AN ANALYSIS OF LANDUSE CHANGES IN NORTHERN PARTS OF KADUNA METROPOLIS USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES

Ph.D. THESIS

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DECLARATION

I, SUNDAY POPOOLA, OLALEYE hereby declare that this project work was carried out by me and has duly been attested to by the supervisor Dr. A.L. Bello.

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CERTIFICATION

The thesis entitled “Investigation Of Landuse Changes In The Northern Part Of Kaduna Metropolis Using Remote Sensing And Geographic Information System Techniques” by Sunday Popoola OLALEYE meets the regulations for presentation for Examination for the degree of Doctor of Philosophy in the Department of Geography, Ahmadu Bello University, Zaria.

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DEDICATION

This project is dedicated to the Almighty,

God the Father
God the Son
God the Holy Spirit

To my Parents, Mrs. Dorcas Oyegbenle, Olaleye
Mr. James Amole, Olaleye
(Both of blessed Memories)

And to My Family Members;
David, Janet, Remi, Bolaji & Wura, Rotimi & Yetunde, Kolapo, Bolanle, Tayo, Ayo and Olaoluwa – The Olaleyes

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ABSTRACT

The study was on the investigation of landuse changes between 1965 and 2003 in the northern part of Kaduna metropolis using remote sensing (RS) and geographic information system (GIS) techniques. Sources of data were primarily airphotos of 1965, 1977 and 1992. The air photos were of different scales but the use of the "dot grid" method helped to consistently identify, sample and estimate proportions of each airphoto year mosaic that had specific landuse types model by model. Landuse changes between 1992 photo-year and 2003 were obtained through digital mapping techniques using Global Positioning System instrumentation: GPS – "Magellan 315" because air photograph of the area was not available for this period and Satellite imagery (strip or spot) was very expensive.

The results of the study showed that between 1965 and 1977, and 1992 landuses changed from rural features to those of urban development indices and very rapidly. Urban residential landuses for example leaped from 62.5ha. in 1965 to 202ha. in 1977 to 392ha., and from 1992 to 507ha. in 2003. Similarly staggering rises were observed in government owned institutional lands and commercial services landuses. The rises were rapid and higher between 1992 photo year and the digital mapping of year 2003 than any previous successive photo years and ranged from 84% for urban road/highway development; for residential it was 122% to 268% for commercial services. The trend was clearly from rural to urban landuse development. However, the increases were complex

and confused with ever threatening risks of high magnitude disaster on the leading edge of urban landuses.

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ABBREVIATIONS, DEFINITIONS AND SYMBOLS

LANDUSE MAP SYMBOLS AND COLOURS

ABR.	FULL	COLOUR
SS	Small Settlements	Grey dot
E	Educational	Yellow
C	Commercial	Blue Light
M	Military	Red
RD	Residential	Brown
IN	Industrial	Purple
R	Religious	Red
P	Public	Red
OS	Open Space	Light Green
VG	Vegetation	Dark Green
FL	Fallow Land	Green

CHAPTER ONE

INTRODUCTION

1.1 Kaduna Urban Expansion

This study is on the application of Remote Sensing (RS) and Geographic Information System (GIS) Techniques to the examination of the nature of landuse changes in the northern district of Kaduna metropolis from 1965 to 2003. Population influx to towns and cities often resulte in urban expansion and sprawling, pushing the urban environment influences into the adjacent rural lands with attendant changes in landuse types, intensity and landscape quality. That is how Kaduna metropolis, a former political regional headquarters for more than half a century, grew. Field observations show that its expansion has had great impact on the surrounding rural lands. Scanty records both in maps and written documents were available to show the nature of the changes that had taken place. Thus, reconstruction of changes in landuse becomes difficult with probable large errors and speculations. Yet, there is a dire need for an understanding of the dynamics of landuses on the urban periphery for effective planning, management and provision of utilities. Nowadays, earth-mapping technology offers good opportunities for investigating landuse changes that have taken place in the past. Hence, this study investigates the landuse changes in the northern part of Kaduna metropolis using Remote Sensing and Geographic Information System Techniques.

1.2 STATEMENT OF THE PROBLEM

Rapid population growth has been a major feature of developing countries with concomitant development of large urban centers in population and areal extent. However, in the Nigeria, urbanization predated the advent of the Europeans. Large traditional cities were already in existence e.g. Lagos, Ibadan, Abeokuta, Ijebu Ode, Ondo, Benin, Oyo, Ogbomosho, Ilorin, Maiduguri, Kano, Sokoto and Zaria (Church, 1965) and (Hance, 1970). With the coming of the British rule, regional administration and economic development, migration from rural areas to towns/cities increased. Thus, increase in growth resulted in urban sprawling (Mabogunje, 1968). Rural-urban

movement of people demands provision of accommodation which in turn results in expansion of the urban environment (sprawling) into adjoining rural lands. In the case of traditional cities, where the city-core would have been effectively occupied with little "open space", with a high demand for accommodation at a rate greater than the town planning engineers can provide, the urban periphery is bound to become the target area for squatter dwellings, land development speculations and confused landuse patterns. Hence, the term "problem zone" is used to describe such a situation. Therefore, there is the need to understand landuse dynamics in the rural lands adjacent to urban centres. For example, the knowledge of the relationship or equilibrium existing among different elements in the urban peripherial ecosystem will help in monitoring the effects of changing landuses. In many Nigerian cities, there is no knowledge or records of what the urban peripheries were like. Here, Remote Sensing and Geographic Information System have high potentials and applications. It is the focus of this study.

(i) In view of the renewed impetus for urbanization in Nigeria following the adoption of a new political structure, many towns and cities particularly in the northern parts have grown larger by between 200% and 300% in population and areal extent (Abbass, 1990; Bello, 1991 and 1993; Mallo, 1997). In the case of Kaduna metropolis, it has expanded to annex small-scattered rural settlements and suburban squatters like Barnawa, Kabala West, Narayi, Kawo, Ungwar Dosa, Ungwar Gwari and Badarawa. The question now is, now that these settlements are nested within the metropolis what landuse problems have been created

Fig. 1: Location of the Study Area

Fig. 1.1: Development of Kaduna in the 1990's

Fig. 1.2: Actual Study Area

Fig. 1.3: Study Area by Models

1.3 AIM AND OBJECTIVES

The aim of this study is to characterize the urban landuse changes in the northern district of Kaduna Metropolis between 1965 and 2003. Using RS and GIS techniques.

In order to achieve the goal, the objectives are to:

i. Identify, classify, map and describe major landuse inventories during the four different periods: up to 1965; 1966 to 1977; 1978-1992 and 1993 to 2003).

ii. Appraise changes in landuse and causal effects between two photo years 1965, 1977, 2003.

iii. Examine the nature of landuse conflicts and development problems in the study area.

1.4 JUSTIFICATION

The rapid growth of Kaduna metropolis has resulted in (i) encouraging rural migration into the urban environment (ii) the development of squatter settlements around the main township (i.e. Kaduna junction and Kaduna North) and (iii) changes in landuse types with attendant conflicting interests through the expansion of the urban environment. Thus, the city planners and engineers are always struggling to cope with the rate of city expansion. Resolutions of problem of landuse changes and conflicts have often resulted in confused/poor urban landscape (Abiodun, 1998). Some of the problems manifest in form of erosion, flooding, poor provisions of utilities and service; poor sanitation and urban environmental health risks. Besides, attempts being made to solve these problems are at best "crisis management" in approach with the risk of losses of lives and property. A study of past condition of what the adjoining rural lands were using RS and GIS technology will certainly provide a first step towards effective solution to poor urban environment problems. It may also give insight into effective urban land management. The earlier landuse maps (e.g. Max Lock 1957; 1967) were based on the conventional land/field surveying which tend to propergate and accumulate errors; and because of limitation in areal coverage they are full of generalizations. On the contrary the maps constructed and landuse demarcated using photogrammetry (which aid landuse interpretation through the land/field surveys) are far superior in precision and details as represented on air photos and imageries.

1.4 CONCEPTUAL FRAME WORK

Landuse is the general term employed to describe the use made of the various part of the earth's surface by man. For the decisions on the optimum use of land, the study of both actual and methods of its employment and what it is good for are essential

components. Igbozurike (1981) defined landuse as the functional aspect of an area with respect to man's activities on the land (i.e. occupational and cultural). Scholars like Anderson (1976) and Bickmore (1970) attempted land classification in different parts of the World with different interests at different times. The latter provided landuse survey classification with nine classes which do not fit well into the tropical rural landuse system.

Forms and functions of land are also major attributes in describing landuse. Thus landuse types are recognizable depending on the purposes and scale of classification.

Early classification often include vegetation cover, forest, grassland, marsh, cultivated crops, water bodies, building and man made open spaces. Hence, landuse may be identified by the appearance or form of the surface cover. When the uses to which the land is put are considered (e.g. built up, administrative offices etc) the classification is based on function. In developed countries a more detailed function such as residential, educational services, retail services, industrials and manufacturing are also recognized.

When attempting to classify land based on uses, whether open space or built areas, a complication arises. For example, resource or building may simultaneously have two or more purposes. Therefore, landuse may be multipurpose. The concept of multipurpose landuse has been applied more often to non-urban than to urban land. For instance, agriculture or agricultural landuse for a long time has been associated with the diversified production of plants and animals as opposed to a monoculture. This strictly refers to the use of the same ground for a wide variety of purposes, which may include farming, forestry, nature conservation, amenity and recreation. Technological development and cultural changes combined with population growth have resulted, particularly during the past century, into two major landuse trends. The first is the increase in the number of different ways in which land can be used, and the second is the replacement of one type of Land by another. While rural Lands may be defined as non-urban in character, the encroachment of urban environment on rural lands has also resulted into the blurring of the once clear-cult distinction between the two types of landuse, making it more difficult now to demarcate where one ends and the other begins. Besides, the specific meaning of the term urban environment (urbanized area) is increasingly becoming difficult to restrict to geographical usage. Specialists such as economist, town planners sociologists and transportation engineers have waded into urban landuse and they are now directing their attention to urban problems that have clear geographical dimensions (Tivy and Johnson 1978). One of the major urban problems with geographical dimensions is the

increasing impoverishment of the urban landscape development and management of urban services (Abiodun, 1998). Thus, the thrust of this study hinges on the impact or problems of continuous urban developments and its expansions into the adjacent rural lands.

1.6 DEFINITION OF TERMS

It is necessary to state here that there is a need for a short section on definition of terms used in this proposal. Since the nature of the subject demands it.

1. **Parallax:** The apparent displacement of the position of a body with respect to a difference in point system caused by a shift in the point observed. Parallax bar (or stereometer). A measuring device containing a micrometer by which the separation of two index marks can be changed to measure parallax difference in terms of height on a stereoscopic pair of photographs.
2. **Stereoscopic View:** The orientation of photograph when properly positioned to give a 3 dimensional view of X, Y, and Z directions.
3. **Model:** A stereoscopically viewable terrain, as at photography. It is formed from 6 standard points 1,2,3,4,5,6. Each of the points (1,3,5) and (2,4,6) from a cross section. (Figure 2).
4. **Standard points:** For projective geometry, the internationally accepted points where the orientation can take place in order to obtain a stereo model.
5. **Overlap:** An overlap is made up of similar terrain features viewed from two aerial photographs taken from two exposure stations.
6. **Colinearity condition:** Linear nature of rays of light from source to the object. It states that the “exposure situation”, the image point and the object on ground are on the same straight line.
7. **Coplanarity condition:** Expresses the range at which the stereoscopic model lies within a plane. It states that the two exposures station, the two image points and the object point must lie in a plane. (Figure 3).
8. **Inner orientation:** This is the resolution of the original bundle of rays that made the photograph. Practically, it is carried out on instruments by setting the principal distance, centering the photographs (diapositives), setting correction clamps (etc).
9. **Relative orientation:** This is also called Y-parallax removal. It is defined as the procedure of intersection of conjugate rays (pair of rays intersections on the terrain from two exposure stations). It is proved from projective geometry that if 5 of such conjugate rays are made to intersect at any 5 of the 6 standard points, stereco model is formed. (the sixth point is used as a check).

10. **Absolute orientation:** This is often referred to as scaling and levelling of the model. It is the procedure of obtaining the orthogonal projection of the various heights of points on to the terrain.
11. **Floating mark:** A black measuring dot on the instrument for measurement (of planimetery and height).
12. **Fiducial Marks:** Marks at the edges of an aerial photograph used for a proper centering of the photo (diapositives) on the X, Y plate carriers.
13. **"Dot Grid" (Template) overlay:** Dot marks in a square or rectangular systematic grid on a transparent overlay for the purpose of identifying and measuring of landuse areas. The spacing of the dots may be expressed as grid density or number of dots per hectare or square kilometre.
14. **Polar planimeter:** An instrument used to measure the area of any figure by passing a tracer around its boundary and recording the area so encompassed. The measurement uses the principles of vectorial angles and radius vector.
15. **Weight apportionment technique:** Weight is the measure of relative reliability worth of a quality as compared with other values of the same quality comparable gratitude.
16. **Photogrammetry:** This is the art, science and technology of taking geometrical measurements by means of photographs.
17. **Air photo year:** The year a photograph was flown at a given scale.
18. **Photo mosaic**: An assemblage of aerial photographs whose edges have been cut and matched to form a continuous photographic representation of a portion of earth surface.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

From the fig. 1 the different methods of landuse survey and mapping include: (a) Direct approach e.g. Land Survey and (b) Remote Sensing. The direct method is old, very tedious, energy involving and labour intensive. Even with few skilled men and many unskilled laborers, the time involved in such an exercise does not pay for the cost. The direct method does not give the opportunity for recalling the past for studies. The method therefore is not applied for this project. The remote sensing methods include the use of (i) Satellite imageries and (ii) Air photographs.

2.2 Satellite Images

Satellite imageries can be obtained from active systems i.e. systems which supply their own source (e.g. energy of Radar SAI or ERS-I) or passive systems that detect naturally the occurring reflected or emitted radiation (e.g. MSS Spot or Space Lab).

2.3 Landuse and Landuse Classification

The definition, analysis and interpretation of landuse have been the subject of interest to scholars. Igbozurike (1981) defines Landuse as the functional aspects of an area with respect to man's participation on the land in terms of his occupations and cultural activities. Several authors, (Anderson et al 1976; Bickmore et al 1970) have attempted Land classifications in different parts of the world, with different interests at different times. Bickmore cited the world land use survey classification with 9 classes which does not fit well into tropical systems of rural landuse (Field and Collins 1986). Tuley (1972) developed a invaluable land system and Land facet classification in a survey of an area of 60,000m^2 using the 1:40,000 scale, 900 aerial photographs of North east Nigeria. In 1949 the World Landuse Survey Commission proposed a classification of landuse which has become an internationally accepted system for landuse and land cover. In this study the Primary classification of Anderson (1976) based on his experiences in tropical and temperate regions and, in particular his studies in West African countries of various landuse and land cover problems is adopted. The eleven different Landuse classes identified include:

1. Cultivated land
2. Grass land (fallow land)

3. Barren (marginal)
4. Residential
5. Commercial activities
6. Recreational
7. Institutional
8. Roads and Highways
9. Airport
10. Railways
11. Paths and tracks.

In Kaduna, landuse activities started with the Army that acted in cooperation with the town planning officers of the Survey Department. In the middle of 1950's this team drew up a survey sketch plan for Kaduna development similar in principles to the following classifications:

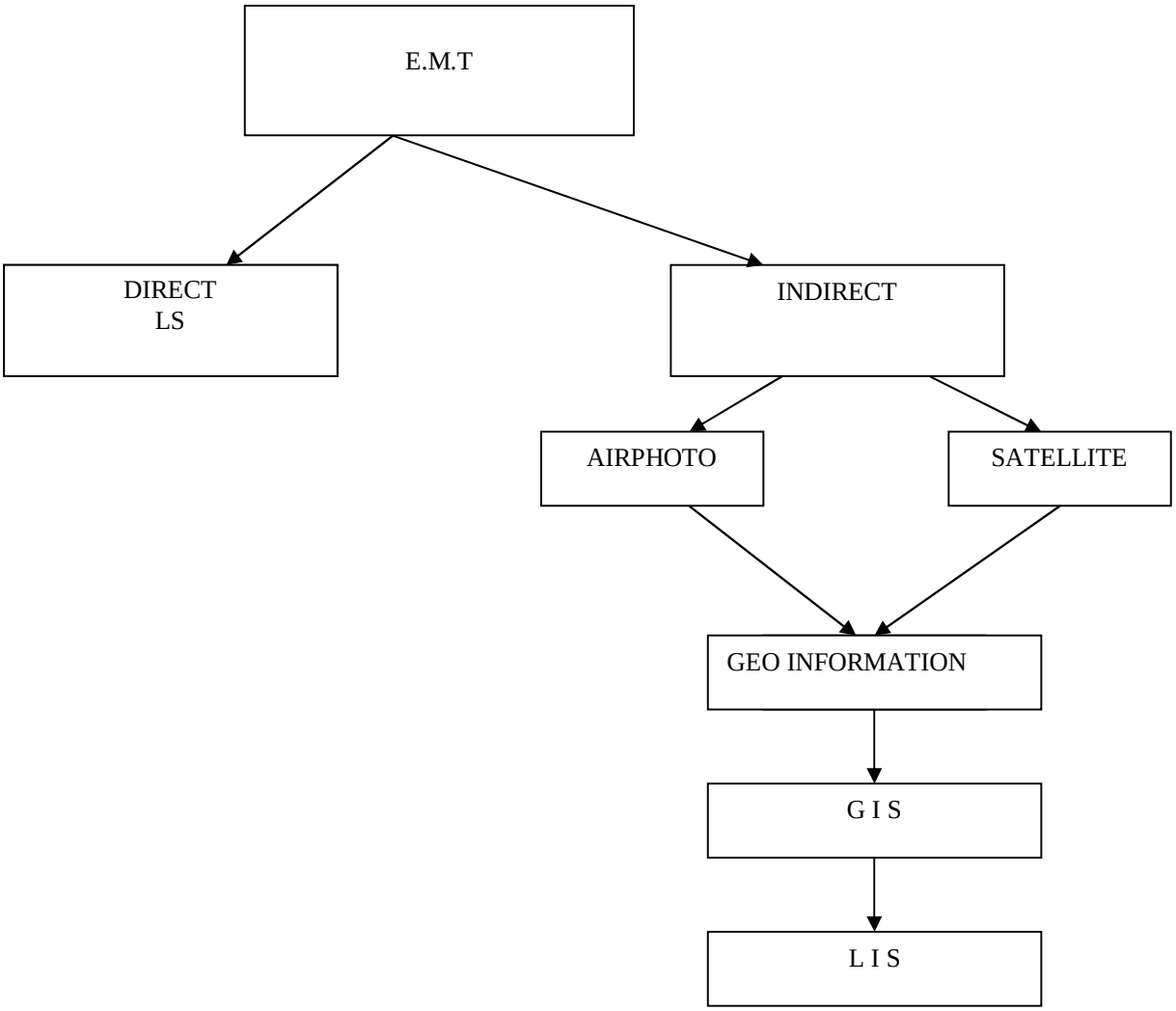
(a) Residential (b) Army (c) Governments (d) Open space (e) Industrial and Commercial.

Avery (1965) discussed the intense competition for space between residential, industrial recreational and other landuses and added that these interests present a continued series of problems to the urban planner. Nunally (1974) referred to few investigations e.g. Avery 1965, Fallner (1968), Kitchen (1969) and Weller (1971). He then advised on the use of special systems solely for the purposes of investigation, data capture and recording of landuse.

2.4 REMOTE SENSING TECHNOLOGY

Remote Sensing technology can be defined as the science of acquiring information about some property of an object through the use of a measuring device which is not in physical contact with the object under investigation. Horton (1974) pointed out that remote sensing offers an important opportunity to help improve the effectiveness of urban management and help predict urban growth, development and hence help maintain and improve the quality of metropolitan environments

Figure 2.1: CONFIGURATION OF THE EARTH MAPPING TECHNOLOGY (EMT) SYSTEMS OF OPERATION



2.4.1 Aerial photographs

Aerial photographs the most common detection and recording equipment or techniques used in remote sensing are shot with the use of aerial camera.

In essence the "Remote sensing task is to collect, analysis and convert remotely sensed data to information for problems solving or decision making" (Anderson, 1977). Hence remote sensing merely provides a means to an end, and not an end in itself. This remote sensing technology (aerial photograph) is logically the least expensive method of data. Collection and analysis that is compatible within the reliability and accuracy of the data, which should be and is adopted".

Anderson (1971) – The hallmark of any landuse and land cover study from aerial photograph is the degree of confidence in the results obtained thus a minimum of about (85% – 90%) is recommended. However, accuracy be it of landuse and land cover studies using remote sensing techniques has been recognized by Hord and Boonor (1976), Esin (1981), Aronoff (1982), Collins and Mead (1983) and Field (1986) as both complex to determine as it is difficult to measure. This is because the terms as related to landuse studies embrace sampling, interpretation classification and mapping of the data acquired. Anderson enumerates the following:

1. Point sampling makes estimation by measurement and/or depiction and delimitation of individual plots very unnecessary.
2. Records of interpreted landuse can be given as simple data sheets.
3. A high level of precision and accuracy may be achieved as desired by increasing the grid density or by an assemblage of the units to be measured.
4. For monitoring and investigating landuse changes data can be collected from the various sets of aerial photographs for comparative purposes.
5. Errors are minimized as results of fixing correct grids even for air photographs with different scales.
6. It is also compatible with computer programmes for interpretation analysis, tests, and prediction.

Accuracy of landuse information is a complex issue both in its definition and measurement (Hord and Booner 1976). Landuse accuracy could be categorized into four, namely:

1. Classification accuracy
2. Interpretation accuracy
3. Sampling accuracy
4. Map accuracy.

Errors in any of the above landuse information no matter how small could seriously affect other aspects of landuse categories and so the error(s) become cumulative.

Among the common errors are those arising from:

1. Misplacing of grid points (i.e. dots similar in position) in different epochs photography when template do not fall on identical features in the respective photographs.
2. Incorrect interpretation of the features under dots
3. Blunders in transferring the data from the interpretation record sheet manually into the storage disk of the microcomputer.

From the above and considerably the economy of accuracy principles of surveys, one would agree with Field (1992) that since the desired results are available from the use of aerial photographs, the costs of labour and time directly from the land surveying approach and the cost acquiring, processing and interpretation from satellite imageries may not be very necessary. The research therefore settled down to the use of 3 air photo sets available for 1965, 1977 and 1992.

2.4.2 **Landsat Imagery**

Landsat Imagery with its numerous advantages over other remote sources is very expensive to produce and the cadre of personnel and equipment to interpret them is not within easy reach of institution in developing countries like Nigeria. However, there are large-scale photos of many different towns in Nigeria that have been flown at one time or the other. As Field and Collins (1986) quoted Philipson (1980) "if the aerial photography is available, the expenses of acquiring and analysis other forms of remote sensing may not be justifiable".

It should be noted that the level of information that can be obtained from remotely sensed data is dependent on both spatial resolution and on temporal frequency. Air photographs such as are used for this research from medium altitudes have high spatial resolution but may only be flown in frequency on a series basis and represent an

extremely high cost for any greater frequency. The LANDSAT MASS images are obtained every 16 days over an area (cloud permitting), which satisfies most temporal urban requirements but the spatial resolution of 80m limits its applications in densely built up areas.

However, Taylor and Francis (1989) have demonstrated that "There are a number of problems related to remote sensing in urban areas". The problems include: -

(b) The level resolution may limit an interpreter's use of the contextual clues of site and association with the result that only land cover classes and not landuse classes (of an area) can be inferred.

(c) Urban areas are typically heterogeneous with many different cover types. For example, tile roofing material, asphalt, concrete, grass, trees, soil and water. Many of these cover areas have less than the resolution of one picture element.

(d) Radiation from a single element on the ground may therefore be derived from a number of surfaces each having its own district spectral signature, giving an addition response that is not representatives of any of any one-land cover types.

The radiation reaching the satellite must pass through a number of components of the sensor before being recorded. This covers a smearing or spreading of the signal. The distribution recorded is therefore dependent on the point – spread function of the sensor, which for LANSATMASS approximately shows that a greater spreading effect occurs along scan-direction, that is at right angles to the direction of flight of the space craft.

The point spread function integrates the response from the observed or target pixel and its surrounding pixel accounts for 50% of the total response, the balance coming from its neighbors (Forester 1981). On homogenous agricultural areas, this is not a problem, except at the interface of two separate cover classes because the target pixel will have the same response as its neighbors. However, the point spread function can significantly effect the response from a single cover class if the surrounding cover is dissimilar, which can occur quite frequently in urban areas.

(e) The standard approach to classification of remotely sensed data is to assume that the area of study comprised of a number of unique and internally homogenous classes, so that a clustering-based classification procedure can be used. However, in

urban areas, a continuum of cover classes exists which cannot be early broken into discrete nominal classes. For example, in one area residential density may be lower with few established trees, and may have a similar density but mature vegetation. Yet another area may be of a high density with little or no vegetation with intermediate examples occurring between each of these urban multi-spectral response are not particularly amenable to cluster based classification techniques because clusters either will have considerable over lap or be extended linear clusters. This makes it extremely difficult or impossible to determine the probability of an unknown value being part of one or other classification.

(f) Radiation reflected by a surface to a satellite sense is attenuated by the atmosphere as it passes through it and a component termed path radiance is added to it. These effects are very much dependent on the amount of haze or pollution in the atmosphere or, simpler, on atmosphere visibility. Visibility can vary considerably over different part of a large city and so the degradation of the recorded response can be spatially variable.

(g) Satellite scenes, from different periods, temporal variation in solar zenith angle, visibility and solar irradiance (at the true of satellite over pass) can cause substantial differences in received response at the sensor. These differences will be at a maximum for summer and winner scenes. The problem is that of different attenuating effects of the atmospheric observation from the image scene.

(h) Temporal changes analysis requires an accuracy of registration at least equivalent to the elements being monitored. It is therefore necessary to consider the resolutions required vis-à-vis what the imagery can give for any project. Air photographs, thus provides a better alternative when available.

CHAPTER THREE
GEOGRAPHICAL SETTING

3.1 INTRODUCTION

This chapter describes the geographical setting of the study area. First, he physical environment is presented in section 2.1 and in section 2.2 the evolution of the city, its population growth, socio-economic, characteristics and landuses are described.

3.2 THE PHYSICAL ENVIRONMENT

3.2.1 Location

The study area extends from the Nigeria Defense Academy (NDA) Kawo, along Kaduna – Zaria Road through Kawo railway junction Northwards to Riga Chikun, and bounded by the Kaduna River to the east. It covers an approximate land area of 72km^2. On topographical map, Kaduna sheet 123, 1:25,000, the study area is bounded by latitudes 10^0 35', N and 10^0 33', N and longitudes 7^0 26' and 7^0 28'E. The city is centred on latitude 10^0 27 N and longitude 7^0 27E and is centrally located for easy access from different parts of the country. Located on the High Plains of northern Nigeria, the terrain is undulating with average elevation of 640m a.s.l and is about 800km from Lagos.

3.2.2 Geology, Relief and Drainage

The geological structures consist of biotite Younger Granites and Older Granites, undifferentiated gneiss with migmatite and granite of the Basement Complex. On this solid geology, deep chemical weathering followed by fluvial erosion, influenced by the bioclimatic nature of the environment have fashioned the characteristically subdued relief that is dissected actively by stream systems. Also isolated residual hills of different origins, sizes shapes interrupt the infinite horizontality of the landscape. However, within the study area, the residuals are mainly of duricrust origin, weathered bedrock mass capped with hardened ironstone (Thomas, 1974; Sivarajasignham, 1961). The residuals have been modified or partly destroyed by quarrying for road construction and urban developments in some quarters and wards (e.g. Old Airport, Ungwar Dan Kande and Mararaba Jos).

River Kaduna is the principal stream that runs through the metropolis and together with smaller tributary systems such as Rigasa, Barnawa, and Rigachikun, the entire city and

study area is well drained. Drainage density varies from ward to ward and range from 3.1km/km^2 for natural stream and 6.41km/km^2 for man-made drains along major roads and streets throughout the urban environment. This condition provide the opportunity for evacuating storm runoff as quickly as possible (Mallo, 1997). In the study area the drainage density, determined using available topographical maps is 3.25km/km^2.

3.2.3 **Climate**

Kaduna Metropolis enjoys a tropical continental type of climate with distinct hot wet and cool dry season. The hot wet season is short and lasts from April/May to September/October. Annual total rainfall is 1209mm, most of which comes in form of sudden cloud bursts and convectional heavy falls of high intensity; up to 120mm/hour particularly those associated with line squalls (Oguntoyinbo, 1978 and Oladipo 1985). Although the average temperatures suggest that it is hot all year round, the mean minimum can be as low as 7^{0}C and the mean maximum may be greater than 30^{0}C. Table 2.1 illustrates the long term monthly mean minimum and maximum temperatures for the city. Both rainfall and temperature characteristics vary considerably from year to year with concomitant effects on land uses and the environment.

Table 3.1 – Mean monthly minimum and maximum temperatures for Kaduna Metropolis (1965 – 1990)

Temperatures (^{0}C)												
	J	F	M	A	M	J	JL	A	S	O	N	D
Mean Minimum	15	17	21	23	22	20	20	20	17	19	15	15
Mean Maximum	31	34	36	35	32	30	28	28	30	32	32	31
Monthly Range	16	17	15	12	10	10	8	8	11	13	17	16

Source: Kaduna State Meteorological Station

3.2.4 **Soils and vegetation**

The soil in the study area is of the tropical ferruginous developed on the weathered bedrock described in section 3.2.2. It is characteristically latosols with little organic matter particularly where land management and conservation practices are very poor.

Bush burning and long dry season are responsible for the rapid decication and cracking. However, in valley bottomlands and flood plains latosols give way to vertisols – “the fadama” soils. The latter soils have attracted dry season irrigation farming and market

gardening into the surrounding suburban or squatter settlements. The activities of these dry season irrigation market gardening farmers play an important role in the study area. Urban landuse expansions and changes are described in section 3.3.2.

Urbanization and expansion of construction have resulted in clearing the natural Northern Guinea Savannah Vegetation which has been replaced by secondary grassland Savannah re-growth. On the surrounding urban margins fuel wood harvesting, bush burning and deliberate clearing for scattered subsistence crop cultivation have reduced the vegetation to derived Isoberlinia Savannah (Areola, 1982). An aerial view of the city shows patchy stands of ornamental plants and fruit trees along streets and water courses (Mallo, 1997) or floristic gardens.

3.3 Development of Kaduna

Kaduna is derived from "Kada" (Hausa word for crocodile – Kaduna is the plural form) and River Kaduna bears the name because the major river draining the area breeds the reptile.

Lord Lugard founded the settlement named after the River as an administrative headquarters in 1912. Prior to that time, dispersed small indigenous "Gbagji" settlements were in existence (Lock and Theis, 1967). The establishment of a cantonment, extension of the railway systems that form a major junction; and later Regional Political administration (in 1954) gave the settlement a leading edge over many other cities to become, not only the Regional administrative headquarters but also the leading industrial and financial centre in the then Northern Region of Nigeria.

Initially the settlement consisted of two distinct sections, the Kaduna Junction (Kaduna South) and Kaduna North. River Kaduna and a 450m wide-open space separated the two settlement that have since become one. The settlement to the North still retains the administrative setup in the study area. Although Kawo had been a small indigenous settlement, city expansion and growth of the settlement as a result of immigrants' demands for accommodation suddenly transformed Kawo into a large and ever growing sub-urban district.

3.3.1 Population

The city has now assumed a metropolis status in out look and function. Its population consists of indigenous, national, ethnic groups and a fairly large proportion of non-

Nigerians from neighboring countries such as Niger, Chad, Cameroon engaged in diplomatic service, social and commercial activities. Although Kaduna south used to be the African settlement, it has transformed into an industrial development area with African residential units as distinct suburbs (e.g. Kakuri and Barnawa, fig.1). Today a lot of functions have been duplicated in both sections. The 1996 political structure has again re-established the two as separate Local Government Areas (LGAs). Indeed, Kaduna has had a rapid growth. From a small settlement occupying 26km^2 in the late 1930s it has become a large metropolis and still sprawling covering over 135km^2 (Mallo 1997 and Bello 1991) Table 2.2 illustrates, the population growth of the metropolis.

Table 3.2 Growth of Kaduna North and Some suburbs.

YEAR	LOCATION	AREA / SQUARE KM	HECTARES	POPULATION	
Prior 1963	Entire city	25.836	2583.6	-	
	Kaduna North	10.651	1065.1	-	
	Kawo	NA	NA	14932	
	Rigasa	NA	-	NA	
	Dosa	NA	-	NA	
	Badarawa	NA	-	NA	
Year 2000	Entire city	135.0	13500	1996	1991
	Kaduna North	45.0	4500	406731	348000
	Kawo	6.0	600	43369	37107
	Rigasa	5.6	560	84716	72483
	Dosa	3.3	330	22976	19658
	Badarawa	2.8	280	38278	32751

Source: Population Commission Kaduna State (2000)

3.3.2 **Landuse and city sprawling**

Table 2.2 shows also the pattern and trend of development within Kaduna Metropolis prior to 1963. This is based on map evidence, ground checks using specific landmarks oral and some archival sources. Prior to 1963, the settlement was limited to the Cantonment, administrative offices, their residential quarters and the railway transport system headquarters established for the northern zone. Expansion and subsequent developments were due to tertiary services that grew from the "three legged foundation" of (i) government capital, (ii) military garrison and (iii) industrial establishments (Max Lock, 1967) as well as the coming of members of foreign diplomatic missions and industrialists. In 1919 the population of Kaduna was estimated at 3,000 and rose astronomically to 150,000 by the 1963 head count. Now the population is estimated to be 895,300 (Bello, 2000) majority of the people live and work in factories, government establishments/office or are engaged in commercial activities.

CHAPTER FOUR

METHODOLOGY

4.1 INTRODUCTION

In this chapter, materials needed, types of data to be extracted and the scope are described in section 3.2 Section 3.3 explains the aerial photograph analysis and statistical analysis employed in handling the data collected.

4.2 MATERIAL AND METHODS

4.2.1 Materials

a) Materials used and types of data collected include (a) sets of aerial photograph of 230 x 230mm format on a black and white panchromatic prints. The 1965 photograph was in one strip at a scale of 1:20,000 while those for the 1977 and 1992 were on a scale of 1:600 and 1:10,000 respectively.

b) Mirror stereoscope, a simple lens mirror stereoscope with two mirro prisms placed to increase the physical separation of the stereoscopic pair so that larger photographs can be viewed without overlapping at the center as it is the case with pocket stereoscope.

Fig. 3.2: 1977 Mosaic

Fig. 3.3: 1992 Mosaic

c) The pocket stereoscope is the hand held one which can be used easily in the field and in the laboratory for quick but less accurate photograph observations.

d) The Wild B8 and Wild A8, These are analogue instruments with means of observing images of the stereoscopic models and devices for measuring coordinates for plotting the observed stereoscope models. While the B8 is a topographic instrument, the A8 is a precision instrument capable of being converted to digital if required.

e) Topographic maps covering the entire Kaduna metropolis (i.e. sheet 123 on scales 1:25,000 and 1:50,000) were used as base maps but those covering northern district were combined with sheet 123 on scales 1:25,000. The latter helped in few checks of model constructed from airphotographs for the study area.

f) Hand held “Magellan - 315" GPS set for rapid digital recordings of detailed field observations and location of features. The mapping and calculation of landuse areas for the year 2003 (for which airphotos were not available).

g) AutoCAD software was used. This was chosen out of many available software e.g. ARCVIEW, MapInfo ARCMAP, ILWIS, IDRISSI, ARCINFO etc. The choice of AutoCAD was strictly based on availability and adaptability to the study problems. This is fully discussed later.

h) Affine transformation: Again this is a mathematical functional model used along with the AutoCAD software. The coordinate transformation and adjustment were carried out using this functional model. This is also fully discussed later in the chapter.

4.3 METHODS

This section includes the approach adopted for the study and the details of different techniques used for various data collected and analysis.

4.3.1 THE APPROACH

Both direct field experiment and measurement were conducted using different appropriate instruments as mentioned above. Also air photographs and topographic maps were followed by ground truthing before delineation of stereo models. The 1965, 1977 and 1992 photograph covering the project area were used in identifying and mapping the available landuse information for comparative analysis in between two successive photo years. However, the 1992-air photograph was used as a base for the digital mapping of the landuses for the year 2003. For the last photo year extensive "ground truthing" took place. It is important to state that the 1992 air photo is the latest available for the study area and it was produced at a very high cost by the Nigeria Airforce (₦850.00m). With the digital mapping using the "Magellan – 315" GPS set in the field, the current landuse status was mapped.

4.3.2 MEASUREMENT OF AREAS AND HEIGHT DETERMINATION

Techniques for measuring areas, height determination and interpretations of features on aerial photographs vary depending on purpose and available instruments. The techniques include the use of parallax Bar, Polar planimeter, Electronic digitizer, and the weight apportionment, grid" and line transects. For example, the "dot grid" method (Bonnor, 1975) was adopted for the investigation of landuse changes as discussed below. The air photo interpretation and adopted landuse classification will be discussed.

The common techniques involve the use of Parallax Bar, Polar Planimeter, electronic digitizer, instruments and weight apportionment technique the line transect method and "dot grid" methods.

The Parallax Bar (also called the stereometer) uses a measuring device containing a micrometer movement, by means of which the separation of two index marks can be changed to measure parallax difference on a stereoscopic pair of photographs. The Parallax differences by measurements define the height variation from one part to another on the same air photograph.

Polar Planimeter method involves moving the tracing point of the instrument (Planimeter) around the outline of the figure. The instrument has an integrating disc which register an amount proportional to the area of the figure. In case of a fixed arm planimeter a graduated drums gives the area.

However, there is a need to apply correction factor when working on air photos of plan maps in order to convert the measurements to actual ground area. The polar planimeter (a specialized planimeter) has a higher precision and should be used for area measurements with irregular outlined boundaries.

The weight apportionment technique uses a very sensitive laboratory balance. According to Paine (1976) a copy of photograph is carefully cut into pieces types which are sorted out to designate various class types such that weight are apportioned to each class precisely determined on the balance. The ground total of all types is then weighed to ensure that the sum total of the cut parts equals the whole. The acreage of the survey unit is distributed among the variable types in proportion to the weight. The method is very efficient for determining the area of various land use types for cadastral purposes.

The electronic digitizer method of area measurement uses a continuous registering X and Y coordinate values of the tracing cursor into the computing processor which transforms

the readings into areas of the figures at the end of the X and Y coordinate reading devices. The procedure is tedious and time consuming although the accuracy obtained is usually very high.

The line transect methods uses the principles of proportions to determine the area of land use types, the length of evenly or random. Speed lines that pass through each type of class type are measured and such areas are apportioned in proportion to the total length of the lines in each class.

4.4 AIR PHOTO INTERPRETATION

Interpretation and analysis of landuse on air photos require specialized instruments (section 2.1) and skilled labour in the reading, observations and measurements. The air photographs were first examined stereoscopically using a folding mirror stereoscope with binocular attachment for magnification as the needs arise. For more detailed measurement, identification, analysis final decoding and the actual mapping the A8 and B8 WILD analogue stereoscopic instruments were used. The two instruments were combined because the Wild A8 has the advantages of adaptability and precision for digitally coded data collection. The data so collected provided opportunity for digital mapping format, using the Affine transformation model (section 2.1). the analogue maps were complied on the wild B8 and A8 instrument. For each set of air photo year, a "dot grid" template was constructed.

However, the developmental trends in earth mapping technology according to methods and types of instruments used had been considered to have moved from ANALOGUE → HYBRIDISED → DIGITAL. So, landuse mapping had been characterized by the age long conventional surveying methods of chain, compass and tape measurements, and have given rise to some being analogue and some digital (using semi-analytical) instruments.

Presently, digital approach includes the auto plotters using computerized systems and the recently using satellite Global Positioning System (GPS). Various techniques have been used for collecting, analyzing, interpreting and mapping landuse data. To chose a particular technique may depend on factors such as the purpose of the study, type of thematic map, available instrument, manpower, hardware and software, level of accuracy envisaged and sometimes time of completion. Also the techniques may range from hybridized to photogrammetry to integrated with digital. Merits and demerits of each have already been discussed elsewhere (Aronuf, 1989, Clark and Jackson, 1965, Kyari, 1997). The digital techniques uses precision instruments with positional errors of less than 0.5m. Such techniques are suitable for most of the surveying works in developing countries. Among precision instruments available in the market is the Global Positioning System instruments ranging from those with mainframe handheld types

4.5 DATA COLLECTION PROCEDURE

Techniques for measuring area, height determination and their interpretations using aerial photographs vary depending on purposes and available instruments.

4.6 DOT GRID TECHNIQUE

Dot grid method Bonnor (1975) consists of dots marked in a square/rectangular systematic grid on a transparent over lay (Template). The spacing of the dots may be expressed as grid density or number of dots per unit area (hectare or square kilometer). To estimate an area using “dot grid” method on an aerial photograph:

i. I carefully demarcated the different landuse observed on the air photo and use the overlay template to estimate the number of dots contained in each (to the nearest whole unit).

ii. I later estimated the area value of each landuse type in proportion to the total area of the air photo.

iii. I placed the overlay (i.e. transparent dot grids) on the air photo space to be determined for the estimation.

iv. I repeated the procedure to get the average value.

The procedure above will minimize errors of measurements. However, errors in areas measurements from air photo may be complicated by variation in scale, photographic tilt and relief displacement. Errors due to variation in scale may not be very important in flat/undulating terrain such as the study area; even when it involves relief displacement. Estimation error becomes serious if it is more than 3% of the station height above datum (Spun 1960). Area measurement near the photo principal points tends to reduce errors. (Field and Collins 1986).

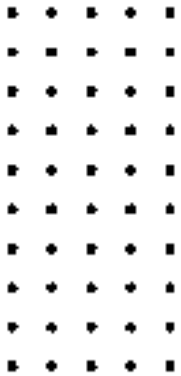


Fig. 4.4: 1965 Dot

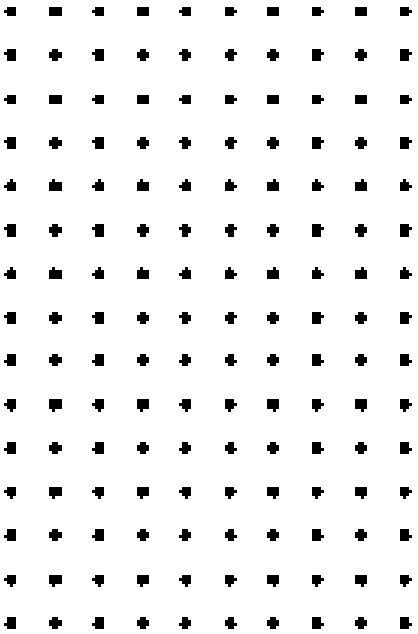


Fig. 4.5: 1977 Dot

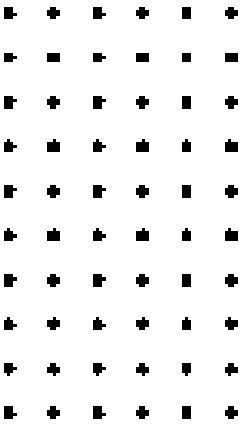


Fig. 4.6: 1992 Dot

Apart from the fact that the "dot gird" method is now widely used, its scientific nature and precision have been tested Dickson (1977), Emmott (1981), Anderson (1971). To achieve acceptable confidence limit of greater than 85% as suggested by Anderson (1972), the formula developed by Snedeckor and Cochran (1966); evolved by Brunt (1967) and Bonnor (1975) Photo year was adopted using the expressions;

$$D = \frac{N}{AP}$$; Snedeckor and Cochran (1966) .....Eqn. 3.1

where N = Total number of dots

A = Area KM^2

D = Dot density/KM^2

and, AP = total number of stereo – model (Snedeckor and Cochran, 1967).

In order to minimize the "gross error" in measurement and estimation of area of landuse types Vis-à-vis number of dots, (Brunt, 1969) and (Bonnor, 1975) formulae were adopted. The equation expressions are:

i. $E = K(100-P)^{\frac{1}{2}}$ (Brunt, 1967)..... Eqn. 3.2

ii. $$PE = \frac{1153.1}{(AD)^{58}}$$ (Bonner, 1975) .....Eqn. 3.3

Where E = half the percentage error of a class in a sample at 95% Confidence limit,

P = Percentage of the class,

K = 196 (a constant based on student T-test of 95% confidence level)

Fig. 3.7: Coplanarity Condition

Fig. 3.8: Stereoscopic Model

However, photogrammetric techniques were used to compute the area and the number of dot in order to compare the Brunt (1966) and Bonnor (1975) derivations. To this end dot grids per stereo model for the air photo years (1964, 1977 and 1992) were used. Thus, the comparison by table between the photogrammeteric approach, the Brunt and the Bonnor values were obtained. The Brunt and Bonnor use of the formulae consistently over estimate the numbers of dots. The reasons are that the formulae did not take into consideration the border line areas of the paired photograph overlaps. This was considered important so as to allow for tolerance limit. For this study, the format size of the air photo was also compared and the average formed the basis for the adopted number of dots.

Table 4.1: Comparisons of number of dots per stereo model using Brunt's and Bonnor's formulae, and those determined using photogrammeteric technique and the adopted for use

Years	Photo scale	No. of photos	No. of models	Brunt's	Bonnor's	Photogrammeteric	Adopted
1964	1:20,000	12	11	190	110	165	170
1977	1:6,000	8	7	52	54	48	50
1992	1:10,000	9	8	100	90	85	80

In planimetry, using between 0.02 and 0.03cm of map scale and in height using 1/1000 factor of the flying height, as tolerance limits. For the result of that of 1964 photo, between 4 and 6 have to be added and here the average was used. However, the 1977 and 1992 air photos have large scales of 1:6,000 and 1:10,000 and that accounted for the lower number of dots. Thus, dots grid templates were constructed using the adopted number of dots. The major important advantage of the construction of dot grid is that it helped me in generating large useful data from air photos and the analysis, synthesis and predictions which were easily handled by using computer programs.

The template which is sometimes referred to as “Quadrats” are the transparent overlay on diapositives for the purpose of measurements. Differences in scales of the three photo years meant that the same type of templates were not used for all air photo sets. Therefore, three dot grids were constructed using the dimension of 1 dot representing 0.25 per ha and placed 1cm apart, Hence the variation in the number of dots contained in each template used for each photograph year.

4.7 MAPPING

4.7.1 MAPPING PRINCIPLES

The mathematically based principles of mapping i.e. (a) derivation of scale as a ratio, (b) collinearity condition; monocular observation (x, y) yielding the planimetric coordinate values and (c) coplanarity condition; stereoscopic observation (x, y, z) yielding the planimetric and height coordinate values adopted in this study have made easy the procedure. Advances in technology introducing high precision and electronic measuring devices in conjunction with computer plus wide range of software have also made digital mapping that incorporates all photogrammetric concepts possible. That is the principle on which the global positioning system was used.

4.7.2 ANALOGUE LANDUSE MAPPING FROM AIR PHOTOS 1965, 1977 AND 1992

The film commonly used in aerial photo is the panchromatic film (“black and white photograph”.) Colored and infrared films are becoming popular. However, the panchromatic films were used for identification and demarcation of landuse types from air photo of 1965, 1977 and 1992. Besides, the black and white aerial photos give clearer picture of cultural features on the terrain, especially the particular landuse types and their patterns are easily discernable. The black and white airphotos also have attributes that enhance landuse recognition such as light/shadow, tone, texture, pattern,

shape/sizes and situation that help differentiate one type of landuse depicted from others. Thus, interpretations and creating of stereo models (fig. 2) were made easier.

Paired aerial photographs were used. In this regard, it is required that the two exposure stations, two image (photographic) points and the identical object points on the same terrain lie on the same plan (i.e. coplanarity condition figure 3). A total of seven overlaps (models) for each photo year were made and used for the study. The models were arranged to form mosaics, one for each photo year (figure 3). Also on each stereo model landuse types and aerial extent were delineated and assessed for each photo year. Detailed working plans of the study progressed in the following order:

(a). Kaduna topographic maps sheets 123 scales 1:25,000; 1:50,000 were used as index maps for ground truthing.

(b). A stereo plotter was used to produce 3-D stereo for observation (showing planimmetery and height).

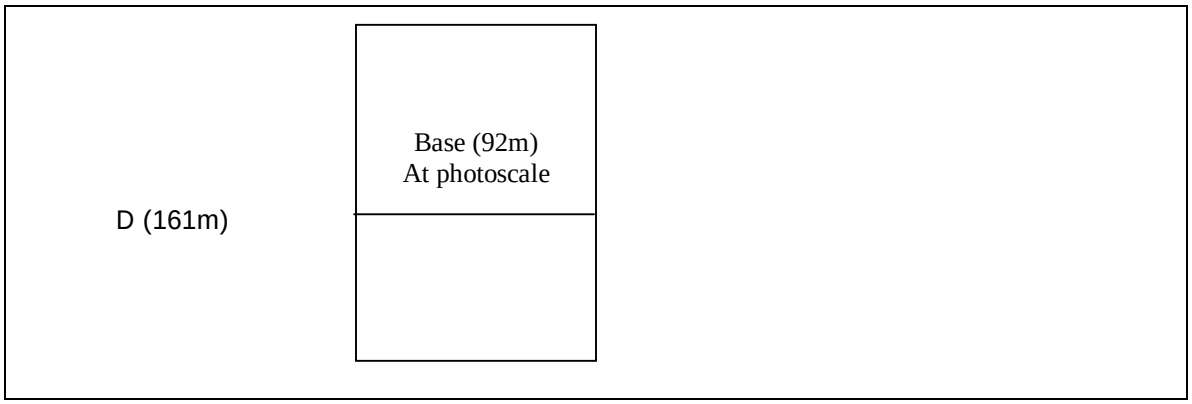
(c). Area estimation and interpretations for the classified landuse type were undertaken with the aid of transparent dot grids.

(d). The interpreted data was transformed in computer compatible codes (digital form) and stored.

(e). The various types of landuses and distributions were then mapped for all the three photograph years: 1965, 1977 and 1992.

For each model specific landuse types were identified and the area occupied computed using the “dot” number and value. It must be said here that the dot number and values vary with each photo year due to the variation in the aerial photograph scale (section 3.1.1). Table 4.1 illustrates the implication of differences in aerial photography scale on model dimension for each photo year.

TABLE 4.1: Model Dimension at Different Aerial Photography Scale



YEAR	PHOTOGRAPH SCALE	BASE (m)	D VALUE (m)
1965	1:20,000	1840	3320
1977	1:6,000	552	966
1992	1:10,000	920	1660

Before discussing the nature of landuse changes it is necessary to explain how remote sensing technology was used to map the different landuse types in the study area at different time interval (photo years) (Fig. 1.3).

Landuse for each photo year was stereoscopically mapped from the models of each photo year mosaic. First, the field surveys establishing the initial controls for absolute orientation was done. Second two types of stereoplotters were used to prepare the landuse types from the three different photo years mosaics (i.e. Wild A8 and Wild B8). This is necessary because of the variations in the air photography scales (Section 3.1.1; Tables 3.1 and 4.1). While the Wild A8 plotter produces good maps with minimal errors Wild B8 is well adapted to plotting maps on small to medium scale air photographs like the 1965 series. So, Wild A8 was used to plot the landuse types observed on models of 1977, (1:6,000) and 1992, (1:10,000) photo year mosaics. However, because the 1965

air photos were aging, interpretations of landuses on them required extra energy for good resolutions and results. Thus, map editing and sheet edge comparisons were necessary on well lit grand projector to complete the mapping. For good comparisons between photo years landuses similar procedure using the grand projector was followed for plotting from 1977 and 1992 air photographs.

Landuse viewed stereoscopically in each model was transferred on to map sheet on the pantograph table with the aid of the projecting arm-length to which a plotting pencil was attached. The pencil-arm is placed on the sheet and all the plotting is done via a compatible mechanical gear ratio that is connected to the pantograph arm for transferring from the model. Maps of landuse types for all the three photo mosaics were plotted on the same scale, 1:20,000 to aid comparisons and interpretations. (Landuse maps A1, A2, A3).

4.7.3 DIGITAL MAPS – 2003 PHOTO YEAR

For the 1993 – 2003 airphoto landuse mapping and delineation, it was not possible using airphotos because they were not available and satellite imagery are very expensive. So to map the emerging landuse types of this had to consider alternative approaches were adopted. The GPS – The "Magellan 315" was used for mapping landuse change(s) between 1992 and 2003 digitally. The procedure for digital mapping with this instrument is only a little less cumbersome than the conventional land surveying technique.

The GPS – "Magellan 315" used is a portable handheld instrument that makes use of a constellation of 24 U.S. satellites for precision location determination of position anywhere on the surface of the earth. Like others of its kind in Nigeria it is Geo referenced to Minna. The digital mapping of selected landuse features through this system was satisfactory.

To this end, data on coordinate of map features were secured in digital form for inputing using the AutoCAD software. The basic operational principles of the AutoCAD software includes; (1) Use of AutoCAD environment and operation window, (2) use of the AutoCAD tools and tool operation, (3) launching AutoCAD software procedures, (4) the DWE filing, (5) Raster and Vector image in AutoCAD, (6) Georeferencing, (7) layer creation and (8) on screen digitizing. These instructions are specified in the operational manual and if followed carefully, can be carried out easily. The end product is the digital map capable of (a) being stored in desired scale, (b) being retrieved for use at any time desired, and (c) being updated as desired.

The digital information from the GPS was down loaded on the computer and with the wild B8 precision plotter a complete list of the coordinates was digitally produced. The coordinates were referenced using the 1992 map as index.

Figure 4.9 represents the schematic diagram illustrating the plan of action and different processes involved in the digital mapping. The 1992 landuse map (Analogue map 1992) from the air photograph formed the BASE MAP. The next step was to use the integrated technique(s) for data capture and it is very crucial. This is explained below.

Techniques for Data Capture

Among major data acquisition techniques are the; (a) Ground surveys (b) Photogrammetry and (c) Integrated techniques. A brief description of each is necessary.

a. The ground survey technique is usually employed for establishment of ground control points for cadastral mapping. It

is, however not economical (time and money wise) for mapping large areas with numerous ground details. Its best use is geomophological studies, for terrain analysis and morphological mapping.

b. Photogrammetry is, in a broad sense, a technology which uses photography of different types and taken on different platforms (i.e. aerial photos and satellite imageries) to obtain reliable information about characteristics of objects in an area without physical contact. Data are obtained through processes of measuring, recording, interpreting and analyzing photographic imagery patterns of electromagnetic radiant energy emitted by various objects as at the time of photography. Thus the shape, height, aerial extent and character of the objects of interest in the area are coded digitally, processed and mapped. The technique incorporates other smaller methods such as remote sensing, photographic and graphic digitizing, which are sub-sections in photogrammetry.

To map an area, first digital data need be derived by stereo digitizing using analytical plotter properly equipped with stereoplotter, floating mark on parallax free stereomodel 3-dimensional photographic image. Hence, the information on the stereomodel is converted into digital format.

Second, the information is processed either on screen (head-up digitization) or automatic scanning digitization. On screen digitization involves interactions among the optical and, operator units and the control (computer). Thus, it is semi-automatic because the presence of an operator is required to monitor (manipulate) the process(es). However, with the automated scanning digitization, the scanning of images is

directly stored into computer files with the vector information already converted into raster as coordinates of lines and symbols of features depicted on aerial photographs and satellite imageries.

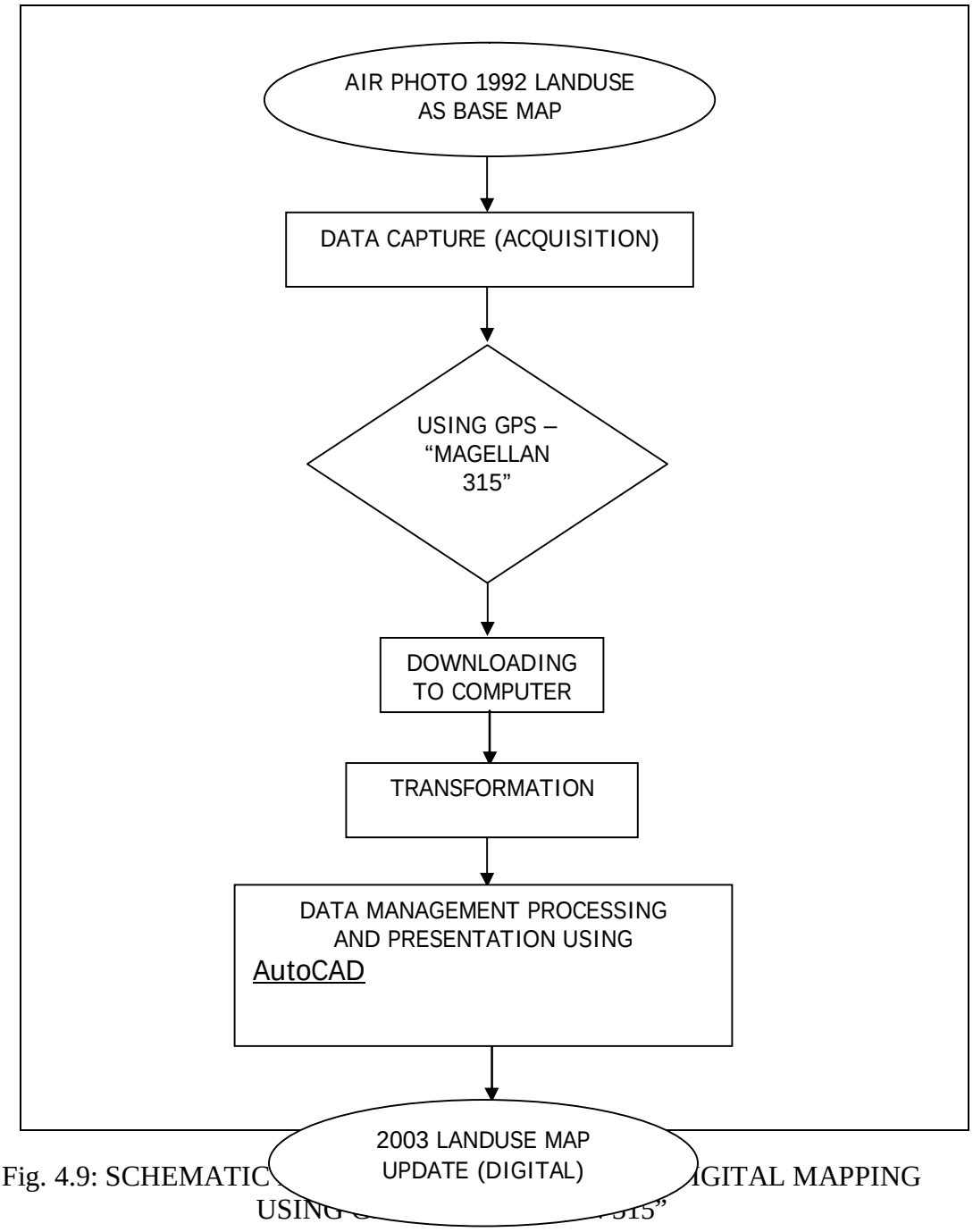


Fig. 4.9: SCHEMATIC [illegible] IGITAL MAPPING USING [illegible]315"

4.7.4 **The Integrated Techniques**

The integrated Technique is a combination of methods used in other survey techniques involving measurements, aerial photos, identification and interpretation, scanning and digitizing. However, because it incorporated methods of other techniques, its accuracy and precision may not and should not be compared with photogrammetry digitization using aerial photos. However, since there was no aerial photos (1992 – 2003) and satellite imageries were too expensive the integrated technique (a kind of hybridized technique) was used along with the GPS "Magellan 315" for data acquisition, as explaine earlier.

Thus, coordinates of points of selected landuse types that have been identified in the field with specific control points on topographic maps and landuse maps of 1992 were collected with the "Magellan 315" and downloaded into a computer system. Using **Wild A8 Autograph Coordinatograph** attached to the computer system the coordinates of all the landuse data collected were compiled and stereo-plotted. Here it is necessary to align all the landuse features tracked to the ground control points recognized on the base maps. This process is termed **griding**. The scale of the photograph or the base map was dully considered during the griding process. After the coordinates had been well grided they were used for data processing.

Data Processing - Transformation and Adjustments

In surveying, photogrammetry and remote sensing, transformation (Biljisma, 1979) is the process of changing the photogrammetric reading system into machine system or vice versa. Various mathematical functions, ranging from algebraic, trigonometric, hyperbolic and inverse are used for transformation. However, the most commonly used functions for mapping processes can be grouped into three. These include Orthogonal, Linear Conformal and Affine mathematical models.

The Orthogonal transformation **is the process of assigning perpendicular projection of images into their respective planes. For example;**

Given $y = Ax$ **---------- Eqn. 1**

The transformation is orthogonal if the matrix A has axis of rotation only as being defined. It has no deformation elements or scale change whatsoever. The matrix

A is said to be orthogonal if $A^{-1} = A^T$ plus some other properties. Thus, because of the restraint, orthogonal transformation cannot and is not used for mapping purposes.

The Linear Conformal **model is similar to the principles of orthogonality but with other functional properties. e.g. change in scale, size, and capability to retain original shape even after transformation. For example, given $y = Ax$, as a linear conformal transformation $A = S \cdot R$. Where R is orthogonal and S is a scalar quantity. When A is also given as a matrix, $A^{-1} = A^T / S^2$ and $Det\, A = \pm S^n$ and some other matrix properties. For much of the mapping purposes, using the simultaneous planimetry and height method (M_7), alternating planimetry height method ($M_{4\,3}$), and the height method only (M_3). The linear conformal (with most mapping experience) is found very useful and most applicable for digital mapping. For planimetric compilation only the linear conformal transformation equation in 2 dimensions is given as;**

$$y = ax + by + cx$$
$$x = -bx + ay + cy$$

---------- Eqn 2

While in the matrix form is expressed as

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ -b & a \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

known as the 2D similarity transformation.

Where, The Rotation, $\theta = \tan^{-1} b/a$

and the Scale, $\lambda = \sqrt{a^2 + b^2}$

Affine transformation**, however, has rigorous functions, which define all the basic parameters expected in transformation. Mathematical function assumes there could be deformation in any stereoscopic measurement(s) which could have been caused by factors such as atmospheric refraction, film distortion, film deformation, non-linearity of rays. The assumption is necessary in order to forestall any grave consequences.**

Thus given an Affine model in planimetry, is given as

$y = Ax$ **---------- eqn 2**

A is said to be affine

If deformation parameters are involved and also scale changes differentially along the y and x axis, six parameters are affected (planimetry only)

θ = Rotation

α = Shear Deformation

***L_x* = differential Scale change in x direction**

***L_y* = differential scale change in y direction**

***C_x* = shift in x direction**

C_y = shift in y direction

In practice, from the above, if α = 0 (i.e. no deformation) and $L_y = L_x = \lambda$ the six parameters are reduced to 4. i.e. θ, λ, C_x and C_y which are same as 2D similarity transformation as given by the Linear Conformal model above. The Affine transformation is used, as all unavailable parameters tend to zero during computation.

The Least Squares Solution

Least Squares Principle: - Gauss and Wopnisky introduced a method of obtaining the most probable value in any measurement with inherent error(s) and it is known as the least squares principle defined as;

$$\frac{\partial \sum V_i^2}{\partial P_a} \approx \min \approx 0$$ **..... Eqn 3** ***(Gauss and Wopnisky, 1927)***

The solution to these parameters are given by the use of the least squares principle. It is when the values of these parameters for transformation have been obtained that they can now be used to transform all measured GPS grided coordinates into the mapping coordinate systems. The Least squares principle was used because of its unique properties for adjustment of coordinates. Different errors and error sources in all measurements necessitated adjustments in surveying, photogrammetry and remote sensing of coordinates. Mapping errors, can either be Gross errors, systematic errors, or random errors. While the gross errors often referred to as mistakes and can be corrected during checking of coordinate listing, the systematic errors are found to follow a particular pattern (systematically) and can be corrected if a negative step to the type of error is taken, the random errors do not follow a particular pattern and they can occur at any point, and in any form. Hence there is the need for a method for their removal.

Least Square solution states that the partial derivative of the sum of squares of residuals with respect to the unknown parameters is minimum. However, the observations must have:

(i) A normal distribution

(ii) Large number of observations (i.e. N-M is the degree of freedom) sometimes called the Redundant Observation

(iii) Such that the observation matrix A has the properties that $A^T A = N$ is normal, systematic positive definite matrix.

(iv) The principle leading to the determination of the most probable value of any estimate

The determination of the transformation parameters a, b, L_x, L_y, C_x, C_y (in the Affine transformation) was carried out as follows; points of known coordinates on the ground were precisely and strategically measured using the GPS – "Magellan 315" as stated earlier. These points defining the features shape were picked usually at

the beginning, middle and end (figure 3.2) were carefully selected and located specifically in the field.

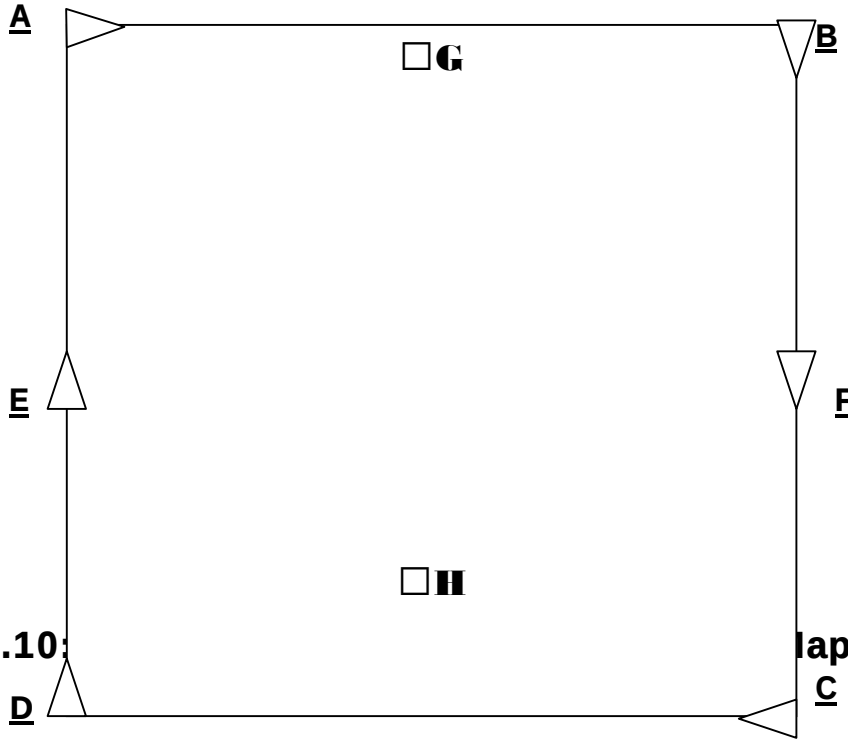


Fig 3.10: lapping

The distribution of control points for such a feature were selected as in fig. 3 A, B, C, D, E, F, G, H or very close to these. All these points so transformed are called the "Transformed and adjusted coordinates", and were used for plotting the map using AutoCAD software. In practice, if these points are obtained, all the infinite number of points of such a feature can be transformed and will be found duly representing their original situations and positions on the ground.

Thus the mapping processes were not only orderly but were also mathematically determined and followed procedural developmental trend of analogue, hybridized techniques and then digital mapping exercises. Accuracy required within the given tolerance limits was defined by the use of the GPS – "Magellan 315" instrumentation and were used to accept and or reject any computations for mapping. Here, the level of accuracy has been given. In this study, using paired sets was unnecessary because the area is on gently undulation plain, and the weather conditions at the time of observation was fine.

4.7.5 **ADOPTED LANDUSE CLASSIFICATION**

As stated previously, in 1949, the world landuse survey commission proposed a classification of landuse which then appeared to be the nearest approach to an internationally accepted system for nature of landuse and land cover (Bickmore, 1970). It was a general classification with 9 classes, which does not fit well into tropical systems of rural landuse. (Filed and Collins 1986), The Nigerian Army and the Kaduna town planning officers of the survey department produced landuse classification map based on the plan of Max Locks (1967). The classification recognized only five landuse types as follows: i.e. (a) Residential, (b) Military cantonment, (c) Government, (d) Open space, and (e) Industrial/commercial.

In this study however, the primary classification of Anderson (1976) which was based on his experience in tropical environment and in particular his studies of landuses and land cover problems in West Africa countries was adopted. Thus, based on this experiences and landuse concepts discussed in section 2.3, eleven landuse categories were adopted and used. They are: (a) cultivatedland, (b) grassland (fallowland), (c) barren (marginalland), (d) residential, (e) commercial, (f) recreational, (g) institutional, (h) road and highways, (I) airport, (j) railways, and (k) paths and tracks.

CHAPTER FIVE
RESULTS

5.1 INTRODUCTION

This chapter presents the results of the study. Section 5.2 describes the different sets of data collected from aerial photographs, topographical maps and from field survey (ground truthing). Results of landuse changes between 1992 – 2003 using digital mapping are presented in section 5.3.

5.2 THE DATA

5.2.1 Landuse Classification

Data collected vary from landuse information on topographic maps, aerial photographs to field evidence (ground truthing). The landuse type data were collected as patterns of natural and man-made features in form of a mosaic of patches of different sizes and patterns distinguishable by shades of shadow, texture and shapes of tone. These characteristics, in conjunction with cultural activities in the area, have helped in discerning and identifying types of landuses including farmlands, marginal land and buildings of settlement types. It is important to mention here that not

every mosaic showed the same range of landuse types, even in the same photo mosaic. Their sizes and shape vary from one model to another.

Table 5.1 illustrates the various landuse types identified on the air photos sets and grouped into the eleven internationally recognised classifications.

Table 5.1: landuse categories identified and observed the study areas.

Landuse types/Models	I	II	III	IV	V	VI	VII
Cultivated lands * (farmlands) 1	X		X	X		X	
Grassland * (fallow) 2	X	X	X				
Baren * (Marginal) 3		X	X		X	X	
Residential 4		X	X	X			
Commercial & services * (Market) 5	X	X	X	X			X
Recreational 7	X		X				
Roads & highway * (Communication) 8	X		X	X	X		
Airport 9			X	X			
Railway 10	X	X	X	X		X	
Paths & Tracks 11	X	X					

** (Market) local terms used.*

5.2.2 **ESTIMATES OF AREAS OF LANDUSE TYPES**

The dot grid technique as a sampling scheme for estimating area of each landuse type has been described above. The results of the measurements of the various landuse types identified on each photo year mosaic model by model are presented here.

(a) **1965 MOSAIC**

The Table 5.2 shows the estimates of the land area covered by each landuse type sampled on each of the seven models that formed the 1965 mosaic. Only six out of the eleven types of landuse types (1-6) were observed in model 1, seven in model 2 (No. 1 - 5, 7 and 8), six in 3 (nos. 1-5 and 8); six in 4. (Nos. 1 & 2, 4, 6, 8 & 9), and seven in model 5 (Nos. 1-5, 7 & 8). Also in model six, seven of the landuse types were observed (Nos. 1 & 2, 4, 6, 8-10) and in model 7 six landuse types were observed (Nos. 1-3, 6, 8, & 10). While not all landuse types were observed in each model, variations in sizes ranging, and from 0.5 to 84.75 ha were obvious. Also, there is no systematic increase or decrease in size of particular landuse types or their occurrences as one moves outward away from the project area.

(b) **1977 MOSAIC**

The estimated land area and the types of landuses observed in the 1977 mosaic are presented in Table 5.3. Here again, the land area covered by each landuse type varied from one model to the other. In model 1

landuse types 1, 2, 4, 5 and 6 dominated, while landuse types Nos. 1-5, 7 and 8 were observed in model 2. In each of models 3 and 4, six landuse types were observable and they are Nos. 1 & 2, 4 & 5, 8 & 11, and Nos. 1 & 2, 3 & 5, 8 & 9 respectively. Only five landuse types were observable in model 5 (Nos. 1 & 2, 4 & 5, and 8). In models 6 and 7, six and five types of landuse were identified respectively (Table 4.3). The table did not show any pattern or trend in landuse size and types. Instead variations and occurrence were random throughout.

(C) **1992 MOSAIC**

The 1992 mosaic data (Table 5.4) show similar sporadic manner in the types of landuse and their spatial distribution throughout the land area covered by the mosaic as observed in the 1965 and 1997 photo mosaic. Besides no single model has all the eleven landuse types represented. Only in models 2 and 6 did one observe up to seven different landuse types. (landuse types nos. 1-5, 7, 8). In model 2 and in model 6 the landuse types observed were nos. 1, 2, 4, 6, 8, 9 & 10.

Another important feature appears is that only a small fraction of the total land area covered by the mosaic was sampled, 14.8% representing approximately one in seven models in each photo year mosaic, the dot technique used, provided opportunity for a fair coverage/representative spread over each mosaic.

Table 5.2: Types of Landuse Identified and Measured Model by Model In the 1965 Mosaic (Land Area in Hectares)

LANDUSE / MODEL	1	2	3	4	5	6	7	8	9	10	11	TOTAL
1	84.75	61	3.5	6	13.5	16.25						185
2	68.25	77.75	6	4	5		2	12				175
3	112.5	38.25	3.5	20	0.5			6				180.75
4	102	38.75		28.75		5		10	1.75			186.25
5	61.5	70	0.75	0.75	0.5		2.25	23				158.75
6	77.25	47.5		3		7		8	1.75	41.75		186.25
7	50.25	94.5	1			10		15.25		13.5		184.5
TOTAL	556.5	427.8	14.8	62.5	19.5	38.25	4.25	74.25	3.5	55.25		1256.5
%	44,28	34.05	1.18	4.97	1.55	3.04	0.04	5.91	0.28	4.40		

Types of landuse: 1 = Cultivated land; 2 = Grassland; 3 = Barren; 4 = Residential; 5 = Commercial; 6 = Recreational; 7 = Institutional; 8 = Roads & Highways; 9 = Airport; 10 = Railways; 11 = Paths & Tracks

Table 5.3: Types of Landuse Identified and Measured Model by Model In the 1977 Mosaic (Land Area in Hectares)

MODEL	1	2	3	4	5	6	7	8	9	10	11	TOTAL
1	84.75	17.25	2.50	56.75	6.50							184.75
2	77.00	30.25		24.00	4.50		4.00	29.25				171.75
3	86.75	15.00		63.75	2.50			6.50			1.75	176.25
4	83.75	32.75		42.75		11.50		11.25	1.75	1.75		183.75
5	108.00	14.75		1.50	5.00			27.00				156.25
6	64.00	64.00		7.00		11.75		9.25	2.25	22.75		181.25
7	76.75	77.00				7.00		11.25		5.00		177.00
TOTAL	558	251	2.500	202	25.5	84.75	4.00	119	10.25	42.50	2.50	(13002)
%	46	19	0.19	15.5	1.96	0.65	0.31	9.14	0.79	3.26		

Types of landuse: 1 = Cultivated land; 2 = Grassland; 3 = Barren; 4 = Residential; 5 = Commercial; 6 = Recreational; 7 = Institutional; 8 = Roads & Highways; 9 = Airport; 10 = Railways; 11 = Paths & Tracks

TABLE 5.4: Types of Landuse Identified and Measured Model by Model In the 1992 Mosaic (land area in hectares)

MODEL	1	2	3	4	5	6	7	8	9	10	11	TOTAL
1	49.5	8.25	1.5		12	34.25						195.5
2	68.75	26.25	2	40.25	6.5		2.00	37.25				1835
3	73.00	12.00	1.5	78.25	6.5			12.50				183.75
4	57.5	16.00		70.75		26.25		11.25	1.75			183.5
5	102	10.25		12	8.25		2.00	41.50				176
6	59.15	37.25		19.25		26.75		12.50	3.00	25.75		183.75
7	86.50	52.00	0.25			23.50		15.50		5.75		183.50
TOTAL	394.5	109.50	5.5	393.00	33	131.00	6.75	158.75	10.50	46.00	2.5	(1,28860)
%	30	8.4	0.03	30	2.53	10	0.5	12.2	0.80	3.53	0.19	

Types of landuse: 1 = Cultivated land; 2 = Grassland; 3 = Barren; 4 = Residential; 5 = Commercial; 6 = Recreational; 7 = Institutional; 8 = Roads & Highways; 9 = Airport; 10 = Railways; 11 = Paths & Tracks

TABLE 5.5: Landuse Changes between Photo Years (values in hectares)

Landuse Types	Photo Year 1965	Photo Year 1977	Photo Year 1992
Cultivated Land	556	558	394.4
Grass Land	427	251	109.49
Barren	15	2.5	2.5
Residential	62.5	202	393.12
Commercial & Services	9.0	25.5	32.97
Recreational	4.25	4.0	6.7
Institutional	84.25	119	158.69
Roads/Highways	60.75	84.75	131.12
Airport	40	42.5	46.11
Railways	11.75	10.25	10.43
Paths & Tracks	91.75	2.5	2.58

5.3 LANDUSE CHANGES (1965 – 1977 – 1992)

The categories of landuses identified in the study area have been described above. It is important, however, to make further groupings considering the focus of the study. The classification shown on Table 5.5) emphasises features on the landuse. The classification shown in tables 5.1 – 5.5 puts emphasis on the use of the land. For example grassland, cultivated land, barren, paths and tracks are regarded as indices of rural landuse. While the others are indices for urban. For example grassland suggests that the land is left for fallow to allow natural regeneration of the fertility status. Similarly cultivated landuse and barren land suggest the general outlook of the areas so described. These eight landuse types are indices of urbanisation expansions. So, in this section analysis of the landuse types was made and used to illustrate the nature and intensity of landuse changes from rural to urban (Table 5.6 & 5.7). in this section the result of a further analysis of the landuse types are presented. The results and urban types as well as the overall use changes from year to year (Table 5.5) and changes between rural and urban uses (Table 5.6 and 5.7). Table 5.5 shows the trend of changes that occur over time from one photo year to another while Table 5.6 shows diffrentiation into rural and urban uses.

TABLE 5.6: Landuse Changes ± Rural-Urban Between Photo Mosaics (values in hectares).

Photo Year/ Indices	**1965**	**1977**	**1992**	**Remarks**
Rural	999.1	811.5 (-187.6)	509.5 (-489.6)	Between 1977 and 1992 (-302)
Urban	257.5	490.5 (+233)	781.5 (+524)	(+291)
% of change	Urban 25.77	60.44	153.39	3 photo year % ratio 26:60:153

The landuse changes that occurred during the 38 years were grouped into two, to appreciate the details of the nature of the changes. The two groups are rural and urban uses. The total hectareage of all sampled areas classified as rural (i.e. types nos. 1, cultivated; 2, grassland; and 3, barren-marginal areas like rock outcrop/degraded) have decreased from 999.1 ha. in 1965 to 509.5 ha in 1992. Conversely, all the landuse types with urbanisation indices show similar magnitude of change from 257.5ha. in 1965 photo year to 781.5ha in 1992. Thus within the space of less than three decades rural types of landuses sampled in the study area had decreased by almost 49%. There is also a corresponding increase in areas that show urban developments. Urban elements such as residential, roads, urban services and commercial areas have particularly transformed the district (Table 4.6). Significant are the increases in residential, highway and roads elements of urbanisation in the district. For example during the period under study residential construction increased by 734%. Similarly, developments of roads and highway increased by 254% (see Appendix B8).

Surprisingly, the percentage decreases in the rural landuse types correspondingly results in percentage increases in the urban landuses growth. For example, urban growth shows the highest magnitude of changes experienced during the intervening period of the photo years. However, variations occurred between models and photo years (Landuse maps A1, A2 & A3).

Also there is a rapid drop in urban indices in some models (e.g. models 6 & 7 located on the periphery of the study area). Between 1965 and 1977 both models show decrease in land area earlier identified as urban, from 62.3ha (33.08%) in 1965 to 53.25 ha (29.69%) in 1977; and 39.0ha (21.5%) in 1965 to 23.25ha (15.23%) in 1977 for models 6 and 7 respectively (Table 5.7). These were temporary phenomena, which evened out by 1992 in both models. Besides, probably they were formally illegal constructions, which were demolished by the urban planning authority between 1965 and 1977.

TABLE 5.7: Comparisons of Landuse Changes Model by Model and between Photo Years Using Rural and Urban Landuse Indices

MODEL	PHOTO YEAR					
	1965		1977		1992	
	R	U	R	U	R	U
1(ha)	149.25	35.75	102	205.0	71.4	124.42
(%)	80.81	18.67	49.58	51.23	32.38	67.62
II (ha)	152.0	22.75	109.75	61.77	97.00	86.50
(%)	86.86	13.12	64.1	35.91	53.06	46.01
III (ha)	154.25	27	101.75	72.75	86.5	97.25
(%)	85.34	14.55	58.01	41.68	47.07	52.92
IV (ha)	140.75	45.75	116.45	67.50	73.5	183.96
(%)	75.58	24.47	63.62	36.59	39.87	60.13
V (ha)	132.25	26.73	112	34.5	112.25	65.02
(%)	82.84	17.16	78.56	20.94	65.01	34.74
VI (ha)	124.75	62.30	71.24	53.25	96.5	86.78
(%)	66.91	33.08	70.41	29.69	52.50	47.56
VII (ha)	144.61	39.00	153.75	23.25	138.5	44.75
(%)	78.46	21.54	84.77	15.23	75.48	24.43
Total (ha)	999.1	257.5	811.5	490.3	509.5	781.6
Sample (%)	75.55	34.22	62.15	37.85	39.12	60.36

5.4 LANDUSE CHANGES BETWEEN 1992 AND 2003

It has been mentioned that digital mapping was used to identify landuse types fot 2003. It is important to state here that because of the large area involved and numerous recent small landuse features that have come into being since 1992 only the eleven classes of landuse recognized earlier (Table 5.1) were selected for digital mapping. Further only an identified type that is more than 0.1 hectare in extent was used.

5.4.1 RESULTS Of 2003 DIGITAL LANDUSE MAP

As hinted above, the selection is based on landuses that explain the rural/urban changes between the years 1992 and 2003. Thus, 1992 landuse map was used as base map to update landuse records for 2003 and to determine the changes in rural and urban uses between the two years. Digital mapping process although tedious, time consuming, it became necessary to provide a good alternative for effective monitoring of landuse changes in the absence of recent air photographs. Using therefore the 1992 map as a base, a comparison can be drawn on the effect of encroachment into

rural land through the activities of man within the adjoining urban area. Table 5.8 shows the result of the changes. It bears stating that some landuse typoes were not observed.

TABLE 5.8: Comparative Study of Landuse Changes between the 1992 and 2003Years (in ha).

Landuse Type	1992	2003 (Digital) Sampled Landuse Urban	2003 Digital total Landuse in the Study Area
Cultivated Land	**394.4**	**Not Observable**	**Not Observable**
Grass Land	**109.49**	**Not Observable**	**Not Observable**
Barren	**2.5**	**Not Observable**	**Not Observable**
Residential	**393.12**	**480.1**	**507.7**
Commercial & Services	**32.97**	**88.6**	**107.1**
Recreational	**6.7**	**Not Observable**	**Not Observable**
Institutional	**158.69**	**260.7**	**311.7**
Roads/Highways	**131.12**	**110.7**	**202.5**
Airport	**46.11**	**50.6**	**50.6**
Railways	**10.43**	**6.5**	**10.5**
Paths & Tracks	**2.58**	**Not Observable**	**Not Observable**

Landuse maps A1 is for 1965, A2 for 1977 for, and A3 for 1992 and A4 for the 2003 digital map. It is important to stress that the observable landuse features do not represent all the different varieties of landuse observable in the field. Rather, the hectarage extent of the landuse was applied for selection in conformity with (a) the dot grid measurement (b) the positional error of the GPS – "Magellan 315" (0.5m) and

(c) the recognition of minimum of not less than 0.1ha landuse area. The results show increases in favor of urban land use features from 781.5ha to 1135.7ha (an encroachment into rural lands). The increases in urban land features include those of residential buildings, roads, and extension of motor parks within commercial areas only as well as urban commercial services such as petrol stations banking and government special lands/institutions (e.g. NDA, Airforce Base and Barracks).

Table 5.8 shows the result of the sampled landuses in column 3 and estimations of each type estimated for the entire study area in column 4. Some landuses were shown as not observable because, as already explained above, most of them were below the measurable threshold. All the elements of urbanisation showed significant increase in expansion ranging from 393.12 to 407.7 for residential and from 32.97 to 107.1 commercial activities in 2003.

Ground truthing shows that the cultivated lands as at 1992, had significantly changed compared with the digital map of 2003; much of the land had transformed into urban uses. Examples are Kawo extension, the legislative buildings around Kawo area, the extension of Barken Lau village and numerous orchards and poultry farmlands that now form the urban periphery along Zaria Road. The complex landuse pattern in Kawo area and Kawo new extension has enhanced the specific selection of 2003 landuse digital points. From Ungwan Sarki to Kawo, residential accommodation, commercial activities and institution can

hardly be demarcated. Physically, the area has become a beehive of activities ranging from domestic, banking, motor transportation to commercial (including petty trading, restaurants) activities, stretching along the street sides. The NDA junction is clustered with railroad, commercial and transportation activities, government lands with pockets of small-scale artisan shops, for welding, vulcanising, local food sales etc. Also many petrol stations have sprung up in large numbers while the new fly-over (under construction) has given a new look to the motor park and railroad junction of Kawo. Various human activities around the Mando junction and the new road from the express joining “Hanyan Banki” have influenced new buildings such that the estwhile sugarcane plantation along the Kawo “Hanyan Banki” express is now a built up area. The haphazard nature of some of these buildings and landuses show that city sprawling has gone out off the town planning authority. The paths and tracks along the Mando road have given way to commercial activities, such as car wash, sales of motor spare-parts, food canteens, and other petty trades with temporary sheds or stalls. The 2003 digital maps are (A) along the concentrated urban areas and (B) within the whole project area (Table 5.8 & 5.9). It is observed that there is a tremendous change in the landuse activities in favour of urbanisation. The cultivated area has reduced in size while the urban related landuses (although mixed) up have replaced them considerably.

TABLE 5.9: Area/Percentage Landuse Change between 1992 Airphoto and 2003 Digital Map

Landuse	1992 Airphoto	2003 Digital (Urban)	2003 Digital (Total)
Residential	393.12ha	480.1ha (122.1%)	507.7ha (129.1%)
Commercial	32.97ha	88.6ha (268.7%)	107.1ha (324.8%)
Institutional	158.69ha	260.7ha (164.2%)	311.7ha (196.4%)
Road/Highway	131.2ha	110.7ha (84.4%)	202.5ha (154.3%)
Airport	187.66ha	167.8ha (89.4%)	263.6ha (140.46%)

Thus, with the aid of Global Positioning System instrumentation supported by a good base map (landuse map, analogue or photogrammetrically mapped), digital mapping of landuses in urban environment has been shown to be feasible. However not many landuses may be monitored this way because each would require detailed landuse may be monitored because each requires physical contact at various sites for acquisition of coordinates for compilation. Such visits could be cumbersome and time consuming. Also digital mapping depends on powerful computer system with attached useable softwares, which plus the required digitization autograph, makes it very expensive and capital intensive. Of course where available airphoto interpretation provides a better result because it provides a better resolution than any of the earth mapping techniques. It also

provides opportunity for improving base maps while accessing landuse changes in between long aerial photographic years, especially in developing countries such as Nigeria.

CHAPTER SIX

DISCUSSIONS OF RESULTS

6.1 INTRODUCTION

The discussions of results in this chapter focus on the nature of landuse changes during the thirty-eight years covered by this study. First, the trend of landuse changes are explained in section 6.2. In section 6.3 the characterization of the evolving landuses in the rural-urban fringes in the study area is undertaken.

6.2 LANDUSE MAPPING

In chapter 5, the dot sampling technique and landuse area measurements generated the data for all the seven models in the mosaics (Appendix B1-B8).

6.3 LANDUSE CHANGES

Data on landuse types generated from models on different air photo years have been described earlier. Summaries of variations from one photo year to another were presented model by model in Table 5.7. The two sub-groupings (i.e. rural and urban) illustrate the trend of landuse change. Each landuse category shows changes both in absolute hectareage and percentage terms. For example, cultivated lands grassland and barren, consistently decreased ranging from 0.7, for cultivated land and 6 times, for barren land in between 1965 and 1992 photo years (Appendix B1 – B7). Similarly, urban development increased in residential construction (by 600%) establishment of commercial and services functions (by 355%); cultural/governmental institutions and development of roads/highways (by 188 and 200% respectively). Abbas (1990) and Bello (1990) demonstrated that urban landuse in types and hectareage increase sharply with urban sprawling during the last decade of the twentieth century.

Landuse maps A1 (1965), A2 (1977) and A3 1992 drawn from air photos show the increases and decreases in the different urban landuse types and the rural landuse types

within these photo years. Landuse is not static and may take the form of gradual change, some of which may not easily be discernible or perceived. Photogrammetry, an aspect of EMT, has helped in quantitatively assessing the nature and changes that have occurred between air photo years. When landuse map A3 (1992) is compared with the two earlier ones the rapid growth in absolute hectearage of urban landuse types is further appreciated. By reference to this trend, an insight into future development and trend could be obtained for accurate predictions.

6.4 CHARACTERIZATION OF RURAL-URBAN LANDUSES

Urban sprawling into adjoining rural lands in the study area has no doubt occurred and is ever increasing. Given the factors at work during the thirty-eight year of study it is not difficult to visualize the complex kinds of landuses that are developing. One major reason is the rapid pace of development in the adjoining rural lands usually before the planning authority even pronounces government's intentions to develop such areas. For example, Max Lock (1967) proposed landuse changes within Kaduna Metropolis. Among the things proposed was that layout north of Luggard Hall, (within the southern part of the present study area) be equipped with facilities, utilities and be provided with other infrastructures such as water, electricity and road network etc. to cater for the ever increasing influx of people. Indeed, Max Lock's plan never saw the light of day. Financial logistics and personal interests of individuals were the major reasons why the plans failed. Here, Max Lock under estimated the urban growth rate and the forces of urban land speculators/developers. Rather than wait for government edict or pronouncements urban land speculators built a settlement, which is neither rural nor urban.

Apart from few governmental edicts establishing (i) the International Trade Fair Complex (built in 1997) (ii) the construction of a road from Kawo to the Sabon Tasha/Ungwan Television and Kaduna Refinery (1989-1990) (iii) the dualization of Kaduna-Zaria-Kano Road that runs northwards and recently (iv) the construction of an Eastern bye-pass and the Kawo Junction fly-over, all in the study area, landuses are complex and confused.

From the pattern of landuse change that have occurred during the study period, extrapolation can be made to suggest that given another twenty years rural land would have eventually given way to urban landuses. Urbanization would be expected to cover the whole study area and make it to appear to be the same stretch of urban land. However, some other factors would militate against the expected normal growth or changes in landuse. These factors include natural occurrences such as the increasing incidental flooding in several parts of Kaduna recently, the last one being in 2003, as well as cultural and religious uproars such as the Kafanchan cum Zangon Kataf sectarian crisis of 1987, the crisis of February 2000 and that of May 2003. such as led to some restructuring of Kaduna metropolis, landuse characteristics within some parts in recent years. For example, many Muslim who are Hausa speaking have relocated to Muslim

dominated areas of Tudun Wada, Rigasa, U/Muazu, Kawo, U/Rimi areas. Indigenes of Southern Kaduna and people from other states who are adherents of the same religion as Southern Kaduna indigenes have relocated predominantly to Sabon Tasha, Television, Narayi and part of the central Kadunaof course parts of the town and wards like U/Muazu, Kabala, Trikania, Barnawa, Kakuri and Makera still still exhibit a mixture of Muslims and Christians residents in varied ratios. However, any further sectarian crisis could disaggregate such residents. The locations of these new internal 'refugees' settlers represent a "socially safe settlement area" (e.g. provision of pig stall pens with certain distinctive features "akwalki aldedu"); residential, schools, churches and expanded market.

This notwithstanding the time interval for the occurrences assuming no more of such crisis, can make for a predictable trend in landuse system. And also if distinguished for special studies, will allowing for the possible prediction for the future of landuse developmental trend and changes. Although the resultant effects of relocation and counter relocation may not zero out or negate themselves in absolute terms. It may be concluded that the sum total effects of such problems may not be strong enough to deter one from predicting the nature of landuse changes for the future years to come.

Thematic maps that such predictions represent are required at local, state, and national governmental levels. Their production is well long overdue for Nigerian cities. The unhealthy demolition exercises in Abuja, the unexpected flooding of Kaduna river basin which culminated into loss of lives and property in recent years; and sometimes ago the Ogunpa flooding of Ibadan could have been avoided with effective use of projected landuse maps. Another recent mishap is the death of 18 pupils of the "AllSaints Secondary School" around Kurmin Mashi express road in Kaduna as a result of huge smoke from a residential building constructed too close to the secondary school. The proliferation of petrol stations close to residential buildings within urban buildings need to be checked. Structures large or small being developed within any available space may cause very distasteful effects on human lives. Landuse maps may provide basis for finding answers to many of these problems.

CHAPTER SEVEN

SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 INTRODUCTION

In this concluding chapter, gives the summaries of results/findings and conclusions of the study and are described in sections 6.1 and 6.2 respectively. Section 6.3 presents some problems encountered during the study and a few recommendations for future or further studies.

7.2 SUMMARY OF RESULTS

As discussed in chapter 4, the dot grid data was subjected to statistical tests to find how the observed data vary about a chosen measure of central tendencies. Using Chi Square tests all the observations for each of the three photo years were tested with each landuse class. The Chi square values for each are presented in Table 4.8. The test for ratio of dots per year per model was taken (special/model), the result gives 17.59 a rejection at 5% df. 12 but accepted at 10% level being 18.55 Chi-Square value.

Table 7.1: CHI SQUARE TABLE

MODEL	C/F	CHI SQUARE TABLE VALUE	OBTAINED CHI SQUARE VALUE	REMARKS
I	8	15.51	501.04	Test accepted
II	10	18.31	313.02	Test accepted
III	8	15.51	252.70	Test accepted
IV	10	18.31	234.63	Test accepted
V	12	21.03	419.49	O values criticized
VI	10	18.31	172.28	Test accepted
VII	10	18.31	155.44	Test accepted
Total Sample	20	31.41	2228.25	Test accepted

See Appendices C1 – C8

It can be said therefore that the project area, using the air photograph, landuse interpretation for 1965, 1977 and 1992 air photographs, there is the validity for urban growth compared to rural landuses (Landuse maps A1, A2, and A3). Thus given the present growth factors (transportation, institution, increases in residential constructions and commercial activities etc) found in the study area, there is a likelihood to have a greater momentum in urbanization growth in the future.

In this study the 'dot grid' template was used to estimate the hectarage of landuses model by model and for each photo-year. This has provided opportunity to evaluate the changes in absolute terms between successive photo-years. The lack of airphoto between 1992 and 2003 (actually the area has not been flown officially since 1984, the 1992 airphoto was obtained curtsey of Nigerian Airforce) forced the adoption of a hybridized technique using the "GPS – Magellan 315". The resultant digital landuse mapping provided the 2003 digital landuse map A4. Apart from confirming landuse changes presented on the analogue maps A1, A2, and A3 it complimented the trend already demonstrated using remote sensing technique. Notwithstanding these limitations the application of aerial photographs as an earth mapping technology in monitoring landuse changes

ha been demonstrated successfully in the Northern District of Kaduna Metropolis between the 1965 and 1992 photo years.

From the base line data of 1965 photo-year there had been steady decreases in rural landuse features in favor of urban ones within the study area. The decreases are of the order 60% and 153.4% during the 1977 – 1992, and 1992 – 2003 periods respectively. Besides, in section 5.2 the pattern of the evolving landuses in the study area was confused, complex and potentially very dangerous. For example in the vicinity of the Mando road junction – Kawo motor park – Kawo market and Dallet Barracks capture shows several petrol stations, confectionery shops, motor mechanic garages, food canteens, barber shops, open fire barbecue (Suya in Hausa) lying side by side thereby creating potential disaster if not controlled. Yet, it is in the same vicinity that a flyover bridge is being constructed.

The reconstructed landuse map of the area for 1965, 1977 and 1992 show vividly that urban landuses have reduced rural types of landuse by up to 74% (e.g. Grassland between 1965 and 1992).

Corresponding increases in area coverage of urban landuse of up to 300% were also observed particularly in residential, institutional and highway and urban road network landuses between the same photo years. Statistical analysis of the observed and predicted landuses using the dot grid samples and measurements suggest that EMT can be used not only for monitoring but for predicting landuse dynamics along urban – rural peripheries such as observed at Kawo Rigachikun Districts of Kaduna metropolis.

7.3 **CONCLUSIONS**

The application of remote sensing techniques adopted in this study to characterise past landuse changes in parts of Kaduna Metropolis, has once again demonstrated the potentials of the technique in monitoring the nature and trend of land use changes that have occurred in a

particular area. Certainly because air photography captures whatever landuses is within the view of the camera in size, and actual location. It provides a basis for monitoring of such changes.

Indeed, advances in earth mapping techniques have simplified the processes of collecting, storing, managing, retrieving, decoding/displaying and measuring earth features (geo-information). Availability of the geo-information in aerial photographs or satellite imagery and the knowledge of retrieving and analyzing the data should make studies of landuse dynamics on local to regional scale a rewarding academic exercise with more valuable returns than the direct land surveying. This digital mapping provided a good alternative to airphoto and its uses can be good substitute in between airphoto years to help monitor landuse changes in the developing country.

7.4 Recommendations

Maps are very essential tools needed for good governance; particularly in planning and executing laudable projects. It is disheartening to note that more than 75% of the land in Nigeria yet to be properly mapped. Where survey plans are available, they are not utilized effectively resulting in unforseen flood and other environmental disasters because of poor or complete lack of monitoring of past and present landuse activities. For example, the situation in Abuja where illegal structures took over would not have arisen if the master plan had been understood and duly followed. The point one is making here is that our large cities need street maps that should be regularly updated. The survey ministries and divisions at the local general state and federal levels that are under utilized should be made to embark on mapping the cities, Kaduna inclusive. It should be noted that advancement in technology is at the uppermost level on daily basis in the developed world and Nigeria must get involved in the new technological trend of the mapping industry. Thus, the governments should finace and support the production, sales and usage of maps. Government should see the importance of maps in the development of a healthy environment at all levels. Similarly relevant institutions should not relent in the acquisition and propagation of technical knowledge. In doing all these ther is a need to be cost and benefits conscious as to the tool necessary for the production of a map at an affordable cost. For effective monitoring of landuse the airphotographs, base maps, survey party team, equipment and means of transportation need

be considered with utmost priority and should be placed on ground before the start of such a study. Periurban areas need to be planned and mapped before the development of the adjoining urban areas encroach on them. Further more it is necessary to create awareness among settlers in the rural area on the meaning and the need to be developed. Researches of this nature need to be sponsored by the governments, at local, state, or federal as the results would be significantly beneficial to the populace. The Department of Geography should encourage further researches or investigations or follow up studies of such a project with a view to advice the governments at all levels of the importance of map for national development. The effects of such studies may not be immediate but whenever they are available can always forestall if used correctly, any distasteful occurrence.

Finally, there is a need for further investigations into the rural-urban landuse changes in all Nigerian cities as well as a follow up to this study in Kaduna. In future investigations it is recommended that satellite imagery and advanced GIS techniques (which have been precluded in the current study due to financial constraints) should be adopted for better results.

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APPENDICES

APPENDIX B: DOT GRID VALUES, HECTARES & PERCENTAGE

Appendix B1: Landuse Distribution: Model 1

Class	Year	No. of Dots	Area (ha)	Percentage
Cultivated Land	**1964**	**339**	**84.75**	**45.81**
	1977	**246**	**84.75**	**38.08**
	1992	**198**	**61.5**	**27.05**
Grass Land	**1964**	**244**	**61.00**	**32.97**
	1977	**69**	**17.25**	**10.68**
	1992	**33**	**8.39**	**4.51**
Barren	**1964**	**15**	**3.50**	**2.02**
	1977	-	-	-
	1992	**6**	**1.15**	**0.82**
Residential	**1964**	**23**	**6.00**	**3.11**
	1977	**227**	**0.50**	**35.14**
	1992	**312**	**78.10**	**42.62**
Commercial & Services	**1964**	54	13.5	7.38
	1977	26	0.5	4.02
	1992	46	12.07	6.28
Roads & Highways	**1964**	65	16.25	8.78
	1977	78	19.5	12.07
	1992	137	34.25	18.72

Appendix B2: Landuse Distribution: Model 2

Class	Year	No. of Dots	Area (ha)	Percentage
Cultivated Land	**1964**	**273**	**68.25**	**38.94**
	1977	**310**	**77.00**	**45.06**
	1992	**275**	**68.75**	**37.41**
Grass Land	**1964**	**312**	**77.75**	**44.50**
	1977	**121**	**30.25**	**17.59**
	1992	**107**	**26.25**	**14.56**
Barren	**1964**	**24**	**6.00**	**3.42**
	1977	**10**	**2.50**	**1.45**
	1992	**8**	**2.00**	**1.09**
Residential	**1964**	**16**	**4.00**	**2.28**
	1977	**96**	**24.02**	**13.95**
	1992	**161**	**40.25**	**21.90**
Commercial & Services	**1964**	20	5.00	2.85
	1977	18	4.50	2.62
	1992	25	6.50	3.40
Recreational	**1964**	8	2.00	1.14
	1977	16	4.00	2.33
	1992	8	2.00	1.08
Institutional	**1964**	48	11.75	6.85
	1977	117	29.25	17.01
	1992	151	37.75	20.54

Appendix B3: Landuse Distribution: Model 3

Class	Year	No. of Dots	Area (ha)	Percentage
Cultivated Land	**1964**	**450**	**112.50**	**62.24**
	1977	**347**	**86.75**	**49.71**
	1992	**292**	**73.00**	**39.72**
Grass Land	**1964**	**153**	**38.25**	**21.16**
	1977	**60**	**15.00**	**8.30**
	1992	**48**	**12.00**	**6.53**
Barren	**1964**	**14**	**3.50**	**1.94**
	1977	**-**	**-**	**-**
	1992	**6**	**1.50**	**0.82**
Residential	**1964**	**80**	**20.00**	**11.07**
	1977	**255**	**63.75**	**36.53**
	1992	**313**	**78.25**	**42.59**
Commercial & Services	**1964**	2	0.50	0.28
	1977	10	2.50	1.43
	1992	26	6.50	3.53
Institutional	**1964**	24	6.50	3.26
	1977	26	6.50	3.72
	1992	50	12.50	6.80

Appendix B4: Landuse Distribution: Model 4

Class	Year	No. of Dots	Area (ha)	Percentage
Cultivated Land	**1964**	**408**	**102.00**	**54.77**
	1977	**335**	**83.70**	**45.58**
	1992	**229**	**57.50**	**31.16**
Grass Land	**1964**	**155**	**38.75**	**20.81**
	1977	**131**	**32.75**	**17.82**
	1992	**64**	**16.00**	**8.71**
Barren	**1964**	**155**	**29.00**	**15.44**
	1977	**171**	**42.75**	**23.27**
	1992	**283**	**70.75**	**38.50**
Institutional	**1964**	**40**	**10.00**	**5.37**
	1977	**45**	**11.25**	**6.12**
	1992	**45**	**11.25**	**6.12**
Road & Highways	**1964**	20	5.00	2.72
	1977	46	11.50	6.25
	1992	107	26.76	14.56
Railways	**1964**	7	1.75	0.94
	1977	7	1.75	0.95
	1992	7	1.75	0.95
Paths & Tracks	**1964**	6	1.5	0.80
	1977	4	1.0	0.54
	1992	4	1.0	0.54

Appendix B5: Landuse Distribution: Model 5

Class	Year	No. of Dots	Area (ha)	Percentage
Cultivated Land	**1964**	**246**	**61.50**	**38.74**
	1977	**432**	**108.00**	**69.12**
	1992	**409**	**102.00**	**56.10**
Grass Land	**1964**	**280**	**70.00**	**44.10**
	1977	**59**	**14.75**	**9.44**
	1992	**65**	**10.25**	**8.91**
Barren	**1964**	**3**	**0.75**	**0.47**
	1977	**-**	**-**	**-**
	1992	**-**	**-**	**-**
Residential	**1964**	**3**	**0.75**	**0.47**
	1977	**6**	**1.75**	**0.96**
	1992	**48**	**12.00**	**6.58**
Commercial & Services	**1964**	2	0.50	0.31
	1977	20	5.00	0.32
	1992	33	8.32	4.53
Recreational	**1964**	9	2.25	1.42
	1977	-	-	-
	1992	8	2.00	1.09
Institutional	**1964**	92	23.23	14.49
	1977	108	27.27	17.28
	1992	166	41.50	22.77

Appendix B6: Landuse Distribution: Model 6

Class	Year	No. of Dots	Area (ha)	Percentage
Cultivated Land	**1964**	**309**	**77.25**	**41.48**
	1977	**256**	**64.64**	**35.31**
	1992	**237**	**59.25**	**32.15**
Grass Land	**1964**	**190**	**47.50**	**25.50**
	1977	**256**	**64.64**	**35.31**
	1992	**150**	**37.25**	**20.35**
Residential	**1964**	**12**	**3.00**	**1.61**
	1977	**28**	**7.00**	**3.86**
	1992	**77**	**19.25**	**10.45**
Institutional	**1964**	**32**	**8.80**	**4.30**
	1977	**38**	**9.50**	**5.24**
	1992	**50**	**12.50**	**6.78**
Roads & Highways	**1964**	28	7.00	3.76
	1977	47	11.75	6.48
	1992	108	26.75	14.65
Airport	**1964**	167	41.75	22.42
	1977	91	22.75	12.55
	1992	103	25.78	13.98
Railways	**1964**	7	1.75	94
	1977	9	2.25	1.24
	1992	12	3.00	1.63

Appendix B7: Landuse Distribution: Model 7

Class	Year	No. of Dots	Area (ha)	Percentage
Cultivated Land	**1964**	**201**	**50.11**	**27.24**
	1977	**207**	**76.75**	**34.05**
	1992	**346**	**86.50**	**47.14**
Grass Land	**1964**	**378**	**94.50**	**51.22**
	1977	**308**	**77.00**	**50.72**
	1992	**208**	**52.00**	**28.34**
Barren	**1964**	**4**	**1.00**	**0.54**
	1977	**-**	**-**	**-**
	1992	**1**	**0.25**	**0.14**
Institutional	**1964**	**61**	**15.50**	**8.26**
	1977	**45**	**11.25**	**7.40**
	1992	**62**	**15.50**	**8.45**
Roads & Highways	**1964**	40	10.00	5.42
	1977	28	7.00	4.61
	1992	93	23.50	12.67
Airport	**1964**	54	13.50	7.32
	1977	20	5.00	3.29
	1992	24	5.75	3.27
Paths & Tracks	**1964**	1	0.25	0.14
	1977	3	0.75	0.42
	1992	3	0.75	0.42

Appendix B8: Landuse Distribution: Total Sample

Class	Year	No. of Dots	Area (ha)	Percentage
Cultivated Land	**1964**	**2226**	**556.00**	**42.72**
	1977	**2233**	**558.00**	**42.88**
	1992	**1577**	**394.40**	**30.62**
Grass Land	**1964**	**1711**	**427.00**	**32.83**
	1977	**1004**	**251.00**	**19.27**
	1992	**438**	**19.49**	**8.50**
Barren	**1964**	**60**	**15.00**	**1.15**
	1977	**10**	**2.50**	**0.19**
	1992	**10**	**2.50**	**0.19**
Residential	**1964**	**249**	**62.50**	**4.78**
	1977	**808**	**202.00**	**15.51**
	1992	**1572**	**393.12**	**30.52**
Commercial & Services	**1964**	**36**	**9.00**	**0.69**
	1977	**102**	**25.50**	**1.96**
	1992	**132**	**32.97**	**2.56**
Recreational	**1964**	**17**	**4.25**	**0.33**
	1977	**16**	**4.00**	**0.31**
	1992	**27**	**6.70**	**0.52**
Institutional	**1964**	**337**	**84.25**	**6.47**
	1977	**476**	**119.00**	**9.14**
	1992	**635**	**158.69**	**12.33**
Roads & Highways	**1964**	243	60.75	4.66
	1977	339	84.75	6.51
	1992	524	131.12	10.17
Airport	**1964**	278	70.00	5.33
	1977	170	42.50	3.26
	1992	184	46.11	3.57

Paths & Tracks	**1964**	7	1.75	0.13
	1977	10	2.50	0.19
	1992	10	2.58	0.19

APPENDIX C: CHI SQUARE VALUES

APPENDIX D: LANDUSE HISTOGRAMS

APPENDIX E: LANDUSE MULTIPLE DIAGRAM