

Agricultural Projects Monitoring Evaluation and Planning Unit
Federal Department of Rural Development
P.M.B. 2178, Kaduna, Nigeria

CROPPING AND LAND USE PATTERNS
AZARE REGION, BAUCHI STATE
NIGERIA

An Experimental Agronomic Assessment Derived from
Systematic Low Altitude Reconnaissance Photography

Resource Inventory and Management Ltd.
Portman House, 32 Hue Street,
St. Helier, Jersey, Channel Islands, U.K.

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1 SUMMARY.

- 1.1 The Agricultural Projects Monitoring, Planning and Evaluation Unit (APMEPU) of the Federal Ministry of Agriculture, Water Resources and Rural Development, is responsible for conducting evaluation studies on all World Bank assisted agricultural development projects in Nigeria. This exercise involves a system of statistical surveys based on sampled farm households. Although sound in method, the present system has weaknesses related to: timeliness, and delays in reporting crop information; clustering of the sample in a relatively small number of villages; a high demand for skilled manpower to conduct the surveys; and the need for accurate estimates of the human population in order to convert sample results to estimates of the whole.
- 1.2 The experimental study reported here was conceived in an attempt to try and overcome some of these problems, by the use of new aerial survey techniques to collect information about crop areas and cultivation. In this way, evaluation resources could be released for problem-specific work.
- 1.3 The experiment involved small format photography from a low flying aircraft. The study area, in Bauchi State, was divided into a 5 kilometer by 5 kilometer grid pattern, and flights were made along the central line of each grid. Ten pairs of photographs were taken per grid using a twin camera system. A wide angle lens on one camera produced photographs suitable for the assessment of cultivated area, human habitation, livestock, land use and environmental features. With the other camera, a synchronised telephoto image was taken of the centre of each wide angle frame. The results were used to identify specific crops and crop mixtures, and to measure crop planting density.
- 1.4 Analysis was by projection of the diapositive film onto a screen marked with both a sampling dot array, and circles within which plant stands were counted. Ground based crop inspection also took place at the time of the photography and this exercise was invaluable for photo-interpretation.
- 1.5 Comparison of the results with ground based sample surveys reveals a close similarity in the proportion of land cultivated. The areas of individual crops or crop enterprises differ between air and ground studies, but comparison between broad groups of crops, such as the grains (sorghum and millet) or the legumes (cowpea and groundnut), are close.
- 1.6 The results from the aerial study are believed to have been affected by the low and erratic rainfall in the study zone. This led to the season being approximately four weeks later than an average year. Crops were less mature, and recognition from the air was, therefore, less certain for the immature crops. This factor is of special importance for the grains: millet and sorghum. Photography of crops such as yam and cassava in other areas suggests that visual identification is not difficult.
- 1.7 With this cautionary note in mind, it is concluded that the results are sufficiently accurate for the technique of Systematic Low Altitude Reconnaissance Photography (SLARP) to be used as part of a wider evaluation data-gathering programme. Specific recommendations are made for the development of computing and other facilities by APMEPU, and for further operational studies and research into the application of this technique.

2 PREFACE.

Resource Inventory and Management Limited (RIM) specialises in the rapid assessment of natural resources over extensive land areas. Up to date information, concerning the distribution and abundance of a broad spectrum of agricultural, human and environmental resources, is collected by low altitude aerial survey and other forms of remote sensing, and closely coordinated with interdisciplinary investigations on the ground. The data obtained are analysed and presented using a variety of modern computer processing techniques, with the results being interpreted by a team of specialists, experienced in a variety of fields. RIM thus provides a fast, efficient service of information collection, analysis and synthesis, covering a wide range of resources, of general interest to government administrators, and of more particular value to project managers and development planners.

This report describes the findings of an experimental study using Systematic Low Altitude Reconnaissance Photography (SLARP) to investigate cropping and land use patterns in the Azare region of northern Nigeria, within the Bauchi State Agricultural Development Programme (BSADP). RIM carried out the survey during the 1983 crop growing season, in conjunction with the Federal Department of Rural Development's Agricultural Projects Monitoring, Evaluation and Planning Unit (APMEPU) in Kaduna, which commissioned the work.

The combined efforts of the following personnel brought this study to a successful conclusion:

| | |
|-----------------------------|---|
| Dr. Kevin Milligan | - Coordinator. |
| Mr. Derek Poate | - Former Chief Evaluation Officer (APMEPU). |
| Dr. David Bourn | - Environmental Biologist. |
| Dr. Nick Chapman | - Senior Evaluation Officer (BSADP-Azare). |
| Mr. Freddie Kroissenbrunner | - Aircraft Pilot. |
| Mr. Mike Fear | - Survey Photographer. |
| Dr. Bill Campbell | - Computer Analyst and Cartographer. |
| Mr. Chris Brookes | - Photo-interpreter. |
| Mr. Robert Chapman | - Photo-interpreter. |

Statistical guidance concerning appropriate techniques of data analysis was given by Dr. Colyear Dawkins of Oxford University. Mrs Pam Daplyn, APMEPU's Principal Statistician, also provided many valuable contributions during the course of numerous technical discussions.

The information and interpretations contained in this report are given in good faith and represent the understandings and opinions of the authors. They should not, however, be construed as necessarily representing the official views or policies of the commissioning organisation, the Bauchi State Agricultural Development Programme, the Federal Government of Nigeria, or the World Bank. Neither should State or administrative boundaries represented on any map be regarded as definitive.

3 INTRODUCTION

3.1 Existing Methods of Collecting Evaluation Data.

The Agricultural Projects Monitoring, Evaluation and Planning Unit (APMEPU), of the Federal Ministry of Agriculture, Water Resources and Rural Development, is charged with the responsibility for conducting evaluation studies on all World Bank supported agricultural development projects in Nigeria. The work involves a considerable amount of data collection, and the primary focus of that data is on smallholder crop production. The current system, which has evolved since 1976, may be considered in two parts. First, there is a single visit baseline study of a large sample of around 1,500 smallholders to provide a record of key socio-economic and agro-economic features for management planning and future assessment of change. It is run before the project, or in the first year of operation. Second, there is an annual agronomic survey, which has become known as the FRADYS (Field Record for Agronomic Data, Yields and Stands) survey, carried out on a sample of around 225 households. This survey, which involves multiple visits during the growing season, is based on objective observation and measurement of the sample farmers' fields, together with questions about his agricultural practices. At harvest time, a sample of each crop is weighed to provide yield and production data.

Both the baseline and the agronomic survey are sound in method and statistical design. They do, however, possess inherent weaknesses which limit their usefulness. The baseline survey gives a good indication of the project area because of its large sample size. But the key cropping information is based on farmers' replies to questions, rather than direct observation. Experience has shown that answers are simplified, and that key details about minor crops are often overlooked. Crop areas are not measured and thus the information available for planners is rather limited.

The agronomic survey needs to be carried out by a carefully trained team of enumerators based in the sample villages for the whole year. Baseline can be undertaken by a small mobile team of enumerators. Resource constraints usually prevent the agronomic survey from being run before the first full year of project operation. Thus the results are not available until the start of year two. Objective measurements are used and the level of detail is adequate, but the sample design is such that households are clustered into a relatively small number of villages, typically fifteen in number; and because of this, spatial coverage is limited.

Concern has been voiced by users of the data, that such a small number of villages cannot be considered as adequately representative. Moreover, tests undertaken by the APMEPU Principal Statistician reveal high levels of intra-cluster correlation (Daplyn, personal communication). That is to say, households in the same village are more likely to share similar characteristics than are households in different villages. This indicates that more villages should be sampled to improve the statistical efficiency of the design. But this is not possible under the existing system, due to resource constraints on survey teams. Finally, both the baseline and the agronomic surveys

sampled to improve the statistical efficiency of the design. But this is not possible under the existing system, due to resource constraints on survey teams. Finally, both the baseline and the agronomic surveys suffer from the serious weakness that they require a reliable estimate of the human population in the survey area, in order to compute "crop population" totals from estimated sample means.

Thus the present system, although satisfactory in the long run, has four major weaknesses related to:

Timeliness, and the late reporting of detailed crop information;

Clustering of the sample and doubts about the representativeness of the data. If, for example, a particular village is not sampled, then the characteristics of that vicinity remain unknown;

Resources required for the agronomic survey include a highly trained team of up to twenty-five field staff, occupied for a whole year;

Human Population and the requirement for good estimates of the number of people and farming families, in order to scale up crop totals for the whole project area.

The study with which this report is concerned was conceived in order to try and overcome some of these fundamental problems.

3.2 Aerial Surveys.

One alternative to ground-based data collection systems is aerial survey. Clearly, such an approach could not be used to enquire in to household behaviour, or crop yields. But for characteristics which can be identified visually, an airborne system is possible. Methods using large format photography from high altitude have been available for many years. They lack the level of detail necessary for cropping studies, cloud cover restricts their use during the main crop growing periods, and their cost mitigates against annual and more frequent use. Low level visual techniques have been developed for surveys of wildlife and cattle (e.g. Norton-Griffiths, 1978; ILCA, 1981), and the technique has been refined to encompass human features and environmental conditions (e.g. Grimsdell, 1978; Milligan and DeLeeuw, 1983).

In a separate but parallel development, scientists have explored the scope of small format (35mm) photography to identify vegetation types, soil moisture and other environmental features (e.g. Curran, 1981). It is a logical extension of this work to try and apply these same techniques to identifying cultivated land and specific crops and crop mixtures.

3.3 Photographic Assessment of Land Use Intensity.

Cultivated land, fallow, natural vegetation and a variety of other land use features are routinely assessed in the course of environmental monitoring, and the surveillance of livestock and wildlife populations, from the air. Although this kind of assessment does not meet the needs for detailed information about cropping patterns, the independent estimate of total area cultivated, that can be provided, is a valuable statistic, which can greatly reduce the uncertainty of "crop population" estimates. These latter estimates are obtained by grossing up ground survey household averages using the best available estimate of the human population.

During the 1983 crop growing season such an aerial survey was conducted over the whole of Bauchi State by Resource Inventory and Management Limited, on behalf of the Bauchi State Agricultural Development Programme (RIM, 1984). The distribution of cultivation in Bauchi State, as revealed by that aerial survey, is shown in Map 1 of this report. The results clearly confirm the feasibility of the method and, together with those from ground based agronomic surveys, have been utilised to assess statewide crop production and the overall food balance of Bauchi State (BASRA/BSADP, 1984). Of particular relevance in the Nigerian context, is the rapidity of interpretation, data processing and reporting that was achieved. The preliminary results of that aerial survey, showing the statewide distribution of cropped land, with estimates of cultivation at both Zonal and Development Area levels, were submitted within two weeks of completion of the survey.

3.4 Joint APMEPU - RIM Study.

The method adopted to identify cultivation in Bauchi State (RIM, 1984) was based on photographic experience gained during livestock surveys, and involved systematic strip sample photography from an altitude of 2,000 feet above ground level. For detailed crop recognition it was clear that a more experimental approach would be necessary in order to evaluate parameters such as aircraft altitude and speed, camera lenses and shutter speed, for satisfactory ground resolution. Accordingly, a joint proposal was drawn up, in which staff of APMEPU would collaborate with RIM in an experimental study over part of an agricultural development project, for which ground based survey data were already available, and where field staff could liaise to provide ground validation of aerial observations.

The study took place over the Northern Zone of the Bauchi State Agricultural Development Programme, and covered a land area of some 4,250 square kilometers around and to the south of Azare town, as indicated in Map 1. Field work was carried out in two phases. The first was used to assess different combinations of aircraft height and camera lens. The full survey was then flown in the second phase, using parameters determined from the first phase trials.

3.5 Objectives.

The main purpose of this study, as originally conceived, was to assess the suitability of Systematic Low Altitude Reconnaissance Photography (SLARP) as a complement to, or partial replacement of, ground based agronomic surveys. Accordingly, four subject areas were identified for examination:

the size and distribution of human settlements;

the extent and distribution of cultivation;

the extent and distribution of major crops and crop enterprises;

supporting land use features, such as fallow, fadama, natural vegetation, water resources and erosion.

As the field work progressed and photographs became available for inspection a number of additional objectives were defined:

to make a comparison of the aerial survey results with those from ground based agronomic surveys;

to calculate stand density (the number of planting locations per unit area) for those crops identifiable from the air;

to stratify the results by other land use, environmental or economic characteristics.

Throughout this report the reader should bear in mind the experimental nature of the work described, and is urged to remember that the objectives of the study essentially concern the accuracy and statistical precision of results obtained from the technique of Systematic Low Altitude Reconnaissance Photography.

4 METHODS.

4.1 Data Collection.

4.1.1 Region Surveyed.

The Azare survey region occupied a land area of 4,250 square kilometers, between the Jama'are river in the west and the Kari river in the east. See distribution Maps 2 - 11. With reference to the Northern Zone map of Bauchi State (BSADP, 1982), the area was divided up into a 5x5 kilometer grid pattern, based on the UTM projection, containing 170 sample cells, as indicated in Map 6. The survey region includes 4 complete Local Government Areas (Shira, Giade, Misau and Katagum) and also the Shira Development Area.

4.1.2 Flight Procedures.

The survey took place on 30th and 31st August 1983, from Azare, with the aircraft, a high-winged Cessna 172, flying alternately east-west along the centre of each line of grids. With the aid of a radar altimeter, an airspeed indicator, and careful navigation, the aircraft was flown at as near a constant height and speed as possible. Initial trials indicated that the altitude should be 500 feet (150 meters), and that ground speed should be 180 kilometers per hour.

A team of three worked on board; a pilot, who was responsible for flying and maintaining the correct altitude; a navigator, who was also responsible for noting altimeter readings and advising the pilot on ground speed; and a photographer, seated to the rear of the aircraft, responsible for camera operations and film changes.

4.1.3 Camera Operations.

Photographs were taken by a pair of vertically mounted Nikon F 35mm cameras, fitted with bulk 250 frame backs, and motor drives. One camera was fitted with a 24 mm wide angle lens, and the other camera with a 200 mm telephoto lens. Both cameras were operated simultaneously using a Nikon intervalometer, so that photographs could be taken automatically at pre-determined time intervals. The camera mount was designed so that the cameras could be removed and brought inside the aircraft for in-flight reloading at the end of flight lines, or as required. Ektachrome 200 bulk film stock was used throughout.

The intervalometer was set to give one frame every 10 seconds, so that, at a ground speed of 180 kilometers per hour, ten photographs were taken over each 5x5 kilometer grid cell. In total, some 1,700 wide angle and some 1,700 telephoto photographs were taken. The field of view of the 24mm lens from 500 feet above ground level was a rectangle approximately 225 meters by 150 meters; that of the 200 mm lens was approximately 27 meters by 18 meters.

4.1.4 Ground Validation.

Ground work to validate photo-interpretation was carried out on plots adjacent to the road running north from Azare to Katagum. The area was visited prior to trial aerial photography, crops were identified, ground photographs were taken for comparison, and discussions were held with enumerators on current farming activities. Knowledge of the latter enabled enumerators to identify crops which had recently been planted, but which had yet to germinate, clearly a difficult feat to achieve from the air. Subsequently, after aerial photographs had been taken, return visits were made to specific plots with colour prints, in order to identify and measure distinct ground features at the centre and towards the edge of photographs. Comparison of measurements made on the ground, with those taken from the photographs, confirmed that there was no significant difference between them, and that distortion effects were minimal (Daplyn, personal communication).

4.2 Data Analysis.

4.2.1 Photo-interpretation.

4.2.1.1 Wide angle photography.

All photographs were examined by projection onto a matt white screen measuring 1.2 x 1.8 meters. In order to overcome problems of image clarity around the boarder, a sub-sampling rectangle, measuring 1.0 x 1.6 meters, was drawn on the screen. A regular array of 40 sample points, distributed in a pattern of 5 rows and 8 columns was drawn within the sampling rectangle. See Figure 1. With the image enlarged just sufficiently to fill the whole screen, the sampling rectangle represented an area 125 x 200 meters on the ground.

Wide angle photographs were used to assess land use, human settlement and livestock parameters. Land use was determined by counting the number of dot sampling points falling within each of the following categories:

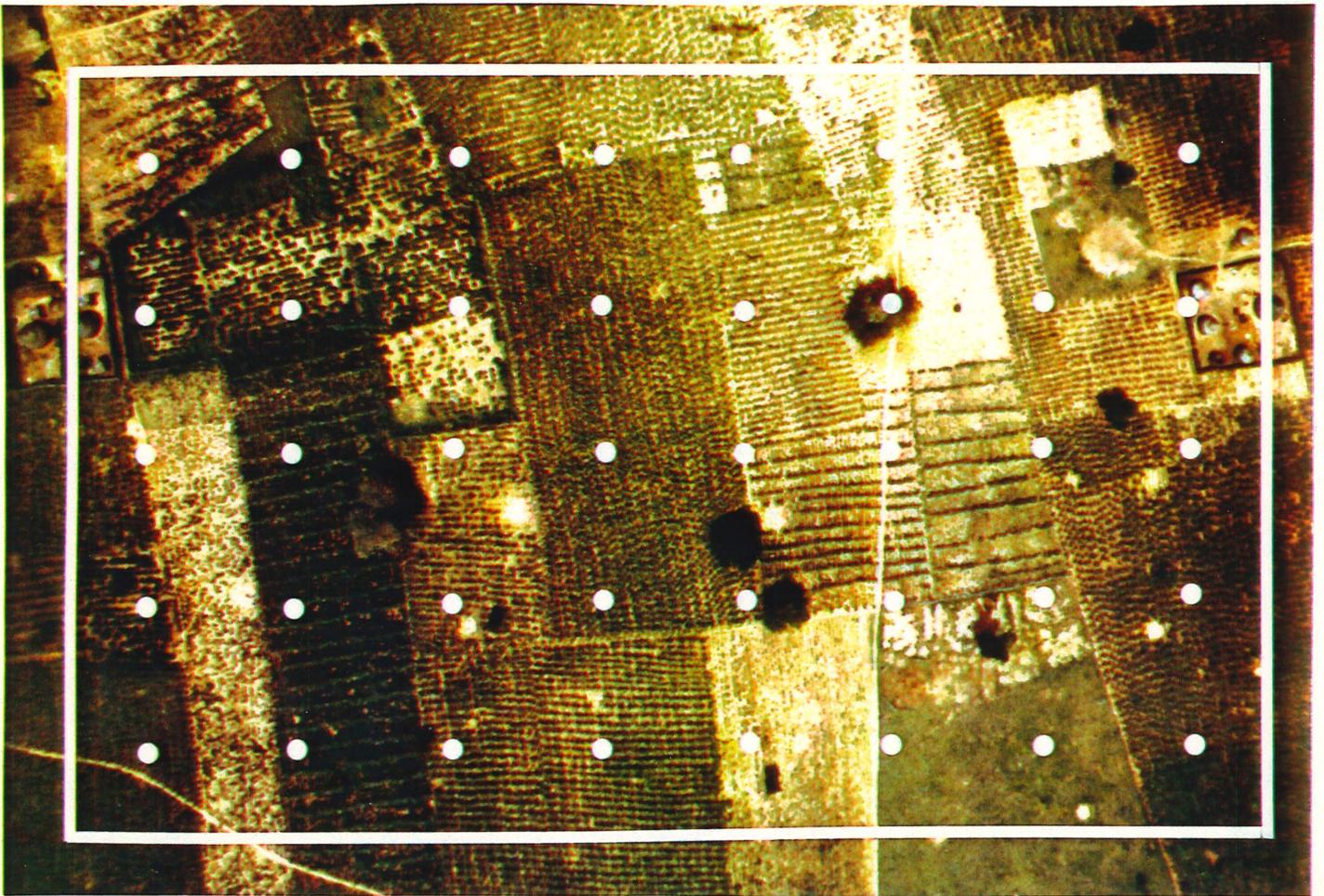
- Cultivated Land
- Recent Fallow Land
- Bush Land
- Grass Land/Fadama
- Riverine/Open Water
- Rocky Ground

In addition, the number of sampling points falling on land judged to eroded was also noted.

The assessment of human habitation was made by counting and recording the total number of grass, tin and earth roofed dwellings occurring within the sampling rectangle, as well as the number of discrete settlements; the latter being defined as a group of dwellings, ranging in size from a small compound to a large village.

Similarly, the rectangular sampling frame was used to define the area within which all cattle, and cattleherds were counted.

FIGURE 1: REPRESENTATION OF PROJECTED WIDE ANGLE IMAGE AND SAMPLING SYSTEM.



8 x 5 array of white dots indicate 40 sampling points for land use assessment.
White rectangle shows the sampling frame within which buildings were counted.

4.2.1.2 Tele-photography.

For interpretation of the tele-photographs an additional five sampling circles, each 53.3 cm in diameter, were drawn on the screen. See Figure 2. With the image enlarged sufficiently just to fill the whole screen, each circle demarcated a sampling area of some 50 square meters on the ground.

In the first instance, the number of separate crop "enterprises" represented on each telephoto image was counted, together with the number of dot sampling points they contained. Then, the number and identity of the various crops within each enterprise was noted, as was the degree of weed infestation (judged on a three point scale), and the method of land preparation (assessed as : hand, oxen, tractor, unknown or none). Finally, for each/any enterprise with recognisable crops, which completely occupied any one of the five sampling circles, the total number of stands of each crop contained within it was recorded.

Where the boundary of a crop enterprise cut across one or more of the sampling circles a decision rule was used for choosing a circle. First choice was always the central circle. If the centre circle cut across a crop boundary, the upper right circle was the first alternative used. If this too cut across a crop boundary, then the remaining circles were inspected, moving in a clockwise direction from the upper right circle. The first circle with a full coverage of a crop enterprise was used for the stand count.

4.2.1.3 Crop identification.

The ease with which individual crops could be identified ranged from the clearly self-evident to the impossible, and inevitably a degree of subjective judgement was sometimes required for interpretation. In the vast majority of cases, however, determinations and distinctions were unambiguous. Some of the distinguishing characteristics between for instance, sorghum and millet, or cowpea and groundnut, were extremely subtle from the air, and to the uninitiated might appear difficult to discern. However, to the experienced eye, especially one with personal experience of conditions on the ground, many, often very minor, features of the plants themselves, or the pattern of planting, would be indicative of a particular crop. Some of these recognition features are very difficult to describe, others are more obvious. They include:

The general stature of plants, and the type of flowers, or seed heads;

The growth habit; e.g. the high tillering of millet, as opposed to the bending stalks and cruciform leaves of sorghum; or the irregular form of cowpea, as opposed to the dense bushy stature of groundnut;

The location of planting; e.g. along plot boundaries, interplanted along ridges, or around settlements and compounds;

The interplanting pattern, and the typical association of particular crops; e.g. 2 rows of millet to one of sorghum was common; the "gicci" pattern of planting millet and sorghum was very distinctive; and millet and groundnut were frequently interplanted together down the same ridge.

FIGURE 2: REPRESENTATION OF PROJECTED TELEPHOTO IMAGE AND SAMPLING SYSTEM.



The white rectangle represents the sampling frame within which the number of crop enterprises was counted; the 8 x 5 array of white dots indicate the 40 sampling points for assessing the relative size of each enterprise; and the five circles demarcate alternative areas for counting crop stands.

Figures 2 - 5 provide some typical examples, but it must be pointed out that much detail has been lost in the reprographic process, and that in reality the projected images were considerably clearer. Figures 2 and 3 indicate two of the distinguishing features between sorghum and millet, namely colour and leaf form. Sorghum tending to be a lighter shade of green and to have wider leaves. Figure 4 illustrates a mixture of mature millet (with upstanding seed heads) and immature sorghum (very much smaller in size and lighter green in colour), planted in a 2-1-2 row sequence. Figure 5 shows the three crop mixture of millet, sorghum and cowpea, with the latter pair of crops occurring in the same row.

In general, crop recognition from the air for the Azare region was considered to be good for sorghum, millet, cowpea, and groundnut, which were widespread and relatively common. In contrast, cassava, ochra, kenaf and cotton, which had limited local distributions were much more difficult to recognise.

Maize is grown in the Azare region, but not was knowingly seen on the aerial survey photographs. Two types of millet are grown locally, an "early" or "short-season" millet, and a "late" or "long-season" millet. Both of which have very similar growth habits and are difficult to distinguish, even on the ground. In addition, "early" millet is sometimes planted late. At the time of the survey, and as a result of the delayed season, the growth of "late" millet could not be distinguished from sorghum, or some late planted "early" millet. Had the flights taken place later, recognition of the various grain crops would have been considerably easier, as the "early" millet would have been cut and drying on the ground, sorghum would have been in flower, and "late" millet would have been in growth or in flower.

4.2.2 Statistical Treatment.

4.2.2.1 Characteristics of systematic samples.

Systematic samples of spatial phenomena, especially when these depend on factors such as land form, climate, or water supplies have the following properties:

Variance tends to be inflated relative to random samples, though in extensive surveys only slightly. The reason for this is because distances between sample units are held constant, no proximities can occur, therefore differences between adjacent units can never be as small as can occur in a random layout. This effect diminishes as the length/spacing ratio of a strip sample increases.

Means of systematic samples tend to be closer to the true population value (Cochran, 1963) than the means of random samples, even if the latter are stratified. This is true for reasons analogous to those given above, because the sample units being uniformly dispersed have a greater chance of detecting all the important sites and variations that occur in the field.

FIGURE 3: WIDE ANGLE AND TELEPHOTO PAIR - MATURE MILLET AND SORGHUM MIXTURE.

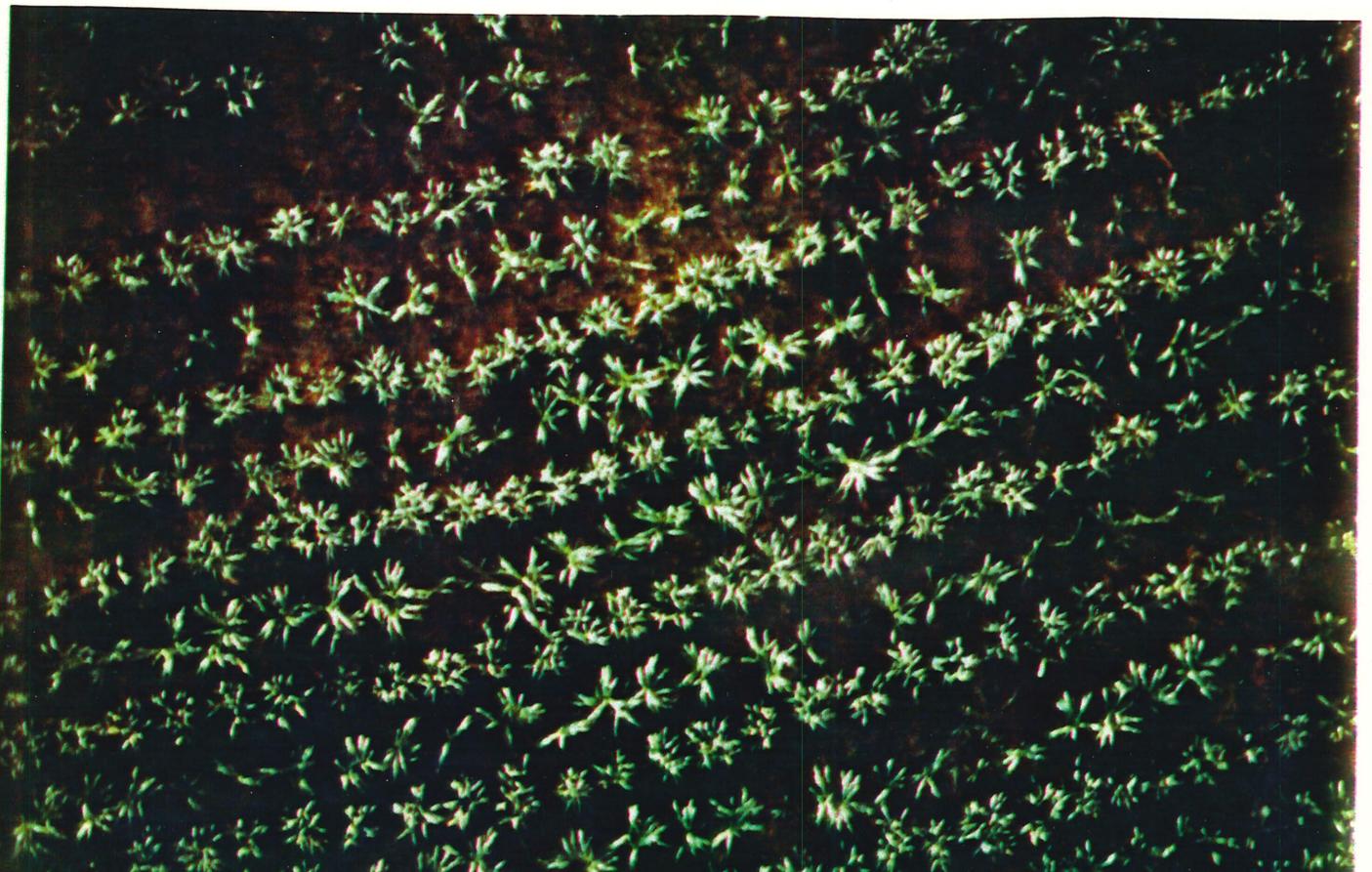
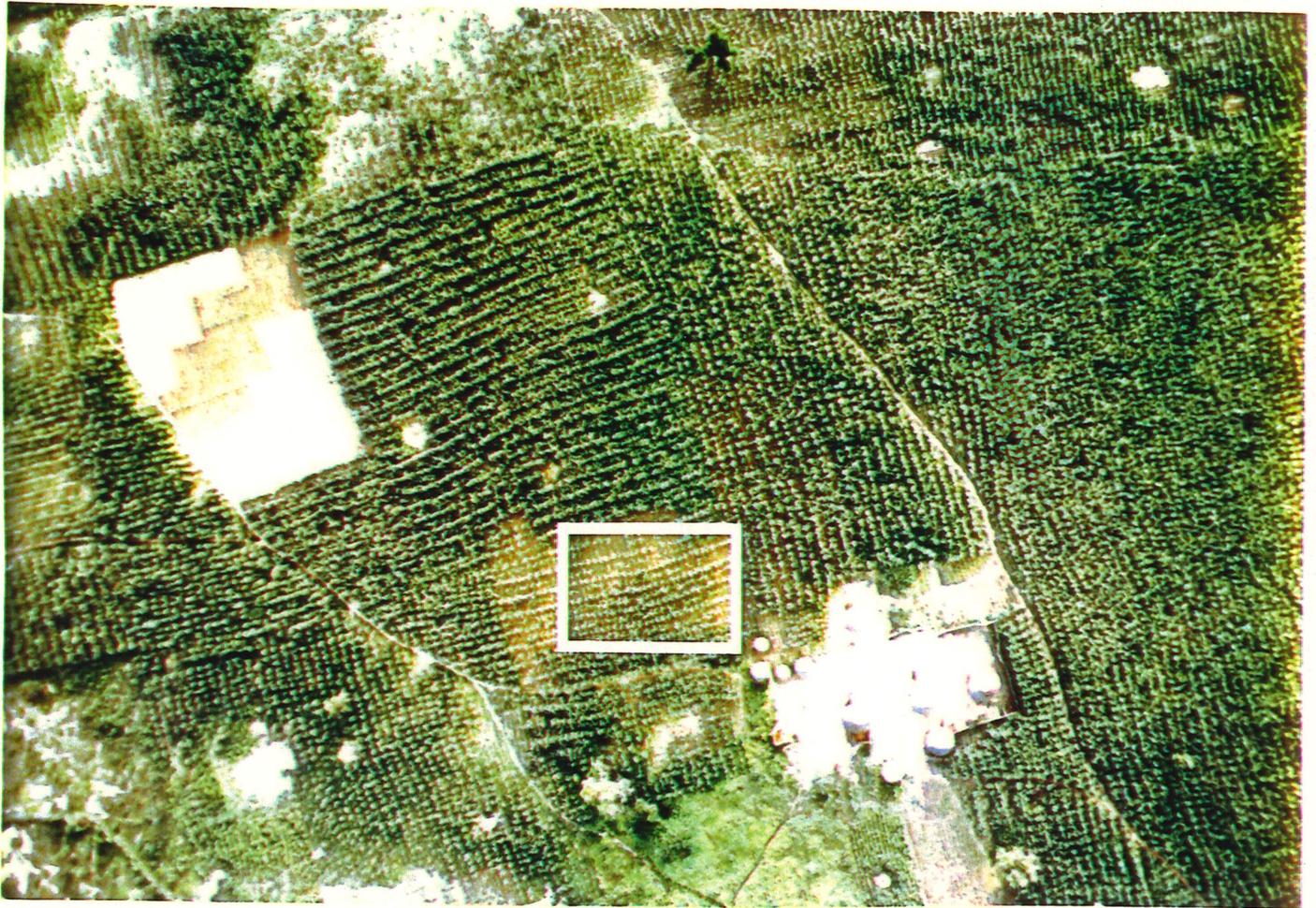


FIGURE 4: WIDE ANGLE AND TELEPHOTO PAIR - MATURE MILLET AND IMMATURE SORGHUM.

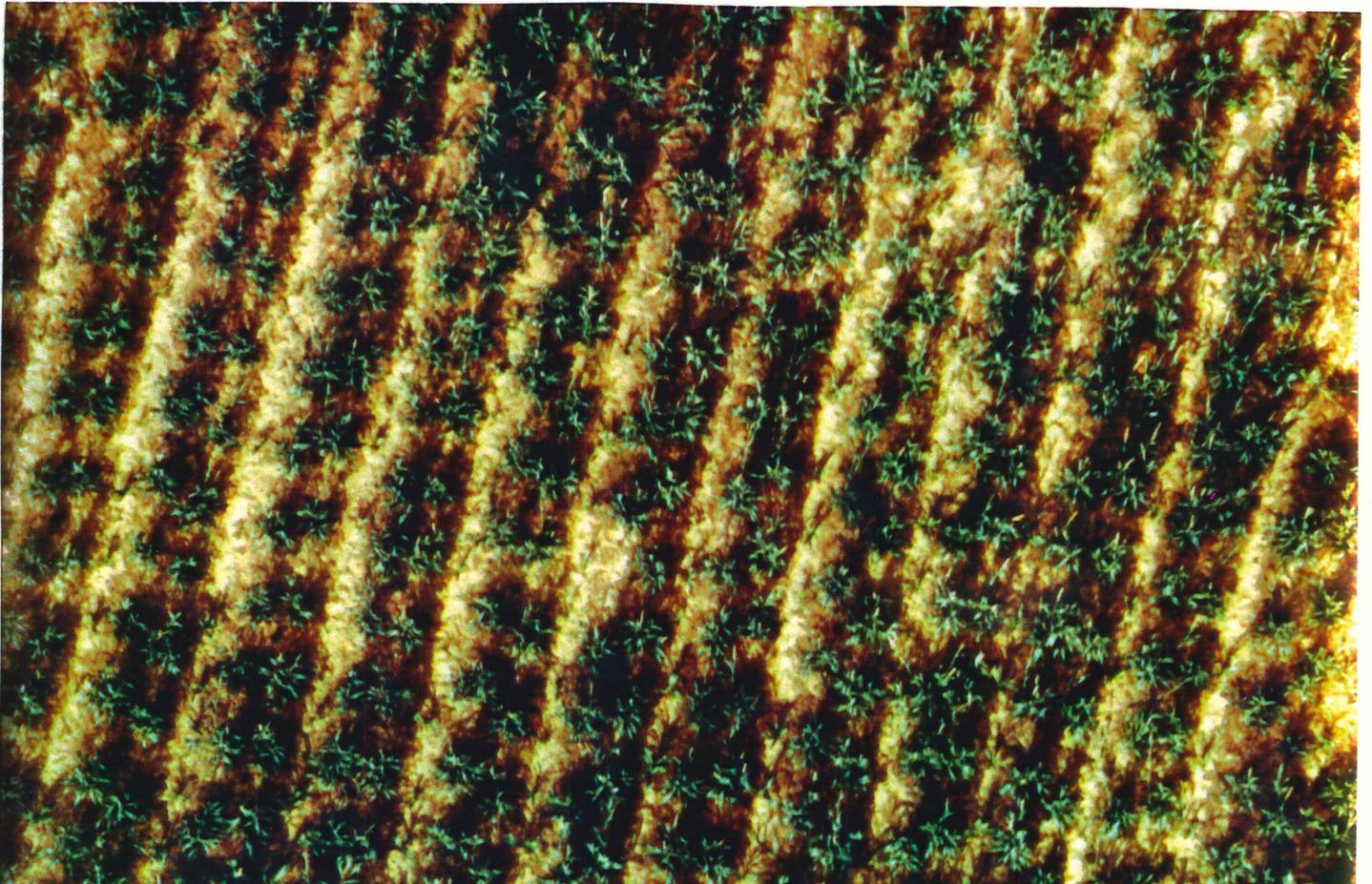
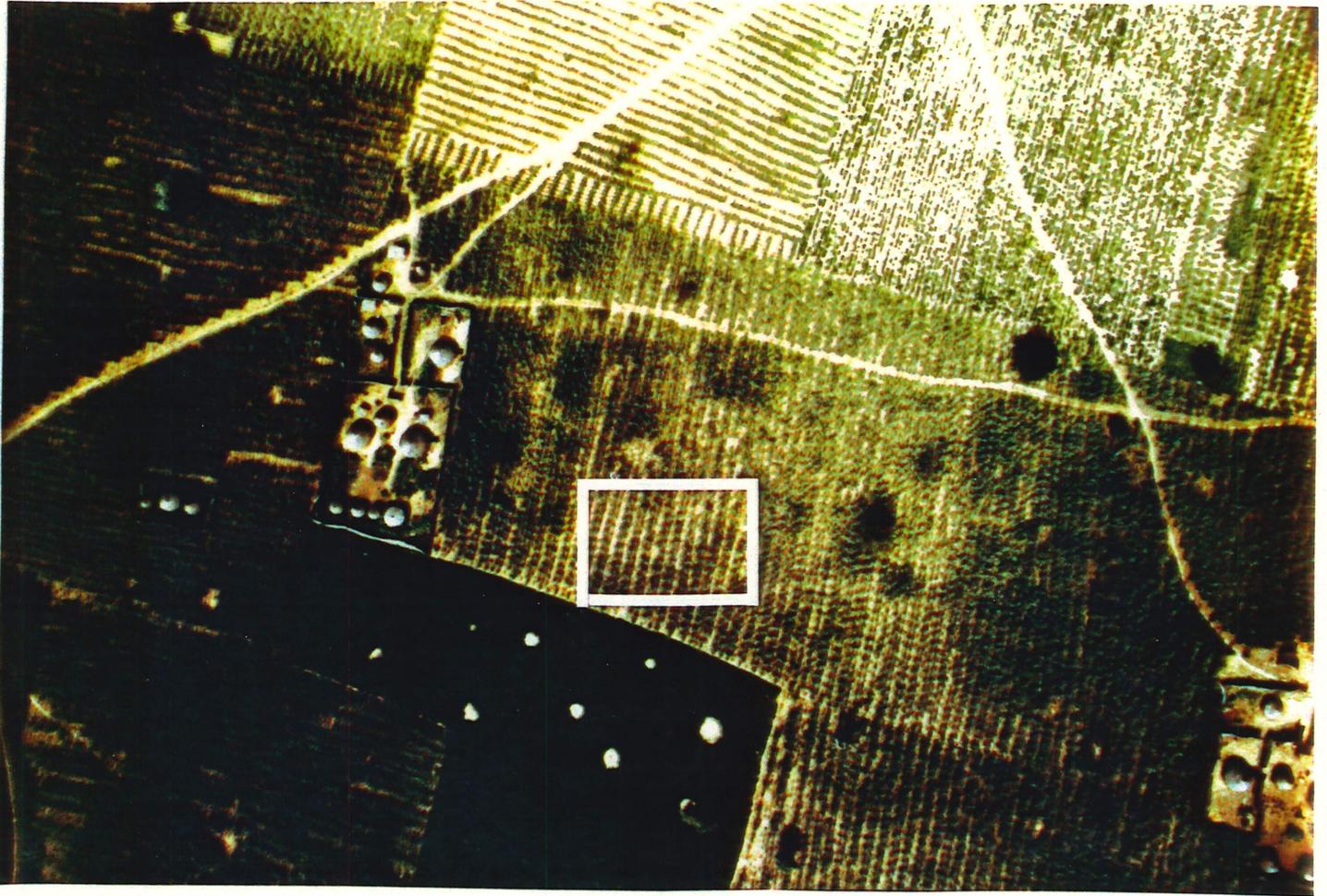
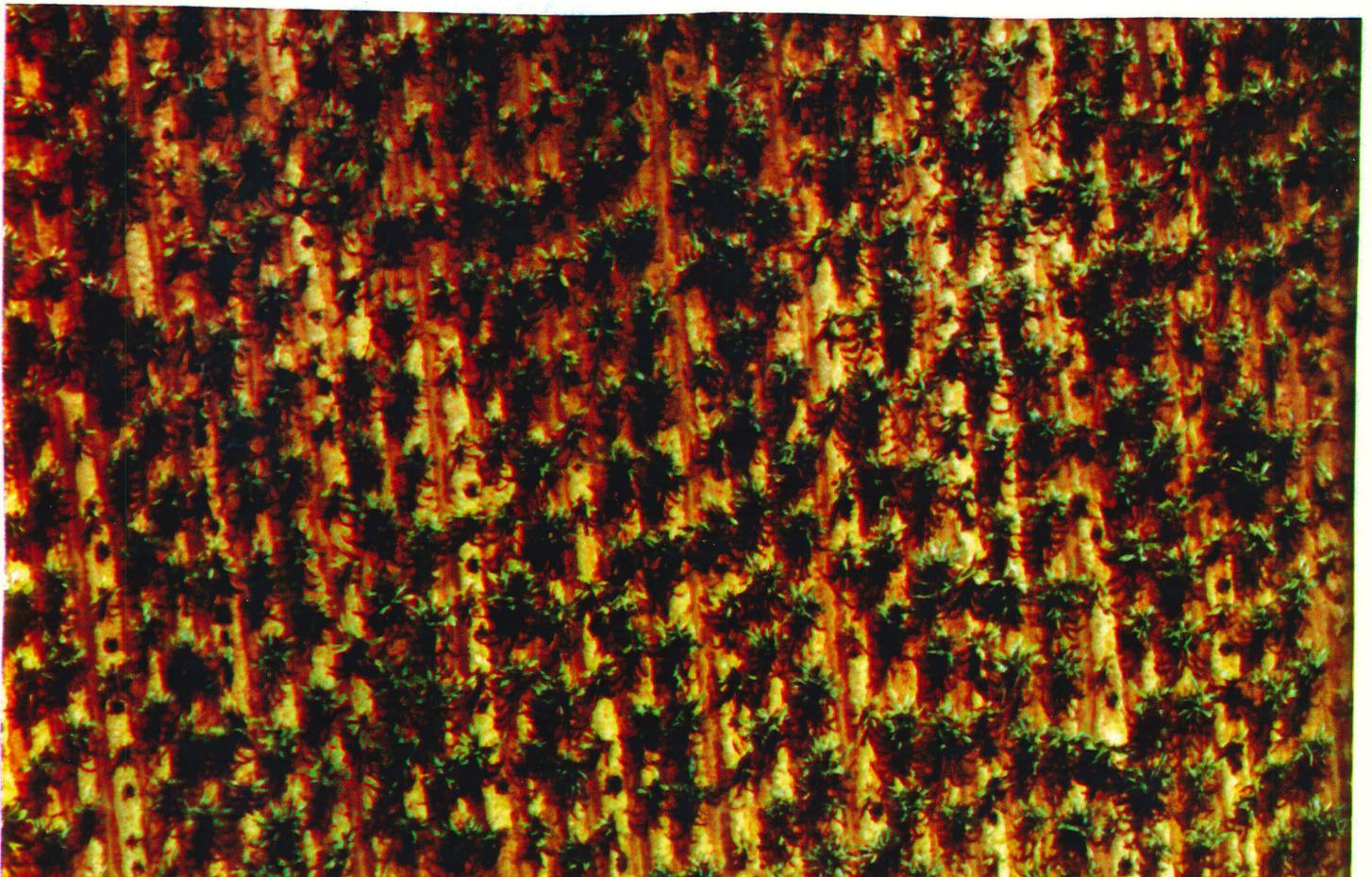
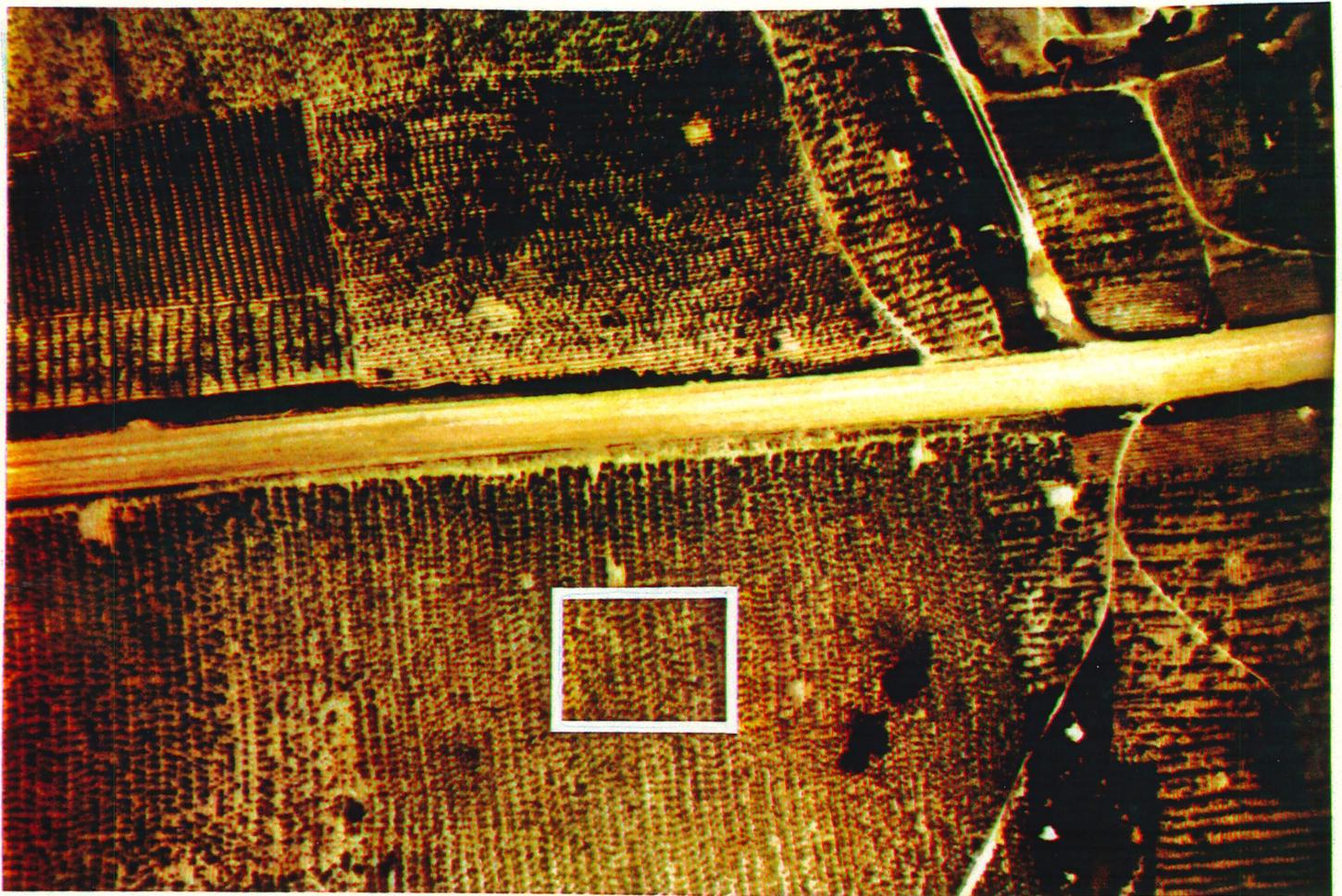


FIGURE 5: WIDE ANGLE AND TELEPHOTO PAIR - MILLET, SORGHUM AND COWPEA.



Rare and spatially limited phenomena are more likely to be detected by systematic, rather than any form of random, sampling, where this is laid down before such phenomena are known. This is a geometric fact easily proved. The maximum unsampled compact or randomly shaped areas - e.g. the void between sample units - is greater in any random layout than it is in a systematic one with the same number, size and shape of units (Dawkins and Field, 1978).

Periodic variation in the field may partially (or even wholly) coincide with the particular spacing chosen for a systematic sample. In such a case, the variance would be spuriously low, and the mean biased up or down, undetectably. Indeed there is no reliable way of correcting or detecting such bias, without further interpolative and random sampling.

However, it is also true that the likelihood of any geographically controlled periodic variation coinciding even partially with systematically spaced flight lines is extremely low, when the ratio of length/spacing is high. The likelihood must also decrease with the number of flight lines, though not so clearly as it does with increasing length/spacing ratio.

4.2.2.2 Sampling errors within photographic sets.

In this survey the sampling units were the sets of photographs, or sub-sets of them, taken along each flight line, rather than the 5 kilometer grids, or the individual photographs themselves. Unlike the photographic survey of the whole of Bauchi State described in RIM (1984), the photographs taken during the Azare survey, which was flown at a quarter of the altitude, did not overlap to form a continuous photographic strip. This, however, makes no difference to the statistical rationale. A sample unit is made up of those photographs from that part of the flight line which lies within the stratum in question. Thus, the ten photographs taken over a given grid cell can be considered as the minimum sampling unit, but the vast majority of samples would be represented by substantially greater number of grid cells, and photographs.

Considering this minimum situation of a single grid cell, ten photographs and 400 sample points, the estimated proportion of land within a given land use category, or under a particular crop or enterprise, would have the following standard error characteristics:

| n/400 Points in Category | Estimated Mean % Cultivation | Standard Error | Standard Error as % of Mean |
|-----------------------------|---------------------------------|-------------------|--------------------------------|
| 0 | 0 | - | - |
| 10 | 2.5 | 0.73 | 31 |
| 50 | 12.5 | 1.79 | 14 |
| 100 | 25 | 2.55 | 10 |
| 200 | 50 | 2.55 | 5 |

4.2.2.3 Sampling error between photographic sets.

Within any stratum, be it a crop, a land use category, or an administrative unit, the standard error of the mean value will be estimated by the equation:

$$SE \bar{y} = \sqrt{\frac{\text{Sum } [w(y - \bar{y})^2]}{\text{Sum } w \times n}} \times \text{fpcf}$$

where: \bar{y} is the mean value for the stratum.

y is a single observation (in the same units as \bar{y}) from a single sample unit i.e. a photographic set.

w is the "weight" (=length, area or number) of a single photographic set.

n is the number of photographic sets in the stratum.

fpcf finite population correction factor (here = 0.99).

Because a systematic sample has been used, the intensity of sampling is constant over the survey region, and therefore the above formula is valid for any grouping, or assemblage of strata, or sub-strata, whether or not they are contiguous.

4.2.3 Computer Analysis and Mapping.

All data were coded as grid totals or averages. Each grid was given a unique location reference in relation to a west-east and south-north coordinate system.

RIM's aerial survey computer package (ANALAIR) carries out the analysis indicated in 4.2.2.3 above, by first summarising each flight line's total for a given parameter, and the length or area of each line. The programme runs for selected strata and sub-strata, which are coded as variables for each grid and are selected by interactive process.

Two forms of graphic information display were chosen. The pie chart, showing land use characteristics for each Local Government Area within the survey region, in which total land area was represented by the overall size of the pie, and the proportions of major land use categories as individual slices. Secondly, an indication of the distribution of the major crops and various crop mixtures was obtained by plotting a circle at the centre of each grid cell, the size of which was proportional to the estimated coverage of the selected crop(s).

5 RESULTS.

This study was primarily concerned with investigating the feasibility of using Low Altitude Systematic Reconnaissance Photography for the assessment of cropping patterns and the rapid surveillance of agriculture over extensive areas of Nigeria. The region selected was a 4,250 square kilometers area around the town of Azare, situated in the Northern Zone of the Bauchi State Agricultural Development Programme. The findings are described in the following paragraphs and presented quantitatively in the accompanying tables. To begin with, the overall land use characteristics of the surveyed region, are summarised. Then, the coverage of major crops and extent of farming enterprises are considered, and stand density estimates for individual crops, as determined by aerial photo-interpretation, are given. From these, specific crop population estimates are made, which are compared with those derived from ground based data collection.

5.1 Land Use Pattern.

Table 1 summarises the land use characteristics of the study area. Figures are given for: the study area as a whole; each of the component Local Government Areas (Shira, Giade, Misau and Katagum); and the Shira Development Area, the only entire BSADP Development Area contained within the surveyed region. The results are represented graphically in Map 6, which also shows the location of each of the Local Government Areas. Land use was divided into seven categories: cultivated land; recent fallow; bushland, with no evidence of previous cultivation; open grassland or fadama; riverine areas or surface water; rock outcrops; and finally, land on which human settlements or roads had been built. The area of each land use category is given both as a percentage, and in terms of the number of hectares of land occupied, together with a standard error, expressed as a percentage of the estimate.

The land use proportions for each of the entire Development and Local Government Areas, and for the study area as whole, were very similar. They are presented separately, partly to indicate the homogeneity of land use within the region, but also to demonstrate the spatial disaggregation possible with data collected by systematic aerial survey. In Map 6 the relative size of each LGA is indicated by the diameter of their respective pies; cultivation is represented by diagonal lines (C); recent fallow by coarse cross-hatching (F); bushland by medium cross-hatching (B); and the remaining minor land use categories by fine cross-hatching.

Almost 40% of the total study area was estimated to be under cultivation, amounting to some 166,415 hectares of land; the standard error of this estimate was 8%. Thus, with 95% confidence, the area under cultivation can be considered to lie within the range 140,321 - 192,509 hectares. Recent fallow accounted for between 11 - 18% of the land area, and thus indicated a cultivation to fallow ratio of around 3 : 1. Eroded areas amounted to less than 1% of the land under cultivation, and have thus not been included in the table.

TABLE 1: LAND USE WITHIN SELECTED REGIONS OF AREA SURVEYED*.

| Land Use | Shira Development Area | Local Government Area | | | | Total Study Area |
|------------------|------------------------------|-----------------------|----------------------|----------------------|--------------------|------------------------|
| | | Shira | Giade | Misau | Katagum | |
| Cultivated Land | 41 79,368 (10) | 39 38,554 (12) | 39 31,330 (15) | 33 20,613 (18) | 42 7,541 (1) | 39 166,415 (8) |
| Recent Fallow | 15 28,758 (8) | 12 11,882 (10) | 18 14,205 (11) | 11 6,875 (20) | 13 2,497 (2) | 13 54,751 (8) |
| Bush Land | 40 78,465 (9) | 40 38,822 (17) | 41 32,800 (17) | 49 30,717 (14) | 37 6,694 (7) | 43 183,204 (9) |
| Grassland/Fadama | 1 1,227 (51) | 2 2,373 (37) | + 268 (86) | + 399 (65) | 0 0 | 1 4,533 (25) |
| Water/Riverine | + 797 (50) | 1 1,071 (36) | + 162 (47) | 2 1,507 (69) | 0 0 | 1 3,986 (32) |
| Rocky Ground | 2 3,232 (55) | 3 3,195 (44) | + 25 (136) | + 199 (36) | + 6 (111) | 1 3,550 (52) |
| Roads/Settlement | 1 2,939 (18) | 2 1,619 (28) | 1 990 (26) | 3 1,974 (48) | 7 1,320 (29) | 2 8,239 (15) |
| Total Area (ha) | 194,786 | 97,516 | 79,780 | 62,274 | 18,058 | 424,678 |

* The top figure of each triplet in the table is the percentage of land within a specific land use category; the middle figure is the area in hectares, occupied by each land use category; and the bottom figure, in parenthesis, is the percentage standard error.

+ Less than 0.5%.

As expected, high standard errors were linked to those land use categories with more limited and clustered distribution patterns, namely the riverine and fadama grassland areas associated with the Jama'are and the Kari/Dingaiya rivers, and rocky outcrops centred on the Shira hills.

5.2 Cropping Pattern.

Table 2, 3 and 4 summarise the cropping pattern, in the style of the APMEPU FRADYS agronomic survey. First, in Table 2, the proportion of land under each of the major crops is given. Care is needed in the interpretation of this table because mixed crops were counted once for each crop in the mixture, and hence there has been double and triple counting of land, with the result that percentage totals exceed 100%.

Crop distribution within the Azare survey region is also indicated in two sets of maps, one of which shows the coverage of each of the major crops, and the other shows the distribution of various crop mixtures. The coverage of a particular crop, or crop mixture, is indicated by the size and distribution of proportional circles, each representing the extent of land occupied within a given grid cell. Map 2 shows the distribution of the Millet crop; Map 3 - Sorghum; Map 4 - Cowpea; and Map 5 - Groundnut. Map 7 indicates the coverage of the Sorghum, Millet and Cowpea mixture; Map 8 - Sorghum and Millet; Map 9 - Millet and Cowpea; Map 10 - Millet and Groundnut; and Map 11 - Sorghum, Millet and Groundnut.

Millet was grown on at least 68%, and sorghum on 47% of the total area of cropped land, with a further 17% of cultivated land being assessed as carrying non-specific grain crops, which could not be distinguished as either sorghum, or millet. Cowpea was seen on 32% of cultivated land, groundnuts on 8%, and a further 3% was identified as being cropped by plants with visual features similar to cowpea and groundnut, but for which positive identification was not possible. Cassava, cotton and kenaf were found on only 2%, each, of cultivated land; and, not surprisingly, their standard errors were correspondingly high. Land with crops that were just germinating accounted for 4% of the cultivated area, and a further 3% was under completely unrecognisable crops.

In Table 3, the land area under sorghum, millet, cowpea and groundnuts is further subdivided on the basis of the number of crops in the mixture. Sorghum was grown predominately in mixtures with one or two other crops. About a quarter of the millet area was sole cropped, with the remainder being in two or three crop mixtures. Cowpea and groundnuts were both grown mostly as mixtures. Two-thirds of the cowpeas were found as three crop mixtures, while groundnuts were grown mainly in two crop mixtures.

The occurrence of individual crop mixtures or enterprises are reported in Table 4. Sorghum, Millet and Cowpea, and Sorghum and Millet were the most important enterprises, each covering 19% of the cultivated area. Together with Sole Millet, they accounted for some 54% of the land area under cultivation.

TABLE 2: PROPORTION OF CULTIVATED LAND UNDER VARIOUS CROPS.

| Crop Type | Percentage of Cultivated Land* | | | |
|---------------------------|--------------------------------|------|------------------|------|
| | Shira Development Area | | Total Study Area | |
| Sorghum | 47 | (15) | 47 | (7) |
| Millet | 69 | (13) | 68 | (8) |
| Non-specific Grain | 15 | (26) | 17 | (15) |
| Cowpea | 26 | (23) | 32 | (12) |
| Groundnut | 8 | (26) | 8 | (20) |
| Non-specific Legume | 3 | (32) | 3 | (26) |
| Cassava | 2 | (92) | 2 | (69) |
| Cotton | 1 | (47) | 2 | (68) |
| Kenaf | 2 | (57) | 2 | (40) |
| Trailing Crop | 1 | (56) | 1 | (38) |
| Germinating Crop | 3 | (26) | 4 | (21) |
| Unknown Crop | 3 | (43) | 3 | (34) |
| Total Hectares Cultivated | 79,368 | | 166,415 | |

* The identification of individual crops, in an area where mixed cropping was typical, has led to double counting with the result that percentage totals exceed 100%. Figures in parenthesis are % standard errors.

TABLE 3: OCCURRENCE OF MAJOR CROPS, AS SOLE CROPS OR IN MIXTURES.

| | Percentage of Cultivated Land* | |
|---------------------|--------------------------------|------------------|
| | Shira Development Area | Total Study Area |
| <u>Sorghum</u> | | |
| Sole Crop | 13 (20) | 8 (25) |
| + 1 | 45 (17) | 43 (12) |
| + 2 | 40 (26) | 48 (16) |
| + 3 | 2 (63) | 1 (47) |
| Hectares Cultivated | 37,177 | 78,166 |
| <u>Millet</u> | | |
| Sole Crop | 27 (16) | 23 (22) |
| + 1 | 44 (12) | 42 (10) |
| + 2 | 27 (27) | 34 (16) |
| + 3 | 1 (63) | 1 (47) |
| Hectares Cultivated | 54,672 | 113,531 |
| <u>Cowpea</u> | | |
| Sole Crop | 2 (63) | 2 (54) |
| + 1 | 32 (14) | 30 (13) |
| + 2 | 62 (32) | 67 (18) |
| + 3 | 3 (70) | 1 (52) |
| Hectares Cultivated | 20,619 | 53,735 |
| <u>Groundnut</u> | | |
| Sole Crop | 14 (41) | 14 (39) |
| + 1 | 58 (28) | 58 (21) |
| + 2 | 21 (36) | 25 (32) |
| + 3 | 7 (65) | 3 (67) |
| Hectares Cultivated | 5,998 | 13,184 |

* Figures in parenthesis are percentage standard errors.

TABLE 4: OCCURRENCE OF CROP ENTERPRISES.

| | Percentage of Cultivated Land Occupied* | | | |
|-------------------------------|---|------|------------------|------|
| | Shira Development Area | | Total Study Area | |
| Sorghum, Millet and Cowpea | 15 | (34) | 19 | (19) |
| Sorghum and Millet | 22 | (21) | 19 | (13) |
| Sole Millet | 19 | (16) | 16 | (22) |
| Millet and Cowpea | 7 | (14) | 7 | (15) |
| Sole Sorghum | 6 | (20) | 4 | (25) |
| Millet and Groundnut | 3 | (40) | 3 | (32) |
| Sorghum, Millet and Groundnut | 1 | (38) | 1 | (35) |
| Sole Non-specific Grain | 10 | | 12 | |
| Sole Non-specific Legume | 2 | | 2 | |
| Sole Non-specific Trailing | 1 | | + | |
| Sole Germinating | 2 | | 3 | |
| Sole Unknown | 2 | | 2 | |
| Other Enterprises** | 10 | (15) | 12 | (17) |
| Total Hectares Cultivated | 79,368 | | 166,415 | |

* Figures in parenthesis are percentage standard errors.

** Includes both identified and unidentified minor crops.

+ less than 0.5%.

5.3 Stand Counts.

Stand counts of all crops were made on every photograph which displayed a clear presentation. If, because of shadow interference between plants, it was not possible to distinguish the presence or absence of a crop across the whole area of measurement, a count was not made. For this reason, stand count sample sizes were considerably below the number of observations of a particular crop. It can also be anticipated that the results are likely to be overestimates, because lower density plantings are more likely to have been passed over, as not being clearly distinguishable. The stand counts of the four major crops, sorghum, millet, cowpea and groundnuts, planted as sole crops or in various mixtures, are presented in Table 5, together with their standard deviations and overall mean values. For comparison, the equivalent FRADYS estimates are given alongside.

5.4 Weeding and Land Preparation.

An assessment was made of the degree of weed infestation of every plot and the method of land preparation. These findings are reported in Table 6. Two thirds of all cultivated land was free of weeds and only 6% was considered to be heavily infested. Land preparation was divided almost equally between hand and oxen, with less than 1% of the ground having been prepared by tractor. A common farming practice in the Azare region is to plant on the ridges which were formed during the previous seasons. In this case the correct land preparation category should have been "none", but this feature is not straightforward to distinguish from the air, and it is probable that this category has been underestimated. After planting, plots are either hand weeded or ridged up by ox plough. Crops which had been planted into old ridges would have been allocated to hand or oxen preparation after these operations took place.

5.5 Selected Human Settlement and Livestock Parameters.

Selected human settlement and livestock parameters derived from interpretation of Systematic Reconnaissance Photography are presented in Table 7. An estimated 211,000 human dwellings were found in the total study area, of which some 126,000 (59%) had grass roofs; 78,000 (37%) had tin roofs; and 8,000 (4%) had flat mud roofs. The ratio of tin to grass roofs varied considerably within the region. In the Shira Development Area, for instance, the ratio was 1 tin : 3 grass roofs, while in Katagum Local Government Area in which the town of Azare is located, the ratio was reversed with five tin roofs for each grass roof. A further estimated 214,000 structures, identified by their size and relative position to be granaries, were associated with human dwelling, and together these were found in an estimated total of some 48,000 settlements, ranging in size from a single compound to a large village.

In terms of livestock, the area contained an estimated 10,000 herds of cattle which amounted to a total cattle population of some 155,000 head. Thus, cattle density was relatively high at 36 animals per square kilometer, and mean herd size was relatively low at about 16 animals per herd. These values are indicative of a resident, or sedentary, form of animal husbandry typical of a mixed farming community

TABLE 5: STAND DENSITIES OF MAJOR CROPS, AS SOLE CROPS OR IN MIXTURES.

| | Photo-interpretation | | | FRADYS |
|------------------|----------------------|-------|-----|---------|
| | Mean/ha | S.D. | n | Mean/ha |
| <u>Sorghum</u> | | | | |
| Sole Crop | 6,775 | 2,843 | 23 | |
| + 1 | 3,174 | 2,180 | 76 | |
| + 2 | 2,296 | 1,023 | 84 | |
| + 3 | 1,610 | 1,104 | 2 | |
| Overall | 3,179 | 2,132 | 124 | 3,700 |
| <u>Millet</u> | | | | |
| Sole Crop | 6,618 | 2,020 | 76 | |
| + 1 | 5,003 | 1,844 | 100 | |
| + 2 | 4,533 | 1,327 | 91 | |
| + 3 | 1,108 | 687 | 2 | |
| Overall | 5,345 | 1,535 | 142 | 6,000 |
| <u>Cowpea</u> | | | | |
| Sole Crop | 7,776 | 6,495 | 5 | |
| + 1 | 4,370 | 3,816 | 22 | |
| + 2 | 2,475 | 1,272 | 27 | |
| + 3 | - | - | 1 | |
| Overall | 3,836 | 3,634 | 48 | 2,900 |
| <u>Groundnut</u> | | | | |
| Sole Crop | 16,755 | 5,233 | 9 | |
| + 1 | 12,883 | 5,755 | 20 | |
| + 2 | 9,402 | 5,196 | 8 | |
| + 3 | 5,216 | 2,587 | 2 | |
| Overall | 12,594 | 6,495 | 34 | 5,900 |

TABLE 6: DEGREE OF WEED INFESTATION AND METHOD OF LAND PREPARATION.

| | Percentage of Cultivated Land* | | | |
|---------------------------|--------------------------------|------|------------------|------|
| | Shira Development Area | | Total Study Area | |
| <u>Weed Infestation</u> | | | | |
| Free | 67 | (13) | 67 | (8) |
| Medium | 24 | (24) | 24 | (16) |
| Heavy | 8 | (20) | 9 | (14) |
| <u>Land Preparation</u> | | | | |
| Hand | 37 | (16) | 40 | (11) |
| Oxen | 43 | (16) | 37 | (12) |
| Tractor | 1 | (63) | + | (66) |
| None | 5 | (64) | 6 | (29) |
| Uncertain | 14 | (19) | 16 | (17) |
| <hr/> | | | | |
| Total Hectares Cultivated | 79,368 | | 166,415 | |

* Figures in parenthesis are percentage standard errors.

+ Less than 0.5%

TABLE 7: SELECTED HUMAN SETTLEMENT AND LIVESTOCK POPULATION PARAMETERS.

| | Shira Development Area* | | Total Study Area* | |
|----------------------------------|-------------------------|------|-------------------|------|
| Number of Settlements | 20,513 | (14) | 47,729 | (13) |
| Number of Tin Roofed Dwellings | 19,718 | (46) | 77,889 | (42) |
| Number of Grass Roofed Dwellings | 59,043 | (20) | 125,549 | (12) |
| Number of Flat Roofed Dwellings | 7,786 | (56) | 7,786 | (62) |
| Number of Granaries | 117,789 | (28) | 213,908 | (15) |
| ----- | | | | |
| Number of Cattle Herds | 4,665 | (17) | 9,732 | (13) |
| Number of Cattle | 68,709 | (15) | 154,896 | (15) |
| ----- | | | | |
| Hectares of Cultivated Land | 79,368 | (10) | 166,415 | (8) |
| Total Hectares of Land | 194,786 | | 424,678 | |

* Figures in parenthesis are percentage standard errors.

5.6 Comparison of Aerial and Ground Based Agronomic Surveys.

As emphasised in the introduction, this study has been an experimental investigation of the usefulness of Systematic Low Altitude Reconnaissance Photography for rapid agricultural surveillance. The results obtained therefore are of particular importance, not so much for their intrinsic value, but more for an assessment of their accuracy and precision. However, because of the very nature of the problems outlined in the introduction, these attributes are difficult to resolve.

The only data available for the study area are the results from the ground based agronomic surveys conducted by the Northern Zone Evaluation Unit of BSADP in 1982 and 1983 cropping seasons (NZEU 1982, 1984, Undated a and b; APMEPU 1983a, 1983b). For the most part the evaluation reports present results for the whole of Northern Zone, but wherever possible data for the study area only has been extracted. Inevitably, however, some comparisons have had to be made with agronomic survey results for the whole zone.

The reader should bear in mind that, whilst the ground agronomic survey has a sound methodological basis, it suffers, as described in the introduction, from problems typically associated with clustering and population estimation. The results obtained from air photo-interpretation are, therefore, not being compared with "true" population figures, but with another set of sample estimates. Thus, there are no a priori reasons for believing the FRADYS data to be more accurate than that of the aerial survey.

The comparison with FRADYS follows a similar pattern to the presentation of the RIM results given in preceding paragraphs. In Table 8 the proportion of land under each major crop category is shown for the study area as a whole. The FRADYS results were relatively stable between the two years and indicate considerably higher estimates of sorghum and cowpea than the aerial data. If the aerial survey's uncertain grain category is added to those of sorghum and millet, the estimated grain area remains some 30% below that of the FRADYS estimates. Likewise, cowpeas and groundnuts are some 20% below the FRADYS figures.

In Table 9 the proportion of crop area with one, two, three or four crop mixtures is given for sorghum, millet, cowpea and groundnut. The FRADYS data are for the whole of the Northern Zone and, at the time of writing, are only available for 1982/83. The aerial sorghum proportions closely match FRADYS, with about 90% of the crop in two or three crop mixtures. Millet appears with a greater proportion of sole and two crop mixtures from the air than in FRADYS. Two and three crop mixtures account for 80% of the area. Cowpea proportions are similar between air and ground with noticeably fewer four crop mixtures seen from the air. A similar pattern is evident for groundnuts. Two and three crop mixtures jointly comprise 80% of the groundnut area. But the aerial data display a higher proportion of sole crop and a lower proportion of four crop mixtures than the ground data. This trend towards simplification of mixtures is thought to be associated with the relatively small sample area of each photograph, which is likely to result in the under recording of low incidence crops, and the problem of canopy closure, which may obscure crops of low stature. This issue is considered further in the the Discussion.

TABLE 8: PROPORTION OF CULTIVATED LAND UNDER MAJOR CROPS
- A COMPARISON OF SLARP AND FRADYS ESTIMATES.

| | Percentage of Cultivated Land* | | |
|---------------------|--------------------------------|------------------|------------------|
| | SLARP 1983 | FRADYS** 1982/83 | FRADYS** 1983/84 |
| Sorghum | 47 (7) | 83 (27) | 86 (11) |
| Millet | 68 (8) | 75 (26) | 89 (8) |
| Non-specific Grain | 17 (15) | - | - |
| | <hr/> 132 | 158 | 175 |
| Cowpea | 32 (12) | 59 (23) | 54 (28) |
| Groundnut | 8 (20) | 7 (15) | 7 (38) |
| Non-specific Legume | 3 (26) | - | - |
| | <hr/> 43 | 66 | 61 |
| Hectares Cultivated | 166,415 | 186,440 | 134,521 |

* Figures in parenthesis are percentage standard errors.

** Based on seven selected sample villages within the study area.

TABLE 9: OCCURENCE OF MAJOR CROPS, AS SOLE CROPS OR AS MIXTURES
- A COMPARISON OF SLARP AND FRADYS ESTIMATES.

| | Percentage of Cultivated Land* | | |
|---------------------|--------------------------------|------------------|------------------|
| | SLARP 1983 | FRADYS** 1982/83 | FRADYS** 1983/84 |
| <u>Sorghum</u> | | | |
| Sole Crop | 8 (25) | | 9 |
| + 1 | 43 (12) | | 35 |
| + 2 | 48 (16) | | 51 |
| + 3 | 1 (47) | | 5 |
| <u>Millet</u> | | | |
| Sole Crop | 23 (22) | | 7 |
| + 1 | 42 (10) | | 31 |
| + 2 | 34 (16) | | 54 |
| + 3 | 1 (47) | | 7 |
| <u>Cowpea</u> | | | |
| Sole Crop | 2 (54) | | - |
| + 1 | 30 (13) | | 20 |
| + 2 | 67 (18) | | 73 |
| + 3 | 1 (52) | | 7 |
| <u>Groundnut</u> | | | |
| Sole Crop | 14 (39) | | 2 |
| + 1 | 58 (21) | | 28 |
| + 2 | 25 (32) | | 51 |
| + 3 | 3 (67) | | 20 |
| <hr/> | | | |
| Hectares Cultivated | 166,415 (8) | 186,440 (24) | 134,521 (9) |

* Figures in parenthesis are percentage standard errors.

** Whole of Northern Zone.

The two sets of estimates for individual crop enterprises are compared in Table 10. With this style of presentation a marked divergence of results is evident. In particular, the aerial estimate of sole millet (noted in Table 9) has a higher proportion in than in the FRADYS, but aerial estimates of sorghum, millet and cowpea are all about half those recorded on the ground. There are no enterprises in the FRADYS figures which are unknown, and the six that are listed in Table 10 account for 86% of the cultivated land area. In contrast, largely because of the non-specific crop categories in the RIM data, which are not included in Table 10, the same six enterprises account for only 66% of the cropped area.

5.7 Estimates of Total Cultivation and Areas under Specific Crops.

The proportional comparisons made in earlier sections are revealing upto a point, but they tend to divert attention away from the absolute magnitude of the results. It must be emphasised that the ultimate purpose of both FRADYS and SLARP surveys is to estimate crop population characteristics. It may be argued, therefore, that a better and more realistic comparison may be made between the estimates for the overall abundance of each of the major crop populations. However, because of the unique boundaries of the study area, here too the comparison is not straightforward.

For a population estimate to be derived from the FRADYS data, it is necessary to know the number of farming households in the study area. The area cuts across a number of the Local Government and Development Area boundaries, but the approximate number of farming households in each complete Development Area is known. The method adopted here was to estimate mean household cultivated area for the wholly enclosed Shira Development Area, from aerial and population data, and apply that mean farm size to the aerial estimate of total cultivated area. The result is a farming population of 59,000 households in the total study area. Survey data from the seven FRADYS villages falling within the aerial survey area were then used to produce an area total, with standard errors computed wherever possible. The results of these calculations are presented in Table 11, alongside those derived from Systematic Low Altitude Reconnaissance Photography.

The main comparison is between SLARP and FRADYS for 1983/1984, but FRADYS 1982/83 is also included for illustration. Total cultivated area was estimated to be 166,00 hectares by SLARP 1983/84, 186,000 hectares by FRADYS 1982/83, and 135,000 hectares by FRADYS 1983/84. There is considerable variation between the FRADYS year. The source of this variation is the estimated mean size of farms, which was 3.16 hectares in 1982 and 2.28 hectares in 1983. Undoubtedly, aerial survey cropping estimates would also vary from year to year, but they would at least be based on a total survey area which would be constant.

The aerial survey appears to have underestimated sorghum, and also, to a lesser extent, millet. Inclusion of the nonspecific grain crop category improves the SLARP estimate to within 7% of FRADYS 1983/84. Cowpea was also underestimated, but groundnuts was not. Taking the four major crops together the SLARP and FRADYS 1983/84 data differ by only 14,000 hectares out of a total of 319,000 hectares, or just 7%. Amongst the crop enterprises, sole sorghum was similar in both surveys; sorghum and millet areas vary by 10,000 hectares; SLARP sorghum and cowpea was 1,400 hectares against FRADYS 5,000 hectares; SLARP millet and cowpea was 12,000 hectares compared with FRADYS 9,000 hectares; FRADYS sorghum, millet and cowpea estimate, at 56,000 hectares, was 24,000 hectares greater than SLARP's.

TABLE 10: THE OCCURRENCE OF MAJOR CROP ENTERPRISES
- A COMPARISON OF SLARP AND FRADYS ESTIMATES.

| | Percentage of Cultivated Land* | | |
|----------------------------|--------------------------------|------------------|------------------|
| | SLARP 1983 | FRADYS** 1982/83 | FRADYS*** 1983/8 |
| Sorghum, Millet and Cowpea | 19 (19) | 39 | 41 |
| Sorghum and Millet | 19 (13) | 20 | 31 |
| Sole Millet | 16 (22) | 7 | - |
| Millet and Cowpea | 7 (15) | 3 | 7 |
| Sole Sorghum | 4 (25) | 9 | 2 |
| Sorghum and Cowpea | 1 (37) | 8 | 4 |
| Hectares Cultivated | 166,415 (8) | 186,440 (24) | 134,521 (9) |

* Figures in parenthesis are percentage standard errors.

** For the whole of Northern Zone.

*** Based on seven selected sample villages within the study area.

TABLE 11: COVERAGE OF MAJOR CROPS AND CROP ENTERPRISES
- A COMPARISON OF SLARP AND FRADYS ESTIMATES.

| | Hectares of Cultivated Land* | | |
|-------------------------------|------------------------------|------------------|------------------|
| | SLARP 1983 | FRADYS** 1982/83 | FRADYS** 1983/84 |
| <u>Major Crops</u> | | | |
| Sorghum | 78,166 (7) | 155,057 (27) | 115,309 (11) |
| Millet | 113,531 (8) | 139,949 (26) | 120,186 (8) |
| Non-specific Grain | 28,055 (15) | - | - |
| | 219,752 | 295,006 | 235,495 |
| Cowpea | 53,735 (12) | 110,613 (23) | 72,374 (28) |
| Groundnut | 13,184 (20) | 12,576 (15) | 9,417 (38) |
| Non-specific Legume | 4,936 (26) | - | - |
| | 71,855 | 123,189 | 81,791 |
| Combined Area | 291,607 | 418,195 | 317,286 |
| <u>Major Enterprises</u> | | | |
| Sole Sorghum | 5,998 (25) | | 3,332 |
| Sole Millet | 26,493 (22) | | - |
| Sorghum and Millet | 31,491 (13) | N/A | 44,446 |
| Sorghum and Cowpea | 1,437 (37) | | 5,068 |
| Millet and Cowpea | 11,997 (15) | | 8,850 |
| Sorghum, Millet and Cowpea | 31,866 (19) | | 55,550 |
| <u>Cultivated Area (ha)</u> | 166,415 (8) | 186,440 (24) | 134,521 (9) |
| <u>Number of Households</u> | 59,000 | 59,000 | 59,000 |
| <u>Mean Farm Size (ha)</u> | 2.82 | 3.16 | 2.28 |
| <u>% Land Area Cultivated</u> | 39 | 44 | 32 |

* Figures in parenthesis are percentage standard errors.

** Based on seven selected sample villages within the study area.

6 DISCUSSION.

6.1 General.

6.1.1 Statistical Precision.

For nearly every variable considered the statistical precision of the SLARP data, expressed by the standard error of the total, is better than the FRADYS. For a given natural variation, the precision of an estimate depends on the number of flight lines used in the RIM study, or the number of villages sampled in the FRADYS. Resource constraints (manpower and finance) impose serious limitations to the sampling of more villages on the ground. For the aerial survey, however, the flight sequence can easily be designed to maximise the number of flight lines for a given grid framework. Thus, the aerial survey is inherently more likely to be precise, because of its basic design features.

6.1.2 Statistical Accuracy.

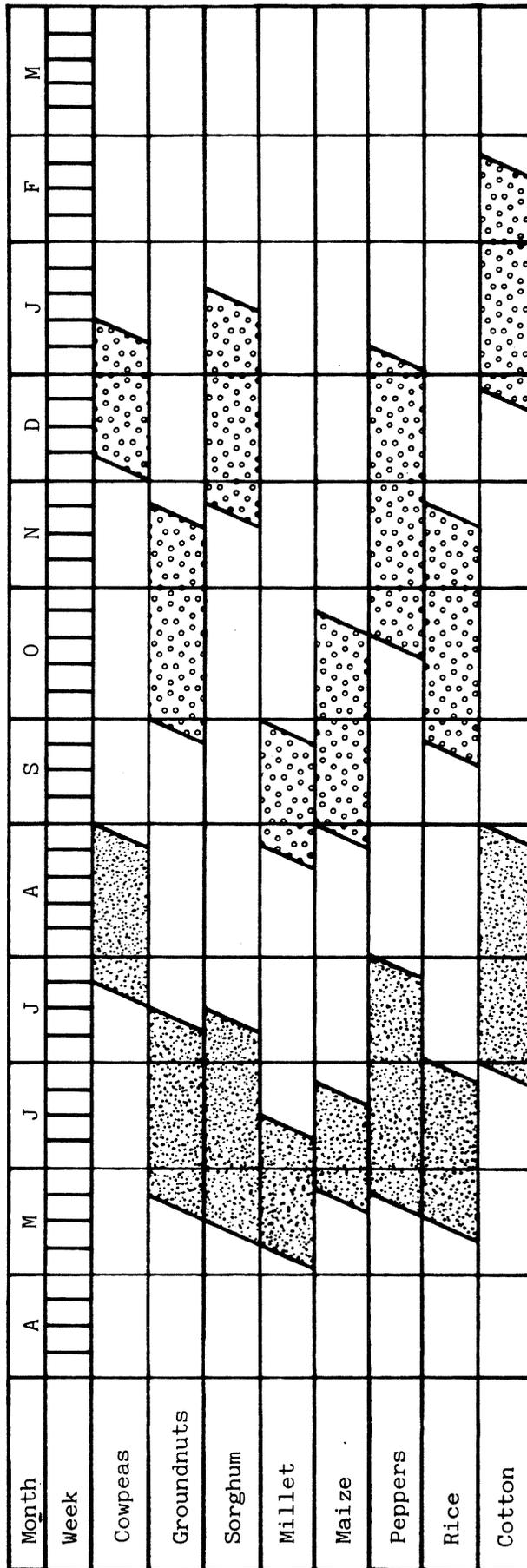
The issue of accuracy is less easy to resolve. Clearly the aerial data lacks the potential for cross checking of detail that is possible with FRADYS. But on the other hand, aerial photographs can easily be re-examined, and the accuracy of aerial estimates could undoubtedly be further improved if the related issues of flight timing, both during the season and during the day, and ground verification, were given greater consideration than was possible in this trial study.

6.1.2.1 Flight timing.

The survey was flown on 30th and 31st August 1983. In a normal season this would have coincided with the maturity of early millet, and the start of harvest. All the sorghum and cowpea would also have been planted. But the 1983 season was disrupted by erratic rainfall, and was effectively at least four weeks late. Sorghum and cowpea were still being planted, which accounts for such a large land area appearing in the unknown and non-specific crop categories. In addition the early millet crop matured unevenly, and it was thus impossible to distinguish "early" from "late" millet. Even if the season had been on time, a later date, chosen to coincide with the early millet harvest, would have been preferable. By this time sorghum would have started to flower, as also would maize. Flowering grains are very distinct for aerial recognition, and similarly, harvested millet would be recognisable, as would any small crops interplanted with the millet. Data on planting and harvesting dates held by APMEPU would permit the construction of cropping calendars for survey planning. Table 12, derived from Balcet and Candler (1982), is an example of such a calendar. However, the aerial survey must also take account of both local climatic patterns and annual variations, and it is thus important to maintain a flight date flexibility.

Photographic interpretation was impaired in one part of the study area. Strong late afternoon sunshine caused heavy and confusing shadow patterns, which obscured the secondary plants in crop mixtures. Photography in clear sky conditions should probably, therefore, not take place after 16.00, or before 08.00 hours.

TABLE 12: PLANTING AND HARVESTING CALENDAR FOR THE MAIN CROPS AT FUNTUA, KADUNA STATE



Planting  Harvesting 

Derived from Balcet and Candler (1982)
 Source: APMEPU Agronomic Data Files 1976-78

6.1.2.2 Ground verification

Ground verification of crop patterns was carried out in the area immediately north of Azare town. This led to a good understanding of the cropping pattern and photo-interpretation was made easier. In the south, and particularly the south-east, interpretation was more difficult and identification of locally minor crops, such as cotton rendered much harder because the photo-interpretation staff involved had less direct personal experience of the crop mixtures. Verification must take place systematically throughout the study area, and should ideally be based on written observations and ground photography of crops showing the stage of growth. This is most important if interpretation is carried out away from the area of study, or much later than the time of survey.

Modifications to the timing and the kind of ground verification would improve the accuracy of estimates and take account of the areas classified as uncertain in this study.

6.1.2.3 Unit of study.

Without more experimental research into cameras and film types a number of differences will always exist between the results obtained from a ground based, as opposed to an aerial system of data collection. Direct observation of the plot, and discussion with farmers must always yield the finest detail about the crops being grown. The aerial survey cannot be expected to achieve this level of detail, but in one respect at least, the limitations are due to the sampling scheme. Irrespective of the total land area sampled by a ground based or an aerial survey, the ground study records observations from the whole of the farmer's plot. Many mixtures of minor crops utilise plot boundaries, or tend to be scattered plantings rather than regular intercrops. Often these crops do not fall within the crop cutting sub-plot, although they are recorded as present. The telephoto sample used in this study covers just 18 meters by 27 meters. Therefore, although it is an efficient sampling device, being small in area but large in number, it cannot draw on the circumstances of the whole plot in the same way as can a ground survey. Each telephoto image is much more of a self-contained entity than a ground visit to a plot, and inevitably is not able to provide such detailed information. However, in partial compensation of this limitation, a greater breadth of view is given by associated wide angle photographs, and it is much easier to remeasure, or cross-check, a photograph than it is to return to a field plot.

6.2 Systematic Low Altitude Reconnaissance Photography (SLARP)
in the context of the APMEPU Evaluation Programme.

The results of this study demonstrate that photographic analysis of land samples can generate data of a satisfactory quality and quantity to determine the cropping pattern, rapidly, over large areas. A number of weaknesses have been identified with the Azare survey, related mainly to the timing of flights; but these are capable of solution within the current system.

Computer mapping techniques offer a valuable new approach to data presentation, which should improve the ability of government officers to make use of survey information. The grid network format of the survey data allows for detailed spatial representation and analysis of key variables, and enables the survey data to be matched with any other mapable source of information. Mapping has only been a minor component of this report, but the reader is urged to examine the report on Farming and Settlement Patterns in Bauchi State (RIM, 1984), for more examples of the technique. Quite apart from analysis of static data, such as land capability or rainfall, the grid network provides a rigid framework for repeated observations over time, or for updating project specific information.

Of particular importance for APMEPU, however, is the potential for significant changes and substantial improvements to be made in the data collecting programme. As outlined in the introduction the current system of evaluation surveys can be criticised on the grounds of timing, clustered samples, resource requirements, and the need for a reliable, independent estimate of the human population. If the results of the aerial survey are satisfactory for crop population estimates of cultivated areas, then the technique offers a solution to each of these four major constraints.

Timing: the aerial survey could be run as an independent exercise before the establishment of project infrastructure, with the results being processed within three months.

Clustering: estimates are derived from strip or point samples selected from a grid network, which would cover the whole of the study area. Aerial survey results, therefore, do not suffer from the problems of sample clustering.

Resources: data collection could be handled Federally, without the need for new training in each survey area prior to initial studies. However, a survey capability would be desirable in each area, once funding permitted.

Human Population: aerial survey crop population totals are completely independent of estimates of the size of the human population. Indeed, building and settlement counts, which can easily be made from photographs at the same time as cultivation assessment, provide the basis for a completely new index of the size and distribution of the human population.

By the use of SLARP to provide crop population estimates for cultivated areas, the evaluation data collection programme could be changed from one constrained by the need to generate global parameters, to one with a problem specific focus. In this way, APMEPU could directly address the issues of project evaluation rather than be encumbered by the present sampling schemes.

The major data item not collected by SLARP is crop production and yield. There is no alternative to direct measurement for accurate production estimates; but if the ground based survey programme were able to focus on technical issues, such as specific crops, crop mixtures, crop varieties, fertilizer use, weed and pest control, then the yield data generated by these topics could, with care, be structured and combined with SLARP to provide an indicative measure of global crop yields.

A five year evaluation programme might, therefore, be drawn up along the following lines:

| Project Year | Action |
|--------------|--|
| 0 | SLARP over the whole project area. |
| 1 | Large Scale Reconnaissance ground survey focussing on SLARP identified crops. Yields and crop technology studies on quota samples of farmers growing specific SLARP identified enterprises. |
| 2 | SLARP over whole project area, possibly stratified to give greater intensity coverage of specific regions. Yield and crop technology studies on project innovations. Other special studies of project activities as required. Post start-up review of project data base and planned activities. |
| 3 | Yield and crop technology studies on quota samples based on the enterprises found in the SLARP in project year 2. Yield and crop technology studies on project innovations. |
| 4 | As required. |
| 5 | As required. |
| 6 | Post project SLARP over whole area. |

7 CONCLUSIONS AND RECOMMENDATIONS.

7.1 Results.

In this experimental study, a method of Systematic Low Altitude Reconnaissance Photography (SLARP), utilizing a twin camera system with long and short focal length lenses, has been used successfully to estimate: the population totals of major crops; the areas of land under specific crops and crop mixtures; the extent and degree of weeding; and the method of land preparation. In addition, the general pattern and proportions of land use were assessed, and a variety of human settlement and livestock population parameters were determined.

Comparison with ground based sample survey information confirms the estimates of total cultivated area, but suggests that sorghum and cowpea areas were underestimated. The aerial survey tended to simplify the real complexity of crop mixtures, and indicated a relatively higher proportion of sole crop and two crop mixtures, than had been recognised on the ground. The aerial estimate of the area of the four principal crops was within 4% of the ground based survey estimate. The discrepancies noted between aerial and ground data were considered to be mainly due to poor timing of the SLARP flights. The 1983 cropping season in the Azare region was late because of delayed and erratic rainfall. As a consequence the aerial survey flights, which took place at the end of August, were conducted before the early millet crop was mature, and whilst sorghum and cowpeas were being planted. With hindsight, in this part of Nigeria the flights should have been timed to coincide with the maturity or harvest of early millet.

Examples of photography provided in earlier sections of this report (Figures 1 - 5) indicate some of the distinguishing characteristics of millet, sorghum and cowpea, found within the Azare study area. Further examples, from Kaduna State, are presented in this concluding section, but again it must be emphasised that considerable detail has been lost in the reprographic process. Maize is illustrated in the upper plot of Figure 6 (note tassels, narrower leaves and difference in colour from plants in adjacent plot, which are probably sorghum); transplanted early millet is shown in the upper plot of Figure 7; yam (dark green) and cassava (light green) are present in the poorly weeded plot in Figure 8; and somewhat fortuitously, the hand application of fertilizer is evident to the discerning, as small white patches at the base of stands in Figure 9. A typical village scene is shown in Figure 10, with grass and tin roofed dwellings and granaries; and Figure 11 represents an area of severe erosion.

7.2 Methodology.

In addition to better timing of the survey flights, the study concluded that, in order to prevent excessive image confusion by crop shadow, photography under clear skies should start no earlier than 08.00, and end no later than 16.00.

Ground observation of the cropping pattern greatly assisted interpretation in the north of the study area. No such ground work was carried out in the south, and there, not surprisingly, interpretation was more difficult. Future studies require a systematic programme of ground observation to familiarise photo-interpreters with the state of crops and crop mixtures at the time of survey, or the training of staff with knowledge of local conditions as photo-interpreters. Written notes and ground photography are recommended.

FIGURE 6: MAIZE AND ANOTHER GRAIN CROP - PROBABLY SORGHUM.

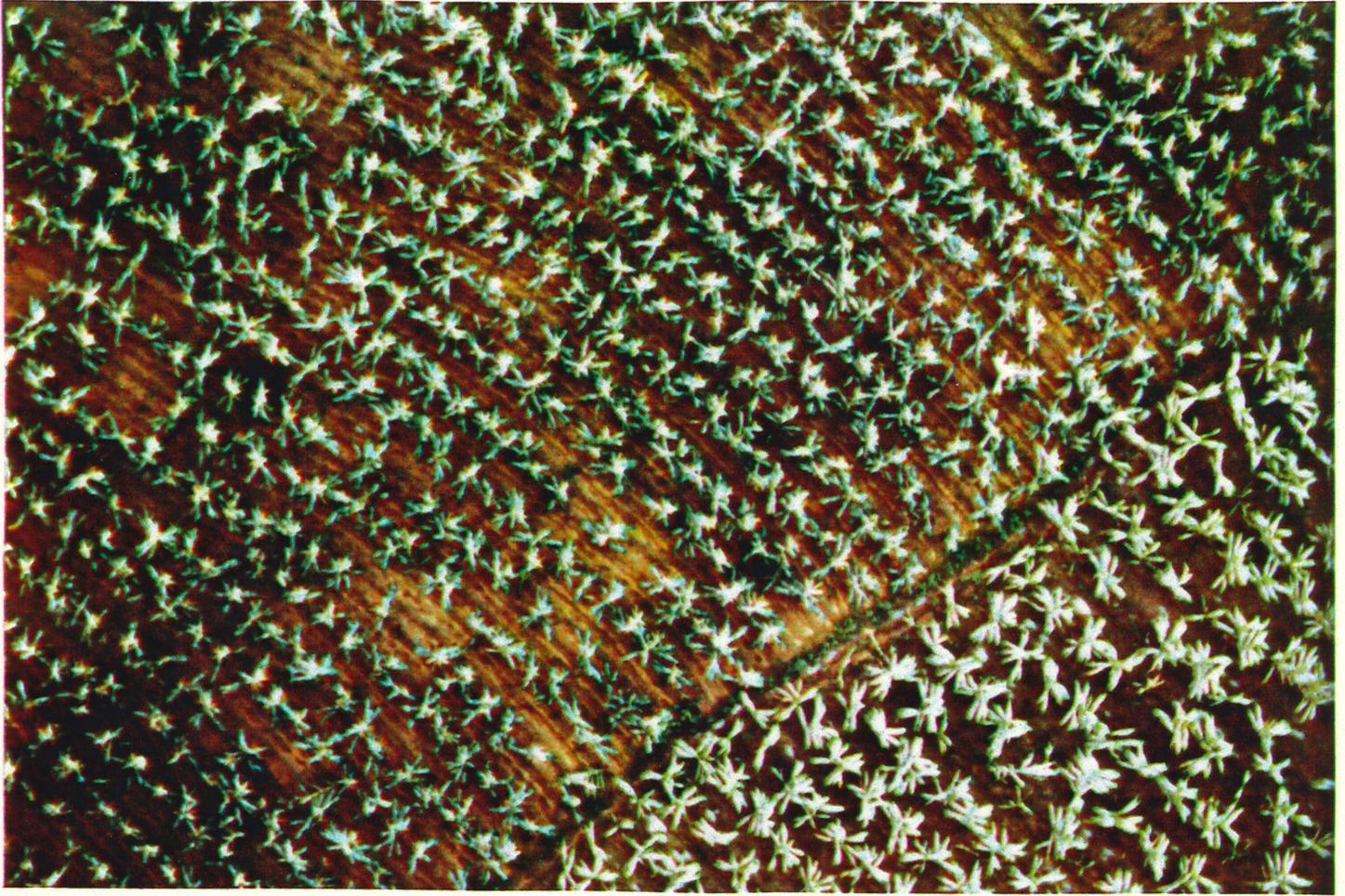


FIGURE 7: TRANSPLANTED MILLET AND RECENT FALLOW.

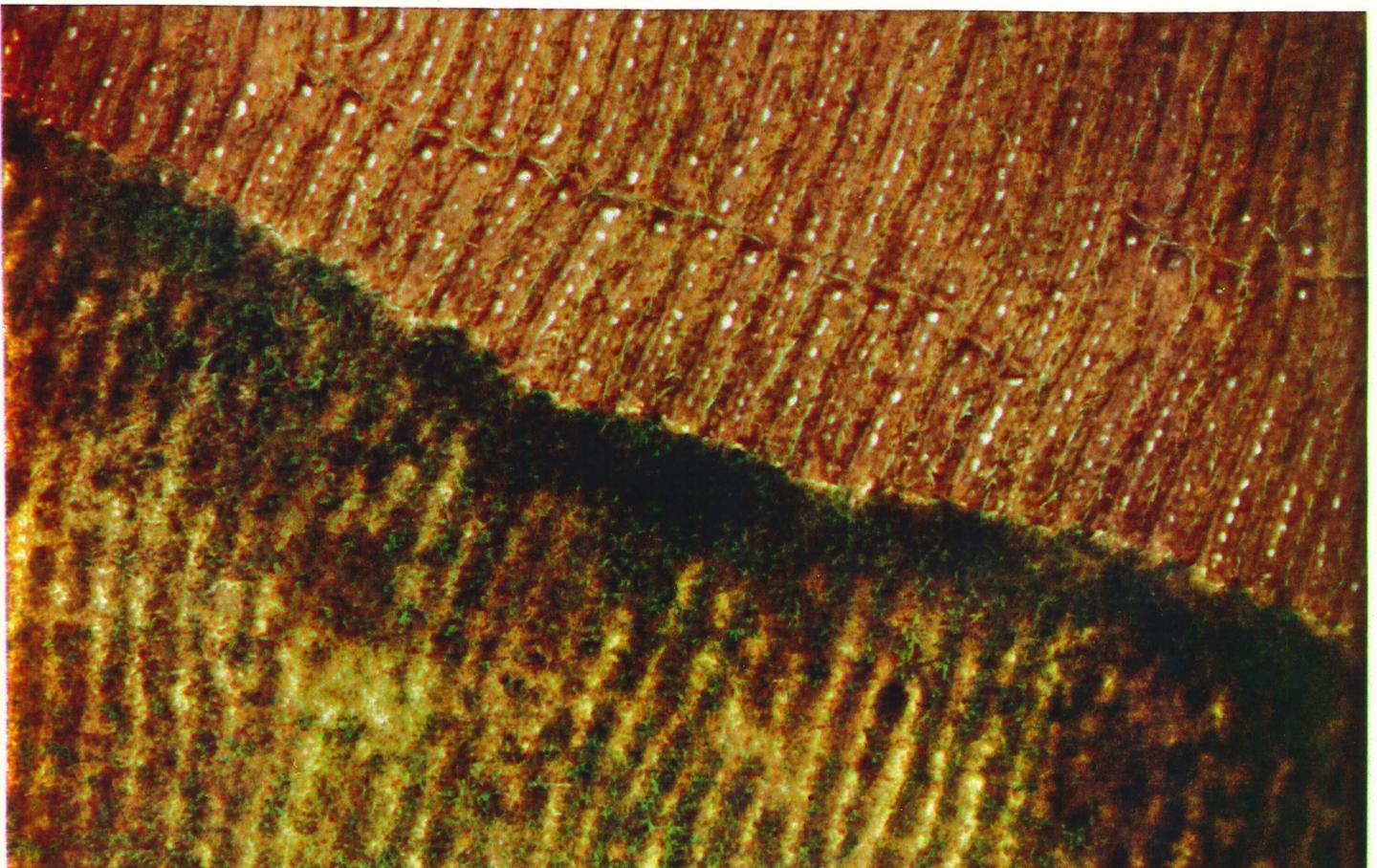


FIGURE 8: YAMS AND CASSAVA IN POORLY WEEDED PLOT WITH LAST YEARS STALKS.

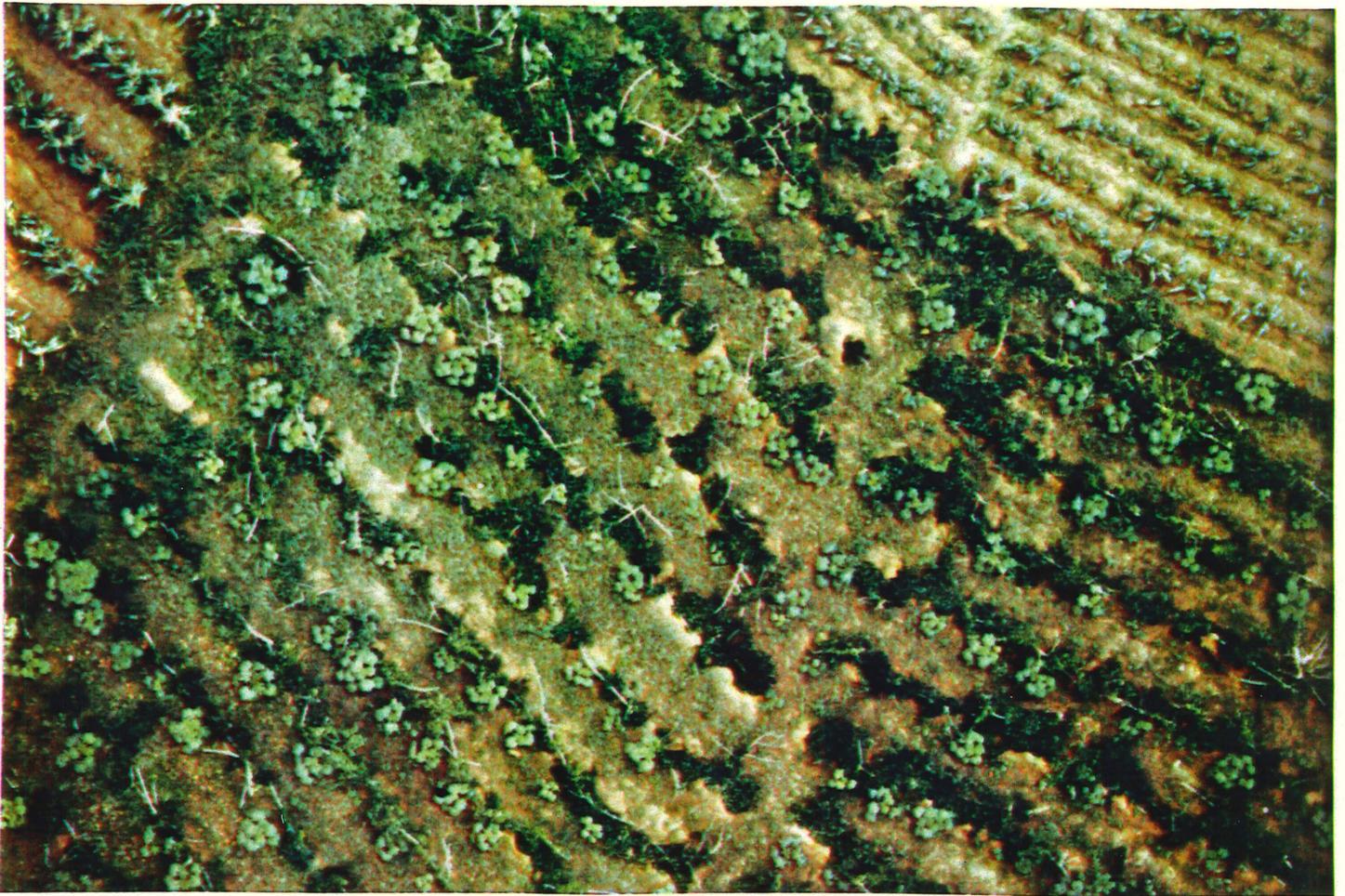


FIGURE 9: SORGHUM WITH RECENT FERTILIZER APPLICATION.

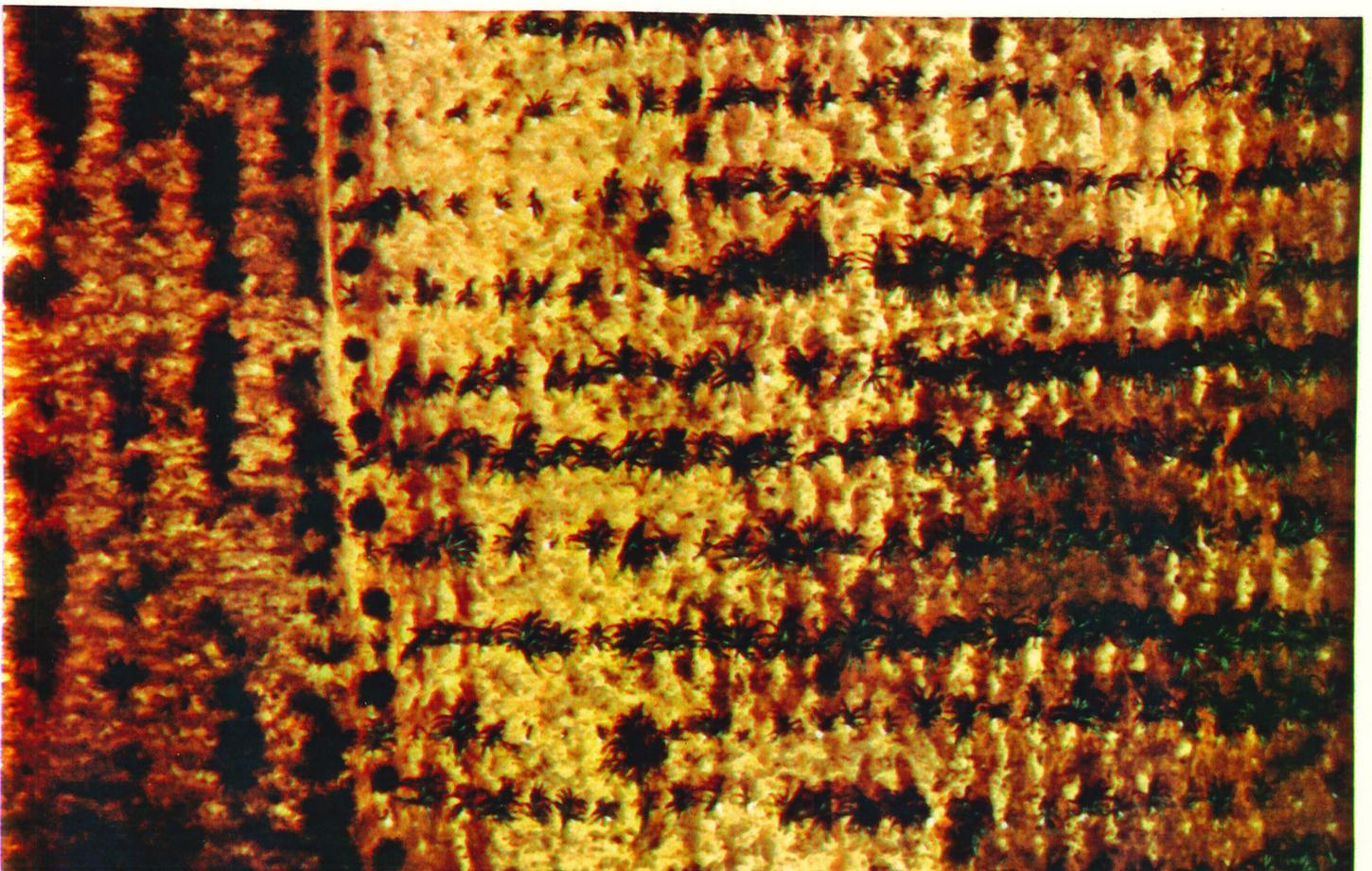


FIGURE 10: VILLAGE SCENE - GRASS AND TIN ROOFED DWELLINGS WITH GRANARIES.

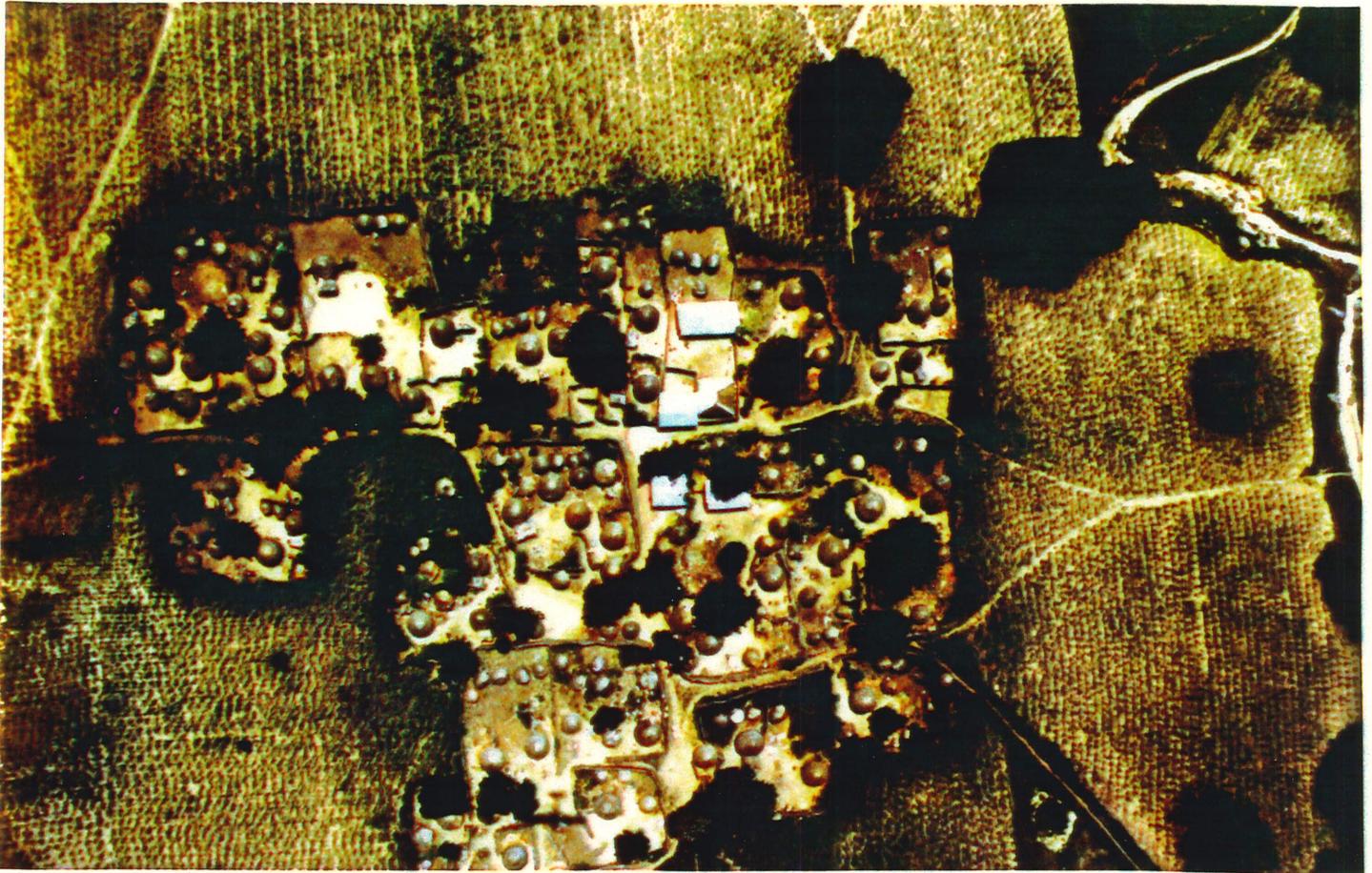
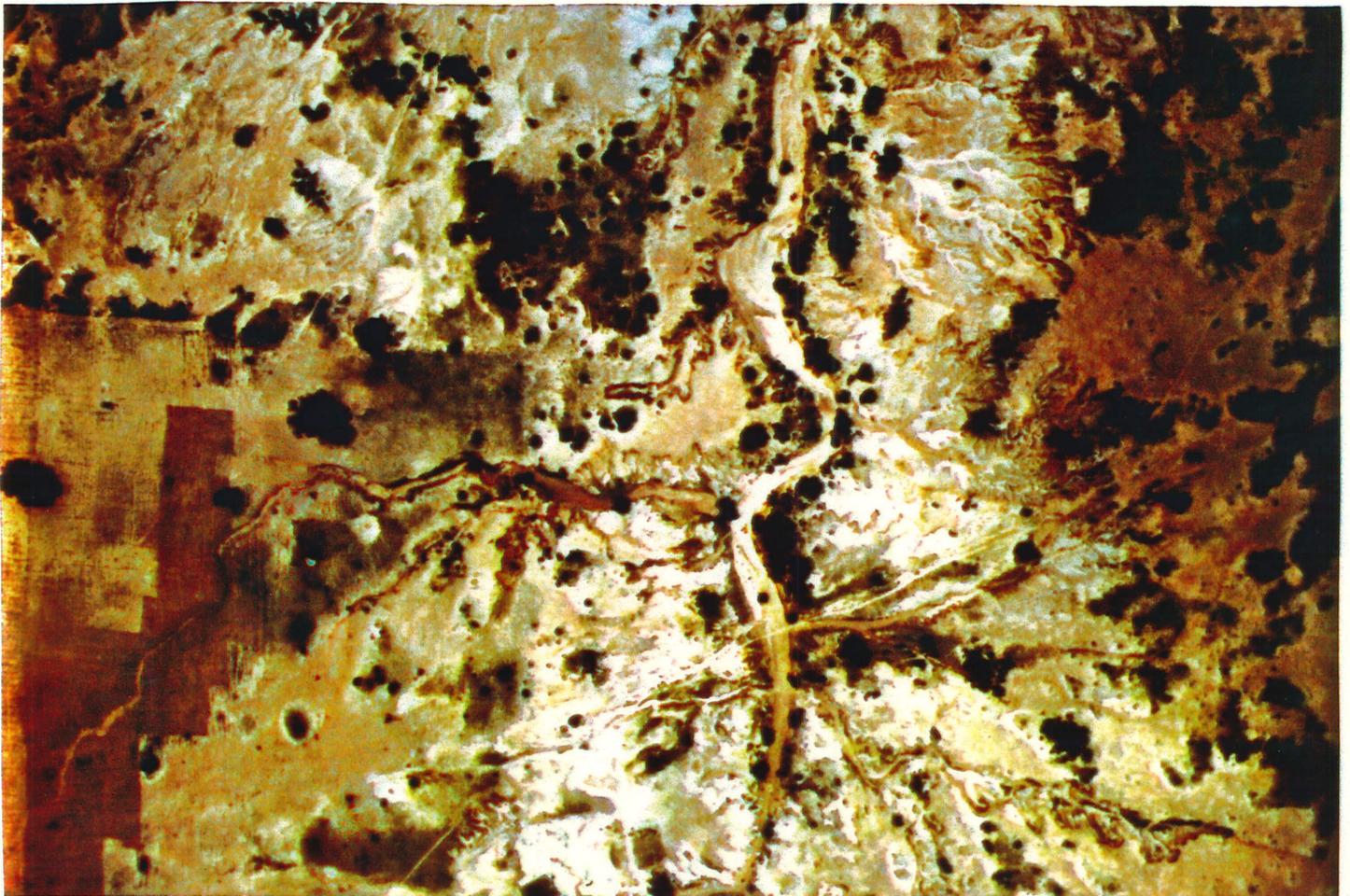


FIGURE 11: EROSION.



7.3 SLARP and Evaluation Data Collection.

Widespread use of SLARP to provide global crop population estimates would free the evaluation programme of the constraints currently imposed by the need to perform this task from information collected on the ground. In order to generate crop production estimates yield data would, of course, still have to be collected from sample farmers; but ground samples could be geared directly towards studies of selected features of the cropping pattern, or of project technical innovations. In other words, the APMEPU ground based surveys could be used more for the immediate evaluation of project activities, rather than for the provision of statistical data series, which are of much longer term interest.

7.4 Recommendations.

The results from Azare survey confirm the potential of SLARP for identifying and quantifying the cropping pattern. However, although Azare was a useful site from which to examine the difficult problem of distinguishing between sorghum and millet, in other respects the area was too homogeneous. Spatial patterns require larger and more diverse areas to become apparent, as well illustrated in RIM (1984).

In view of the results presented in this report, it is recommended that:

- 7.4.1 Systematic Low Altitude Reconnaissance Photography (SLARP) should be used over a large area, such as a whole State, during the 1984/5 crop growing season;
- 7.4.2 specific provision should be made for more research into aircraft, camera, lens and film combinations, to improve resolution and maximise sampling efficiency;
- 7.4.3 provision should also be made to develop a micro-computer based suite of data entry, validation, and analysis programmes.
- 7.4.4 APMEPU should conduct a feasibility study into the provision of a computer mapping facility for the Data General MV/8000 computer in Kaduna.

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