MODELLING OF SYMMETRIC RADIAL DISTORTION IN AERIAL PHOTOGRAPHY

BY

MUSIBAU ADEBAYO ADEWOLU

M.TECH/088/93/94

BSc. (HONS) PHYSICS; PROF. DIPLOMA (SURVEYING); REGISTERED SURVEYOR; MNIS

SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE IN MASTER OF TECHNOLOGY IN REMOTE SENSING APPLICATIONS.

JANUARY, 1999

CERTIFICATION

This is to certify that this thesis-"Modelling of Symmetric Radial Distortion In Aerial Photography" - by M. A. Adewolu (M.Tech/088/93/94) was supervised and approved by:

Supervisor

H.O.D. (Geography Department)

External Examiner

DEDICATION

TO

MY LATE MOTHER

Madam Mosunmola Abike Adewolu

ACKNOWLEDGEMENT

All praises to the Almighty Father.

My special thanks to those personalities who in one way or the other assisted in making the academic program possible for me, the FUT, Minna for starting such laudable course, the combination of the then Dean of Postgraduate School, Professor D. O. Adefolalu and the Head of Department of Geography, Dr. G.N. Nsofor who gave so much energy to impart the knowledge. The departmental team was very much encouraging. I wish to thank and call the lady and gentlemen "kind people".

I should remember my uncle Alhaji Lateef Tijani who contributed financially to start my course. I am greatly indebted. My everlasting thanks to my father who kept the prayers on.

My sincere thanks to my friend and cousin Professor T. A. Adedoja who was then at Bayero University, Kano, Mr. Olasupo Adekunle, the Managing Director of Leady Pharma Limited, and my colleagues, Messrs A. A. Adebayo, G. Ufoegbune, M. Jubril, N. A. Isiaku, T. I. Isiaku, D. O. Oluwole, M. S. Adegbola, S. M. Hassan, E. Ilyas, A. Hussein, M. K. Muhammed, I. J. Nwadialor and Mrs O. A. Ojaleye for the numerous contributions.

Messrs R. A. Ogundele, S. A. Ajibade, S. O. Soipe, S. Oloyede-Kosoko, Nwaghodor, I. Okolo, Akingbona and a host of others including the typist of the Federal School of Surveying, I extend my appreciations.

All, I thank from the bottom of my heart; may the Blessing of the Almighty Allah be upon them, Amen.

ABSTRACT

The original intention was mapping a synoptic terrain. The procedure of mapping in general, is a system that falls into three stages. The acquisition of data, the processing and the dissemination of the data which is the map itself. This study involved all the three stages.

The acquired data were the photographs, control coordinates, distortion in points etc.

What the map was to be used for, was to depict the spatially referenced informations on the terrain. In order to produce this base-map, the use of a remote sensing technique was employed for data acquisition. There are quite a number of data acquisition methods by remote sensing. The utilized datasets in this study is Photography. In the processing of these photographs, a lot of corrections had to be applied. One important problem was quite large systematic error and most troublesome is the Radial Lens Distortion. This distortion had always been corrected for by adjusting the stereoscopic viewing in the interior orientation of the stereo-autograph by trial and error, but had been result-oriented, through a cumbersome process. This study looked at the analytical theory of lens calibration. Empirically, the amount of distortion can be determined on a point by plotting the graph of Radial Distortion against Radial Distance. From the shape of the graph, a relationship in functional analysis can be established to correct the distortion for easy application. If random errors are negligible, then the systematic error in the processes would be taken care of successfully. This was carried out by creating a mathematical model to correct the distortion. As usual, the distortions were made point by point using the comparator to compare the value obtained from the model. Any four points were hand-picked at random while the distortions in the rest twelve points were corrected for, easily. These were compared with the values obtained from the comparator.

In the preamble of the report, the location and climate of the site (Lagos) were enumerated which gave the influences they had on the occupation of the people.

The methods of investigation and presentation was analogue photogrammetry. The photographs were set in sequences for interior, exterior and absolute orientations while the necessary adjustments were applied using the comparator on the WILD B8S

autograph plotter. After the required measurements and computations, the graph showed a polynomial type of function which looked like most distortions curves in photographs. Coefficients of the polynomials were determined by the use of Least Square method adjustment using POLY-BAS software. The determination of the coefficients concluded the model to be useful in deciding the distortions in the other twelve points. The model was tested and a satisfactory result for finding radial distortion in aerial photographs was arrived at.

The dissemination of the data was done in analogue using the autograph plotter directly for 1980 data sets to a scale of 1 in 10,000. The 1973 datasets were plotted through the Stereopret to a scale of 1 in 25,000. This was then enlarged to the scale of 1 in 10,000 to compare with the 1980 map.

The two base-maps now depicted the changes that had occurred in the area of choice and showed the analysis of the categories of association.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

The initial idea to map an area using a remote sensing method exposed some of the difficulties facing most developing nations like Nigeria in solving its Land-use and Land-cover problems.

One major handicap is negligence of educational research due to lack of funds for technological development. This has affected so far, the acquisition of current technologies to discover the extent of land-use and land-cover problems. The available material on ground in the field of remote sensing is the aerial photographs and the use of aerial analogue plotting machines. This is yet to be obsolete in mapping any synoptic area. Acquiring any other remote sensing processes seemed to be constrained by lack of fund, inaccessibility and unavailability of such modern technological gadgets for images.

Depicting spatially referenced information in form of maps had been in existence long before now. The displays are means to an end and were achieved by all kinds of processes.

Mapping directly from photographs themselves is not automatic because carrying out the 'snapping' of the camera from the air are affected by a number of natural factors, such as the atmospheric disturbances, on the platform, payload, and also the equipment used are error-prone. So much has developed in the usage of photographs for metric measurements of images. The adage in the local African context that "there is no cheating in photographs, you will find yourself as you pose" made it possible to re-appraise what changes that had come to an area temporally.

In photogrammetry, quite a number of corrections are applied before any tangible or accurate measurements are achieved. These corrections include lens distortion, tilt, crab and drift corrections, to mention a few, thus causing all kinds of error. These distortions and their corrections are important in aerial mapping. The most important one is the troublesome correction for Symmetric Radial Lens Distortion.

Lens distortion causes an incoming ray of light to be deflected from its original direction. There are three kinds of lens distortion (Moffitt and Mikhail, 1980) in a lens assembly.

1. Symmetric radial distortion;
2. Asymmetric radial distortion and
3. Tangential radial distortion.

When all three are defined by calibration, allowances could be made to produce mathematically straight light rays. Both asymmetric and tangential radial distortions are quite small. The symmetric radial distortion is always large and would be the bone of contention in this research. A mathematical model is anticipated for a particular camera lens to eliminate the substantial symmetric radial distortion. Hence, our objective is to create an empirical model for the correction of symmetric radial lens distortion in the utilized aerial metric camera. In the end, it could be once upon a time when symmetric radial distortions were corrected for by trial and error on the autograph plotting machines by analytical aero-triangulation which was never removed completely.

Since photogrammetry is a process of remote sensing and a fast method in mapping any synoptic terrain, it is inevitable to assess photographic imageries by mapping an area twice accurately, depicting at the same time changes that had come to the area within certain period of years and showing the categories of association on the base maps drawn from the mapping.

1.2 THE SITE

The imageries available were obtained from the archives of the Federal Survey Department in Lagos. Images of Murtala Muhammed Airport Runways and its environs in Lagos were used for terrain analysis. A total area of about 30 square kilometres were used as the study site. The site lies within the periphery of latitude 6^o 36'N and longitude 3^o 19'E in Ikeja Local Government of Lagos State. Lagos, the former capital city of Nigeria lies in the South west coast of Nigeria (Fig. 1.1).

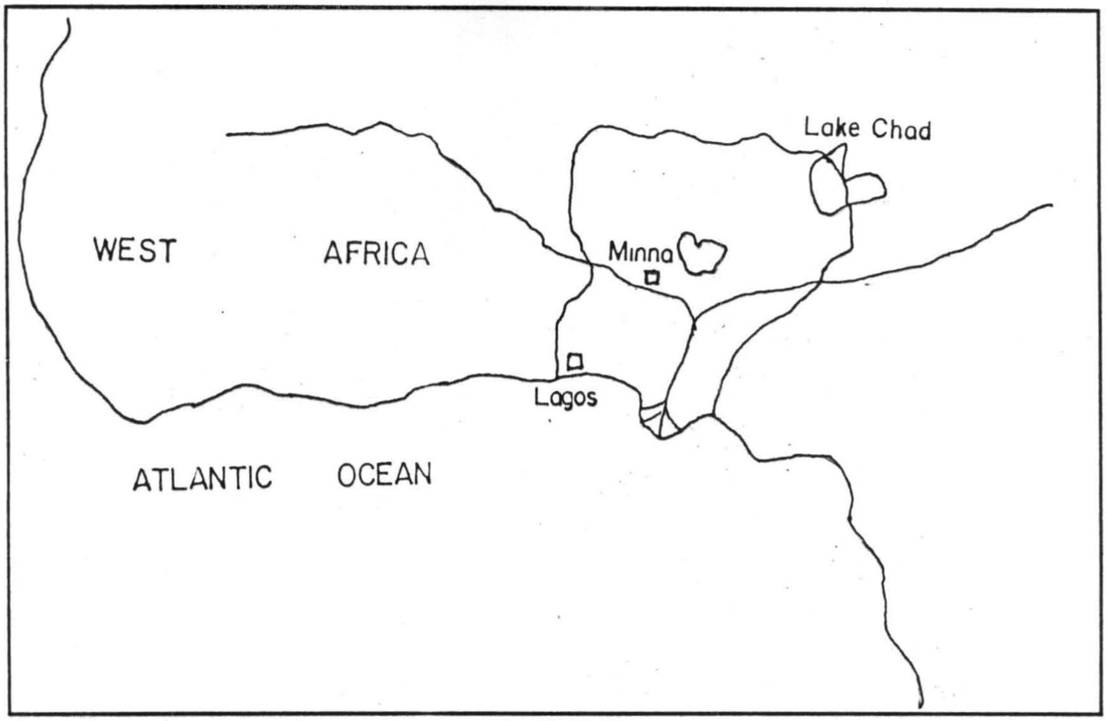


Fig. 1.1 Location of Lagos in West Africa Subregion.

1.3 WEATHER CONDITIONS OF THE STUDY AREA

Lagos has the Atlantic ocean at the Southern boundary with a number of small islands and peninsulas. It always has humid and moist breeze most of the time. It experiences the harmattan haze from the North westerly winds (Harrison - Church, 1980) from the desert within the dry seasons of late November to February. (Harrison-Church, 1980). The South westerly wind from the ocean causes rainfall between March and October. The Tropical Maritime air becomes predominant in May through to October. (Harrison-Church, 1980). The environment which is usually cloudy during the rainy periods experiences average temperature of about $26^{o}C$ and the Relative Humidity in the wet seasons with an average of 80 percent and about 60 percent in the dry seasons (Harrison-Church, 1980).

1.4 STATEMENT OF THE PROBLEMS

The initial problems were: how to produce a base map for 30 kilometres square site; how to detect the rapid changes that had occurred in the land within the seven years; how to make metric measurements of points and how to analyse and map the different categories of landuse and landcover through the interpretation of the aerial photographs.

All the above could not be carried out unless all the vital distortions in the photographs are corrected for. One troublesome and important correction to be made is Symmetric Radial Lens Distortion in photography. It had always been corrected for by trial and error in the autograph plotters by analytical aero-triangulation method (Baker et.al, 1980).

This study now tries to correct this distortion empirically by plotting the graph of Radial Distortion against Radial Distance and then form a model (an equation) to correct for the required Symmetric Radial Distortion.

1.5 SPECIFIC OBJECTIVES

The objective of this study is to create a model empirically for the correction of the Symmetric Radial Lens Distortion inherent in lenses of cameras which is depicted in aerial photographs. Next is to, use the model to see if it can be utilized to correct the distortions in photographs taken by the same type of lenses.

With such a correction, this study would now produce two base-maps for the site; detect the changes that had occurred in the land; make accurate metric measurements of points and analyse the categories of association.

1.6 HYPOTHESIS

1. Correction for radial distortion of a point on an aerial photograph from an equation is possible.
2. There are rapid changes in the area of study within the period of seven years.
3. As Landuse increases, Landcover decreases.

1.7 DATA ACQUISITION

Electromagnetic radiation can be detected in a wide range of wavelengths and frequencies. Within the wavelength of visible light, the eyes can easily observe what was detected. In the methods of analysis, there are six various remote sensing equipment and processes that were utilized.

1.7.1 MATERIALS AND METHODS OF ANALYSIS

There are various remote sensing methods and equipment that could be utilized to acquire data of the site for analysis:

1. Microwave imager method;
2. Multispectral Scanning method;
3. Thermal Infrared Scanning method;

4. Vidicon television camera method;
5. Electro-optical detector method and
6. The Photographic method.

The method used in this study was the Photographic where a type of metric camera was used. Flight planning had been carried out with the aerial photographs snatched in forward and side overlapping system. The negatives were developed and the diapositives produced for the stereoplotter.

The mosaics were assembled to ease the detection of the site. These mosaics defined the area of interest. The 1962 topographic map of Lagos and environs was made available from Federal Survey Department, Lagos with scale 1 in 50,000. It helped to indicate the True North of the Photographs. The mosaics gave the direction of the flight lines, and were used to find useful points used as postmarked and premarked control points for the mapping. Two points are at least needed for scaling of the maps and at least three vertical control points are required for heighting. Sixteen points were however provided for, in aero-triangulation compilation.

The diapositives were set on the B8S autograph plotter after acquiring all necessary data for plotting the maps to required scales. Only the 1980 set of photographs were applicable for the plotter. The 1973 photographs were mapped by the stereopret.

Sixteen points were located on the photographs in which the 3-dimensional ground control coordinates had been determined by geodetic surveying. These coordinates would determine their radial lengths. On the plotter, the radial distortions were measured one by one using the comparator to plot a graph length. The graph should be a sine type graph since the expansion of sine by Taylor's theorem would give the type of model to expect. One property of glass used in this analysis is refraction. The identification of the material used for the glass lens are easily seen in its refractive index given as:

$$n = \frac{\text{sine } i}{\text{sine } r}$$

where n = refractive index

i = angle of incidence

r = angle of refraction

The model was tested for by some of the points on the photographs.

After plotting, map completion was carried out to ascertain the ground truth and to check the names of streets and important places for placement on the maps.

1.8 LIMITATIONS OF THE STUDY

To effect the development of a mathematical model for Symmetric Radial Distortion, a lot of things had to be put into the material and equipment needed. The model needs to be tested and used to map a particular place to an accuracy required. The method utilized here is the Photogrammetry method which uses camera as its sensor within the payload in an aircraft as the platform. Some of the things carried out with the empirical modelling include:

1. Procurement of aerial photographs;
2. Assembling the photographs into mosaics;
3. A trial interpretation of the photographs;
4. Aerial triangulation using B8S Analogue Plotter;
5. Metric measurements of radial distortion;
6. Computations of radial distances;
7. Electronic computation through Least Square method;
8. Establishing the base maps;
9. Filed checking for accuracy;
10. Map compilation;
11. Map completion;
12. Land resources classification categories;
13. Landuse and Landcover Change Detection and
14. Report to provide for the regional setting.

1.9 ASSUMPTIONS

The photographs had been taken in 1972 and 1979 respectively. This implies that procedure of contracting the acquisitions of the photographs does not arise. Other assumptions in this work include:

a. The datasets were assumed
b. The Survey control coordinates were also assumed to be accurate
c. The photographs were perfectly vertical

d. The topography of the terrain were assumed to be gentle

e. Flying height was assumed to be constant throughout the flights. Hence, there were no tilts, crabs nor drifts with an agreement to specifications of aerial photographs

f. All those computations required in flight planning and direction of orientation were also assumed to be correct.

From here it is important to look at such works that had been carried out before. Quite a number of empirical researches that were done had been useful in this study.

CHAPTER TWO

2.0 LITERATURE REVIEW

This study is on a method of correcting a distortion inherent in photography, as well on land use change detection to be disseminated on a base map eventually to be produced.

With the use of aerial photographs, Moffitt and Mikhail (1980) analysed the three phases of photogrammetry, "In a more comprehensive sense, photogrammetry includes:

a. Photographing an object;

b. Measuring the image of the object on the processed photographs and

c. Reducing the measurements to some useful form such as a topographic map".

This is similar to Geographic Information System (GIS) as classified by (Kufoniyi, 1995); namely data collection and input, data storage and retrieval, data manipulation and analysis, visualization and reporting. Modern photogrammetry also employs systems which acquire data through methods other than conventional photographic systems, for example, radar imaging, radiant electromagnetic energy radiation and X-ray imaging.

If there are two basically broad categories of practice of photogrammetry or remote sensing, that is Metrical and Interpretation, (Baker et.al, 1980, Moffitt and Mikhail 1980; Avery 1977; Paine, 1981). This research is using both practices for presentation.

Metrical photogrammetry makes quantitative measurements from which ground positions and elevations, distances, areas, volumes can be computed and hence planimetric and topographic maps can be drawn. Whereas, Photo-Interpretation evaluates things like timber stands, detect water pollution, classify soils, interprete geological formations, identify crops or obtain military intelligence (Avery, 1977; Paine, 1981).

Photogrammetry is remote sensing which includes: detection, identification and analysis of objects or features through the use of imaging devices (sensors) located at positions remote from the subjects of investigation (Avery, 1977).

Since metric photogrammetry or aerial survey shall be utilized to form the model and subsequently map the area concerned, it is necessary to examine the rationale behind the use of remote sensing. The International Institute of Photogrammetry (ITC) defined photogrammetry as "the art, science and technology of obtaining reliable information about physical objects, features and environment through the process of recording, measuring and interpreting imagery and digital presentation of energy pattern derived from non constant sensor system".

Leberl (1988) claimed that "remote sensing" is a word invented in 1986, originally to describe the topic of a conference held at the University of Michigan, U.S.A. The Federal Surveys Geoinformation Group (1997) opined that remote sensing is a discipline that evolved from photogrammetry. It has became enlarged in the past few years that the data produced and the samplings to follow can not be easily analysed.

Most academic authors define Remote Sensing as a set of techniques of collecting; measuring and interpreting information about objects at some distance without physical contact by means of radiation from electromagnetic spectrum. (Townshend, 1981; Wolf, 1983; Lo, 1986; Campbell, 1987; Liliesand and Kiefer, 1987).

Involved in this study also is image interpretation to depict the association of categories within the period of investigation with land-use and land-cover change detection. The process of image interpretation is highly dependent on the capacity of the mind to generalize. (Avery, 1977; Paine, 1981). Learning to identify objects on aerial imagery, one needs to study known features on many photographs so that the characteristic clues of shape, size, tone, pattern, shadow and texture became automatically associated with particular subject. (Paine, 1981; Lo, 1986; Avery, 1977; Liliesand and Kiefer, 1987).

At the end of the day, a base-map has to be produced because "the norms of showing the location and attributes of any place is mapping" (Robinson et.al., 1984). The usual methods of carrying out such norms is surveying. As the Laws of Federation of Nigeria, (Chapter 194, 1958) puts it, "Survey means the measurements made by a surveyor of all such linear and angular measurements as may be necessary in order to determine the dimensions, extent, features or relative positions of the earth's surface". Surveying, therefore is the act of mapping or recording a portion of the earth surface including aerial survey or remote sensing.

This study is also on land-use change detection. The use of aerial photography, which is a more efficient method of mapping than surveying, had been carried out before. Avery (1985) used United States Department of Agriculture (USDA) aerial photography at 1 in 20,000 scale for 1944 and 1960 to evaluate land use change in Clarke County, Georgia. In a more simplified way, Lo, (1986) matched two land use maps of two different dates to delineate any change for a more up-to-date study of land use change of Clarke County in Georgia between 1970 and 1983 using aerial photographs at the nominal scale of 1 in 12,000. The land-use scheme was the Level II United States Geological Surveys (USGS) system.

Adeniyi (1980) used a digital approach to land-use change detection in the rapidly changing environment of Lagos using aerial photography. The studies also used different scale of photographs. The aerial photographs of 1962 on a scale of 1 in 40,000 was compared with that of 1974 on a scale of 1 in 20,000. The classification scheme devised was for nine major categories of land-use and land-cover with forty-five sub-categories. The nine major categories were residential, commercial, industrial, transportational, utilities, recreational, vacant land, non-urban land and water. The interpretation was carried out under a mirror stereoscope over an acetate overlay. This interpreted land was field completed.

So far, some corrections had to be applied before a base-map could be produced. The most important and vast application of photogrammetry is in mapping; such as conventional maps, photomaps, digital maps, thematic maps and so on (Avery 1997).Hence to produce these maps, one must be conversant with the causes of distortions in the aerial photographs.

Baker, et. al. (1980) emphasised that analysis and experimental evidences on lens aberration showed that a single lens element can not produce a mathematically perfect image point.

Fig. 2.1 shows the conventional presentation of aberration. Its explanation is based on the concept of geometric optics, in which aberrations are treated as departures of ray intercepts and image positions from the ideal.

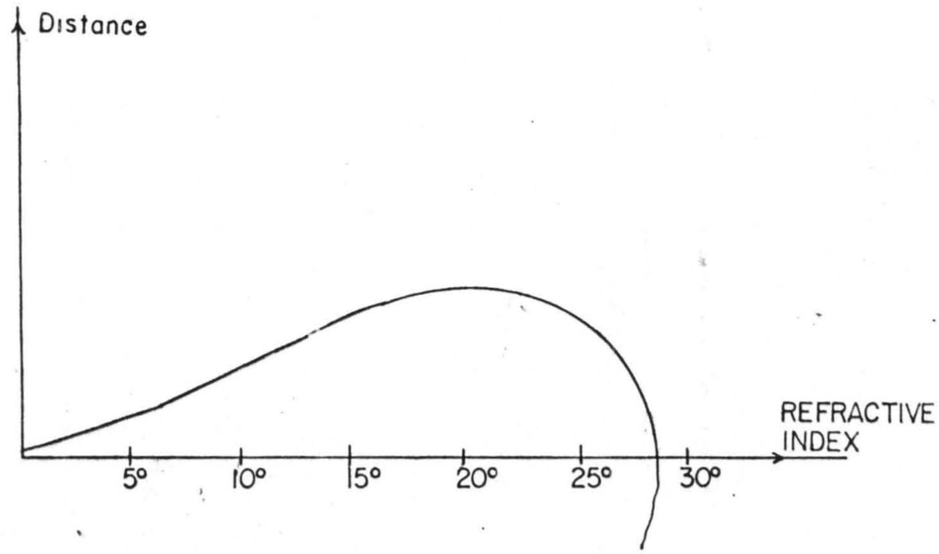


Fig 2.1. Graph of Radial Distortion Adapted From (American Manual of photogrammetry 1980)

Lens designers often need to improve on this presentation by resorting to the realistic concepts of physical optics in which aberration are considered as various kinds of deformations of image - forming wavefronts from their ideal forms, spherical or planar, as the case may be.

It had been however identified (Moffitt and Mikhail, 1980 ; Baker et. Al 1980) that lens aberration classification are, the spherical aberration, coma, astigmatism, curvature of field and distortion. These various aberrations have something to do with quality of the optical image. Paine (1980) opined that the combined effects of such aberrations are therefore disturbing to the photogrammetrists only when the deterioration of the images prevent one from identifying details of interest or increases the uncertainties of measurement.

Distortion, however, has something to do with the position of the image point in the image plane but not with the image quality (Baker, et.al 1980; Paine 1981). The presence of distortion is therefore of great importance to the photogrammetrist and must be taken into account in making plots of locations and in measuring distances between images in the image plane. Distortion leads also to a variation of the scale of an image as a function of position in the image plane. (Paine, 1981; Avery 1977). The ultimate task of the photogrammetrists is to produce maps of uniform scale from the measured images, hence distortion's presence is very disturbing (Baker, et.al 1980). Distortions are classified into three types: symmetric radial distortion, asymmetric radial distortion and tangential radial distortion (Moffitt and Mikhail, 1980). Distortion is that displacement of the image point from its ideal position, radially inward or outward from the optical axis; hence its measure is always lateral (Baker et.la 1980). For non-rotational systems, it must be defined by Internal displacement errors in two coordinates such as in X and Y, or if small, in terms of radial and tangential displacements in the image plane from the image point. A coordinate system obtained from real ground survey, if compared with the coordinates system obtained from photographs should be equal. The amount of distortion in the two values is the Symmetric radial distortion. This can, therefore, be corrected for empirically by measuring the distortion metrically using the analogue plotter comparator. A graph of radial distortion against radial distance forms the model to correct the anomaly of symmetric radial distortion.

Baker, et.al (1980) pointed out further that all of the aberrations, except distortion may be expressed in either longitudinal or transverse measure. These types of measure are easy and hence of easy corrections on the photographs. But for distortion, perfect correction has never been easy. Perfectly correcting radial distortion enables us to produce a perfect and accurate map to be utilized in all sorts of mapping to detect changes that had occurred in the area of interest and helps to analyse the categories of association (Baker et.al 1980; Moffitt and Mikhail, 1980; Avery 1977; Paine, 1981).

From the American Manual of Photogrammetry (Baker, et.al 1980), the usual procedure for computing the distortion of a plane image formed by a centered lens system is based on two conditions:

(i) the position of the image plane satisfies the equation

$$f = s/h \quad \ldots\ldots \quad (2.1)$$

where f is the focal length;

s the image distance;

and h the relative height of the Gaussian rays coming from an axial object point.

(ii) the position of any given image point is determined by the intersection of the corresponding principal ray with the image plane.

Inherent in the second condition is that the bundle of rays converging to the image point is symmetrical around the principal ray.

If y is the radial distance of the object point from the optical axis in the object plane, and y_o is the ideal distance of the corresponding image point from the optical axis in the image plane, and if θ is the slope angle of the principal ray in the object space, then freedom from distortion is defined by:

$$y_o = my \text{ (for a finite object distance)} \quad \ldots\ldots \quad (2.2)$$

$$y_o = f \tan \theta \text{ (for an infinite object distance)} \quad \ldots\ldots \quad (2.3)$$

m is the paraxial lateral magnification and f is the focal length determined from Gaussian theory (Baker et.al., 1980).

Notice is made from equations (2.2) and (2.3) that they apply for a simple projection between parallel planes through a perspective center which the lens system intend to accomplish. In mathematical terms one wants to map one plane onto another by means of collineation which optically is represented by the equations of Gaussian theory.

In the presence of distortion, the actual position y' of the image point differs from y_o, as may be determined by an exact ray trace. Then, the measure of the radial distortion is given by, while D is the percentage radial distortion.

$$d_r = y' - my \quad \ldots\ldots \quad (2.4) \text{ (for a finite object distance)}$$

$$d_r = y' - f \tan \theta \quad \ldots\ldots \quad (2.5) \text{ (for infinite object distance)}$$

The percentage distortion is given by

$$d_r = 100D/y_o \quad \ldots\ldots \quad (2.6)$$

Note that y' is the actual distance in the image plane of an image point from the optical axis.

Every optical system has a real stop or aperture stop which is used to limit the diameter of the image - forming bundles of rays accepted by the system. Without careful design, the entrance pupil in general will not be a sharp image of the stop in object space for all rays over aperture, field and spectrum (Pestrecov, 1959). The exit pupil may not be a sharp image of the real stop.

If the aberrations of the ray bundles also have asymmetric components, the intercept of the chief rays on the image plane in the outer field may not truly represent the effective centroids of the respective bundles of rays focused by the system. Asymmetric aberrations in the images formed by a mapping lens under design must therefore be eliminated.

As (kilford 1979; Horder A. 1975; Baker et.al, 1980) put it, distortion is the displacement of an image point from its true geometric position. It hence affects the accuracy of measurements made on the face of a photograph. It can be radial or tangential to this point which can be thought of as the CENTER OF SYMMETRY OR CONFORMAL point. Tangential is very small compared with radial distortion. Radial distortion is the sides of a square symmetrical about the point of symmetry to become concave outwards, known as Positive or PINCUSHION distortion Fig. 2.2

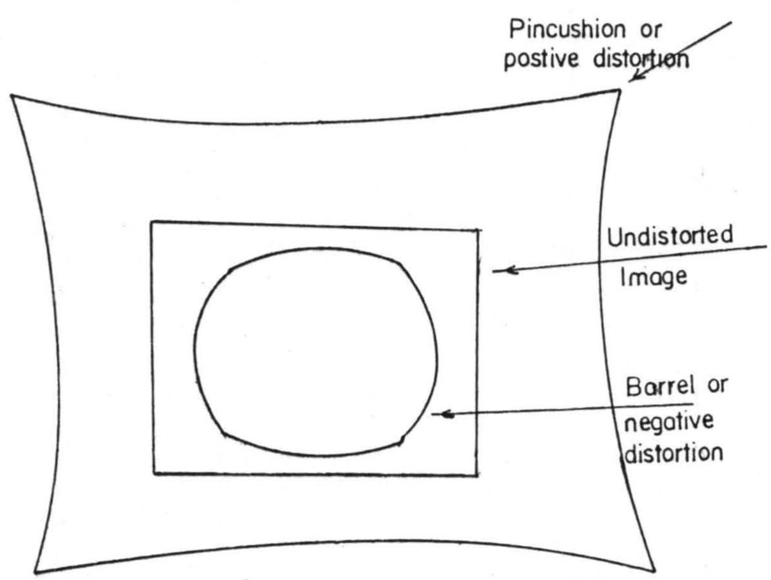


Fig. 2.2 The 3 kinds of images that could be produced.

(Burnside,1985) analysing what a model for correction for lens distortion is, analysed the order of lens distortion that used to be about 50 micrometer in aerial survey camera lens. Tangential effects were about an order of magnitude smaller. (Burnside 1985) however explained that modern lenses have now a maximum radial distortion of less than 10 micrometers and tangential values are correspondingly less.

Corrections for radial lens distortion were never particularly easy to incorporate into analogue plotting instruments, and tangential corrections were not even attempted. The following three techniques have been used to compensate for these effects in such equipment (Burnside, 1985, Baker et.al 1980).

(a) In optical projection instruments, projection lenses with the same distortion characteristics as the camera lens can be used to remove all image distortions. Such is the Porro-Koppe principle.

(b) Image displacement can be removed using an aspheric plate in mechanical projection instrument employing orthogonal viewing of the photograph as shown in Fig. 2.3

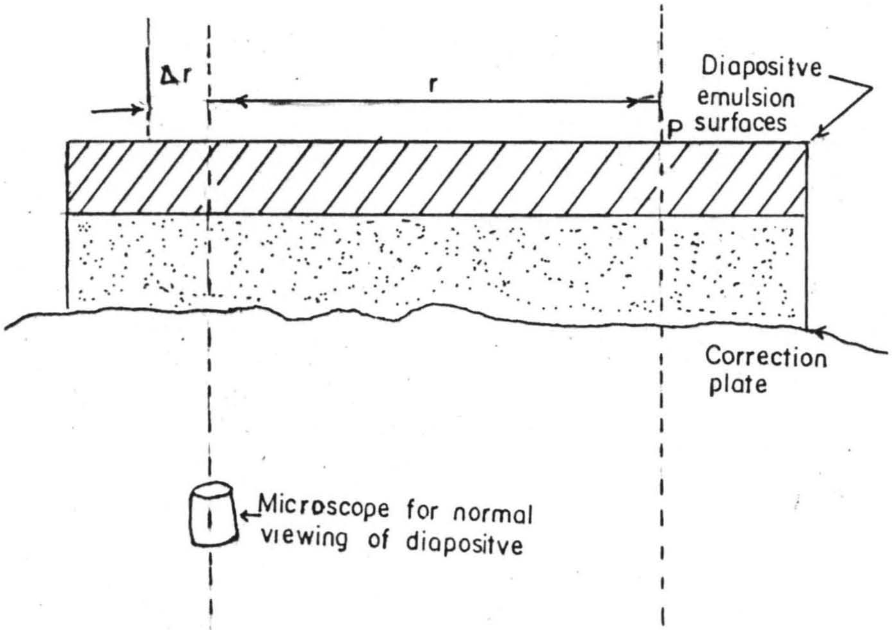


Fig. 2.3 Compensation for Lens Distortion by means of Aspheric Plate

(c) The small axial movements of the outer nodal point Fig. 2.4 can be reproduced mechanically by correspondingly small movements of the projector lens. For example, the Samtoni Instruments and the Kelsh plotter are able to do this.

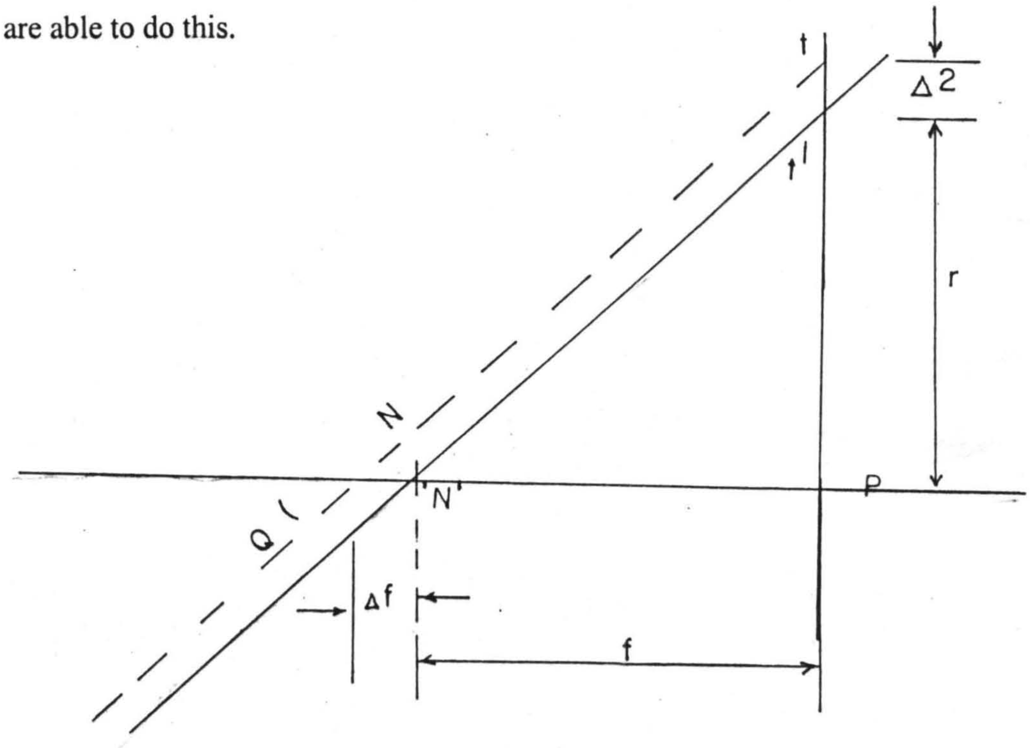


Fig. 2.4 Radial Lens Distortion (Adapted from Manuals of Photogrammetry, 1980)

On the other hand, in analytical plotting instruments and in analytical method generally, as this research intends to investigate, the effects of lens distortions can adequately be compensated for by relatively simple mathematical modelling (Burnside 1985).

Radial distortion curve will be of the form in Fig. 2.5

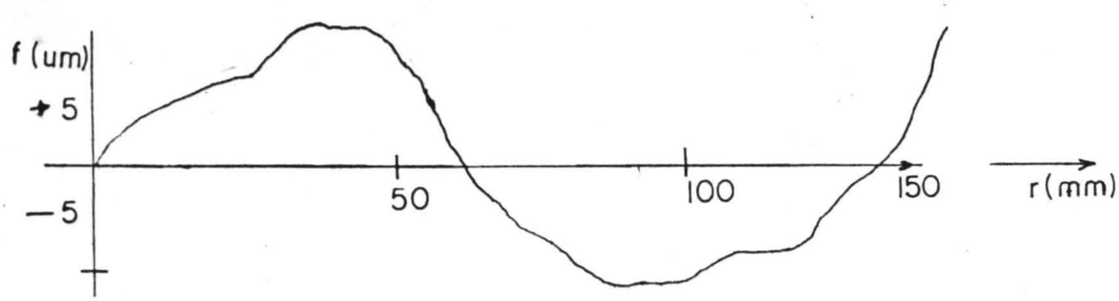


Fig. 2.5 Lens distortion Curve for Modern Lens (Adapted from Manuals of Photogrammetry, 1980)

For radial lens distortion of the form in fig 2.6, the following expression are commonly used (Burnside, 1985; Baker et.al, 1980)

$$\Delta r = Ar^3 + Br^5 + Cr^7 + \text{----------}$$

$$\text{where } r^2 = x^2 + y^2$$

$$\text{hence } \Delta x = x(Ar^2 + Br^4 + Cr^6 + \text{-------})$$

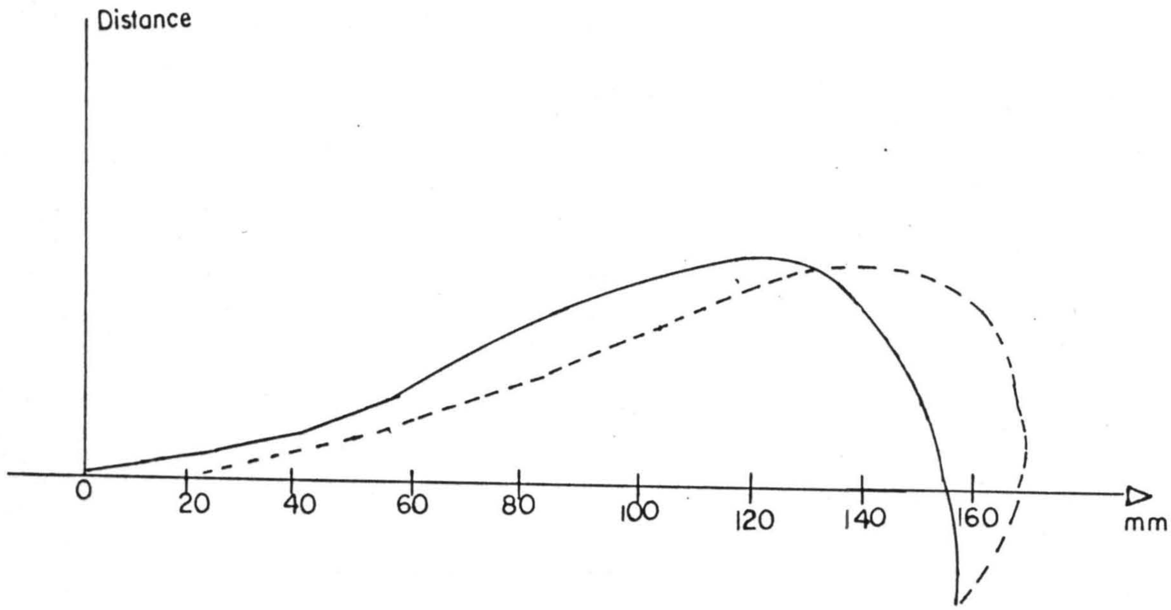
$$\text{and } \Delta y = y(Ar^2 + Br^4 + Cr^6 + \text{---------})$$

Measurements from photographs are lengths of lines between image points, angles between points, coordinates of points and image densities. Rectangular coordinates are used in many photogrammetric equations. Measurements are usually made positive. (Wolf, 1983).

Molenaar (1978) confirmed this from a statistical point of view when testing on calibration to create a model. Definitely, a block is flown in an area where enough ground control is available. By an adjustment, the block is connected to the terrestrial coordinate system. In this study, the peripheral control for planimetry is used. The remaining point (check points) are used for a test on the accuracy of the adjusted block. In practice (Molenaar 1978), x, y is often seperated from height (z).

Compensating lenses in photogrammetry instrumentation serve to correct the most troublesome lens aberration inherent in aerial photography, namely symmetric radial distortion. The task of eliminating this property from an existing photograph, or of reshaping its distortion curve to adapt it to the requirements of a given plotting machine, is a problem which involves the design of a lens to a predetermined distortion curve (Graham and Read, 1986; Horder, 1965). This curve should be the mirror image of the curve expressing the distortion property of the taking lens (Fig. 2.6).

Compensating plates for correction of radial distortion are used in several types of plotting machine and projection printers. They are either plane-parallel glass plates or glass plates on which a special aspheric curve has been ground and polished on one surface. If a curve is selected with ordinates equal in magnitude but opposite in sign to the distortion curve of the lens, it can be used to compensate the lens distortion to zero throughout the field (Graham and Read, 1986).



Linear Distance from center of Negative (mm)

Fig. 2.6 Distortion Correction by a Compensation Lens.

It is important here to look at the mode of reliability in measurements. There are two basic errors in measurements. Systematic and Random or accidental errors (Topping, 1972; Wolf, 1980). Systematic errors follow physical laws, and that if the condition producing them are measured, corrections to eliminate these can be computed and applied. Such is the case of radial lens distortion. However, random errors will still exist in all observed values which follow the mathematical law of probability; and that any group of measurements will contain random errors that conform to a "normal distribution"; (Wolf, 1980); mistakes are not errors.

Molenaar (1980) suggested that modern research and adjustment should be more directed to the analysis of the reliability and precision of the point of determination. Amer (1981) in a paper presentation, claimed that since 1976, the International Society of Photogrammetry Congress (ISPC) held in Helsinki made a considerable emphasis in photogrammetric research which has been placed on reliability. That reliability should describe the qualities of an adjustment procedure with respect to the possibility of detecting gross errors in the observations and the influence of the undetected errors on the calculated data (e.g coordinates). Rigorous application of reliability studies to problems with large number of unknowns, such as block adjustments, have proved to be rather difficult because of the need to manipulate and invert very large matrices which may require tremendous computational effort beyond practical considerations. Consequently, partitioning large systems into smaller units is often recommended. In aerial triangulation, especially for on-line procedures, it is advisable to study the reliability of small units such as a single photo, stereopairs or triplets (Amer, 1981).

After this review of theories on the basic principles of remote sensing, error analysis, and land-use/land-cover change detections methodologies, it is now necessary to see how these theories can be carried out in practice. These constitute the tasks carried out in this study.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

To arrive at a mathematical model for eliminating radial distortion on photographs, much data are needed to be acquired or collected. The panchromatic black and white photographs had to be set on an automatic autograph plotter for aero-triangulation. The 3-dimensional stereo had to be observed and radial distances measured metrically. From the stereo observation, a trial interpretation is carried out as well.

From the computation of radial length and measurements of radial distortions, a graph is plotted. The coefficients of the polynomial obtained using Least Square method to develop the model were computed. After correcting the distortions, the base maps were created. Data interpretation were transferred to form the static maps. Field checking or the ground truth was carried out for accuracy. This was followed by Map Compilation and Land resources classification to analyse Land Use and Land Cover change detection. Results are then to be compiled with discussions and report to provide for the regional setting.

3.1 DATA ACQUIRED AND CHARACTERISTICS

Data acquired for this research are:

1. Panchromatic black and white photographs (1973 and 1980);
2. Ground coordinates of some of the identified points on the photographs;
3. Topographical map sheet of Lagos of 1962.
4. Measured photographic data using the plotter.

Table 3.1 gives a summary of the acquired data and their characteristics.

Table 3.1 Data Acquired and Characteristics.

Data Acquired	Date	Type	Source
Aerial Photographs	1973	Panchromatic	Federal Survey Dept., Lagos
Aerial Photographs	1980	Panchromatic	Federal Survey Dept., Lagos
Ground Coordinates	1980	3-dimensional	Federal Survey Dept., Lagos
Topographical Map	1962	Lagos 1 in 50,000	Federal Survey, Map Depot, Lagos
Radial Length	1998	Metric Measurement	B8S Autograph Plotter

3.2 CORRECTIONS FOR LENS DISTORTIONS

Lens distortion causes an incoming ray of light to be deflected from its original direction. There are three kinds of Radial lens distortion in a lens assembly.

1. The Symmetric radial distortion
2. The Asymmetric radial distortion
3. The Tangential distortion.

Allowance for the three can be made if they are well defined by calibration. The methods of eliminating both tangential and asymmetric distortions, both of which are quite small are complex.

Radial lens distortion is quite large and can be determined by lens calibration. Empirically, it is more convenient to decide this distortion by plotting on graph, i.e DISTORTION as ordinates to a curve for a metrogon lens and let RADIAL DISTANCE be the abscissa. From such graph, the radial distortion d_r can be scaled from the curve at any time for a particular lens.

Radial lens distortion is hence presented in the form of an odd-power polynomial in the form $dr = Ar + Br^3 + Cr^5 + \text{----------}$

where A, B, C ----- are coefficients obtained by fitting the polynomial curve to the distortion data obtained from camera calibration by the method of least squares.

Usually, after the value of the radial distortion of a point is determined, the coordinates of the point is corrected to eliminate the effect of the distortion. The corrected image coordinates are determined as described below and shown graphically on Fig. 3.1.

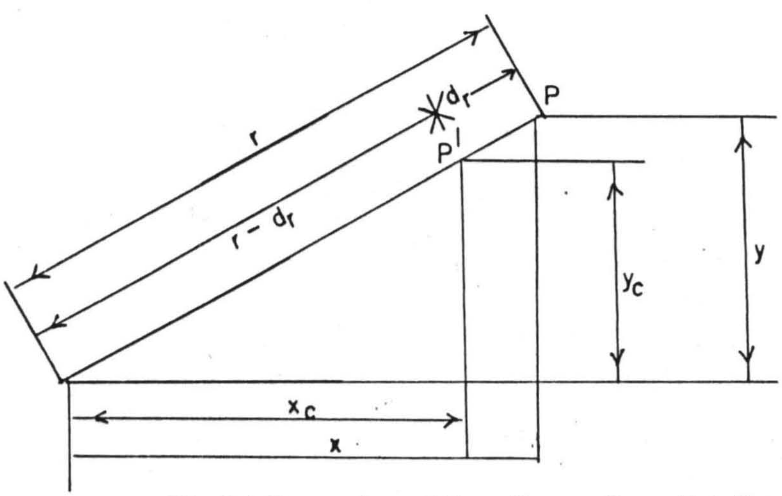


Fig 3.1 Correction of Coordinates for radial distortion.

Fig. 3.1 shows how any point P' can be displaced to its image position P by radial distortion d_r. The coordinates of P, uncorrected for lens distortion are x and y. The corrected coordinates are x_c and y_c. By similar triangles.

$$\frac{x_c}{r - d_r} = \frac{x}{r}$$

and

$$\frac{y_c}{r - d_r} = \frac{y}{r}$$

Therefore,

$$x_c = x\left(1 - \frac{d_r}{r}\right)$$

and

$$y_c = y\left(1 - \frac{d_r}{r}\right)$$

(Moffitt and Mikhail, 1980)

3.3 PLANIMETRIC MAPPING WITH PLOTTERS

The plotter allows the operator to view a pair of photographs stereoscopically while tracing out the planimetric features underneath the instrument. It contains the pencil connected to two transparent arms each of which can rotate about the centers of the two photographs. Lines inscribed on the arms appear to intersect in the stereoview. As the pencil is moved, so also is the apparent intersection of the two lines. Thus, a planimetric feature is traced and located in its correct map position by a continuous intersection. Scale change can be accommodated by adjusting the tracing linkage.

3.3.1 MAP COMPILATION

The first step is to establish scale to which the map is to be plotted. The scale is a function of flying height of the photography, total ground relief, vertical measurement limitations in the instrument, and the pantograph or coordinatograph range of enlargement and reduction. The map grid is then constructed on a map sheet which should be a well-seasoned stable material. All control points are then plotted with respect to the grid. The appropriate stereomodel scale is introduced into the elevation counter of the instrument.

The diapositives are carefully centered in the carriers. Relative orientation and scaling are then performed by first setting the rotational elements, by and bz to zero. The distance between the principal point (PP) and the conjugate principal points are measured.

All planimetry features in the model are traced by following the features both horizontally and vertically by means of the measuring mark.

Field editing completes the plotting by classifying roads, highways, drainage and determining the accepted names in the mapped area.

3.4 DATASETS

The datasets are the imageries of area to be modelled and mapped. The photographs are products of Kenting Africa Limited. A mosaic of photographs taken in July 1972 and those of June 1979 are presented in diapositive forms and placed on the appropriate stereopret (Plates 1 to 8) and stereoplotter WILD B8S respectively.

3.5 THE STEREOPRET

This plotter consists of a Base Plate, a Photo-Carriage, a pair of stereoscopes, a stereomicrometer, a lighting system, a pantograph and a rigid tracing arm. (Plates 10 - 11)

3.5.1 PRACTICAL ADJUSTMENT OF THE STEREOPRET

Focusing is first set on the two monoculars. The eye-piece are usually turned clockwise until maximum sharpness is obtained. The monocular separation is adapted to the eye-base by turning the Knurled screw (13/21) Plates 10 and 11.

Under observation through the monoculars, the large circular marks on the photo-holder plates must be symmetrically arranged within the field of view. Once the adjustment has been completed the two Knurled screws are retightened.

3.6 DEVELOPMENT OF LANDUSE - LANDCOVER CLASSIFICATION

In order to classify landuse and landcover for mapping, a thorough interpretations of the imageries were done under stereoview in both the autograph and stereopret machines. Hence, a selection of a classification scheme was designed.

Lo, (1986) with reference to the United States Geological Survey (USGS) classifications, classified land use and land cover into levels I, II, III and IV. This is to make the classification scheme clearer for understanding (Adeniyi 1980, Anderson et.al, 1972). Table 3.2 shows the different categories of association used in this research for the two different periods. This was arrived at after some pre-interpretation and field checking.

Table 3.2 Landuse/Landcover Classification Scheme for Change Detection for both 1973 and 1980 situations:

S/N	LEVEL I	LEVEL II
1	BUILT UP AREAS	1.1 Offices 1.2 Depot and Hangers 1.3 Settlements 1.4 Recreation areas
2.	ROADS	2.1 Runways 2.2 Other roads
3.	AGRICULTURAL LANDS	3.1 Farm lands 3.2 Grass lands 3.3 Plantations
4.	WATER BODIES	4.1 Rivers and streams 4.2 Pools and lakes
5.	FOREST AREAS	5.1 Reserves 5.2 Mixed forest 5.3 Untouched forest
6.	FADAMA	6.1 Marshy land 6.2 Swamps

3.7 CORRECTION FOR SYMMETRIC RADIAL DISTORTION

Radial distortion arises from lens aberration. Lens aberration is a characteristic of the lens which prevents it from forming an image of a point. Instead, the image of a point is formed as a small blur. (Baker 1980; Graham and Read 1986, Moffitt 1959).

The principal point (P.P) of a photograph is defined mathematically as the foot of the perpendicular drawn from the rear nodal point to the focal plane. If the elements of the lens are perfectly ground and centered at the time of manufacture, the optical axis will pass through the lens system undeviated in direction.

In most cases, the P.P is never physically defined. Hence, a correction could be applied by forming a mathematical model. The radial distortion of each point could be measured directly by the comparator/collimator on the autograph plotter. The radial distances could be computed directly from the control coordinates. Plotting a graph of radial distortion as ordinate against the radial distance as abscissa, the distortion curve would be obtained Fig. 4.5, Page 41.

Moffitt and Mikhail (1980) reiterated that the distortion curve should be symmetrical about the Principal Point of Autocollimation (PPA). Graphically, if curves are not symmetrical, a different point called the Principal Point of Symmetry

(PPS) should be selected to force the symmetric condition. Hence, correction could be effected through the collimator in the plotter.

Having described the methodology that was followed for acquiring the data and processing of the data, we now give the results obtained. These include among others, computations and analyses of the observed results of the interpretations.

CHAPTER FOUR

4.0. DATA ANALYSIS AND DISCUSSION OF RESULT

Acquired data were the remotely sensed data from an aircraft in the electromagnetic spectrum region of 0.4 to 0.7 micrometers. The coordinates of the photo points must agree with those observed from the field geodetically. So also must the radial lengths measured directly from the autograph agree with computed ones from the field coordinates. The remotely sensed data were panchromatic black and white photographs obtained from the archives of Federal Survey Department of the Federal Ministry of Works and Housing, Lagos.

4.1. PRESENTATION OF DATA

The aerial photographs are overlapping panchromatic photographs at 60 percent forward overlap and 25 percent side overlap which are necessary for stereoview. The eight photographs were in specified sizes of 23 x 23 square centimeters as shown in (Plates 1 to 8). The Survey control points have coordinates as shown in table 4.1.

4.1.1. PRESENTATION OF CONTROL POINTS COORDINATES

Few points on the ground which are on the photographs either premarked or postmarked are usually surveyed geodetically to assist in scaling the map to be produced. Table 4.1. below shows the coordinates of points on the ground which were obtained by geodetic surveying. Also Table 4.2. below shows the real measured data of Radial Distortion for each point as was practised before on the photographs and the computed Radial distances data of the equivalent points obtained from the coordinates on the ground control points. Once obtained, it is applied for correction. The question now is, can we obtain these data of Radial Distortion by modelling?

Table 4.1: Coordinates of Control Points

Control Points	Northings Y	Eastings X	Height Z
	(m)	(m)	Above MSL (m)
P.611	286,134.204	99,584.486	19.307
P.612	285,969.209	100,396.349	31.514
P.614	286,023.374	102,225.103	33.107
P.629	282,791.935	98,360.160	25.790
P.630	282,663.541	99,358.595	7.531
P.631	282,647.466	100,057.703	12.531
P.632	282,792.464	101,114.467	16.689
P.638	281,146.507	101,174.328	6.552
P.639	281,178.691	101,501.894	5.014
P.640	281,193.067	99,956.235	15.026
P.641	281,108.757	99,409.903	23.193
P.642	281,338.920	98,453.182	20.090
P.645	287,558.392	99,413.261	39.952
P.646	287,569.486	100,468.086	17.142
P.647	287,542.910	101,320.225	36.807
P.648	287,584.011	102,243.983	37.349

Source:F.S.D. (Geodesy and Planning Section Data, 1980)

4.1.2 RADIAL DISTORTION AND RADIAL LENGTH DATA

Radial distortion of each point on the photographs were measured directly by the comparator. The radial length of each point were computed as analysed in chapter 4.2.2 and as shown on Table 4.2. These are valid method of obtaining these data to correct radial lens distortion (Moffitt and Mikhail, 1980) The research method is to plot the graph and form a model using Least Square Principles to solve for the coefficients. Would the model obtained give the same distortion value?

Table 4.2: Bivariate Data of Distortions and Distances

Control Points	Radial Distortion	Radial Distance
	d_r (mm)	r (mm)
P.640	-0.003	2.981×10^8
P.641	-0,005	2.982×10^8
P.639	-0,010	2.986×10^8
P.642	-0.004	2.981×10^8
P.638	-0.015	2.988×10^8
P.631	-0.020	$2.99\ 9 \times 10^8$
P.630	-0.019	2.996×10^8
P.632	-0.018	3.003×10^8
P.629	-0.016	2.994×10^8
P.612	+0.016	3.031×10^8
P.611	+0.015	3.030×10^8
P.614	+0.025	3.037×10^8
P.645	+0.035	3.043×10^8
P.646	+0.040	3.046×10^8
P.647	+0.044	3.049×10^8
P.648	+0.050	3.052×10^8

Source: Radial Distortions as measured by the Comparator

: Radial Distance as calculated from Coordinates.

4.2 DATA PROCESSING

Necessary checks and corrections were applied before mapping and after mapping respectively and curve plotting had to be done. After mapping, angles to the True North or bearings and distances between two points can be checked. So also are computations for distances between two points; and radial length computations. The following computations are taken as examples.

4.2.1. DISTANCES AND BEARINGS BETWEEN TWO CONTROLS

Taking two points, for example, coordinates of points P.630 and P.631 were used to determine the distance between the two controls for scaling and bearing checks.

DISTANCE (L) between points P.630 to P.631

$$L = ((X_2-X_1)^2 + (Y_2-Y_1)^2)^{1/2} \quad \text{.......... (4.1)}$$

where (X_1, Y_1) and (X_2, Y_2) are the coordinates of P.630 and P.631 respectively.

$$L = ((282{,}647.466-282{,}663.541)^2 + (100{,}057.703-99{,}358.595)^2)^{1/2}$$

$$= ((-16.075)^2 + (699.108)^2)^{1/2}$$

$$= (258.405625 + 488751.9957)^{1/2}$$

$$= (489010.4013)^{1/2}$$

$$= 699.2927865\text{m}$$

This distance between these two points were checked later on the produced map.

The BEARING (B) of line P.630 to P.631 is obtained from

$$B = \text{Arc tan } \frac{X_2 - X_1}{Y_2 - Y_1} \quad \text{.......... eqn (4.2)}$$

$$= \text{Arc tan } \frac{699.108}{-16.075}$$

$$= \text{Arc tan } -43.490388$$

$$= 91^{\circ} \quad 41' \ 58.07''$$

The bearing is the angle which a line on a map makes with the True North and could be checked on the map to be produced later.

4.2.2. RADIAL DISTANCE COMPUTATIONS

Distortion is the displacement of the image point from its ideal position, radially inward or outward from the optical axis; hence its measure is always lateral. For non-rotational systems, (Slama, 1980; Baker et al, 1980, Moffitt and Mikhail, 1980), distortion is defined by lateral displacement errors in two coordinates, such as in X and Y, or if small, in terms of radial and tangential displacement in the image plane from the image point.

The value of Radial Distances for points in the photographs are determined from their coordinates on the "Ground Truth" observation by the equation:

$$r = (X^2 + Y^2)^{1/2} \quad \text{...eqn (4.3)}$$

where r is the radial length in millimeters.

For procedures only, take P.611 for example. The radial distance (r) is computed as follows:

Taking a point P.611 for example, the Radial Distance $r = (X^2 + Y^2)^{1/2}$

$$r = (99{,}584.486^2 + 286{,}134.204^2)^{1/2}$$

$$r = (9.178985255 \times 10^{10})^{1/2}$$

$$r = 302968.4019\text{m}$$

$$r = 3.03 \times 10^8\text{mm}$$

4.2.3. GRAPH OF RADIAL DISTORTION AGAINST RADIAL DISTANCE

The shape of this graph is a polynomial $A + Bx + Cx^3 + Dx^5 + Ex^7 + \ldots\ldots$

$+ \propto x^{2n-2}$ ....(4.4)

as in Fig.4.1. Studying this equation, it is a sine wave equation if expanded by Maclaurin's Series.

It should therefore not be suprising because the property of waves passing through a glass lens obey the refractive index law, the Snell's law. The Snell's law is n = sine i/sine r, where n is refractive index, i is angle of incidence and r is angle of refraction.

4.2.4 FITTING THE POLYNOMIAL CURVE

From graph Fig.4.1, Radial Distortions was plotted against Radial Distances. The function or mapping that resulted was of the form of a polynomial. The constants A,B,C.D,.........., α were to be determined by fitting the polynomial curve to the distortion data by the method of Least Squares. This was concluded by the use of electronic data processing using the POLY. BAS Software.

The value of Radial Distance X for a point had been determined by the equation, Table 4.1.

$$r = (X^2 + Y^2)^{1/2}$$

The distortion data were to be obtained from lens calibration which is actually measured directly from the comparator in the analytical plotter (Table 4.2).

The model however was obtained by solving by the Least Square method for the values of the coefficients A,B,C............ α from

$$d_r = A + Bx + Cx^3 + \ldots\ldots\ldots\ldots\ldots\ldots + \alpha x^{2n-2}$$

where d_r is the radial distortion.

There were Sixteen points within the overlaps of the imageries. The next question is what is equation (4.5) fit in the points taking 4 points for adjustments, the remaining 12 points should given the distortion if the corresponding distances were substituted into the equation. If these applications into the model were correct, the points then have fitted into the model. This means that, if any point's distortion is to be corrected, the radial distance needs to be computed directly from the ground coordinates which is then fitted into the model. The resulting distortion can then be applied straight in the Plotter.

4.2.5 SOLVING THE POLYNOMIAL

$$d_r = A + Bx + cx^3 + Dx^5 + \ldots\ldots\ldots\ldots\ldots\ldots (4.5)$$

Taking any four points, the measured values of d_r and the corresponding calculated values of radial distance are substituted into equation (4.4) above. i.e

$$-0.003 = A + (2.981)B + (2.981)^3C + (2.981)^5D$$

$$-0.015 = A + (2.988)B + (2.998)^3c + (2.988)^5D \ldots\ldots\ldots\ldots\ldots (4.6)$$

$$+0.016 = A + (3.031)B + (3.031)^3C + (3.031)^5D$$

$$+(0.050) = A + (3.052)B + (3.052)^3C + (3.052)^5D$$

Equation (4.6) is a set of four calibration equations in four unknowns. Using then software, POLY.BAS, the values of A, B, C and D were obtained as follows:

A =5555.2

B = -3435.6

C = 249.08

D = -8.12

The values obtained from computation of A, B, C and D are now substituted back into equations (4.6) while the radial distance of any point on the set of photographs taken by the same camera is put in as r values . The radial distortion is obtained from any of the set of equation of (4.6)

So far, the values of d_r and r for the points P.640, P.631, P.612 and P-648 were used to determine the constants of calibration A, B, C and D. It is now necessary to test the model

$$d_r = 5555.2 - 3435.6x^3 + 249.08x^3 - 8.12x^5 \qquad (4.7)$$

Where d_r = distortion on the photograph

and x = radial distance obtained from computing the ground coordinates.

To test the model, the remaining 8 distortion of 8 points were now to be computed to check if the model is viable. Substituting back the value of r of each point into equation (4.7) to obtain the value d_r of the distortion, the following were the results of the back-computation of the rest of the points using the POLY. BAS software.

Table 4.3 below shows the measured and the computed values of the radial distortion (d_r) of any point on the photographs of the same camera lens as obtained from the model obtained in equation (4.7) above.

Table 4.3. Distortion Values Obtained From The Modelled compared with measured values

Control Points	Radial Distances	Radial Distortion	
	r (mm)	d_r (mm) Modelled Value	d_r (mm) Measured Values
P.641	2.982×10^8	-0.005	-0.005
P.631	2.999×10^8	-0.02	-0.020
P.630	2.996×10^8	-0.02	-0.019
P.632	3.003×10^8	-0.02	-0.018
P.629	2.994 x 108	-0.02	-0.016
P.614	3.037 x 108	+0.02	+0.025
P.645	3.043 x 108	+0.04	+0.035
P.647	3.049 x 108	+0.05	+0.044
P.639	2.986 x 108	-0.01	-0.010

Source: Computed from Model Equation (4.7) and Table 4.2

These data were obtained from the substitutions made on the mathematical model obtained empirically. r is the computed value of radial distance obtained from the coordinates of the ground control points which are the same points on the photographs.

4.3. DISCUSSION OF FINDINGS

Mapping any area, no matter how small, is not a joke. It is costly and labour intensive. Using the old conventional systems of mapping is also time consuming. The end-product (map) would be outdated by the time of completion. The method usually entails a system of measuring in an environment of harshweather. In such environment, the observer is prone to commit both random and systematic errors (Topping, 1972) which would eventually be transferred to the calculations. That will subsequently produce a faulty map.

4.3.1. BASE MAPPING AND PLOTTING

Remote Sensing is a tool to map not only as alternatives but also as a precise and perfect method which has been developed to map any area of synoptic characteristics or of large proportions. The method of remote sensing uses the properties of electromagnetic waves for data acquisition and analysis.

In the present situation, non-photographic image systems were not available. The author managed to collect datasets of photographic imageries. The processing of image interpretation is utilized to produce the required information. There is the computer assisted processing of aerial photographs. Such method requires the digitization of the photographs. There is also the method of computerized imageries from satellite data. All these need the processing of Database Management Systems (DBMS) before retrieving through Information Presentation Subsystems (Kufoniyi, 1998) through Graphic Displays.

This study could not make use of any of the above systems for cost and non-availability of equipment. One other processing is the use of the analogue autograph plotter. This requires a lot of calculations and error management. There were a number of corrections to be applied due to non-verticality and imperfection of the photographs. The radial distortion were however corrected for through empirical and analytical method.

Now, the mapping had been completed with correct checks on records of angles, constant change in horizontal scale which preclude accurate measurement of distances on simple overlay. Hence, the produced planimetric base-map now shows the correct horizontal distance or plan position of natural and cultural features. It should be clear that the construction of an original base-map can be expensive and time consuming. It is therefore necessary to think of a method, the computer assisted method that will finish the processing in good time.

4.3.2. MODELLING OF RADIAL DISTORTION

This became possible because of the analytical system in stereo plotter. Orientations made it possible. There are two types of orientations. These are Interior and Exterior orientations. These two were achieved by two processes called Relative and Absolute orientations, (Moffitt, 1959). Interior orientation has that set of three elements (x_o, y_o, f). The f element is the focal length of the lens of the camera. The 3-dimensional coordinates recover the geometry of the bundle of rays inherent in each photograph at the instant of exposure. The Interior orientation elements are obtained from the camera calibration data. These gave the Radial Distortion data.

Exterior orientation, however, are set of six elements (X_L, Y_L, Z_L, W, ϕ, K). These elements fix the spatial position and altitude of each individual bundle of rays with respect to ground coordinate system. Hence, these elements must be determined for each exposure. This was however done indirectly by means of ground control points (Table 4.1).

From table 4.1, the radial distances were determined from each of the control points, Equation 4.1 (Moffitt and Mikhail, 1980).

From the WILD autograph B8S, the radial distortion were obtained. Plotting the graph of radial distortion against radial distance, a polynomial curve was obtained (Fig. 4.1).

This implies that a model obtained from the polynomial has empirically decided the distortions in all other points on the piece of the terrain. Computations were carried out by Least Square Adjustment on the polynomial to determine the coefficients of the polynomial. (Table 4.3) on page 32

4.3.3. EFFECTS OF MAPPING

From all analysis, it is now important that planners and policy makers need to utilize whatever could be produced in maps by converting plans to action programs in land-use management. Hence, before any land resources could be managed effectively, and plan for the future, land-use patterns of the past and present must be understood. Vast amount of information on land resources must be related to socio-economic factors (Avery 1977). Without a systematic means of tabulating, reporting and updating land resources information, decision makers will realize that a non-standard database leads to inconsistencies or anomalies in planning processes. Avery (1977) pointed out that since remote sensing is part of intelligence information, military intelligence in air, land and sea would not suffer. So also are urban and industrial planning, landforms and physiographic features, forestry, agriculture, soils and archaeological information would grow. The machinery to carry the geoinformation for all the above is Land Information Systems (LIS) which is ready for action and assistance.

4.3.4 NEED FOR MAPPING

van Genderen et.al (1978) explained in an article of ITC Journal that a detailed methodology for producing small scale rural land use maps from data obtained by remote sensing techniques could have immediate practical applications. The objective then, has been to produce a methodology that could be applied using relatively accessible equipment and materials, as many developing countries lack suitable qualified staff, technology and equipment.

However, with ensuing changes in agricultural products and land management procedures, a system for establishing permanent and systematic records of landscape changes are being provided with remote sensing techniques.

4.4 ACTION IMPLICATIONS

Avery (1977) under Land Information Systems and Land Cover Mapping divided the process of Land-use planning into four chronological phases:

- **(i) Awareness and Organisation:** The recognition that a problem exists and that detailed studies based on specific objectives will be required for successful planning;
- **(ii) Inventory:** The collection, collating, reporting and analyzing of information on land and natural resources;

(iii) **Decision Making:** Consideration of alternatives, evaluation of impacts of proposed action, and resolution of land-use conflicts; and

(iv) **Action:** The conversion of plans to action programs in land-use management.

It is clear that before land resources can be managed effectively and plan for the future, land-use patterns of the past and present must be understood. Hence, vast among of information on land resources must be related to socio-economic factors. Without a systematic means of tabulating, reporting and up-dating land resources information, decision makers will realise that a non-standard database leads to inconsistencies or anomalies in the planning process.

This study had acquired data that are synoptic in nature. The data were analyzed both by autograph analytical machine and then interpreted. These gave the full information that could be required in any development. Such information as Akanbi (1998) relayed how scientists demonstrated the use of such data acquired in-situ from sensors to effectively survey and map surface temperatures as well as analyzed by Otterman (1984), Pinker and Corio (1983), Porch (1974), Adefolalu (1990) also analyzed how such information are utilized to forecast the extent of desertification. Thenkabail and Nolte (1995) used this type of data to analyzed the ecosystems of West Africa and Central Africa.

Land resources are considered to include the surface, sub-surface and super surface features of the earth (Paine 1981; Avery 1977). These affect the activities and environment of humans. These resources include soils, minerals, water, climate, space and other earth features to an extent that they could be observed, classified and spatially fixed. All these, this study have tried to conclude upon. Anyone, who therefore has primary access to the information has an advantage in controlling land-use and land-cover resources.

4.5 ANALYSIS OF LANDUSE AND LANDCOVER

It is necessary at this point to identify the proportions of Landcover to their classifications for the two different periods and see how much of the land that had been usurped by different land use. Tables 4.4. shows the amount of area of land cover that were utilized for landuse over the period of seven years.

For almost seven years period, more homes were built which could be said to be 68 percent of what was on ground. This proves the amount of socio-economy boost of the time. More roads were built to 64 percent including the extensions of the runways to that of international standard. These improvement of landuse affected the reduction on the land-covers. The Agricultural land area were reduced by 8 percent. The water bodies also were filled up for settlements by 33 percent. The Forested Areas were cut down for the runways by 60 percent while the marshy areas were sand-filled to cut the Fadama area by 54 percent. It is obvious from table 4.4. that as Landuse increases, landcover diminishes. Hence, there is this inverse proportionality between Landuse and Landcover. The amount or proportionality depend on the socio-economic boost of that period.

Table 4.4. Land Cover/Landcover In 1973 and 1980

Level I-Classification	Area in Square Kilometers			Usage Level II
	1973	1980	Percentage Increase or Decrease	
1. Built Up Areas	7,87	13.22	+68%	Office Buildings, Industrial Depot, Residential, Recreational,
2. Roads	0.67	1.099	+64%	Runways, Trunk 'A', Trunk 'B', Hangers Flyover,
3. Agricultural Lands	5.05	4.64	-8%	Farm Lands, Grass Lands, Plantations,
4. Water Bodies	0.36	0.24	-33%	Rivers, Streams, Pools Aquaduct,
5. Forest Areas	0.9	0.36	-60%	Reserves, Mixed Forests, Untouched Forests
6. Fadama	0.48	0.22	-54%	Marshy Land, Swamps

What made the government to build an airport on this particular terrain hence a runway at the beginning is the broad topographic flat features of the whole terrain coupled with the little or no development of settlement at the time. This is as depicted on the height of the terrain from the geodetic heighting on table 4.1. At that period, Remote Sensing was yet to be appreciated in Nigeria but the old levelling method carried out by Surveyors was utilized to produce the topographic map of the area.

Looking at the base-maps produced by this study, this terrain could as well be utilized for some other things like community development, University and colleges, Industrial centers, farms, military cantonment and host of other landuse. It is therefore necessary to have a basemap before any development is thought of. Akanbi (1998) reiterated in the National Conference of Nigerian Institution of Surveyors that

"In the pursuit of our national goals and objectives, we must take step and accord high priority to acquisition of up-to-date inventory of our Nations' endowment for their effective planning, development and sustainable management. In practical terms, what we need to survey and map are all those elements, features and physical components which constitute our contry's territorial environment". In Abiodun's (1998) paper with a brief history of importance of mapping, he confirmed that Surveying and Mapping were as old as colonization as the various explorers and even missionaries prepared maps and sketches of the new territories. These were followed by the Armed Forces and Administrative Officers of the colonial power. Surveying and Mapping were placed on such a very high pedestal to the extent that the Deputy Governor-General was also at a time the Surveyor General of Nigeria. Hence, without mapping, no feasible development can be attained.

Anyone, therefore that has primary access to information in a map has an advantage in controlling landcover for landuse.

Concluding two base maps for such a large size of land is made possible within a short period or rather practicalized because of the role of remote sensing. Remote Sensing would depict or unveil all information about land resources no matter the size, remoteness, diversity, variability and vulnerability of the resources. On the whole, the two base-maps are the same for both periods. The Landuse and landcover were not the same. Serious changes within the seven years period had taken place. There are drastic changes in the runway. There are now two runways in 1980 as against one runway in 1973. The surrounding Landcover had changed for Landuse. The forest had diminished, most of the marshy land or Fadama had been sand-filled for concrete bitumen. More houses and roads had been built in the settlement areas. Where there were no flyovers in 1973, over-head bridges are now flying by 1980. All these showed the amount of affluence that had come within the decade.

Whereas, at that period, the farm land had diminished, lakes, fadama and pools were sand-filled, forest cut down for development and hence landcover gave way to landuse.

The ease in remote sensing or photogrammetry system should be developed. The faster and better methods of computerization called Geographic Information

System (GIS) had gone far. There is the computer assisted digital method of plotting the photographs with the use of Softwares.

Ogunlami (1998) pointed out some of the factors for consideration in mapping by saying that "the rate of degradation and depletion of natural resources in Africa has been accelerated as a result of increase population pressure." To count population in an African context detailed maps of the local areas are needed. Ogunlami (1998) continued by reiterating that "The lack in Africa countries of reliable quantitative and qualitative information and data on vegetation cover, landcover and landuse patterns at national and regional levels has been the major limiting factor in orderly and accelerated development planning, sustainable management of agriculture, forestry resources, desertification, drought early warning systems, food security, environmental monitoring as well as bio-diversity assessment and protection and several other multisectoral/multidisciplinary applications in all areas of human endeavours.

Since Africa is characterised as the richest continent in the whole world in land resources but yet hosting most of the poorest countries due to their inability to utilize efficiently modern technology in exploration, exploitation and management of natural resources (Ogunlami 1998) concluded that the African nations have refused so far to know how to make use of maps to possibly, reliably and timely decide for the betterment of their people. All these were arose among African governments by the resolution of the 9th United Nations Cartographic Conference for Africa held in ECA Headquarters in Addis, Ababa, Ethiopia in November 1996.

4.6 IMPLEMENTATION

It is obvious that now and in future; governments, planning commissions and even enterpreneurs would increasingly need detailed knowledge of land resources, both in the natural aspects and as effected by humans, to guide public and private decisions. Shortages of natural resources and conflicts in land-use attract world-wide attention. A major step towards assuring improved management of existing land resources is to make land information more accessible. This requires the systemization and storage of what is known and the provision for rapid information retrieval in forms acceptable to a broad array of users.

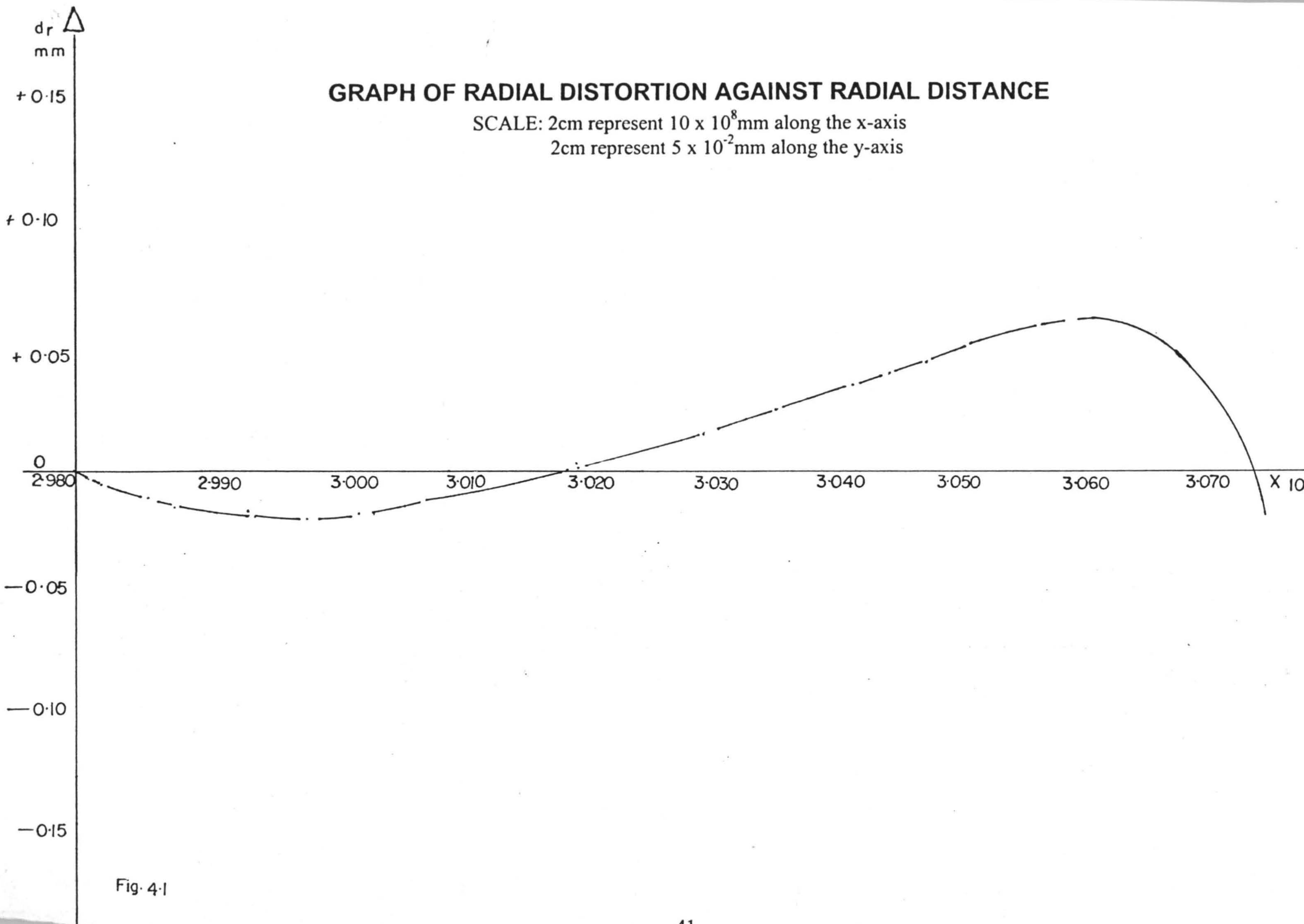
If technical characteristics of land information systems are given primary considerations, questions relating to the sponsorship of, financing of, users access to, and control of such systems would be left to the political scientists or policy makers. It could as well be agreed that the political scientists are not well informed about this system of information. Avery (1977) emphasised on the need for intelligence systems. He wrote, "Intelligence activities may be defined as the process of gathering a myriad of facts and bits of information, making a coherent pattern of them, and drawing inferences from that pattern. In the American concept of intelligence, emphasis is on the use of overt or open sources of data, i.e., information that is legitimately available from foreign newspapers, military and scientific journals, foreign political discussions or debates, encyclopaedias, radio broadcasts and statistical compilations".

The above merely shows how serious our policy makers want to or take information. Remote Sensing is a tool for gathering genuine information about anything. It is therefore important for policy makers to assist educational institutions offering such courses by asking the government to fund them. In the end, satellite launching would be a reality when it comes to mind.

Perhaps a national society of remote sensing should take off. Such institution could raise the morale of the profession, present exhibitions to the nation and to be more aware of the usefulness of the course.

In the end, military intelligence in air, land and sea would grow; urban and industrial planning would improve; engineering application and mining would develop, land forms and physiographic features would be known; forestry would be grown; agriculture and soils would be taken care of, historic archaeology would be detected and Land Information Systems would assist planners in all their occupations.

There is serious need for a base-maps in all its ramifications if any kind of planning is to be executed on land resources. For a plot or few acres of land, local planners may need to acquired datasets from the HRV Spot in large scales of 1 in 25000. For an extensive or synoptic area, small scales would be used. But for all kinds of mapping, remote sensing is still the best method of acquiring data.



GRAPH OF RADIAL DISTORTION AGAINST RADIAL DISTANCE
SCALE: 2cm represent 10 x 10^8mm along the x-axis
2cm represent 5 x 10^-2mm along the y-axis
dr
mm
+0·15
+0·10
+0·05
0
−0·05
−0·10
−0·15
2·980
2·990
3·000
3·010
3·020
3·030
3·040
3·050
3·060
3·070
X 10

Fig. 4·1

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSIONS

5.1 SUMMARY

The initial intention to map a place twice was to depict the land resources of the area at two different periods. It was to interpret the resources as they were in 1973 and 1980 scientifically, analyzing the spatially referenced information of the area. The problem of imperfection in the acquired data arose. One of the most troublesome distortion to be corrected is the symmetric radial lens distortion. Its correction had always been by trial and error with a lot of error management. This study was to determine this correction, empirically by creating a mathematical model for the distortion. After correction base-maps can be produced to depict the categories of association. Two base-maps were produced for two different periods to compare the extent of landcover that were consumed by landuse. From the results, the extent of landuse was seen to be increasing while the extent of landcover was diminishing.

5.2 PROBLEMS ENCOUNTERED

Associated with so many problems is the issue of money. To get through a successful research is to obtain educational grant for data acquisition, equipment, transportation, fees, books and so many other things related to living expenses. None of these exist in our present nation. Efforts made so far are individualistic.

Acquiring datasets was the most nagging problem. The cost of acquiring datasets is exhorbitant. Government agencies and departments having data looked at recipients as secret agents of sabotage even after presenting letters of credence. Those government institutions also complained about the cost of acquisition.

For the modus operandi of this particular study, the most ideal thing was to get to the terrain of interest and survey the perimeter for base-mapping. Although the entire area is about 30 square kilometers, the survey field work alone could have taken about a year to complete. The landcover was not as it was at the time of study. The study was comparing the past. Only remote sensing as a tool could preserve the past, the present and the future for planning. No one can survey the past since so much had taken place on the terrain. Events had overtaken the times. Events connote the changes that had taken place in landuse and landcover.

For map compilation, the costs and comparing the situations as it was in 1980 with that of today 1998 were not easy. Reluctant security agents had to assist in the end. Studying the situations at hand as it is today by Ground Truth and the photographs since 1980, little had taken place. For 1973 situation, almost nothing is left to be identified except some of the untouched mashy and swampy land areas and some balding farm lands.

The imageries of 1973 were in a scale of 1 in 25,000. Those of 1980 were in a scale of 1 in 10,000. The 1980 photographs were mapped accordingly to their scale with WILD B8S autograph plotter while the 1973 photographs were mapped with the stereopret. The 1973 base-map was then enlarged to 1 in 10,000 using conformal mapping.

With some of these constraints, there are some interesting things one can as well think of.

5.3 COMMENDATION

To map any place is not an easy thing to do. The early Surveyors determine positions by star observation. Then came the plane-table and constructive geometry. Later, the vernier theodolite and the dragging of chain across the country-side were used to map the world into details. Today, Geo-spatial Information System (GIS) could map the world into details in a matter of days. Kufoniyi (1995) classified GIS into four main subsystems for handling the four interrelated phases in information processing, namely data collection, data storage, data manipulation and data visualization. Within GIS is remote sensing or its component for data acquisition or collections. But its processing of which the most vital component on which the four subsystems operate is the Spatial Database (Kufoniyi, 1995).

It is sufficient to commend the researches that had built those machineries known as platforms and their payloads that capture or acquire data. Such are the satellites and airplanes and their payloads like the metric cameras, radar, scanners, radiometers, and so on. With all these, the earth is becoming a global village.

The Federal University of Technology at Minna (FUTM) should be commended for starting the remote sensing course. Kudos to the pioneer Head of Department for encouraging younger lecturers. It is clear that remote sensing is so much useful in many professional practice. For national development, the course would permit easy access in Highway, Civil, Electrical, Surveying engineerings, Biological, Architecture, Space exploration, Strategic planning in military intelligence, Rapid transit systems, Geology, Forestry, Land and mineral explorations, Medicine, Resource surveys, Oceanography, Archaeology, Meteorology, Cadastre practices and all those professions applied by human on the surface of earth and obtain easy solutions to the problems that might arise.

5.4 CONCLUSIONS

Maps have been produced to depict spatially referenced information. To do this, data have to be acquired. The method of acquisition is the remote sensing as different from the labour intensive measurement on the ground. Remote sensing also has so many method of acquisition. Here, the photographic method was used. This method carries along with a number of distortions. The most difficult to correct is the Symmetric Radial Lens Distortion. This can now be corrected for by simply using a mathematical formula determined by the Least Square principle for a particular lens camera. This was attained by first measuring the distortions directly for each point on the photographs using the comparator as the overlapping photographs are arranged in stereo analytically on the plotting machines. The equivalent coordinates of the same point decides the amount of displacement relative to the distortion. Hence a graph of radial length against radial distortion was plotted and a certain curve emerged. The curve is of the polynomial type. This mimics the sine wave of the refraction of rays passing through a camera lens. Such polynomial is of odd power which decides the model. To decide the coefficients of the model, a 4 x 4 matrix was concluded upon to be solved by Least Square method. This model was now tested for by substituting the radial lengths of other points to find the radial distortion. The result was overwhelming when it tallied with the measured quantities. This shows that the model worked and hence can be used to find any other distortion on any photographs taken by the same lens to correct the distortion inherent in the camera lens. This will then be applied into the coordinatograph. A basemap is therefore produced and concluded upon.

Two basemaps were concluded upon for comparison. The spartially referenced information were compared. It was found that as Landuse increases, Landcover decreases hence they are inversely proportional to themselves.

On conclusion, correction for Symmetric radial distortions of a point on an aerial photograph from an equation is possible.

With reference to table 4.4, there were rapid changes in the area of study within the period of seven years.

Due to the rapid changes, as landuse increases, landcover diminishes.

From these conclusions, it is necessary to look at the advantages of remote sensing that made the study possible.

5.5 ADVANTAGES OF REMOTE SENSING

Among many applications of this noble tool, MAPPING is the one exciting end-product and the most needed by every users in Land Resource Management. In addition to topographic and planimetric mapping, many other special purpose maps are also prepared photogrammetrically or by remote sensing in recent times. The maps which can vary from small-scale to large-scale are utilized in planning and designing for highways, railroads, rapid-transit systems, bridges pipelines, aqueducts, transmission lines, hydroelectric dams, flood-control, structures, rivers and harbour development and improvements, urban renewal projects, railways designs to mention a few.

The main objective of remote sensing or photogrammetry is the extraction of environmental and natural resources data related to the land on earth (Anderson, et.al, 1976). It is therefore useful in Land Resources Management such as in Geology, Forestry, Mineral Exploration, Medicine, Oceanography, Archaeology, Maintenance Engineering including Architecture, Meteorology, Population count, etc.

Avery, (1977) defined Intelligence Activities as "the process of gathering a myriad of facts and bits of information, making a coherent pattern of them, and drawing inferences from that pattern". Remote Sensing falls into this definition. Whether secret information come from overt or covert sources, remote sensing is the tool needed for both sources. In international affairs, intelligence is foreknowledge, and foreknowledge is a powerful peacetime tool for making advance predictions of hostile nations reactions to varying political, economic and military crises. As an illustration, skilful photo reconnaissance work by the British interpreters during World War II led to the destruction of launching sites for German V-bombs on the European continent (Avery 1977). As a result, a long-range attack which might have been catastrophic was averted, so also is the catastrophic movement of the Hurricane across the pacific every year being averted by remote sensing. Remote Sensing could be used for gathering intelligence information which could be cyclic and continuous process. It usually begins with a listing of data requirements, followed by the location and exploitation of information sources, and finally leads to the dissemination of the intelligence report or estimate. National Security interests must require agencies to maintain an alert flexible aerial reconnaissance posture at all times. A strong reconnaissance capability can inhibit the outbreak of hostilities if aggressors know that their actions are fully seen, analyzed and understood, because they have been denied the singular advantage of surpass. During war-time operations, an established capability in intelligence and photo reconnaissance can help assure an early victory by supplying up-to-date information on enemy forces, terrain factors, communication factors, weaponry installations and weather conditions.

This study had shown that with proper training in the courses of remote sensing, military logistics is at an overriding advantage in secret knowledge of enemy country occupations either in secret industrial designs, agricultural improvement know-how as in the case of Large Area Crop Inventory Experiment (LACIE) project (Lo, 1986). Land resources of foreign power and many other things that needs to be known shall be possible from any nations' Land Resources Management.

5.6 RECOMMENDATIONS

The overall utilization of Remote Sensing Applications is yet to be appreciated within the Nigerian nations. It is necessary that publicity be given to let the power that be understand the extent of usefulness of the tool. Solving the national problems should start form reconnaissance stages of planning. Any planning has its base from what we have on ground. The extent of the ground must however be known: the base map.

According to Avery's (1977) analysis of planning phases, there is the assumption that governments must have at least reached some stage within the first phase of "Awareness and Organisation". Since this study is largely devoted to the second step of planning phases i.e collection, collating, reporting and analyzing information on land and natural resources; state or regional land information systems and land cover mapping should be taken seriously.

By now, every public agency should have based their reports, maps, related land resources data on a different format and with different resource classification scheme. The need for a standardized database would be painfully obvious and should be a prime requisite as agencies face up to their land informational planning needs.

One major problem in the establishment of a regional land information system is that of assembling the desired data and then re-structuring it to a standardized computer-compatible format. The ideal systems which had since been used and still under improvement in designs which is to serve a wide diversity of users should be acquired and used for national development. These systems would be capable of continuously updating as new or supplementary land resource data became available.

Since Remote Sensing has a diversity of applications, all professions should be encouraged in its utilization as a tool. This will entail a hierarchical system to incorporate features of several existing classification systems that are amenable to data derived from remote sensors, including imagery from satellites and high-altitude aircraft.

For national security, remote sensing should be taken seriously because it is basically utilized for secret and military purposes.

Now efforts should be made by governments and non-government organisation (NGO) to collaborate in establishing and implementing policies in adopting science and new technology hence mapping for regional, national, state and local development.

The aircraft or satellites are the platforms, the cameras, radiometers and others are the payloads. The photographs were taken and developed. The remote sensing specialist interpretes whatever is on the terrain to the requirements of the users. The interpretations are in form of maps or diagrams. The accuracies were tested by ground truth. The Murtala Muhammed Airport and environs was just a case in point. If it had been any other terrain, the accuracies could as well be attained.

So many constraints were encountered. Acquiring data, costs of anything related to the course itself, ascertaining the ground truth, ignorance on the part of the public and decision makers on the difficulties of producing a map, lack of budgetary voting, low human resources, unavaliability of infrastructures, lack of facilities, non creation of data source systems, non establishment of agencies to capture data, non-cooperation within states sectionalism, envying the interested personnel in education etc. are part of the difficulties confronting national development.

With all these delays, the researcher had tried to prove that the job could be done if given the datasets, equipment necessary and encouragement to help the nation to attain its goals in field of economic development and security. Datasets obtained were studied with the available B8S autograph plotter and the stereopret while the categories of association were analysed, identified and interpreted with care. With all the above constraints, available data and equipment, the proposed objectives were achieved.

From all the applications, the role played by remote sensing in landuse and landcover mapping can not be over emphasised. It is the fastest method and best in terms of reliability in data acquisition. The major advantage was the prospect of instant, accurate interpretation over large areas.

As this study has also shown, aerial photography can be used by archaeologists to discover sites of past human settlements with the help of tonal change or shadow effect, a characteristics of interpretation. For population estimation, a great variety of remotely sensed aerospace imagery are being used along with conventional aerial photography (Paine, 1980).

Non-photographic sensors have also made significant impact on applied remote sensing in the study of lithosphere. These different kind of sensors complement each other in the extraction of geological, geomorphological and hydrological information at different levels of required accuracies. There are now gradual shift from aerial cameras towards the use of non-photographic sensors. There is the utilization of thermal infra-red and microwave channels in thermal inertia mapping. There is the use of microwave sensing (synthetic aperture radar) detecting lineaments; and passive microwave sensing monitoring water resources. The Landsat imageries are widely used for regional structure interpretation and for environmental geomorphology. There had been successes in applied remote sensing in the field of integrating the geological, geomorphological and hydrological aspects with landuse and landcover of a region (UNESCO, 1973).

One can not exclude the integration of geomorphological and hydrological aspects of land resources with the biosphere and world population increases. Applied remote sensing stand to solve the problems and detailed studies are not stagnant.

Plotting a graph of Radial Distortion against Radial Distance, a polynomial type of curve was obtained which is of the type in Equation (4.3). After using the POLY.BAS to solve for the coefficients of the equations and unknowns, a model was attained from (Table 4.3). Comparing the graph with the same type of functions in other aerial photography, it was the same shape. This showed that what was measured manually, can now be decided mathematiclly.

Mapping an environment twice with traditional survey method is absolutely cumbersome, especially if the area is about 30 square kilometers. Why would anyone or department do it. The cost and lack of development could not allow such a thing. Remote Sensing made it possible and very easy. The records would be for keeps for ever. It could even be compared in hundred years time. The association categories were easy to identify and interpret. The changes that had taken place within the seven years were actually analysed.

BIBLIOGRAPHY

Abiodun, T.A. (1998): "Institutional Framework for a Surveying and Mapping Policy For Nigeria". April 1998 Paper Presented and Published at Annual General Meeting of NIS in Ilorin, Kwara State, with theme Evolving a Surveying And Mapping Policy For Nigeria.

Adefolalu, D.O. (1990): "Densification Studies, (With Emphasis on Nigeria)". Microwave Remote Sensing For Oceanographic and Marine Weather Forecast Models, edited by R. A. Vaughan, Kluwer Academic Publishers, Netherlands.

Adeniyi, O.P., (1980): "Land-use Change Analysis Using Sequential Aerial Photography And Computer Techniques". Photographic Engineering And Remote Sensing, Vol.40, No.11.

Akanbi, S.O., (1998): "An X-ray of Fundamental Parameters For Formulating An Integrated Surveying And Mapping Policy For Nigeria". April 1998 Paper Presented and Published at Annual General Meeting of NIS in Ilorin Kwara State with Theme, Evolving a Surveying And Mapping Policy For Nigeria.

Amer, F.A.A.F., (1981): "Theoretical Reliability of Elementary Photogrammetry Procedures". ITC Journal 1981-3 278pp.

Anderson, J.R., Hardy, E.E., Roach. J.T., and Witmer, R.E., (1976): "A Land-use and Land-cover Classification System For Use With Remote Sensing Data". Geological Surveys Professional Paper 964, US Government Printing Office, Washington , U.S.A.

Anderson, J.R., (1977): "Land-use and Land-cover Changes, A Framework For Monitoring". Journal of Research United State of America Geological Survey 5 (2).

Avery, G. (1965): "Measuring Land-use Changes on USDA Photographs". Photogrammetry Engineering, No.31, 661-8pp.

Avery, T.E., (1977): Interpretation of Aerial Photographs, 3rd edition, Burgess Publishing Company, Minneapolis, USA.

Baker, J.G., Magill, A.A., Tayman, W. P., Pestrecov, K. Washer. F.E., (1980): "Elements of Photogrammetric Optics", 4th edition of Manuals of American Society of Photogrammetry.

Burnside, C.D., (1985): Mapping From Aerial Photographs, 2nd edition, Collins, London 11-12pp.

Campell, J., (1987): Introduction to Remote Sensing, The Guildord Press NY. U.S.A.

Graham, R. and Read , R,E., (1986): British Manual of Photography, 1st edition, Focal Press, London.

Geoinformatic Group (1997): "Geographic Information System and Digital Map Revision", Paper Presented at 1997 Survey-Coordination and Advisory Board on Survey.

Hallert, B. (1960): Photogrammetry Basic Principle and General Survey, 1st Edition, McGraw-Hill Book Company, Inc., London.

Harrison-Chruch. R., (1980): West Africa, 8th edition, Longmans, London.

Horder, Alan (1965): The Manuals of Photography, 6th edition, Focal Press, London and New York.

Kilford, W.K., (1979): Elementary Air Survey, 4th edition, ELBS and Pitman Publication, Bath, 33pp.

Kufoniyi, O. (1995): Spatial Coincidence Modelling Automated Database Updating and Data Consistency in Vector GIS, ITC Publication No.28, Enschede and Ph.D Thesis, Department of Surveying and Remote Sensing, Wageningen Agricultural, The Netherlands, 158pp.

Kufoniyi, O. (1998): "Database Design and Creation", From the Principles and Applications of Geographic Information Systems, edited by C.U. EZEIGBO, Series in Surveying and Geoinformatics, Panaf Press, Lagos.

Lerbel, F.W. (1988): Remote Sensing I, Standard Course (P1-P5) in Photogrammetry at ITC, Netherlands.

Liliesand T.M. and Kiefer R.W. (1987): Remote Sensing And Image Interpretation, 2nd edition, John-Wiley and Sons, NY. USA.

Lintz. J. and Simonett, D.S., (1976): Remote Sensing of Environment, Addison-Wesley Publishing Company, Michigam. USA.

Lo. C.P. (1986): Applied Remote Sensing, Longman Scientific and Technical Publication, Hong-Kong.

Mofitt, F.H. (1959): Photogrammetry, 1st edition, International Textbook Company, Scianton, Penn, USA.

Mofitt, F.H. and Mikhail, M.E. (1980): Photogrammetry, 3rd edition, Harper and Row Publishers, NY.

Molenaar, M. (1978): "Essay On Emperical Accuracy In Aerial Triangulation". ITC Journal 1978-1, 81-83pp.

Molenaar, M, (1980): "What a Future Photogrammetrist Should Know About Statistics and Adjustments". ITC Journal, 1980-3, 543pp.

Nigeria (1958): The Laws of Federation of Nigeria, Chapter 194.

Ogunlami, J.A. (1998): "Some Factors For Consideration In Establishing Enduring and Useful Surveying and Mapping Policy For Nigeria for Sustainable Development". April 1998 Paper Presented and Published at the Annual General Meeting of NIS in Ilorin, Kwara State with Theme, Evolving a Surveying and Mapping Policy For Nigeria.

Otterman, J. and Tucker, C.J. (1984): "Satellite Measurements of Surface Albedo and Temperatures in Semi-Desert", as Published in The Journal of Climate and Applied Meteorology, Vol.24, No.3, March 1985.

Paine, P.D. (1981): Aerial Photography and Image Interpretation For Resource Management. John-Wiley and Sons, NY, USA.

Pestrecov, V.K. (1959): "Radial Distortion, its Calibration In Non-Gaussian Image Planes and Compensations", Photogrammetric Engineering, Vol.25, No.5. 702-712pp.

Pinker, R.T. and Corio, L.A., (1983): Surface Radiation Budget From Satellites, Department of Meteorology, University of Maryland.

Porch, W.M. (1974): "Fast-Response Light Scattering Measurements of Aerosol Suspension In a Desert Area". Paper Published in Atmosphere Meteorology Vol.8 . pp.897, Pergamon Press Great Britain.

Robinson, A. H., Sale R.D., Morrison, J.L. and Muehrcke, P.C. (1984): Elements of Cartography, 5th Edition, John-Wiley and Sons, NY. USA.

Thenkabail, P.S. and Nolte, C., (1995): Mapping and Characterizing Inland Valley Agrosystems of West and Central Africa. Published by International Institute of Tropical Africa (IITA).

Slama, C.C. (1980): Manual of Photography, 4th edition.

Topping, J. (1972): Errors of Observations and Their Treatment. 4th edition, Chapman and Hall Science Paperback.

Townshend, J.R.G., (1981): Terrain Analysis and Remote Sensing, George Allen and Urwin Publication.

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

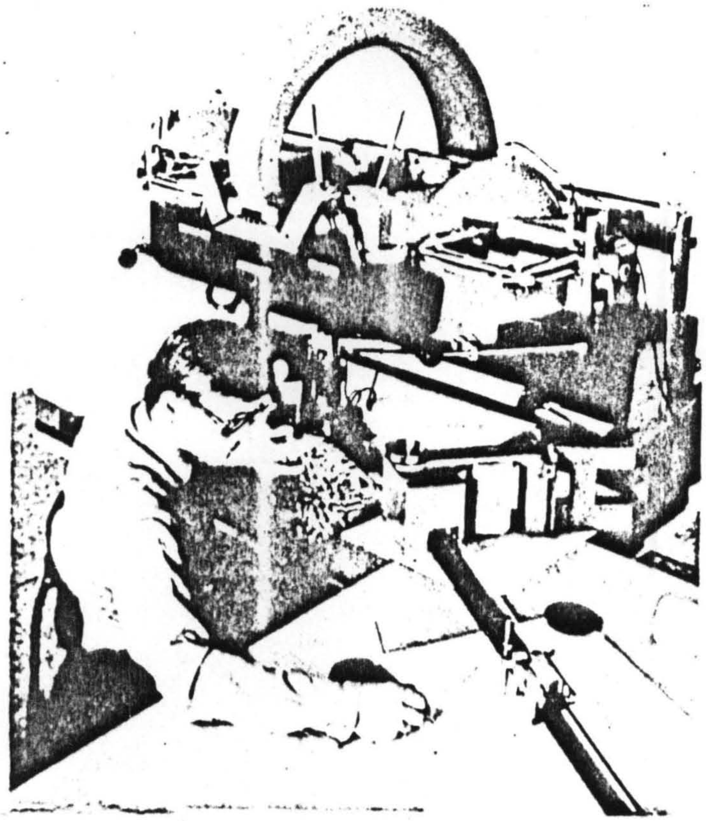
van Genderen, J.L., Vass, P.A., Lock, B.F., (1978): "Guidelines For Using Landsat Data For Rural Landuse Surveys in Developing Countries", ITC Journal, 1978-1, 31pp.

WOLF, P.R., (1980): "Survey Measurement Adjustments by Least Squares", as edited in Survey Handbook extracted from Adjustment Computations - Practical Least Square For Surveyors, 2nd edition, Rancho - Cordova, Carlifonia, Landmark 1980.

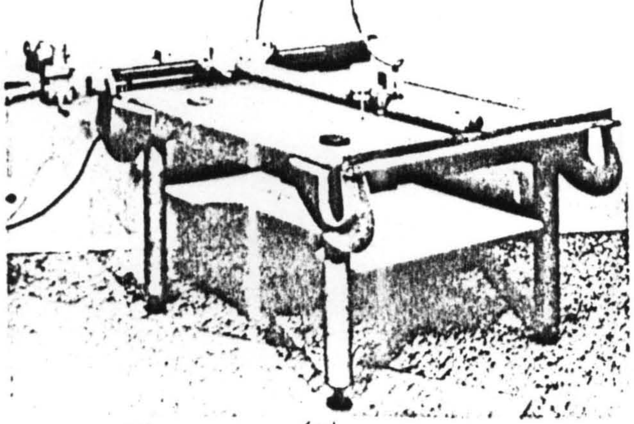
WOLF, P. R., (1983): Elements of Photogrammetry, 2nd edition, McGraw-Hill Publications.

ABBREVIATIONS

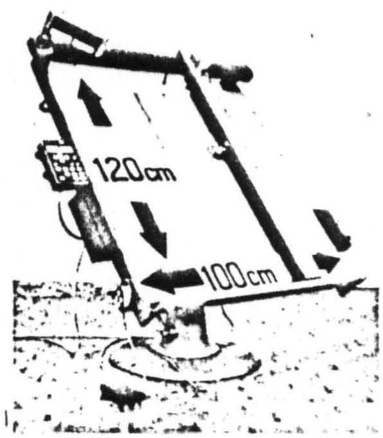
AGM	-	Annual General Meeting
Cap	-	Chapter as in the Laws of Federations of Nigeria
E.C.A.	-	Economic Community for Africa
E.L.B.S.	-	English Language Book Society
F.M.W.& H	-	Federal Ministry of Works and Housing
F.S.D.	-	Federal Survey Department
G & P	-	Geodesy and Planning
GIS	-	Geo-spatial Information System
	-	Geographic Information System
I.I.T.A.	-	International Institute For Tropical Agriculture
I.S.P.C.	-	International Society of Photogrammetry Congress
I.T.C.	-	International Institute for Aerial Survey and Earth Sciences
LACIE	-	Large Area Crop Inventory Experiment
M.S.L.	-	Mean Sea Level
N.G.O.	-	Non Governmental Organisation
N.I.S.	-	Nigerian Instituions of Surveyors
N. Y.	-	New York
Ph.D.	-	Doctor of Philosophy
P.P.	-	Principal Point of a Vertical Photograph
P.P.A.	-	Principal Point of Autocolimation
P.P.S.	-	Principal Point of Symmetry
RECTAS	-	Regional Centre For Training in Aero-Space Survey
U.S.A.	-	United States of America
U.S.D.A.	-	United States Department of Agriculture
U.S.G.S.	-	United States Geological Survey



Wild Aviograph B8S showing linear pantograph and plotting table. Courtesy of Wild Heerbrugg Instruments, Inc.



(a)



(b)

. Coordinatographs. (a) Mechanical connection to instrument motions. (b) Electrical connection to instrument motions. Courtesy of Wild Heerbrugg Instruments, Inc.