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Map Intensification from Small Format Camera Photography

35 mm and 70 mm photography taken from light aircraft proved to be more cost/effective than conventional ground surveys for map intensification.

Abstract: *In spite of great advances in theory and instrumentation in relation to aircraft, photography, and plotting, there exist many situations where simple equipment can be used to obtain aerial photographs and to intensify map detail from them. The theory, techniques, and costs of methods that have been developed for mapping plantation extensions by using vertical aerial photography from 70 mm and 35 mm film format cameras in light aircraft are described. The efficiency of the aerial method is compared with conventional field survey techniques, and it is shown that intensified maps can be obtained which are at least as accurate for a cost saving of up to 75 percent and a labor saving of 86 percent. It is concluded that similar quick, simple, and low cost methods could be used in many other applications, both within and outside the forestry sphere.*

Introduction

Since the 1840's photogrammetry has become a basic procedure for all types of mapping, from broad coverage maps at small scales to very detailed contour maps of cities and construction sites. Associated with this increasing use has been a continuous development of theory and instrumentation, the result of which is a high degree of sophistication with respect to aircraft, photographic equipment, and plotting equipment. Nevertheless, there still exist many situations where relatively simple equipment can be used to obtain aerial photographs and to map from them. The aim of this paper is to examine such a situation: the mapping of detail in plantation extensions.

Substantial extensions to many state-owned plantations of *Pinus radiata* in the state of Victoria in Australia are currently being made, and for various reasons it is necessary to prepare maps of these extensions as quickly as possible. A similar situation exists for private plantings and for other states of Australia. In Victoria much of this mapping was based until recently on chain and compass survey, an expensive and time-consuming method.

Because a greater use of aerial photographs was an obvious means for streamlining this process, attention has been given to the development of simple, low cost, and rapid methods for obtaining photographs with a 70 mm or 35 mm camera. The methods that have been developed, which are described below, are intended to supplement but not replace the major aerial surveys that are carried out periodically for the preparation of accurate base plans.

Because the major role of these small format photographs is map revision or intensification, a function also recognized by others (e.g., Lines, 1962; Cook, 1969; Zsilinsky,

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1969; Klein, 1970), photogrammetric control is less demanding. In addition, since only major features are required, such as topography, new roads, tracks, and boundaries of clearings, interpretation can be accomplished from photographs at relatively small scales.

Camera Considerations

The purpose of this section is to discuss camera requirements for supplementary aerial photography and to illustrate some of the major differences between photography with small format cameras and photography with aerial survey cameras. In these illustrations discussion is confined to 70 mm and 35 mm cameras because these are the most common types available.

Any 70 mm or 35 mm camera with a good quality lens and fast shutter speed (preferably down to 1/500 sec.) can be used to obtain supplementary photographs. However, cameras with motorized assemblies and large film capacity have obvious advantages and are essential if access to the camera is not possible during flight. It is also essential that the shutter should be of a type that will operate at low temperatures, a danger which is eliminated when shutters lubricated with silicones are used (Zsilinsky 1969). It is also advantageous if the camera has the facility for interchange of lenses.

The formats of 70 mm and 35 mm cameras are, respectively, 56 by 57 mm (2.18 by 2.25 in.) and 24 by 36 mm (0.94 by 1.44 in.) and their focal lengths are normally 80 mm and 50 to 55 mm, respectively. These lenses have narrower fields of view than the lenses commonly used in aerial survey cameras. Therefore, if comparable coverage is required, photographs must be taken either from higher altitudes or with lenses of shorter focal length. For example, a 50 mm lens on a 35 mm camera has a field angle of 41°12′ (the angle subtended by the diagonal of the format) compared to a value of 60° to 75° for "normal" survey lenses. Table 1 (after Spencer, 1972a) further illustrates this point. Here the lenses of 9-in., 70 mm, and 35 mm cameras have been classified by focal lengths into the four lens classes given for aerial photography by the American Society of Photogrammetry (1966). The 9-in. format is used for comparison because it is now the most common employed for aerial survey. Thus, according to aerial terminology 70 mm and 35 mm cameras with lenses of focal lengths exceeding 70 mm and 38 mm, respectively, are considered to be narrow-angle.

Table 1. Lens Classes in Aerial Terminology for 9-in., 70 mm, and 35 mm Cameras where Field of View is the Angle Subtended by the Diagonal of the Format.

Lens Class	Field of View	Focal Lengths (in mm) for Different Camera-Types: 9-inch	70 mm	35 mm
Narrow	Less than 60°	281	70	38
Normal	60 – 75°	281–232	70 –60	38 –31
Wide	75 – 100°	232–136	60 –34	31 –18
Super-wide	Greater than 100° e.g. 122° R.C.9	88	22	12

Note that the "field of view" in Table 1 refers to the angle subtended by the *diagonal* of the format, which is the normal way of expression (Horder, 1958). Although this angle is of great importance when mounting the camera so that its view is unobstructed, it is generally simpler and more meaningful, when making comparisons between the above three camera systems, to consider the angles subtended by the axis of the format, i.e., the focal-length-to-picture ratio. In the case of 9-in. and 70 mm cameras which have square formats, the angle subtended by each axis is the same. However, with the rectangular 35 mm format the angles are different, and this affects comparisons relating to ground coverage and image displacement. The first of these points is illustrated in Figure 1.

Figure 1a shows the relative areas of coverage obtained from the *same* height with 9-in., 70 mm, and 35 mm cameras having equivalent fields of view (i.e., equal angles subtended by the *diagonal*). Thus, if the coverage for the square formats is A, then for the 35 mm format it is 0.9A.

Figures 1b and 1c illustrate the cases for equal angles subtended by the axis. The coverage of the 9-in. and 70 mm cameras is still the same and is designated A. With equal focal-length-to-picture ratio, using the longitudinal axis of the rectangular 35 mm format, the coverage is 0.7A (Figure 1b) whereas for the transverse axis it is 1.5A (Figure 1c).

In all cases where large coverage is sought with small format cameras, the scale of photography must necessarily be small and herein lies a great disadvantage for many purposes. Small format photography is not suitable for jobs where it is necessary to discern fine detail and still obtain broad coverage because many flight lines and photographs are required to cover a given

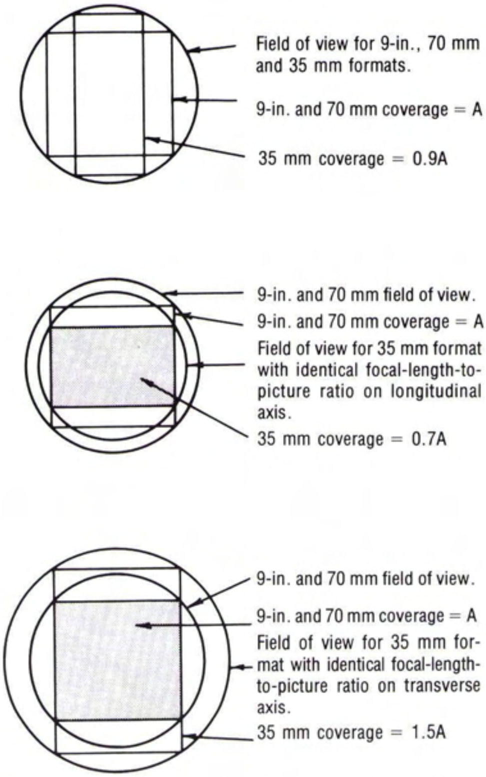

FIG. 1. Ratios of ground coverage obtained from the same flying height for 9-in., 70 mm, and 35 mm cameras. (a) Identical fields of view. (b) Identical focal-length-to-picture ratio for longitudinal axis of 35 mm format. (c) Identical focal-length-to-picture ratio for transverse axis of 35 mm format.

area. This point is clearly demonstrated in Table 2 which shows the ratios of area coverage and numbers of photographs applying to the three systems when photographs are taken at the same scale. For example, to cover the same area as a 9-in. photograph would require sixteen 70 mm or sixty 35 mm photographs.

Thus, 70 mm and 35 mm cameras with "wide-angle" lenses are the most practical for complete coverage from light, low performance aircraft. However, if the aircraft ceiling can be increased to permit good photo coverage with narrow-angle lenses, there is an accompanying advantage of reduced image distortions, a definite advantage when simple mapping equipment is used. Also, because of the small format of 70 mm and 35 mm cameras, enlargements provide the most practical form for mapping. The degree of enlargement may be based on the ease of handling, annotation, and storage, or it may be fixed so that the scale of enlargements matches the scale of existing survey photographs or maps.

AIMS

The aims of these studies were—

- To develop operational procedures for obtaining complete photographic coverage of limited areas with a small format camera, light aircraft, and simple and inexpensive navigational equipment.
- To use these techniques to obtain vertical aerial photographs for mapping boundaries of clearings, roads, and other features in new plantations.
- To analyse the costs of mapping with small format photographs and to compare these with the cost of ground survey techniques.

EQUIPMENT AND METHODS

AIRCRAFT AND PHOTOGRAPHIC EQUIPMENT FOR 70 MM PHOTOGRAPHY

In preliminary trials which are not reported here, the potentials and problems of using supplementary 70 mm aerial photography for plantation mapping were explored. In these trials photographs were taken with a 70 mm camera which was mounted outside the open doorway of a Cessna 182 aircraft (Figure 2) and flight line navigation was based primarily on unaided visual observations.

The success of these trials ensured a continuing use of the approach but, in order to improve the accuracy of flight line navigation and the comfort of flying, a light aircraft was modified for internal mounting of the camera and a drift sight. The items of equipment used in this system were

TABLE 2. COMPARISON OF RELATIVE GROUND COVERAGE AND NUMBERS OF PHOTOGRAPHS FOR AERIAL PHOTOGRAPHY TAKEN AT THE SAME SCALE WITH 9-INCH, 70 MM, AND 35 MM CAMERAS.

Camera	Format (mm)	Area Coverage	Photos Along Run	No. of Runs	Total Photos
35 mm	24 × 36	1 unit	10	6	60
70 mm	56 × 57	4 units	4	4	16
9-in.	230 × 230	60 units	1	1	1

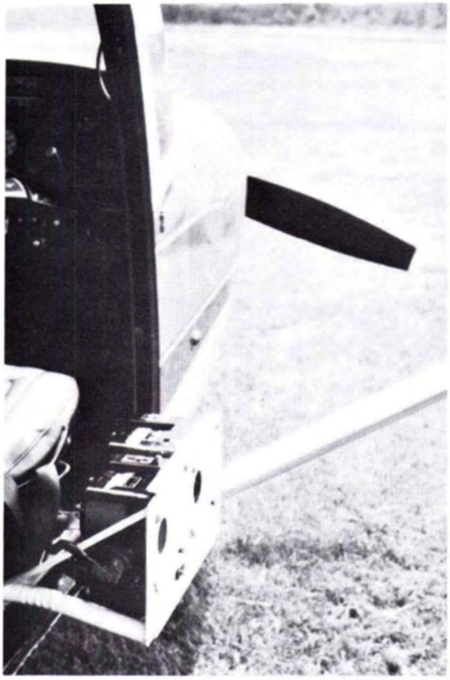

FIG. 2. In early trials, 70 mm photographs were taken with a Vinten camera mounted outside the open main doorway of a Cessna 182 aircraft, such as in the dual-camera mount shown here.

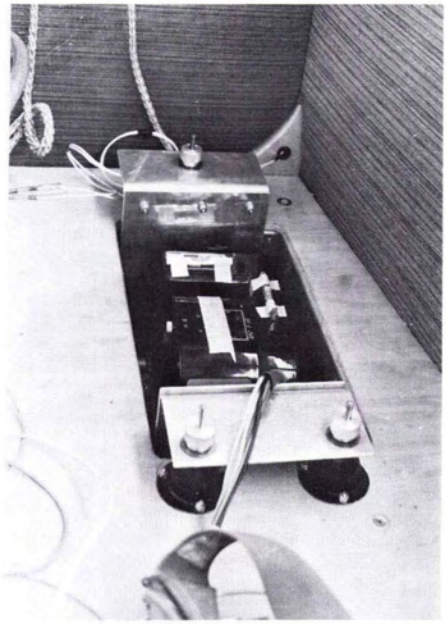

FIG. 3. Specially designed mount for the Vinten camera and Beechcraft Musketeer aircraft. The mount has facilities for in-flight adjustment of tip, tilt, and swing. It also provides for easy access to and quick removal of the camera for making changes in exposure as well as changes of filters and magazines.

- Modified Beechcraft Musketeer aircraft,
- Aerial camera,
- Camera mount,
- Control box and intervalometer,
- 24 Volt D.C. power supply, and
- Drift sight.

Three major modifications of the aircraft were involved:

- A hole for internal mounting of the camera,
- a second hole for mounting the drift-sight, and
- an additional inbuilt 12 Volt D.C. battery. This battery was coupled in series with the aircraft battery for camera operation and in parallel for recharging.

Minor modifications to the aircraft included removal of the front passenger's seat and modification of the back rest of the rear seat so that it could be removed during flight to improve access to the camera in the luggage compartment.

The camera was a Vinten 70 mm fitted with a lens of 3-in. focal length. It had a format of 56 by 57 mm and was electrically operated. It was equipped with a roller blind shutter in the focal plane with speeds of 1/500 or 1/1,000 second. The magazine, which was loaded in a darkroom, had a film capacity of 100 ft (approximately 500 frames).

The camera mount (Figure 3) was designed and constructed by Civil Aerial Surveys. It was supported at three points on rubber cushions. Vertical adjustment could be made at each of these points to level the camera. Rotation about the vertical axis (swing rotation) also was provided to compensate for non-parallelism between the aircraft axis and its track along flight lines. The facility for doing this cannot be seen in Figure 3.

A modified F24 control box was used for remote control of the camera in the single shot mode and for automatic "firing" at intervals ranging from 2 to 50 seconds. It also has a frame counter.

The drift-sight, an Aldis, had three functions:

- to determine the drift of the aircraft and the swing adjustment required on the camera,
- to facilitate accurate navigation along each flight line, and
- to determine the exposure-interval for stereoscopic overlap.

SYSTEM FOR 35 MM PHOTOGRAPHY

The major 35 mm system was much simpler. It consisted of a specially designed mount that projected the camera through the open doorway of the rear luggage compartment in a light aircraft, usually a Cessna 172 or 182. This mount had adjustments for in-flight levelling but no adjustment for drift because the system did not include a drift sight. The camera could be retracted into the aircraft for reloading film and setting exposure, but the film was advanced manually in the in-flight position and the shutter was operated by a remote control cable. The camera was an Asahi Pentax Sp II and was fitted with a lens of 35 mm focal length, which simulated approximately the geometry of a 9-in. camera with a focal length of 8.8 in. (223 mm). Because the system was inexpensive and required no permanent modification of the aircraft, a number of units have been in use in Victoria, allowing flexibility in the timing of photography, choice of aircraft, and place of departure.

In a second 35 mm system the camera was mounted over a hole in the floor of the aircraft. The camera operator viewed the ground through the reflex system of the camera. In this way the camera performed some of the functions of a drift sight. The camera mount in this system had adjustments for tip and tilt, and modifications could have been made to permit adjustments for drift.

FLIGHT PLANNING

Conventional standards for flight planning were adopted, with sidelap being approximately 30 percent and forwardlap approximately 60 percent. The former was to ensure complete photographic coverage of the area and the latter was to permit stereoscopic study of each area.

The orientation of flight lines was determined by two factors, namely, the shape of the area to be photographed and the location of easily recognizable landscape or cultural features. Where possible, the beginning and end of each run (or extensions of these) were made to pass over recognizable features. A suitable plan was arrived at by trial and error by using different flight line orientations, different placement of the flight lines, and in some cases by reducing the flight line spacing.

With the 35 mm camera on an external mount, a drift-sight was not used, and flight lines were oriented to correspond with the direction of wind and all photographic runs were made with the wind. This system greatly simplified flight line navigation by eliminating drift, although it did increase flying time. However, this was of little concern in comparison with the advantages gained. The direction of wind for the flying height was obtained from a forecast, and it was checked in a trial flight over the project area or over open country where landmarks were conspicuous.

A final flight plan for this method cannot be drawn before the day of a flight because the wind direction is not known in advance. One system used to overcome this was to draw flight lines at the correct spacing on a transparent overlay which can be positioned over the flight map or photograph on the day of the flight. The other approach is to draw the entire flight plan after take-off. In both cases the plan is designed for a camera with the long axis of its negative perpendicular to the direction of flight because it requires fewer flight lines and permits larger errors in flight-line navigation when sidelap is maintained at 30 percent.

The best "map" for flight-line navigation was an annotated aerial photograph. For this purpose photographs at a scale of 1:80 000 proved very valuable. By taking appropriate care, planning usually was done directly on these photographs but, where doubt existed as to the degree of topographic displacements, the flight lines were drawn first on a map at an appropriate scale and then transferred to the photograph.

Photography was usually taken from 10 000 ft above sea level, which is the upper permissible level for flying without extra supplies of oxygen. Thus, for the majority of plantations, contact scales of 1:28 000 to 1:40 000 were obtained with the 3-in. lens.

Given suitable weather, another consideration in planning flights was to determine when photography could commence in the morning and when it should be terminated in the afternoon, times which are a function of solar altitude. For black-and-white photography and where topography is not steep, a minimum solar altitude of 20 degrees is a common standard (American Society of Photogrammetry, 1968). Because Kodak Plus X panchromatic 5061 film was used, the standard of 20 degrees was adopted.

Maximum solar altitudes were also considered in order to avoid the occurrence of a "hotspot", a bright area deficient in detail. The hotspot occurs in a photograph in an area surrounding the point where a line joining the sun and the aircraft intersects the ground. It is, therefore, more likely to appear at high sun angles and when cameras with wide-angle lenses are used. Its acceptibility is related to the purpose for which the photographs are to be used and to the proportion of each photograph it degrades; hence, the scale and format are important. With 70 mm photographs at the above scales, it is best avoided.

Nomograms based on latitude, time of year, and limiting solar altitude were used to determine the length of the photographic day, the position of the hotspot, and the times that the hotspot enters and leaves the area of the photograph (Fleming, 1964; American Society of Photogrammetry, 1968).

Film exposures were determined with a Kodak Aerial Exposure Computer (Eastman Kodak, 1966) in which the input variables were aerial exposure index, flying height, solar altitude, and condition of haze.

The films for 35 mm cameras have not been designed specifically for aerial photography, and the correct exposures for different conditions have been learned by experience. An exposure guide for Plus X black-and-white film is given in Spencer (1974).

Exposure intervals for stereoscopic forwardlap of photographs taken without the aid of a drift sight are determined from the scale of photography, format of the camera, and ground speed of the aircraft. Spencer (1971) provides details of these calculations for 70 mm and 35 mm cameras, and intervals for a 35 mm camera with a focal length of 35 mm have also been tabulated (Spencer, 1972b, 1974). When a drift sight is used, these intervals are determined in flight from the time an image takes to traverse a graticule in the sight.

FLYING PHOTOGRAPHIC MISSIONS

Successful navigation of the flight lines without a drift sight depends to a great degree on the skill of the pilot, whose job it is to bank the aircraft at the beginning of each run so that he can see the position of the run, and then to level the aircraft and set its course to fly along the run. A mirror system is used to check flights over identifiable pass points.

Visual navigation is used to locate the start of each run, but navigation along flight lines is solely by instrument (the directional gyro) to achieve straight flight lines. If a run goes off its course, it should be reflown rather than corrected in flight. When the drift-sight is in use, however, minor course corrections are made by means of flat turns. Exposure intervals for stereoscopic forwardlap in this case are determined in flight.

Even under good conditions the work demands a high degree of pilot skill and concentration. The pilot should be briefed in detail and trained for the work. His job can be made easier by good planning of flight-line positions which start and finish over recognizable points.

MAPPING TECHNIQUES

The mapping techniques employed were—

(1) Mapping was from 6 by 6 in. prints (i.e., 2.7× enlargements) at scales of 1:10 300 to 1:15 000, but most commonly at approximately 1:11 900. This format was selected because the scales so produced were readily convertible to the common scale of plantation maps of 1:7 920 or 1:15 840. The format was also a convenient size for handling and annotation.

(2) Photographs were then examined stereoscopically, and various features within the effective area of each photograph were marked with a fine-pointed ink pen of chinagraph. These features included clearing boundaries, roads, creeks, ridges, and cadastral boundaries, as well as any other features which would help to "tie in" the area being mapped.

(3) Detail was then transferred to a topographic base-map with the aid of a Zeiss vertical sketchmaster. This is a monocular transfer instrument which is of a portable design and facilitates superposition of the photographic image onto the map. It accommodates scale ratios between the photograph and map of 0.4× to 2.7×, and it provides for adjustment of the photo plane to any position relative to the map plane. As a result, the scale throughout the photo projection can be varied, thus improving the scope for overcoming any lack of correspondence between the photo image and the map. These adjustments provide the means to obtain accurate results provided that the topographic base-map is reliable and that care is taken to "fit" detail within points of control.

(4) When the draft map was completed it was taken to the field to determine road classifications and distances from roads to planting edges, as well as to check measurements and interpretations for doubtful features.

RESULTS AND DISCUSSION

PHOTOGRAPHY

By using techniques such as those described, some 8100ha of plantations were photographed during 1971. These areas were in seven localities and were photographed during three separate missions. The largest single area was 4050ha (5 by 8 km) of established plantations, and this required six sidelapping runs for complete coverage. The remaining 4050ha were extensions and only these were subsequently mapped.

MAPPING

Errors in maps are of two types, metric (i.e., quantitative) and non-quantitative. A common but costly procedure for assessing metric errors is to conduct detailed sample surveys and then calculate the standard error (root mean square error) of deviations from the survey data (Thompson *et al.*, 1971). However, even with this approach there is an area of interpretation which must be recognized in order to avoid the rigid application of rules that do not reflect the purpose for which the map is prepared.

Non-quantitative errors are errors of interpretation other than metric origin. Examples are the incorrect recording of species or year of planting, or the incorrect classification of roads. Although the bulk of this information was obtained from field checks or existing records, features such as the type of clearing (broadcast or windrow) and the direction of windrows were readily obtained from photographs.

In the present studies, resources did not permit the calculation of standard errors. However, careful inspection of the maps, by employing field and office checks, led to the conclusion that the maps intensified by this procedure were at least as accurate as maps intensified from normal chain and compass survey data. Factors contributing to this conclusion were—

- Detail was transferred to topographic base maps of a suitable scale and quality (when such maps are not available, the same results might not be obtained);
- Photographs provided numerous control points for referencing detail and "tying in" newly mapped areas;
- Irregular boundaries of uncleared areas were more accurately defined on aerial photographs, for example, boundaries of areas reserved for special purposes such as flora reserves, fauna reserves, and gullies for the protection of water supplies (Figure 4);
- The shapes of dense and complex networks of roads (Figure 5) were more accurately defined and referenced to topographic features on aerial photographs; and
- Photographs provided an accurate check that all areas had been accounted for, a point of particular importance in highly dissected country with many small but individual plantation units.

The methods which have been described also afforded considerable savings of time and costs.

ANALYSES OF COSTS AND TIMES

A summary of the costs is presented in Table 3 for the 70 mm photography and map intensification of approximately 4000 hectares of plantation extensions in central and north-east Victoria. These costs were for nine project areas which were photographed in three missions. The costs were dissected into major components of photography, drafting, and field-checking. Costs per photographic mission have been apportioned to individual plantations in proportion to their area and account for all direct costs including salaries of officers. The average per hectare costs for photography and mapping are shown to be 12.2 and 29.7 cents respectively, thus giving a total map production cost of 41.9 cents per hectare.

Table 4 is a summary of the major components of total cost, both in terms of dollars

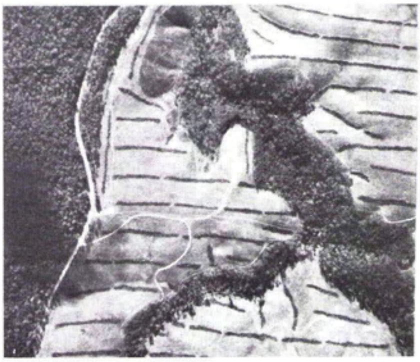

FIG. 4. Examples of 70 mm photographs (scale approx.1:32 000) employed for determining irregular boundaries of uncleared areas of native hardwoods retained for special purposes such as flora, fauna, and recreation reserves and gullies for protection of water supplies.

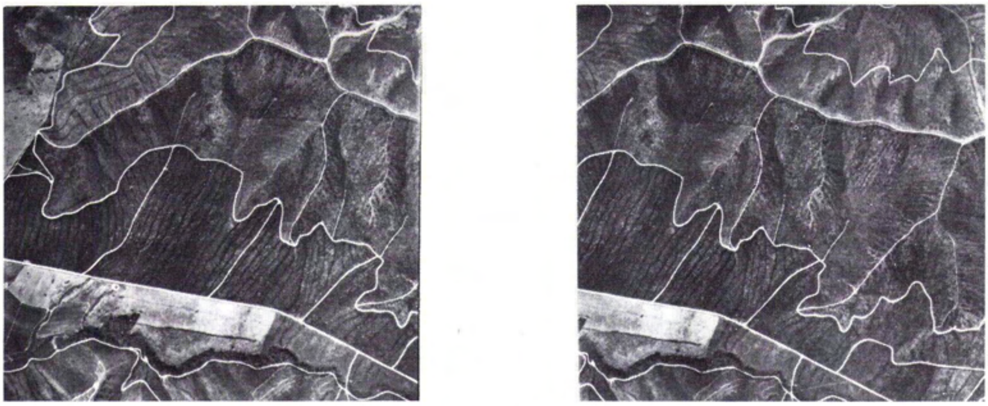

FIG. 5. Examples of 70 mm photographs (scale approx. 1:32 000) employed for mapping the dense and often irregular network of roads in new plantations in hilly topography. Note the location of roads and road junctions in relation to topographic features, features that provide numerous control points for mapping detail and the "tying in" of newly mapped areas on existing base maps. Note also the clear distinction between areas with windrows and those without them.

and of percentages. Thus, we can see that photography accounted for 16 percent, aircraft hire 13 percent, and map-compilation 71 percent of the total cost.

In order to compare the efficiency of the aerial survey techniques with the field survey techniques, costs and labor inputs were determined for both methods and are presented in Table 5. The values in this table apply to the mapping of 365 hectares of clearing in project area "G", an area 270 kilometres from the aircraft base and with a complex network of roads and uncleared reserves.

Costs of the photographic survey given in Table 5 are presented in two ways. In the first instance they are a record of costs which were incurred when the area was photographed in conjunction with two other areas. In the second case they represent estimates for photographing the area as a single project. In the first case the mapping cost per hectare was 48.8 cents, compared with a value of 79.0 cents for the second case and $1.97 for the field survey technique.

The man-day requirements were also in the same order, being 7 to 8 days for the photographic method and 49 days for the field-survey method. Thus, when the area was photographed as part of a joint project, the cost of producing a map using the photographic techniques was 25 percent of the cost for field survey methods and the labor requirement was 14 percent. Had the area been photographed as a single project, the cost of the photographic techniques would have increased to 40 percent of the cost of the field survey methods, but the labor requirement would have increased only slightly to 16 percent.

These results clearly illustrate the value of using the aerial photographic techniques described above. The techniques have the additional advantage of providing a detailed and permanent record in the form of photographic images, which may be used in future studies of each area.

CONCLUSIONS

The mapping studies described in this paper have involved the use of methods which are intended to supplement, but not replace, the major aerial surveys that are carried out periodically for the preparation of accurate base plans of plantations. Indeed, accurate base maps are required for scaling with the "sketchmaster" technique.

Specific conclusions from the studies are—

(1) Small-format cameras in light, low-performance aircraft provide a simple, quick, and low cost method for obtaining current photographs for use in mapping plantation extensions.

(2) 70 mm and 35 mm cameras with wide-angle lenses are the most practical types when complete coverage is required from low performance aircraft. However, if the aircraft ceiling can be increased to permit good photo coverage with narrow-angle lenses, image distortion can be reduced.

(3) Any 70 mm or 35 mm camera with a good quality lens and fast shutter speed can be used to obtain supplementary photographs, although cameras with motorized assemblies and large film capacity have obvious advantages. It is also essential that the

Table 3. Summary of Costs for Mapping 1970 and 1971 Plantation Extensions in Central and North-East Victoria using 70 mm Aerial Photographs

Project Area	Distance from Base (km)	Area (Hectares) 1970 Planting	1970 Clearing	Total	Costs $'s Photography	Drafting	Field Checking	Total	Cost per hectare (cents) Photography	Mapping	Total map cost
A	50	579	—	579	133	143	29	305	23.0	29.7	52.7
B	180	418	527	945	58	233	46	337	6.1	29.7	35.8
C	190	88	142	230	14	57	12	83	6.1	29.7	35.8
				(+3,904)	(240)	—	—	—	(6.1)	—	—
D	110	497	648	1,145	70	283	57	410	6.1	29.7	35.8
E	100	271	255	526	101	130	26	257	19.2	29.7	48.9
F	190	—	203	203	39	50	10	99	19.2	29.7	48.9
				(+203)	(39)	—	—	—	(19.2)	—	—
G	270	—	365	365	71	90	18	179	19.5	29.7	49.2
PX Photography and mapping		1,853	2,140	3,993	486	986	198	1,670	12.2	29.7	41.9
All photography		—	—	8,100	765	—	—	—	9.4	—	—

Comments:

1. Photography for the above projects was completed in three missions and the total costs per photographic mission have been apportioned to individual plantations in proportion to their area.
2. Costs for the photography are actual values. In the case of the second mission, the costs include photography for all established plantations at Area C, totalling 3,904 hectares, taken so that the extent of snow damage could be determined. In the case of the third mission, they include photography of 203 hectares of roaded but as yet uncleared 1972 extensions at Area F.
3. Costs for drafting and field checking are estimated at the rate of $250 and $50 per thousand hectare respectively.
4. Areas for 1970 plantings are actual; those for 1970 clearings are estimates and coincide with the clearing targets for each plantation (Except for Area G where the actual area is given).
5. The per ha costs for Area A is higher because the first attempt to photograph this area was abandoned due to unfavorable cloud cover.

TABLE 4. BREAK-DOWN OF TOTAL COST INTO MAJOR COMPONENTS FOR PHOTOGRAPHING AND MAPPING 4000 Ha OF PLANTATION EXTENSIONS.

Item	Cost in Dollars	Percentage of Total Cost
Photography	271	16
Aircraft hire	217	13
Map compilation	1,184	71
TOTALS	1,672	100

shutter be of a type that will operate at low temperatures.

(4) Enlarged prints provide the most practical form of photograph for mapping. The degree of enlargement is based on the ease of handling, annotation, and storage, or it may be fixed so that the scale of enlargements matches the scale of existing survey photographs or maps.

(5) Analysis of the major components of total cost for mapping 4 000 ha of plantation extensions showed that photography accounted for 16 percent, aircraft hire 13 percent, and map compilation 71 percent of the total cost.

(6) For an area of 365 ha located 270 km from base the cost of intensifying a map with the photographic techniques was 25 to 40 percent of the cost of field survey methods. The variation in cost depended on whether the area was photographed as part of a joint project or as a single project.

(7) The man-day requirement for intensifying a map with the photographic technique was 14 to 16 percent of the requirement for field survey methods.

(8) Photographs provide a detailed, permanent, and quickly retrievable record which can be used in future studies of an area.

There are certainly many advantages to the small-format camera system in plantation mapping. The same methods could be used with similar benefits in many other applications, not only in the field of forestry but also in other fields.

ACKNOWLEDGMENTS

The projects described have been conducted mainly for the Forests Commission, Victoria, but in part have evolved from postgraduate studies at the School of Forestry, University of Melbourne. Assistance has been provided in a variety of forms from colleagues in both organizations. In particular, the author is grateful to Dr. J. A. Howard of the School of Forestry at the University of Melbourne (now with the Remote Sensing Unit of the Agriculture Department, F.A.O.,

TABLE 5. COMPARISON OF COST AND LABOR INPUTS FOR MAP INTENSIFICATION BY FIELD SURVEY AND PHOTOGRAPHIC SURVEY TECHNIQUES FOR 365 Ha OF PLANTATION CLEARING IN AREA G WHICH IS LOCATED 270 km FROM BASE.

	Actual Photo Survey		Photo Survey as a Single Job		Field Survey	
	Man days	Cost* (Dollars)	Man days	Cost* (Dollars)	Man days	Cost* (Dollars)
Photography	1	71	2	180	—	—
Prepare/check/certify map	5	90	5	90	5**	100
Field Survey	1	18	1	18	32	418
Compilation/plotting in District.	—	—	—	—	12	200
TOTALS	7	179	8	288	49	718
Cost per ha		0.488		0.790		1.971
Percentage of field survey method.	14	25	16	40	100	100

* Inputs of cost are not proportional to inputs of labor (man-days) because of variations in rates of pay according to the class of work performed and variations in other cost factors.

** Checking of field compilations and plotting is necessary before final certification of plans by the responsible officer.

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