325

Specific Applications of Air Photo-Interpretation in Agricultural Development Planning

by

R. G. B. Jones MI Agr. E.

SPECIFIC APPLICATIONS OF AIR PHOTO-INTERPRETATION IN AGRICULTURAL DEVELOPMENT PLANNING

by

R. G. B. JONES, MI AGR E*

Presented at the Spring National Meeting of the Institution at Silsoe, Bedford on 27 March 1969

ABSTRACT

In countries where heavy seasonal downpours of rain are a characteristic of the climate, a pre-requirement to land use planning based on erosional hazards of use and the capacity of the soil to produce on a sustained economic basis is, ideally, either a detailed Soil or Land-Use Capability Classification Survey related to the major factors of soil depth, surface texture, permeability, degree of slope and existing erosion.

Aerial photographs can speed up the field investigations which are an essential part of these surveys, thereby substantially reducing costs, whilst in subsequent planning operations they can be used as specific aids in the design of conservation layouts, as well as for water resources assessment, erosion control and other purposes.

1. INTRODUCTION

In the tropics and sub-tropics, where heavy and prolonged downpours of rain are characteristic of the climate during the rainy season, the prevention and control of erosion can be achieved by biological and mechanical conservation measures which include:

1.1 The provision of adequate vegetative cover to encourage infiltration and protect the soil against wind, raindrop impact, and run-off.

1.2 The re-establishment of vegetation along water-courses by isolating them from livestock by means of fences also designed to form part of planned sub-divisional fences.

1.3 The maintenance and improvement of soil fertility by mulching, green manuring, fertilizers, and rotational systems of cropping and grazing management including the proper assessment of stocking density in relation to bush encroachment control.

1.4 The introduction of improved pasture species.

1.5 Selective methods of ploughing and cultivating with emphasis on the reduction of the speed of cultivating implements and of the number of workings to a minimum.

1.6 Structural measures such as terraces, ridges and bunds, stormwater drains and grassed waterways, and the reclamation of gullies.

*Land Resources Division, Directorate of Overseas Surveys

2. SOIL SURVEY AND LAND CLASSIFICATION

The foregoing measures can be applied most effectively if the land is used in accordance with land-use capabilities determined by topography, vegetation, soils and other natural features. A detailed soil survey or land-use capability classification—based on the major factors of soil depth, surface texture, permeability, degree of slope and existing erosion—is therefore very often an essential pre-requirement to any catchment re-assessment programme mounted to determine the changes in land-use practices required on eroded land, erosion hazard areas, and in the catchments as a whole (Soil Survey Staff U.S.D.A. 1951). Moverover, from an engineering standpoint, the land capability data provide essential information on the run-off and erosion characteristics of the different soils, a knowledge of which is helpful in deciding the design of control structures and what type of machinery is best suited for land clearing, road construction, and general agricultural operations.

2.1 Initial Stereoscopic Air Photo-Interpretation

Air photo-analysis and interpretation, if properly executed, not only play an important role in increasing the speed of mapping in the most expensive phase of soil survey and land classification—the fieldwork—but also result in better quality maps (Buringh 1954; Jones 1958. 1959). For this reason, when air photo cover is available, a thorough initial stereoscopic interpretation of the aerial photographs prior to field reconnaissance is one of the most important factors contributing to the accuracy of these surveys. Unfortunately, however, it still remains the greatest weakness because—in the author's experience, based on the training of more than 2,000 graduates—most field scientists only use a stereoscope for demarcating mountain land, tone and pattern at the expense of other more important information which can and should be defined stereoscopically.

Tone and pattern are qualitative characteristics of photo-interpretation—as distinct from topographical elements which can be assessed quantitatively in terms of shape, size and site—and can be defined equally as well on an air photo mosaic, provided it is large enough in scale, as they can stereoscopically. Consequently, many field scientists feel it is a waste of time to carry out a proper stereoscopic interpretation of the aerial photographs and, instead, over-concentrate on tones and patterns at the expense of what really matters.

To overcome this weakness and to emphasize the important difference between topography, as a primary physical element of terrain, and the secondary and qualitative characteristics of tone and pattern, it is suggested that the following systematic sequence of photo-interpretation, which the author has contrived to design on convergence of evidence principles, will help to ensure that only definite, reliable and significant information is extracted stereoscopically—for this is the only information which has any scientific value.

2.1.1 *Method:*

2.1.1.1 Decide clearly the objectives of the particular exercise. The photo-interpretation should then be related to these objectives in terms of what and how much detail should be extracted stereoscopically. It is, for instance, obviously a waste of time to delineate information which is not required.

2.1.1.2 Study all available climatic, topographic, geologic, vegetation and soil maps and reports covering the area. If these are available it is wasteful not to make use of them as they yield valuable information which can substantially assist the initial photo-interpretation—and it is surprising how *often* they are ignored.

2.1.1.3 Assess the stereo-base of the instrument, if a mirror stereoscope is being used, and base-line the photographs by locating the principal points, transferring these stereoscopically to the adjacent photographs, and ruling in the flight lines.

2.1.1.4 Study the flight plan or photo index mosaic to determine the flight orientation of the photography. NOTE:—For photogeomorphological interpretation it is best to have the photograhy flown across the line of the main geomorphological boundaries whenever possible.

2.1.1.5 Mark the boundaries of the area on the field mosaics and study these to see what broad regional trends exist, separating any clearly visible land system boundaries with wax marking pencil.

2.1.1.6 Make a photo-laydown with the stereo-cover to decide which photographs to delineate. Mark these (alternates) with a cross in one corner and draw in the boundaries of the area on them to prevent doing any unnecessary annotation outside the boundary area during the subsequent photo-interpretation.

2.1.1.7 Stack the stereo-cover on the drawing hand side of the stereoscope with paper separators between each flight run. Orderliness of this nature is a great time-saver when a lot of photographs are involved.

2.1.1.8 From a stereoscopic study of a cross-section of the photographs, and bearing in mind any information derived from existing maps and reports, try and assess:—

2.1.1.8.1 The type of geomorphological formation.

2.1.1.8.2 The actual process (denudation or tectonic) responsible for it.

2.1.1.8.3 The stage of development classifiable in terms of the Cycle of Erosion as 'Youth', 'Maturity' or 'Old Age'. (Jones 1962).

Information of this sort can be a useful guide to the types of soil and soil profiles in the area to be reconnoitred.

2.1.1.9 Define terrain data methodically on each alternate photograph:—

2.1.1.9.1 One topic at a time.

2.1.1.9.2. From the known to the unknown.

2.1.1.9.3. From the general to the specific.

2.1.1.9.4 From small scale to large scale considerations.

These basic principles apply to all fields of air photo-interpretation and the information defined on each selected alternate photograph should be within the limits of vertical and horizontal match lines drawn parallel to the photo edges through the satellite principal points and approximately midway within the lateral overlaps between flight strips.

NOTE:—A 'match' line as defined by the U.S.D.A. Soil Survey Manual is 'an arbitrary line drawn in the overlap area of a photograph to serve as a boundary line for the mapping on the photograph to be matched to the same line drawn through identical points on the adjoining photograph'. In simpler terms it is merely a line drawn to ensure that information carried forward between each alternate photograph in the line of flight, and between successive flight strips, does in fact 'join up'.

2.1.1.10 Application of the 'Convergence of Evidence' principles mentioned in 2.1.1.9.1 to 2.1.1.9.4 above is reflected in the author's own recommended sequence of interpretation which is in the following three stages:—

2.1.1.10.1 *Stage I—Using the Stereoscope (Obligatory)*

2.1.1.10.1.1 *Delineate the full drainage pattern* This implies the demarcation of the whole drainage network with the centre lines of all minor depressions as well as streams carried almost up to the crest in each case. Subsequently, this proves extremely valuable in planning land protection and water disposal layouts.

Drainage is particularly important as it is not only related to the age of the river system and the geology but dictates almost all other factors in land-use planning—namely:—

2.1.1.10.1.1.1 Communications.

2.1.1.10.1.1.2 Arable land units and sizes.

2.1.1.10.1.1.3 Protection and water disposal pattern.

2.1.1.10.1.1.4 Watering points and water conservation potential.

2.1.1.10.1.1.5 Irrigation potential.

2.1.1.10.1.1.6 Siting of dams, cattle dipping tanks, houses, labour compounds and other farm buildings.

2.1.1.10.1.1.7 Fencing layouts.

2.1.1.10.1.1.8 The design of paddocking systems for maximum utilization of summer and winter grazing.

2.1.1.10.1.1.9 Beef policy (indirectly from 2.1.1.10.1.1.8)—besides being a reflection of the Geology, Parent Material and Soils.

The central line of all channels should be delineated, preferably in Blue chinagraph-type pencil as this colour is psychologically correct as an indicator for water.

NOTE:—In erosion surveys the cross sectional shape of eroded channels, which are visible under the stereoscope, can be an indicator of soil type e.g. V-shaped channels tend to form in clays, U-shaped channels in sands, and square-sided channels in contact soils.

2.1.1.10.1.2 *Outline all obvious non-arable rocky waste and mountain land*

It is suggested that Red chinagraph pencil be used for this as being psychologically appropriate to infer land which is non-arable in nature and where any attempt at cultivation would be dangerous.

NOTE:—Only obvious non-arable land will be able to be recognized stereoscopically. A proportion will remain unidentifiable and only capable of being picked up on field check.

2.1.1.10.1.3 *Mark in all relevant crest lines*

Except in the case of catchment boundary delineation this implies all crests *relevant to the correct siting of roads and mechanical conservation works.* Crests and drainage pattern together are fundamental to the interpretation of surface terrain configuration and field orientation. The demarcated crest lines are also a most useful navigational aid—especially in virgin areas—and in their capacity as potential roads are important because:—

2.1.1.10.1.3.1 Communications are an essential part of arable land protection.

2.1.1.10.1.3.2 They can be the over-riding factor in land selection on the basis of work study for full efficiency of field operations.

2.1.1.10.1.3.3 Crest-sited roads involve minimum care and maintenance as, in this position, they form the basis for properly designed water disposal layouts.

Brown chinagraph pencil is suggested for marking in crests—this colour being consistent with that of farm earth roads.

NOTE:—*All* relevant crests should be defined as only then is it possible to assess their relative merits in the overall communications plan. It is of no consequence if nothing appears to 'join-up' in the first instance.

2.1.1.10.1.4 *Demarcate all slope breaks along the margins of drainage depressions and within possible arable areas*

Slope should always be defined as a specific entity in the stereoscopic interpretation as failure to mark minor slope changes is an all too common fault despite the fact that slope is a primary topographical element. Slope length and gradient are associated with speed of run-off and degree of erosion and therefore of the utmost importance in land classification, many land classification systems being directly geared to slope in the first instance.

The first slope breaks to be marked should always be those bordering the drainage depressions (vleis, dambos, etc.) as, when these slope breaks exist, they nearly always form a reliable common boundary between the swamp areas and the possible arable land which remains, thereby making it easier to identify any other slope breaks *within* the possible arable areas.

The foregoing Stage I data define the skeleton of the landscape, and, as they consist of land factors only, they are not liable to change on field check provided only definite information has been delineated. This applies even where the field scientist is not familiar with the soils in the area being stereoscopically examined beside being basic to the proper design of roads and mechanical conservation works. For this reason, even if the Stage I data were the only information to be extracted under stereoscopic observation it would still be of great value.

2.1.1.10.2 *Stage II Without using the Stereoscope (or with confirmatory use only)*

Transfer all the information extracted in Stage I to the field mosaic and then record on the mosaic:—

2.1.1.10.2.1 *All apparent boundaries between swamp areas and possible arable land if not already defined on the basis of slope break in Stage I.*

2.1.1.10.2.2 *All areas suspected of having a wetness factor not critical enough to preclude them from 'dry land' cultivation*

2.1.1.10.2.3 *Place a question mark within all eroded areas and homogeneous tonal and vegetation differences provided they are clearly visible*

It is not recommended that a solid line be drawn between these differences as once such a line has been drawn there is a tendency for it to form a psychological barrier the interpreter is loath to change even on field check. In this connection it should be noted that the factors delineated in this second stage are often unreliable, by no means final, and quite liable to change on being field-checked.

2.1.1.10.3 *Stage III—Using the Stereoscope (Obligatory)*

2.1.1.10.3.1 *Select provisional soil profile examination pit sites unless an auger grid system of classification is being used*

This must be done stereoscopically as homogeneous areas based on slope changes (Fig. 3) have to be carefully examined to avoid transition zones which can yield atypical soils information.

2.1.1.10.3.2 *Wipe the stereo-cover clean and select all possible dam sites on the basis of stream gradient changes (Section 3.4.4.1)*

This exercise is deliberately left until last as reference needs to be made to the interfingering crest and stream patterns already transferred to the mosaic, these dictating the size of catchment areas.

NOTE:—The meaning of the term 'homogeneous area' needs clarification. As applied to air photo-interpretation for soil survey and land classification purposes it can be defined as:

'An area in which there are no *significant changes*, which can be outlined on aerial photographs as a result of the stereoscopic analysis or comparison of all differences or similarities in the landscape which result from differences in soil or vegetation conditions. It is therefore a recognizable photo-analytical unit'. (Figs. 1-2)

2.2. Second Stereoscopic Air Photo-Interpretation

After the soil profile examination pits have been studied in the field the relevant landscape and soils data can be written on the field mosaics next to the pit positions. A second stereoscopic examination of the area should then be undertaken.

Whereas the Initial Stereoscopic Interpretation was exploratory in nature the Second Stereoscopic Interpretation is partially confirmatory in that its object is the location of provisional mapping unit boundaries. In many respects, therefore, it is the more important of the two photo-interpretations.

Looking at the photographs a second time, after having been over the ground, all the more subtle differences in the air photo image can be appreciated so that the stereoscopic examination can then be directly related to specific differences in landscape and soil characteristics.

Adjacent soil pit information is compared and if the difference lies in land characteristics such as degree of erosion, slope, or wetness—the emphasis should be placed on landscape features. If, on the other hand, the difference is in profile characteristics—then the emphasis of the photo-interpretation should be placed on those features such as landform, tone and pattern, *which in the field reconnaissance* have been found to relate to those particular characteristics.

Thus *only* in the Second Stereoscopic Interpretation should any homogeneous areas of tone and pattern be taken *specifically* into account.

At this stage it is usually necessary to site additional pits on the photographs in conjunction with planned auger traverses designed to cross the mapping unit boundaries at right angles to establish their positions accurately.

The provisional mapping unit boundaries picked up during the Second Stereoscopic Interpretation must, therefore, still be confirmed on the ground by further field reconnaissance.

3. PLANNING

Subsequently, planning for optimum land use is based on the facts provided by the Soil or Land Classification Map considered in relation to the land user's inclinations and available capital resources. This approach is realistic in that it fulfils the broad objective of soil conservation:—

'The use of each acre of agricultural land within its capabilities and the treatment of each acre of agricultural land in accordance with its needs for protection and improvement'.

Here again stereoscopic pairs of aerial photographs, used in conjunction with air photo-mosaics, on to which the soils or land-use capability classification data have been annotated to produce photo-maps, are extremely helpful in designing an efficient sequence for the development of a plan. This stems from the fact that the aerial photograph and air photo-mosaic, despite the fact that they contain certain distortion errors, have the advantage of being pictorial representations of the ground, showing all detail in its proper place, and are not merely symbolic representations as maps really are despite their accuracy. Moreover, for explaining planning programmes to the public, the overall presentation of an annotated air photo-mosaic is more attractive and easier to understand by both peasant cultivators and sophisticated farmers alike.

The more specific advantages of using aerial photographs are apparent in the following planning approach sequence, applicable to the development of single farm units as well as to areas of land, which the author was associated with developing for conditions prevailing in Central Africa (Planning Staff, Federal Dept. of Conservation and Extension, Rhodesia, 1962):—

3.1 Planning Procedure

3.1.1. *Stage I—Extraction and Blocking-out of Basic Landforms*

On studying any land unit on a soils or land-use capability classification photo-map, in conjunction with the relevant stereo-cover, the following basic visible detail should be extracted and delimited as the first stage of planning:—

3.1.1.1 Watercourses (vleis, dambos, etc.)

3.1.1.2 Predominantly wet areas.

3.1.1.3 Rough, broken and steep terrain.

3.1.1.4 Land unsuitable for agricultural production.

When these areas have been defined, normally with coloured wax pencils which are very helpful in clarifying the different information, the resultant pattern shows the overall drainage pattern and type of topography in relation to the approximate possible arable/non arable ratio and its distribution.

3.1.2 *Stage II—Grouping of Broad Types of Arable or Grazing Areas*

Homogeneous areas of basically similar arable and grazing units can then be grouped together and outlined in terms of:—

3.1.2.1 Soils derived from similar parent materials or grazing areas having a similar homogeneous pattern.

3.1.2.2 Broken or scattered units of possible arable land or extensive areas of land which predominantly are possibly arable in nature.

3.1.2.3 Predominantly dry or well-watered areas.

3.1.2.4 Predominantly steep, undulating, or flat areas.

When these areas have been demarcated and studied in conjunction with Stage I a more detailed picture of the key physical factors relating to potential land-use emerges.

3.1.3 *Stage III—Demarcation of Potential Communications*

At this stage the potential communications dictated by the topography can be annotated. This skeleton pattern of communications will be found to bear a logical relationship to the two previous stages and will illustrate the accessibility of the various possible arable, non-arable and grazing land units.

3.1.4 *Stage IV—Sub-division into Natural Land Units*

This stage is closely associated with Stage II in that the grouping of the natural land units of similar type is critically re-examined to ensure that each unit is adequately served by the overall communications pattern and yet stands as an entity within itself.

3.1.5 *Stage V—Demarcation of individual arable lands, conservation layouts and basic fencing*

The ability of the stereo-image to reveal land contour makes it possible, after examining the stereo-cover, to design on the photomosaic a suitable protection layout for each land in keeping with its communications.

A conservationist, working in an area for any length of time, will soon learn to recognize the various micro-landforms lending themselves to properly designed conservation layouts. In Central Africa, for instance, which, geomorphologically, is composed of large uniform stretches of uplifted peneplane surfaces, there are four basic landforms, recognizable under the stereoscope, each of which demands individual treatment in layout design (Wiggill 1955). These are:—

3.1.5.1 The Sloping Ridge
3.1.5.2 The Riverine Slope
3.1.5.3 The Dome
3.1.5.4 The Saddleback.

In practice these features can occur each as a whole (Figs. 4-7), as part of a whole, or in combinations of the four (Fig. 8).

From stereoscopic examination it is also possible to calculate provisional earthwork quantities and costs of the total length of contour ridging required as well as the type of machinery needed for their construction.

Arable lands are blocked out to ensure that, wherever possible, each arable unit is homogeneous and can be sub-divided into equitable sub-units for rotational purposes. This exercise is best carried out for the whole of the area irrespective of immediate land-use requirements.

Having studied the blocked out arable units in the light of the four previous stages the skeletal fencing over the whole of the area will be apparent as it is closely dependent on all these factors. This fencing is then annotated.

All the demarcation, stereoscopic extraction and assessment of the land up to this stage has been dictated by physical terrain characteristics fundamental to any form of land-use practice regardless of individual human preferences. It is only now that the farmer's, rancher's, or land-user's inclinations are taken into account and it is the planner's function to fit these specifically-required enterprises where possible into those land units for which they are best suited and to design suitable rotations and management systems based on whatever capital resources are available to ensure that all these factors are integrated into a systematic, efficient and economic production unit.

3.2 Annotation of Land-use Plans

In the preliminary design stage the drawing of land-use plans is preferably made on stable transparent overlay, such as Permatrace, superimposed on the soils or land-use classification photo-map. In this way the soils and classification data, as well as the fundamental land characteristics, are clearly visible during the whole of the planning and drawing operation.

Again the liberal use of different coloured pencils makes for a ready appreciation of each significant aspect of the plan and standard symbols and as much detail as possible should be included on the draft overlay so that the plan can be easily understood without reference to any accompanying explanatory write-up.

3.3 Presentation of Plans

Final drawing is best done in black and white ink on further reproductions of the original base mosaics in the interests of clearer understanding on the part of the land-user.

This is most essential as the presentation of a land use-plan is undoubtedly one of the most important aspects of the whole planning exercise. A plan that is not well-presented, and therefore not clearly understood, is not likely to be accepted.

One of the greatest weaknesses in the presentation of plans is brought about by the fact that the planner, having a detailed knowledge of the aims and objectives of a plan and the intricate inter-relationships of the various aspects, tends to assume that what is clear to him is equally clear to the land-user. This does not necessarily follow and despite the plan having been designed in keeping with the user's inclinations it still has to be 'sold' to him—otherwise it stands little chance of being implemented.

A planner must ensure that he imparts his ideas clearly and concisely in a logical sequence similar to that used in its development—viz:—

3.3.1 A review of the overall objective.
3.3.2 An assessment of the factual situation of the area as found by the detailed classification.
3.3.3 The distribution and significance of the natural land units.
3.3.4 The detailed appreciation of each unit within the overall area.
3.3.5 The proposed land use pattern to be superimposed on each unit.
3.3.6 The natural relationships and inter-relationships of all aspects of the plan.

As previously mentioned, the presentation of the classification and planning data on photo-mosaics is a natural aid to ease of understanding by the land-user whilst the availability of the stereo-cover and a stereoscope during the explanation helps maintain his interest as well as assisting the presentation as a whole.

3.4 Types of Planning.

The foregoing planning approach can be employed in varying degrees of detail in:—

3.4.1 *Initial Development Planning*

This type of planning involves the maximum use of air photo-interpretation and the minimum amount of field checking and has as its principal objective that, in the absence of more detailed planning, initial development of virgin and newly opened areas and farms takes place in accordance with natural land features, and that a correct sequence of development and land selection is undertaken to ensure that the initial development will form a framework into which any future more detailed planning will fit with the minimum adjustment and expense.

In many instances these plans can be based entirely on air photo-interpretation to show on a photo-map:—

3.4.1.1 Watercourses (rivers, dambos, vleis, etc.)
3.4.1.2 Obvious non-arable mountain land.
3.4.1.3 Crest alignments.
3.4.1.4 Possible arable land.
3.4.1.5 Water disposal pattern.
3.4.1.6 Possible dam and weir sites.

3.4.2 *Farm Planning*
This is the other extreme from Initial Development Planning, the preliminary air photo-interpretation and land classification being in their most intensive and precise form. The maximum amount of information is extracted from the aerial photographs and the maximum amount of field checks are necessary. (Section 2).

The objectives are to provide the land-user with a sound design for future development based on long-term economic productivity in addition to a comprehensive understanding of his soils and their capabilities.

As previously described the results of farm planning are recorded on air photo-maps, the land use classification map showing the results of the survey and classification of information, whilst the farm plan map shows the recommended layouts and rotation practices for the farm.

3.4.3 *Regional and Catchment Planning*
These two types of planning are considered together as they can be coincidental—being essentially the same in overall approach.

A regional area, though frequently a catchment, is not necessarily so, often being dictated by political boundaries, area size and other considerations.

Regional planning usually has a set predetermined objective. It may, for instance, be that of ensuring that the natural farming system applicable to an area can be fully expressed on a conservation basis irrespective of farm boundaries—in which case homogeneous areas would probably be extracted from aerial photographs as a preliminary aid to subsequent soil and vegetation investigations.

In catchment planning, on the other hand, the intensity of investigation is dictated entirely by the planning objectives in each catchment. These may be:—

3.4.3.1 Erosion control by measures designed to eliminate erosion from all sources simultaneously in which case full farm planning at individual unit level would be required.
3.4.3.2 The siting and construction of dams for irrigation, silt detention, stock watering, water conservation to increase dry-season flow, or to detain and store peak discharges of flood water and release them at a rate not exceeding lower channel capacities.
3.4.3.3 The realignment of existing communications to conform more realistically with local conditions of topography and stream position.
3.4.3.4 Broad topographic appreciations and other measures.

With such a wide variation in the intensity of planning the degree and character of the air photo-interpretation will likewise vary in catchment planning from initial development planning to full farm planning level.

3.4.4 *Specialized applications of air photo-interpretation*
3.4.4.1 Dam Siting
A particularly important conservation engineering aspect of air photo-interpretation is the siting of dams for the purposes outlined in Section 3.4.3.2 relating to Catchment Planning.

Dam siting should also be considered in the overall context of resources appraisal where an essential aspect, particularly of First-Stage Reconnaissance Surveys, is an assessment of what resources exist that could be developed. In this connection an appreciation of the availability and potential availability of water in areas of inadequate rainfall is very often the first resource which has to be considered. (Robertson et al 1968).

Whilst the siting of large dams, such as those required for flood control, can be comparatively simple once the geology is known and local catchment flood history has been analysed, the site selection of small conservation dams is much more difficult as wall heights seldom exceed 20 feet.

Because of the unusual photo-interpretative problems posed by the size of these dams the following method of stereoscopically selecting the best possible site areas evolved by the author and his associates (Jones et al 1962; Jones 1964) is recommended:—

3.4.4.1.1 The boundaries of the area under consideration are marked on the stereo-cover and on a photo-reproduction of the aerial mosaic.
3.4.4.1.2 The drainage pattern and all crests are delineated stereoscopically on the stereo-pairs using wax marking pencil.
3.4.4.1.3 The data in 3.4.4.1.2 is transferred to the mosaic reproduction, the overall picture of stream and crest patterns giving a clear idea of the extent of catchment areas, this being a critical factor in cut-earth spillway design.
3.4.4.1.4 The drainage pattern is then erased from the stereo-cover leaving the stream channels clear for detailed stereoscopic observation.
3.4.4.1.5 Where the topography permits, all drainage lines having a bed gradient in excess of predetermined permissible percentages are discarded, as any steeper gradients will not result in sufficient throwback to give an economic capacity. This does not of course apply in areas of sharply fluctuating relief where only steep gradients exist and where dams may still be a vital necessity for water storage purposes.

Gradient assessment is primarily a matter of photo-field experience on the part of the interpreter. In this respect, however, stereogram photo-keys showing bed gradients of varying percentages are very useful as training aids (Fig. 9). At this stage of the interpretation, the interpreter carries out a stereoscopic reconnaissance of all the streams as well as of the terrain in their immediate vicinity, watching carefully for all physical phenomena of the land surface which indicate flatness of gradient. These include:

3.4.4.1.5.1 Areas of natural wetness such as swamps, sponges and reedbeds.

3.4.4.1.5.2 Meandering streams, ox-bows and cut-offs.

3.4.4.1.5.3 Silt bars in river bottoms.

3.4.4.1.5.4 Right-angled junctions of tributaries with main streams.

3.4.4.1.5.5 Wide contour terrace interval of nearby cultivated lands.

Additional factors which always have to be borne in mind and looked for are:

3.4.4.1.5.6 Stream junctions — for maximum storage.

3.4.4.1.5.7 Natural bottlenecks, e.g. where geological dykes cross streams.

3.4.4.1.5.8 Potential borrow areas—to facilitate building.

3.4.4.1.5.9 Rocky sites which may provide ideal erosion-free spillways or foundations for concrete construction (Fig. 10).

3.4.4.1.5.10 Rock bars on river bottoms which favour weir construction.

3.4.4.1.6 On the drainage lines not discarded in 3.4.4.1.5 all points where an increase in gradient occurs are marked. These, and/or the nearby upstream areas, are the logical places for dam construction, ground conditions permitting, as maximum throwback will be achieved (Fig. 11).

3.4.4.1.7 The pin-pointed sites and nearby areas are thoroughly scrutinized stereoscopically to assess spillway conditions, spillways with a return in excess of local permissible limits being generally undesirable because of the erosion hazard. This does not of course apply in rocky areas where sites may prove ideal for rock spills or for the construction of weirs.

3.4.4.1.8 Using a parallax wedge, approximate wall heights are measured and approximate wall volume quantities and water storage capacities calculated from relevant formulae.

3.4.4.1.9 All site areas where wall volume/capacity ratios are obviously uneconomic are discarded.

In very flat terrain, where changes in stream gradient may not always be apparent, site area selection is largely a matter of taking into account all those physical phenomena of the land surface enumerated in 3.4.4.1.5 as well as having an intuitive 'Eye for a Site' built up from photofield interpretative correlations. By following the procedure outlined, all possible areas where conservation dams can be sited are stereoscopically pin-pointed. Subsequent field examination might, however, prove some of these areas to be not feasible or uneconomic owing to factors not apparent on the photographs and it is stressed that aerial photographs are only a useful tool in the selection of conservation dam site areas. Gradient assessment and parallax measurements are limited in accuracy even for experienced interpreters as tree, bush, and grass canopy can seriously affect the interpretation of site conditions. Thus final site selection on the photographs is not possible, the interpretation being confined to the pin-pointing of the best possible site areas for field investigation and to the assessment of provisional wall volume quantities and water storage capacities with a view to determining economic feasibility of construction. In much the same way, therefore, as with air-photo analysis in its application to soil survey and land classification, the stereoscopic examination has been designed to economize on the amount of field control necessary and thereby reduce overheads in this the most expensive phase of the dam selection survey.

The estimation of approximate wall heights, earthwork volumes, and water storage capacities can be carried out with the aid of a parallax wedge (Fig. 12). When using this instrument for assessing approximate wall heights, the height measured in each case is that from the *true* stream bed to the proposed spillway level. As no measurement of the height of an *in situ* structure is involved, but merely the spatial assessment of the height of an imaginary water line, extreme accuracy is not possible, and the following procedure for using the wedge has been found to be the most practical:

3.4.4.1.10 The differential parallax value in feet corresponding to each of the smallest graduations on the wedge is calculated from the adjusted photo scale and the precise parallax formula

$$h = \frac{H \times dP}{P + dP}$$

where h = height of measured object in feet
H = height of aircraft above ground datum in feet
P = absolute stereoscopic parallax in inches
dP = parallax differences in inches.

On 1:20,000 scale photographs flown to within prescribed present day tolerances, the differential parallax value will be found to amount to approximately 5 feet per calibration.

3.4.4.1.11 The wedge is then oriented until a single calibration rests exactly on the stream bed within the stereo-image of the potential site area (Fig. 13-14).

3.4.4.1.12 The spatial position of the calibration corresponding to a difference of 15 feet (the maximum water depth of most conservation dams) is noted and the wedge shifted so that this calibration cuts each stream bank in turn, these points being marked on the photographs with a fine needle point (Fig. 15-16). As the walls of conservation dams seldom exceed 500 feet in length, this distance being equivalent to less than 0.4 inches on 1:20,000 scale photographs, anomalies in the differential parallax values caused by deformations of the stereo-model will be comparatively insignificant when the wedge is only moved over this short distance.

3.4.4.1.13 From the two points marked on the stream banks, the full supply level throwback is then form-lined stereoscopically by eye (Fig. 17-18). The parallax wedge is not used for this purpose as the tilts and model deformations present in varying degrees in all so-called vertical air photographs can cause appreciable errors in the differential parallaxes read between points more than about ½ inch apart on 1:20,000 scale photographs.

3.4.4.1.14 Approximate wall volume quantities and water storage capacities are then calculated in the usual way. For practical purposes of photo-measurement, the wall length measured along the crest is taken to be the same as the length of the water-line measured along the wall at full supply level, but to allow for actual ground differences between these two lengths caused by the freeboard a 10 per cent costing factor should be added to the wall volume quantities calculated from the parallax readings.

This dam siting procedure may form part of each of the different planning procedures mentioned or it may be undertaken as an entirely separate exercise for a specific purpose. The same technique of stereoscopically pinpointing sites on the basis of fluctuations in stream gradient and calculating their approximate wall volumes and storage capacities is now being used in France to site hillside reservoirs to meet the need for additional water supplies resulting from increasing farmer and tourist demands. (Corbet 1966).

3.4.4.2 *Erosion Assessment and Control*

On stereo-cover of 1.25,000 scale or larger it is quite easy to see whether erosion gullies are active or stabilized and to differentiate between those that can be repaired by simple hand methods and those that can only be repaired with the aid of heavy mechanical equipment. In addition, if the positions of individual gullies are plotted on gridded stable polyester overlays, and the total yardage of each type of gully obtained with magnifying distance measurers it is quite apparent where the erosion 'blackspots' are when the overlays are superimposed on photo-mosaic reproductions of the same scale. It is then a simple matter to allocate priorities for reclamation work. (Jones and Keech 1966).

3.4.4.3 Range Management

An important aspect of the erosion technique mentioned is the siting of conservation dams in the way previously described (Section 3.4.4.1).

The spacing of these dams is important. Wherever possible it is advisable to site them 2-2½ miles apart, practical experience having shown that cattle utilize grazing most efficiently when they do not have to walk more than 2,000 yards in any direction to obtain water.

Again, gridded polyester overlays with a 2½ square mile grid are useful—this grid interval acting as a check on the correct spacing of the dam sites and on where additional cattle dipping tanks might be needed.

Besides improving the grazing 'spread' such a dam-siting exercise helps to arrest the movement of sediment and gives better distribution of water supplies leading to increased irrigation potential and an improvement in human and animal carrying capacities. It also helps indirectly to control erosion by reducing the risk of gullied cattle tracks, excessive overgrazing and the trampling characteristic of too heavily used watering points—whilst encouraging the local inhabitants of an area to take a hand in any needed gully repair work themselves.

In areas which have obviously been subjected to heavy overgrazing over long periods of time a stereoscopic study of old and new air photo-cover, if it exists, can be extremely useful in helping to assess the amount of bush encroachment which has taken place in the time interval between the successive air photo missions (Figs. 19-20).

In surveys for the planning of pastoral utilization the same general principles as used for planning in cropping areas are called on. The vegetation is surveyed and the field mapping unit is an area of homogeneous vegetation type visible on the aerial photograph as a physiognomic photoanalytical unit. The vegetative and floristic characteristics of the area can then be coded together with physical soil characteristics to give an overall indication of the site condition so helping to arrive at an intelligent estimation of the carrying capacity as a basis for planning.

Owing to the rapid changes which are possible in vegetation when it is being used, and the difficulties of translating utilization characteristics from one area to another, attempts to design specific vegetation use—capability classifications have not proved successful. The most generally satisfactory scales of aerial photographs and air photo mosaics used for field mapping and final mapping in ranching areas is 1:20,000 to 1:25,000.

4. CONCLUSION

4.1 Standard operational procedure

It has been shown in this discussion that stereoscopic pairs of aerial photographs, used in conjunction with air photo-mosaic reproductions, are most useful aids to agricultural development planning, the standard operational procedure for terrain investigations at all levels assuming the following more or less uniform pattern:—

4.1.1 Study of all available maps, geologic and agronomic references.

4.1.2 Initial stereoscopic study of aerial photographs.

4.1.3 Selective field reconnaissance after 'on the spot' consultations with local staff.

4.1.4 Selective field sampling and provisional control of air photo boundaries.

4.1.5 Laboratory testing and summary of data.

4.1.6. More detailed stereoscopic study of aerial photographs and mapping.

4.1.7 Selective field checking and detailed control of air photo boundaries.

4.1.8 Transfer of controlled air photo boundaries to base maps.

4.1.9 Preparation of reports and tables and reproduction of maps.

From the foregoing it can be seen that the use of the aerial photograph does not preclude the necessity for field investigation. It does however enable areas to be investigated much more quickly and accurately, which is very significant as the field work can account for more than 50% of the total costs of a survey.

4.2 Methods of extracting data and rates of working

Depending on the size of the area under investigation information can be extracted from the stereo-cover either run by run according to the Flight Plan or Photo Index

Mosaic—this is the fastest method and for this reason the more usual—or alternatively, in the case of large areas, it can be extracted by landscapes. This is a slower method of working but a more detailed interpretation usually results.

The rate of working varies with the photographic scale and amount of information called for. For detailed surveys, such as those required for planning down to farm unit level, 15,000—25,000 acres per day can be stereoscopically analyzed and defined on 1:25,000 scale aerial photographs—viz. about 5 complete photographs per day on the basis of demarcations being carried out within match lines drawn parallel to the photo edges through the transferred principal points and approximately mid way within the lateral overlaps between flight strips.

Stereoscopic air photo-interpretation is very exacting, if done properly, and imposes a certain amount of mental strain. For this reason it should be done, whenever possible, in the morning when the mind is clearest and the judgement sharpest. In the author's experience the rate of interpretation is always appreciably faster in the morning than in the afternoon, when interpretative efficiency also falls off sharply.

A whole morning's work of about 5 hours should be allowed for the initial stereoscopic interpretation of a 2,000 acre farm unit and transfer of the photo-analytical data to a field mosaic in the manner explained in Section 2.

Many field scientists claim they cannot afford the time to do a proper initial stereoscopic examination little realizing that by neglecting to do so they are more likely making extra work for themselves. No time at all is saved by going straight on to the ground—this practice, more often than not, resulting in less accurate field survey.

They also fail to appreciate that much of the value of a careful initial stereoscopic air photo-interpretation lies in the preliminary stereoscopic appraisal of the terrain *regardless* of whether any physical information is defined on the photographs or not as it is this stereoscopic *examination* which enables the scientist to make an appreciation of the type of terrain in which he will be working and so plan his access routes and sequence of field examinations accordingly.

4.3 Common Weaknesses

The most common weaknesses in the forms of photo-interpretation described are:—

4.3.1 Failure to align successive stereo pairs of photographs with the photo air base and instrument base in coincidence and at the correct separation distance. This results in incorrect orientation, a deformed stereo-image, eye-strain and inability to see stereoscopically using magnifying binoculars.

4.3.2 Failure to demarcate information within match lines. This results in duplication of detail in the overlap areas of the photographs in the line of flight and between flight strips and so wastes time.

4.3.3 Insufficient use of magnifying binoculars. The mirror stereoscope's accommodation lenses are non-magnifying and should be used for the scanning of terrain on an area basis. For accurate delineation of the data required for agricultural development planning binocular attachments of 3 to 4 power magnification must be used.

4.3.4 Lack of appreciation of the effects of photo-distortions and mosaic errors especially in regard to accurate scale determination and planimetry. It is necessary to guard against the tendency to regard the aerial photograph and uncontrolled air photo-mosaic as accurate maps and to realize that they have limitations as well as advantages in this respect.

4.3.5 Failure to bear in mind the vertical exaggeration of the stereo-image.

Many field scientists, inexperienced in using aerial photographs throw what is possible arable land into a non-arable class on the basis of vertically-exaggerated slopes. This is another argument in favour of using magnifying binoculars which reduce the vertical exaggeration by an amount approximately equal to the binocular power.

Dam sites, slope breaks and crests need initial identification with the accommodation lenses only—for *maximum* vertical exaggeration effect—but subsequent delineation under binocular observation in the interests of accuracy.

4.3.6 Inadequate and unsystematic extraction of physical terrain data, especially minor slope breaks in possible arable and opened arable areas, and too great a tendency to define photo-analytical boundaries on the basis of photo-tones and 'patterning' rather than on more reliable land factors.

4.4 Philosophy of Interpretation

As the aerial photograph is a pictorial representation of the ground, on which all detail is shown in its correct relative position, the general approach to interpretation should be that if there is failure to obtain the basic terrain information required by stereoscopic air photo study then this is not so much the fault of the photographs but of the person using them who has simply not progressed sufficiently, or completed enough research or selective field checking, to obtain the maximum amount of data, which is *reasonably* extractable, from the stereo-image.

REFERENCES

5.1 BURINGH, P., 'The Analysis and Interpretation of Aerial Photographs in Soil Survey and Land Classification', *Netherlands Journal of Agricultural Science*, Vol. II, No. 1, 1954.

5.2 CORBET, M., 'Une Methode de Detection de Sites Retenue Collinaires', *Revue 'PHOTO-INTERPRETATION'* No. 1—1966 fascicule 2, Janv.-Fevr. 1966 (TECHNIP, 7, rue Nelaton, PARIS XV).

5.3 JONES, R. G. B. 'The Application of Air Photo-Analysis and Interpretation to Soil Survey and Land Classification', *Rhodesia Agricultural Journal*, Vol. 55, No. 2, 1958.

5.4 JONES, R. G. B., 'Air Photo-Interpretation in Soil and Land Classification Surveys', *South African Journal of Science*, Vol. 55, 1959.

5.5 JONES, R. G. B., 'Geomorphological Considerations in the Assessment of Terrain Conditions from Aerial Photographs', *Federal Department of Conservation and Extension*, Technical Memorandum No. 7, 1962.

5.6 JONES, R. G. B., HACK H. R. and VINCENT, V., 'Aerial Photography in Land-Use Planning in the Federation of Rhodesia and Nyasaland', *Sols Africains*, Vol. VII, Nos. 1 and 2, 1962.

5.7 JONES, R. G. B., 'Some Engineering Aspects of Air photo-interpretation in Catchment Development Programmes, *The Photogrammetric Record*, Vol. IV, No. 24, 1964.

5.8 JONES, R. G. B., KEECH, M. A., 'Identifying and Assessing Problem Areas in Soil Erosion Surveys using Aerial Photographs', *The Photogrammetric Record*, Vol. V, No. 27, 1966.

5.9 PLANNING STAFF, Federal Dept. of Conservation and Extension, '*Land-Use Planning Procedures*'—Govt. Printer, Salisbury, Rhodesia, 1962.

5.10 ROBERTSON, V. C., JEWITT, T. N., FORBES, A. P. S., LAW, R., 'The Assessment of Land Quality for Primary Production' —*Papers of a C.S.I.R.O. Symposium organized in Co-operation with U.N.E.S.C.O.*—Canberra 26-31 Aug. 1968. MacMillan of Australia 1968.

5.11 SOIL SURVEY STAFF U.S.D.A.—'Soil Survey Manual'— *U.S.D.A. Agricultural Handbook No.* 18 1951.

5.12 WIGGILL, M. D., 'Contour Ridge Layout in Mashonaland', *Rhodesia Agricultural Journal*, Vol. 52, No. 2, 1955

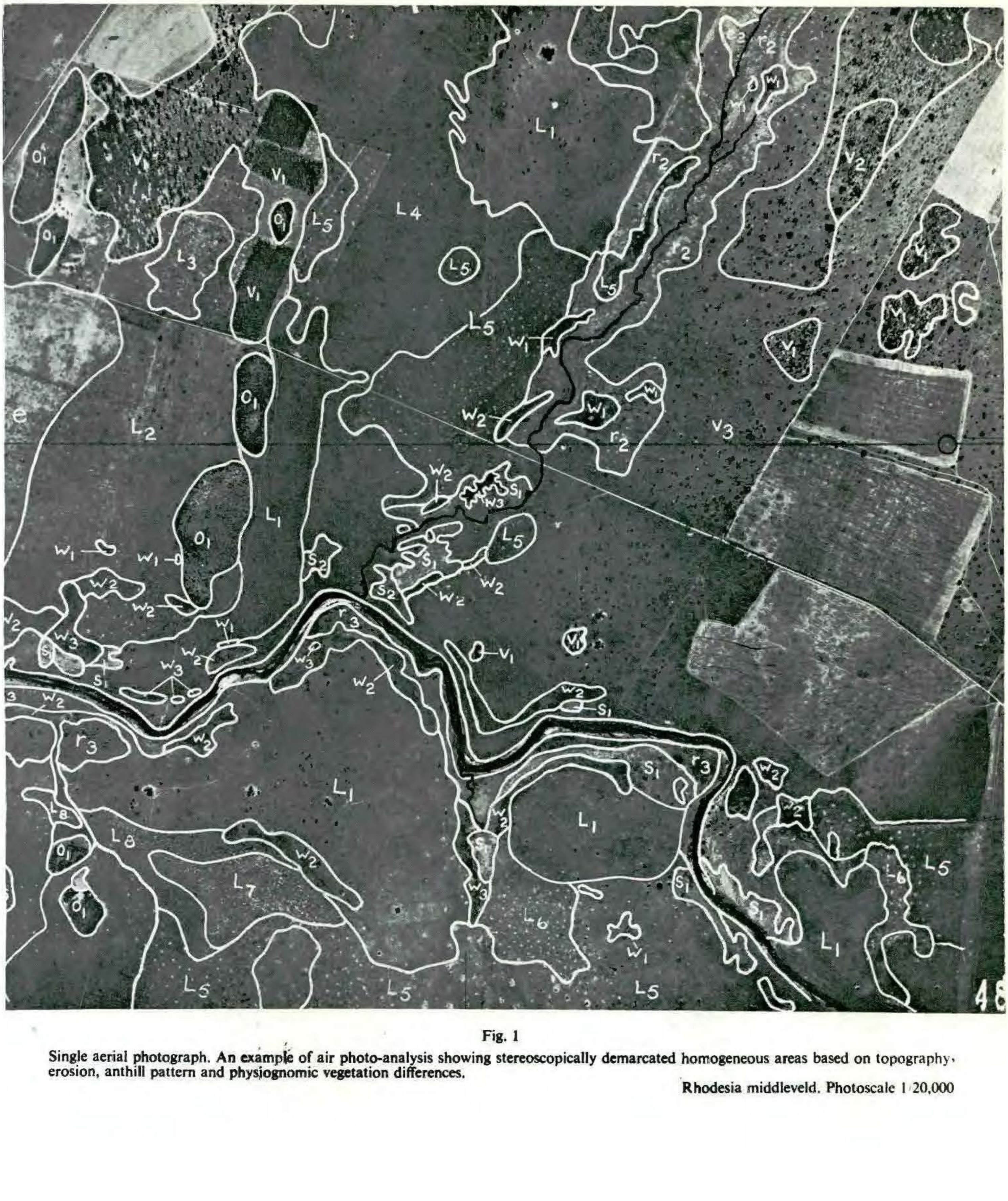


Fig. 1

Single aerial photograph. An example of air photo-analysis showing stereoscopically demarcated homogeneous areas based on topography, erosion, anthill pattern and physiognomic vegetation differences.

Rhodesia middleveld. Photoscale 1/20,000

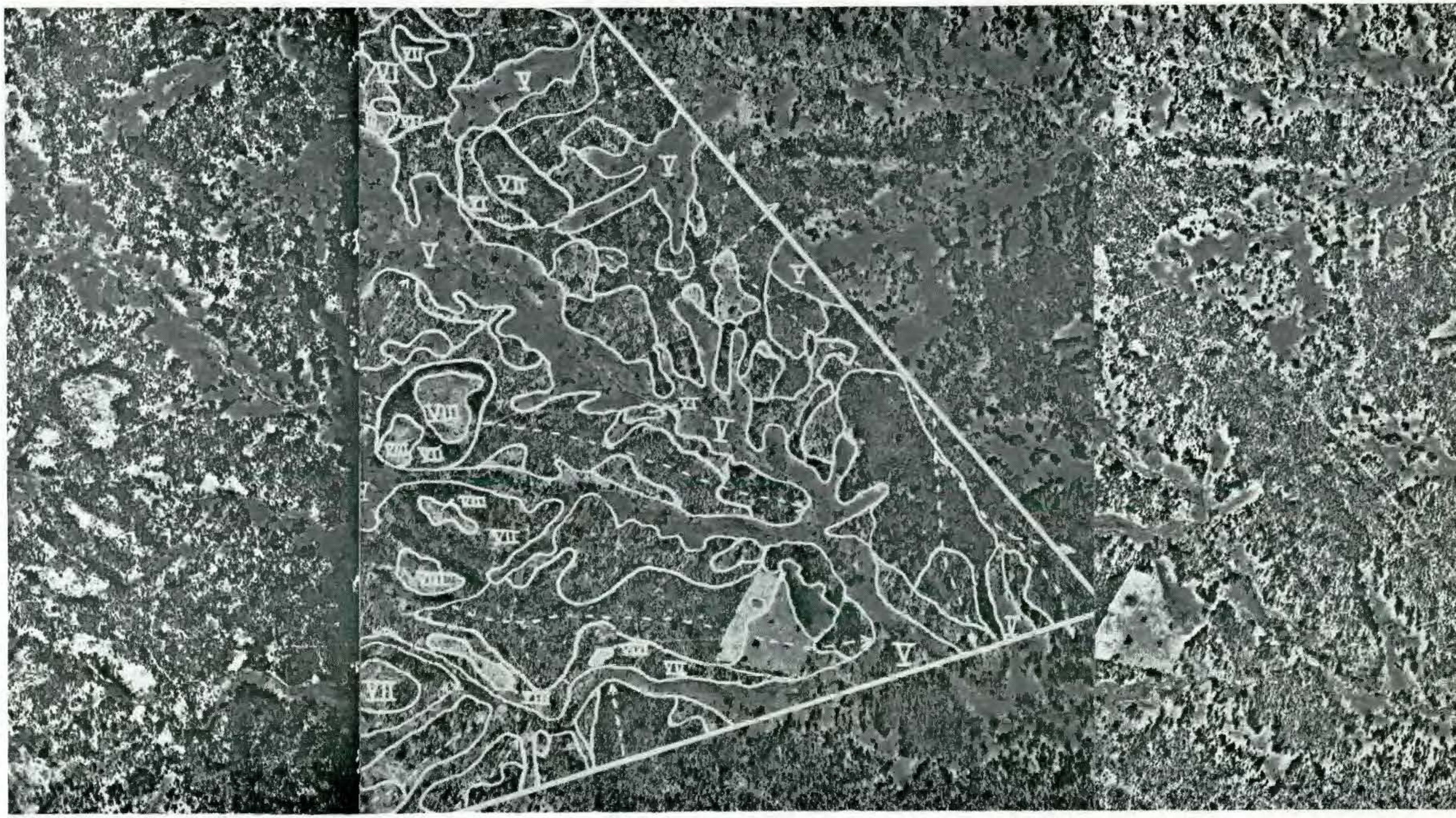


Fig. 2

Stereotriplet showing 'homogeneous areas' delineated on the basis of landform, vegetation stand, and grey-tone patterns related to wetness

Photoscale 1/20,000

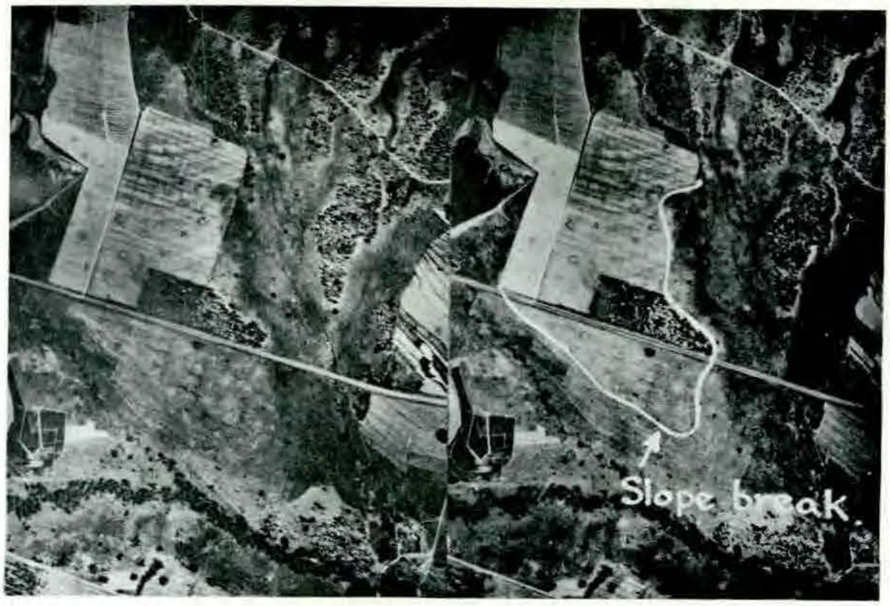


Fig. 3

Stereogram showing a minor 'slope break' coinciding with a change in soil conditions.

Photoscale 1/20,000

Fig. 4

THE SLOPING RIDGE

(Drainage Lines or Streams of approximately equal Floor Gradient)

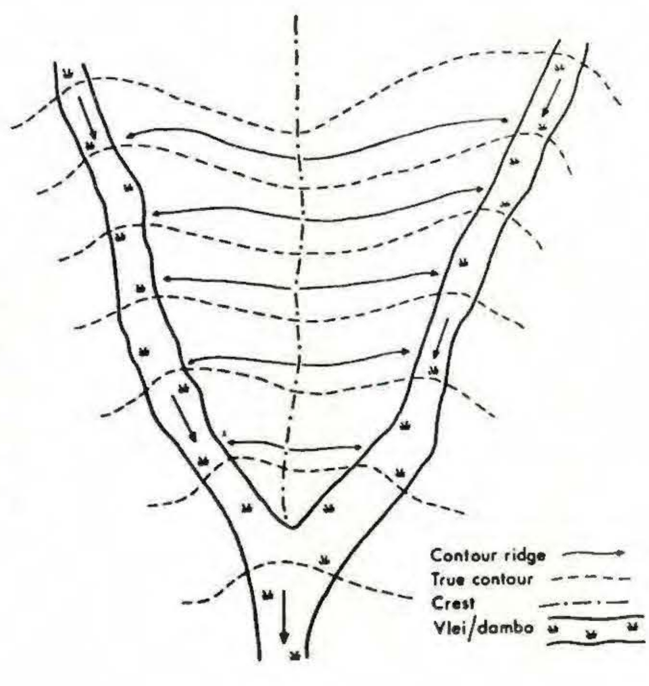
This is the simplest layout in practice but becomes complicated when; (i) The ridge is too wide even for contour ridges spilling each way from the crest or; (ii) when the waterway on one or both sides has been encroached upon.

In the case of (i) extra waterways should be provided, if possible in natural depressions fingering from either one or both of the drainage depressions (vleis/dambos).

In the case of (ii) no protection of the land should be attempted until the waterways are established.

Where waterways are demarcated for establishment the markings should be of a permanent nature.

Best road access is provided by a crest road with laterals along the top of or immediately below the contour ridges when required.



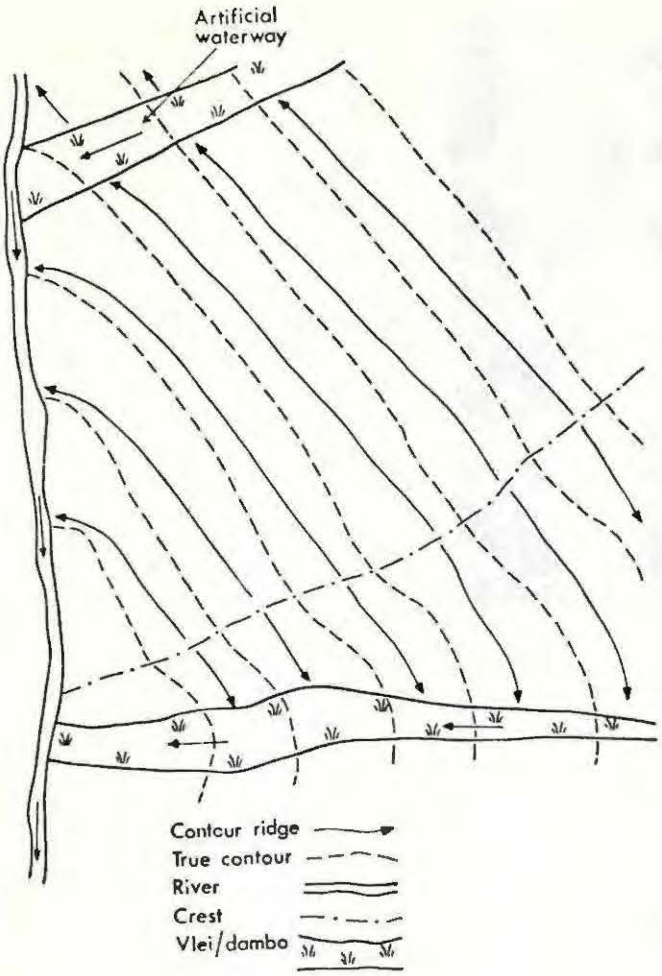


Fig. 5

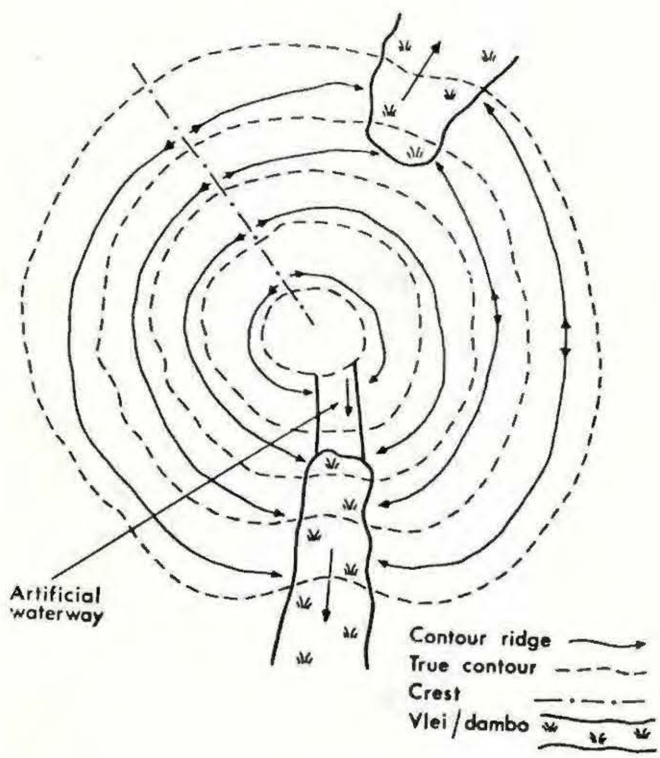


Fig. 6

Fig. 5

THE RIVERINE SLOPE

(Drainage Lines of Widely Differing Floor Gradient)

This layout often calls for an artificial waterway because the flat gradient of the river causes the contours to become too long. If such waterways are necessary they should be demarcated and established before protection is attempted.

Examples of this topography are frequently encountered along near-graded rivers and their larger tributaries.

Access roads can be provided down minor crests where contours split or down the side of a waterway when contours do not have to be crossed.

Fig. 6

THE DOME

This is not an easy layout because the whole dome usually cannot be seen from one point and if there is long grass or timber it becomes extremely difficult to visualise.

The permanent layout should only be attempted when the whole dome is opened up and completely clear.

The extension of a natural waterway to the top of the dome is the correct way of starting such a layout.

Waterways should be added as the circumference of the dome increases. Except at the top of the dome natural waterways usually occur and should not be cultivated.

Access roads can be provided without crossing contours if the contour split points are carefully sited.

Fig. 7

THE SADDLEBACK

The topography requiring this layout is quite common but it is seldom correctly protected.

The Y waterway limbs usually have to be artificial but are seldom needed on both sides of the saddleback.

The Y limbs have first to be established before efficient protection can be carried out.

Y limbs are not necessary when the domes are not higher than the V.I. being used on the contours.

This is the most difficult to recognise and the most awkward to protect. If a portion of such a feature is block-stumped and the rest is still under timber only temporary protection can be given.

Access roads need not cross contour ridges if the split points are carefully sited.

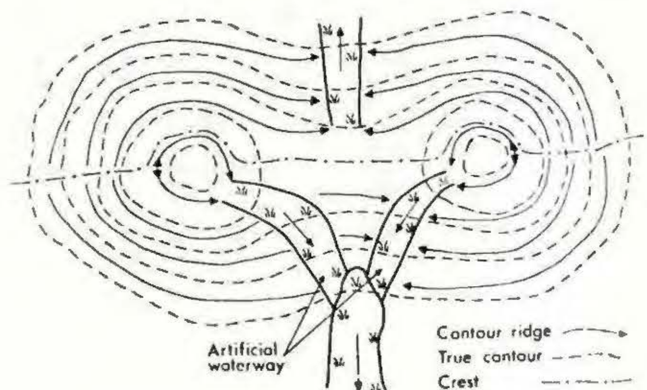


Fig. 7

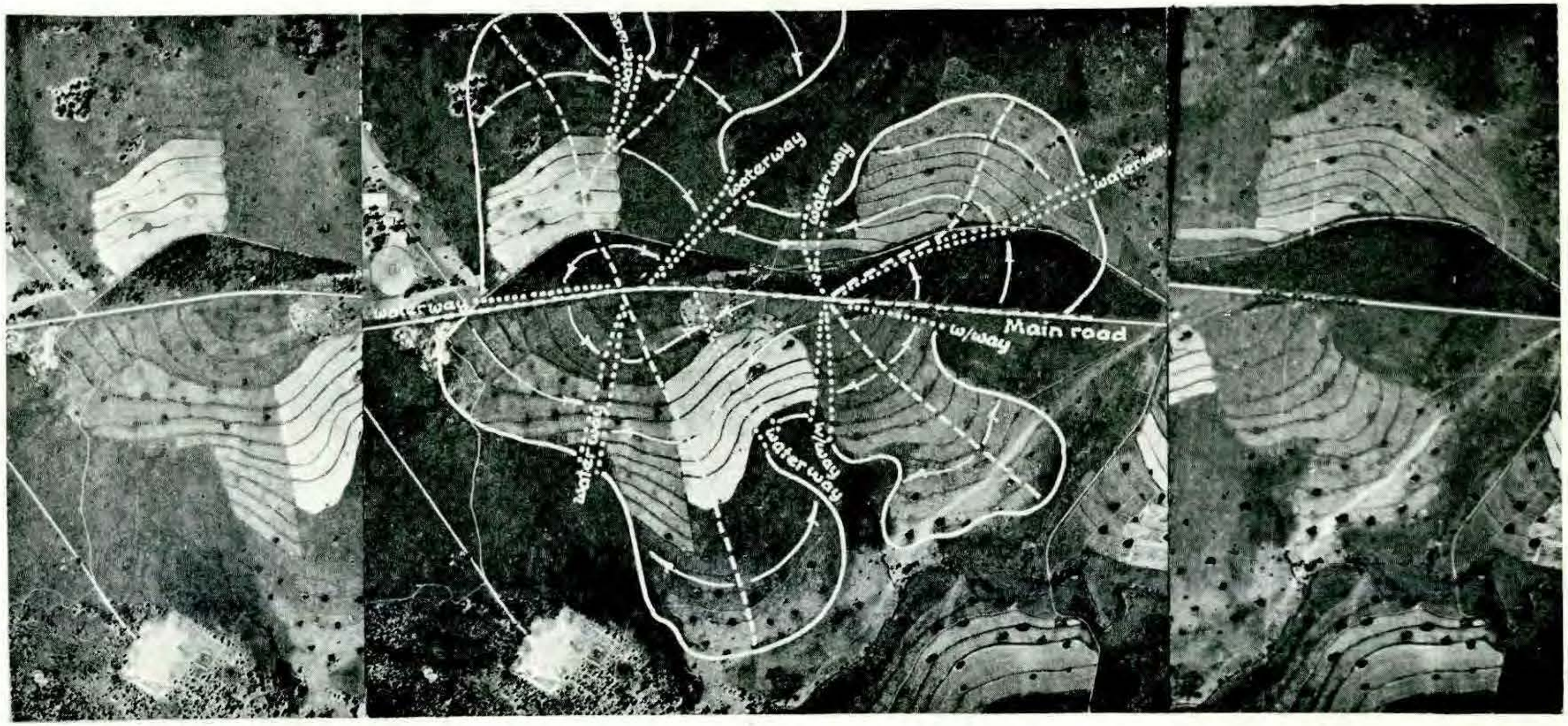


Fig. 8

Stereotriplet showing designed Conservation Layout in which the main characteristics of the Sloping Ridge, Dome & Saddleback are all recognizable.

Photo Scale 1/20,000

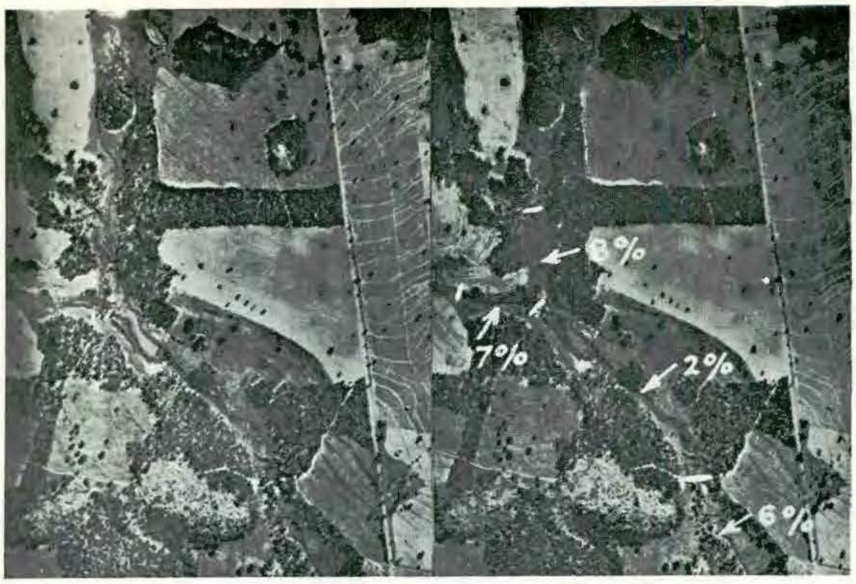


Fig. 9

Training Stereogram—Stream gradients
Photo Scale 1/20,000

Fig. 10

Stereogram of Dam site. Note rock outcrop at arrowhead—ideal for 'keying in' dam wall.
Photo Scale 1/20,000

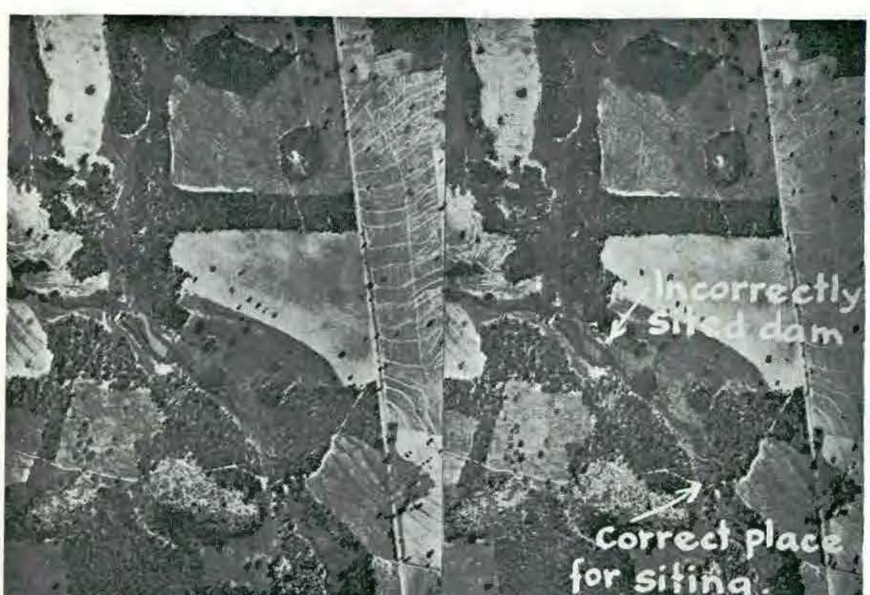


Fig. 11

Training Stereogram showing incorrectly sited existing dam and its correct siting position.
Photo Scale 1/20,000

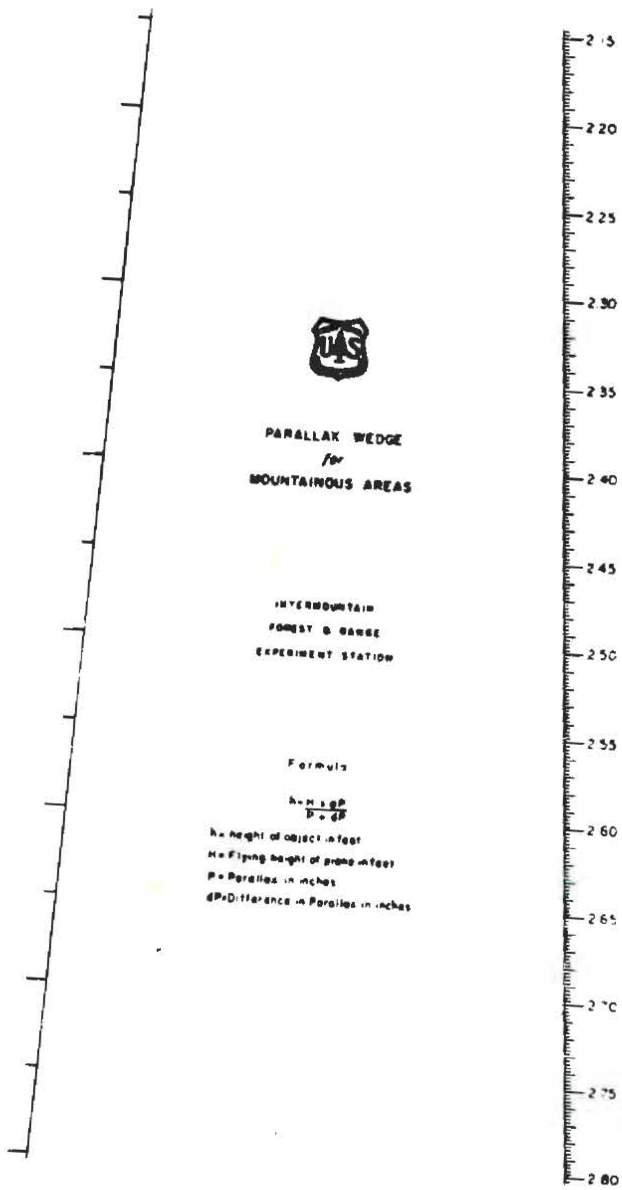


Fig 12.

Parallax Wedge - Actual Size

Fig. 13

Stereogram showing Dam sites on stream gradient changes, marked by arrowheads.

Photo Scale 1/20,000

Fig. 14

Stereogram showing Parallax Wedge reading on true streambed of top dam site 2.288 in.

Photo Scale 1/20,000

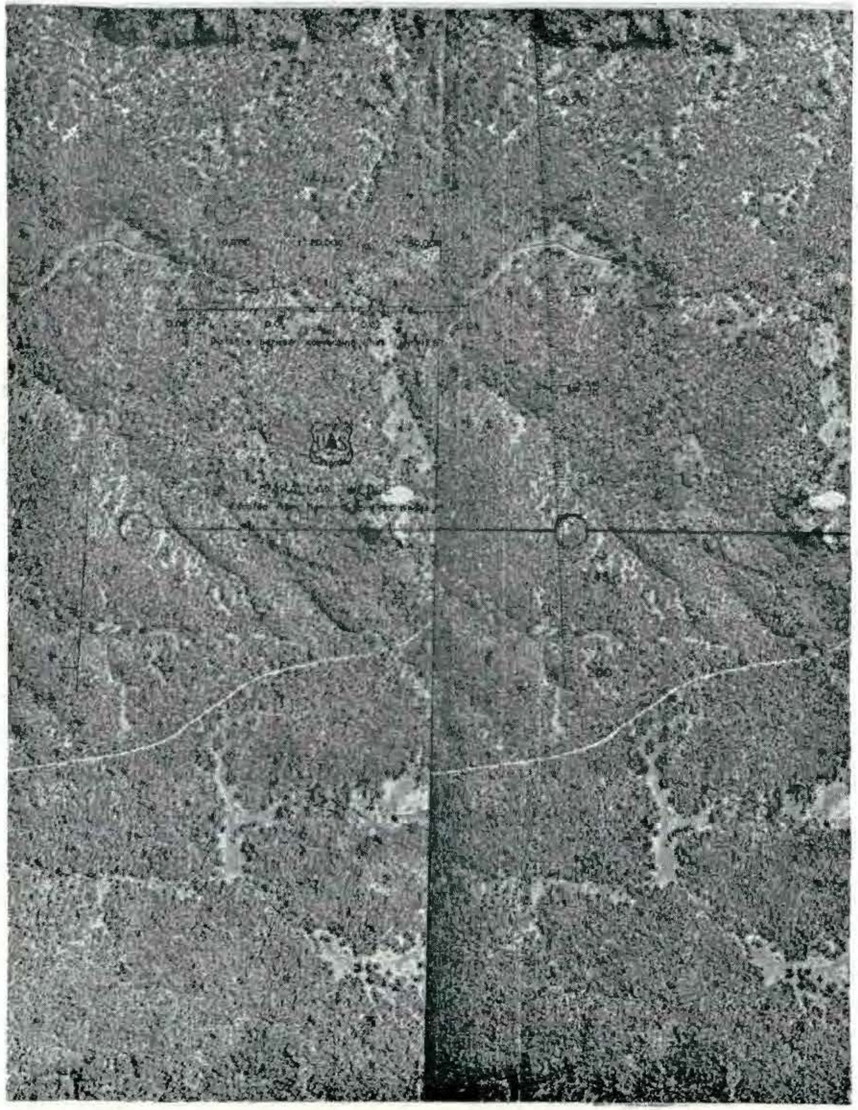


Fig. 15

Stereogram showing Parallax Wedge reading on left hand streambank of same site at Full Supply Level 2.282 in.

Photo Scale 1/20,000

N.B. Stream flowing from Right to Left.

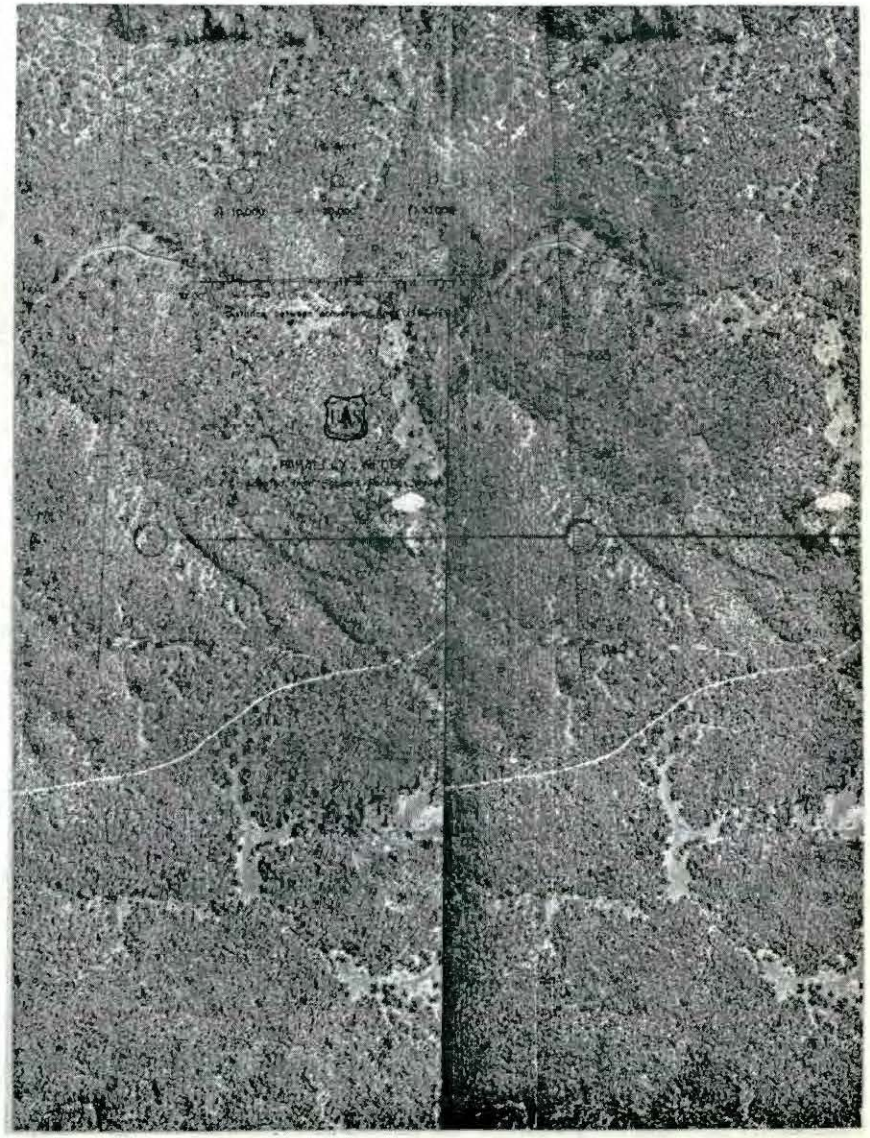


Fig. 16

Stereogram showing Parallax Wedge reading on right hand streambank at Full Supply Level 2.282 in.

Photo Scale 1/20,000

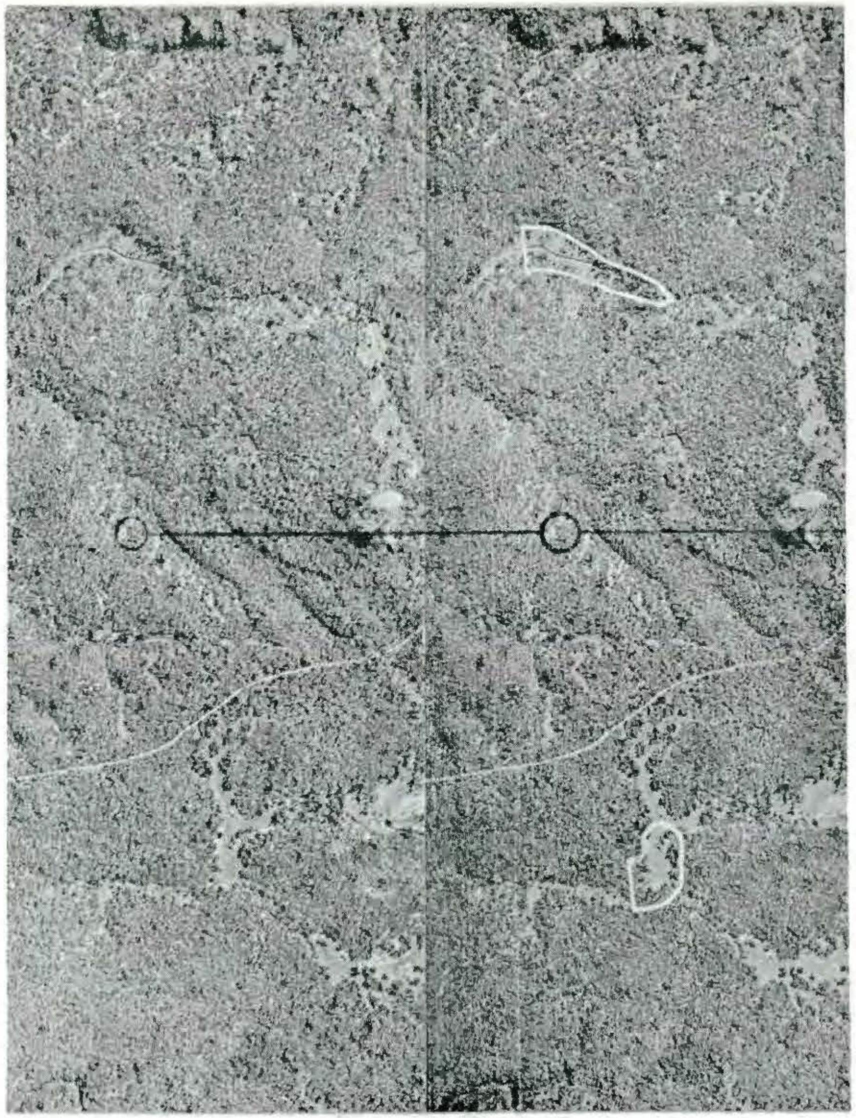


Fig. 17

Stereogram showing the same dam sites with Full Supply Levels stereoscopically form-lined.

Photo Scale 1/20,000

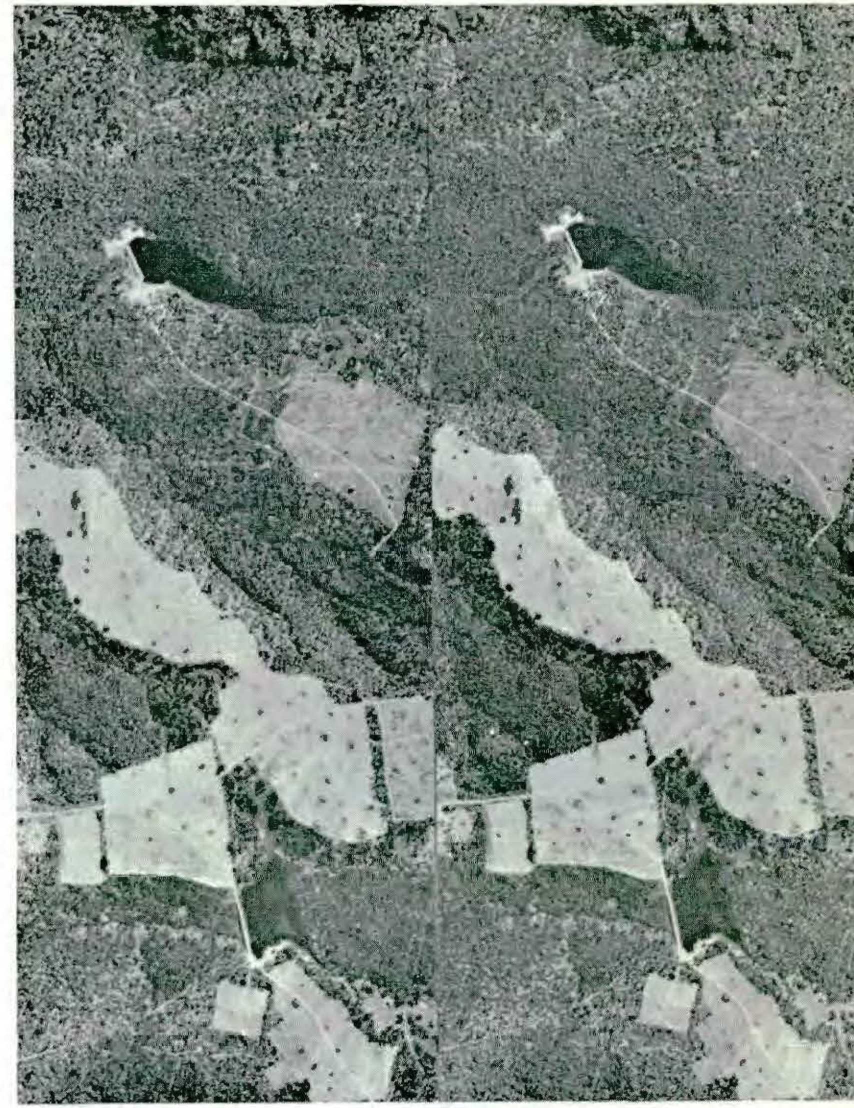


Fig. 18

Stereogram showing the same stream a few years later. The dams have been built and filled by the previous season's rains. The stereogram also shows opened-up tobacco fields with crest-sited access roads and contour ridges.

Photo Scale 1/20,000

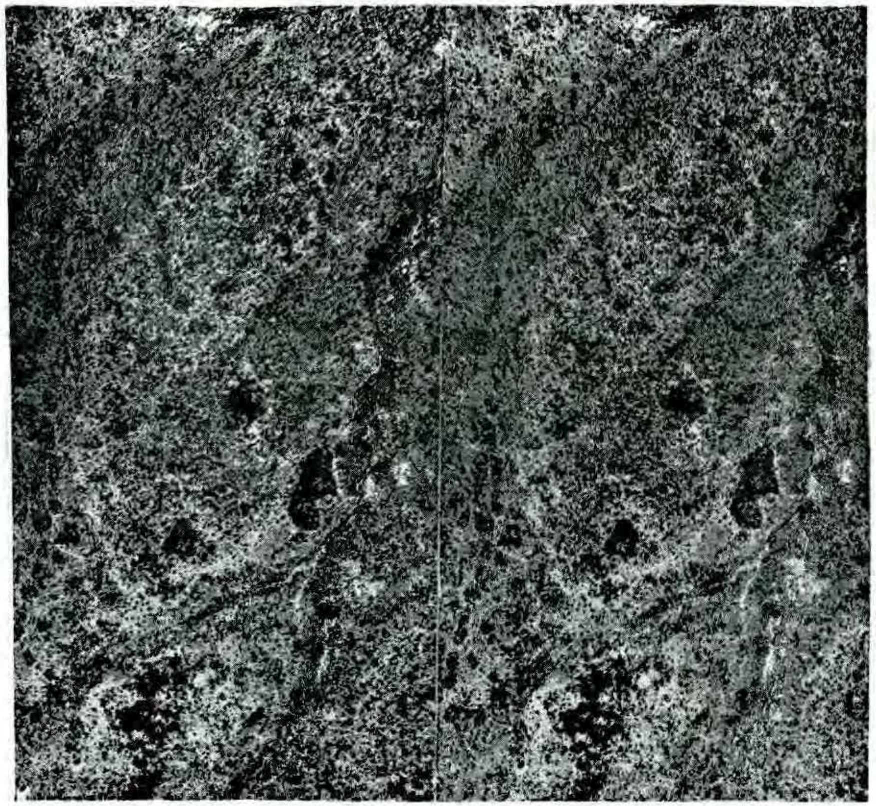


Fig. 19 (1950)

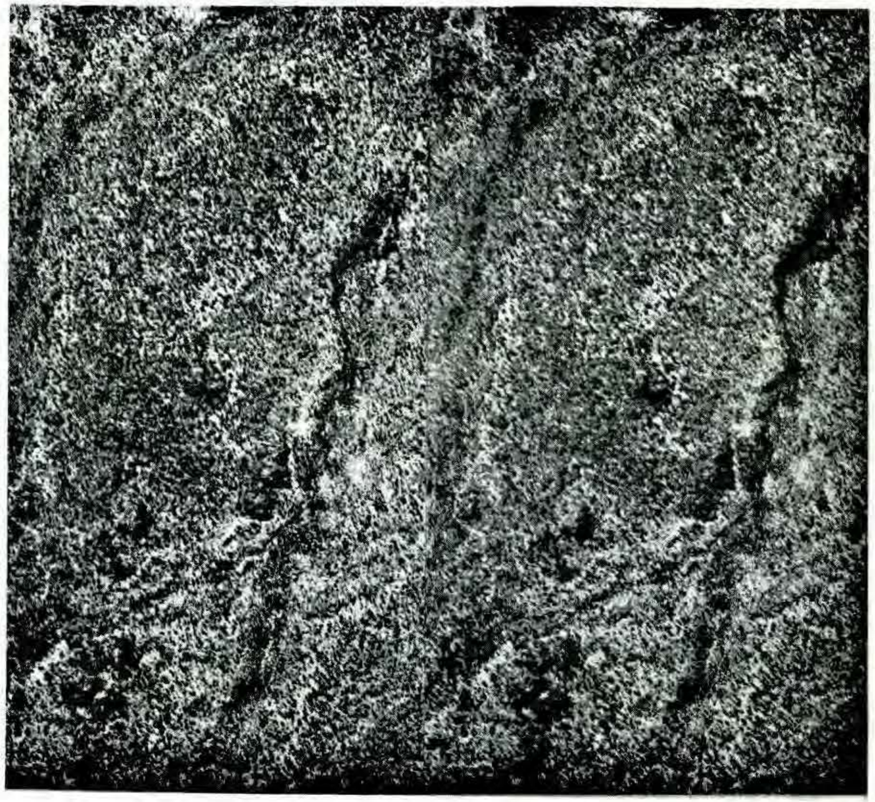


Fig 20 (1955)

Bush Encroachment Evaluation—Matabeleland—Rhodesia Lowveld

Stereograms demonstrating value of examining aerial photography of different dates covering the same area.

Photo Scale 1/20,000