SAMPLING OF LAND USE FROM LARGE SCALE

AERIAL PHOTOGRAPHS

BY

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Degree of MASTER OF SCIENCE (Land Surveying)

Department of Surveying

Fa**cu**lty **o**f Engineer**ing**

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MAY, 1988

DIGITIZED

DECLARATION

I hereby declare that this thesis has been composed by me and that it is a record of my research work. It has not been accepted in any previous application for a higher degree. All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

EJARO, SUNDAY PETER

DATE: 23/5/88

The above declaration is confirmed.

Prof. N. J. Field

Chairman , Supervisory Committee

DEPT. OF

Date:----------

CERTIFICATION

This thesis entitled SAMPLING OF LAND USE FROM LARGE SCALE AERIAL PHOTOGRAPHS, by Ejaro, Sunday Peter meets the regulations governing the award of the degree of Master of Science, Ahmadu Bello University, and is approved for its contribution to Knowledge and literary presentation.

_____ Date:----------

Chairman, Supervisory Committee

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Member, Supervisory Committee

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Head of Department

_____ Date: 30-1-89

Dean, Post graduate School

DEDICATION

With love to my father,

Mr Francis A. Ejaro.

ACKNOWLEDGEMENT

I express great appreciation to my supervisor, Prof. N. J. Field; for his immense painstaking and untiring guidance during the entire period of this research. His assistance in the computer analysis is indescribable.

I readily owe my indeptedness to many sources of information, for which reason I have included a reference at the end.

Although all debts cannot be acknowledge, I wish to express my thanks to Mr H. A. Freiwald of Kenting Africa Resources Survey, Kano, for the assistance given me in acquiring the aerial photographs for this research and Mr A. A. Bammeke, Postgraduate Co-ordinator, Surveying Department.

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I thank all others who contributed to the success of my thesis.

ABSTRACT

A land use classification has been developed for the inventory of land use **in a Nigerian forest area, Sabon** Gida Ora, using large scale aerial photography.

The dot grid method of sampling covering 14% of the area is used in estimating the various land use categories. Bonnor (1975) and Kolbl and Trachsler (1980) formulae are used in estimating the error of the land use categories. Estimated land use categories are displayed in a series of computer maps.

			Page
		Declaration	ii
		Certification	iii
		Dedication	iv
		Acknowledgement	v
		Abstract	vi
		List of figures	x
		List of tables	xi
		List of appendices	xii
Chapter	1.0	INTRODUCTION	1
	1.1	Background of the research	1
	1:1:1	Research theme and statement of problem	3
	1:1:2	Need for land use study	6
	1:1:3	Objective of study	6
	1:1:4	Organisation of the thesis	6
	1.2	The study Area	7
	1:2:1	Aspects of the study area	7
	1:2:1:1	Vegetation	9
	1:2:1:2	Rainfall and temperature	9
	1:2:1:3	Topography and hydrology	9
	1:2:1:4	Population and communication	11
Chapter	2.0	REVIEW OF LITERATURE	13
	2.1	Theoretical perspectives	13
	2:1:1	Concept of land use	13
	2:1:2	Review of land use classification schemes	14
	2:2	Criteria for land use classification scheme	22
	2:3	Classification scheme adopted	24
	2:4	Definition and categorization characteristic of land use adopted	32
	2:5	Land use classification problem	40
	2:6	Background of statistical methods used in land use studies.	41

			Page
Chapter	3:0	RESEARCH DESIGN AND METHODOLOGY	
	3:1	Materials and equipment	48
	3:1:1	Photography	48
	3:1:2	Equipment	48
	3:2	Point sampling on aerial photographs	49
	3:2:1	Limitation of choice of sampling technique	49
	3:2:2	Choosing a sampling procedure	50
	3:3	The dot grid, grid density and error estimate	5
	3:4	The accuracy question	54
	3:5	Interpretation procedure	56
	3:6	Recording base	57
	3:7	Result presentation.	57
Chapter	4:0	ANALYSIS	58
	4:1	Analysis procedure	58
	4:1:1	Data handling	58
	4:1:2	Data processing	58
	4:2	Land use	59
	4:2:1	Selected land use map	59
	4:2:2	Selected land use table	61
	4:3	Distribution of land use	63
	4:3:1	Settlement and associated features	64
	4:3:1:1	Residential	64
	4:3:1:2	Commercial and Services	67
	4:3:1:3	Institutional	67
	4:3:1:4	Transport	68
	4:3:2	Farmland	68
	4:3:2:1	Enclosed farmland under 2ha	71
	4:3:2:2	Unenclosed farmland under 2ha	71
	4:3:2:3	Unenclosed farmland over 2ha	73

		Page
4:3:2:4	Cropland unfarmed	73
4:3:3	Uncultivated lands	76
4:3:3:1	Forest land	78
4:3:3:2	Wood land	78
4:3:3:3	Scrub land	82
4:3:3:4	Shrub land	82
4:3:3:5	Grass lawns	85
4:3:4	Barren land	85
Chapter 5:0	Summary and Conclusion	87
	References	89
	Appendices	93

List of Tables

		Page
1	World land use Survey land classification	15
2	Tuley P et al (1972) land use and vegetation classes	16
3	Land Use and land cover classification System for use with remote sensor data	17
4	Esin (1981) Hierarchical classification Key for Oron built-up environment	19
5	Field and Collins (1986) Land Use Classification in a Nigerian Savannah test area	21
6	Land use classification scheme adopted	25
7	Hierarchical land use selected categories used in analysis	30
8	Selected land use distribution	61
9	Residential Sub-category land use	67
10	Farmland land use Sub-categories	70

LIST OF FIGURES

Page

1. Map of Nigeria showing the study area Sabon Gida Ora 8
2. Map of Sabon Gida Ora showing topography and hydrolology 10
3. Map of Sabon Gida Ora showing communication lines.... 12
4. Selected land use map 60
5. Sabon Gida Ora land use category 1 (settlement and associated features) 65
6. Sabon Gida Ora land use category 11 (Settlement) 66
7. Sabon Gida Ora land use category 2 (cultivation) 69
8. Sabon Gida Ora land use category 23 (uneclosed farmland under 2ha) 72
9. Sabon Gida Ora land use category 236 (mixed cropping in unenclosed farmland under 2ha..74
10. Sabon Gida Ora land use category 25 (cropland unfarmed) 75
11. Sabon Gida Ora land use category 3 (cultivated land) 77
12. Sabon Gida Ora land use category 31 (forest land) 79
13. Sabon Gida Ora land use category 313 (riparian forest) 80
14. Sabon Gida Ora land use category 32 (wood land) 81
15. Sabon Gida Ora land use category 33 (scrub land) 83
16. Sabon Gida Ora land use category 34 (shrub land) 84
17. Sabon Gida Ora land use category 41 (bare uncultivated ground)..... 86

LIST OF APPENDICES

Appendix		Page
1	Sabon Gida Ora land use category 111 (Residential)	94
2	Sabon Gida Ora land use category 1111 (isolated buildings)	95
3	Sabon Gida Ora land use category 1112 (buildings in compound)	96
4	Sabon Gida Ora land use category 234 (root crops in unenclosed farmland under 2ha)	97
5	Sabon Gida Ora land use category 24 (uneclosed farmland over 2ha)	98
6	Sabon Gida Ora land use category 251 (Tillage)	99
7	Sabon Gida Ora land use category 252 (Cleared land)	100
8	Sabon Gida Ora land use category 253 (Early bush fallow)	101
9	Sabon Gida Ora land use category 3112 (light forest)	102
10	Sabon Gida Ora land use category 35 (Grass lawns)	103

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE RESEARCH

The need for land use information is so basic, for so little is known, officially and unofficially, at the present time and the changes that will take place eventually will be relatively so much greater, amounting in time to a revolution. Planning for future development and increased production must be preceded by the adequate survey of existing conditions, as a basis for new development.

Researching into land use monitoring and inventory using remote sensors is not conducted for the first time. Past decades many surveys, studies and projects have successfully demonstrated that remote sensor technology can be used as a pragmatic tool for land use inventory and mapping. (Anderson 1974). Some have concentrated on describing existing cultural landscape; others have concentrated on change detection focusing mostly on monitoring of rapidly changing phenomena.

Air photo interpretation is the least sophisticated remote sensor technique and has been most widely used. Its use in conjunction with computer analysis to obtain land use information has increased the efficiency of land use inventory by adding speed, economy and accuracy as well as adding certain land use/land cover information that is impossible, difficult or economically

impracticable to obtain by routine ground Survey about present land use and the changes in land use that are occurring.

An aerial photograph has about 25 x 10^9 units of information per square cm. (Paine 1981), but there is an obvious relationship between scale of photography and what is reasonably discernable. Therefore, the scale of the aerial photograph determines (to a large extent) the land use information obtainable from aerial photographs.

It is pertinent to mention that rainy season photography is used in this study and the scale of photography is large (1:5,000). The scale is large enough for accurate location and identification of any quickly developing or growing phenomenon.

A wealth of information about land use can be obtained from these aerial photographs. These bits of land information need to be identified, collected and recorded in accordance with some system for the classification of such uses.

There is a need for classification of land use information because "classification schemes of objects seek to organize knowledge so that the properties and relationships of the objects can be most easily remembered and understood for some specific purpose" (Henry and Schafer 1980). There are generally two approaches to classification of land resources information.

1. The cover oriented approach described as classification according to the vegetational and artificial constructions covering the surface.
2. The activity categorization in accordance with type of man's activities on land which are directly related to the land. (Anderson 1974).

In this study the two approaches have been jointly used to draw up a classification scheme of different levels of categorization.

There is a relationship between classification level and data source (and scale). Remote sensing data from different altitudes do not have the same degree of resolution, hence of detailed classification. To obtain detailed inventory the classification levels ought to be detailed. In this study a four level land use/cover classification scheme is developed for the estimation of existing land use in Sabon Gida Ora and is applicable in neighbouring environments. In all, there are four generalized level I classes, Sixteen level II classes, "the fulcrum of the classification". Level III, a sub-categorization of II, appear to provide land cover information. Level IV, an extension of level III provide detail inventory on man's activity on land which are directly related to the land.

With a four level classification the volume of information obtainable is enormous. Since interpreting all information on each Stereomodel is tedious and time consuming a simple sampling technique is employed. A regular dot grid of 25 sample points, 5 by 5, placed on each Stereomodel covering the block of photographs is used in obtaining the land use information. Each sample point land use interpreted is assigned an identification (code) number. The apple II Micro-Computer with floppy disk is used for the data storage and analysis.

The analysis includes accuracy assessment of the selected land use catgories estimated using the well tested Bonnor (1975) and Kölbl and Traschler (1980) formulae. Finally the land use information is presented in the form of computer maps.

1:1:1: RESEARCH THEME AND STATEMENT OF PROBLEM.

The study is aimed at using relatively simple techniques and less expensive data source at reasonable accuracy in acquiring land use information in quick enough time. To meet this requirement attention is being concentrated to careful identification and classification of homogenuous categories into logical hierarchical levels; identification and quantification of appropriate sampling techniques and accuracy assessment of the method used; and selected land use estimates.

Land use analysis as described by Anderson (1974), has the following components:

1. Inventory of current use of land.
2. Monitoring or detection of changes in land uses.
3. Explanation of current pattern and the changes in land use that are occurring over time.

Due to inavailability of different generations of photographs of the study area and large scale photography used this study is limited to inventory of current use of land. The concentration will be:

1. Identification, collecting and recording the different types of current land uses in accordance with the classification scheme drawn.

2. Provision for the capability to locate the various uses geographically in the form of maps. This essentailly consists of the preparation of maps of existing resources and their current uses along with an analytical narrative and tabular summary.
3. Development of data storing and handling techniques which will permit these data to be used in the change detection if another generation of photographs exist and for the explanation phase of land use analysis.

1:1:2 NEED OF STUDY

Acquired land use data is needed to provide:

(i) Information on the uses being made of land resources for the monitoring of environmental quality.

(ii) Necessary information for land use planning and management of lands.

1:1:3 OBJECTIVE OF STUDY

This thesis sets out:

1. To test the dot grid method of acquiring, and computer analysis and presentation of land use information obtained from large scale aerial photographs in a Nigerian forest zone. Thus extending investigation of land use interpretation currently in the Savannah to a forest area-Sabon Gida Ora.

2. To develop a land use classification scheme for use with large scale photography in a rainforest rural-small town-Sabon Gida Ora.

1:1:4 ORGANIZATION OF THE THESIS

The thesis is in five chapters.
Chapter 1, the introductory chapter, gives a prelude on remote sensing application, a brief preview of succeeding chapters and outlines the utility and objective of the study.

Chapter 2, reviews available literature on land use classification schemes and statistical methods applied on aerial photo interpretation.
Chapter 3, discusses the research design and methodology.

Chapter 4, contains analysis of data and discussion on result obtained. The last chapter, reviews the study and outlines observations in conclusion.

1:2 THE STUDY AREA

The choice of the study area is:

(i) A matter of what was available as a complete block of photographs. However, it became interesting for extension of current investigation methods employed in the Northern Savannah to the Southern forest zone.

(ii) Desire to inventorise land use using large scale aerial photography.

1:2:1 ASPECTS OF THE STUDY AREA

The study area is covered by the national map series Nigeria 1:50,000 sheet 284 N.E IFON N.E, and is an awkward figure area with its four outline tips bounded by latitudes 6° 50 '30" and 6° 54 '30" N, and Longitude 5° 53 '20" and 6° 00 '00" E. The area covers the Southern part of Sabon Gida Ora.

Sabon Gida Ora is in the North west of Bendel State of Nigeria. (see fig. 1). It is about 243km and 22.5km by Crow Fly from the State Capital Benin City and Auchi respectively.

FIG. 1: MAP OF NIGERIA SHOWING STUDY AREA - SABON GIDA ORA



1:2:1:1 VEGETATION

The study area lies in an ecological zone generally described as moist-semi deciduous forest zone (Keay, R.W.J. 1959). In common with most of the forest of Nigeria, the vegetation is dominated by areas of secondary vegetation growth, farming at one time or another having taken place over them.

1:2:1:2 RAINFALL AND TEMPERATURE

The rainy season is from March to October including the period of "little dry season" and the dry season is from November to February. Mean annual varies from 1270-1524mm. Mean annual number of rainy days 80-100. (Fed. Surveys Atlas 1978).

Temperature: (a) Mean annual temperature 25.55^{oc} (78^{oF}). (b) Mean annual maximum temperature 27.77^{oc} (82^{oF}). (c) Mean annual minimum temperature 22.22^{oc} (72^{oF}).

1:2:1:3 TOPOGRAPHY AND HYDROLOGY

The area is a gently rolling plain. A Cross Section through the topographical map of the area reveals a gently rising plain from 240m in the South west to 300m in the North east. (see fig. 2).

A dendritic pattern River Owan flows aeross the study area with Rivers Ule and Onuan as tributaries. The area is well drained.

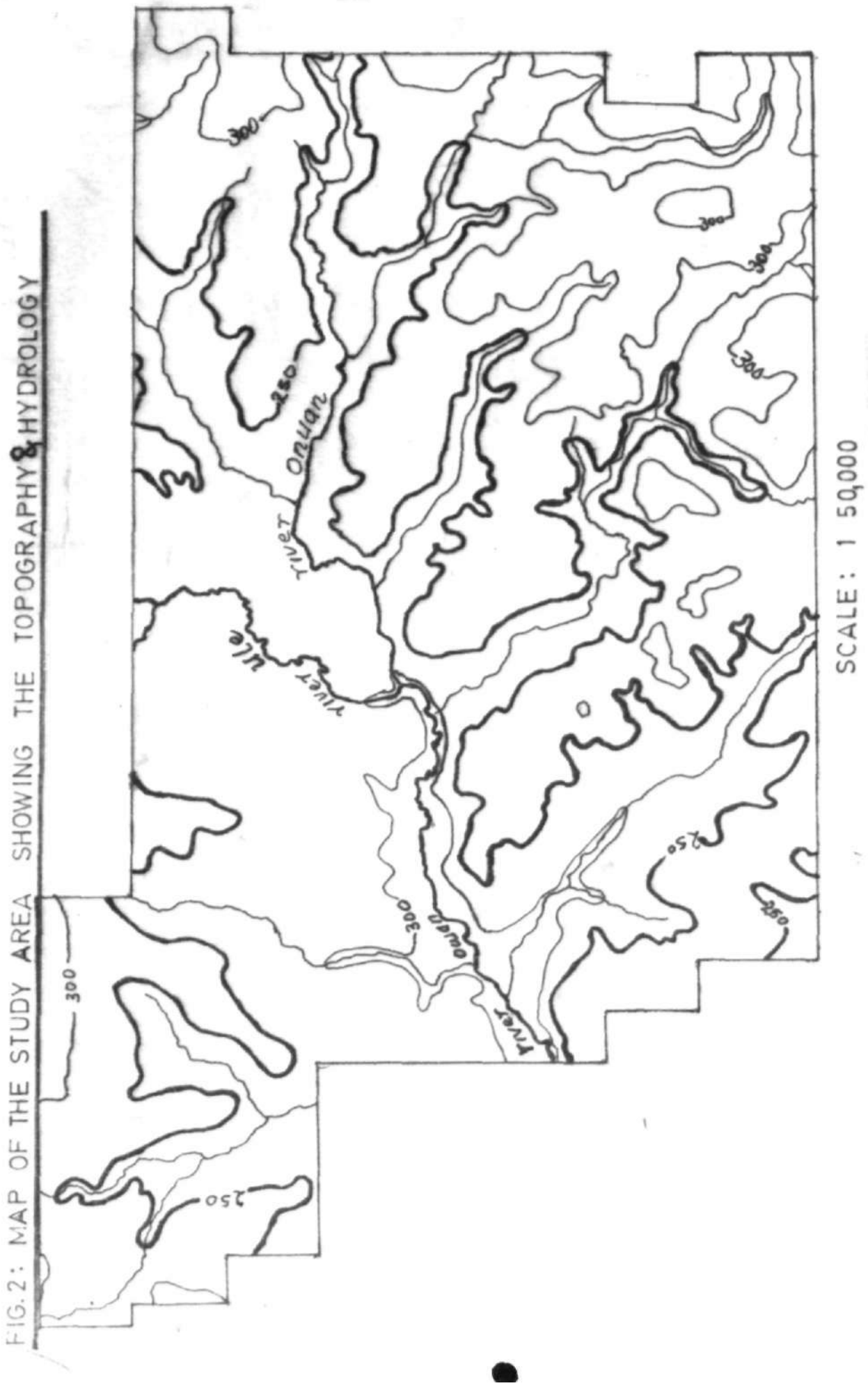
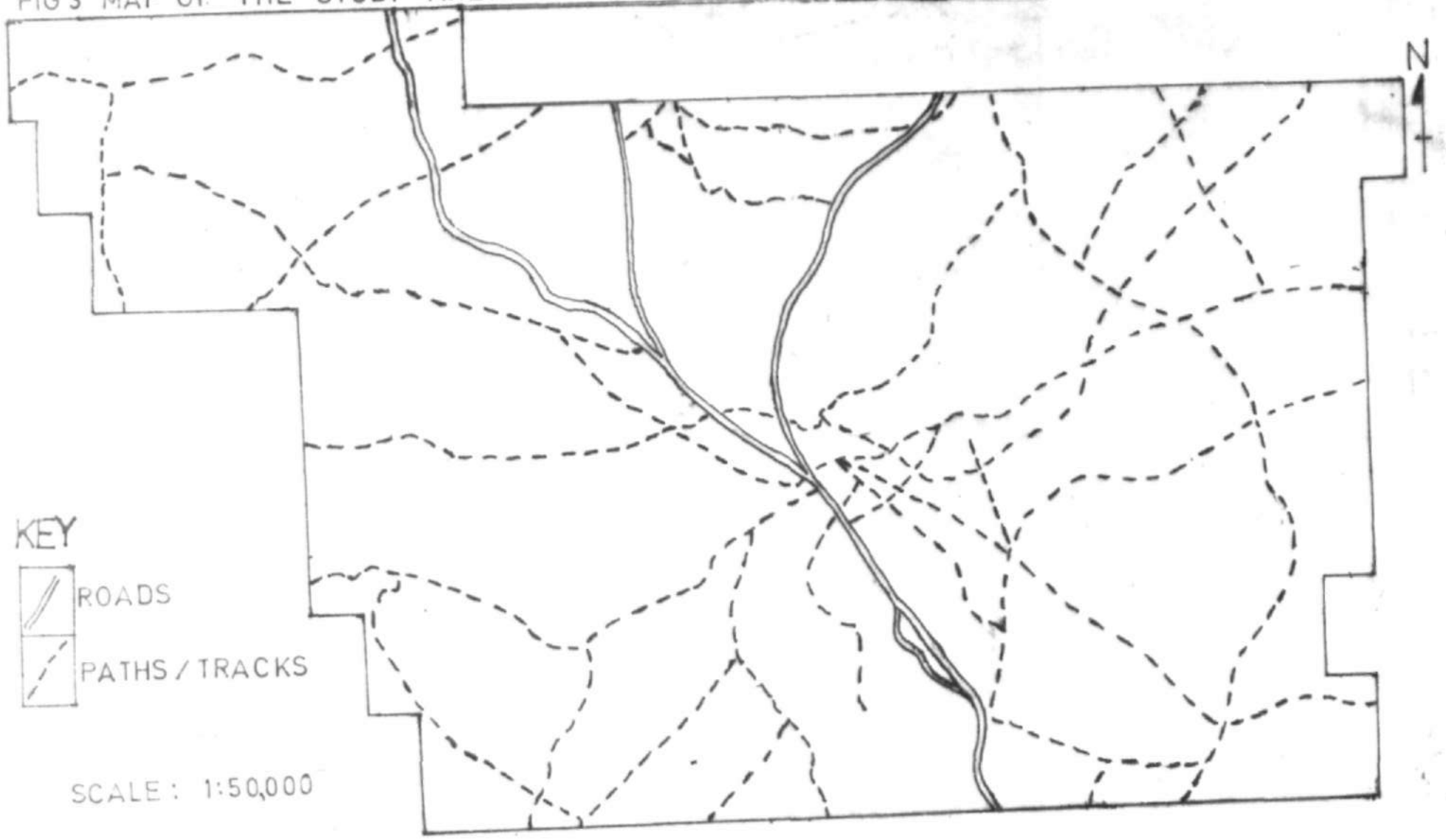


FIG. 2: MAP OF THE STUDY AREA SHOWING THE TOPOGRAPHY & HYDROLOGY

1:2:1:4 POPULATION AND COMMUNICATION

Population density is between 350-400 persons per square km. (Projection of 1963 Census). Communication facilities is barely good. There are main roads linking the town to other parts of the State. There is an intricate web of paths and tracks covering the study area. (see fig. 3).

FIG 3 MAP OF THE STUDY AREA SHOWING COMMUNICATION LINES



CHAPTER 2

REVIEW OF LITERATURE

Many studies on land use analysis exist, published by Scholars in various literature. A search of the literature is undertaken to review and evaluate the various works on classification schemes used for different sensor imagery with particular interest to aerial photographs. The different Statistical techniques are also appraised.

With the various options it is essential to develope and use an appropriate classification scheme and an efficient Statistical method suiting my need.

2:1 THEORETICAL PERSPECTIVES

2:1:1 CONCEPT OF LAND USE

Land use is a broad term. It stretches from the location of a single residential building and the layout of roads and manufacturing industries through the patronage of recreational parks and cultivation of farmlands to the drilling of oil wells and disposal of refuse. (Igbozurike 1981). This refers to the functional aspect of the area with respect to man's occupations and his culture. It represents the end effect on land of economic, social and physical interaction of man with his environment.

In most classification schemes the approach covers the functional aspect as well as the vegetational and artificial construction covering the land. In this study land use will mean the two, thus covering data on the land resource which is relevant to the way in which land is presently used, and natural and artificial covering.

2:1:2 REVIEW OF LAND USE CLASSIFICATION SCHEMES

Different researchers in different parts of the world with different interest at different times have drawn up various land use classification schemes. These schemes have been designed for use at specified scales, for designated areas, and within the capability of the information gathering technique being used (Anderson et al 1976).

This section reviews and evaluates some attempts that have been made at developing a suitable land use classification scheme. It is largely exploratory in nature.

The salient features of a few schemes will be cited.

In 1949, the World Land Use Survey Commission proposed a classification of land use which then appeared to be the nearest approach to an internationally accepted system for notation of land use and land cover. Bickmore et al (1970) cited the World Land Use Survey Classification, " a general classification with 9 classes which does not fit very well into tropical systems of rural land use ". (Field and Collins 1986).

TABLE I WORLD LAND USE SURVEY LAND CLASSIFICATION:

1. Settlement and associated non - agricultural lands.
2. Horticulture.
3. Tree and other perennial Crops.
4. Croplands; (a) continual and rotation cropping.
   (b) land rotation.
5. Improved permanent pasture, managed or enclosed.
6. Unimproved grazing land; (a) used.
   (b) not used.
7. Woodlands; (a) Dense
   (b) Open
   (c) Scrub
   (d) Swamp forest
   (e) Cut over or burnt over forest areas
   (f) Forest with subsidiary cultivation.
8. Swamps and Marshes-fresh and salt water; non-forested.
9. Unproductive land.

2 In 1972 Tuley et al developed a workable land system and land facet classification in a survey of some 60,000ml^2 (150543.36km^2) using the 1:40,000 scale, 900 aerial photographs of North east Nigeria. The land use and vegetation classes are given in table 2.

TABLE 2: TULEY et al (1972) LAND USE AND VEGETATION CLASSES

1.	Buildings and Compounds	16.	Forest
2.	Roads/Railways	17.	Closed woodland
3.	Paths and tracks	18.	Thicket
4.	Rivers and streams	19.	Open woodland
5.	Rivers and stream beds	20.	Tree Savanna
6.	Other water bodies	21.	Tree and shrub Savanna
7.	Bare rocks, Sandbanks etc	22.	Shrub Savanna
8.	Erosion scars	23.	Acacia tree Savanna on heavy clay
9.	Cropping unrecognized		
10.	Guinea Corn	24.	Grassland
11.	Crop or fallow	25.	Parkland
12.	Fallow-all herbaceous		
13.	Fallow-all primarily herbaceous		
14.	Fallow-all woody		
15.	Fallow-all primarily woody.		

3. In 1975 the Department of the Environment (DOE) of the U.K. set up a joint central and local government study of the classification of land uses and a National Land Use Classification was formulated (Smith et al 1977). Five main land uses within developed areas were defined in physical terms rather than in terms of activities.

A Predominantly residential use.

B Predominantly industrial/or commercial use.

C Predominantly educational/community health/indoor or recreational use.

D Transport use.

E "Urban" Open Space.

4 In 1976 Anderson J. R. et al published a revised land use classification system as presented in U.S. Geological Survey Circular 671. This classification system was presented for use with remote sensor data, for the first time the concept of classification levels was introduced.

The classification consist of levels I and II and "intentionally left open-ended so that users can have flexibility in developing more detailed land use classifications at the third and fourth levels". (Anderson et al 1976).

TABLE 3: THE LAND USE AND LAND COVER CLASSIFICATION SYSTEM WITH REMOTE SENSOR DATA

Level I		Level II	
1	Urban or Built-upland	11.	Residential
		12.	Commercial and services
		13.	Industrial
		14.	Transportation, Communications and utilities.
		15.	Industrial and Commercial
		16.	Mixed Urban or Built up land
		17.	Other Urban or Built up land.

2	Agricultural land	21.	Cropland and pasture
		22.	Orchards, Grooves, Vineyards, Nuseries, Ornamental and Horticultural areas.
		23.	Confined Feeding Operations
		24.	Other Agricultural land.
3	Rangeland	31.	Herbaceous Rangeland
		32.	Shrub & Bush 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.	Non Forested 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 Bush Tundra
		82. Herbaceous Tundra
		83. Bare Ground Tundra
		84. Wet Tundra
		85. Mixed Tundra
9	Perennial snow or ice	91. Perennial snowfields
		92. Glaciers

(5) In 1981 Esin in his research titled "Expeditious and inexpensive technique for Survey of Built-up environments in developing nations, drew a hierarchical classification key for Oron built-up environment. Below is the classification scheme.

TABLE 4: Esin (1981): HIERARCHICAL CLASSIFICATION KEY FOR ORON BUILT-UP ENVIRONMENT

Primary Code	Level I	Secondary Code	Level II	Tertiary Code	Level III
0	Residential	01	Housing Est.	011	Housing Est. H/Dens
				012	Housing Est. M/Dens
				013	Housing Est. L/Dens
		02	Non-Housing Estate		
				021	Non-Housing Est. H/Dens
				022	Non-Housing Est. M/Dens
				023	Non-Housing Est. L/Dens
		03	New Development		
				031	Urban Non Development
				032	Urban Non ReDevelopment.

Primary Code	Level I	Secondary Code	Level II	Tertiary Code	Level III
1	Commercial	11	Open market.	111	Market shops
		12	Super market	122	Corner shops
		13	Central business district	133	Commercial Houses
		14	Workshop	141	Vehicle workshop
2	Industrial	21	Extractive Industry		
		22	Processing Industry		
		23	Manufacturing Industry		
		24		241	Industrial Non Development
				242	Industrial ReDevelopment.
3	Transportation	31	Railways/ streets		
		32	Railways		
		33	Harbours		
		34	Airports.		

Primary Code	Level I	Secondary Code	Level II	Tertiary Code	Level III
4	Utilities and Services	41	Electricity Transmission line		
		42	Petrol/Radio Stations		
5	Institutional	51	School Structures		
		52	Prison		
		53	Church/ Mosques		
		54	Barracks		
		55	Museum		
6	Improved open space	61	Stadium	611	Town hall
		62	Parks		
7	Others (not in the above categories).				

(6) Field and Collins (1986) in a pioneering work in the Nigerian Savanna adapted the following classification:

TABLE 5: LAND USE CLASSIFICATION IN A NIGERIAN SAVANNA TEST AREA.

1	Settlement and associated features		
		11	Settlements
		12	Communication
		13	Industry.
2	Cultivation	21	Enclosed farmland enclosure less than 10ha
		22	Enclosed farmland enclosure greater than and equal to 10ha
		23	Unenclosed farmland.

3	Grass/Shrub	31	Fadama (flood plains)
		32	Grassland not in fadama
		33	Scrub and small trees
		34	Swamps and marshes
4	Wood land	24	Tree Plantation
		35	Wood land
		36	Gallery forest and Kutame
5	Waste land	41	Inselberg and bare rock out crop
		42	Rivers and lake beds.

Other noteworthy classification schemes examined were those by Collins (1966) in his "tropical land use application of aerial photography". Hopkins (1974) and Moss (1959).

2:2 CRITERIA FOR LAND USE CLASSIFICATION SCHEMES

Land use classification is "the systematic appraisal of uses of land and their designation by categories on the basis of similar characteristics" (Vink 1975). Classification schemes of natural objects and artificial features, as corroborated by Henry and Schafer (1970), seeks to organize Knowledge so that the properties and relationships of the objects can be most easily remembered and understood for some specific purpose.

Esin (1981) quoted Armand (1965) as suggesting that a "Classification can be built on various principles; morphological, genetic, temporal, spatial, quantitative etc. But must follow certain general and unalterable laws of logic".

In drawing up a land use classification scheme the following criteria should be noted and observed:

1 It is pertinent that the categories should be mutually exclusive and arranged in logical divisions and subddivisions, avoiding overlap of categories.

2 All phenomena investigated should fall into one category or the other.

3 Be able to identify each category on the material being used. Moreso the classification scheme should be suitable for use with imagery taken at different times during the year.

4 Determine Unit of Classification and level of classification considering the scale of the imagery.

5 Determine basis of classification either form or function. Mixing of categories from morphological and functionally oriented classification schemes should be avoided. Mixing of morphology and function can be taken care of by adoption of appropriate levels of classification.

6 Define each category clearly. Precise statements and objective description of individual categories is very essential for a sound classification. Clear and sharp definitions of land use categories which can be used without major modification from one time to another is necessary to ensure repeatable or repetitive results attainable from one interpreter to another and from one time of sensing to another.

7 The interpretation accuracy for each category in the classification should be well-balanced.

8 A classification scheme should have an open ended approach allowing great flexibility so that it can be useable or adaptable for use over an extensive area. (After Anderson J.R 1971)

Obviously all the criteria cannot be met with the same level. However, these criteria serve as useful basis for evaluation of classification scheme.

2:3 CLASSIFICATION SCHEME ADOPTED -FOR USE WITH LARGE SCALE PHOTOGRAPHY.

The search for a single land-use classification system which will serve all users for all time is a fruitless one. Hence "there is no one ideal classification of land use and land cover, and it is unlikely that one could ever be developed. Each classification is made to meet the needs of the user---------" (Anderson et al 1976).

After an appraisal of the available classification schemes a more detailed level III and IV categories are developed to suit local condition and need. In drawing these levels of classification I have tried to remain compatible with the "standard or international" levels of generalization.

The initial stage in the classification exercise was compilation of a list of all the crops and land use types that are likely to exist in Sabon Gida Ora and determine which of these would be readily identifiable on the aerial photographs.

TABLE 6

LAND USE CLASSIFICATION SCHEME ADOPTED

LEVEL I	LEVEL II	LEVEL III	LEVEL IV
1. SETTLEMENT AND ASSOCIATED FEATURES	11. SETTLEMENT	111. RESIDENTIAL	1111. Isolated buildings
			1112. Buildings in compound
			1113. Buildings of more than one storey
		112. COMMERCIAL AND SERVICES	1121. Market
			1122. Large commercial buildings
			1123. Office buildings (administration)
			1124. Parking lots
			1125. Motor parks
			1126. Petrol stations
			1127. Shops
			1128. Others
		113. RECREATIONAL	1131. Sports arena
			1132. Gardens and parks
		114. INSTITUTIONAL	1141. Educational
			1142. Religious houses and prayer grounds

		114. INSTITUTIONAL	1143. Health services 1144. Others
		115 MIXED SETTLEMENT	
	12. TRANSPORT	121. ROADS AND HIGHWAYS	1211. Main roads 1212. Secondary roads 1213. Minor roads
		122. PATHS AND TRACKS	1221. Main paths and tracks 1222. Minor paths and tracks
		123. Railways	
	13. INDUSTRY	131. Manufacturing	
	21. ENCLOSED FARMLAND UNDER 2 ha.	211. Vegetables 212. Tree fruit crops 213. Cereal crops 214. Root crops 215. Mixed cropping	

22. ENCLOSED FARMLAND OVER 2 ha.	221. Tree crops 222. Cereal crops 223. Root crops 224. Mixed cropping
23. UNENCLOSED FARMLAND UNDER 2 ha.	231. Vegetables 232. Tree fruit crops 233. Cereal crops 234. Root crops 235. Tree crops 236. Mixed cropping
24. UNENCLOSED FARMLAND OVER 2 ha.	241. Vegetables 242. Tree fruit crops 243. Cereal crops 244. Root crops 245. Tree crops 246. Mixed cropping

		25. CROPLAND UNFARMED	251. Tillage 252. Cleared land 253. Early bush fallow	
		26. FORESTRY	261. Eucalyptus 262. Teak	
	31. FOREST LAND		311. TROPICAL RAIN FOREST	3111. Heavy forest 3112. Light forest
			312. SWAMPS AND MARSHES	3121. Mangrove swamps 3122. Fresh water swamps 3123. Marshes
			313. RIPARIAN FOREST	
3. UNCULTIVATED LANDS				
	32. WOODLAND			
	33. SCRUBLAND			
	34. SHRUBLAND			
	35. GRASSLAWNS			

4 BARREN LAND	41. BARE UNCULTIVATED GROUND	411. STONY GROUND	
		412. GULLIES	
		413. SANDY AREAS	
	42. WATER BODIES	421. STREAMS AND RIVERS	
		422. PONDS, LAKES AND RESERVOIRS	

TABLE 7 HIERARCHICAL LAND-USE

SELECTED CATEGORIES USED IN ANALYSIS

MULTI-LEVEL DIGITAL CODES	FIRST -ORDER LAND-USE TYPE SECOND ORDER LAND-USE TYPE THIRD ORDER LAND-USE TYPE Fourth Order Land-Use Type
1	SETTLEMENT AND ASSOCIATED FEATURES.
11	SETTLEMENT
111	RESIDENTIAL
1111	Isolated buildings
1112	Buildings in compounds
112	COMMERCIAL AND SERVICES
1121	Market
1127	Shops
1128	Others.
114	INSTITUTIONAL
1141	Educational
12	TRANSPORT
121	ROADS AND HIGHWAYS
1211	Main roads
1212	Secondary roads
1213	Minor roads
122	PATHS AND TRACKS
1221	Main paths and tracks
1222	Minor paths and tracks.

2			CULTIVATION
	21		ENCLOSED FARMLAND UNDER 2 ha.
	23		UNENCLOSED FARMLAND UNDER 2 ha.
		234	Root crops
		235	Tree crops
		236	Mixed cropping
	24		UNENCLOSED FARMLAND OVER 2 ha.
		246	Mixed cropping
	25		CROPLAND UNFARMED
		251	Tillage
		252	Cleared land
		253	Easly bush fallow.
3			UNCULTIVATED LANDS
	31		FOREST LAND
		311	TROPICAL RAIN FOREST
		3111	Heavy forest
		3112	Light forest
	32		WOODLAND
	33		SCRUBLAND
	34		SHRUBLAND
	35		GRASS LAWNS
4			BARREN LAND
	41		BARE UNCULTIVATED GROUND.
	42		WATER BODIES
		421	Streams and rivers

Test interpretation of the classification scheme with ten randomnly selected stereomodels was done.

In drawing up the final classification adopted I bore in mind:

(i) The applicability of the classification in adjoining territories (if required), and

(ii) Types of land use and land cover identifiable primarily on aerial photographs, and the criteria in 2:2 as the basis for organizing this classification system.

The final classification scheme used for interpretation of land use is given in table 6. However, due to the Cumbrous nature of this classification, in practice, for purpose of data analysis several categories have been collapsed into a selected classification shown in table 7. This is due to the irrelevance of inventorying land uses in a rural area/small towns at the more detailed level, thus limiting categories to those of utmost interest.

2:4 DEFINITION AND CATEGORIZATION CHARACTERISTICS OF LAND USE ADOPTED.

Distinct outline of the land use categories is presented here. This is useful in better understanding of what is included in each category at all the levels.

1 SETTLEMENT AND ASSOCIATED FEATURES:

This refers not only to use for residence but also to those of man's activities which make communal living meaningful. (Umar 1985).

This is broad, however, it is in consonance with a level I category which is a generalized classifcation.

Level II category is classified on the basis of function. Classification by function utilizes what, in the opinion of the interpreter, is considered the dominant function. These functional classifications are essentially based on a combination of general observation and logical deduction.

Level III is a detailed categorization of purpose in level II.

Level IV is a further breakdown on the basis of type, form or pattern.

11 SETTLEMENT

Land use for a group of persons living in permanent abode, engaging in a variety of social-welfare and economic activities.

111 RESIDENTIAL: Land with built up structures for habitational purpose. A further breakdown of this level III category (residential land use) is based on house type and form.

1111 Isolated buildings - Separated residential houses, detached from the string of buildings.

1112 Buildings in Compound - Groups of building surrounded by a separated or defined enclosure in form of a (wall) fence. Also groups of buildings themselves forming a close surround in rectangular or square shape with an open space in the middle of the compound.

1113 Buildings of more than one storey - what is commonly referred to as a building having a ground floor (one storey) and other floor(s) upstairs.

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ZARIA, NIGERIA

112 COMMERCIAL AND SERVICES - Premises or areas used predominantly for the sale of products and services.

1121 Market - a meeting place of people for the buying, selling or exchange of goods. This is distinct from shops (1127) which include supermarkets, roadside stalls and Kiosks.

112 RECREATIONAL LAND - areas exclusively recreation oriented or used for recreation activity. A further subdivision, potrays the type of recreation in level IV. They include:

1131 Sports arena - the sports complexes, playing fields with or without enclosures and standing or seating capacity.

1132 Gardens and parks - a public recreation place either area of natural beauty usually with fine grass lawns with trees or public botanical/zoological park.

114 INSTITUTIONAL LAND - Land used for public services. Such as the following facilities in the level IV category.

1141 Educational institutional lands.

1142 Religious houses (Churches, Mosques) and prayer grounds.

1143 Health services-hospitals, dispensaries etc.

1144 Others: include corrective homes (prisons), barracks etc.

115 MIXED SETTLEMENT - areas with less than $ occupation of the level III categories defined.

12 TRANSPORT:

This refers to a service or facility by which persons, goods or properties and messages are conveyed from one location to another. These facilities and services are conveyed through the various meduim classified in level III according to transport mode. The level IV category employs the criteria of type of surface, road width, engineering construction and hence standard as the discriminating factors.

121 ROADS AND HIGHWAYS - Any improved line of transport for passage or travel between different places that is wide enough for vehicles.

1111 Main roads - Wide-tarred roads with traffic guiding lines (painted white) at the centre of the road designed to move larger volume of traffic on inter-towns trips. Entrances to the main roads are at restricted locations.

1212 Secondary roads - Tarred but narrower than main roads and with limited entrances linking smaller towns.

1213 Minor roads - Small roads mostly with lateritic surfaces.

122 PATHS AND TRACKS - Way made across fields, through woods etc. by people walking and also include small rough 'roads' made by persons and animals. The paths and tracks can be described as main (1221) or minor (1222) depending on its size.

2 CULTIVATION:

These are agricultural land uses; primarily for the production of food. Here it covers all uses for growing crops and forestry. This level I category is called farmland in the succeeding chapters. The level II category employs criteria of geometric size and the surround nature whether enclosed or unenclosed.

Size obviously is an important distinction between farmlands and is the one traditionally readilly used by the public to identify various classes for comparative purpose.

One important distinction between classification by size and others (such as classification by function or location and site etc) is that it employs some numerical data. The aim of the usage of geometric size and many subcategories of crop types is to investigate elements of the farming practice, whether commercial farming is practiced along with the common subsistence type.

21 Enclosed farmland under 2ha

22 Enclosed farmland over 2ha - farmlands with a closed surround.

23 Unenclosed farmland under 2ha - small farms with no enclosures.

24 Unenclosed farmland over 2ha - large fields with clear outer boundary. Large scale farming.

25 Cropland unfarmed-farmland not currently cropped as at the time of investigation.

26 Forestry - land used for planting and caring for tress such as a tree plantation. Seen in photographs as trees in rows in a regular parttern.

In level III, crop type is the classification criteria.

Vegetables - land used for gardending. When in "enclosed" category (level II) it refers to growing of vegetables on small sized plots around dwelling units.

Tree crops cropping-farmland with perennial crops with long gestation period. (e.g rubber, cocoa etc).

Cereal cropping-farmland with cetain 'grasses' that produce seeds or grains for food (e.g maize, rice etc).

Root crops cropping-farmland with either cassava, yams or cocoayam.

Tree fruit crops cropping-farmland for growing banana, plantain, citrus fruits, pineapple etc.

Mixed cropping-farmland for interplanting of crop types. As a category is a convenient means of classifying the residual which is generally difficult to classify.

25 CROPLAND UNFARMED:

251 Tillage: Has been used to describe land ploughed or hoed in the current year but not yet sown.

252 Cleared land: Has been freshly produced by clearing off either forest, thicket or bush regrowth, without yet planting a crop. The upper vegetal element include the remnants of recently coppiced or defoliated trees, while the surface may be clear or covered by a thick growth of herbs.

253 Early bush fallow: Land normally used for growing crops but left uncultuivated for a period and showing signs of regrowth of bush. The qualifier 'early' has been used to differentiate fallow land that can not be easily differentiated from scrubland with fallow easily distinguishable.

3 UNCULTIVATED LANDS

Land not used by man for any particular activity rather has land covered by vegetation of various type. It is based on physiognomic characteristics of the vegetation cover. Factors considered in identifying and classifying vegetation types are floristic composition and gross structural characteristics. Gross structural characteristics are the tree size, degree of stocking and understorey condition.

Following are the level II categories

31 FOREST LAND:

Defined as "all lands bearing vegetative associations dominated by trees of any size, exploited or not, capable of producing wood or other forest products, of exerting an influence on the climate or on the water regime or producing shelter for live stock or wild life" (F.A.O). Forest being a large area of forest lands currently stocked with trees.

311 TROPICAL RAIN FOREST - Is a type of vegetation consisting predominantly of woody plants (trees, shrubs, herbs and climbers) and from which grasses are virtually absent (Hopkins B. 1974).

3111 Heavy forest - Dense forest and fully stocked, top canopy almost touching each other, having ground cover or under-growth of ferns and herbs.

3112 Light forest - Moderstely dense to thin forest and fully stocked in some areas. This is mostly secondary forest regrowth.

312 SWAMPS AND MARSHES - Shrubby herbs and other trees growing where the Soil is water logged for at least a part of the year. Location factor is crucial in level IV Classification.

3121 Mangrove swamps - in bands in tidal areas.

3122 Fresh water swamps

3123 Marshes - shrubby herbs growing near salt waters.

313 RIPARAIN FOREST - Trees growing on slopes of river valleys characterised by high canopy and thick growth.

32 WOODLAND:

An area of ground wholly or partly covered by trees. There is no clearly defined distinction in meaning between the terms forest and wood land, although forest implies a large area with denser, less open, formation and woodland is most often restricted to a small area covered with trees of more open type formation with grass. Pockets of tree stands such as thickets, groups of trees along roads, shelter belts are in this category.

33 SCRUBLAND:

Land covered with vegetation consisting of small trees or bushes, with scattered clumps of grass and patches of bare earth.

34 SHRUBLAND:

Vegetal cover characterised by woody plants either with multiple stems or branching near the ground.

35 GRASSLAWNS:

Closely cut and smooth grass turf in a private garden or yard or separating buildings or fronting compounds.

4 BARREN LAND:

Land that has no vegetative association and is not used for cultivation. Level II category include bare uncultivated ground (41) and water bodies(42).

2:5 SABON GIDA ORA LAND USE CLASSIFICATION PROBLEM

In drawing up the classification scheme used some problems were encountered. Some of these problems are directly associated with classification itself others in the photo interpretation problem affecting the classification. Following is an outline of the problems:

(1) Existing mix of land use. Example is a compound or building providing accomodation and shop. This is compounded where there is a change of function without change of form. There are cases of change of original function of a building meant for dwelling to a different purpose of offices or shops but its form remain same.

In some cases such change of function could be identified, sometimes not. The photo interpreter is in a dilemma and wouldn't know where to categorize the conflicting land use.

(2) Scattered and unco-ordinated pattern of rural development.

(3) Difficulty of having an ideal basis of classification for comparison of works.

(4) Difficulty of arriving at a unit of area to use in classifying farmland.

(5) The riot of vegetation and tangled greenery of inter-cropped plants such as the tubers and maize on one hand and wildly or semi-wildly growing tree fruit crops on the other, presents a well-nigh chaotic sense creating identification and interpretation problem concomittantly creating classification problems.

2.6 BACKGROUND OF STATISTICAL METHODS USED IN LAND USE STUDIES.

A search of the literature reveal that several authors have described sampling techniques used to collect land-use data from aerial photographs. It is pertinent to review and evaluate sampling procedures by some workers. Notably are Walter (1955) who demonstrated the use of stratified random sampling and statistical analysis in locating and mapping the swamps and marshes of Eastern Wisconson.

Berry (1962) reviewed papers on the relative efficiency of several sampling methods, including dot grids and point transects.

He reported differences in variance in samples obtained by different method of dot distribution. In his study, for woodland cover, with four trials of complete coverage dot grids, the expected variance using a simple random distribution of dots was 21.5 times greater than the variance using systematic stratified unaligned dots and 5.65 times greater than arbitrarily stratified random dots. However, he recorded little difference for six methods of dot distribution when he conducted a similar test on a different population (Shovic and Frazier, 1980).

While some authors (Sloggett and cook (1967), Frey and Dill (1971) eto) agree with Berry that variances are a result of the sampling technique used, others hold contrary views. Frazier and Schovic believe that such variations may be due to the different forms of the population.

Cochran (1977) agrees with Frazier and Shovic on this but went on to point out that if the population is of random order, the sample be they obtained by random or systematic methods their variances are essentially the same. Contrary to expectation that random samples produce better results he argues, that some other populations may give more precise results with the various forms of systematic samples.

Morrison (1968) undertook a study of the most appropriate sampling plan for distribution of control points for constructing an isarithmic map as an indicator of the accuracy of the isarithmic map.

He investigated six common areal sampling plans relative to their efficiency in yielding ãn acceptable depiction of the form of a known distribution. The relative efficiency of the sampling plans investigated can be ranked in descending order as follows: (i) Aligned stratified random, A.S.R. (ii) Unaligned stratified random, U.S.R. (iii) Aligned systematic,A.S. (iv) Unaligned systematic, U.S. (v) Unaligned random, U.R. (vi) Aligned random, A.R.

It was conclusively demonstrated that (a) aligned random sampling plan was unacceptable for sampling of a spatial distribution, (b) the reliability of the depiction of the form was greatly enhanced by using areally stratified samples as opposed to unaligned random, (c) a reliable depiction of the form of the distribution should have a scatter of sample points that is more evenly spaced than random.

In the last decade the systematic sample in the form of dot grid or square grid has frequently been used for estimating the size of land areas on maps or air photographs. Esin (1981) demonstrated the use of the dot-cells methods to collate land use information in built-up environments in developing nations. He concluded that the dot grid is a faster method with more categories identified.

The dot &rid method has been more favoured and this lies on its great simplicity. The systematic point sample has been used for the recording and measurement simultaneously of a number of land use categories within an area.

This method has been applied for research in the U.K. by Emmott and Collins (1980), a new national land use survey of Switzerland by Kölbl and Trachsler (1980) [Emmott 1981]. Many other researchers have successfully employed the dot grid method.

Many workers have developed formulae for the estimation of the theoretical sampling error of a systematic point sample. Kölbl and Trachsler (1980) developed a formula based on the binomial distribution:

$$E\% = k\sqrt{\frac{(100 - P)}{nP}} \qquad (1)$$

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

n = the total 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%).

Bonnor's (1975) formula for estimating the error of area estimates from dot grids is

$$E\% = \frac{153.1}{(A.D)^{0.58}} \qquad (2)$$

where E%= the % error of a class in a sample at 95% confidence level.

A = area of the class (in ha or sq km)

D = Dot density per sq km or ha.

Brunt (1966) formula for estimating the numerical accuracy of the dot grid is:

$$E = \frac{(100 - P)\ 38400}{4PN} \qquad (3)$$

E = ½ the % error of a class in a sample at 95% confidence level.

P = % area of the class.

N = total number of dots.

Zohrer (1978) has shown that "the application of the binomial formula to systematic sampling gives greatly over estimated standard errors" but holds true for random samples. (Emmott 1981).

A series of regression equations have been derived from experimental measurements by different researchers for estimating the error of area estimates from systematic dot grid. These formulae are considered more realistic error estimates than the formulae based on the binomial distribution better applied to random samples.

Zohrer (1978) after theoretical and experimental considerations suggest the use of the following regression equation for the estimation of standard error percent of the estimate for the measurement of the area:

$$\log(S\ \%) = 1.739 - 0.755 \log N + 0.457 \log P \qquad (4)$$

where N = number of dots falling within the parcel

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

Yuill (1971) observed after test measurement by dot grids on land parcels of a variety of shapes and sizes; that parcel size or number of dots used to measure the area is the only significant determinant on the precision of area estimated. His regression equation being:

$$\sqrt{S\%} = 3.625 - 0.493 \text{ In } X \quad (r^2 = 0.85) \text{ ---------(5)}$$

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

X = number of points used to measure the area.

r^2 = co-efficient of total determination.

Formular 5, is for single parcel size determination. In the more complex case, where the areas of mosaics within a larger unit are to be determined as is the case in determining the area of each land use category within a study area, a different formular is applied. Yuill in pointing out in this second case that the total number of points used to sample the whole area and the category percentage area, are the two factors that influenced accuracy produce this multiple regression equation:

$$\sqrt{S\%} = 17.11 - 1.849 \text{ In } X_1 - 1.338 \text{ In } (X_2\%) \text{ ----------(6)}$$

$$R^2 = 0.868$$

where S% = the average expected error (ie the category percentage error).

X_1 = the number of points required to measure the entire area.

X_2 = the areal % of the given land use (ie the category percentage area).

R^2 = co-efficient of total determination.

Yuill's results were based on repeated random placing 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. (Esin 1981).

Emmott and Collins (1981), after examining a series of dot grids placed directly over air - photo overlays of a test urban land use suggested the following regression equation for measurements on air photographs:

$$\sqrt{S\%} = 11.36 - 0.93 \ln X_1 - 1.66 \ln (X_2\%) \text{ --------(7) } R^2 = 0.676$$

where S%, X_1 and X_2 mean the same as in equation (6)

The relationship between sample and population; closeness of the depiction of the form of the sample distribution to the actual distribution, is partly conditioned by the size of the sample, partly by the method of obtaining the sample and also the actual distribution (population) characteristic.

Also the error of estimating individual parcel area (ie land use category)is determined by the total sample points, the category percentage area and total area.

In conclusion, which sampling method to use is a compromise between the purpose of the sampling survey, time and cost considerations.

CHAPTER 3.

3.0 RESEARCH DESIGN AND METHODOLOGY

3:1 MATERIALS AND EQUIPMENT USED

3:1:1 PHOTOGRAPHY

The air photography was taken by Kenting Africa Resources Limited Nigeria in June 1981. The panchromatic vertical photograph is at 1:5,000 scale and available as 23cm by 23cm paper prints. The quality of the photographs is good.

The block of photographs covering the area are in eight strips, of varying number $1^{E}(19)$, $2^{E}(19)$, $3^{E}(21)$, $4^{E}(21)$, $5^{W}(21)$, $6^{W}(25)$, $7^{W}(27)$ and $8^{W}(9)$. Bringing the total number of photographs to 162, covering an area approximately. 7152ha.

3;1:2 EQUIPMENT

A folding mirror stereoscope with binocular attachment is used for stereoscopic examination of single stereomodels. A pantograph is used for tracing maps.

A 48K APPLE II microcomputer with floppy disk storage and an Epson dot matrix printer is used for storage, analysis and print out of the digital-symbolic land use data.

3.2 POINT SAMPLING ON AERIAL PHOTOGRAPHS

The amount and distribution of land uses, as well as limited time and funds, clearly indicate that not all of it could be studied. Some form of sampling is imperative. Sampling methods are usually used because of the impracticability of studying the whole phenomena.

The aim of any sampling procedure is to draw sample units which, when grouped together, possess the same degree of diversity as the population from which drawn and a researcher must choose his sample in a such a way as to give every item or element in the population an equal chance of being chosen.

3.2.1 LIMITATION OF CHOICE OF SAMPLING TECHNIQUE

Land use in a locality changes qualitatively and quantitatively, it changes abruptly from one kind to another. This makes sampling difficult due to necessity to choose an unbiased type to represent this changes in kind and in degree.

Certain ingredients of the landscape, such as relief, changes in degree from place to place at a more or less even rate. This being changes in magnitude rather than kind must of necessity be based on samples whose procedures are simple. Land use since it changes in kind and in degree, limits the choice of sampling techniques to reflect the two.

3:2:2 CHOOSING A SAMPLING PROCEDURE.

In choosing a sampling procedure to use, the merits and limitations of sampling techniques are appraised. The stratified random sampling method should have been preferred if one knew enough about the area to recognize that which is truly typical of the different areas, to divide the area into strata or groups, and a separate sample taken for each stratum. Thus only a representative sample stereomodels of the area should have been studied. Its merit lies in closeness of form of sample to population spatial distribution.

In a land use inventory when questions of 'where' and 'how much' are to be answered even areal coverage is pertinent as well as representativeness of the sample units. are determinants.

Considering the data source is aerial photography, to ensure fairly even areal coverage as well as representativeness of the sample points, the systematic dot grid sampling technique is used.

3.3 THE DOT GRID, GRID DENSITY AND ERROR ESTIMATE.

A dot grid consists of dots marked in a square or rectangular systematic grid pattern on a transparent overlay. The spacing of the dots may be expressed as grid density or number of dots per hectare or square Kilometre-(Bonnor 1975).

The dot grid sampling method has the following outlined advantages quoted by Emmott (1981) after Dickinson and shaw (1977).

(i) Point sampling makes the measurement and thus the depiction and delimitation of individual plots unnecessary.

(ii) The interpreted land uses can be recorded on a simple data sheet.

(iii) Any specified level of accuracy may be achieved by adjusting the sample size i.e by either increasing the grid density or by aggregating the units to be measured.

(iv) Land use change is measured simply by collecting data for the same set of points at the required time interval.

(v) Once a system of fixed points is in operation, it is likely the level of error will remain relatively constant.

(vi) The interpreted information since its digital is in a form immediately amenable to computer storage, processing and display.

The total sample points covering the area is calculated using Brunt (1966) formular:

$$N=\frac{(100 - P)\ 38400}{4PE}$$

where N = Total number of dots.

P = % of the total area within natural area occupied by the 'most critical' land use category.

38400 = a constant based on students' T taken at 95% level of probability.

E = % error within which results can be expected to fall in 95% of cases.

The number of dots per model (D) is then arrived at as follows:

$$D = {}^{N}/_{AP}$$

where AP = number of models to be sampled.

where N = 3825

AP = 153

D = 25

Hence 25 dots are used per model arranged 5 rows, 5 columns.

The dot separation is arranged one centimetre on photographs. Relating this to the scale of the photograph (1:5,000) each dot fall in the centre of an area of 0.25ha.

This unit of area is chosen using Bonnor (1975) and Brunt (1966) formulae which estimate the error at 95% confidence level of a given sample according to its coverage and density.

The total sample points are 3825. Regarding 0.25ha as the basic unit per dot, a sample of this size would include 0.09% of the total on each stereomodel giving a sample of about 14% of the total area.

Admittedly this is a small sample, but size alone is not the sole measure of sample validity. Infact what matters is not the proportion of sample to total area, but the absolute size of the sample categories and accuracy of estimating the sample (i.e choice of sample).

A search of the literature reveal that the accuracy of estimating land use categories with systematic point sampling method is determined by grid density, the area size and the shape of the area and its boundaries. Smaller and more irregular areas will have large errors while larger, more regular areas will have smaller errors (Bonnor 1975).

From the study area size and dot density the precision of estimating various land use categories is calculated. Bonnor (1975) (1) and Kölbl and Trachsler (1980) (2) formulae for estimating the numerical accuracy of the dot grid method land use categories estimates is used in this study.

Others Brunt (1966), Yuill (1971), Alford et al (1972), Zohrer (1978), Emmott (1981) have done similar empirical analysis to determine the accuracy of any particular pattern of dots on different area sizes and shapes applicable to either rural or urban land use.

The formulae:

$$(1)\quad E = \frac{153.1}{(A.D)^{0.58}}$$

where E = the % error of a category in a sample at 95% confidence interval.

A = area (in ha or km^2) of the category

D = dot density.

$$(2)\quad E = KX100\sqrt{\frac{(100 - P)}{np}}$$

where E = $^1/_2$ the % of a category in a sample at 95% confidence interval.

P = % area of the category

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

K = a constant based on the student's t distribution (K=1.96 for a confidence limit of 95%).

.4 THE ACCURACY/PRECISION QUESTION

Data acquisition is subject to errors, which could seriously affect the researchers interpretation of his results.

More measurement errors are introduced when the subject under study is open to outside influences and not taken at a constant condition and concentration.

Accuracy of land use information is a complex issue, both in its definition and measurement (Hord and Brooner 1976). Land use information accuracy can be categorised into four; classification accuracy, interpretation accuracy, sampling accuracy and map accuracy.

It is difficult to define one clear set of criteria for accuracy and precision of land use inventory using aerial photographs. The primary objective is to give the user a reasonable degree of confidence in the results. Since it is salient that the user have a true idea of the accuracy and precision in the data, the accuracy assessment procedures should produce statistically sound, clear and unambiguous results. (Esin 1981).

The following are indications of the accuracy assessment of land use information in this study.

(i) Repeated land use interpretation of air photograph's with random check interpretation by another interpreter for consistency of interpretation.

(ii) Field spot checks for ground verification.

(iii) Since the sampling method affects the closeness of sample data characteristic to the population the well tested dot grid sampling method is used.

(iv) Establishment of a sampling error with a probability of 95%. In chapter 4, the precision of land use categories estimates is given.

(v) Computer analysis and distribution maps.

3.5 INTERPRETATION PROCEDURE

The aerial photographs are examined stereoscopically using a stereoscope and binocular.

1 The land use information is obtained by overlaying on each stereomodel covering the area a transparent acetate paper with regular grid of dots, the various land use being recorded point by point.

2 The grid carried systematic distribution of 25 points arranged in 5 by 5 to sample the area of effective model coverage around the principal point of the photographs, allowing for the normal fore-and-aft overlap of 60% and lateral lap of 20%.

3 Observation (interpretation) of the points is made with a moving mirror stereoscope with binocular attachment.

4 The recording is by land use category code numbers.

3.6 RECORDING BASE

The recording base is a specially prepared data coded "interpretation (code) data sheet". For each point a one-to-four digit land use code is being recorded in its correct relative position. In this digital form the data is stored and processed by the computer. In recording the uses (data), only uses that fall under the dots are recorded. From the sampling the total number of dots occupying each category are counted and aggregated.

3.7 DATA (RESULT) PRESENTATION

Consists of the preparation of a map of existing resources and their current uses along with an analytical narrative and tabular summary. The summary tables show the amount of each land resource type and use, and the number of hectares devoted to each use.

Tabular data alone are of little use in planning processes, however, maps of a variety of themes are necessary to show the spatial relationship among the various uses (Paine 1981). Recognising this, thematic computer maps showing their distribution is done.

CHAPTER 4

ANALYSIS

4:1 ANALYSIS PROCEDURE

The full potential of aerial photography as a source of land use information can best be realised by the combination of conventional photo interpretation techniques with widely available computer facilities. This provides an efficient means for the measurement, storage and presentation of land use data (Emmott 1981). Recongnising this the analysis is done using the APPLE II computer.

4:1:1 DATA HANDLING

The sample data in digital form is transferred manually from the "interpretation (coded) record sheet" to the storage disk of the computer where it is held available for analysis. A BASIC program was adapted for entering each model data creating 153 small data files.

4:1:2 DATA PROCESSING

The land use data generated have been analysed by a series of Standard BASIC Programmes using as a guide the BASIC Programmes Published by Cooke et al (1982).

The BASIC analysis programs consist essentially of the following:

1. Co-ordinate plotting of the study area outline and the 'dendritic' pattern major roads running across the area. This is done using the x, y Co-ordinate system of the turning points within 0-279 to 0-159 plotting range limits.

2. Merging the 153 small data files created earlier into one big basic data file for analysis. The complete data file consisted of 3825 elements.

3. Reading the data file.

4. Plotting and printing out of the selected land use categories. An efficient searching mechanism is employed for the selection of plot requests. This establish the coverage of each category and show how the distribution varied from place to place within the sample.

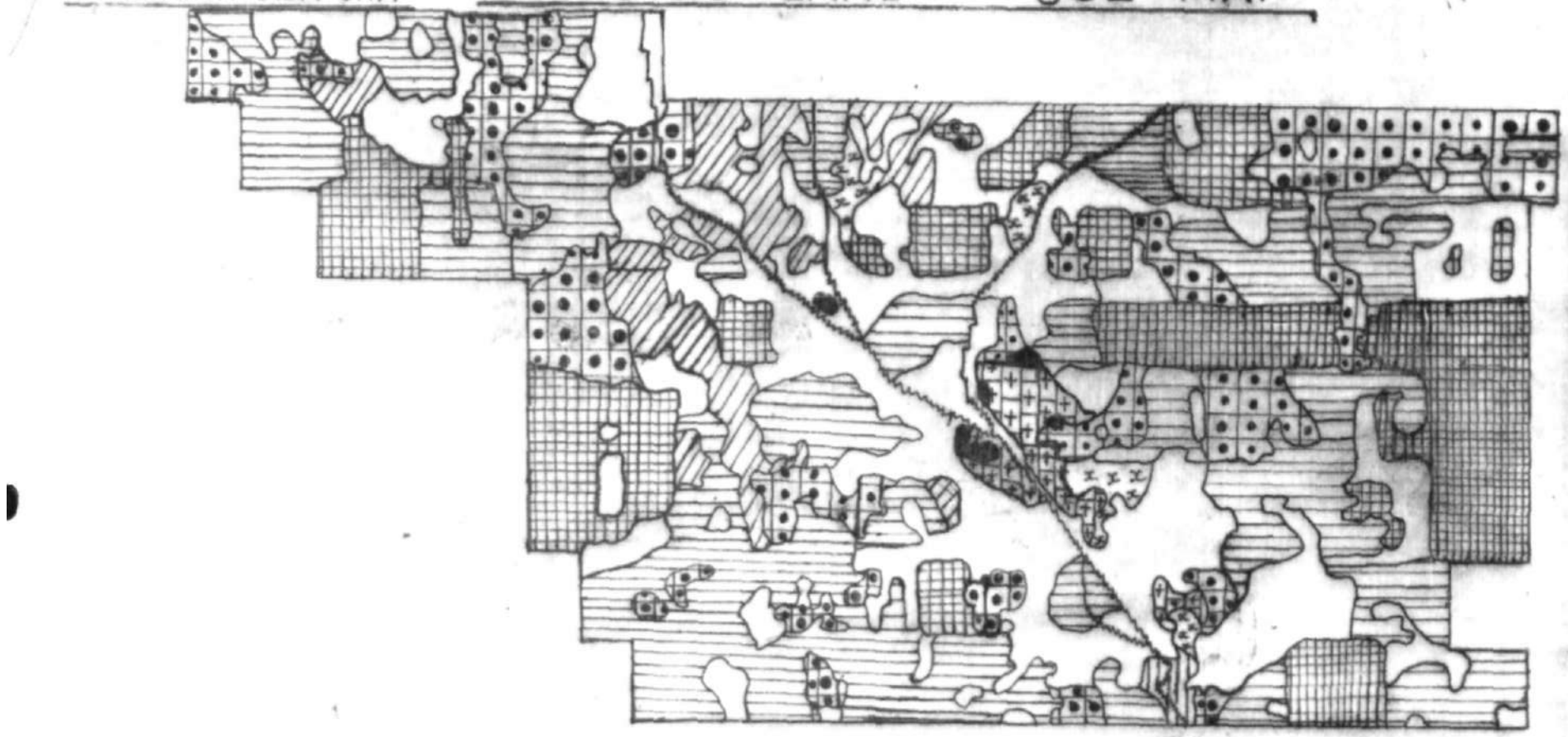
4.2 LAND USE

4:2:1 SELECTED LAND USE MAP

A map invariably is considered as a reliable representation of'an area' depicted, at the time which, it is surveyed or photographed, and within the limitations of its scale. A generalised land use map of the study area is produced as a visual guide to the quick interpretation of the trend and tendencies (see fig 4).

FIG4 SABON GIDA ORA

SELECTED LAND – USE MAP



KEY

RESIDENTIAL

COMMERCIAL / INSTITUTIONAL

FARMLAND

GRASS LAND

FORESTLAND

WOOD LAND

SCRUBLAND

SHRUBLAND

To maintain detail in a patchy distribution, such as land use, a shading map is preferred as it allows for easy construction and give better results than producing contrived Isarithm or Isoline patterns (Dickinson 1973).

As patterns of landscape are often complex, both the land use and land cover are composite mapping units and some generalization, simplification and combination is inevitable (Alford et al 1974). Thus the selected land use map drawn is generalized, with simplified patterns showing the spatial distribution of these categories. Though a generalised land use map is given (fig 4), however, computer maps of land use categories are included in the discussion of land use distribution and in the appendices.

4:2:2 SELECTED LAND USE TABLE

Following is a table of selected land use categories estimates and their respective theoretical sampling error estimates. These are indices of precision, using the Bonnor (1975) and Kölbl and Trachsler (1980) formulae quoted in 3:3.

TABLE 8: SELECTED LAND USE DISTRIBUTION

CODE	LAND USE	NUMBER OF DOTS	AREA (HA)	% AREA	PRECISION	
					BONNOR'S FORMULAR	KOLBL AND TRACHSLER FORMULAR
					(1)	(2)
1	SETTLEMENT AND ASSOCIATED FEATURES	117	29.25	0.41	32.3	24.7

2	FARMLAND	608	152.00	2.13	12.4	10.7
	Cropland farmed	246	61.50	0.86	21.0	17.7
	Cropland unfarmed	362	90.50	1.27	16.8	14.0
	Early bush fallow	248	62.00	0.87	20.9	16.9
3	UNCULTIVATED LANDS	3038	759.50	10.62	4.9	4.6
	Forest land	775	193.75	2.71	10.8	9.5
	Wood land	610	152.50	2.13	12.4	10.7
	Scrub land	1311	327.75	4.58	8.0	7.2
	Shrub land	297	74.25	1.04	18.8	15.5
4	BARREN LAND	62	15.50	0.22	46.7	33.8

Examination of the above table reveals the following:

(i) Error in estimating land use categories is inversely proportional to the size of the category area. Smaller and more irregular area categories have larger errors while larger, more regular area categories have smaller errors.

The larger, more regular scrubland and forestland has a precision of 8.0(1), 7.2(2) and 10.8(1), 9.5(2) respectively, which is better estimated than the smaller and less regular barren land with precision values of 46.7(1) and 33.8(2).

(ii) Over half of the land surface is uncultivated land being vegetation cover (this is about 76%).

(iii) Unfarmed cropland in current season (1.27%) is more than cropland farmed (0.86%).

(iv) It is impracticable to obtain sufficiently large samples of a category if that category occupies only a very small proportion of the total area. In this case, less reliable estimates of accuracy (as seen above) will have to be accepted for these minority categories, which is probably an acceptable solution in normal usage (Hardy J. R. 1980).

4.3 DISTRIBUTION OF LAND USE

The categories of land use are not evenly distributed, responding as they do to a number of pertinent variables such as the numerous aspects of the physical environment; density and distribution of population; availability of various kinds of transport, traditions, customs, social and other institutional constraints.

Generally the discussion on spatial distribution of land use categories quickly arouses academic inquisitiveness since in revealing where and in what numbers a phenomena exist, it inevitably poses the question: Why? It becomes a task to analyse and try to explain how far the revealed distribution pattern may be due to the influence of physical, social, economic and other agencies, working either singly or in combination.

This is essentially based on a combination of general observation and logical deduction.

In describing the distributional characteristics of the selected land use categories, the computer map for each category is included. Dots represent category occurrence.

4:3:1 SETTLEMENT AND ASSOCIATED FEATURES

The fundamental observation is the attractiveness of residential, commercial concerns and service facilities, and institutional features to transport lines (see fig 5).

4:3:1:1 RESIDENTIAL

The residential area is continuous with dispersed compounds adjoining each other. One note worthy feature of the residential pattern in the continuous-residential area results from the network of roads and paths, many people constructing houses by the road side. The continuous zone is clustered at the first junction (i.e reckoned from the bottom of the map•see fig 6). Some dwelling units are found at the top of the central road.

Along the stretches of roads, the succession of houses in trellised-development fashion is most obvious. Most houses have their frontage along service and main roads, while in some the backs of the compounds confront the road users.

Residential land use account for 86% of the settlement category.

FIG. 5: SABON GIDA ORA LAND USE CATEGORY 1 (SETTLEMENT AND ASSOCIATED FEATURES)

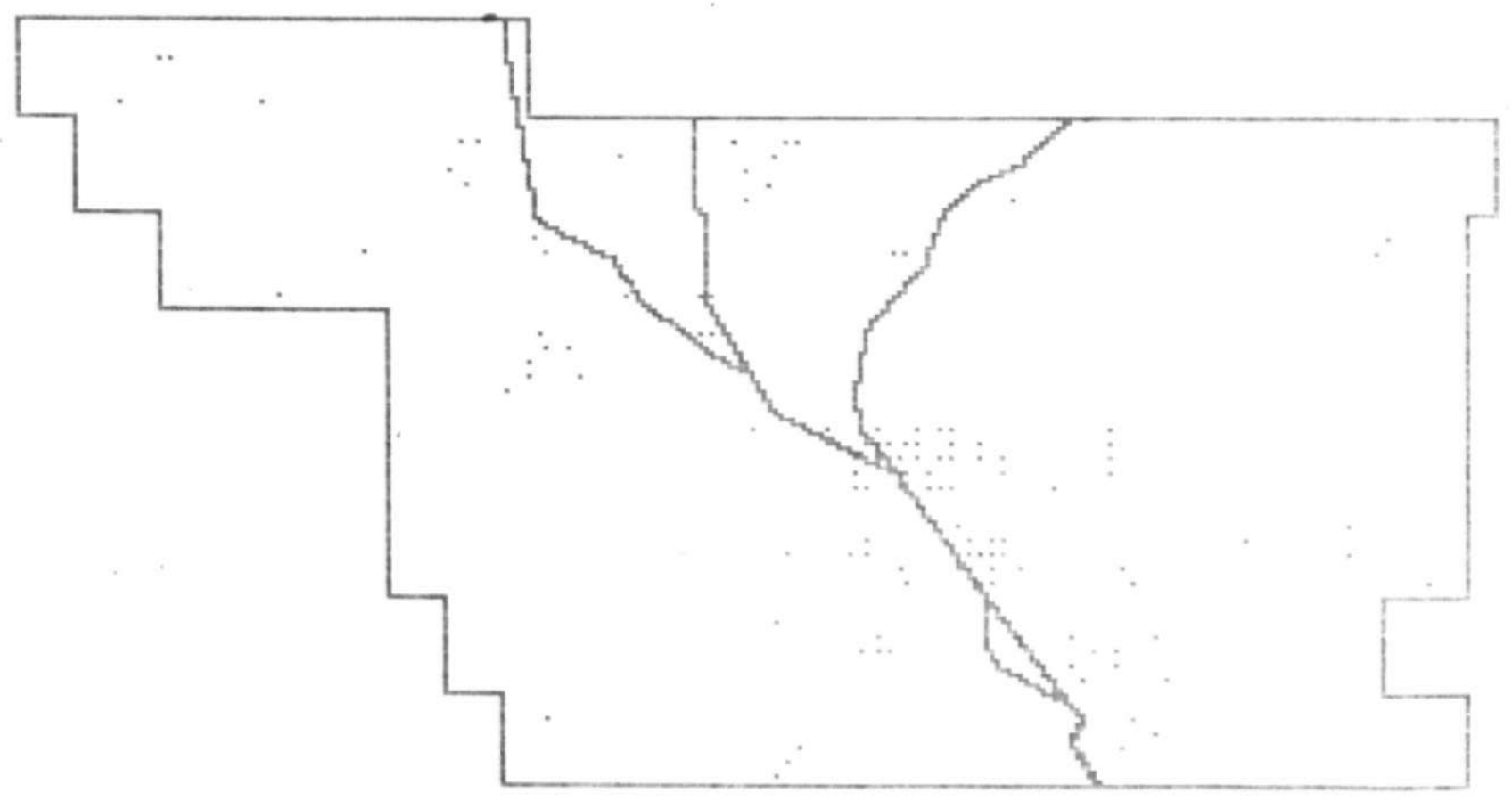
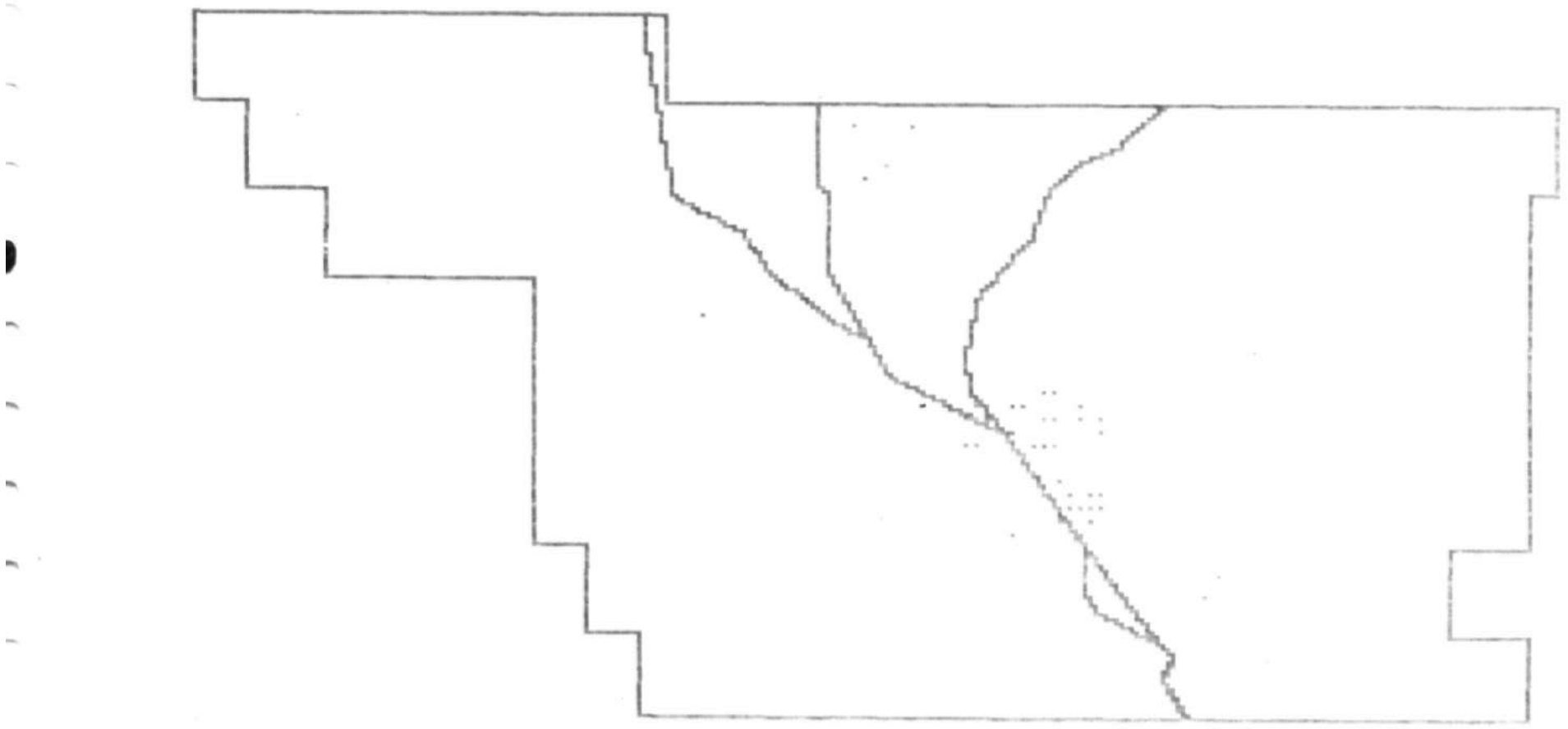


FIG. 6: SABON GIDA ORA LAND USE CATEGORY 11 (SETTLEMENT)



Below is a table illustrating a breakdown of the fourth level categories distribution.

TABLE 9: RESIDENTIAL SUB-CATEGORIES LAND USE*

Sub-Category type of residential land use	Area (ha)	% Area of total area
RESIDENTIAL	7.50	0.10
Isolated buildings	4.75	0.07
Buildings in compound	2.50	0.03
Buildings of more than one storey	0.25	0.00

*Precision values are greater than 50.

See appendix for distribution maps of the level IV categories shown in the table above.

4:3:1:2 COMMERCIAL AND SERVICES

Commercial facilities and services, are associated with residential areas since they are to serve the people. A small market is found on the left side near the first junction. Small Kiosks are found at the frontages of some dwelling units or compounds. This land use class accounts for a meagre 6% of the settlement category.

4:3:1:3 INSTITUTIONAL

Noticeable institutional facilities in the study area include a school at the far north of the residential area on the right side of the junction.

A hospital or dispensary on the east of the first junction is provided.

Institutional land use occupies only 9% of the settlement category.

4:3:1:4 TRANSPORT

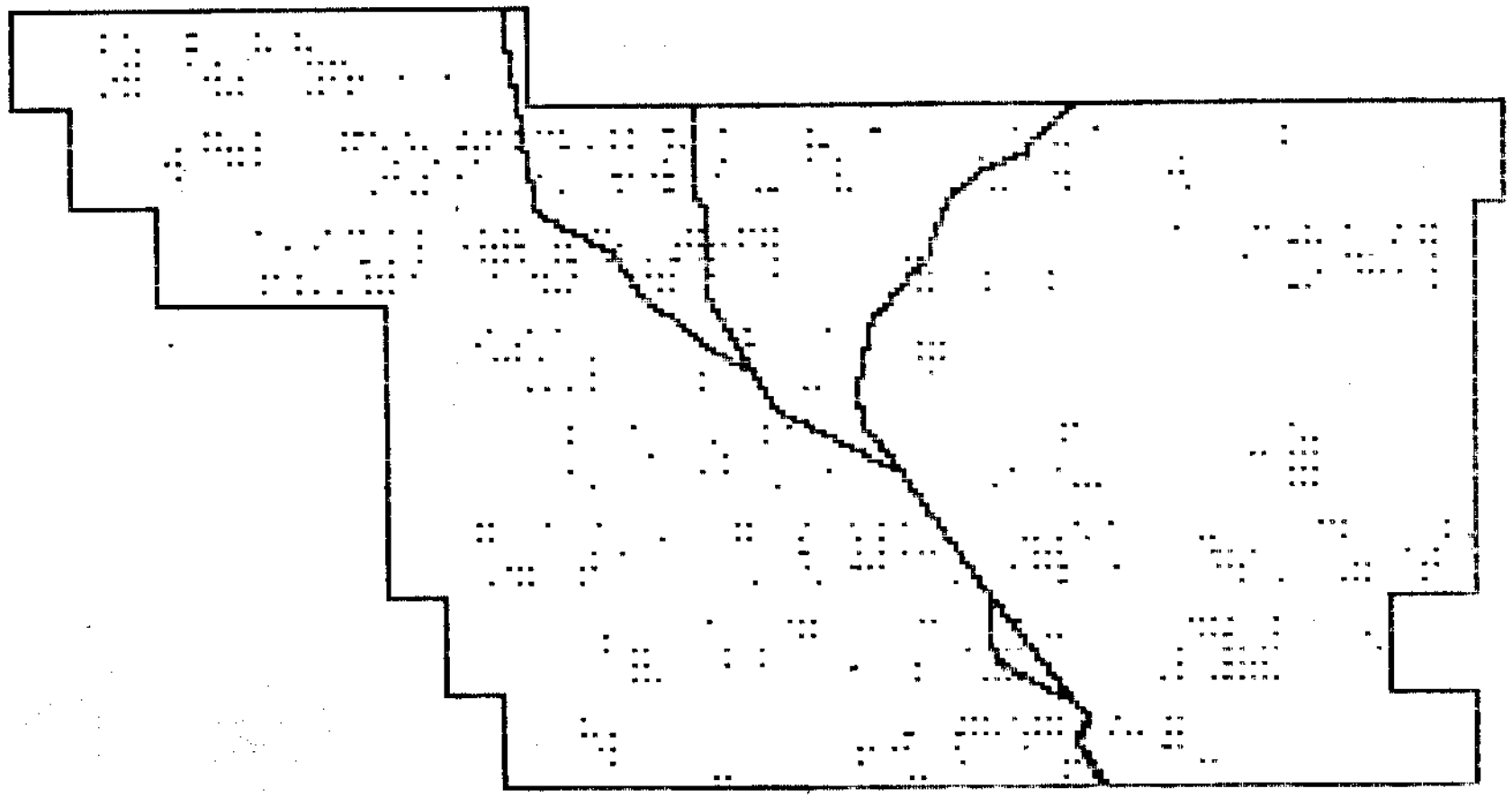
Sabon Gida Ora is traversed by numerous roads and paths of different qualities. The dendritic pattern main road with two junctions traversing the central part of the study area is the first noticeable feature on the dot maps (see fig 3). There is an appreciable number of foot paths and forest trails radiating from the settlement over the intervening plain. The intricate web of 'bush' tracks connect residences to farm lands.

4:3:2 FARMLAND

Sabon Gida Ora inhabitants utilise a small percentage of its land surface for producing crops, just about 152 ha (2.13%) areal coverage (of which about 41% is in bush fallow).

The distributional pattern of farmland is best described as scattered all over the study area. However, it seem to be more plentiful near to transport lines (see figs 4 and 7). They are differences in size and shape of cultivated plots and in crops raised. These obviously should be as a result of effect of variations in soil, terrain, vegetal cover, rain fall, tenurial system, hindering agricultural implements, dietary prefrences or social customs related to the consumption of food, and so forth. Generally this is the Nigerian agricultural problem.

FIG. 7: SABON GIDA ORA LAND USE CATEGORY 2 (CULTIVATION)



It is established that rural agricultural practice operates. The farm sizes are small, varying between 0.25 ha to 1.5 ha. Crops grown, as would be expected, are yams, cassava, cocoayam, maize and vegetables. Wildly and semi-wildly growing tree fruit crops such as bananas, plantains, oranges mangoes and paw-paw are common.

An observable nuisance is scattered small irregular patches of poorly-cleared forest containing a mixture of crops and weeds in what seems to be entirely random disorder, creating interpretation problem.

Following is a table of estimates of farmland sub-categories. It is included because they are excluded in the selected land use categories in table 8 and also to highlight details of agricultural practice in Sabon Gida Ora.

TABLE 10: FARMLAND LAND USE SUB-CATEGORIES

CODE NO	LAND USE	AREA (HA)	% AREA	PRECISION	
				BONNOR	KÖLBL & TRACHSLER
2	FARMLAND	152.00	2.13	12.42	10.74
21	ENCLOSED FARMLAND ∠2ha	1.75	0.02	>50	>50
23	UNENCLOSED FARMLAND ∠ 2ha	56.75	0.79	21.99	17.76
231	Vegetables	4.00	0.06	>50	>50
232	Tree fruit crops				
234	Root crops	8.75	0.12	>50	45.72
235	Tree crops	2.50	0.03	>50	>50
236	Mixed cropping	41.50	0.58	26.37	20.75
24	UNENCLOSED FARMLAND > 2ha	3.00	0.04	>50	>50

246	Mixed cropping	3.00	0.04	50	50
251	Tillage	17.00	0.24	44.25	32.31
252	Cleared lands	11.50	0.16	50	39.58
253	Early bush fallow	62.00	0.87	20.89	16.91
	CROPLAND FARMED	61.50	0.86	20.99	17.01
25	CROPLAND UNFARMED	90.50	1.27	16.78	13.97

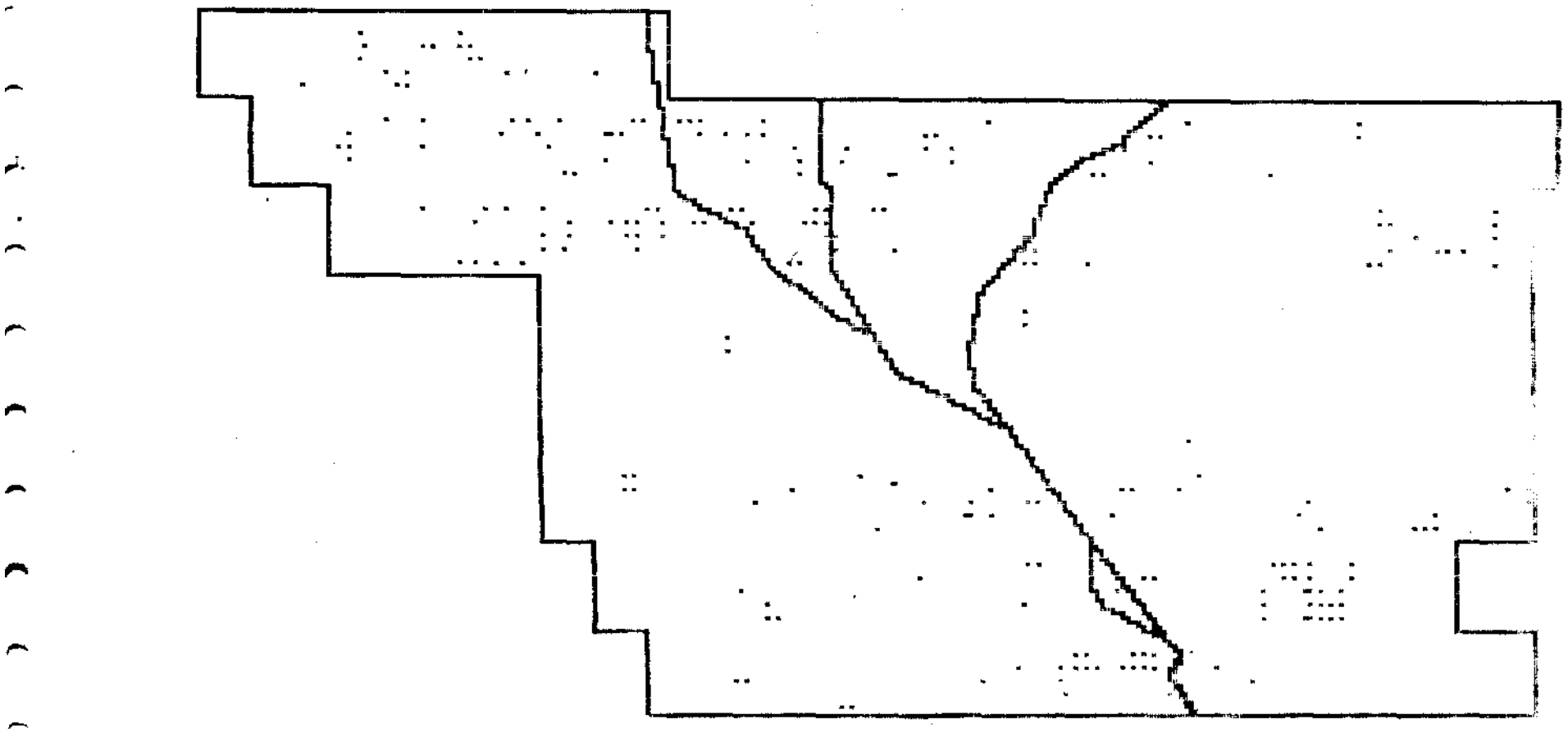
4:3:2:1 ENCLOSED FARMLAND UNDER 2ha.

The practice of enclosing farmland is rare. There are a few scattered small plots close to residences. These enclosed farmlands are for raising Kitchen-garden crops. This sub category contributes a meagre 1% area to farmland category- being 0.02% of total study area.

4:3:2:2 UNENCLOSED FARMLAND UNDER 2ha.

A larger portion of the study area proportion of farmland belongs to this subcategory, about 27% of the farmland. In table 10; 56.75ha (0.79%) of the total area is devoted to this sub-category. Though this sub-category is unevenly distributed, the north western and south central part of the study area have a higher occurrence (see fig 8).

FIG.8: SABON GIDA ORA LAND USE CATEGORY 23 (UNENCLOSED FARMLAND UNDER 2HA)



Three subclasses of this category are worth mentioning; root crops, tree crops, and mixed cropping, contributing 15%, 4% and 73% respectively to this farmland category. Their aerial coverage in relation to total area is given in table 10. See fig 9 for mixed cropping category distribution. Root crops distribution is shown in appendix 4.

4:3:2:3 UNECLOSED FARMLAND OVER 2ha

Sabon Gida Ora has a meagre 0.04% coverage of this category. Only two clusters are noticeable on the dot map at the east central portion of the study area (see appendix 5). The farmland is that of mixed cropping and should be an aggregation of contiguous small farm holdings into one whole.

4:2:2:4 CROPLAND UNFARMED

There are three sub-categories in this category. In table 10, the tillage category covers 17ha (0.24%), cleared lands 11.5ha (0.16%) and early bush fallow 62ha (0.87%) of the total area. The distributional pattern illustrated in fig 10, is being described as scattered isolated plots all over the study area except two areas. These are the continuous zone of settlement and zone of heavy concentration of secondary forest in the north east section of fig 10.

Though much forest land has been cleared for cultivation, at any given time there is a greater proportion of fallow than of cultivated land.

FIG.9: SABON GIDA ORA LAND USE CATEGORY 236 (MIXED CROPPING IN UNENCLOSED FARMLAND UNDER 2HA)

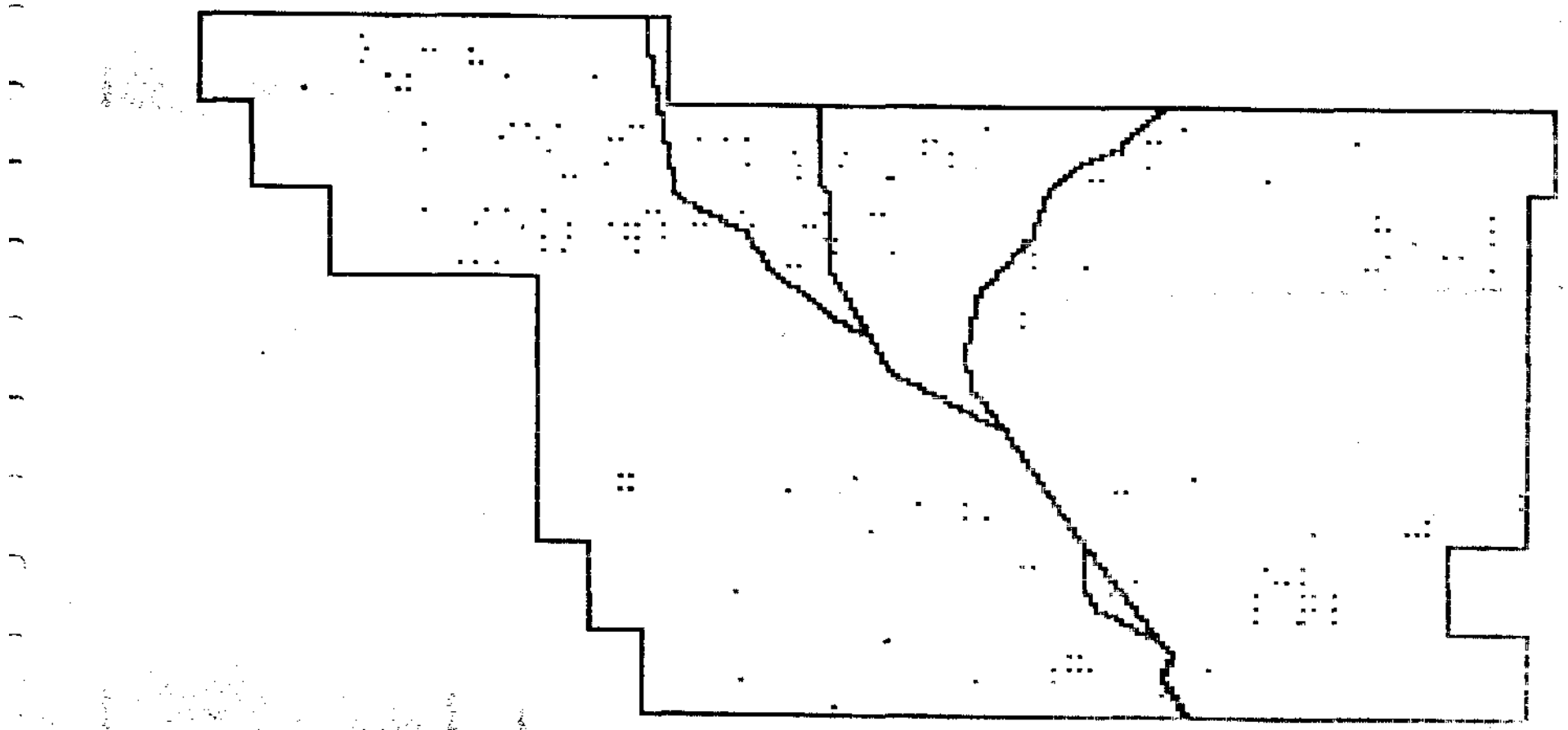
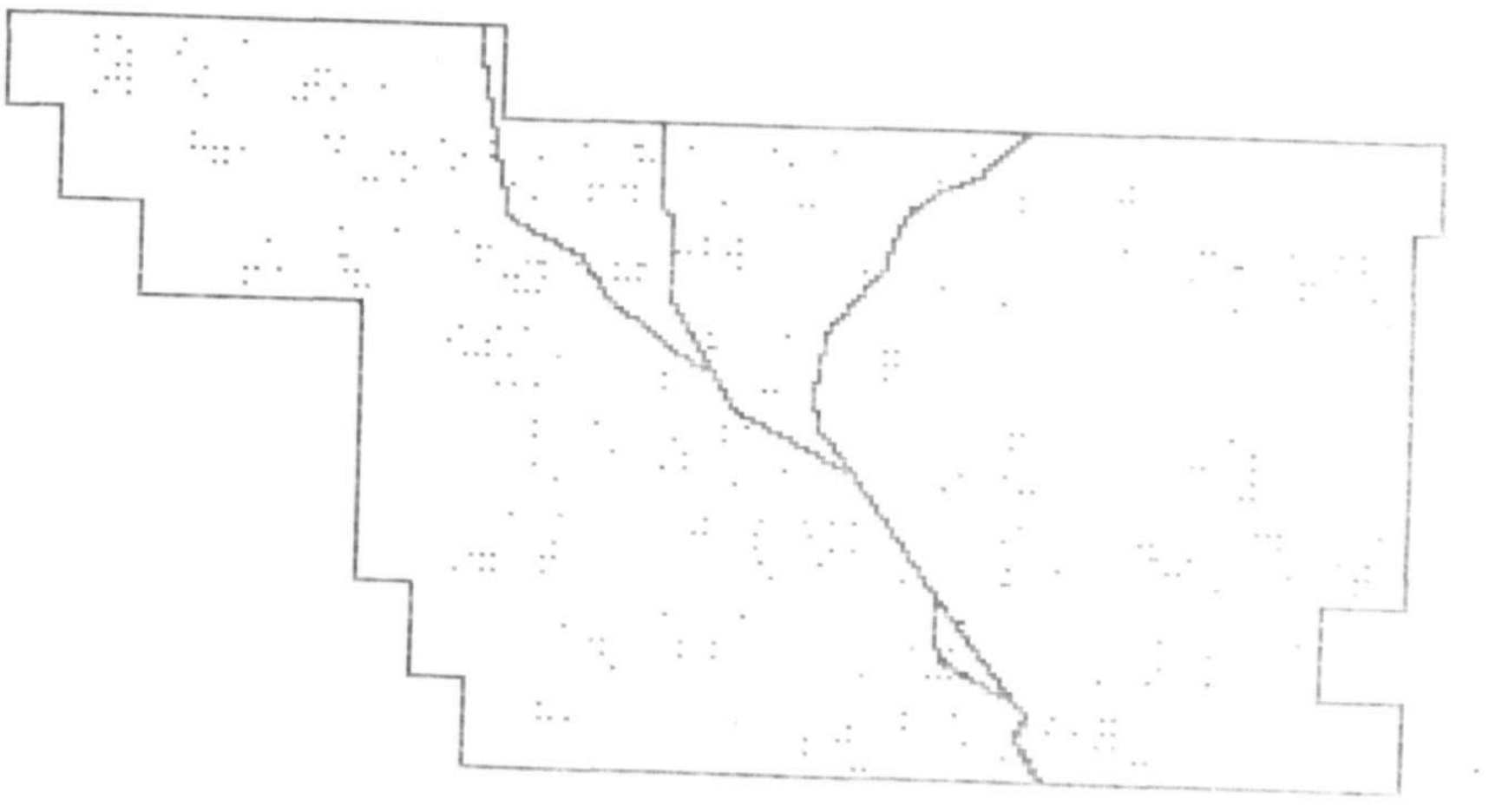


FIG.10: SABON GIDA ORA LAND USE CATEGORY 25 (CROPLAND UNPARKED)



Early bush fallow is about 0.01% larger than crop land farmland (see table 10). The distributional pattern of tillage, cleared land and early bush fallow categories is given in appendices 6,7,8 respectively.

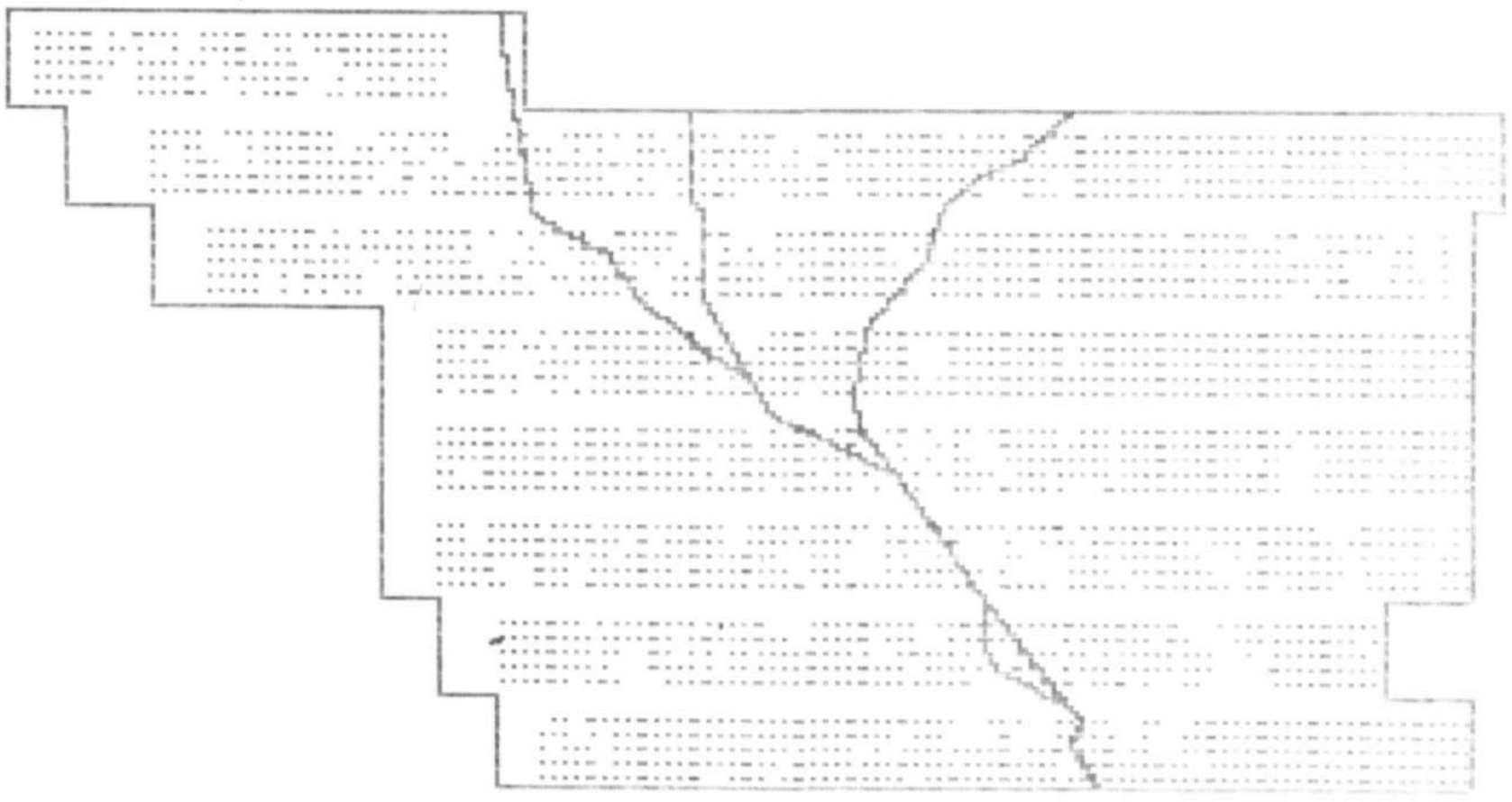
4.3.3 UNCULTIVATED LANDS

A glance at the dot map creates an apprehensive impressio of an entirely vegetation covered study area (see fig 11). Uncultivated lands account for 759.50ha (10.62%) of the land surface.

Much of the primary vegetation of Sabon Gida Ora has been altered or even obliterated by cutting trees or burning bush for cultivation and housing need. A complex patchwork of vegetation has resulted, of different ages and origin. It is therefore, difficult to give full details of the actual vegetation without supplemental information, instead, an attempt is made to show vegetation zones which indicate the distribution of natural types under present climatic conditions and development.

Actually these vegetation types classified do not indicate homogeneity of a particular type; rather they represent a mixture of types, each area being characterised by the most extensive type which occurs within it. The distributional characteristic of the various vegetation types will be discussed in the succeeding sections.

FIG.11: SABON GIDA ORA LAND USE CATEGORY 3 (UNCULTIVATED LAND-VEGETATION COVER)



4:3:3:1 FOREST LAND

Forest land consists of an intricate mosaic of farms, farm fallow and young secondary forest. The forest, in practically every case, is very complex and composed of a large number of species. Pure stands are rare, creating difficulty in recognition and identification of tree species. A typical problem of tropical forest inventory using aerial photography. (Lueder 1959).

The distribution of forest is shown in fig 12, on which four stretches of forest are delineated:

(a) the north west cluster,

(b) the diagonal south west to north central strip, through the second main junction.

(c) the eastern concentration; and

(d) the thin south east strip.

Forest land accounts for 193.75ha (25.5%) of the vegetation cover and 2.71% of the study area. A thin gallery forest line the slopes of river Owan running across the study area as shown in fig 13. See appendix 9 for light forest distribution.

4:3:3:2 WOOD LAND

152.5ha (20.1%) of vegetation cover is woodland. Unlike forest land, the woodland distribution is scattered (see fig 14). Pockets of woodland are found all over the study area; scattered in dwelling areas, as trees in fence rows, along transport lines and in the plains.

FIG.12: SABON GIDA ORA LAND USE CATEGORY 31 (FOREST LAND)

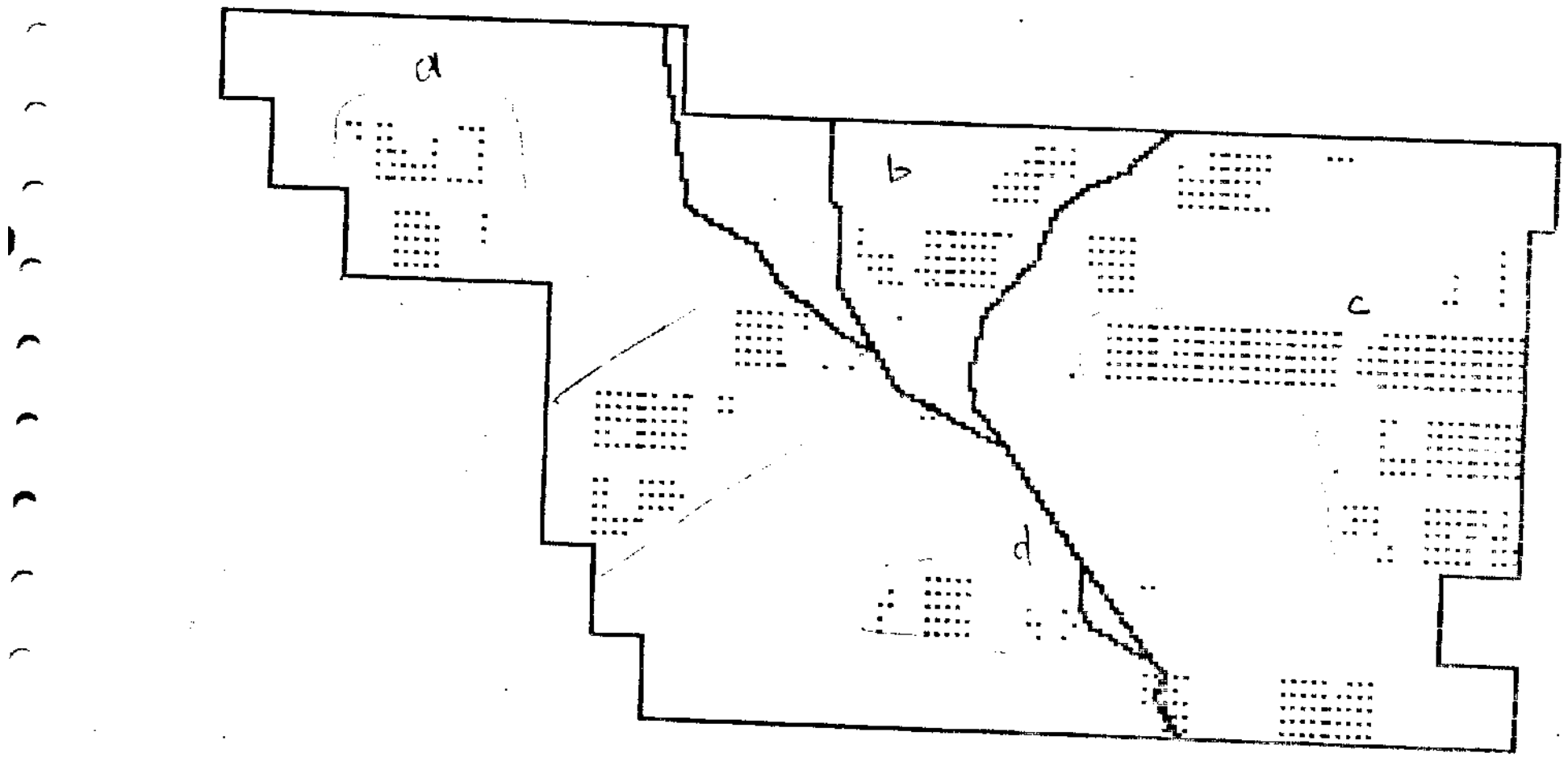


FIG.13: SABON GIDA ORA LAND USE CATEGORY 313 (RIPARIAN FOREST)

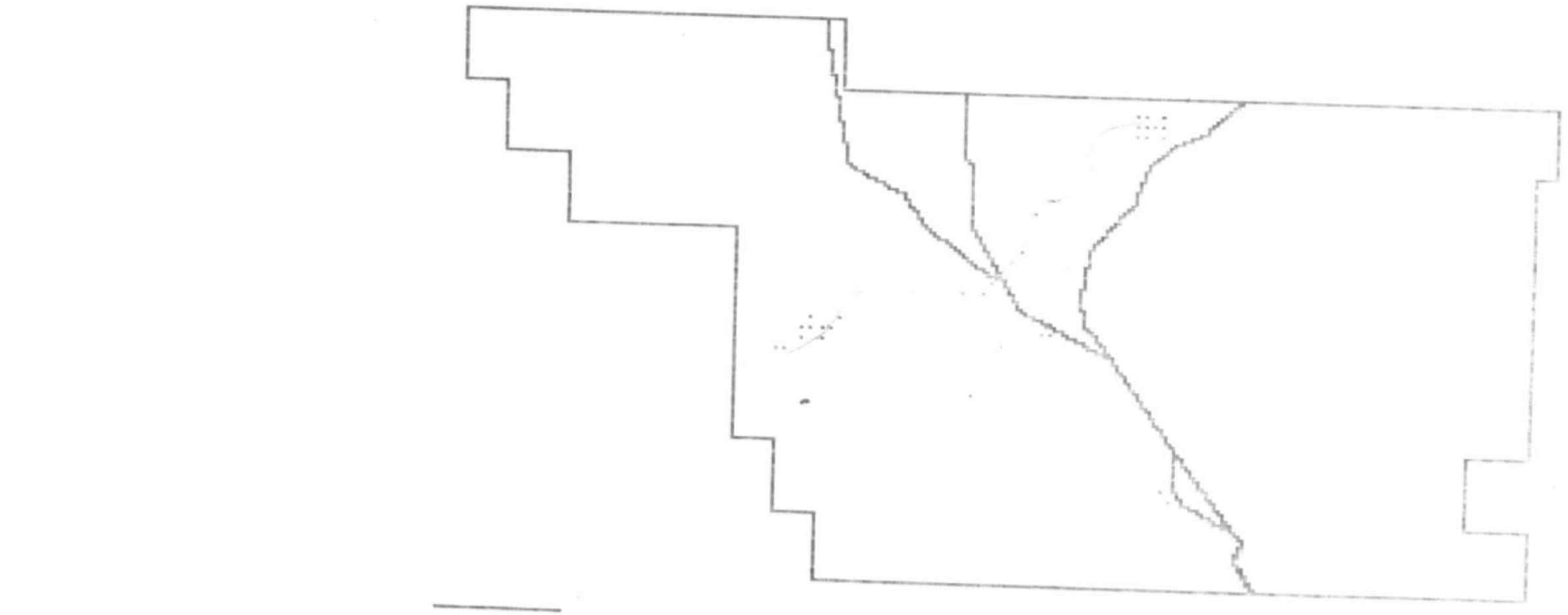
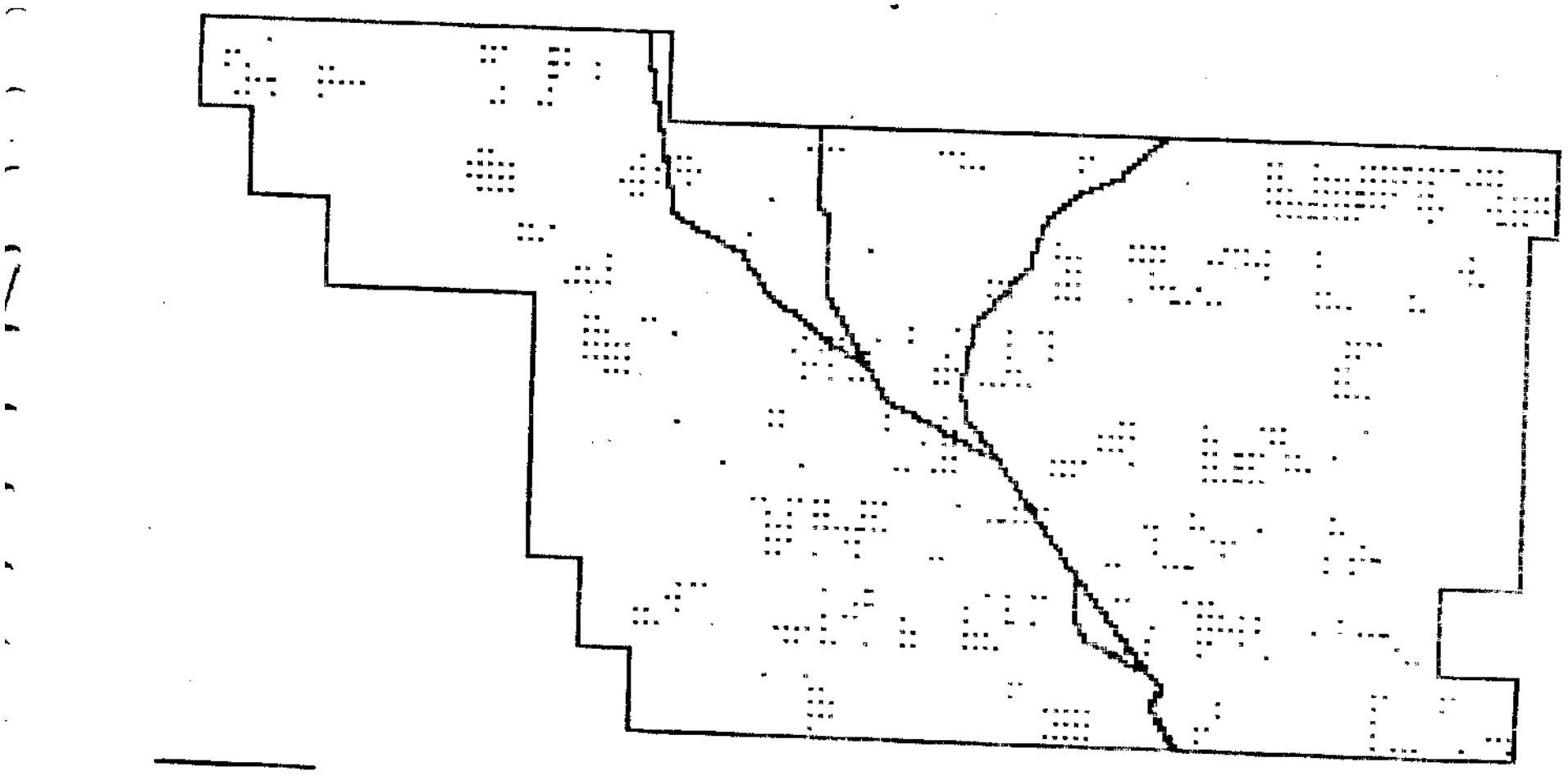


FIG. 14: SABON GIDA ORA LAND USE CATEGORY 32 (WOODLAND)



Most of the natural forest vegetation has, through constant clearing and firing, reverted to a woodland mosaic.

4:3:3:3 SCRUB LAND

Supprisingly scrubland accounts for a larger areal coverage of the vegetation category and the total study area, 43.2% and 4.58% (327.75 ha), respectively. Actually this is a regenerative stage of bush fallow preceeding secondary forest, scrubs supersede those of woody platforms. This is a result of fire over long period of time.

Examination of fig 15 shows that with the exception of the residential-central area, thickly covered forest land of central western and eastern sections, all the eight strips of photographs making up the study area contain the occurrence of scrubland. About 1% or 2% of scrubland actually is wildly or semi-wildly growing tree fruit crops notably banana and plantain growing along with scrubs grouped in this category.

4:3:3:4 SHRUB LAND

Shrubs are found growing mostly along road sides and around residences. A larger proportion of shrubland in the map is in the north central section towards the western part between the two main roads after the second main road junction (see fig 16).

Shrubland contributes 9.8% of the vegetation cover and a meagre 1.04% (74.25 ha) of the study area.

FIG. 15: SABON GIDA ORA LAND USE CATEGORY 33 (SCRUBLAND)

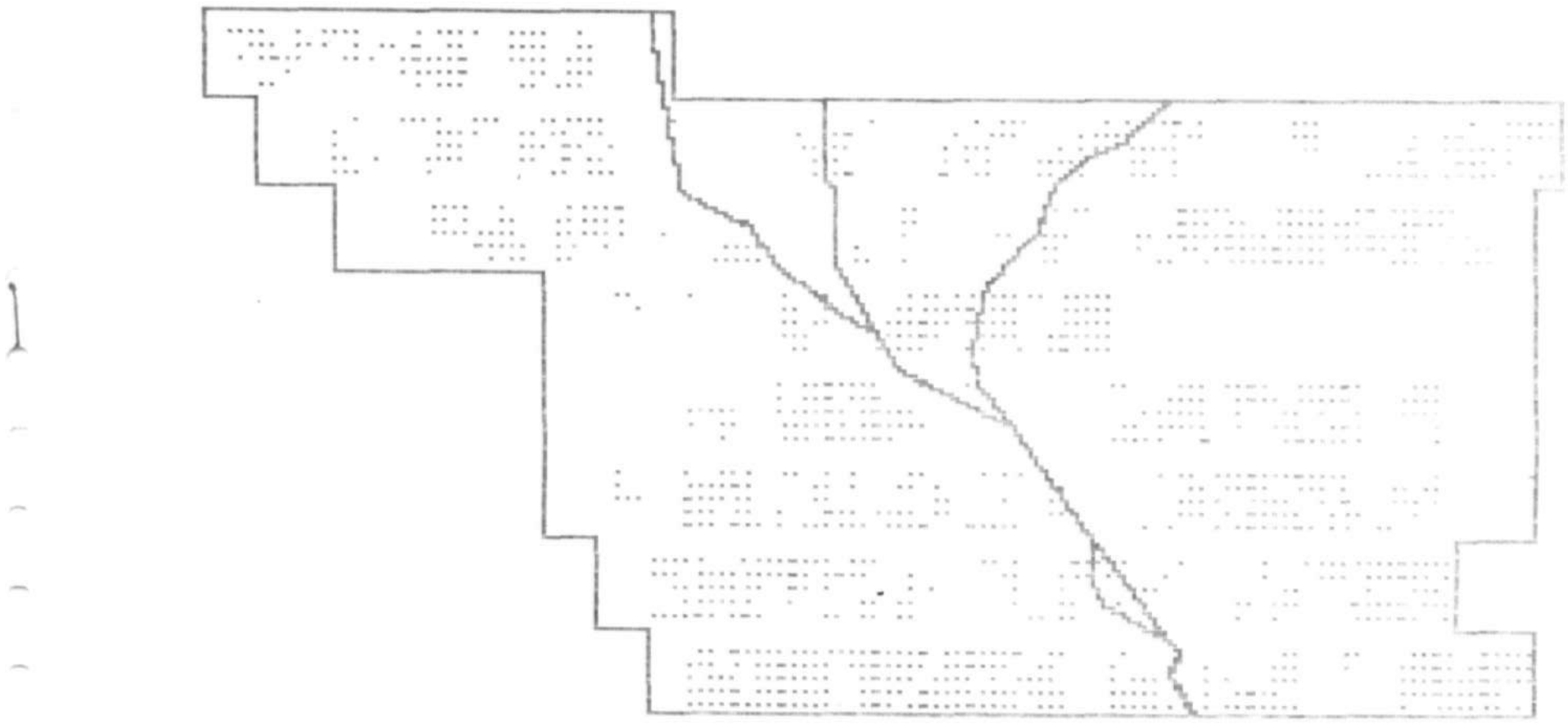
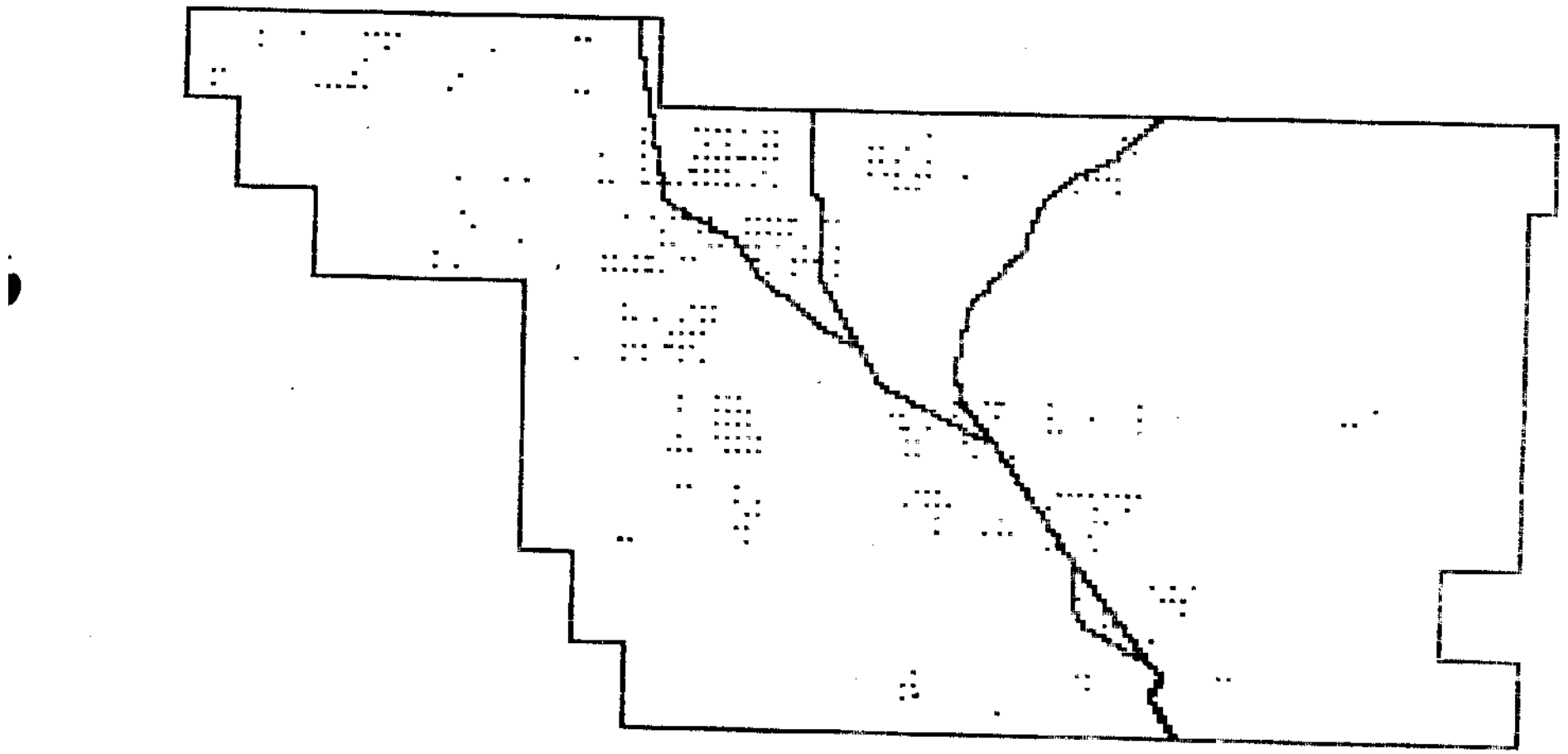


FIG 16: SABON GIDA ORA LAND USE CATEGORY 34 (SHRUBLAND)



4:3:3:5 GRASS LAWNS

The least category in areal coverage of the uncultivated lands. Grasslawns, as would be expected, are found in residential areas, adjoining isolated buildings or compounds and fronting compounds.

In appendix 10 occurrence is in the first main road junction and east top of the central road. Grasslawns covers 1.5% of the vegetation cover category and 0.16% (11.25 ha) of the total area.

4:3:4 BARREN LAND

Save for stream and river sub-category, unproductive land class is essentially irrelevant. The only noticeable bare uncultivated grounds are the sandy compound frontages and one or two isolated pockets. Bare uncultivated ground category shown in fig 17, is 0.07% (4.75 ha) of the study area. This is 30.6% of barren land category while visible water bodies make up the remaining percentage.

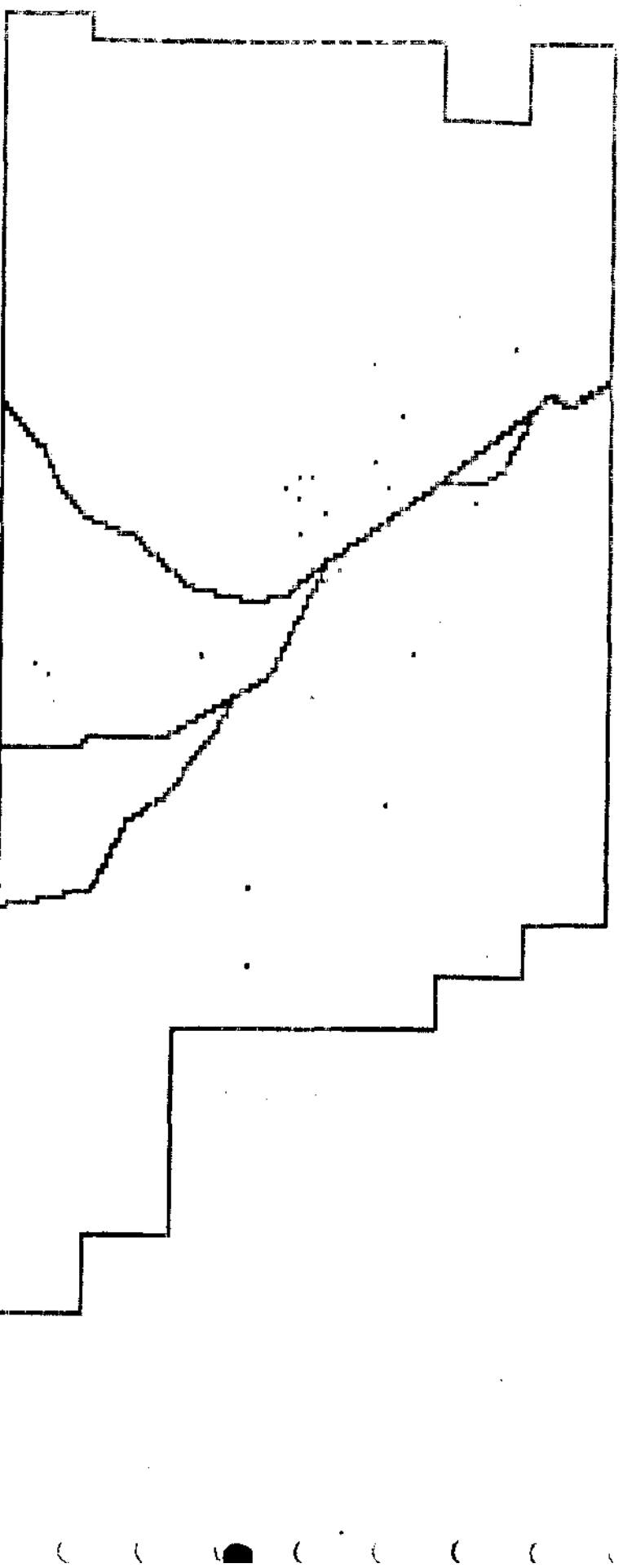


FIG.17: SABON GIDA ORA LAND USE CATEGORY 41 (BARE UNCULTIVATED GROUND)

CHAPTER 5

SUMMARY AND CONCLUSION

Using large scale photographs and the dot grid sampling method with computer analysis I have been able to estimate the land use in a Nigerian forest area-Sabon Gida Ora. I have concentrated on describing the existing cultural landscape.

A review of this study reveal the following:

(1) Though attempt was made no reasonable accurate interpretation of air photos was made in identifying and estimating the individual crop type. This is because of the very small size of the plots and because of the practice of interplanting as many as three of four different crops in the same plot.

The precision of estimating crop type categories was low (see table 10).

(2) A major disadvantage in the use of dot grids is that only the uses that fall directly under the dots are recorded while the dominant uses which did not fall directly under the dots are not recorded.

Though systematic dot grid gives an even areal coverage; if there is a spatial pattern in the data being collected the regularly spaced sampling points could correspond with some parts of the pattern and so give a 'biased' impression. However, it is used because of reasons stated in 3:3.

(3) Analyses reveal perfect positive correlation between area occupied by a particular category, the density of observations per unit area of a particular category and the accuracy with which that category could be identified and estimated.

(4) Unused land (Barren Land) is the least, infact insignificant occurrence in the study area. This presents better prospects for development. Considering more so that most land is vegetation cover.

(5) Scattered small fragmented farm plots doesn't provide for good agricultural practice.

In reviewing the work surrounding the use of aerial photographs in land use research, it is generally safe to draw the following conclusions regarding its impact, limitations and potential in Semi-Urban and rural areas.

1. Aerial photo-interpretation has played a role in the inventorying of land use.

2. Land use information obtained from aerial photographs are increasingly analysed by computer.

3. Aerial photo-interpretation/application is now being applied in less than optimum manner in Nigeria.

It is expedient that due to the inavailability of up-to-date land use information in Nigeria, and with the capabilities provided by aerial photo-interpretation and computer analysis, there is need for a National land use and resources Survey Data Bank.

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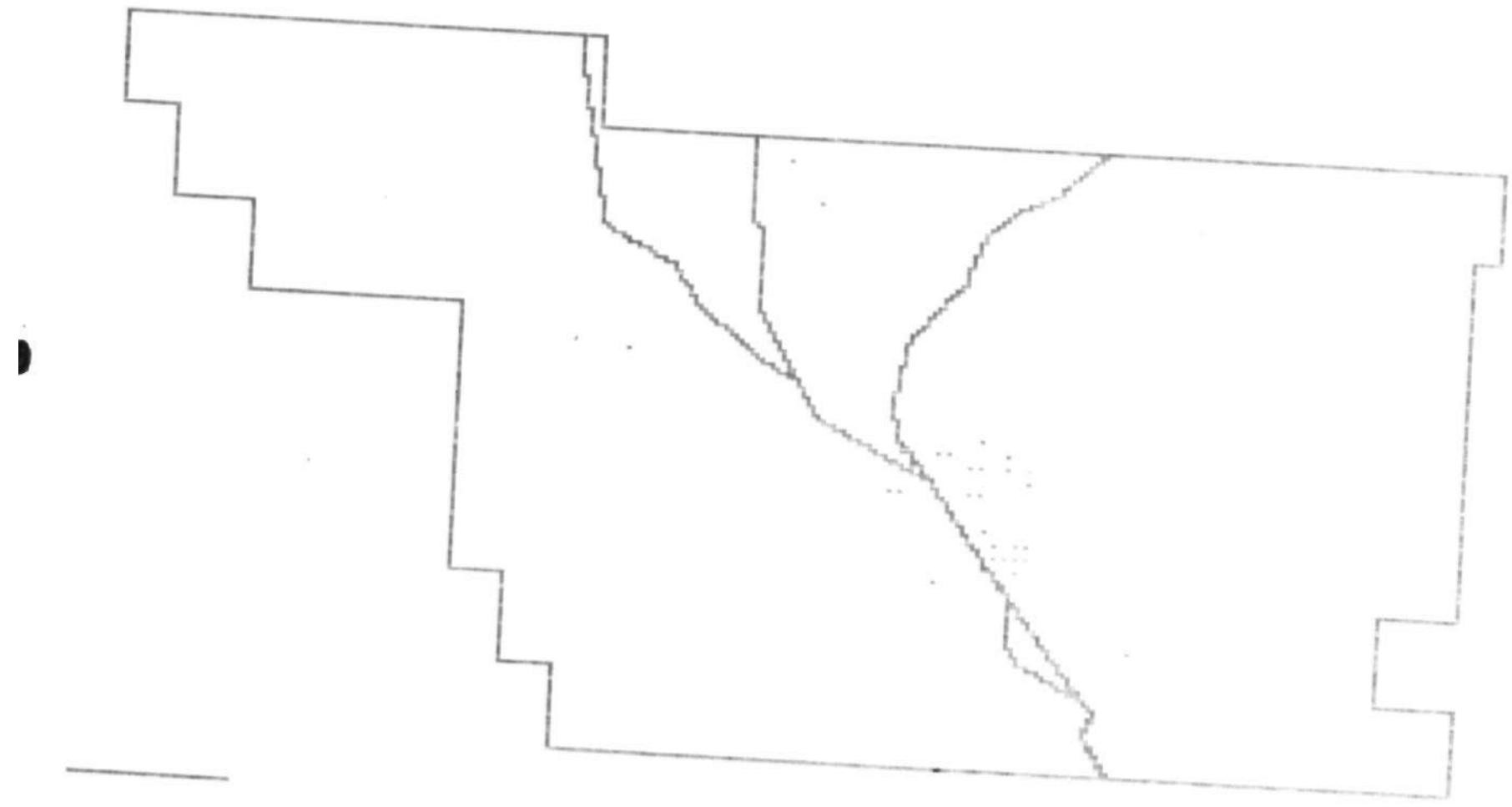
APPENDICES

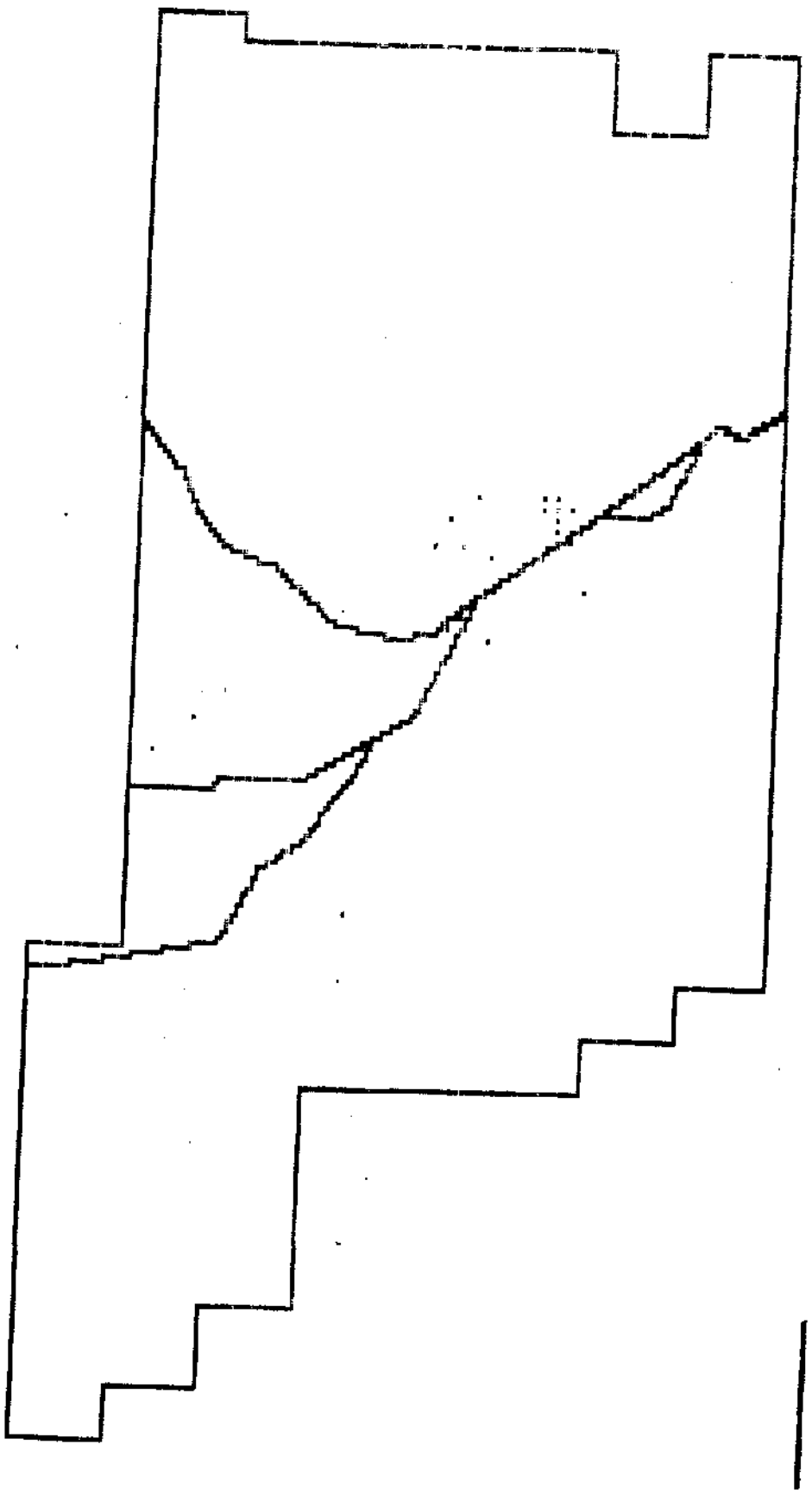
The appendices are computer maps showing the distribution of some land use categories not included in the main body of the thesis but their distribution discussed there in.

Following are the computer maps of these Sabon Gida Ora land use categories.

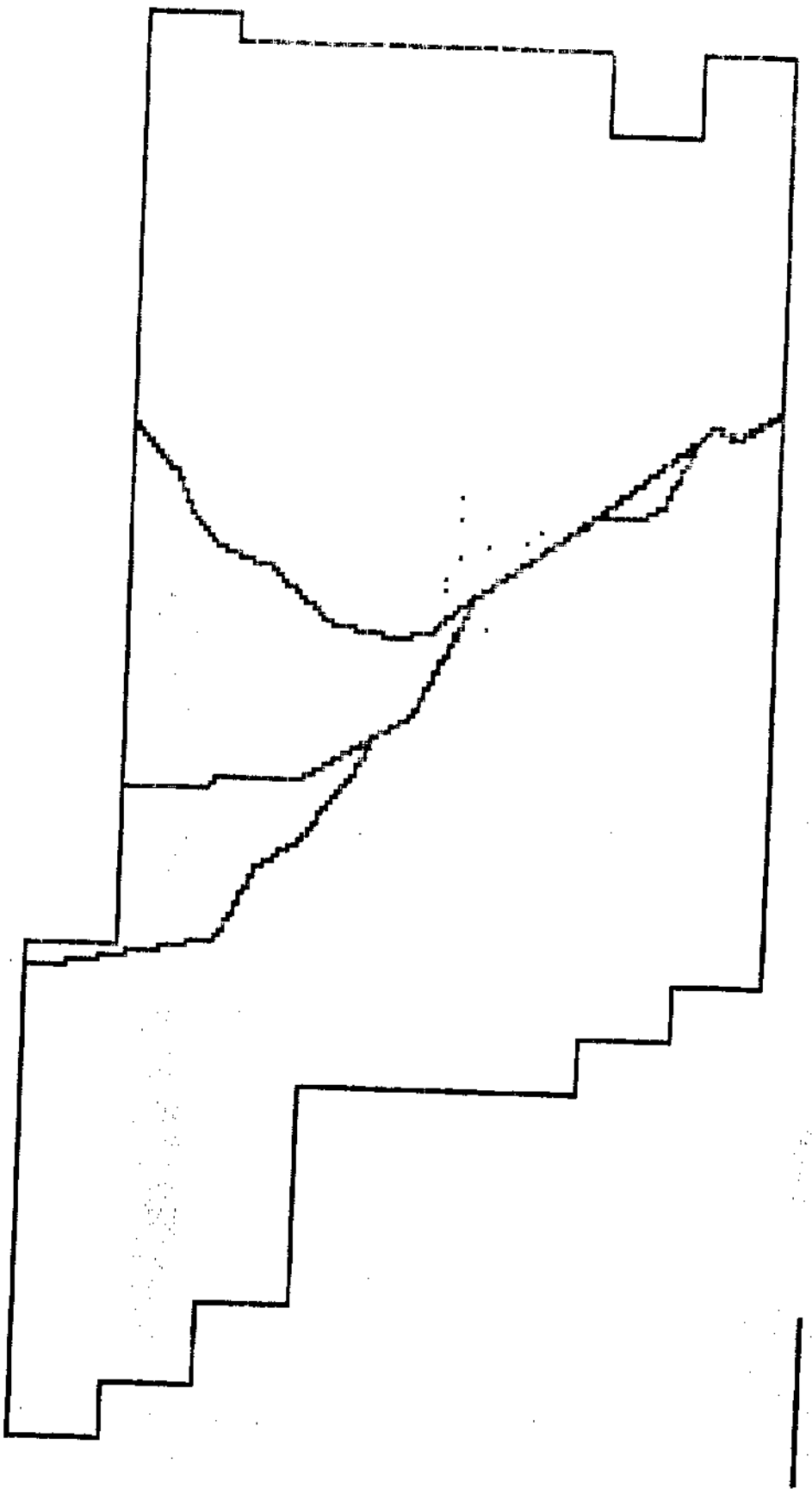
1 category 111, residential
2 category 1111, isolated buildings
3 category 1112, buildings in compound
4 category 234, root crops in unenclosed farmland under 2ha
5 category 24, unenclosed farmland over 2ha
6 category 251, tillage
7 category 252, cleared lands
8 category 253, early bush fallow
9 category 3112, light forest
10 category 35, grass lawns.

1: SABON GIDA ORA LAND USE CATEGORY 111 (RESIDENTIAL)



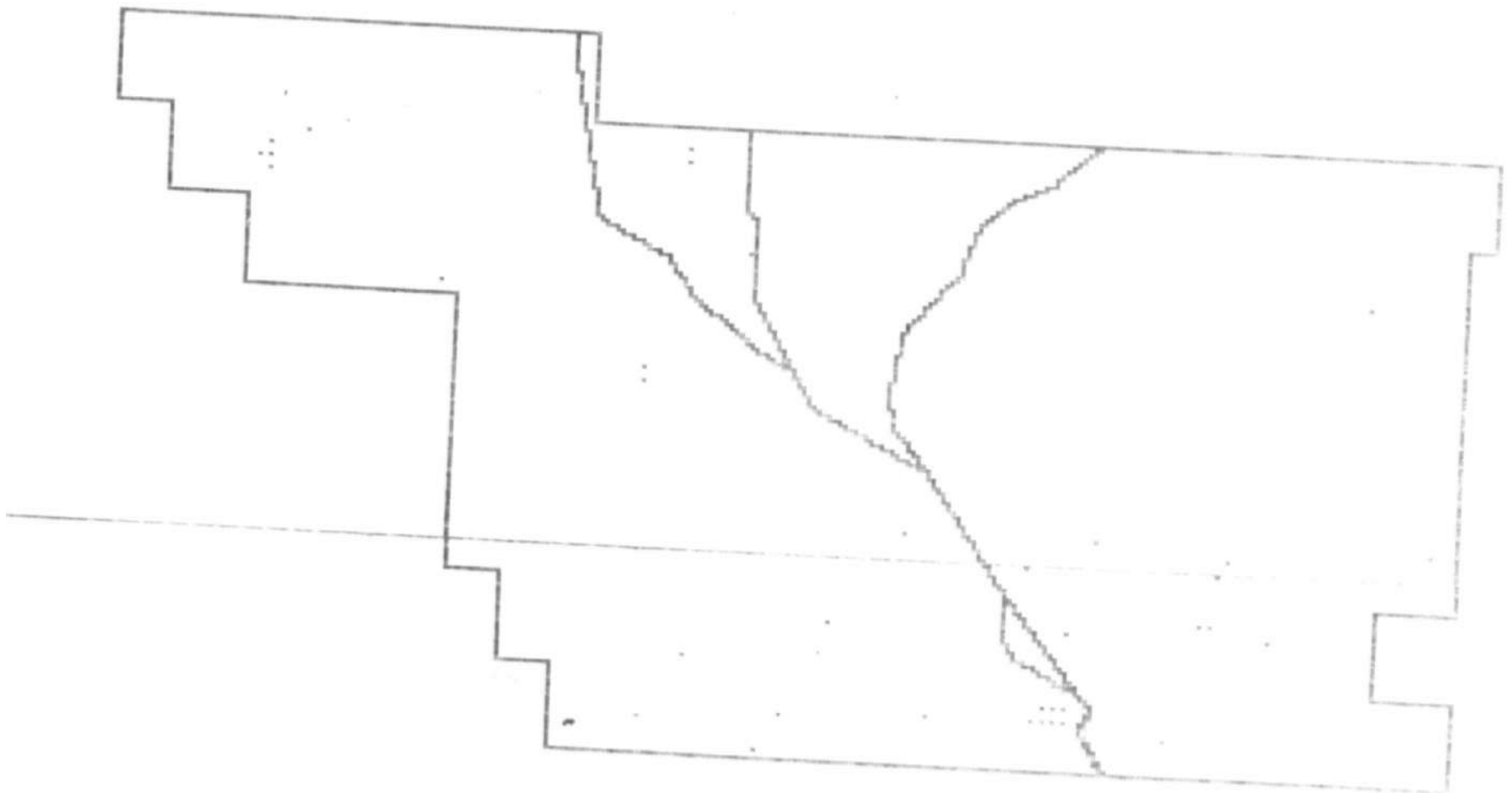


2: SABON GIDA ORA LAND USE CATEGORY 1111 (ISOLATED BUILDINGS)



3: SABON GIDA ORA LAND USE CATEGORY 1112 (BUILDINGS IN COMPOUND)

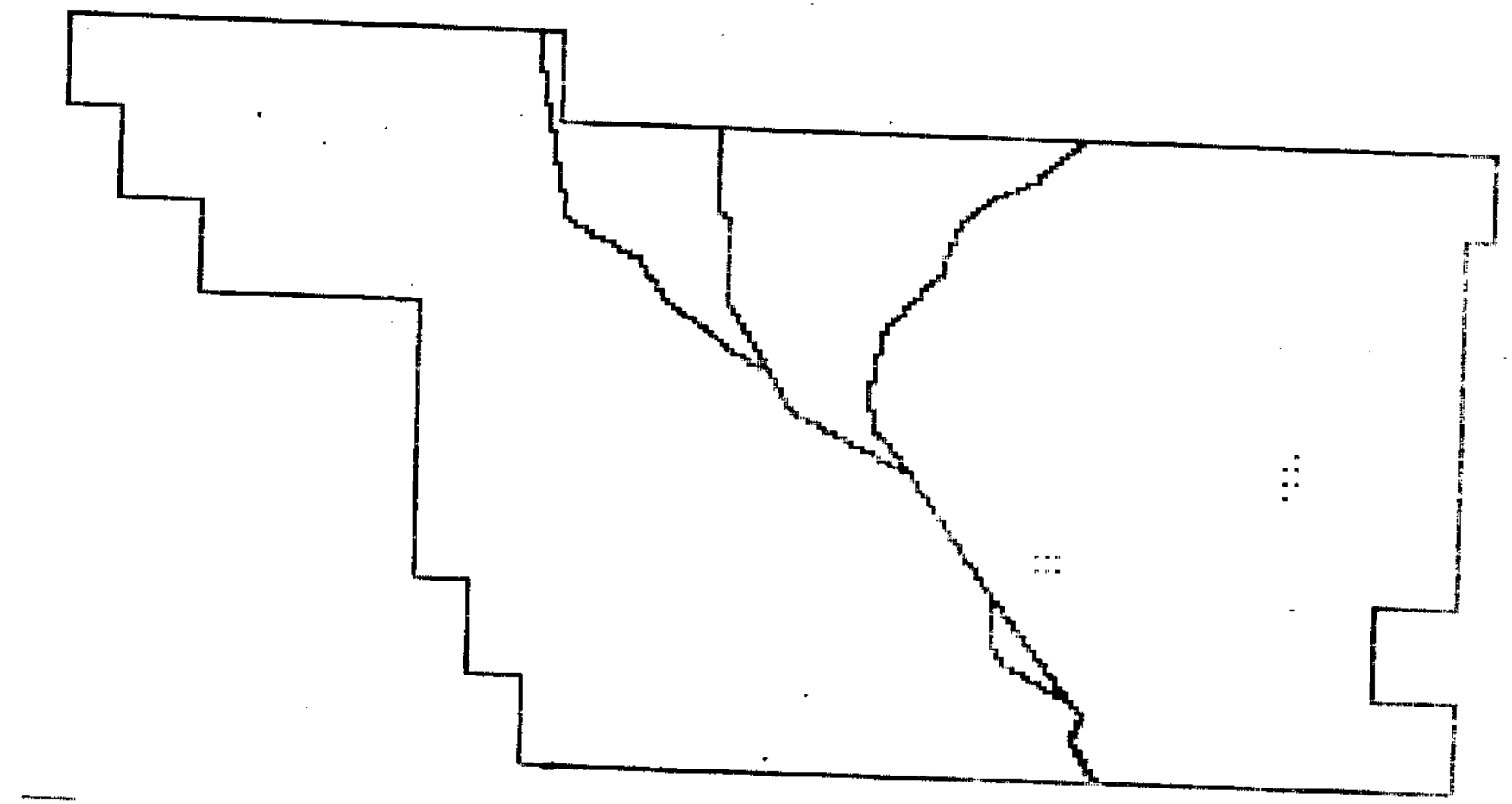
4: SABON GIDA ORA LAND USE CATEGORY 234 (ROOT CROPS IN UNENCLOSED FARMLAND UNDER 2HA)



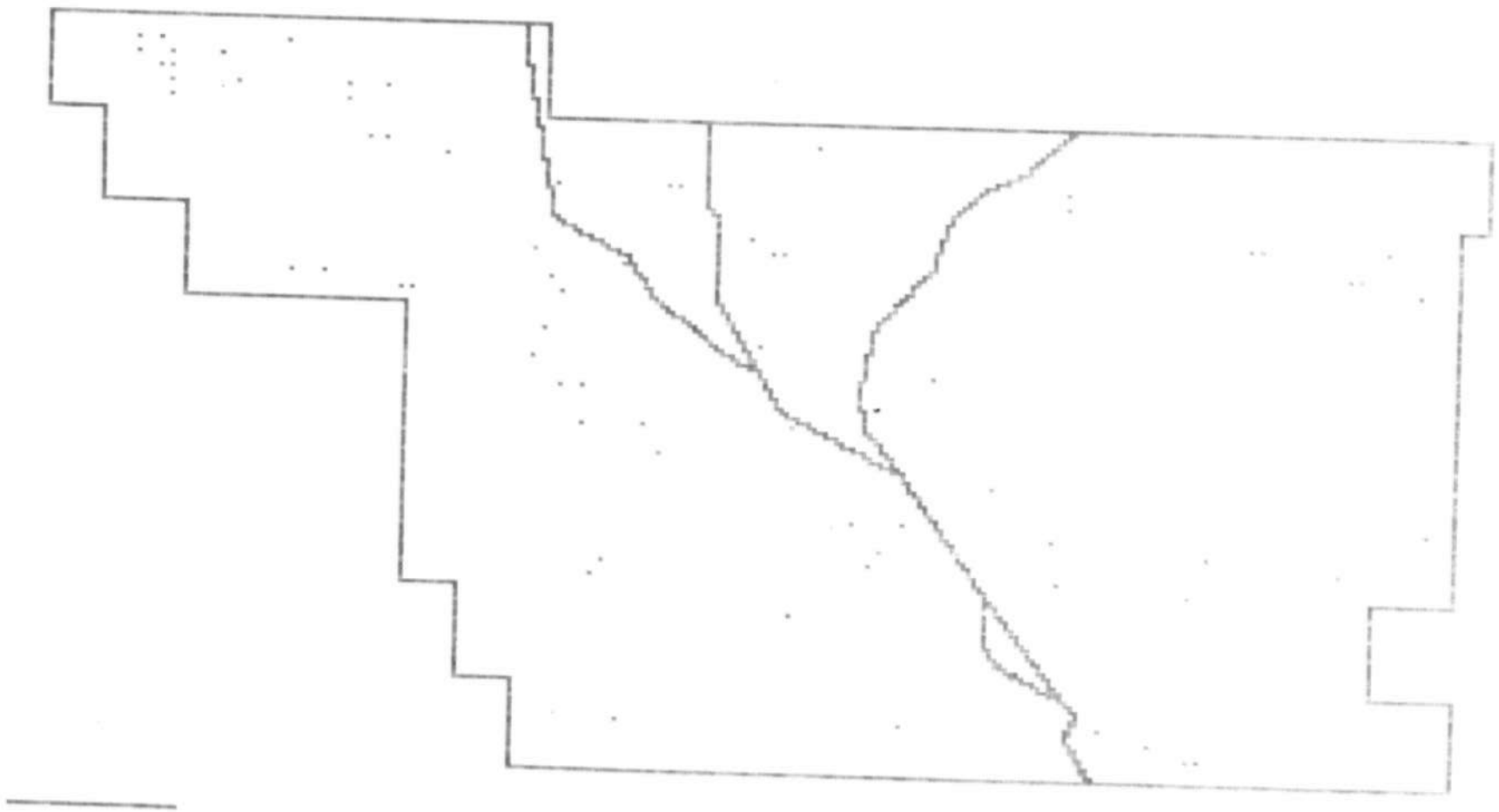
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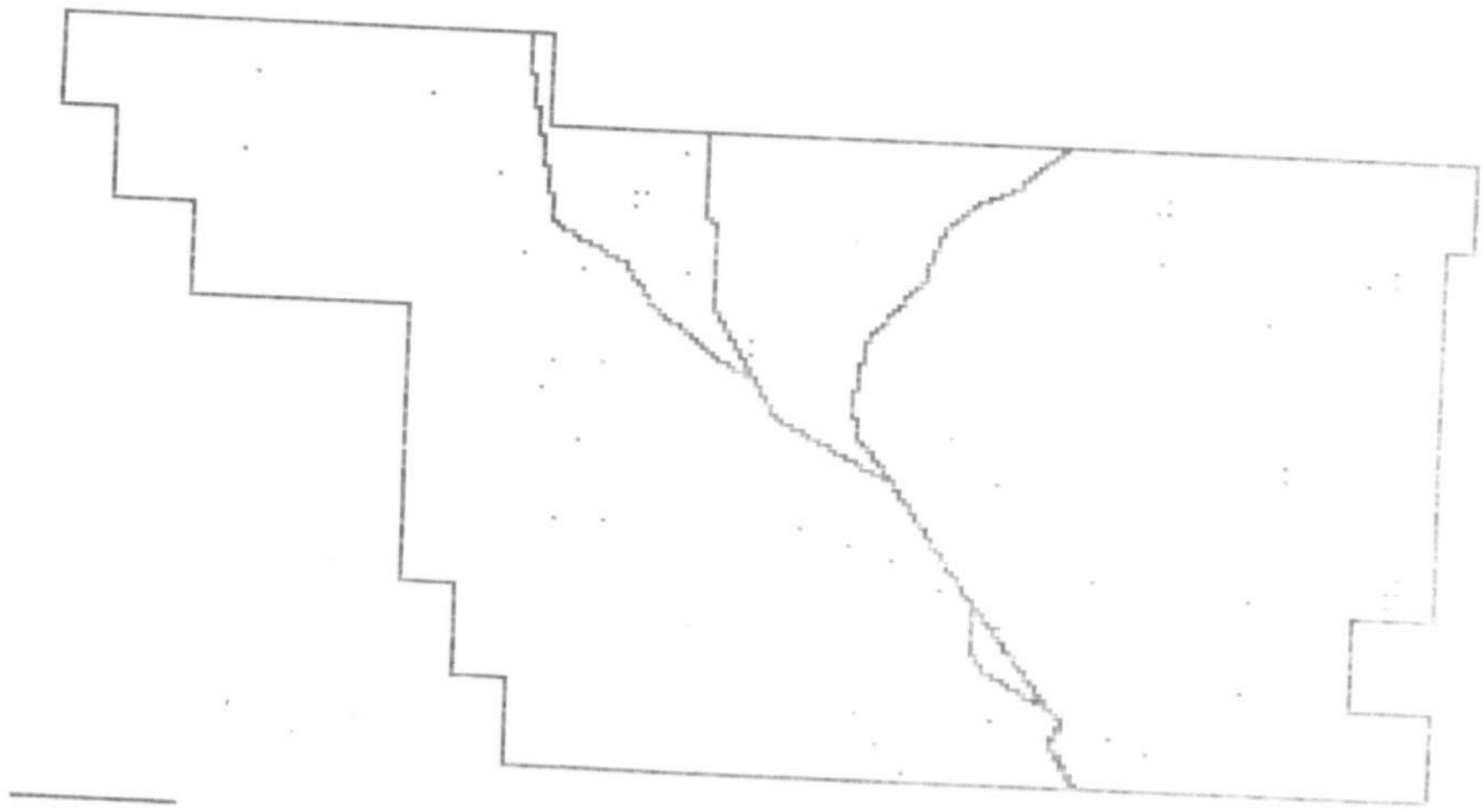
5: SABON GIDA ORA LAND USE CATEGORY 24 (UNENCLOSED FARMLAND OVER 2HA)



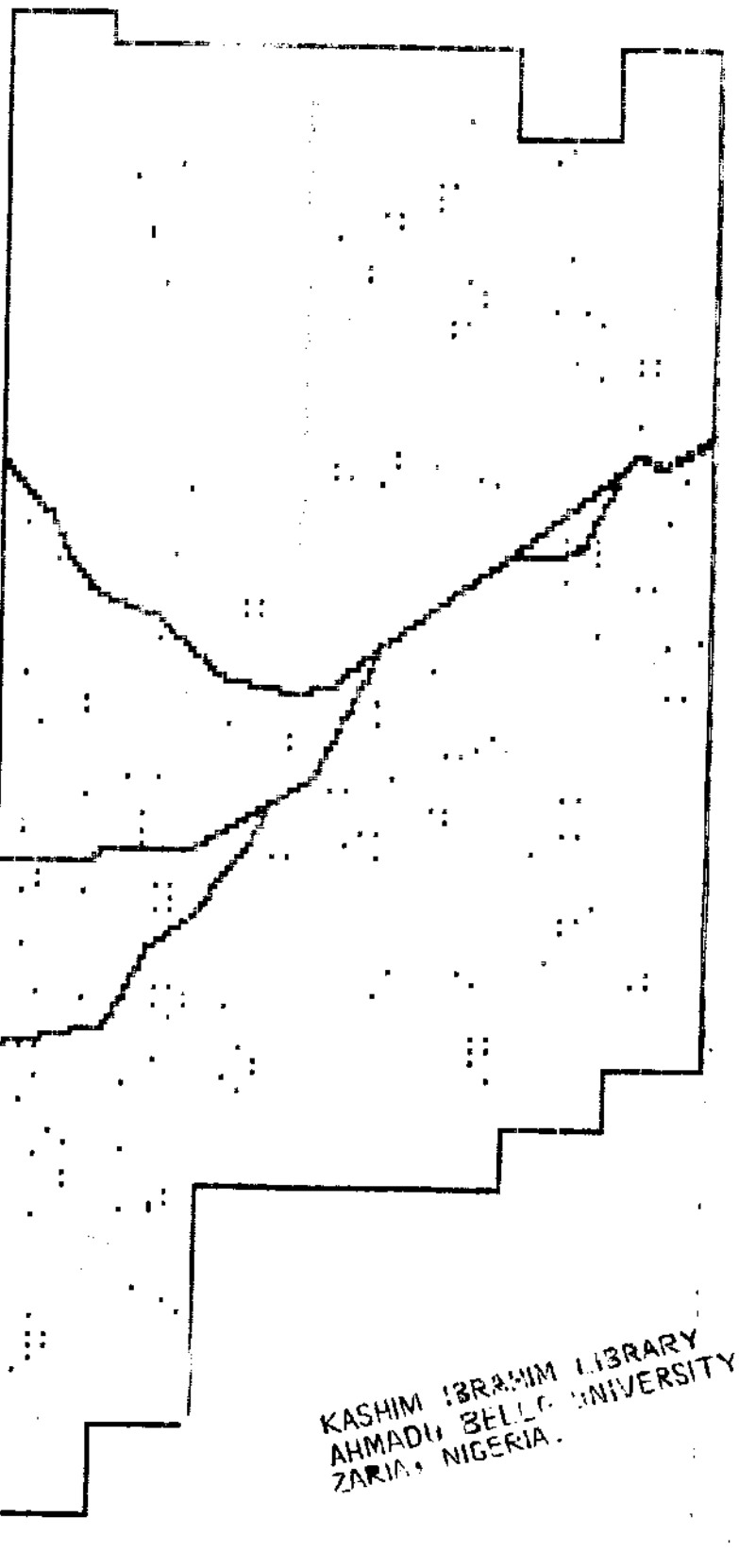
6: SABON GIDA ORA LAND USE CATEGORY 251 (TILLAGE)



7: SABON GIDA ORA LAND USE CATEGORY 252 (CLEARED LANDS)

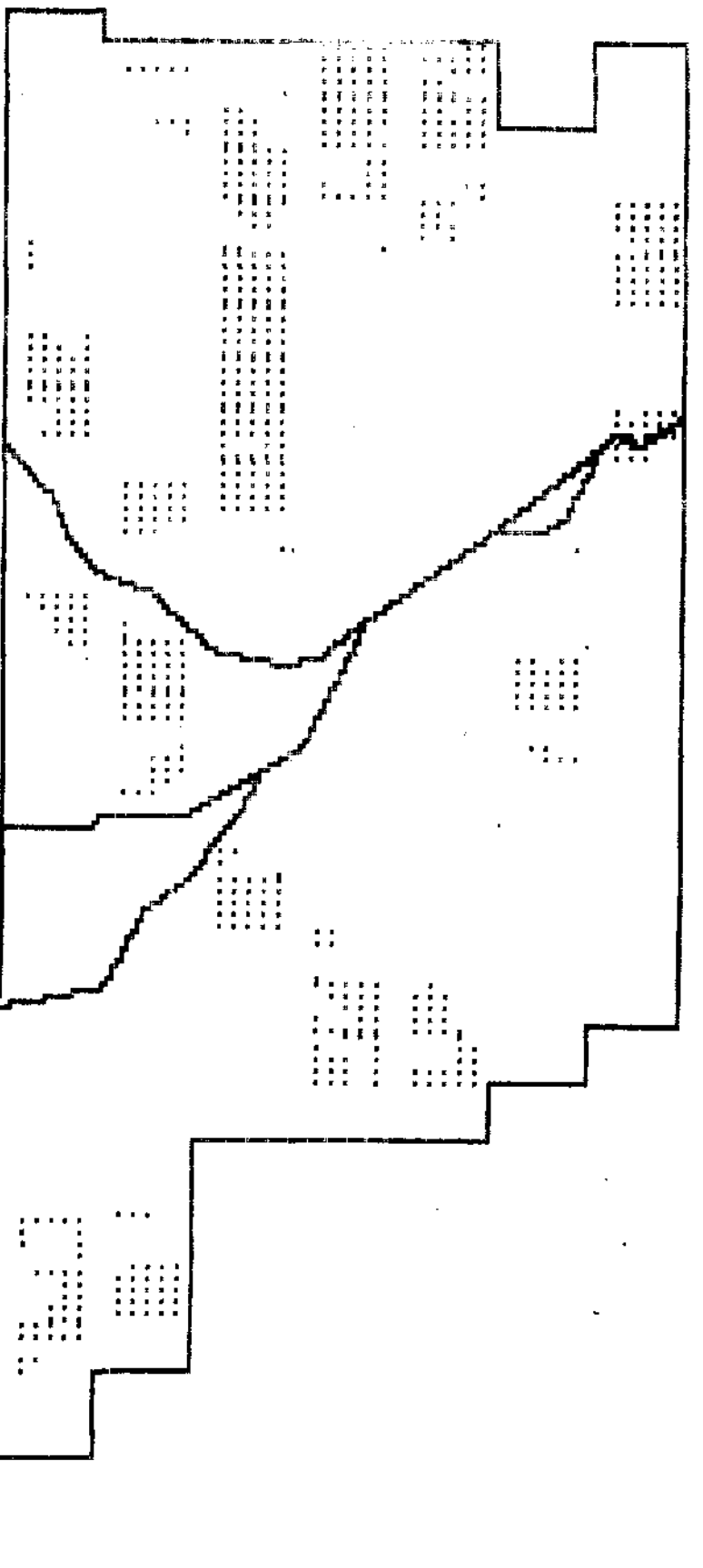


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8: SABON GIDA ORA LAND USE CATEGORY 253 (EARLY BUSH FALLOW)

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9: SABON GIDA ORA LAND USE CATEGORY 3112 (LIGHT FOREST')

10: SABON GIDA ORA LAND USE CATEGORY 35 (GRASSLAWNS)

