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LAND USE MONITORING IN THE NIGERIAN SAVANNA USING AERIAL PHOTOGRAPHS

BY

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For the degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF ASTON IN BIRMINGHAM

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S U M M A R Y

Aerial photography was used to determine the land use in a test area of the Nigerian savanna in 1950 and 1972. Changes in land use were determined and correlated with accessibility, appropriate low technology methods being used to make it easy to extend the investigation to other areas without incurring great expense. A test area of 750 sq km was chosen located in Kaduna State of Nigeria. The geography of the area is summarised together with the local knowledge which is essential for accurate photointerpretation. A land use classification was devised and tested for use with medium scale aerial photography of the savanna. The two sets of aerial photography at 1:25 000 scale were sampled using systematic dot grids. A dot density of 8 1/2 dots per sq km was calculated to give an acceptable estimate of land use. Problems of interpretation included gradation between categories, sample position uncertainty and personal bias. The results showed that in 22 years the amount of cultivated land in the test area had doubled while there had been a corresponding decrease in the amount of uncultivated land particularly woodland. The intensity of land use had generally increased. The distribution of land use changes was analysed and correlated with accessibility. Highly significant correlations were found for 1972 which had not existed in 1950. Changes in land use could also be correlated with accessibility. It was concluded that in the 22 year test period there had been intensification of land use, movement of human activity towards the main road, and a decrease in natural vegetation particularly close to the road. The classification of land use and the dot grid method of survey were shown to be applicable to a savanna test area.

KEY WORDS: NIGERIA SAVANNA LANDUSE AERIAL PHOTOGRAPHY

ECCLESIASTES 3:22

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The people of Kajuru welcomed me on my visits.

My family gave support and help in many different ways.

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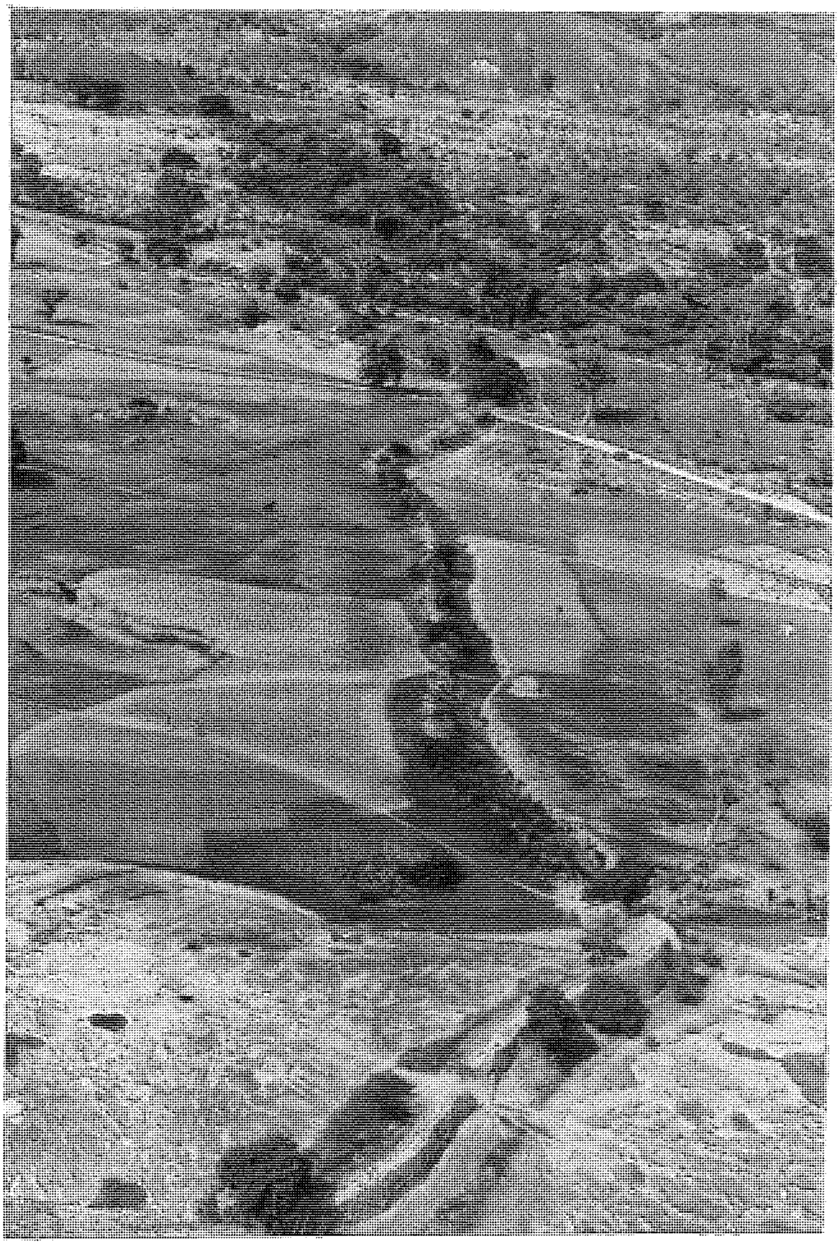

Photograph 1

Farmland on the outskirts of Kajuru village. Centre is the village wall. Gallery forest along a stream in the middle distance.

CHAPTER ONE

INTRODUCTION

1.1 THE OBJECT OF THIS PROJECT

This project was designed to monitor the land use patterns and land use changes in a representative area of the Nigerian savanna over a period of twenty two years from 1950 to 1972. Techniques and instrumentation were kept simple, using only the equipment which was available. The material used for interpretation was aerial photography flown for mapping. Keeping the project simple and inexpensive gave some hope that it would be possible to extend the work to other areas in the future.

Vertical black and white aerial photography was used and interpreted with the aid of a mirror stereoscope. Dot grids overlaid on the prints provided the sample locations from which occurrence, distribution and changes in land use could be estimated to a measurable precision. The results of the work were sorted and analysed using a micro-computer with mostly standard programmes. An attempt was made to correlate accessibility and land use, with some success.

1.2 SIMPLE METHODS

Why simple methods? This question is best answered by the short essay in contrasts which follows. The first impression received by a visitor from Africa to Britain is that there is a superabundance of information available. The remote sensing laboratories are a joy to visit with their arrays of interpretation equipment and their abundant computer terminals. There is a wealth of interpretation material lying around and the spare copies are hung decoratively on the walls. In Africa it is different. The laboratories contain out of date equipment which is run down, badly maintained and short of spare parts. Computers are scarce and extremely expensive, working only when the intermittent power supply is functioning. Material for interpretation is difficult to get and the photograph on the wall may be the only one in the building. LANDSAT imagery for instance has to be ordered from abroad and paid for in hard currency, the mails imposing delays which have been known to extend into years. The difficulties encountered in producing any scientific work are therefore immense, and the use of simple methods and materials is more or less essential. Under these circumstances it is appropriate to adapt a phrase and say that "available is beautiful" with perhaps a hint of "any port in a storm".

1.3 AERIAL PHOTOGRAPHY

Aerial photographs are available. They are also comparatively cheap and easy to interpret. Most developing countries have several generations of them taken originally for the purpose of topographical mapping. Their quality is variable, the newest not always being the best, most are on panchromatic film but some is on near infrared. The scales are usually quite small, 1:40 000 being normal and 1:25 000 occurring less frequently. Of course the films have to be found. The large aerial contractors fly the area to be mapped and when the work is completed deliver the films plus repromat to the clients. After that the film cans are stored in a safe place and gradually forgotten, but with a little persistence and a certain amount of bureaucracy copies can be obtained. The prints contain a great deal of interesting information on land use, vegetation and other land resources which has not been abstracted onto the topographic maps. This information can be very useful in development studies of many kinds. Wright (1985) makes this point.

1.4 SIMPLE EQUIPMENT

The same arguments apply to the choice of equipment for interpretation and analysis. Costly sophisticated machines are wonderful when they are well maintained and you can get spare parts for them but they rapidly become dust collecting white elephants in the harsh environments of Third World laboratories. Whenever possible it is best to used rugged uncomplicated equipment which is reliable and needs the minimum of adjustment. For photointerpretation the folding mirror stereoscope fits the bill perfectly, it may be inconvenient but it works. An exception to the rule has been made in this study by using a micro-computer for data processiong. With a large test area and quantities of data this was the only tool which would give reliable answers to the questions which were to be asked. However it is note worthy that all the delays encountered in the project were caused by computer failure. Either the power supply was cut off or its irregularity caused component failure or it was difficult to get the right match of hardware and software from agents at the other end of the country.

1.5 ACCESSIBILITY

In this project an attempt is made to correlate accessibility with the changes in and distribution of land use interpreted from the aerial photography. There are two reasons for concentrating on this rather than other factors. The first is that information on accessibility is to a large extent available on the photographs. The distance from a place to the nearest road can be measured. Footpaths and tracks can be distinguished from metalled roads. Railways are clearly visible. Information on other interesting things like soil types, geology and population has to be found elsewhere and is seldom available. To take an example, the last two censuses of Nigeria were taken in 1963 and 1972. Both of them were controversial and politically sensitive; the results of neither are regarded as reliable. Detailed census data are not readily available and then only for large units such as Local Government Areas which may cover thousands of square kilometres. Information on soils and geology is also very scanty because there have been few detailed surveys.

The second reason for investigating accessibility is more positive, it is that accessibility is important. It is nice to live near a road or a railway station where you can catch a bus or train into the comparatively bright lights of the town and people can come from there to visit you on Sunday. Local authorities and governments tend to put their facilities near the road as well, possibly because the planners do not like walking too far from their cars when on a site visit. Dispensaries, schools and other good things are found near the motor roads, thinning out or disappearing inside the bush. Accessibility also makes transport easier. A 50 kilo bag of fertiliser is as much as can be carried on a bicycle and considerably more than most people would want to headload very far. Similarly a bundle of firewood may not be very heavy but it is extremely awkward to carry. Lorry transport is five times faster and fifty times more capacious than off road carriage; it is also several hundred times more comfortable. Clark and Haswell (1967) calculated that motor transport is 8.6 times more efficient per ton mile than headloading; they probably never had to carry anything themselves so they dont mention convenience. In the dry season almost all villages can be reached by a lorry or minibus driven along dirt tracks; but in the rains when most farming takes place the reach of wheeled transport is restricted to the tarred roads and the more permanent tracks. A broken bridge may cut off large areas for months or even years. So it is likely that accessibility is going to be important in influencing people when they decide where to live and where to farm.

1.6 SUMMARY

1.61 This project investigates land use and land use change in a test area of the savanna between 1950 and 1972.

1.62 Simple methods, equipment and material are used because of their relevance in the local situation.

1.63 Aerial photographs originally used for topographic mapping are available in most developing countries where other material is not.

1.64 Equipment which is rugged and easily maintained is essential.

1.65 Accessibility can be measured from the aerial photography. It is important because it influences people in deciding where to live and where to farm.

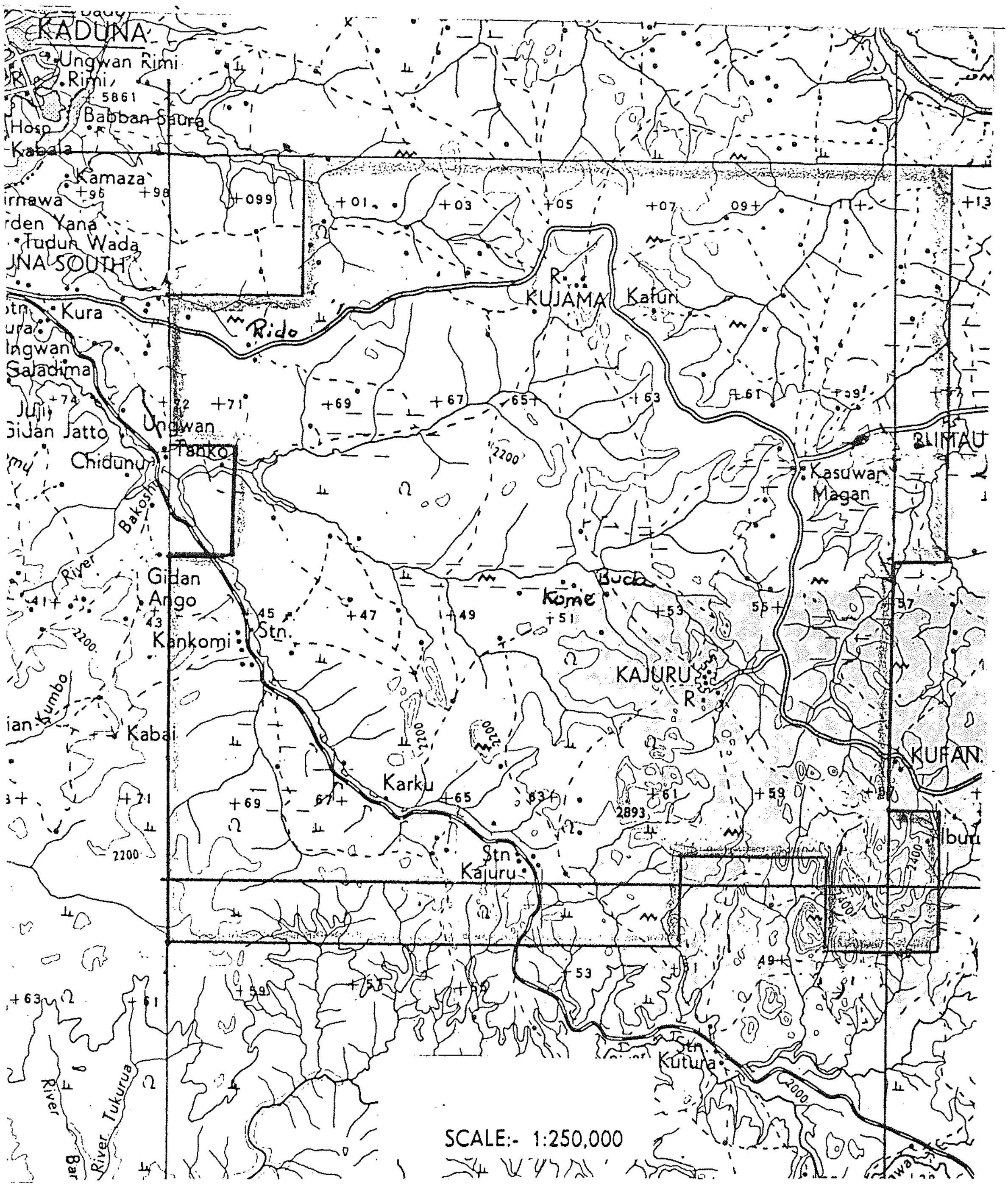

Fig.1 The Kajuru test area

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Photograph 2

The people of Kajuru (1)

Above pounding acha - below drinking burukutu

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Photograph 3

The people of Kajuru (2)

Going to - (above) harvest beans (below) hunt

C H A P T E R   T W O

T H E   T E S T   A R E A

2.1 GENERAL DESCRIPTION

The test area around Kajuru chosen for this project consists of approximately 750 sq km of the Nigerian savanna lying fairly close to the centre of the country between latitudes 10 deg 15 min N and 10 deg 30 min N and longitudes 7 deg 30 min E and 7 deg 45 min E. (see figure 1). Its boundaries are about the same as those of the 1/4 deg sheet of the national map series NIGERIA 1:50 000 sheet 145 NW KAJURU, with slight modifications to accommodate the available coverage of aerial photography. The Kajuru area is in the southern part of Kaduna State of Nigeria immediately to the south east of the large industrial and administrative centre of Kaduna. It is even now almost entirely rural in character. From the hill overlooking the old walled village of Kajuru (Photo 1) one can look north to the nearby Earth Satellite station, while beyond are the flares of the oil refinery and the pan roofs of the city suburbs. Turning southwards one sees the thinly settled wooded savanna extending to the horizon beyond which it is virtually unbroken until the new Federal Capital of Abuja is reached after 150 kms.

The topography of the Kajuru area consists of gently undulating plains drained by a network of mostly seasonal streams, which eventually lead to the Kaduna River, an all season left bank tributary of the River Niger. Most of the stream valleys are shallow and many of them expand to form wide floodplains (fadamas) which are valuable for farming and grazing. The plains are interrupted by occasional steep rocky hills (inselbergs) which become much more numerous in the south east of the Kajuru area. The highest points are Ludo Hill (880 m) and Kujama Hill (847 m) but apart from these the general level is about 650 m above mean sea level, part of what Buchanan and Pugh (1955) euphoniously but slightly inaccurately term "The High Plains of Hausaland".

About one third to one half of the area is farmed or is under some form of bush fallow, but two-fifths is wooded; or was at the time of the survey. Even in farmland many of the trees are left standing so the general impression is of well wooded parkland with plenty of grass under and between the trees. Villages and scattered compounds are mostly formed of round or rectangular grass roofed huts which blend into the landscape. The scene is only occasionally interrupted by a larger roadside village with pan roofed whitewashed buildings, markets and petrol sellers. Otherwise most of the human activity appears to be directly connected with the land.

The climate is strongly seasonal, virtually no rain falling between early October and April. In the dry season the countryside is parched, the vegetation brown and nothing grows except in the irrigated gardens near the valley bottoms. During the rainy season everything is green and farming activity is at its most strenuous. At this time of year everyone goes to the farm and whole villages will be empty during the daytime of all but the very old and the infants. Apart from the farmers, who are mostly Kadara people there are also the Fulani, traditionally nomadic pastoralists keeping cattle and small domestic animals. These people still maintain their seasonal journeys according to a calendar timed by the rains (Binns 1985). Their camps are constructed of branches and grass. Allan (1965) describes their interdependence with the neighbouring farmers.

The Kajuru area contains elements of most of the typical landscapes and peoples of the savanna. Although there will be many variations over such a vast expanse this small portion appears to be reasonably typical and suitable for a study of this kind.

2.2 CRITERIA FOR CHOICE OF AREA

2.20 Five factors were considered when selecting the test area:

1. Size
2. Availability of photography
3. Terrain

4. Location

5. Ease of access

2.21 Size

The area had to be large enough to yield a reasonable amount amount of data but not too large otherwise the work would take too long. One stereo overlap took about 3/4 hour to sample and gave 72 data points. A quarter degree map sheet contained about 90 overlaps, which as there were two sets of photography gave 130 hours of photointerpretation and 13 000 data points. This seemed sufficient and the size of the area was decided as the 1/4 deg sheet of 750 sq km about 27 km each way.

2.22 Availability of photography

Two sets of aerial photography had to be available for monitoring of land use. They had to be separated by a reasonably large time interval so that changes would be noticeable. The season at which the photography was taken should be the same so that ground conditions would be similar and make comparisons easier. Photographic scales should be fairly large and much the same on both sets; this would make it easy to identify features and to locate them on the other photographs. Panchromatic film emulsion is preferable to infra-red which is difficult to interpret, settlements in particular being almost invisible on the latter. In fact there are only three sets of photography which cover reasonably large areas of the savanna. There

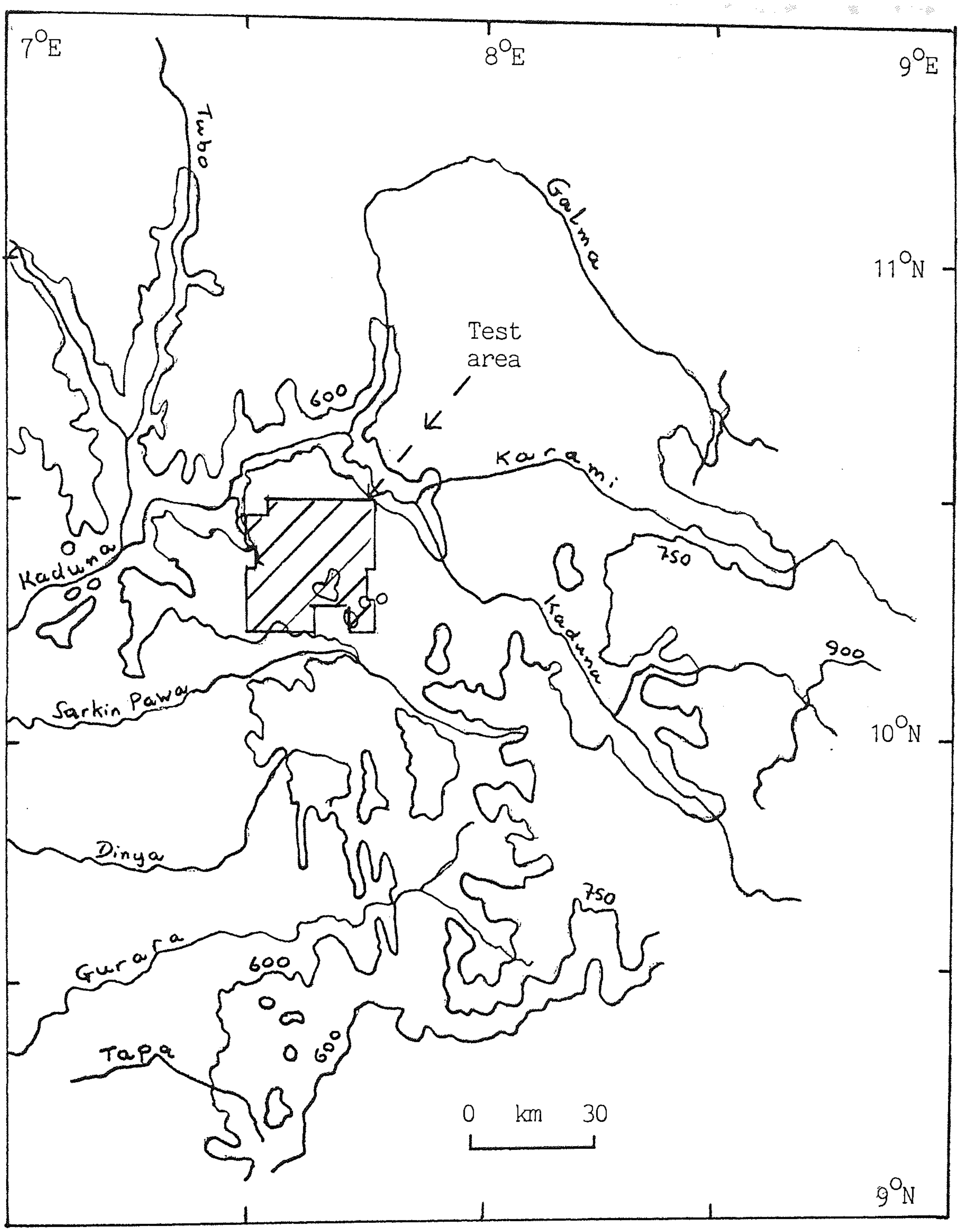

Fig 2 Kaduna Plains relief

are others taken for special projects but these cover only areas of restricted size and particular interest. The RAF photography taken in 1950/51 at 1:25 000 scale is the earliest: it was flown for the topographical mapping which replaced the 1:125 000 scale plane table sheets prepared before World War II. Coverage is very good, though there are some gaps, and quality is variable but on the whole quite acceptable. This valuable archive material is preserved by the Ordnance Survey as successors to the Directorate of Overseas Surveys and can also be found in some places in Nigeria.

The next set of photographs was taken in the early 1960's by companies on contract, again for topographical mapping, at smaller scales of between 1:40 000 and 1:45 000. The quality is variable and its smaller scale is a disadvantage.

The latest photography is that taken in 1972 at 1:25 000 scale for the large scale mapping of some fast developing or densely settled areas. There are several large blocks but the only one in the savanna is around Kaduna. All this photography was flown in the dry season when the atmosphere was reasonably clear and the skies cloudless. This climatic window has almost always been used for flying large areas in the past. Where other seasons have been used or where the prevalence of clouds makes photography difficult infra-red film has been used. A disadvantage of dry season photography is that nothing is growing, so very little crop information can be obtained except by looking at ridges and residues.

From the small choice available the 1950/51 and the 1972 sets of photography were chosen. They are at the same scale, which the 1960 set is not, and are 22 years apart giving a good time separation. They were both taken at the same season on panchromatic film. The choice therefore narrowed down to an area within the Kaduna block with the proviso that the RAF photography should be checked for complete coverage and acceptable quality.

2.23 Terrain

Bennett et al (1977) investigated the land forms and soils of what they termed the the Kaduna Plains, an area of approximately 39 850 sq km extending between latitudes 9 deg 00 min N to 11 deg 30 min N and longitudes 7 deg 00 min E to 9 deg 10 min E. (see figure 2). The plains are bounded by the downscarp to the Jema'a platform in the south, the Jos Plateau in the east, and the Niger-Chad watershed in the north-east. To the north they pass into the Kano Plains which are drier and less undulating while westwards the plains continue to the Nigerian border and beyond, interrupted only by the Niger Trough of Buchanan and Pugh (1955). Bennett et al divided the Kaduna Plains into ten physiographic units (figure 3) of which six are undulating plains comprising 82% of the total area. These plains are formed on ancient igneous and metamorphic rocks of the Basement Complex lying at an elevation of between 600 and 700 metres. The Kajuru area includes parts of three of these units, the Tubo Plains, the Galma Plains and the Dinya Plains, which together make up 53% of the whole of the Kaduna Plains and appear to give a selection of their typical features. The fourth unit represented is the Idon Plains which contain frequent rocky hills and makes up 17% of the whole Kaduna Plains area.

2.24 Location

Climatically the Kaduna Plains lie within the northern movement of the Inter Tropical Convergence Zone (ITCZ) which separates the Equatorial Maritime and Tropical Continental air masses. The movement of the ITCZ in response to the Sun but lagging somewhat behind it controls the rains which begin earlier and last longer in the south. The length of the rains determines the length of the growing season as the temperatures are high throughout the year. The vegetation is thus controlled mainly by rainfall. All the Kaduna Plains fall within the savanna, two of the three zones described by Keay (1953) being present, the Southern Guinea and the Northern Guinea Savanna. The two zones are typically distinct although they grade into one another. The Southern Guinea Savanna is more heavily wooded and contains forest outliers (kurame). The Northern Guinea Savanna is more open, with thick woodland only in galleries along the streams and at the bases of inselbergs (Keay 1960, Hopkins 1974). The boundary between the two zones also roughly marks the change from one farming type to another, the cereal based farming systems to the north and the mixed root crop - cereal systems to the south. For the sake of simplicity it was decided to locate the test area wholly within one of the vegetation zones, the Northern Guinea Savanna being selected in response to other factors.

Communications and settlement were also considered in the selection of the test area. As the intention is to look at land use change there should be some roads if possible to bring the change. This requirement ruled out an otherwise very interesting area in which there are only footpaths, although subsequent inspection has shown that similar changes have also occurred there. Accessibility is useful when doing fieldwork too.

Kajuru lies close to the large urban areas of Kaduna, no other town of any significance being within 100 km. All access to the test area can therefore be presumed to be from this one centre.

2.25 Ease of access

The last factor to be considered in the selection of the test area was how easy it was going to be to reach it, stay there for several weeks, and move about within it. This was the decider. The Survey Camp at Kajuru is in the centre of the area finally selected. The camp is run by Kaduna Polytechnic and has been used by generations of students since before Independence. It is 3 km from the

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Fig 3 Kaduna Plains physiographic regions

After Bennett et al (1977)

main road, 60 km from Kaduna and provides basic accommodation for field workers at a very pleasant site whose only disadvantage is the lack of running water in the dry season. The village of Kajuru is the centre of a network of paths leading to other villages and to farms. One of the two feeder roads in the area runs through it. Most important is that the people (see photos 2 & 3) are used to surveyors measuring over their farms and positively welcome their presence. They were not unduly put out by meeting me with sun hat, dark glasses, aerial photographs and thermos flask. Even the camera caused only occasional raised eyebrows. The Kajuru area was very suitable for study from this point of view and it was this which decided the location of the test area in preference to other places which may have been equally interesting.

2.3 PHYSICAL GEOGRAPHY

2.31 Geology

The Kaduna Plains are underlain by metamorphic and igneous rocks of the Basement Complex with important superficial deposits of laterite and alluvium. The Kajuru area has not been geologically mapped in detail but descriptions by McCurry (1970 and 1976) and Bennett et al (1977) for wider areas give an adequate picture which can be augmented by casual observations of my own. The generalised geological succession is shown in table 1. McCurry gives the Paleozoic and Pre-Cambrian succession as follows:

1. <u>Basement Complex sensu strictu</u>

Extensively metmorphosed rocks occurring as migmatite and granite gneiss.

2. <u>Younger Meta sediments</u>

Composed of schist with phyllite and interbedded quartz occuring in north-south synclinal belts.

3. <u>Older granite series</u>

Mainly granite and granodiorite with some syenite and migmatite. Widespread in the Kaduna area and thought to be predominant in the test area.

The Basement Complex including the Younger Meta sediments has been subjected to two phases of folding in the Pan-African orogeny (McCurry 1976). This has produced ENE/NSE and N/S trending structures and faulting. The structure of these rocks can be seen exposed occasionally in stream beds but otherwise they do not make an obvious impact on the scenery except in the orientation of inselberg complexes. The outcrops of inselberg forming Older Granite are particularly noticeable in the south east of the Kajuru area where they reach considerable heights.

Superficial deposits particularly laterite are extremely important. Thomas (1974 p49) gives the following definition of laterite: "a highly weathered material rich in secondary oxides or iron, aluminium, or both. It is nearly void of bases and primary silicates, but it may contain large amounts of quartz and kaolinite. It is either hard or capable of hardening on exposure to

TABLE 1

KADUNA PLAINS

GENERALISED GEOLOGICAL SUCCESSION

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Source: Bennett et al (1977)

weathering and drying". Which makes it good for bricks but not so wonderful for growing crops (Gourou 1953 p21). Laterite formation is favoured by conditions of peneplanation and seasonal rainfall (Thomas 1974 p58) which both exist on the Kaduna Plains. The original laterite cover, according to McCurry (1976) built up during the Pliocene, and is designated the Older Laterite. It forms cappings 2 - 3 m thick on many of the interfluves of the area. The distinctive red-brown colour, cellular aspect, and hardness are characteristic and very significant to land use. The Younger Laterite is distinguished by its topographically lower position (Bennett et al 1977). It is supposed to have been formed by the breakup of the older deposits, although Thomas (1974 p70) disputes this. It is generally not so thick, is browner and forms thin cappings or cuirasses on the lower valley slopes. Figure 4 shows a typical profile downslope from a laterite capping in the Kajuru area.

Alluvial deposits are also extremely important agriculturally. They are described by Hey (1967) as grey-brown sands, silts and clays over 10 m thick in places and they occur on the wide floodplains of the present stream valleys. They contain substantial amounts of ground water throughout the dry season. In the Pleistocene there was a sequence of humid and arid climatic periods (Grove and Warren 1968) which may have added a large aeolian content to the alluvial deposits. A similar process may be seen at work in the valleys in the sahel region of the extreme north of Nigeria.

2.32 Geomorphology

Northern Nigeria, like Norfolk, is very flat. Driving across it is boring, particularly on a new road which by passes all the villages. The brown plain with its scatter of inselbergs stretches for miles towards the blue hills on the horizon. Unlike East Anglia there are no cloudscapes to attract the eye, for most of the year the sky is a washed out blue like a pair of old jeans. These High Plains of Hausaland are in fact a set of very shallow wide steps. Now and again the monotony of a journey is broken as the road winds up or down through defiles for 20 km or so, past the wrecks of vehicles which did not make the corners, ending up on another plain maybe 100 m higher or lower. This interruption is the riser of one of the steps, in geomorphological terms the dissected zone at the edge of a peneplain. The Kaduna Plains are part of this pattern, bounded by dissected zones on the east, west and south and shading into other plains at a similar level to the north over the Niger-Chad watershed.

The rivers and streams on the plains are mostly seasonal. They flow in wide flat bottomed valleys. The change in relief is not great but there is a welcome break in the landscape from the dry gently undulating countryside. A miniature scarp up to 5 m in height often marks the edge of these valleys and the larger rivers will flow in a trench maybe 10 m below the flood plain itself. In the dry season most of them are just a series of long pools joined by a rivulet of running water. On the wide low interfluves laterite sheets are common, the top 2 - 3 m becoming indurated (Thomas 1974) to form ironpan cappings. At their edges these cappings form little cliffs the slopes of which are littered with boulders of broken cappings and red pebbles. The horizon directly under the capping is often white and clayey. Some of the smaller streams are narrow, deep, and gullied, cutting back into unconsolidated alluvium. These gullies can be deep, one near Kajuru bridge is 8 m deep at its mouth. According to Ologe (1974) they can recede at 4 - 5 m a year.

The planation according to King (1962) dates from the Tertiary period. In the long interval since subsurface weathering has produced a thick layer of decomposed rock (Thorp 1970). This, together with the Quaternary alluvial and aeolian deposits (Grove and Wilson 1968) hides most of the Basement Complex which underlies the area. However the country rock is exposed in the inselbergs and kopjes (bornhardts and tors of Thomas 1974) and ruwares (King 1948) which are rock sheets or swells. The hills rise straight out of the plain, sometimes like a wall so that you can stand on level farmland and lean on them. Inselbergs are mostly bare rock with domed summits, good for viewpoints but nerve racking to climb in the wet. The surveyor's description of the route to the top of an inselberg further south concludes: "Visitors to this hill

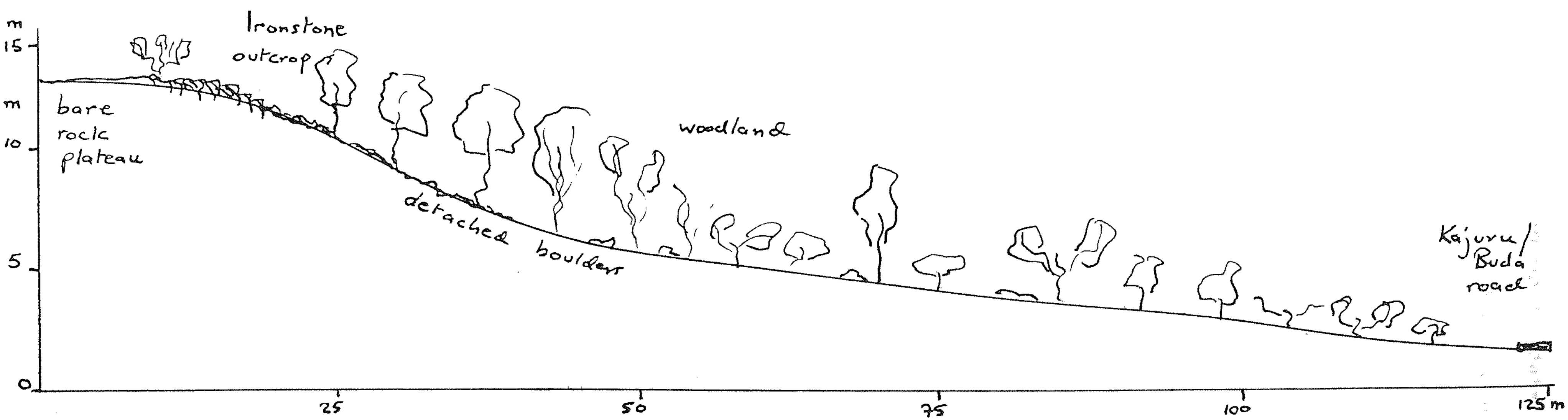

Fig.4 Ironpan outcrop on interfluve
Kajuru - Buda road.

should carry a stout rope and an up to date life assurance policy". None of the hills in the Kajuru area is as bad as that but the 45 deg bare rock access to Ludo Hill is the stuff of nightmares. Sometimes inselbergs are massed together, the spaces being filled with fallen boulders, home of monkeys and baboons which raid the crops below. Kopjes are jointed inselbergs, huge boulders piled upon one another like spilled Oxo cubes. They tend to support more vegetation and animal life including birds and reptiles; and are good places for hunters.

The Kaduna Plains have been divided by Bennett et al (1977) into physiographic units corresponding to the Land Regions of Brink et al (1966) and Mitchell (1973). Parts of four of these units fall within the Kajuru area (see figure 3 and table 2). The first three units occupy 53% of the Kaduna Plains and 76.6% of the Kajuru area. They are the typical monotonous plains decribed above, gently undulating, with low relief and a dominant slope of only 1 deg - 2 deg. Many ironpan cappings occur on the interfluves and there are occasional rock outcrops. Two groups of rocky hills occur within these plains in the test area, one the large granite inselberg at Kujama, and three elongated hills 3 - 5 km north east of Karku. The Idon Plains are much more topographically varied than the other three physiographic units and form the mixture of plains and high hills in the south east of the area. Bennett et al describe them as complex in structure with granite predominating although gneiss, migmatites and schists are

T A B L E   2

PHYSIOGRAPHIC UNITS IN THE KAJURU AREA

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Source: Bennett et al (1977)

also present. I have noticed that a good deal of metamorphic rock is exposed in the high ground around Kufana but the hill tops appear to be of granite. The four physiographic units are divided by Bennett et al into land systems, which will be considered in the next section.

2.33 Soils

Pierre Gourou (1953 p3) says "Tropical soils are poorer and more fragile than those of temperate regions. He speaks in his dramatic French way of laterite as a 'pedological leprosy' drawing attention to the rapid leaching and vigorous bacterial activity under tropical conditions; these cause low fertility. The composition of laterite as we have seen is not very encouraging for farmers and there is a lot of it about. Bennett et al report on the reconnaissance soil survey made by the LRDC on the Kaduna Plains (Table 3). Shallow soils less than one metre thick over massive ironpan account for 29.3% of the pits dug on the Galma Plains and 19.8% of those on the Tubo Plains. There is no reason to think that the test area is any different. The Soils Limitation Category (SLC) for a particular profile is decided by its properties of depth, drainage, texture and coarse material content. It is expressed as a code number from 1 to 5 for a crop in descending order of suitability (op cit p 251). For these widespread shallow soils over massive ironpan the SLC is poor for nearly all crops. If our sample is representative then maybe a quarter to a third of the Kaduna Plains is of limited value for agriculture. Shallow soils are also widespread on Basement Complex rocks. These however appear to be more fertile; their SLC varying from poor to good as their depth increases. Forty percent of the pits in the Idon Plains reveal this group of soils, though admittedly six pits out of fifteen is not many from which to draw a conclusion. The LRDC did not survey soils in the valley bottoms (op cit p31) but Klinkenberg (1970) writing about the Zaria area where conditions are similar says that they are dark grey clays, with poor to very poor drainage, formed on alluvial material. These fadama soils are of special importance as they are rich in nutrients and have a good to excessive water supply which persists in the dry season (op cit p58). In the Kajuru area fadamas are clearly important, influencing farming and settlement patterns. Not all of them are crossed by streams, some form saucer shaped depressions at valley heads and obviously retain much water in their soils; they seem comparable with the "dambos" of Central Africa mentioned by Thomas (1974 p147).

The type of soil will vary according to its position on the slope between interfluve and valley bottom. A typical profile will show a soil catena (Hopkins 1974) which might consist of very shallow soils full of ironstone gravel over massive ironpan on the interfluve with deep well drained fine textured soils further down the slope below the ironpan outcrop. Another sudden drop will lead down to the fadama with its clay soils and poor drainage. If the

TABLE 3

SOILS ON THE KADUNA PLAINS

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Source: Bennett et al (1977)

stream is incised into the flood plain the drainage will be improved but there may be gully formation. This catena of soil distribution will determine the land use and probably the settlement pattern as well. The presence of inselbergs is also important to the soil pattern. Pullan (1969 p168) gives an example showing a collar of "gravelly raw mineral soils and lithosols formed of well-rotted granite" extending for 160 m around an inselberg. Areas around inselbergs also have advantages from rain water seepage and may therefore be be favoured for cultivation. Such a feature may be present at the base of the Ludo hill complex (see figure 1).

2.34 Land systems

The LRDC divided the Kaduna Plains into physiographic units which were further sub-divided into land systems which have a recurring pattern of geology, soils and landforms (Bennett et al 1977), Thomas (1972 p109 et seq). Seven of these occur within the Kajuru area, see table 4.

2.35 Climate

The tropical savanna climate (Aw) has distinct wet and dry seasons, the rains occurring in the summer months; it is this climate which is prevalent in our area. The movement of the Inter Tropical Convergence Zone (ITCZ) northwards from February to August and southwards from September to December brings two contrasting air masses over the savanna plains. In the dry season the weather is dominated by the dry tropical continental air (cTs) originating in the

Sahara. There is no rainfall, the temperature range is high with a low minimum, humidity is very low, sometimes less than 10%. A dry wind develops in the daytime from the north carrying fine dust which obscures visibility. This wind, the harmattan, gives its name to the whole season.

The onset of the rains, and of the growing season, is a prolonged and uncertain affair, the ITCZ advancing northwards in the form of an oscillatory movement (Hore 1970 p44). The first rains are the product of line squalls moving north east to south west along the edge of the ITCZ and are short very intense showers usually accompanied by thunder. After several weeks of this, with alternating conditions of wet and dry air, the moist Equatorial air mass gets a grip and the rainfall becomes more regular and established, with moist conditions, cloudy skies, more even temperatures and heavy rain. There is often, though not always, a temporary easing of the rainfall in late July or early August because the belt of heaviest rain has migrated further north. Then the rains onset again and reach their main peak. At this time of the year the sky is cloudy most of the time, sunshine levels are low, and the humidity is high. There is little variation in the temperature which remains between 20 deg C and 28 deg C day and night.

The ITCZ withdraws southwards much more rapidly than it advances, and the end of the rains is quite sudden. The rainfall falls off over a few weeks from its September peak, the skies clear and the maximum daily temperature

TABLE 4

KAJURU AREA : LAND SYSTEMS

Land Sy[illegible]		
Area Kaduna [illegible] Kajuru [illegible]		[illegible]
Geology		[illegible]mplex [illegible]iated [illegible]sol
General		
Drainag[illegible]		
Relativ[illegible]		
Dominan[illegible]		
Rock ou[illegible]		[illegible]all
Main so[illegible]		[illegible]ate

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Source: Bennett et al (1977)

climbs to over 30 deg C For two months the weather is fine and the countryside is still green. Then the harmattan begins bringing dust from the north, a sharp drop in minimum temperature and very low humidity. The dry season has begun and will last with varying severity until March or April of the following year.

For agricultural purposes Blair Rains et al (1977) consider five climatic factors to be of importance:

1) The amount, seasonal distribution, reliability and intensity of rainfall.

2) The periods of positive and negative water balance.

3) The length of the growing season.

4) Day length.

5) The pattern of radiation and temperature.

Climatic records are available for Kaduna, which is just on the edge of the test area. These, taken over 31 years, show a mean annual total rainfall of 1163 mm with a minimum expected total of 1024 mm. Virtually all of this is received between March and October with bimodal peaks in July and August. The bar chart of rainfall shows it to be skewed towards the end of the year (see figure 6) with a long build up and a sharp cut off. Uncertainty in the amount of rain is crucial for agriculture particularly when the totals are not very high anyway. Kowal and Knabe (1972) calculated that the mean minimum expected total rainfall at latitude 10 deg 30 min N would be only 735 mm at 95% confidence level. The mean annual total would be 1015 mm giving a variation of 28%. Since 1968 the whole of

°C

Fig 5 Kaduna - maximum & minimum temperature.

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After Kowal & Knabe (1972)

the sudan grassland belt of Africa has suffered from prolonged drought which has had its most dramatic consequences in the sahel region; Ethiopia, Chad and Niger being the most publicised examples. But areas much further south have also suffered serious consequences, for instance for three years in the Kajuru area farmers have been unable to plant rice because of the water shortage.

The onset of the rains is important as the beginning of the growing season. The early rains are somewhat limited in value because of their nature. They occur in very intense falls of short duration during which surface runoff and sheet wash transfer most of the water and a lot of the top soil straight into the rivers. Immediately after a storm the sun usually comes out and the dry air re-establishes itself for a few days. Any rain that has soaked in is dried out again. The really useful rains come later, Kowal and Knabe (1972) defining the start of the rainy period as that decade of days in which the rain is greater than 25.4 mm (one inch) followed by two subsequent decades in which rainfall is greater than half the evapotranspiration (ETp). This point is reached at 10 1/2 deg N on May 17th (see table 5). The end of the rains is not so critical because water levels in the ground will be high and crops will continue to grow. How long they do so will depend on the amount of water held in the top half metre of the soil, silty and fine sandy soils being considered the most water retentive (Blair Rains et al 1977). The mean growing period may anyway be extended by

TABLE 5

CLIMATIC PREDICTIONS

FOR LATITUDE 10 deg 30 min N

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Source: Kowal & Knabe (1972)

12 to 24 days after the end of the rains which are defined as the decade with less than 1/2 inch of rain with ETp in the previous decade being not less than the precipitation (Kowal and Knabe).

The growing period for Kajuru will be between 156 and 168 days depending on the type of soil. Benoit (1976) calculated that Kaduna has a growing season of 180 days. The main control over plant growth in the savanna is the availability of water and the rainy season is by and large the growing season. Temperature is not a major inhibitor of growth, so irrigated crops can be grown all the year round. Although there is only a limited amount of irrigation it is important for vegetable crops on small market gardens where the shaduf is still the method used for raising water from the river. Harmattan wind and low minimum temperatures may inhibit the growth of irrigated crops, though many small plots are protected by fences which act as stock protectors and wind breaks.

The mean day length varies throughout the year by only 1 1/4 hours (see figure 7), reaching a maximum of 12.7 hours during the growing season. Blair Rains et al (1977) note that "the area is most favourable to intermediate day photosensitive crops (12 - 14 hours) such as maize, sorghum, cotton and tobacco".

The patterns of global radiation and evapotranspiration are both affected by the amount of cloud in the rainy season (see figure 7). They are at a minimum in August and reach their maximum at the end of the dry season. ETp balanced against availability of water from the soil will be the deciding factor in the length of the growing season as already mentioned.

2.36 Vegetation

Like most of the savanna the Kajuru area has been influenced by Man for thousands of years. Fire, farming, and grazing by cattle have destroyed the original vegetation. It is thought that a dry evergreen forest may have covered most of the area (Blair Rains et al 1977). Khaya senegalensis (madaci) and associated thicket species still occur scattered throughout the area, particularly in refuges such as streamsides and inselberg edges.

Kajuru falls within the Northern Guinea savanna zone of Keay (1960) in which Isoberlinea doka, Monotes kerstingii and Uapaca togoensis are the characteristic woody species. They occur as savanna woodland with a light closed canopy if left undisturbed but they are usually cut for fuel or cleared for farming before they can reach their full growth of maybe 10 - 15 m. (see photos 4 & 5) Instead they are found as coppice (see table 6). Underneath the trees is the grass, growing in the rainy season to a height of one to one and a half metres. The main species are shown in table 7. Soil and drainage conditions will modify this situation. On the shallow dry soils over ironpan the tree Boswellia dalzieli is very common although Nielsen (1965) notes it as characteristic of the Sudan savanna further north. There are also special grass communities on fadamas and over exposed ironpan, trees being almost absent (table 8).

There will be a profound change in the vegetation when an area is farmed. Trees are cut down and burnt leaving only those which are useful for fruit, shade, bark, or fodder (table 9). One of the most useful trees is the kuka (Adansonia digitata) in which every part except the squeak is of value, the bark for rope, the leaves for soup, the fruit to eat. Other trees such as the mango are maybe not deliberately planted but at least are encouraged once they appear.

Vegetation also changes when farmland returns to the bush in the system known as bush fallowing. The progression will be as follows if allowed to run its course:

Farmland - grass savanna - shrub savanna - savanna woodland.

The terms grass savanna and shrub savanna are not very precise as they decribe parts of a continuum. Grasses invade abandoned farms, followed by shrubs and regenerated trees, leading eventually to woodland on all soils except the shallowest or wettest. Blair Rains et al estimate that Isoberlinea doka coppice has a density of 11300 to 16500 per hectare in scrubland, which is reduced by farming to 2400 - 2500 per hectare. That is one to every four square metres, and is plenty to grow from.

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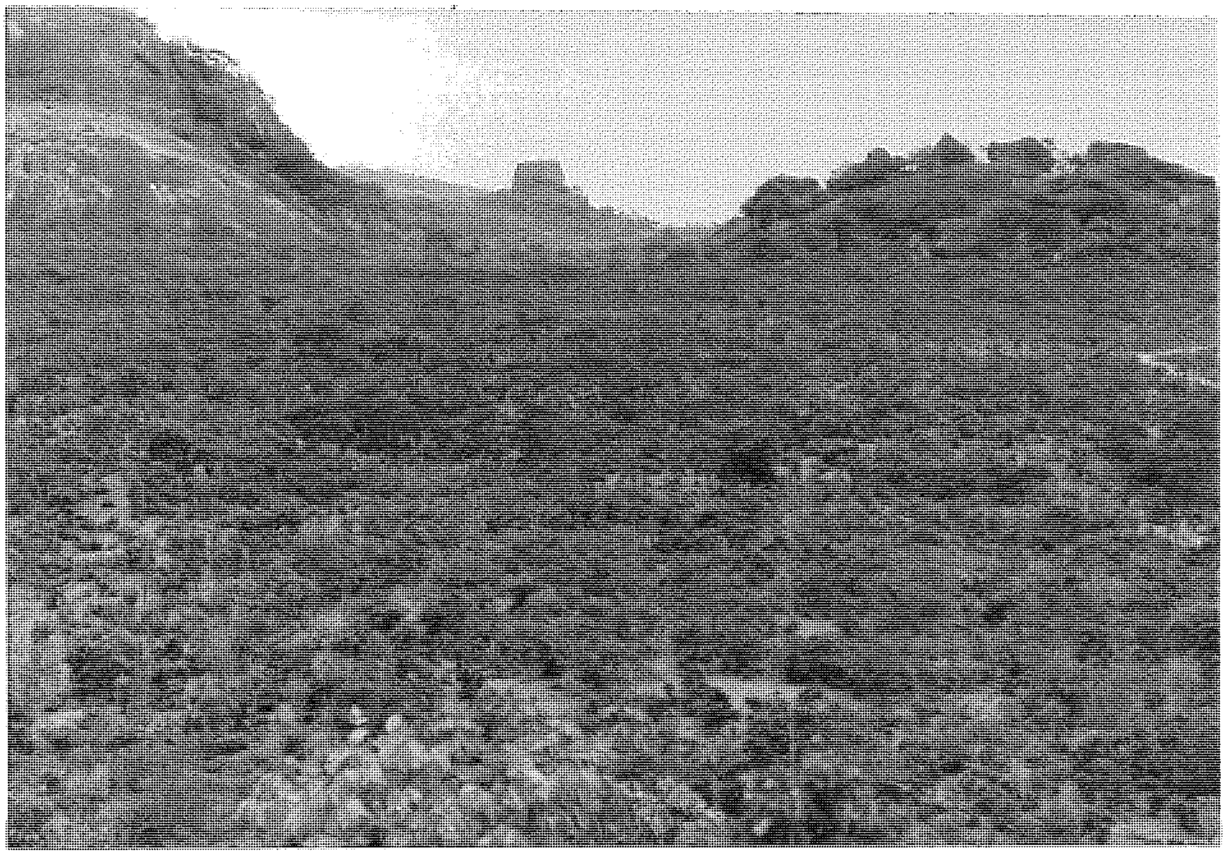
Fig 7 Other climatic factors.

After Kowal & Knabe (1972)



Photograph 4

Woodland cut over for fuel (1)

Photographed in the dry season

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Photograph 5

Woodland cut over for fuel (2)

Photographed in the wet season

T A B L E 6

NORTHERN GUINEA ZONE

SAVANNA TREE SPECIES

Combretum spp

Isoberlinea doka

I. tomentosa

Monotes kerstingii

Swartzia madagascarensis

Terminalia avicennioides

T. macroptera

Uapaca togoensis

Source: Hopkins (1974)

TABLE 7

NORTHERN GUINEA SAVANNA

GRASS SPECIES

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TABLE 8

GRASS SPECIES IN PARTICULAR LOCATIONS

A) Fadama

B) Ironpan

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Chloria robusta

Source: Blair Rains et al (1977)

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0 km 10

Fig 8 The Kajuru area - land systems

After Wall et al (1979)

2.4 HUMAN GEOGRAPHY

2.41 Farming systems

There are not many people in the Kajuru area and land is plentiful, though as we have seen much of it is not very fertile. Farming is mostly for subsistence with a few cash crops plus food crop surpluses being sold. There are nowadays one or two large farms run at long range by civil servants and business men from Kaduna; and there are also some irrigated gardens growing vegetables and fruit for market. The traditional farm implements are the hoe and cutlass, all work being done by hand labour. Even now (1986) a tractor is a very rare sight and at the times under study would have caused a furore.

The main crops grown are guinea corn, maize, and millet with yams and acha also important (see table 10). Apart from these a large number of subsidiary food crops are grown and cotton is cultivated as a cash crop. Mixed cropping is common, guinea corn and groundnuts or yams and maize being combinations which are often seen. All the crops are grown on ridges except for acha and rice which are sown broadcast on the flat ground. (see photos 6 & 7) In some places heaps replace ridges depending on the local tradition. The farming year opens with the beginning of the rains in April and virtually closes with the cereal harvest in October and November. Yams are planted and harvested throughout the dry season and fadama cultivation will continue beyond the end of the rains. There is however a largely blank period towards the end of the dry season when there are no crops in the fields. Unfortunately this is the time which is most suitable for aerial photography.

Zoning of land around settlements in rings of decreasing intensity of use in the von Thunen manner has been noted in the Nigerian savanna. The best known study of this is the work by Prothero (1957) at Soba near Zaria. Three types of farm can be recognised around many, though not all, villages; Prothero describing:

a) Compound gardens; small plots which lie within the fenced compound in which okra, spinach, tomatoes, peppers, tie-tie, bananas and pawpaws are grown. These will be manured by domestic refuse and provide for day to day household wants.

b) Home farm; adjoining the village and stretching for up to a kilometre from it. This is manured with domestic refuse and is farmed every year, usually with the main cereal crop. Scattered economic trees grow to a large size within the home farm giving it a park like landscape. (see photos 8 & 9)

c) Bush farms; located away from the village and up to ten kilometres from it. They are cropped for 4 - 5 years before being allowed to rest and return to bush. If the bush farm is very far away from the village, say more than an hour's walk, a small house may be built there to be occupied for a week at a time by the farmer and his sons. The length of the bush fallow will depend on how quickly the land regains its fertility as gauged by the regrowth of trees; when they become vigorous and well established the land can be cleared for a new cycle of cultivation. Depending on how much land is available the bush fallow may last for 2 - 10 years, though it is unlikely that a two year rest would allow time for full recovery. Pressure on land is nowadays an important factor in shortening the length of fallow to below what is necessary to restore fertility.

Fertiliser is applied regularly on the home farm and less commonly to the bush farm; its availability has not altered the system of farming appreciably. Nomadic pastoralists are invited to kraal their cattle on farmland during the dry season. The farmer will keep only sheep, goats and chickens himself with the occasional stall fed cow. As Jackson (1972) remarks, the African farmer does not generally seek to maximise returns on each unit of land. If he wants more dawa he clears an extra farm. Crops grown purely for cash such as cotton are generally planted away from the village. Food crop surpluses may also be sold once the needs of the family, including those working in the towns, are satisfied.

This system of farming is commonplace throughout the "Middle Belt" of Nigeria, the savanna away from the areas of dense population such as the Kano Close Settled Zone described by Mortimore and Wilson (1965). Allan (1965) describes a very similar arrangement north of Kumasi in

Ghana. A combination of shifting cultivation, bush fallowing and permanent cultivation in various proportions covers the area. Morgan (1969) defines rotational bush fallow as that in which "time in fallow exceeds the time that the land is cultivated". Ruthenberg (1980) while conceding the variable length of fallow states that bush fallow is "usually characterised by clearly defined holdings with largely permanent field divisions . . . and de facto ownership of land". Shifting cultivation he notes as having ill defined boundaries, migratory housing, and less precisely defined land rights. He computes cropping years as a percentage of the total cultivation cycle obtaining an R - index value:

$$R = \frac{\text{(no of years cultivation)}}{\text{(length of cycle)}} \times 100$$

Bush fallow systems according to Ruthenberg range from 33% to 66% typically and shifting cultivation will have an R value of less than 33%. Permanent cultivation will range from 66% to 100% and beyond where several crops are taken each year.

Gosden (1978) investigated farms on the Kaduna Plains including those in two villages close to Kajuru. He found that the total land holding per farmer was between 2 and 7 hectares divided into several home farms of 1/2 hectare and up to 8 bush farms each of which was larger with a maximum of 3 hectares each. Some farmers also own fadama farms of up to 1/2 hectare in size. The R values obtained for the

TABLE 9

SOME ECONOMIC TREES

IN FARMLAND

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Sources: Keay et al (1960), Nielson (1965) two villages differ greatly as in one (Kujama) the pressure on land is obviously greater as it is more easily farmed being flat and accessible. Applying Ruthenberg's formula to Gosden's figures we have R = 57% for upland farms and R = 100% for fadama farms. The other village which Gosden visited is Kufana which is situated in the Idon Plains physiographic unit and is quite hilly (see figure 1). There is however a large fadama close by. Here R = 83% for upland farms near the village, R = 33% for upland farms far from the village, and R= 71% for fadama farms. At Kujama the crop: fallow ratio is stated as 4:2 and at Kufana it is 5:10.

The farming system therefore varies within quite a small area depending on soils, availability of land and location. Personal preferences which depend to a large extent on cultural background are also important. Not everyone for instance lives in a nucleated village and the smaller hamlets do move periodically with their farms.

Spatial organisation of cropping also occurs in response to soil types. A typical arrangement would be for maize and groundnuts to be grown on the shallow interfluve soils followed by guinea corn and millet or yams further downslope with much more land being farmed near the valley bottoms. Along the edge of the fadama will be gardens with cassava and sweet pototoes, the fadama itself having swamp rice plots.

2.42 Ethnic factors

The southern part of the Kaduna Plains contains a mixture of ethnic groups. The people of Hausa language (the word "tribe" is unfashionable nowadays) form the overwhelming majority north of Kaduna which is a modern city founded by Lord Lugard at the turn of the century. South of Kaduna the Hausa people are in a minority, living mainly in the small towns as traders and as tenant farmers. Gwari (strictly Gbagyi) language people extend over the south west of the Kaduna Plains leaving the south east to a bewildering variety of small groups known collectively as "Plateau". Gwari and plateau people together are often referred to as "Southern Zaria".

The dominant group in the test area are Plateau, in particular Kadara people. Gwari form the majority in the north at Kujama together with a minority of Hausa who also trade in the small town of Kasuwan Magani.

Farming methods differ in detail between Southern Zaria on the one hand and Hausa on the other. The former tend to construct smaller ridges when cultivating and to sow cereal seed at a lower density. The Hausa usually employ only one type of hoe, quite a small one, whereas the other groups use at least three, one of enormous size with two handles. These cultural differences are important to the farmers (and the anthropologists) but do not have a marked effect on their farming. They are difficult to recognise on the ground let alone on the aerial photographs. A cultural difference which is significant is the growing of acha (Digitaria exilis) by Southern Zaria people. Acha is a grass whose cultivation is characteristic of these people and is regarded by Murdock (1960), with other minority crops, as a relict of an earlier food system. The tiny seeds of acha are sown broadcast on flat land without ridges and are lightly covered with soil to protect them from birds and insects. Harvesting after a three month growing period is by pulling the stems, a knife cannot be used because the plants often lie flat. Threshing is difficult and the smallest seeded variety has to be separated by foot friction rather than with a flail. Production of this traditional crop is declining because of the labour required, but it is still highly regarded as a food. Acha appears to be identical to the plant known as "t'ef" in Ethiopia where it holds a similar place as a traditional grain crop neglected by plant breeders (MacKenzie 1985). The neglect is a pity because as Vietmayer (1986) notes "the plants poor people grow are usually robust, productive, self reliant and useful - the very type needed to feed the hungriest parts of the planet".

The final element in the ethnic pattern is the Fulani. They are traditionally nomadic pastoralists whose way of life has been decribed by de St Croix (1945) and Stenning (1959). Some Fulani are settled or semi settled, living in villages and cultivating crops as well as herding cattle. They even send their sons to school, but not their daughters of course. Although Southern Zaria keep the occasional cow, plus sheep, goats and pigs the Fulani are stock keepers on a large scale. Their herds are moved out of the area in the wet season because of the danger from tsetse fly, the carrier of trypanosomiasis. They go northwards towards Zaria and Sokoto, and eastwards to the Jos Plateau and Bauchi. During the dry season they move back into the Kajuru area, some staying and others passing southwards to the main grazing areas around Abuja (large sections of which have been appropriated for the new federal capital).

Farmers and pastoralists are important to one another. Cattle eat crop residues thus clearing the land for cultivation. They manure the soil thus restoring fertility. Land on which cattle have been kraaled will yield good crops the following season provided it is allowed to rest and get some rain on it before being sown.

2.43 Settlement and communications

The Southern Zaria people seem to quite like living by themselves on their farms, there is a lot of scattered settlement in the form of small groups of compounds. People build their houses with mud and thatch them with grass supported by light bush sticks, materials which are available almost everywhere. (see photo 10) The only constraints on location are the whereabouts of your farms, friends and relatives (or your mothers-in-law) and how far your wives have to walk for water. The compound will consist of several huts, round or rectangular according to

TABLE 10

MAIN FOOD CROPS

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Arachis hypogea groundnut

Source: Gosden (1978)

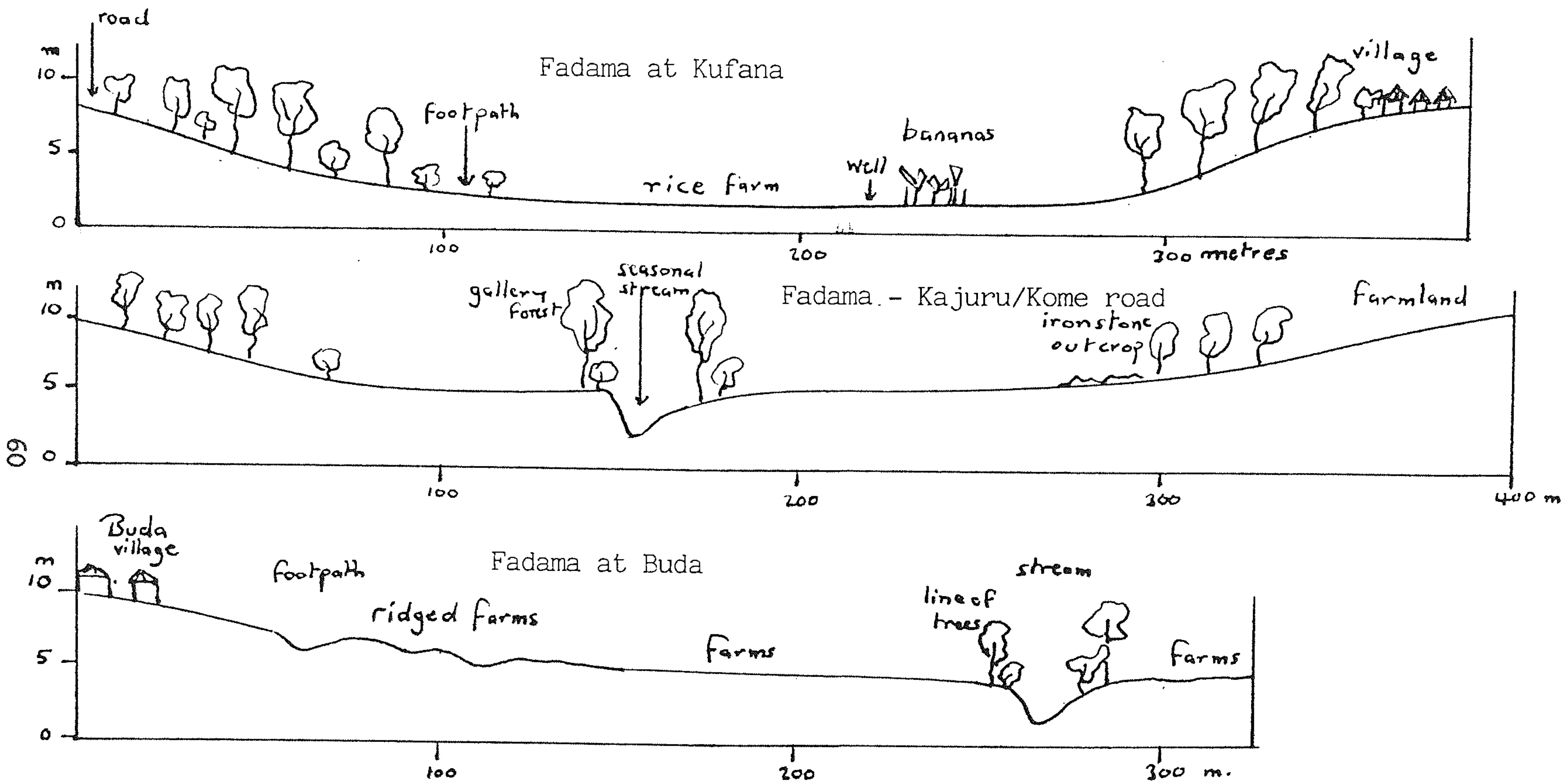
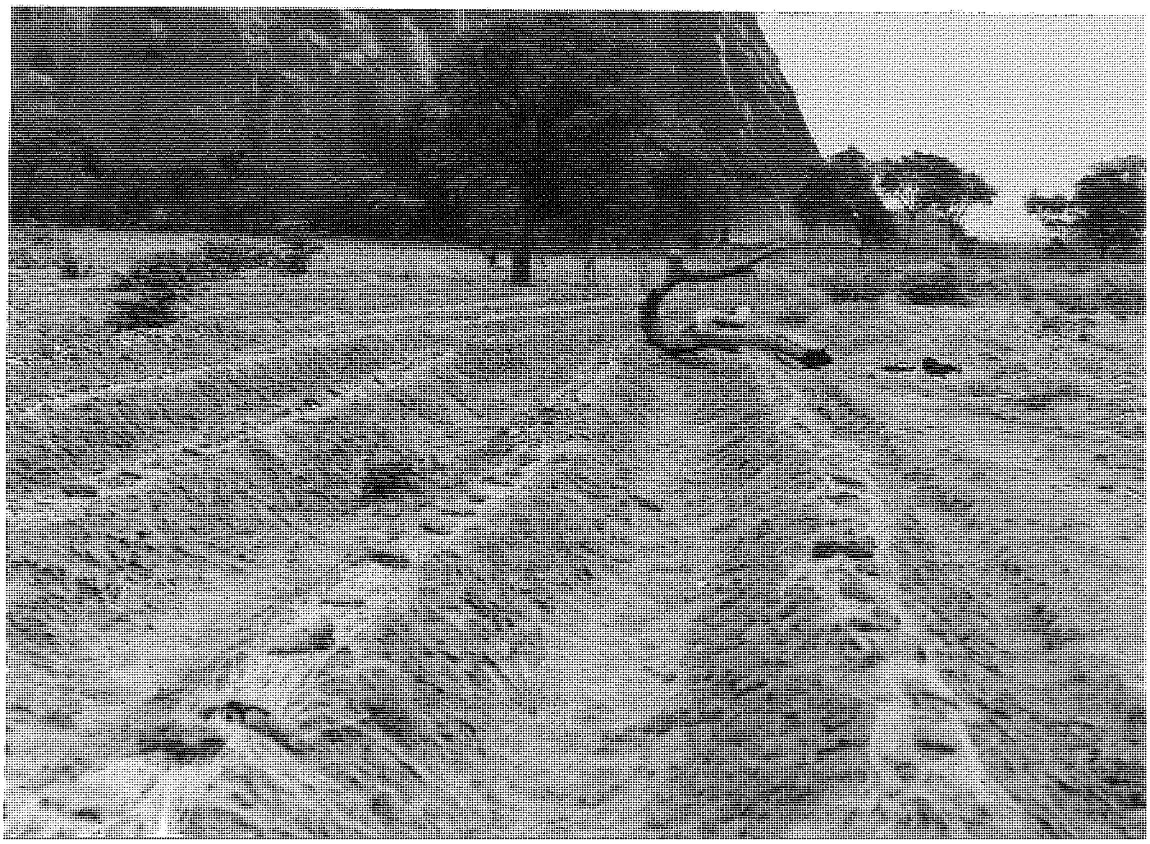


Fig.9 Fadama cross sections in the test area.



Photograph 6

Farmland ridged for yam cultivation

Photograph 7

Farming - rice cultivation

Photograph 8

Useful trees - mango

Planted near a village

Photograph 9

Useful trees - kuka

Adansonia digitata with village wall in background

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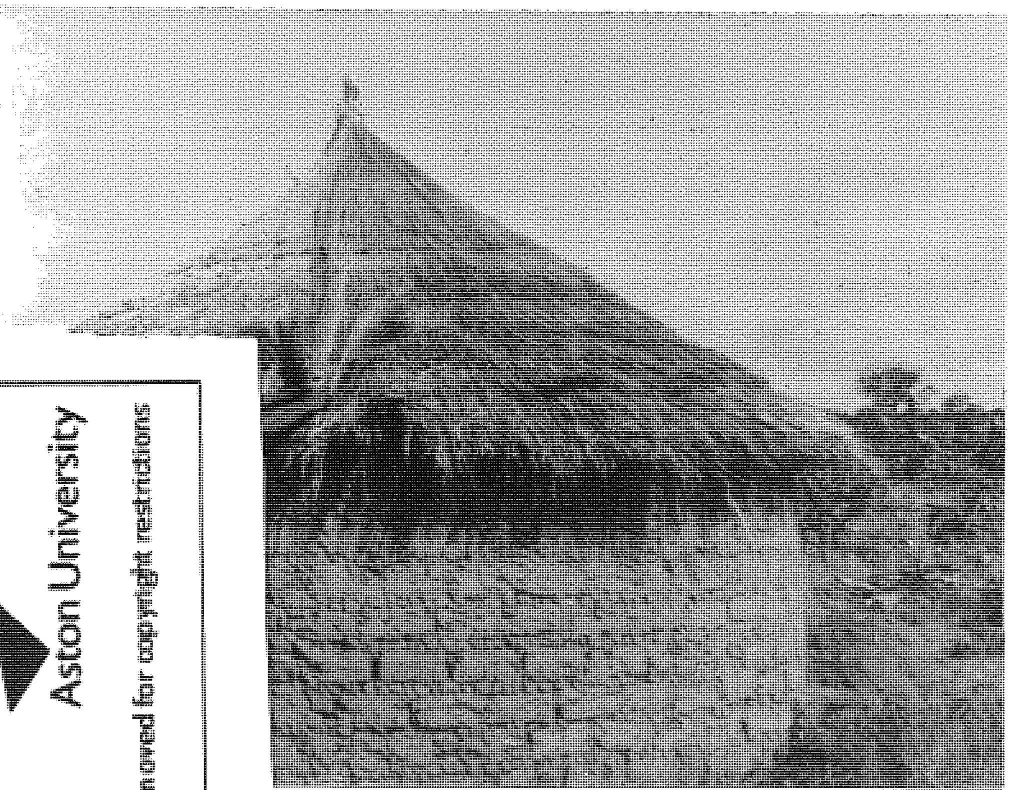
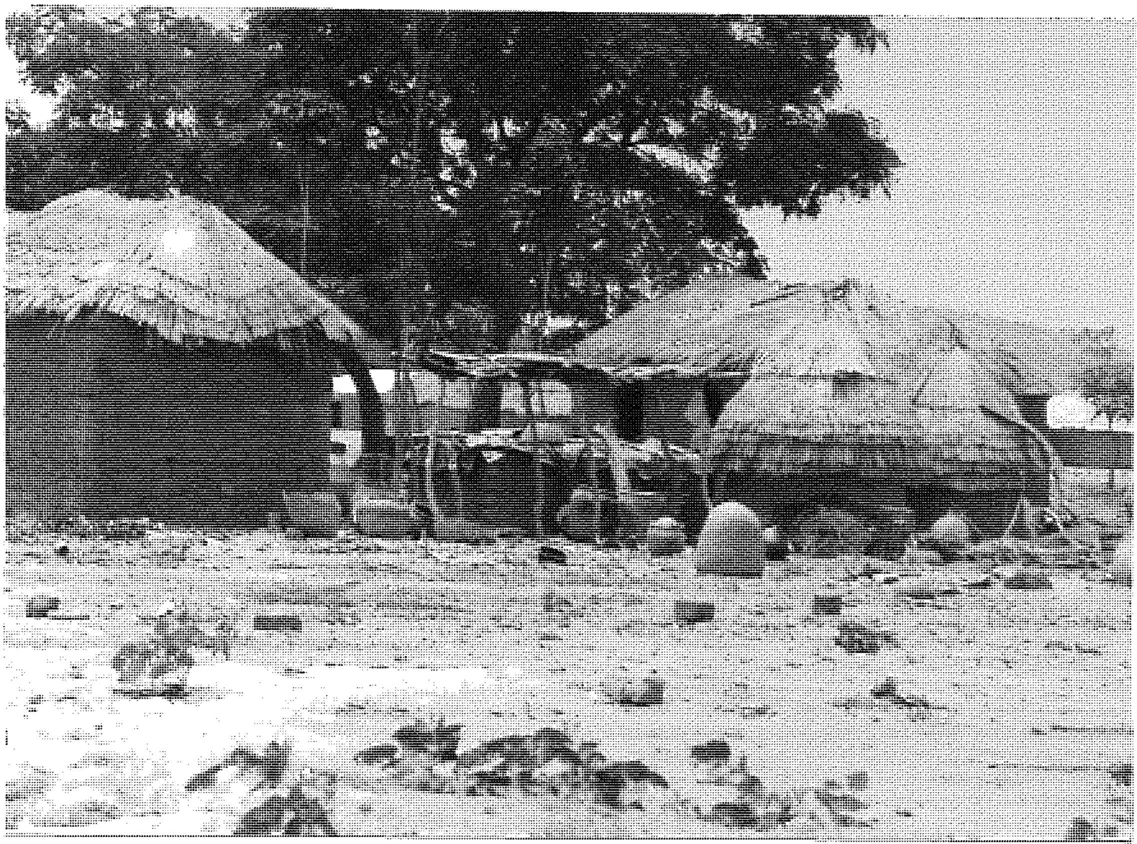


Photograph 10

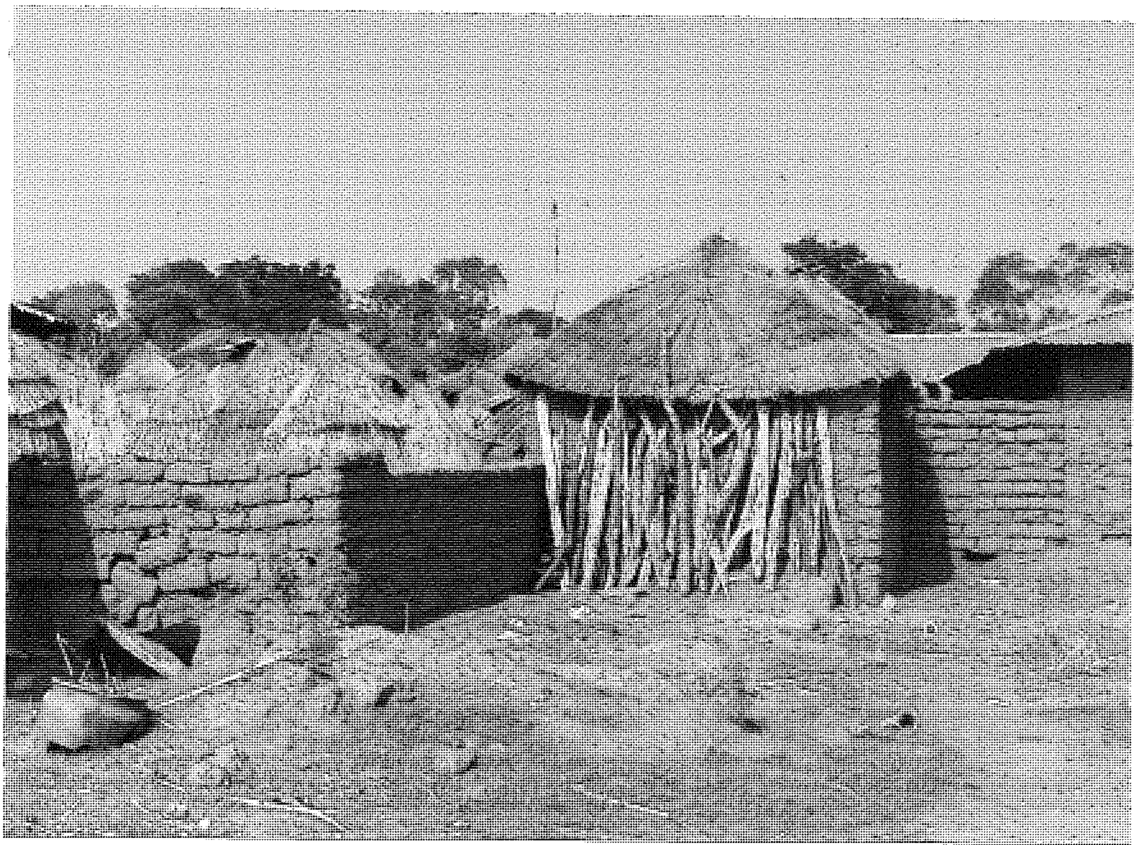
Thatching a house



Photograph 11

Settlement (1)

A compound with rectangular huts, round granaries and a crop drying rack



Photograph 12

Settlement (2)

A compound with rectangular and round huts, wood drying under the eaves

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local custom; enough are built to provide a room for each adult plus a kitchen and shelter for the goats. There will be one or more granaries of traditional rotund shape balanced on little legs and having a small thatched roof. Isolated compounds may not be fenced, those close to neighbours or roads usually have a fence 2 to 3 metres high made of grass matting with supports of a shrub called "lalle" which roots from stakes. Much of life is lived in the open air. Allan (1965 p433) remarks: "The importance of African rural housing is commonly over emphasised; a dwelling hut is a place to sleep in, to store one's possessions, to shelter from the rain in the wet season, and there is still no general desire that it should be more than this. Urban housing is quite another matter". (see photos 11 & 12).

Scattering of settlement about the bush is quite recent. This is part of the Middle Belt which was systematically raided for slaves and tribute by the Fulani cavalry until 1901 when Lugard proclaimed the Protectorate of Northern Nigeria and established the Pax Britannica (Lugard 1964, Glover and Aitchison 1970). Before that defensive sites were essential; most old villages are near inselbergs and have walls around them, Kajuru is a good example and Kujuma another. At some places the old village is on the hilltop and has only recently been rebuilt on the plain below. During this century settlement has been free to expand and to concentrate in response to economic factors. The attractions of the roads have already been mentioned; their facilities, easy access and opportunities for trade have encouraged the growth of villages along them at the expense of those on more remote sites. The process is still going on. The railway is also attractive, but not to the same degree. Other very important influences on settlement are the fadamas, fertile farming areas. A village sited on the slope just above the fadama will be very conveniently placed.

The Kajuru area is crossed by one main road and one railway line. The railway is the eastern branch of the national 3 ft 6 in gauge system between Port Harcourt and Kano via Kafanchan and Kaduna; it was completed in 1927. Travel by train is remarkably cheap, passenger fares working out at 1 kobo per kilometre (1/8th of a penny). A journey is slow and leisurely, the timetable being treated as a guide rather than a plan. The local train stops at every station but if you speak to the driver he may agree to drop you off in between. The line follows a wide valley through the test area and villages such as Kankomi have obviously taken advantage of the good land and easy communication.

The main road is part of the trunk road system from Kaduna through Makurdi to Port Harcourt. It existed in 1950 as an all season dirt road serving Southern Zaria Province although it did link up with roads further south (Buchanan and Pugh 1955 p 212). Reconstruction and tarring took place about 15 years ago since when the road has become the main route to Benue State. The opening of the Kaduna-Abuja road in the late 1970's has taken a lot of the long distance traffic.

There are two other roads, both are unsurfaced and rarely if ever maintained. Most dirt roads become difficult in the rainy season because of the soft surfaces caused by bad drainage but bridges are the weakest link. The wooden decking decays after a few years and unless there is an alternative drift (the Irish bridge) no vehicle will be able to pass during the main farming months from May to September. Harvest evacuation will be possible though because the roads will be open again by that time. The short road from Kasuwan Magani to Kaua has no bridges but the longer one through Kajuru has three which are not always in good repair.

When other means of transport fail you walk, go by bicycle, or nowadays by motor bike; there are very few donkeys in this area. Footpaths form a dense network, some linking large villages, others leading to a farm then petering out. These paths are the basic means of communication, shifting as the villages grow or decay and as cultivation moves around its rotation. Whereas roads and railways attract settlement, footpaths are a function of it.

2.5 SUMMARY

2.51 The Kajuru area is 750 sq km in extent and is situated between latitudes 10 deg 15 min N to 10 deg 30 min

N and longitudes 7 deg 30 min E to 7 deg 45 min E. The boundaries of the area are approximately those of the national map series Nigeria 1:50 000 sheet 145 NW Kajuru.

2.52 The criteria for choice of the test area were size; availability of photography; representative terrain; uniform natural vegetation; reasonable communications; and ease of access for fieldwork.

2.53 The area is underlain by Basement Complex metamorphic rocks with significant intrusions of Older Granite. Lateritic and alluvial deposits are important and widespread. Topographically the whole area consists of undulating plains, with hills which become more frequent in the south east.

2.54 Soils are light and often shallow over ironpan. A catena develops on the valley slopes.

2.55 The natural vegetation of the area is Northern Guinea savanna. This has been much modified by farming and wood cutting.

2.56 Farming is for guinea corn, maize, millet and yams as the main food crops with many subsidiary food crops and cotton for cash. There is zoning of farmland into compound land, home farm and bush farm. The latter are fallowed to restore fertility but the farms near the village are permanently cultivated. Soil and slope position also affect the distribution of farmland.

2.57 Four ethnic groups live in the area, Kadara, Gwari, Hausa and Fulani. Cultivation and pastoral practices are different for each group.

2.58 Settlement has scattered from the traditional defensive village sites. Recently there has been increased movement towards the main roads and the railway. Fadama land also attracts settlement to its edges.

2.59 There is one main road in the Kajuru area with two feeder roads. A network of footpaths has been generated by the settlement pattern.

CHAPTER THREE

LAND CLASSIFICATION

3.1 THE REQUIREMENTS OF A CLASSIFICATION

3.11 Land use or land cover?

Land use may be classified in two ways, either by activity or by form. Rhind and Hudson (1980) distinguish between the two, activity being land use and form being land cover. They adopt the following definitions:

<u>Land use</u> - "Man's activities on land which are directly related to land" (Clawson & Stewart 1965)

<u>Land cover</u> - "The vegetation and artificial constructions covering the land surface". (Burley 1961)

Dickinson and Shaw (1977) discuss the subdivision of activity within a site. Writing about urban land use they say that a factory could be subdivided into workshops, offices, canteens, toilets, car parks and so on. Their conclusion is that grouped activity within a "curtilage" is appropriate when devising classifications of land use. This concept can be usefully applied to rural land use also. (see section 4.24)

Sites in rural areas will normally serve several purposes which will together result in a particular form. For instance woodland could be a class of land cover. A piece of woodland will be used in several ways:

a) As long term fallow to allow the soil to regain fertility before being cleared for farming.

b) Timber for building, carpentry, and firewood will be cut from it.

c) Cattle, sheep and goats will be grazed upon it.

d) It will be the home of wild animals and a place in which to hunt them for food.

e) Fruits, seeds, and bark will grow there and be gathered for food and medicine.

All these activities will be carried on at various times in the same area and will affect its form. Farmland will also have numerous functions (activities performed upon it). There will be a variety of crops, often planted together, and the crop residues will be grazed by cattle in the dry season. The land form will have a multi-purpose function.

This relationship between form and function is not always simple. Fadama will have a multi-purpose function being used for rice farms in the wet season and grazing in the harmattan. It will also be used for growing vegetables, bananas and cassava, this activity going on through the dry season and grazing being no longer possible, indeed the plots are often fenced to exclude cattle. There will be fadama which is available for grazing and fadama which is not available. There may well be fadama which is available for grazing but not used for this purpose. One form will have at least three separate functions.

Here we have to acknowledge the limitations of remote sensing. It is not easy to tell from a photograph whether cattle use a particular piece of grassland or not, the only infallible test is to walk over the area and kick up the cow dung. Ground survey is required. This is apparently what enabled Lebon (1965) to separate used from unused grazing in his classification for the Sudan. Large scale photography would help by revealing cattle tracks and trampled watering places, but this would require a micro rather than a macro study. The same argument applies to thick woodland, the view of the treetops on the aerial photographs tells little of what goes on underneath; a look at ground level is required.

Function and form are closely linked together, with most land having a multi-purpose function which determines its appearance. This form is recognisable from aerial photographs which usually do not provide sufficient unsupported evidence of function. The classification used for this study will consequently be based on land cover (form) rather than land use (function).

3.12 Classification criteria

Anderson et al (1976) distinguish four levels of land use and land cover classification and note the typical data characteristics required to survey at each level. (Table 11). Anderson (1971) gives a list of ten criteria for land classifications used with remote sensing material. He says, "The criteria apply mainly to classification schemes developed for use at intermediate scales ranging from 1:250 000 to 1:1 000 000 for the United States". This would be Level II whereas the 1:25 000 photography used in this study could yield Level III information given supplemental ground survey. The criteria however still hold good for larger scales and for places other than North America; they are discussed below:

1. <u>The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensing data should be at least 85%.</u>

This figure was chosen to harmonise with the proven reliability of ground enumeration in the U.S. In the absence of comparable surveys in the present study area this is a suitable target to aim at. Anything less would reduce the chances of detecting changes in land use.

2. <u>The accuracy of interpretation for the several categories should be about equal.</u>

Very difficult to achieve in practice. Some features, such as settlement, are small and difficult to see, their presence having to be deduced before they can be picked out. Others are large in extent, such as woodland, but grade into others without a clear dividing line. The definitions and ways of distinguishing categories differ and the accuracy of interpretation is bound to vary. Some categories can easily be mistaken for one another; it is interesting to note than in Arizona "difficulty is experienced in differentiating dark bare rock areas from

T A B L E 1 1

CLASSIFICATION LEVELS

LEVEL	TYPICAL DATA CHARACTERISTICS
I	LANDSAT data
II	High altitude data at 40 000 ft (12 400 m) or above (less than 1:80 000 scale*
III	Medium altitude data taken between 10 000 & 40 000 ft (3 100 & 12 400 m) 1:20 000 to 1:80 000 scale*
IV	Low altitude data taken below 10 000 ft (3 100 m) over 1:20 000 scale*

*Assuming a camera with 6 inch focal length lens (152 mm)

Source: Anderson et al (1976)

low dark green, desert shrub areas". (op cit p381) Bare rock and farmland have a similar appearance on photography taken in the dry season in Nigeria.

3. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.

Again very difficult to achieve in practice because many categories shade into one another; one man's forest is another man's woodland. Field boundaries are only marked distinctly in areas of high population density where most of the land is continuously used. It is important to define categories that can be recognised on different generations and types of imagery; the classification must be made bearing in mind the remote sensing material which will be used for data collection.

4. The classification should be applicable over extensive areas.

The savanna is fairly uniform over wide areas and a classification developed for Kajuru should apply generally. Further northwards in the sudan savanna and sahel regions further categories would be needed. To the south in the forest much of the classification would be inapplicable.

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

Here Anderson makes a similar point to that discussed in section 3.11 though for slightly different reasons. In the

U.S.A. ground information is easier to come by than in the tropical savanna.

6. <u>The classification scheme should be suitable for use with remote sensor data obtained at different times of the year.</u>

There are dramatic changes in the appearance of the vegetation in the savanna during the year because of its seasonal climate. Remote sensing material gathered during the rains would make interpretation of crops possible and permit subdivision of the general "farming" category.

7. <u>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.</u>

Farmland and bush fallow are the categories most likely to yield further information from ground surveys, or larger scale photography. Big ridges or heaps built for yams, often with a topping of mulch held down by earth, can be contrasted with the small ridges made for cereal crops. These could be seen on photography at 1:10 000 scale or larger. Land is left to fallow when crop yields decrease. The age of this bush fallow is difficult to distinguish from aerial photography, but ground surveys would yield more sub-categories.

8. <u>Aggregation of categories must be possible.</u>

This capability is useful when analysing data, which can be collected into a few categories of reasonable size.

9. Comparison with future land use should be possible.
Big changes in land use outside the present very general categories are not to be expected in the savanna. But provision should be made for the increase of mechanised farming and irrigation.

10. Multiple uses of land should be recognised when possible.
This has already been discussed in section 3.11. Many areas have multi-purpose use which without additional information cannot be differentiated. "At Level III . . . use of substantial amounts of supplemental information in addition to some remotely sensed information at scales of 1:15 000 to 1:40 000 should be anticipated". (Anderson et al 1976 p7). The present study uses background information only in the form of local knowledge in the absence of detailed ground enumeration.

3.13 Classification principles

McDonald (1971) points out that classification is a logical device which must proceed by the principles of logical division. The purpose of the classification must first be established so that the population to be studied is known. Land use surveys can be based on form or function; we have already decided to study form. The classification must be comprehensive, nothing being left out. Rhind and Hudson (1980 p34) say "It has to be exhaustive in that all 'geographical individuals' under consideration must be classified even if only in an 'other uses' dustbin". Too many miscellanies however are caused by hair splitting or an ill thought out scheme. McDonald p4 continues, "if we wish to subdivide a class it must be done on one basis only and not on more than one basis". Farmland can be sub divided in many ways such as type of crop, years of use before fallow (if any), or distance from village or farm buildings. Each of these will give a set of subdivisions which must be made at a different level. Neglect of this principle caused trouble in the development of the classification used in this study. Cross division is likely to occur and the interpreter will be able to put an observation in several classes. If the principles are followed the result will be a ' hierarchical order' (op cit p6) rather than a list.

3.14 Basis of classification

To summarise, the requirements of a land classification for use with remote sensing material are:

1. Each class should be distinct from all others; no overlaps.
2. There should be no land which does not fit into any class.
3. The definition of each class should be complete so that inventory may be repeated.
4. All classes should be recognisable on the material available for interpretation.

3.2 A LOOK AT SOME CLASSIFICATIONS

3.20 Every teacher of surveying sooner or later gets together with one or two colleagues and writes a text book on compass traversing. It is a good way to make money out of their lecture notes and less blatant than selling them directly to the students. Similarly everyone who has to make a land use survey makes out his own classification. It saves having to master the details of one written by someone else. Anyway no completely universal classification yet exists with any depth to it. The purposes of surveys are different, whether for reconnaissance or detail, planning future development or monitoring past changes. The classifications are similarly diverse. Before discussing the one developed for this study we examine eight others, two designed to have a wide application., three from other tropical areas, and three used in Nigeria for other studies.

3.21 World Land Use Survey (WLUS) land use classification

The WLUS was a Commission of the International Geographical Union (IGU) and grew out of the work of Dudley Stamp who 50 years ago published the first Land Utilisation Survey of Britain (Stamp 1931). The WLUS Land Use Classification was designed as a basis for all land use mapping and was expected to be further sub divided in local circumstances (Rhind & Hudson 1980 p35). Nine basic categories are provided, four of which - cropland, unimproved grazing land, woodland, swamps and marshes - are divided giving a total of 17 categories altogether. Table

12 gives the full classification.

The first level of classification is based on form, land cover. Some of the classes are not clearly defined by the key words provided. For instance does a plant nursery go into class <u>2 Horticulture</u> or <u>3 Tree and other perennial crops?</u> There will also be problems with the terms "improved" and "managed" in class <u>5 Improved permanent pasture</u> which distinguish it when unenclosed from <u>6 Unimproved grazing land.</u> What constitutes improvement?.

The second level of classification is a mixture of form and function depending on which main class is being divided. Woodland is divided into six categories mainly on consideration of its density, which is form. Cropland is split into two according to its use, which is function.

The WLUS classification was not specifically designed for use with remote sensing. Even in this general form ground information will be required to separate classes such as 4a from 4b and to distinguish the cultivation within (under the trees of) the forest which defines 7f. However many workers have used the WLUS as a convenient starting point or have compared their classifications with its categories.

3.22 USGS classification

See table 13. This was developed by J R Anderson and three collaborators as the result of a conference on land use information and classification in Washington DC in 1971.

T A B L E 1 2

WORLD LAND USE SURVEY

LAND USE CLASSIFICATION

1 Settlements & associated non agricultural lands

2 Horticulture

3 Trees & other perennial crops

4 Croplands

a) continual & rotation cropping

b) land rotation

5 Improved permanent pasture (managed or enclosed)

6 Unimproved grazing land (used)

(not used)

7 Woodlands

a) dense

b) open

c) scrub

d) swamp forests

e) cut over or burnt over forest areas

f) forest with subsidiary cultivation

8 Swamps & marshes (fresh & salt water-non forested)

9 Unproductive land

Source: Collins (1966) after IGU (1956-57)

The aim was "to develop and test a land use and land cover classification system that could be used with remote sensing and with the minimal reliance on supplemental information at the more generalized first and second levels of categorization" (Anderson et al 1976 p3). The criteria already examined in section 3.12 were applied and a classification was developed with nine categories at Level I based entirely on land cover (form). These were divided at Level II into 37 categories some of which, but not all, rely on function rather than form for their definition (land use). Urban land is treated in this way as would be expected, but <u>23 Agricultural land: confined feeding operations</u> also has a touch of function. There are several dustbin categories at Level II, described as 'mixed' or 'other' (16, 17, 24, 33, 43, 77, 85); water and snow seeming to be exempt from uncertainty.

The USGS classification would require additional classes at Level II if it were to be extended into tropical areas. Categories <u>2 Agricultural land</u> and <u>3 Rangeland</u> would have to be reworked and there would be minimal entries at the cold end in categories 8 and 9. Viewed in context though it is very a effective classification developed along orderly lines.

3.23 Other tropical areas: Jamaica

W G Collins made a study of the existing land use of the parish of St. Catherine Jamaica which covers an area of approximately 1300 sq km. Land use data was obtained from

TABLE 13

USGS LAND USE & LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

	Level I		Level II
1	Urban or built-up land	11	Residential
		12	Commercial & services
		13	Industrial
		14	Transport communications & utilities
		15	Industrial & commercial complexes
		16	Mixed urban or built-up land
		17	Other urban or built-up land
2	Agricultural land	21	Cropland & pasture
		22	Orchards, groves, vine-yards, nurseries & ornamental horticultural areas
		23	Confined feeding opera-tion
		24	Other agricultural land
3	Rangeland	31	Herbaceous rangeland
		32	Shrub & brush rangeland
		33	Mixed rangeland
4	Forest land	41	Deciduous forest land
		42	Evergreen forest land

		43	Mixed forest land
5	Water	51	Streams & canals
		52	Lakes
		53	Reservoirs
		54	Bays & 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 & gravel pits
		76	Transitional areas
		77	Mixed barren land
8	Tundra	81	Shrub & 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

Source: Anderson et al (1976)

aerial photographs at 1:25 000 scale and 3 months was spent in the field developing a land use classification (Collins 1966). This was derived from the WLUS classification but was modified and enlarged because of the large scale of the photographs and of the mapping at 1:12 500 which was prepared from them. Table 14 shows the classification.

The purpose of the work was to provide information about present land use to assist in planning agricultural development. The classification is based on land cover throughout, using only form visible on the aerial photographs, the prerequisite of a successful remote sensing survey. The WLUS key divided to Level II gives categories under tree and other perennial crops for 24 Coconut 25 Banana and 27 Citrus. Rice, sugar and tobacco could also be seen and are separated from other crops. Swamps and marshes are divided to include a category for salina.

The basis of form not function was retained in deciding not to include a category for 'ruinate' land, farmland which has returned to bush. This type of land seems to correspond with African bush fallow and is represented at different stages by unimproved pasture, cut over forest and scrub.

Collins mentions the difficulty of separating certain categories without ground survey. Cocoa and coffee, growing under shade, will be classified as dense woodland (op cit p254). A delightfully named category is 22 Food Forest, not defined in the paper but presumably woodland in which food plants are grown. This must have been difficult to recognise directly. The problems of differentiating between the categories of grassland are discussed. It proved impossible to separate improved from unimproved and used from unused on the photographs or even with ground field checks. The attempt was abandoned during the survey and a single land cover category 11 Grassland was the classification used.

3.24 Other tropical areas: Sri Lanka

A land use survey of Ceylon is reported by S.Sridas. The 65 000 sq km of the island were surveyed using 1:40 000 scale aerial photographs compiled at a scale of 1:31 680 (2 inches to 1 mile). The purpose was stated by Sridas (1966 p77), "The ultimate objective of the survey was to ensure proper resource management and the proper use of arable land for maximum production of food with due consideration to the maintenance of soil fertility". The classification at Level I follows the WLUS system. At Level II there is a concentration of effort on the existing farmland. There are 21 categories subdividing the Level I classes of 2 Horticulture, 3 Tree & other perennial crops and 4 Cropland; but classes 5 and 7 are undivided. See table 15. The classification is on form only and named crop units were apparently large enough to be mapped. It is noted however that "even though other crops cannot be conclusively interpreted on the photographs it is

T A B L E 1 4

KEY COMPILED FOR THE LAND USE OF

ST CATHERINE JAMAICA

		WLUS 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	7b
41	Scrub	7c
41	Scrub lowland	7c
c/o41	Cut over forest & shrub	7d
38	Mangrove swamp	7d
35	Marsh & swamp	8
30	Salina	8
70	Cleared land	
71	Unproductive land	9

*These were eventually deleted & the term 11 Grassland was the classification used.

Source: Collins (1966)

nevertheless possible to identify most of them due to their occurrence in very limited, defined quarters of the island. If found elsewhere, their extent seldom justified mapping (op cit P79).

Another view of land use mapping from Sri Lanka is given by R. Wikkramatileke. He does not give a classification but he does discuss the problems of land use mapping in the tropics, referring to a 150 sq km sample survey in the south central lowlands of Sri Lanka. The work of mapping at 1:12 672 scale (5 inches to 1 mile) was accomplished by ground survey assisted by observations made from a light aeroplane. The problems of wading rivers and interviewing peasants are described with feeling (Wikkramatileke 1959). The mapping of complexes of land use is advocated to overcome the problems of fragmented holdings, small crop areas and mixed uses. The same approach will be seen in the Nigerian forest inventory (section 3.26). The examples of complexes such as "chana" - land rotation - and "gangoda" - villages with associated coconut plantations and vegetable gardens - are cited. The writer also suggests that when mapping scrub and jungle, areas where the former is a climax vegetation should be identified (he does not say how). This would be useful for development planning if it could be done.

3.25 Africa: the Sudan

J H G Lebon (1965) completed a land use survey of the Republic of Sudan publishing the results at a map scale of

TABLE 15

RURAL LAND USE FROM PHOTOGRAPHS IN CEYLON

1	Settlements & associated non-agricultural lands		
2	Horticulture	2H	Homestead garden
		2M	Market garden
3	Tree & other perennial crops	3C	Coconut
		3Ca	Cocoa
		3Cd	Cardomoms
		3Cn	Cinnamon
		3Ct	Citronella
		3E	Coffee
		3K	Kapok
		3O	Orchid
		3P	Palmyra
		3Q	Cinchona
		3R	Rubber
		3T	Tea
4	Cropland	4C	Sugar cane
		4D	Land under development
		4P	Paddy
		4Pa	Pineapple
		4Pd	Permanent dry cropping
		4S	Shifting cultivation
		4T	Tobacco
5	Improved permanent pasture		
6	Grassland & scrub	6D	Damana grassland

6K	Kekilla fernland
6P	Patana grassland
6S	Savannah
6Sc	Scrubland
6V	Villu grassland
6X	Other grassland

7	Woodland	
8	Swamp & marsh	
9	Unused land	Saltern
		Water

Source: Sridas (1966)

1:1 000 000. The classification (table 16) is particularly interesting as the southern part of the Sudan is similar in many ways to the north of Nigeria. The climate, structure and vegetation are very much the same, all part of the belt of savanna stretching westwards to the Atlantic Ocean. The photographs in Lebon's monograph could be duplicated in Nigeria today.

The WLUS system was used as a basis and adapted, Professor Lebon states that three principles were followed in the adaptation:

> "1. The scheme should be appropriate to a tropical country, in an early stage of economic development, in which types of land use characteristic of temperate and more advanced countries have intruded to only a very limited extent.
>
> 2. The classification should conform to the actual disparities between economies.
>
> 3. All the types included in the classification should be readily identifiable on the air photographs".

(op cit p67-68)

The interpretation material was trimetrogon photography at a basic scale of 1:40 000 with baselines 16-20 miles apart. In addition extensive field expeditions were made to collect ground information. Although the photographs were at medium scale the published maps were much reduced and Level II information could not be shown directly. Instead

T A B L E 1 6

SUDAN LAND USE SURVEY

1	Settlements (towns)
4a	Perennially irrigated cropland
4a' – 6a	Intermittently cultivated flush irrigated cropland with grazing
	<u>Land rotation types</u>
4b–6a(7c)	(Undifferentiated local types) with grazing, in low savanna or woodland savanna
$4b^{i}$–6a(7c)	(Embanked fields $4b^{it}$) + small areas of flush irrigation ($4b^{if}$) with grazing in semi desert or low savanna
$4b^{ii}$ –6a(7c)	(Northern Clay Plains including grass-firing) with grazing in low savanna
$4b^{iii}$ –6a(7c)	(Sand zone types) with grazing in low savanna
$4b^{iv'}$ –6a(7c)	(Nuba mountains terrace type) with grazing, in woodland savanna
$4b^{iv''}$ –6a(1)	(Nuba pediments & clav plains) with grazing, in woodland savanna
$4b^{v}$ –6a(7c)	(Jebel Marra type) with grazing, in montane woodland savanna
$4(a')b^{vi}$ –6a(7c)	(Wadi Azum type) with grazing, in woodland savanna
$4b^{vii}$ –6a(7b,7c,7')	(Nilotic type) with grazing in woodland savanna or "High" land of the Southern Clay Plain
$4b^{viii}$ –6a(7b)	(Terraced upland & Piedmont types of

	Equatoria) with grazing in woodland savanna
	Used unimproved grazing types
6a(7b)	In woodland savanna
6a(7c)	In low savanna
6a(9)	In semi-desert grassland
6a(8')	Seasonally wet grassland of Southern Clay Plain
6a(8")	Perennially moist riverain grassland of Southern Clay Plain
6a'(9)	Sparse semi-desert alternating with desert
6b(7b)	In woodland savanna
6b(7c)	In low savanna
6b(8')	Unused unimproved grazing in seasonally wet grassland of Southern Clay Plains
7a-e	Evergreen tropical rain forest
7a-e(m)	Montane evergreen tropical rain forest
7a-e/sd	Semi deciduous high woodland savanna with some closed forest
7b-d	Deciduous high woodland savanna
7f(i)	Tropical rain forest or high woodland savanna with shifting cultivation
8	Permanent swamp
9	Unproductive (desert)
w	Water area of principal perennial rivers

Source: Lebon (1965)

the classification provided classes which covered complexes of land use. This gives rise to notation which seems cumbersome at first but is a succinct description of associations of farming, grazing, and natural vegetation which together comprise a distinct subsistence farming economy. Each complex is described at length in the monograph. The classification is based on land use rather than land cover when it deals with cropland, but reverts to form in the categories reserved for natural vegetation.

3.26 Nigeria: forest inventory

The vegetation of Nigeria was mapped in 1976-77 at 1:250 000 scale for the Federal Department of Forestry. The purpose of the survey was to prepare an inventory of the forest resources of the country at a particular date for use in calculating projections of timber resources into the future. Because of the frequent cloud cover in the south and the harmattan dust haze in the north aerial photography and LANDSAT imagery were ruled out as data sources. Side looking aspect radar (SLAR) was used instead. This active sensor technique is able to penetrate cloud and haze. The resolving power of the technique is low and the type of image recorded on the scanner depends on the relative position and orientation of the reflecting surface and radar beam. Consequently interpretation and classification were not easy. A large amount of ground work was required to fit images to vegetation types. Most of the roads in Nigeria seem to have been used for inspection traverses (Parry & Trevett 1979, Trevett 1979). The result is a series of maps which very successfully fulfil the objects of the project, but one wonders whether there might not have been an easier way using satellite imagery.

The classification adopted (table 17) gave 9 formations at Level I. These were divided at Level II into 29 sub formations. Also at this level 15 mosaics of mixed use were specified. Woodland and forest received much more attention than other categories which is understandable bearing in mind the nature of the project. For each sub formation a species list was drawn up from ground survey. There was no attempt to define plant associations or main and secondary crops.

3.27 Nigeria: Kano State

E Y Kedar used LANDSAT imagery to examine the distribution of farming types in the 32 400 sq km of one scene which covered Kano State. Five categories of farming were identified and verified by unspecified "ground truth" (Kedar 1982 p471). The results are given in table 18.

3.28 Nigeria: north east

The Land Resources Development Centre made a sample vegetation survey over 154 000 sq km of the north east of Nigeria (Alford et al 1974) Aerial photographs at 1:40 000 scale were interpreted using a vegetation key which permitted accurate identification of point samples.

TABLE 17

NIGERIA : VEGETATION BY RADAR

FORMATION	SUB-FORMATION
Grassland	Grassland
	Aquatic
	Wooded shrub
Wooded transition	Wooded shrub grassland with patches of grassland
Wooded shrub grassland	
Woodland	Broad leaved
Forest	Mature
	Mature disturbed
	Immature
	Swamp
	Riparian
	Oil palm
	Rubber
	Raphia palm
	Mosaic-oil palm/swamp
	Mosaic-mature disturbed/immature
Farmland	Derived savanna
	Forest zone
	Mosaic-farmland/oil palm forest
	Mosaic-farmland/rubber forest
	Mosaic-farmland/immature forest
	Mosaic-farmland/oil palm forest/ immature forest

	Mosaic-farmland/wooded shrub grassland with patches of woodland
	Mosaic-farmland/swamp forest
Plantations & agri-cultural forests	Forestry plantation
	crop plantation
Water	

Source: Trevett (1979)

Note: This is only a partial classification taken from a specimen sheet no JOG NB32-5

TABLE 18

KANO AREA : FARMING TYPES

LAND USE NO	DESCRIPTION	% OF TOTAL AREA
1	Upland farming	1.2
2	Grazing & bush fallowing	5
3	Fadama farms	*15.5 (4.3)
4	Mixed farming	5.8
5	Kano close farms	12.5
		Total 40.0 (28.8)

*Two figures are given; in the text p473; in a diagram p474.

Source: Kedar (1982)

Table 19 shows the classification which is keyed as follows:

<u>Vegetation key example</u>

Vegetation cover well developed - predominantly herbaceous communities (woody plants present less than 50% cover) - trees and/ or shrubs present - trees/shrubs in discrete pattern - isolated trees -

<u>Category parkland</u>: less than 300 trees per square mile (tree cover usually less than 5%)

Source: Alford et al (1974)

The classification contains 25 categories with no subdivisions and is confined to what can be seen on the photographs. There is no detailed discussion of interpretation problems in the paper but some are evident from the classification. Guinea Corn is the only individual crop that can be identified, presumably the dried stalks left lying in rows on the ground could be seen. Category <u>11 Crop or fallow</u> shows the difficulty of separating farmland from land which has recently been laid fallow and has not yet developed a shrubby vegetation. The categories of savanna must have been difficult to separate because of the way they grade into one another.

3.3 CLASSIFICATION FOR MONITORING LAND USE CHANGES

3.30 The WLUS system of land use classification was taken as the starting point for development of a classification suitable for monitoring land use changes from remote sensing in the savanna. The original intention was to subdivide down to a third level of categories. However this proved too detailed in practice without a lot of supplementary information being obtained. The criteria already discussed in section 3.12 were applied and attention was paid mainly to land cover rather than land use. The recognition of complexes of land use was not necessary at the large scale of the photography. Mapping was not proposed as an end product. The development of the classification was guided by checks in the field and on the photographs to make sure that the criteria were satisfied and that the final categories were visible on the material available.

3.31 The ideal classification (a first attempt)

A notional classification was drawn up first with categories for all that was expected to be present in the savanna area. Previous authorities were not consulted, partly because a fresh start was thought to be a good idea but mainly because at that time none were available. The result was a long list (see table 20) with three levels of sub-division starting with the nine categories of the WLUS. At the second level there were 24 categories some of which were further sub-divided to a third level with 38 categories in all. There were no less than nine under the heading of settlement and even seven under unproductive land. When the photographs and maps of the Kajuru area were examined closely it was clear that the classification was too detailed. Four problems were encountered in its

T A B L E 19

LRDC : NORTH EAST NIGERIA

1	Buildings & compounds
2	Roads/railways
3	Paths & tracks
4	Rivers & streams
5	River & stream beds
6	Other bodies of water
7	Bare rock, sandbanks etc
8	Erosion scars
9	Cropping unrecognizable
10	Guinea corn
11	Crop or fallow
12	Fallow - all herbaceous
13	Fallow - all woody
14	Fallow - all primarily herbaceous
15	Fallow - all primarily woody
16	Forest
17	Thicket
18	Closed woodland
19	Open woodland
20	Tree savanna
21	Tree & shrub savanna
22	Shrub savanna
23	Acacia tree savanna on heavy clays
24	Grassland
25	Parkland

Source: Alford et al (1974)

application

1. <u>Empty categories</u> Many of the categories at the third level would be empty or have minimal contents, particularly those under settlement. Modern planned layouts are not a feature of rural Nigeria and enclosed rangeland sounds more like the home of John Wayne than of Audu Abdullahi. If the work were to be extended to other areas these categories could be useful but they are not necessary for Kajuru.

2. <u>Identification</u> Even though some categories are present in significant quantity they could not necessarily be identified on the photographs. The possibility of recognising <u>42 Fadama: 421 unfenced (annual crops)</u> was very remote. Rice is grown on fadama during the wet season in unfenced unridged plots. By the time the rains have ended and photography is flown the harvest has been safely gathered in and no signs of cultivation remain.

3. <u>Differentiation</u> Categories such as <u>43 Rotational bush fallow: 431 cultivated or cleared</u> and <u>432: early regrowth</u> could not be separated from one another with any certainty. Even on the ground it is not easy to do so.

4. <u>Gradation</u> Most natural vegetation categories grade into one another, a notable exception being forest and savanna. Thickly wooded savanna on the lower part of a valley will lose most of its trees as the soil becomes shallower and drier on the upper slopes, ending up as

TABLE 20

FIRST CLASSIFICATION FOR KAJURU AREA

1 Settlement & associated non agricultural areas

11 Compound land predominately residential with gardens

:111 traditional, irregular layouts & irregularly shaped buildings

:112 modern planned layouts & regularly shaped buildings

:113 abandoned compounds

12 Non residential compounds

:121 services

:122 industrial

13 Transport & communications

:131 roads

:132 tracks & paths

:133 railways

:134 airports

2 Horticulture

21 Gardens outside compound land

:211 irrigated

:212 non irrigated

3 Tree & other perennial crops

31 Timber plantations

32 Orchards

4 Cropland

41 Permanent rainfed

:411 without trees

:412 with scattered trees

42 Fadama

:421 unfenced (annual crops)

:422 fenced (perennial/biennial crops)

43 Rotational bush fallow

:432 cultivated or cleared

:432 early regrowth

5 Improved farmland, managed or enclosed

51 Enclosed rangeland

52 Enclosed arable land

:521 five hectares or more

:522 less than five hectares

6 Unimproved land

61 Shrub savanna

:611 with evidence of past cultivation

:612 no signs of past cultivation

62 Grass with few or no trees or shrubs

:621 rainfed, no signs of past cultivation

:622 fadama, uncultivated

63 Tree savanna, grassland with discontinuous tree cover

7 Woodland

71 Savanna woodland with continuous light tree canopy

72 Riparian forests

73 Tropical high forest remnants (kurame)

8 Swamps & marshes

9 Unproductive land

91 Bare rock or soil with high relief & steep slopes

92 Bare rock or soil with low relief & gentle or no slope

93 Dissected eroded terrain

94 Sand with little or no vegetation

95 Excavations, borrow pits, quarries

96 Water features

:961 seasonal

:962 permanent

shrubby grassland or even pure grassland on the primary laterite ironpan at the interfluve. Clumps of trees will grow among rocks, surrounded by isolated trees in grassland. Categories such as 61,62,63 in unimproved land and 71 Woodland have to be strictly defined to avoid overlaps.

The conclusion was that this first attempt at classification was too detailed for use with remote sensing material without a large input of ground information. It was not suitable for monitoring and needed to be simplified.

3.32 Practical application (a second attempt) in which the objections to the first classification were countered. This time division was only to the second level and one third fewer categories were used. Among others settlement was reduced from nine to five categories and cropland from six to two. The problem of bush fallow was dealt with by including early regrowth with farmland in one category. The sub-divisions of natural vegetation were also reduced in number.

At this stage a visit was made to the Kajuru area, which was generally familiar, to make a quick revision of the land cover on the ground before starting interpretation.

TABLE 21

SECOND CLASSIFICATION FOR KAJURU AREA

(used for first trial sample)

1 Settlements & associated non-agricultural areas

11 Permanent settlements

12 Abandoned settlements

13 Temporary nomadic camps

14 Services, transport, communications

15 Industry

2 Horticulture

21 Gardens & orchards

3 Trees & other perennial crops

31 Tree plantations other than fruit trees

4 Cropland

41 Upland in cultivation or early fallow stage

42 Fadama in cultivation or early fallow stage

5 Improved farmland, managed or enclosed

51 Enclosed farmland or 10 hectares or more

6 Grazing land

61 Fadama

62 Grass savanna

63 Shrub savanna

64 Tree savanna

65 Savanna woodland

7 Woodland

71 High forest (kurame) and inselberg forest

72 Riparian gallery forest

8 Swamps & marshes

81 Swamps & marshes without signs of cultivation

9 Unproductive land

91 Rock outcrop with high relief & steep slopes

92 Rock or ironpan outcrop with low relief

93 Dissected or gullied terrain with scant vegetation

94 Sand associated with water bodies

95 Excavations, borrow pits, quarries

10 Water

101 Streams, rivers, lakes, reservoirs, etc

TABLE 22

THIRD CLASSIFICATION FOR KAJURU AREA

(used for second trial sample)

		Remarks
1	Settlements & associated features	
11	Permanent settlement	Including compounds
12	Abandoned settlement	All buildings derelict
13	Nomadic camps	
14	Communications	Roads, tracks, paths, railways & stations
15	Industrial sites	
16	Excavations	Quarries, borrow pits town walls
2	Cultivation	
21	Enclosed cultivation less than 10 hectares	Gardens, orchards, irrigated farms
22	Enclosed cultivation of 10 ha or more	Managed or improved farms
23	Unenclosed farmland	Including early fallow usually less than 3 years
3	Uncultivated land	
31	Fadama	Floodplain seasonally inundated
32	Shrub savanna	Grassland with scattered shrubs
33	Tree savanna	Grassland with scattered trees

4	Woodland	
41	Open woodland	Discontinous canopy
42	Closed woodland	Continuous canopy
43	Riparian gallery forest	
44	High forest	Remnants
45	Tree plantations	Fuel reserves
5	Unproductive land	
51	Rock or ironpan outcrop	Including land with very thin soil
52	Dissected terrain	Gullies, edges of ironpan
53	Inselbergs	Rock outcrops with high relief
6	Water & associated features	
61	Swamps & marshes	
62	Sand	
63	Water	

The trial run was made immediately afterwards using the 1972 photography. Two overlaps were examined and 17 of the 24 categories were recognised on the photography, the empty classes being mainly in settlement, horticulture, tree crops, and swamps and marshes.

The apparent difficulties in interpretation come from the categories of <u>6 Grazing land.</u> Other difficulties existed but were not so obvious. The definitions of <u>63 Shrub savanna,</u> <u>64 Tree savanna,</u> and <u>65 Savanna woodland</u> had been taken from Hopkins (1974) but did not prove very helpful because of their gradation into one another. Most of the trees had been cut over which altered their appearance even further. <u>62 Grass savanna</u> was elusive. Apart from on the fadama pure grassland is very scarce. Even in the most unpromising places shrubs will grow, if necessary from cracks in the ironpan, only waterlogged roots seem to stop them. The problem of gradation still remained therefore and a third classification was needed before the full trial sample could be taken.

3.33 A third classification. See table 22

This classification departs from the WLUS at the first level. There are only six main categories of which the last is reserved for water. Twenty three categories are defined at the second level. Cropland is replaced by the category Cultivation and the category of horticulture merges with it. Natural vegetation has eight categories at the second level divided between uncultivated land and woodland.

This classification was tested to see whether it corresponded to what was on the ground and if interpretation could be repeated with similar results. It did not do too well on either count. Five pairs of the 1972 photographs were chosen at random and sampled using regular dot grids. Spacings were such that each overlap had 36 points on it with a density of 1 dot per 25 hectares.

The photographs were taken to the field and each of the 180 points was located on the ground. The existing land cover and that on the photograph were then compared. Not surprisingly the exercise was not very successful. Eleven years had gone by since the photographs were taken and the farmers had been busy all the time. Almost every man made feature had changed, the only remnants of the former path system were at the villages, bridges and gaps in the hills. Most others had moved or disappeared. There had been time for a full crop rotation plus fallow although the areas of permanent cultivation were still there. Changes in the natural vegetation were less obvious, in many cases it appeared to be much the same. But not much reliance could be placed on this bearing in mind what had happened to cultivated areas. Making allowances for these problems a field interpretation was made of what the area probably contained at the time of photography. When this was compared with the office interpretation only 56 out of the

180 points fell in the same category, a 30% success rate.

The work was set aside for a week while I concentrated on running a field camp, then a new interpretation was made from the photographs. This time there was a 30% difference from the field key and a 50% difference from the first office interpretation. There was obviously something seriously wrong when only half the points were placed in the same category during a rerun. After a lot of thought and despondency it was decided that the classification was causing the difficulties. To avoid the implication that the bad carpenter was blaming his tools some reasons had to be given and these were:

1. Exclusivity The classification had not been made on one basis only but on several, and the categories had become mixed.

a) 41 Open woodland often grows on 51 Ironpan outcrop and on 52 Dissected terrain.

b) 33 Tree savanna frequently has 23 Unenclosed farmland under the trees.

2. Gradation The boundaries between 32 Shrub savanna and 33 Tree savanna; 41 Open woodland and 42 Closed woodland are difficult to place. Cut over woodland has no canopy anyway and this is the basis of the subdivison.

3. Poor definition of categories There was no detailed

key to each category and the interpretation consequently varied in standard from photograph to photograph. A stricter definition was required.

A simpler classification was therefore required in which mixed categories could be avoided by concentrating on vegetation rather than landforms. Each category should be clearly defined and that definition should be observed throughout the work.

3.34 The final classification (Table 23)

The result of this trial and error process was to produce a classification which works for the Kajuru area and for the aerial photography available. It meets most of the criteria discussed above including that of possible extension to other areas by adding classes at the second level. The basis for division is that of form rather than function, although the two cannot be entirely separated. Location is considered when distinguishing <u>31Fadama</u> from <u>32Grassland not in fadama</u> but the two categories have a distinct vegetational composition (see table 8) which gives a different appearance on the photographs. The categories are clearly defined and should be repeatable. This and the remaining problems of interpretation are dealt with in chapter 4.

T A B L E   2 3

THE FINAL CLASSIFICATION

1 Settlements & associated features

11 Settlements: domestic and public buildings including compounds.

12 Communications: roads, railways, tracks, footpaths and associated features.

13 Industry: excavations and pits not associated with road construction, quarries, factories.

2 Cultivated

21 Enclosed farmland less than 10 hectares in area: small farms, gardens and orchards enclosed by walls, hedges, or fenced gardens without domestic buildings.

22 Enclosed farmland of 10 hectares or more: large enclosed farms or rangeland with or without buildings.

23 Unenclosed farmland & early bush fallow: cleared land with signs of recent cultivation. Isolated trees and shrubs may be present, usually with well developed crowns.

24 Tree plantations: trees closely planted, excluding orchards.

3 Uncultivated

31 Fadama: flat valley floors with few if any trees or shrubs and low grass under 1 m in height. No signs of cultivation.

32 Grassland not in fadama: grassland with occasional trees or shrubs not more than 10% cover. Outcrops of ironpan or bare rock may be present.

33 Scrub & small trees: amount of herbaceous vegetation between 50% and 90%. Trees small under 10 m often cut over. Shrubs under 5 m occasionally forming thickets.

34 Swamps & marshes: permanently wet or flooded. Tall (2 m - 5 m) herbaceous vegetation.

35 Woodland: woody vegetation more than 50%. Single storey of trees with open or closed canopy.

36 Gallery forest & kurame: woody vegetation more than 50%; stratified cover with tall trees over 15 m. Often associated with rocky hills and with stream courses.

4 Barren land

41 Bare rock outcrop: vegetation very sparse, mainly occuring in rock fissures.

42 Rivers, streams and lakes: water may or may not be present.

3.4 SUMMARY

3.41 Land cover is the basis for the land classification used in this study. Form - land cover - is recognisable on aerial photography whereas function - land use - usually requires ground information. Form and function are related but are not coincident; many areas have a multipurpose function which contributes to their form.

3.42 Ten criteria are applicable to land cover or land use classifications. Levels I to IV are definable according to the data available.

3.43 Classification must be made on one basis only. If other bases are to be used another level must be introduced.

3.44 The WLUS and USGS classification are of general application. The former is very general but useful as a starting point; the latter is more detailed and designed for use with remote sensing data particularly in the United States.

3.45 Collins's Jamaican and Sridas's Sri Lankan work generated classifications in which several categories were allocated to individual crops.

3.46 Wikkramatileke in Sri Lanka advocated and Lebon in the Sudan devised a classification recognising complexes of land use.

3.47 The forest inventory of Nigeria by SLAR imagery used a classification with 29 sub-formations and 15 mosaic categories covering all forms of vegetation. A LANDSAT study of farming types in Kano State defined 5 categories of farming. The LRDC sample vegetation survey of north east Nigeria listed 25 categories, the natural vegetation being defined in a key.

3.48 The WLUS system was used as a basis for the classification for the Kajuru project. Development of a classification included field checks and tests of repeatability. Problems encountered included poor definition of categories, gradation of vegetation, mixture of classification bases, and over elaboration of the key.

3.49 The final classification comprises 4 main classes and 15 categories.

C H A P T E R   F O U R

METHODS

4.1 MATERIALS AND EQUIPMENT

4.10 Aerial photographs were the prime source of information supported by topographical maps. The equipment used was for interpretation and for analysis of the data.

4.11 Aerial photography

Two sets of panchromatic aerial photography were used. The earliest was that taken by the Royal Air Force in early November 1950. (see Appendix A). Flying at 16 000 feet with a camera lens of focal length 153 mm (6 inches) the nominal scale was 1:27 000. Coverage of the Kajuru area was achieved on 77 photographs arranged in six strips. The aircraft flew in a spiral around a beacon at Bauchi so the strips are slightly curved and here are oriented approximately North-South. There is no cloud and the quality of the prints is reasonable considering the age of the film. Their main defect is lack of contrast which may be because of age, the film emulsion, or harmattan haze which is often present in November.

The second set of aerial photography was taken for mapping of Federal Block C around Kaduna in late February 1972.

(see Appendix A). There are seven strips of East West orientation, 90 prints covering the test area. Flying height was 15 500 feet and the camera lens focal length 152.07 mm (6 inches) giving a nominal scale of just under 1:27 000. There is no cloud on the prints and their quality is good.

An investigation of scale variations on a small sample of the 1972 photography showed that they were quite small, not more than 3%. Measurements were made between prominent points of detail on the photographs and compared with those scaled off the 1:50 000 map. The scale tended to vary most between strips, the altitude of the aircraft changing slightly each time. However the variation is very small and no doubt contains factors of paper shrinkage, misidentification and scaling error. Table 24 shows the results.

4.12 Maps were available at 1:50 000 scale. The 1950 photographs had been used to compile a planimetric provisional edition which was published in black and white in 1959. Prominent hill features were outlined by modified hachures. The first edition was published in 1965 in colour with contours. It was compiled from photography taken in 1962. Very little field completion was done, there are only a few village names, mostly along the main road or railway.

4.13 Equipment

Interpretation was done using a mirror stereoscope with binocular attachment. Some work was done with a CP1 stereoplotter which takes paper prints and gives a good evenly illuminated image at high magnification. However the time taken to set up the steroscopic model was a nuisance and high magnification is not essential for this kind of work. Use of this equipment was discontinued.

Storage and analysis of data was carried out on an APPLE II Europlus micro-computer with disk drive interfaced with an EPSON MX80F/T line printer. This was the weak link although the project could not have easily been done without it. Most of the statistical and data handling programmes were modified versions of BASIC algorithms by Cooke et al (1982). Screen graphics programmes and graphics transfer programmes were specially written. Two of the latter are given in Appendix D.

4.2 SAMPLING

4.20 Four questions should be asked when beginning a task using remote sensing data:

1. What are the targets? (i.e. objects, keys, indicators).
2. What level of interpretation is needed?
3. How can the targets be sensed?
4. What are the available resources and required data?

(Philipson 1980 p1336)

TABLE 24

VARIATIONS IN SCALE

BETWEEN PHOTOGRAPHS & 1:50 000 MAP

Photo number	Photo/map scale ratio		Deduced photo scale
16/179	0.510 87		1: 25 540
18/178	0.538 71		26 940
19/100	0.530 69		26 530
20E/179	0.535 46		26 770
20E/184	0.521 47		26 070
	0.527 44	means	1: 26 370

The first three have been disposed of, the last will have to be considered. Cost and time make it necessary to sample land use rather than attempt to survey it completely. The method of sampling and the sample size have to be decided.

4.21 Planimeter, squares or dots?

One way of measuring the area of a figure is to draw a line round the boundary, if you can, having first plotted at a suitable scale or using the photograph direct. Then run a planimeter round it three times. The mean reading gives a measure of the area, which may be quite accurate given a steady hand, infinite patience and plenty of time. For those of us with other things to do a quicker way is to count the squares on a grid overlay. To avoid having to estimate the part squares on the boundary the line grid may be replaced by a dot grid. Area is then calculated by counting the dots falling within the boundary. Abell (1939) found that this was the best method. In trials with five different observers and three maps the dot grid calculations differed from the planimetered value by 1.84% whereas the line grid gave a 4.50% difference.

By extension of this discrete area measuring technique point samples may be taken and analysed to give the areas of categories of land use without the need to draw boundaries. This is a most important advantage in places, like the one being studied, where land use is often very fragmented and the larger categories grade into one another so that boundaries are very difficult to locate. Emmott (1981 p3) notes that the systematic point sample has been extensively used for sampling vegetation and states its advantages as follows:-

(a) point sampling makes the measurement & thus the depiction of individual plots unnecessary.

(b) the interpreted land uses can be recorded on a single data sheet.

(c) 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.

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

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

(f) the interpreted information is in a form immediately amenable to computer storage, processing and display.

(after Dickinson and Shaw 1977)

Colcord (1972) also notes that grid analysis of photographs takes one-eighth of the time of a field survey. So provided that maps are not required the dot grid is the most convenient method available for land use survey.

4.22 Systematic or random?

From the practical point of view it is much easier to use systematic rather than random dot patterns. For random sampling you need a lot of overlays each with a different pattern on it. Alford et al (1974) used 30 templates in their sample vegetation survey of N.E. Nigeria; systematic sampling requires one. Another reason for preferring systematic rather than random samples is that they are easier to store, a list will contain all the position information needed. In a 5 row 10 column systematic sample the 6th dot will be at the beginning of the second row and the 50th will be at the bottom on the right hand side. A random dot sample has to carry position information as well as the sample category, this takes up space and makes data handling more complicated. Finally, although dot grid samples cannot generate true maps nevertheless the results of a survey using them can be displayed as diagrams. If the pattern is regular they can be formed more easily and convey a better impression. All other things being equal therefore it would be preferable to use systematic dot grids rather than random ones.

Rosenfield and Melley (1980 p1288) say, "The manner of sampling does not have to be random. Sampling in a systematic manner may be treated as if it were random provided that systematic effects in the population are made ineffective by the sampling". Rosenfield (1982) notes that systematic sampling has been used to test the accuracy of USGS land cover and land use maps. Cochran (1977 p229) summarises that systematic sampling may be used "where the ordering of the population is essentially random or contains at most a mild stratification", and for "subsampling cluster units".

Is rural land use stratified? There is certainly a pattern, related to underlying geological structure, soils and moisture. In some places the pattern repeats itself in a regular way. The extreme north east of Nigeria is covered by fossilised seif dunes left by an ancient extension of the Sahara (Grove 1957). Vegetation belts along the trend of these dunes can be clearly seen on aerial photographs. But this type of obtrusive pattern is unusual, rural land use can be assumed to possess only mild stratification. The use of systematic sampling with regular dot grids is therefore justified.

4.23 How many dots?

Frulov and Maling (1969) state that the errors which arise in the calculation of the areas of separate parcels on a map will approximate to the binomial distribution. The relative error f will be given by:

$$f = \sqrt{\frac{1-p}{p} \cdot \frac{1}{n}} \quad \ldots\ldots\ldots (1)$$

where p = the probability that any point lies within the parcels

n = the number of points which coincide with the parcels to be measured

This relationship is commonly used in land use surveys to determine the error of one category in relation to the total area sampled (Brunt 1966; Alford et al 1974; Bonnor 1975; Emmott 1981) the formula becoming:

$$E\% = k\sqrt{\frac{100 - P}{n.P}} \quad \ldots\ldots (2)$$

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

P = the percentage of the total area occupied by that category.

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

k = the standard normal deviate (for a confidence level of 95%, k=1.96 x 100)

When rearranged the formula (2) can be used to calculate the number of dots needed to give a required precision:

$$n = \frac{(100-P).38400}{P.(E\%)^2} \quad \ldots\ldots (3)$$

where 38400 is k^2 at 95% confidence level.

If the dots are to be evenly distributed then the number of dots per photograph (D) can be calculated:

$$D = n/A \quad \ldots\ldots\ldots\ldots (4)$$

where A = the number of photographs to be sampled.

Note that the distribution of the dots or their density is immaterial, only the relative area covered by the category to be measured and the amount of error tolerated are significant.

There are objections to the use of the binomial distribution as an error estimator. Theoretically it can only be used if the dots are randomly distributed over the whole area to be measured. Dot grids are regular and they are often applied to the central part of an aerial photograph giving a cluster pattern. Bonnor (1975) studied the errors in dot grid area estimation taking into account three factors, the grid density, area size, and the shape of the area. Tests showed a logarithmic relationship between the percentage error and the number of dots:

$$\log(E\%) = a + t.S - b.\log(n) \quad . \quad . \quad (5)$$

where a = sample regression constant

b = sample regression coefficient

t = 1.645 (n tending to infinity, p=0.05, one tailed test)

S^2 = sample residual variance of regression.

Converted to non logarithmic form and with the component part of n introduced:

$$E\% = c/(A.D)^{b} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

and

$$n = (c/E\%)^{-b} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where c = antilog (a + t.s)

D = dot density

A = area under the category

For areas with regular or irregular shape, boundaries irregular and for combinations or sums of individual areas:

a = 1.4440 b = 0.5814 S^2 = 0.2029

giving (Frazier and Shovic 1980 p1072):

$$E\% = 153.1 / (A.D)^{0.58} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Emmott and Collins (1980) compared systematic dot grids and planimeter measurements of areas on photographs using a 4 sq km urban test site in the United Kingdom. They obtained the following regression equation:

$$\sqrt{(S\%)} = 11.36 - 0.931\log(X1) - 1.66\log(X2) \quad (9)$$

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

X1 = the number of points required to measure the whole map.

X2 = the areal percentage of the given land use.

The Emmott and Collins formula (9) was derived from urban land use studies and was not considered suitable for application to the present area without additional verification. The other formulae (2) and (8) were used to decide on the optimum dot density.

4.24 Changes

One of the objectives of this project is to study the changes in land use that occurred between 1950 and 1972. Paired samples, with the dots located in the same position on each set of photographs, will be very convenient for this purpose. Changes can then be directly deduced from the differences at each point. We shall have to be sure that the points really are in the same place; but this is not so difficult as it may seem because of the way the interpreter estimates the land use. Around the dot a little imaginary circle is drawn and the land use within that circle is what is recorded. Any category of land use is made up of a complex of features which together give it a special character. To isolate one of these features would be incorrect. A dot sitting in the branches of a dorowa tree in the middle of a guinea corn patch will correctly be classified as "farmland" not "tree". If an overlay is slightly misplaced not too much harm is done because of the fuzzy nature of the point sample.

Observed changes can therefore be taken from the differences between the two point samples. An unbiassed estimate of the change in population is obtained by subtracting one sample mean from the other. The variance of the change in population is given by the sum of the variances of the two means (Rosenfield 1982 p798). Confidence limits of 95% are obtained from:

$$+/- 1.96\ (v(dY))^{1/2}\ .\ .\ .\ .\ .\ .\ .\ (10)$$

where v(dY) = sum of the variances of each sample.

4.3 APPLICATION TO KAJURU

4.31 Optimum dot density

Calculation of the number of dots requires a preliminary estimate of the proportions of the area occupied by each land use category. Twenty five of the 1972 photographs were selected randomly from the ninety available (Appendix B). A rectangular area around the principal point of each photograph was examined steroscopically; the land use being interpreted at 72 points on a 6 mm dot grid overlay. The resulting 1800 points could be taken as roughly 5% of the total area. The results of this trial sample gave the estimate on which the calculation could be based. (Table 25). As the precision of the area estimation is inversely proportional to the percentage of the total area covered by the land use category it was obvious that some of the smaller categories would require undue effort before yielding an acceptable result. Six groups were therefore formed, each of which except for settlement covered a substantial area. The expected error E% was then calculated for different dot densities at 95% confidence level using formulae (2) and (8) from section 4.23. A note on the calculation is required here. If the formulae are used as written they give values for E% which differ by very nearly a factor of two. The problem appears to be one of definition. Alford et al (1974 p119) following Brunt (1966) state "E: the percentage error within which results can be expected to fall in 95% of cases". Bonnor (1975 p14) says: "In practical applications, the user would want to specify a maximum allowable error (E%) of the area estimate". Frazier and Shovic (1980 p1072) referring to Bonnor's formula define E as "half the width of the 95% confidence interval for maximum error". The last definition is used here and the values obtained from Brunt's formula are halved.

The criteria for selection of the dot density were as follows:

1. <u>The dot densities used by others should be examined.</u>

Frazier and Shovic (1980) working on a 337 sq km test area in the north west of the United States found that the most useful distribution was 2704 dots in quadrats of 1 sq mile (2.6 sq km) or 1/2 sq mile (1.25 sq km). This gives a dot density of 8 dots per sq km. Alford et al (1974) sampled 9000 points for their survey of land resource data in north east Nigeria. Fifteen points were randomly placed on each photograph, the whole project covering 60 000 sq miles (96 000 sq km), a dot density of 1.4 dots per sq km.

2. <u>The work load should be consistent with the time and resources available.</u> This project lies somewhere at the deprived end of the spectrum defined by Colwell (1978 p196) ranging from "An entire multi disciplinary team of analysts...." to "One analyst...., poorly funded, poorly equipped, and little appreciated". The work load has to be tailored to one observer and the limited time available.

3. <u>There should be a convenient number of dots on each photograph.</u> Too many dots crowded into a small area would make sampling very difficult and minimise the advantages of dot grids over discrete area measurement. By experiment with different grids it was found that spacings of much less than 5 mm obscured detail and made it difficult to see the patterns of vegetation within one category.

4. <u>The most important categories should be estimated to a precision of +/- 2 1/2% at 95% confidence level.</u> A change of 5% between 1950 and 1972 would then be real, outside the

TABLE 25

TRIAL SAMPLE 1972 PHOTOGRAPHY

1	Settlements & associated features	1.95%
11	Settlement	1.56%
12	Communications	0.39
13	Industry	0
2	Cultivated	36.49%
21	Enclosed farmland under 10ha	0.39
22	Enclosed farmland 10ha or more	0
23	Unenclosed farmland & early bush fallow	36.10
24	Tree plantations	0
3	Cultivated	58.39%
31	Fadama	7.28
32	Grassland not in fadama	0.67
33	Scrub in small trees	19.33
34	Swamps & marshes	0.06
35	Woodland	29.88
36	Gallery forest & kurame	1.17
4	Barren land	3.17%
41	Bare rock outcrop	3.17
42	Rivers streams & lakes	0
		100%

errors of sampling. From the calculations the three main groups of land use - farmland, grass & scrub, and woodland fall within this level of precision at a sample size of 6000 dots, see table 26. Barren land is not economically significant and fadama, being physically rather than vegetationally defined, should not change greatly over 22 years. Settlement is the smallest group and therefore the one which will be the least precisely sampled. The number of dots needed to give +/- 2 1/2% precision would be 80 per sq km or 60 000, a very large workload indeed.

Having considered the criteria it was decided that 6000 dots would be the optimum number, bearing in mind the estimated values of E% shown in table 26. For convenience 6408 dots were used, 72 to each of the 89 stereo models in the 1972 photography. These were arranged in a rectangular 12 x 6 grid with an interval of 6 mm, giving a ground separation of 150 metres or 1 dot per 2 hectares.

4.32 Method of interpretation

Data collection was done using the 1972 points first. The 6 mm grid plotted on clear acetate was placed over the photographs with its axes corresponding with the fiducial marks. The dot at the 6th row, 1st column of the grid coincided with the photo principal point. The print and its neighbour were placed under the stereoscope. The area in the vicinity of each dot was examined and a decision made about the category of land use within an imaginary circle about 2 mm in diameter centred on the dot. Three

TABLE 26

DOT DENSITY ERRORS

(95% confidence)

Dots/sq km	1	2	4	8	10	20
Dot total	750	1500	3000	6000	7500	15000
Groups						
Settlement	23.4	18.0	12.7	9.0	8.0	5.6
(11-13)	32.3	21.6	14.4	9.6	8.5	5.7
Farmland	4.7	3.4	2.4	1.6	1.5	1.0
(21-23)	5.9	4.0	2.6	1.8	1.6	1.0
Fadama	12.7	9.0	6.4	4.5	4.0	2.8
(31,34)	15.0	10.0	6.7	4.5	4.0	2.6
Grass/scrub	7.2	5.0	3.6	2.6	2.2	1.6
(32,33)	8.4	5.6	3.8	2.5	2.2	1.5
Woodland	5.4	3.8	2.7	1.9	1.7	1.2
(24,25,26)	6.5	4.4	2.9	2.0	1.7	1.2
Barren	19.8	14.0	9.9	7.0	6.3	4.4
(41,42)	24.4	16.3	10.9	7.3	6.4	4.3

Formulae: top Brunt (1966); bottom Bonnor (1975)

Areas estimated in the trial sample Table 25 rows could be seen conveniently under the high power of the stereoscope, the work could then be completed in four east-west passes. Each category number was recorded in its correct place on a squared pad. When all 72 dots had been sampled the record was checked for totals and legibility. Both checks were necessary as recording was done while looking at the model, saving time and the eye strain caused by repeated fusing of the stereopair. The record was annotated and the next model was set up. Each model took from half to one hour to complete including arranging the photographs, placing the grid and checking. The time varied with the complexity of the land use, decisions about gradation, and the number of models already examined during the working session. Concentration lapsed quite soon, the work became quicker, too many assumptions were made about doubtful categories and the interpretation became useless. Sessions had to be limited to three or four models only. Often it was just a quick one before breakfast.

4.33 The 1950 sample was taken at the same points as those used for the 1972 photographs making it necessary to locate the grid on the same area. This was done by the Union Jack method. A number of fine lines were ruled across the acetate on which the grid was plotted, radiating from the grid centre. A duplicate grid was placed on the 1950 print and was moved until the ruled lines intersected the same details on both sets of photographs. The grid was then in position and interpretation was done stereoscopically as before. Fortunately the test area is not very hilly so there were few problems with differential height distortion. The photo scales were similar so in nearly all cases the 6 mm grid could be used without problems. There was some discrepancy between grid and ground in the hills south of Kajuru but they are mostly bare rock anyway and a shift in position did not make much difference to the interpretation.

4.34 Data storage

The last stage of the data collection was the transfer of the interpretation record to the computer disk (APPLE diskette). Most of the programming was based on the data input algorithms written in BASIC by Cooke et al (1982). The procedure for data transfer and storage was as follows:

(1) Input data from the record sheet to the APPLE via the keyboard using Algorithm 4.1 from Cooke et al (1982). This requires the operator to verify the input values before they are accepted.

(2) Convert the category identifiers (11,12, etc) into consecutive numbers (1,2,3,.....,15) before storage to simplify subsequent programming.

(3) Make a frequency count using Algorithm 4.3 (op.cit) for each of the 15 categories.

(4) Save the data and frequency count in a text file on disc. One file is used for each model; files are numbered consecutively N1,N2,.....,N89 for 1972 records; O1,O2,.....,O89 for 1950 records.

(5) Each text file was verified using the FID programme supplied by APPLE. This step was essential

in a climate where dust covers any unsealed surface and electrical power supplies fluctuate unpredictably.

(6) Each disc was copied using the APPLE programme COPYA. The original disc was then stored separately as a precaution against disc or computer failure.

4.4 PHOTO INTERPRETATION

4.40 In this section the details of the interpretation are discussed and an identification key is given.

4.41 Repeatability

One of the criteria for a land use classification is that results should be repeatable (Anderson 1971, section 3.12). Soon after the trial sample had been taken and field checked three models were reinterpreted to test whether the categories would change. Out of 216 points 6 were assigned to different categories at the second attempt:

No. of differences	Category changes	
3	32 Grassland	33 Scrub
1	23 Farmland	41 Bare rock
1	32 Grassland	41 Bare rock
1	12 Communications	33 Scrub

The 2.8% repeatability error cannot be relied upon for three reasons. Firstly the sample was small and not necessarily representative. Secondly the test was run by the same observer quite soon after he had made the first

interpretation. The same results could be expected. Thirdly this was done at the beginning of the work before much experience had been gained on this photography. Later on the results might have been more consistent. The differences observed were of the sort to be expected, and reasons for them are included in the next section.

4.42 Problems in interpretation

Photointerpretation is a subjective activity and the results are influenced by many factors. Apart from the general ones such as whether the observer was among the wickets yesterday and how long he has just spent in the scrum at the bank there are three particular ones; they are inertia, rarity and similarity. These are explained below.

Complete misidentification of the image is unusual although some small features such as rural buildings may not be seen. But some categories, particularly natural vegetation, may grade into one another, each observer having his own idea about where the boundary should run, even that idea not being fixed. When looking at a gradation between, let us say, grassland (32) and scrub (33) the tendency when interpreting is to start with one category and stay with it, minimising the appearance of shrubs in the grass and pushing the boundary far into the next category before changing to it. This <u>inertia factor</u> may result in a very uniform classification within one model which changes abruptly when the next pair of photographs is viewed. The inexact location of the sample is also a problem. Looking at the dot is not sufficient because land cover is a complex of vegetation not a uniform spread of the same kind of plant. Information is gathered from a small area around the dot before the category is decided. This is necessary for extensive categories such as farmland or woodland, but man made features tend to be small and sharply bounded, roads and footpaths being particularly good examples. If an uncommon feature such as a footpath comes into view the rarity factor may apply, the operator sampling it even if a dot does not exactly fall on it, thinking. "We haven't had one of them for some time". Communications are probably the most overestimated category because they are very easily seen but occur infrequently. The temptation to include them is not easily resisted.

Some categories do look very much alike, and can be mistaken for one another. This similarity factor often affects the identification of bare rock or ironpan where this outcrops on a level surface. Tone and texture are very similar to those of farmland. The ridges in farmland give it a striped appearance but they cannot always be seen. Visibility depends on their depth and alignment, whether they cast a shadow. Grassland and bare rock are often mixed together on the interfluves, some times there is enough soil for grass to grow, sometimes the rock shows through. A fissure in the rock may be colonised by fig trees and other bushy plants forming a thicket. The tonal differences are very slight and rock (not ironpan) often has algal and lichenal growth making it darker and more difficult to distinguish from grass.

A special problem is posed by burnt ground, which is just bare soil with a layer of black ash on top. The usual classification is into farmland (23) unless the burnt ground is well wooded when it will be woodland (35). However grassland and fadama (31) and (32) are also frequently burnt over by pastoralists looking for a flush of grass and small boys looking for rats and other edibles.

Fadama is separately defined mainly because of its economic importance. Unfortunately it is difficult to recognise on the earlier photographs because of their generally low contrast and also because on the ground at that time there were fewer fringing farms to show its outlines. For some purposes of analysis in this study it has been merged into the group Grass & Scrub.

4.5 INTERPRETATION - NOTES AND EXAMPLES

Examples are shown in photographs 13-15

<u>i Settlement & associated features</u>

<u>ii Settlement</u>

The example shows Kajuru village. Varying tones from dark to light because of the alternation of vegetation and bare ground. Fruit and shade trees are black circles. Texture is rough. Pattern shows as small irregular shapes and linear features. Shape irregular but some straight boundaries. Very small individually and difficult to detect except by "associative interpretation" (Steiner 1965). Position at footpath nodes. Larger settlements are different, lighter in tone as there is much cleared ground and roofs are often pan (corrugated iron). Pattern more regular, houses and compounds rectangular.

<u>12 Communications</u> Very light tone. Smooth texture. Linear shape. Railways darker in tone with some texture. Tight, very regular curves and no branches or junctions. Narrow. Roads light toned, curved where engineered, otherwise with very abrupt corners. Footpaths like roads except often narrower and more broken. Many branches. Disappear when crossing streams. Uncertain course.

<u>13 Industry</u> None in the test area.

<u>2 Cultivated</u>

<u>21 Enclosed farmland of less than 10 hectares</u> The example comes from the extreme east of the test area. Blocks of varying tone and texture form a patchwork. Rectangular shape usually quite small in size. Situation close to or on valley bottom near water, usually irrigated. Also occur on fringes of villages for crops like bananas.

<u>22 Enclosed farmland of 10 hectares or more</u> Difficult to distinguish. Usually tone and texture change along a straight boundary line. Tone light, texture smooth. Signs of layout, roads, paths, tree avenues. Large rectangular

buildings with pan roofs may be present. No occurrence in 1950.

23 Unenclosed farmland & early bush fallow Light tone and smooth texture often patterned by ridges. Sharply defined boundaries. Home farm very light in tone with large black dots indicating isolated economic trees. Location near or around village. Bush farm darker in tone with rougher texture. Trees narrow crowned and less conspicuous. More often located on the lower valley slopes. Bush fallow has rougher texture and darker tone as vegetation grows. (see also photo 16).

24 Tree plantations None in the test area.

3 Uncultivated

31 Fadama Dark tone but can be light. Very uniform, smooth texture. Very few trees, only grass. Usually sharp edges often bordered by a marked low bluff. Located in wide valley bottoms and fringed by farmland which often encroaches onto it.

32 Grassland not in fadama Medium toned with a uniform texture. Usually some shrubs in clumps. Associated with ironpan or rock outcrop at the interfluves.

33 Scrub and small trees Medium tone and varying texture. Usually some larger trees. In association with farmland

but darker in tone and not patterned. A stage towards woodland.

34 Swamps and marshes Limited occurrence in the test area.

35 Woodland Medium tone, very rough varied texture. Some individual trees larger but generally a uniform pattern.

36 Gallery forest and kurame Very dark, rough textured. Sharp outlines. Narrow linear features along streams or at the base of inselbergs.

4 Barren land

41 Bare rock outcrop Light to dark in tone depending on illumination and algal or lichenal growth. Slight texturing. No regular pattern. Some rock outcrops rise sharply out of their surroundings, giving strong shadows. Others outcrop at interfluves as scarps or flat bare surfaces.

42 Rivers streams and lakes Not usually visible except by association with trees and forest along the stream course. Winding course either incised or across fadama. (see photo 17). Where the river is large sand banks show as very light, water as any tone from dark to light.

4.6 SUMMARY

4.61 Two sets of 1:25 000 scale aerial photography were available for interpretation. The first was taken in November 1950, the second dated from February 1972. Maps were also available at 1:50 000 scale in provisional and first (contoured) editions.

4.62 A mirror steroscope with binocular attachment was used for interpretation. Trials with a CP1 stereoplotter were discontinued because the time taken in setting up the model was not counterbalanced by the higher magnification and scanning motion. An APPLE II micro-computer was used for data storage and analysis.

4.63 Systematic dot grids were used for sampling. They have advantages of speed and convenience over discrete area measurement and are acceptably accurate. Formulae developed by Bonnor (1975) and Brunt (1966) were used to determine the accuracy of the sample which depends on the number of dots and the proporion of the land use category to the total area. Precision of change estimation depends on the accuracy of the two samples from which it is calculated.

4.64 An optimum dot density of 8.5 dots per sq km was chosen from a trial sample of land use in the test area. Consideration was given to previous studies, work load, convenient dot density, and an acceptable precision of +/- 2 1/2% when calculating the optimum.

4.65 A rectangular 72 dot grid was placed at the centre of each stereomodel on the 1972 photography. The 1950 sample was positioned at the same points by the Union Jack method.

4.66 Data were stored on computer disc using standard BASIC programmes.

4.67 A test for repeatability of sampling gave a 2.8% difference between first and second samples of the same points. Little reliance can be placed on this figure because the sample was small, the observer was the same, and the interval between sampling was short. The test was made when experience of the area was minimal.

4.68 Problems of interpretation arise because of gradation of categories into one another and of the exact location of a sample. Human factors also influence the work which is subjective in nature.

4.69 Notes are given on the appearance and interpretation of each land use category in the test area.

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Photograph 13

Examples of classification (1)

11 Settlement 12 Communications 22 Enclosed farmland over 10ha.

23 Unenclosed farmland & early bush fallow

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Photograph 14

Examples of classification (2)

21 Enclosed farmland under 10ha. 31 Fadama 32 Grassland not in fadama 33 Scrub and small trees

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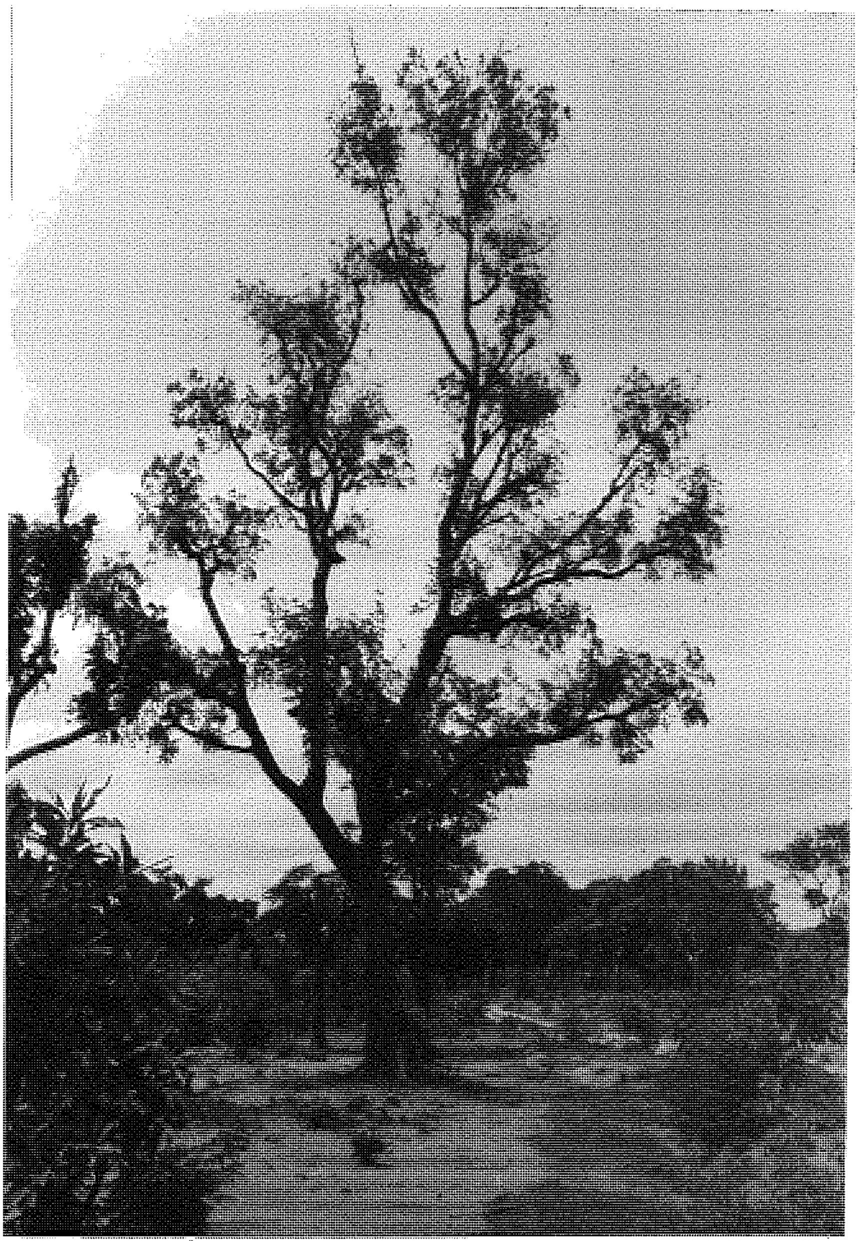
Photograph 15

Examples of classification (3)

35 Woodland 36 Gallery forest & kurame 41 Bare rock outcrop

42 Rivers streams & lakes



Photograph 16

Bush fallow

which has not progressed far enough for fertility to be restored. Note the bare ground.

Photograph 17

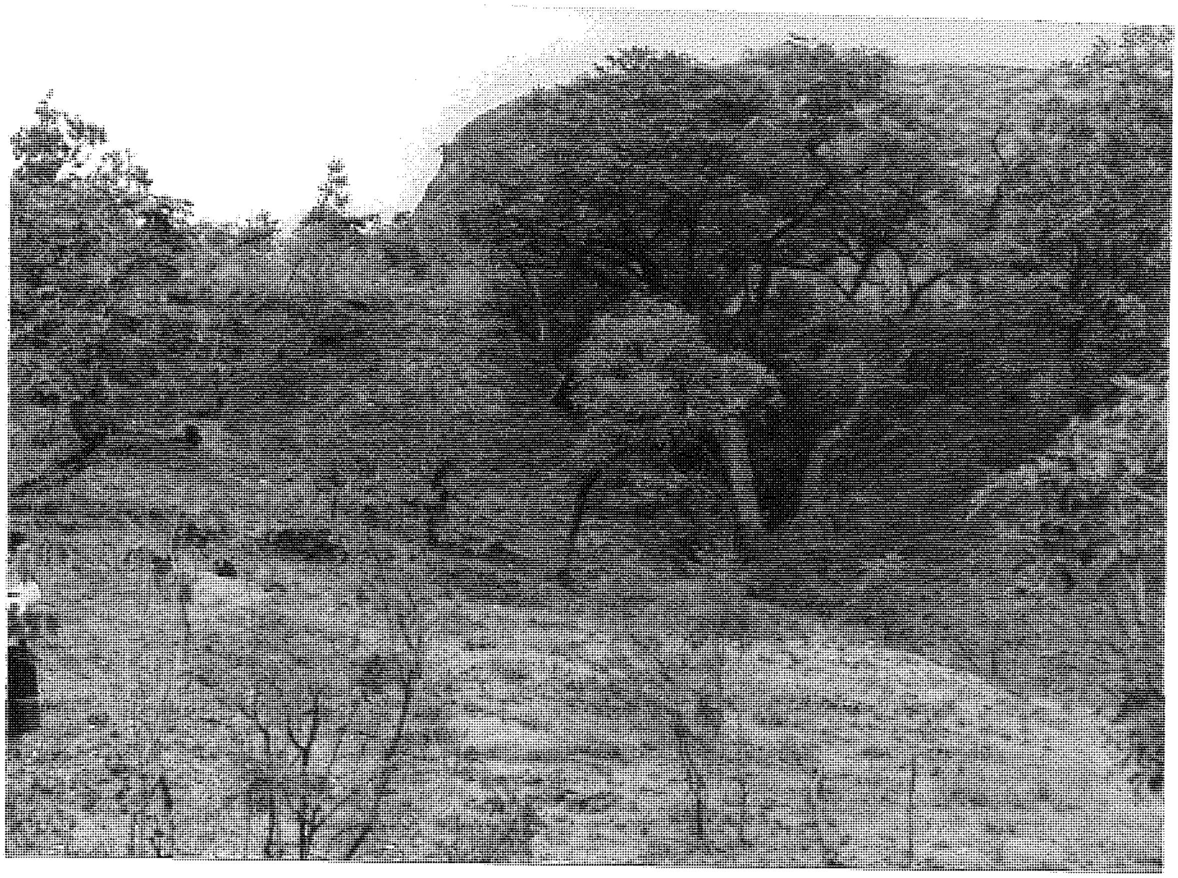
Gully erosion

Deep gully in alluvium, farmland on the right, woodland on the left.

Photograph 18

Woodland (1)

with an inselberg in the background



Photograph 19

Woodland (2)

with a gully developed below a scarp of secondary ironpan.

Photograph 20

Gallery forest

beside a stream. The large tree is a dinya - black plum.

CHAPTER FIVE

PROPORTIONS & CHANGES

5.1 LAND USE PROPORTIONS

5.10 The tables and pie charts tables 27-29, figures 10-14 show the proportions of land use extrapolated from the samples taken from the 1950 and 1972 photographs.

5.11 Proportions from the 1950 sample

The Kajuru area had a very low intensity of land use in 1950. Only 12 1/2% was under cultivation and over four-fifths of the land was covered by natural vegetation. Barren land made up 31 sq km (4.1%) of the 750 sq km test area, mainly in the rocky hills of the south east. Settlement was less than 1%, being spread very thinly indeed apart from three or four small villages.

Within the group 1 Settlement & associated features the category 12 Communications appears most frequently with 42 out of 58 occurrences. The estimate of 5.3 sq km occupied by roads, railways and footpaths is probably high for reasons which were explained in chapter 4. On the other hand 11 Settlement is probably under estimated. Huts are circular, not more than 3 metres in radius, less than 1/4 mm across at 1:25 000 scale; they have grass roofs.

Compounds are often unfenced and the vegetation comes right up to the doorway, through it if you are not careful. Altogether this feature is very difficult to see on the aerial photographs. There are no population figures available for the Kajuru area itself but the density was obviously very low. 13Industry is not represented in the sample and probably did not occur anywhere.

The 94 sq km under cultivation was almost entirely made up of 23 Unenclosed farmland & early bush fallow. This was mostly "bush farm" cleared out of the surrounding woodland and cultivated for a few years before being allowed to return to the bush. Very few farms show the prominent ridges and large isolated trees which occur in the permanent "home farm". There was plenty of land and extensive cultivation was the normal farming method; now it is restricted to a few places (Gosden 1978 vol 2 p161). There are two records of small enclosed farms (category 21). These are usually but not always irrigated; hence the fences to stop goats and cattle getting at the green vegetation when everything else is parched and brown.

Over four-fifths of the Kajuru area was uncultivated in 1950, just over half of it under 35 Woodland or 36 Gallery forest and Kurame. These two categories are the predominant and maybe original land cover. Although some areas may have been farmed in the past there would have been sufficient time for traces of cultivation to have disappeared. Probably most of it had not been farmed, when

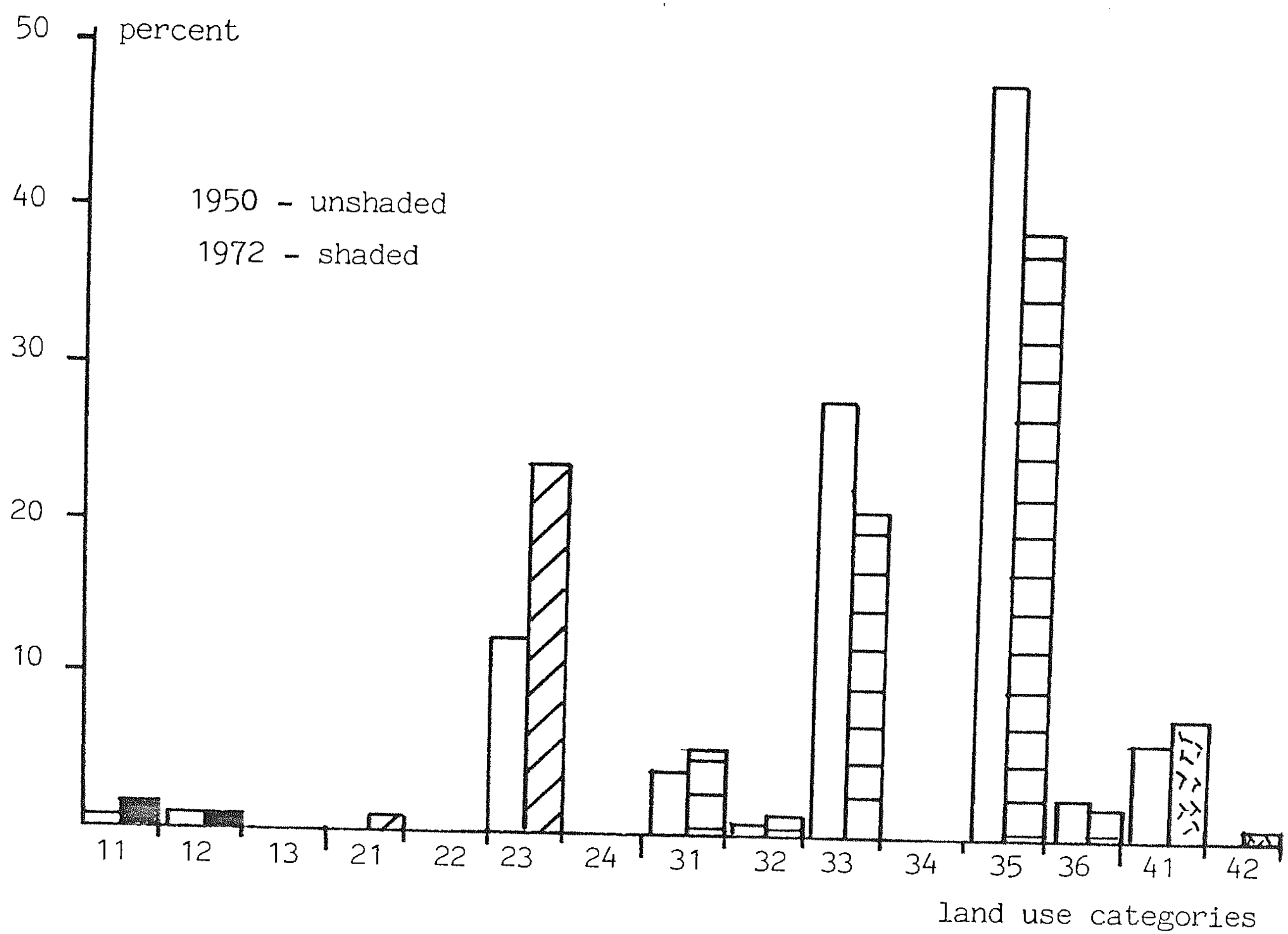


Fig 10 Land use by category.

TABLE 27

LAND USE SAMPLE 1950

Category	No	%	E%	km2	max%	max at model
1 Settlement & associated features						
	58	0.9	14.5	6.8		
11Settlement	16	0.2	30.6	1.5	4.2	78
12Communications	42	0.7	17.5	5.3	8.3	6
13Industry	0	0				
2 Cultivated	803	12.5	3.2	94.0		
21Enc.farm under 10ha	2	0.0	102.2	0.2	2.8	44
22Enc.farm 10ha & over	0	0				
23Unenc. farm & b.f.	801	12.5	3.2	93.8	41.7	11
24Tree plantations	0	0				
3 Uncultivated	5283	82.4	1.1	617.9		
31Fadama	263	4.1	6.0	30.8	30.6	19
32Grass not in 31	21	0.3	26.1	2.2	12.5	19
33Scrub & small trees	1763	27.5	2.0	206.2	75.0	39
34Swamps & marshes	0	0				
35Woodland	3071	47.9	1.4	359.2	88.9	5
36Gallery for & kurame	165	2.6	7.9	19.5	31.9	69
4 Barren land	264	4.1	6.0	31.2		
41Bare rock outcrop	261	4.1	6.1	30.8	44.4	73
42Rivers,streams etc	3	0.0	80.8	0.4	1.4	80
	6408	99.9		749.9		

Note: E% calculated from Bonnor's formula.

land is plentiful only the most rewarding will be chosen, the rest being exploited for hunting, natural products, firewood and grazing. 33 Scrub & small trees cover 27.5%. In 1950 most of this category was probably found where woodland did not develop because soils were shallow or where there was little moisture in the ground. As the amount of farmland was small there was little scrub formed by the later stages of bush fallow. The fallow period being long (20-30 years) savanna woodland was formed, large trees scattered in the grassland. (Hopkins 1972)

Category 31 Fadama occupied 30.8 sq km. It is not easy to pick out on the low contrast 1950 photographs. This is not the only reason why fadama is difficult to see. In 1950 woodland and grassland dotted with trees graded into the fadama without any clear boundary; the break of slope at the valley bottom edge not being accompanied by any marked tonal change. Because of this the category was probably under estimated.

4 Barren land made up the remaining 4.1% mainly as outcrops of rock or ironpan. This again is probably under estimated. The low contrast of the 1950 prints makes it difficult to tell low relief rock outcrops from the grass land or farms in which they lie.

5.12 Proportions from the 1972 sample

Twenty two years after the first sample the proportions of land use had changed markedly. The pattern of land use was more complex with more occurrences of the smaller categories. Part of this may have been a result of clearer photographs making for easier identification of small features, but a genuine spread of human activity had left its mark.

1 Settlement & associated features now occupy 2% with 11 Settlement proper covering 9 sq km. The single scattered compounds are still difficult to see but much of the increase is in the growth of large villages along the roads. 12 Communications have remained stable at 0.8% and there is no occurrence of 13 Industry. Kajuru in 1972 remained truly rural.

2 Cultivation at 24.2% had doubled since 1950, still mainly 23 Unenclosed farmland & early bush fallow. Much more of this category was farmed over a long period. The sharply defined boundaries, clearly shown ridges, and large isolated trees suggest that the farm is not here today and gone somewhere else next year. 21 Enclosed farmland under 10 ha now covers a much bigger area of 2.2 sq km although it is still rare here compared with other areas close by. The sample did not pick up any large enclosed farms (category 22) but one actually existed, the Prison Farm at Kujama.

With over two-thirds uncultivated Kajuru could not be said to suffer from over population, although Fulani graziers would use much of this land. 35 Woodland and 36 Gallery forest & kurame are the dominant land use at 40%. (see photos 18, 19, 20) 33 Scrub & small trees cover 21% (157.5 sq km) much more of this being the later stages of bush fallow and cut over woodland. 31 Fadama occupies 42 sq km. It is much more clearly demarcated in the 1972 prints and can therefore be estimated quite precisely. Cultivated fadama is placed in one of the farmland categories. 4 Barren land covers 5.1%, a slight increase partly due to easier identification.

5.13 Accuracy

In the tables 27,28 and 29 E% is calculated from Bonnor's formula (Bonnor 1975; discussed in section 4.33 above). The factor E% is defined as half the width of the 95% confidence interval for maximum error. Category 23 for instance is estimated to an accuracy of +/-3.2% (1950) and +/-2.2% (1972). It is 95% certain that the area lies in the range 117.8-69.8 sq km in 1950 and 195.7-162.7 sq km in 1972. The figures for category 35 are 369.7-348.7 sq km in 1950 and 302.2-278.2 sq km in 1972. The ranges of values and their different sizes are related only to the proportion of the total area in the category and the dot density. There is no allowance for the fact that some of the identifications may be wrong. Van Genderen (1977) writing about this problem suggests that four main aspects need to be considered when the sample is designed:

1. How often land use type 'A' is wrongly assigned to another category.
2. How often land use type 'A' is wrongly

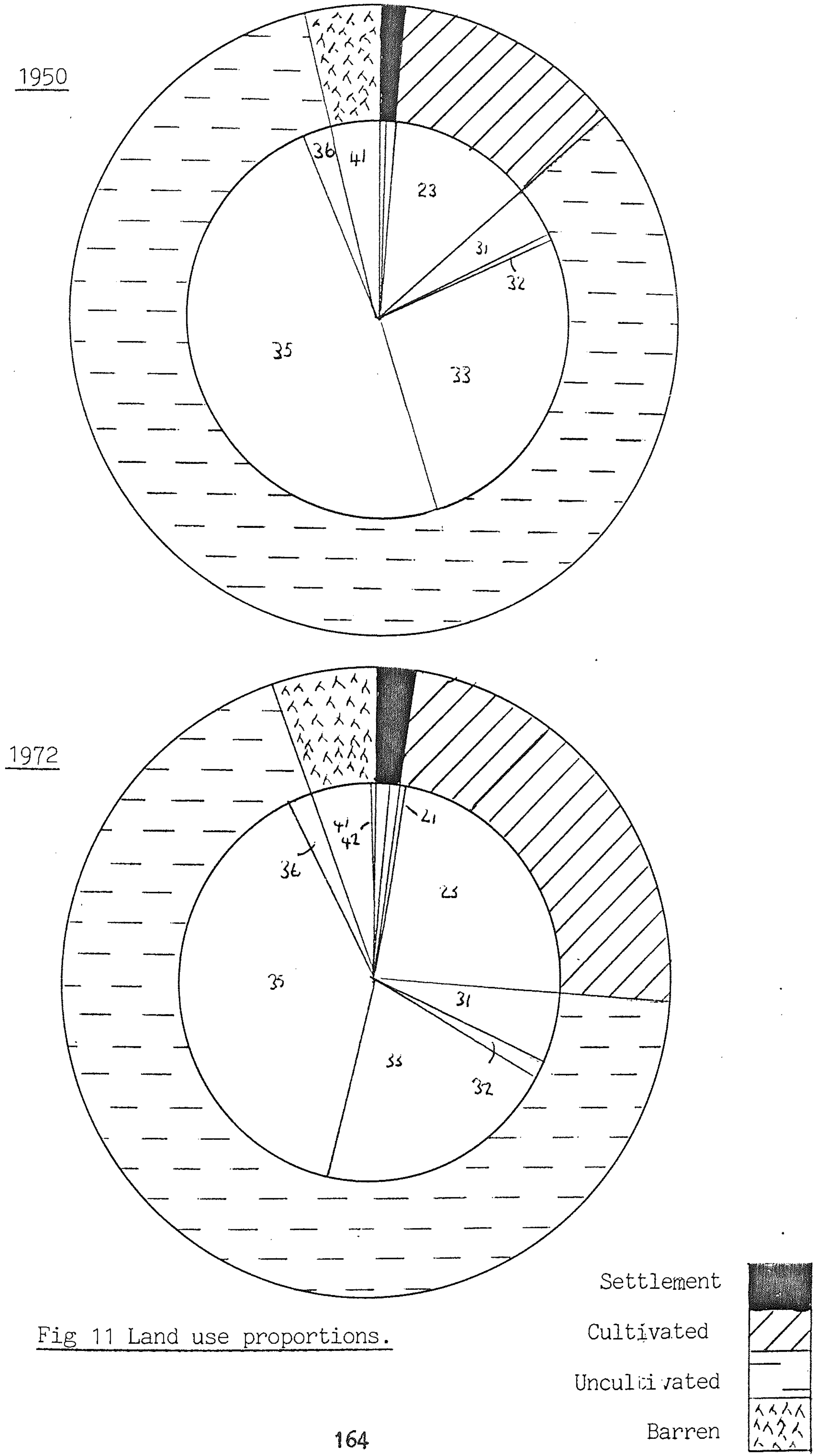


Fig 11 Land use proportions.

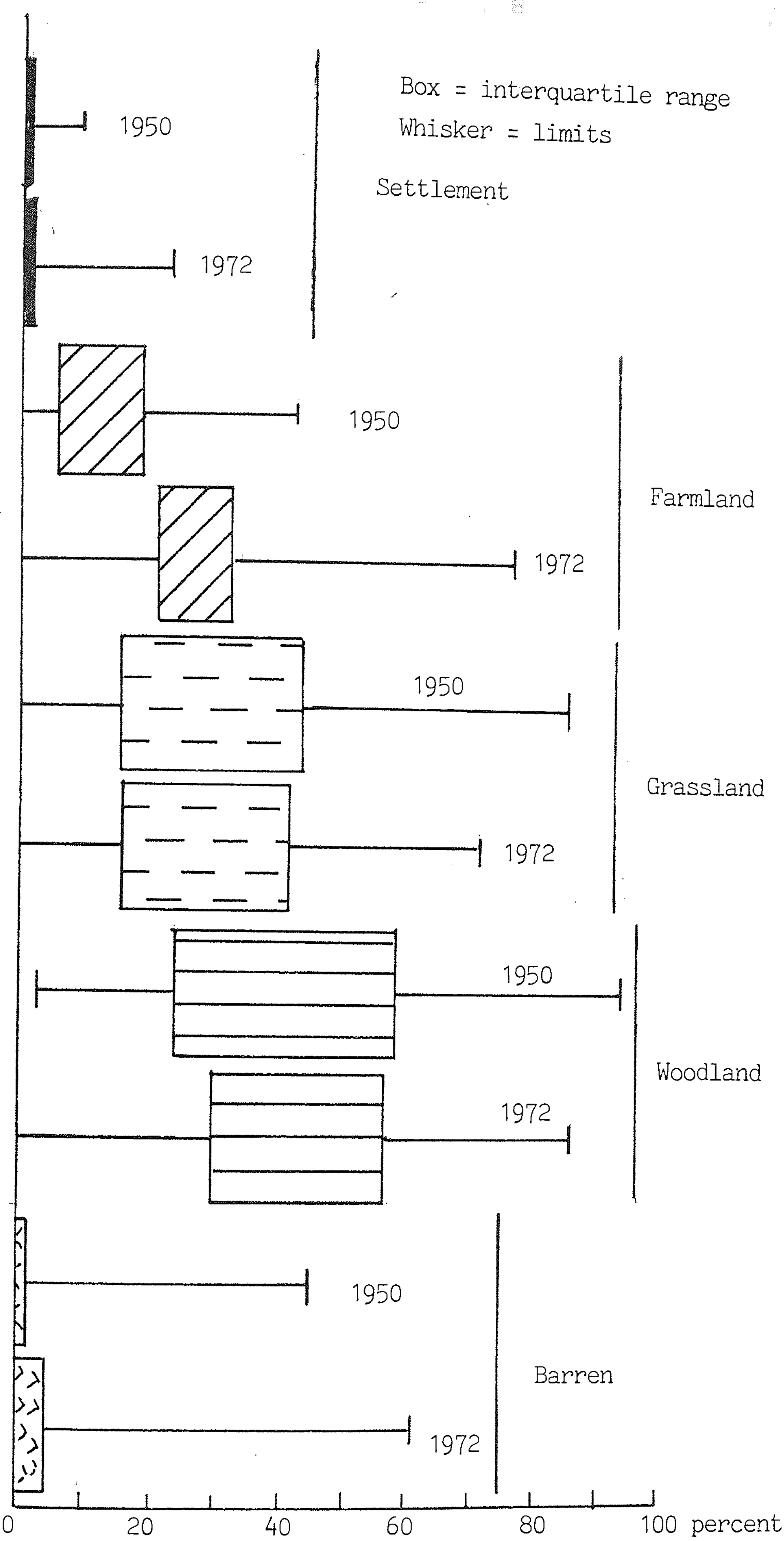


Fig 12 Major land use distribution 1950 & 1972.

TABLE 28

LAND USE SAMPLE 1972

Category	No	%	E%	km2	max% model	Max at
1 Settlement & associated features	129	2.0	9.2	15.0		
11Settlement	77	1.2	12.3	9.0	20.8	37
12Communications	52	0.8	15.4	6.0	6.9	13
12Industry	0	0				
2 Cultivated	1547	24.2	2.2	181.4		
21Enc.farm under 10ha.	17	0.3	29.5	2.2	4.2	37
22Enc.farm 10ha & over	0	0				
23Unenc. farm & b.f.	1530	23.9	2.2	179.2	72.2	37
24Tree plantations	0	0				
3 Cultivated	4387	68.5	1.2	513.8		
31Fadama	361	5.6	5.0	42.0	34.7	44
32Grass not in 31	77	1.2	12.3	9.0	20.8	60
33Scrub & small trees	1343	21.0	2.3	157.6	70.8	13
34Swamps & marshes	1	0.0	152.7	0.1	1.4	86
35Woodland	2478	38.7	1.6	290.2	80.6	80
36Gallery for & kurame	127	2.0	9.2	15.0	16.7	74
4 Barren land	345	5.4	5.1	40.6		
41Bare rock outcrop	337	5.3	5.2	39.8	61.1	88
32Rivers,streams etc	8	0.1	45.7	0.8	1.4	86
	6408	100.1		750.8		

Note: E% calculated from Bonnor's formula assigned to category 'B'.

3. The proportion of all identifications which are wrong.

4. Whether mistakes are randomly distributed.

The difficulties of identification have already been discussed in chapters 3 and 4. They are not the same across the whole classification and mistakes are certainly not random. However it does not seem possible to quantify the problem except in an ideal situation. If photographs were taken and a sample from them immediately compared with a ground survey questions 1-4 above could be answered. But if you are monitoring land use changes at least one set of photographs must be old and the interpretation cannot be checked. More likely both sets will be old and ground comparison will not be possible except in the most general way. P O Adeniyi studied land use change in Lagos using aerial photography taken in 1962 and 1974. Fieldwork was done in 1977 giving gaps of 15 years and 3 years between photography and ground survey. The only features which he could assume to be in the same place were big easily recognisable objects like schools, markets and GRA (Government Residential Area) boundaries (Adeniyi 1980). The important safeguard was that the observer knew the area well and could use his local knowledge to find the correct category. If monitoring is to be done successfully the skill and local knowledge of the observer are crucial, and virtually uncheckable, factors in determining the accuracy of the result.

5.2 CHANGES 1950 - 1972

5.21 Significance testing

When the two samples were taken and the proportions of each land use category had been calculated it was possible to deduce the changes which had taken place in the 22 years between 1950 and 1972. The samples are subject to error of which the tabulated values of E% are a partial estimation. Each dot is placed at the same location on the two sets of prints and a pair of samples will be obtained whose differences can be listed. Are these differences significant? If the extrapolated total areas from the two years +/-E% do not overlap then they are, as the change will be 95% certain to be real, not due to the vagaries of sampling. The reliability of the value for change will depend on the propagation of sampling errors thus:

$$(dE\%)^2 = (E\%_{1950})^2 + (E\%_{1972})^2$$

The Wilcoxon signed-rank test can be applied to the paired samples to test the null hypothesis that the differences between them have a median of zero (Clarke et al 1983). Table 30 shows the result of this test. As the sample is large the standard normal deviate is computed and found to exceed the 95% confidence level value. The null hypothesis is rejected and the alternative hypothesis accepted implying that the two populations are distinct from one another. There has been significant change in land use in the area.

5.22 Category changes

Are shown in figures 13 and 14 and also in table 29. Over 22 years there was a general increase in settlement and cultivation with a corresponding decrease in uncultivated land. Farmland doubled, adding an average of 400 hectares every year or 8500 ha in all. Allowing a generous average of 7 hectares for a family (Gosden 1978 vol i p41) this would support 6000 or more people. There was a general loss of woody vegetation, the three categories 33,35,36 losing 20% of their area. An annual average of 5.6 sq km was cleared, 122.2 sq km altogether. The loss was not entirely to settlement and agriculture, small gains being recorded by grassland and bare rock outcrops which were replacing the thicker vegetation.

1 Settlement & associated features increased by 1% of the total, or 8.2 sq km. Most of this was in 11 Settlement which increased 5 times.

2 Cultivated land showed a significant increase of 93% of the 1950 value or 11.7% of the total gaining 87.4 sq km mostly in unenclosed farmland (category 23). There was also an important growth of small enclosed farms (Category 21).

3 Uncultivated land decreased by 13.9% losing 104.1 sq km 35 Woodland and 36Gallery forest & kurame recorded the largest decline of nearly 20% of the 1950 value. A total of 73.5 sq km was lost over 22 years. 33 Scrub & small trees also decreased losing 48.7 sq km or a quarter of the 1950 area. The two grassland categories 31 & 32

recorded small gains as the result of the losses in the other categories.

4 Barren land increased by 1.3%. The general decrease in woodland and scrub will have removed a lot of vegetation and exposed more bare rock to view. The clearer 1972 prints will also make it easier to see.

5.3 DISTRIBUTION OF LAND USE

5.30 The 15 categories of land use have been collected into five groups for further discussion and analysis. They are listed in Table 31. The groups are: Settlement, Farmland, Grass & scrub, Woodland, and Barren land. Each group is quite large in size and can be estimated with reasonable accuracy. Settlement is a special case which does not merge satisfactorily with anything else. Each of the 89 stereo-models is treated as a separate sample unit containing 72 point observations. Frequency counts and histograms are calculated for each model. The frequency and distribution diagrams show the test area, main roads and the railway in more or less their correct relationships, resembling maps of the London Underground in this if in no other way.

5.31 Settlement was very sparse in 1950 with only 57 recorded occurrences in 6408 observations. On most models there was none. The upper limits were low, a maximum of 6 points on one model and the upper quartile of 1.4% represented only 1 occurrence in a 72 point model. The

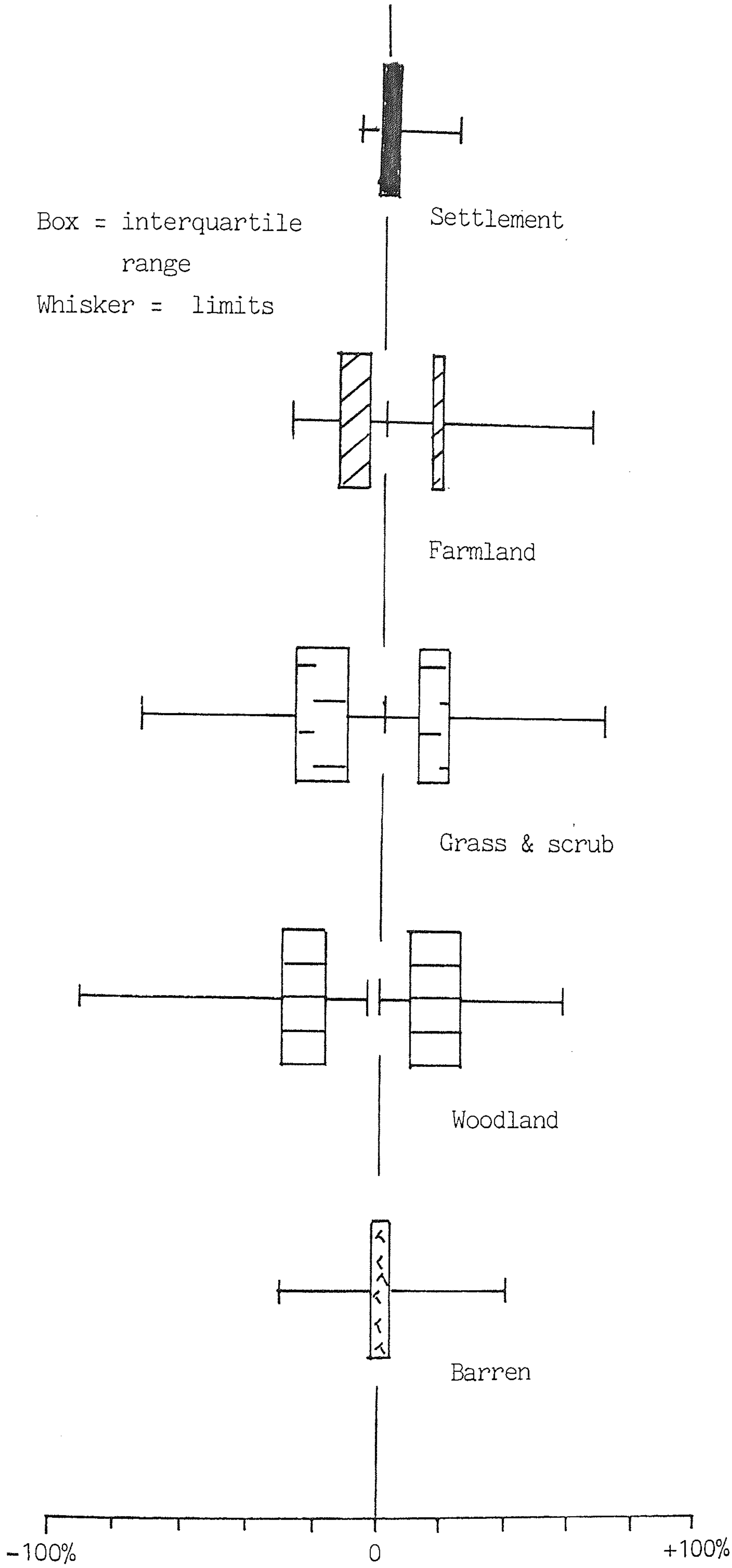
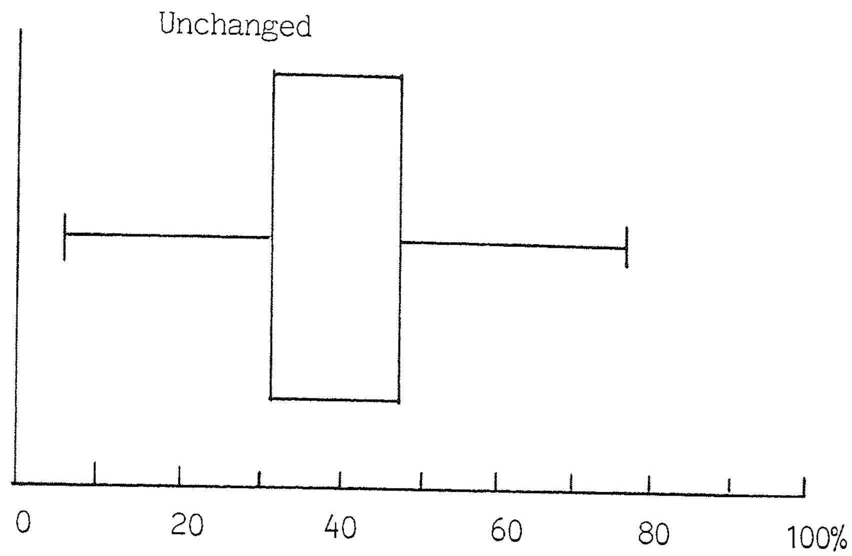
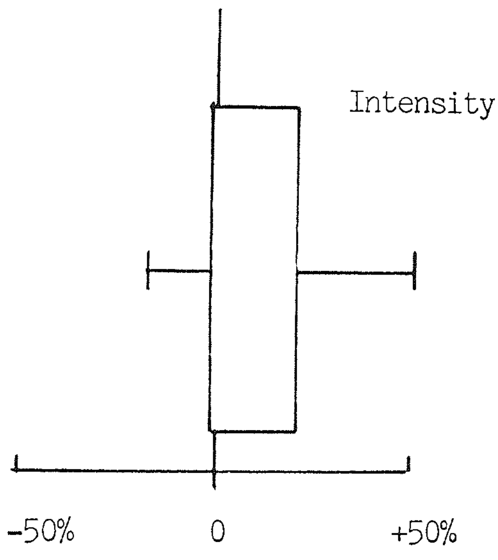


Fig 13 Changes in major land use 1950/72





Box = interquartile range

Whisker = limits

Fig 14 Changes in intensity of land use

T A B L E 29

LAND USE CHANGES

1950 - 1972

Category	Area sq km 1950	1972	change	Change % of 1950	of total	dE
1 Settlement & associated features	6.8	15.0	+8.2	+120	+1.1	17.2
11Settlement	1.5	9.0	+7.5	+500	+1.0	33.0
12Communications	5.3	6.0	+0.7	+13.2	+0.1	23.3
13Industry	0	0				
2 Cultivated	94.0	181.4	+87.4	+93.0	+11.7	3.9
21Enc.farm under 10ha	0.2	2.2	+2.0	+1000	+0.3	106.4
22Enc.farm 10ha & over	0	0				
23Unenc.farm & b.f.	93.8	179.2	+85.4	+91.0	+11.4	3.9
24Tree plant-ations	0	0				
3 Uncultivated	617.9	513.8	-104.1	-16.8	-13.9	1.6
31Fadama	30.8	42.0	+11.2	+36.4	+1.5	7.8
32Grassland not in 31	2.2	9.0	+6.8	+309	+0.9	28.9
33Scrub & small trees	206.2	157.5	-48.7	-33.6	-6.5	3.0
34Swamps &						

marshes	0	0.1	+0.1	nil	+0.0	--
35Woodland	359.2	290.2	-69.0	-19.2	-9.2	2.1
36Gallery for						
.& kurame	19.5	15.0	-4.5	-23.1	-0.6	12.1
4 <u>Barren land</u>	<u>31.2</u>	<u>40.6</u>	<u>+9.4</u>	<u>+30.5</u>	<u>+1.3</u>	<u>7.9</u>
41Bare rock out-						
crop	30.8	39.8	+9.0	+29.2	+1.2	8.0
42Rivers,streams						
etc	0.4	0.8	+0.4	+100	+0.1	92.8
	749.9	750.8	+0.9		+0.2	

Note: $dE = (E1^2 + E2^2)^{1/2}$

TABLE 30

WILCOXON SIGNED - RANK TEST

<u>Differences</u>	<u>Number</u>	<u>Sum of ranks</u>
Sample 1950 less than 1972	32	1009
Sample 1972 less than 1950	57	2996
Sample 1950 = 1972	0	
Standard normal deviate	-4.06	

Algorithm 10.3 Cooke et al (1982)

TABLE 31

LAND USE GROUPS

FOR ANAYLSIS

Group	1950 %	1950 area km2	1950 E%	1972 %	1972 area km2	1972 E%	changes km2
Settlement							
11 - 13	0.9	6.8	14.5	2.0	15.0	9.2	+ 8.2
Farmland							
21 - 24	12.5	94.0	3.2	24.2	181.4	2.2	+87.4
Grass & scrub							
31 - 34	31.0	239.2	1.8	27.8	208.6	2.0	-30.6
Woodland							
35 - 36	50.5	378.7	1.4	40.7	305.2	1.6	-73.5
Barren							
41 - 42	4.1	31.2	6.0	5.4	40.6	5.1	+ 9.4
Totals	99.9	749.9		100.1	750.8		+ 0.9

frequency diagram (figure 16) shows that settlement concentrated on the old villages of Kujama, Kajuru (photo 21) and Kufana. These are sited each at the foot of a high inselberg. There is a scatter of settlement over the rest of the area. Bear in mind that some of the dots will be communications not compounds. By 1972 settlement had doubled to cover 2% of the area. A large number of models had no recorded occurrences; but the median was slightly higher at 1 per model. (table 32). The histogram (figure 15) shows that most of the increase was in a few places, the frequency and distribution diagrams locating increases along the main road in the north east and near the railway stations. Decreases occurred mostly in the hilly area of the south east. The settlement distribution has changed, the attractions of the roads and railway being shown in the diagrams.

The main road in 1950 was narrow and surfaced with laterite. It was constructed on the military principle, go as far as possible in one direction then turn sharply onto a new bearing. The track and settlement pattern disregarded the road which ran through lightly wooded countryside about its own private business, which seemed to be to go from Kaduna to Kachia along the line of least resistance. By 1972 the settlement pattern had adjusted itself to the road which had itself changed into a hard surfaced properly constructed highway. The tracks and main footpaths now radiated from new villages which had grown up by the roadside. The cross-country footpaths that had not

TABLE 32

DISTRIBUTION OF CHANGES IN LAND USE %

Group		lower limit	lower quartile	Median	Mean	upper quartile	upper limit	skew	kurtosis
Settlement	1950	0	0	0	0.9	1.4	8.3	46.4	56.5
	1972	0	0	1.4	2.0	2.8	22.2	2.0	5.0
Farmland	1950	0	5.6	12.5	12.5	18.1	41.7	0.0	2.0
	1972	0	20.8	20.8	24.1	33.3	76.4	1.5	4.4
Grass & Scrub	1950	0	15.3	30.6	31.9	43.1	84.7	0.0	2.3
	1972	0	15.3	25.0	27.8	41.7	70.8	0.8	4.0
Woodland	1950	2.8	23.6	54.2	50.5	58.3	93.1	0.0	2.0
	1972	0	29.2	44.4	40.6	56.9	86.1	0.0	2.1
Barren	1950	0	0	1.4	4.1	1.4	44.4	9.8	13.3
	1972	0	0	1.4	5.4	4.2	61.1	9.0	12.7

been converted into roads were far less distinct and therefore probably far less used. Why walk when you can catch a bus? An example of this is the track southwards from Kajuru village to Katura station (photo 22). There was a new road from Kajuru to the railway station, but the road from Kajuru to Kaua and the fertile fadama farmlands near the Kaduna river had been replaced by a direct route to the main road.

Three examples are shown of villages developing along the main road. Rido stretches along the road with a well defined area of home farm dotted with large trees. A network of tracks and paths leads from it in all directions into the bush. In 1950 there was no settlement nearby and onlv bush farms in the area. (see figure 21 and photo 23). The village of Kujama was originally on top of the inselberg, ruins can still be seen there if you climb the hill. The new site is at the base of the hill close to a small stream. The main road makes a detour round the inselberg and Kujama is connected to it by 2-3 km of motorable tracks. By 1972 another village, aptly known as Kasuwan Kona (Hausa for Corner Market) existed at one of the road corners and a wide main track ran northwards from it (figure 22 & photo 24).

The village of Kujama itself had changed little in 22 years. The last example, Kasuwan Magani (Hausa for Medicine Market - actually a dispensary) is a small town which has developed from nothing over the period (photo 25

TABLE 33

DISTRIBUTION OF CHANGES IN LAND USE %

Group		lower limit	lower quartile	Median	Mean	upper quartile	upper limit	skew	kurtosis	change
Settlement	plus	0	0	1.4	1.9	2.8	22.2	2.0	5.6	ha. +838
	minus	0	0	0	0.8	1.4	6.9	51.9	61.4	
Farmland	plus	0	13.9	16.7	19.8	18.1	63.9	1.6	4.8	+8707
	minus	0	4.2	6.9	8.2	13.9	27.8	0.0	2.0	
Grass & Scrub	plus	0	11.1	18.1	17.3	19.4	70.8	4.9	8.1	-3113
	minus	0	12.5	20.8	21.5	25.0	73.6	0.0	2.5	
Woodland	plus	0	8.3	19.4	16.2	27.8	58.3	0.7	3.5	-7393
	minus	1.4	15.3	22.2	26.0	31.9	90.3	1.2	4.6	
Barren	plus	0	0	0	3.5	4.2	38.9	9.3	12.4	+945
	minus	0	0	1.4	2.2	1.4	30.6	7.1	13.4	
Total	intensity	-18.8	-2.3	4.1	7.0	19.7	50.9	2.0	6.8	
	same	5.6	30.6	41.7	41.2	47.2	76.4	0.3	3.6	

and figure 23). Apart from the dispensary and the market there are shops, schools and lots of pan roofed houses. A new road runs eastwards to Kaua replacing the one which used to go from Kajuru.

The railway has also attracted settlement near the two stations. At Kankomi, the northernmost, there was just a station in 1950 with some mango trees (big black blobs on the photograph) and a small village near the river (photo 26 and figure 24). In 1972 a large scattered village had grown up on level land to the west of the station and a track ran westwards from it. Kajuru station developed in the same way (photo 27). These villages have a different form from the roadside ones. They are scattered over a large area and do not cluster near the station. There is no need to be very close to the track whereas it is always an advantage to be on the roadside socialising with the travellers and selling them cigarettes, boiled sweets and petrol.

There are no new villages away from the main road and railway. The existing ones have not grown very much although there are many new compounds in new farmland. The old village of Kajuru (see figure 20) is 3 km from the main road. Although it is linked to it by a feeder road there was no growth in 22 years (see photos 28 & 29).

The river valley village of Buda grew only very slowly despite a large increase in fadama farming over the study period (photo 30 & figure 32).

5.32 Farmland

In 1950 the upper limit of farmland on any model was 41.7% by 1972 this had grown to 76.4%. There were still models without farmland but the median had increased from 12.5% to 20.8% and the mean had doubled.

The upper limit of changes to farmland was 63.9% with a median value of 16.7% (see figures 25-31). Distribution was not uniform. In 1950 most of the southern half of the area had less than 7% under farmland and only 4 models anywhere had over 30%. By 1972 farming had spread to the southern area although less than 30% was covered. The big increases were in the north east where 8 models had over 40% under cultivation and 15 were over 30%. The distribution diagrams (figure 27) show the general spread of cultivation over the whole area. Comparison of the diagrams showing changes (figures 28 and 29) shows that in the central area cultivation actually decreased.

Farmland is going to increase in three ways, by adding on to what is already there, by intensifying existing cultivation, or by moving into new areas. All these are happening in Kajuru, although intensification does not show up in the statistics it can often be inferred by looking at the photographs.

Taking up more land is what the farmers were doing in the

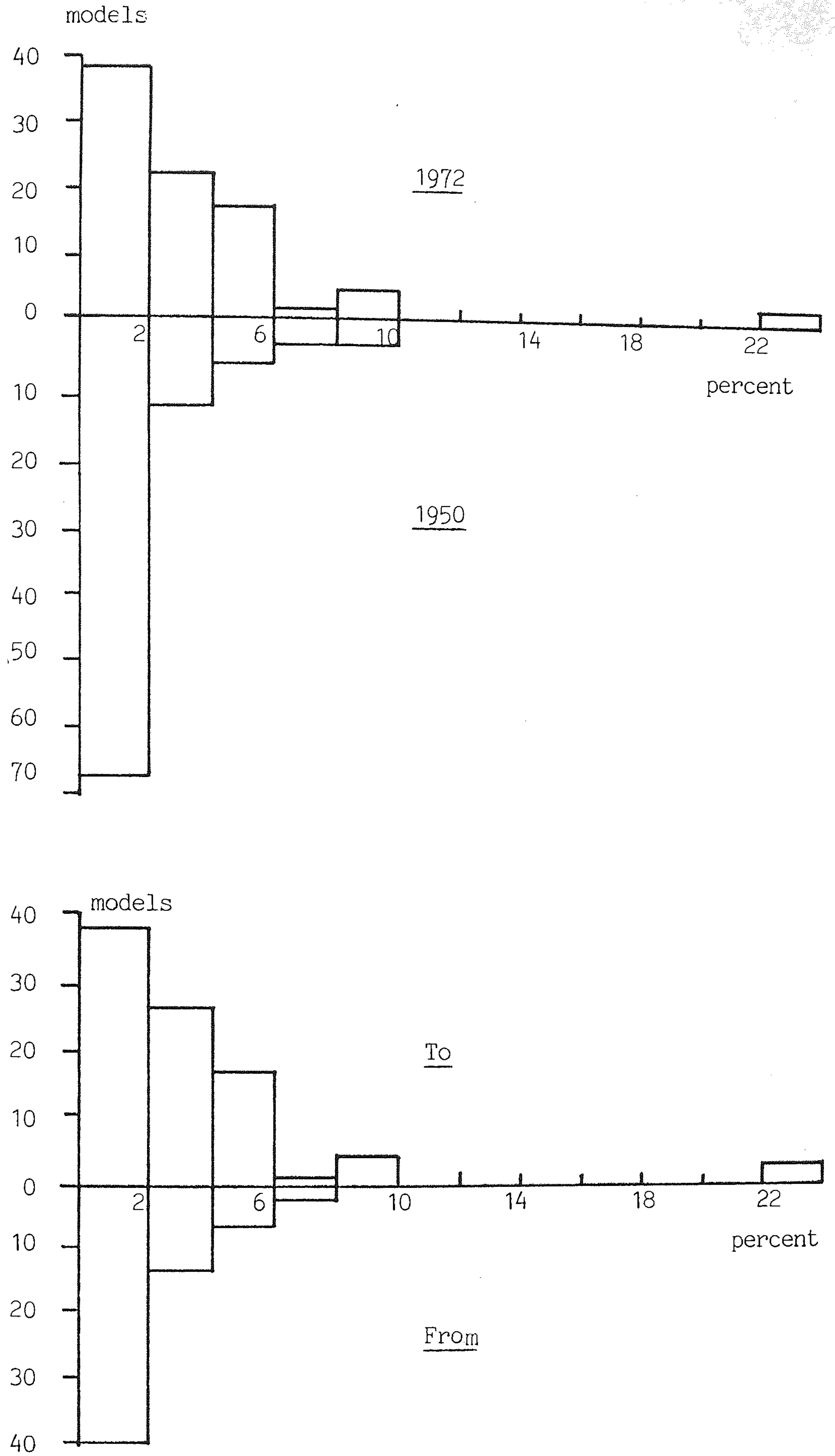
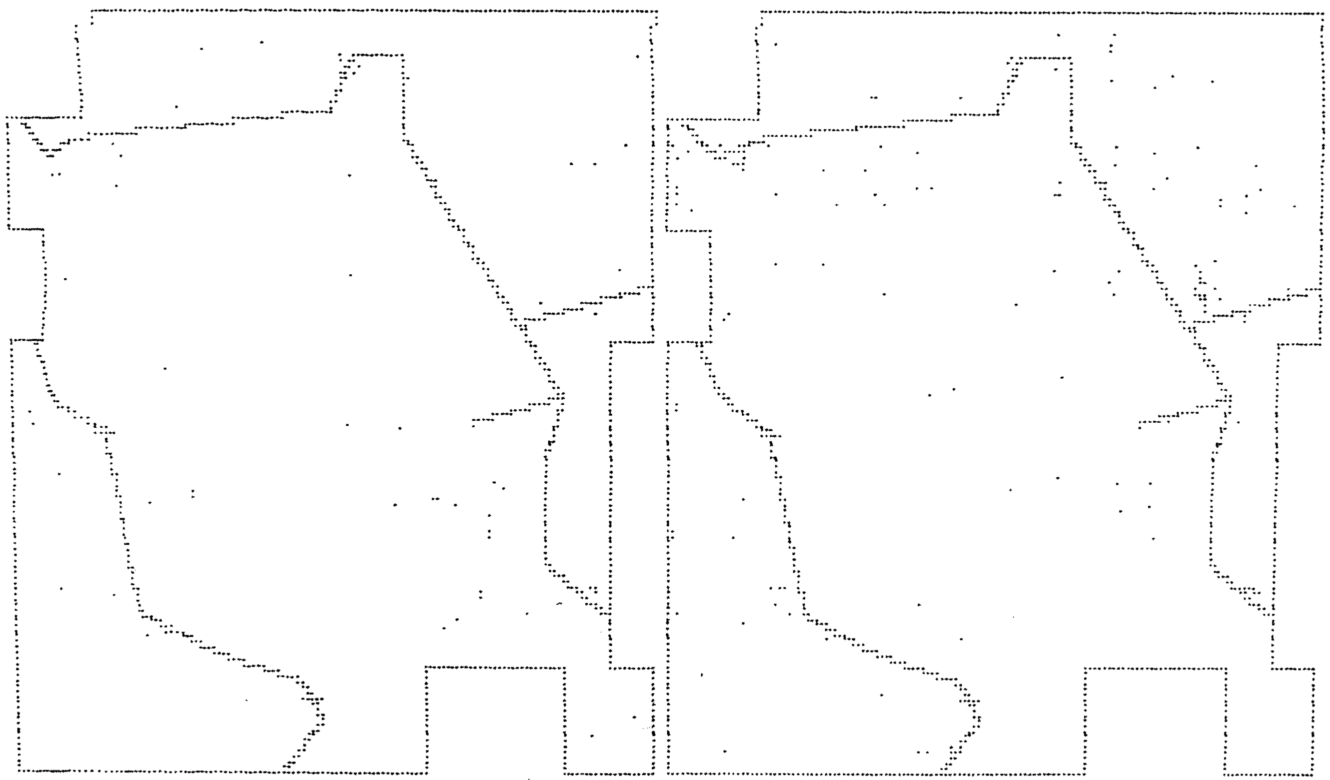


Fig. 15 Settlement



1950 1972

Fig 16 Distribution of settlement.

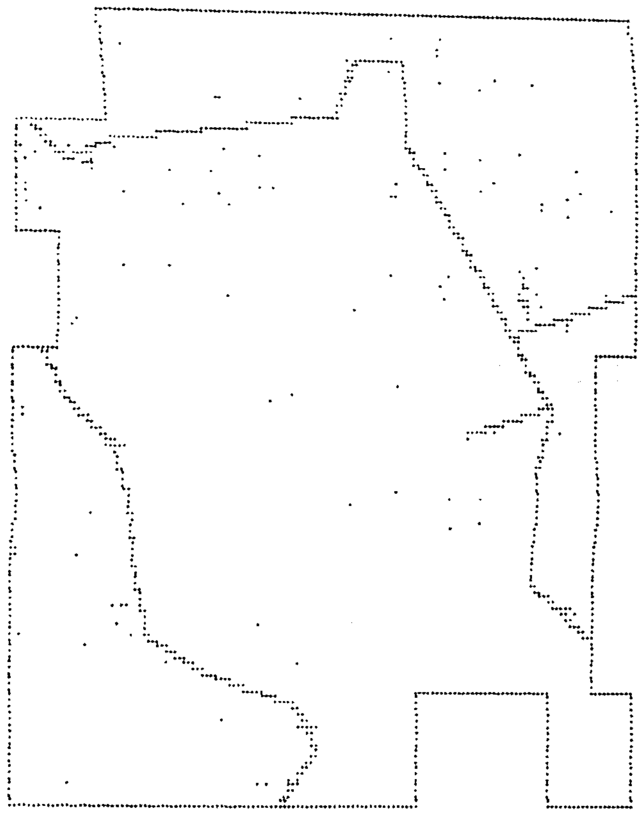


Fig 17 Changes to settlement 1950/72

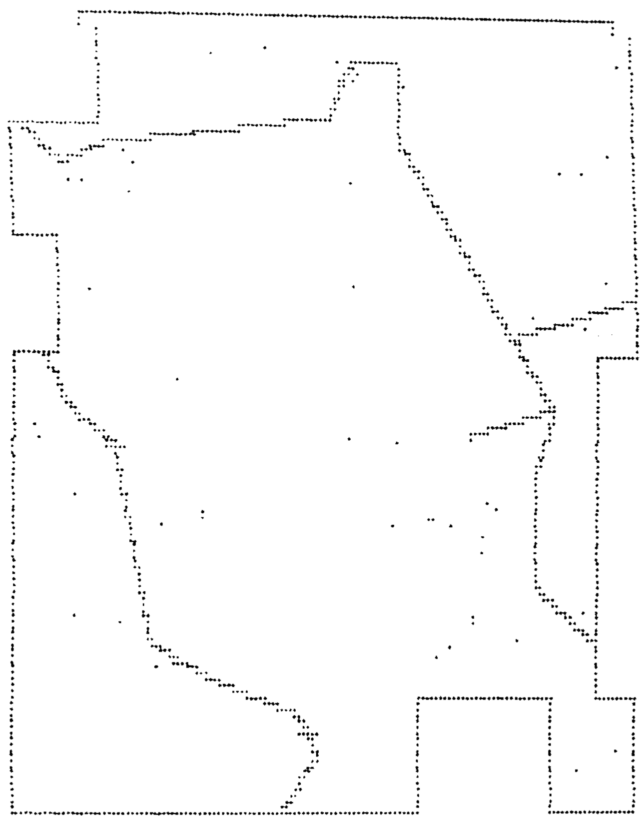
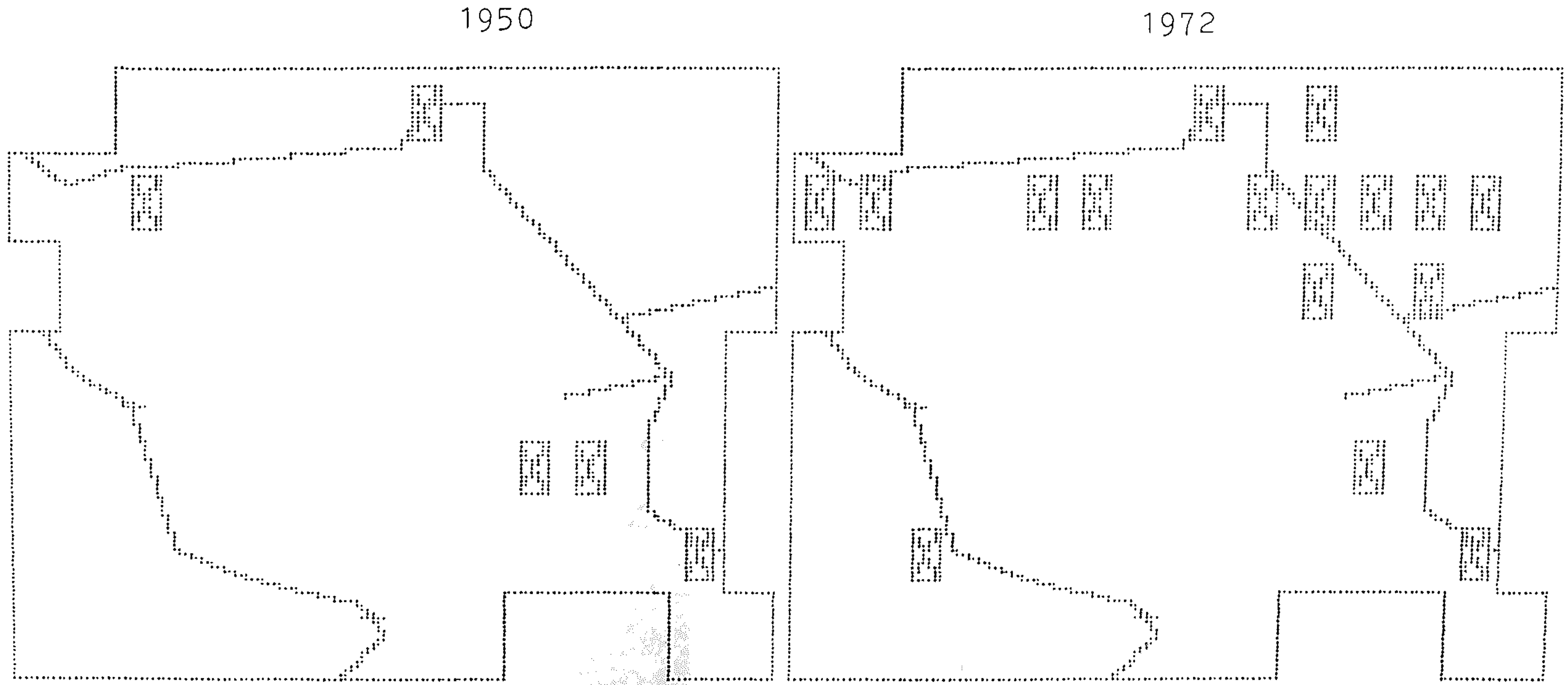
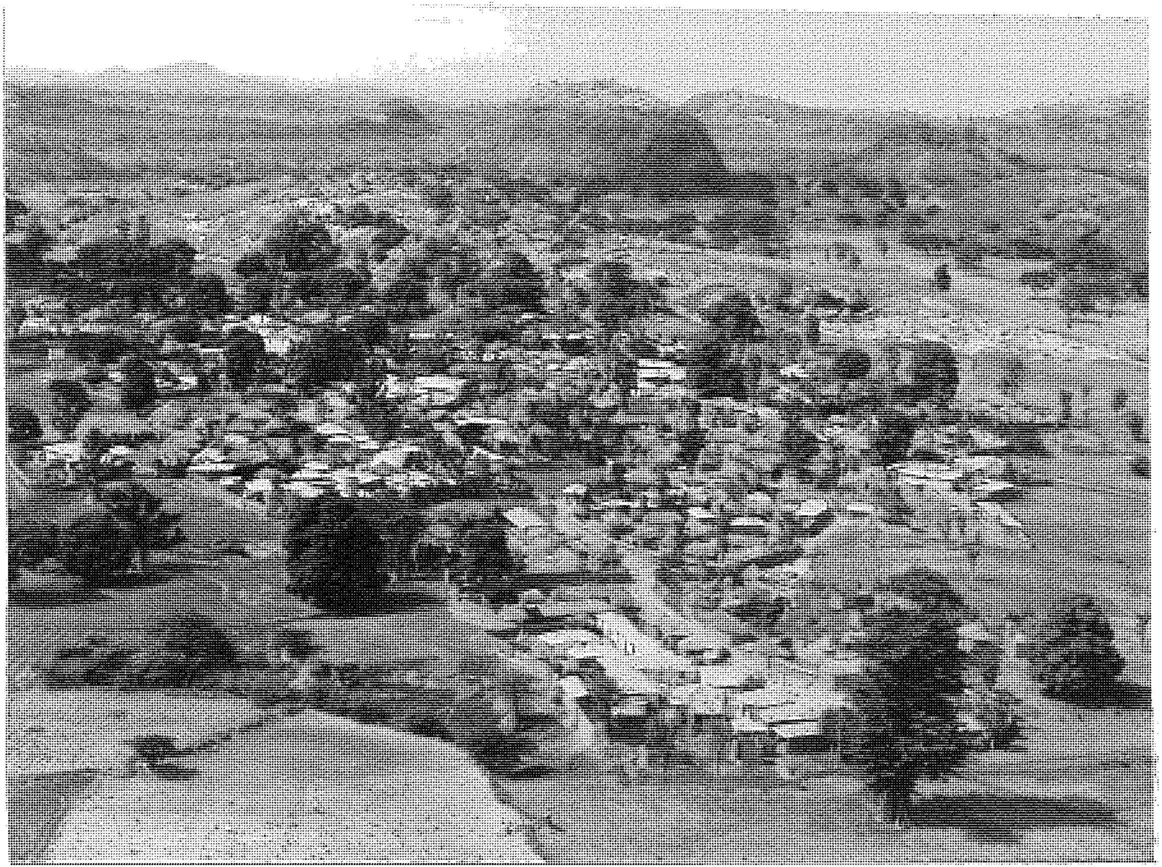


Fig 18 Changes from settlement 1950/72

Fig 19 Models with more than 3% settlement.





Photograph 21

Kajuru village

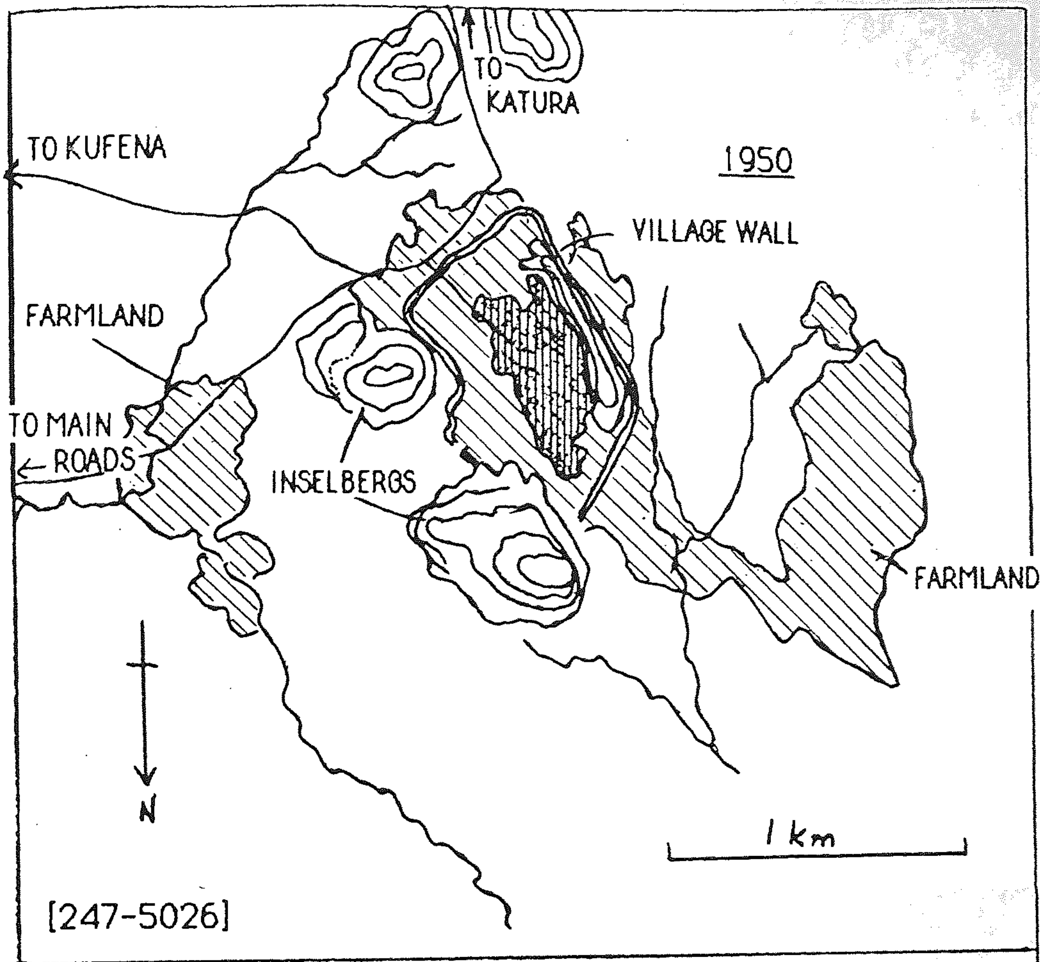
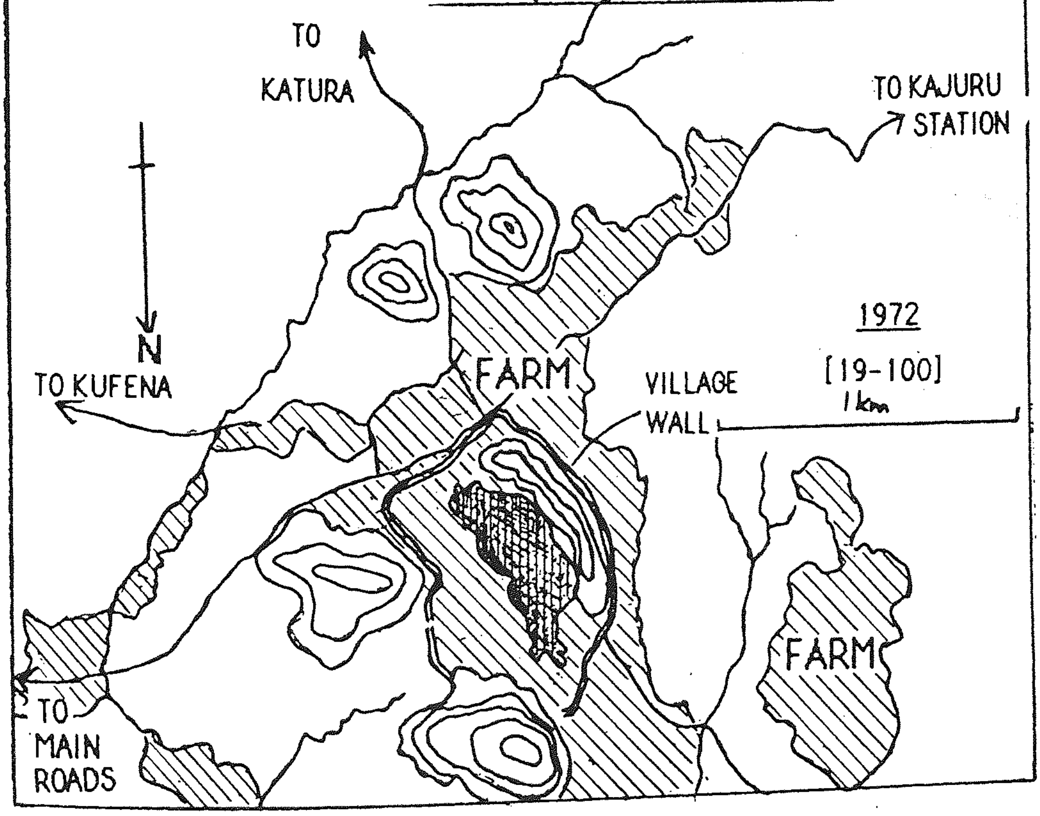


Fig 20 The walled village of Kajuru 1950 & 1972.



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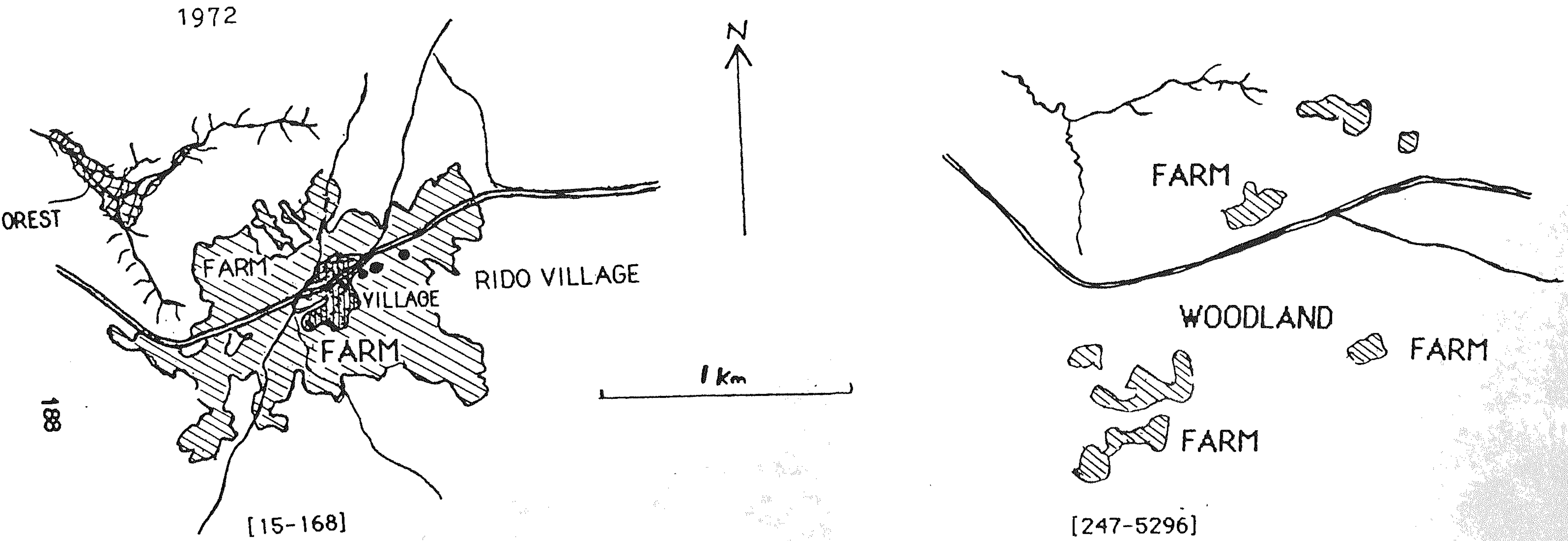
Photograph 22

Tracks at Kajuru

Above 1950 below 1972

Fig 21 The growth of Rido village.



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Photograph 23

Growth of Rido village

Above 1950 below 1972

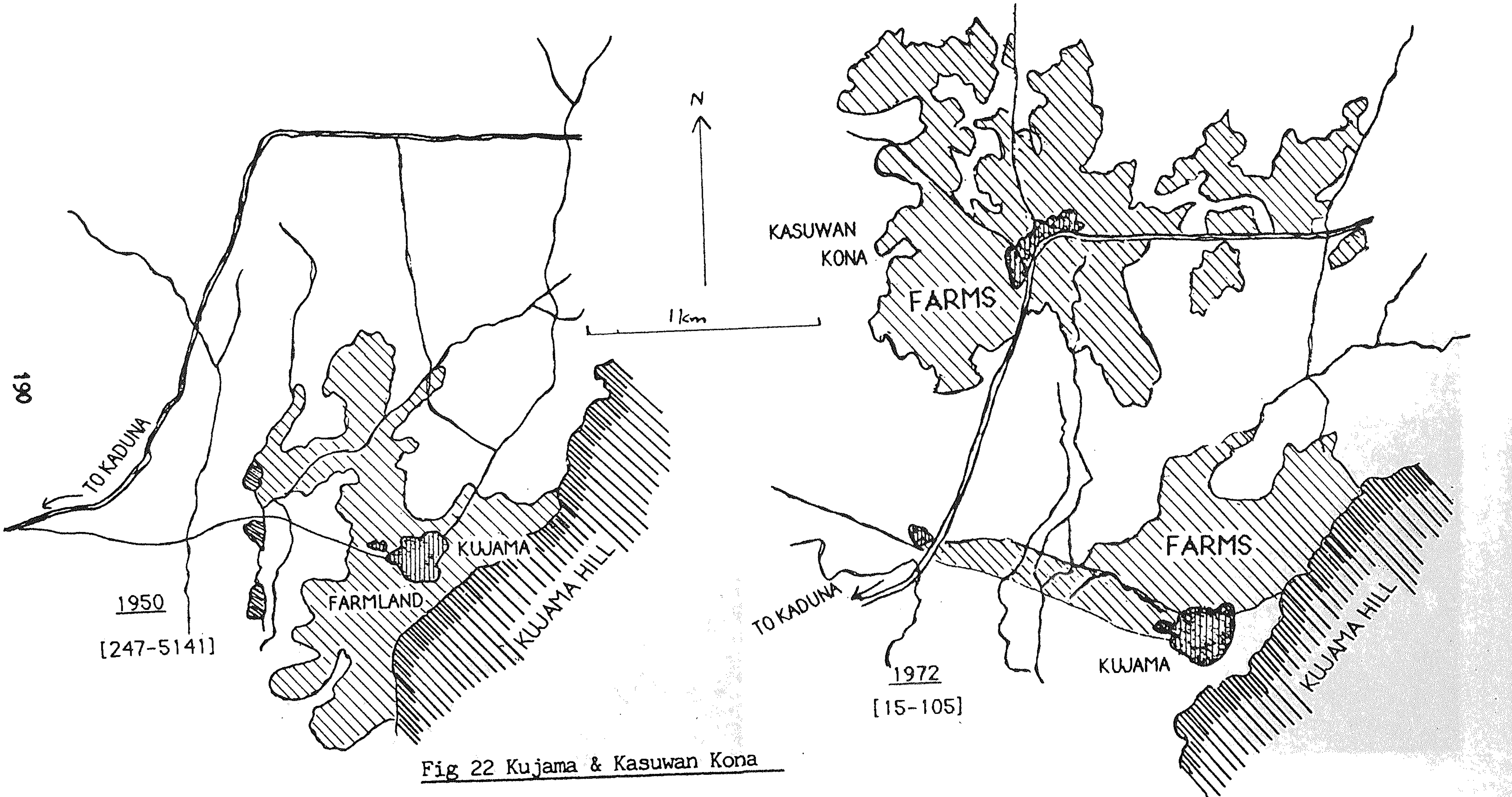

Fig 22 Kujama & Kasuwan Kona

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Photograph 24

Kujama & Kasuwan Kona

Above 1950 below 1972

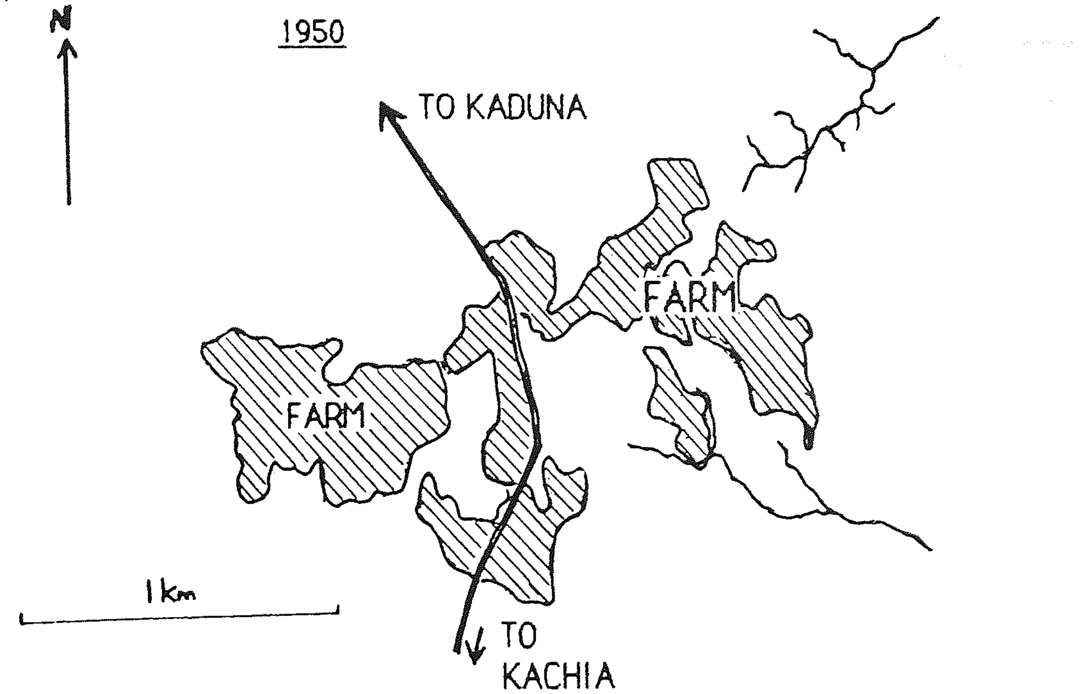

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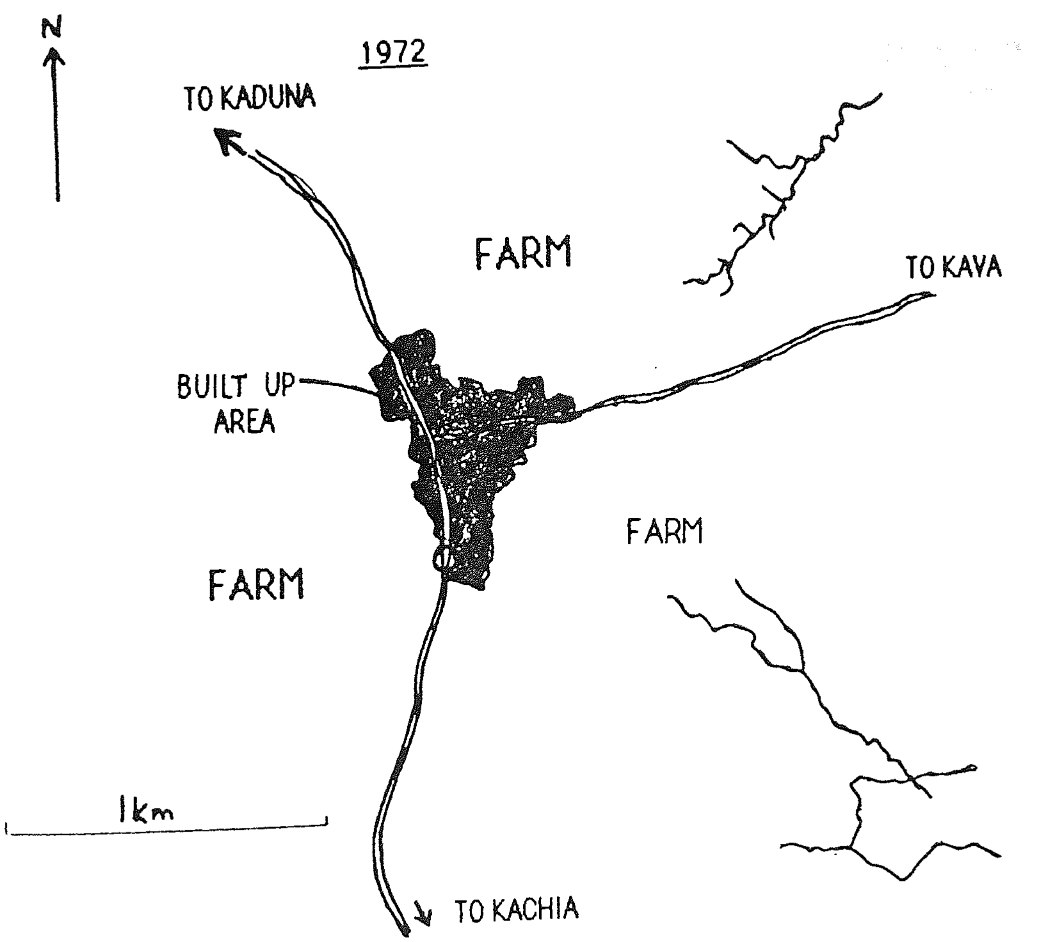
Fig 23 Kasuwan Magani village.



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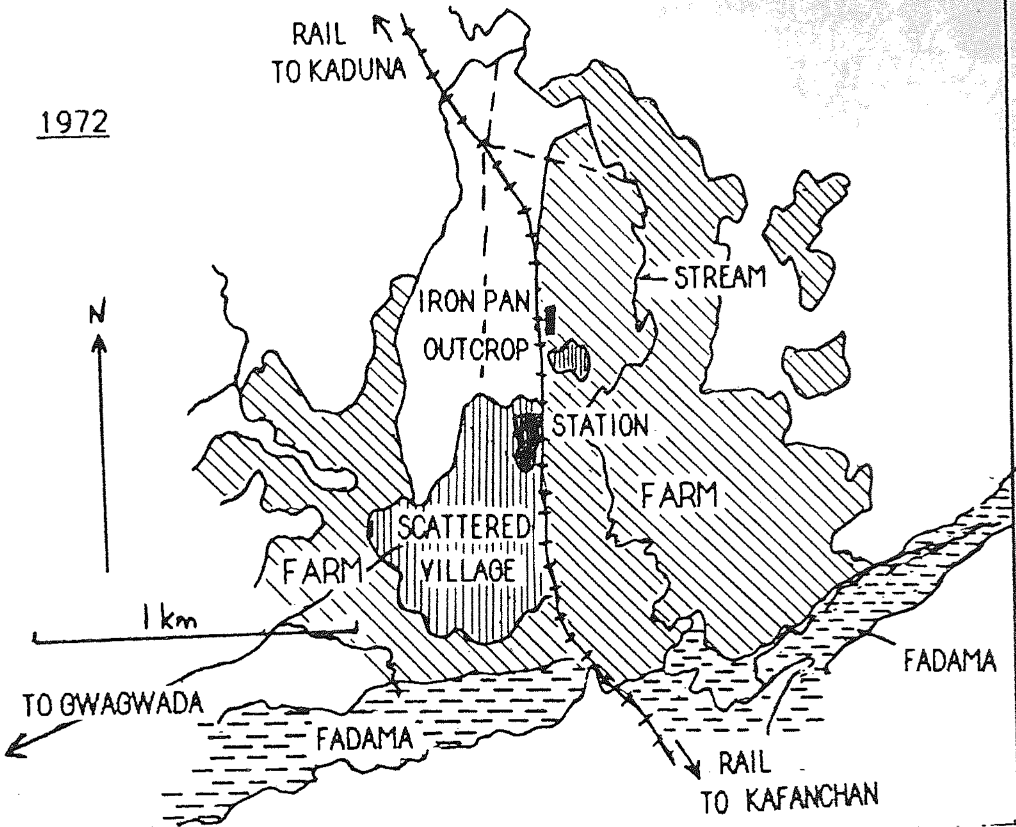
1950

1972

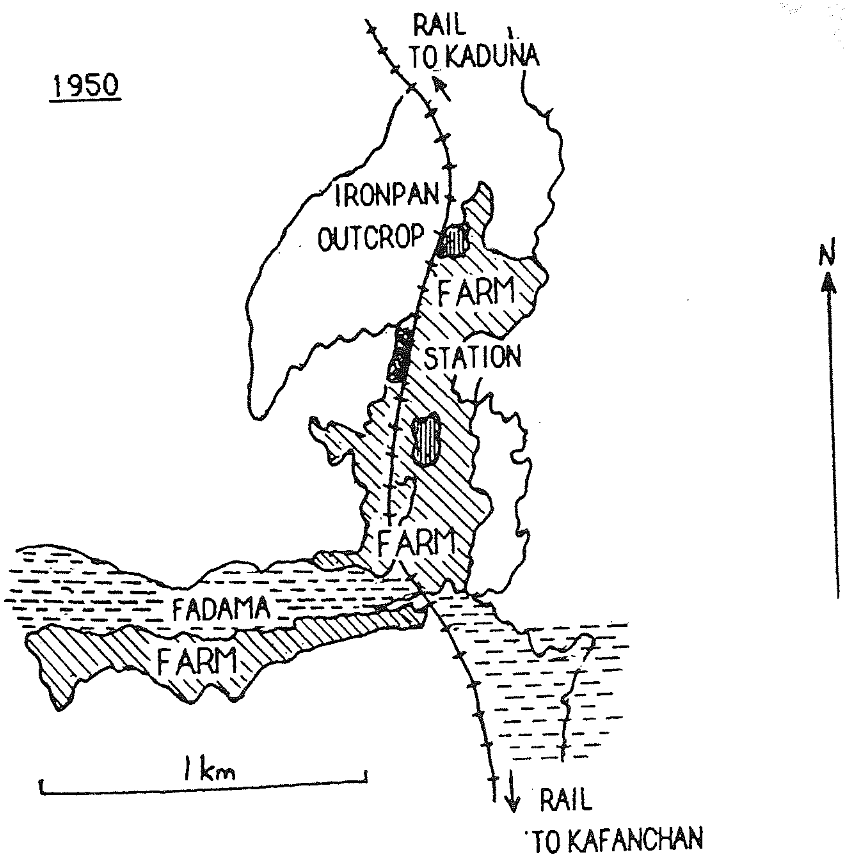
Photograph 25

Kasuwan Magani



[17-109]

Fig 24 Kankomi village.



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1972

1950

Photograph 26

Kankomi village & the railway

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Photograph 27

Kajuru station

Above 1950 below 1972

north east of the test area. There was already quite a lot of farmland there in the 1950's. This was added to and made more accessible by tracks from the new villages along the main road. In the example (see photo 31) there were scattered bush farms on the flat interfluves in 1950; some were quite large, one of them is 12.9 hectares. The bush fallow system was used, most of the suitable areas showing signs of cultivation. By 1972 all the interfluves were cultivated or had been farmed quite recently except for one outcrop of ironpan. The stream valleys were also farmed apart from parts which look particularly wet, no spare land remained.

Intensification can be illustrated by the example of the land round the new village of Kasuwan Kona (figure 22). Instead of cultivating bush farms and shifting them round every few years to give the land a rest farmers now use the same plots continuously. There is a shortage of uncultivated land near the road and social pressures encourage people to live in accessible places. The aerial photographs show up permanently cropped land by its lighter tone and lack of texture caused by the absence of vegetation in the dry season. Home farms also tend to have large isolated trees in them and well developed ridges. Bush farms are more textured because there is always some vegetation left on them and there are no large trees. The distinction between this and 'bush farms' is probably not clear enough for reliable statistical analysis though.

New land may be far away or it may be land which was not previously very much used for farming. One of the most noticeable changes has been the take over of many of the fadamas for farming. In 1950 most of them were grassland available for grazing. By 1972 a large number of them were farmed particularly those near the road or railway. The fadama at Buda has already been mentioned, upstream of the village the fadama was mostly farmed in 1972 while in 1950 it was grassland. Another example is in the river valley followed by the railway. The whole valley has become intensively farmed, a part of it being shown in the photograph number 32. Whereas in 1950 the valley slopes were farmed and the fadama was empty, by 1972 the valley floor was fully occupied, many of the fields showing high ridges used for yams.

Some areas were almost empty of farmland in 1950. People moved into them if they were prepared to forgo the delights of the main road villages. They chose the best land. The example (photo and figure 33) shows two clusters of compounds and farmland at the head of a small valley. The lower slopes and valley bottom are also cultivated, further down there is forest. The common practice is to zone crops, with rice on the wet floor of the valley, followed higher up the slope by tamba (bulrush millet) and by maize in the driest part. Away from the valley the usual crops of guinea corn, maize and yams will be grown. In 1950 the same area was uncultivated. The valley bottom was forested and the rest of it covered with varying densities of savanna woodland. The lighter patches on the photograph are mostly ironpan or rock outcrops.

A favoured site for farming is at the bases of inselbergs. The reasons for this have already been mentioned in section 2.33. Around these hills there is often a zone of rotted granite which retains moisture and makes good soil. Runoff from the hill is useful too. The example shows such a site (photo 34). A small stream runs along the steep eastern face and two others rise at its base. A strip of permanent cultivation 100 m - 400 m wide extends almost all round the hill and into the recesses between the boulders. A small village is built on rock at the northern end. In 1950 there was only a little farmland along the western side. There was no village at the foot of the hill but the photograph shows signs of buildings on its flat top, apart from lack of water a perfect defensive site. A similar example of the relationship between cultivation and inselberg is shown in the next set of photographs (photo 35). A stream runs along the base of the hill and the valley bottom is farmed. A path runs on higher ground linking a number of compounds. The area was already developed in 1950, but farming has spread.

Decrease in farmland is much more uncommon than increase. It seems to have occurred mainly in places which are at some distance from the road or railway. Probably the people moved to the road allowing their farms to return to the bush. In 1950 two kilometres of the small valley shown on the photograph (photo 36) were cultivated on both sides and there were bush farms higher up the slope as well. The fadama itself was grassland. A main north-south track crossed the valley and was obviously well used. By 1972 there were no signs of cultivation. The valley was empty and the track had become much less distinct, the main paths running eastwest on the slopes below an ironpan scarp (see photo 37).

5.33 Grass and scrub

The decline of 13% in the study period represents a loss of 31 sq km. The general distribution was similar although the upper limit declined from 84.7% to 70.8% (61 to 51 out of 72) on any model. The histograms (figures 34 and 35) do not show any marked shift, the changes which occurred being generally below 20% with gains almost balancing losses. Scrub is often just another name for late bush fallow so this shifting about can be expected as land falls out of cultivation and is farmed again. The distribution diagrams (figures 36-38) tell the same story, except for one model in the extreme south west losses are fairly scattered and are almost, but not quite, compensated for by gains.

Large increases occur mostly in the northern part of the area, associated with a similar increase in farmland. An example is located just to the south of the main road (photo 41). The area is gently undulating with small streams which run in valleys which expand to form small fadamas. In 1950 the interfluves were covered in woodland within which were a few large bush farms. Old farms can be seen, overgrown with scrubby vegetation. The valley heads were heavily wooded, the small fadamas being grassed with farms on the lower valley slopes adjoining them. Lines of large trees ran along the fadama edges and followed the streams. By 1972 the woodland had gone except near the streams. The interfluves were covered with a mixture of active farms and scrubby bush fallow.

Losses of grass and scrub are also mostly caused by more intensive farming, there being a gain from woodland and a loss to cultivation. In the example (photo 33) an area of open land with a lot of grass and only small trees has been taken over by farmland. Light grassland still occupies the higher areas which can be recognised as ironpan outcrops by their location and scarped edges.

About a quarter of the grass and scrub group is found on the fadamas as pure grassland. The example shows an area near Kufana (photos 38,39,40 & 42). The valley bottom is all grass with very few trees. Farming plots merge into the grass, they are used to grow rice which is sown broadcast and will not look much different even on the ground.

5.34 Woodland

Nichol (1983) studied the changes in woodland near Kano as part of a project on rural energy resources. This is the second most valuable use of woodland, for firewood, the first being for grazing and soil fertility renewal. Unfortunately the two uses are incompatible, cut down the woodland for firewood and there is only scrub left. With the contemporary pressure on resources it never gets a chance to regenerate. Nichol did however find an 18.5% increase in tree numbers between 1972 and 1981 but this is 1 1/2 deg further north than Kajuru in a different vegetation zone and was attributed by her to recovery after the drought years of 1968-74.

Distribution of woodland in Kajuru was fairly uniform in 1950 although the extemes were wide apart, 2.8% and 93.1%. Most lightly wooded were the areas around the central valley and in the extreme north east. Other models were predominantly woodland with only the occasional clearing for farming and the shallow soils over massive ironpan. Twenty two years later there had been extensive clearing in the north east with most models having less than 20% woodland, some having been completely cleared. On the other hand there were still some areas with over 75% coverage, but there were fewer than before (9 compared with 18 in 1950). Some places had actually become more wooded, as people left the bush and moved to the roadsides. Figures 39 to 45 illustrate the distribution of this group.

The first example (photo 31) shows how an area which was already extensively farmed could be deprived of more trees. The increase in cultivation is not the farming of new areas but a shortening of the fallow period and conversion of shifting cultivation into a bush fallow system. The 1950 photograph shows that most of the area has been farmed at some time although the actual clearings occupy only about one quarter of it. Elsewhere trees grow quite thickly, some are small while there is a scattering of large specimens which will have been left untouched during farming. The 1972 photograph shows the same large trees but now the undergrowth has gone. More of the land is farmed and the traces of previous cultivation are more visible. Trees, except for those preserved, will have had less chance to regenerate. The town of Kasuwan Magani is nearby and its inhabitants will be quick to lop any attractive branch for firewood.

The second example is near Kajuru station (photo 43). In this rather isolated area woodland and forest remained undisturbed. Thickest on the steep slopes of an ironstone scarp, woodland spreads northward across the uncultivated interfluves becoming thick gallery forest along the streams. In 1950 this pattern was much more widespread.

5.35 Barren land

The distribution of this type of land use is related to the topography being common in the hilly south east and rare elsewhere. The distribution diagrams (figures 48 and 49) show this relationship well. The wider scatter in 1972 is partly an artefact of the photography which permits easier identification but is also caused by the general lightening of the vegetation revealing bare rock and very shallow soils. (see photos 44-47).

5.4 TOTAL CHANGE & ITS INTENSITY

5.41 Instead of examining each group of land use separately we can take the two samples, see how many points have changed, and what they have changed into. Forty per cent of the points did not change; an area being more stable if it was away from the road or railway. (figures 50 to 52). In 19 models there was a large change of 50% or more (36 points out of 72). The locations of these models is shown in table 34 and figure 51. This confirms earlier conclusions about the location of change around communications in areas where there is good soil and topography. The north east falls into the LRDC Land System number 429 which is noted (Wall et al 1979 p41) as having only minor limitations to crop growth and suitable for growing maize, millet, guinea corn, groundnuts, cotton and yams.

5.42 Land use can be considered to be of a low or high intensity. If one regards settlement as the most intensive form and barren land as the least intensive then an ordinal scale from 1 to 15 will roughly represent levels of intensity. Comparison of category numbers will show whether a point has been upgraded towards settlement or regressed to non-cultivation.

$$\text{Intensity} = \frac{\text{1950 category} - \text{1972 category}}{(15 - 1) \times 72} \times 100\%$$

From this calculation a general increase of intensity can be seen with a mean of + 7.0% and a median value of +4.1% (table 33). The interquartile range of -2.3% to +19.7% is quite large showing that changes have not been uniform. How they are linked to controlling factors is examined in the next chapter.

TABLE 34

MODELS WITH 50% OR

MORE CHANGES 1950-72

North East around Kujama & Kasuwan Magani	12
Kajuru main road junction	1
South West near Kajuru station	5
Kankomi area	1
	19

5.5 SUMMARY

5.51 This chapter examined the proportions of land use in the two years of the study, saw what changes had occurred and looked at the distributions of groups and changes.

5.52 In 1950 the intensity of land use was low, 82.4% of the area being uncultivated and 4.1% barren. Only 12.5% was cultivated with the remaining 0.9% under settlement.

5.53 By 1972 the proportion of uncultivated land was 68.5%, barren land 5.4%, cultivation 24.2%, and settlement 2.0%.

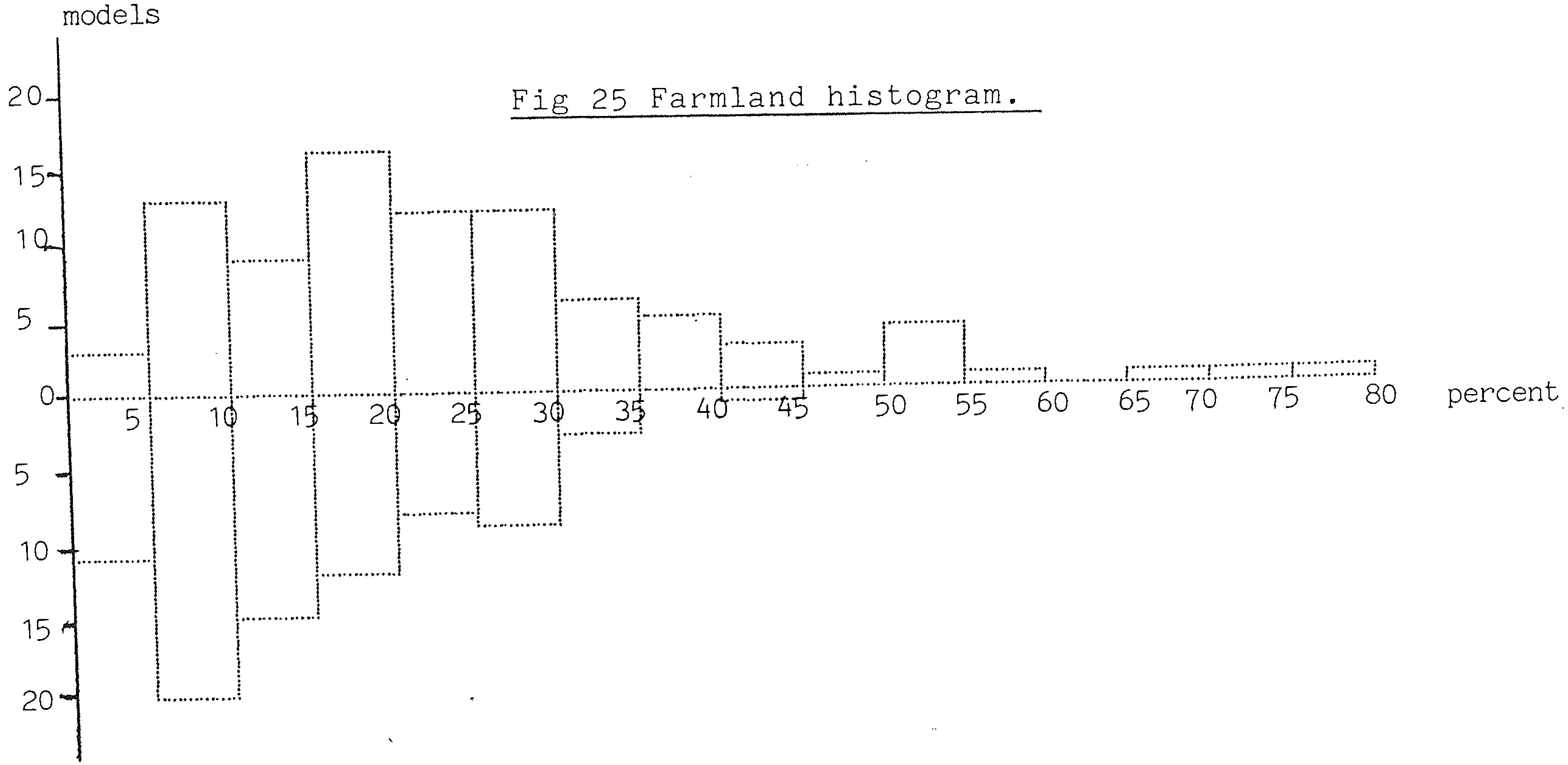
5.54 The accuracy of these figures is dependent on their proportions of the total and also on the reliability of identification, which is variable and cannot easily be put into figures.

5.55 Changes between 1950 and 1972 were tested using the Wilcoxons signed-rank test and found to be highly significant. Settlement increased by 120% on 1950 figures, cultivation doubled, and there was a 16.8% fall in uncultivated land including a loss of 6900 hectares of woodland. Barren land increased by 30.5%.

5.56 Distribution of and changes in land use is uneven and can be related to communications, soils and topography.

5.57 Intensity of land use can be quantified by taking a scale from settlement (most intensive) to barren (least intensive). Both total changes and intensity show a distribution similar to that noted in 5.56.

Fig 25 Farmland histogram.



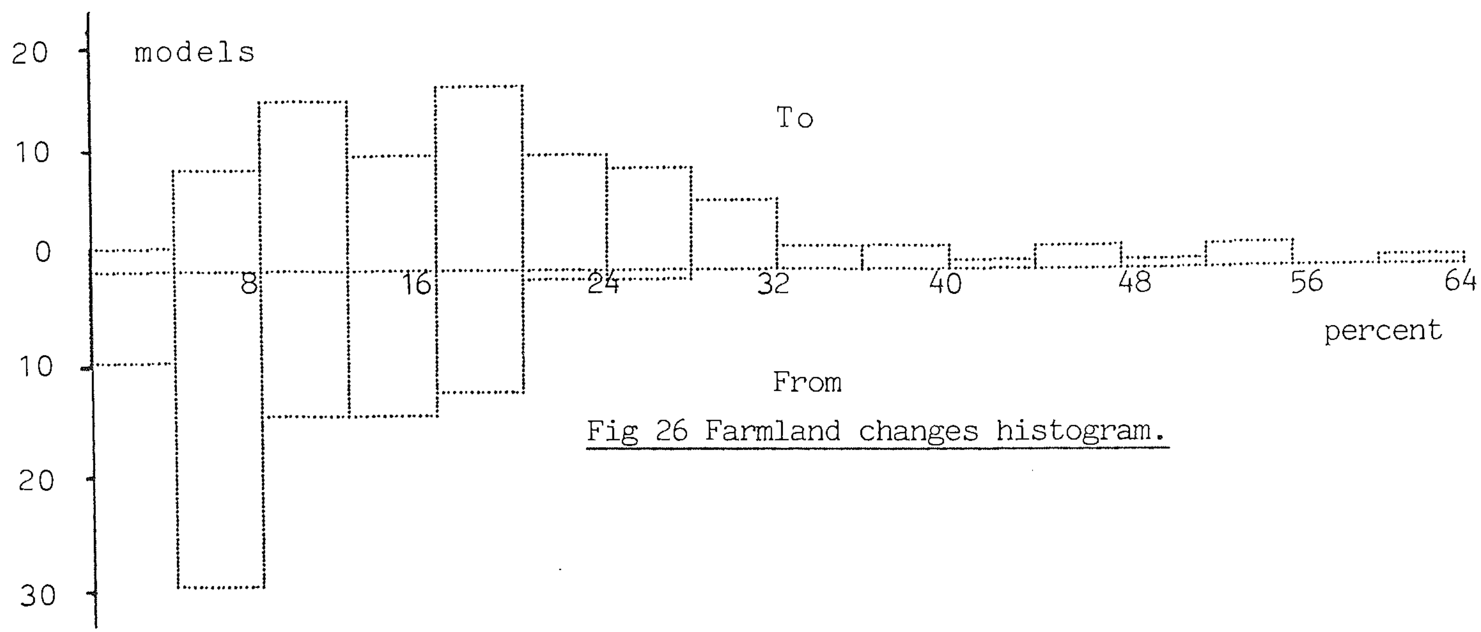


Fig 26 Farmland changes histogram.

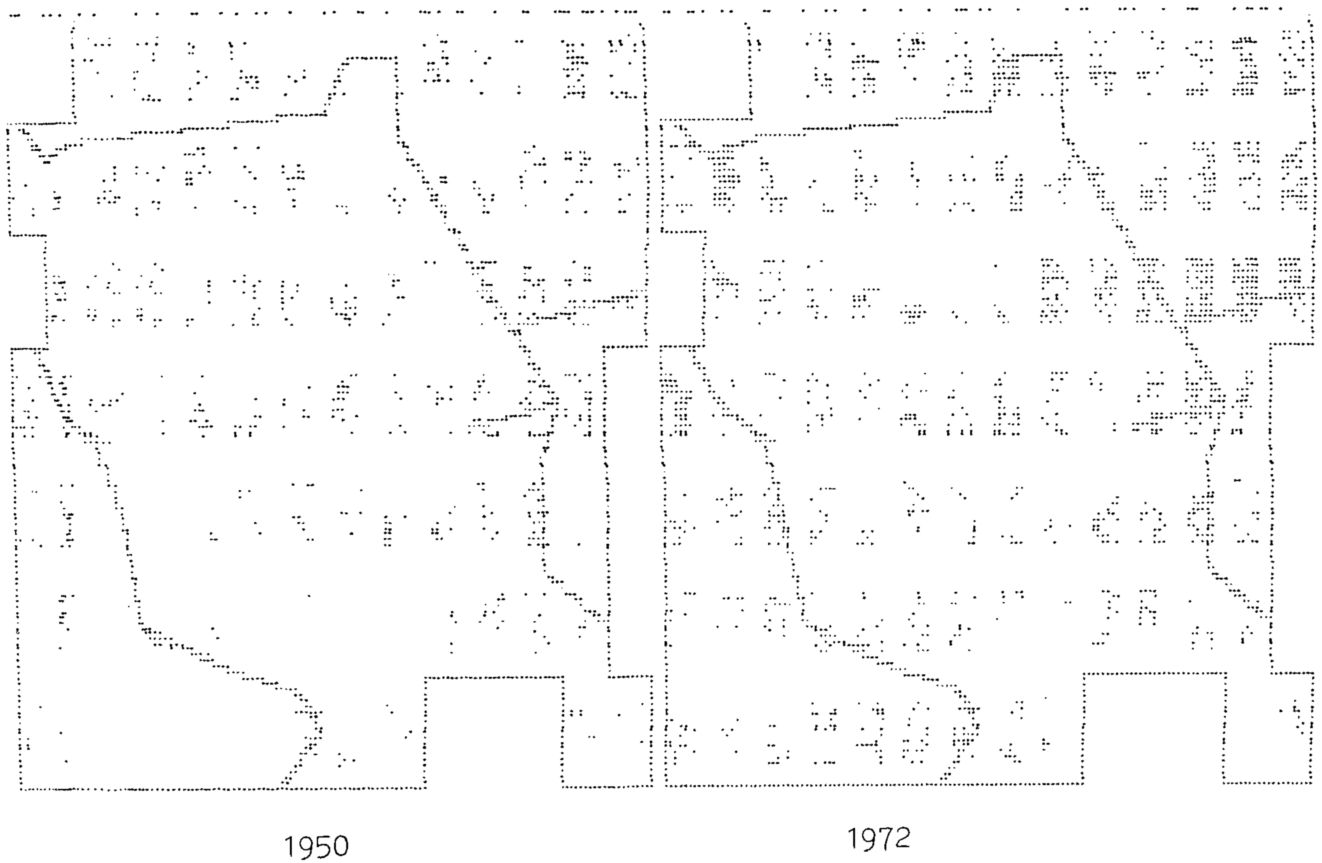


Fig 27 Distribution of farmland.

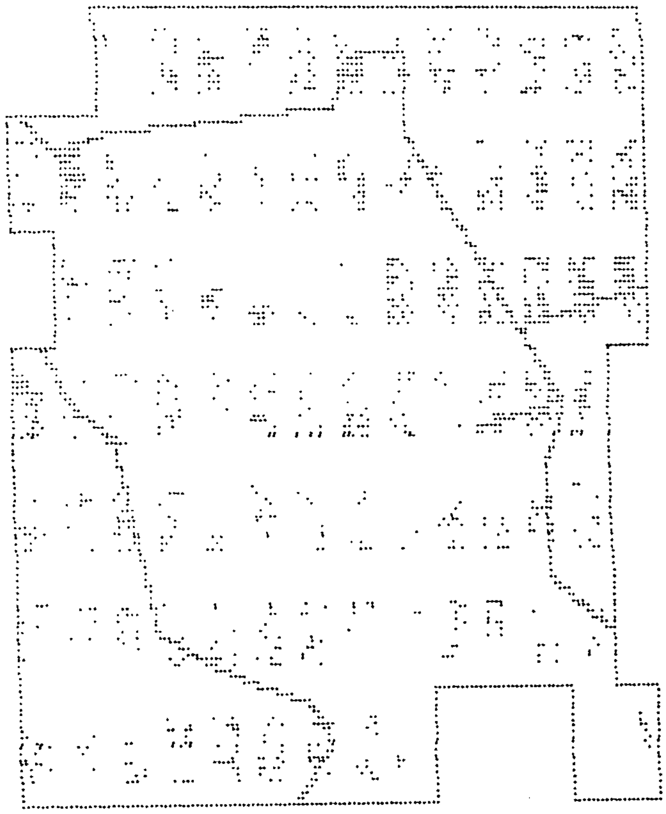


Fig 28 Changes to farmland 1950/72.

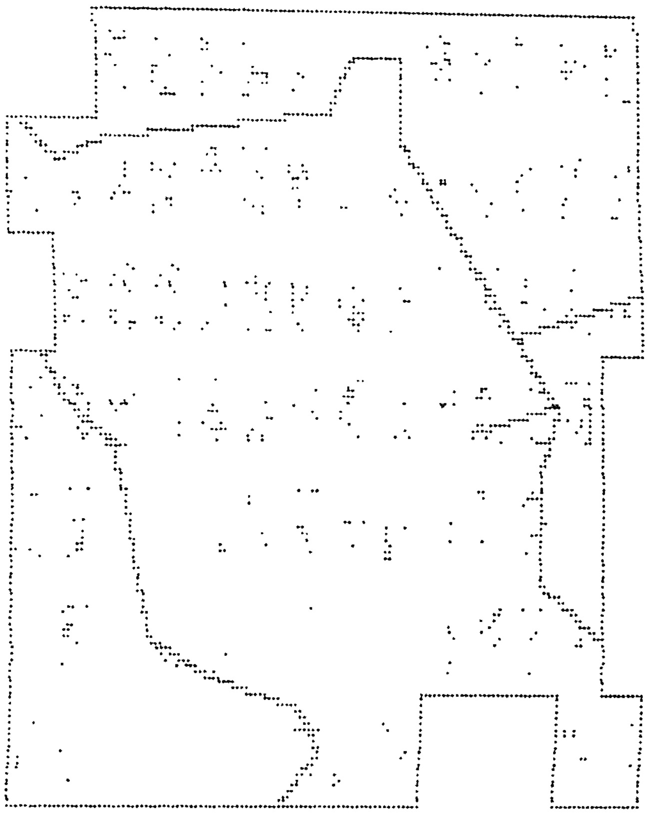


Fig 29 Changes from farmland 1950/72.

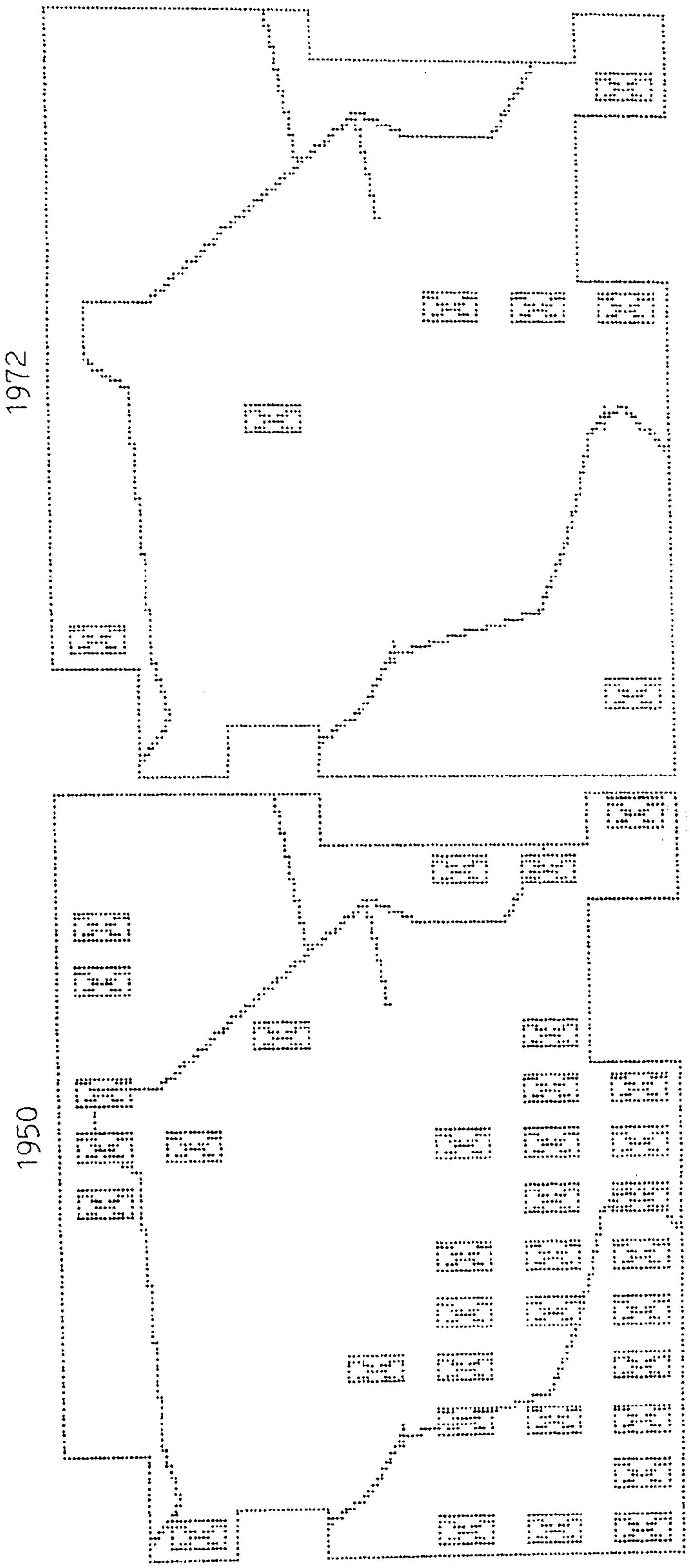


Fig 30 Farmland less than 7% of sample.

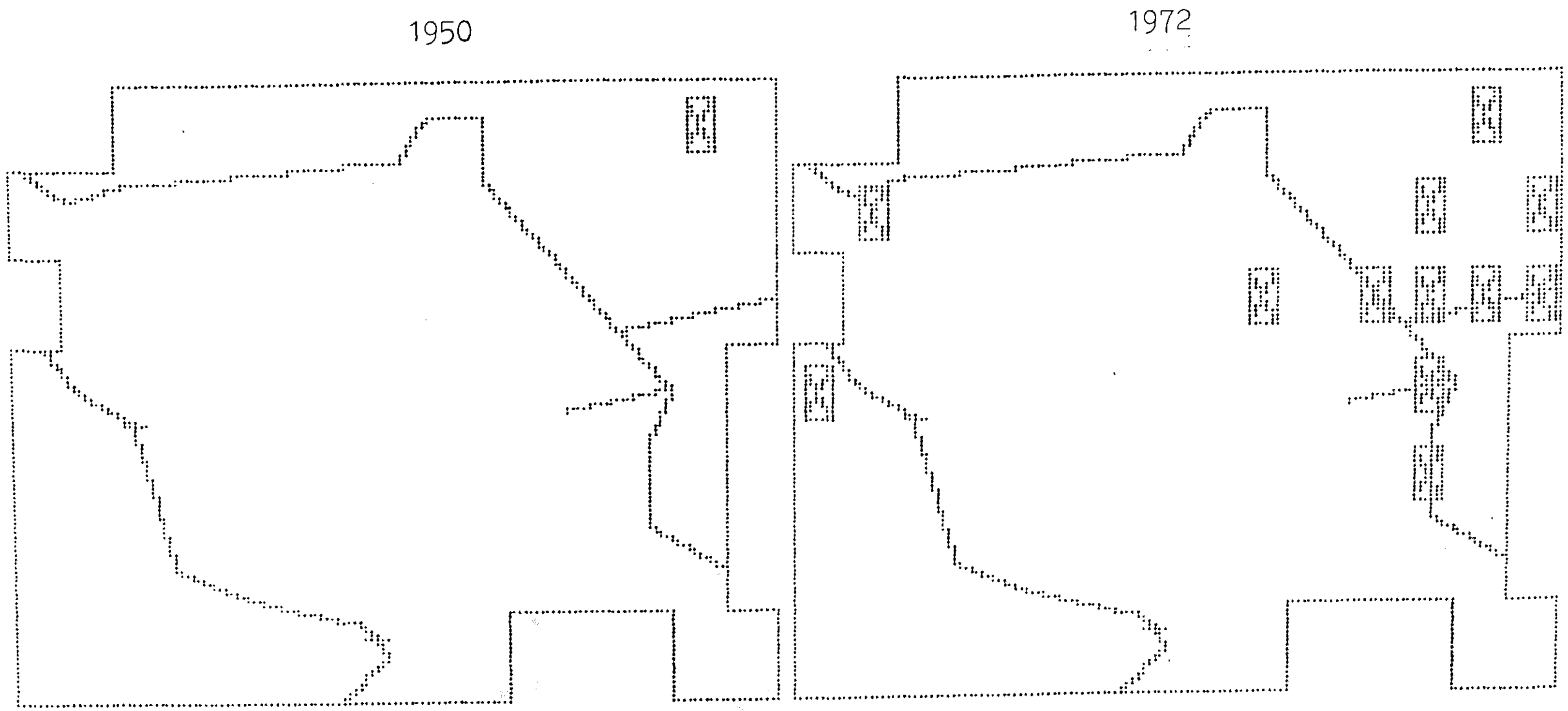
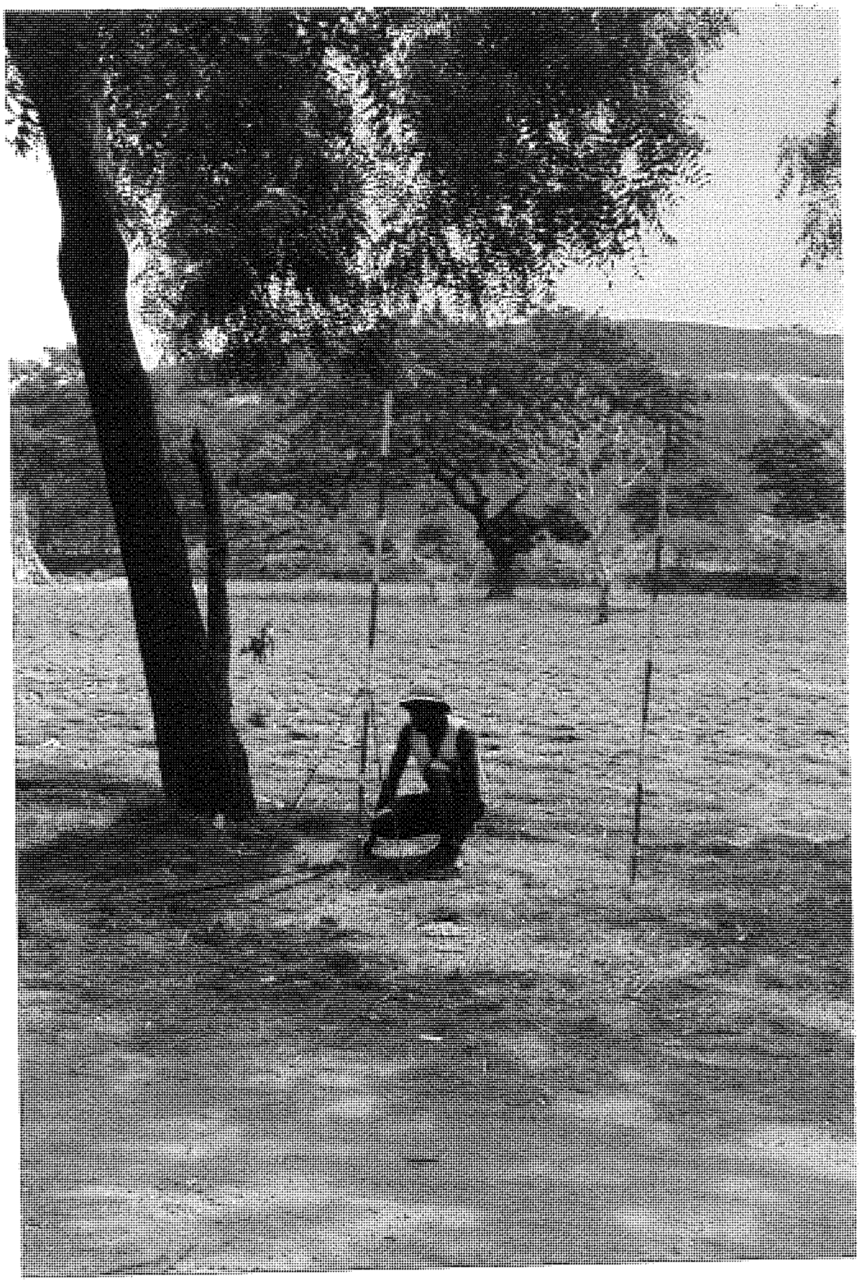


Fig 31 Farmland over 40% of sample.



Photograph 28

Permanent farmland at the end of the dry season.

Photograph 29

Farmland & bare rock

Dorowa tree standing on the edge of farmland at the base of an inselberg.

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Content has been removed for copyright reasons

Photograph 30

Buda village, farms & fadama 1972

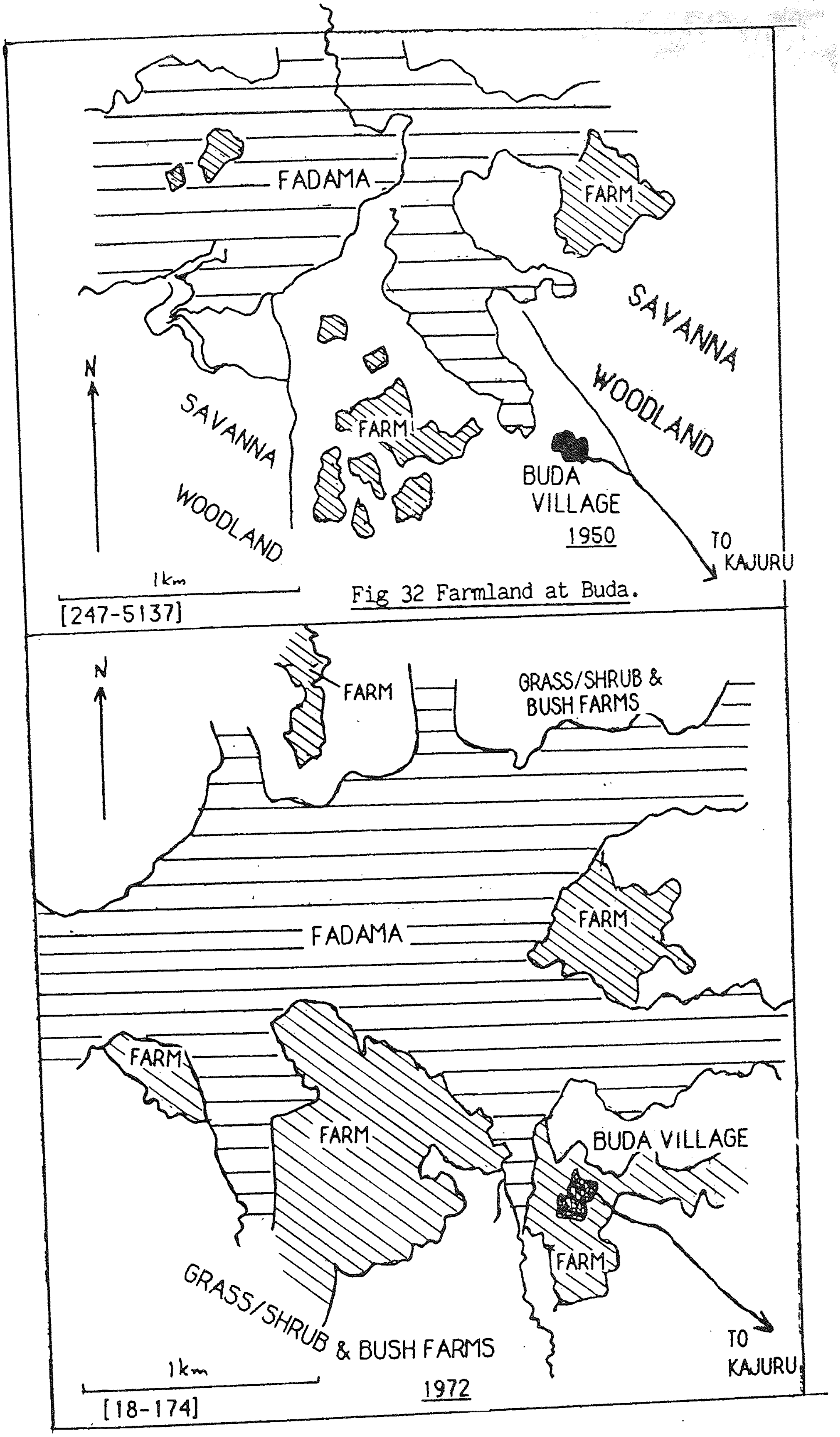

Fig 32 Farmland at Buda.

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1950 1972

Photograph 31

Taking up more land

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1950 1972

Photograph 32

New farms on the fadama

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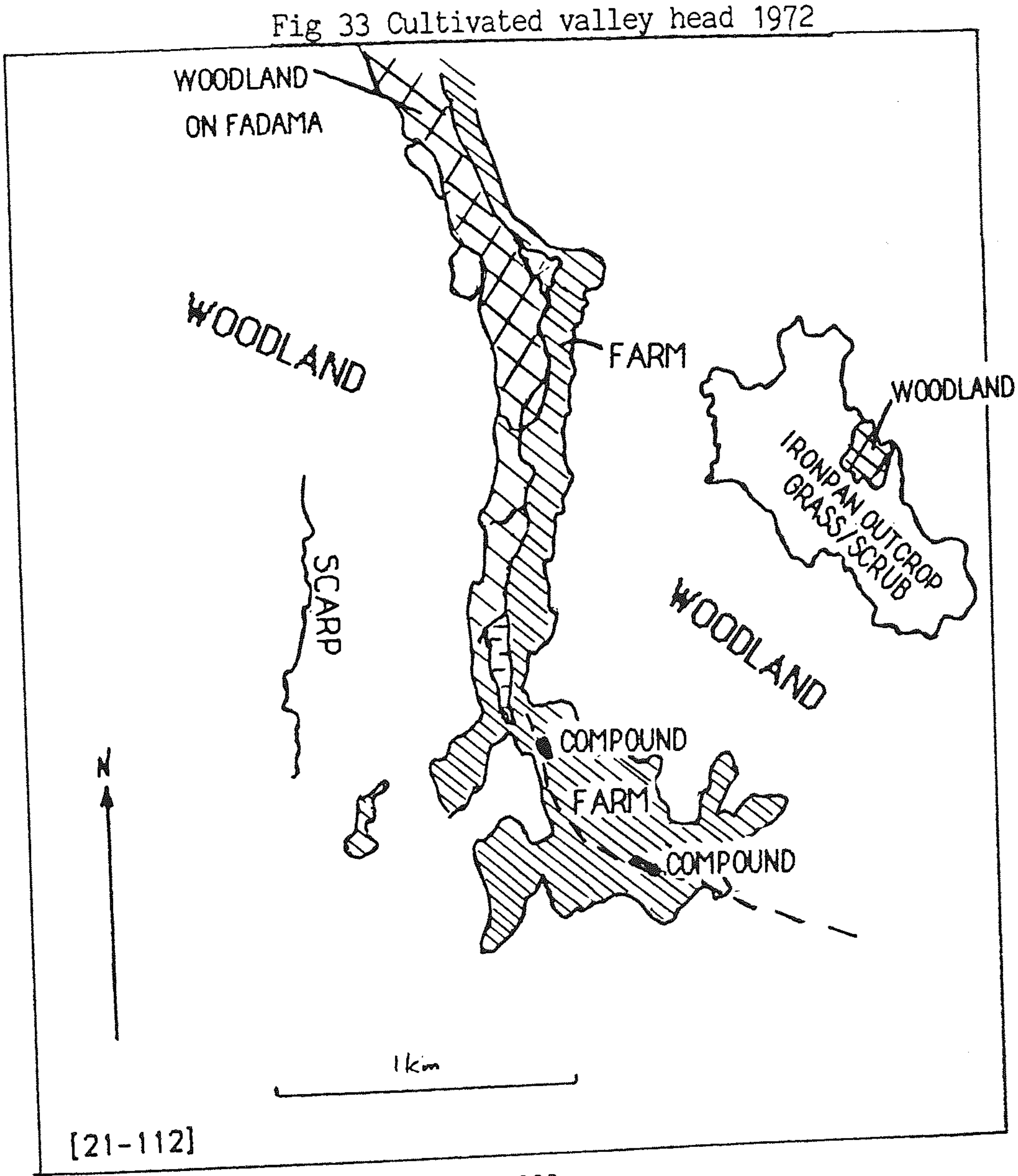
Photograph 33

Farming at a valley head 1972

Fig 33 Cultivated valley head 1972



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Photograph 34

A favoured site for farming (1)

At the base of an inselberg - above 1950, below 1972

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Photograph 22

A favoured site for farming (2)

At the base of an inselberg - above 1950, below 1972

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Photograph 36

Decrease in farming

In a valley away from the road - above 1950, below 1972

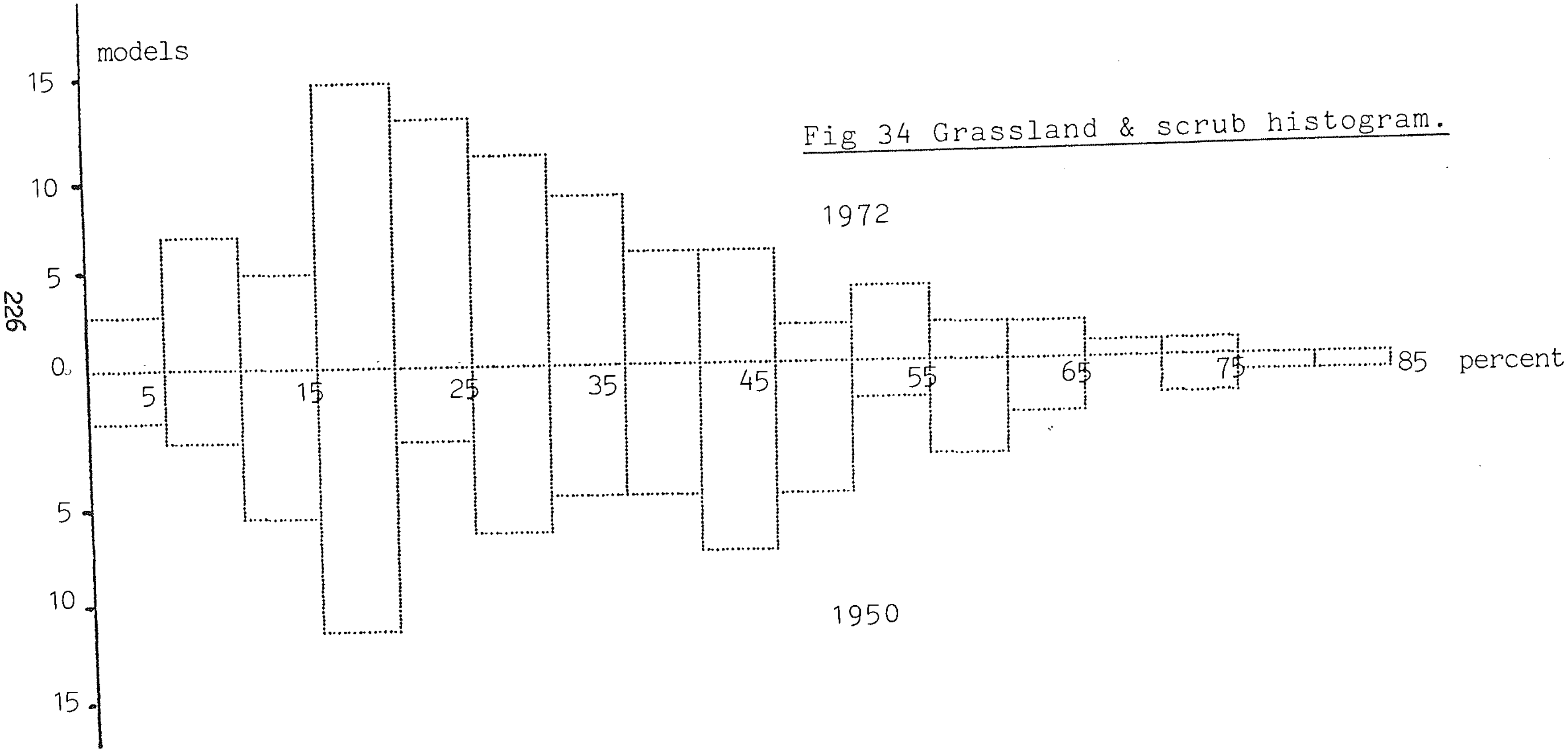


Fig 34 Grassland & scrub histogram.

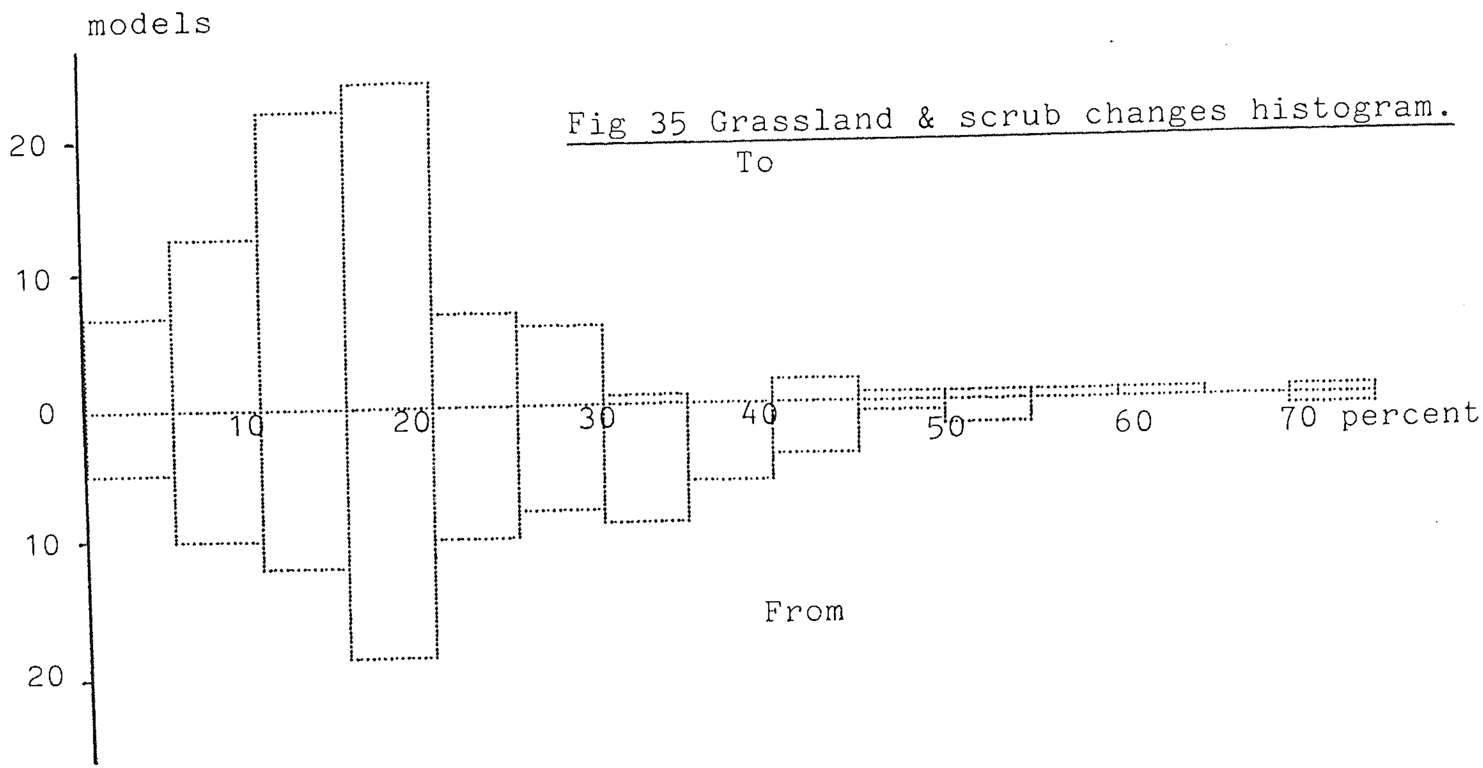
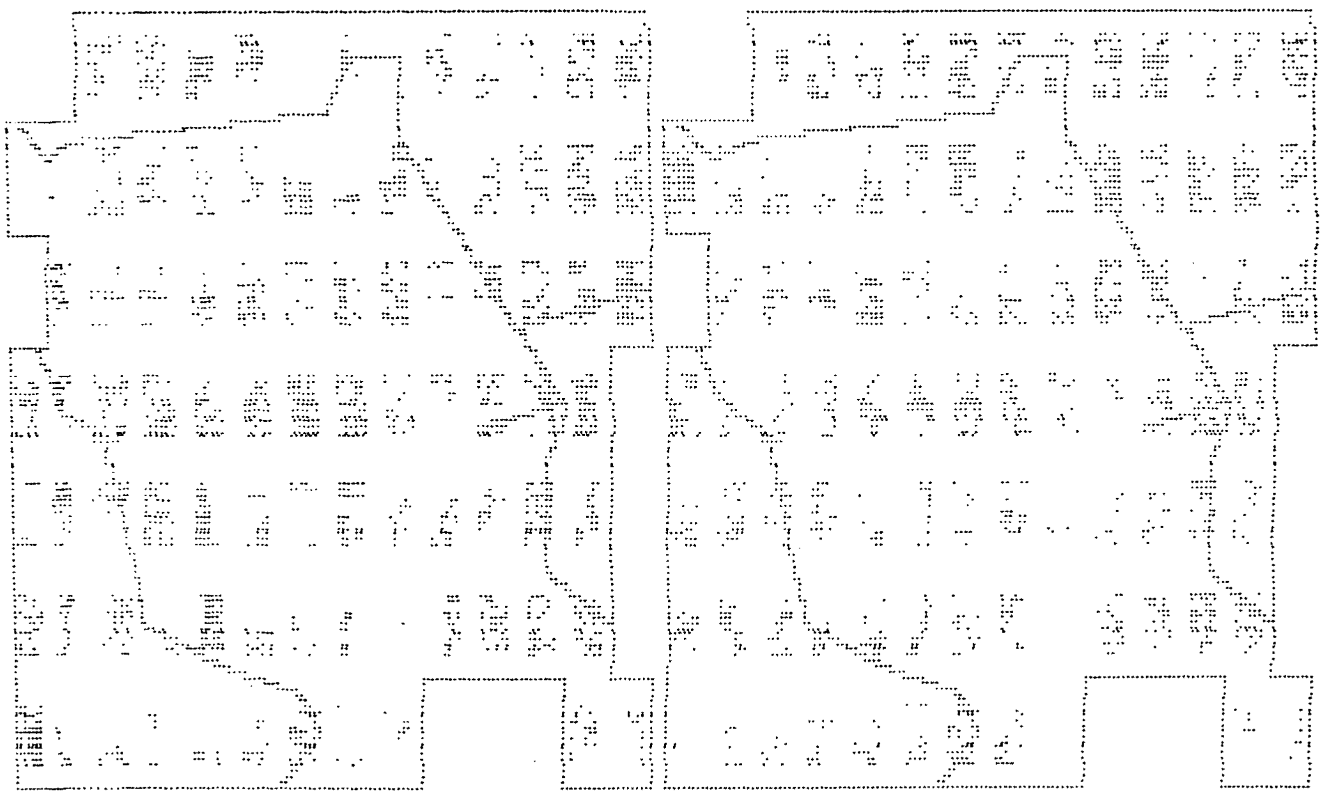


Fig 35 Grassland & scrub changes histogram.



1950 1972

Fig 36 Grassland & scrub distribution.

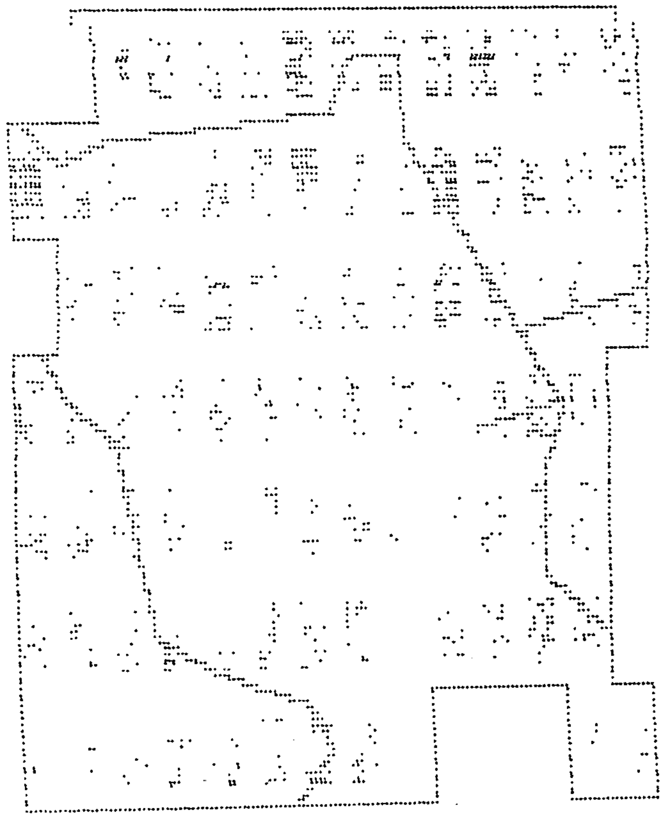


Fig 37 Changes to grassland & scrub 1950/72.

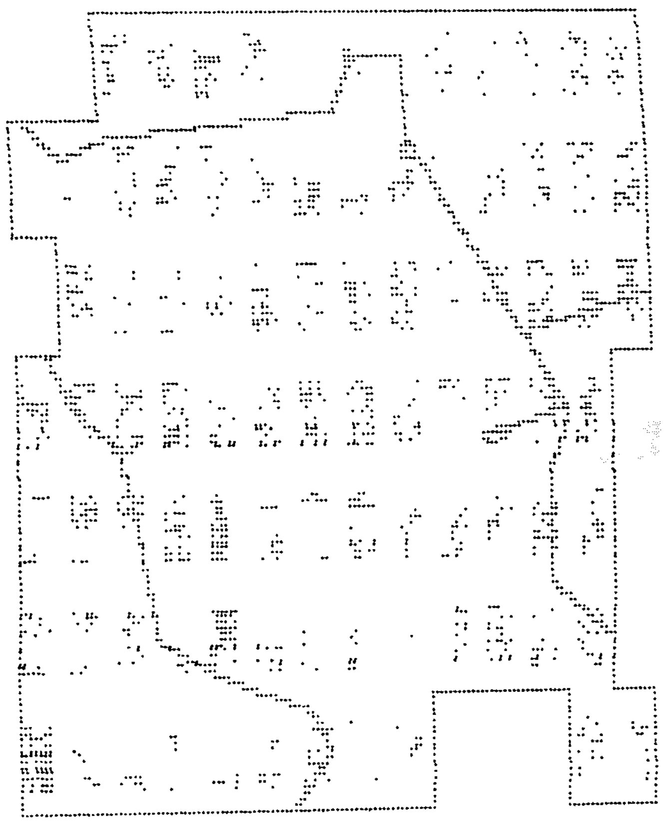
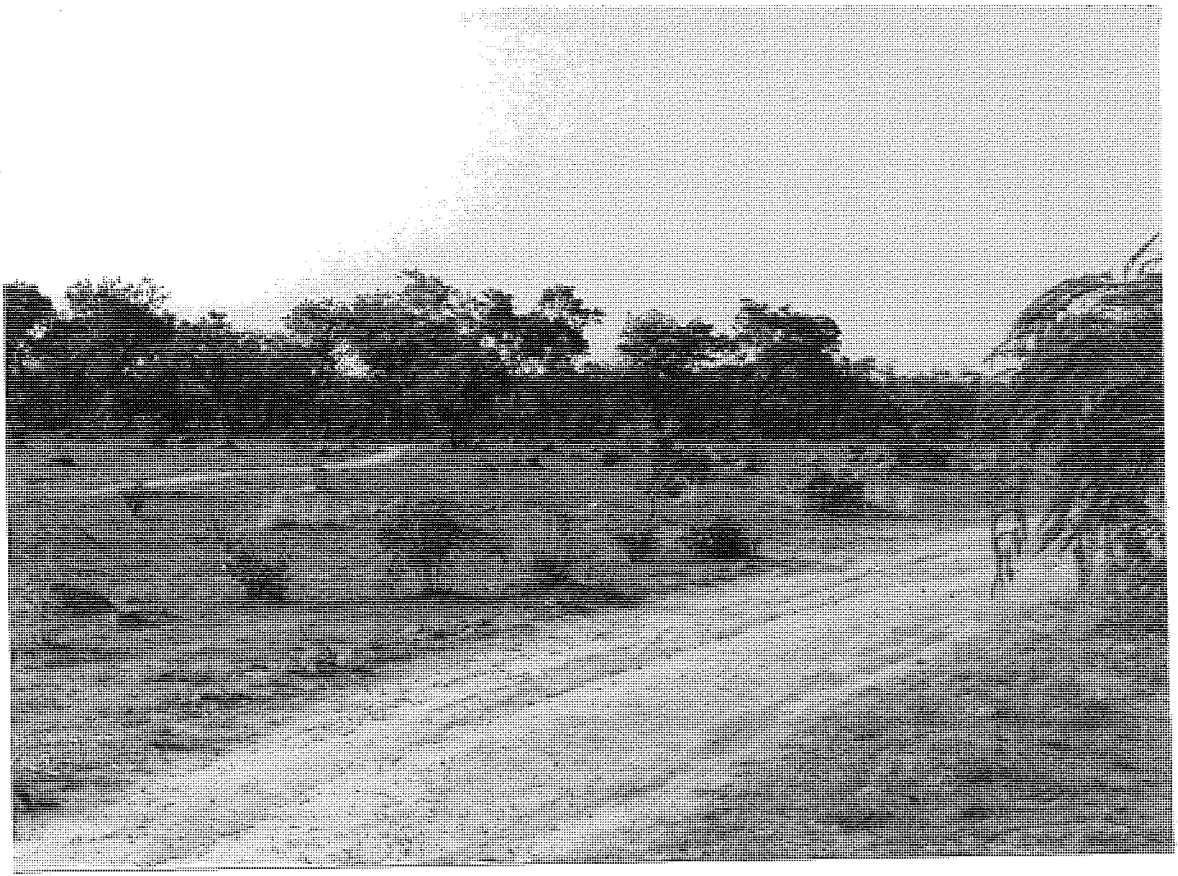
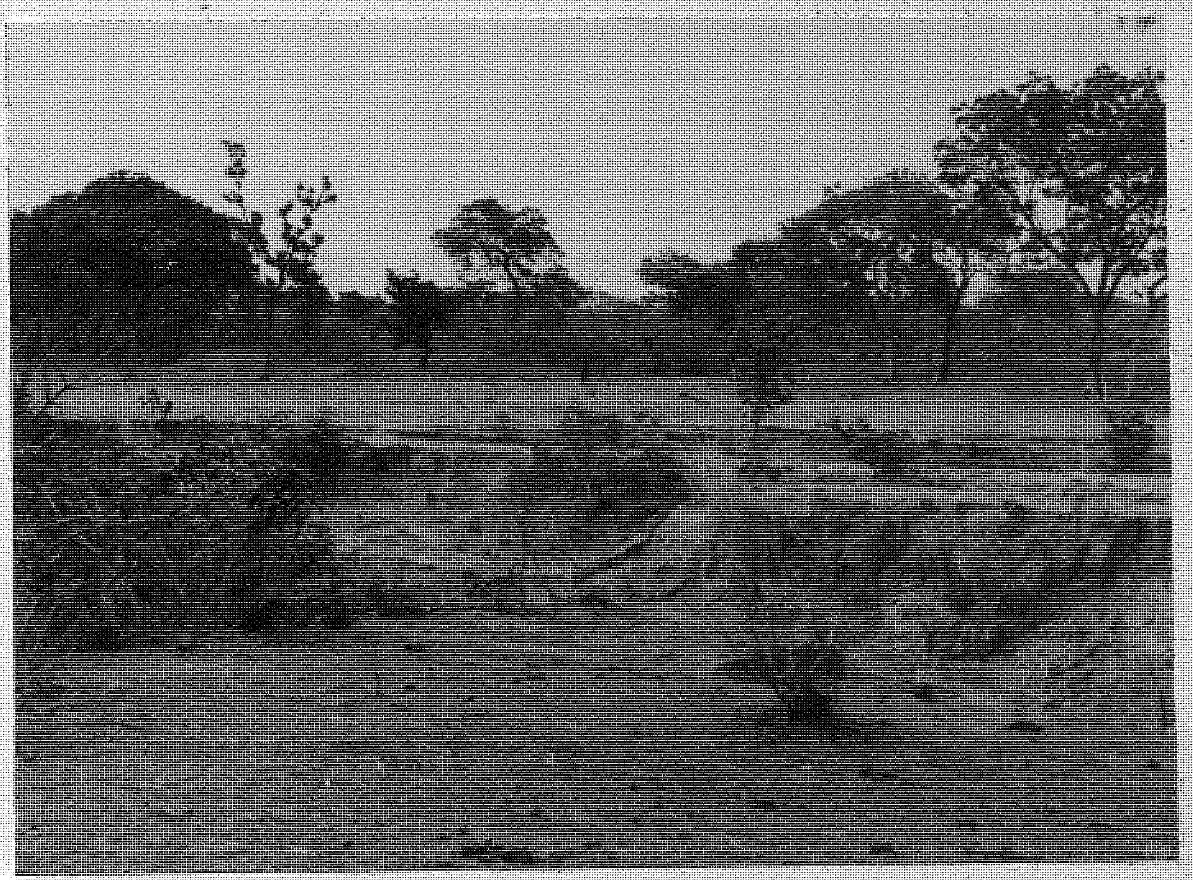


Fig 38 Changes from grassland
& scrub 1950/72.



Photograph 37

Grassland on shallow soil
over massive ironpan. Note the mushroom
shaped termitaries.



Photograph 38

Fadama in the dry season.

Scarped edge and a gully occupied by a small seasonal stream.

Photograph 39

Fadama with cultivated plots
including a fenced garden for bananas.

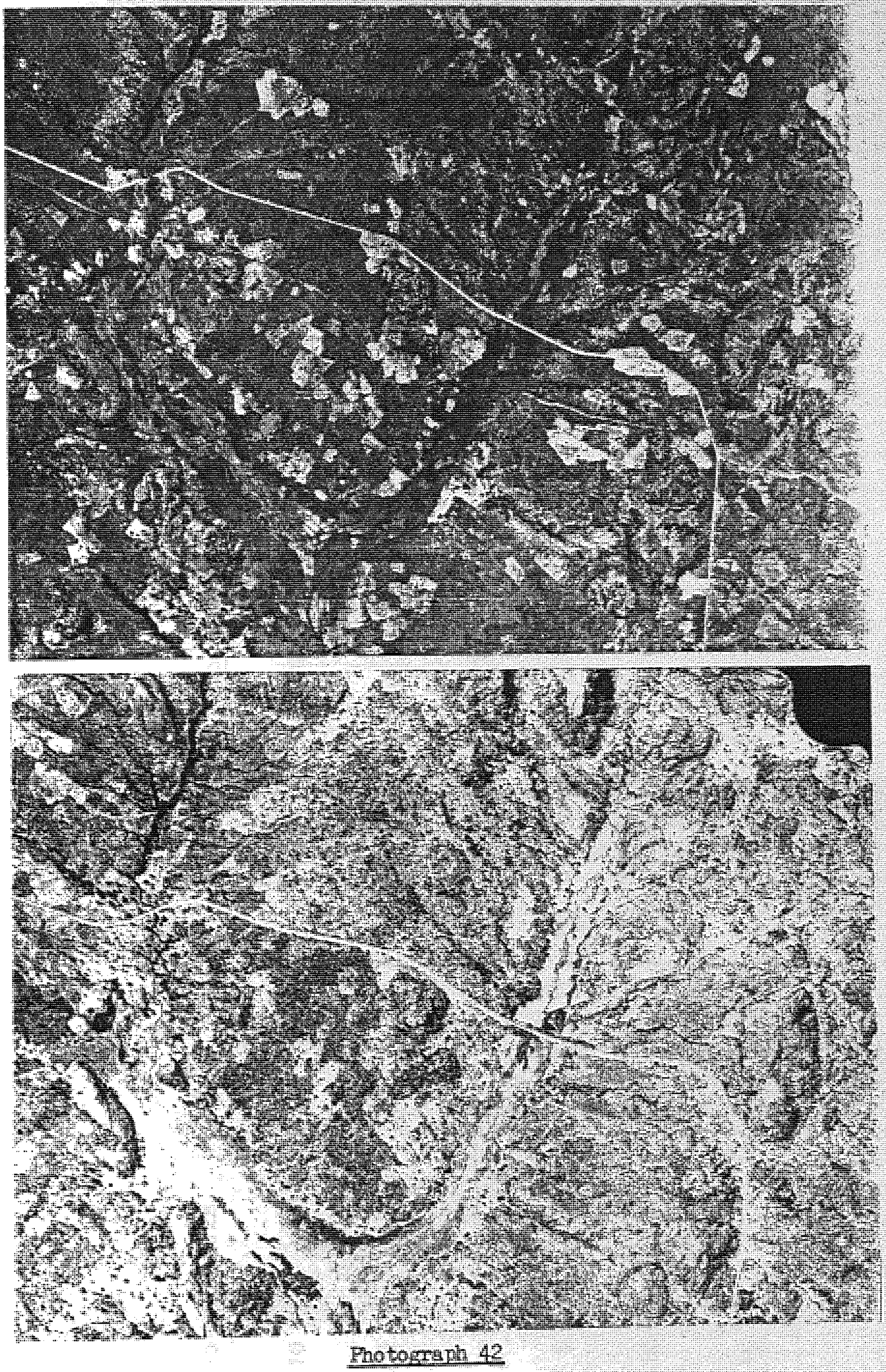
Photograph 40

Fadama with plots for rice.

Photograph 41

Increase in grass and scrub

Above 1950, below 1972

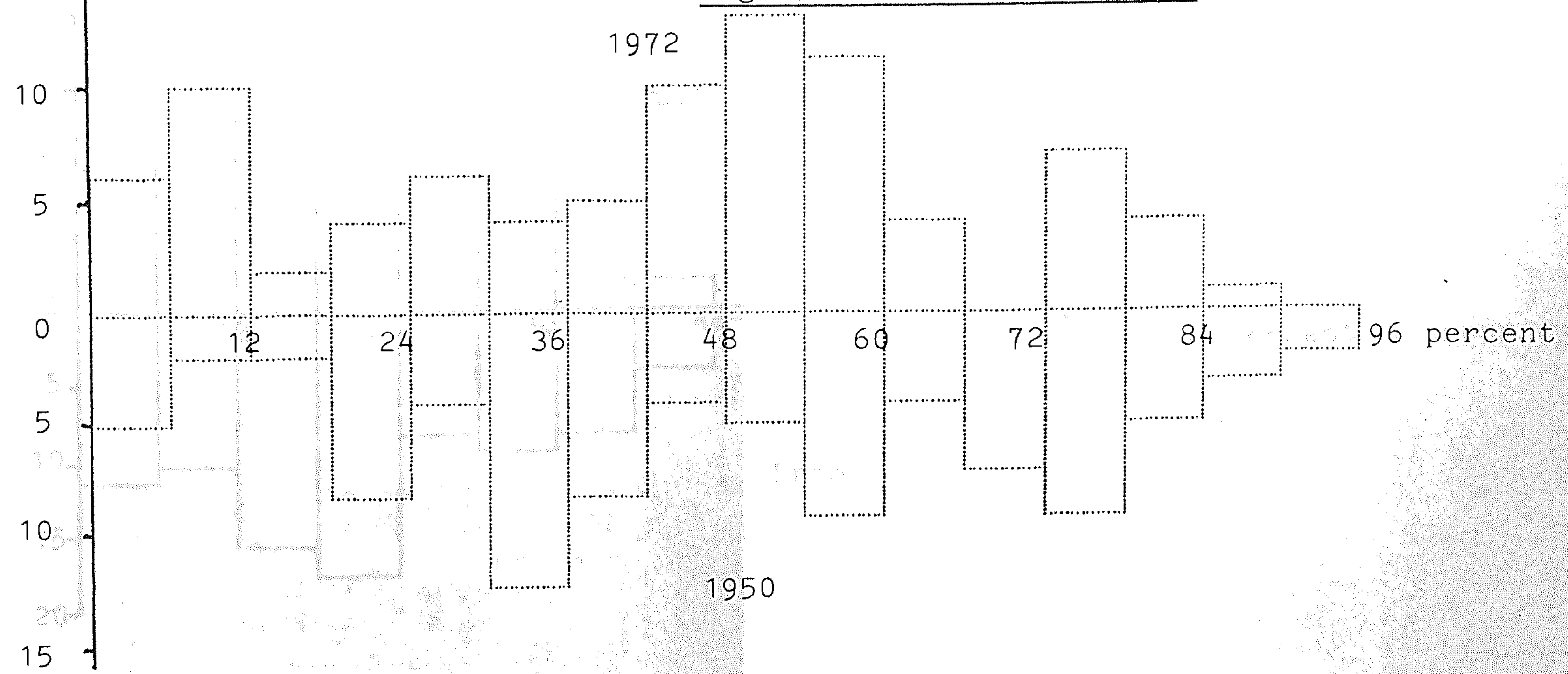


<u>Photograph 42</u>

Fadama grassland

Above 1950, below 1972

Fig 39 Woodland histogram.



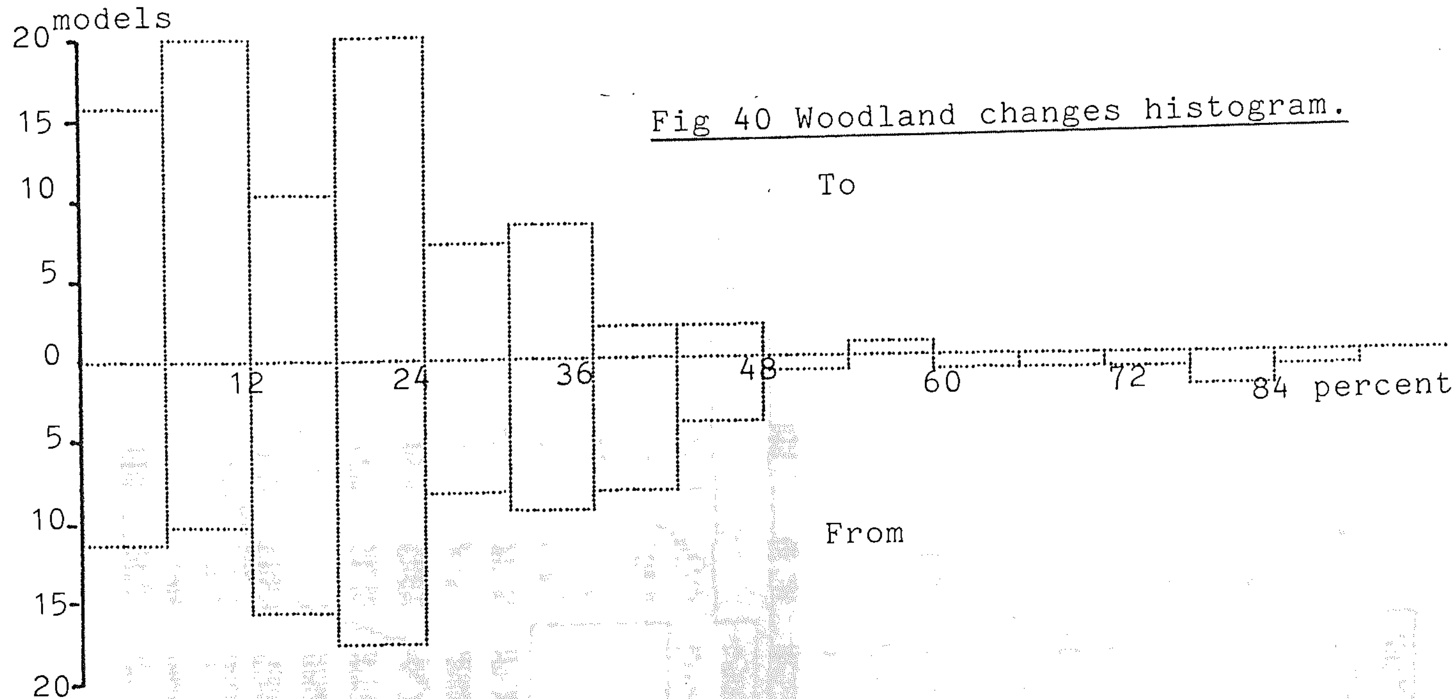
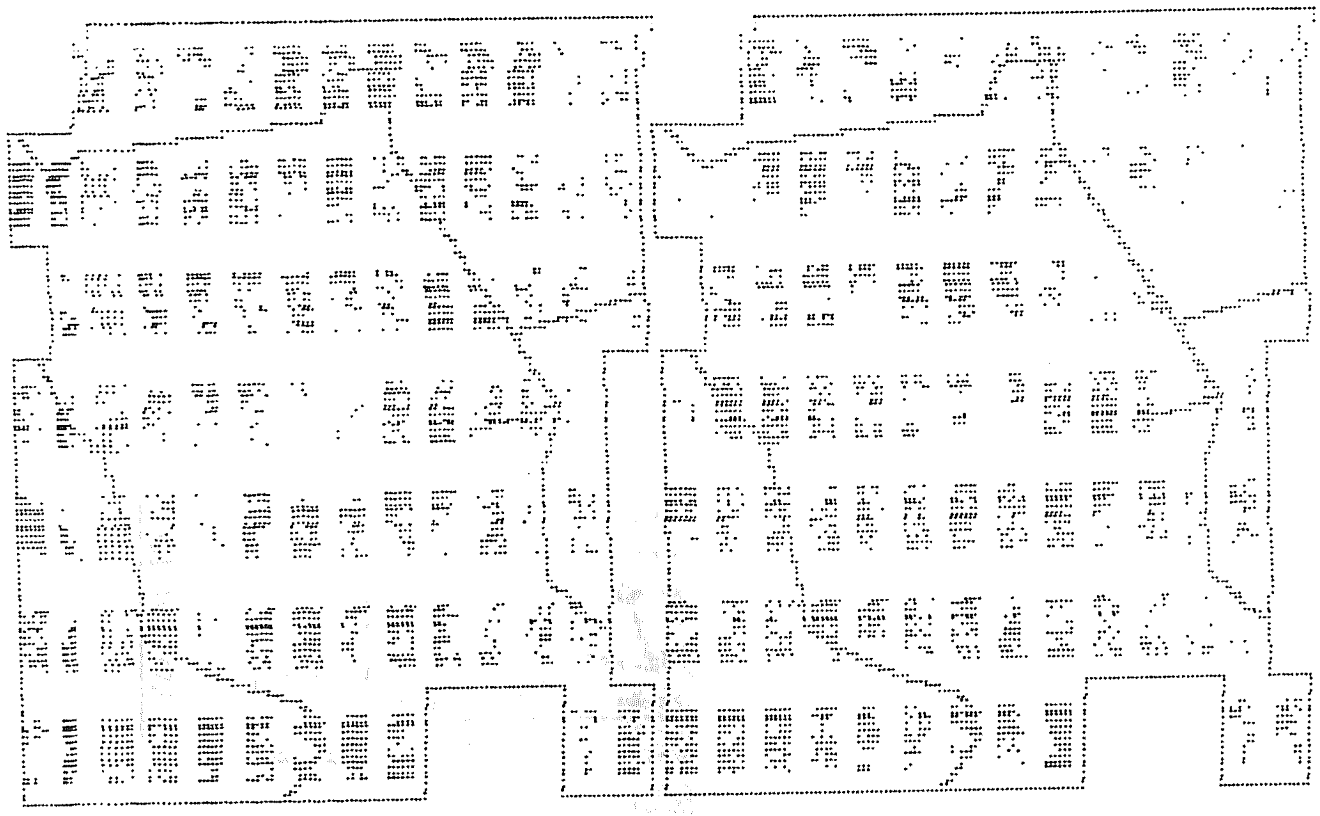


Fig 40 Woodland changes histogram.



1950 1972

Fig 41 Distribution of woodland.

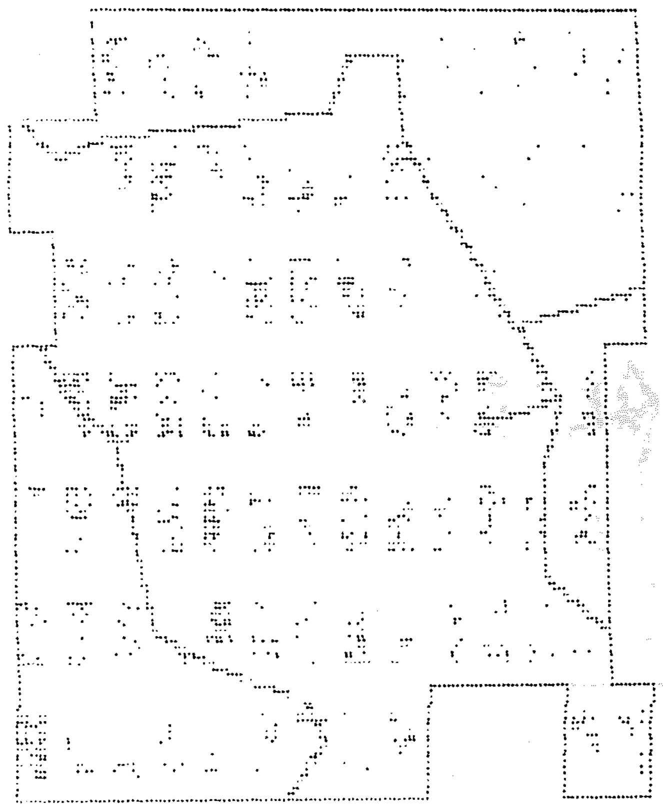


Fig 42 Changes to woodland 1950/72

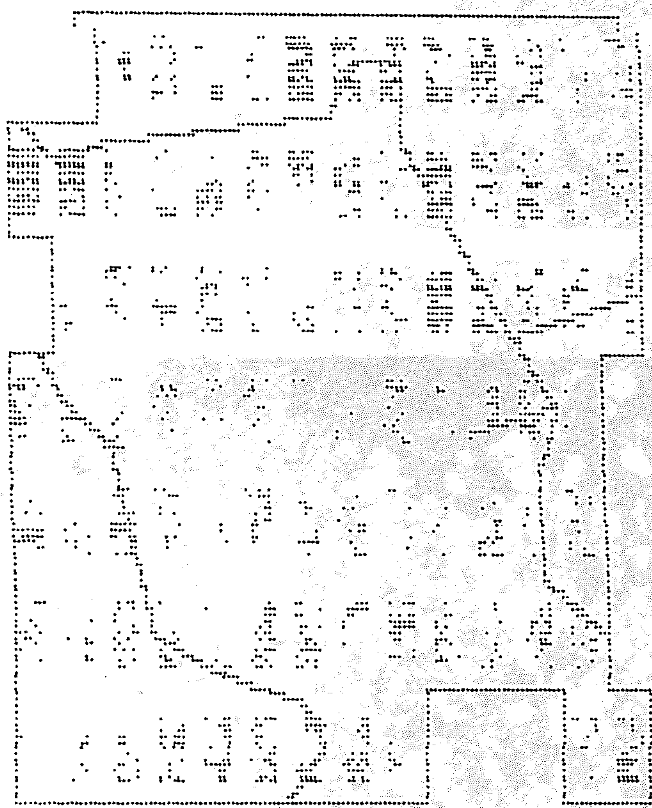
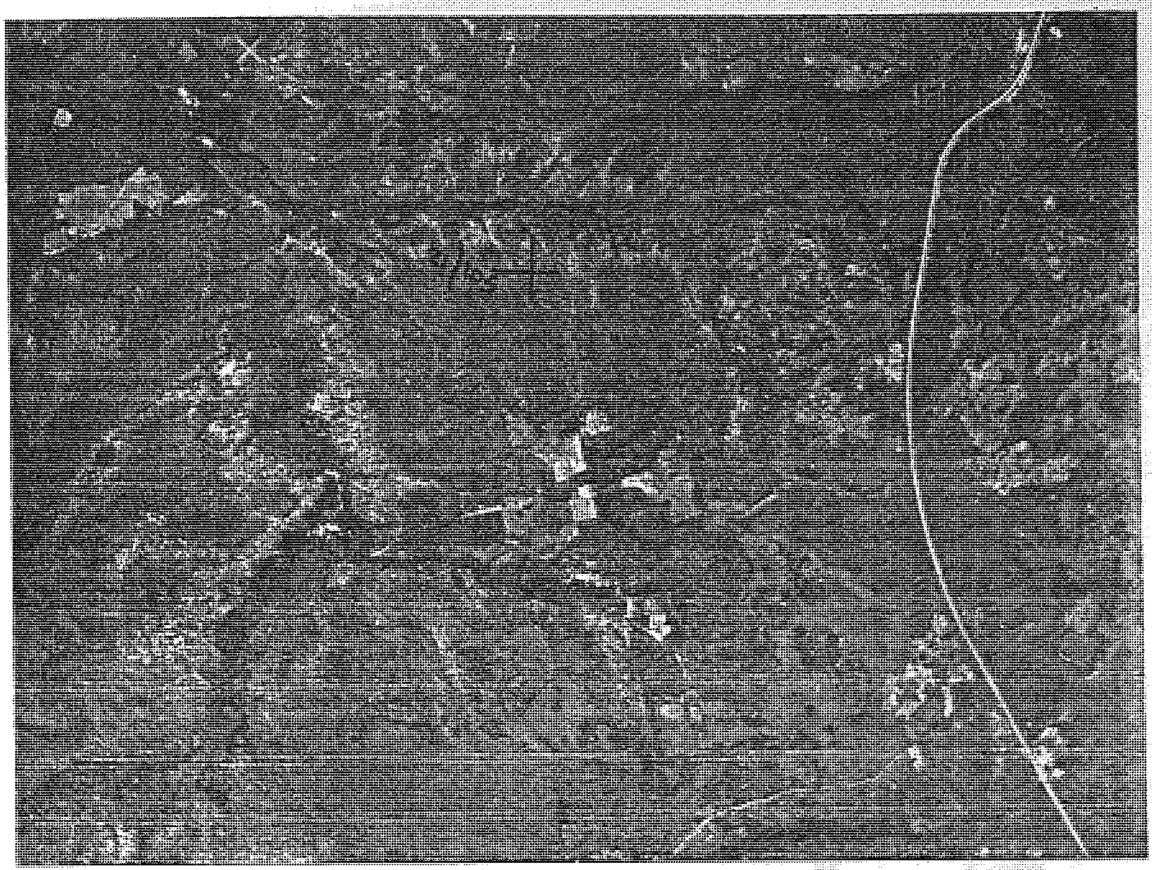


Fig 43 Changes from woodland 1950/72.



Photograph 43

Loss of woodland

Above 1950, below 1972

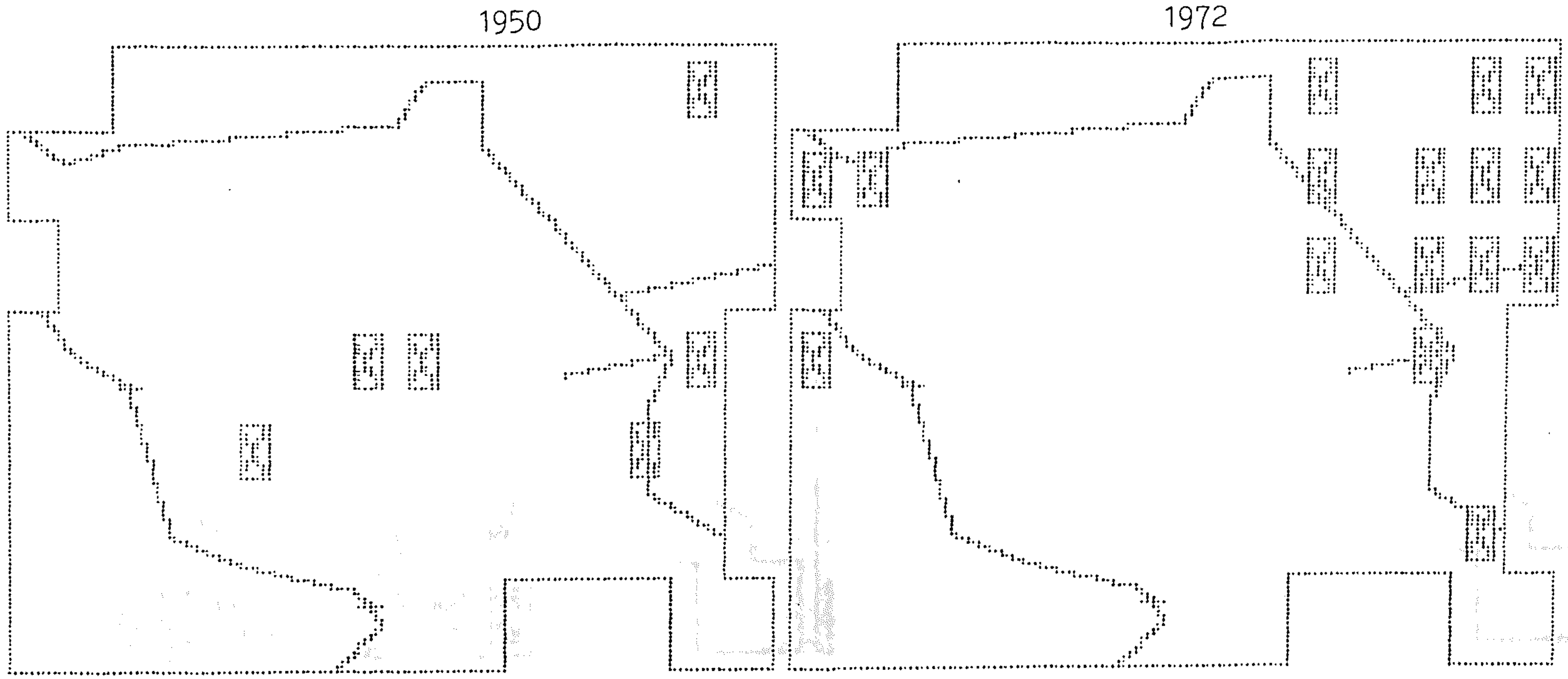


Fig 44 Woodland less than 10% of sample.

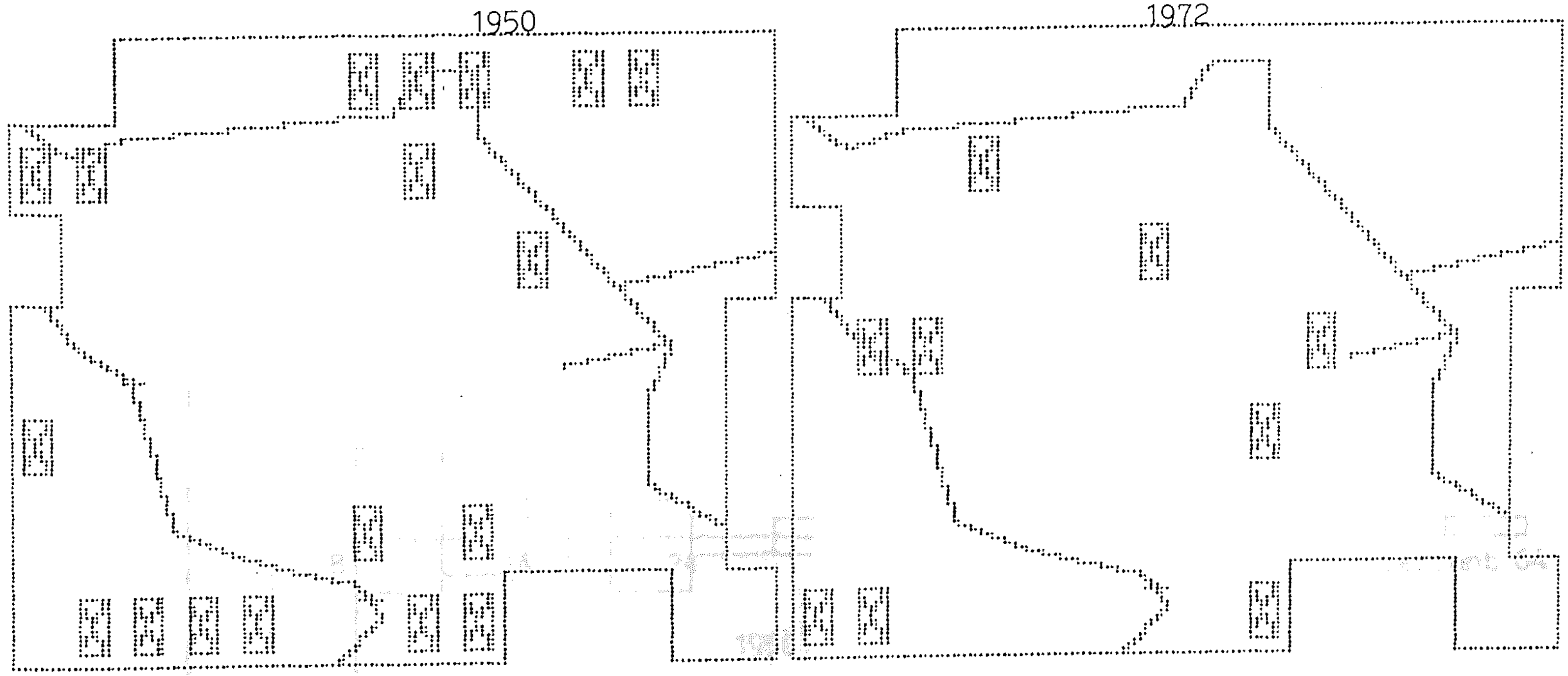


Fig 45 Woodland more than 75% of sample.

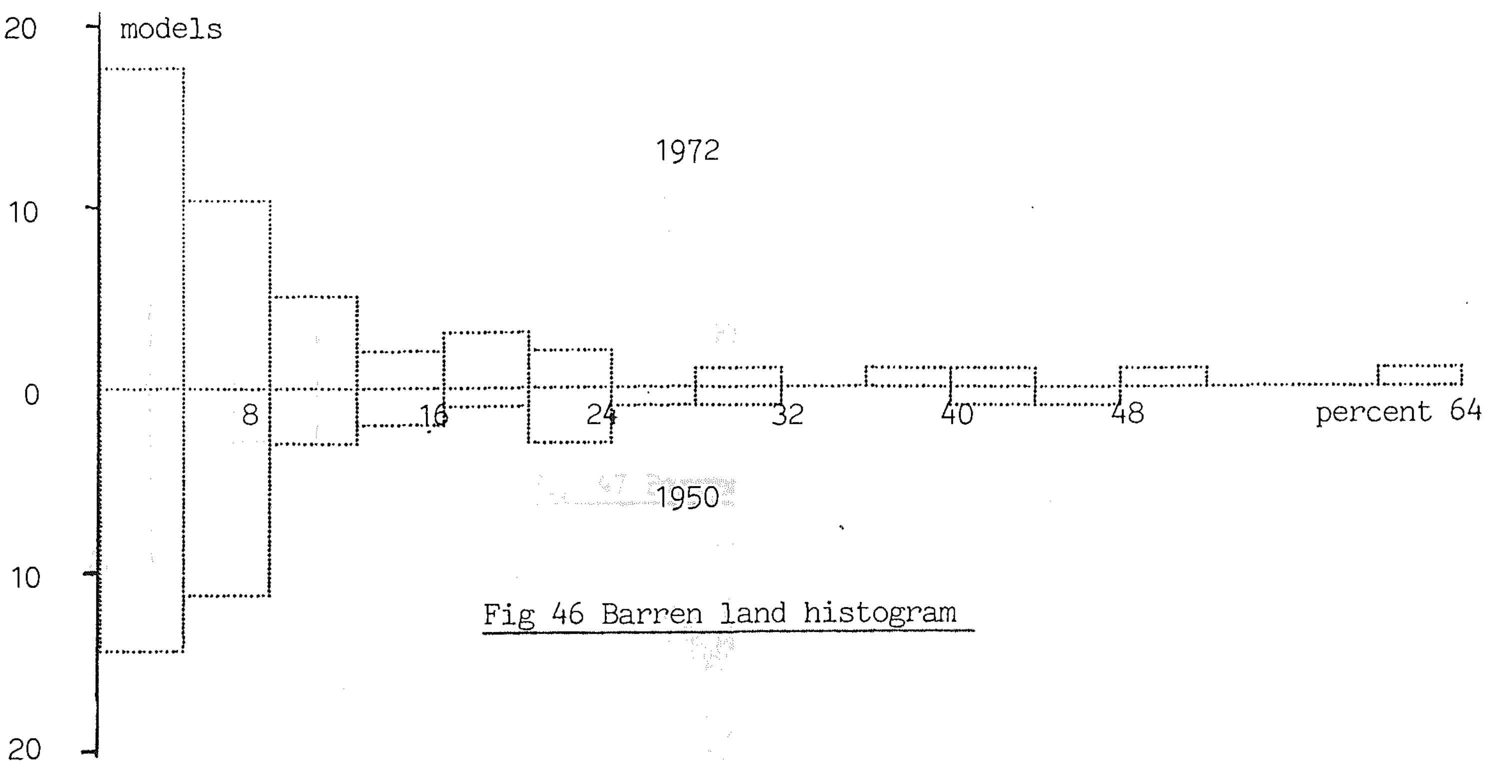


Fig 46 Barren land histogram

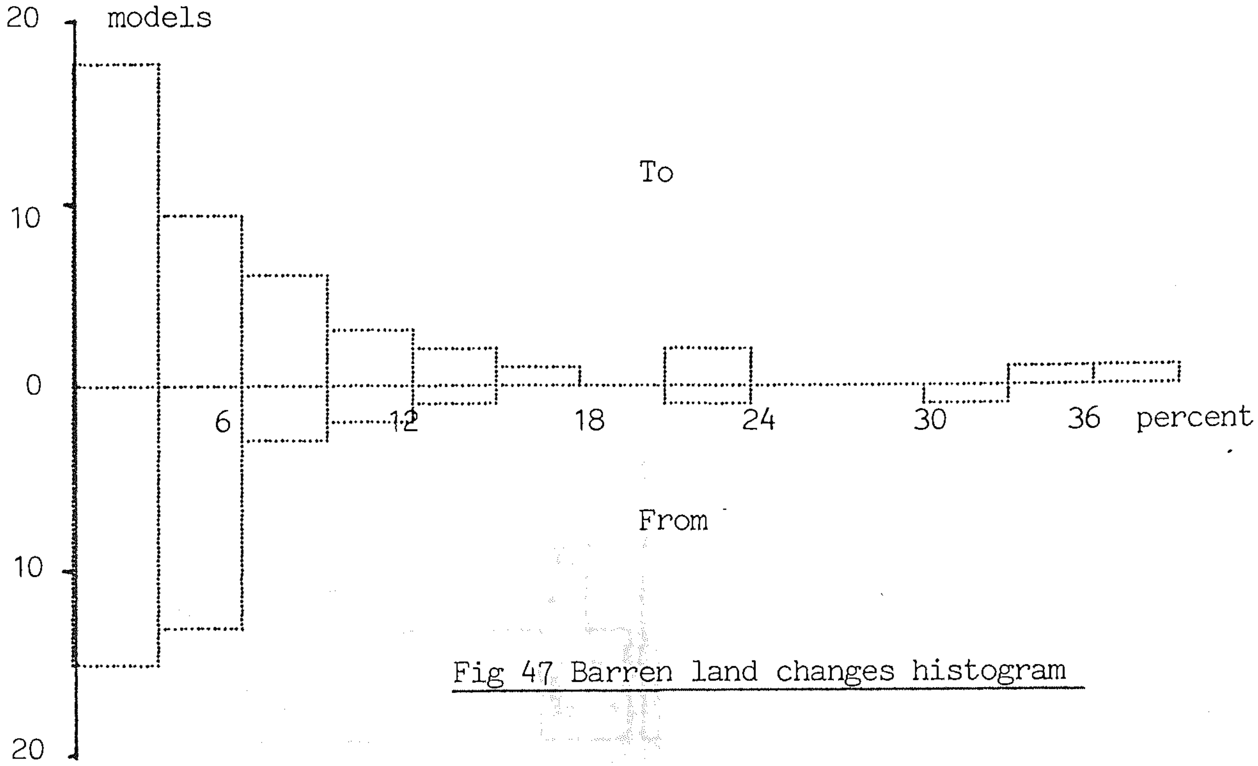


Fig 47 Barren land changes histogram

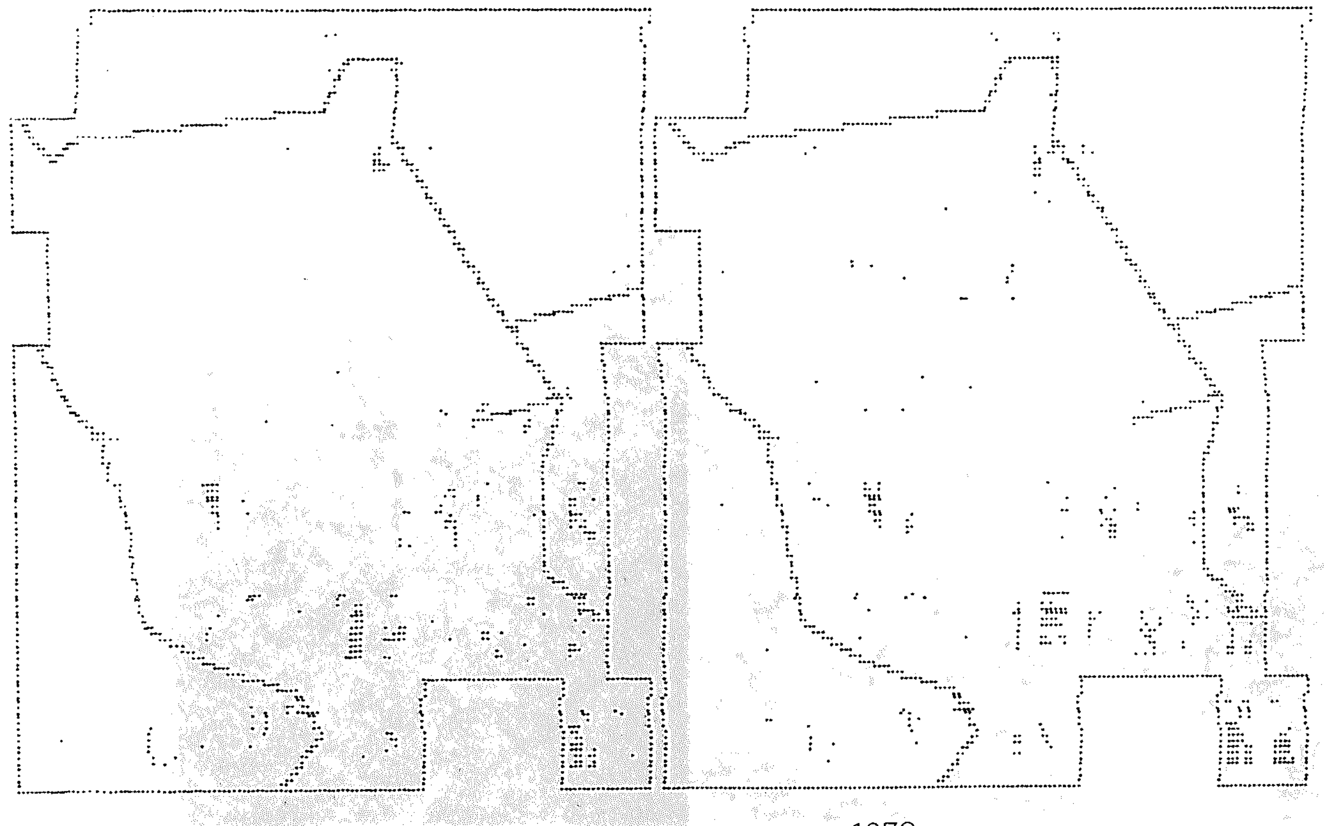


Fig 48 Barren land distribution.

Photograph 44

Steep sided inselbergs
support vegetation in their joints,
such as this fig tree.

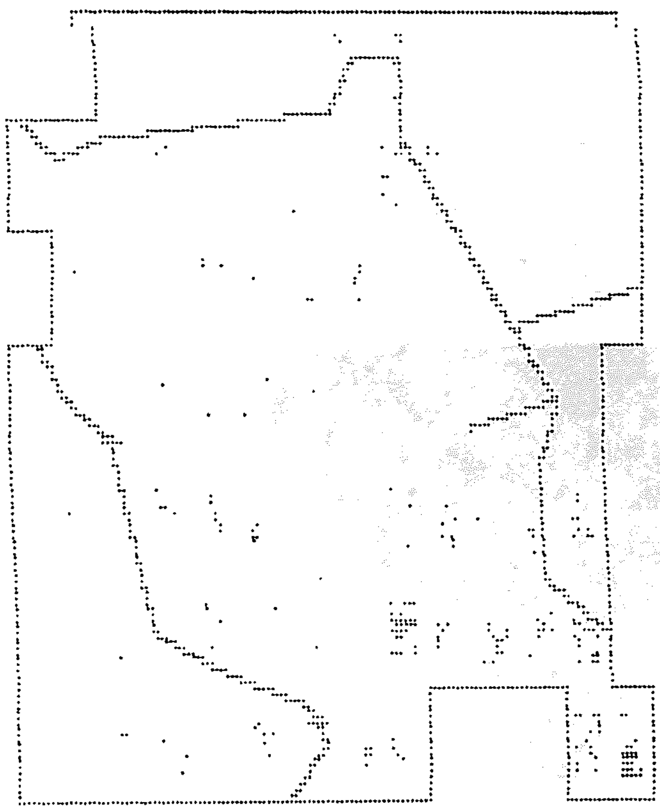
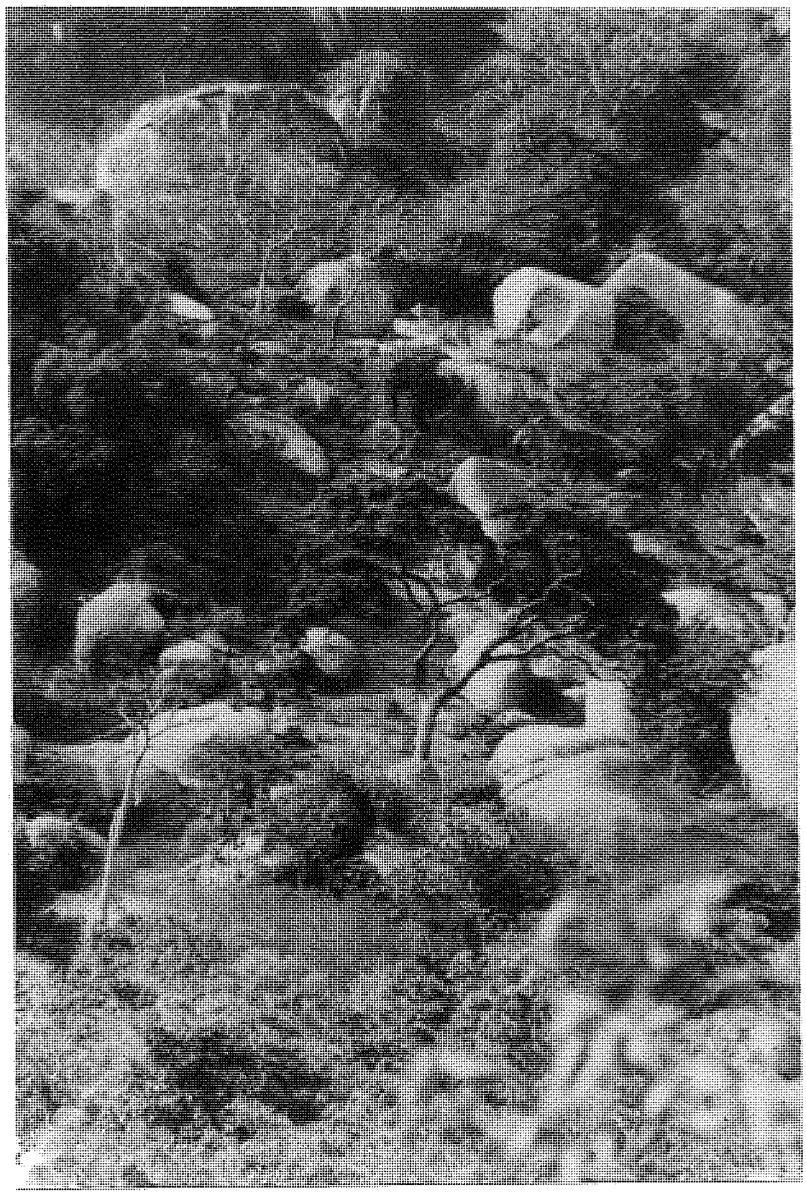


Fig 49 Changes to barren land 1950/72.

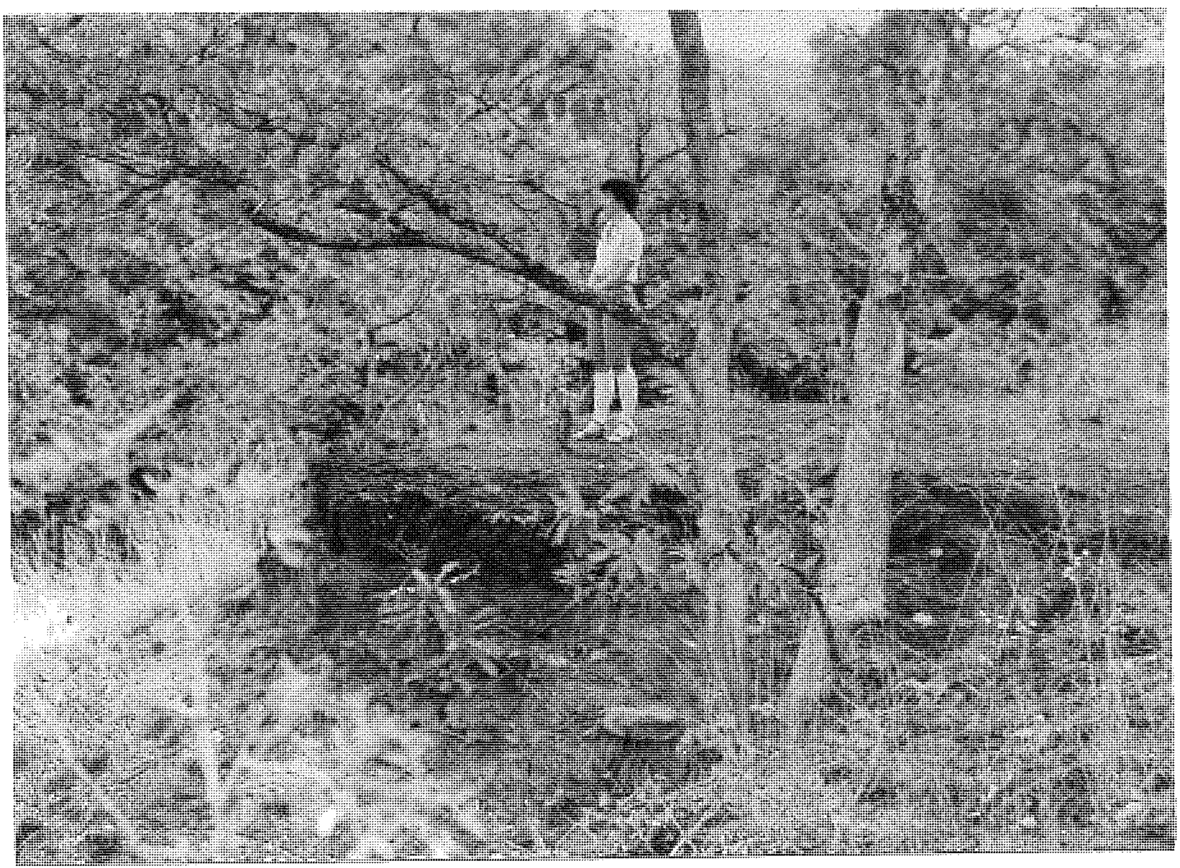


Photograph 45

A kopje - home for animals and birds.

Photograph 46

The edge of a massive ironpan capping.



Photograph 47

The edge of a secondary ironpan scarp in a valley. Gallery forest in the background.

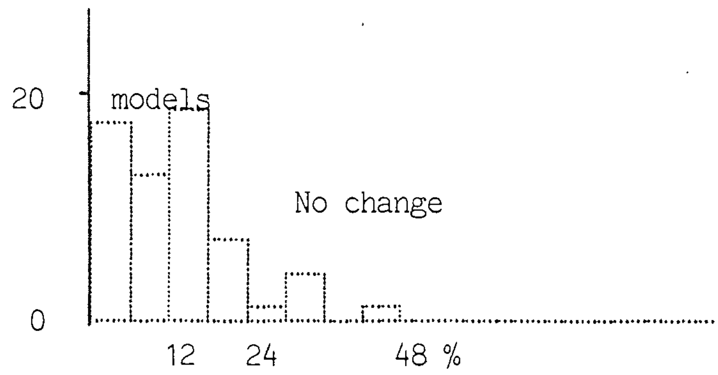
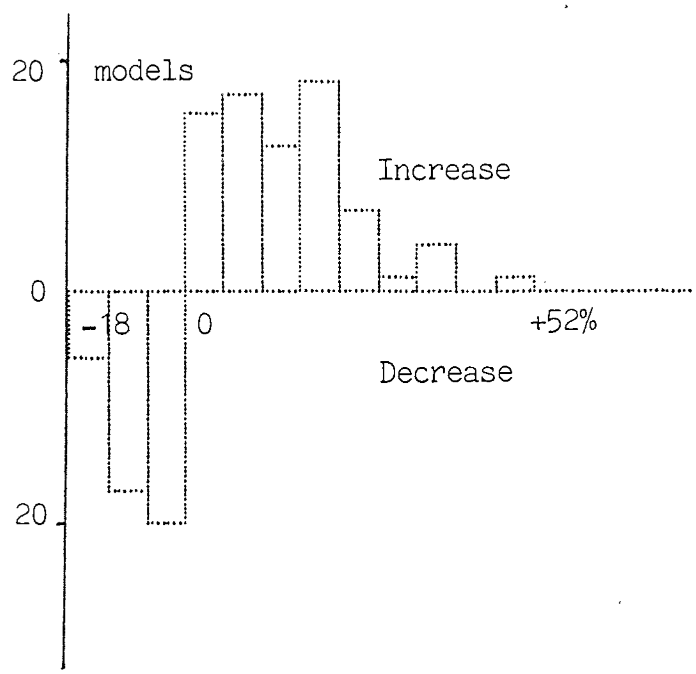


Fig 50 Changes on total land use.



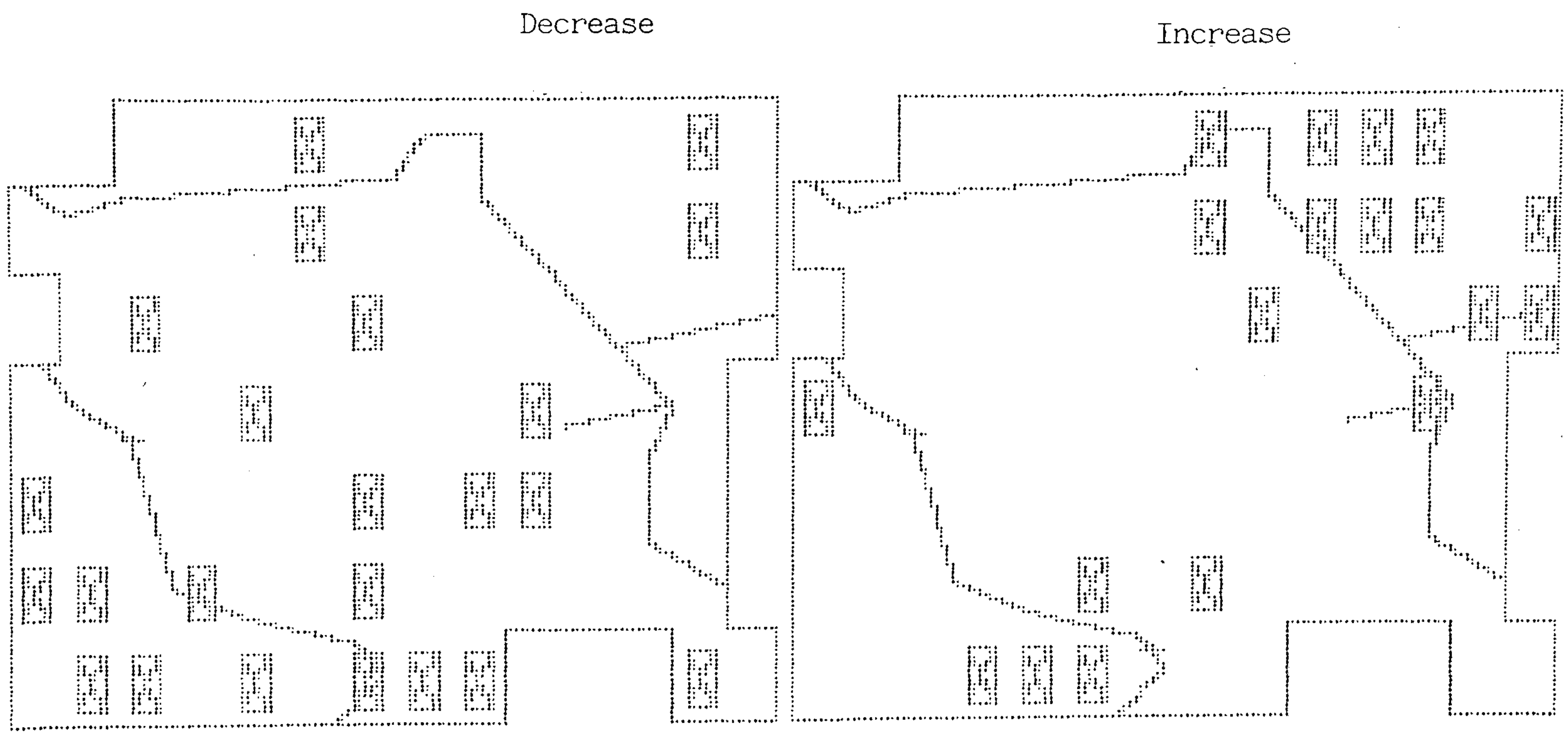
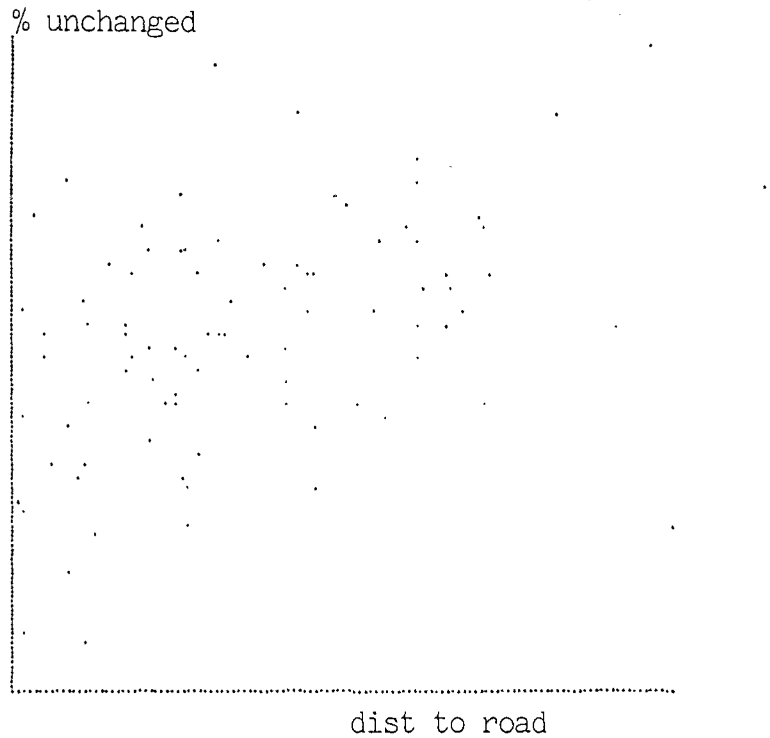


Fig 51 Changes in land use greater than 50%



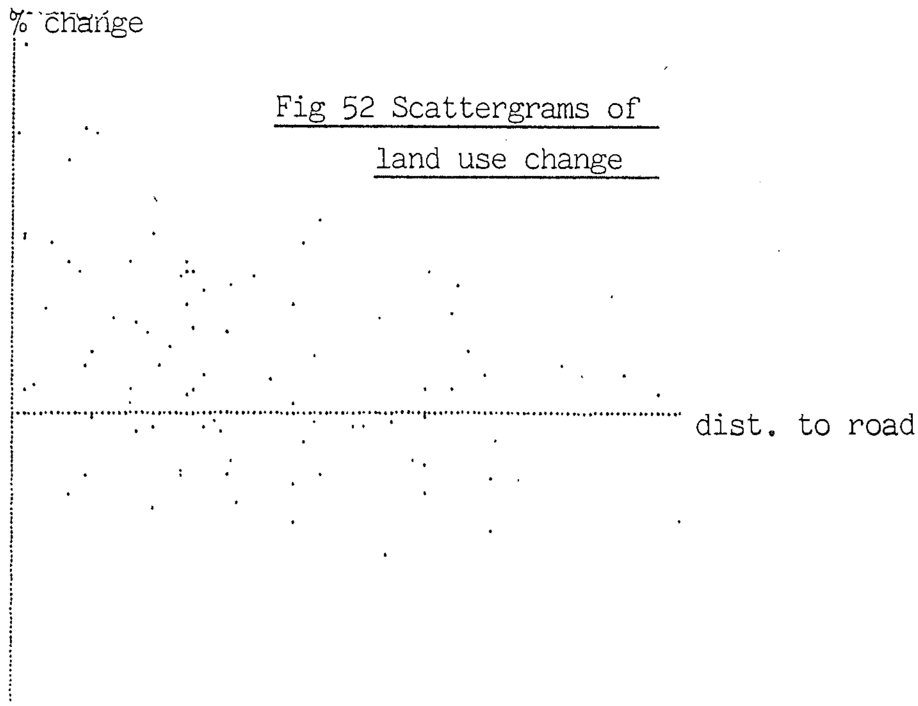


Fig 52 Scattergrams of land use change

C H A P T E R   S I X

ANALYSIS OF DISTRIBUTION

6.1 FACTORS AFFECTING LAND USE DISTRIBUTION

In the last chapter we saw that changes in land use had several causes which could be inferred from the aerial photographs aided by local knowledge and background sources. We can now examine some of these causes and if possible quantify their effects.

Land use changes will be affected by the following factors:

a) Population changes

b) Availability of good farming land

c) Communications

The first two are not easily put into figures, particularly for the small project area. Population is known to be increasing generally, Iloeje (1980) giving a figure of 2.3% for the annual population increase in West Africa. During the study period the population of Zaria Province, of which Kajuru forms part, changed as follows:

Population	Reliability
806 000	1952-53 census
1 553 000	1970 estimate

Sources: Buchanan & Pugh (1955), Uyanga (1980)

Uyanga also calculated that 93.3% of the 1970 population was rural. The Kajuru area presumably enjoyed participating in this increase although many of its products, even if engendered in the villages, end up in the towns. The flight to the city has speeded up in the last 20 years, villages becoming the refuge of in-laws, unloved wives and young children.

Good farming requires level ground, deep well drained soils, and water. We have seen that by choice the farmers will cultivate the lower valley slopes provided they are not too steep, moving up to the interfluves if the soils are not too shallow. Fadamas are important for wet season crops such as rice and for their retention of moisture in the dry season. If areas of this kind have not been used it would seem, from the evidence of the photographs, that it is because they are not easily reached.

This brings us to the one factor which can be measured easily, that is accessibility. Chisholm, (1979 p63) notes "At the small scale of phenomena, the farm and village, . . . the cost of overcoming distance arises largely, if not exclusively, from the amount of human time expended, both in accompanying all imports and products and in transferring from one site of operations to another". He further states (op.cit.p68) "Much of Africa, South and Central America, large areas of Asia, Borneo, New Guinea and elsewhere have never witnessed modern forms of transport, or possess but rudimentary networks. Here are ideal conditions in which zoning about single lines of transport can and does occur". Uyanga (1980 p62), writing about Nigeria notes "It means that because there are (sic) no access and motorable roads to most rural areas development is limited". Ogundana (1973) mentions the generally poor quality of roads in rural areas and their low density. He found that in Ife Division of Oyo State only 294 out of 557 rural settlements were on a road. Ogundana also correlated the condition of the roads with the reliability of the vehicles plying them. This is a familiar feature of the Nigerian rural scene; old untaxed unreliable vehicles with unlicensed underage drivers pick their way through the pot holes of the back roads leaving the main highways to the newer more reliable taxis with more mature, though still unlicensed, drivers.

6.2 ACCESSIBILITY

Distance is one of the two elements in the vector of spatial distribution. It can be easily scaled from a map; perhaps this accounts for its popularity with geographers for correlation studies, particularly for description. Norcliffe (1977 p230) remarks: "Regressions of this type abound in the literature and in student dissertations. The variable that is most commonly used as an independent variable is distance, for the very good reason that several of the theories and models used by geographers require a variable to change as a function of distance from a given node. Distance - dependent relationships are specified in both agricultural and urban land use theory and in diffusion and interaction models".

For the purposes of this analysis each model of the sample was considered as a cluster of points based on the principal point of the photograph. The distance variable could therefore be measured from the principal point which could be located on the map by inspection. From each principal point the distance to the nearest road could be measured. The direct distance was measured, not that along tracks or footpaths. Admittedly these are the routes used in practice, but they are ephemeral, changing from year to year. This direct sample to road distance is the basic unit of accessibility. If a railway station was nearer than a road then the distance was measured from the station.

Once the main road is reached most people get on a vehicle and go somewhere. There are small market villages along the roads, Kasuwan Magani and Kufana are examples, but the big centre is Kaduna itself. A second measure of accessibility is therefore the distance from the principal point to Kaduna. This was taken as comprising the direct distance to the main road or railway station plus the distance along the road or railway to Kaduna. No allowance was made for the different modes of travel.

The Nigerian man in the street is not noted for his sense of time, and is quite accustomed to long delays when making journeys. Nevertheless the laws of economics are not entirely suspended and time spent on the way to market must have its effect. A third indicator of accessibility could therefore be the journey time to the main centre of Kaduna. This will be made up of two out of three components. Distance/time conversion factors are a matter of opinion. How quickly does a vehicle travel on the main road? Should allowance be made for waiting time? Did the average speed of vehicles increase between 1950 and 1972? When the computer programme for correlations was written the time factors were made variable, but it was soon clear that changing the values within reasonable limits had only very small effects on the calculated correlation coefficients. The speeds were therefore standardised as follows:

Code no.	Type of travel	Speed km/hour
1	Off the road	8
2	Main road	56
3	Train	24

Off the road speed was set quite high to allow for part of the distance probably being covered by bicyle. Train speeds were calculated from the timetable.

6.3 CORRELATION

The product-moment coefficient, sometimes known as Pearson's r, is used to test for correlation between pairs of data. The coefficient is calculated as follows (Clarke & Cooke 1983 p325):

$$r = \frac{\sum_{i=1}^{n} (xi - \bar{x})^2 \; . \; (yi - \bar{y})^2}{\left[\sum_{i=1}^{n} (xi - \bar{x})^2 \; . \; \sum_{i=1}^{n} (yi - \bar{y})^2\right]^{\frac{1}{2}}}$$

where xi , yi = pairs of measurements

x, y = arithmetic means

n = number of measurements

i = 1,2,3, ...,n

r = product-moment correlation coefficient

Pearons's r takes values between -1 and +1, strong correlation being indicated by values tending towards 1, no correlation giving a zero value. The calculation may be included in a bivariate sample analysis such as Algorithm 6.6 by Cooke et al (1982).

The correlation coefficient is tested for significance by comparing it with the values taken by a percentage of the theoretical population based on zero. The test is two tailed and may be made at 5%, 1% and 0.1% levels, the null hypothesis being that there is no correlation. (Clarke 1980 p183)

Tests were carried out to find the correlation between accessibility and land use. Four of the principal land use categories were tested:

11 Settlement

23 Unenclosed farmland & early bush fallow

33 Scrub and small trees

35 Woodland

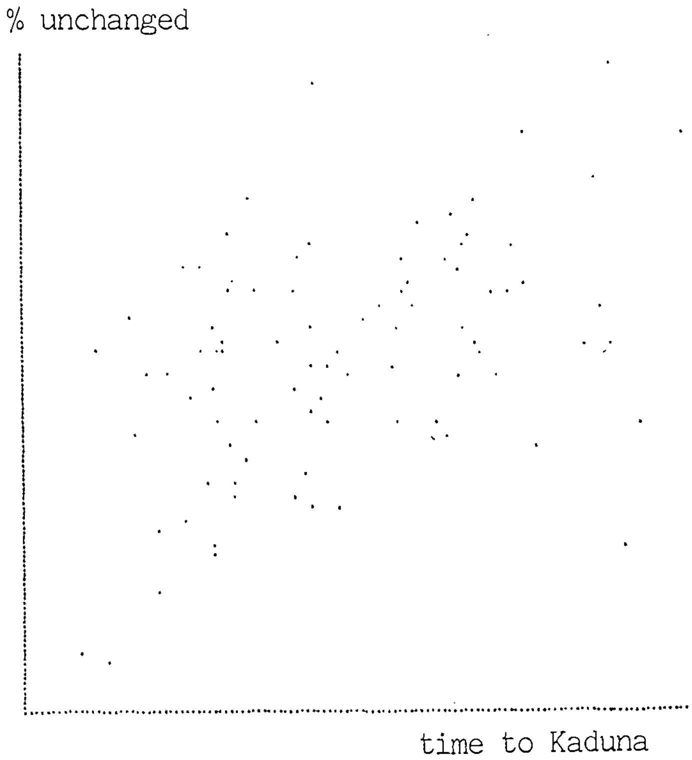
Thev were tested in 1950, in 1972, and in the form of changes to or from each category. Total land use change was also investigated (it is defined in section 5.42). The significant results are shown in the tables 35-38, the full record of all tests is in Appendix C.

6.31 Land use & accessibility 1950 (Table 35)

Generally in 1950 there was only a slight correlation of land use with accessibility. This confirms the qualitative judgment made by looking at the aerial photographs, that the communications at that time had very little influence on where people lived or what they did with the land. The impression is one of self contained subsistence farming with few external influences. The significant correlations may indicate a causal relationship or they may be the result of variations in soil and topography, the area furthest from Kaduna is also the most rugged and therefore more likely to be sparsely farmed. However the negative correlation at 1% level of woodland with distance to Kaduna is interesting. The supply of firewood to the township in 1950 has apparently not caused a diminution of the woodland nearby, at least not in this direction.

6.32 Land use & accessibility (Table 36)

By 1972 there were twice as many significant correlations and half of them are at the 0.1% level; communications had



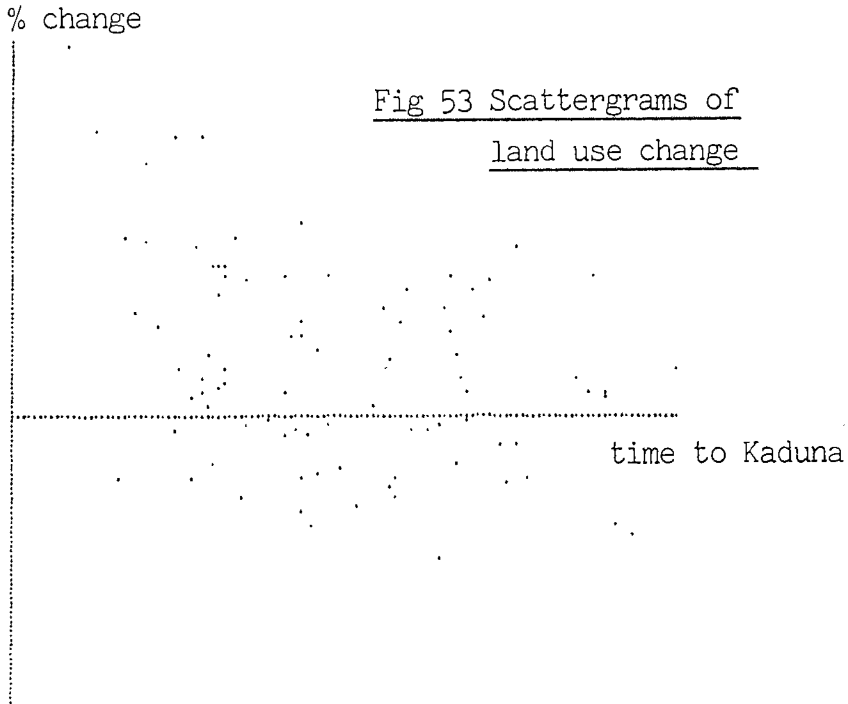


Fig 53 Scattergrams of land use change

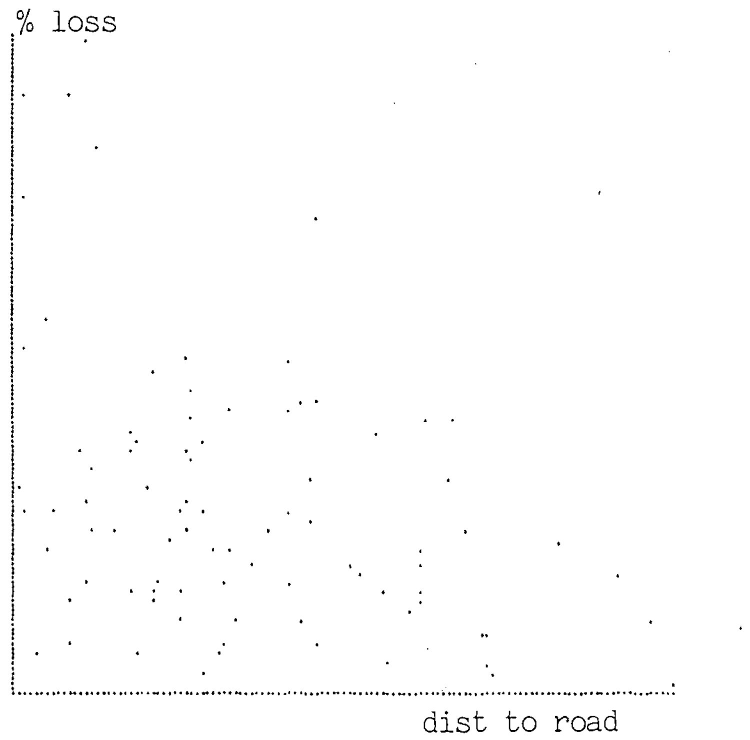
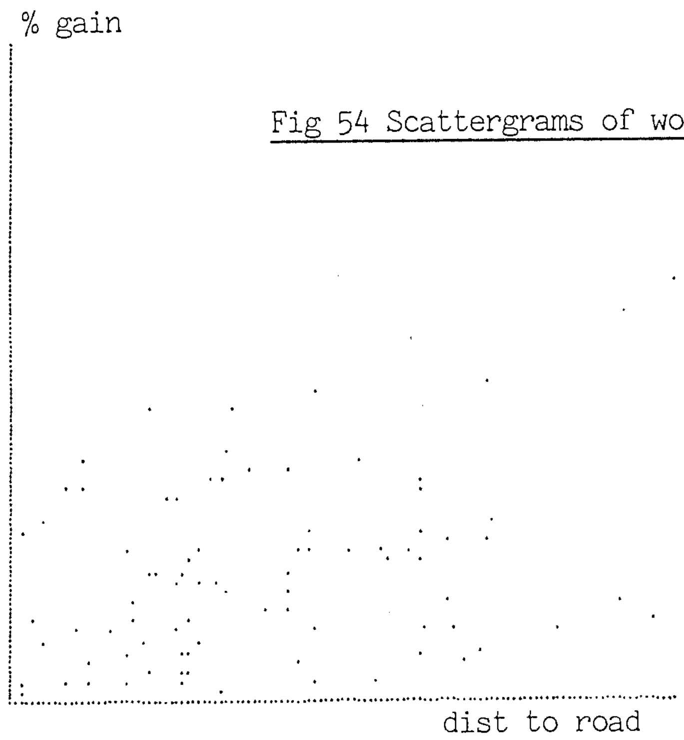


Fig 54 Scattergrams of woodland change



LAND USE & ACCESSIBILITY

SIGNIFICANT CORRELATIONS

TABLE 35

1950

Land use	Access factor	Correlation coefficient	Sign. level
Farmland	Time to Kaduna	-0.246	5%
Scrub	Distance to Kaduna	0.256	5%
Woodland	Distance to Kaduna	-0.314	1%

TABLE 36

1972

Settlement	Distance to road (ln)	-0.562	0.1%
Farmland	Distance to road (ln)	-0.399	0.1%
	Time to Kaduna	-0.309	1%
Scrub	Distance to road	-0.393	0.1%
	Time to Kaduna	-0.396	0.1%
Woodland	Distance to road	0.346	1%
	Time to Kaduna	0.332	1%

Note: (ln shows that the natural logarithm of the access factor has been taken.

become important in the land use pattern. Causal relationships can be inferred from the correlation between four land use categories and distance to the road or railway station. Settlement, farmland, and scrub (land cleared and recently farmed) have a 0.1% level negative correlation with this access factor. Noteworthy is the strong positive association of woodland with distance from the road or railway station and with time to Kaduna. Scrub is now negatively correlated with time to Kaduna, it may have replaced the woodland of 1950. Again the impression derived in Chapter 5 is confirmed. The growth of roadside villages and the decay of settlements away from the roads has been noticed. Farm and scrub (or the late stages of bush fallow) are usually near the village: woodland disappears near the road and becomes restricted to more remote areas. The influence of Kaduna is apparent in the correlations of farmland and scrub (negative) and woodland (positive) with the journey time to the town.

6.33 Land use & accessibility changes 1950-72 (Table 37)

Changes in all four categories of land use tested are significantly correlated with distance to the road or railway station. In the cases of settlement, farmland, and scrub the balance between changes to the category and changes from it becomes more positive as distance decreases. With woodland the reverse is true. This association also holds for time to Kaduna.

6.34 Land use & accessibility, total changes (Table 38)
Examination of the correlations generated by the total changes in land use summarises the situation. There is a 0.1% level negative correlation with log. distance to the road or railway station showing the strong attraction of communications to development. The less significant negative correlation of change with time to Kaduna has to be examined bearing in mind that other factors may also make a contribution. Generally, although it is not possible to say that intensification of land use is directly caused by good communications and proximity of a large town it is reasonable to deduce a strong connection between them.

6.4 LINEFITTING

6.40 A number of significant correlations have now been established between categories of land use and accessibility. We may now consider whether there is a linear relationship between them. Scattergrams (figures 52-54) show that the relationship if it exists is not solely between accessibility and land use; other factors are also important. Most of the graphs show a cloud of points through which it would seem difficult to draw a trend line. Some however, such as those of total change against distance to the road/railway station (figure 52) or against time to Kaduna show some tendency towards linearity. Prediction of land use from a linefit calculation cannot be expected to be very accurate, but

LAND USE & ACCESSIBILITY

SIGNIFICANT CORRELATIONS

TABLE 37

CHANGES 1950-72

Land use	Access factor	Correlation coefficient	Sign. level
Settlement	Distance to road (ln)	-0.579	0.1%
	Time to Kaduna (ln)	-0.333	5%
Farmland	Distance to road (ln)	-0.341	1%
Scrub	Distance to road	-0.378	0.1%
	Distance to Kaduna (ln)	-0.292	1%
	Time to Kaduna (ln)	-0.437	0.1%
Woodland	Distance to road (ln)	0.436	0.1%
	Time to Kaduna (ln)	0.410	0.1%

TABLE 38

TOTAL CHANGES

Distance to road (ln)	-0.457	0.1%
Time to Kaduna	-0.312	1%

such a calculation may be useful to describe trends and relationships.

6.41 Linear regression calculation

The technique of linear regression is well known. It is described by Clarke & Cooke (1983) in their 21st chapter. The calculations were made using Algorithms 5.5 Scattergram, 11.1 Linefit, and 11.2 Linefit output by Cooke et al (1982). The regression is of a land use category upon accessibility in the form:

$$y = a + b.x$$

where a = y-axis intercept coefficient

b = slope coefficient

x = access type, the independent variable

y = land use category, the dependent variable

if appropriate the natural logarithm of x is taken, indicated by ln(x).

The output of the computation is shown in figures 55-67. An estimate is given of the coefficients, their standard errors, the sum of squares, degrees of freedom, and the mean squares. A scattergram of the residuals is also provided. The reliability of the coefficients at the 95% confidence level may be found by multiplying the standard errors by the 0.05 value of Student's t with the appropriate degrees of freedom. An F value may be obtained as follows:

$$F = \frac{\text{MS regression}}{\text{MS residuals}}$$

This may be compared with the F distribution to test the significance of the linefit calculation (Clarke 1980 p97).

6.42 Linefit results

Computations were made for all the relationships which gave a correlation coefficient of 5% or better. The results are given in full in Appendix E. Eleven out of the thirty eight relationships gave an F test value significant at the 0.1% level. They are summarised in table 39. All four land use categories have a significant relationship with the distance from a road or a railway station. Settlement, farmland, and scrub were all related to this factor in 1972. Changes in the three categories of settlement, scrub, and woodland were also related to the same factor. The travelling time to Kaduna also affected the changes which took place in the distribution of scrub and woodland between 1950 and 1972. Finally the total change in land use was related both to the time factor and the distance to a road, most strongly to the latter.

TABLE 39

LINEAR REGRESSIONS

SIGNIFICANT AT 0.1% LEVEL

Formula: y = a + b.x

y = land use category

x = accessibility factor

(ln) = natural logarithm

Land use		Coefficients a	95% conf. +/-	b	+/-	Access factor
Settlement	1972	+2.862	0.806	-1.246	0.619	Dist to rd(ln)
	changes	+2.475	0.812	-1.379	0.620	Dist to rd(ln)
Farmland	1972	+21.609	3.009	-4.543	2.241	Dist to rd(ln)
Scrub	1972	+22.287	4.072	-1.868	0.949	Dist to rd(ln)
	1972	+25.882	5.638	-7.665	3.859	Time to Kaduna
	changes	+4.823	6.300	-12.732	1.459	Dist to rd
	changes	-2.301	3.630	-15.639	7.027	Time to Kad(ln)
Woodland						
	changes	-15.072	5.337	+8.999	3.990	Dist to rd(ln)
	changes	-10.134	4.229	+16.722	8.071	Time to Kad(ln)
Total changes		+0.678	0.404	-0.723	0.300	Dist to rd(ln)
		+0.185	0.322	-0.976	0.635	Time to Kad(ln)

6.5 SUMMARY

6.51 Land use and land use changes may be affected by population changes, availability of good farming land, and communications. The first two cannot easily be measured for the test area, but roads and railways can be seen and measured on the aerial photographs.

6.52 Accessibility is a function of communications. Three measures are proposed:

1. Distance to a main road or to a railway station.
2. Total distance to Kaduna.
3. Travel time to Kaduna.

6.53 The product-moment coefficient of correlation was calculated to find the correlations between the three measures of accessibility and four selected categories of land use, plus the total changes in land use.

6.54 Significant correlations were found between all the selected categories and distance to the road or railway station in 1972 but not in 1950. Changes were also correlated with this factor. Travel time to Kaduna was significant in some cases.

6.55 Linear regression confirmed the correlations showing a linear relationship between land use changes and accessibility.

```
REGRESSION OF CLASS 1 ON 1
YEAR 2
FITTED LINE IS  Y = A + B*LNX

COEFFICIENT    ESTIMATE    ST.ERROR
     A           2.8[illegible]       .4
     B          -1.25        .31

SOURCE          SS          DF    MS

REGRESSION     73.[illegible]          1    73.07
RESIDUAL       157.[illegible]        36    4.37[illegible]

SCATTERGRAM OF RESIDUALS
9.27  I
      I
      I
      I
      I
      I
      I
      I
      I
      I       *
      I                     *
      I        *
      I   *  *
      I19  *  *  *
      I      2*2 2
      I         *
      I
-2.87 I               *     *
      ----------------------------
        0                    5.73
```

Fig 55 Regression - settlement on distance to road/rail. 1972

```
REGRESSION OF CLASS 1 ON 1
CHANGES 50/72
FITTED LINE IS  Y = A + B*LNX

COEFFICIENT    ESTIMATE   ST.ERROR
      A        2.48        .4
      B        -1.36       .31

SOURCE         SS          DF    MS

REGRESSION   73.49        1     93.49
RESIDUAL     184.91       40    4.62TOTAL278.4

SCATTERGRAM OF RESIDUALS
9.35  I
      I
      I
      I
      I
      I
      I
      I
      I     *             *
      I      *
      I *
      I 20** *
      I     **3  2*
      I*        *
      I    **
      I                   *
      I
-4.18 I             *
      ------------------------

       -.19                 5.65
```

Fig 56 Regression - settlement on distance to road/rail 50/72

```
REGRESSION OF CLASS 6 ON 1
YEAR 2
FITTED LINE IS   Y = A + B*LNX

COEFFICIENT    ESTIMATE    ST.ERROR
       A         21.51        .91
       B          [illegible]      1.13

SOURCE         SS            DF    MS

REGRESSION  [illegible]         1     [illegible]
RESIDUAL    [illegible]      [illegible]    [illegible] 07 2.56

SCATTERGRAPH OF [illegible]
28.3    I
        I
        I            2*        *
        I
        I         **      *
        I            * *  *
        I        *     *  *
        I         *  *2
        I          *  2***
        I        *2332   *
        I         ****2
        I         **3*2   *     *
        I        *23  2**    2
        I           *2*2*
        I          *22*  *
        I           **      *  *
        I               *
-18.92I                  *     *
        ------------------------------------
         0                          32.07
```

Fig 57 Regression of farmland on distance to road/rail 1972.

```
REGRESSION OF CLASS 6 ON 1
CHANGES 50/72
FITTED LINE IS  Y = A + B*LNX

COEFFICIENT   ESTIMATE   ST.ERROR
      A        11.64       1.42
      B        -3.54       1.06

SOURCE        SS         DF    MS

REGRESSION  1029.35     1     1029.35
RESIDUAL    7821.13    85     92.01TOTAL8850.48

SCATTERGRAM OF RESIDUALS
24.66 I
      I          2   *
      I         *      *
      I       *
      I      2 *   *
      I         2*         *
      I    2*1* *
      I     ***  **   *
      I     *33**2
      I2   *   **  *  *
      I     *   2** *
      I      *****2 3  **
      I       * 2*2
      I     ******     *
      I      *  **         *
      I             *      *
      I        * *
-20.02I              *
      ------------------------
       0                     19.8
```

Fig 58 Regression of farmland on distance to road/rail 50/72.

```
IPREO
REGRESSION OF CLASS 10 ON 1
YEAR 2
FITTED LINE IS  Y = A + B* X

COEFFICIENT    ESTIMATE   ST.ERROR
       A       22.297     2.046
       B       -1.863     .477

SOURCE        SS          DF    MS

REGRESSION  1698.35      1      1698.35
RESIDUAL    9291.98      84     110.62TOTAL10990.34

PEARSON'S R -.393 NO OF OBS 86

RESIDUALS ? N
SCATTERGRAM ? Y
30.768I
      I          *
      I                 *
      I              *     *
      I                  2
      I         *   *    *   *
      I                  ** *
      I           *         **
      I               *
      I         *        *  *
      I2          2* **  2 3*
      I    2*    ** * *  * ***
      I       * ** * *2**33  *
      I         **2 * *  ***
      I                 2*
      I                 2 * **
      I                  2
-17.606I                     *
      ------------------------
       0                    21.914
```

Fig 59 Regression of scrub on distance to road/rail 1972.

```
REGRESSION OF CLASS 10 ON 2
YEAR 2
FITTED LINE IS  Y = A + B* X

COEFFICIENT    ESTIMATE    ST.ERROR
        A        25.862      2.833
        B        -7.645      1.939

SOURCE        SS          DF    MS

REGRESSION  1721.35       1     1721.35
RESIDUAL    7235.??       34    110.317
```

```
PEARSON'S R -.396 NO OF OBS 66

RESIDUALS ? N
SCATTERGRAM ? Y
```

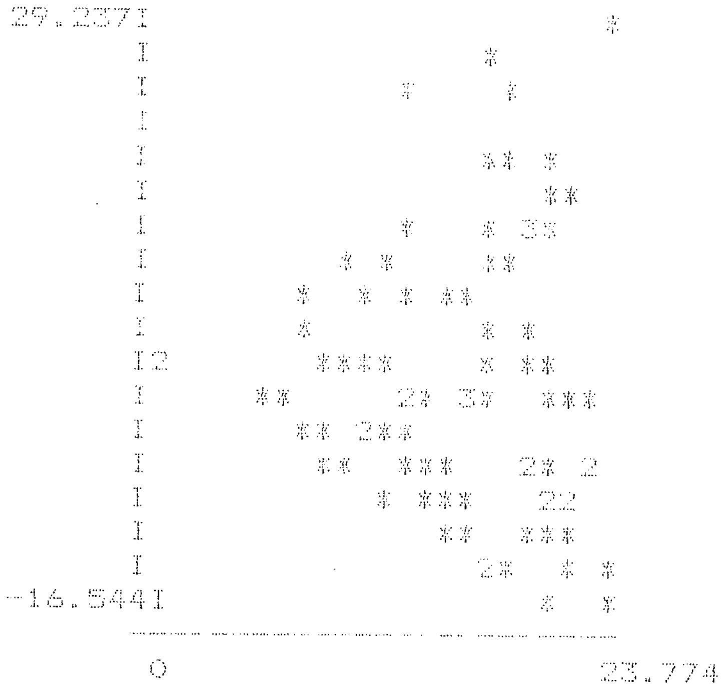


Fig 60 Regression of scrub on time to Kaduna 1972.

```
REGRESSION OF CLASS 10 ON 1
CHANGES 50/72
FITTED LINE IS  Y = A + B* X

COEFFICIENT    ESTIMATE    ST.ERROR
      A        4.923       3.166
      B        -2.732      .733

SOURCE        SS          DF    MS

REGRESSION  3711.63    1     3711.63
RESIDUAL    22211.08   83    267.6TOTAL25922.71

PEARSON'S R -.378 NO OF CAS 85
SCATTERGRAM OF RESIDUALS
49.1821
      I
      I             *   *   *
      I
      I
      I          *         *
      I       * 2       *
      I *      *    **  * 2
      I    *    *   * *  *2  *
      I       2** * 3  2   **
      I        *       3  4
      I  *      2   *  32* 2
      I         *       *2  3
      I                 * *  3
      I      *   **   *   *
      I       *          *  *
      I*               *
-33.55I             *
       ......................
       -22.494              4.95
```

Fig 61 Regression of scrub on distance to road/rail 50/72.

```
REGRESSION OF CLASS 10 ON 3
CHANGES 50/72
FITTED LINE IS  Y = A + B*LNX

COEFFICIENT    ESTIMATE    ST.ERROR
       A       -2.301      1.824
       B       -15.637     3.531

SOURCE         SS          DF    MS

REGRESSION   4955.86    1     4955.86
RESIDUAL     20966.85   83    252.61TOTAL25922.71

PEARSON'S R -.437 NO OF OBS 85
SCATTERGRAM OF RESIDUALS
36.788I         *   *
      I               *
      I *          *
      I *
      I  *    ** *  *
      I     *
      I* * 2*3    **   *
      I * * *  2***2
      I   * ***2 *4*  **
      I    * *22*
      I    2     *  *
      I  *   *   2* *
      I     *  2   * 2
      I *   *    *       *
      I  **   *             *
      I            * *
      I
-36.73I  *
      ------------------------
       -17.858               17.898
```

Fig 62 Regression of scrub on time to Kaduna 50/72.

```
REGRESSION OF CLASS 12 ON 1
YEAR 2
FITTED LINE IS  Y = A + B* X

COEFFICIENT    ESTIMATE    ST.ERROR
         A        20.49        3.06
         B        2.30          .7

SOURCE         SS            DF     MS

REGRESSION  [illegible]     1      [illegible]
RESIDUAL    [illegible]     [illegible]   [illegible]

SCATTERGRAM OF RESIDUALS
33.38 I                  ** *
      I                     2
      I                        *
      I                       *
      I                 2  *2
      I                   *42 *   *
      I                 * ** 2 *
      I                  **2* *2
      I4                * 3* 2*2
      I                 *  2*    2
      I                    *    *
      I                  **2 *
      I                    *   *
      I                 *32     * *
      I                 *2** *      *
      I                    *
      I                     *
-31.78I                         2
       --------------------------------------
        0                              44.1
```

Fig 63 Regression of woodland on distance to road/rail 1972.

```
REGRESSION OF CLASS 12 ON 1
CHANGES 50/72
FITTED LINE IS  Y = A + B*LNX

COEFFICIENT   ESTIMATE   ST.ERROR
       A       -15.07     2.68
       B       8.9        2.01

SOURCE       SS        DF   MS

REGRESSION  6431.23   1    6431.22
RESIDUAL    27434.83  84   326.61TOTAL33866.06

SCATTERGRAM OF RESIDUALS
35.58 I           *   *
      I   *    *   *     ** *
      I                 2
      I*      *    * ** *
      I               *22 *24
      I           *    *    *
      I         *  * *   * 2*
      I   *       *   *3***3*
      I            *  * * * 2
      I        *     2 2  2  *
      I                22   2
      I   *           *     *
      I                2   **
      I   *               *
      I
      I
      I           * *
-46.78I            *      *
      ------------------------
       -35.56                5.42
```

<u>Fig 64 Regression of woodland on distance to road/rail 50/72</u>

```
REGRESSION OF CLASS 12 ON 3
CHANGES 50/72
FITTED LINE IS  Y = A + B*LN>

COEFFICIENT   ESTIMATE   ST.ERROR
      A        -10.13      2.13
      B        16.72       4.06

SOURCE        SS         DF    MS

REGRESSION  5698.58   .      5698.58
RESIDUAL    28167.48  84     335.33TOTA. 33866.06

SCATTERGRAM OF RESIDUALS
37.27 I  *
      I                **
      I          *   *      **
      I         * *   3
      I               * ** *
      I          *  2  *3 * * *
      I        * 3  * *   *
      I             2   *2* *
      I              *    4 *
      I           23* 2 *
      I       **      *2*22  *
      I             2   *
      I           *        *
      I                    2 *
      I*       *
      I  *                **
      I        *
-41.32I           *  *
      -----------------------
      -31.72                 6.5
```

Fig 65 Regression of woodland on time to Kaduna 50/72.

```
REGRESSION OF TOTAL CHANGES ON :
CHANGES 50/72
FITTED LINE IS   Y = A + B*LNX

COEFFICIENT    ESTIMATE    ST.ERROR
        A         .68          .2
        B         .72          .15

SOURCE          SS          DF    MS

REGRESSION   43.46           1    43.46
RESIDUAL     164.27         87    1.89[illegible] 107.79

SCATTERGRAM OF RESIDUALS
3.3     I
        I          *
        I    *      *
        I  2 *   *   *
        I* * * *2
        I       3 *  *
        I * * ***      *
        I* 4 * *     *
        I  3*  *22*
        I   * *  *           *
        I   ** *    *   *    *
        I* 2 2   ** *
        I   *3 2*** *
        I  2   **
        I     **2       **
        I   **      *
        I        *           *
-2.84   I            *
         -------------------------
          -.99                  2.34
```

Fig 66 Regression of changes on distance to road/rail.

REGRESSION OF TOTAL CHANGES ON %
CHANGES 50/72
FITTED LINE IS Y = A + B*LNX

COEFFICIENT	ESTIMATE	ST.ERROR
A	[illegible]	[illegible]
B	[illegible]	[illegible]

SOURCE	SS	DF	MS
REGRESSION	20.1[illegible]	1	20.17
RESIDUAL	18.[illegible]	87	[illegible]

SCATTERGRAM OF RESIDUALS

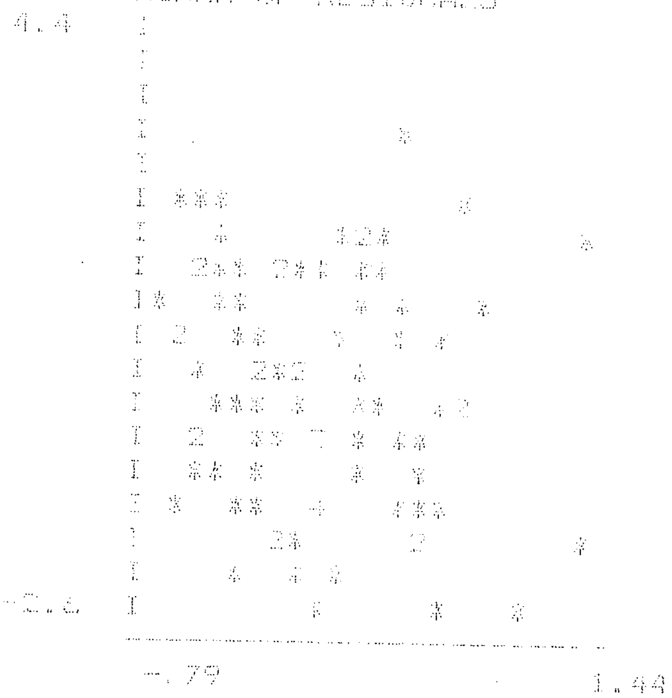


Fig 67 Regression of changes on time to Kaduna.

CHAPTER SEVEN

CONCLUSIONS

7.0 FOUR MAIN TRENDS in land use can be inferred from a study of the aerial photographs taken in 1950 and 1972. These are:

a) An increase in settlement and farming.

b) An intensification of land use.

c) A movement of settlement and farming towards the main road.

d) A decrease in natural vegetation.

7.1 AN INCREASE IN SETTLEMENT AND FARMING

Land under settlement and cultivation doubled in the study period. A fair guess is that the population increased in proportion, although there are no detailed statistics available, suggesting another 6 000 people living off the land. Not many for an area of 750 sq km, a population density of 16 per sq km in 1972 contrasting sharply with ten times that figure further north around Zaria. However the land is not particularly fertile, poor soils with ironpan being widespread and water supplies scarce.

7.2 AN INTENSIFICATION OF LAND USE

In 1950 farming was extensive, cleared patches in the savanna woodland, shifting to new sites every few years leaving traces visible on the aerial photographs. Intensive cultivation was rare, limited to the immediate surroundings of large villages and a few of the fadamas. In 1972 there was much more land under more or less continuous cultivation, the signs on the photography being well defined ridges and large isolated trees, the scattered patches in the bush were mostly gone. This change must have affected the nature of settlement also, fewer small family compounds and more villages, less shifting of houses and more permanent sites. This trend has continued until nowadays it is unusual to find an isolated compound, they are usually grouped together in lines along fadama edges or in similar favourable places.

7.3 A MOVEMENT OF SETTLEMENT AND FARMING TOWARDS THE MAIN ROAD

Roads attract settlement, people prefer to live near them. New villages are being built on the roadside the whole time, those in the bush remaining static or declining. Paradoxically roads are usually built away from the best farming areas; they run along the interfluves, saving money on bridges, culverts and embankments. The best farming land is on or near the valley bottoms and that is where villages were formerly sited. More money spent on valleyside roads would be a good investment.

Railways have a similar, lesser attraction, which is of course only exercised at stations. The railways do run along valleys because of gradient restrictions and thus are close to good farming areas.

The trend towards the roads developed despite improvements in transport and thus of accessibility. One day someone else should write a thesis about the effects of the minibus and the motorcycle on rural development. These, with the transistor radio which is the other Japanese contribution to civilisation, were introduced to Nigeria in the 1960's. The first two cut journey times while the third makes them seem shorter (or longer depending on your taste in music). However only the head of the family will have a motor cycle (a "machine"), which may occasionally be borrowed by the young bloods for their courting journeys. Wives and children walk. They may have to wait hours for a bus to penetrate the remoter bush, and some villages are only connected on market days, a parallel with rural England. It is normal to meet half a dozen people waiting under the tree at the Kajuru feeder road junction. Some may be going to Kaduna, others the 3 1/2 km to the village. In 1950 there were no buses and they would have walked, now they are reluctant to do so. Who can blame them when the sun is fierce and the temperature 40 deg C? The strong correlation of settlement with distance from the main road is therefore understandable.

7.4 A DECREASE IN NATURAL VEGETATION

Firewood is the most commonly used cooking fuel in much of Africa South of the Sahara. The smell of wood smoke is as evocative of early morning in Africa as is the whirr of the United Dairies milk float in an English suburb. Most firewood is cut from the bush, specially planted fuel resources making only a small contribution to the total requirement. Piles of wood and heavily loaded Mercedes lorries are familiar roadside sights near the big towns. The demand for fuel is greater than the regenerative powers of savanna woodland, causing a decline in wooded areas which as we have seen gives a highly significant linear relationship between accessibility and changes from woodland to other forms of land use. In the Kajuru area very little mature woodland lies near the main road, there are only remnants in the form of scrubby trees or coppice. To see woodland you have to trek into the bush. Forest is entirely confined to stream sides and the rocky bases of inselbergs.

The increase in farming and settlement has also led to a decrease in the natural vegetation. In 1950 the low population density and the shifting cultivation pattern allowed regrowth of savanna woodland over large areas. By 1972 there was insufficient time between cycles of cultivation for complete recovery, with the resultant spread of scrubland which, although reduced in area, showed a highly significant negative correlation with distance from the road or a railway station. The picture therefore is a decrease in natural vegetation, particularly near the roads, woodland having become more and more confined to inaccessible areas.

LIST OF APPENDICES

APPENDIX

APPENDIX A

AERIAL PHOTOGRAPHS

USED IN THE STUDY

ROYAL AIR FORCE

82E/242/5287 - 99	5 Nov 1950	f154 mm	16 000 ft
82E/247/5288 - 99	11 Nov 1950	f154 mm	16 000 ft
82E/247/5158 - 71	11 Nov 1950	f154 mm	16 000 ft
82E/247/5131 - 43	11 Nov 1950	f154 mm	16 000 ft
82E/247/5018 - 29	11 Nov 1950	f154 mm	16 000 ft
82E/246/5214 - 26	10 Nov 1950	f153.3 mm	16 000 ft

Supplied by the Directorate of Overseas Surveys.

FEDERAL BLOCK C

Taken on 26 Feb 1972 f 153.07 mm 15 500 ft

RUN	ROLL	NOS
15	72878	99-110
16	72877	167-180
17	72877	96-107
18	72880	167-179
19	72880	98-109
20E	72880	173-185
21	72876	99-112

Flown by Kentings, supplied by Director of Federal Surveys, Nigeria.

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APPENDIX C

CORRELATION OF

LAND USE & ACCESSIBILITY

Category (y)	Access	r (x)	signif.	r ln(x)	signif.	no.obs.
Settlement (11)						
1950	1	-0.362	ns	-0.264	ns	13
	2	0.266	ns	0.255	ns	
	3	-0.147	ns	-0.044	ns	
1972	1	-0.340	1%	-0.562	0.1%	38
	2	-0.017	ns	-0.038	ns	
	3	-0.274	ns	-0.277	ns	
changes	1	-0.353	5%	-0.579	0.1%	42
	2	-0.193	ns	-0.185	ns	
	3	-0.292	ns	-0.333	5%	
Farmland (23)						
1950	1	-0.090	ns	-0.048	ns	79
	2	-0.022	ns	-0.032	ns	
	3	-0.246	5%	-0.168	ns	
1972	1	-0.306	1%	-0.399	0.1%	88
	2	0.034	ns	0.028	ns	
	3	-0.309	1%	-0.299	1%	
changes	1	-0.221	5%	-0.341	1%	87
	2	0.037	ns	0.056	ns	
	3	-0.058	ns	-0.108	ns	

Scrub (33)

1950	1	0.138	ns	0.120	ns	86
	2	0.252	5%	0.256	5%	
	3	0.110	ns	0.160	ns	
1972	1	-0.393	0.1%	-0.337	1%	86
	2	-0.047	ns	-0.046	ns	
	3	-0.396	0.1%	-0.357	0.1%	
changes	1	-0.378	0.1%	0.298	1%	89
	2	-0.284	1%	-0.292	1%	
	3	-0.419	0.1%	-0.437	0.1%	

Woodland (35)

1950	1	-0.094	ns	-0.106	ns	89
	2	-0.314	1%	-0.295	1%	
	3	-0.039	ns	-0.121	ns	
1972	1	0.346	1%	0.338	1%	85
	2	-0.150	ns	-0.137	ns	
	3	0.332	1%	0.292	1%	
changes	1	0.428	0.1%	0.436	0.1%	86
	2	0.179	ns	0.187	ns	
	3	0.367	0.1%	0.410	0.1%	

Total changes

	1	-0.346	0.1%	-0.457	0.1%	88
	2	-0.149	ns	-0.140	ns	
	3	-0.246	5%	-0.312	1%	

Notes:

a) Accessibility:

1 = distance to road or railway station.

2 = distance to Kaduna.

3 = distance to Kaduna.

b) Transformation: The accessibility factor (x) is used directly in the first instance and then as a natural logarithm.

c) Significance testing: The coefficient 'r' is tested for significance using tables in Clarke (1980) p183.

APPENDIX D SCREEN DUMP PROGRAMMES

```
1  REM  ** DISKPRINT **
2  REM  SAVES HIRES PAGE1 ON DISK IN PRINT COMPATIBLE FORM
3 SIZE = 155
5  DIM BUFF%(7,SIZE)
10 D$ =  CHR$ (13) +  CHR$ (4)
20 ETX$ =  CHR$ (3)
40  DEF  FN M3(A) =  INT ((A / 8 -  INT (A / 8)) * 8 + .05)
60  DEF  FN CLIP(A) =  INT ((A / 128 -  INT (A / 128)) * 128 + .0
    5)
80  DEF  FN MOD(A) =  INT ((A / 64 -  INT (A / 64)) * 64 + .05) *
     SGN (A / 64)
100  GR : POKE  - 16297,0
110  INPUT "ENTER FILE NAME ";Q$
115  PRINT D$;"BLOAD ";Q$;",A8192,D2"
150 NAME$ = Q$ + ".PRN"
210  PRINT "EVALUATING SCREEN ADDRESSES"
215  PRINT Q$
220  DIM ADDRESS%(192)
221 A1% = 8192
222 A2% = A1%:A3% = A1%
223 C1% = 0:C2% = 0
225  FOR I = 1 TO 192
230 ADDRESS%(I) = A3%
235  IF C2% = 63 THEN  GOTO 260
238 C2% = C2% + 1
240  IF C1% = 7 THEN  GOTO 250
242 A3% = A3% + 1024
245 C1% = C1% + 1
247  GOTO 290
250 C1% = 0
252 A2% = A2% + 128
254 A3% = A2%
256  GOTO 290
260 C2% = 0
262 A1% = A1% + 40
264 A2% = A1%
266 A3% = A1%
268 C1% = 0
290  NEXT I
295  PRINT : PRINT
500  PRINT D$;"OPEN ";NAME$;",D1"
600  PRINT D$;"DELETE ";NAME$
700  PRINT D$;"OPEN ";NAME$
800  PRINT D$;"WRITE ";NAME$
1000  GOTO 2500
2500  FOR J = 1 TO 40 STEP 3
2800  FOR K = 1 TO 7
2860 BUFF$(K) = ""
2890  NEXT K
2895 X =  FRE (0)
```

```
2900  FOR I = SIZE TO 1 STEP  - 1
2940 T2 =  PEEK (ADDRESS%(I) + J + 1)
2945  IF T2 >  = 128 THEN T2 = T2 - 128
2947  IF J = 40 THEN T2 = 0
2950 RE = T2
2953 T2 =  PEEK (ADDRESS%(I) + J)
2956  IF T2 >  = 128 THEN T2 = T2 - 128
2958  IF J = 40 THEN T2 = 0
2960 RE = RE * 128 + T2
2963 T2 =  PEEK (ADDRESS%(I) + J - 1)
2966  IF T2 >  = 128 THEN T2 = T2 - 128
2970 RE = RE * 128 + T2
4000  FOR K = 1 TO 7
4300 TEMP =  FN M3(RE)
4500 RE =  INT (RE / 8)
4600 T1 = 0
4650  IF TEMP >  = 4 THEN T1 = 16:TEMP = TEMP - 4
5000  IF TEMP >  = 2 THEN T1 = T1 + 4:TEMP = TEMP - 2
5250 T1 = T1 + TEMP
5500 BUFF%(K,SIZE - I + 1) = T1
6000  NEXT K
8000 X =  FRE (0)
8500  NEXT I
8525  POKE ADDRESS%(160) + J,127
8550  FOR K = 1 TO 7
8560 P1% = BUFF%(K,1):N1% = 1
8580  FOR I = 2 TO SIZE
8600  IF BUFF%(K,I) = P1% THEN  GOTO 8650
8610  PRINT N1%: PRINT P1%
8620 N1% = 1
8630 P1% = BUFF%(K,I)
8640  GOTO 8670
8650 N1% = N1% + 1
8670  NEXT I
8690  IF P1% <  > 0 THEN  PRINT N1%: PRINT P1%
8700 N1% = 1:P1% = 127
8710  PRINT N1%: PRINT P1%
8815  NEXT K
8825  NEXT J
8900  PRINT D$;"CLOSE ",NAME$
8998  PRINT "STRIKE ANY KEY TO EXIT"
8999  GET T$
9000  HOME
10000  TEXT
20000  END
20001  REM  * WRITTEN BY B.E.J.BAINES *
```

```
5  REM  ** COPIES **
6  REM  TAKES TEXT FILE CREATED BY "DISKPRINT" AND OUTPUTS TO LIN
   E PRINTER
10 D$ =  CHR$ (13) +  CHR$ (4)
20 ETX$ =  CHR$ (3)
29 BIG = 3000
30  DIM SPACE%(BIG,2)
100  INPUT "ENTER FILE NAME ";Q$
120  INPUT "HOW MANY COPIES ? ";NUMBER
140  PRINT "CHECK THAT THE PRINTER IS ON LINE"
150  PRINT "STRIKE ANY KEY WHEN READY"
160  GET T$
170 NAME$ = Q$ + ".PRN"
200 SIZE = 96
350  PRINT D$;"OPEN ";NAME$
360  PRINT D$;"READ ";NAME$
370 COUNT = 0
380  FOR I = 1 TO SIZE
450  INPUT SPACE%(COUNT,1)
470  INPUT SPACE%(COUNT,2)
480 COUNT = COUNT + 1
500  IF SPACE%(COUNT - 1,2) <  > 127 THEN  GOTO 450
800  NEXT I
820  PRINT D$;"CLOSE ";NAME$
825  PRINT "COUNT IS ";COUNT
850  PRINT D$;"PR#1"
855  FOR I = 1 TO NUMBER
870  PRINT ETX$;
900  FOR J = 1 TO 50
905  PRINT  CHR$ (0);
910  NEXT J
950  PRINT ETX$ +  CHR$ (11);
975 BUFF$ = ""
1000  FOR J = 0 TO COUNT
1025  IF SPACE%(J,2) = 127 THEN  GOTO 1270
1180  FOR K = 1 TO SPACE%(J,1)
1190 BUFF$ = BUFF$ +  CHR$ (SPACE%(J,2))
1200  NEXT K
1220 X =  FRE (0)
1225  GOTO 1300
1270  PRINT BUFF$;
1275 BUFF$ = ""
1280  PRINT ETX$ +  CHR$ (11);
1300  NEXT J
1450  PRINT ETX$ +  CHR$ (2)
1500  PRINT : PRINT : PRINT
1550  PRINT Q$
1600  PRINT  CHR$ (12)
2000  NEXT I
2050  PRINT D$;"PR#0"
2100  TEXT : HOME
9000  END
9001  REM  WRITTEN BY B.E.J.BAINES
```

APPENDIX E

LINEFIT CALCULATION

Access type	Coefficients a	b	Confidence 95% a	b	F	signif.
			Settlement (11)			
			1972			
1	3.066	-0.341	1.250	0.319	4.71	5%
ln(1)	2.862	-1.246	0.806	0.619	16.64	0.1%
			changes			
1	2.640	-0.374	1.265	0.315	5.71	5%
ln(1)	2.475	-1.379	0.812	0.620	20.24	0.1%
ln(3)	1.629	-1.701	0.792	1.538	5.00	5%
			Farmland (23)			
			1950			
3	13.686	-2.819	3.467	2.523	4.94	5%
			1972			
1	22.411	-1.424	4.038	0.949	8.91	1%
ln(1)	21.609	-4.543	3.009	2.241	16.27	0.1%
3	25.170	-5.803	5.618	3.837	9.06	1%
ln(3)	18.636	-6.744	2.416	4.619	8.44	1%
			changes			
1	11.667	-0.936	3.787	0.892	4.36	5%
ln(1)	11.644	-3.540	2.822	2.107	11.19	1%

Scrub (33)

1950

2	10.530	0.243	8.726	0.203	5.71	5%
ln(2)	-12.794	9.111	27.460	7.478	5.88	5%

1972

1	22.287	-1.868	4.072	0.949	15.35	0.1%
ln(1)	19.630	-4.168	3.355	2.525	10.79	1%
3	25.882	-7.665	5.638	3.859	15.63	0.1%
ln(3)	17.136	-8.258	2.450	4.686	12.29	0.1%

Scrub (33)

changes

1	4.823	-12.732	6.300	1.459	13.87	0.1%
ln(1)	-0.046	-5.260	5.003	3.687	8.06	1%
2	9.646	-0.361	11.359	0.267	7.29	1%
ln(2)	43.831	-13.422	35.027	9.586	7.76	1%
3	11.641	-12.565	8.585	5.952	17.65	0.1%
ln(3)	-1.301	-15.639	3.630	7.027	19.62	0.1%

Woodland (35)

1950

3	50.527	-0.396	10.905	0.257	9.51	1%
ln(2)	83.485	-13.475	34.021	9.311	8.30	1%

1972

1	20.493	2.360	6.091	1.397	11.30	1%
ln(1)	23.138	5.995	4.933	3.652	10.68	1%
3	16.621	9.138	8.463	5.679	10.25	1%
ln(3)	27.062	9.818	3.676	7.035	7.71	1%

changes

1	-19.654	3.653	7.023	1.674	18.88	0.1%
ln(1)	-15.072	8.899	5.337	3.990	19.69	0.1%
3	-23.816	12.534	10.125	6.887	13.11	0.1%
ln(3)	-10.134	16.722	4.229	8.071	16.99	0.1%

Total changes

1	0.791	- 0.223	0.551	0.129	11.82	0.1%
ln(1)	0.678	- 0.723	0.404	0.300	22.99	0.1%
3	0.864	- 0.642	0.792	0.539	5.61	5%
ln(3)	0.185	- 0.976	0.332	0.635	9.34	0.1%

Note. Linefit calculated from the formula y = a + b.x

where y = land use category or the change

x = accessibility factor or its natural logarithm

APPENDIX F

ACCESSIBILITY DATA

Model	A	B	C	Model	A	B	C	Model	A	B	C
1	3.3	19	0	31	2.9	21	0	61	2.2	22	0
2	2.1	23	0	32	0.9	28	0	62	0.2	29	0
3	0.5	30	0	33	2.6	30	0	63	4.6	30	0
4	6.7	36	0	34	7.1	47	0	64	6.9	47	0
5	1.1	12	0	35	0.2	14	0	65	0.5	16	0
6	1.1	18	0	36	1.9	20	0	66	2.6	22	0
7	2.7	24	0	37	2.9	26	0	67	1.8	35	0
8	0.2	36	0	38	1.8	36	0	68	2.1	40	0
9	3.2	42	0	39	2.6	47	0	69	3.2	14	0
10	3.9	16	0	40	4.5	16	0	70	5.5	20	0
11	6.2	23	0	41	6.2	38	0	71	4.2	38	0
12	2.5	38	0	42	1.3	39	0	72	1.2	42	0
13	0.1	44	0	43	0.6	45	0	73	0.9	48	0
14	2.7	0	25	44	2.1	0	25	74	3.4	0	25
15	5.3	0	25	45	7.2	0	25	75	9.2	56	0
16	7.3	56	0	46	5.7	56	0	76	4.5	56	0
17	3.1	48	0	47	1.1	48	0	77	1.0	48	0
18	2.9	48	0	48	2.0	0	25	78	2.5	0	25
19	4.2	0	25	49	6.2	0	25	79	7.2	0	40
20	6.6	0	40	50	5.1	56	0	80	3.0	56	0
21	0.9	54	0	51	0.4	54	0	81	0.2	52	0
22	1.9	56	0	52	2.4	59	0	82	6.2	0	25
23	6.0	0	25	53	6.6	0	25	83	6.2	0	40
24	4.6	0	40	54	3.3	0	40	84	2.6	0	40

25	3.6	0	40	55	4.6	56	0	85	4.2	54	0
26	2.5	54	0	56	1.8	56	0	86	1.2	58	0
27	10.0	0	25	57	9.7	0	25	87	8.3	0	40
28	6.3	0	40	58	4.4	0	40	88	2.7	0	40
29	1.5	0	40	59	2.7	0	40	89	4.4	0	40
30	5.6	58	0	60	4.2	60	0				

Note. A = distance in km to road or railway station measured as the crow flies.

B = distance in km along the road to the centre of Kaduna.

C = distance in km along the railway to Kaduna.

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