A METHODOLOGY, USING AERIAL PHOTOGRAPHS, FOR MAPPING URBAN LAND-USE IN NIGERIA

A thesis presented by Engr. EFIONG U. ESIN, Department of Civil Engineering, University of Aston in accordance with the regulations governing the award of the degree of Master of Philosophy of the University of Aston in Birmingham, England.

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SUMMARY

This research was stimulated by a growing need to provide some guidance in the choice of handling tropical urban land use data derived entirely from aerial photography.

A general review of urban land use surveys, including those based on aerial photographs, carried out in Britain, Europe and North America, is followed by a brief account of the limited amount of work done in this field in the tropics.

Classification theory is considered, and an initial urban land use classification is drawn up, based on the categories observed from aerial photographs. The classification was tested and subsequently modified, and used to compile a set of air photo, urban land use, trace overlays of Calabar City, Nigeria.

Seven of these trace overlays were selected for detailed analysis and for each the various units of urban land use were measured:

i) by digitizing the discrete site boundaries
ii) by dot grids of varying density
iii) by grid squares of varying density

the results were compared both qualitatively and quantitatively.

Some initial adjustments were made to the observed grid area measurements and these 'adjusted' area values were then compared with the 'standard' area values to determine the errors.

These adjusted values were also used to determine the most influential factors affecting the accuracy of the measurement, by the use of multiple correlation and regression analyses in a mathematical model which related:

i) density of observation
ii) category size (as a percentage)
iii) accuracy (as a percentage of sample area measurements).

A series of graphs were compiled which showed these relationships, and which enable the user to select those values which most suit his need.

In general the dot grid is more suitable when land use statistics only are required, whilst the 'dominant use' grid square is more suitable for computer mapping.

Key words: Aerial Photography
Urban Land Use
Area Calculations
Nigeria

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Finally I would like to express my appreciation to my family in Nigeria for their understanding and patience during my period of absence.

"A modern nation, as a modern business must have adequate information on many complex interrelated aspects of its activities in order to make decisions. Land use is only one such aspect, but knowledge about land use and land cover has become increasingly important as the nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, ..."

Anderson et al (1976)

Dedicated to the memory of my beloved mother

MADAM IQUO ESSANG

Sadly missed

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CHAPTER ONE

1 BACKGROUND

1.1 Introduction

Developing nations in the tropics are faced with problems associated with accelerated urbanization. This results largely from uncontrolled population growth and the subsequent concentration of people in large urban agglomerations. Since the recent civil war, these factors have become especially significant in Nigeria. With the advancement in technology, a rise in living conditions, irrational allocation of resources and the general abuse of urban land by squatters, there is an urgent need for proper control of the dynamic process of development.

Ideally all decisions regarding the development and redevelopment of land should be based on an adequate knowledge of the existing position regarding the size and distribution of land use types. Any changes proposed are changes in the existing situation and may only be planned rationally if the existing pattern of distribution is known. Such information can best be obtained by the development of an accurate data base for urban land use.

> "In this dynamic situation accurate meaningful current data on land use are essential. If public agencies and private organizations are to know what is happening and are to make sound plans for their own future action, then reliable information is critical."
>
> Clauson and Steward (1965)

For objectivity, such information systems must be purely factual, such as those based on actual observations either in the field or on photographs. Such data are an essential base for the development of rational planning strategies, research programmes, population studies and urban development and redevelopment schemes. This requirement for current comprehensive information regarding urban land use has stimulated the search for a suitable methodology which forms the core of the research project reported here.

Such surveys are difficult in developing countries owing principally to shortage of funds and of trained personnel, as well as to the prevalence of difficult field conditions. Conventional methods of land use data collection are expensive and time-consuming so that data often becomes available only after the decisions (for which the information was required) have been made. The method investigated here involves the application of remote sensing techniques to provide the data for inventories of urban land use.

1.2 Objective of the research

The main aim of this research is to develop a method - based on the use of aerial photography - for gathering information, in both statistical and map form, relating to urban land use inventories.

The method will use sampling, and will seek to identify the relationships that contribute to the accuracy of identifying various urban land use categories.

A further aim is that the end product should be a methodology suitable for use in Nigeria and in those other tropical countries concerned with the acquisition of urban land use data and maps.

1.3 Remote sensing techniques

Remote sensing is defined by the American Society of Photogrammetry (1980) as

> "the measurement or acquisition of information of some property of an object or phenomenon by a recording device

that is not in physical or intimate contact with the object or phenomenon under study".

White (1977) defines remote sensing as follows:

"all methods of obtaining pictures or other forms of electromagnetic records of the Earth's surface from a distance, and the treatment and processing of the picture data. The term has even been extended to some forms of sea-bed survey and atmospheric monitoring. It covers the use of sensing instruments - cameras and others - and the handling and interpretation of the photographs or other images and non-picture data that these produce".

For the present research the use of LANDSAT satellite imagery (figure 1.1) was first considered. However, on examination it was evident that the resolution of LANDSAT imagery was so coarse as to preclude the easy recognition of urban land use types in the detail required. According to Beaumont (1977):

"The resolution of the satellite scanner is limited to a pixel size (a pixel is the smallest element making up a picture) of 79 metres square on the ground. Significant surface features are revealed without loss of definition when the images are enlarged to scales of 1:250,000 and above. Where tonal contrasts are high between surface phenomena, features such as 10 metres (approx 35 feet) wide have been identified."

Consideration of the above and of the timing, cost and availability of research materials (such as up-to-date base maps and computer software) indicated that the use of aerial photography would be a more practical alternative, since urban features are easily distinguished on most readily available photography.

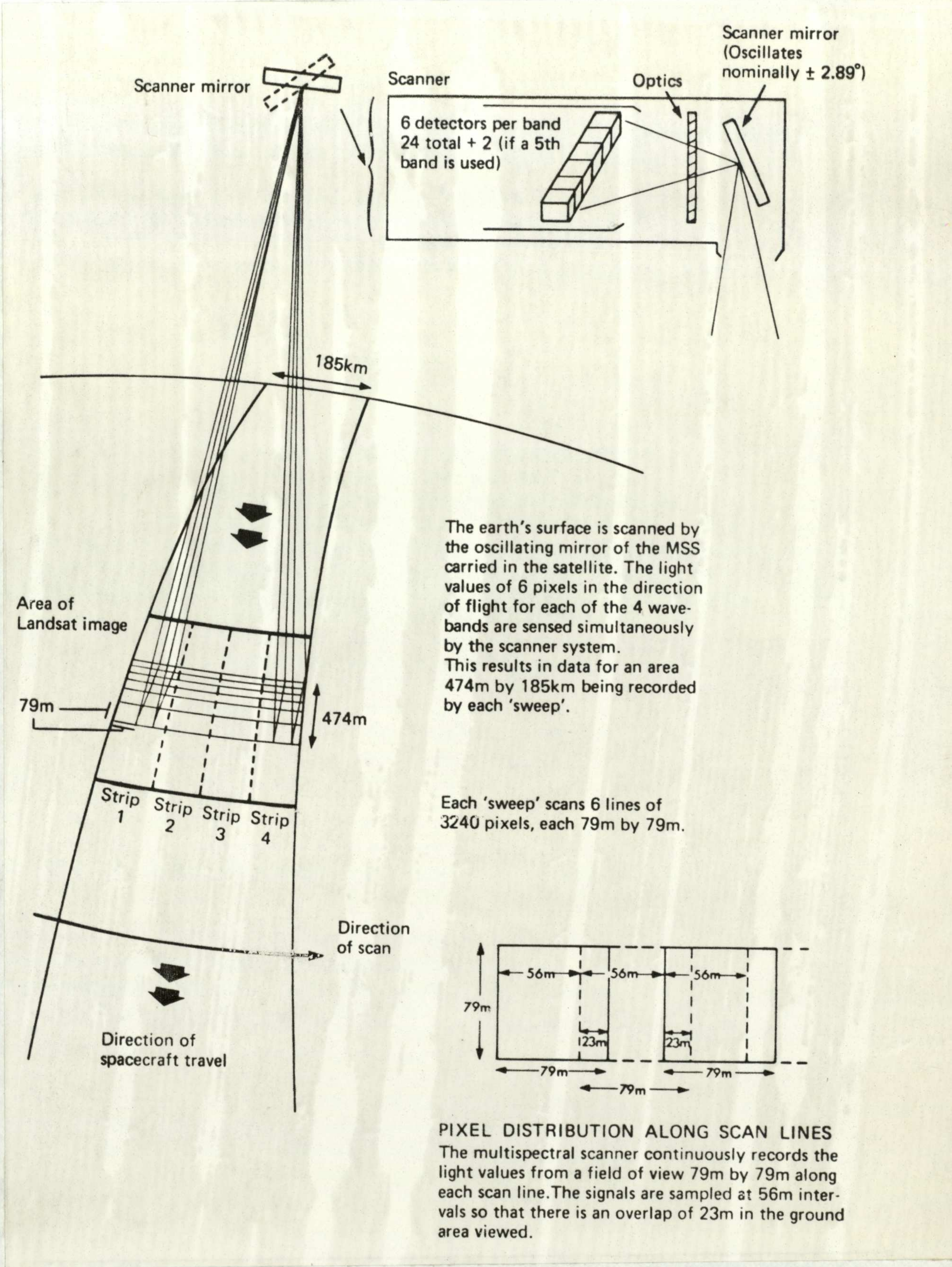


Figure 1.1 Imaging of the Earth's surface by LANDSAT satellite.

1.4 Some applications of remote sensing techniques

As may be seen from figure 1.2, only a small portion of the electromagnetic spectrum, the "visible region", is utilized by the human eye. Cameras which produce picture images generally employ film sensitive to this visible region and to the adjacent near infra-red portion of the non-visible spectrum. Other sensors have been developed which are able to detect radiation in those parts of the spectrum outside the visible region, such as the infra-red, ultraviolet and microwave bands.

Remote sensing techniques employ such sensing devices as well as conventional cameras. The following is a brief resume of the uses to which remote sensing techniques have been applied.

1.4.1 Urban surveys and planning;

These have generally employed aerial photography for a wide range of projects including town mapping, land use classification, monitoring derelict land, choosing sites for waste disposal, open space surveys, traffic studies and population studies.

1.4.2 Engineering;

Engineering applications of remote sensing are many and varied. They include the use of aerial photographs for soil studies, route planning surveys, the location of construction materials and site investigations for a wide range of engineering projects.

1.4.3 Geology and mineralogy;

Geological mapping and exploration has made use of a wide range of remotely sensed data. These include conventional aerial photography, satellite imagery and radar imagery. Mineral prospecting, in addition, utilised non-imaging sensors such as seismographs and airborne magnetometers.

1.4.4 Agriculture and forestry;

Multispectral imagery obtained from LANDSAT and from aircraft as

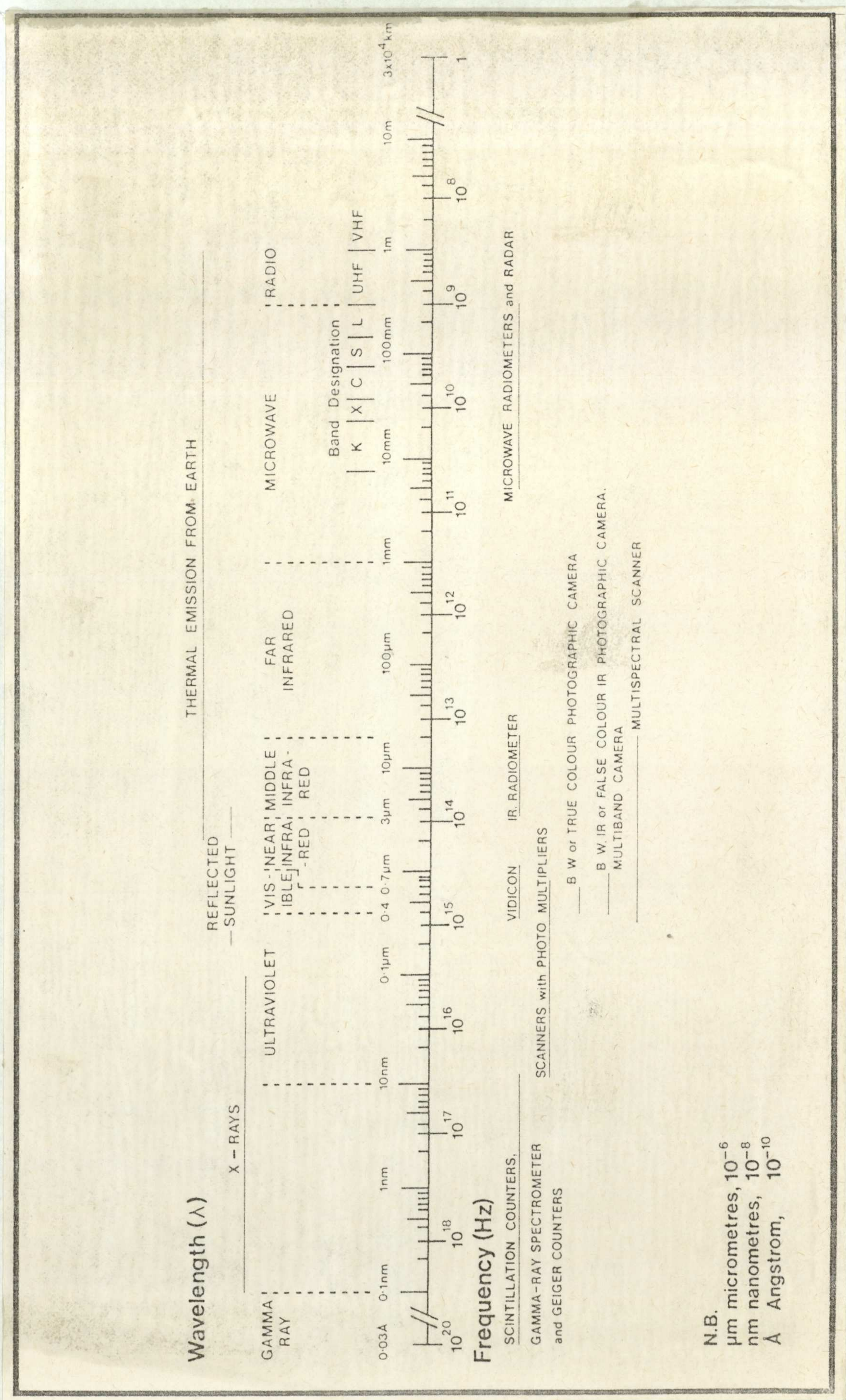


Figure 1.2 The Electromagnetic Spectrum.

well as conventional aerial photography have been widely used for agricultural and forestry surveys. Among the many characteristics studied by these means are land capability, soil erosion, crop health, cropping estimates, forestry inventory and forest fire control.

1.4.5 Hydrology, marine resources and hazards;

Remote sensing techniques have been used for such varied studies as monitoring changes in river channels, subsurface water supplies (using thermal infra-red photography), water pollution monitoring in rivers and in oceans, fresh water invasion by salt water and flood control along rivers and coasts.

1.4.6 Meteorolgy;

Satellite images from LANDSAT and special meteorological satellites such as METEOSAT and NIMBUS have revealed features of cloud circulation patterns and upper cloud conditions on a global scale. This information is being used for research and for routine weather forecasting.

1.5 <u>Aerial photographic interpretation</u>

The interpretation of aerial photography involves three stages; examination of the images, identification of individual objects, judgement of the significance of objects and groups of objects.

Morain and Campbell (1974) state that:

> "Conventional photo interpretation performed on vertical aerial photographs involves a complex process of evaluating a number of image characteristics such as size, shape, texture, tone, shadow and stereo-parallax. The analysis of these factors combined with the additional power of the human brain (i.e. subjective reasoning, intuition, convergence of evidence, past experience etc.) allows the interpreter to recognise, identify and deduce the significance of objects or

conditions seen on the photographs".

1.5.1 Interpretation techniques;

The identification of objects on aerial photographs can be a simple process of direct recognition. This is known as photo reading and is not to be confused with photo interpretation, which is a much more involved and comprehensive procedure. Many authors (including Lueder, 1959; Buringh, 1960; Vink, 1968; Collins, 1967; Collins and El Beik, 1971 and Goosen, 1967) have acknowledged the importance of the object recognition stage in this procedure, since the identification of individual objects is an essential pre-requisite for the interpretation of categories and activities.

In the context of urban land use surveying, the broad groups of uses are easily distinguished. There is little possibility of confusion between, say, buildings, open spaces and communication lines, so that these may be identified by the simple process of photo reading. However, interpretation is required in order to distinguish between the various uses within these broad groups. For example a building may be a house, a warehouse, a factory etc.; a communication line may be a railway line, a motorway or a track.

The standard processes involved in the interpretation of land use are well documented (see, for example, American Society of Photogrammetry, Manual of Remote Sensing U.S.A., 1975) and need not be detailed here.

CHAPTER TWO

2 THE STUDY AREA: CALABAR CITY, NIGERIA

2.1 Introduction

Calabar, formerly the capital of the Oil River Protectorate, and the present capital of Cross River State, was, for the following reasons, an appropriate choice as the study area for the project:

(a) Calabar, like most cities in the tropical world, has no systematic land-use information system.

(b) The city, once an isolated community, has encroached upon, and absorbed other nucleated settlements to create a cosmopolitan, heterogeneous urban tract making a varied and interesting subject for research.

(c) The research is sponsored by the University of Calabar where there is an active interest in developing a practical methodology for undertaking inventories of urban land use.

2.2 Historical Background and Culture

Calabar had earlier contacts than most other parts of Nigeria with European traders and missionaries. Although the city existed as a cultural entity before the arrival of these 17th Century traders, it existed only as a small settlement on the bank of the Calabar River until the Second World War.

Now the city is growing rapidly and is culturally one of the richest in Nigeria. The people are hospitable and traditionally conservative.

2.3 Location and Geography

Calabar is situated in the extreme south eastern corner of Nigeria at about latitude $4^{o}56'$N and longitude $8^{o}22'$E (Figure 2.1).

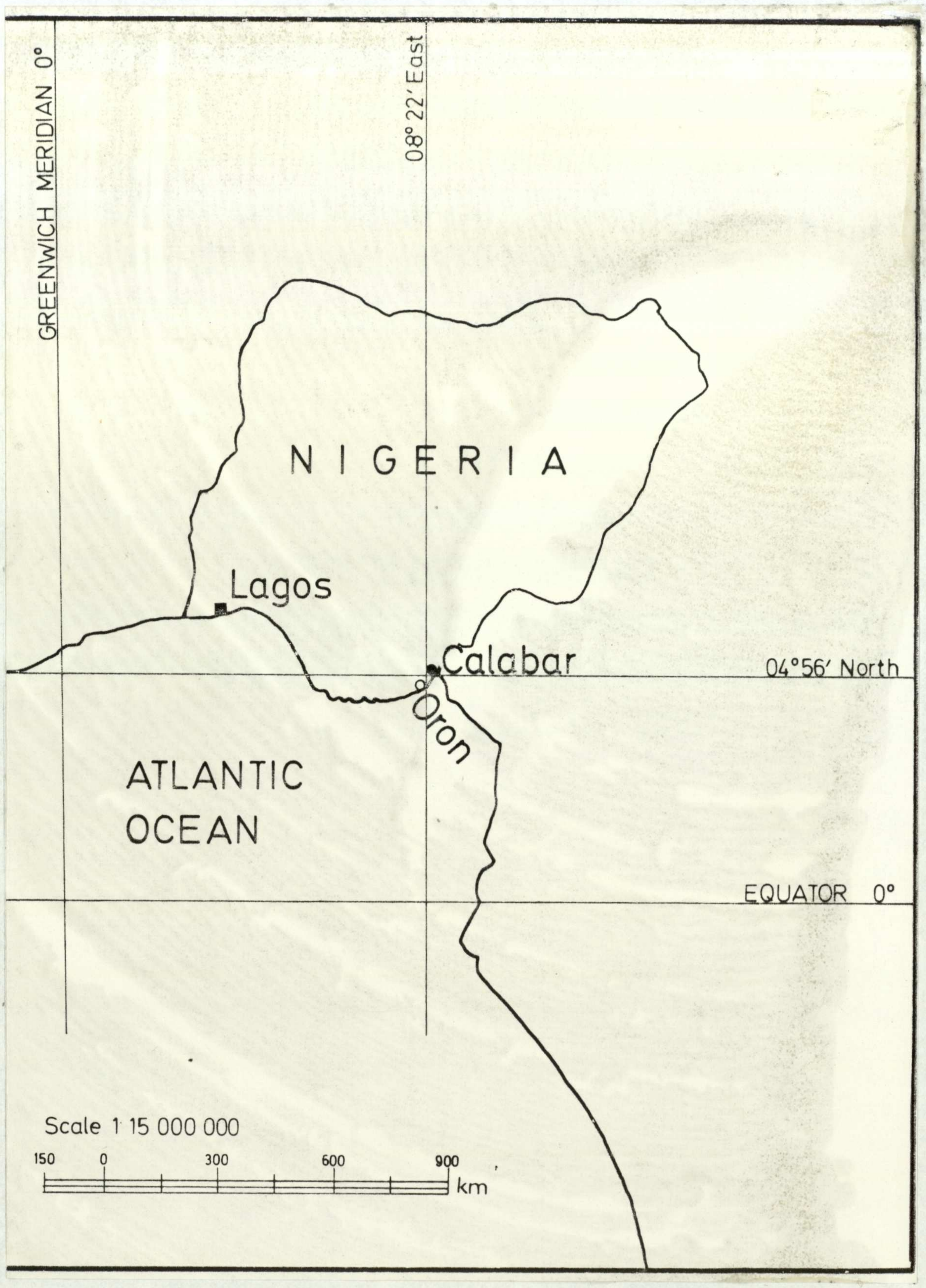


Figure 2.1 Location of Calabar, Nigeria, West Africa

The town is sited on a peninsular between the Calabar River on the west and the Great Kwa River to the east, both of which are tributaries of the Cross River (Figure 2.2). Calabar, some 56 kilometres inland from the Atlantic, lies on the western side of the fairly steeply sloping interfluve, the highest point in the town being at about 50 metres above the river.

2.4 Climate and Vegetation

Calabar lies in the tropical zone of West Africa. Two seasons may be distinguished; the dry season from October to March and the wet season from April to September. During the dry season the area experiences the hot, dry Harmattan wind blowing from the Sahara in the north-east whilst the wet season results from the moist south-westerly air stream associated with the northward movement of the equatorial low pressure belt.

The mean annual temperature is about $24^{o}C$ with a mean annual rainfall of some 308 cms. (Calabar Master Plan, 1969). The relative humidity is high, with minimum and maximum values during the wet and dry seasons respectively. The mean value of 84% is the highest recorded in Nigeria (Calabar Master Plan, 1969).

The riverine areas are forest covered, and from the mangrove swamps at the water's edge the vegetation changes to tropical forest and then through forests and scrubland to mixed grassland as the ground rises inland from the river. To the south, the area bordering the Cross River is characterised by mangrove on saline mud flats with creeks, islands and sandbars.

2.5 Population and Economic Activities

2.5.1 Population

The present population projection for Calabar from the 1963

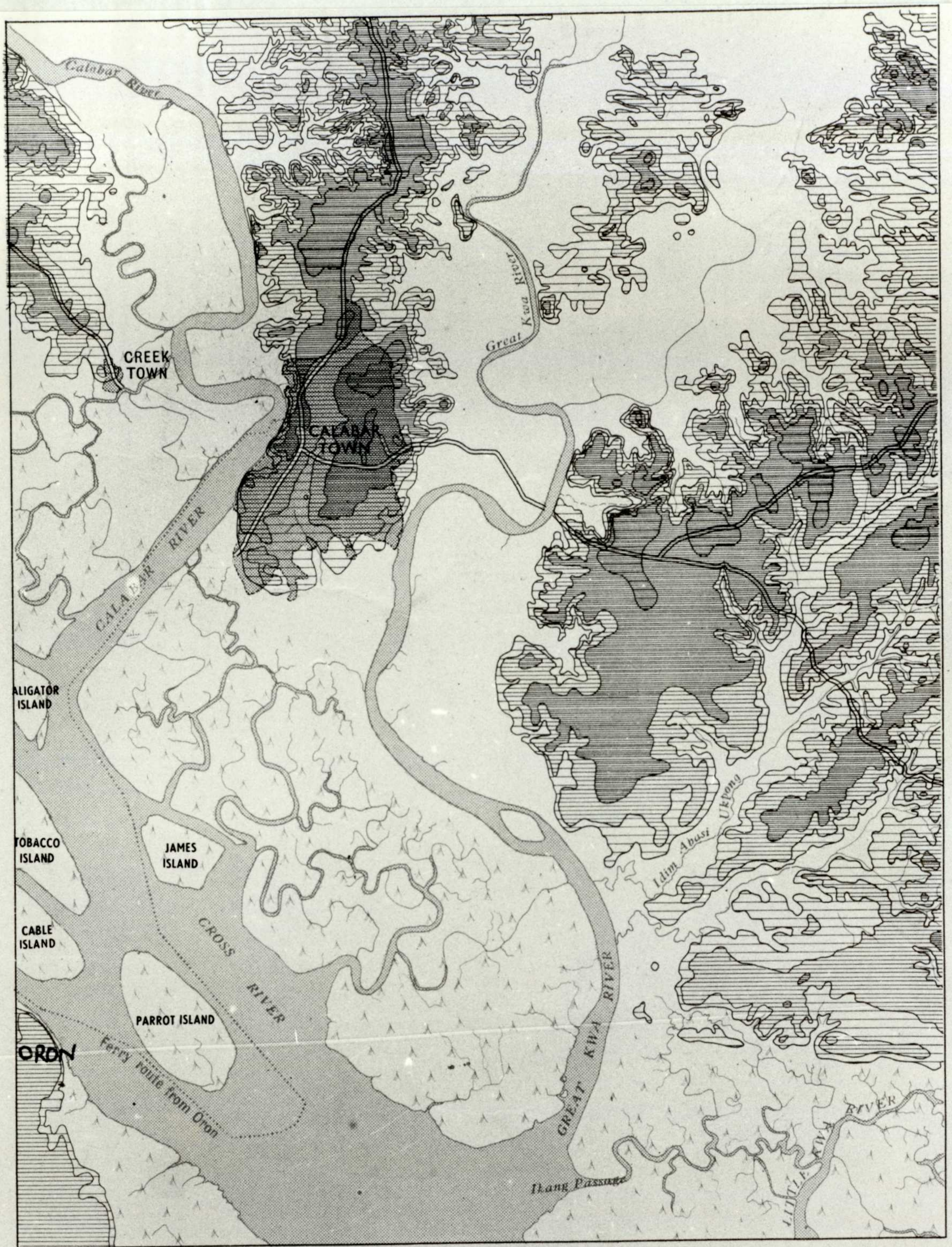
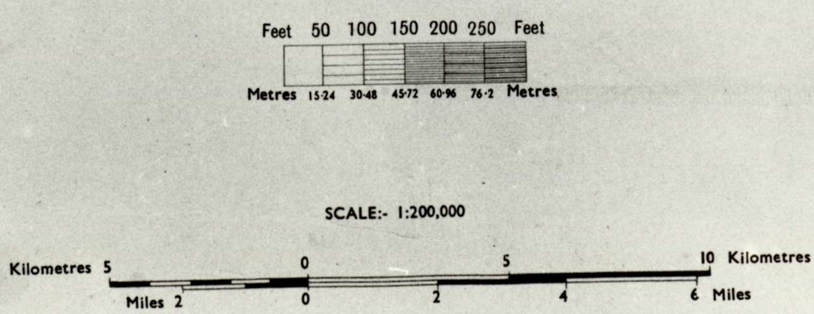


Fig. 2.2 **Topography of Calabar and Environs**



census, gives an estimate of about 125,000 inhabitants within the 200 square kilometre area of the town. Most of these people are concentrated in the old town centre around the central business district.

2.5.2 Economic Activity

There is a wide diversity of industry: cement, metal sheets, plastics and timber, as well as those to be expected which are associated with agriculture. These include oil and palm kernel processing and rubber processing.

The tourist industry - whilst still relatively young and catering mainly for local and regional needs - is developing quite well. The Kwa Falls and the Calabar Wild Life Park are major attractions together with good beaches and fishing facilities and an increasing number of hotels.

A major economic asset which should do much to stimulate growth in the area is the new (1979) port complex, equipped with modern cargo loading facilities and considerable warehouse capacity.

Trade is linked to the local and regional industry, and although palm produce is the most important, other commodities: cocoa, rubber, smoked fish and other foodstuffs are also significant.

Several major banks, national and international, have branches in Calabar City.

There is a long tradition of crafts which include canoe making, raffia products and weaving.

2.6 Land Tenure System

Consideration of land use in Nigeria cannot be made without attention to the historical land tenure system since the present pattern of use in Nigeria as a whole, and certainly in Calabar, has been influenced by the various estate rights over the land that the people have and have had.

In Nigeria the principal divisions of the land according to tenure are, according to Obenson (1977):

(a) Communal Land

(b) Stool Land

(c) Chieftaincy Land

(d) Family land

(e) Individual Land

(f) Government or State Land

(a) Communal Land

As the phrase implies, this is land held in trust for the community by the chief, or chiefs-in-council as in Calabar, and they are the sole lessors. The land might have been obtained for example by dint of clearance and first cultivation of virgin forest, by conquest in war with former occupants or as a gift in marriage.

(b) Stool Land

This is common among the Yoruba communities in the south-west of Nigeria. Title is limited to the 'Oba' (chief) and cannot be transferred to commoners, nor can it be inherited by the chief's heirs or assigns.

(c) Chieftaincy Land

Title to land in this category is held by chieftaincy families. The chief and members of the owning families have fee simple, absolute title to such land.

(d) Family Land

This is ancestral land handed down from generation to generation within a family.

> "When an individual acquires absolute ownership of land either through self-help or through a grant from the traditional authority, or by purchase or gift from a previous

owner, on his death it devolves on his children as family property unless and until the land is partitioned between the children"

(Olawoye, 1974)

(e) Individual Land

Individual land may be held by succession, purchase, as leasehold, pledge or mortgage through family apportionment, gift, as easement by prescription or by clearance of a portion of virgin forest.

However, in Calabar, in the urban area most land in the old city core is held in trust by the chiefs councils. Sale of land is rare, but leasehold is practised

"Among the Efiks (inhabitants of Calabar), for example, long term leases are in vogue and outright sale has not found a strong foothold"

(Obenson, 1977)

(f) State Land or Government Acquired Land

This is land acquired from the original owners through appropriation for purposes of orderly planning, and the prevention of undesirable land transactions. In Calabar it is only in these areas that the orderly use of land may be seen. The old built up "plan-for-yourself" areas are multifunctional in use.

2.7 The Sample Areas

Aerial photographs covering the whole of Calabar City, were systematically studied under a stereoscope, and the urban land use annotated on trace overlays. (Appendix I. Plates 1-7)

These overlays recorded the type and distribution of urban land use and together comprised a total survey of Calabar City and its suburbs.

From this total survey, seven sample areas, each covering a single aerial photograph, were selected to represent a wide cross section of urban land use types. Each sample area has a dominant characteristic and, as can be seen from figure 2.3 they are well distributed right across the City, from centre to outer suburbs.

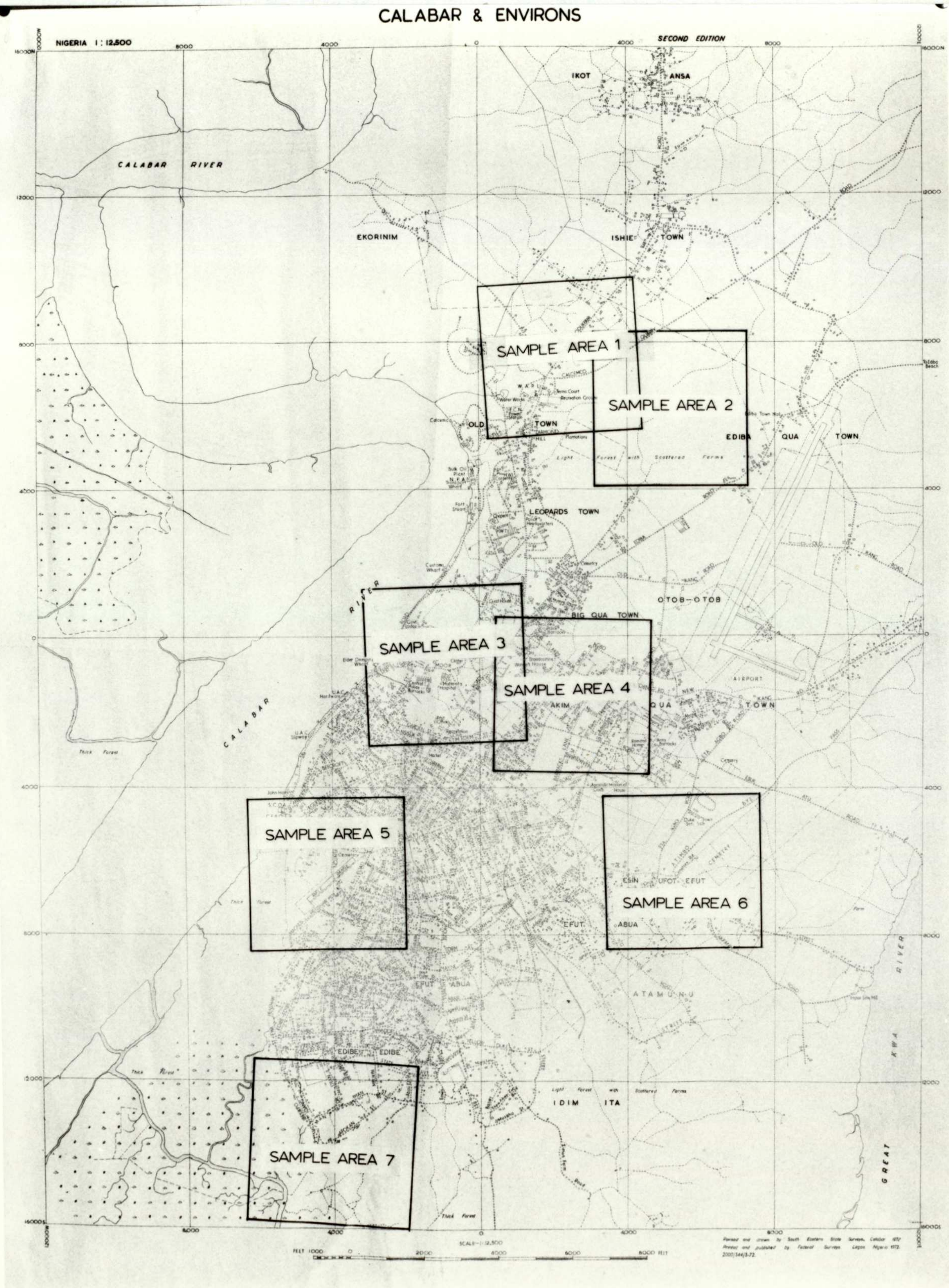


Figure 2.3 Location of the seven sample areas.

2.7.1 Sample area No. 1

Photograph 208 Plate 2.1

See also: Appendix I, Aerial photograph and urban land use trace overlay, Plate I.1

This area lies on the northern side of the City, and includes part of the ribbon development between Old Town and Ishie Town.

The area is a mixture of high and low density housing with some newer industrial development.

About 50% of the area is still undeveloped open space.

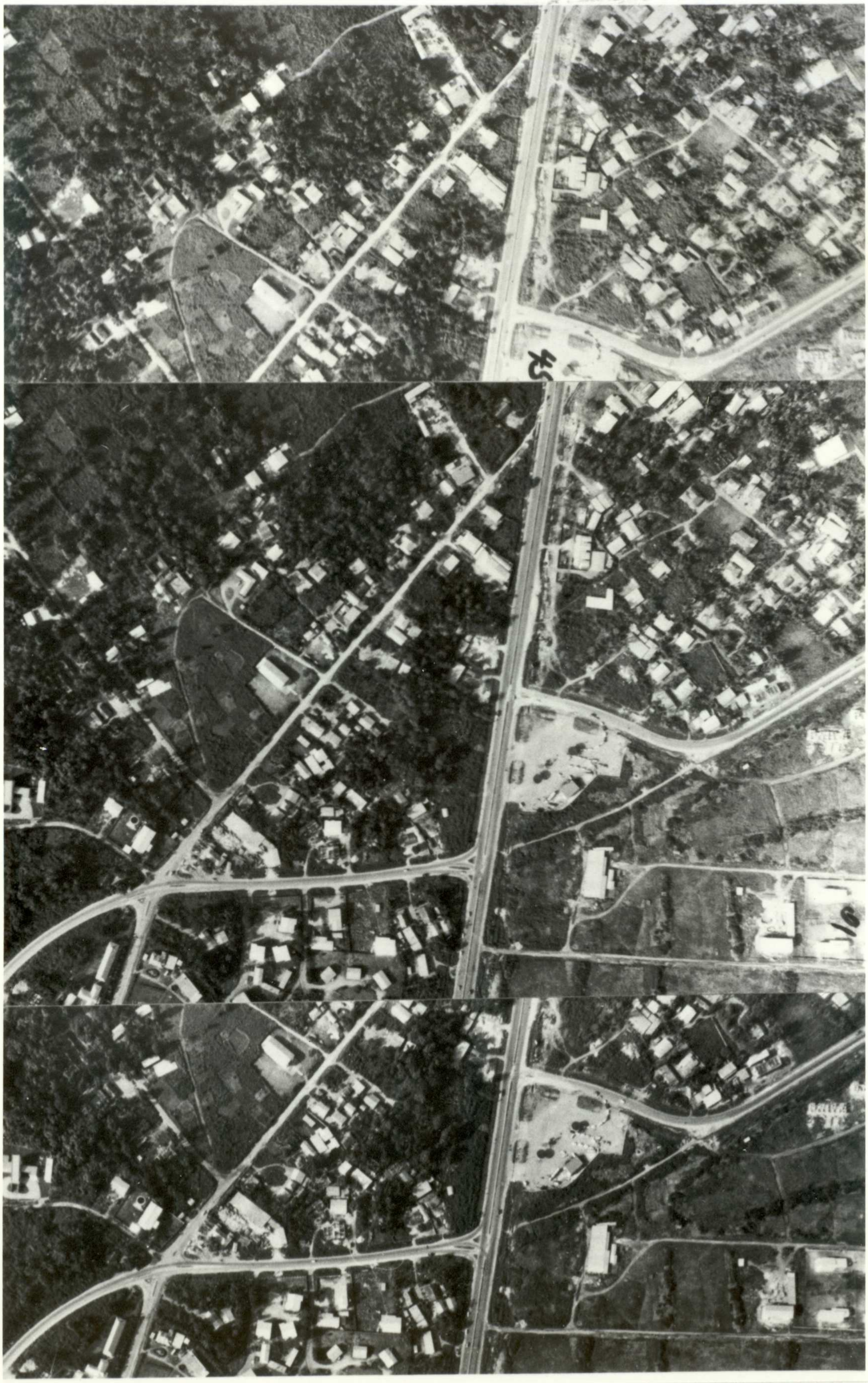


Plate 2.1 Stereotriplet of sample area 1.

2.7.2 Sample area No. 2

Photograph 27 Plate 2.2

See also Appendix I, Aerial Photograph and urban land use trace overlay, Plate I.2

This area lies in the northern fringe of the town. It consists mainly of housing - a mixture of well arranged, high density estates, and the more usual randomly sited residences.

About 75% of the area is built up.

Plate 2.2 Stereotriplet of sample area 2.

2.7.3 Sample area No. 3

Photograph 142 Plate 2.3

See also Appendix I, Aerial Photograph and urban land use trace overlay, Plate I.3

In terms of area this is dominantly institutional, containing Hospitals, Law Courts and Government offices and establishments.

Commercial development has taken place along the main road and elsewhere there are some older, non-estate dwellings.

Plate 2.3 Stereotriplet of sample area 3.

2.7.4 Sample area No. 4

Photograph 213 Plate 2.4

See also Appendix I, Aerial Photograph and urban land use trace overlay, Plate I.4

This area is occupied mainly with a wide variety of Government buildings. These include a number of military and police barracks.

Some scattered mixed, non-estate residential areas are evident, with a few commercial and industrial plots.

About 80% of the area is built up.

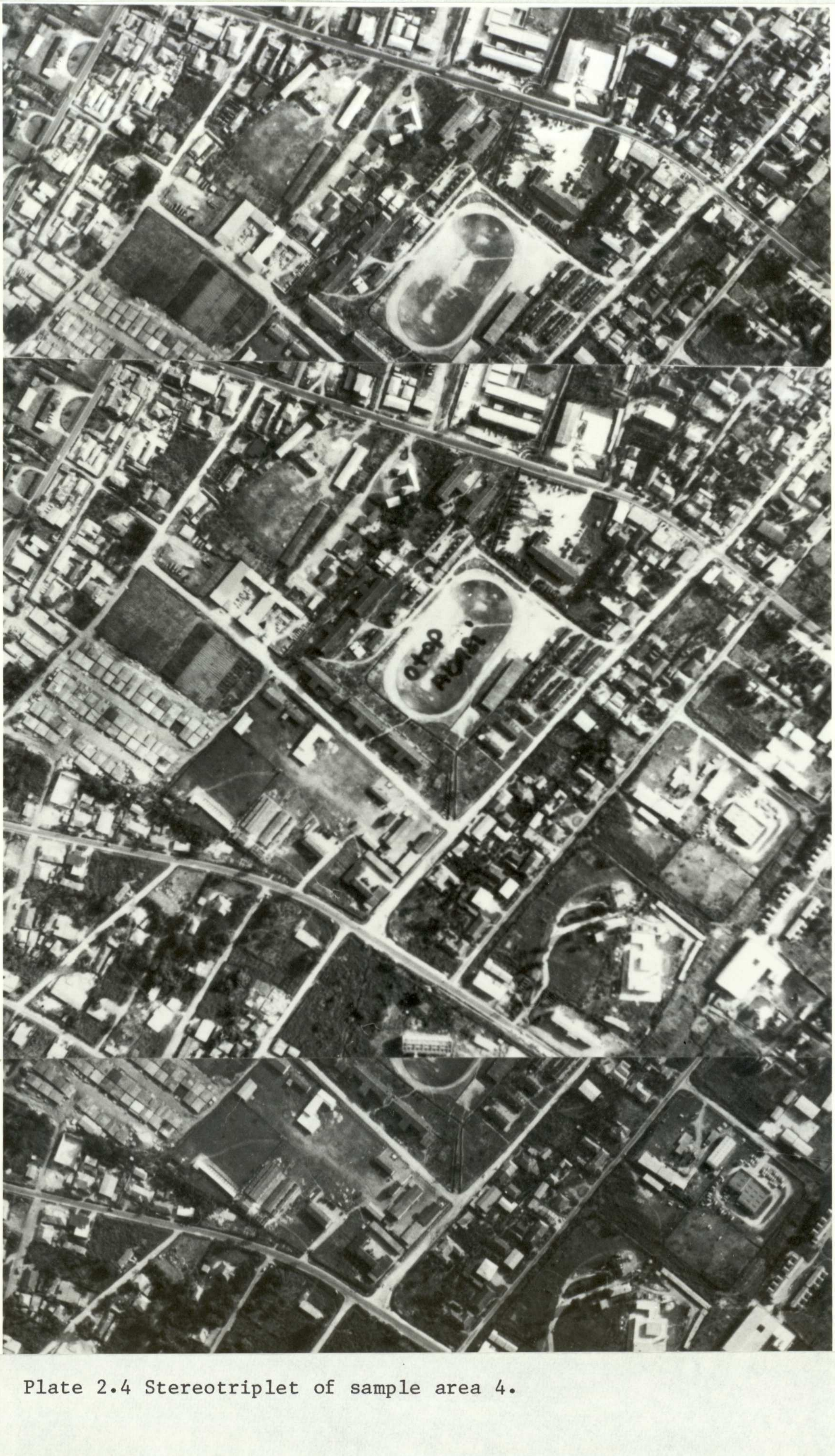


Plate 2.4 Stereotriplet of sample area 4.

2.7.5 Sample area No. 5

Photograph 243 Plate 2.5

See also Appendix I, Aerial Photograph and urban land use trace overlay, Plate I.5

This area contains mostly residential property which is old, non-estate, and densely settled.

In the middle is a very extensive cemetery, whilst there is an area of waterfront and dense forest at the bottom of the photograph.

Plate 2.5 Stereotriplet of sample area 5.

2.7.6 Sample area No. 6

Photograph 20 Plate 2.6

See also Appendix I, Aerial Photograph and urban land use trace overlay, Plate I.6

This area lies on the urban/rural fringe and is part of the recently expanded city of Calabar.

It contains mostly modern, non-estate, fairly dense settlement.

Part of this newly developed area includes the University of Calabar and the University Hospital.

It is not yet totally built up and still contains a fairly large area of the original cultivated farm land.

About 50% of the area is built up.

Plate 2.6 Stereotriplet of sample area 6.

2.7.7 Sample area No. 7

Photograph 247 Plate 2.7

See also Appendix I, Aerial photograph and urban land use trace overlay, Plate I.7

This is dominantly an area of suburban expansion, consisting of modern, non-estate, high density residences.

The urban expansion stops abruptly at the mangrove swamp boundary.

About 60% of the area is built up.

Plate 2.7 Stereotriplet of sample area 7.

CHAPTER THREE

3. LAND USE CLASSIFICATION

3.1 Introduction

Classification is the orderly arrangement of information, for a specific purpose. On the other hand, a land use classification scheme is a means of describing, in a systematic and abbreviated form, the many and varied types of land use which occur in a particular region.

Armand (1965) considers that:

> "classification can be built on various principles: morphologic, genetic, temporal, quantitative etc. But all must follow certain general and unalterable laws of logic."

He further states that there must be some basic prerequisites for mapping urban land use in order that problems of illogical classification might be avoided. Also, the purpose for which the land use data are required should be known before the classification is designed.

In addition to the above principles, it is suggested that whatever principle is used in compiling a classification, the final scheme should be arranged hierarchically so that the information can be considered and mapped at different scales and levels of detail. MacDonald (1971), states that:

> "The first principle upon which classification should be based is that it should be exhaustive. The sum of the classes must be equal to the scope of the classified generic concept."

He considers, also, that if land use is the generic concept to be classified, then the classification should be confined to this concept alone and not (as do some classification schemes) include categories based on such principles as ownership or condition. The implication here is that classification should proceed on a single basis only.

Van Genderen and Smith (1976), define the process of classification as:

> "The grouping of objects into classes on the basis of properties or relationships which they have in common."

They consider that in the case of an urban land use survey, carried out by remote sensing techniques, a suitable classification scheme requires two stages in its compilation.

(a) the interpretation of the land use types in detail, (b) the grouping of the interpreted uses into a classification scheme.

3.2 The Development of an Urban Land Use Classification

In order to collect urban land use data efficiently, certain basic requirements must be met. These are:

(a) the classification scheme is based only on the uses to which the land is put, and not on any other characteristics.

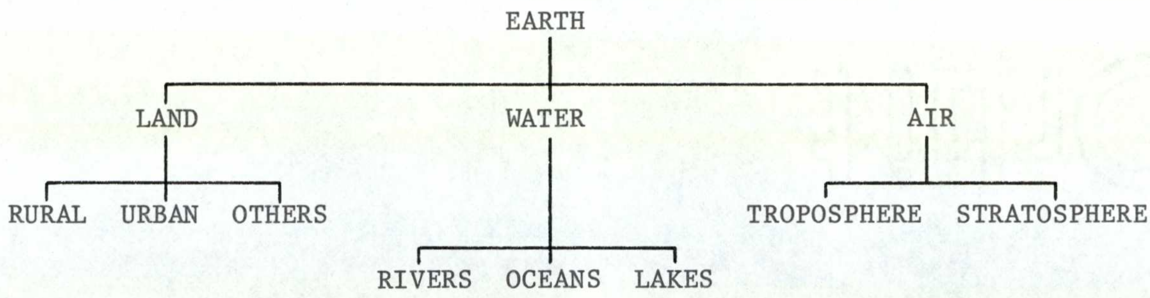
(b) the categories should be mutually exclusive, and be arranged in logical divisions and sub-divisions, as, for example, the scheme given in Table 3.1, which illustrates how the main features of the planet might be classified.

(c) for land use mapping, there must be a suitable recording base at such a scale that the recorded categories may be represented clearly.

3.2.1 Hierarchical Levels in Classification

In order to avoid problems of misidentification and inconsistencies in the grouping of sub-categories, classification must not skip logical levels. A satisfactory classification scheme may be achieved either through logical division of items thought to exist, or by the grouping of identified objects according to similarity or relationship. Also, classification should be exhaustive so that all objects thought to exist, or have been identified in the survey

(Table 3.1) LOGICAL CLASSIFICATION OF THE EARTH



(Table 3.2) LAND UTILIZATION SURVEY BY DR. DUDLEY STAMP, (1930)

Land Use Category	Identifying letter	Map Colour
1. Forest and Woodland	F	Dark Green
2. Permanent grass and meadows	M	Light Green
3. Arable land	A	Brown
4. Heath, moorlands, commons and rough pasture	H	Yellow
5. Allotments, gardens and orchards	G	Purple
6. Land of no agricultural value	W	Red

(whether by air photo interpretation or by ground methods) have a place in the scheme.

An hierarchical classification facilitates the achievement of these criteria. In such a system, identified items may be placed at the appropriate level in the classification and without further re-arrangement the information can be studied at the required level of detail.

Most workers concerned with land use surveys agree that a hierarchical classification scheme is most convenient and appropriate. Differences of opinion occur, however, concerning the method by which such a classification should be compiled.

Nunnally and Witmer(1970), recommend the method by which land uses are recorded in as great a detail as possible with no 'a priori' classification scheme. The classification is then compiled so as to contain only those uses identified.

This approach eliminates the redundant categories often included in 'a priori' classification compiled by logical sub division or deduction, but, on the other hand, these are unlikely to be exhaustive.

Such classifications have other disadvantages, such as the maintenance of consistency in the level of detail to be interpreted, especially when more than one interpretation is involved.

The case for 'a priori' classification has been well stated by Emmott (1979); an 'a priori' classification is not only an aid both to interpretation and to consistency of interpretation, but also facilitates the compilation of relevent interpretation aids. He also suggests that the ideal method of proceeding is to carry out a detailed interpretation of a representative sample area, using a 'a priori' classification, and then from these results to compile a classification scheme for use in the survey of the whole study area.

Furthermore, he suggests that in making decisions regarding the use of a pre-determined classification scheme, account must be taken of the data to be surveyed. At the regional level, perhaps using satellite or other small scale imagery, where very detailed mapping is neither required nor feasible, it may well be better to map by the direct interpretation method having no pre-determined classification scheme. On the other hand, when using large scale imagery, an 'a priori' classification scheme seems better in terms of consistency and ease of mapping and recording data.

In any event, a land use classification scheme should be designed for a specific purpose and for use with a specific type and scale of imagery.

3.3. Land Use Classification in the United Kingdom

The first serious attempt in modern times to map land use on a national scale was the Land Utilisation Survey (L.U.S.), begun by Dudley Stamp in the 1930's. This survey concentrated on agricultural uses and produced information on urban land as a by-product only.

This characteristic may be seen from the classification used (Table 3.2).

This absence of detail within the urban land use category is further seen in the classification scheme (Table 3.3) developed by the International Geographical Union (I.G.U.), which was based on the first Land Use Survey classification for the U.K.

The absence of information regarding the extent and internal composition of urban land in Britain stimulated the work of such researchers as R.H. Best, A.G. Champion and R.C. Fordham. Best's work (Best, 1957, 1958, 1959, Best and Coppock, 1962), was concerned primarily with the estimation of the total area of urban land in Britain. His calculations were based on data supplied by local

(Table 3.3) LAND USE CLASSIFICATION KEY COMPILED BY INTERNATIONAL GEOGRAPHICAL UNION (I.G.U.)

No.	Description	Colour
1	Settlements and associated non-agricultural	Dark and light red
2	Horticulture	Deep purple
3	Tree and other perennial crops	Light purple
4	Cropland	
	(a) continual and rotation cropping	Dark brown
	(b) land rotation	Light brown
5	Improved permanent pasture (managed or enclosed)	Light green
6	Unimproved grazing land (used)	Orange
	(not used)	Yellow
7	Woodlands:	
	(a) dense	Dark green
	(b) open	Medium green
	(c) scrub	Olive green
	(d) swamp forests	Blue green
	(e) cut over or burnt over forest areas	Green stipple
	(f) forest with subsidiary cultivation	Green and brown dots
8	Swamps and marshes (fresh and salt water non-forested)	Blue
9	Unproductive land	Grey

authority planning departments which recorded urban land use in the categories listed in Table 3.4.

The classification scheme shown in Table 3.4, was the product of a detailed ground survey: no air survey was used. A government circular (No 92) on Reproduction of Survey and Development Plan Maps (Ministry of Housing and Local Government, 1951) was used as a guide in the compilation of the classification.

There seem to be some suprising omissions in the classification units. e.g. 'Land for road uses'; whereas there is a unit 'Land for railway purposes'.

Also, in view of the fact that this data was collected by field survey, it does not seem sensible to collect data in such an aggregated form, e.g. there is no sub-division of residential and industrial.

Best grouped the various urban uses as follows:

(i) housing

(ii) industry

(iii) open space

(iv) education

(v) residential uses

This classification, based on the data available from the MHLG survey, gave a broad and very useful picture of the composition of the total urban tract in the country.

Champion (1974), basing his later estimates on the same source material, employed the same classification of urban land.

Fordham (1974), worked on published Ordnance Survey maps to make his estimates of the total area and internal composition of the urban land. Because of the way that urban areas are depicted on these maps, he limited his classification to the categories:

(Table 3.4) M.H.L.G. TOWN MAP SUMMARY (TABLE 2, M.H.L.G., 1955), Britain

Reference to Town Map

(1)

1. Area primarily for residential and ancillary uses

2. Area primarily for industrial use

3. Land for railway purposes

4. Waterways (whether docks, harbours or inland waterways or traffic importance)

5. Area primarily for principal business use (ie offices and wholesale warehouses) for the town as a whole

6. Area for shopping use in town centre or main district centre

7. Area for groups of buildings for civic, cultural or other specific uses

8. Area for educational purposes not included in any of the above areas

9. Open spaces not included in any of the above areas:
   - (i) Area for public playing fields
   - (ii) Area for other public open space
   - (iii) Area for allotments
   - (iv) Area for cemeteries
   - (v) Area for private playing fields
   - (vi) Area for other open spaces not open to the general public

10. Any other significant areas shown by notation on the Town Map

Buildings

Transport Land

Open Land.

Such urban land use classification schemes limited to three or four categories may well be adequate for an assessment of total areas on a national scale. They would certainly not be appropriate, in terms of level of detail, for land use surveys of individual towns.

More recently the Second Land Use Survey (Coleman, 1961), has been engaged in the complete mapping of the land use of Britain. The classification scheme employed may be seen in Table 3.5.

The Second Land Use Survey classification has produced valuable data; opinions differ, however, regarding the desirability of a 'blanket' survey such as this by which land use information is gathered but for no <u>specific</u> purpose. It is certainly arguable that any land use survey and land use classification scheme should be designed for a pre-specified and thoroughly considered purpose.

This survey was undertaken by field work only, and its rural bias is reflected in the number of sub-divisions of Arable Land (6) and Market Gardening (6) in relation to Settlement (4) and Industry (4).

Furthermore under Settlement there is a sub-category of 'Commercial and Residential' which appears to be a very unnecessary aggregation of urban land use types, which it would be of value to differentiate. Where, one wonders, would a unit be put that is both 'newly built up', and contains 'houses with gardens'. There appears to be no slot under Industry for Processing, and Derelict Land should be a sub heading under Open Space.

A recent survey of developed areas in England and Wales has been carried out by the Department of Environment (Van Genderen and Smith, 1976; D.O.E, 1978). Table 3.6.

The survey employed aerial photography, at approximately 1:60,000

(Table 3.5) SECOND LAND USE CLASSIFICATION OF BRITAIN - A. COLEMAN, (1961)

SETTLEMENT

- Commercial and Residential
- Houses with gardens
- Newly built-up areas
- Caravan sites

INDUSTRY

- Manufacturing
- Extractive
- Tips
- Public Utilities

TRANSPORT

DERELICT LAND

OPEN SPACE

GRASSLAND

- With juncus rush
- With scrub

ARABLE LAND

- Cereal
- Ley legumes
- Roots
- Green Fodder
- Industrial Crops
- Fallow

MARKET GARDENING

- Market gardening
- Nurseries
- Allotments
- Flowers
- Soft fruit
- Hops

ORCHARDS

- With grass
- With arable land
- With market gardening

WOODLAND

- Deciduous
- Coniferous
- Mixed
- Coppice
- Coppice with standards
- Woodland scrub

HEATHLAND AND ROUGH LAND

- Heath
- Heath scrub

WATER AND MARSH

- Water
- Marsh

UNVEGETATED

(Table 3.6) URBAN LAND USE CLASSIFICATION IN U.K.
(After Van Genderen and Smith, 1976)

(A) Predominantly Residential Groups

(i) Private Dwellings
(ii) Barracks
(iii) Holiday Camps and Caravans (including the grounds in which they stand), but in rural areas, ornamental gardens are shown excluding the house in garden parkland.

(B) Industrial and Commercial

(i) Manufacturing
(ii) Processing
(iii) Extracting
(iv) Utilities

(C) Educational and Transportation

(i) Schools
(ii) Universities
(iii) Places of worship
(iv) Courts
(v) Prisons
(vi) Hospitals
(vii) Entertainment centres

(D) Transportation

(i) Railways
(ii) Airports
(iii) Waterways
(iv) Transport Terminals

*(E) Open Space

* The open space here is the open space used primarily for urban purposes and could be public or private.

scale, flown in 1969. The products of the survey include overlays to the 1:50,000 scale Ordnance Survey maps and land use areas calculated by digitising boundaries on the maps.

The definition of 'developed areas' used was:

> "all areas of continuous development, development being taken to include all areas covered by bricks and mortar or structures of other materials. This includes transportation features as well as buildings. Also included are land uses associated with these features and such open spaces as exist primarily for urban use".
>
> (D.O.E., 1978)

The land use classification scheme was designed so as to be appropriate to the method of survey, i.e. the interpretation of 1:60,000 aerial photographs. It consisted simply of the five broad categories given in Table 3.6. This very general classification of land use may be appropriate for a national survey from small scale aerial photography, but, is certainly too broad for application to individual towns.

This U.K., air photo orientated, land use survey has a number of defects. Accepting the fact that this survey utilised all available and relevant sources of data - aerial photographs, maps and other documents - it is unlikely to fulfil its aims to serve as a reliable data base for monitoring changes in the type or extent of urban land use.

The main reasons for this are:

(i) The classification is too generalised. e.g. Predominantly Residential requires some quantitative criteria to identify residential which is not 'Predominant'.

(ii) It is often very difficult to distinguish between manufacturing and processing industries.

(iii) Some categories cannot be identified with a reasonable degree of accuracy e.g. Universities, while others are most unlikely to be recognised at all e.g. Government Centres.

(iv) Even at 1:50,000 scale it is possible to identify, with a reasonable degree of accuracy, various types of open space. In view of the importance of urban open space in the built environment the inclusion of some sub-categories would have added to the value of the survey.

There is limited value in using a system which has an in-built error greater than the amount of change which is being monitored.

In Britain most detailed classification schemes have been developed by local planning authorities for their use only or by individual researchers (see for example MacDonald, 1971; Emmott, 1979).

3.4. Land Use Classification in North America

In the United States, most early work in the field of land use survey was concentrated on rural areas. One notable example is that of the Tennessee Valley Authority.

> "the land classification scheme employed by the Tennessee Valley Authority in the 1930's has considerable significance. This significance stems from the detailed attempt to develop a technique which would permit several important or major characteristics of land to be related to one another, and from the extensive use made of aerial photographs, in a major effort to deal with land use problems."
>
> (Anderson, 1971)

In 1940 F.J. Marschner, an agricultural economist, compiled land use information at the scale of 1:1M using aerial photograph mosaics. This early attempt at land use mapping was compiled in 1950, and was used for census, land management and forestry services. The classification scheme was morphological and generalized with additional functional categories such as grassland, marshland and swamp.

3.4.1. Urban Land Use Classification in North America

Major work on urban land use began in the United States and in Canada after the second world war. The main efforts were directed towards the problem of rapid urbanizations and its impact on land use. In the United States of America the city of Rockville, a suburb of Washington D.C., was used as a test site for the solution of a range of urban problems including the monitoring of land use changes (Witenstein, 1954 and 1955), Table 3.7. These studies involved the use of aerial photographs and the results were assembled as overlays keyed to a photo mosiac of the area.

Witenstein (1954), later drew up a classification scheme for land use. (Table 3.8) The main defect in this classification is the inclusion of Governmental i.e. ownership, on the same level as the rest which are concerned with land use.

By 1971 the US Geological Survey was engaged in the design, related to remotely used imagery, of a land use and land cover classification to meet the following criteria:

"(i) The minimum level of interpretation accuracy should be at least 85 percent in the identification of land use and land cover categories from remotely sensed data.

(ii) The accuracy of interpretation for the several categories should be about equal.

(iii) Repeatable or repetative results should be obtainable from one interpreter to another and from one time of sensing to another, possibly several years later.

(iv) The classification should be applicable over extensive

(Table 3.7) CLASSIFICATION SCHEME FOR URBAN ADMINISTRATION PROBLEMS ROCKVILLE CITY, U.S.A. (WITENSTEIN, 1954 and 1955)

(i) Land Use

(ii) Movement of people and goods

(iii) Utilities, community services and public facilities

(iv) Industry and Commerce

(v) Recreation

(Table 3.8) THE WITENSTEIN L.U. CLASSIFICATION FOR ROCKVILLE, (U.S.A.)

1. Industrial
2. Commercial
3. Governmental
4. Institutional
5. Recreation
6. Port
7. Railway
8. Residential

areas.

(v) The categorization should permit vegetation and other types of land cover to be used as surrogates for activity.

(vi) The classification should be suitable for use with remotely sensed data obtained at different times of the year.

(vii) Effective use of sub-categories that can be obtained from ground surveys, or from the use of larger scale or enhanced remote sensor data, should be possible.

(viii) Aggregation of categories must be possible.

(ix) Comparison with future land use data should be possible.

(x) Multiple uses of land should be recognised when possible."

(Anderson et al, 1972)

The end product of this comprehensive and seminal specification was the compilation in 1972 of a land use classification system, (Anderson et al, 1972) which was modified in 1976 and published as the United States Geological Survey Professional Paper 964 (Anderson et al, 1976). This classification scheme is listed in Table 3.9.

The Urban or Built-up Land category is subdivided into seven sub-categories which the compilers considered might be recognised in accordance with the specifications given above and which are acceptable in a general classification, designed for regional surveys using small scale imagery. Although they are too generalized for the detailed mapping of specific urban areas they may well provide a satisfactory basis for subdivision into more detailed categories.

The subdivision of the Urban category does not appear very logical or clear cut. The inclusion of Utilities with Transportation and Communications does not provide a very coherent subgroup.

If a new and separate category is allocated to a mixed use - Industrial and Commercial Complexes - then other possible mixed uses

(Table 3.9) U.S GEOLOGICAL SURVEY LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTELY SENSED DATA.

	Level I		Level II
1	Urban or Built-up land	11	Residential
		12	Commercial and Services
		13	Industrial
		14	Transportation, Communications and Utilities
		15	Industrial and Commercial Complexes
		16	Mixed Urban or Built-Up Land
		17	Other Urban or Built-Up Land
2	Agricultural Land	21	Cropland and Pasture
		22	Orchards, Groves, Vineyards, Nurseries and Ornamental horticultural areas
		23	Confined Feeding Operations
		24	Other Agricultural Land
3	Rangeland	31	Herbaceous Rangeland
		32	Scrub and Brush Rangeland
		33	Mixed Rangeland
4	Forest Land	41	Deciduous Forest Land
		42	Evergreen Forest Land
		43	Mixed Forest Land
5	Water	51	Streams and Canals
		52	Lakes
		53	Reservoirs
		54	Bays and Estuaries
6	Wetland	61	Forested Wetland
		62	Nonforested Wetland
7	Barren Land	71	Dry Salt Flats
		72	Beaches
		73	Sandy areas other than Beaches
		74	Bare Exposed Rock
		75	Strip Mines, Quarries and Gravel Pits
		76	Transitional Areas
		77	Mixed Barren Land
8	Tundra	81	Shrub and Brush Tundra
		82	Herbaceous Tundra
		83	Bare Ground Tundra
		84	Wet Tundra
		85	Mixed Tundra
9	Perennial Snow or Ice	91	Perennial Snowfields
		92	Glaciers

(e.g. Residential and Commercial) ought to be categorised.

3.5. Land Use Classification in the Tropics

The literature concerning land use surveys in Europe and North America indicates that the compilation of satisfactory classification schemes is a difficult art which has as yet found few adepts. This is seen to be even more true when attention is turned to the tropical lands, and may be attributed to lack of funds, expertise, incentive, lack of research material and conflicting preferential needs.

Wikkramatileke (1959) commented that:

> "Mid-latitudes techniques, criteria, classification categories and nomenclatures do not fit tropical conditions and do not produce effective land use maps."

Some work involving the classification of tropical land was carried out in the 1930's.

Such a research project (Collins, 1972) concerned the assessment of land use, land use potential and level of utilisation of land in Jamaica. The land use classification scheme, specifically designed to satisfy the needs of the survey and for use with aerial photography, is given in Table 3.10.

This classification scheme was used successfully for the compilation of over 30 land use maps at 1:12,500 scale.

In Nigeria, especially in the Cross River State and the Western States, the rural land classifications which exist are mainly for forestry inventories. According to Kio (1971):

> "The survey proceedures of the land use survey of Western Nigeria and the inventory of a group of forest reserves in the Cross River State were based on photo-interpetation for forest type delineation, and photogrammetry for forest crop compilation."

(Table 3.10)

KEY COMPILED FOR THE LAND USE OF ST. CATHERINE, JAMAICA

No.	Description	IGU equivalent
19	Settlement	1
12	Mining	1
22	Food forest	2
24	Coconut	3
27	Citrus	3
25	Banana	3
53	Sugar	4a
56	Rice	4a
58	Other crops	4a
62	Tobacco	4a
*44	Grassland Improved	5
*	Grassland Unimproved	6
*11	(a) Used	6a
*6	(b) Unused	6b
	Woodland	
45	Dense	7a
51	Open	7c
41	Scrub	7c
41′	Scrub Lowland	7c
c/o41	Cut over forest and scrub	7d
38	Mangrove swamp	7d
35	Marsh and swamp	8
30	Salina	9
70	Cleared Land	
71	Unproductive land	9

*These were subsequently deleted and the term 11, Grassland was used without further subdivision.

(Compiled by Collins, 1972)

In 1976, the Federal Government of Nigeria commissioned the Nigerian Radar Project (NIRAD) for mapping the vegetation of the whole country. This recently completed project employed the generalized and very specialized type of classification scheme required for the interpretation of small scale radar imagery.

3.5.1. Urban Land Use Classification in Nigeria

There appears to be very little literature on urban land use mapping or classification projects in tropical lands. In Nigeria, however, some work has been done in this field.

Land use in Kano, Northern Nigeria, was mapped in 1966 by the Department of Geography, Ahmadu Bello University, Zaria, Nigeria (Mortimore et al, 1966) using 1:10,000 scale, 1962 aerial photography. The mapping scale was 1:12,500, and five major land use categories and eighteen subcategories were used. Table 3.11. This classification scheme is open to citicism on a number of grounds. The major category, Undeveloped Urban Land, is imprecisely defined; it is not clear whether, for example, this refers to open spaces of all kinds within the urban area (which might include the enclaves of grazing land and small holdings commonly found within the urban fabric of Northern Nigerian cities) or specifically to open land having urban categories (such as school playing fields, unused land awaiting development etc.)

Not all the subcategories are mutually exclusive; industrial establishments are included in two subcategories, whilst Markets is a separate subcategory, and not a subdivision of Commercial.

These detailed, but relevant criticisms do not detract from the value of the Kano survey as a useful and important early example of land use study in tropical Africa.

In south eastern Nigeria land use in the city of Calabar was mapped at 1:50,000 scale in 1975 by the Federal Survey Department.

(Table 3.11) LAND USE IN KANO - CITY & TOWNSHIP (MORTIMORE et al, 1966)

1: 12,500

NON-RESIDENTIAL DEVELOPMENT

1 Educational Institutions
2 Public Buildings and Government Property
3 Principal Industrial Establishments
4 Commercial and other Industrial Establishments
5 Markets
6 Amenity Land

RESIDENTIAL DEVELOPMENT

7 Traditional High Density Housing (City type)
8 Traditional Housing, grid plan (Fagge type)
9 Modern Housing, high density (Sabon Gari type)
10 Modern Housing, low density (Senior Service type)
11 Rural Compounds

UNDEVELOPED URBAN LAND

12 Quarries, borrow pits
13 Unused open space

AGRICULTURAL LAND

14 Upland arable land
15 Cassava fields
16 Fadama arable land

NON-AGRICULTURAL LAND

17 Woodland and Scrub
18 Grassland

(Table 3.12) CALABAR URBAN LAND USE CLASSIFICATION

(FEDERAL SURVEYS, NIGERIAN GOVERNMENT,1975)

(1) Modern Housing High Density

(2) Modern Housing Low Density

(3) Traditional Housing

(4) Public Buildings

(5) Industrial Areas

(6) Commercial Areas

(7) Educational

(8) Amenity Land (including open spaces)

(9) Forest Reserves

The nine land use categories listed in Table 3.12, were used for this survey. These provide land use information at a useful level of detail, however, the value of this information is somewhat limited by the small mapping scale of 1:50,000.

The structure of the classification is not very systematic. It would have been preferable to have had Housing as a main category with various subcategories based on either age, density, or type.

This land use classification scheme relates to the existing rather complicated structure of the residential areas. Firstly, areas of purely traditional housing do not usually exist without an admixture of later, modern houses, and secondly the division of modern housing into only two density groups is an over simplification of the situation.

It may well be that such shortcomings in the existing land use map were the stimulus for Animashaun's call for comprehensive planning according to modern principles and taking into account the functional merits of all urban features, (Animashaun, 1978). This would replace the existing Calabar Master Plan on which he comments:

> "the so called Master Plan with its simplistic belts of land use and reckless mixing of incongruous land uses is evidently a patchwork which needs to be totally revised."
>
> (Animashaun, 1978)

The drawing up of a new master plan for Calabar was commissioned by the Cross River State Government of Nigeria and carried out in 1969 by Tesco-Kozti Ltd (Hungarian Town Planning consultants), (Tesco-Kozti, 1970).

Another researcher, Adeniyi (1980), carried out a study to examine the combined utility of remote sensing, especially sequential aerial photography, and computer techniques for the acquisition of basic urban land-use change information for Lagos, Nigeria. In his

(Table 3.13) THE LAND USE CLASSIFICATION SCHEME (ADENIYI, 1980)

1 RESIDENTIAL	10	Large plot, 1-2 story, (Flat) Buildings with vegetated open spaces
	11	Medium plot, mixed, 1-2 story (Flat) buildings without vegetated open spaces
	12	Medium plot, mixed, 1-2 story (Flat) buildings with small individual open spacs
	13	Single story row houses with moderate common open spaces
	14	Mixed traditional and modern 1-3 story buildings
	15	Old Traditional 'Court-type' rooming buildings
	16	Traditional single story rooming buildings interspersed with 2-3 story buildings
	17	Apartment buildings (four story and above)
	18	New developing residential areas (completed and uncompleted residential structures in close juxtaposition)
2 COMMERCIAL	20	Main commercial centre
	21	Scattered, and road side development
	22	Shopping centre
	23	Traditional market
3 INDUSTRIAL	30	Industrial complex areas
4 INSTITUTIONAL	40	Educational (schools and colleges)
	41	Hospital
	42	Public and correctional establishments
	43	Police establishment
	44	Military establishment
	45	Other institutional premises
5 TRANSPORTATIONAL AND UTILITIES	50	Airport premises
	51	Railway stations and terminals
	52	Marine terminals (wharf areas)
	53	Highway rights of way
	54	Automobile parking areas
	55	Utilities
6 RECREATIONAL AND OPEN SPACES	60	Indoor recreation areas
	61	Sports grounds
	62	Parks
	63	Cemetery
	64	Beach
7 VACANT LAND	70	Site under construction
	71	Underdeveloped (dry) vacant land (usually cleared)
	72	Underdeveloped (dry) vegetated land
	73	Underdeveloped (wet) non-forested land
	74	Underdeveloped (wet) forested land
8 NON-URBAN LAND	80	Undifferentiated rural villages
	81	Agricultural plantations
	82	Farmland
	83	Forested wetland
	84	Non-forested spottily vegetated wetland
	85	Shrub and secondary forest areas
	86	Sandy areas other than beach
	87	Sand and gravel pits
9 WATER	90	Open water body

research, he pointed out the inadequacy of relevant land use information systems in developing countries in general and Nigeria in particular. He noted that,

> "In Nigeria, there is a general lack of pertinent land-use classification schemes. This situation reflects the lack of land-use maps for the urban areas in Nigeria . . . Consequently, effective planning is rendered more difficult."

This lack of pertinent land-use maps motivated his interest in a land-use classification scheme for Lagos and its environs. In his classification, Table 3.13, land-use is divided into two hierarchical levels. At the first level there are nine general categories of land use which seem to cover most, if not all, those land use types likely to be found in Lagos.

The main defect in this 'classification' is the manner in which the subcategories have been organised. Indeed the complex structure of this subdivision provides a complicated list rather than a sound hierarchical classification.

For example, under the major category of Residential, Adeniyi includes - on the same hierarchical level-

(i) size of plot

(ii) age of building

(iii) style of building

(iv) number of storeys

(v) absence or presence of vegetation

Such a system of ordering data does not conform to the fundamental rules of classification theory.

In spite of the defects of classification Adeniyi has made a very useful contribution to the development of a methodology for urban land use mapping in Nigeria.

CHAPTER FOUR

4 DEVELOPMENT OF A LAND USE CLASSIFICATION SCHEME FOR CALABAR CITY NIGERIA

4.1 Introduction

As little research work had been undertaken involving urban land use studies in the humid tropics, there was little guidance or help available in the compilation of a suitable classification.

Although many urban land use studies have been carried out in the temperate zones, the classifications derived for these studies are not particularly relevant to tropical areas.

It was essential that the classification should take into account the fact that aerial photographs were to be used as the sole source of urban land use information.

The classification would therefore have to be based on the physical form and/or condition of urban land use units - features which it is possible to identify on aerial photography.

Other factors, such as ownership and value, cannot usually be identified from aerial photographs and therefore would have no place in the air photo interpretation aspects of this urban land use classification.

4.2 The air photo as a data source

The task of land use mapping from aerial photographs is subject to a number of constraints and limitations as well as some major advantages.

a) The date of the survey is related to the date(s) on which the aerial photography was taken.

This is more an advantage than a disadvantage in that the data for the survey is collected in a relatively short time, and can for all practical purposes be regarded as an 'instant' survey. Field work on the other hand, is a much more time consuming task and may take several weeks, months, or even years to complete.

b) The type of information to be collected is dependant upon the type of information which can be recorded on a photograph.

On the other hand the aerial photograph is a true record of all the visible features of the landscape - unlike field work in which only selected aspects of land use are recorded.

In this study the data source were the 1:6000 scale black and white, vertical aerial photographs of Calabar.

c) In urban land use surveys of the built environment using aerial photography the usual process is to attempt to identify the <u>form</u> of the feature and hence determine its <u>function</u>.

d) Generally the smallest unit that could be identified from the available aerial photography was about 0.5 mm representing about 3 m on the ground.

e) The problem of <u>recording</u> buildings which have a multiple use is one which affects both air photo and field based surveys. However it is easier to <u>identify</u> multiple use by field survey.

In this study it was sometimes possible to identify multiple use e.g. a flat above a shop, and in such cases the use which occupied most area was that which was recorded.

4.3 The assessment of accuracy levels

Collins (1971) outlined a number of factors which influence the degree of accuracy attained in land use mapping from aerial photographs. These include:

i) The quality and scale of the photography

ii) The definition of the photography

iii) The notation compiled

iv) The type of unit included in the legend

v) The expertise of the interpreter

vi) The methods and equipment used to extract the information

vii) The method of assessing the accuracy of the air photo interpretation

i) In this study both the quantity and scale of the photography was suited to the task being carried out.

ii) The definitions used in this study did not present any problems in identification as they were compiled with the knowledge that aerial photography would be used as the data source.

iii) If the urban land use notation is very generalised e.g. consists only of Built Up and Non Built Up Land, then the accuracy levels should be very high indeed.

On the other hand, if the notation is highly detailed, consisting perhaps of forty sub units of urban land use, then the accuracy levels will be much less.

iv) The effect on accurate land use mapping is greatly influenced by the type of unit used in the survey. For example urban open space is easily identified, and accuracies approaching 100% would be expected.

On the other hand if Doctors Clinics were included then the accuracy level of these would be zero, as they cannot be identified from aerial photographs.

In new towns, which are purpose built there is a very close relationship between form and function. In older towns this relationship often does not occur. For instance in Calabar a Presbyterian Church was being used as a Magistrates Court, but there was no evidence on the aerial photograph of this change of function.

v) The Interpreter must have a knowledge of

i) The area under study

ii) The topic of the study (e.g. geology, soils, agriculture).

It must be stressed that it is not possible to be an air photo interpretation expert 'per se'. One needs some professional expertise in which the techniques of air photo interpretation can be applied.

vi) All other things being equal, it is reasonable to expect some variation in accuracy levels with the different types of equipment used to extract the data, and the various methods used in analysing this information.

The Carl Zeiss Interpretoscope allows the interpreter every facility to extract information from a wide range of photography and imagery. In contrast a simple lens stereoscope will not be nearly so efficient.

Visual study of satellite imagery does not usually extract as much detailed information as when an interactive computer and visual display unit present images direct from satellite tapes.

vii) In most cases where air photo interpretation is carried out to perform a mapping operation, some degree of accuracy is specified in the contract, or reported in research.

In many instances a specific value is given (e.g. 80%) on the accuracy required or obtained. However often it is not stated whether this accuracy level relates to the area covered or to the percentage of units or categories correctly identified.

For a given survey the use of different methods of accuracy assessment can give markedly different levels of accuracy.

For instance Figure 4.1 portrays a land use map containing six different categories (a - f).

Assuming that categories a, b and c, were correctly identified the two alternative accuracies are:

i) Number of units

$$\frac{a + b + c}{a + b + c + d + e + f} = \frac{3}{6} = 50\% \text{ accuracy}$$

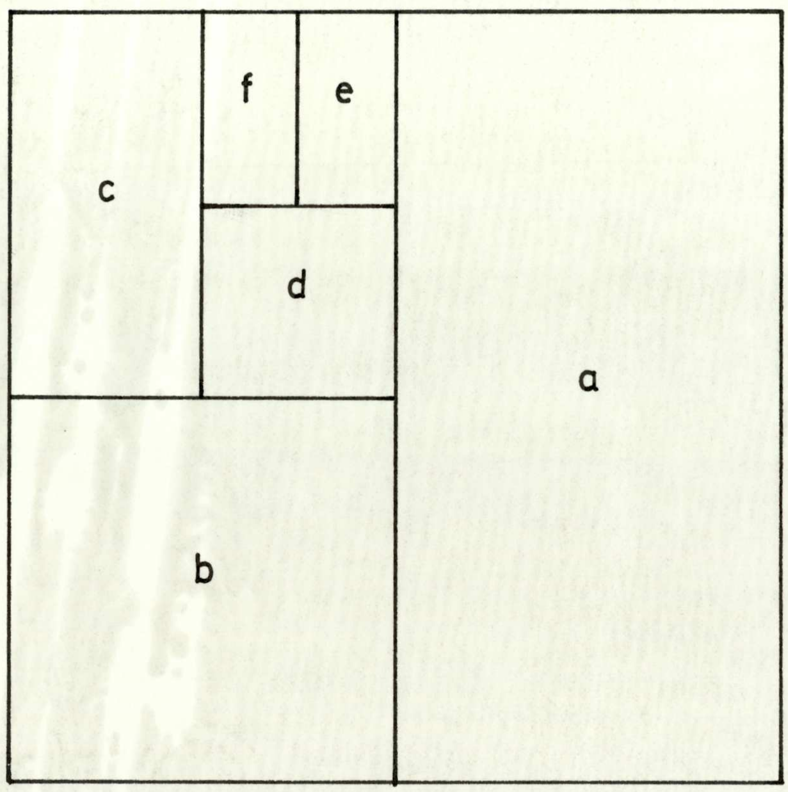


Figure 4.1 Interpretational accuracy.

ii) Area

$$\frac{a + b + c}{100} = \frac{87.5}{100} = 87.5\% \text{ accuracy}$$

4.4 Compilation and Classification

4.4.1 First Level Classification

It was felt desirable to compile an activity-orientated set of urban land use categories in an attempt to make the end product compatible and comparable with locally used classifications.

To this end the details on the 1:2400 scale urban cadastral maps of Calabar were used as a starting point.

Table 4.1 shows the provisional first level classification which contains sixteen categories.

This classification was compiled before studying the aerial photographs and it was evident, after examining the photography, that certain units could not be identified - even from 1:6000 scale photography.

This led to some modifications, and the compilation of a Final First Level Classification (Table 4.2) which eliminated categories - such as 'Government Offices' which relate to ownership rather than land use.

4.4.2 Subsequent divisions of Classification

The eleven major categories in the classification were each considered to determine how they might be subdivided into hierarchical levels.

An initial list of nearly one hundred categories was originally compiled, but this was subsequently reduced to about sixty, Table 4.3.

The various categories were arranged in sequential levels, each of which is allocated a numerical identification

e.g. Urban Residential 0

(Table 4.1) PROVISIONAL FIRST LEVEL CLASSIFICATION FOR CALABAR URBAN AREA, NIGERIA

L.U. Code	Category
0	Urban Residential
1	Commercial
2	Residential/Commercial
3	Transportation
4	Utilities and Services
5	Government Offices
6	Educational
7	Hospital and Health Centres
8	Agricultural
9	Forests and Bush
10	Water and Wetland
11	Open spaces and Parks
12	Government Reservations and Green Areas
13	Derelict Land
14	Institutional
15	Others

(Table 4.2) FINAL FIRST LEVEL LAND USE CLASSIFICATION FOR CALABAR URBAN AREA, NIGERIA

ITEM	PROJECT NOTATION	CALABAR LOCAL PLAN NOTATION	COLOUR AND I.G.U. * EQUIVALENT Derwent Crayon Number #
Residential	0	Deep brown (No code)	1 (grey) # 19-68
Commercial	1	Deep blue	1 (grey) # 19-68
Industrial	2	Purple	1 (red) # 19-14
Transportation	3	White with horizontal stripes	2 (orange) # 19-10
Utilities and Services	4	Nil	-
Institutional	5	a) yellow for education b) red striped hospital	1 (grey) # 19-68
Agricultural	6	Light green with black circle	4 (purple) # 19-23
Forests and Woodlands	7	Nil	7 (dark green) # 19-45
Water and Wetlands	8	a) light green with swamp sign b) water - blue	8 (light blue) # 19-32
Open Space Improved and Unimproved	9	White	9 (light yellowish green) or lime green # 19-48
Others	10		

* I.G.U. International Geographical Union

(Table 4.3) SECOND AND THIRD LEVEL HIERARCHICAL LAND-USE CLASSIFICATION USED FOR CALABAR URBAN MAPPING

FIRST LEVEL CODE	CATEGORIES	SECOND LEVEL CODE	CATEGORIES	THIRD LEVEL CODE	CATEGORIES
0	URBAN RESIDENTIAL	01	Estate Housing	011	High Density Estate Housing
				012	Medium " " "
				013	Low " " "
		02	Non-Estate Housing	021	High Density Non-Estate Housing
				022	Medium " " " "
				023	Low " " " "
		03	New	031	Urban Residential New Development
				032	Urban " Redevelopment
1	COMMERCIAL	11	Open and Covered Markets		
		12	Shops/ Supermarkets		
		13	Urban Core (CBD)		
		14	Commercial Development	141	Commercial New Development
				142	Commercial Redevelopment
				143	Vehicle Workshop
2	INDUSTRIAL	21	Extractive Industries		
		22	Processing Industries		
		23	Manufacturing Industries		
		24	Indus Development	241	Industrial New Development
				242	Industrial Redevelopment
3	TRANSPORT-ATION	31	Roadways		
		32	Railways		
		33	Airports and Naval Base Sites		
		34	Harbours and Other Ferry Pts.		
		35	Navigable Rivers		
4	UTILITIES AND SERVICES	41	Electric Power Transmission		
		42	Post and Telegraphs		
		43	Telecoms (Radio, T.V. Stn)		
		44	Petrol/Gas/Other Fuel Stn		
5	INSTITUT-IONAL	51	Educational	511	Schools
				512	Universities
		52	Educational Dev		
		53	Places of Worship	531	Church
				532	Mosque
		54	Barracks	541	Military Barracks
				542	Police Barracks
				543	Prison Barracks
				544	Naval Barracks
		55	Prisons		

(Table 4.3 continued)

FIRST LEVEL CODE	CATEGORIES	SECOND LEVEL CODE	CATEGORIES	THIRD LEVEL CODE	CATEGORIES
		56	Hospitals	561	General Hospitals
				562	Health Centre
6	AGRICULTURAL	61	Crops(Yams, Cassava etc.)		
		62	Horticulture/ Vegetable		
		63	Plantations	631	Palm Tree Plantation
				632	Rubber Plantation
7	FOREST AND (WOODLAND) BUSHES	71	Dense Forest		
		72	Open Forest		
		73	Grassland with Scattered trees		
		74	Grassland		
		75	Mangrove Forest		
		76	Scrubland		
8	WATER AND WETLANDS	81	Rivers/Creeks, (Non Navigable)		
		82	Streams and Rivulets		
		83	Lakes and Reservoirs		
		84	Marsh and Inundated areas		
		85	Reclaimed Wetland		
9	OPEN SPACE	91	Improved Open Space	911	Sports Stadium
				912	Public Parks
				913	Town Square/Open Playground
				914	Cemeteries
		92	Unimproved Open Space	921	Eroded Areas
				922	Derelict Land
10	OTHERS	10	(Unidentified Uses)		

Urban Residential: Estate: 01

Urban Residential: Estate: Low density 012

The classification was compiled so that additional categories could be added, even at the first level, without altering its basic structure.

It is hoped that this will avoid any dramatic changes when the classification is applied to other areas in Nigeria, or even to other tropical lands.

4.5 Legend description of land use types

4.5.1 Urban Residential Code 0

The basic residential categories are defined in terms of whether they are estate or not, whether they are new development or redevelopment, and the density of development.

Most urban residential buildings are readily identified. The distinction between 'estate' and 'non estate' is based mainly on the 'pattern' of development.

The distinction between 'new' and 're' development is often related to location. The 'new' urban expansion is taking place mostly in the suburbs whilst the 'redevelopment' is associated with the older city centres.

Guidelines have been established to enable residential densities to be determined on a three point scale

High density	more than 8 dwellings per acre
Medium density	between 3 and 7 dwellings per acre
Low density	less than 3 dwellings per acre

though it is accepted that this is an arbitary division which may need subsequent revision.

4.5.2 Commercial Code 1

The ease with which the various commercial categories can be identified varies considerably.

At one end of the scale are the open and covered markets. These are revealed by the extent of the site and the pattern exhibited by the roofing.

The larger shops may be identified by the size and location of the buildings and also by the extensive area reserved for parking.

It is the smaller isolated shops situated in the residential areas that it is most difficult to consistently and accurately identify.

A fair amount of commercial activity occurs in the 'urban core' or Central Business District (CBD). Much of the land use is very mixed often with different activities taking place at different levels in a building e.g. a shop on the ground floor with a flat above.

4.5.3 Industrial Code 2

The ability to identify Industry varies considerably with its type. Extractive industry is very evident with quarries, material and plant all being in the open.

Most industries concerned with processing and manufacturing are under cover, though some clues may be obtained from the site and size of the building and plant; and evidence of raw materials or finished products which may be visible on the site.

Some authors have compiled detailed lists of the key features associated with industry.

Chisnell and Cole (1958), for example, itemised those features which are generally evident in the processing industries, Table 4.4.

These are meant to be general guides and do not indicate that all these features are always present on any one site.

4.5.4 Transportation Code 3

Most of the elements of Transportation are in the open and are thus very readily identified.

At a photographic scale of 1:6000 roads can even be classified as

(Table 4.4) THE PROCESSING INDUSTRY KEY FEATURES

(A) <u>Mechanical Processing Industries:</u>

(1) Few pipelines or closed tanks
(2) Little fuel
(3) Few stacks
(4) No kilns

(B) <u>Chemical Processing Industries</u>

(1) Many closed or full tanks, including gasholders
(2) Many pipelines
(3) Much larger outdoor processing equipment

(C) <u>Heat Processing Industries</u>

(1) Few pipelines or tanks
(2) Large chimneys or many stacks
(3) Large quantity of fuel
(4) Kilns

major or minor, and can be precisely measured if required.

Although no railways occur in the study area, this unit has been included in the key for the sake of completeness and to make the classification applicable to other areas in Nigeria.

Airports are strikingly evident, the runways showing most distinctive characteristics.

Harbours and other water orientated activities are restricted to certain sites, and the existence of various types of craft indicate the particular activity which is taking place.

In terms of land use it is important to distinguish whether a waterway is navigable or not. The main clues to determine this are the presence (or absence) of waterfalls, rapids and shallows along the river itself, and the type and number of craft and their direction of travel and the location of dock facilities.

4.5.5 Utilities and Services Code 4

A wide range of different types of activities are included under this heading. Because the aerial photography was at a reasonably large scale (1:6000) it was possible to include those services in which the main external plant was visible. These included power and telegraph lines.

The traditional European type sewage treatment plant is not very common in the tropics where septic bunkers and soak-away pits are the more usual. Petrol stations are mostly open with pumps outside, and have associated buildings. A combination of site, situation and evidence of motor vehicles are all clues to the existence of service stations.

4.5.6 Institutional Code 5

A wide range of different functions are performed by the various buildings included under this major heading. Prisons, Barracks, Hospitals and Places of Worship all feature buildings which have a close form/function relationship and are therefore readily identifiable.

Schools with their associated play areas, and Universities with their distinctive complex of buildings are both readily discernable.

4.5.7 Agriculture Code 6

There is still a fair amount of agricultural activity taking place within the city of Calabar boundary, though this will decrease as the city expands. The pattern of the plantations stand out in contrast to the other farming practices.

4.5.8 Forest and Woodland Code 7

No problems of identification occurred in this group, and all can be recognised with a high degree of accuracy. The distinction between dense and open forest is whether the crowns touch or not.

A little more arbitrary is the distinction between 'grassland' and 'grassland with scattered trees', because some subjective decision is required to decide at what stage there are enough scattered trees for a unit to be included in this second category.

4.5.9 Water and Wetlands Code 8

With one exception all the categories under this heading are areas of permanent water or subject to periodic flooding. Water is readily identified, though it is sometimes not so easy to decide whether it is a river or stream. Reclaimed wetland has been included because the photo evidence shows that the area was originally wetland.

This is evident from the smooth and cleared land surface, and the presence of machinery and earth moving plant, but there is no evidence of the future use of that land. Where such land is now in a new use it has been classified under that new use.

4.5.10 Open Space Code 9

These are areas of non agricultural land which are not covered by buildings. The areas of improved open space have close form/function relationship, and are therefore easy to identify. To identify the various types of unimproved open space, the condition of the land is significant.

Areas of natural erosion vary in the extent of the damage caused, but have a common factor in current non usage. Areas of derelict land vary considerably in the cause, nature and extent of the degraded land, and in their current and proposed use. Some sites are used as dumps, whether for waste or cars, whilst other sites do not appear to be currently used for any purpose.

4.5.11 Others Code 10

Two categories are included under this heading.

i) Those units which are not identified at all, and therefore cannot be allocated to any specific category in the classification, and

ii) Those units which are identified, but the particular category has not been allocated a place in the classification.

CHAPTER FIVE

5 MATERIALS AND EQUIPMENT USED IN MAPPING CALABAR LAND USE

5.1 Data source

In this study the following materials and instruments were used:

5.1.1 Aerial photography

Black and white, vertical aerial photographs at a nominal scale of 1:6000 flown in 1977/1978 by Kenting Earth Surveys.

A total of about 600 photographs covered Calabar City and the immediately surrounding region.

These were good quality and the overlaps allowed stereoscopic study over the whole area.

5.1.2 Maps and diagrams

In addition to the above, the following maps and diagrams were also used:

(a) A provisional urban land use map of Calabar at 1:50 000 (produced by Federal Surveys, Nigeria, 1975).

(b) A political map of Calabar and Environs at a scale of 1:25 000 (produced by Survey Department, Calabar, from 1969 photography).

(c) Calabar "Master Plan" maps at a scale of 1:10 000 (produced by Tesco-Kotzi, Budapest from 1969/1970 photography).

5.2 Instruments

5.2.1 Pocket lens stereoscope

This is an inexpensive, light, portable instrument which is small and used widely in field work. The lens magnification is 2x, and there may be a facility for altering the eye base to suit the observer. The main problem with this instrument is that the photographs have to be folded up to view the whole stereo-overlap.

5.2.2 Mirror stereoscope (Wild ST4) (plate 5.1)

This instrument uses prisms and mirrors to enable the entire area of overlap, along the flight line, to be stereoscopically observed without the need to fold up the photography.

The standard instrument is on four legs, has fine adjustment for the inter-ocular distance of the observer, and a viewing lens of 1x.

Accessories include a cantilever arm so that the trace overlays can more easily be annotated, and a parallel guide mechanism so that the stereo model is not lost when scanning the photo overlap.

To increase the scale of the stereo model viewed separate sets of binocular lenses are available at magnifications of 3x and 8x. The use of these reduces the area of the model being studied and generally requires the repositioning of the photographs to obtain a good stereo model.

5.2.3 "Old Delft" scanning stereoscope (plate 5.2)

In the two instruments described so far it is necessary to move either the instrument or the photographs when scanning the stereo model.

A further refinement is the ability to obtain a good stereo image by optically moving one image relative to the other independently in the X and Y directions, hence the photographs need not be precisely positioned to obtain a solid model. There is no facility however to rotate either photograph, and their axes must be properly oriented.

The magnification system is built in and permits viewing at 1.5x and 4.5x the photo scale. One very useful feature with these instruments is that they can be used in pairs allowing two instruments, and therefore two observers, to view simultaneously the same overlapping pair of aerial photographs. As each operator controls independently his own scanning it is necessary to physically mark the location of the point under joint study.

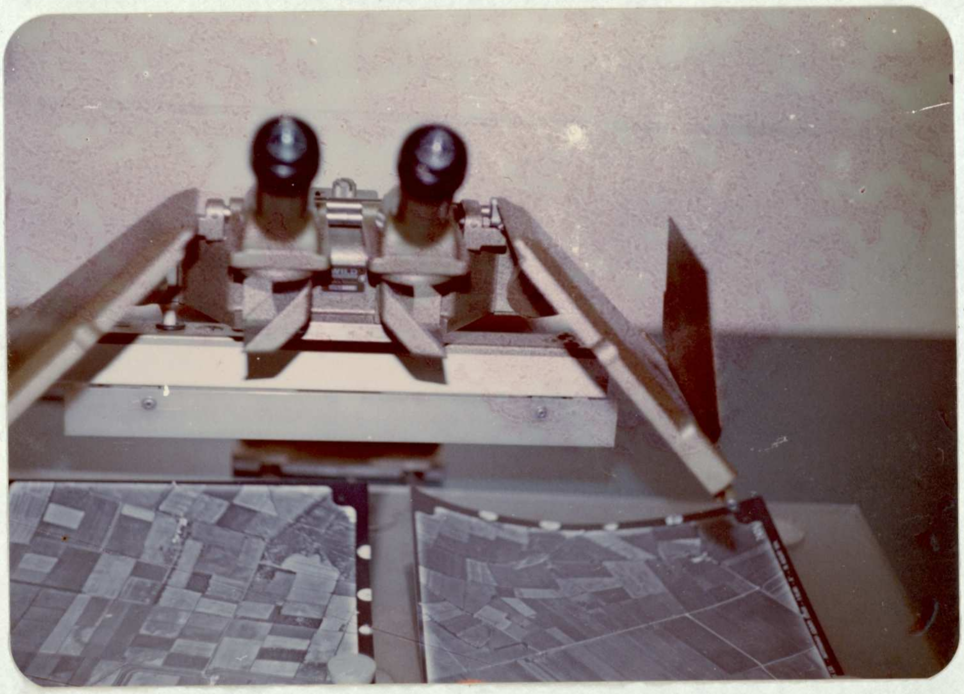


Plate 5.1 Wild ST4 mirror stereoscope, mounted on a cantilever arm with a transparent parallax guide mechanism to mount the overlapping pair of aerial photographs.

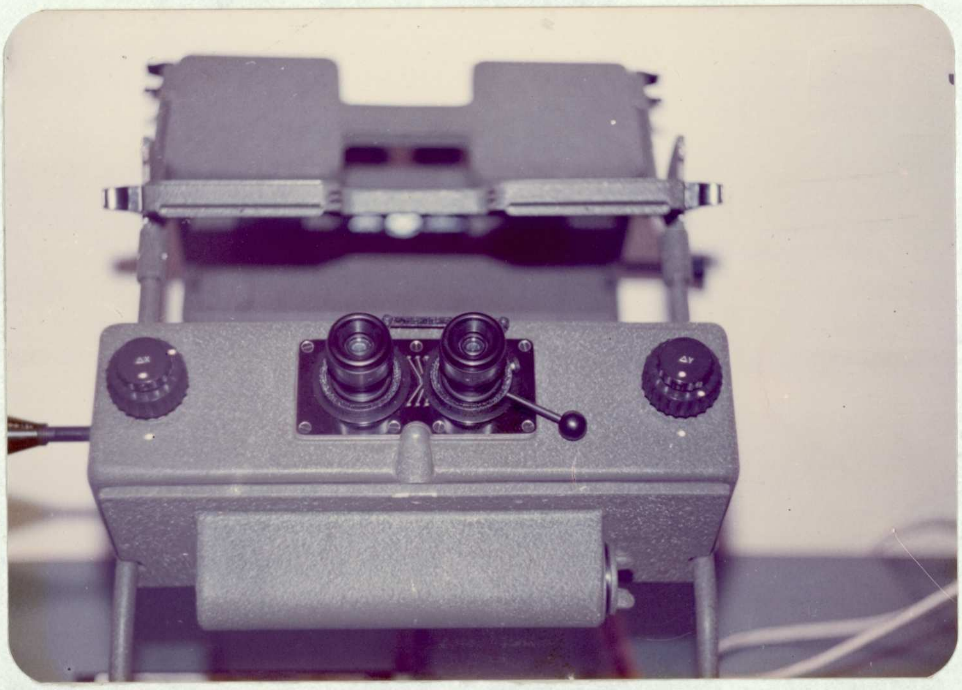


Plate 5.2 "Old Delft" scanning stereoscope.

5.2.4 Interpretoscope - Carl Zeiss Jena (plate 5.3)

In terms of size, cost and complexity this instrument stands in a class on its own. It is a large, stable, complex and expensive piece of equipment. This instrument is constructed so that it is possible to have a version in which two observers can simultaneously view the same stereo pair. The objective lenses are mounted on a gantry which allows the stereo pair to be scanned in the X and Y directions.

As with the Old Delft, this instrument has the facility to obtain a good stereo image by the differential movement of one image in relation to the other in both X and Y. There is also a facility for measuring parallax differences in the X direction.

One very useful feature is the zoom facility which operates in two ranges: 2x to 6x and 6x to 15x, the changeover from one range to another is effected by the correct setting of the objective lenses.

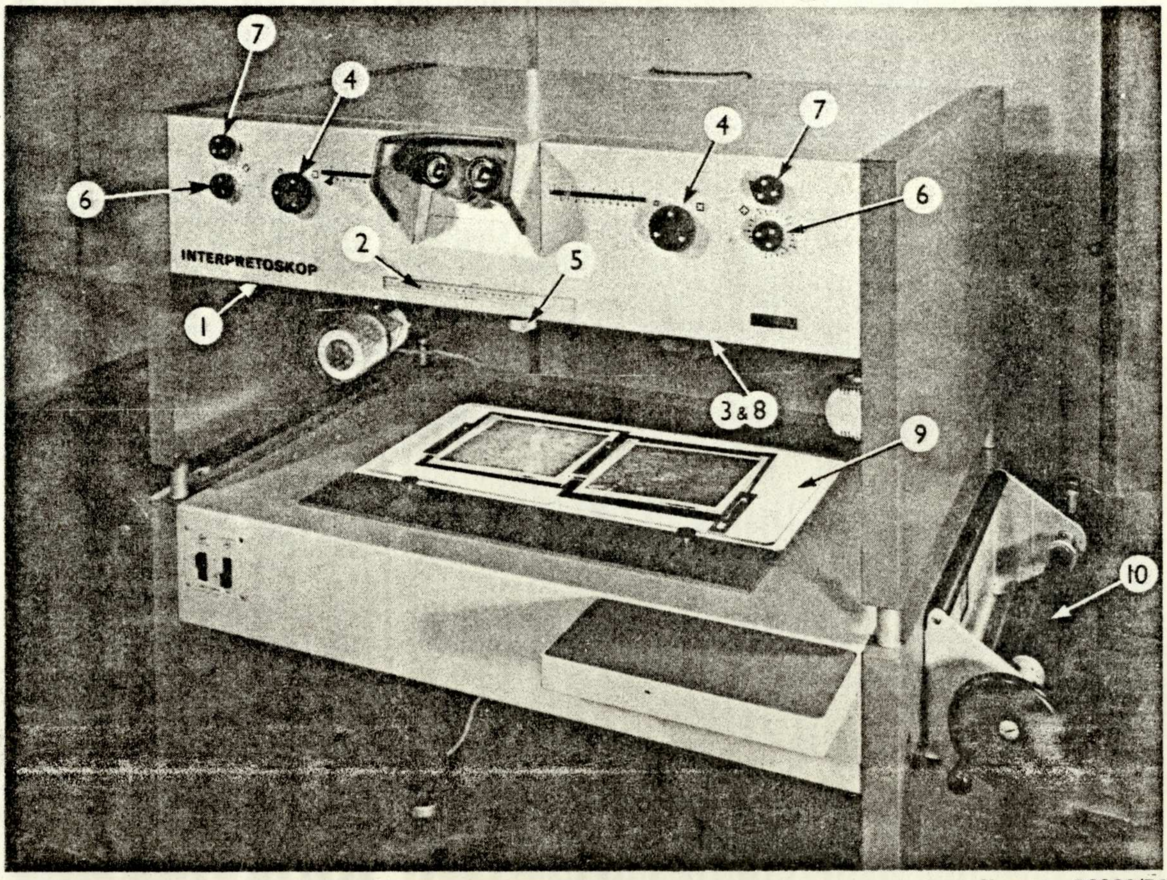
It is possible, using this system to obtain a stereo model of aerial photographs of different scale i.e. 1:5000 and 1:25000 scale photographs of the same site can, by proper use of the optical system, be made to construct a stereo model.

5.2.6 Zoom Transferscope (plate 5.4)

The major function of this instrument is to permit the transfer of data (land use, geology, topography etc.) from aerial photography to base map. The instrument can accommodate scale differences between the air photo, usually at the smaller scale, with the base map which is usually at a larger scale.

5.3 <u>Hewlett-Packard computer and digitiser.</u>

The main function of the digitiser is to automaticaly record the X and Y co-ordinates of a point. If the co-ordinates of an enclosed boundary are recorded then, using the appropriate program, the area can be rapidly determined. All the information can be stored on tape



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1. Incident (reflected) light equipment.
2. Scale for reading horizontal parallax differences.
3. Handles for shifting the objective lenses in x and y directions.
4. Panchratic system for stepless magnification variations; elimination of scale differences between left and right images.
5. Change-over objectives for the magnification steps x 2 to x 6 and x5 to x15 respectively.
6. Optical rotation of left and right images.
7. Brightness control of transmitted and incident light for left and right images.
8. Parallax elimination.
9. Image stage for putting on photographic material. Beneath the glass plate is the transmitted light equipment.
10. Removable roll-film holders

Plate 5.3 The Carl Zeiss Jena Interpretoscope.

or disc to form a useful data bank.

The digitiser instruction can be executed either from the keyboard "live", or within a programme, but in both cases the computer must be used to control its activities.

The digitiser is more accurate and very much faster to use than the traditional planimeter. On the other hand it is more complex and much more expensive.

Plate 5.4 The Zoom Transferscope (ZT4-H)

Plate 5.5 The Hewlett Packard digitizer and computer.

CHAPTER SIX

6 MEASUREMENTS AND ANALYSIS METHODOLOGY

6.1 Introduction

Area measurements may be obtained in various ways from maps, aerial photographs and diagrams.

The most precise, but the most time consuming method is to determine the area by measuring round the discrete boundary of each figure. To carry out this measurement an electronic digitizer was used to record the x and y co-ordinates of points around the boundary, and a programme devised which used those co-ordinates to calculate the areas.

It may not be necessary - or even possible - to carry out a total survey, and a number of sampling techniques are available.

Dominant among these is to sample on a grid basis - either dots or squares - at varying densities.

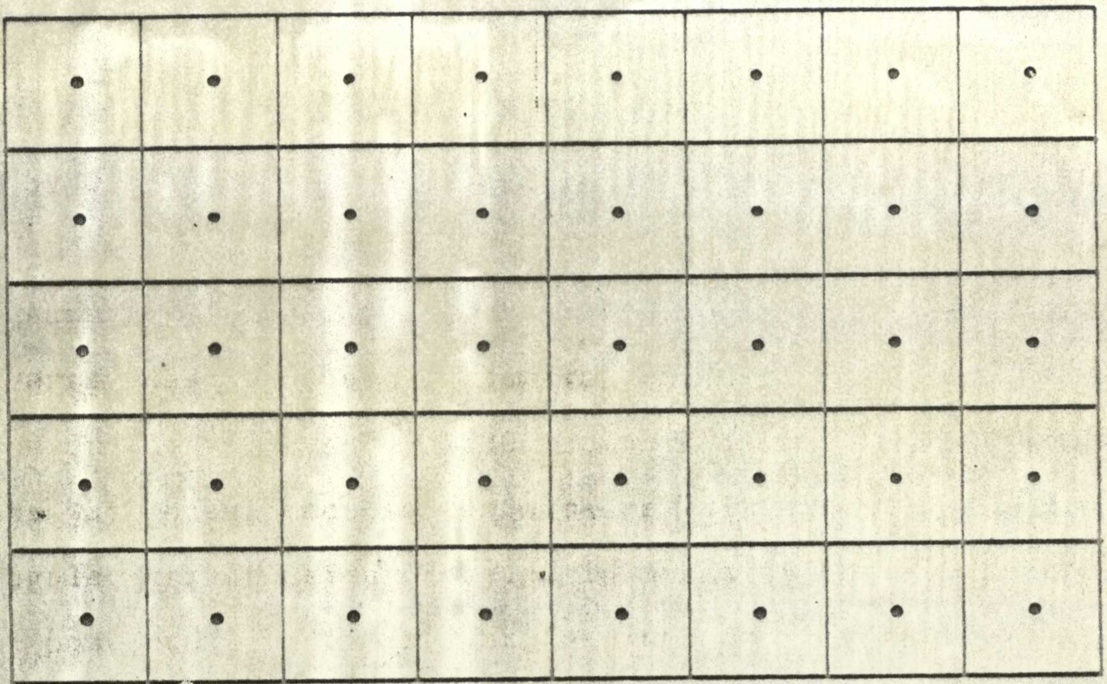
6.2 Grids and Dots, methods for area measurement

By subdividing a map or aerial photograph into a regular grid of equal squares, each of a known dimension, it is possible to use these to calculate or estimate the total area of the map or aerial photograph.

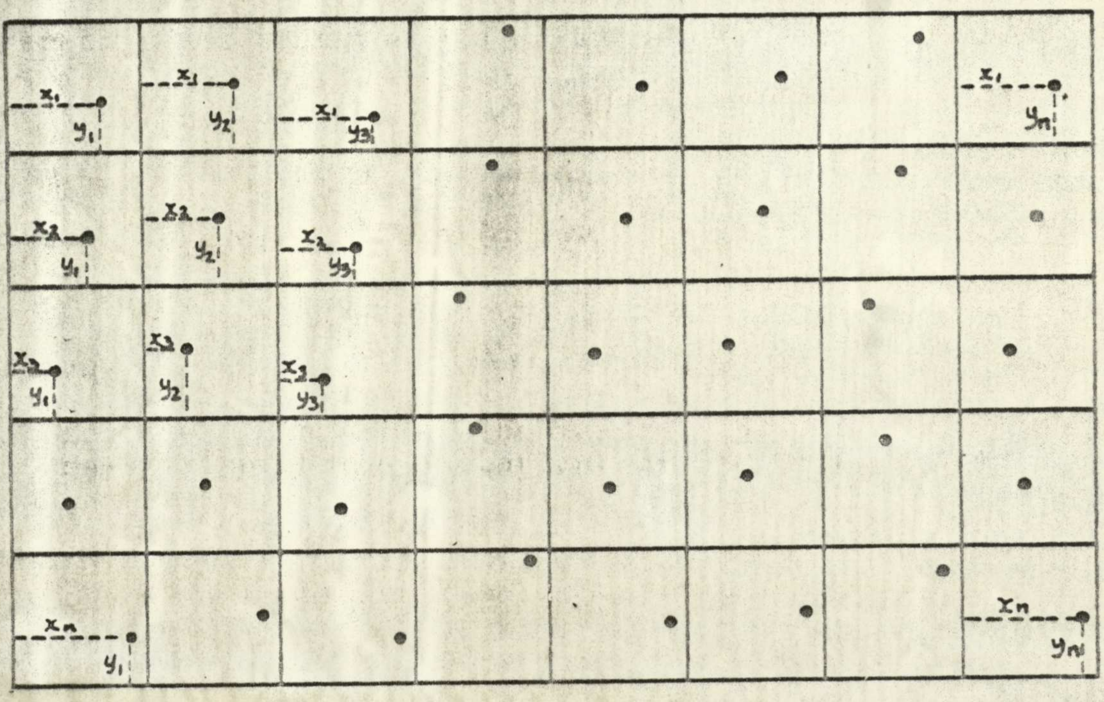
A common method for mapping and measuring land use is to record the dominant use in each square, and allocate the total area of the square to that simple category.

An alternative method is to place a single dot in each square: the dot being placed either in the centre, or randomly within each square. (Figure 6.1)

In this instance it is the specific land use which occurs under the dot which is recorded for the total area of the square. It may



(a) Orthogonal grid with systematic, aligned point sample pattern.



(b) Orthogonal grid with systematic, unaligned point sample pattern.

Figure 6.1 Systematic point sample patterns well be that the dot falls on a unit which may occupy only a very small portion of the grid square, and that this may appear to be an inaccurate method of sampling.

6.3 Sampling Techniques : Dot Grids

Seven sample areas were identified after interpretation of the Calabar aerial photographs. These were chosen in such a way that each type of area in the city (city centre, outer suburb, commercial, industrial, residential and others) was represented.

Berry (1962), suggested for land use surveys the stratified, systematic and unaligned array as the most effective sampling pattern when using either ground methods, maps or air photographs.

From tests, he concluded that point sampling has a unique advantage of providing most precise estimates of the percentage cover with most satisfactory variance of the estimates. He also noted that these facilitated studies of relationships between distribution in space through time, and in facilitating storage of data and mapping by machine.

Dickinson and Shaw (1977), carried out a land use survey of Leeds, England using a stratified systematic unaligned pattern of points. The density of the mapping was one point per hectare from an area of one square kilometre. The array being used to sample land use of the survey area on the Ordnance Survey 1:2,500 scale plans.

From the tests, they listed the following advantages of point sampling:

"a) Point sampling makes the measurement, and thus the definition and delimitation, of individual plots unnecessary,

b) Any specified level of accuracy may be achieved by adjusting the sample size,

c) Change is measured simply by collecting land use data for precisely the same set of points in successive years,

d) Using a simple, previously defined, convention for points landing on boundaries, it is possible to consider each point affected by change as a moving wholly from one land use to another, by contrast, plots subject to change often require sub-division,

e) The storage and updating of point data is simple, once a system of fixed points is in operation it is likely that the level of error will remain relatively constant,

f) Because the total information requirement is smaller, points sampling allows routine checking to be accomplished more rapidly, so making maintenance of up-to-date records easier,

g) In point sampling, with probability of selection proportional to the site area, small areas are not over-represented compared with their size, and trivial changes do not overload the system,

h) Since no area measurement is involved, effort can be concentrated on checking classification and updating of records."

The above arguments are powerful enough to support the use of sampling methods for the measurement of land use, but, although this is convenient, it has its own disadvantages in that its accuracy is lower than that obtained by direct measurement methods. Consequently, a number of workers have attempted to assess the accuracy of areas measured by sampling.

Notable among these were Frolov and Maling (1969), who carried out experiments to assess such accuracy. From their tests, they indicated a relationship between the coefficient of variation of the measurement and the area of a single parcel measured using dot grids. This according to them is related mathematically as:

"Log S% = 1.719 + 1.5 log t - 0.75 log A (6.1)

where S = the standard deviation (i.e. standard error of a single measurement).

S% = (S/A.100%), the coeffiecient of variation.

t = the side length of the unit cell in centimetres.

A = the area of the parcel in square centimetres."

In view of the constant use of the sampling technique, it is necessary to assess their methods before using them as a basis for land use measurement.

6.4 Methodology

The following procedure was established:

i) The various densities were selected at which the observations were to be made. These were to give at photo scale, grids of the values 2-hectares, 1-hectare, 0.5-hectare and 0.25-hectare respectively.

ii) The dimensions were calculated which enabled these four grids to be constructed.

iii) Using the various grids superimposed over the air photo trace overlays (Figure 6.6), the areas were determined for each grid density of each category of land use. This was done for both the grid squares and the dot grids and provided two sets of area data for each of the four densities of observations.

iv) The air photo urban land use trace overlays were then digitized to provide precise area measurements for each separate discrete land use unit.

These separate area units were aggregated to provide a) total area of each land use type and b) total area of all area measurements for each air photo trace overlay.

v) In some cases the total area of a sample (an annotated air photo overlay) derived from the discrete boundary digitization, did not agree with the sum of all the categories derived from the grid square and dot grid measurements. (Tables 6.1 and 6.2)

In these instances the discrete values were regarded as correct and the relevant dot and grid total areas were adjusted to agree with the digitized values. (Tables 6.3 and 6.4)

vi) Using the total discrete boundary area and the total dot (or square) grid area for each sample, a correction factor was derived to adjust the sample values (dot and square) of each separate category to agree with those values derived from digitizing.

vii) These 'adjusted' areas for each separate category of dot and grid survey were then compared with the area values derived from the 'digitized' values.

The differences between the 'adjusted observed' area values from the dot and grid surveys, and the digitized area values were shown as errors. These errors were recorded in hectares (Tables 6.5 and 6.6) and as a percentage (Tables 6.7 and 6.8) for each category of land use.

6.4.1 Calculation of grid densities

If the average scale of the aerial photography is known, then a grid of any required density can be calculated. On this project the photography used was at a nominal scale of 1:6000, and it was required to compile a set of grids which could quickly and easily be related to a known area.

The four areas chosen were to be equivalent to 2ha, 1ha, 0.5ha and 0.25ha respectively, and Table 6.9, sets out the calculations and dimensions of the four grids which gave densities of 81, 169, 324 and 625 squares (or points in those squares) respectively.

Figures 6.2, 6.3, 6.4 and 6.5, give examples of these four grid square densities.

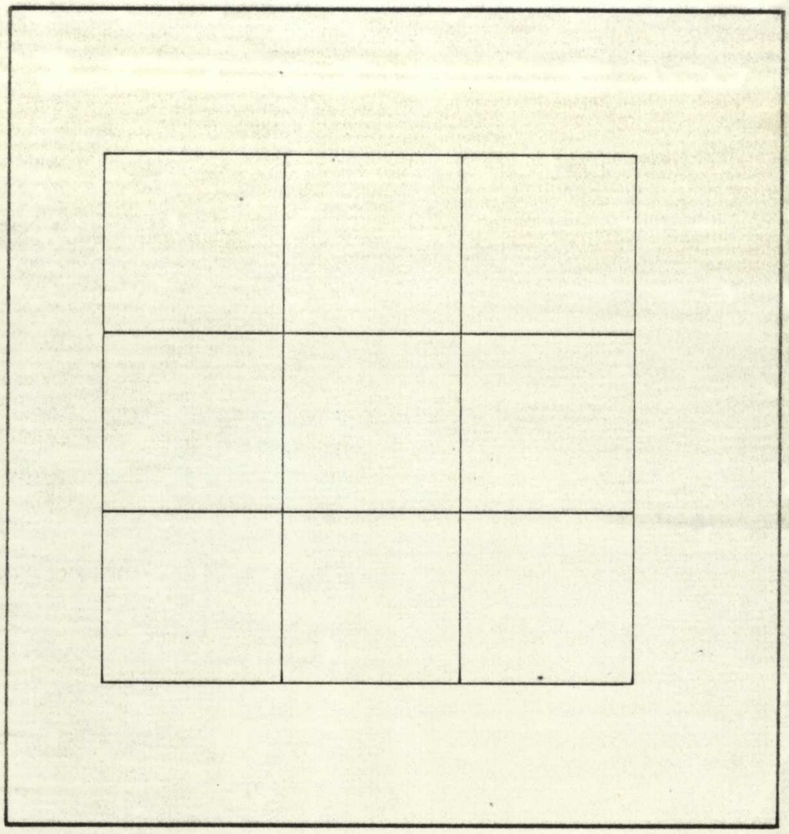


Figure 6.2 Pattern of Two-Hectare Grid Squares at 1:6000

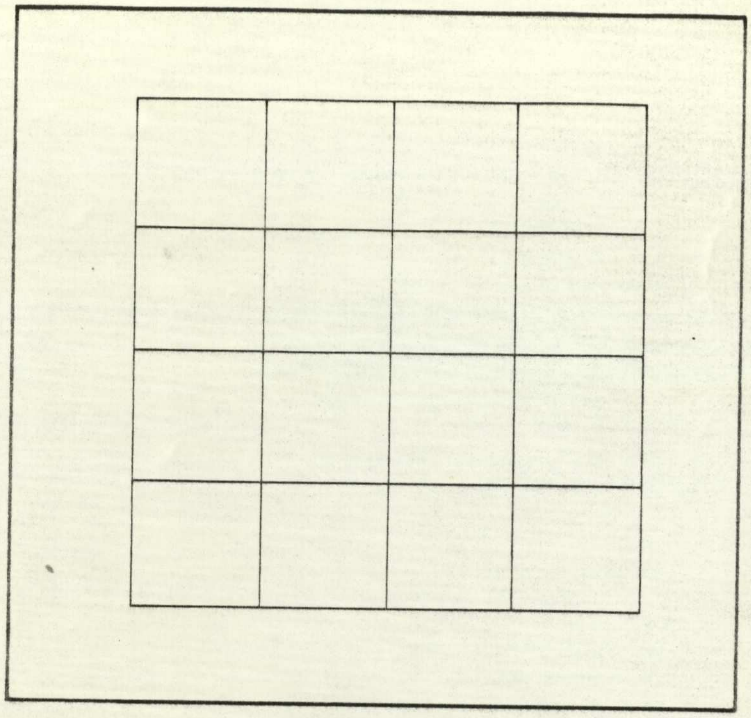


Figure 6.3 Pattern of One-Hectare Grid Squares at 1:6000

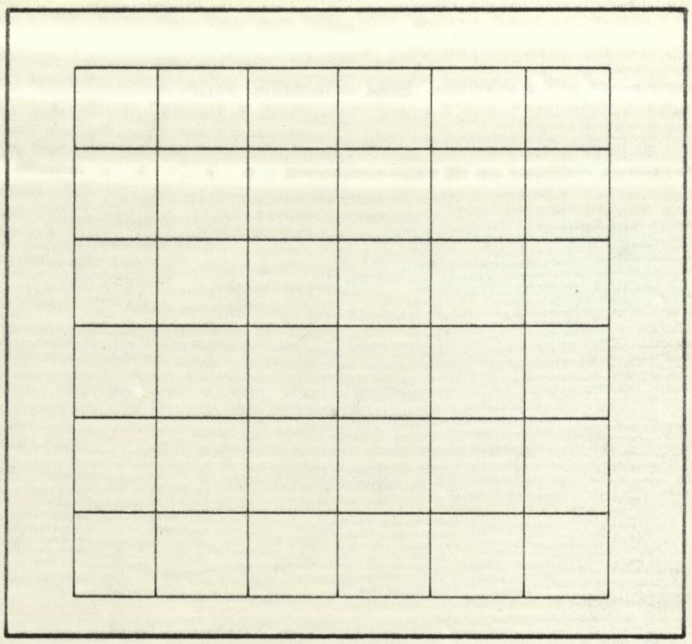


Figure 6.4 Pattern of Half-Hectare Grid Squares at 1:6000

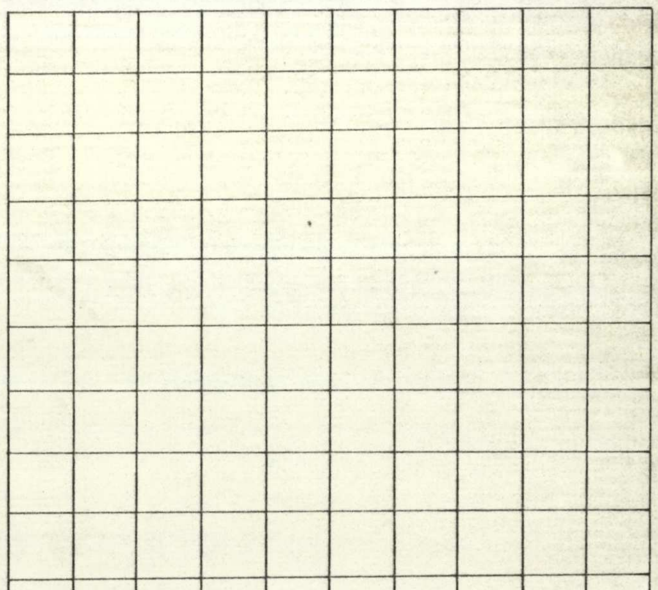
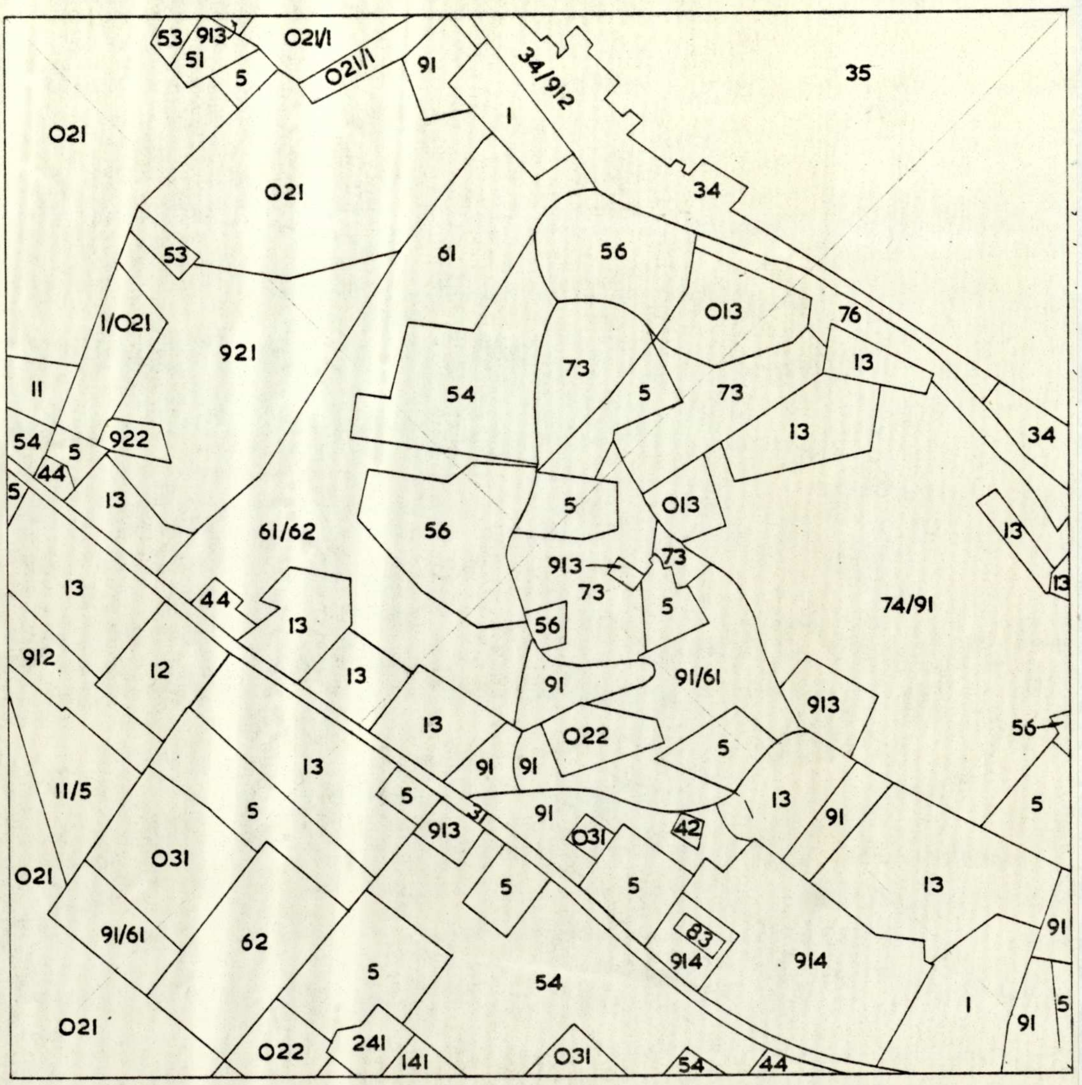


Figure 6.5 Pattern of Quarter-Hectare Grid Squares at 1:6000



LINE 8-N PHOTO # 142.

Figure 6.6 Land Use Trace of Sample Area Number 3

(Table 6.1) CATEGORY AREAS USING GRID SQUARES - SAMPLE NUMBER 3

LAND USE CODE	L.U. CATEGORIES	20 MINS	30 MINS	50 MINS	80 MINS	110 MINS
	TIME TAKEN / DENSITY OF OBSERVATION	81 2 ha	169 1 ha	324 0.5 ha	625 0.25 ha	SAME AREA DIGITISED
013	Urban Housing Estate Low Density	2.000	3.000	2.000	2.250	2.202
021	Non-Estate Low Density	22.000	21.000	20.000	20.250	21.576
022	Non-Estate Med Density	-	1.000	1.500	1.750	1.641
031	Urban Res. New Dev.	2.000	3.000	2.500	2.750	2.984
1	Commercial	4.000	6.000	4.000	5.250	3.149
11	Open Market	-	1.000	2.500	2.750	2.423
12	Shops	2.000	2.000	1.500	1.750	1.391
13	Urban Core	18.000	16.000	17.000	16.750	15.327
141	Comm. New Dev.	-	-	-	0.250	0.265
241	Indust. New Dev.	-	1.000	0.500	0.750	0.525
31	Roadways	-	-	-	0.500	1.561
34	Harbour & Ferry	4.000	3.000	2.500	2.000	4.052
35	Rivers Navigable	18.000	19.000	17.500	16.000	18.021
42	Post & Telegraph	-	-	-	0.250	0.095
44	Petrol/Fuel Stn.	-	-	-	0.750	0.598
5	Institutional	8.000	9.000	12.500	10.000	10.882
51	School	-	1.000	0.500	0.750	0.469
53	Church/Mosque	-	-	-	0.250	0.505
54	Barracks	14.000	13.000	11.000	11.250	10.461
56	Health Centres	8.000	6.000	5.000	5.250	5.324
61	Crops	14.000	11.000	10.500	10.250	10.035
62	Horticulture/Veg	6.000	4.000	4.000	3.000	2.908
73	Grassland with Scattered Trees	2.000	3.000	6.000	6.250	3.868
74	Grassland	12.000	15.000	15.000	13.750	13.718
76	Scrubland	-	1.000	1.000	1.500	1.774
83	Lakes & Water Resv.	-	-	-	-	0.138
91	Open Space Improved	8.000	11.000	10.500	10.000	11.871
912	Parks	2.000	1.000	1.500	3.750	1.304
913	Town Sq/Play ground	4.000	5.000	1.000	0.750	1.374
914	Cemeteries	6.000	7.000	5.500	5.250	5.172
921	Eroded Areas	6.000	6.000	7.000	6.000	6.400
922	Derelict Land	-	-	-	0.500	0.320
	TOTAL HECTARES	162.000	169.000	162.000	162.500	162.333

(Table 6.2) CATEGORY AREAS USING DOT GRIDS - SAMPLE NUMBER 3

LAND USE CODE	L.U. CATEGORIES / TIME TAKEN	25 MINS	40 MINS	50 MINS	60 MINS	90 MINS
	DENSITY OF OBSERVATION	81	169	324	625	SAME AREA
		2 ha	1 ha	0.5 ha	0.25 ha	DIGITISED
013	Urban Housing Estate Low Density	2.000	2.000	2.000	2.250	2.202
021	Non-Estate Low Density	16.000	20.000	19.000	18.500	21.576
022	Non-Estate Med Density	-	3.000	1.500	1.000	1.641
031	Urban Res. New Dev.	2.000	5.000	3.000	2.750	2.984
1	Commercial	2.000	5.000	4.000	5.000	3.149
11	Open Market	4.000	3.000	2.500	2.500	2.423
12	Shops	2.000	-	1.000	1.000	1.391
13	Urban Core	18.000	17.000	18.500	17.500	15.327
141	Comm. New Dev.	-	-	-	-	0.265
241	Indust. New Dev.	-	1.000	0.500	0.500	0.525
31	Roadways	2.000	3.000	1.000	1.000	1.561
34	Harbour & Ferry Points	4.000	5.000	4.000	4.500	4.052
35	Rivers Navigable	18.000	19.000	18.000	15.750	18.021
42	Post & Telegraph	-	-	-	0.250	0.095
44	Petrol/Fuel Stn.	-	1.000	-	0.500	0.598
5	Institutional	6.000	10.000	10.000	9.500	10.882
51	School	2.000	1.000	0.500	0.750	0.469
53	Church/Mosque	-	-	0.500	0.250	0.505
54	Barracks	14.000	11.000	9.500	10.250	10.461
56	Health Centres	4.000	7.000	5.000	5.000	5.324
61	Crops	10.000	10.000	11.000	9.250	10.035
62	Horticulture/Veg	4.000	3.000	3.500	3.250	2.908
73	Grassland with Scattered Trees	8.000	7.000	6.500	8.000	3.868
74	Grassland	16.000	19.000	14.000	13.250	13.718
76	Scrubland	-	-	1.000	1.500	1.744
83	Lakes & Water Resv.	-	-	0.500	-	0.138
91	Open Space Improved	12.000	11.000	10.000	9.250	11.871
912	Parks	4.000	2.000	1.500	1.750	1.304
913	Town Sq/Play ground	-	1.000	1.500	1.000	1.374
914	Cemeteries	6.000	5.000	5.000	5.500	5.172
921	Eroded Areas	6.000	7.000	6.500	6.250	6.400
922	Derelict Land	-	-	0.500	0.500	0.320
	TOTAL HECTARES	162.000	169.000	162.000	156.250	162.333

(Table 6.3) ADJUSTED CATEGORIES AREA OBTAINED BY USE OF GRID SQUARES - SAMPLE NUMBER 3

LAND USE CODE	L.U. CATEGORIES	2 ha	1 ha	0.5 ha	0.25 ha	CAT. AREA OBTAINED BY DIGITIZING
013	Urban Housing Estate Low Density	2.004	2.882	2.004	2.338	2.202
021	Non-Estate Low Density	22.045	20.172	20.041	21.038	21.576
022	Non-Estate Med Density	-	0.961	1.503	1.818	1.641
031	Urban Res. New Dev.	2.004	2.882	2.500	2.857	2.984
1	Commercial	4.000	5.763	4.008	5.454	3.149
11	Open Market	-	0.961	2.505	2.857	2.423
12	Shops	2.004	1.921	1.503	1.818	1.391
13	Urban Core	18.037	15.369	17.035	17.402	15.327
141	Comm. New Dev.	-	-	-	0.260	0.265
241	Indust. New Dev.	-	0.961	0.501	0.779	0.525
31	Roadways	-	-	-	0.519	1.561
34	Harbour & Ferry	4.000	2.882	2.505	2.078	4.052
35	Rivers Navigable	18.037	18.250	17.536	16.623	18.021
42	Post & Telegraph	-	-	-	0.260	0.095
44	Petrol/Fuel Stn.	-	-	-	0.779	0.598
5	Institutional	8.016	8.645	12.526	10.389	10.882
51	School	-	0.961	0.501	0.779	0.469
53	Church/Mosque	-	-	-	0.260	0.505
54	Barracks	14.029	12.487	11.023	11.688	10.461
56	Health Centres	8.016	5.763	5.010	5.454	5.324
61	Crops	14.029	10.566	10.522	10.649	10.035
62	Horticulture/Veg	6.012	3.842	4.008	3.117	2.908
73	Grassland with Scattered Trees	2.004	2.882	6.012	6.493	3.868
74	Grassland	12.025	14.408	15.031	14.285	13.718
76	Scrubland	-	0.961	1.002	1.558	1.774
83	Lakes & Water Resv.	-	-	-	-	0.138
91	Open Space Improved	8.016	10.566	10.522	10.389	11.871
912	Parks	2.004	0.961	1.503	3.896	1.304
913	Town Sq/Play ground	4.008	4.803	1.002	0.810	1.374
914	Cemeteries	6.012	6.724	5.511	5.454	5.172
921	Eroded Areas	6.012	5.763	7.014	6.234	6.400
922	Derelict Land	-	-	-	0.519	0.320

(Table 6.4) ADJUSTED CATEGORY AREA OBTAINED BY USE OF DOT GRIDS - SAMPLE NUMBER 3

LAND USE CODE	L.U. CATEGORIES	DENSITY OF OBSERVATIONS				CAT AREA OBTAINED BY DIGITIZING
		2 ha	1 ha	0.5 ha	0.25 ha	
013	Urban Housing Estate Low Density	2.004	1.921	2.004	2.338	2.202
021	Non-Estate Low Density	16.033	19.211	19.039	19.220	21.576
022	Non-Estate Med Density	-	2.882	1.503	1.039	1.641
031	Urban Res. New Dev.	2.004	4.803	3.006	2.857	2.984
1	Commercial	2.004	4.803	4.008	5.195	3.149
11	Open Market	4.008	2.882	2.505	2.597	2.423
12	Shops	2.004	-	1.002	1.039	1.391
13	Urban Core	18.037	16.329	18.538	18.181	15.327
141	Comm. New Dev.	-	-	-	-	0.265
241	Indust. New Dev.	-	0.961	0.501	0.519	0.525
31	Roadways	2.004	2.882	1.002	1.039	1.561
34	Harbour & Ferry	4.008	4.803	4.008	4.675	4.052
35	Rivers Navigable	18.037	18.250	18.037	16.363	18.021
42	Post & Telegraph	-	-	-	0.260	0.095
44	Petrol/Fuel Stn.	-	0.961	-	0.519	0.598
5	Institutional	6.012	9.606	10.021	9.870	10.882
51	School	2.004	0.961	0.501	0.779	0.469
53	Church/Mosque	-	-	0.501	0.260	0.505
54	Barracks	14.029	10.566	9.520	10.649	10.461
56	Health Centres	4.008	6.724	5.010	5.195	5.324
61	Crops	10.021	9.606	11.023	9.610	10.035
62	Horticulture/Veg	4.008	2.882	3.507	3.377	2.908
73	Grassland with Scattered Trees	8.016	6.724	6.513	8.311	3.868
74	Grassland	16.033	18.250	14.029	17.766	13.718
76	Scrubland	-	-	1.002	1.558	1.744
83	Lakes & Water Resv.	-	-	0.501	-	0.138
91	Open Space Improved	12.025	10.566	10.021	9.610	11.871
912	Parks	4.008	1.921	1.503	1.818	1.304
913	Town Sq/Play ground	-	0.961	1.503	1.039	1.374
914	Cemeteries	6.012	4.803	5.010	5.714	5.172
921	Eroded Areas	6.012	6.724	6.513	6.493	6.400
922	Derelict Land	-	-	0.501	0.519	0.320

(Table 6.5) ERRORS IN CATEGORY AREA USING GRID SQUARES - SAMPLE NUMBER 3

LAND USE CODE	L.U. CATEGORIES	2 ha	1 ha	0.5 ha	0.25 ha	TRUE AREA DIGITIZED
013	Urban Housing Estate Low Density	0.198	0.680	0.198	-0.136	2.202
021	Non-Estate Low Density	-0.469	1.404	1.535	0.538	21.576
022	Non-Estate Med Density	-	0.680	0.138	0.177	1.641
031	Urban Res. New Dev.	0.980	0.102	0.484	0.127	2.984
1	Commercial	0.851	2.614	-0.859	-2.305	3.149
11	Open Market	-	1.462	0.082	0.434	2.423
12	Shops	0.613	0.530	0.112	-0.427	1.391
13	Urban Core	2.710	0.042	1.708	2.075	15.327
141	Comm. New Dev.	-	-	-	0.005	0.265
241	Indust. New Dev.	-	0.436	0.024	0.254	0.525
31	Roadways	-	-	-	1.042	1.561
34	Harbour & Ferry	0.052	1.170	1.547	1.974	4.052
35	Rivers Navigable	0.016	0.229	0.485	1.398	18.021
42	Post & Telegraph	-	-	-	0.165	0.095
44	Petrol/Fuel Stn.	-	-	-	0.181	0.598
5	Institutional	2.866	2.237	1.644	0.493	10.882
51	School	-	0.492	0.032	0.310	0.469
53	Church/Mosque	-	-	-	0.245	0.505
54	Barracks	3.568	2.026	0.562	1.227	10.461
56	Health Centres	2.692	0.439	0.314	0.130	5.324
61	Crops	3.994	0.531	0.487	0.614	10.035
62	Horticulture/Veg	3.104	0.934	1.100	0.209	2.908
73	Grassland with Scattered Trees	1.864	0.986	2.144	2.625	3.868
74	Grassland	1.693	0.690	1.313	0.567	13.718
76	Scrubland	-	0.813	0.772	0.216	1.774
83	Lakes & Water Resv.	-	-	-	-	0.138
91	Open Space Improved	3.855	1.305	1.349	1.482	11.871
912	Parks	0.700	0.343	0.199	2.592	1.304
913	Town Sq/Play ground	2.634	3.429	0.372	0.564	1.374
914	Cemeteries	0.840	1.552	0.339	0.282	5.172
921	Eroded Areas	0.388	0.637	0.614	0.166	6.400
922	Derelict Land	-	-	-	0.199	0.320

(Table 6.6) ERRORS IN CATEGORY AREA USING DOT GRIDS - SAMPLE NUMBER 3

LAND USE CODE	L.U. CATEGORIES	DENSITY OF OBSERVATION 2 ha	1 ha	0.5 ha	0.25 ha	TRUE AREA DIGITISED HECTARES
013	Urban Housing Estate Low Density	0.198	0.281	0.198	0.136	2.202
021	Non-Estate Low Density	5.543	2.365	2.537	2.356	21.576
022	Non-Estate Med Density	-	1.241	0.138	0.602	1.641
031	Urban Res. New Dev.	0.980	1.819	0.022	0.127	2.984
1	Commercial	1.145	1.654	0.859	2.046	3.149
11	Open Market	1.585	0.459	0.082	0.174	2.423
12	Shops	0.613	-	0.389	0.352	1.391
13	Urban Core	2.710	1.002	3.211	2.854	15.327
141	Comm. New Dev.	-	-	-	-	0.265
241	Indust. New Dev.	-	0.436	0.024	0.006	0.525
31	Roadways	0.443	1.321	0.559	0.422	1.561
34	Harbour & Ferry	0.044	0.751	0.044	0.623	4.052
35	Rivers Navigable	0.016	0.229	0.016	1.658	18.021
42	Post & Telegraph	-	-	-	0.165	0.095
44	Petrol/Fuel Stn.	-	0.363	-	0.079	0.598
5	Institutional	4.870	1.276	0.861	1.012	10.882
51	School	1.535	0.492	0.032	0.310	0.469
53	Church/Mosque	-	-	0.004	0.245	0.505
54	Barracks	3.568	0.105	0.941	0.180	10.461
56	Health Centres	1.316	1.400	0.314	0.219	5.324
61	Crops	0.014	0.429	0.988	0.425	10.035
62	Horticulture/Veg	1.100	0.026	0.599	0.469	2.908
73	Grassland with Scattered Trees	4.148	2.856	-2.645	4.443	3.868
74	Grassland	2.315	4.532	0.311	4.048	13.718
76	Scrubland	-	-	0.772	0.216	1.774
83	Lakes & Water Resv.	-	-	0.363	-	0.138
91	Open Space Improved	0.154	1.305	1.850	2.261	11.871
912	Parks	2.704	0.617	0.199	0.514	1.304
913	Town Sq/Play ground	-	0.413	0.129	0.335	1.374
914	Cemeteries	0.840	0.369	0.162	0.542	5.172
921	Eroded Areas	0.388	0.324	0.113	0.093	6.400
922	Derelict Land	-	-	0.181	0.199	0.320

(Table 6.7) PERCENTAGE CATEGORY ERRORS USING GRID SQUARES-
SAMPLE NUMBER 3

LAND USE CODE	L.U. CATEGORIES	DENSITY OF OBSERVATION 2 ha	1 ha	0.5 ha	0.25 ha	TRUE AREA DIGITISED
013	Urban Housing Estate Low Density	8.99	12.76	8.99	6.18	1.36
021	Non-Estate Low Density	25.69	20.23	11.76	10.92	13.29
022	Non-Estate Med Density	-	75.62	8.41	36.68	1.01
031	Urban Res. New Dev.	32.84	60.96	0.74	4.26	1.84
1	Commercial	36.36	52.52	27.28	64.97	1.94
11	Open Market	65.41	18.94	3.38	7.18	1.49
12	Shops	44.07	-	27.97	25.31	0.86
13	Urban Core	17.68	6.54	20.95	18.62	9.44
141	Comm. New Dev.	-	-	-	-	0.16
241	Indust. New Dev.	-	83.05	4.57	1.14	0.32
31	Roadways	28.38	84.63	35.81	28.32	0.96
34	Harbour & Ferry	1.09	18.53	1.09	15.38	2.50
35	Rivers Navigable	0.09	1.27	0.09	9.20	11.10
42	Post & Telegraph	-	-	-	173.68	0.06
44	Petrol/Fuel Stn.	-	60.70	-	13.21	0.37
5	Institutional	44.75	11.72	1.10	9.30	6.70
51	School	327.29	104.90	6.82	66.10	0.29
53	Church/Mosque	-	-	0.79	48.51	0.31
54	Barracks	34.11	1.00	9.00	1.72	6.44
56	Health Centres	24.72	26.30	5.90	2.42	3.28
61	Crops	0.14	4.28	9.85	4.24	6.18
62	Horticulture/Veg	37.83	0.89	20.60	16.13	1.79
73	Grassland with Scattered Trees	107.24	73.84	68.38	114.87	2.38
74	Grassland	16.88	33.04	2.27	29.51	8.45
76	Scrubland	-	-	43.51	12.18	1.09
83	Lakes & Water Resv.	-	-	263.04	-	0.09
91	Open Space Improved	1.30	10.99	15.58	19.05	7.31
912	Parks	207.36	47.32	15.26	39.42	0.80
913	Town Sq/Play ground	-	30.06	9.39	24.38	0.85
914	Cemeteries	16.24	7.13	3.13	10.48	3.19
921	Eroded Areas	6.06	5.06	1.77	1.45	3.94
922	Derelict Land	-	-	56.56	62.19	0.20

(Table 6.8) PERCENTAGE CATEGORY ERRORS USING DOT GRIDS - SAMPLE NUMBER 3

LAND USE CODE	L.U. CATEGORIES	DENSITY OF OBSERVATION 2 ha	1 ha	0.5 ha	0.25 ha	TRUE AREA DIGITISED CAT. PERCENTAGE AREA
013	Urban Housing Estate Low Density	8.99	30.88	8.99	6.18	1.36
021	Non-Estate Low Density	2.17	6.51	7.11	2.49	13.29
022	Non-Estate Med Density	-	41.44	8.41	10.79	1.01
031	Urban Res. New Dev.	32.84	3.42	16.22	4.26	1.84
1	Commercial	27.02	83.01	27.28	73.20	1.94
11	Open Market	-	60.34	3.38	17.91	1.49
12	Shops	44.07	38.10	8.05	30.70	0.86
13	Urban Core	17.68	0.27	11.14	13.54	9.44
141	Comm. New Dev.	-	-	-	3.77	0.16
241	Indust. New Dev.	-	83.05	4.57	43.38	0.32
31	Roadways	-	-	-	66.75	0.96
34	Harbour & Ferry	1.28	28.87	38.18	3.05	2.50
35	Rivers Navigable	0.09	1.27	2.69	7.76	11.10
42	Post & Telegraph	-	-	-	173.68	0.06
44	Petrol/Fuel Stn.	-	-	-	30.27	0.37
5	Institutional	26.33	20.56	15.11	4.53	6.70
51	School	-	104.90	6.82	66.10	0.29
53	Church/Mosque	-	-	-	48.51	0.31
54	Barracks	34.11	19.37	5.37	11.73	6.44
56	Health Centres	50.56	8.25	5.90	2.44	3.28
61	Crops	39.80	5.29	4.85	6.12	6.18
62	Horticulture/Veg	106.74	33.91	73.73	90.27	1.79
73	Grassland with Scattered Trees	48.19	25.49	55.43	67.86	2.38
74	Grassland	12.34	5.03	9.57	4.13	8.45
76	Scrubland	-	45.83	43.52	12.18	1.09
83	Lakes & Water Resv.	-	-	-	-	0.09
91	Open Space Improved	32.47	10.99	11.36	12.48	7.31
912	Parks	53.68	26.30	15.26	198.77	0.80
913	Town Sq/Play ground	191.70	249.56	27.07	41.05	0.85
914	Cemeteries	16.24	30.00	6.55	5.45	3.19
921	Eroded Areas	6.08	9.95	9.59	2.59	3.94
922	Derelict Land	-	-	-	62.19	0.20

6.4.2 Area measurement of the urban land use categories.

Having completed the mapping of the seven urban land use, air photo, trace overlays (Appendix I) the next step was to carry out a series of area measurements of the various land use categories.

Three types of area measurement were made:

i) using the four densities of grid squares in which the dominant use of each square was recorded (Table 6.1) and allocated an area equivalent to the whole grid square.

ii) using the four densities of dot grids in which only that land use which lay directly under the dot was recorded, but which also was allocated an area value equivalent to the whole grid square. (Table 6.2)

iii) using a digitizer to determine the area of each discrete and separate unit of each category of urban land use.

The digitizer records the co-ordinates of the boundary and a computer programme converts this to an area (Table 6.10).

6.4.3 Sampling of urban land use category areas

i) Grid squares

ii) Dot grids

i) Grid squares

The transparent grids were laid over the land use overlay and the dominant use was recorded of each square; each square having a known area value.

Each land use category was separately recorded and a table constructed as in the case of sample area 3 (Table 6.1) to show all the values for each of the four densities.

In order to aid comparison the areas for each separate land use category obtained from the digitization of the discrete boundaries were also included (Table 6.1).

ii) Dot grids

In this instance a regular grid of dots was used, each dot occupying the centre point of the grid square, and each dot being allocated an area value equivalent to the whole grid square.

In tabulating the land use only that use which lay directly under the dot was recorded irrespective of the proportion of the square it occupied (Table 6.2).

As with the grid squares, the areas obtained by digitizing the discrete boundaries were included, to permit comparison with those obtained in the dot grid sampling.

In the sampling, using dots or squares, it was possible to make a check on gross errors by comparing the total area of all the separate land use categories, in each sample, with the total known size of the sample area measured as a single unit.

6.4.4 Digitization of urban land use category areas

In order to assess the accuracy of the data obtained by sampling, the category areas were measured by boundary digitization of the interpreted overlays.

These digitized values were regarded as the best estimate against which all other methods of area measurement were to be compared.

The equipment used to carry out the boundary digitization were a Hewlett Packard 9827A digitizer, interfaced with a H.P. 9825A mini computer (Plate 5.5).

The standard digitizing programme normally used with this equipment was modified to accept the numerical classification codes, convert the measured areas from absolute digitizing units to hectares, sum the areas measured in each sample-category by category, and to aggregate the total sample areas. Also, a condition was included in the same programme such that when an error was made during the measurement, the erroneous measurement would be deleted from the total area by entering a code number ′999‵ on the computer key board.

Care was taken that the boundaries to be digitized were not

(Table 6.9) GRID SQUARES DIMENSIONS AT VARIOUS DENSITIES

Approximate Photographic Scale	Dimension of stereo model	Dimension of Unit Cell				Density of cells/Sample			
		2-ha	1-ha	.5-ha	.25-ha	2-ha	1-ha	.5-ha	.25-ha
1:6000	21.20 x 21.20 sq. cms.	2.36 cm.	1.67 cm.	1.18 cm.	0.83 cm.	81	169	324	625

(Table 6.10) DISCRETE LAND-USE AREAS OBTAINED BY DIGITIZING-
SAMPLE NUMBER 3

SAMPLE NO 3 DIGITIZED

L.U.	TOTAL AREA
13	2.202
21	21.576
22	1.641
31	2.984
100	3.149
110	2.423
120	1.391
130	15.327
141	0.265
241	0.525
310	1.561
340	4.052
350	18.021
420	0.095
440	0.598
500	10.882
510	0.469
530	0.505
540	10.461
560	5.324
610	10.035
620	2.908
730	3.868
740	13.718
760	1.774
830	0.138
910	11.871
912	1.304
913	1.374
914	5.172
921	6.400
922	0.320

sheet 162.333 ha

covered twice by the cursor for each unit area as this would give erroneous areas, and caution was also taken during each measurement to start from a known corner (within 'the active digitizing areas'), and to terminate on the same corner.

At the end of the measurements, those category areas with the same classification code were summed together, and all the categories aggregated into a single total as shown in Table 6.10 (Sample area number 3).

In order to check on gross errors in the measurement of areas by boundary digitization, the total areas of all the separate categories were added together and compared with a simple measurement of the area of each sample.

6.5 Adjustment of the areas measured by sampling

Before comparing the area values derived from digitizing, with those derived from sampling various grids of squares and dots, it is neessary to make some adjustments to the values derived from the sample surveys.

This adjustment is to ensure that the sum of the areas of all the separate categories of a given sample, should either be about or equal the total known area of that sample.

For each of the seven areas a separate correction factor was determined for every set of sample measurements made. This was calculated by using the ratio:

$$\frac{\text{Total known area (Digitized value)}}{\text{Total grid (dot or square) area}} = \text{G.A.F.}$$

and the resultant value was termed the Grid Area Factor.

Example

Given: Total known area of sample = 158.544 ha

Total 2ha grid square area = 162.000 ha

Single category unit area = 4.000 ha

The adjusted single category unit area will be

$$\frac{158.544}{162.000} \times 4.00 = 3.915 \text{ ha}$$

These adjustments were made:

i) For all seven sample areas

ii) For the four densities of grid squares

iii) For the four densities of dot grids

iv) For every separate unit of urban land use recorded.

As an example the results of sample area 3 are given. Table 6.3 shows the adjusted category values for dot grids. All these values are in hectares.

A comparison of these 'adjusted' area values with known (digitized) area values will indicate the 'error', in hectares, of each separate category. These are set out in Tables 6.5 and 6.6 for grid squares and dot grids respectively.

In order to compare the relative importance of these 'errors' it is necessary to convert these hectare values to percentage errors. This is done separately for each land use category as shown in Tables 6.7 and 6.8 for grid squares and dot grids respectively.

6.6 Accuracy of sampling

Stobbs (1968), described a random point sampling technique employed by the U.K. Directorate of Overseas Surveys in an Agricultural land use survey of Malawi. Even though this was on a rural/agricultural theme, its sampling technique is an important guide for urban land use survey.

The survey, using aerial photographs, was to determine the distribution of types of cultivated and uncultivated land.

In the test, each aerial photograph was sampled by means of a patterned template, with randomly arranged dots. In order to avoid sampling the same area twice, only the central portion of each photograph used was sampled. The number of points to be used on a template and their distribution were calculated in advance in order to obtain area estimates of the various land use categories. The formula used was:

"$N = (100 - P)38,400/(P \times E^2)$ (6.2)

where

N = the total number of sampling points

P = the percentage of the total area of the ecological or administrative unit occupied by the most critical land use category (in the first instance, P is usually an estimate)

38,400 = a constant based on Students 't', taken at the 95 percent level of probability

E = the percentage error within which results can be expected to fall in 95 percent of cases."

Using the above formula, for a critical land use with a 5 percent coverage of the total unit, and to delimit sampling error to 5 percent, the total number of sampling points would need to be

$$N = (100 - 5) \times \frac{38,400}{5 \times 5^2} = 29,184$$

6.6.1 Accuracy of systematic point sampling

Hitherto, the accuracy of systematic point sampling has been assessed on the binomial distribution as discussed by Stobbs (1968), and Kolbl and Trachsler (1980), where;

$$S\% = k \frac{P(100 - P)}{n} \qquad (6.3)$$

where

S% = the percentage error of one individual category in relation to the total area sampled, taken as 100%

n = the number of point samples used for the whole area

k = a constant based on the 't' distribution (k = 1.96 for a confidence limit of 95%)

P = category percentage area.

However, Bonnor (1975) and Zohrer (1978) have pointed out that the binomial formula is relevant to random rather than systematic samples. Furthermore, Zohrer has shown that the binomial formula gives an overestimate of error when applied to systematic samples. Rather more realistic error estimates should be based on the use of regression equations derived from experimental measurements. Zohrer suggests the following equation for the estimation of standard error percent of the estimate for area measurements:

$$\text{Log } (S\%) = 1.739 - 0.755 \text{ Log } n + 0.457 \text{ Log } P \qquad (6.4)$$

where,

n = number of dots falling within a parcel

P = the perimeter ratio i.e. the perimeter of the parcel divided by the perimeter of a circle of the same area. (P varies from 1.0 for a compact shapes to 4.0 for very irregular shapes)

Yuill (1971), after repeated measurements by dot grids of a variety of parcels of different shapes and extent, concluded that shape had no significant effect on the precision of area measurement, but rather, the parcel size and the dot densities were the most influential factors. The mathematical model he used in his test was:

$$\sqrt{S\%} = 3.625 - 0.493 \text{ Ln}X \qquad (6.5)$$

$(R^2 = 0.85)$

where,

S% = the average expected error (1 standard deviation from the mean)

R^2 = coefficient of total determination

Yuill carried the research further and developed a more complex mathematical model to support his assertion. His regression equation was:

$$\sqrt{S\%} = 17.11 - 1.849 \ \mathrm{Ln}X_1 - 1.338 \ \mathrm{Ln}(X_2\%) \qquad (6.6)$$

where (Coefficient of Multiple Determination $R^2 = 0.868$)

S% = the average expected error (i.e. category percentage error)

X_1 = number of points used in the measurement

X_2 = category percentage area

Yuill's results were based on repeated random placings of a regular grid of dots. Since no other method was tried for the sake of comparability, it would be unjustified to use the method as a source of reference for land use accuracy measurement.

Emmott and Collins (1980), employed the parameters suggested by Yuill in order to assess the accuracy of areas obtained by the use of dot grids on maps and aerial photographs.

Land use was interpreted on 1:10560 scale aerial photographs and recorded on overlays. These units were then transferred to the corresponding Ordnance Survey Maps and measured by means of a disc polar planimeter. Category areas were then determined by the use of a series of dot grids placed over the maps and over the photographs. Their results were as follows:

Measurement on maps:

$$\sqrt{S\%} = 11.62 - 1.01 \ \mathrm{Ln}X_1 - 1.57\mathrm{Ln}(X_2\%) \qquad (6.7)$$

$R^2 = 0.672$

Measurement on air photos:

$$\sqrt{S\%} = 11.36 - 0.93 \ \mathrm{Ln}X_1 - 1.66\mathrm{Ln}(X_2\%) \qquad (6.8)$$

($R^2 = 0.676$)

As indicated by the two equations, there exists a negative correlation in both the Y- and X- directions. The relevance of this is that the fitted model is statistically significant, however, since $100(R^2)$, of the equation (6.6), has 67.2% variation due to regression at the set probability level, 32.8% of its variation is undetermined.

Similarly, equation (6.7) has 67.6% variation due to regression and the undetermined variation equals 32.4%.

6.7 Multiple correlation and multiple regression analyses of the Calabar land use sample survey

The techniques of multiple correlation and regression analyses were used to test the relationship of error to the number of dots used and the category percentage area.

6.7.1 Multiple regression analyses techniques

Multiple regression analysis provides an analysis of the relationship among a set of variables for the purpose of prediction, estimation or smoothing of data. The basic assumption is that the variable of interest could be approximated by a linear function of several independent variables. If the functions or variates are non-linear, they could be linearised by extracting the square root of the dependent variable, and taking logarithms to base 'e' to convert the non-linear independent variable into linear forms. The errors involved in the approximations are assumed to be uncorrelated random variables with zero means and a constant variance.

This basic concept is deduced from the equation of a straight line fitted through a series of non-collinear points; where, theoretically, when a pair or more of points plotted on a diagram lie on a straight line, they satisfy a linear relationship thus:

$$Y = A + BX_1 + CX_2 + \ldots\ldots\ldots NX_n \qquad (6.9)$$

where,

A = intercept term,

B,C and others are the constants of the independent variables and the $X_1, X_2 \ldots\ldots X_n$ = the independent variables.

6.8 Input data for the regression analysis programme

The regression equation used was the modification of Yuill's equation (6.6) referred to earlier used by Emmott and Collins (1980), i.e.

$$\sqrt{S\%} = A + BLnX_1 + CLn(X_2\%) \quad (6.10)$$

and by removing the square root terms,

$$S\% = [A + BLnX_1 + CLn(X_2\%)]^2 \quad (6.11)$$

in which,

$$S\% = \frac{(\text{True Category Area} - \text{Measured Category Area}) \times 100}{\text{True Category Area}}$$

A = the intercept term to be determined.

B = the multiple regression coefficient for the total number of dots counted per sample area. This also is to be determined.

C = the multiple regression coefficient for the percentage category areas in each sample measured.

X_1 = total number of dots or grid squares counted in each sample.

X_2 = percentage category area expressed as:

$$\left(\frac{\text{category area}}{\text{total sample area}} \times 100\right)$$

There were altogether 1,232 observations made. Of these, 616 were measured using grid squares at densities of 2 hectares, one hectare, half hectare and quarter hectare respectively. The same procedures were used for the dot grids, which produced also 616 observations.

The first column in the input data (as may be seen in Appendices II and III respectively) represents the square root of the errors obtained in the measurements and this was denoted in the computer programme as CN0001, the dependent variable,

The second column in the observations (denoted by CN0002) the independent variable, is the natural logarithm of the number of dots or grid squares in each sample respectively; while the last independent variable in column three in the data is the natural logarithm of the category percentage area measured in each sample.

Multiple regression analyses were carried out to determine the constants A, B, and C of equation (6.9), for the results obtained by grid squares counting and by dot grids. These were performed by means of an I.C.L. 1900 Statistical Analysis package XDS3/27 (International Computers Limited, 1971).

This is a standard statistical procedure (see for example Harnett, 1975; Emmott, 1979), by which this package has been used to compute arrays of relationship between the variables of the dependent block and those of the independent block.

The results obtained from the regression analyses are shown in Tables 7.1 and 7.2 for the use of dot grids and grid squares respectively. These results are discussed in the next chapter.

The experiments were carried out to compare accuracy of area measurement on air-photos by means of dots and grids.

Since the 'true' areas were also measured on the air photo overlays, no estimate of equivalent 'map areas' could be made, but, Emmott (1979), indicated that when using commercial aerial photographs at medium scales (for urban areas having small relief variations), measurements made by grids on aerial photogrpahs and maps were of very similar accuracy.

CHAPTER SEVEN

7 RESULTS OF REGRESSION AND CORRELATION ANALYSES.

7.1 Dot Grids : Regression Analysis.

From the results of the regression and correlation analyses (Table 7.1), it may be seen that:

The coefficient of multiple correlation (R) of 0.715 (with 616 observations), a unity weight assigned, indicated that the multiple regression equation is significant at the 0.1% confidence level.

The coefficient of Multiple Determination (R^2) of 0.511 indicated that 51.1% of the variance of $\sqrt{(S\%)}$ was explained by the regression equation relating $\sqrt{(S\%)}$ to LnX_1 and $Ln(X_2\%)$. Hence the generalisation and the use of equation (6.10) was justified.

The values of the 't' statistics indicate that both LnX_1 and $Ln(X_2\%)$ were significant to $\sqrt{(S\%)}$ at the 0.1% confidence level with $Ln(X_2\%)$ being the more influential factor.

The partial correlation coefficients for LnX_1 and $Ln(X_2\%)$, were -0.39 and -0.68 respectively. These indicate a strong relationship in the model and removed any 'bias' about the nature of 'R' computed, since some variates were removed during the computation.

Standard error for $Ln(X_2\%)$ was better in the approximation than that of LnX_1. These indicated the precision in which the digitized percentage areas were as compared to those of the dot grids.

7.2 Grid Squares : Regression Analysis.

From the results of the regression and correlation analyses (Table 7.2), it may be seen that:

The coefficient of multiple correlation (R) of 0.679 (with 616 observations), a unity weight assigned, indicated that the multiple regression equation was significant at the 0.1% confidence level.

The coefficient of multiple determination (R^2) of 0.461 indicated that 46.1% of variance in $\sqrt{(S\%)}$ was due to regression at 40% probability level. This shows that the fitted model (equation 6.11), is statistically significant, however, 53.9% of the variability could be explained due to approximations in the model.

The 't' statistics for LnX_1 and $Ln(X_2\%)$ were significantly related to $\sqrt{(S\%)}$ with relationship being closer to $Ln(X_2\%)$ than LnX_1.

The partial correlation coefficients for LnX_1 and $Ln(X_2\%)$, were -0.39 and -0.63 respectively. These indicated a strong relationship in the model and furthermore, removed any false impression or bias about the nature of 'R' computed during the regression analyses. They also confirmed the strong relationship still existing despite the fact that some variates have been removed.

The precision indices (i.e. the mean square errors) for LnX_1 was 0.132 and 0.068 for $Ln(X_2\%)$. These indicated that the category percentage areas had a more significant role in the measurement than the densities and were more precisely measured than the grid squares counting and both were significant at the 0.1% confidence level. Hence the model minimised the residuals.

7.3 Mathematical models from regression equations

Using the results shown in Tables 7.1 and 7.2 respectively, two regression equations could be formed thus:

For the use of dots:

$$\sqrt{S\%} = 13.688 - 1.381\ LnX_1 - 1.602\ Ln(X_2\%) \qquad (7.1)$$

$R^2 = 0.511 \quad R = 0.7148 \quad 100R^2 = 51.10\%$

For the use of grid squares:

$$\sqrt{S\%} = 13.534 - 1.390\ LnX_1 - 1.397\ Ln(X_2\%) \qquad (7.2)$$

$R^2 = 0.461 \quad R = 0.6789 \quad 100R^2 = 46.1\%$

These regression lines are plotted in Figures 7.1 and 7.2 for a

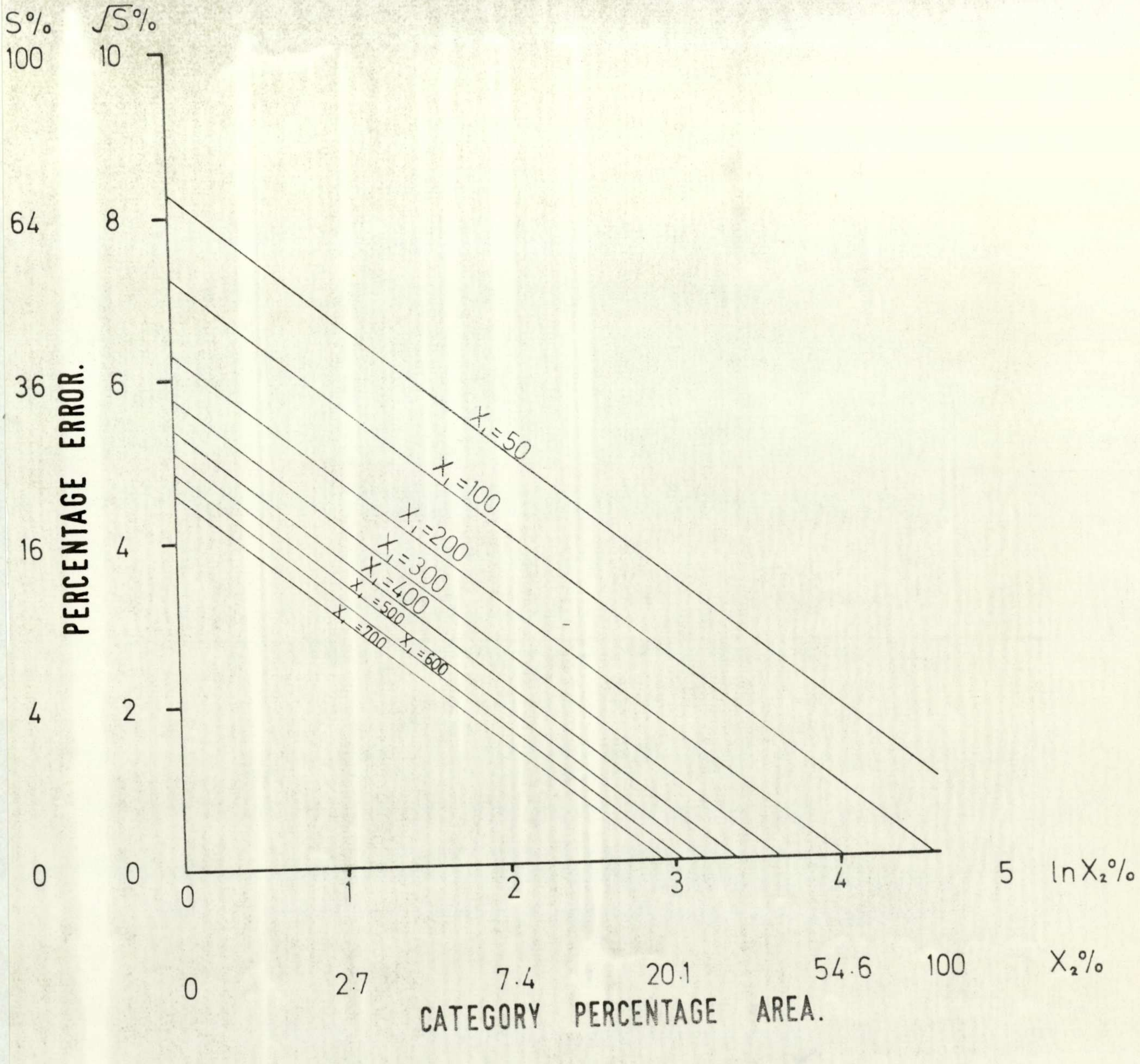


Figure 7.1 Percentage error against category percentage area: (dot grids)

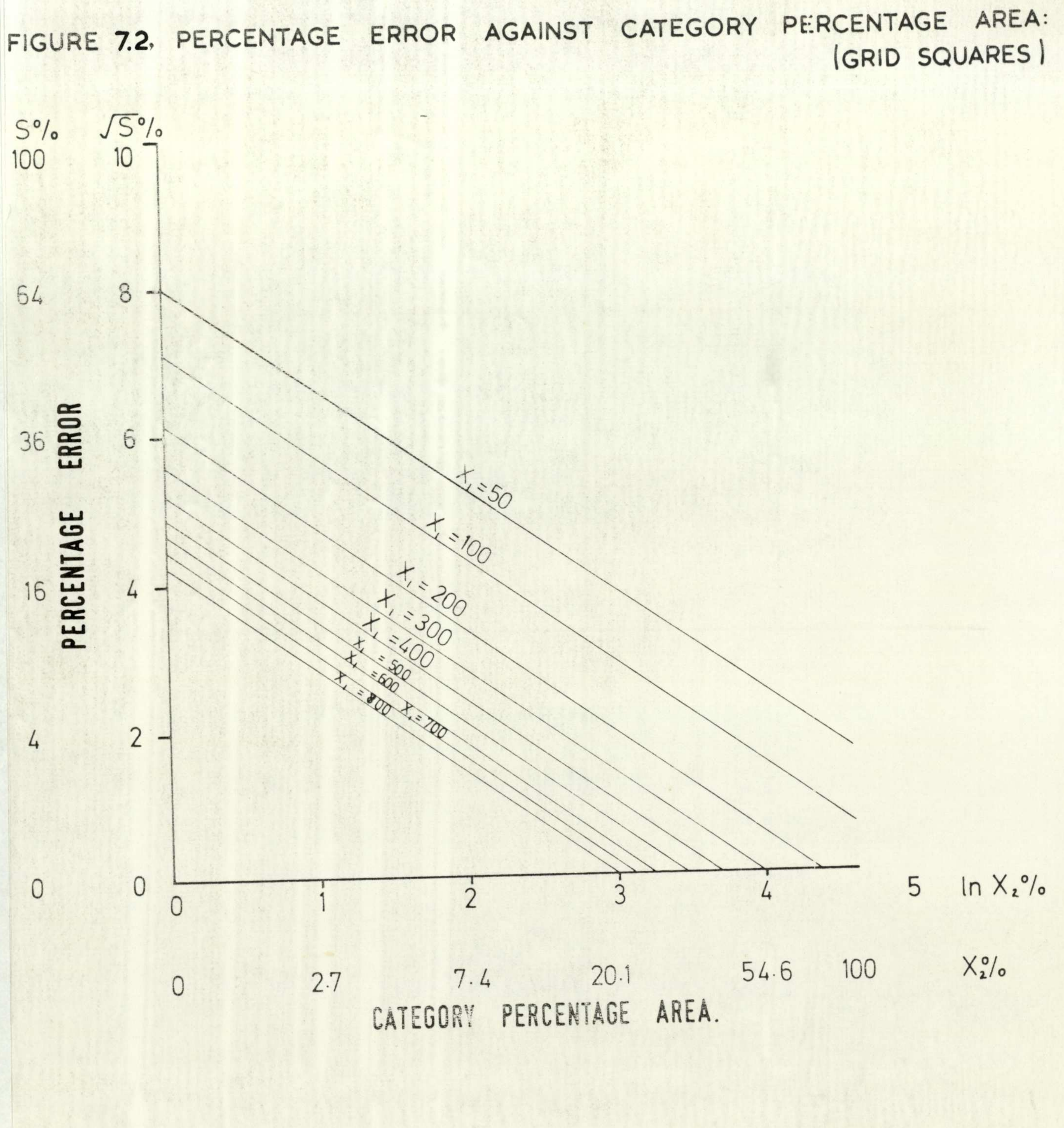


Figure 7.2 Percentage error against category percentage area: (grid squares)

range of values of X_1 (i.e. from X_1 = 50, to X_1 = 800).

Statistically, two variates are said to be correlated positively, if both variates increase or decrease together. In both graphs, the categories percentage errors and the percentage categories areas both decreased together. This indicates a positive correlation.

If, on the other hand, an increase in errors would have been associated with a decrease in the areas measured, this would have been a negative correlation. But, this was not the case in the analyses.

In multiple regression analysis, the closer the multiple correlation coefficient 'R' is to +1 or -1, the closer is the relationship between the dependent variable and the independent variables; and, the closer 'R' is to 0, the less close is the relationship. Hence, the full interpretation of the multiple correlation coefficient 'R' depends on circumstances. The higher the 'R', the better is the estimate between the variables. In the test, the 'R' for the use of dot grids was 0.715, while the 'R' obtained with the use of grid squares was 0.679.

The statistical significance of this was that the model in the regression analyses fitted better with the dot grids than with the square grids.

It may be noticed that the graphs get closer and closer as the origin is approached. This was so because the regression lines were plotted using equal increments of X_1, on a natural logarithmic scale.

On the other hand, had the lines been plotted for a geometric series of increments of X_1 (i.e. 50, 100, 200, 400 and 800 respectively), the lines would have been evenly spaced.

Also, judging from the two graphs, both the percentage category errors, the category percentage areas, get smaller and smaller with the increment in the value of 'X_1' from 50 to 700. This indicates that a very close relationship exists between the number of dots or grid squares counted, the percentage category areas and the percentage category errors obtained from each combination of the three variables.

The implication of this is that a smaller area, with a greater number of dots or grid square counts will have a smaller error than the same area with lesser number of dots or grid square counts. Therefore, to increase accuracy (i.e. to decrease $\sqrt{S\%}$), 'X_1' must be increased greatly.

It is also noticed that small values of $X_2\%$ produce large errors $\sqrt{S\%}$. This is a result of the use of percentage values with actual errors not decreasing in proportion as category areas decrease.

(Table 7.1) DOT GRID STATISTICS FROM REGRESSION ANALYSES

VARIATES	'OUTPUT' VALUES	COMMENTS
Intercept term	13.688	Major statistics
Multiple Correlation Coefficient	0.715 = R	for the whole
Coefficient of Multiple Determination	0.511 = R^2	approximation in
$100R^2$	51.10%	in the Regression
Regression Coefficient for X_1	-1.381	
Standard error for X_1	0.134	
Confidence Interval for X_1	0.112	Data for X_1,
'T' statistics for X_1	10.340	the dot grids
Partial correlation coefficient	-0.390	densities counted
Multiple correlation coefficient X_1	0.652	per samples
Regression coefficient for ($X_2\%$)	1.607	
Standard error	0.069	Data for ($X_2\%$),
Confidence interval	0.058	the percentage
'T' statistics	23.07	category areas
Partial correlation coefficient	-0.680	used in the sample
Multiple correlation coefficient	0.292	

(Table 7.2) GRID SQUARE STATISTICS FROM REGRESSION ANALYSIS

VARIATES	'OUTPUT' VALUES	COMMENTS
Intercept term	13.534	Major statistics
Multiple Correlation Coefficient	0.679 = R	for the whole
Coefficient of Multiple Determination	0.461 = R^2	approximation in
$100R^2$	46.10%	in the Regression
Regression Coefficient for X_1	-1.390	
Standard error for X_1	0.132	
Confidence Interval for X_1	0.111	Data for X_1
'T' statistics for X_1	10.530	the grid square
Partial correlation coefficient	-0.390	densities counted
Multiple correlation coefficient X_1	0.602	per samples
Regression coefficient for (X_2%)	-1.397	
Standard error	0.069	data for (X_2%)
Confidence interval	0.058	the percentage
'T' statistics	20.340	category areas
Partial correlation coefficient	-0.630	used in the sample
Multiple correlation coefficient	0.310	

CHAPTER EIGHT

8 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary

The City of Calabar, Nigeria was selected as the region for the research project. An initial urban land use classification was compiled and its suitability tested by making a first study of the aerial photography. From the experience gained in this, a revised classification was compiled which was considered more suitable and relevant to the urban land use mapping of Calabar City.

Using this revised classification the aerial photographs of the whole of Calabar City were stereoscopically examined and the urban land use information was marked on transparent overlays (about 400) on the photography. A total of 65 different categories of urban land use were identified from the aerial photographs.

It was considered inappropriate in a research project to attempt to measure areas on <u>all</u> the annotated overlays, hence sampling methods were used to acquire information on the type and extent of the various urban land use categories of Calabar City.

From this total survey of Calabar City and environs, seven samples were selected, each comprising the area of a single aerial photograph, which together represented 7% of the total study area.

These samples were chosen to represent a cross section of the different types of urban land use which exist in the City. The seven annotated urban land use overlays were used as the data source to test the efficiency and accuracy of the alternative methods of measuring areas.

The urban land use areas of each sample were measured by three different methods.

i) By digitizing the co-ordinates of the boundaries of each land use category.

ii) By grid squares, using separately four different densities of grid (81, 169, 324 and 625 observations per sample) which correspond to a fixed area per square (2ha, 1ha, 1/2ha and 1/4ha respectively).

iii) By dot grids, using the same four densities as in the grid square method.

Th discrete boundary values were accepted as the 'standard' against which the results obtained from the four sets of values from each of the squares and the dot grids were to be compared.

Before making this comparison it was necessary to make some minor adjustments to the values obtained by the square and dot grid methods. This was to ensure that the total sample areas derived from the dot and grid square measurements, agreed with the total sample areas derived from boundary digitization. A 'correction factor' was derived for each set of measurements.

These 'adjusted' area values were then compared with the 'standard' area values and the errors were determined, both in hectares and percentages, for each category of land use.

These adjusted values were tested, to determine the most influential factors affecting the accuracy of the measurement, by the use of multiple correlation and regression analyses in a mathematical model which related,

i) density of observation

ii) category size (as a percentage of sample area)

iii) accuracy (as a percentage of sample area measurements using square and dot grids).

A series of graphs were compiled which showed these relationships, and which enabled the user to select those values which most suited his need.

8.2 Land Use Categories Identified.

Table 8.1 lists the number of land use categories identified from the aerial photographs, and use as the unit of reference the number found when digitizing the discrete boundaries.

The number of land use categories are recorded

i) for each of the seven sample areas

ii) for each of the four densities

iii) for both grid squares and dot grids.

In addition the time taken for each of these measurements is recorded in Table 8.1.

In general more categories were identified as the density of observations were increased. However there were a number of instances (10 out of a total of 24) in which no additional categories were identified in spite of an increase in the density of observations.

In only seven instances (out of 56) did the sampling identify all the categories of land use which were found in the discrete mapping, and it is most likely that those not identified were the smaller categories.

As to be expected the time taken to record the data increases with the increasing density of observations, though the time increase is not regular.

In theory it would have been anticipated that for a given density of observation the time taken would have been the same for each sample. In fact as experience was gained in doing the task the time taken was generally reduced.

8.3 Comparison of Results

For every single category of urban land use identified and marked on the seven transparent overlays, the following data were determined.

a) the area of each category

b) the area error in hectares

(Table 8.1) CATEGORIES MEASURED BY THE USE OF GRID SQUARES AND DOT GRIDS

METHODS	SAMPLE NUMBER	Total sample categories	Number of categories included				Time Taken (minutes)				Digitizing time (minutes)
			81 2ha	169 1ha	324 .5ha	625 .25ha	81 2ha	169 1ha	324 .5ha	625 .25ha	
GRID SAMPLES	1	25	17	19	21	25	30	45	60	90	88
	2	28	24	25	25	27	25	35	50	60	65
	3	32	20	25	25	31	20	30	42	45	60
	4	13	10	13	13	13	15	30	45	50	55
	5	21	14	15	17	19	30	40	50	60	65
	6	17	10	12	14	16	25	40	45	55	60
	7	20	12	16	16	20	25	45	50	55	60
DOT SAMPLES	1	25	20	20	23	25	30	36	60	95	88
	2	28	24	24	26	28	30	40	55	65	65
	3	32	22	25	29	30	25	40	50	60	60
	4	13	10	12	13	13	20	35	42	50	55
	5	21	13	16	17	19	35	46	55	65	65
	6	17	12	15	15	17	30	38	50	60	60
	7	20	14	17	17	19	27	40	54	65	60

(Table 8.2) RELATIONSHIP BETWEEN % ERROR AND GRID SIZE FOR SELECTED VALUES OF CATEGORY PERCENTAGE AREA

CATEGORY PERCENTAGE AREA (X_2%)	GRID SQUARE SIZES 2HA X_1=81		1HA X_1=169		.5HA X_1=324		.25HA X_1=625	
	S%	S^2%	S%	S^2%	S%	S^2%	S%	S^2%
1%	7.43	55.0	6.40	41.01	5.55	30.82	4.64	21.63
5%	5.18	26.8	4.15	17.21	3.25	10.59	2.33	5.45
10%	4.20	17.75	3.19	10.18	2.29	5.23	1.37	1.87
20%	3.24	10.47	2.21	4.90	1.31	1.72	0.39	0.15
50%	1.96	3.85	0.94	0.88	0.04	0.0	-0.88	0.78

where S = ERROR %

X_1 = TOTAL DOTS OR GRIDS COUNTS PER SAMPLE MODEL

(Table 8.3) RELATIONSHIP BETWEEN % ERROR AND GRID SIZE FOR SELECTED VALUES OF CATEGORY PERCENTAGE AREA

CATEGORY PERCENTAGE AREA (X_2%)	DOT GRID SIZES 2HA X_1=81		1HA X_1=169		.5HA X_1=324		.25HA X_1=625	
	S%	S^2%	S%	S^2%	S%	S^2%	S%	S^2%
1%	7.63	58.15	6.60	43.60	5.71	32.56	4.79	22.98
5%	5.04	25.41	4.02	16.20	3.13	9.78	2.22	4.91
10%	3.93	15.48	2.92	8.51	2.02	4.08	1.11	1.23
20%	2.81	7.93	1.80	3.23	0.90	0.81	-0.01	0.00
50%	1.35	1.83	0.34	0.11	-0.56	0.31	-1.47	2.17

Where S = ERROR%

X_1 = TOTAL DOTS OR GRIDS COUNTS PER SAMPLE MODEL

c) the area error as a percentage

d) the density of observation.

The next step was to identify how these factors are related, and a mathematical model was used to determine the quantitative values of these relationships. The results obtained from the mathematical model of the multiple regression and correlation analyses were used to compute the statistics shown in Tables 8.2 and 8.3, which set out these values for five grades of category percentage area for grids and dots.

To aid an understanding of these relationships the information is shown in graph form. Figures 8.1 to 8.5 each show the relationships between percentage error and density of observations when the category unit area is a specific proportion of the sample area.

Figures 8.6 to 8.9 each show the relationship between percentage error and percentage size of unit (category) area with a specific density of observation.

8.4 Conclusions

For both grid squares and dot grids there is an increase in accuracy with

i) an increase in the density of observations

ii)an increase in the size of the category area.

The general pattern of accuracy is similar for both squares and dots but they differ marginally in magnitude.

In the measurements recorded in Table 8.2 the most striking differences in accuracy are related more to the category of percentage area than to density of observations.

Where the category percentage area is very small i.e. 1%, then at all densities of observation the square grid yields slightly higher accuracies.

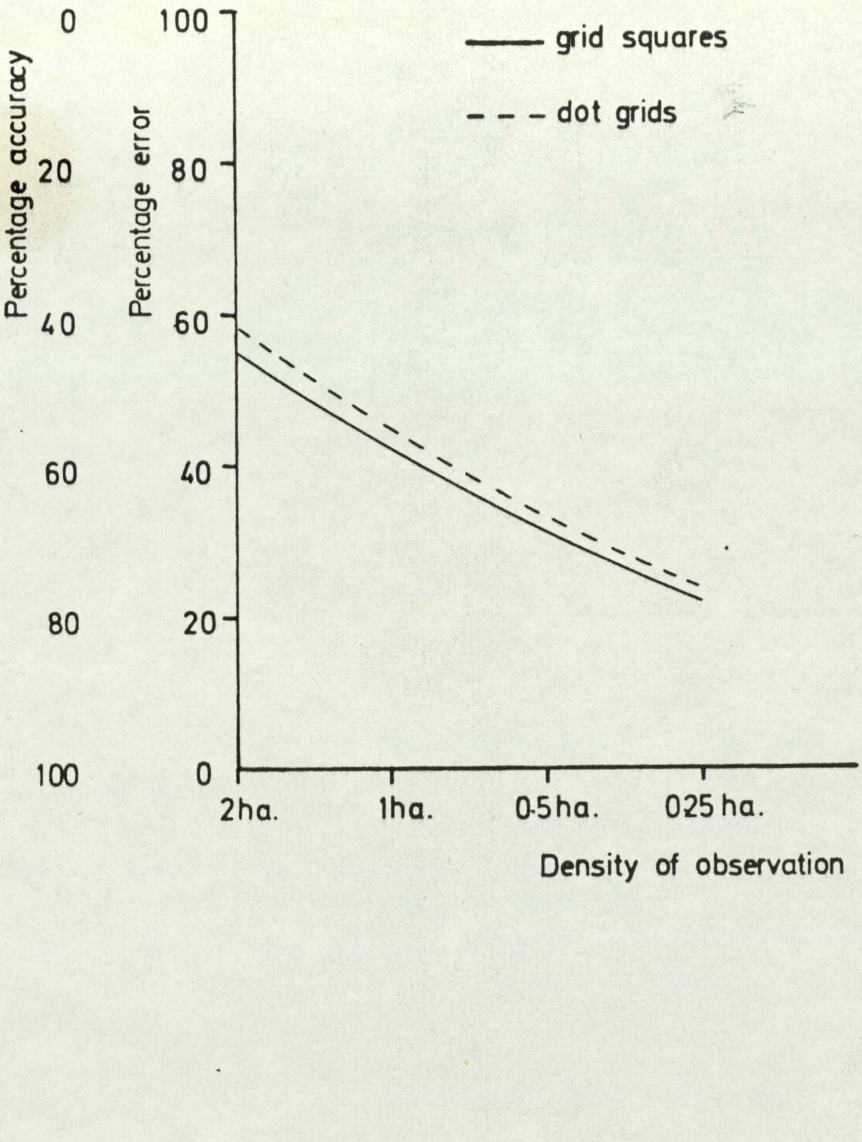


Figure 8.1 Relationship between percentage error and density of observation: When a given unit is 1% of survey area.

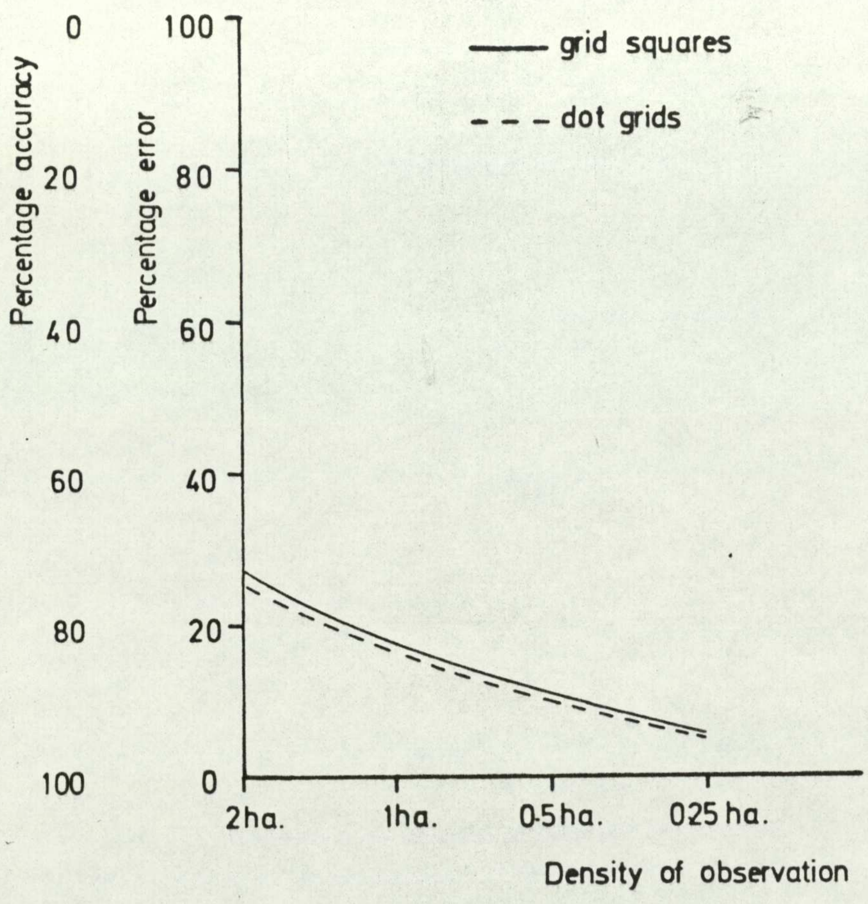


Figure 8.2 Relationship between percentage error and density of observation: When a given unit is 5% of survey area.

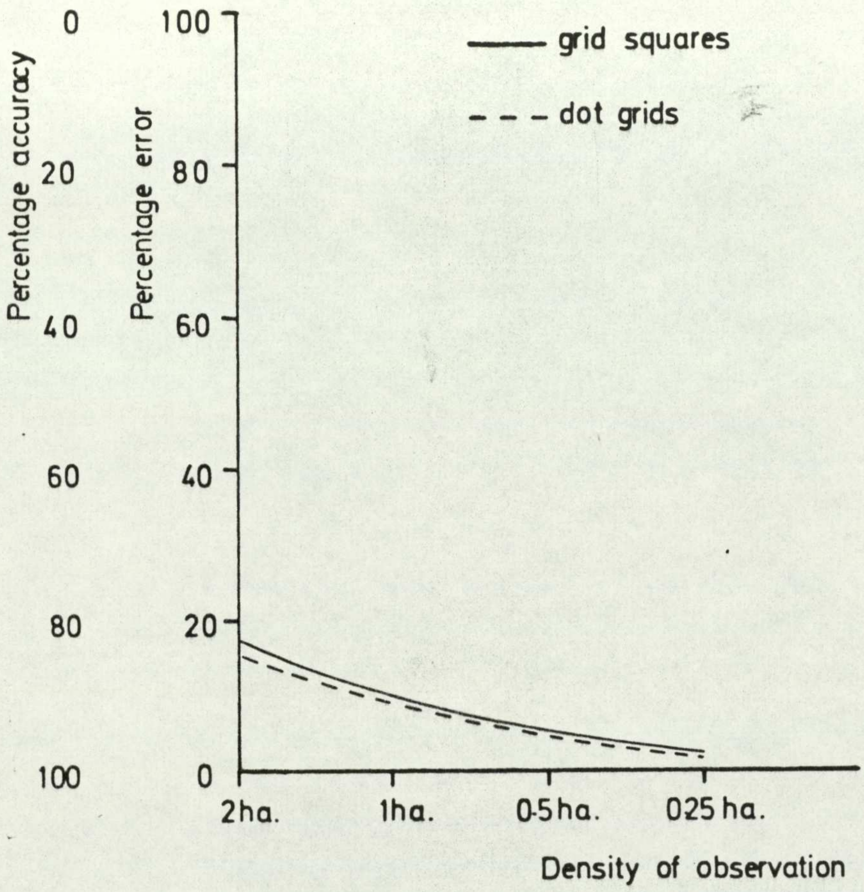


Figure 8.3 Relationship between percentage error and density of observation: When a given unit is 10% of survey area.

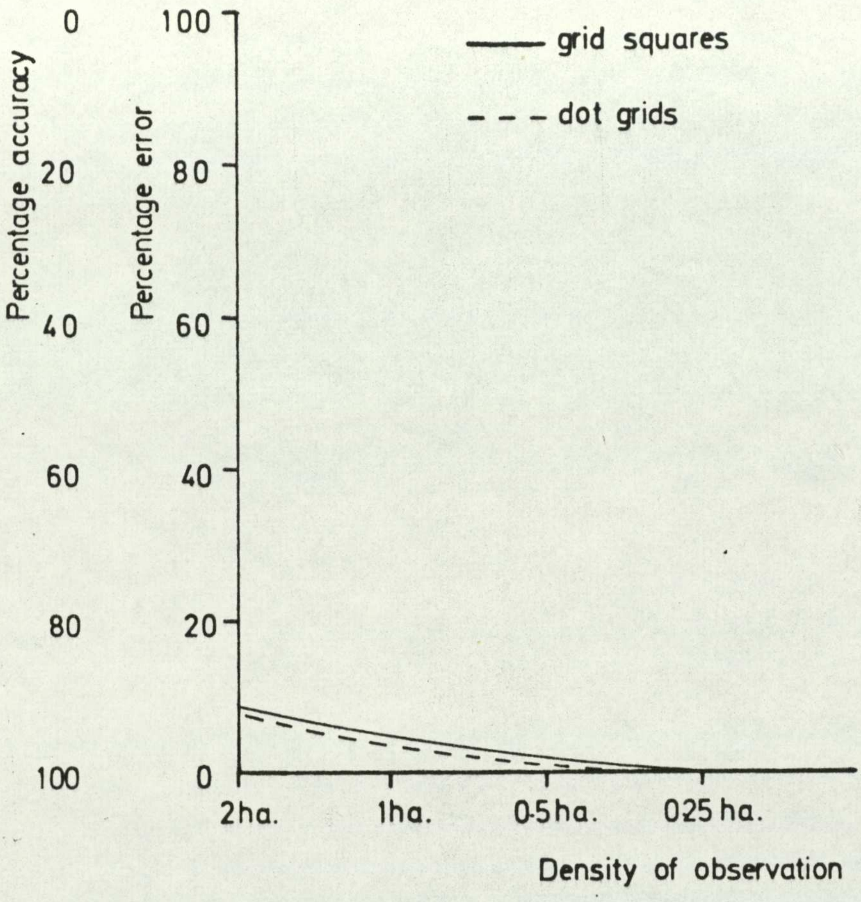


Figure 8.4 Relationship between percentage error and density of observation: When a given unit is 20% of survey area.

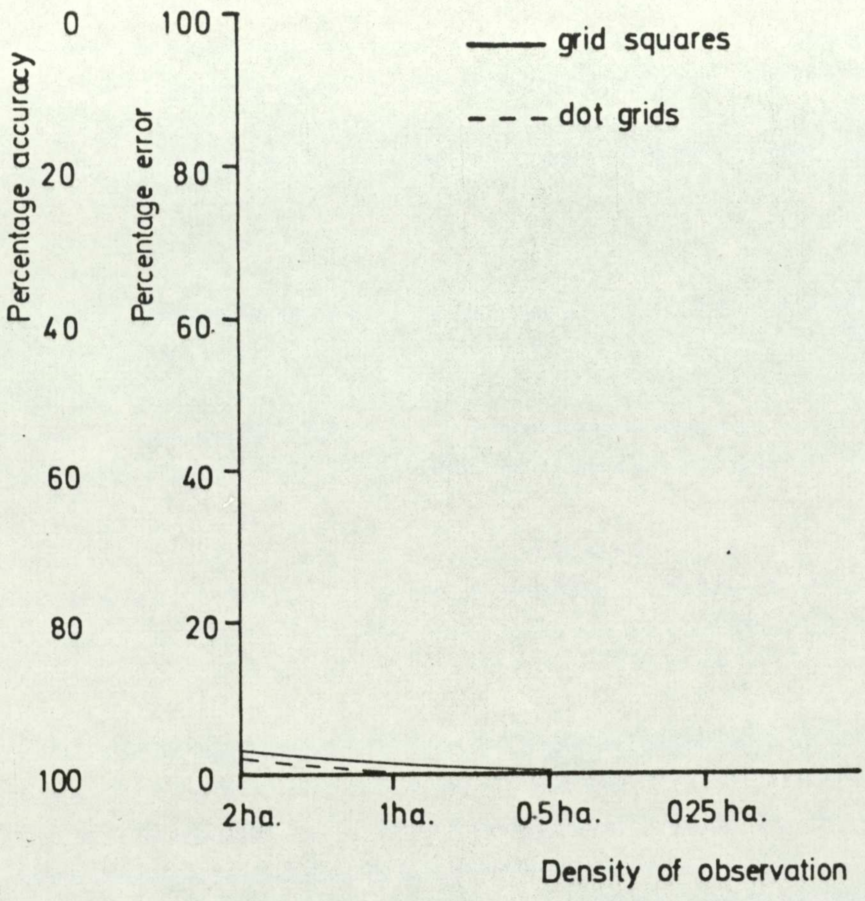


Figure 8.5 Relationship between percentage error and density of observation: When a given unit is 50% of survey area.

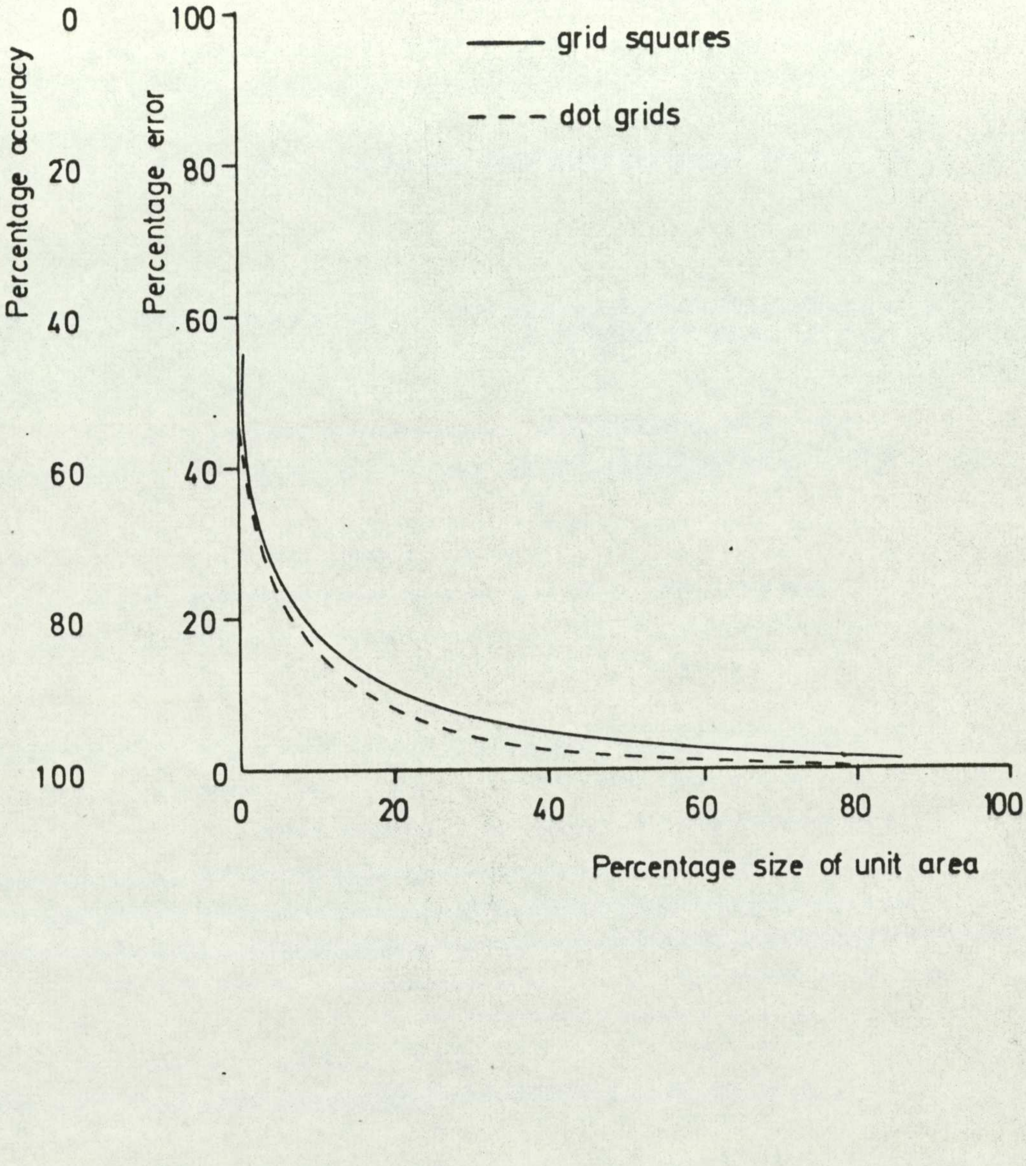


Figure 8.6 Relationship between percentage error and density of observation: Given density of 81 observation per sample area. (2-Hectare grid).

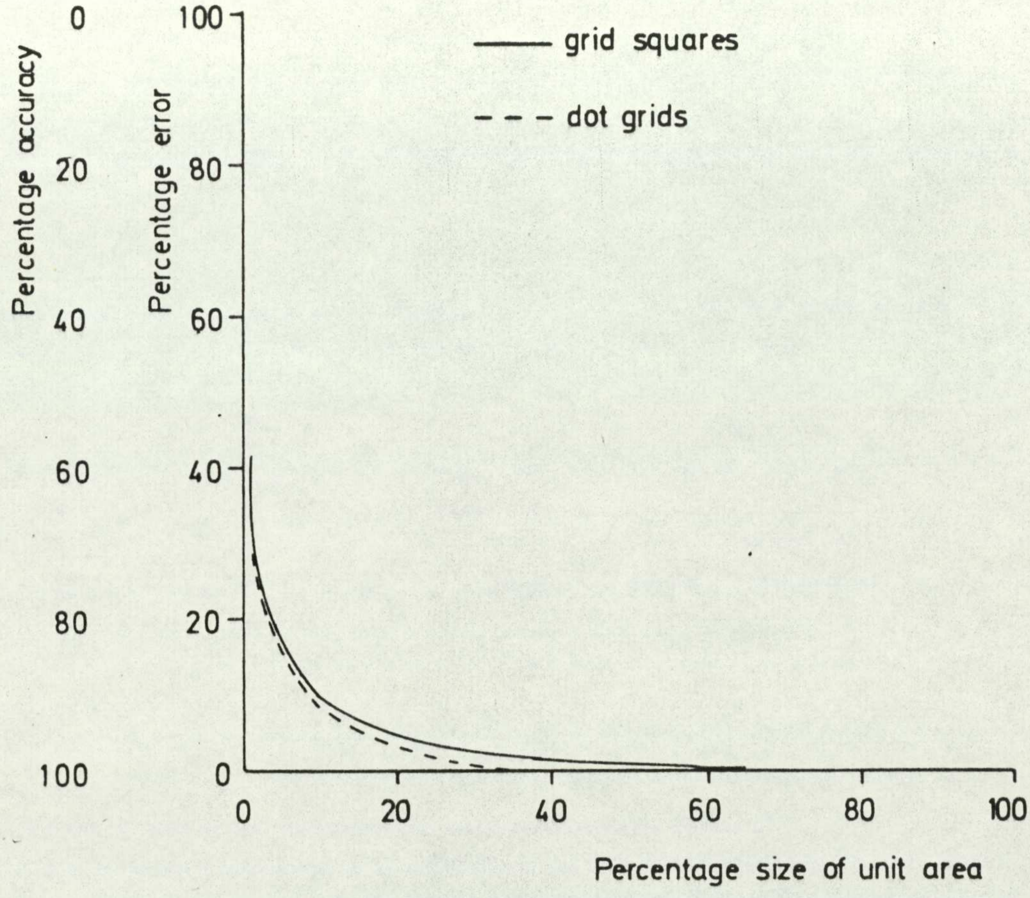


Figure 8.7 Relationship between percentage error and percentage size of unit area: Given density of 169 observations per sample area. (1-Hectare grid).

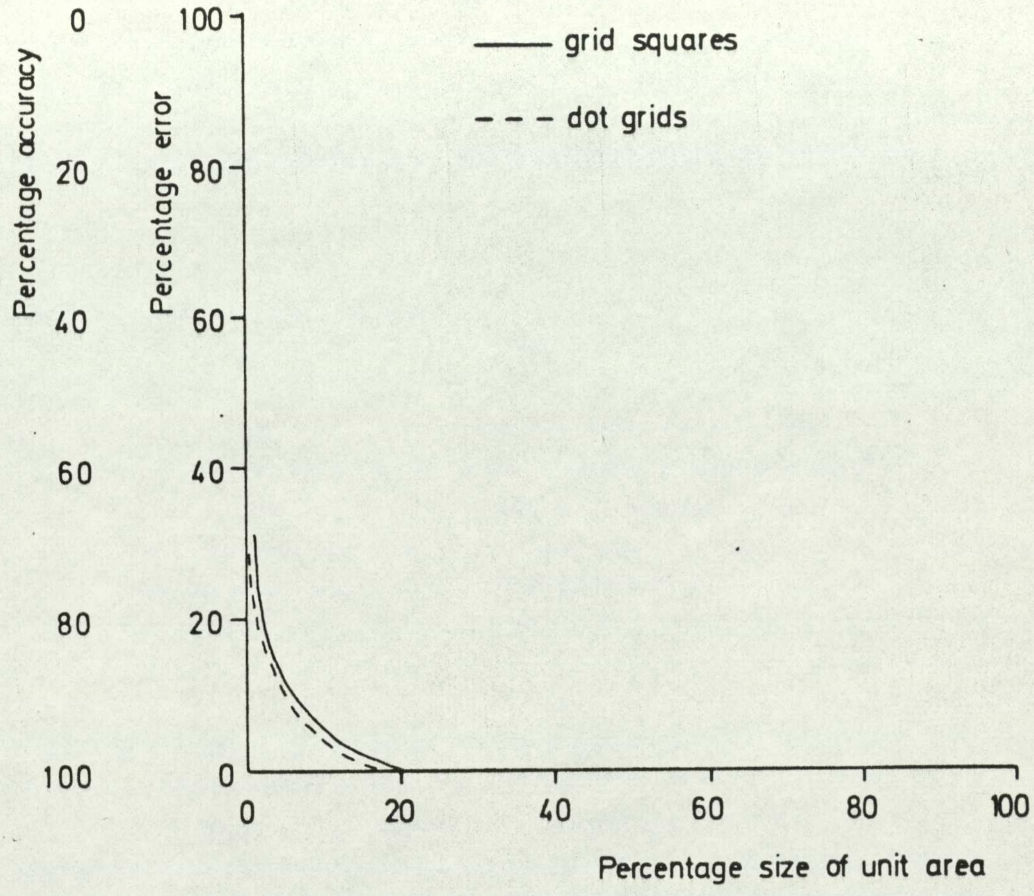


Figure 8.8 Relationship between percentage size of unit area: Given density of 324 observations per sample area. (0.5-Hectare grid).

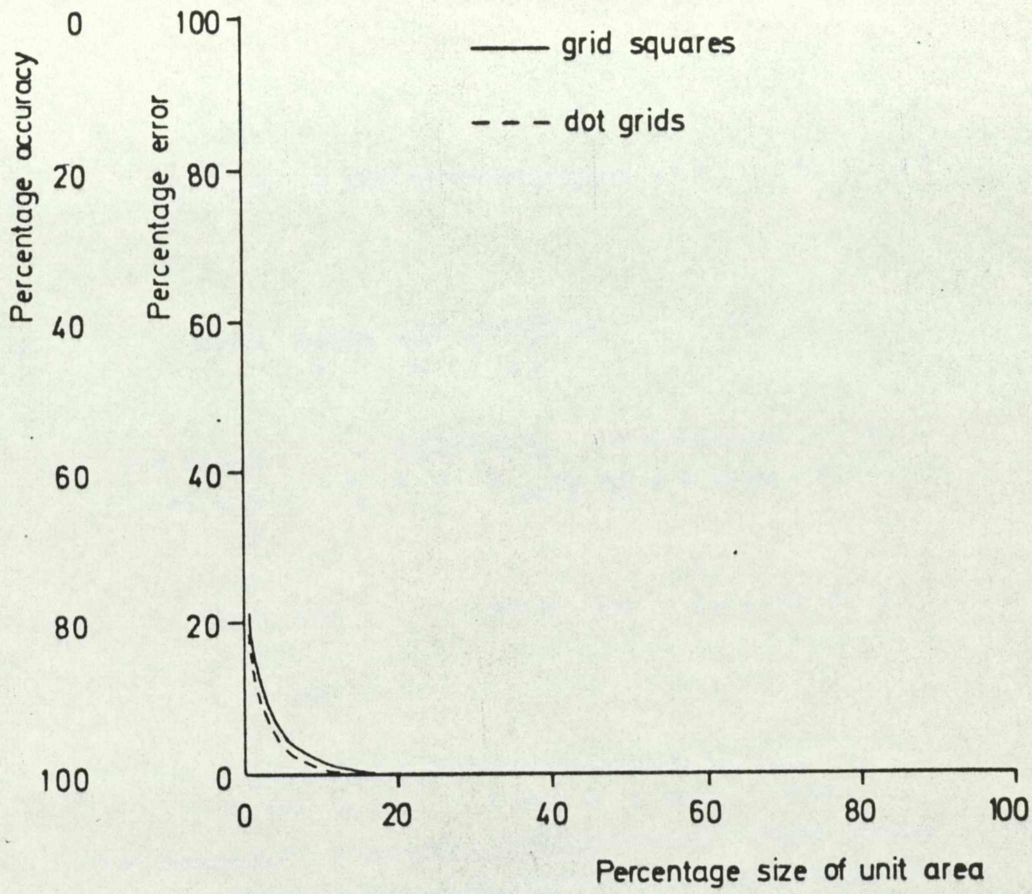


Figure 8.9 Relationship between percentage error and percentage size of unit area: Given density of 625 observations per sample area. (0.25-Hectare grid).

Where the category percentage area is greater, i.e. 5% and above, then at all densities of observations the dot grids yield slightly higher accuracies than the grid squares.

Figures 8.1 and 8.4 show a steady increase in accuracy with an increase in the category percentage area, whilst figures 8.6 to 8.9 show a much more dramatic increase in accuracy with category percentage area, especially when the latter is above 20%.

These results suggest that when the category percentage area is under 20% the need to increase the density of observations is very much greater than if the category occupies more then 20% of the sample area.

On the other hand figures 8.6 to 8.9 also show that there is no advantage in increasing the density of observations above the 0.5ha grid when this value of 20% is reached.

It is hoped that the information and relationships evident in figures 8.1 to 8.9 will be of some value to those wishing to carry out sample surveys of urban land use in other cities in Nigeria.

8.5 Recommendations

In a country like Nigeria, with its rapidly growing urban centres, there is an urgent need to map and monitor urban development.

There is ample evidence that aerial photographs provide a very quick, cost-effective method of gathering urban land use data. The method offered here, of sampling by grid squares and dot grids is well within the resources of other Nigerian researchers, though the acquisition and use of electronic digitizers might be a constraint in some instances.

There is therefore a need for others to investigate, test and modify this initial methodology. In particular the urban land use classification should be tested in other Nigerian cities to identify what alterations might be necessary to enable the classification to be use nationally. It would be useful to use multi-scale aerial photography to determine the optimum scale required to provide a specified level of detail.

Studies of urban land use in Nigeria are very rare, and there is a need to extend this type of study to other Nigerian cities to determine to what extent the values and results obtained may also apply elsewhere. Studies should also be launched in which multi-temporal aerial photography is used to monitor the growth and changes in Nigerian cities.

Although this study has not concerned itself with the accuracy of urban land use mapping with the aid of aerial photographs, some studies are required which quantify the accuracies attainable under various conditions and with various types of photography.

Clearly there is much to do, but it is hoped that this initial study will make some useful contribution to the need for acquiring information which is urgently needed for survey and urban planning in Nigeria.

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Anderson et al, 1972 3.7
Anderson et al, 1976 3.7
Animashaun, 1978 3.9
Armand, 1965 3.1
Best, 1957 3.3
Best, 1958 3.3
Best, 1959 3.3
Best and Coppock, 1962 3.3
Buringh, 1960 1.6
Calabar Master Plan, 1969 2.2
Champion, 1974 3.4
Chisnell and Cole, 1958 4.7
Clawson and Steward, 1965 1.1
Coleman, 1959 3.4
Coleman, 1964 3.4
Collins, 1967 1.6
Collins and El Beik, 1971 1.6
Collins, 1972 3.8
Collins, 1974 4.2
D O E, 1978 3.5
Emmott, 1979 3.3,3.6
Fordham, 1974 3.4
Goosen, 1967 1.6
Kio, 1971 3.8
Leuder, 1959 1.6
MTCP, 1951 3.4
MacDonald, 1970 3.1
MacDonald, 1971 3.6
Morain and Campbell, 1974 1.5
Mortimore et al, 1966 3.9
Nunally and Witmer, 1970 3.2
Obenson, 1977 2.3,2.5
Olawoye, 1974 2.4
Reference Survey and Development Plan of Calabar, 1969 3.10
Robertson and Stoner, 1970 3.1
Van Genderen et al, 1975 3.1
Van Genderen and Smith, 1976 3.5
Vink, 1963 1.6
Wikkramatilek, 1959 3.8
White, 1977 1.3
Witenstein, 1954 3.7
Witenstein, 1955 3.7

(Appendix II) Computer Programme used with Hewlett-Packard Digitizer.

```
0: "Driver for Area subroutine":
1: dim A$[15],N$[15],L$[72],A[72],T[74],C[74]
2: 0→C[1];10→C[2];11→C[3];12→C[4];13→C[5];20→C[6];21→C[7]
3: 22→C[8];23→C[9];30→C[10];31→C[11];32→C[12];100→C[13]
4: 110→C[14];120→C[15];130→C[16];140→C[17];141→C[18];142→C[19]
5: 200→C[20];210→C[21];220→C[22];230→C[23];240→C[24];241→C[25]
6: 242→C[26];300→C[27];310→C[28];320→C[29];330→C[30];340→C[31]
7: 350→C[32];400→C[33];410→C[34];420→C[35];430→C[36];440→C[37]
8: 500→C[38];510→C[39];520→C[40];530→C[41];540→C[42];550→C[43]
9: 560→C[44];570→C[45];600→C[46];610→C[47];620→C[48];630→C[49]
10: 631→C[50];632→C[51];700→C[52];710→C[53];720→C[54];730→C[55]
11: 740→C[56];750→C[57];760→C[58];800→C[59];810→C[60];820→C[61]
12: 830→C[62];840→C[63];850→C[64];900→C[65];910→C[66];911→C[67]
13: 912→C[68];913→C[69];914→C[70];920→C[71];921→C[72];922→C[73]
14: 1000→C[74];0→U
15: 706→D;ent "ENTER DIGITIZER SELECT CODE(706)",D
16: int(D/100)→A;int(D-A*100)→B
17: if A<0 or A>16 or B<0 or B>31;jmp -2
18: "HECTARES"→N$
19: 6000→P;ent "Scale of photo 1:",P
20: fxd 3;if P>1;fxd 2
21: prt "Fa -FINISHED","DIGITIZING AREA","Fb -STOP";prt " ";prt " "
22: wrt D,"df;at"
23: gto "Area subroutine"
24: "Print answers":fmt 1,c6,f7.3,c3
25: wrt 16.1,"AREA= ",A," ha"
26: fmt 2,f6.3;wrt D+.2,"lb",A
27: 0→J
28: ent "L.U.code",L
29: fmt 5,c8,f6.0
30: wrt 16.5,"L.U.code",L;prt " "
31: if L=999;gto "Area subroutine"
32: for I=1 to 74
33: if L=C[I];I→J
34: next I
35: if J=0;jmp -7
36: U+A→U
37: T[J]+A→T[J]
38: "Area subroutine":
39: 0→E→X→Y;"BEGIN DIG"→A$;gsb "Display"
40: wrt D,"bp;cn32000,1;sk1"
41: gsb "Input"
42: if K=2;gto "Fb"
43: if X=0 and Y=0;jmp -2
44: X→F→G;Y→M→N
45: "L1":gsb "Input"
46: gsb "Sum"
```

```
dsp (X-F)*.96851938/1000*1,(Y-M)*.96851938/1000*1
fmt 3,f.2,c,f.2
wrt D+.3,"lb",(X-F)*.00096851938*1," ",(Y-M)*.00096851938*1
X→G;Y→N
if K=0;gto "Finish"
"Fa":if K=1;gto "L1"
"Fb":wrt D,"df"
"PROG DONE"→A$;gsb "Display"
prt " ";prt " L.U  TOTAL AREA"
for I=1 to 74
if T[I]=0;jmp 3
fmt 4,f4.0,f12.3
wrt 16.4,C[I],T[I]
next I
fmt 7,c5,f8.3,c3
wrt 16.7,"sheet",U," ha"
prt " ";prt " "
dsp " ";stp
"Sum":X-G→H;.5*H*(Y+N)→T
E+T→E;ret
"Finish":wrt D,"sk0;bp150,200"
E+(F-G)*(N+M)/2→E
E*(.025/1000)↑2*P↑2→A;A/10000→A;gto "Print answers"
"Input":wrt D,"os";red D,S
if Smod256>=128;jmp 3
if Smod8<4;jmp 2
wrt D,"od";red D,X,Y,Q,R
wrt D,"ok";red D,K;ret
"Display":
238→A[1];254→A[2];156→A[3];252→A[4];158→A[5];142→A[6];190→A[7]
110→A[8];96→A[9];112→A[10];0→A[11];28→A[12];0→A[13];42→A[14];252→A[15]
206→A[16];230→A[17];10→A[18];182→A[19];30→A[20];124→A[21];0→A[22]
0→A[23]→A[24]→A[26];118→A[25];58→A[27];62→A[28];26→A[29];122→A[30]
222→A[31];142→A[32];246→A[33];46→A[34];32→A[35];112→A[36];0→A[37]→A[39]
96→A[38];42→A[40];58→A[41];206→A[42];230→A[43];10→A[44];182→A[45]
30→A[46];56→A[47];0→A[48]→A[49]→A[50];118→A[51];0→A[52]→A[53]
96→A[54];218→A[55];242→A[56];102→A[57];182→A[58];62→A[59]
224→A[60];254→A[61];230→A[62];252→A[63];1→A[64];156→A[65];240→A[66]
130→A[67];2→A[68];32→A[69];68→A[70];64→A[71];202→A[72]
if len(A$)>15;"LINE TOO LONG"→A$
"ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz "→L$[1,53]
"1234567890.[]=-,'?"→L$[54,72]
for I=1 to len(A$)
pos(L$,A$[I,I])→N
if N=0;27→N
wrt D,"dd"&str(I)&","&str(A[N])
next I;ret
*31219
```

Appendix (III) Input Data Obtained from Dot Grids Measurements used in the Multiple Regression Analysis Programme.

```
     *****   *  *   ****  *****  *      *****  ***
 **  *       *  * *           *  *      *      *
 **  *       *  * *           *  *      *      *
     ****    *  *   ***   *****  *****  *****  *
 **  *       *  *      *      *  *   *      *  *
 **  *        * *      *      *  *   *      *  *
     *****     *    ****  *****  *****  *****  ***
```

```
#LISTING OF :EVS3650.ESIN1DOTS(8/)  PRODUCED ON 14NOV80

#G8.63EC AT ASTON    IN :EVS3650.MOPJA' ON 17NOV80 AT 1

DOCUMENT    ESIN1DOTS

 0 UASTATSXDS3
 1 REGRES,LP
 2 OBSERVATION MATRIX,,DATA
 3 MATRIX,3,DATA
 4  R0155,   7.03,    4.39,    0.89
 5  R0156,   7.69,    4.39,    0.44
 6  R0157,   2.71,    4.39,    3.03
 7  R0158,   3.34,    4.39,    1.90
 8  R0159,   6.26,    4.39,    1.40
 9  R0160,  12.24,    4.39,   -0.71
10  R0161,  10.00,    4.39,   -1.24
11  R0162,   4.88,    4.39,    1.10
12  R0163,   3.80,    4.39,    0.55
13  R0164,   2.08,    4.39,    0.25
14  R0165,   4.30,    4.39,    0.76
15  R0166,  10.00,    4.39,   -1.08
16  R0167,   9.12,    4.39,   -0.34
17  R0168,   9.29,    4.39,   -0.42
18  R0169,  15.29,    4.39,   -0.01
19  R0170,   6.31,    4.39,    1.41
20  R0171,  10.00,    4.39,   -1.47
21  R0172,   3.53,    4.39,    2.98
22  R0173,   2.22,    4.39,    0.96
23  R0174,   0.82,    4.39,    1.32
24  R0175,   0.66,    4.39,    1.82
25  R0176,  10.00,    4.39,   -0.17
26  R0177,   2.58,    4.39,    1.38
27  R0178,  10.00,    4.39,   -2.53
28  R0179,   1.73,    4.39,    2.44
29  R0180,   9.36,    4.39,   -0.46
30  R0181,   3.52,    4.39,    1.95
31  R0182,   2.96,    4.39,    3.07
32  R0183,   3.77,    4.39,    0.08
33  R0184,   6.53,    4.39,    0.77
34  R0185,   7.51,    4.39,    1.04
35  R0186,   3.20,    4.39,    0.32
36  R0187,   3.56,    4.39,    0.34
37  R0188,   7.90,    4.39,    0.82
38  R0189,   5.01,    4.39,   -0.01
39  R0190,   6.69,    4.39,    0.94
40  R0191,   6.92,    4.39,    0.51
41  R0192,  10.00,    4.39,   -1.10
42  R0193,   6.68,    4.39,   -0.16
43  R0194,  10.00,    4.39,   -1.47
44  R0195,   6.10,    4.39,    1.77
45  R0196,   2.92,    4.39,    1.52
46  R0197,   3.33,    4.39,    2.89
47  R0198,   5.51,    4.39,    2.18
48  R0199,   0.57,    4.39,    1.31
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49	R0200,	10.07,	4.39,	-0.49
50	R0201,	6.96,	4.39,	-0.19
51	R0202,	10.00,	4.39,	-0.36
52	R0203,	10.00,	4.39,	-2.66
53	R0204,	7.06,	4.39,	1.42
54	R0205,	4.25,	4.39,	0.74
55	R0206,	10.50,	4.39,	0.16
56	R0207,	2.35,	4.39,	0.85
57	R0208,	2.10,	4.39,	0.31
58	R0209,	5.07,	4.39,	2.59
59	R0210,	10.00,	4.39,	0.01
60	R0211,	5.73,	4.39,	0.61
61	R0212,	6.03,	4.39,	0.66
62	R0213,	8.09,	4.39,	0.40
63	R0214,	6.64,	4.39,	-0.15
64	R0215,	4.20,	4.39,	2.24
65	R0216,	10.00,	4.39,	-1.83
66	R0217,	10.00,	4.39,	-1.14
67	R0218,	5.33,	4.39,	-0.04
68	R0219,	1.04,	4.39,	0.92
69	R0220,	0.30,	4.39,	2.41
70	R0221,	10.00,	4.39,	-2.81
71	R0222,	10.00,	4.39,	-0.99
72	R0223,	6.69,	4.39,	1.90
73	R0224,	12.09,	4.39,	-1.24
74	R0225,	10.00,	4.39,	-1.17
75	R0226,	5.84,	4.39,	1.86
76	R0227,	4.97,	4.39,	1.19
77	R0228,	0.37,	4.39,	1.82
78	R0229,	6.15,	4.39,	0.58
79	R0230,	10.36,	4.39,	0.87
80	R0231,	4.11,	4.39,	2.13
81	R0232,	10.00,	4.39,	0.09
82	R0233,	10.00,	4.39,	-2.40
83	R0234,	1.14,	4.39,	1.99
84	R0235,	14.40,	4.39,	-0.22
85	R0236,	10.00,	4.39,	-0.16
86	R0237,	4.03,	4.39,	1.16
87	R0238,	2.46,	4.39,	1.37
88	R0239,	10.00,	4.39,	-1.61
89	R0240,	3.30,	4.39,	1.72
90	R0241,	1.70,	4.39,	2.89
91	R0242,	4.15,	4.39,	2.70
92	R0243,	10.00,	4.39,	-0.71
93	R0244,	2.91,	4.39,	2.24
94	R0245,	5.26,	4.39,	1.35
95	R0246,	3.48,	4.39,	1.89
96	R0247,	10.00,	4.39,	-0.16
97	R0248,	4.94,	4.39,	0.68
98	R0249,	1.76,	4.39,	0.91
99	R0250,	5.38,	4.39,	1.05
100	R0251,	1.89,	4.39,	3.47
101	R0252,	10.00,	4.39,	-0.34
102	R0253,	1.06,	4.39,	3.96
103	R0254,	6.92,	4.39,	-0.19
104	R0255,	10.00,	4.39,	-0.49
105	R0256,	10.00,	4.39,	-0.39
106	R0257,	7.23,	4.39,	1.64
107	R0258,	7.12,	4.39,	-0.20
108	R0259,	12.71,	4.39,	0.82
109	R0260,	6.76,	4.39,	-0.06
110	R0261,	10.00,	4.39,	0.30
111	R0262,	4.18,	4.39,	1.44
112	R0263,	10.00,	4.39,	0.15
113	R0264,	8.80,	4.39,	1.58
114	R0265,	4.21,	4.39,	-0.65

115	R0266,	7.52,	4.39,	1.05
116	R0267,	10.00,	4.39,	-1.90
117	R0268,	1.10,	4.39,	2.37
118	R0269,	10.00,	4.39,	0.38
119	R0270,	12.82,	4.39,	-0.76
120	R0271,	10.00,	4.39,	-0.82
121	R0272,	2.49,	4.39,	2.07
122	R0273,	10.00,	4.39,	-1.90
123	R0274,	1.66,	4.39,	3.67
124	R0275,	10.00,	4.39,	-2.12
125	R0276,	2.71,	4.39,	1.90
126	R0277,	10.00,	4.39,	-1.35
127	R0278,	10.00,	4.39,	-2.04
128	R0279,	8.87,	4.39,	0.32
129	R0280,	8.64,	4.39,	-0.34
130	R0281,	3.39,	4.39,	0.10
131	R0282,	0.94,	4.39,	2.17
132	R0283,	10.00,	4.39,	-2.04
133	R0284,	15.64,	4.39,	-1.02
134	R0285,	6.60,	4.39,	0.78
135	R0286,	4.96,	4.39,	2.07
136	R0287,	10.00,	4.39,	-0.92
137	R0288,	8.73,	4.39,	0.74
138	R0289,	4.48,	4.39,	3.14
139	R0290,	6.29,	4.39,	1.67
140	R0291,	3.01,	4.39,	3.88
141	R0292,	5.98,	4.39,	2.04
142	R0293,	10.00,	4.39,	-2.53
143	R0294,	6.71,	4.39,	0.81
144	R0295,	10.00,	4.39,	-1.77
145	R0296,	5.82,	4.39,	0.63
146	R0297,	10.00,	4.39,	-1.77
147	R0298,	10.00,	4.39,	-1.43
148	R0299,	3.11,	4.39,	0.40
149	R0300,	5.09,	4.39,	1.61
150	R0301,	3.81,	4.39,	1.75
151	R0302,	6.27,	4.39,	0.57
152	R0303,	5.25,	4.39,	0.54
153	R0304,	2.67,	4.39,	0.14
154	R0305,	10.00,	4.39,	0.39
155	R0306,	10.00,	4.39,	0.80
156	R0307,	2.95,	4.39,	2.96
157	R0308,	8.04,	4.39,	-0.29
158	R0463,	4.59,	5.13,	0.89
159	R0464,	4.73,	5.13,	0.44
160	R0465,	2.94,	5.13,	3.03
161	R0466,	2.56,	5.13,	1.90
162	R0467,	5.58,	5.13,	1.40
163	R0468,	10.00,	5.13,	-0.71
164	R0469,	10.00,	5.13,	-1.24
165	R0470,	6.20,	5.13,	1.10
166	R0471,	1.68,	5.13,	0.55
167	R0472,	2.87,	5.13,	0.25
168	R0473,	6.68,	5.13,	0.76
169	R0474,	8.45,	5.13,	-1.08
170	R0475,	10.00,	5.13,	-0.34
171	R0476,	3.28,	5.13,	-0.42
172	R0477,	8.86,	5.13,	-0.01
173	R0478,	1.01,	5.13,	1.41
174	R0479,	10.00,	5.13,	-1.47
175	R0480,	2.66,	5.13,	2.98
176	R0481,	2.97,	5.13,	0.96
177	R0482,	3.33,	5.13,	1.32
178	R0483,	4.86,	5.13,	1.82
179	R0484,	5.46,	5.13,	-0.17
180	R0485,	2.10,	5.13,	1.38

181	R0486,	10.00,	5.13,	-2.52
182	R0487,	2.65,	5.13,	2.44
183	R0488,	8.95,	5.13,	-0.46
184	R0489,	3.02,	5.13,	1.95
185	R0490,	2.59,	5.13,	3.07
186	R0491,	9.01,	5.13,	0.08
187	R0492,	10.00,	5.13,	0.77
188	R0493,	6.82,	5.13,	1.04
189	R0494,	5.39,	5.13,	0.32
190	R0495,	7.62,	5.13,	0.34
191	R0496,	8.60,	5.13,	0.82
192	R0497,	6.33,	5.13,	-0.01
193	R0498,	2.74,	5.13,	0.94
194	R0499,	2.51,	5.13,	0.51
195	R0500,	10.00,	5.13,	-1.11
196	R0501,	6.22,	5.13,	-0.16
197	R0502,	10.00,	5.13,	-1.47
198	R0503,	3.21,	5.13,	2.43
199	R0504,	2.00,	5.13,	1.52
200	R0505,	2.21,	5.13,	2.89
201	R0506,	4.50,	5.13,	2.98
202	R0507,	3.49,	5.13,	1.31
203	R0508,	1.87,	5.13,	-0.49
204	R0509,	6.50,	5.13,	-0.19
205	R0510,	3.90,	5.13,	-0.36
206	R0511,	10.00,	5.13,	-2.66
207	R0512,	3.72,	5.13,	1.42
208	R0513,	3.64,	5.13,	0.74
209	R0514,	0.89,	5.13,	0.16
210	R0515,	4.91,	5.13,	0.85
211	R0516,	3.57,	5.13,	0.31
212	R0517,	4.50,	5.13,	2.59
213	R0518,	8.70,	5.13,	0.01
214	R0519,	7.81,	5.13,	0.61
215	R0520,	7.25,	5.13,	0.66
216	R0521,	4.35,	5.13,	0.40
217	R0522,	10.00,	5.13,	-0.15
218	R0523,	2.56,	5.13,	2.24
219	R0524,	10.00,	5.13,	-1.83
220	R0525,	9.11,	5.13,	-1.14
221	R0526,	9.20,	5.13,	-0.04
222	R0527,	4.30,	5.13,	0.92
223	R0528,	1.13,	5.13,	2.41
224	R0529,	10.00,	5.13,	-2.81
225	R0530,	7.79,	5.13,	-0.99
226	R0531,	3.42,	5.13,	1.90
227	R0532,	10.24,	5.13,	-1.24
228	R0533,	10.00,	5.13,	-1.17
229	R0534,	1.00,	5.13,	1.86
230	R0535,	5.13,	5.13,	1.19
231	R0536,	2.07,	5.13,	1.82
232	R0537,	0.94,	5.13,	0.58
233	R0538,	8.59,	5.13,	0.87
234	R0539,	5.75,	5.13,	2.13
235	R0540,	10.00,	5.13,	0.09
236	R0541,	10.00,	5.13,	-2.41
237	R0542,	3.32,	5.13,	1.99
238	R0543,	6.88,	5.13,	-0.22
239	R0544,	5.48,	5.13,	-0.16
240	R0545,	2.67,	5.13,	1.16
241	R0546,	2.25,	5.13,	1.37
242	R0547,	10.00,	5.13,	-1.61
243	R0548,	2.40,	5.13,	1.72
244	R0549,	2.82,	5.13,	2.89
245	R0550,	2.18,	5.13,	2.70
246	R0551,	4.56,	5.13,	-0.71

247	R0552,	3.58,	5.13,	2.24
248	R0553,	2.87,	5.13,	1.35
249	R0554,	5.33,	5.13,	1.89
250	R0555,	10.48,	5.13,	-0.16
251	R0556,	8.88,	5.13,	0.68
252	R0557,	6.53,	5.13,	0.91
253	R0558,	1.75,	5.13,	1.05
254	R0559,	2.33,	5.13,	3.47
255	R0560,	4.13,	5.13,	-0.34
256	R0561,	2.02,	5.13,	3.96
257	R0562,	10.61,	5.13,	-0.19
258	R0563,	9.77,	5.13,	-0.49
259	R0564,	10.00,	5.13,	-0.39
260	R0565,	1.75,	5.13,	1.64
261	R0566,	6.67,	5.13,	-0.20
262	R0567,	9.38,	5.13,	0.82
263	R0568,	4.69,	5.13,	-0.06
264	R0569,	10.00,	5.13,	0.30
265	R0570,	2.35,	5.13,	1.44
266	R0571,	1.53,	5.13,	0.15
267	R0572,	6.79,	5.13,	1.58
268	R0573,	10.00,	5.13,	-0.65
269	R0574,	4.15,	5.13,	1.05
270	R0575,	17.31,	5.13,	-1.90
271	R0576,	4.04,	5.13,	2.37
272	R0577,	7.70,	5.13,	0.38
273	R0578,	5.17,	5.13,	-0.76
274	R0579,	10.00,	5.13,	-0.82
275	R0580,	1.75,	5.13,	2.07
276	R0581,	10.00,	5.13,	-1.90
277	R0582,	0.88,	5.13,	3.67
278	R0583,	10.00,	5.13,	-2.12
279	R0584,	3.35,	5.13,	1.90
280	R0585,	11.47,	5.13,	-1.35
281	R0586,	10.00,	5.13,	-2.04
282	R0587,	3.79,	5.13,	0.32
283	R0588,	4.03,	5.13,	-0.34
284	R0589,	6.82,	5.13,	0.10
285	R0590,	2.23,	5.13,	2.17
286	R0591,	19.12,	5.13,	-2.04
287	R0592,	19.89,	5.13,	-1.02
288	R0593,	6.77,	5.13,	0.78
289	R0594,	4.41,	5.13,	2.07
290	R0595,	6.98,	5.13,	-0.92
291	R0596,	6.58,	5.13,	0.74
292	R0597,	0.67,	5.13,	3.14
293	R0598,	3.39,	5.13,	1.67
294	R0599,	2.97,	5.13,	3.88
295	R0600,	3.91,	5.13,	2.04
296	R0601,	10.00,	5.13,	-2.53
297	R0602,	4.57,	5.13,	0.81
298	R0603,	15.97,	5.13,	-1.77
299	R0604,	5.16,	5.13,	0.63
300	R0605,	15.48,	5.13,	-1.77
301	R0606,	10.00,	5.13,	-1.43
302	R0607,	7.68,	5.13,	0.40
303	R0608,	5.49,	5.13,	1.61
304	R0609,	1.56,	5.13,	1.75
305	R0610,	5.79,	5.13,	0.57
306	R0611,	2.03,	5.13,	0.54
307	R0612,	6.98,	5.13,	0.14
308	R0613,	7.73,	5.13,	0.39
309	R0614,	5.67,	5.13,	-0.80
310	R0615,	4.05,	5.13,	2.96
311	R0616,	10.00,	5.13,	-0.29
312	R0771,	1.03,	5.78,	0.89

313	R0772,	4.52,	5.78,	0.44
314	R0773,	2.14,	5.78,	3.03
315	R0774,	2.72,	5.78,	1.90
316	R0775,	2.54,	5.78,	1.40
317	R0776,	5.00,	5.78,	-0.71
318	R0777,	10.00,	5.78,	-1.24
319	R0778,	4.18,	5.78,	1.10
320	R0779,	5.01,	5.78,	0.55
321	R0780,	2.07,	5.78,	0.25
322	R0781,	1.06,	5.78,	0.76
323	R0782,	3.26,	5.78,	-1.08
324	R0783,	5.51,	5.78,	-0.34
325	R0784,	2.62,	5.78,	-0.42
326	R0785,	2.63,	5.78,	-0.01
327	R0786,	3.59,	5.78,	1.41
328	R0787,	5.61,	5.78,	-1.47
329	R0788,	1.79,	5.78,	2.98
330	R0789,	2.22,	5.78,	0.96
331	R0790,	0.82,	5.78,	1.32
332	R0791,	3.09,	5.78,	1.82
333	R0792,	5.18,	5.78,	-0.17
334	R0793,	2.98,	5.78,	1.38
335	R0794,	10.00,	5.78,	-2.53
336	R0795,	0.54,	5.78,	2.44
337	R0796,	1.48,	5.78,	-0.46
338	R0797,	1.91,	5.78,	1.95
339	R0798,	1.74,	5.78,	3.07
340	R0799,	3.79,	5.78,	0.08
341	R0800,	3.74,	5.78,	0.77
342	R0801,	5.57,	5.78,	1.04
343	R0802,	6.60,	5.78,	0.32
344	R0803,	3.03,	5.78,	0.34
345	R0804,	4.33,	5.78,	0.82
346	R0805,	2.49,	5.78,	-0.01
347	R0806,	3.95,	5.78,	0.94
348	R0807,	2.76,	5.78,	0.51
349	R0808,	10.00,	5.78,	-1.11
350	R0809,	6.68,	5.78,	-0.16
351	R0810,	10.00,	5.78,	-1.47
352	R0811,	3.14,	5.78,	1.77
353	R0812,	3.44,	5.78,	1.52
354	R0813,	1.60,	5.78,	2.89
355	R0814,	2.83,	5.78,	2.18
356	R0815,	0.57,	5.78,	1.31
357	R0816,	7.05,	5.78,	-0.49
358	R0817,	3.36,	5.78,	-0.19
359	R0818,	5.72,	5.78,	-0.36
360	R0819,	18.10,	5.78,	-2.66
361	R0820,	1.61,	5.78,	1.42
362	R0821,	3.38,	5.78,	0.74
363	R0822,	4.60,	5.78,	0.16
364	R0823,	2.35,	5.78,	0.85
365	R0824,	2.10,	5.78,	2.59
366	R0825,	3.43,	5.78,	0.31
367	R0826,	2.90,	5.78,	0.01
368	R0827,	0.86,	5.78,	0.61
369	R0828,	5.22,	5.78,	0.66
370	R0829,	1.84,	5.78,	0.40
371	R0830,	5.29,	5.78,	-0.15
372	R0831,	4.58,	5.78,	2.24
373	R0832,	10.00,	5.78,	-1.83
374	R0833,	2.14,	5.78,	-1.14
375	R0834,	5.94,	5.78,	-0.04
376	R0835,	1.04,	5.78,	0.92
377	R0836,	0.30,	5.78,	2.41
378	R0837,	10.00,	5.78,	-2.81

379	R0838,	10.00,	5.78,	-0.99
380	R0839,	1.05,	5.78,	1.90
381	R0840,	2.61,	5.78,	-1.24
382	R0841,	0.89,	5.78,	-1.17
383	R0842,	3.00,	5.78,	1.86
384	R0843,	2.43,	5.78,	1.19
385	R0844,	3.14,	5.78,	1.82
386	R0845,	4.54,	5.78,	0.58
387	R0846,	8.27,	5.78,	0.87
388	R0847,	1.51,	5.78,	2.13
389	R0848,	6.60,	5.78,	0.09
390	R0849,	16.22,	5.78,	-2.41
391	R0850,	3.95,	5.78,	1.99
392	R0851,	3.91,	5.78,	-0.22
393	R0852,	3.06,	5.78,	-0.16
394	R0853,	1.77,	5.78,	1.16
395	R0854,	1.33,	5.78,	1.37
396	R0855,	7.52,	5.78,	-1.61
397	R0856,	0.84,	5.78,	1.72
398	R0857,	2.52,	5.78,	2.89
399	R0858,	0.81,	5.78,	2.70
400	R0859,	5.10,	5.78,	-0.71
401	R0860,	3.42,	5.78,	2.24
402	R0861,	3.42,	5.78,	1.35
403	R0862,	1.39,	5.78,	1.89
404	R0863,	6.78,	5.78,	-0.16
405	R0864,	2.97,	5.78,	0.68
406	R0865,	3.41,	5.78,	0.91
407	R0866,	1.80,	5.78,	1.05
408	R0867,	2.02,	5.78,	3.47
409	R0868,	3.67,	5.78,	-0.34
410	R0869,	0.73,	5.78,	3.96
411	R0870,	6.92,	5.78,	-0.19
412	R0871,	1.39,	5.78,	-0.49
413	R0872,	10.00,	5.78,	-0.39
414	R0873,	2.74,	5.78,	1.64
415	R0874,	4.97,	5.78,	-0.20
416	R0875,	1.38,	5.78,	0.82
417	R0876,	4.70,	5.78,	-0.06
418	R0877,	10.00,	5.78,	0.30
419	R0878,	2.14,	5.78,	1.44
420	R0879,	4.46,	5.78,	0.15
421	R0880,	6.31,	5.78,	1.58
422	R0881,	4.20,	5.78,	-0.65
423	R0882,	2.81,	5.78,	1.05
424	R0883,	10.00,	5.78,	-1.90
425	R0884,	2.75,	5.78,	2.37
426	R0885,	3.90,	5.78,	0.38
427	R0886,	5.67,	5.78,	-0.76
428	R0887,	10.54,	5.78,	-0.82
429	R0888,	1.06,	5.78,	2.07
430	R0889,	10.00,	5.78,	-1.90
431	R0890,	0.62,	5.78,	3.67
432	R0891,	25.87,	5.78,	-2.12
433	R0892,	1.38,	5.78,	1.90
434	R0893,	4.58,	5.78,	-1.35
435	R0894,	10.00,	5.78,	-2.04
436	R0895,	5.74,	5.78,	0.32
437	R0896,	3.56,	5.78,	-0.34
438	R0897,	3.39,	5.78,	0.10
439	R0898,	1.63,	5.78,	2.17
440	R0899,	10.00,	5.78,	-2.04
441	R0900,	15.64,	5.78,	-1.02
442	R0901,	6.60,	5.78,	0.78
443	R0902,	3.60,	5.78,	2.07
444	R0903,	7.43,	5.78,	-0.92

445	R0904,	4.26,	5.78,	0.74
446	R0905,	3.28,	5.78,	3.14
447	R0906,	2.16,	5.78,	1.67
448	R0907,	1.52,	5.78,	3.88
449	R0908,	2.11,	5.78,	2.04
450	R0909,	10.00,	5.78,	-2.53
451	R0910,	4.19,	5.78,	0.81
452	R0911,	10.00,	5.78,	-1.77
453	R0912,	3.95,	5.78,	0.63
454	R0913,	8.87,	5.78,	-1.77
455	R0914,	10.00,	5.78,	-1.43
456	R0915,	4.93,	5.78,	0.40
457	R0916,	2.21,	5.78,	1.61
458	R0917,	1.23,	5.78,	1.75
459	R0918,	2.12,	5.78,	0.57
460	R0919,	3.08,	5.78,	0.54
461	R0920,	5.82,	5.78,	0.14
462	R0921,	3.10,	5.78,	0.39
463	R0922,	6.15,	5.78,	-0.80
464	R0923,	0.81,	5.78,	2.96
465	R0924,	7.67,	5.78,	-0.29
466	R01079,	2.19,	6.44,	0.89
467	R01080,	2.68,	6.44,	0.44
468	R01081,	0.52,	6.44,	3.03
469	R01082,	1.99,	6.44,	1.90
470	R01083,	4.15,	6.44,	1.40
471	R01084,	5.44,	6.44,	-0.71
472	R01085,	3.42,	6.44,	-1.24
473	R01086,	1.93,	6.44,	1.10
474	R01087,	2.71,	6.44,	0.55
475	R01088,	4.91,	6.44,	0.25
476	R01089,	4.45,	6.44,	0.76
477	R01090,	7.32,	6.44,	-1.08
478	R01091,	3.14,	6.44,	-0.34
479	R01092,	5.25,	6.44,	-0.42
480	R01093,	1.87,	6.44,	-0.01
481	R01094,	2.32,	6.44,	1.41
482	R01095,	6.02,	6.44,	-1.47
483	R01096,	0.56,	6.44,	2.98
484	R01097,	4.46,	6.44,	0.96
485	R01098,	1.73,	6.44,	1.32
486	R01099,	0.80,	6.44,	1.82
487	R01100,	5.73,	6.44,	-0.17
488	R01101,	10.00,	6.44,	1.38
489	R01102,	9.69,	6.44,	-2.53
490	R01103,	2.48,	6.44,	2.44
491	R01104,	0.96,	6.44,	-0.46
492	R01105,	2.07,	6.44,	1.95
493	R01106,	0.86,	6.44,	3.07
494	R01107,	3.37,	6.44,	0.08
495	R01108,	1.89,	6.44,	0.77
496	R01109,	3.10,	6.44,	1.04
497	R01110,	2.13,	6.44,	0.32
498	R01111,	1.32,	6.44,	0.34
499	R01112,	2.98,	6.44,	0.82
500	R01113,	5.43,	6.44,	-0.01
501	R01114,	2.47,	6.44,	0.94
502	R01115,	4.85,	6.44,	0.51
503	R01116,	1.68,	6.44,	-1.10
504	R01117,	2.53,	6.44,	-0.16
505	R01118,	6.16,	6.44,	-1.47
506	R01119,	2.29,	6.44,	1.77
507	R01120,	1.34,	6.44,	1.52
508	R01121,	1.62,	6.44,	2.89
509	R01122,	1.67,	6.44,	2.18
510	R01123,	1.96,	6.44,	1.31

511	R01124,	5.50,	6.44,	-0.49
512	R01125,	1.10,	6.44,	-0.19
513	R01126,	2.90,	6.44,	-0.36
514	R01127,	11.80,	6.44,	-2.66
515	R01128,	0.91,	6.44,	1.42
516	R01129,	4.86,	6.44,	1.45
517	R01130,	4.29,	6.44,	0.16
518	R01131,	2.10,	6.44,	0.85
519	R01132,	2.49,	6.44,	0.31
520	R01133,	3.30,	6.44,	2.59
521	R01134,	6.06,	6.44,	0.01
522	R01135,	2.06,	6.44,	0.61
523	R01136,	8.06,	6.44,	0.66
524	R01137,	2.68,	6.44,	0.40
525	R01138,	5.03,	6.44,	-0.15
526	R01139,	4.32,	6.44,	2.24
527	R01140,	10.00,	6.44,	-1.83
528	R01141,	1.07,	6.44,	-1.14
529	R01142,	5.32,	6.44,	-0.04
530	R01143,	3.92,	6.44,	0.92
531	R01144,	3.03,	6.44,	2.41
532	R01145,	13.18,	6.44,	-2.81
533	R01146,	3.63,	6.44,	-0.99
534	R01147,	3.05,	6.44,	1.90
535	R01148,	8.13,	6.44,	-1.24
536	R01149,	6.96,	6.44,	-1.17
537	R01150,	1.31,	6.44,	1.86
538	R01151,	1.56,	6.44,	1.19
539	R01152,	2.06,	6.44,	1.82
540	R01153,	4.02,	6.44,	0.58
541	R01154,	10.72,	6.44,	0.87
542	R01155,	5.43,	6.44,	2.13
543	R01156,	3.49,	6.44,	0.09
544	R01157,	10.00,	6.44,	-2.41
545	R01158,	4.36,	6.44,	1.99
546	R01159,	6.28,	6.44,	-0.22
547	R01160,	4.94,	6.44,	-0.16
548	R01161,	3.24,	6.44,	1.16
549	R01162,	1.20,	6.44,	1.37
550	R01163,	7.89,	6.44,	-1.61
551	R01164,	2.69,	6.44,	1.72
552	R01165,	0.14,	6.44,	2.89
553	R01166,	1.41,	6.44,	2.70
554	R01167,	2.39,	6.44,	-0.71
555	R01168,	2.07,	6.44,	2.24
556	R01169,	1.84,	6.44,	1.35
557	R01170,	1.49,	6.44,	1.89
558	R01171,	3.03,	6.44,	-0.16
559	R01172,	2.65,	6.44,	0.68
560	R01173,	2.69,	6.44,	0.91
561	R01174,	1.35,	6.44,	1.05
562	R01175,	1.02,	6.44,	3.47
563	R01176,	2.79,	6.44,	-0.34
564	R01177,	0.73,	6.44,	3.96
565	R01178,	8.52,	6.44,	-0.19
566	R01179,	4.55,	6.44,	-0.49
567	R01180,	4.55,	6.44,	-0.39
568	R01181,	3.39,	6.44,	1.64
569	R01182,	4.14,	6.44,	-0.20
570	R01183,	4.32,	6.44,	0.82
571	R01184,	3.54,	6.44,	-0.06
572	R01185,	10.00,	6.44,	0.30
573	R01186,	2.94,	6.44,	1.44
574	R01187,	3.28,	6.44,	0.15
575	R01188,	6.45,	6.44,	1.58
576	R01189,	4.69,	6.44,	-0.65

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R01190,  2.51,    6.44,    1.05
R01191,  2.81,    6.44,   -1.90
R01192,  3.62,    6.44,    2.37
R01193,  4.80,    6.44,    0.38
R01194,  5.61,    6.44,   -0.76
R01195,  3.11,    6.44,   -0.82
R01196,  1.80,    6.44,    2.07
R01197, 10.00,    6.44,   -1.90
R01198,  2.02,    6.44,    3.67
R01199,  5.73,    6.44,   -2.12
R01200,  1.99,    6.44,    1.90
R01201,  9.37,    6.44,   -1.35
R01202,  5.20,    6.44,   -2.04
R01203,  2.71,    6.44,    0.32
R01204,  5.67,    6.44,   -0.34
R01205,  3.95,    6.44,    0.10
R01206,  1.65,    6.44,    2.17
R01207,  5.08,    6.44,   -2.04
R01208, 14.59,    6.44,   -1.02
R01209,  7.96,    6.44,    0.78
R01210,  5.21,    6.44,    2.07
R01211,  7.73,    6.44,   -0.92
R01212,  0.66,    6.44,    0.74
R01213,  4.14,    6.44,    3.14
R01214,  3.40,    6.44,    1.67
R01215,  1.13,    6.44,    3.88
R01216,  3.81,    6.44,    2.04
R01217, 10.00,    6.44,   -2.53
R01218,  5.99,    6.44,    0.81
R01219,  1.99,    6.44,   -1.77
R01220,  3.36,    6.44,    0.63
R01221,  9.24,    6.44,   -1.77
R01222,  5.65,    6.44,   -1.43
R01223,  1.81,    6.44,    0.40
R01224,  3.89,    6.44,    1.61
R01225,  2.42,    6.44,    1.75
R01226,  2.61,    6.44,    0.57
R01227,  3.94,    6.44,    0.54
R01228,  4.99,    6.44,    0.14
R01229,  2.98,    6.44,    0.39
R01230,  5.34,    6.44,   -0.80
R01231,  3.24,    6.44,    2.96
END OF DATA
CROSS PRODUCT,DATA
COVARIANCE,DATA
CORRELATION,DATA
PRINT OBSERVATION,33,DATA
PRINT CORRELATION,34,DATA
REGRESSION ANALYSIS,DATA,COVA
DEPENDENT VARIABLE,CN0001
INDEPENDENT VARIABLES AT SIG LEVEL,40.0
 CN0002,CN0003
PRINT REGRESSION
GET OFF
****

*PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
*PPPPPPP                                PPPPPPPPPPPPPPPP
*PPPPPPP         NUMBER OF PAGES   10   PPPPPPPPPPPPPPPP
*PPPPPPP                                PPPPPPPPPPPPPPPP
*PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
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worked

(Appendix IV) Input Data Obtained from Grid Squares Measurements used in the Multiple Regression Analysis Programme.

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    *****    *    *    ****   *****   *       *****   *****   Y
**  *        *    *   *           *   *       *       *   *   Y
**  *        *    *   *           *   *       *       *   *   Y
    ****     *    *    ***    *****   *****   *****   *   *   Y
**  *        *    *       *       *   *   *       *   *   *   Y
**  *         * *         *       *   *   *       *   *   *   Y
    *****     *       ****    *****   *****   *****   *****   Y
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#LISTING OF :EVS3650.ESIN1GRIDS(7/) PRODUCED ON 17NOV80 AT 10
#G8.63EC AT ASTON    IN :EVS3650.MOPJA' ON 17NOV80 AT 10.50.0
DOCUMENT    ESIN1GRIDS

 0 UASTATSXDS3
 1 REGRES,LP
 2 OBSERVATION MATRIX,,DATA
 3 MATRIX,3,DATA
 4  R01,      1.03,    4.39,    0.89
 5  R02,      7.69,    4.39,    0.44
 6  R03,      5.59,    4.39,    3.03
 7  R04,      3.34,    4.39,    1.90
 8  R05,      2.96,    4.39,    1.40
 9  R06,     10.00,    4.39,   -0.71
10  R07,     10.00,    4.39,   -1.24
11  R08,     10.00,    4.39,    1.10
12  R09,      5.34,    4.39,    0.55
13  R010,     2.07,    4.39,    0.25
14  R011,    10.00,    4.39,    0.76
15  R012,    10.00,    4.39,   -1.08
16  R013,    10.00,    4.39,   -0.34
17  R014,     9.28,    4.39,   -0.42
18  R015,     4.91,    4.39,   -0.01
19  R016,     3.10,    4.39,    1.41
20  R017,    10.00,    4.39,   -1.47
21  R018,     3.55,    4.39,    2.98
22  R019,     2.22,    4.39,    0.96
23  R020,     5.70,    4.39,    1.32
24  R021,     6.35,    4.39,    1.82
25  R022,     6.81,    4.39,   -1.74
26  R023,     6.15,    4.39,    1.38
27  R024,    10.00,    4.39,   -2.53
28  R025,     1.73,    4.39,    2.44
29  R026,     9.76,    4.39,   -0.46
30  R027,     3.52,    4.39,    1.95
31  R028,     3.81,    4.39,    3.07
32  R029,     3.77,    4.39,    0.08
33  R030,     3.83,    4.39,    0.77
34  R031,     7.51,    4.39,    1.04
35  R032,     3.20,    4.39,    0.32
36  R033,     3.56,    4.39,    0.34
37  R034,     6.77,    4.39,    0.82
38  R035,     5.01,    4.39,   -0.01
39  R036,     7.19,    4.39,    0.94
40  R037,     6.92,    4.39,    0.51
41  R038,    10.00,    4.39,   -1.11
42  R039,     6.68,    4.39,   -1.63
43  R040,    10.00,    4.39,   -1.47
44  R041,     4.04,    4.39,    1.77
45  R042,     5.97,    4.39,    1.52
46  R043,     3.07,    4.39,    2.89
47  R044,     6.65,    4.39,    2.18
48  R045,     5.75,    4.39,    1.31
```

49	R046,	10.07,	4.39,	-0.49
50	R047,	6.96,	4.39,	-0.19
51	R048,	10.00,	4.39,	-0.36
52	R049,	10.00,	4.39,	-2.66
53	R050,	4.46,	4.39,	1.42
54	R051,	4.25,	4.39,	0.74
55	R052,	10.50,	4.39,	0.16
56	R053,	2.35,	4.39,	0.85
57	R054,	2.99,	4.39,	0.31
58	R055,	1.47,	4.39,	2.59
59	R056,	10.00,	4.39,	0.01
60	R057,	5.73,	4.39,	0.61
61	R058,	5.19,	4.39,	0.66
62	R059,	10.00,	4.39,	0.40
63	R060,	6.63,	4.39,	-0.15
64	R061,	4.20,	4.39,	2.24
65	R062,	10.00,	4.39,	1.83
66	R063,	10.00,	4.39,	-1.14
67	R064,	10.00,	4.39,	-0.04
68	R065,	1.13,	4.39,	0.92
69	R066,	0.30,	4.39,	2.41
70	R067,	10.00,	4.39,	-2.81
71	R068,	10.00,	4.39,	-0.99
72	R069,	5.13,	4.39,	1.90
73	R070,	10.00,	4.39,	-1.24
74	R071,	10.00,	4.39,	-1.17
75	R072,	5.84,	4.39,	1.86
76	R073,	7.11,	4.39,	1.19
77	R074,	6.30,	4.39,	1.82
78	R075,	10.33,	4.39,	0.58
79	R076,	6.94,	4.39,	0.87
80	R077,	3.51,	4.39,	2.13
81	R078,	10.00,	4.39,	0.09
82	R079,	10.00,	4.39,	-2.41
83	R080,	5.70,	4.39,	1.99
84	R081,	7.66,	4.39,	-0.22
85	R082,	13.85,	4.39,	-0.16
86	R083,	4.03,	4.39,	1.16
87	R084,	2.47,	4.39,	1.37
88	R085,	10.00,	4.39,	-1.61
89	R086,	5.81,	4.39,	1.72
90	R087,	3.12,	4.39,	2.89
91	R088,	3.99,	4.39,	2.70
92	R089,	10.00,	4.39,	-0.71
93	R090,	2.91,	4.39,	2.24
94	R091,	2.07,	4.39,	1.35
95	R092,	3.48,	4.39,	1.89
96	R093,	10.00,	4.39,	-0.16
97	R094,	4.94,	4.39,	0.68
98	R095,	0.87,	4.39,	0.91
99	R096,	3.74,	4.39,	1.05
100	R097,	2.02,	4.39,	3.47
101	R098,	8.54,	4.39,	-0.34
102	R099,	1.89,	4.39,	3.96
103	R0100,	13.97,	4.39,	-0.19
104	R0101,	10.00,	4.39,	-0.49
105	R0102,	10.00,	4.39,	-0.39
106	R0103,	5.32,	4.39,	1.64
107	R0104,	7.11,	4.39,	-0.20
108	R0105,	5.55,	4.39,	0.82
109	R0106,	6.76,	4.39,	-0.06
110	R0107,	10.00,	4.39,	0.30
111	R0108,	3.45,	4.39,	1.44
112	R0109,	10.66,	4.39,	0.15
113	R0110,	1.29,	4.39,	1.58
114	R0111,	10.00,	4.39,	-0.65

115	R0112,	5.43,	4.39,	1.05
116	R0113,	10.00,	4.39,	-1.90
117	R0114,	1.10,	4.39,	2.37
118	R0115,	3.90,	4.39,	0.38
119	R0116,	12.82,	4.39,	-0.76
120	R0117,	10.00,	4.39,	-0.82
121	R0118,	2.58,	4.39,	2.07
122	R0119,	10.00,	4.39,	-1.90
123	R0120,	2.58,	4.39,	3.67
124	R0121,	10.00,	4.39,	-2.12
125	R0122,	3.35,	4.39,	1.90
126	R0123,	10.00,	4.39,	-1.35
127	R0124,	10.00,	4.39,	-2.04
128	R0125,	10.00,	4.39,	0.32
129	R0126,	8.64,	4.39,	-0.34
130	R0127,	10.00,	4.39,	0.10
131	R0128,	0.94,	4.39,	2.17
132	R0129,	10.00,	4.39,	-2.04
133	R0130,	15.64,	4.39,	-1.02
134	R0131,	6.60,	4.39,	0.78
135	R0132,	6.34,	4.39,	2.07
136	R0133,	10.00,	4.39,	-0.92
137	R0134,	6.40,	4.39,	0.74
138	R0135,	3.84,	4.39,	3.14
139	R0136,	4.04,	4.39,	1.67
140	R0137,	3.41,	4.39,	3.88
141	R0138,	1.89,	4.39,	2.04
142	R0139,	10.00,	4.39,	-2.53
143	R0140,	10.00,	4.39,	0.81
144	R0141,	10.00,	4.39,	-1.77
145	R0142,	5.82,	4.39,	0.63
146	R0143,	10.00,	4.39,	-1.77
147	R0144,	10.00,	4.39,	-1.43
148	R0145,	4.14,	4.39,	0.40
149	R0146,	5.09,	4.39,	1.61
150	R0147,	3.81,	4.39,	1.75
151	R0148,	10.00,	4.39,	0.57
152	R0149,	6.69,	4.39,	0.54
153	R0150,	10.69,	4.39,	0.14
154	R0151,	10.00,	4.39,	0.39
155	R0152,	10.00,	4.39,	-0.80
156	R0153,	3.88,	4.39,	2.96
157	R0154,	10.00,	4.39,	-0.29
158	R0309,	4.59,	5.13,	0.89
159	R0310,	3.80,	5.13,	0.44
160	R0311,	1.71,	5.13,	3.03
161	R0312,	3.35,	5.13,	1.90
162	R0313,	3.54,	5.13,	1.40
163	R0314,	10.00,	5.13,	-0.71
164	R0315,	10.00,	5.13,	-1.24
165	R0316,	6.20,	5.13,	1.10
166	R0317,	5.61,	5.13,	0.55
167	R0318,	2.87,	5.13,	0.25
168	R0319,	10.00,	5.13,	0.76
169	R0320,	10.00,	5.13,	-1.08
170	R0321,	4.09,	5.13,	-0.34
171	R0322,	3.28,	5.13,	-0.42
172	R0323,	8.86,	5.13,	-0.01
173	R0324,	1.96,	5.13,	1.41
174	R0325,	10.00,	5.13,	-1.47
175	R0326,	1.38,	5.13,	2.98
176	R0327,	2.97,	5.13,	0.96
177	R0328,	3.33,	5.13,	1.32
178	R0329,	2.23,	5.13,	1.82
179	R0330,	6.35,	5.13,	-0.17
180	R0331,	4.39,	5.13,	1.38

181	R0332,	10.00,	5.13,	-2.53
182	R0333,	1.82,	5.13,	2.44
183	R0334,	2.12,	5.13,	-0.46
184	R0335,	4.19,	5.13,	1.95
185	R0336,	2.06,	5.13,	3.07
186	R0337,	3.08,	5.13,	0.08
187	R0338,	4.19,	5.13,	0.77
188	R0339,	6.10,	5.13,	1.04
189	R0340,	3.74,	5.13,	0.32
190	R0341,	4.03,	5.13,	0.34
191	R0342,	6.93,	5.13,	0.82
192	R0343,	6.33,	5.13,	-0.01
193	R0344,	2.74,	5.13,	0.94
194	R0345,	5.40,	5.13,	0.51
195	R0346,	10.00,	5.13,	-1.11
196	R0347,	10.39,	5.13,	-0.16
197	R0348,	10.00,	5.13,	-1.47
198	R0349,	5.51,	5.13,	1.77
199	R0350,	4.12,	5.13,	1.51
200	R0351,	1.30,	5.13,	2.89
201	R0352,	2.62,	5.13,	2.18
202	R0353,	1.95,	5.13,	1.30
203	R0354,	1.87,	5.13,	-0.49
204	R0355,	6.49,	5.13,	-0.19
205	R0356,	3.90,	5.13,	-0.36
206	R0357,	10.00,	5.13,	-2.66
207	R0358,	5.31,	5.13,	1.42
208	R0359,	3.64,	5.13,	0.74
209	R0360,	0.89,	5.13,	0.16
210	R0361,	4.91,	5.13,	0.85
211	R0362,	5.56,	5.13,	0.31
212	R0363,	2.55,	5.13,	2.59
213	R0364,	6.44,	5.13,	0.01
214	R0365,	1.85,	5.13,	0.61
215	R0366,	9.11,	5.13,	0.66
216	R0367,	7.77,	5.13,	0.40
217	R0368,	6.17,	5.13,	-0.15
218	R0369,	0.52,	5.13,	2.24
219	R0370,	10.00,	5.13,	-1.83
220	R0371,	9.11,	5.13,	-1.14
221	R0372,	10.00,	5.13,	-0.04
222	R0373,	5.37,	5.13,	0.92
223	R0374,	1.13,	5.13,	2.41
224	R0375,	10.00,	5.13,	-2.81
225	R0376,	10.00,	5.13,	-0.99
226	R0377,	4.53,	5.13,	1.90
227	R0378,	10.24,	5.13,	-1.24
228	R0379,	10.00,	5.13,	-1.17
229	R0380,	4.40,	5.13,	1.86
230	R0381,	2.87,	5.13,	1.19
231	R0382,	2.30,	5.13,	1.82
232	R0383,	5.82,	5.13,	0.58
233	R0384,	5.05,	5.13,	0.87
234	R0385,	2.24,	5.13,	2.13
235	R0386,	6.77,	5.13,	0.09
236	R0387,	10.00,	5.13,	1.99
237	R0388,	3.32,	5.13,	-0.22
238	R0389,	5.13,	5.13,	-0.16
239	R0390,	15.80,	5.13,	1.16
240	R0391,	5.48,	5.13,	1.37
241	R0392,	3.15,	5.13,	-1.61
242	R0393,	10.00,	5.13,	-1.61
243	R0394,	3.99,	5.13,	1.72
244	R0395,	1.17,	5.13,	2.89
245	R0396,	0.90,	5.13,	2.70
246	R0397,	10.00,	5.13,	-0.71

247	R0398,	0.54,	5.13,	2.24
248	R0399,	2.87,	5.13,	1.35
249	R0400,	1.23,	5.13,	1.89
250	R0401,	5.48,	5.13,	-0.16
251	R0402,	7.00,	5.13,	0.68
252	R0403,	4.35,	5.13,	0.91
253	R0404,	1.75,	5.13,	1.05
254	R0405,	1.72,	5.13,	3.47
255	R0406,	4.13,	5.13,	-0.34
256	R0407,	3.42,	5.13,	3.96
257	R0408,	10.59,	5.13,	-0.19
258	R0409,	1.50,	5.13,	-0.49
259	R0410,	10.00,	5.13,	-0.39
260	R0411,	1.75,	5.13,	1.64
261	R0412,	5.27,	5.13,	-0.20
262	R0413,	9.38,	5.13,	0.82
263	R0414,	7.08,	5.13,	-0.06
264	R0415,	10.00,	5.13,	0.30
265	R0416,	1.22,	5.13,	1.44
266	R0417,	1.37,	5.13,	0.15
267	R0418,	6.79,	5.13,	1.58
268	R0419,	10.00,	5.13,	-0.65
269	R0420,	6.16,	5.13,	1.05
270	R0421,	10.00,	5.13,	-1.90
271	R0422,	6.25,	5.13,	2.37
272	R0423,	4.69,	5.13,	0.38
273	R0424,	5.17,	5.13,	-0.76
274	R0425,	10.00,	5.13,	-0.82
275	R0426,	1.75,	5.13,	2.07
276	R0427,	10.00,	5.13,	-1.90
277	R0428,	0.88,	5.13,	3.67
278	R0429,	10.00,	5.13,	-2.12
279	R0430,	1.51,	5.13,	1.90
280	R0431,	10.00,	5.13,	-1.35
281	R0432,	10.00,	5.13,	-2.04
282	R0433,	3.79,	5.13,	0.32
283	R0434,	4.03,	5.13,	-0.34
284	R0435,	6.82,	5.13,	0.10
285	R0436,	1.34,	5.13,	2.17
286	R0437,	10.00,	5.13,	-2.04
287	R0438,	19.55,	5.13,	-1.02
288	R0439,	8.54,	5.13,	0.78
289	R0440,	6.47,	5.13,	2.07
290	R0441,	10.00,	5.13,	-0.92
291	R0442,	6.58,	5.13,	0.74
292	R0443,	1.73,	5.13,	3.14
293	R0444,	0.57,	5.13,	1.67
294	R0445,	1.65,	5.13,	3.88
295	R0446,	3.91,	5.13,	2.04
296	R0447,	10.00,	5.13,	-2.53
297	R0448,	6.88,	5.13,	0.81
298	R0449,	15.97,	5.13,	-1.77
299	R0450,	2.24,	5.13,	0.63
300	R0451,	10.00,	5.13,	-1.77
301	R0452,	10.00,	5.13,	-1.43
302	R0453,	4.38,	5.13,	0.40
303	R0454,	5.49,	5.13,	1.61
304	R0455,	5.32,	5.13,	1.75
305	R0456,	5.79,	5.13,	0.57
306	R0457,	6.23,	5.13,	0.54
307	R0458,	1.63,	5.13,	0.14
308	R0459,	4.41,	5.13,	0.39
309	R0460,	5.67,	5.13,	-0.80
310	R0461,	3.66,	5.13,	2.96
311	R0462,	10.00,	5.13,	-0.29
312	R0617,	1.03,	5.78,	0.89

313	R0618,	4.52,	5.78,	0.44
314	R0619,	2.14,	5.78,	3.03
315	R0620,	2.72,	5.78,	1.90
316	R0621,	2.54,	5.78,	1.40
317	R0622,	5.00,	5.78,	-0.71
318	R0623,	10.00,	5.78,	-1.24
319	R0624,	4.18,	5.78,	1.10
320	R0625,	4.74,	5.78,	0.55
321	R0626,	2.07,	5.78,	0.25
322	R0627,	1.01,	5.78,	0.76
323	R0628,	3.26,	5.78,	-1.08
324	R0629,	5.51,	5.78,	-0.34
325	R0630,	2.62,	5.78,	-0.42
326	R0631,	2.63,	5.78,	-0.01
327	R0632,	3.59,	5.78,	1.41
328	R0633,	5.08,	5.78,	-1.47
329	R0634,	1.79,	5.78,	2.98
330	R0635,	2.22,	5.78,	0.96
331	R0636,	0.82,	5.78,	1.32
332	R0637,	3.09,	5.78,	1.82
333	R0638,	5.18,	5.78,	-0.17
334	R0639,	2.98,	5.78,	1.38
335	R0640,	10.00,	5.78,	-2.53
336	R0641,	0.54,	5.78,	2.44
337	R0642,	1.55,	5.78,	-0.46
338	R0643,	2.83,	5.78,	1.95
339	R0644,	0.42,	5.78,	3.07
340	R0645,	3.79,	5.78,	0.08
341	R0646,	5.32,	5.78,	0.77
342	R0647,	4.48,	5.78,	1.04
343	R0648,	7.42,	5.78,	0.32
344	R0649,	3.03,	5.78,	0.34
345	R0650,	6.77,	5.78,	0.82
346	R0651,	2.49,	5.78,	-0.01
347	R0652,	2.92,	5.78,	0.94
348	R0653,	2.76,	5.78,	0.51
349	R0654,	10.00,	5.78,	-1.11
350	R0655,	2.91,	5.78,	-0.16
351	R0656,	10.00,	5.78,	-1.47
352	R0657,	3.14,	5.78,	1.77
353	R0658,	3.44,	5.78,	1.52
354	R0659,	3.07,	5.78,	2.89
355	R0660,	3.87,	5.78,	2.18
356	R0661,	2.95,	5.78,	1.31
357	R0662,	0.81,	5.78,	-0.49
358	R0663,	5.08,	5.78,	-0.19
359	R0664,	5.72,	5.78,	-0.36
360	R0665,	10.00,	5.78,	-2.66
361	R0666,	3.18,	5.78,	1.42
362	R0667,	1.83,	5.78,	0.74
363	R0668,	8.59,	5.78,	0.16
364	R0669,	4.33,	5.78,	0.85
365	R0670,	2.10,	5.78,	0.31
366	R0671,	2.67,	5.78,	2.59
367	R0672,	2.90,	5.78,	0.01
368	R0673,	4.03,	5.78,	0.61
369	R0674,	5.23,	5.78,	0.66
370	R0675,	1.84,	5.78,	0.40
371	R0676,	2.84,	5.78,	-0.15
372	R0677,	3.34,	5.78,	2.24
373	R0678,	3.16,	5.78,	-1.83
374	R0679,	2.14,	5.78,	-1.14
375	R0680,	10.00,	5.78,	-0.04
376	R0681,	6.18,	5.78,	0.92
377	R0682,	1.64,	5.78,	2.41
378	R0683,	10.00,	5.78,	-2.81

379	R0684,	10.00,	5.78,	-0.99
380	R0685,	3.89,	5.78,	1.90
381	R0686,	2.61,	5.78,	-1.24
382	R0687,	10.00,	5.78,	-1.17
383	R0688,	2.32,	5.78,	1.86
384	R0689,	2.43,	5.78,	1.19
385	R0690,	2.20,	5.78,	1.82
386	R0691,	8.59,	5.78,	0.58
387	R0692,	7.45,	5.78,	0.87
388	R0693,	3.09,	5.78,	2.13
389	R0694,	6.60,	5.78,	0.09
390	R0695,	10.00,	5.78,	-2.41
391	R0696,	3.37,	5.78,	1.99
392	R0697,	3.91,	5.78,	-0.22
393	R0698,	5.20,	5.78,	-0.16
394	R0699,	2.56,	5.78,	1.16
395	R0700,	3.10,	5.78,	1.37
396	R0701,	10.00,	5.78,	-1.61
397	R0702,	4.77,	5.78,	1.72
398	R0703,	1.99,	5.78,	2.89
399	R0704,	2.19,	5.78,	2.70
400	R0705,	5.10,	5.78,	-0.71
401	R0706,	2.28,	5.78,	2.24
402	R0707,	3.42,	5.78,	1.35
403	R0708,	1.39,	5.78,	1.89
404	R0709,	6.78,	5.78,	-0.16
405	R0710,	2.97,	5.78,	0.68
406	R0711,	3.63,	5.78,	0.91
407	R0712,	4.27,	5.78,	1.05
408	R0713,	2.89,	5.78,	3.47
409	R0714,	3.67,	5.78,	-0.34
410	R0715,	1.55,	5.78,	3.96
411	R0716,	6.91,	5.78,	-0.19
412	R0717,	1.39,	5.78,	-0.49
413	R0718,	10.00,	5.78,	-0.39
414	R0719,	2.74,	5.78,	1.64
415	R0720,	4.97,	5.78,	-0.20
416	R0721,	1.38,	5.78,	0.82
417	R0722,	4.70,	5.78,	-0.06
418	R0723,	10.00,	5.78,	0.30
419	R0724,	1.66,	5.78,	1.44
420	R0725,	6.83,	5.78,	0.15
421	R0726,	6.79,	5.78,	1.58
422	R0727,	6.42,	5.78,	-0.65
423	R0728,	3.70,	5.78,	1.05
424	R0729,	10.00,	5.78,	-1.90
425	R0730,	2.75,	5.78,	2.37
426	R0731,	3.90,	5.78,	0.38
427	R0732,	5.83,	5.78,	-0.76
428	R0733,	6.38,	5.78,	-0.82
429	R0734,	1.67,	5.78,	2.07
430	R0735,	10.00,	5.78,	-1.90
431	R0736,	1.40,	5.78,	3.67
432	R0737,	10.00,	5.78,	-2.12
433	R0738,	1.39,	5.78,	1.90
434	R0739,	4.58,	5.78,	-1.35
435	R0740,	10.00,	5.78,	-2.04
436	R0741,	5.74,	5.78,	0.32
437	R0742,	3.56,	5.78,	-0.34
438	R0743,	4.04,	5.78,	0.10
439	R0744,	0.94,	5.78,	2.17
440	R0745,	10.00,	5.78,	-2.04
441	R0746,	20.42,	5.78,	-1.02
442	R0747,	6.60,	5.78,	0.78
443	R0748,	3.60,	5.78,	2.07
444	R0749,	4.72,	5.78,	-0.92

445	R0750,	4.26,	5.78,	0.74
446	R0751,	3.28,	5.78,	3.14
447	R0752,	3.24,	5.78,	1.67
448	R0753,	2.00,	5.78,	3.88
449	R0754,	0.65,	5.78,	2.04
450	R0755,	10.00,	5.78,	-2.53
451	R0756,	6.71,	5.78,	0.81
452	R0757,	10.00,	5.78,	-1.77
453	R0758,	3.95,	5.78,	0.63
454	R0759,	8.37,	5.78,	-1.77
455	R0760,	10.00,	5.78,	-1.43
456	R0761,	1.90,	5.78,	0.40
457	R0762,	1.12,	5.78,	1.61
458	R0763,	3.03,	5.78,	1.75
459	R0764,	2.12,	5.78,	0.57
460	R0765,	3.08,	5.78,	0.54
461	R0766,	4.43,	5.78,	0.14
462	R0767,	2.24,	5.78,	0.39
463	R0768,	5.57,	5.78,	-0.80
464	R0769,	0.83,	5.78,	2.96
465	R0770,	10.00,	5.78,	-0.29
466	R0925,	2.19,	6.44,	0.89
467	R0926,	2.68,	6.44,	0.44
468	R0927,	2.07,	6.44,	3.03
469	R0928,	0.91,	6.44,	1.90
470	R0929,	3.06,	6.44,	1.40
471	R0930,	5.44,	6.44,	-0.71
472	R0931,	3.42,	6.44,	-1.24
473	R0932,	1.27,	6.44,	1.10
474	R0933,	2.71,	6.44,	0.55
475	R0934,	4.91,	6.44,	0.25
476	R0935,	4.20,	6.44,	0.76
477	R0936,	2.70,	6.44,	-1.08
478	R0937,	3.14,	6.44,	-0.34
479	R0938,	1.85,	6.44,	-0.42
480	R0939,	1.87,	6.44,	-0.01
481	R0940,	2.32,	6.44,	1.41
482	R0941,	5.63,	6.44,	-1.47
483	R0942,	0.56,	6.44,	2.98
484	R0943,	4.46,	6.44,	0.96
485	R0944,	2.70,	6.44,	1.32
486	R0945,	1.79,	6.44,	1.82
487	R0946,	2.27,	6.44,	-1.74
488	R0947,	2.69,	6.44,	1.38
489	R0948,	9.69,	6.44,	-2.53
490	R0949,	1.84,	6.44,	2.44
491	R0950,	4.91,	6.44,	-0.46
492	R0951,	2.59,	6.44,	1.95
493	R0952,	0.76,	6.44,	3.07
494	R0953,	1.90,	6.44,	0.08
495	R0954,	1.84,	6.44,	0.77
496	R0955,	3.08,	6.44,	1.04
497	R0956,	4.04,	6.44,	0.32
498	R0957,	3.64,	6.44,	0.34
499	R0958,	3.97,	6.44,	0.82
500	R0959,	5.45,	6.44,	-0.01
501	R0960,	0.14,	6.44,	0.94
502	R0961,	3.71,	6.44,	0.51
503	R0962,	10.00,	6.44,	-1.10
504	R0963,	2.50,	6.44,	-0.16
505	R0964,	6.24,	6.44,	-1.47
506	R0965,	2.40,	6.44,	1.77
507	R0966,	2.26,	6.44,	1.52
508	R0967,	1.92,	6.44,	2.89
509	R0968,	2.18,	6.44,	2.18
510	R0969,	2.99,	6.44,	1.31

511	R0970,	5.52,	6.44,	-0.49
512	R0971,	4.80,	6.44,	-0.19
513	R0972,	2.37,	6.44,	-0.36
514	R0973,	11.80,	6.44,	-2.66
515	R0974,	1.71,	6.44,	1.42
516	R0975,	2.85,	6.44,	0.74
517	R0976,	4.27,	6.44,	0.16
518	R0977,	3.07,	6.44,	0.85
519	R0978,	2.49,	6.44,	0.31
520	R0979,	1.58,	6.44,	2.59
521	R0980,	3.28,	6.44,	0.01
522	R0981,	2.06,	6.44,	0.61
523	R0982,	8.56,	6.44,	0.66
524	R0983,	4.23,	6.44,	0.40
525	R0984,	5.54,	6.44,	-0.15
526	R0985,	3.68,	6.44,	2.24
527	R0986,	1.94,	6.44,	-1.83
528	R0987,	6.96,	6.44,	-1.14
529	R0988,	8.17,	6.44,	-0.04
530	R0989,	1.75,	6.44,	0.92
531	R0990,	2.79,	6.44,	2.41
532	R0991,	13.18,	6.44,	-2.81
533	R0992,	5.50,	6.44,	-0.99
534	R0993,	2.13,	6.44,	1.90
535	R0994,	8.13,	6.44,	-1.24
536	R0995,	6.96,	6.44,	-1.17
537	R0996,	3.42,	6.44,	1.86
538	R0997,	1.56,	6.44,	1.19
539	R0998,	2.47,	6.44,	1.82
540	R0999,	9.50,	6.44,	0.58
541	R01000,	8.24,	6.44,	0.87
542	R01001,	2.03,	6.44,	2.13
543	R01002,	3.49,	6.44,	0.09
544	R01003,	10.00,	6.44,	-2.41
545	R01004,	3.53,	6.44,	1.99
546	R01005,	14.10,	6.44,	-0.22
547	R01006,	6.41,	6.44,	-0.16
548	R01007,	2.33,	6.44,	1.16
549	R01008,	1.61,	6.44,	1.37
550	R01009,	7.89,	6.44,	-1.61
551	R01010,	4.77,	6.44,	1.72
552	R01011,	2.18,	6.44,	2.89
553	R01012,	2.99,	6.44,	2.70
554	R01013,	5.89,	6.44,	-0.71
555	R01014,	3.21,	6.44,	2.24
556	R01015,	2.85,	6.44,	1.35
557	R01016,	4.00,	6.44,	1.89
558	R01017,	3.65,	6.44,	-0.16
559	R01018,	3.40,	6.44,	0.68
560	R01019,	3.18,	6.44,	0.91
561	R01020,	2.33,	6.44,	1.05
562	R01021,	1.11,	6.44,	3.47
563	R01022,	3.46,	6.44,	-0.34
564	R01023,	1.49,	6.44,	3.96
565	R01024,	5.83,	6.44,	-0.19
566	R01025,	2.39,	6.44,	-0.49
567	R01026,	5.39,	6.44,	-0.39
568	R01027,	3.39,	6.44,	1.64
569	R01028,	1.53,	6.44,	-0.20
570	R01029,	1.30,	6.44,	0.82
571	R01030,	1.23,	6.44,	-0.06
572	R01031,	10.00,	6.44,	0.30
573	R01032,	3.53,	6.44,	1.44
574	R01033,	1.77,	6.44,	0.15
575	R01034,	5.63,	6.44,	1.58
576	R01035,	7.25,	6.44,	-0.65

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R01036,  3.44,      6.44,      1.05
R01037,  2.81,      6.44,     -1.90
R01038,  3.62,      6.44,      2.37
R01039,  4.80,      6.44,      0.38
R01040,  5.61,      6.44,     -0.76
R01041,  1.85,      6.44,     -0.82
R01042,  1.10,      6.44,      2.07
R01043, 10.00,      6.44,     -1.90
R01044,  1.79,      6.44,      3.67
R01045,  5.27,      6.44,     -2.12
R01046,  0.82,      6.44,      1.90
R01047,  6.31,      6.44,     -1.35
R01048, 10.00,      6.44,     -2.04
R01049,  4.70,      6.44,      0.32
R01050,  3.59,      6.44,     -0.34
R01051,  1.66,      6.44,      0.10
R01052,  2.17,      6.44,      2.17
R01053,  4.59,      6.44,     -2.04
R01054, 20.38,      6.44,     -1.02
R01055,  7.60,      6.44,      0.78
R01056,  4.06,      6.44,      2.07
R01057,  1.10,      6.44,     -0.92
R01058,  1.91,      6.44,      0.74
R01059,  1.10,      6.44,      3.14
R01060,  3.44,      6.44,      1.67
R01061,  2.06,      6.44,      3.88
R01062,  2.88,      6.44,      2.04
R01063,  0.93,      6.44,     -2.53
R01064,  9.26,      6.44,      0.81
R01065,  1.99,      6.44,     -1.77
R01066,  1.66,      6.44,      0.63
R01067,  2.71,      6.44,     -1.77
R01068,  5.65,      6.44,     -1.43
R01069,  2.72,      6.44,      0.40
R01070,  1.54,      6.44,      1.61
R01071,  2.37,      6.44,      1.75
R01072,  3.12,      6.44,      0.57
R01073,  3.94,      6.44,      0.54
R01074,  1.68,      6.44,      0.14
R01075,  2.98,      6.44,      0.39
R01076,  5.34,      6.44,     -0.80
R01077,  3.24,      6.44,      2.96
R01078,  3.82,      6.44,     -0.29
END OF DATA
CROSS PRODUCT,DATA
COVARIANCE,DATA
CORRELATION,DATA
PRINT OBSERVATION,33,DATA
PRINT CORRELATION,34,DATA
REGRESSION ANALYSIS,DATA,COVA
DEPENDENT VARIABLE.CN0001
INDEPENDENT VARIABLES AT SIG LEVEL,40.0
 CN0002,CN0003
PRINT REGRESSION
GET OFF
****

*YYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYY
*YYYYYYY                                  YYYYYYYYYYYYYYYYYYYY
*YYYYYYY                                  YYYYYYYYYYYYYYYYYYYY
*YYYYYYY          NUMBER OF PAGES    10   YYYYYYYYYYYYYYYYYYYY
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                03/19/10    20/11/80     ICL  1900 STATISTICAL ANALYSIS    XDS3/27
REGRESSION ANALYSIS     COVA     DATA     CUT OFF PARAMETER  .999999E- 6
DEPENDENT VARIABLE    CN0001      DEGREES OF FREEDOM          613
INDEPENDENT VARIABLES AT SIGNIFICANT LEVEL       40.00 %
  CN0002  CN0003
   VARIABLES     IN THE REGRESSION SET

 VAR     REGRESSION        STANDARD      CONFIDENCE    T STAT  PART     MULTIPLE          E S S
 NAME       COEFF            ERROR         INTERVAL              CORR  CORRELATION
CN0002 -    1.3902541     .132083E  0  .111214E  0   10.53  -0.39   0.602          .449988E  4
CN0003 -    1.3973768     .686971E- 1  .578430E- 1   20.34  -0.63   0.310          .638348E  4
E.S.S.          .381109E  4
RESIDUAL ERROR  .249341E  1
MULT CORR       0.679
INTERCEPT TERM          13.5335644
GET OFF
+DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
+DDDDDDD
+DDDDDDD                                  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
+DDDDDDD         NUMBER OF PAGES    73    DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
+DDDDDDD                                  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
+DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
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(Appendix V) Computer Statistics For The Use Of Grid Squares In The Multiple Regression Analysis

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              18/27/30    18/11/80      ICL   1900 STATISTICAL ANALYSIS     XDS3/27

REGRESSION ANALYSIS      COVA     DATA        CUT OFF PARAMETER  .999999E- 6

DEPENDENT VARIABLE     CN0001        DEGREES OF FREEDOM             612

INDEPENDENT VARIABLES AT SIGNIFICANT LEVEL          40.00 %

  CN0002  CN0003

   VARIABLES      IN THE REGRESSION SET


 VAR      REGRESSION       STANDARD       CONFIDENCE     T STAT   PART      MULTIPLE           E S S
 NAME        COEFF          ERROR          INTERVAL               CORR   CORRELATION

CN0002 -      1.3813808     .133558E  0   .112456E  0    10.34   -0.39   0.652              .455744E  4

CN0003 -      1.6016088     .694170E- 1   .534491E- 1    23.07   -0.68   0.292              .725367E  4

E.S.S.               .387934E  4

RESIDUAL ERROR       .251769E  1

MULT CORR            0.715

INTERCEPT TERM                13.6884039
GET OFF
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+BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
+BBBBBBB   BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
+BBBBBBB   NUMBER OF PAGES   73   BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
+BBBBBBB   BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
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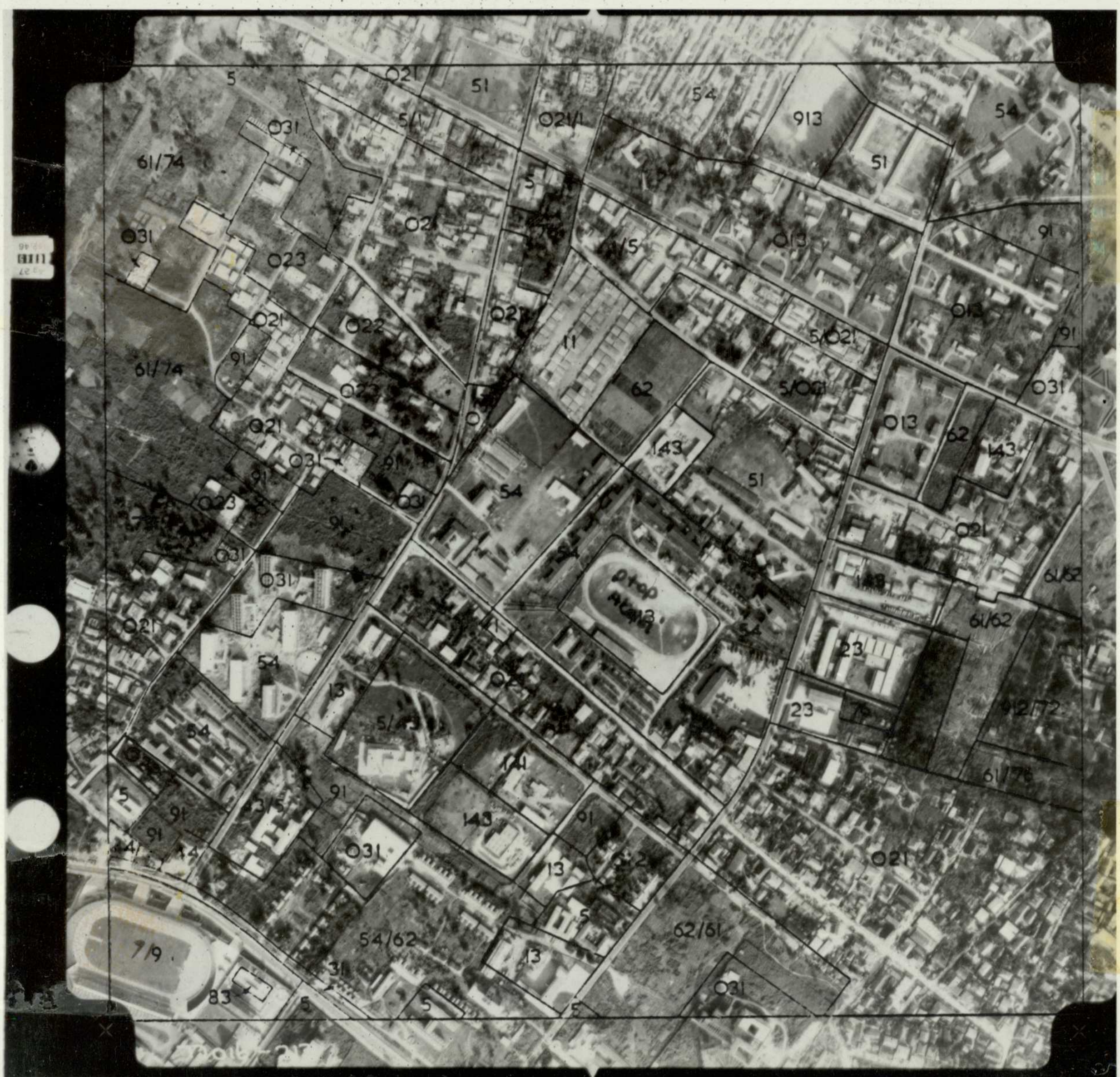
(Appendix VI) Computer Statistics For The Use Of Dot Grids in the Multiple Regression Analysis

(Appendix I) Land Use Air Photos Overlays Sample 1 - 7.

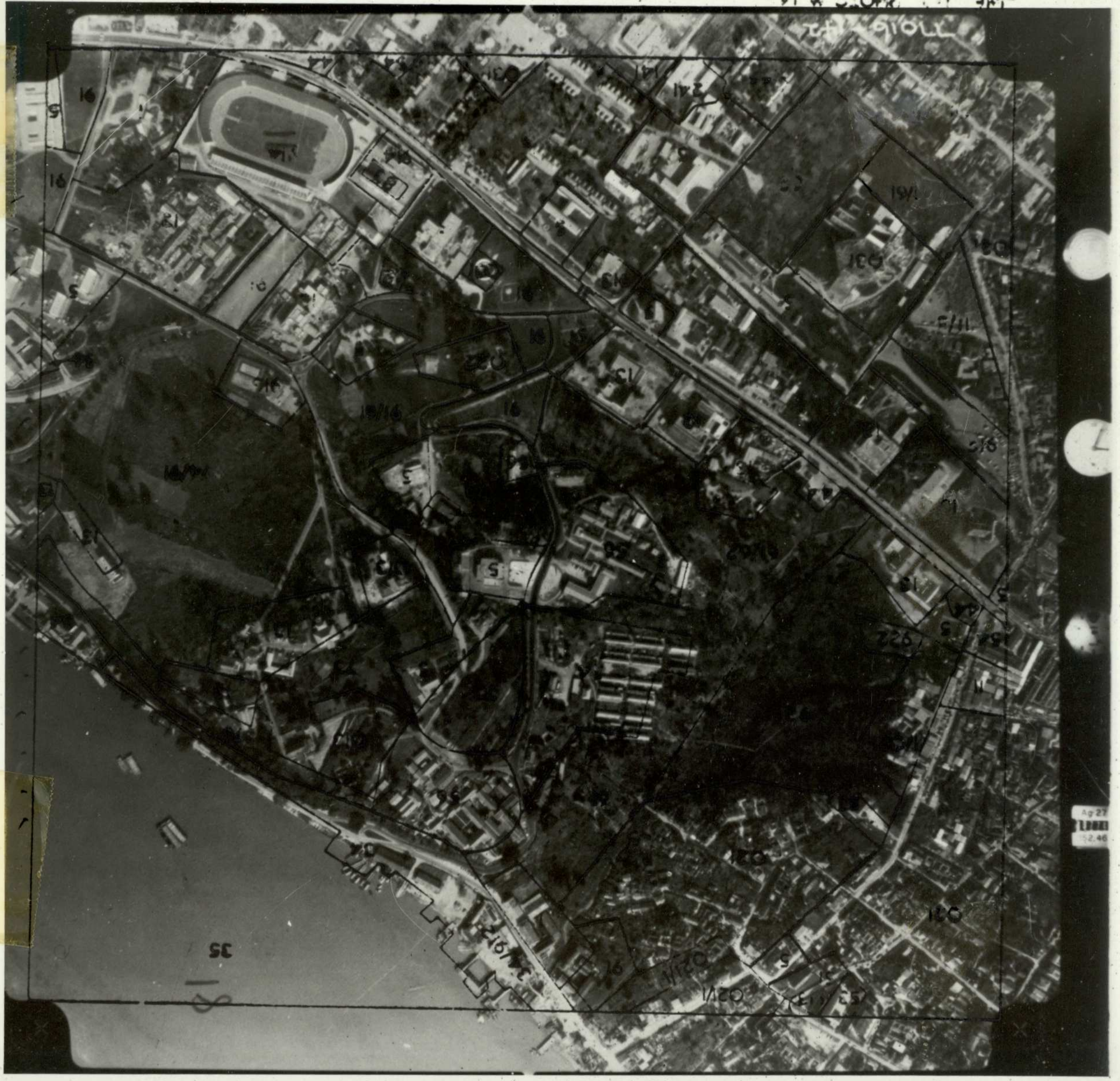
LINE 10-N PHOTO # 20

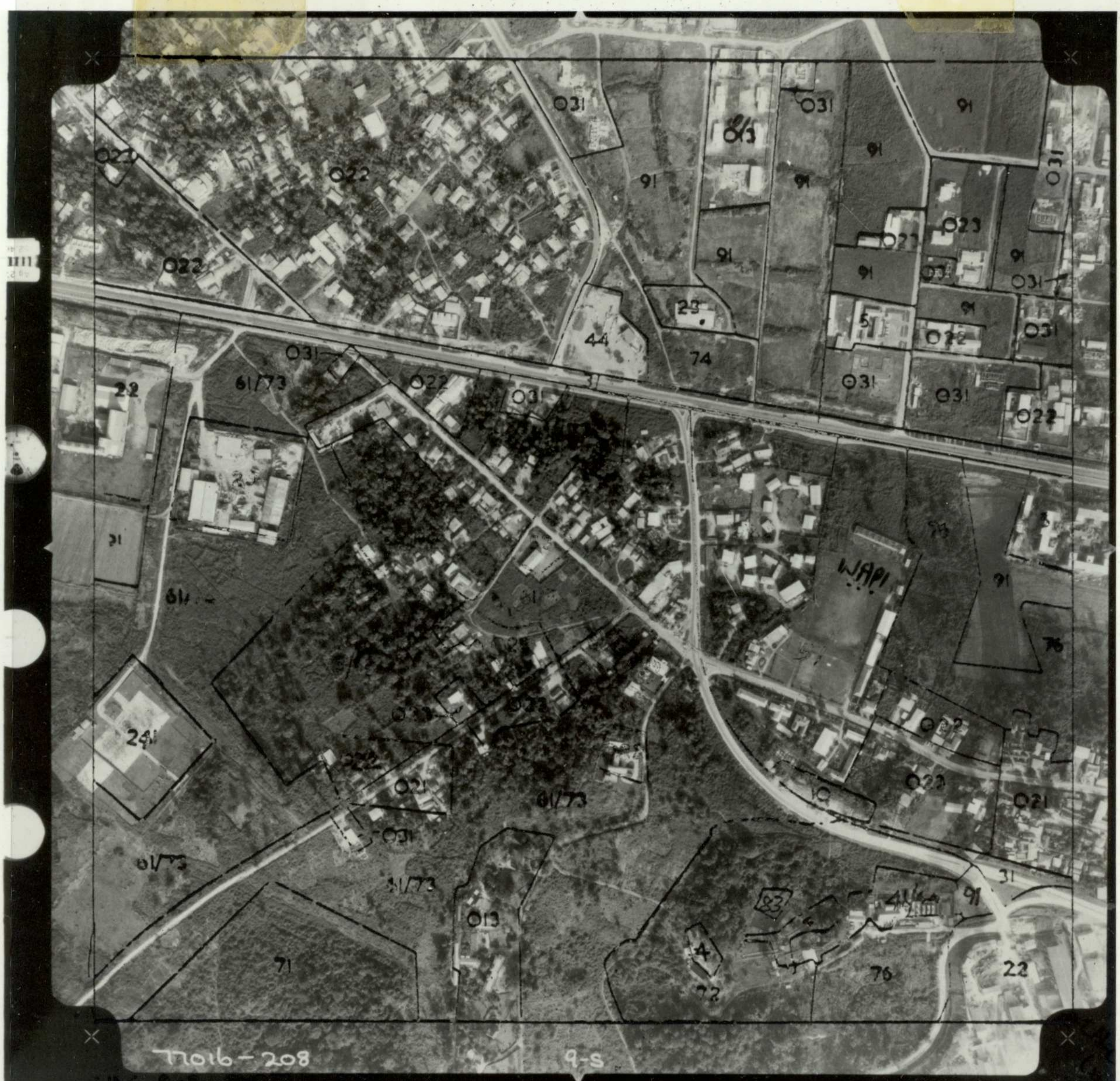
LINE 7-S PHOTO # 247



LINE 9-5 PHOTO # 213.


77012-243
7-S





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61/73
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WAPI
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83
4
72
76
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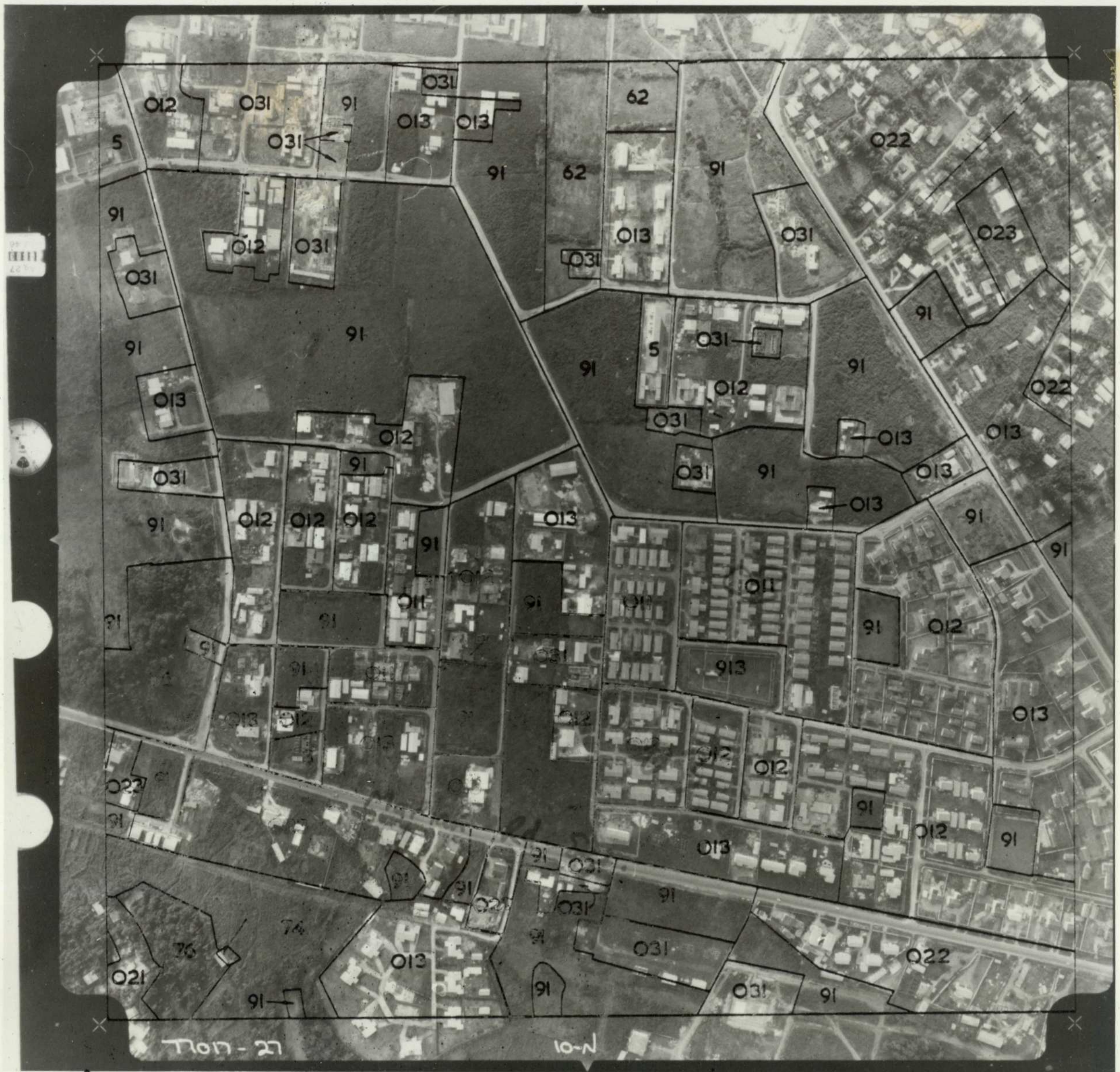
T016-208
9-S



LINE 10 N PHOTO # 27