facilities such as laboratories, hostels and staff housing were expanded in other schools between 1993 and 1997. All these development efforts contributed to urban growth in the study area.

Table 5.7: Summary of Available Housing Stock by 1998

S\No	Location	No. of units
1	Garki District	4232
2	Wuse District	2436
3	Maitama District	238
4	Asokoro District	346
5	Karu	1129
6	Nyanya	6923
7	Kubwa Low Cost	3094
8	Kubwa Resettlement	440
9	Gudu District	715
10	Ushafa	399
11	Kado Housing Estate	490
12	Garki II	240
13	Development Areas	1696
	Total	22,278

Source: Ministry of Federal Capital Territory (MFCT), Abuja; 1998.

The stage of urban growth as at year 2001 was assessed, using Landsat ETM+ image (appendix 9) with 30-meter resolution taken in December 2001. The image was processed and a land use\land cover map (figure 5.6) was composed. The map reveals a continuation of urban expansion in Abuja and the surrounding settlements. The built-up area had increased to 199.51 Km^2 with a total road network of about 670.32 Km (table 5.8). The rock outcrops and water bodies maintained the 1994 area coverage while the vegetation\agricultural land decreased from 1,154.0 Km^2 in 1994 to 1,066.0 Km^2 in 2001.

Table 5.8: Land use\Land cover Statistics, 2001

S\No.	Land use\Land cover Class	Area (Km^2)	% of Total
1	Built-up area	119.51	13.6
2	Rock outcrop	188.53	12.9
3	Water body	10.88	0.7
4	Vegetation\agricultural land	1,066.0	72.8
	Total Area (Km^2)	1, 464.93	100

Source: Author's Analysis, 2003

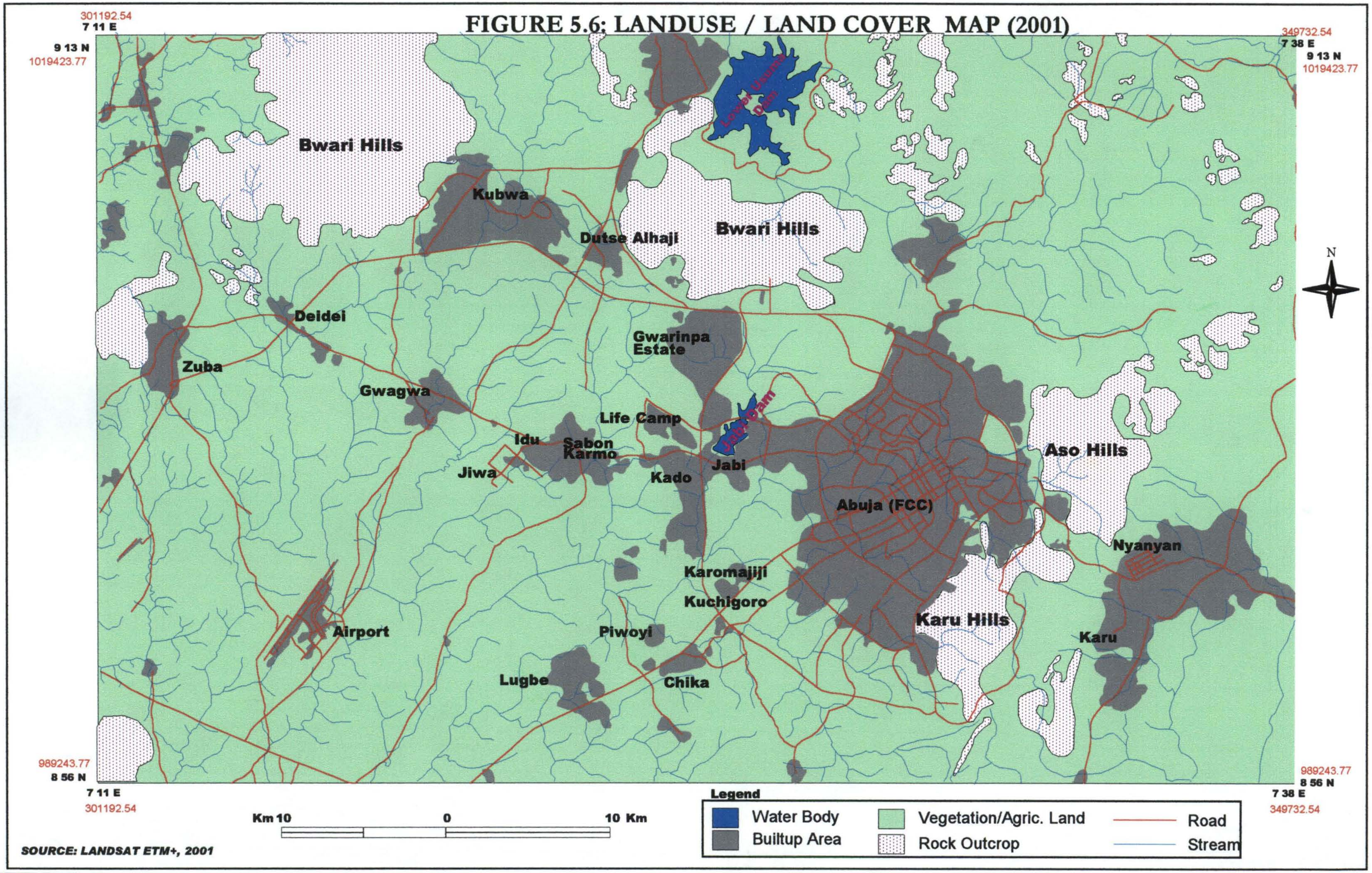


FIGURE 5.6: LANDUSE / LAND COVER MAP (2001)

A change detection analysis was done by superimposing the developments in 1994 on those of year 2001 (figure 5.7). The composite map shows the extent of urban growth in 1994 and the new additions in 2001. The change statistics (table 5.9) reveals that settlement built-up area increased by about 88.0 Km^2 while additional 104.8 Km of roads were constructed. The increase in built-up area caused the vegetation\agricultural land to decrease by 88.0 Km^2. As noted earlier, major change in land use\land cover in the area is from vegetation\agricultural land to settlement and the pattern of development in 2001 follows the trend observed since 1987.

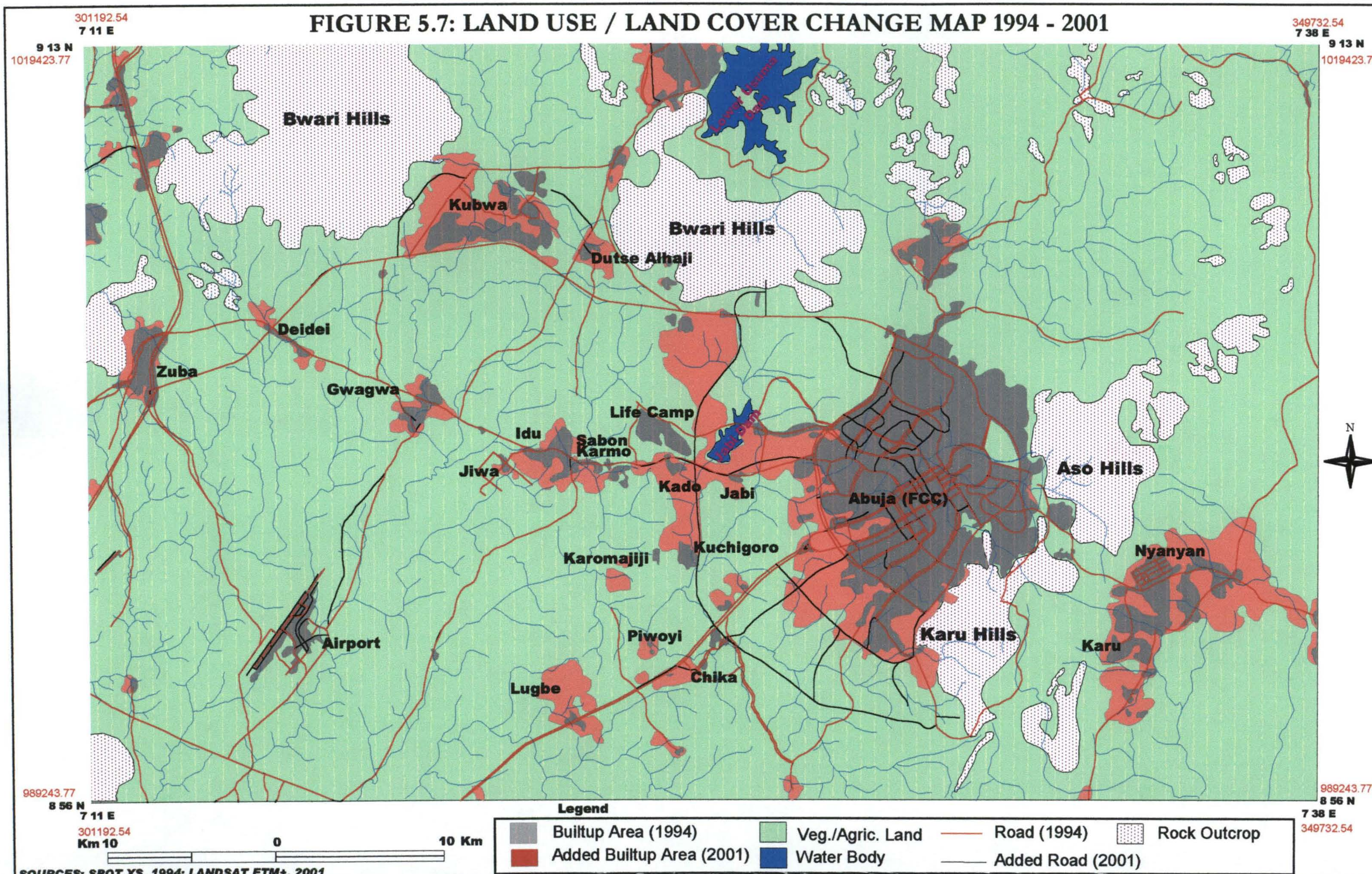
Table 5.9: Land use\land cover Change Statistics, 1994 – 2001

S\No.	Land use\land cover Class	Area (Km^2)\Length		Increase\ Decrease	Percentage Change
		1994	2001		
1	Built-up area	111.52	199.51	+88.0	44.1
2	Rock outcrops	188.53	188.53	0.0	0.0
3	Water body	10.88	10.88	0.0	0.0
4	Vegetation\Agricultural land	1,154.0	1,066.0	- 88.0	8.3
5	Roads	565.51	670.32	+104.81	15.60
6	Streams	1,027.18	1,027.18	0.0	0.0

Source: Author's Analysis, 2003

The above time series analysis reveals that spectacular urban expansion has occurred in Abuja and its immediate environment in the last two and a half decades. Major urban growth was recorded in the FCC, which accounted for 50.6%, 60.7% and 52.7% of the total built-up area in 1987, 1994 and 2001 respectively. Indeed, the political decision to construct the FCC has generated physical development influence in the territory. Streams of migrants whose destination was Abuja have continued to populate the nearby satellite settlements because the city could not accommodate them. The increases in population (table 5.10) have resulted in physical developments and the eventual growth of these settlements. The next section of this chapter examines how ten selected satellite settlements have grown over the years.

FIGURE 5.7: LAND USE / LAND COVER CHANGE MAP 1994 - 2001



SOURCES: SPOT XS, 1994; LANDSAT ETM+, 2001

Table 5.10: Actual and Projected Population of Selected Satellite Settlement, 1981 – 2008

Settlements	1981 Pop.	1991 Pop.	2001 Pop. (Projected)	2008 pop. (Projected)
Karu	4, 384	14, 397	20, 308	25, 387
Nyanyan	1, 570	20, 748	29, 267	36, 586
Kubwa	162	15, 950	22, 499	28, 125
Sabon Karmo	848	8,483	11, 966	14, 958
Idu	NA	3,605	5, 085	6, 357
Gwagwa	1, 641	1, 502	2, 119	2, 649
Zuba	671	5, 373	7, 579	9, 474
Lugbe	779	1, 339	1, 888	2, 360
Kuchingoro	NA	924	1, 303	1, 629
Dutsen Alhaji	196	1, 984	2, 799	3, 499
Total	10, 251	74, 305	104, 813	131, 069

NA = Figure not available

Sources: Doxiadis Associates, 1983; National population Commission (NPC), 1998 and Author's projection, 2003.

Note: The 2001 figures were calculated with the NPC's 3.50 (high variant) projected average annual growth rate for 2000 – 2005 while the 2008 figures were calculated with 3.24 (high variant) projected growth rate for the year 2005 – 2010.

5.4 Analysis of the Growth of Selected Rural Settlements, 1976 - 2001.

It is evident from figure 5.1 that most settlements in the study area were, for several decades, rural centres prior to the construction of the FCC. The sizes of the settlements were generally small in the formative years of Abuja city (1976 – 1987). In 1976 for instance, the area of each of the ten settlements was below 1 Km^2 while in 1987, only Karu (1.455 Km^2) and Nyanyan (1.270 Km^2) were slightly above 1 Km^2 (table 5.11). The rate of physical development in these settlements however, picked up in Kubwa, Zuba, Dutse Alhaji and Nyanyan by 1987.

Table 5.11: Settlement sizes and Growth Rates, 1976 – 1987

S\No.	Settlements	Size in 1976 (Km^2)	Size in 1987 (Km^2)	Newly created Settlement Area (Km^2)	Growth Rate (%)
1	Dutse Alhaji	0.011	0.092	0.081	66.9
2	Gwagwa	0.095	0.237	0.142	13.6
3	Idu	0.028	0.097	0.069	22.4
4	Karu	0.302	1.455	1.153	34.7
5	Kubwa	0.006	0.112	0.106	160.6
6	Kuchigoro	0.015	0.024	0.009	5.5
7	Lugbe	0.041	0.105	0.064	14.2
8	Nyanyan	0.109	1.270	1.161	96.8
9	Sabon Karmo	0.072	0.227	0.155	19.6
10	Zuba	0.065	0.649	0.584	71.5

Source: Author's Analysis, 2003

The 1987 – 1994 period witnessed tremendous growth in the satellite settlements (figure 5.4). Physical developments in the ten settlements occurred alongside that of the FCC, which grew from 15.86 Km^2 in 1987 to 67.73 Km^2 in 1994. The impact of Abuja was much felt in this period due to the movement of government's ministries and civil servants as well as the transfer of the Federal capital from Lagos to Abuja. As shown in table 5.12, the period witnessed high increases in the newly created areas of settlements within seven years with high growth rate recorded for Kuchigoro (330.9 %), Idu\Sabon Karmo (63.9 %), Gwagwa (71.4 %) and Kubwa (658.7 %).

Table 5.12: Settlement Sizes and Growth Rates, 1987 – 1994

S\No.	Settlements	Size in 1987 (Km^2)	Size in 1994 (Km^2)	Newly created Settlement Area (Km^2)	Growth Rate (%)
1	Dutse Alhaji	0.092	0.350	0.258	40.1
2	Gwagwa	0.237	1.422	1.185	71.4
3	Idu\ Sabon Karmo	0.464	2.539	2.075	63.9
4	Karu\ Nyanyan	2.725	6.979	4.254	22.3
5	Kubwa	0.112	5.276	5.164	658.7
6	Kuchigoro	0.024	0.570	0.546	330.9
7	Lugbe	0.105	0.270	0.166	22.4
8	Zuba	0.649	3.042	2.393	52.7

Source: Author's Analysis, 2003

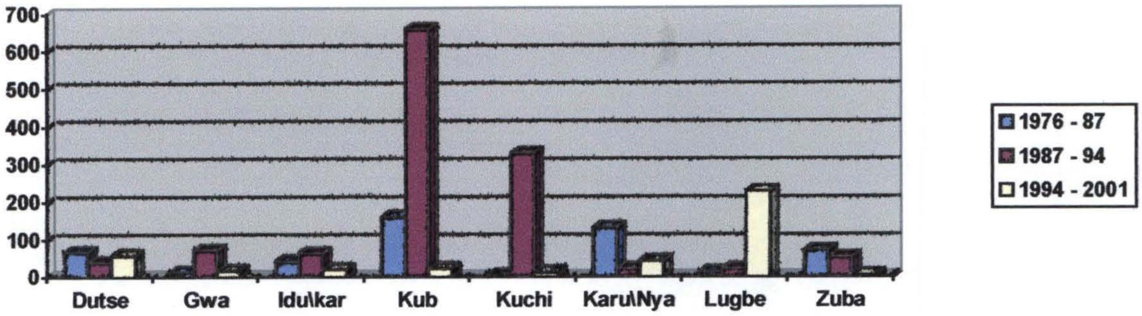
The pace of settlement growth set up in the 1987 – 1994 period continued in the 1994 – 2001 period with all the settlements recording increase in their sizes (table 5.13). Physical expansion of settlement area was more significant in Idu\Sabon Karmo, Kubwa, Karu\Nyanyan, Dutse Alhaji and Lugbe, which recorded 58.0, 61.1, 75.0, 80.0 and 94.1 percentage increase in size respectively within seven years. It is however noticeable that, apart from Dutse Alhaji (56.9%) and Lugbe (228.8%) that maintained a progressive growth rate, the growth rates of other settlements dropped from the previous years as development stabilised in the year 1999 and beyond (figure 5.8). This trend is particularly significant for Kuchigoro and Kubwa whose growth rates dropped from 330.9 % and 658.7% respectively in the 1987 – 1994 period to 12.9 % and 22.4% respectively in the 1994 – 2001 period. A possible explanation for this sharp drop in growth rate is the fact that Kuchigoro has been declared an illegal settlement marked for future demolition.

Table 5.13: Settlement Sizes and Growth Rates, 1994 – 2001

S\No.	Settlements	Size in 1994 (Km^2)	Size in 2001 (Km^2)	Newly created Settlement Area (Km^2)	Growth Rate (%)
1	Dutse Alhaji	0.350	1.743	1.393	56.9
2	Gwagwa	1.422	3.147	1.725	17.3
3	Idu\ Sabon Karmo	2.539	6.051	3.512	19.8
4	Karu\ Nyanyan	6.979	27.965	20.986	43.0
5	Kubwa	5.276	13.565	8.289	22.4
6	Kuchigoro	0.570	1.084	0.514	12.9
7	Lugbe	0.270	4.594	4.324	228.8
8	Zuba	3.042	4.298	1.256	5.9

Source: Author's Analysis, 2003

Figure 5.8: Trend in Growth Rate, 1976 - 2001



Source: Author's Analysis, 2003

Despite the evidence of a stabilised rate of growth in recent times, the level of growth recorded in the 1994 – 2001 period (7 years) is quite substantial. Except for Kuchigoro, the amount of physical development in other settlements is more than that of the 1976 – 1994 (18 years) put together. This shows that more development impact was felt in the satellite settlements after Abuja became fully functional as the administrative capital of Nigeria.

The observed physical expansion in the ten settlements studied was marched with population increases (table 5.10) and socio-economic growth. The socio-economic changes in the area were investigated through a field survey in which 858 (99.4%) of the respondents agreed that the settlements have grown in size over the years (appendix 10 shows output of data analysis). For 83.6 per cent of the respondents, settlement growth in the past ten years is rapid (table 5.14) and the perceptible areas of change are in high population increases, high rate of building construction, settlement expansion and increases in commercial activities. As shown in table 5.15, 606 (70.3%) of the respondents agreed that significant changes have occurred in all the areas mentioned.

Table 5.14: Residents' Rating of Settlement Growth.

Rate of Growth	Frequency	Percentage	Cum. Percentage
Very rapid	481	56.0	56.0
Rapid	237	27.6	83.6
Moderate	92	10.7	94.3
Slow	30	3.5	97.8
Very slow	19	2.2	100.0
Total	859	100.0	

Source: Author's Analysis, 2003.

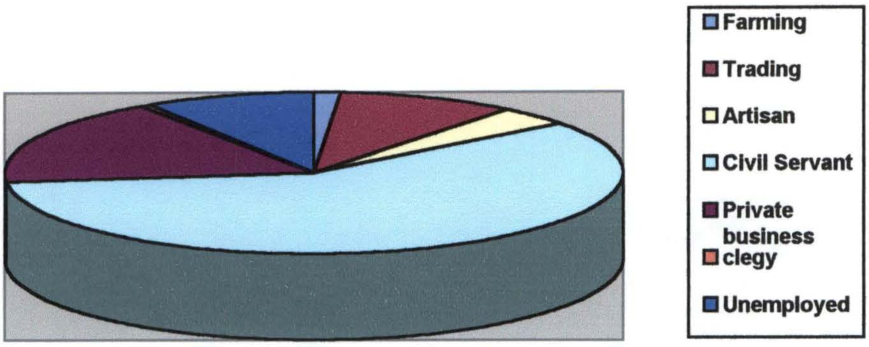
Table 5.15: Areas of Most Significant Changes

Areas of change	Frequency	Percentage	Cum. Percentage
High population Increases	148	17.2	17.2
High rate of building construction	62	7.2	24.4
Increases in settlement size	30	3.5	27.8
Increases in commercial activities	16	1.9	29.7
All of the above	606	70.3	100
Total	862	100	-

Source: Author's Analysis, 2003

It was also realised that the economic base of the settlements has been diversified from basic agriculture, which was the major occupation in 1976. Figure 5.9 shows that majority of the residents now engage in non-primary activities such as trading (9.3%), artisan (3.8%), private business (17.3%), clergy (0.5%) and civil service (58.6%) works. The people fall mainly into the low (with between less than ₦ 10, 000.00 and ₦ 20, 000.00 monthly salary) and medium (with between ₦ 21,000.00 and ₦ 40, 000.00 monthly salary) income groups. Only about 4.4 per cent of the residents can be categorised as high-income earners.

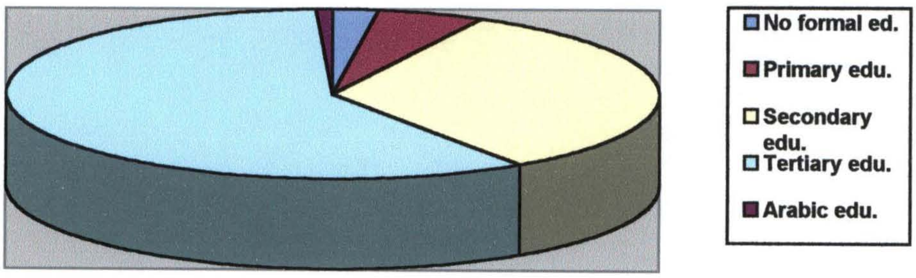
Figure 5.9: Occupational Distribution of the Residents



Source: Author's Analysis, 2003.

The resident population of the satellite settlements were also found to be largely literate due to in-migration of skilled and semi-skilled workers. As illustrated in figure 5.10, the literate population is high with 58.7 per cent having tertiary education, 32.8 per cent having secondary education while 5.3 per cent have primary education.

Figure 5.10:Educational Attainments of Residents



Source: Author's Analysis, 2003

Zopt, 1970). According to the authors, tertiary occupation, large community with high population density (in terms of persons per square kilometre, social contracts, opportunity to specialise and superior schools) and complex social groups (diversity in culture, education, ideas, beliefs, religion and economic positions etc.) are essential features of urban settlements. Given this conceptual background and our empirical findings on the physical growth, occupational difference, educational attainment and soci-economic diversity in the study area, the ten settlements could be affirmed to have transformed from rural settlements in the pre-FCC period to urban settlements in the post-FCC period.

5.5 Variables of Settlement Growth and Land use\land cover Change

The preceding analysis of temporal variation in settlement sizes reveals rapid growth of the ten satellite settlements in the period under review. The periodic mapping of settlement growth over the years shows the unique, physical data capture capability of remotely sensed satellite images on a temporal basis. However, this unique capability is limited by the inability of the images to provide information on the socio-economic variables that explain the observed growth. This limitation necessitated an alternative data source since our analysis of settlement growth will be incomplete without the understanding of the socio-economic factors of change. Thus, analysis of the growth variables was carried out using field data from the ten satellite settlements.

It is noted under statement of research problem (section 1.2) that, counterurbanization in the FCT results from the construction of the FCC and the subsequent transfer of the Federal capital to Abuja without adequate housing provision for the low-income group. In order to understand the forces of counterurbanization at work, background information on the reasons for population build-up and the subsequent physical growth of the satellite settlements was sought and analysed. First, the survey established that about 73.8 per cent of the respondents were tenants while only 26.2 per cent were owner-occupiers. Majority of the tenants and house owners work in Abuja as 438 (58.9%) of the 744 respondents confirmed that their workplace is located in city. The respondents gave various reasons for living in the satellite settlements. These, amongst others, include cheaper and affordable accommodation, allocation of government quarters, proximity to Abuja\workplace, accommodation shortage and high rent in Abuja, peaceful environment, availability of social facilities and the settlements being native homes to few respondents (See appendix 10). Among others, cheap\affordable accommodation and nearness to Abuja\workplace account for 70.5 per cent of the responses given and these are the major reasons for population concentration in the satellite settlements.

With reference to the location of workplace, 569 (77.3%) out of 736 respondents indicated that they prefer to live in Abuja city. On the basis of this preference, the respondents were asked to rank three major reasons why they could not reside in the city as at the time of the study. The rankings were assigned minimum scores of 1 for the lowest and 3 for the highest. The scores were summed up to determine the relative importance of the factors. As shown in table 5.16, the most important factors that repelled the low and the medium income groups from Abuja city and which set off the process of counterurbanization are accommodation shortage and high rent. This is followed by high cost of living in the city and high cost of land for development.

Table 5.16: Rating of Reasons Why Respondents Could not Reside in Abuja City.

Reasons for not Residing in Abuja City	Score Under Each Rating			Total Score	Overall Rating
	1st	2nd	3rd		
Accommodation shortage and high rent	1035	328	54	1417	1st
High cost of land for development	252	278	333	863	3rd
High cost of living	408	506	169	1083	2nd

Source: Author's Analysis, 2003

The rent and land value situation in Abuja were examined in order to appreciate the magnitude of the accommodation problem as a major factor. As shown in table 5.17, the rent per annum for different types of accommodation have increased geometrically over the years with absolute increase of ₦ 100,000.00 for a single room and as much as ₦ 2.3 million for duplex building within a period of fifteen years. The percentage rent increases for all types of accommodation are well over 100 (between 150 and 1150 %) and this is considered exceptionally high. The high rent situation in Abuja is compounded by high cost of land. Survey findings reveals that a 1000 square meters plot of land in phase I of the city costs about ₦1.5 million in 1990. According to NAWA Properties Limited (2003), this price increased from ₦1.5 million in 1990 to ₦3 million in 1996, ₦15 million in 1999 and N25 million in year 2002.

Table 5.17: Trend in Housing Rent, Abuja (1987 – 2002)

Types of Accommodation	Housing Rent (₦)				Absolute Increase	Percentage Increase (a) – (d)
	1987 (a)	1993 (b)	1999 (c)	2002 (d)		
Single Room	30,000	45,000	120,000	130,000	100,000	333.3
1-Bedroom Flat	60,000	120,000	180,000	250,000	190,000	150.0
2-Bedroom Flat	80,000	150,000	300,000	450,000	370,000	462.5
3-Bedroom Flat	150,000	250,000	700,000	850,000	700,000	467.0
Duplex & BQ	200,000	450,000	1,500,000	2,500,000	2,300,000	1150.0

Source: Computed from the Records of NAWA Properties Ltd., Abuja, 2003.

The accommodation shortage\high rent problem and high land value in Abuja combined with other problems such as absence of both private and official low-income residential estates to divert the city's migrant population to the surrounding satellite settlements. Having confirmed that these settlements have grown rapidly over the years, the residents were asked to identify the factors that accounted for the observed growth. Among others, factors identified by the respondents include proximity to Abuja as a centre of administration and opportunities, availability of business opportunities in the satellite settlements, population increases due to in-migration of Abuja workers and people displaced by the Kaduna and Jos ethnic and religious crises of between 1992 and 2000, transfer of the Federal capital from Lagos to Abuja and availability of cheaper accommodation in the satellite settlements (table 5.18).

The different factors identified were streamlined into five major variables that could best explain the growth of the settlements. These growth variables include, nearness to Abuja city and ease of commuting, population increases due to spill over from Abuja, availability of cheaper accommodation in the satellite settlements, cheap land for development and increased rate of car ownership. The respondents were asked to score these variables in order of importance (1 for the least and 5 for the most important). The scores for each of the

Table 5.18: Factors Explaining Rural Settlement Growth

Factors of Growth	Frequency	Percentage	Cum. Percentage
Proximity to Abuja city	64	11.0	11.0
Business opportunities in the settlements	86	14.8	25.8
Population increases due to in-migration	241	41.4	67.2
Transfer of Federal capital to Abuja	96	16.5	83.7
Availability of cheaper accommodation	74	12.7	96.4
Availability of social amenities	21	3.6	100.0
Total	582	100.0	

Source: Fieldwork, 2003.

selected settlements were summed and tabulated against settlement sizes for analysis. Each of the variables (x) was correlated with settlement size (y) to determine the degree of association using the Pearson's Product-moment Correlation Coefficient (r). The results of the analysis show strong positive correlations which, are significant at 0.05 alpha level for all the variables (appendix 11a). The coefficients of determination (r^2) shown in table 5.19 indicate the level of explanation provided by each of the growth variables. It is evident from the table that nearness to Abuja city and ease of commuting with r-value of 0.919 is the most important variable of settlement growth and it is significant at 0.01 alpha level.

Table 5.19: Correlation Between Settlement Size and Growth Variables

Growth Variables	Correlation Coefficient (r)	Coefficient of determination (r^2)
Nearness to Abuja city and ease of commuting	0.919**	0.844561 (84.5%)
Population increases due to spill over from Abuja	0.802*	0.643204 (64.35%)
Availability of cheaper accommodation	0.784*	0.614656 (61.53%)
Cheap land for development	0.733*	0.5537289 (53.7%)
Increased rate of car ownership	0.802*	0.643204 (64.35%)

** Significant at 0.01 alpha level * Significant at 0.05 alpha level

Source: Author's Analysis, 2003.

The explanatory variables of settlement growth were further subjected to stepwise regression analysis to determine their individual strength and\or explanatory power. The results (appendix 11b) show that nearness to Abuja city and ease of commuting with R-value of 0.946 remains the strongest variable of growth. The factor is significant at 0.000 alpha level (which is the highest level of significance) and it explains 89.5 per cent of growth. Population increases due to in-migration and spill over from Abuja is the next to enter the model and it helps improve the R-value to 0.989. This value is also significant at 0.000 alpha level and the two variables jointly explain 97.8 per cent of growth

It is noted that the factor – cheap land for development in the satellite settlement, ranked third in the first level of stepwise analysis with -4.193 t-value and 0.009 level of significance. However, this factor, together with the remaining two are not statistically significant at the second level of analysis and could therefore not enter the model. This shows that the factors are redundant as they jointly explain only 2.2 per cent of growth. Thus the model for explaining settlement growth in the study area is written as:

Y = 474455. 5 + 37962. 9 (nearness to Abuja and ease of commuting)
– 21921.0 (population increases due to spill over from Abuja).

Our findings on the reasons why residents (mostly workers) could not reside in the FCC and the factors responsible for rural settlement growth help confirm the findings of earlier studies with differences in the underlying circumstances and local peculiarities. For instance, the problems of accommodation shortage\ high rent and general high cost of living as the major factors that prevent the average people from residing in Abuja despite their preference for the city agree with the findings of Pahl (1966) in North London where he confirmed the presence of low income urban workers (the 'reluctant' commuters forced out of the city by high property prices) in metropolitan villages. However, while the low-income residents may have been forced out of the city due to high property prices in the North London's case, most of those of Abuja never had the opportunity to reside in the city due to complete lack of low-income accommodation.

With respect to causes of counterurbanization, Clout (1984) identified the factors of increasing affluence, efficient public transport and rising rate of private car ownership in Britain while he associated the flight from the city in America with folk movement away from dirt, violence, racial and religious tensions. Also, Spencer and Goodall (1992) recognised the shift of industrial investment to rural localities, the growth of the rural service sector and back to the land sub-culture of retirees and ex-urbanites as the three main causes of counterurbanization while Potts and Mutambirwa (1998) associated the increased urban – rural 'return' migration in Zimbabwe with the retrenchment of urban workers due to the impact of Structural Adjustment Programme (SAP).

These case studies show that there are different factors of rural settlement growth depending on local peculiarities or underlying conditions. As we found out, the situation in Abuja, Nigeria agrees partly with universal principles in terms of the proximity\ease of commuting as well as increasing rate of car ownership as factors of rural settlement growth. However, it differs largely in terms of the population spill over effects and the attraction of available and cheaper rural accommodation in the satellite settlements. This reveals that the political decision to build a millionaire capital city, which by omission or commission did not provide adequate accommodation for the average citizens can generate forces of counterurbanization. This is the underlying condition which account for accelerated rural settlement growth in the FCT.

5.6 Nature of Physical Development and Implications for Rapid Growth

The images used in monitoring physical developments in the study area are of low resolution and could not show details of the characteristics of ground features and the quality of development. Information on the nature of physical development was obtained through ground survey carried out in May 2003. The data were collected through field observations, oral interview and the use of digital camera to capture the scenario in the different settlements.

The ground survey exercise reveals that development in the ten satellite settlements features areas of different physical characteristics and quality. Generally, the entire housing environment is characterised by planned, unplanned and slum areas which are present in different degrees in all the settlements. Planned developments are mainly restricted to parts of Karu, Nyanyan, Kubwa (Federal Housing area) and Lugbe (Lugbe estate). As shown in plates II and III, these areas are characterised by modern, well laid out buildings and improved access. The buildings are of modern designs and they range from single flat apartments to duplexes and low-rise buildings.

Unplanned developments in the settlements manifest in urban sprawl and slum housing and their spatial extent vary from one settlement to the other. The problem of urban sprawl is noticeable in the new areas of Lugbe and Gwagwa where extensive housing areas have been built haphazardly with poor access and services (plates IV and V). Slum development is a universal phenomenon in all the settlements. While localised slums have developed in the old areas of Karu, Nyanyan, Lugbe and Biaji areas of Kubwa, large-scale slum areas have developed in Zuba, Gwagwa, Idu and Sabon Karmo. Generally, the slum areas are characterised by poor housing environment. The houses are substandard, small, congested and poorly ventilated. They are built of assorted, poor quality materials such as mud, planks and old zinc. Plates VI and VII show typical slum houses in Gwagwa and Sabon Karmo.

Plate II: Planned Residential Environment in Kubwa

Source: Fieldwork, May 2003.

Plate III: Modern Residential Houses in New Areas of Karu

Source: Fieldwork, May 2003.

Plate IV: Urban Sprawl with Difficult Access in Lugbe

Source: Fieldwork, May 2003

Plate V: Urban Sprawl with Difficult Access in Gwagwa

Source: Fieldwork, May 2003

Plate VI: Slum Housing in Gwagwa

Source: Fieldwork, May 2003

Plate VII: Large Scale Slum Development in Sabon Karmo

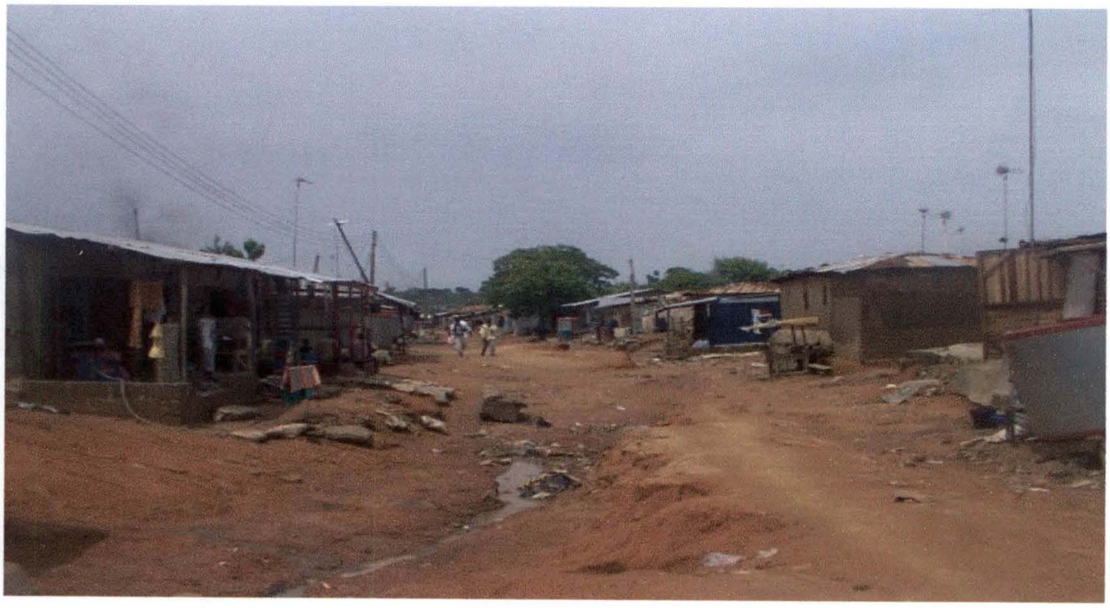
Source: Fieldwork, May 2003

Apart from the substandard and poor housing quality, the slum areas also feature poor access roads and deteriorated environment. In Gwagwa, Idu and Sabon Karmo for instance, there are no tarred roads except the single carriage Diedie – FCC link that passes through the settlements. The entire residential areas in these settlements are serviced by narrow, winding roads with sever drainage problem (plates VIII and IX). The general environmental quality of the slum settlements is poor with common cases of heaps of refuse taking over the roads and residential properties (plate X).

Plate VIII: Poor Residential Environment with narrow Access road in Sabon Karmo

Source: Fieldwork, May 2003

Plate IX: Severely Eroded Access Road in Gwagwa.



Source: Fieldwork, May 2003

Plate X: Access Road and Residential Properties Swallowed up by Refuse in Idu.

Source: Fieldwork, May 2003

The rapid growth of the Satellite settlements studied and the preponderance of unplanned and poorly serviced environment have certain negative consequences for the entire FCT. In physical terms, development pressure, arising from population influx and high demand for housing and infrastructure, has resulted into illegal, congested and haphazard development. Land speculators and informal building investors have taken the advantage of increasing housing demand to build ramshackle and poorly serviced accommodation. Thus, physical developments in Zuba, Gwagwa, Idu, Sabon Karmo, Kuchigoro and parts of Lugbe, Yanyan, Karu and Kubwa are characterised by substandard buildings as well as encroachment on public lands and river flood plains (plate XI). These problems combined with poor neighbourhood quality, due to poor hygiene, to create a generally overcrowded, unsanitary and polluted environment, which has negative implication for health and the well being of the residents.

Plate XI: Development Encroachment on River Flood Plain in Zuba

Source: Fieldwork, 2003.

The satellite settlements are also faced with the problem of infrastructure inadequacy and stress on the existing ones. Electric power supply is epileptic in all the settlements while Lugbe, Kuchigoro, Zuba, Gwagwa, Idu and Karmo are not connected to pipe borne water at all. The crowded housing environments of the settlements also harbour and nurture social vices such as prostitution, alcoholism, petty stealing and robbery activities. The residents confirmed that insecurity due to crime and social vices is a major negative consequence of rapid growth of the settlements. Some of the settlements thus constitute threat to urban security and are potential sources of urban violence.

5.7 Estimation\Modelling of Future Growth of the Satellite Settlements.

Estimation of future growth of the settlements was carried out to provide data for future planning. Information from the 2001 satellite image was used to determine the areas and the perimeters of Abuja city and the selected satellite settlements. Following the rating method of of Rao (1995), the influence rate of built-up area of the settlements (IR), attraction potential rate (APR) of Abuja (assuming the built-up areas of the settlements are under the influence of the FCC as the only attraction potential in the study area) were computed. The IR and the APR values were used to calculate the growth potential (GP) values of the settlements. The growth potential of settlements for 1987 and 1994 were also computed alongside that of 2001 and the average was used in the final computation to account for growth fluctuation over the years. Based on the assumption that the established growth trend (1987 –2001) will not change direction suddenly, the average growth potential (AGP) values were used as smoothing constants in a time-series analysis to estimate the future built-up area of the ten settlements for the year 2008 (table 5.20).

Table 5.20: Estimation of Built-up Area for the Satellite Settlements 2001 - 2008

Settlements	Area in 2001 (M^2)	Perimeter (M^2)	IR	APR	GP	AGP	Calculated Values for 2008 (M^2)
Dutse Alhaji	1742682.38	6260.41	0.003	1.0×10^{-3}	0.33	0.27	2213206.62
Gwagwa	3148687.00	9574.92	0.003	1.0×10^{-3}	0.33	0.39	4376674.93
Idu\Şabon Karmo	6051128.50	16603.76	0.002	1.0×10^{-3}	0.50	0.37	8290046.05
Karu\ Nyanyan	27965362.00	37624.54	0.013	1.0×10^{-3}	1.00	0.60	44744579.2
Kubwa	13564981.00	25629.71	0.002	1.0×10^{-3}	0.50	0.35	20483121.31
Kuchigoro	1083860.38	5827.47	0.005	1.0×10^{-3}	0.20	0.20	1300632.46
Lugbe	4594354.00	13236.06	0.002	1.0×10^{-3}	0.50	0.28	5880773.12
Zuba	4298097.50	10141.19	0.002	1.0×10^{-3}	0.50	0.48	6361184.30

Source: Author's Analysis, 2003

IR = Influence rate
APR = Attraction potential rate of FCC
GP = Growth potential of satellite settlements
AGP =Average Growth potential of satellite settlements

Table 5.21 shows the values for expected future increases in sizes and the projected built-up area by 2008 is shown graphically in figure 5.11. The future values calculated for all the settlements are considered realistic as they confirm the growth trend established between 1994 and 2001 from the actual image data. For instance, a comparison of values of the newly created areas of settlement in the year 2001(see table 5.13) and the expected increases in settlement areas in the year 2008 reveals that development will further stabilise in the years ahead with moderate growth anticipated in settlements like Dutse Alhaji (0.470 Km^2), Kuchigoro (0.217 Km^2) Gwagwa (1.227 Km^2) and Lugbe (1.286 Km^2). However, the expected growths of 2.239 Km^2 in Idu\Sabon Karmo, 2.063 Km^2 in Zuba, 6.918 Km^2 in Kubwa and 16.779 Km^2 in Karu\Nyanyan within the next seven years are still considerable.

Table 5.21: Expected Future Increases in Settlement Sizes.

Settlements	Area in 2001 (M^2)	Estimated Values for 2008 (M^2)	Future Increases (M^2)	Equivalent increases (Km^2)
Dutse Alhaji	1742682.38	2213206.62	470524.24	0.470
Gwagwa	3148687.00	4376674.93	1227987.93	1.227
Idu\ Sabon Karmo	6051128.50	8290046.05	2238917.55	2.239
Karu\ Nyanyan	27965362.00	44744579.2	16779217.2	16.779
Kubwa	13564981.00	20483121.31	6918140.31	6.918
Kuchigoro	1083860.38	1300632.46	216772.08	0.217
Lugbe	4594354.00	5880773.12	1286419.12	1.286
Zuba	4298097.50	6361184.30	2063086.80	2.063

Source: Author's Analysis, 2003

The merit of the rating approach lies in the use of satellite image-based geometrical parameters of both the FCC and the settlements studied to establish a relationship between growth in the settlements and the attraction potential of the FCC. The reference made to the 1987, 1994 and 2001 image data in the calculation is to establish a consistent development trend which takes care of possible growth fluctuations that may arise from such development constraints as land cost and affordability as well as government's acquisition and protection of land from development.

Although the approach provides estimates for future built-up areas with minimum error (Rao, 1995), its utility is limited by the short-term nature of the allowable range of future projection. The number of years of future projection is limited to the time interval of the earlier data set used. Thus, the future built-up areas estimated for the selected satellite settlements could not be taken beyond the year 2008. Projecting into a more distant future (i.e 2015) requires the data for 2008, which is not yet available.

Regression analysis is an alternative approach that could be used to predict future built-up area of the settlements. Bivariate regression analysis was computed for each of the settlements using the settlement sizes as the criterion variables and the years as the predictor variables. Using the formula: $Y = a + bx$, the regression (R) values and the coefficients (See appendix 12) were derived. As shown in table 5.22, the regression values for nine of the ten settlements range between 0.776 and 0.945 and this shows a high positive relationship between the criterion and the predictor variables. The R^2 were calculated to determine the level of prediction and the results show that between 60.2 per cent and 89.4 per cent of settlement size increases is predicted by the year variable.

Table 5.22: Regression (R) Output Values

Settlements	Regression Values	R^2	Adjusted R^2
Dutse Alhaji	0.923	0.853	0.841
Gwagwa	0.945	0.894	0.885
Idu\Sabon Karmo	0.895	0.801	0.785
Karu\Nyanyan	0.913	0.833	0.820
Kubwa	0.926	0.858	0.847
Kuchigoro	0.776	0.602	0.572
Lugbe	0.906	0.821	0.807
Zuba*	0.310	0.096	0.027

Source: Author's Analysis, 2003. * Result not significant

One major requirement of predictive models is a stable or constant relationship between the criterion and the predictor variables so as to be able to make accurate forecast (Eno Okoko, 2001). With the strong positive relationship found between the two variables in nine settlements, the prediction models for each of the settlements were written as shown in table 5.23. The forecast for any given future year is determined by substituting for the value of x

in the linear equation. Based on the model estimates, the built-up areas of the settlements were calculated for year 2008 and 2015 respectively (table 5.24).

Table 5.23: Growth Prediction Models for the Satellite Settlements

Settlements	Growth Prediction Models
Kuchigoro	$Y = 203036.4 + 44954.009x$
Gwagwa	$Y = 31923.439 + 158034.2x$
Idu\Sabon Karmo	$Y = 313485.6 + 269072.3x$
Dutse Alhaji	$Y = -271729 + 102540.1x$
Kubwa	$Y = - 2576398 + 844045.6x$
Karu\Nyanyan	$Y = - 1663322 + 1408670x$
Lugbe	$Y = - 451741 + 381829.1x$
Zuba*	$Y = - 255149333.847 + 60152534.0x$

Source: Author's Analysis, 2003.

* Result not significant

Table 5.24: Predicted Built-up Area of Settlements, 2008 and 2015

Settlements	Predicted Built-up Area	
	2008	2015
Kuchigoro	1192024.598	1506702.661
Gwagwa	3508675.839	4614915.239
Idu\Sabon Karmo	6233076.20	8116582.3
Dutse Alhaji	1984153.20	2701933.9
Kubwa	15992605	21900924.4
Karu\Nyanyan	29327418	39188108
Lugbe	7948499.20	10621302.9
Zuba	1068206414	1515374152

Source: Author's Analysis, 2003.

The predicted values presented in table 5.24 are average values of a range. The lower and the upper bonds of the regression estimates were further established to ascertain the range within which the estimated built-up areas of the settlements lie (table 5.25). The range establishes 95% confidence limit for the predicted built-up areas. This indicates that we are 95% sure that the predicted values are correct and the probability that our forecast is wrong is only 5%.

Table 5.25: Predicted Estimates and Value Range for Built-up Areas at 95% Confidence Limit

Settlements	Predicted values (2008)		Regression Estimate Range at 95% Confidence limit (2σ)	
	Rao's Estimates	Regression Estimates	Lower Bound	Upper Bound
Kuchigoro	1300632.46	1192024.598	511669.698	1872379.596
Gwagwa	4376674.93	3508675.839	2492805.6	4524545.6
Idu\Sabon Karmo	8290046.05	6233076.20	3732989.6	8733162.6
Dutse Alhaji	2213206.62	1984153.20	1190454.5	2777851.3
Kubwa	20483121.31	15992605.20	958299804	22402223
Karu\Nyanyan	44744579.2	29327418	17583181	41071634
Lugbe	5880773.12	7948499.20	3623594.8	10273403.6
Zuba	6361184.30	1068206414	- 1308688615	918796015.8

Source: Author's Analysis, 2003

The standard error values carry both positive and negative signs to be able to establish the lower and upper limits of the regression estimates. In our case, there is an indication that the standard error values carry positive signs. It is therefore realised that the estimated built-up area values derived from the use of Rao (1995)'s rating method are generally closer to upper limit values of the regression models. As seen in the table, all of the values derived from Rao's estimates fall within the range established by the 95 % confidence limit. This helps establish the reliability of Rao's approach.

The two approaches could complement each other. While the rating method incorporates elements, which relate the growth of the satellite settlements to the influence of Abuja city, the modelling approach is deterministic, mathematically more robust and offers the opportunity to forecast built-up area of the settlements into a more distant future. However, the regression model approach gives average values of a possible range rather than the actual estimates of settlement built-up area.

The forecast exercise reveals considerable future developments of the satellite settlements in the next seven years and beyond. There is the need to prepare for the challenges of the anticipated development in the settlements under consideration. One major task is the identification of areas where development is likely to take place for the purpose of planning. Section 5.8 considers the direction and pattern of future development in the area.

5.8 Directions and Pattern of Future Growth

Development pattern in the study area generally followed an east – west direction as noted earlier. The direction and pattern of future growth in the satellite settlements is considered within the context of the observed trend. In order to have the overall view of the possible areas of future development, the 2001 image data was classified into built-up area, developable land and un-developable area (figure 5.11). As shown in the map, Kuchigoro, Lugbe, Idu\Sabon Karmo and Gwagwa have the potential to grow in all directions due to absence of major development constraints. Other settlements have some development constraints. Settlement expansion in Karu\Nyanyan, for instance, is expected in the north – south and east direction, along Keffi road. Also, Kubwa is expected to grow in a north – south and southwest direction due to massive rock outcrops in the east and northwest.

Apart from the physical constraints, it is noted that other socio-economic development constraints such as the accessibility factor, presence of infrastructure, government acquisition of land, land use zoning and degree of development control as well as prices of land exist. These constraints are capable of influencing the rate and direction of growth in the satellite settlements. However, their effects are less potent than the physical barriers, not immediately determinable and are dictated by the prevailing socio-economic circumstances.

Figure 5.12 presents a static view of the distribution of developable lands. These are areas to be occupied by future developments. The spatial distribution of the developable areas gives a good indication of pattern of future development and areas where planning and development control should focus in the years ahead.

5.9 Conclusion

The foregoing analysis reveals substantial urban growth in Abuja and environs in the past twenty-five years. As it were, the construction of FCC and the eventual movement of the Federal capital to Abuja sparked off tremendous physical development activities in the hitherto small and stagnating rural settlements in the early 1980s. The trend of growth generated in the formative years (1976 – 1987) was sustained in the 1994 – 2001 period. Estimation of future growth of the settlements reveals that about 23.928 Km^2 of new developments are expected by the year 2008. The anticipated growth will have to be managed to ensure proper functioning of these settlements in the future.

FIGURE 511: SIZES OF SELECTED SETTLEMENTS IN 2008 AND DEVELOPABLE/UNDEVELOPABLE LAND

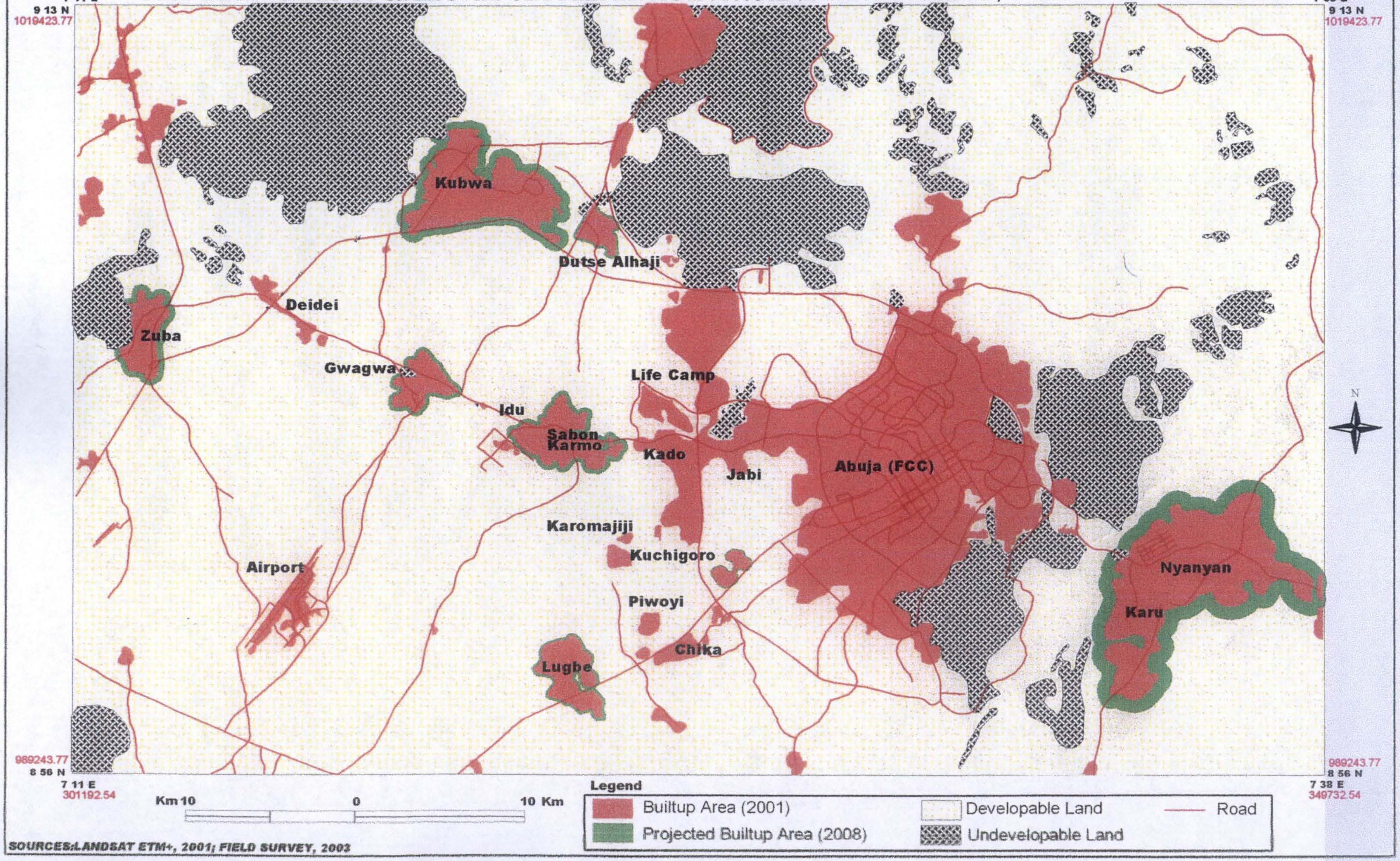
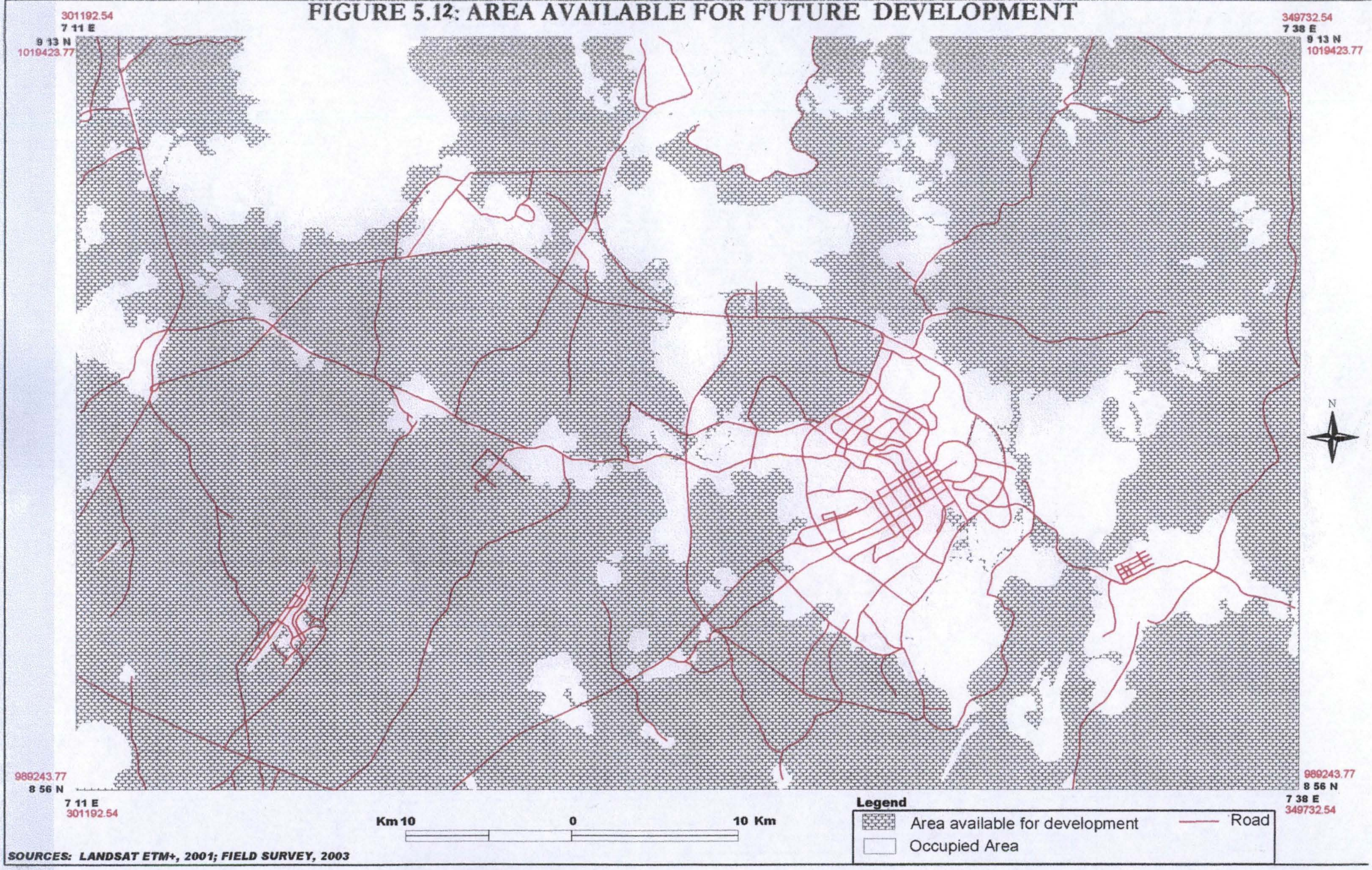


FIGURE 5.12: AREA AVAILABLE FOR FUTURE DEVELOPMENT



SOURCES: LANDSAT ETM+, 2001; FIELD SURVEY, 2003

CHAPTER SIX

6.0 DISCUSSION OF FINDINGS, RESEARCH BENEFITS\ IMPLICATIONS AND DIRECTION FOR FURTHER RESEARCH

6.1 Introduction

This chapter presents and discusses the findings of the analysis carried out in chapters four and five of this thesis. It highlights the research outcomes and benefits, indicating the implications of the findings and practical policy requirements for addressing the issues raised. The chapter concludes with an indication of the direction for further research.

6.2 Discussion of Findings

The elements of human landscape are affirmed to be in a constant flux of continuous change due to natural processes and human activities. Some of the findings of this research confirm this global assertion. At the onset, the study presents the accounts of various authors, which help establish that the settlements in the FCT had undergone dynamic development processes of disintegration, migration, amalgamation, displacement and relocation. These historic processes are observed to give context to the spatial distribution of settlements that we see today.

The study established that the distribution pattern of settlements in the FCT is clustered. The results of the quadrat count and nearest neighbour analyses carried out thus give empirical statistical validity to the subjective assertions of some authors like Doxiadis Associates (1983) and disprove others like Gaza (1990) and MFCT (1999) who opined that the settlements are evenly spread, suggesting a regular pattern.

The study also noted a departure from the nature of spatial interaction in the pre- FCC period as discussed by authors like Nadel (1951) and Doxiadis and Associates (1983). With the construction of the FCC, the nature of spatial interaction is observed to have departed from the small-scale mother – daughter relationship that characterised the early rural centres and subsystems to a more complex one. The mapping of the mean interaction field of Abuja and the study of the nature of interaction within the field revealed the type of highest order – lower order settlement relationship described by Walter Christaller (1933).

The urban field mapping exercise shows that the mean field of the FCC (otherwise referred to as area of intensive and\or effective interaction) covers an area of 1,678.17 km^2. The 128 satellite settlements within the zone are found to continuously interact with Abuja city on hourly and daily basis. The daily interaction is noted to exhibit a pattern dictated by the home – workplace relationship that exist between Abuja and the satellite settlements. Our findings on the nature of interaction thus reveal an influx of people into the city in the early hours of the day (7.00 am – 11.00 am) and an exodus in the evening hours (3.00 pm – 7.00 pm). The high volume of daily traffic observed in the area expresses the intensity of interaction.

Generally, the pattern of interaction found in the area shows the work-day-length and time-of-the-day effect, which condition the travel behaviour of the people. This finding conforms to that of Mehendiratta et al. (2001) who came up with similar finding in his study of intercity business travels in California, USA.

Chapter five of the study presents a time series analysis of the general level of urban expansion and the growth of some selected settlements between 1976 and year 2001. First, the study establishes that there was no urban settlement in the area in 1976. The analysis revealed that only 1.22 km^2 (0.1%) of the area was occupied settlements which were mainly hamlets and villages. The findings thus help confirm the assertions of Mabogunje and Abumere (1981), Olusule (1987) and Balogun (2001) which established that the FCT was less developed, agrarian and occupied by settlements which can not be described as urban.

The construction of the FCC commenced in 1980. Urban growth monitored in the post 1980 period reveals a significant change in the 1976 situation. The built-up area statistic generated from the 1987 Landsat TM image shows that minor and major urban growth had occurred in the area with settlements' built-up area increasing from 1.22 km^2 in 1976 to 31.32 km^2 in 1987. The tempo of urban growth was found to increase with massive construction activities in the formative years and the subsequent transfer of the Federal capital from Lagos to Abuja in 1991.Consequently, the level of urban growth in the area increased from 31.32 km^2 in 1987 to 111.52 km^2 in 1994 and to 119.5 km^2 in the year 2001.

The time series analysis generally reveals a spectacular urban growth in the study area in the post FCC period. Major urban expansion within the 25-year period was recorded in Abuja city, which accounted for 50.6 %, 60.7% and 52.7% of the total built-up area in 1987, 1994 and 2001 respectively.

Against the background of the rapid rate of urban expansion, the growth of ten satellite settlements was monitored. Research findings show that most settlements, which remained rural for several decades back, experienced little growth in the formative years of the FCC. Within a period of eleven years (1976 – 1987) the newly created settlement area of eight of the settlements was below 1 km^2 each while only Karu and Nyanyan had slightly above 1

km^2 each. This indicates that little development impact was felt in the satellite settlements in the early construction days of Abuja.

The study establishes that the rate of growth picked up all in all the settlements in the 1987 – 1994 period and this culminated into the tremendous growth experienced in the 1994 – 2001 period. Although the rate of growth stabilised over the years, the amount of physical development experienced in the 1994 – 2001(7 years) period was found to be more than that of 1976 – 1994 (18 years) put together. This finding thus indicates that more development impact (growth) was felt in the satellite settlements after the FCC became fully functional as the administrative capital of Nigeria.

It is noted that the physical growth of the settlements was matched with population growth and socio-economic development. Using the indices of size, population density, occupational difference and socio-economic diversity as parameters for rural – urban dichotomy (as discussed by Smith and Zopt, 1970), the study concluded that the satellite settlements studied have transformed from rural in the pre-FCC to urban settlements in the post-FCC period.

The study demonstrated the utility of remote sensing and GIS data\tools in large-scale regional study, which will otherwise be difficult and costly if not impossible to achieve within the limited time framework of this research. This further proved that remote sensing and GIS are powerful tools for cost effective and speedy large-scale time series analysis of the elements of the earth's surface. This confirm the assertions of several authors like Shang Yang et al (2001), Annrong et al. (2002) and Yu-Cheng-Ming et al. (2002) who established the effectiveness of remote sensing data and tool in the study of long-term urban expansion and dynamics.

Despite the immense advantage of the remote sensing data, the study notes its limitation in the collection of non-spatial socio-economic data necessary to explain the growth of the satellite settlements. Besides, the resolutions of the images used are low such that they could not provide information on the nature and quality of the development observed over the years. These limitations necessitated the use of the traditional ground survey method to collect information on the variables that explain settlement growth as well as the nature of physical development in the study area. The combined use of remote sensing and ground data in this study emphasises the basic fact that remote sensing data could hardly be used alone but that it combines favourably with other reference data in all social science studies.

Amongst others, the study reveals that five major factors explain the rapid growth of the satellite settlements. These are: nearness to Abuja and ease of commuting, population increases due to spill over from Abuja, availability of cheaper accommodation in the satellite settlements, cheap land for development in the satellite settlements and increase in the rate of car ownership. These factors show strong relationship (with correlation coefficient values of between 0.733 – 0.919) with settlement growth. However, the stepwise regression analysis shows that only two of the factors adequately explain growth, the other three factors being redundant variables. Thus the model for explaining rapid settlement growth in the study area was written as:

Y= 474455.5 + 37962.9 (nearness to Abuja and ease of commuting) – 21921.0 (population increases due to spill over from Abuja)

This finding partly agrees with that of Phal (1966) who recognised the presence of the 'reluctant commuters', forced out of the city by high property prices in North London. It however differs significantly from the findings of Spencer and Goodall (1992), which associated rural settlement growth with shift in industrial investment to rural localities, growth of rural service sector, back to the land sub-culture of ex-urbanites and that of Mutambirwa (1998) which linked urban – rural return migration in Zimbabwe to urban workers retrenchment.

With respect to the nature of physical development, the study reveals that development in most of the settlements is largely unplanned. Planned physical development is restricted to parts of Karu, Nyanyan and Kubwa while large-scale urban slums have developed in Kuchigoro, Zuba, Gwagwa, Idu, Sabon Karmo and Dutse Alhaji. The high population concentration and rapid settlement growth are found to have some negative consequences, which include overcrowding, poor facility and services, general poor environmental quality as well as increasing crime and social vices. Our findings on crime increase corroborate that of Agbola (2002) who noted that reported cases of crime (e.g armed robbery, fraud and car theft) in the FCT rose from 125 in 1999 to 410 in the year 2000 and that Idu – Karmo axis, Nyanyan, Karu, Dutse Alhaji and Zuba were among the hot spots identified by the Nigerian Police Force.

In the final analysis, the study demonstrated how the rating method and regression analysis could be used to estimate future growth of the settlements. It establishes the tendency for a consistent trend in the future growth of the settlements. The estimated growth values for year 2008 shows that the rate will further stabilise in the years ahead. However, the expected size increases of 2.239 km^2 for Idu\Sabon Karmo, 3.934 km^2 for Kubwa and 12.584 km^2 for

Karu\Nyanyan are still considered as substantial. The current situation in the satellite settlements therefore has the tendency for future complication. Section 6.3 considers the benefits and implications of research findings as well as desirable policy response to manage the growth of the settlements.

6.3 Research Benefits, Implications and Policy Requirements

The benefits of the research findings are immense. First, the findings afford us the opportunity to identify the area coverage of the mean interaction zone of the FCC, the settlements and the estimated resident population as well as the nature of spatial interaction within the zone. This provides useful data for physical development and facility planning in the area. The fact that Abuja and the settlements within the mean interaction zone now function more or less as a single spatial entity has some planning implications. It shows that developments in any part of the zone will affect the entire spatial entity. Since a sizable proportion of the residents of the satellite settlements spend the greater part of their daily and weekly lives in the city, the planning and infrastructure provision in Abuja has to be done in cognisance of the needs of the entire population of the settlements within the zone. The level of interaction found also has implications for road improvement, sub-regional road construction as well as the provision of effective mass transit system to manage the high volume of traffic observed along the major intercity route axes.

The empirical findings on the rapid rate of settlement growth portend the need for development control. The inability of the FCC to cope with new entrants and its consequence on population build up and the rapid, poor physical development in the satellite settlements reveals official insensitivity and, to a large extent, poor implementation of the Abuja Master Plan. The general poor quality of development (slums) captured in this research and its negative consequences such as overcrowding, poor infrastructure and services, rising crime and social vices have severe implications for the well-being of the residents as well as the existence and functioning of Abuja city. The crime and the anti social activities building up in many of the satellite settlements are potential sources of urban violence and this has implications for effective policing and crime control in the area.

The haphazard development that occurred in most of the settlements studied is a testimony to the laissez-fair planning attitude, which is considered unacceptable in modern societies. This poor planning attitude was identified in the report of the Ministerial Committee for the appraisal of physical planning and development issues in the FCT in 1999. Amongst others, the committee identified the inability of the Zonal Planning Offices to prepare and implement Action Plans for the satellite settlements, poor coordination among the Zonal Offices, the Area Councils and Traditional Institutions as well as poor development control due to manpower and material shortage as the major problems inhibiting effective planning and land administration in the FCT. The manifestation of these problems is the development sprawl we see on the ground today.

One major benefit of this research is the practical demonstration of the nature and dimension of development problems in the study area. The population projection and the estimation of settlement sizes by the year 2008 provide ample data for future planning and development control. Besides, the spatial mapping of the areas of possible future development provides direction for areas where attention should focus in the years ahead. What is left is the evolution of a pragmatic settlement planning policy for Abuja and its satellite settlements.

Based on the findings of this study, an integrated settlement policy, which considers Abuja and the settlements within its mean field as a single spatial entity, is recommended. The policy should focus on the preparation of Strategic Action Area Plan, which will tackle the immediate problems of the satellite settlements. In this regard, a rapid response physical planning Task Force should be constituted within the Urban and Regional Planning Division of the FCDA to urgently arrest the situation in the satellite settlements. The Task Force should be concerned with harmonization of land interests, regularisation of tenure for those who acquired land through the traditional land tenure system, settlement upgrading and planning of the new areas of the settlements. The recommended strategy for renewal programme implementation is settlement improvement. Eviction and large-scale demolition should be discouraged because they are socially and economically costly. Experiences all over the world have shown that slum demolition is not a planning solution but only leads to the re-emergence of slum(s) elsewhere. A renewal scheme that involves the stakeholders in settlement upgrading efforts should therefore be instituted to manage the situations in the satellite settlements.

There is also the need to accelerate the implementation of Abuja Master Plan. Phases II and III of the city should be opened up for development and adequate low-income houses should be provided to house government workers and the city's service population. Where government could not provide housing directly, different enabling strategies such as easy access to land, site and services, private estate development and cooperative housing should be put in place to make decent houses available for the majority. This will stem the tide of the population spill over effect which a major factor contributing to urban sprawl in the satellite settlements.

6.4 Direction for Further Research

Amongst others, this research sets out to monitor urban growth and the nature of physical development in the selected settlements. It is noted in section 5.6 of the thesis that the nature and\or quality of physical development in the area could not be mapped directly from the satellite images used due to low spatial resolutions. Hence the use of digital camera for ground survey. At best, the camera captured micro scenes as showcases of the nature of physical development. In the light of the recommended settlement upgrading, further studies should be directed towards large-scale mapping of slum development in the area.

The capability of satellite image data to map detail elements of urban landscape has been enhanced in the recent times. Revolution in remote sensor development has greatly improved space imaging with the ability to produce 0.6 and 1-metre resolution colour images. The Ikonos (1 to 4 – meter resolutions) and the Quickbird (0.6 – meter resolution) images could therefore be acquired to identify and map improvement areas in the satellite settlements. Efforts should be made to use these images and GIS to create a database of the houses, infrastructure and other socio-economic characteristics of the improvement areas for the purpose of physical planning.

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Appendix 1: Sample Questionnaire.

(19)

ANALYSIS OF URBAN INFLUENCE ON RURAL SETTLEMENT GROWTH AND ENVIRONMENTAL CHANGE IN THE FEDERAL CAPITAL TERRITORY (FCT) USING REMOTELY SENSED DATA.

QUESTIONNAIRE FOR RESIDENTS OF SATELLITE SETTLEMENTS

Dear Respondents,

This questionnaire is designed to collect information on the growth of satellite settlements of Abuja. The information required is purely for academic purpose. All information supplied will therefore be treated as confidential. Thanks for your co-operation.

Please **Fill in** or **Tick** as appropriate

1. Name of Settlement...Kubwa Village..............
2. Area Council.....Bwari...
3. Settlement Status: (a) Legal/Permanent (✓) (b) Illegal/Temporal ( )
   (c) Others (Specify)...

4. Nature of Settlement: (a) Planned (✓) (b) Unplanned ( )

5. Age of building.........10 years................

6. Building Type: (a) Small detached bungalow ( ) (b)Traditional Compound building ( )
   (c) Flat apartment (✓) (d) Duplex (e) Others (specify).............................

7. Age of Respondents: (a) 18-20 years ( ) (b) 21-30 years ( )(c) 31-40 years (✓)
   (d) 41-50 year ( ) (e) 51-60 years ( ) (f) 61 years and above ( ).

8. Sex: (a) Male ( ) (b) Female (✓)

9. Educational Background:(a) No formal education ( ) (b) Primary Education ( )
   (c) Secondary education ( ) (d) Tertiary education (✓) (e) Arabic education ( )

10. Occupation: (a) Farming ( ) (b) Trading ( ) (c) Artisans ( ) (d) Civil Servant (✓) (e) Private Business Employee ( ) (f) Unemployed ( )
    (f) Others (Specify)...
11. Income per month : (a) Less than 5,000.00 ( ) (b) 5 - 10,000.00 ( )
    (c) 11 - 15,000.00 ( ) (d) 16 - 20,000.00 (✓) (e) 21-25,000.00 ( )
    (f) 26 - 30,000.00 ( ) (g) 31 – 35,000.00 ( ) (h) 36 – 40,000.00 ( )
    (i) Above 40,000.00 ( )
12. Household Size: ...Average.....

13. Please give the following information on each member of your household.

S\No.	Age	Sex	Education	Occupation
1	48	m	Tertiary	Medical Practitional
2	40	f	Tertiary	Civil Servant
3	30	f	Tertiary	Civil Servant
4	23	m	Secondary	Unemployed

14. Residence status: (a) Owner occupier ( ) (b) Tenant (✓) (c) Others............

15. How long have you been residing in this settlement: (a) < 5 years (✓) (b) 5 – 10 years ( ) (c) 11 - 15 years (d) 16 – 20 years ( ) (e) above 20 years ( )

16. Give reasons for residing in this settlement
(a) Not as expensive as the city centre
(b) Not too far from the city centre and well developed

17. Where is your place of work located? Kubwa ....(LGA). Bwari ....

18. With reference to your place of work, where would you have preferred to reside?.. Abuja city centre ......

19. If your answer to question 18 is Abuja, rank the following reasons in order of importance for not residing in Abuja (e.g 1st, 2nd, 3rd)
(a) Accommodation shortage and high rent ....1st..........
(b). High cost of living................3rd..................
(c) High cost of land for development.......2nd...............

20. Please specify any other reason(s)..

21. Do you agree that this settlement has grown in size over the years? (a) Yes (b) No

22. If yes, in which of the following areas have you noticed the most significant changes.
(a) High population increases ( ) (b) High rate of building construction ( )
(c) Increases in settlement size ( ) (d) Increases in commercial activities ( )
(e) All of the above (✓)

23. How will you qualify the growth of this settlement in the past 10 years? (a) Very rapid (✓)
(b) Rapid ( ) (c) Moderate ( ) (d) Slow ( ) (e) Very slow ( )

24. Mention some of the factors in order of importance that helps explain the observed growth (i) Inflow of people from other states due to fight,
(ii) City centre is filled up and no accomodation.
(iii) Well planned with vast land that is affordable.

25. How will you rate the following factors of growth in this settlement? (e.g 1st, 2nd, 3rd)
(a) Nearness to Abuja city and ease of commuting....4th..........
(b) Population increases due to spill over from Abuja.....1st..............
(c) Availability of cheaper accommodation in this settlement..2nd..........
(d) Cheap land for development in this settlement....3rd..................
(e) Increased rate of car ownership........5th......................

26. Please mention some of the negative consequences of rapid growth noticeable in this settlement. (i) High cost of rent and over population........
(ii) High cost of land...
(iii) ..Insecurity...

27. Give suggestions on how to control the growth of this settlement to prevent future Problems. Develop other satellite towns...............

Appendix 2; Sample Data Collection Structure for Urban Field Delimitation

ANALYSIS OF URBAN INFLUENCE ON RURAL SETTLEMENT GROWTH AND LAND USE\LAND COVER CHANGE IN THE FEDERAL CAPITAL TERRITORY (FCT) USING REMOTELY SENSED DATA.

DATA SHEET FOR BUS SERVICE AND COMMUTING

Selected Motor Park.. Location ....

S \No.	Bus Route	Distance From Abuja (Km)	Average No. of buses per route	Daily average Trip per bus
1	Abuja-Nyanya-Keffi	50	350	5
2	Abuja - Karu		″	″
3	″ - Nyanya		″	″
4	″ - Mararaba		″	″
5	″ - New Nyanya		″	″
6	″ - Masaka		″	″
7	″ - Keffi		″	″
8				
9	Abuja-Karmo-Gwagwa	30	215	6
10	Abuja-Utako		″	″
11	″ - Jabi		″	″
12	″ - Life Camp		″	″
13	″ - Kado		″	″
14	″ - Karmo		″	″
15	″ - Idu		″	″
16	″ - Tasha		″	″
17	″ - Gwagwa		″	″
18				
19	Abuja-Zuba-Suleja	45	510	3
20	Abuja-Gwarimpa		″	″
21	″ - Galadima		″	″
22	″ - Dutse Alh.		″	″
23	″ - Kubwa		″	″
24	″ - Diedie		″	″
25	″ - Zuba		″	″
26	″ - Madalla		″	″
27	″ - Suleja		″	″
28				″
29	Abuja-Kuje-Gwagwalada	54	70	3
30	Abuja - Karomajiji	″	″	″
	″ - Kuchiko	″	″	″
	″ - Aleita	″	″	″
	″ - Pinnyi	″	″	″
	″ - Gaube	″	″	″
	″ - Kuje	″	″	″
	″ - Gwagwalada	″	″	″

Appendix 3: Chi-Square Computation for Settlement Cluster Analysis

Sett.\quadrat	Municipal	Bwari	Gwagwalada	Kuje	Abaji	Kwali	RT
0	42 (48)	28 (30)	24 (24)	53 (47)	36 (32)	31 (33)	214
1	33 (36)	27 (22)	19 (18)	36 (35)	18(24)	26 (24)	159
2	23 (17)	9 (10)	9 (8)	15 (17)	7 (11)	12 (12)	75
3-7	11 (9)	4 (6)	3 (5)	4 (9)	12 (6)	5 (6)	40
CT	109	68	55	108	73	75	488

RT = row total
CT = column total
GT = grand total

Expected values = $\frac{RT \times CT}{GT}$

Note: Expected values in brackets in the table

$$\chi^2 = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{\{0ij - \Sigma ij\}}{\Sigma ij}$$

$$\chi^2 = \frac{(42-48)^2}{48} + \frac{(28-30)^2}{30} + \frac{(24-24)^2}{24} + \frac{(53-47)^2}{47} + \frac{(36-32)^2}{32} + \frac{(31-33)^2}{33} +$$

$$\frac{(33-36)^2}{36} + \ldots\ldots + \frac{(6-6)^2}{6}$$

χ^2 = 0.75 + 0.13 + 0.0 + 0.77 + 0.50 + 0.12 + 0.25 +..................+ 0.0

χ^2 = 20.15 (calculated value)

Degree of freedom (DF) = (r – 1) (c – 1) = (4 – 1) (6 – 1)

DF = (3) (5) = 15

Table value at DF = 15 and 0.1 alpha level = 37.70

Table value at DF = 15 and 0.5 alpha level = 32.80

H_0 =There is no significant variation in settlement clustering across the Area councils of FCT

H1 = There is significant variation in settlement clustering across the Area councils of FCT

Decision: Result not significant at 0.1 alpha level, therefore H_0 is accepted

Appendix 4: Nearest Neighbour Statistics Output Table

Distance	ProbAllPnt	Prob1Pnt	Prob2Pnt	Prob3Pnt	Prob4Pnt	Prob5Pnt	Prob6Pnt
0.0	0.0000	0.0211	0.0000	0.0000	0.0000	0.0000	0.0000
0.0	0.0001	0.0379	0.0000	0.0000	0.0000	0.0000	0.0000
0.0	0.0002	0.0779	0.0021	0.0000	0.0000	0.0000	0.0000
0.0	0.0003	0.1158	0.0147	0.0000	0.0000	0.0000	0.0000
0.0	0.0004	0.1495	0.0253	0.0021	0.0000	0.0000	0.0000
0.0	0.0005	0.1811	0.0379	0.0042	0.0000	0.0000	0.0000
0.0	0.0006	0.2337	0.0442	0.0126	0.0000	0.0000	0.0000
0.0	0.0007	0.2737	0.0568	0.0168	0.0021	0.0000	0.0000
0.0	0.0009	0.3305	0.0716	0.0274	0.0084	0.0000	0.0000
0.0	0.0011	0.3747	0.0947	0.0274	0.0168	0.0000	0.0000
0.0	0.0013	0.4379	0.1158	0.0421	0.0232	0.0063	0.0021
0.0	0.0017	0.5011	0.1874	0.0653	0.0274	0.0126	0.0021
0.0	0.0018	0.5263	0.2084	0.0821	0.0316	0.0147	0.0042
0.0	0.0022	0.6084	0.2632	0.1074	0.0463	0.0211	0.0063
0.0	0.0027	0.6589	0.3453	0.1537	0.0674	0.0358	0.0147
0.0	0.0032	0.7032	0.4063	0.2189	0.1032	0.0400	0.0189
0.0	0.0037	0.7411	0.4926	0.2779	0.1242	0.0568	0.0232
0.0	0.0045	0.8189	0.5874	0.3621	0.2042	0.0884	0.0400
0.0	0.0055	0.8716	0.6842	0.4632	0.2779	0.1537	0.0800
0.0	0.0065	0.9179	0.7537	0.5663	0.3537	0.2295	0.1200
0.0	0.0075	0.9495	0.8232	0.6463	0.4505	0.2905	0.1853
0.0	0.0086	0.9621	0.8716	0.7284	0.5537	0.3895	0.2505
0.0	0.0103	0.9768	0.9116	0.8063	0.6758	0.4989	0.3853
0.0	0.0121	0.9832	0.9432	0.8611	0.7642	0.6295	0.4947
0.1	0.0141	0.9958	0.9684	0.9179	0.8379	0.7389	0.6274
0.1	0.0166	0.9958	0.9811	0.9516	0.8968	0.8211	0.7453
0.1	0.0202	1.0000	0.9937	0.9726	0.9453	0.8968	0.8463
0.1	0.0243	1.0000	1.0000	0.9937	0.9726	0.9389	0.9053
0.1	0.0291	1.0000	1.0000	0.9979	0.9853	0.9768	0.9537
0.1	0.0344	1.0000	1.0000	0.9979	0.9895	0.9874	0.9768
0.1	0.0416	1.0000	1.0000	0.9979	0.9979	0.9937	0.9832
0.1	0.0488	1.0000	1.0000	1.0000	0.9979	0.9958	0.9937
0.1	0.0580	1.0000	1.0000	1.0000	1.0000	0.9979	0.9979
0.1	0.0674	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.0779	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.0990	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.1109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.1349	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.1601	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.1875	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.2149	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.3	0.2597	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.3	0.3035	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.3	0.3512	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.4	0.3991	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

0.4	0.4467	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.4	0.5101	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.5	0.5749	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.5	0.6376	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.6	0.7103	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.6	0.7917	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.7	0.8601	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.8	0.9183	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.8	0.9536	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.9	0.9781	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0	0.9912	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.1	0.9976	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.2	0.9998	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
?	?						

Appendix 5: Settlement Within the Mean Field of FCC and their 1991 Population

ID No.	Settlement	Population	ID No.	Settlement	Population
1	Gwagwalada	19,288	62	Kubwa	15,960
2	Kuje	5,872	63	Bazango	428
19	Igu	1,026	64	Kagini 1	668
21	Gaba 1	398	65	Dakwa	218
22	Gaba 2	Na	66	Tunga Samu	Na
23	Sabon Gari	209	67	Zuba	5,373
24	Guto	302	68	Rafin Daidayi	521
25	Bwari	7,351	69	Bahusa	Na
26	Gyeidna	Na	70	Kagini 2	Na
27	Sunape	299	71	Sabuyi	Na
28	Payi	389	72	Zauda	Na
29	Piko	248	73	Jiwa	11,886
30	Shere Koro	529	74	Gwagwa	1,502
31	Shere Gwari	Na	75	Kasana 1	Na
32	Galuyi	Na	76	Kasana 2	Na
33	Dankuru	Na	77	Bwasere	Na
34	Baupe	491	78	Tatajiya	Na
35	Zango	Na	79	Idu	3,605
36	Durumi	714	80	Sabon Karmo	8,483
37	Jikoko	Na	81	Gwaripa	612
38	Mashsfa	Na	82	Kado	1,309
39	Npape	1,068	83	Karmo Tsoho	859
40	Gurushe	Na	84	Mabushi	1,197
41	Nukuchi	385	85	Wupa	Na
42	Shishipe	Na	86	Kukwaba	702
43	Pedagma	Na	87	Karomajiji	Na
44	Jimpe	Na	88	Kuchigoro	924
45	Kwarana	Na	89	Jidu	Na
46	Kabusa Koro	1,320	90	Pajife	Na
47	Kubabo	Na	91	Hulumi	723
48	Jigakuchi	384	92	Danama	Na
49	Galadima	1,066	93	Lugbe	1,339
50	Dutse Koro	682	94	Pyakasa	638
51	Dutse Alhaji	1,984	95	Galadimawa	1,066
52	Sagwari	912	96	Lokogwom	Na
53	Baufa	Na	97	Kabusa	1,320
54	Dakuma	Na	98	Sherete	790
55	Bunko	Na	99	Kutubuyi	Na
56	Ushafa	1,150	100	Pazama	Na
57	Guito	Na	101	Waru	510
58	Kuchibuyi	479	102	Sabon Pigba	195
60	Chikakore	Na	103	Kusape	Na
61	Byazhin	436	104	Kago	Na

Number the table

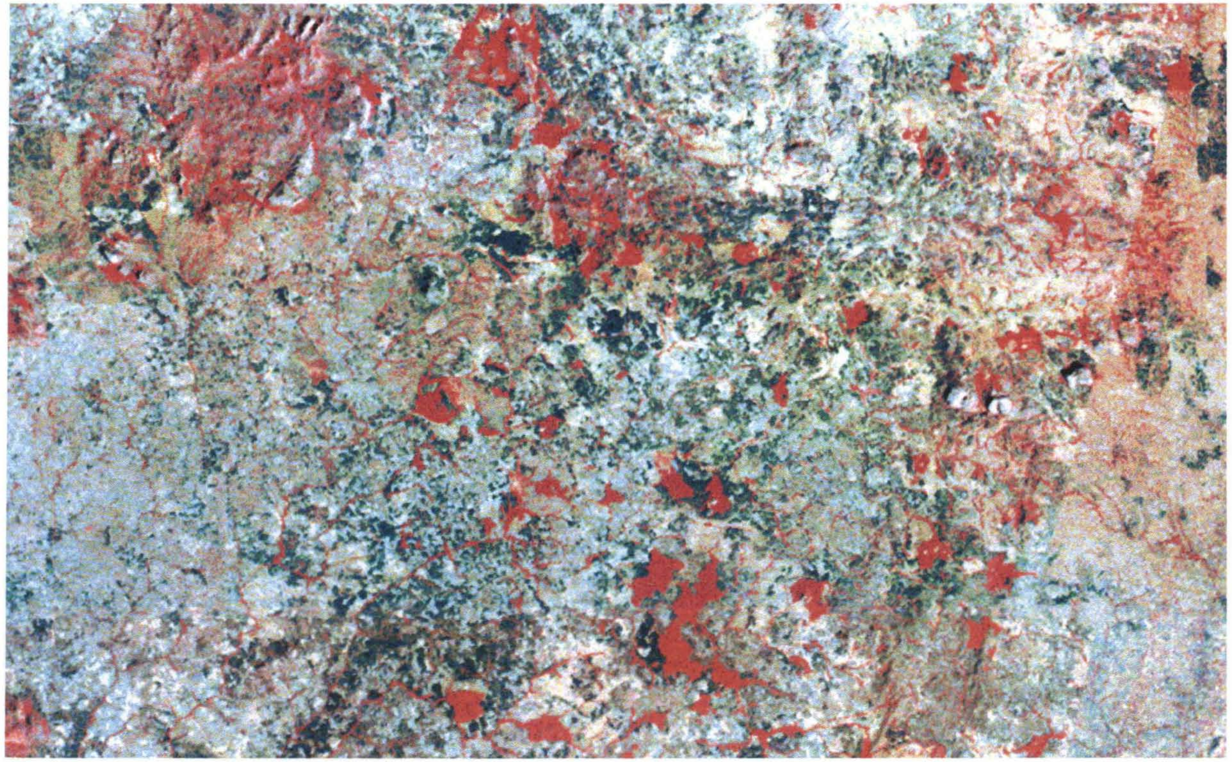
ID No.	Settlement	Population	ID No.	Settlement	Population
105	Karunduma	734	126	Rafin Pa	Na
106	Poroko	Na	127	Giri	1,864
107	Boyi	Na	128	Gudaba	Na
108	Nyayan	20,748	129	Baban Kurmi	418
109	Karu	14,397	130	Bamishi	Na
110	Kabin Madaki	513	131	Kuyi	Na
111	Tunga Madaki	558	132	Rige	Na
112	Yalwa Zuba	Na	135	Barwa	Na
113	Shishida	Na	150	Sherete Cheche	Na
114	Tungan Pa	Na	151	Buru	Na
115	Mailumi	Na	155	Gbawu	635
116	Tunga Ali	Na	156	Jikwoyi	1,012
117	Idon Kasa	Na	157	Kurudu	643
118	Mabuchi 2	Na	158	Ajata	Na
119	Sauka	Na	297	Petti	681
120	Gulpma	652	298	Chukuku	704
121	Bassa Jiwa	Na	299	Kiyi	861
122	Toge	472	300	Chibiri	1,308
123	Kwalita	862	302	Ekpa	Na
124	Saguja	Na	303	Tunga Maje	1,765
125	Idon Bisa	407	304	Hanagada	386

Note: (i) Na = Figure not available

(ii) Total 1991 population of Settlements + Population of Abuja = 207, 492

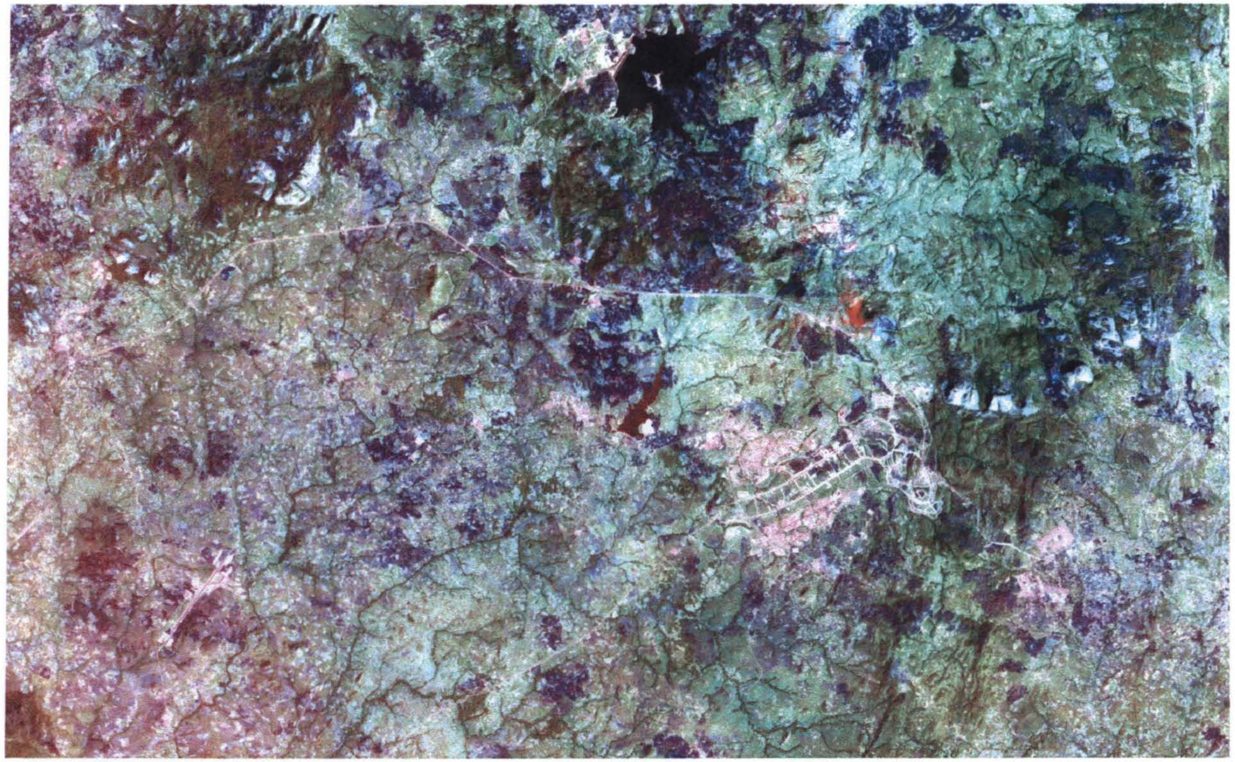
(iii) Projected Total Population for year 2003 = 313, 535 Approximately

Appendix 6: landsat MSS, 1976



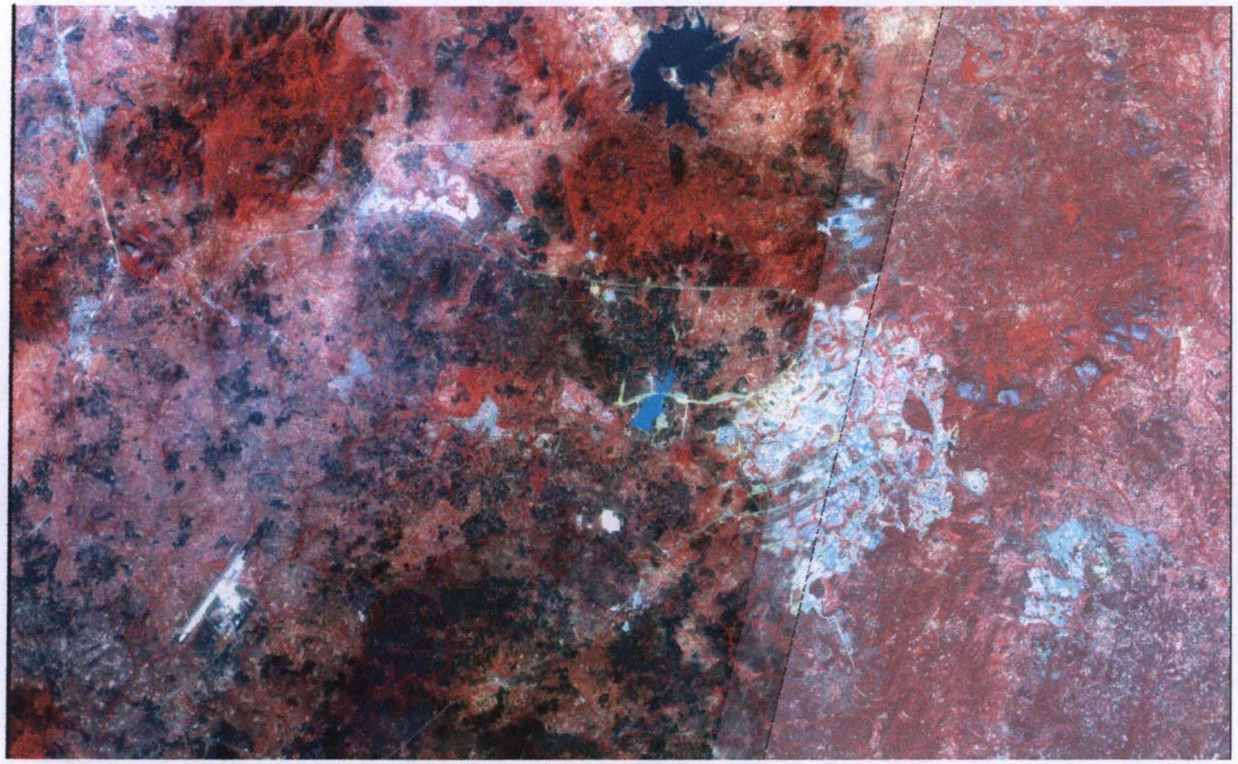
Scale 1:10, 000

Appendix 7: Landsat TM, 1987



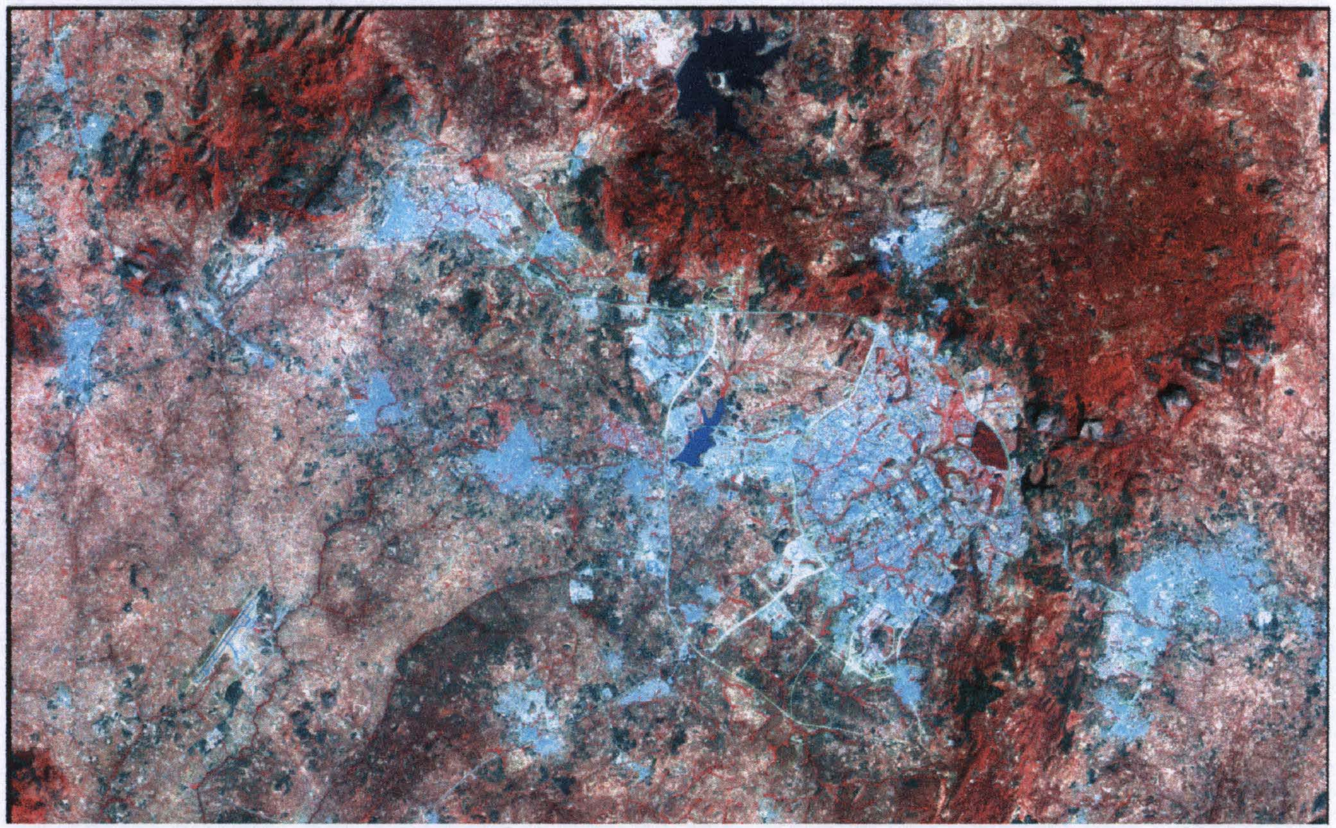
Scale 1 : 10,000

Appendix 8 : SPOT XS, 1994



Scale 1: 10, 000

Appendix 9 : Landsat ETM+, 2001



Scale 1 : 14, 161,935

Appendix 10: SPSS 9.0 Summary Statistic Output.

Accommodation shortage and high rent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	345	39.8	61.3	61.3
	2	164	18.9	29.1	90.4
	1	54	6.2	9.6	100.0
	Total	563	64.9	100.0	
Missing	System	304	35.1		
Total		867	100.0		

Area council

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Municipal	641	73.9	73.9	73.9
	Bwari	193	22.3	22.3	96.2
	Gwagwalada	33	3.8	3.8	100.0
	Total	867	100.0	100.0	

Area of most significant change

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High population increases	148	17.1	17.2	17.2
	High rate of building construction	62	7.2	7.2	24.4
	Increases in settlement size	30	3.5	3.5	27.8
	Increases in commercial activities	16	1.8	1.9	29.7
	All of the above	606	69.9	70.3	100.0
	Total	862	99.4	100.0	
Missing	System	5	.6		
Total		867	100.0		

Availability of cheaper accommodation in the sett

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	168	19.4	21.4	21.4
	4	236	27.2	30.0	51.4
	3	225	26.0	28.6	80.0
	2	139	16.0	17.7	97.7
	1	18	2.1	2.3	100.0
	Total	786	90.7	100.0	
Missing	System	81	9.3		
Total		867	100.0		

Building Type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small detached bungalow	220	25.4	25.6	25.6
	Traditional compound building	280	32.3	32.6	58.1
	Flat apartment	348	40.1	40.5	98.6
	Duplex	6	.7	.7	99.3
	Others	6	.7	.7	100.0
	Total	860	99.2	100.0	
Missing	System	7	.8		
Total		867	100.0		

Cheap land for development

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	48	5.5	6.1	6.1
	4	111	12.8	14.1	20.2
	3	194	22.4	24.7	44.9
	2	298	34.4	37.9	82.8
	1	135	15.6	17.2	100.0
	Total	786	90.7	100.0	
Missing	System	81	9.3		
Total		867	100.0		

Do you agree that sett has grown over the years?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	858	99.0	99.4	99.4
	No	5	.6	.6	100.0
	Total	863	99.5	100.0	
Missing	System	4	.5		
Total		867	100.0		

Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No formal education	20	2.3	2.3	2.3
	Primary education	46	5.3	5.3	7.6
	Secondary education	284	32.8	32.8	40.4
	Tertiary education	509	58.7	58.7	99.1
	Arabic education	8	.9	.9	100.0
	Total	867	100.0	100.0	

Factors of growth

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Proximity to Abuja city	64	7.4	11.0	11.0
	Business opport. in this sett. and job opport. in Abuja	86	9.9	14.8	25.8
	Population increases due to in-migration	241	27.8	41.4	67.2
	Transfer of Fed. capital from	96	11.1	16.5	83.7

	Lagos to Abuja				
	Housing availability and cheap rent	74	8.5	12.7	96.4
	Availability of amenities	21	2.4	3.6	100.0
	Total	582	67.1	100.0	
Missing	System	285	32.9		
Total		867	100.0		

Higfh cost of land for development

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	84	9.7	15.1	15.1
	2	139	16.0	25.0	40.1
	1	333	38.4	59.9	100.0
	Total	556	64.1	100.0	
Missing	System	311	35.9		
Total		867	100.0		

High cost of living

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	136	15.7	24.4	24.4
	2	253	29.2	45.3	69.7
	1	169	19.5	30.3	100.0
	Total	558	64.4	100.0	
Missing	System	309	35.6		
Total		867	100.0		

Income

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 10,000.00	113	13.0	15.2	15.2
	10,000.00 - 20,000.00	381	43.9	51.3	66.5
	21,000.00 - 30,000.00	152	17.5	20.5	86.9
	31,000.00 - 40,000.00	64	7.4	8.6	95.6
	Above 40,000.00	33	3.8	4.4	100.0
	Total	743	85.7	100.0	
Missing	System	124	14.3		
Total		867	100.0		

Increased rate of car ownership

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	14	1.6	1.8	1.8
	4	22	2.5	2.8	4.6
	3	83	9.6	10.6	15.2
	2	80	9.2	10.2	25.5
	1	582	67.1	74.5	100.0
	Total	781	90.1	100.0	
Missing	System	86	9.9		
Total		867	100.0		

Location of place of work

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Abuja city	438	50.5	58.9	58.9
	Kubwa	56	6.5	7.5	66.4
	Zuba	18	2.1	2.4	68.8
	Idu	31	3.6	4.2	73.0
	Sabon Karmo	51	5.9	6.9	79.8
	Gwagwa	17	2.0	2.3	82.1
	Karu	43	5.0	5.8	87.9
	Nyanyan	90	10.4	12.1	100.0
	Total	744	85.8	100.0	
Missing	System	123	14.2		
Total		867	100.0		

Name of Settlement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Kubwa	159	18.3	18.3	18.3
	Dutse Alhaji	34	3.9	3.9	22.3
	Zuba	33	3.8	3.8	26.1
	Kuchigoro	33	3.8	3.8	29.9
	Lugbe	44	5.1	5.1	34.9
	Idu	104	12.0	12.0	46.9
	Sabon Karmo	142	16.4	16.4	63.3
	Gwagwa	41	4.7	4.7	68.1
	Karu	102	11.8	11.8	79.8
	Nyanyan	175	20.2	20.2	100.0
	Total	867	100.0	100.0	

Nature of Settlement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Planned	317	36.6	36.8	36.8
	Unplanned	544	62.7	63.2	100.0
	Total	861	99.3	100.0	
Missing	System	6	.7		
Total		867	100.0		

Nearness to Abuja and ease of commuting

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	348	40.1	44.3	44.3
	4	168	19.4	21.4	65.7
	3	132	15.2	16.8	82.5
	2	115	13.3	14.6	97.2
	1	22	2.5	2.8	100.0
	Total	785	90.5	100.0	
Missing	System	82	9.5		
Total		867	100.0		

Negative consequences of rapid growth

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Insecurity due to crime and social vices	229	26.4	31.0	31.0
	Overcrowding, unsanitary environment and pollution	166	19.1	22.5	53.5
	Accommodation shortages and high rent	94	10.8	12.7	66.2
	Development of sub-standard and unplanned housing environ.	56	6.5	7.6	73.7
	Increased cost of living	36	4.2	4.9	78.6
	Infrastructure inadequacy and stress on social facilities	141	16.3	19.1	97.7
	Increasing rate of unemployment	7	.8	.9	98.6
	Transportation and accessibility problem	10	1.2	1.4	100.0
	Total	739	85.2	100.0	
Missing	System	128	14.8		
Total		867	100.0		

Occupation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Farming	13	1.5	1.5	1.5
	Trading	80	9.2	9.3	10.8
	Artisan	33	3.8	3.8	14.7
	Civil Servant	503	58.0	58.6	73.2
	Private business	149	17.2	17.3	90.6
	Unemployed	77	8.9	9.0	99.5
	Clergyman	4	.5	.5	100.0
	Total	859	99.1	100.0	
Missing	System	8	.9		
Total		867	100.0		

Population increases due to spillover from Abuja

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	209	24.1	26.6	26.6
	4	243	28.0	30.9	57.5
	3	152	17.5	19.3	76.8
	2	155	17.9	19.7	96.6
	1	27	3.1	3.4	100.0
	Total	786	90.7	100.0	
Missing	System	81	9.3		
Total		867	100.0		

Qualification of growth in the past ten years

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very rapid	481	55.5	56.0	56.0
	Rapid	237	27.3	27.6	83.6
	Moderate	92	10.6	10.7	94.3
	Slow	30	3.5	3.5	97.8
	Very slow	19	2.2	2.2	100.0
	Total	859	99.1	100.0	
Missing	System	8	.9		
Total		867	100.0		

Reasons for residing in Settlement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cheap and affordable accommodation	327	37.7	42.6	42.6
	Displacement elsewhere	5	.6	.7	43.3
	Allocation of government quarters	83	9.6	10.8	54.1
	Availability of amenities	11	1.3	1.4	55.5
	Proximity to or location of workplace	214	24.7	27.9	83.4
	Peaceful environment	43	5.0	5.6	89.0
	Shortage of accommodation and high rent in Abuja city	72	8.3	9.4	98.4
	Native home	12	1.4	1.6	100.0
	Total	767	88.5	100.0	
Missing	System	100	11.5		
Total		867	100.0		

Residential status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Owner occupier	222	25.6	26.2	26.2
	Tenant	626	72.2	73.8	100.0
	Total	848	97.8	100.0	
Missing	System	19	2.2		
Total		867	100.0		

Settlement preferred to reside

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Abuja city	569	65.6	77.3	77.3
	Kubwa	46	5.3	6.3	83.6
	Zuba	4	.5	.5	84.1
	Idu	12	1.4	1.6	85.7
	Sabon Karmo	17	2.0	2.3	88.0
	Gwagwa	7	.8	1.0	89.0
	Karu	33	3.8	4.5	93.5
	Nyanyan	48	5.5	6.5	100.0
	Total	736	84.9	100.0	
Missing	System	131	15.1		
Total		867	100.0		

Appendix 11a: Correlation Output Tables for Relationships Between Settlement sizes and Growth Variables

Descriptive Statistics

	Mean	Std. Deviation	N
Settlement size	6.7063	.4149	8
Availability of cheaper accommodation	2.3625	.4125	8

Correlations

		Settlement size	Availability of cheaper accommodation
Settlement size	Pearson Correlation	1.000	.784
	Sig. (2-tailed)	.	.021
	N	8	8
Availability of cheaper accommodation	Pearson Correlation	.784	1.000
	Sig. (2-tailed)	.021	.
	N	8	8

* Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Settlement size	6.7063	.4149	8
Cheap land for development	2.2313	.4106	8

Correlations

		Settlement size	Cheap land for development
Settlement size	Pearson Correlation	1.000	.733
	Sig. (2-tailed)	.	.038
	N	8	8
Cheap land for development	Pearson Correlation	.733	1.000
	Sig. (2-tailed)	.038	.
	N	8	8

* Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Settlement size	6.7063	.4149	8
Increased rate of car ownership	1.9250	.4886	8

Correlations

		Settlement size	Increased rate of car ownership
Settlement size	Pearson Correlation	1.000	.802
	Sig. (2-tailed)	.	.017
	N	8	8
Increased rate of car ownership	Pearson Correlation	.802	1.000
	Sig. (2-tailed)	.017	.
	N	8	8

* Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Settlement size	6.7063	.4149	8
Nearness to Abuja and ease of commuting	2.3425	.4208	8

Correlations

		Settlement size	Nearness to Abuja and ease of commuting
Settlement size	Pearson Correlation	1.000	.919
	Sig. (2-tailed)	.	.001
	N	8	8
Nearness to Abuja and ease of commuting	Pearson Correlation	.919	1.000
	Sig. (2-tailed)	.001	.
	N	8	8

** Correlation is significant at the 0.01 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Settlement size	6.7063	.4149	8
Population increases due to spill over from Abuja	2.3550	.4347	8

Correlations

		Settlement size	Population increases due to spill over from Abuja
Settlement size	Pearson Correlation	1.000	.802
	Sig. (2-tailed)	.	.017
	N	8	8
Population increases due to spill over from Abuja	Pearson Correlation	.802	1.000
	Sig. (2-tailed)	.017	.
	N	8	8

* Correlation is significant at the 0.05 level (2-tailed).

Appendix 11b: Step-Wise Regression output Tables for Explanatory Power of the Growth Variables

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	Nearness to Abuja city and ease of commuting	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	Population increases due to spill over from Abuja	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: Settlement size

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.946	.895	.877	3155521.8806
2	.989	.978	.969	1584431.4225

a Predictors: (Constant), Nearness to Abuja city and ease of commuting
b Predictors: (Constant), Nearness to Abuja city and ease of commuting, Population increases due to spill over from Abuja

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	509162998179381.000	1	509162998179381.000	51.135	.000
	Residual	59743910031997.200	6	9957318338666.190		
	Total	568906908211378.000	7			
2	Regression	556354793548656.000	2	278177396774328.000	110.809	.000
	Residual	12552114662721.830	5	2510422932544.366		
	Total	568906908211378.000	7			

a Predictors: (Constant), Nearness to Abuja city and ease of commuting
b Predictors: (Constant), Nearness to Abuja city and ease of commuting, Population increases due to spill over from Abuja
c Dependent Variable: Settlement size

Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	-772069.004	1638208.119		-.471	.654
	Nearness to Abuja city and ease of commuting	25445.200	3558.350	.946	7.151	.000
2	(Constant)	474455.527	871363.335		.544	.609
	Nearness to Abuja city and ease of commuting	37962.894	3395.252	1.411	11.181	.000
	Population increases due to spill over from Abuja	-21921.011	5055.927	-.547	-4.336	.007

a Dependent Variable: Settlement size

Excluded Variables

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Availability of Cheaper accommodation in satellite sett.	-.627	-3.782	.013	-.861	.198
	Cheap land for development in Satellite sett.	-.729	-4.193	.009	-.882	.154
	increased rate of car ownership	-.917	-3.388	.019	-.835	8.691E-02
	Population increases due to spill over from Abuja	-.547	-4.336	.007	-.889	.277
2	Availability of Cheaper accommodation in satellite sett.	.995	.797	.470	.370	3.057E-03
	Cheap land for development in Satellite sett.	.046	.027	.980	.014	1.964E-03
	increased rate of car ownership	1.315	1.075	.343	.473	2.862E-03

a Predictors in the Model: (Constant), Nearness to Abuja city and ease of commuting

b Predictors in the Model: (Constant), Nearness to Abuja city and ease of commuting, Population increases due to spill over from Abuja

c Dependent Variable: Settlement size

Appendix 12: Regression Output Tables for Future Growth Prediction Models

Gwagwa

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	YEAR	.	Enter

a All requested variables entered.
b Dependent Variable: SETSIZE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.945	.894	.885	253068.9686

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6992949728592.180	1	6992949728592.180	109.190	.000
	Residual	832570737479.035	13	64043902883.003		
	Total	7825520466071.210	14			

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

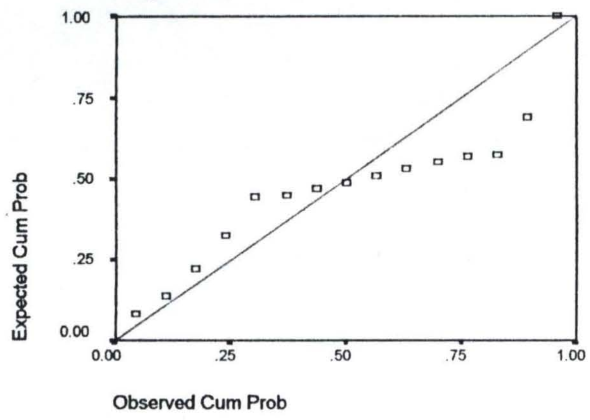
Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	31923.439	137507.090		.232	.820	-265142.553	328989.431
	YEAR	158034.238	15123.764	.945	10.449	.000	125361.335	190707.141

a Dependent Variable: SETSIZE

Normal P-P Plot of Regression Standardized Residua

Dependent Variable: SETSIZE



Idu\Sabon Karmo

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	YEAR	.	Enter

a All requested variables entered.
b Dependent Variable: SETSIZE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.895	.801	.785	622810.6635

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20271973526713.770	1	20271973526713.770	52.262	.000
	Residual	5042610593497.490	13	387893122576.730		
	Total	25314584120211.260	14			

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

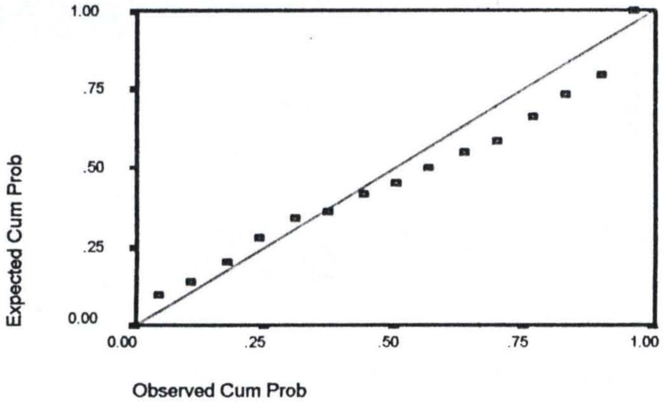
Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	313485.591	338409.259		.926	.371	-417603.125	1044574.308
	YEAR	269072.305	37220.056	.895	7.229	.000	188663.267	349481.344

a Dependent Variable: SETSIZE

Normal P-P Plot of Regression Standardized Residual

Dependent Variable: SETSIZE



Kuchigoro

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	YEAR	.	Enter

a All requested variables entered.
b Dependent Variable: SETSIZE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.776	.602	.572	169486.9911

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	565841628938.065	1	565841628938.065	19.698	.001
	Residual	373435921877.401	13	28725840144.415		
	Total	939277550815.465	14			

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

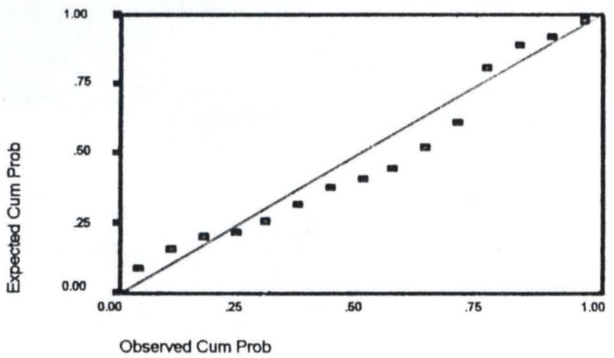
Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	203036.439	92092.140		2.205	.046	4083.476	401989.402
	YEAR	44954.009	10128.785	.776	4.438	.001	23072.101	66835.918

a Dependent Variable: SETSIZE

Normal P-P Plot of Regression Standardized Residual

Dependent Variable: SETSIZE



Kubwa

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	YEAR	.	Enter

a All requested variables entered.
b Dependent Variable: SETSIZE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.926	.858	.847	1596732.7506

a Predictors: (Constant), YEAR

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	199475629303063.000	1	199475629303063.000	78.239	.000
	Residual	33144221198532.130	13	2549555476810.164		
	Total	232619850501595.100	14			

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

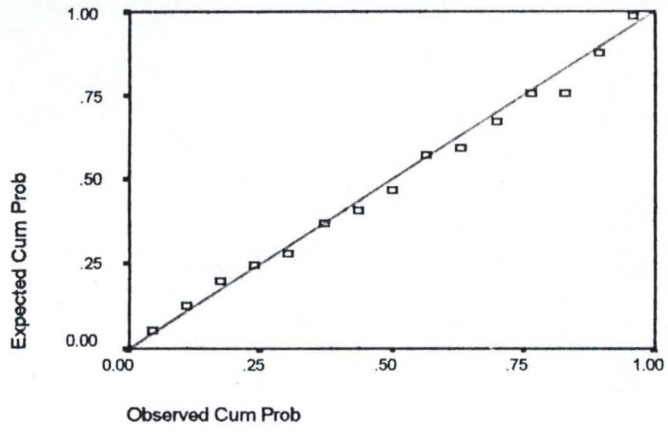
Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-2576398.053	867597.777		-2.970	.011	-4450728.996	-702067.111
	YEAR	844045.592	95423.033	.926	8.845	.000	637896.673	1050194.511

a Dependent Variable: SETSIZE

Normal P-P Plot of Regression Standardized Residual

Dependent Variable: SETSIZE



Dutse Alhaji

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	YEAR	.	Enter

a All requested variables entered.
b Dependent Variable: SETSIZE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.923	.853	.841	197722.5634

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2944049936411.833	1	2944049936411.833	75.307	.000
	Residual	508224757221.716	13	39094212093.978		
	Total	3452274693633.550	14			

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

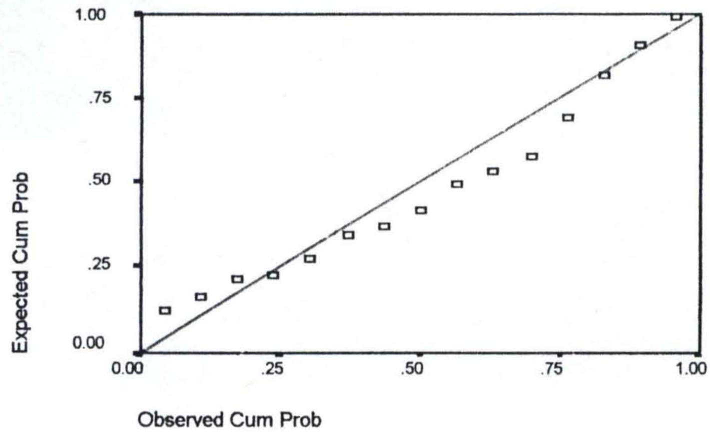
Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-271728.873	107434.169		-2.529	.025	-503826.273	-39631.474
	YEAR	102540.061	11816.183	.923	8.678	.000	77012.750	128067.371

a Dependent Variable: SETSIZE

Normal P-P Plot of Regression Standardized Residual

Dependent Variable: SETSIZE



Karu\Nyanyan

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	YEAR	.	Enter

a All requested variables entered.
b Dependent Variable: SETSIZE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.913	.833	.820	2925670.4654

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	555618130669859.000	1	555618130669859.000	64.912	.000
	Residual	111274119740294.900	13	8559547672330.380		
	Total	666892250410154.000	14			

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

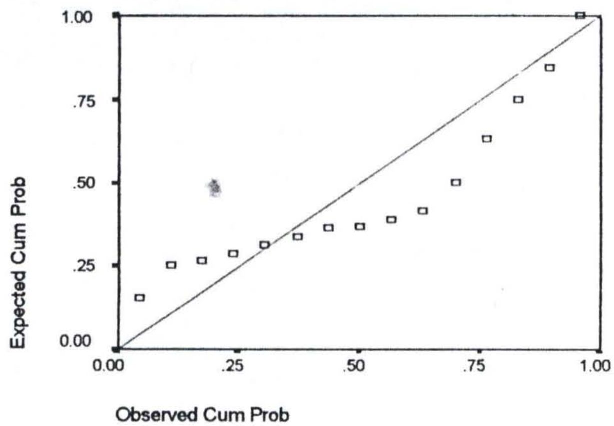
Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-1663321.527	1589686.935		-1.046	.314	-5097631.168	1770988.115
	YEAR	1408669.751	174842.252	.913	8.057	.000	1030946.050	1786393.452

a Dependent Variable: SETSIZE

Normal P-P Plot of Regression Standardized Residual

Dependent Variable: SETSIZE



Lugbe

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	YEAR	.	Enter

a All requested variables entered.
b Dependent Variable: SETSIZE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.906	.821	.807	828285.4995

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	40822173045288.140	1	40822173045288.140	59.503	.000
	Residual	8918739293281.290	13	686056868713.945		
	Total	49740912338569.400	14			

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

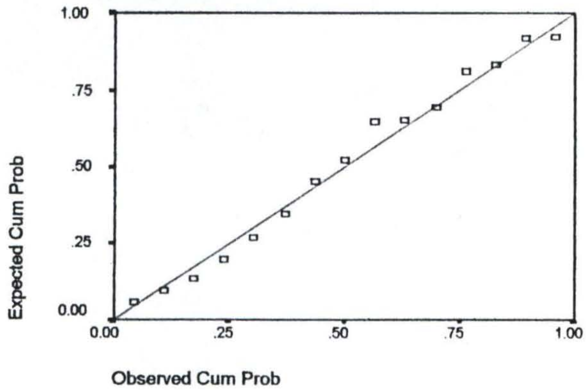
Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-1451741.257	450055.689		-3.226	.007	-2424027.409	-479455.106
	YEAR	381829.118	49499.526	.906	7.714	.000	274891.898	488766.337

a Dependent Variable: SETSIZE

Normal P-P Plot of Regression Standardized Residual

Dependent Variable: SETSIZE



Zuba

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	YEAR	.	Enter

a All requested variables entered.
b Dependent Variable: SETSIZE

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.310	.096	.027	854739442.2916

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1013131657058736000.000	1	1013131657058736000.000	1.387	.260
	Residual	9497533684716420000.000	13	730579514208955000.000		
	Total	10510665341775150000.000	14			

a Predictors: (Constant), YEAR
b Dependent Variable: SETSIZE

Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-255149333.847	464429654.733		-.549	.592	-1258488548.647	748189880.952
	YEAR	60152534.000	51080451.748	.310	1.178	.260	-50200066.928	170505134.929

a Dependent Variable: SETSIZE