MONITORING URBAN GROWTH USING AERIAL PHOTOGRAPHS: KADUNA AS A CASE STUDY

By

RAZAK KOLAWOLE YUSUF, *B.Sc.*

AUGUST, 2001

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(M.Tech./SSSE/99/2000/409)

THESIS SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY, SCHOOL OF SCIENCE AND SCIENCE EDUCATION, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF TECHNOLOGY (M.TECH.) DEGREE IN REMOTE SENSING APPLICATION, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA

AUGUST, 2001

DECLARATION

I, Razak Kolawole Yusuf, hereby declare that the thesis entitled "Monitoring of Urban Growth Using Aerial Photographs: Kaduna As a Case Study" is a product of my own research work under the supervision of Dr. A. A. Okhimamhe.

....

YUSUF, R. K.
(M.Tech./SSSE/99/2000/409)

DEDICATION

To my father, Pa Yesufu Areo, for his love and care for me.

CERTIFICATION

is is to certify that this thesis is an original work undertaken by Razak Kolawole Yusuf . Tech./SSSE/99/2000/409) under the supervision of Dr. A.A. Okhimanhe and has been prepared accordance with the regulations governing the preparation of thesis in the Department of ography and School of Postgraduate Studies, Federal University of Technology, Minna. The thesis been read and approved by:

....
DR. A.A. OKHIMAMHE **Date**
(Supervisor)

Usman
.... 24/9/2001
DR M. T. USMAN **Date**
(Head of Department)

Abalaka 3/x/03
Professor J. A. Abalaka
....
EAN, POSTGRADUATE SCHOOL **Date**

.... 31 – 8 – 2001.
EXTERNAL EXAMINER Date
Prof. E-J. Usoro

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ABSTRACT

Among the outstanding features of urbanization trends all over the world are the spectacular increase in urban populations, city sizes, information about the land, its uses, and the changes occurring with time. These changes may take place at such a rapid rate that planning authorities, local and state government administrators may find it difficult to cope with the fluctuating situation. Furthermore, lack of adequate data makes it impossible to prepare logical and implementable plans. This is the purpose for which this study on Kaduna, an urban centre in northern Nigeria, was carried out. Remote sensing technique was employed to acquire basic land-use data for monitoring urban growth in Kaduna.

In order to acquire basic urban land-use change data for Kaduna South, Nigeria, sequential black-and-white aerial photographs for 1962 (1:10,000), 1977 (1:6,000) and for 1991 (1:10,000) were employed. Uncontrolled mosaics were prepared from these photographs. The land-use classification was at a two-digit level, broadly divided into "built-up areas" and "non-built-up areas". Land-use types were interpreted and the boundary of each was delineated on the photo mosaics. Each photo mosaic was over-laid with a transparent film and the delineated boundaries traced. The magnitude/area of the delineated boundary of each land-use type was calculated using the compensating planimeter.

The study showed a clear evidence of the conversion of cultivated lands to urban land for as much as 52% and 52.5% for the periods 1962 - 1977 and 1977 - 1991 respectively. The annual growth rate was 3.8% for the 1962 - 1977 period while that of the 1977 - 1991 was only 1.2%. Statistical analysis of the data generated indicated that there was a linear positive relationship between urban growth with time. The regression equation developed was of the form $y = 11.26x + 434.95$ with

correlation coefficient of 0.99, significant at 10% probability level. The coefficient of determination was also found to be 0.97 and this judges the quality of the regression equation. Since 0.97 approximates very close to +1.0, this indicates the goodness of fit of the regression line.

The method employed for the study and the result obtained suggest that remote sensing technique, especially sequential aerial photographs can be used for the acquisition of basic urban land-use data for the study of urban growth necessary for the planning and management of urban areas in Nigeria as well as in many developing countries.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

The visual interpretation of aerial photographs is, perhaps with the exception of topographic map analysis, the most widely used technique of obtaining data about earthly phenomena and of mapping their distribution. The aerial photograph, along with other types of imagery, has become an important tool in the monitoring of the environment. In remote sensing generally, aerial photography occupies an important position to the extent that the visual interpretation of the other types of imagery is based on the same fundamental principles that guide aerial photo-interpretation. The continuous evaluation of the environment is needed in order to be able to control the impact of human activities on the environment and thus be able to avert potential social and environmental disaster.

The aerial photograph has some qualities which makes it such a useful tool in studying the face of the earth and its features. "The aerial photograph is thus very useful because it displays very clearly the spatial relationships between the elements of the landscape. Each element can be viewed and assessed in relation to the total landscape and the relative importance of various landscape units or patterns can be assessed from the overall perspective of the landscape that the aerial photograph provides. Consequently, the aerial photograph can be very useful when deciding the type and size of mapping unit to adopt in mapping any land element and in the actual delineation of boundaries between different geographic units" (Areola, 1985, p.15).

1.2 STATEMENT OF THE PROBLEM

Among the outstanding features of urbanization trends all over the world are the spectacular increases in urban population and city sizes. The metropolitan Kaduna was the capital of the former Northern Region of Nigeria. Today, it doubles as the capital of Kaduna State and unofficial capital of the nineteen Northern States.

The town is centrally located with respect to the whole country. Politicians, businessmen, serving and retired military personnel, etc have always scrambled for landed property for development purposes in Kaduna. It is therefore necessary to investigate the growth of this town since the time of independence from Britain in 1960. Aerial photographs of three different epochs (1962, 1977 and 1991) have been used for this study. Black-and-white aerial photograph had been used "since it is the most widely used type of aerial photograph for photo-interpretation, at least in Africa" (Areola, 1985, p.14).

1.3 OBJECTIVE AND JUSTIFICATION OF THE STUDY

Changes in urban land usually involve the conversion of other lands into urban use. The purpose of the investigation is to make a broad assessment of the growth of the town.

The objective is therefore to show that where aerial photographs are available at regular time intervals, a great amount of information can be collected and would provide time series data on urban growth. The information so obtained will assist administrators, decision makers and planners) make policy proposals for development purposes.

1.4 RESEARCH QUESTIONS

As a basis for the development of policies and decision making, accurate and timely data about the amount, distribution, quality and changing conditions of the various land uses is needed.

The questions that readily come to mind include:

(i) What was there?

(ii) What changes had occurred and by how much?

(iii) Where had the changes taken place?

(iv) When and possibly why the changes?

Answers to these questions afford planners good foundations for proper planning.

Aerial photography gives a viewer a scale of observation not open to him with the naked eye and not easily deliverable to him in map form. Photographs also serve as good sources of historical records as they contain an infinite amount of information.

This study is to present a method of acquisition of reliable data from aerial photographs using simple equipment readily available from which answers to the above questions would be correctly deduced by way of analysis of data using different epochs of photography.
Information on the rate and kind of change in the use of land resources is essential to the proper planning, management and regulation of the use of such resources. This is to overcome problems associated with haphazard and uncontrolled growth, loss of prime agricultural lands, etc.

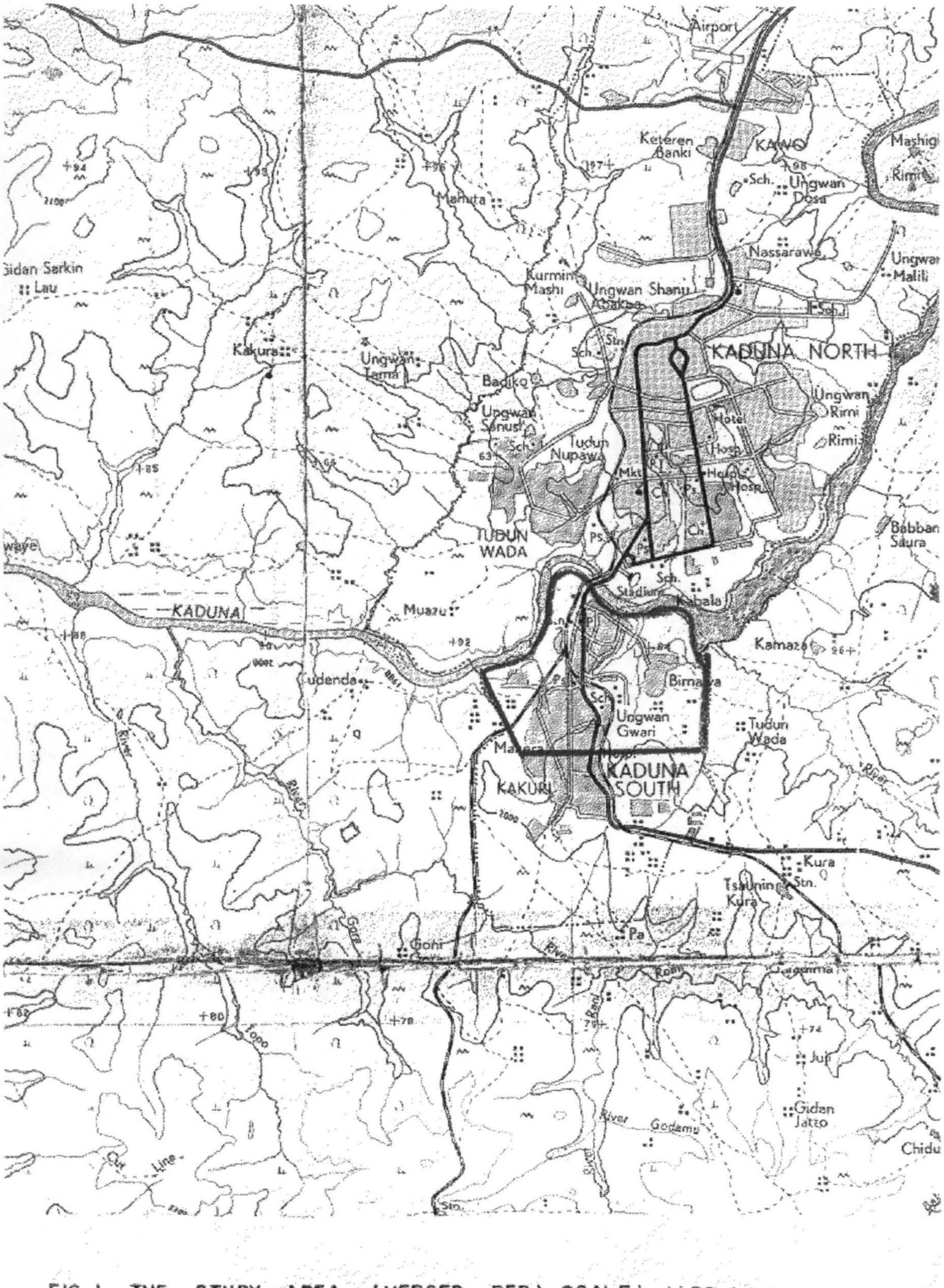


FIG I. THE STUDY AREA (VERGED RED). SCALE:- 1:50,000

5 THE STUDY AREA

1.51 Location

Part of Kaduna which is south of River Kaduna is the study area. Kaduna South has been selected for the study for the following reasons:

(i) Availability of sequential black-and-white aerial photographic coverage for 1962 (1:0,000), 1977 (1:6,000) and 1991 (1,10,000).

(ii) The area is a fast growing urban centre centrally located with respect to the whole country.

(iii) Lack of background information to aid its development.

(iv) The familiarity of the researcher with the area.

(v) It is the unofficial capital of the nineteen Northern States of Nigeria.

Kaduna South, a part of the Kaduna Metropolis is located around latitude 10° 29' 22"N and longitude 07° 25' 26" E. The study area is shown in figure 1.

1.52 Climate

Kaduna has a tropical climate. The rainfall pattern is generally governed by the movement of the Inter-Tropical Convergence Zone (ITCZ) which shows a steady decrease from south to north. The study area shares this characteristics and has distinct wet and dry seasons. The mean annual rainfall is about 1400mm and the length of the rainy season is about 165 days. The rainy season starts between April and May and lasts to October (5-6 months) when the dry season sets in. The dry season starts around October/November and extends to March. The cold, dry and dusty north-easterly harmattan winds prevails during the months of November to January, blowing from the Sahara Desert.

The highest mean temperature is usually recorded between March and May and it is about 35°C. The lowest mean monthly temperature occurs between July and August and it is about 30°C.

1.53 Topography and Soil

The topography is gently undulating with slopes of about 10%. The town is underlaid mainly by undifferentiated basement complex of igneous and metamorphic rocks from which the soils are developed. The soil is under the ferruginous tropical soils.

1.54 Vegetation

The town falls within the Sudan Savanna vegetation. This vegetation zone is characterized by short grasses interpersed by short trees. The trees in this vegetation always occur singly rather than in clumps.

1.6 SCOPE AND LIMITATION OF STUDY

The study covered an area of about 900 hectares. It is defined in the north by River Kaduna. The south, east and west boundaries were chosen in consideration of the aerial photographic coverage common to the three epochs. As stated earlier, materials included black-and-white photographs of 1962 (1:10,000), 1977 (1:6,000) and 1991 (1:10,000). While the flight azimuth for the 1962 and 1991 photography was east-west, that of 1977 was north-south. Another constraint imposed by the characteristics of the photographs was the differences in scale that precluded a direct comparison of the sequential photographs. There was also the problem of a missing photograph in respect of the 1991 photography. This missing gap has, however, not affected the study nor its analysis and accuracy.

1.7 DEFINITION OF SOME TERMS

It is necessary to define or explain certain terms as used in this study:

1.71 Towns, Cities and Urban Centres:

The words "Towns," "Cities" and "Urban Centres" have been used interchangeably. Urban centres are towns and cities as distinct from rural areas. "Urban centres contribute significantly in the diffusion of innovation, provision of skilled and specialized manpower, and, above all, are the production centres for manufactured goods and services. They are therefore the engines of growth and development" (Zubairu and Yari, 1996, p.19). Unfortunately, there is no acceptable definition of both towns and cities as no definition will apply to all the manifestations of cities and no single description will cover their transformations. The various definitions vary with authors and widely with each country of the world. In simple terms, however, a city is a place where people come together to live, work and play. The Nigeria's definition of a city is a place with a minimum population of 20,000.

1.72 **Metropolitan:**

A metropolis is a chief city of a country or region.

1.73 **Urban Growth:**

Urban growth is used in this study to mean the sprawling of cities into wider geographical areas.

CHAPTER TWO

LITERATURE REVIEW

2.0 Aerial photographs have been used for urban survey purposes in studying land use, residential patterns, population estimation and the spatial growth of urban centres. These studies which have been carried out mainly by academics and planning experts have yielded marvelous results. The approach adopted for the monitoring of spatial growth of urban centres has been based on the comparative analysis of sequential photographs, that is, aerial photographs taken at different years.

Adeniyi (1980) was able to determine changes in land use in metropolitan Lagos between 1962 and 1974 using the aerial photographs of the city taken in those two years. The primary data source comprised two sets of sequential aerial photographs of Lagos for 1962 (1:40,000) and 1974 (1:20,000). The interpretation was carried out with the aid of a mirror stereoscope. The methodology adopted involved two major interdependent components - data acquisition and data handling. The data acquisition component dealt with data source, development of land-use classification, data interpretation, creation of data base, transfer of data to base and field checking. Data handling, on the other hand, involved the conversion of the data into computer acceptable form. Two major constraints imposed by the characteristics of the photographs are (i) the differences in scale that precluded a direct comparison of the sequential photographs and (ii) the minimum mapping unit as well as the level of detail was influenced by the differences in scale. Identification and classification of land uses also presented some difficulties. The most noticeable development in metropolitan Lagos in those years was the conversion to urban land uses of vacant land and cultivated land within the metropolis. While urban land experienced an increase of 5184 hectares between 1962 and 1974 representing a percentage increase of 80.8% vacant land increased by 1181 hectares representing a percentage increase of 22.7% and non-urban land experienced a decrease of 6354 hectares representing a percentage decrease of -23.4%.

As indicated by Olorunfemi (1983), aerial photographs of different epochs would provide time series data on urban growth. The objective of his study was to attempt an area measurement of some Nigerian cities from aerial photographs and to relate this to population in order to understand the spatial relationship between area and population of Nigerian cities and to use the data for making inter-censal population estimation. His choice of cities was determined largely by the availability of aerial photographic cover. For each city, either the photo mosaic or the photo print for the period 1959 - 66 was used. The conclusion of the study was the acceptance of the use of aerial photography as a source of data on the built-up area of a city. The correlation and regression models were used to test the possible relationship between population and area. The two resulting population estimating equations were:

1. $P = 2113 + 158A$ based on the 1952/53 relationship with a correlation of 0.88.
2. $P = 12396 + 141A$ based on the 1963 relationship with a correlation of 0.90

Where P is population and A is area.

Lo (1986) estimated the population of Athens, Georgia, United States of America, using the dwelling unit count method from 1:12,000 - scale black - and - white aerial photographs with the aid of a stereoscope. Land-use and land-cover mapping was carried out by photo interpretation and field checks in order to identify residential structures and to establish a photo interpretation Key of dwelling types. It was found that three dwelling types namely, single - family dwellings, multiple - family dwellings and group homes could be distinguished. The number of dwelling units in each type was estimated from the aerial photographs. Housing block data from the 1980 census were obtained for comparison with the photo count. In addition, population census data projected to the date of photography were employed as a standard for comparison. It was found that the dwelling unit count errors for the entire study area gave relative error of only - 9.2 percent. For the population estimation, this gave rise to an overall relative error of - 1.7 percent. He later found that the relative errors of the dwelling unit count and the population estimation were not correlated. Other factors notably the nature of the photographic data, the skill of the interpreter and the family size factors, have an important impact on the accuracy of the estimates. The researcher concluded that the approach presented a realistic appraisal of the population estimation methodology as applied to a complete city.

Lutchman (1987) investigated land subdivisions on the Fringe of Paramaribo, the capital of Suriname, South America, using aerial photographs. Black-and-white panchromatic photographs of 1956, 1967 and 1973 were supplemented by 1978, 1982, 1983 and 1985 photographs. The scale of the 1982 photographs was 1:20,000; that of the other years was approximately 1:5,500. The interpretation did not pose significant problems. Houses could be counted without any real difficulty. Interpretation variable such as size, shape, tone and associated features were used to distinguish houses from other buildings. Inhabited houses could be distinguished from uninhabited ones by such associated features as the narrow footpaths leading to the houses from the entrance, as well as from houses to pit latrines, which clearly contrasted with the surrounding grass-grown areas. Field observations and confirmation were preceded by a reconnaissance survey. The researcher concluded that because fringe zones are the most dynamic parts of urban systems, they are most appropriately studied using aerial photography for:

- Analyzing land subdivision mechanisms and the resulting physical developments and changes.
- Quantifying and qualifying spatial developments, especially with regard to housing to arrive at policy measures to benefit the low-income city dwellers.

The study clearly showed that a process approach to land development using aerial photography is quite feasible.

Bruijin (1987) monitored a large squatter area in Dar es Salaam with sequential aerial photography. For a long time, Dar es Salaam remained a small town on the east coast of Africa. The existing urban structure could not accommodate the high post-independence population growth rate, resulting in large squatter areas built in haphazard manner. Squatter areas are a very important part of Dar es Salaam, and their full integration into the urban structure was a major planning task. Equal access to such facilities as education and health was to be made available to all city residents and not limited to only certain sectors of the city. The processes that led to the creation and growth of squatter areas were to be understood and used creatively to develop new concepts and strategies for the future, both inside and outside the squatter areas. The physical development process of the largest squatter area, Manzese was studied by Bruijin with the help of aerial photographs of 1967, 1975 and 1980. Data thus obtained were processed and analyzed using Usemap geo-data processing software. Two basic types of houses were classified: traditional three - room houses and six-room houses. The finding was that the traditional small houses were built first to meet immediate housing needs and that these were progressively followed by large houses when an owner's situation allows him to expand or replace the small house. Based on figures available to the researcher and assuming a density of 2.4 persons per room, three rooms per a small house and six rooms per a large house, it was possible to compute population estimates for Manzese, based on the number of houses as interpreted. Population estimated was 33,800, 81,200 and 97,900 for years 1967, 1975 and 1980 respectively.

Adaji (1989) carried out assessment of land use changes from aerial photographs using Daura, a Northern Nigeria town as a case study. The method was used over the test area, Daura, using three generations of aerial photographs. The paper discussed the technique used in obtaining reliable data from aerial photographs from which changes in land uses over a period of time could be assessed. A land use classification scheme applicable to most small towns of the extreme north of Nigeria was adopted. Major changes in residential settlement and farmlands were highlighted in areal values as well as percentages of the whole area. The changes which could be incremental or decremental were adequately quantified. Residential use in the study showed some steady incremental changes from 1954 to 1977 but the proportion of changes was not the same for the periods 1954-66 and 1966-77 respectively. The researcher concluded that time interval alone was not enough factor to influence such changes in land uses. The study also revealed the steady decrease in cultivated land over the years under investigation. It decreased from the 493 hectares in 1954 to about 280 hectares in 1977.

Similarly Mahavir and Marjon Galema (1991) also used aerial photographs with spot images to monitor urban growth of the city of Chiangmai in Northern Thailand. Materials used included black-and-white aerial photographs of 1976 (1:20,000), 1985 (1:20,000) and 1989 (1:10,000). Prints of the 1989 panchromatic spot image were also available in 1:20,000 and 1:50,000 scales. The study revealed some interesting growth pattern in Chiangmai between 1976 and 1989. The city had a built-up area of 9,302 hectare in 1989. Of this area 62% was high density, 28.6% was low density and 06% consisted of open spaces. Less than 01% of this area was occupied by industry. The city expanded at a fast pace between 1976 and 1989, growing from a total built-up area of 4,689 hectares in 1976 to 7,550 hectares in 1985 and 9,302 hectares in 1989. The rate of growth in the two intervals remained between 6 and 7 percent per annum. A detailed comparison of the situations in 1976 and 1989 revealed that most changes occurred in "agricultural fields" becoming "other non-built-up" which actually indicates that less agricultural land was being sown; "agricultural fields" becoming "high density" and "other non-built-up" becoming "high density". Also 148 hectares of open space and 2 hectares of water bodies were taken up for development between 1976 and 1989. An overall accuracy of 84.2 percent was achieved in the interpretation of the aerial photographs.

CHAPTER THREE

DESIGN AND METHODOLOGY

3.0 The methodology adopted involves the following components:

1. Data Source and Equipment
2. Preparation of Mosaics
3. Development of Land-use Classification Scheme
4. Data Interpretation
5. Preparations of Line Maps
6. Field Checking

3.1 DATA SOURCE AND EQUIPMENT

The primary data source for the study is comprised of three sets of sequential aerial photographs for 1962 (1:10,000), 1977 (1:6,000) and 1991 (1:10,000). These photographs were obtained from the Department of Lands and Survey, Kaduna, Kaduna State. While the flight azimuth for the 1962 and 1991 aerial photography is east-west, that of 1977 is north-south.

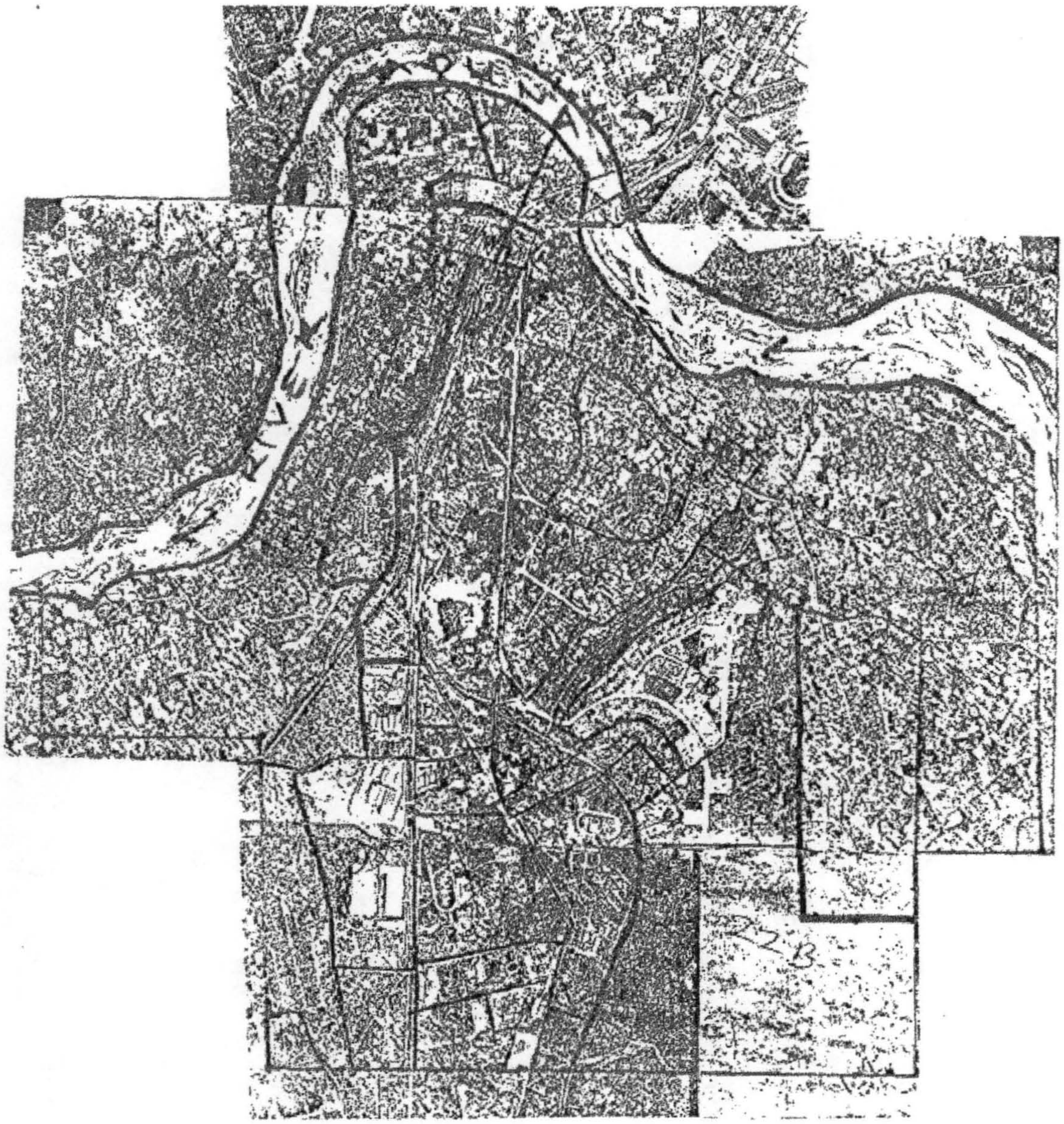
The equipment used fall into two categories, namely, viewing and measurement instruments:

(i) Stereoscopes are simple instruments used to view overlapping photographs stereoscopically, that is, in three dimensions. The interpretation for the study was carried out with the aid of a mirror stereoscope (Wild ST 4 with 3x magnification). The equipment enabled the observer to view the entire overlap area of a standard aerial photograph format used for this study. The use of mirror stereoscope was supplemented with pocket stereoscope for field checks because it is more convenient to be carried about.

(ii) Measurement instruments used were the scale rule and planimeter. The compensating planimeter was used for the area calculations using the exterior pole method, that is with the needle point outside the area to be calculated. The Japanese-made Sokkisha Planimeter used was first-of-all checked for reliability before being employed for the study. This was by measuring a known area of 909 square metres with the planimeter. The result was a planimeter value of $913m^2$ giving a relative error of only 0.4%.

3.2 PREPARATION OF MOSAICS

Uncontrolled mosaics were prepared from photostat copies of the aerial photographs of 1962, 1977 and 1991. A mosaic is an assembly of a series of overlapping/adjoining photographs into one continues picture. It is an overhead view of the terrain and, like a map, shows the relative horizontal positions of terrain features. It is used as a map substitute in this study. The mosaics for the three periods are numbered as plates I, II and III.



11 RESIDENTIAL HIGH DENSITY
12 RESIDENTIAL LOW DENSITY
13 INDUSTRY
14 COMMERCE
15 INSTITUTION
16 TRANSPORTATION
17 OPEN SPACES
18 VACANT LAND
21 AGRICULTURAL PLANTATION
22 CULTIVATED LAND

PLATE I: PHOTO MOSAIC OF THE SOUTHERN PART OF METROPOLITAN KADUNA (1962)

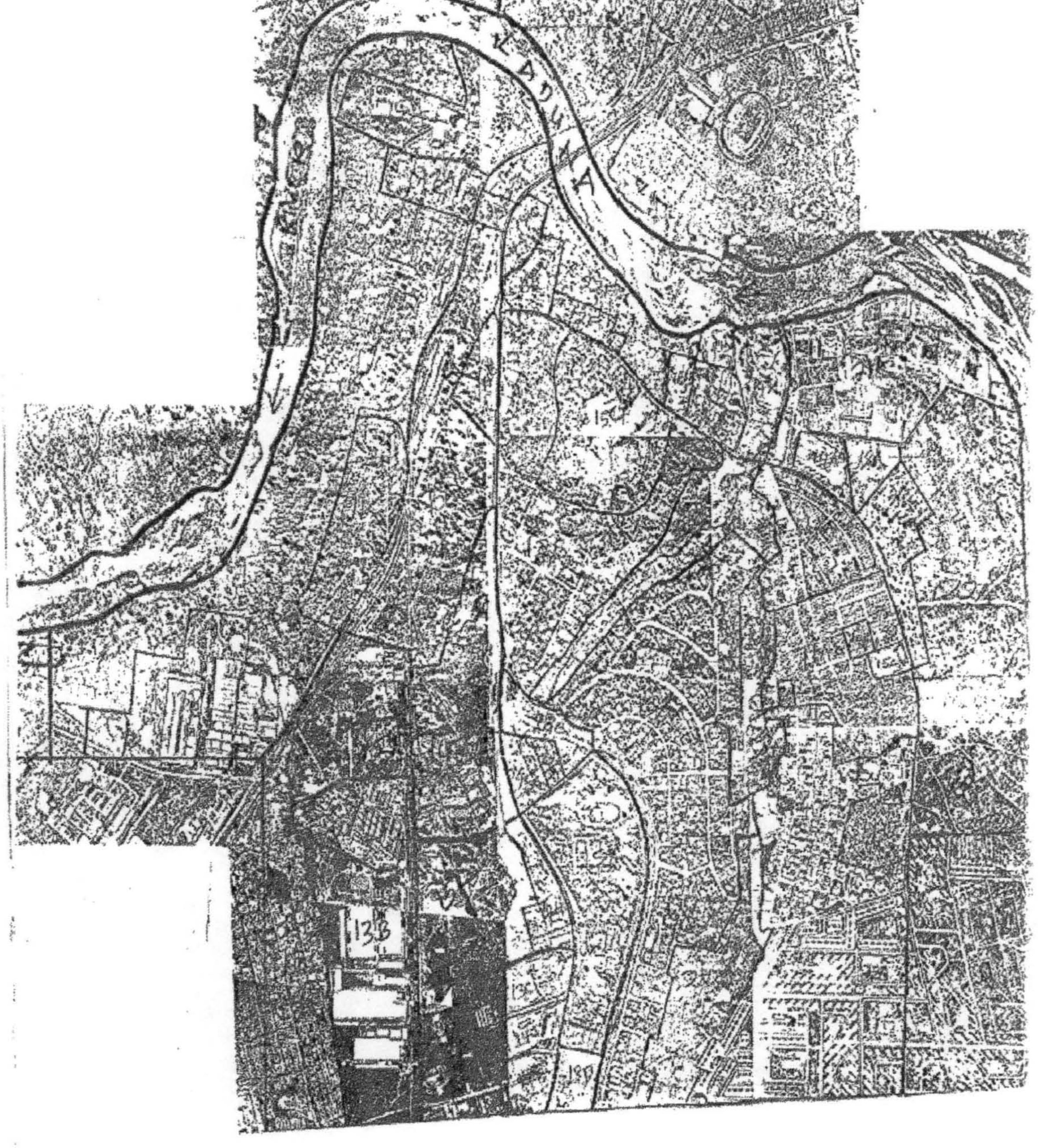
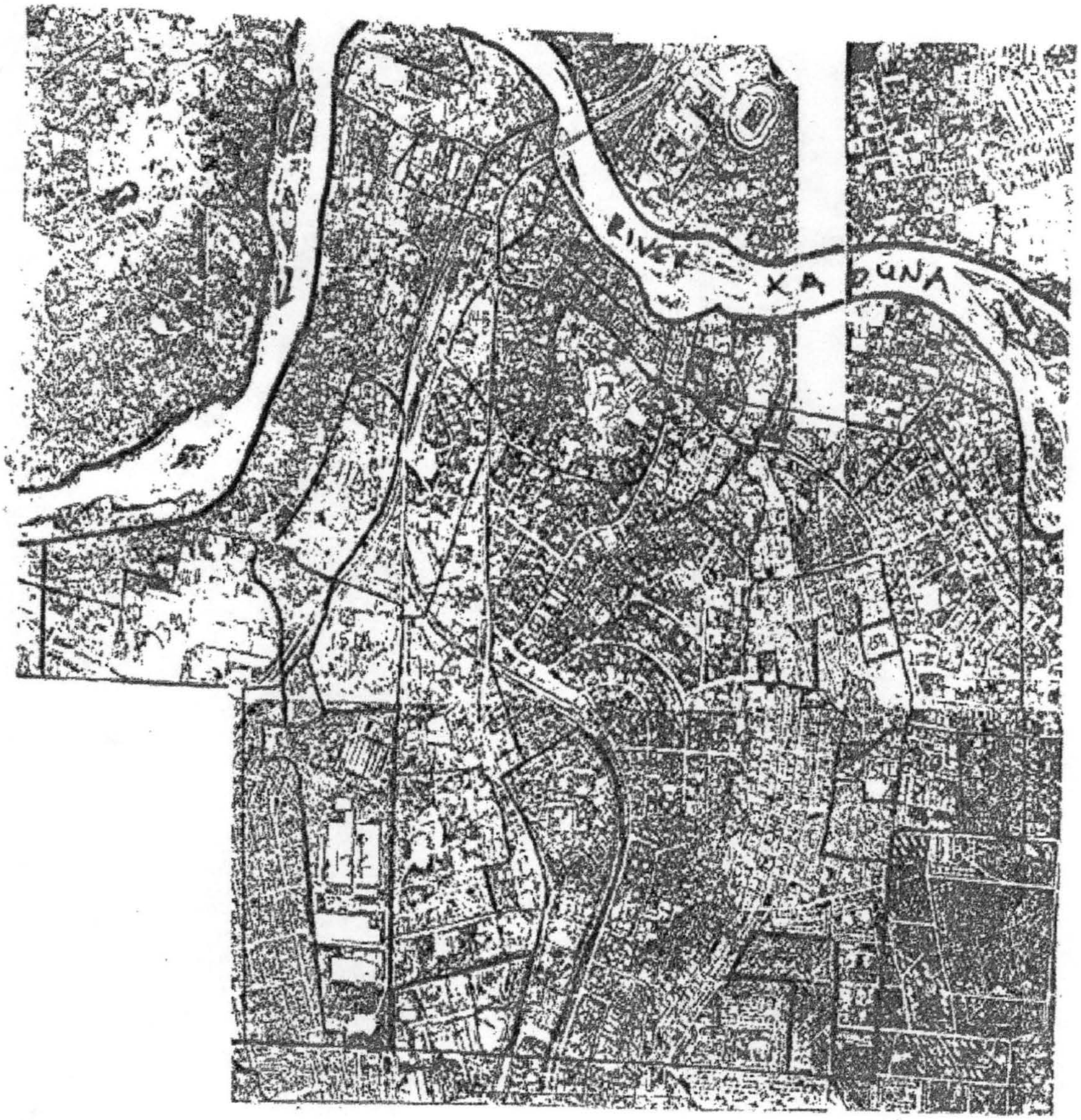


PLATE II: PHOTO MOSAIC OF THE SOUTHERN PART OF METROPOLITAN KADUNA (1977)



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22 CULTIVATED LAND

PLATE III: PHOTO MOSAIC OF THE SOUTHERN PART OF METROPOLITAN KADUNA (1991)

3.3 LAND-USE CLASSIFICATION SCHEME

Land-use is a broad term reflecting different meanings. Everyone who makes a land use survey draws up his own classification. We are all, of course, special cases with our own particular needs. In this study it is used to reflect all recognizable human activities on the land as well as vegetative features on the earth's surface within the area of study. In developing the land-use classification scheme for this study, the particular characteristics of the study were taken into consideration.

The classification was at a two-digit level, broadly divided into "built-up areas"and "non-built-up areas". The class "built-up area" consisted of eight sub-classes: residential high density, residential low density, industry, commerce, institution, transportation, open space, and vacant lands. The class "non-built-up areas" consisted of three sub-classes: agricultural plantations, cultivated farm lands and water bodies.

Built-up areas encompass land that is used for housing, industry, commerce, institutions, recreational facilities/ open spaces, transportation facilities and utilities and vacant land.

Residential Land Use:

This category includes parcels of land which are primarily developed for housing and dwelling purposes. Three classes were recognized. The three different types of residential patterns are characteristic of many sub-saharan African towns. There is the unplanned pre-industrial traditional sector with small dwelling units and the building density being so high that there is hardly any open space or sign of green vegetation except at some spots and along the streams. The multitude of small dwelling units found in this sector contrasts with the larger-sized buildings and more spacious surroundings of the modern sector of the town. This modern sector had in turn been subdivided into two different residential classes. First, three are the relatively planned, high-density residential areas which merged into more recent residential layouts. There are, secondly, the low density residential areas of the Government Reserved Areas (G.R.A) established during the colonial era, areas which sport lawns, trees and hedge-rows. Not included in this category are residential zones associated with military, police, schools and colleges.

Industrial Areas:

These include manufacturing, processing and textile industries. Such industrial complexes include Nigerian Brewery Limited (N.B.L), Kaduna Textile Limited (K.T.L) and United Nigeria Textile Limited (U.N.T.L).

Commercial Land Use:

This includes parcels of land developed and used for activities involving purchase and consumption of goods and services. The main commercial centres are the Barnawa and Kakuri markets with wholesale and retail shops.

Institutional:

This category includes all activities that are associated primarily with community organization, protection, and general social and cultural welfare. It includes schools, colleges, hospitals, military and police areas, other public establishments, churches, mosques, water works and energy supplies.

Transportational:

This category includes activities involving vehicles in the conveyance of passengers and goods. Examples are railway stations and motor parks.

Recreational and Open Spaces:

These include activities involving indoor assembly for entertainment and outdoor activities and sports ground, but it excludes those in schools, colleges, and military and police areas.

Vacant Land:

These are parcels of land within the built-up areas which are not used for any of the activities mentioned above. Some small pockets of such vacant parcels are being used indiscriminately for temporary activities such as erection of Kiosks for petty trading or different forms of workshops. Parcels of land on which are foundations of buildings and uncompleted buildings have also been categorized as vacant lands because such lands are transitional and could not easily be classified into any particular urban use.

The class “non-built-up-areas” includes all other land outside the built-up areas. The class consisted of three subclasses: agricultural plantations, cultivated farmlands and water bodies. The subclass “water bodies” excluded canals and streams which were treated as linear rather than areal elements.

The final classification scheme is as shown below:

10. **"Built-Up Areas"**

11. High Density

12. Low Density

13. Industry

14. Commerce

15. Institution

16. Transportation

17. Recreational and Open Spaces

18. Vacant Lands

20. **"Non-Built-Up Areas"**

21. Agricultural Plantations

22. Cultivated Farmlands

23. Water Bodies

3.4 DATA INTERPRETATION

During the process of establishing the land-use classes, a reconnaissance survey of the area was conducted. Although certain characteristics of the images and the surface features, such as tone texture, pattern, size, shape and shadow, were used as identification parameters, the pre-survey provided essential interpretation clues. The built-up areas including vacant lands were first identified and delineated, followed by non-built-up areas, in that order, on the mosaics.

The interpretation was carried out with the aid of a mirror stereoscope (Wild ST 4 with 3x magnification) supplemented by pocket stereoscope for field checks. Throughout the interpretation, existing uses as identifiable on the photographs were delineated.

Generally, identification of residential patterns was relatively easy. Identification and classification of industrial areas which are characterized by large buildings did not, also, present any difficulty. Transportational facility which was mainly the railway station was also very easy to identify. However the identification and classification of markets was difficult as the unplanned traditional high density residential areas. Some land-use classes such as police premises do not have consistent "site" attributes on aerial photographs to aid their identification. Those which could not be absolutely assigned to a particular class of use were left for field verification.

3.5 **PREPARATION OF LINE MAPS**

The photo mosaic on which the land-use classes were identified and delineated were, in each case, over-laid with a transparent paper and the external boundary of the built-up areas and the non-built-up-areas traced (Figures 2, 3 and 4). The compensating planimeter was used in the area calculations from the tracings, using the exterior pole method. The area of each class was thus determined and changes in their proportions were accounted for.

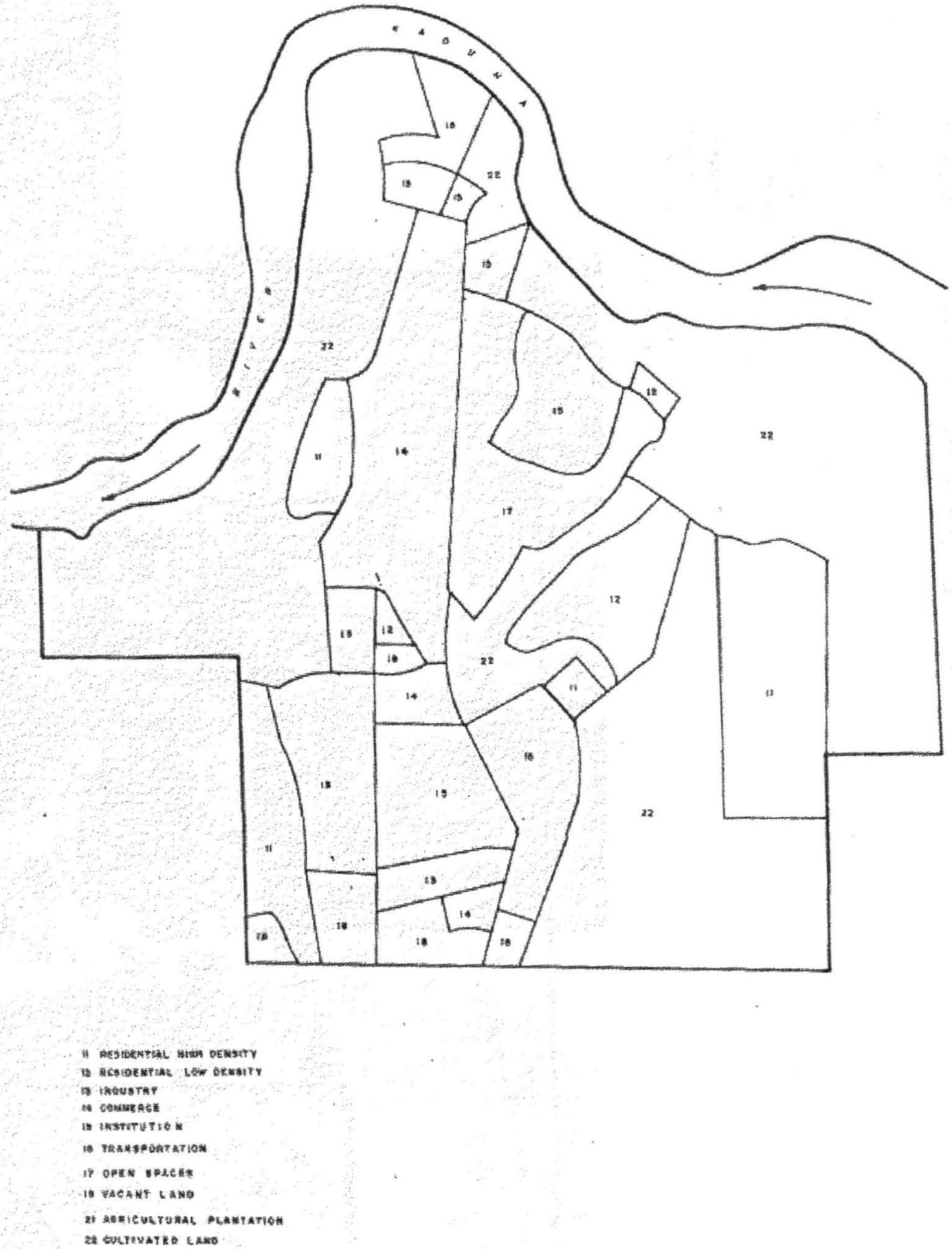

FIG 2. LAND USE CLASSIFICATION OF THE SOUTHERN PART OF METROPOLITAN KADUNA DERIVED FROM 1:10,000 PHOTOGRAPHY TAKEN IN 1962

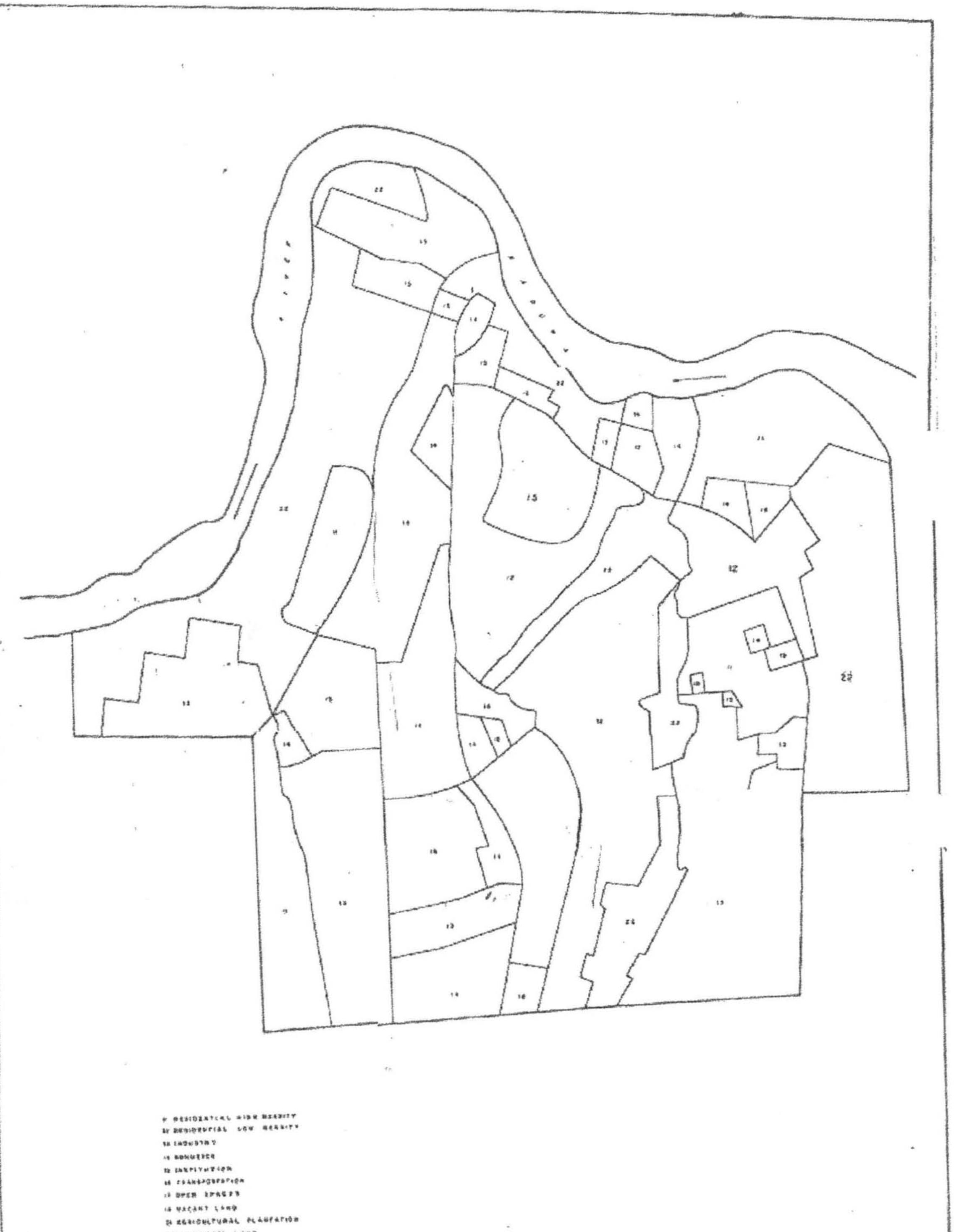

FIG 3. LAND USE CLASSIFICATION OF THE SOUTHERN PART OF METROPOLITAN KADUNA
DERIVED FROM 1: 6,000 PHOTOGRAPHY TAKEN IN 1977

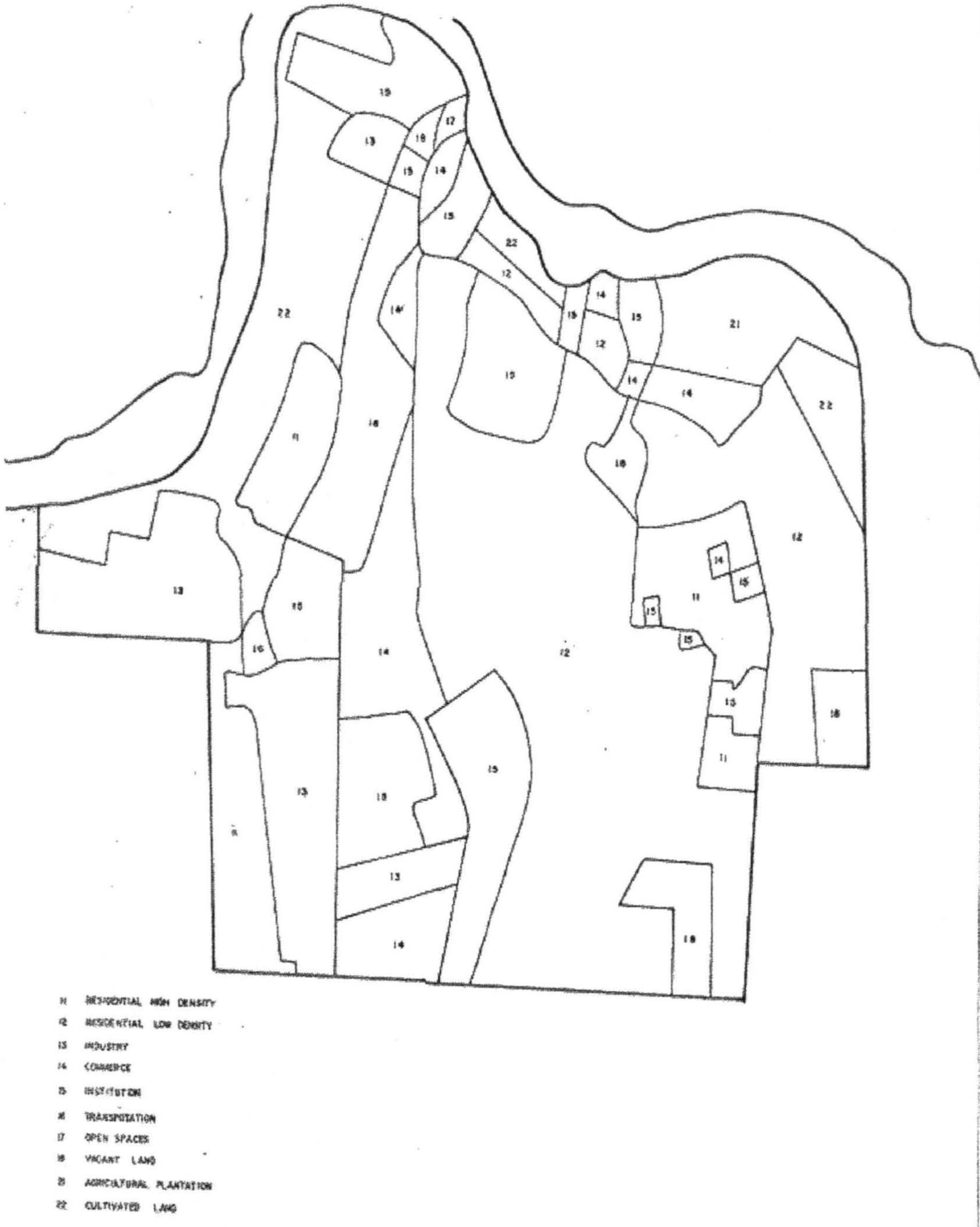

FIG 4. LAND USE CLASSIFICATION OF THE SOUTHERN PART OF METROPOLITAN KADUNA DERIVED FROM 1:10,000 PHOTOGRAPHY TAKEN IN 1991

3.6 FIELD CHECKING

Some areas where doubts existed as to their correct identification were checked in the field. In order to ensure a fair coverage of the study area, some land-use classes were selected for checking. Included in the list are schools, markets, police station and army barracks. All the pre-selected markets, police and army barracks were correctly interpreted.

Another approach employed was related to boundary checks. Boundaries between such land-use classes as residential and commercial areas and boundaries separating one residential class from the other were field checked.

CHAPTER FOUR

DATA ANALYSIS AND FINDINGS OF STUDY

4.1 DATA INTERPRETATION

During the process of establishing the land-use classes, a reconnaissance survey of the area was conducted. Although certain characteristics of the images and the objects such as scale, resolution, tone, texture, pattern, size, shape and shadow, were used as identification parameters, the pre-survey provided essential interpretation clues. On the mosaic, the different land-use classes were identified and delineated. The result was the many irregularly shaped land-use parcels for each of the three periods. The land-use classification adopted was at a two-digit level broadly divided into "built-up areas" and "non-built-up areas". Table I below shows the land-use classification scheme adopted.

4.2 DATA HANDLING FOR CHANGE DETECTION

The photo mosaics of the three periods were each over-laid with a stable transparent film and the boundaries of the delineated land-use parcels traced. The compensating planimeter was used in the area calculations from the tracings Table 2 below shows the data for the land-use pattern for 1962, 1977 and 1991.

TABLE 1: THE LAND-USE CLASSIFICATION SCHEME

10	"Built-Up Areas"		
11	Residential High Density	(i)	Settlements
		(ii)	Traditional/Indigenous Areas
		(iii)	Unplanned Residential Classes
12	Residential Low Density	(i)	Planned Residential Sector
		(ii)	Newly Developing Residential Areas
		(iii)	Government Reserved Areas
13	Industrial	(i)	Industrial Complex Areas
14	Commercial	(i)	Traditional Markets
		(ii)	Hotels
		(iii)	Business Offices
		(iv)	Petrol Filling Stations
		(v)	Banks
		(vi)	Ware Houses/Offices
		(vii)	Newspaper Companies
		(viii)	Construction Companies
		(ix)	Depots
		(x)	Motor Companies
15	Institutional	(i)	Educational (Schools and Colleges)
		(ii)	Hospitals
		(iii)	Police Establishment
		(iv)	Military Establishment
		(v)	Mosques and Churches
		(vi)	Government Offices
16	Transportation	(i)	Railway Station and Quarters
		(ii)	Private Motor Parks
		(iii)	Government Motor Parks
17	Open Space	(i)	Parks
		(ii)	Sport Ground Outside Institutions
		(iii)	Cemetery
18	Vacant Land	(i)	Site Under Constructions
		(ii)	Demolished Buildings
20	"Non-Built-Up Areas"		
21	Agricultural Plantations	(i)	Irrigated Land
		(ii)	Plant Nursery
22	Cultivated Land	(i)	Farmlands

Table 2: LAND-USE DATA FOR 1962, 1977, 1991			
Land-Use Categories	**1962 Area (Ha)**	**1977 Area (Ha)**	**1991 Area (Ha)**
Residential High Density	92.276	72.956	78.599
Residential Low Density	78.477	218.969	306.902
Industry	43.704	86.101	92.393
Commerce	10.870	75.870	72.892
Institution	101.019	122.688	127.078
Transport	66.050	40.093	39.151
Open Space	0	0	1.836
Vacant Land	29.255	14.513	28.415
Agricultural Plantations	0	31.188	31.509
Cultivated Farm Land	462.612	221.890	105.492
Total Study Area	**884.268**	**884.268**	**884.267**

4.3 MAGNITUDE AND RATE OF CHANGE

Tables 3 and 4 show the area of land under each major land-use categories for 1962, 1977 and 1991 respectively, as well as the magnitude and rate of change between 1962 - 1977 and 1977 - 1991 periods. The study revealed some interesting growth patterns between 1962 and 1977. Non-built-up areas diminished by as much as 45%, vacant land also decreased by 50% while the built-up areas expanded by 57% with institutional, industrial, commercial and residential low density land-use categories increasing by 22%, 97%, 598% and 179% respectively. This was to be expected as the 1970s were the years of the oil boom in Nigeria. Transportational land-uses was mainly land belonging to the Nigerian Railway Corporation. This latter land-use category reduced drastically by as much as 39% because the corporation leased the land to commercial organizations. The average annual growth rate for this period was 3.8%. With respect to the period 1977-1991, vacant land increased by as much as 95.8%. This was the result of the collapse and demolition of some low-cost houses in Barnawa District in 1979. Despite this disaster, land-use for residential low density experienced the largest increase of 40.2% and followed by residential high density with 7.7%. As it was the case in the earlier period non-built-up area decreased by about 45% with cultivated farm land accounting for a decrease of 52.5%. Figure 5 below illustrates the relative situations of built-up areas and non-built-up areas for the periods of study.

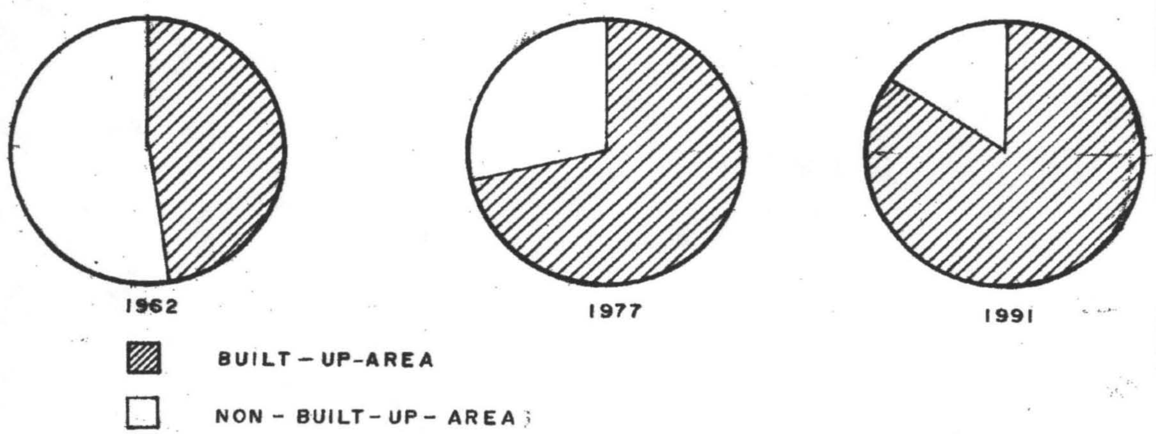

Figure. 5. RELATIVE LAND-USE IN KADUNA SOUTH 1962, 1977 & 1991.

TABLE 3: LAND-USE CHANGE IN KADUNA SOUTH (1962 - 77)				
Land Use Categories	**1962 Area (Ha) A**	**1977 Area (Ha) B**	**Change Area (Ha) B - A**	**Change (%) 100 (B-A)/A**
Residential High Density	92.276	72.956	-19.320	-20.9
Residential Low Density	78.477	218.969	140.492	179.0
Industrial	43.709	86.101	42.392	97.0
Commercial	10.870	75.870	65.000	598.0
Institutional	101.019	122.688	21.669	21.5
Transportational	66.050	40.093	-25.957	-39.3
Open Spaces	0.000	0.000	0.000	0.000
Sub-Total Urban	**392.401**	**616.677**	**224.276**	**57.2**
Sub-Total Vacant Land	**29.255**	**14.513**	**-14.742**	**-50.4**
Agricultural Plantation	**0.000**	**31.188**	**31.188**	
Cultivated Farm Land	**462.612**	**221.890**	**-240.722**	**-52.0**
Sub-Total Non-Urban	**462.612**	**253.078**	**-209.534**	**-45.3**
Total Study Area	**884.268**	**884.268**	**-**	**-**

TABLE 4: LAND-USE CHANGE IN KADUNA SOUTH (1977 - 91)				
Land-Use Categories	**1977 Area (Ha) B**	**1991 Area (Ha) C**	**Change Area (Ha) C - B**	**Change (%) 100 (C-B)/B**
Residential High Density	72.956	78.599	5.643	7.7
Residential Low Density	218.969	306.902	87.433	40.2
Industrial	86.101	92.393	6.292	7.3
Commercial	75.870	72.892	-2.978	-3.9
Institutional	122.688	127.078	4.390	3.6
Transportational	40.093	39.151	-0.942	-2.3
Open Space	0.000	1.836	1.836	
Sub-Total Urban	**616.677**	**718.851**	**102.174**	**16.6**
Sub-Total Vacant Land	**14.513**	**28.415**	**13.402**	**95.8**
Agricultural Plantation	**31.188**	**31.509**	**0.321**	**0.0**
Cultivated Farm Land	**221.890**	**105.497**	**-116.393**	**-52.5**
Sub-Total Non-Urban	**253.0**	**137.001**	**-116.077**	**-45.9**
Total Study Area	**884.268**	**884.267**	**-**	**-**

4.4 STATISTICAL ANALYSIS

TABLE 5: URBAN GROWTH ANALYSIS WITH TIME							
x_i (TIME)	**y_i (AREA)**	**x_i^2**	**$(x_i-\bar{x})^2$**	**$(y_i-\bar{y})^2$**	**$(x_i-\bar{x})$ X $(y-\bar{y})$**	**$\hat{y}$**	**$(y_i - \hat{y})^2$**
1962 (0)	421.7	0	215.121	31826.56	2616.593	434.95	175.562
1977 (15)	631.2	225	0.111	967.21	10.356	603.85	748.023
1991 (29)	747.3	841	205.435	21667.84	2109.818	761.49	201.356
SUM		**1066**	**420.667**		**4736.767**		**1124.942**

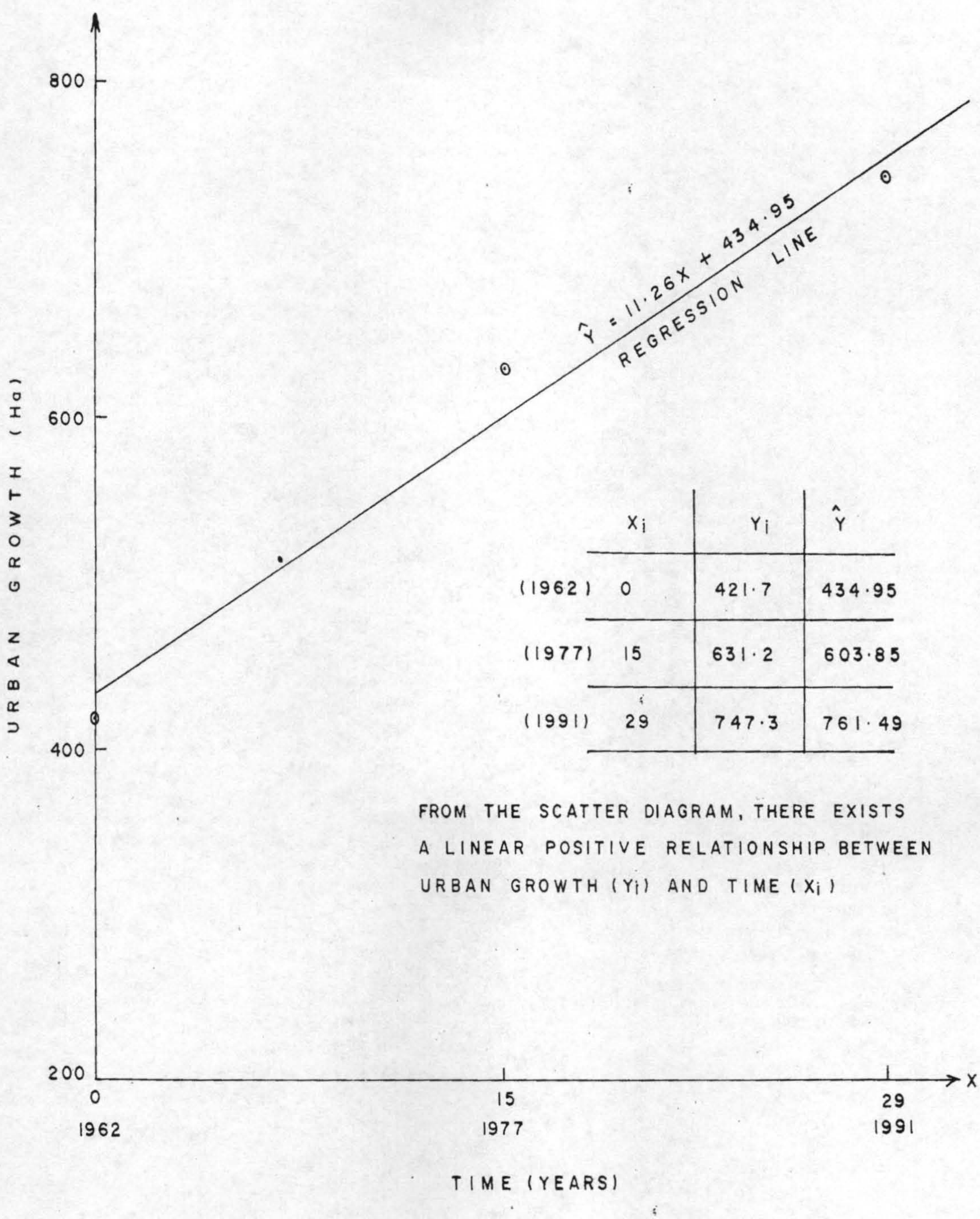

Fig. 6: URBAN GROWTH – TIME RELATIONSHIP

$\bar{x} = 14.667, \quad \bar{y} = 600.1$

The scatter diagram for the above is shown as figure 6. The formula for regression equation line is of the form.

$$y = a + bx \quad \text{...} (1)$$

where y is the size/area of urban growth at a particular time or year x, **a** is the intercept and **b** is the regression equation coefficient.

The regression analysis was to find out the extent of the relationship between size/area of urban growth with respect to time in years.

$$a = \bar{y} - b\bar{x} \quad \text{...} (2)$$

$$b = \frac{\sum (x_i-\bar{x})(y_i - \bar{y})}{\sum(x_i - \bar{x})^2} \quad \text{.................................} (3)$$

$$= \frac{4736.67}{420.667} = 11.26$$

$$a = 600.1 - 11.26(14.667) = 434.95$$

Regression Equation line is $\hat{y} = 11.26x + 434.95$

Coefficient of correlation, r, indicates the strength and direction of a relationship between one dependent variable and an independent variable.

$$r = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{[\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2]}} \quad \text{......................} (4)$$

$$= \frac{4736.767}{\sqrt{[(420.667)(54461.6)]}}$$

$$= 0.9896 \text{ or } 98.96\%$$

The interpretation of this value of $r = +0.99 \doteq +1$ is that there is a very strong positive linear relationship between the growth of Kaduna South (y_i) with respect to time x_i in years.

Co-efficient of determination, R^2, judges the quality of a regression equation model.

$$R^2 = 1 - \frac{\Sigma(y_i - y)^2}{\Sigma(yi - y)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$= 1 - \frac{1845.61}{54461.60} = 0.97 \text{ or } 97\%$$

This value of R^2 which is very close to 1.0 indicates the goodness of fit of the developed regression equation line y = 11.26x + 434.95.

Again, we see that $r = \sqrt{R^2} = \sqrt{0.9793} = 0.9896$ or 98.96%

It is also necessary to test the level of significance for the parameters **a** and **b** in order to state confidence interval. The variances of **a** and **b** are S^2 (a) and S^2 (b) respectively.

Variance of **a,** $S^2(a) = \frac{\Sigma(y - y)^2}{n - k}\left[\frac{\Sigma x_i^2}{n\Sigma(x - x)^2}\right]$ ....(6)

Variance of **b,** $S^2(b) = \frac{\Sigma(y - y)^2}{n - k}\left[\frac{1}{\Sigma(x - x)^2}\right]$ ....(7)

where n = number of observations

k = number of parameters estimated

n-k = 3 - 2 = 1 degree of freedom

$$S^2(a) = \frac{1124.942}{3 - 1} \times \left[\frac{1066}{3 \times 420.667}\right] = 950.227$$

$$S(a) = \sqrt{[S^2(a)]} = \sqrt{950.227} = 30{,}827$$

$$S^2(b) = \frac{1124.941}{1} \times \frac{1}{420.627} = 2.674$$

$$S(b) = \sqrt{[S^2(b)]} = \sqrt{(2.674)} = 1.635$$

Two statistical hypotheses, the null hypothesis H_o and the alternative hypothesis H_1 are set.

First Hypothesis; H_o : **a** = o versus H_1 : **a** ≠ o

Second Hypothesis; H_o : **b** = o versus H_1 : **b** ≠ o

The hope in regression is to reject H_o and to accept H_1 that a and b are not equal to zero. To test the statistical significance of **a** and **b** the t - distribution was used because **a** and **b** are assumed to be normally distributed whereas the "true" values of **a** and **b** cannot be known since population variance, 0^{-2}, is unknown and n<30.

$$\text{For } t(a) = \frac{\hat{a} - a}{S_a} = \frac{434.95-0}{30.827} = 14.109$$

Two tail test with 1 degree of freedom at 10% level of significance, t - table value is 6.314. Since the computed value 14.109 is greater than 6.314, the null hypothesis that **a** = o is rejected. The inference is that **a** is statistically significant at 10% confidence level.

$$\text{For } t(b) = \frac{\hat{b} - b}{S(b)} = \frac{11.26 - 0}{1.635} = 9.625$$

In this case also the computed value of 9.625 is greater than 6.314. The null hypothesis is thus rejected and then conclude that **b** is statistically significant at 10% confidence level.

To define the 90% confidence level for **a:**

$$\mathbf{a} = \hat{\mathbf{a}} \pm 6.314\ (30.827)$$

$$= 434.95 \pm 194.644$$

So that, 240.308 < **a**<629.592

To construct the 90% confidence level for **b:**

$$\mathbf{b} = \hat{\mathbf{b}} \pm 6.314\ (1.635)$$

$$= 11.26 \pm 10.323$$

So that 0.937 < **b** < 21.583

This means that the value of **a** lies between 240.31 and 629.59 while the value of **b** lies between 0.94 and 21.58.

Thus we have seen that neither the value of **a** (intercept) nor the value of **b** (gradient) will be zero. The study also showed an annual growth rate of 3.8% for the 1962 - 1977 period. This is higher than the national average growth of 2.5%. In this case the rate of urban growth can be said to be positive. This is to be expected as "The 1970 oil boom years witnessed budget surpluses. A considerable amount of money was made available largely for public sector investments in township roads and construction of drainage, public housing and on electricity supply. Though access to land was not fully opened up, land was cheap and affordable" (Garnvwa, 1996). The annual growth rate of 1.2% was determined for the 1977 - 1991 period indicating the case in which the rate of urban growth can be said to be negative. The 1980s witnessed a depressed economy. The Land Use Decree No.6 of 1978 was promulgated earlier on. The law advocated the principle of "one man, one plot" and pegs the size of land an individual could acquire in urban centres to half of one hectare. The decree vested control of all urban land in the hands of the State Governors, sought to make the acquisition of land for public purposes easier, and to simply access to land by all Nigerians. "Unfortunately, the implementation of this law has left much to be desired, as the demand for urban land has always exceeded the available supply through government layout schemes. This scarcity makes it difficult for low income earners, who constitute majority of the urban population, to gain access to land through the formal allocation process. Unfortunately also, the open market prices for plot are not affordable to them either" (Zubairu and Yari, 1996).

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

Information about the land, its uses, the settlement pattern, the changes occurring with time and the growth rate of urban centres are significant in a modern society. This is particularly relevant to governmental policy makers at all levels faced with the dynamics of change and the need for improved forecasting, planning and management.

The use of sequential aerial photographs has made it possible to generate some land-use data for Kaduna South.

Land uses of any particular area are not static but dynamic, changing in types and magnitude depending on so many factors including natural and man-made causes.

While some land uses showed remarkable incremental changes, others experienced decremental changes. The magnitude and rate of change provide an overview of the growth process.

An examination of Tables 3 and 4 shows a clear evidence of the conversion of cultivated farmlands to urban land, accounting for as much as 52% and 52.5% for the periods 1962-77 and 1977-91 respectively. This represented a strong expansion of the study area in all directions. Besides, commercial land-uses increased by 598%, residential low density by 179%, industrial land-use category by 97% during the first period 1962-1977. The Nigerian Railway Corporation land, also witnessed a decrease of 39.3% having been converted to commercial land-use during that period. Land occupied by institutions also expanded by 21.5%. During the same period vacant land became reduced by 50.4%. The annual growth rate was 3.8%.

For the period 1977-1991, land uses for residential high density, residential low density, industry and institutions had increases of 7.7, 40.2, 7.7, and 3.6 percent respectively. Cultivated farmland, transportational and commercial land uses decreased by 52.5, 2.3 and 3.9 percent. Another significant result revealed in Table 4 was the increase in vacant land by as much as 95.8 percent. As explained earlier this was as a result of the collapse and demolition of some houses in parts of the Barnawa District in 1979. The annual growth rate during this period was 1.2%.

In summary, a detailed comparison of the situations in 1962, 1977 and 1991 reveals that most changes occurred in agricultural fields becoming built-up.

5.2 CONCLUSION

Aerial photographs are a very useful and relatively cheap source of material when monitoring urban growth and when studying towns and the land use changes which take place within them. The accuracy of the interpretation can always be ascertained by field checking and/or site visits. The skill and integrity of the interpreter/observer is very important. One does not need to make a complete survey of an area to find out what the land is being used for as it has been the case in this study. Where large areas are involved, the technique of systematic sampling may be involved.

As it is evident from this study, aerial photographs served as a useful data source for overall assessment of urban growth trends (quantitative as well as qualitative). A variety of features can be recognized. Development - especially urban development - is a complex phenomenon that includes social and economic aspects, administrative and political aspects, etc. Thus the interpretation of remote sensing products should be carried out by a trained interpreter familiar with the area of study.

The regression analysis of the form $y = a + bx$ was to find out the extent of the relationship between size of urban growth with respect to time. In this study, figure 6 indicates that there exists a linear positive relationship. The correlation co-efficient of 0.99 is significant at 10% probability level. The regression equation is of the form:

$$y = 11.26x + 434.95$$

A comprehensive and universal estimating equation may be developed in future.

Landsat or SPOT imagery may also be used with computer techniques if the necessary computer software can be obtained. This will demand for a very skilled interpreter.

5.3 RECOMMENDATION

Studies relating to land-use structure of cities in developing countries, including Nigeria, are scarce. In the western world, the spatial structures of cities are generally known. Such knowledge about cities in Nigeria is often lacking.

Effective planning is frequently rendered difficult owing to a lack of up-to-date information on land use and of the means of acquiring such information.

This study suggests strongly that remote sensing techniques, especially interpretation of sequential aerial photography offers the most promising opportunity for the acquisition of basic data which are necessary for the monitoring of urban growth.

It is recommended that research programmes similar to the one reported in this study be carried out in all urban centres in Nigeria as well as in other developing countries. This will provide the detailed level of information required to get an overall broad assessment of urban areas from which the city planners or managers can make policy proposals.

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