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Aerial Photographic Techniques for Soil Conservation Research

Soil erosion and catchment conditions were assessed in New Zealand's North Island by using a combination of conventional wide angle aerial photography and 70-mm format multispectral aerial photography.

Abstract: *Aerial photographic equipment and techniques used for soil conservation research in New Zealand are described. The equipment includes a large format aerial survey camera, for panchromatic aerial photography, and four 70-mm Hasselblad cameras mounted together for multispectral and multiemulsion aerial photography. Both systems are operated from a modified Cessna 206 aircraft.*

Introduction

Remote sensing techniques for rapid, cost-effective assessment of erosion in New Zealand have been discussed by Stephens (1976), Trustrum and Stephens (1978), and Stephens and Page (1980). For this research, aerial photographs using optimum film/filter combinations and scales must be taken in suitable times of day and seasons; further, film exposure, processing, and printing must be repeatable within very close tolerances. As New Zealand's aerial survey companies are generally not available to perform small aerial photographic jobs at strategic times, research organizations usually acquire and process their own imagery. The use of small format 70 mm cameras mounted in light aircraft and helicopters for research purposes has been discussed for Australian and European conditions by McCown *et al.* (1973) and Rhody (1977). The authors have found these cameras to be ideally suited for research work in New Zealand.

This paper describes the equipment and techniques used by the remote sensing group, Aokautere Science Centre, to conduct aerial photographic research for soil conservation in New Zealand, a geologically unstable country, where transitory changes of erosion and vegetation are more frequent than in most.

Equipment

Aircraft

A Cessna 206 has been modified (Figure 1) so that either a Wild RC-8 camera mount or a Williamson camera mount can be supported inside a protective bubble outside the aircraft cabin. The rear passenger door is removed and replaced by a camera mount support. This is a 6-mm thick aluminium plate, bolted to the aircraft floor and supported fore and aft by struts bolted to the fuselage. It has a 405-mm diameter hole in its center. The camera mounts are bolted on to the plate.

A large streamlined aluminium bubble encloses the mount support. It is in two parts: the forward part is attached to the forward passenger door permitting its use; the aft part is attached to the mount support, and protects the camera lenses and filters from the slipstream.

In flight, a Kollsman Mark VI driftsight is inserted into an aluminium tube protruding through the aircraft floor (Figure 1).

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FIG. 1. Streamlined aluminium bubble attached to the side of Cessna 206. The driftsight can be seen protruding through the floor of the aircraft.

The aircraft is equipped with a Scott Aviation portable oxygen system to enable an operating ceiling of 5500 m. An intercom system enables three-way conversation between navigator, photographer, and pilot.

CAMERAS

Two camera systems are used—a nest of four 70-mm format Hasselblads and a 230-mm format Williamson aerial survey camera.

The Hasselblad system comprises four 500 EL/M Hasselblad camera bodies and a matched set of four 150-mm Zeiss Sonnar lenses with 26° angle of view. The 500 EL/M is a light-weight, motor driven unit which has a self-contained 6 volt power supply. The cameras are mounted in a duplicate of the prototype multispectral camera mount developed by the Physics and Engineering Laboratory, DSIR (Physics and Engineering Laboratory, 1976). This, in turn, fits into a Wild RC-8 mount. Other Hasselblad camera mount systems have been described by Marlar and Rinker (1967), Keenan *et al.* (1970), and Ulliman *et al.* (1970).

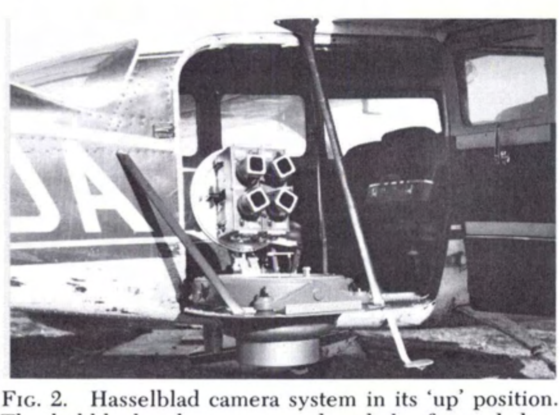

FIG. 2. Hasselblad camera system in its 'up' position. The bubble has been removed and the forward door opened for this photograph. Narrow band multispectral interference filters are fitted to the four lenses.

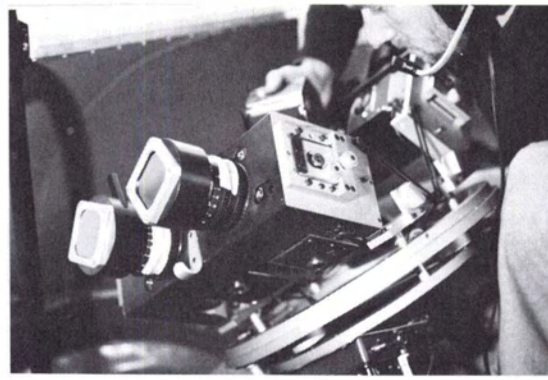

FIG. 3. Changing a magazine on one of the Hasselblad cameras. With the hinged mount adaptor, and cameras housed in two banks, this is easily accomplished while flying. The alignment screws for the camera in the foreground are seen on the end of the hinged camera support.

The hinge on the mount swings the cameras up from the mount support into the aircraft (Figure 2). The mount unfolds so that the filters and magazines can be fitted, and shutter speed/aperture settings adjusted (Figure 3). A Hasselblad command unit and intervalometer fire the four cameras simultaneously. Both are powered by the cameras' power supply. This camera system can be used for multispectral aerial photography as well as for multi-emulsion photography (i.e., with or without multispectral interference filters).

The mount is aligned parallel with an optically flat metal plate, by projecting a point source of light from a collimator on the plate, onto a mirror in the mount. The collimator is inclined at slight angle to the vertical so that the reflected beam strikes a target on the collimator base. By adjusting the mount so that the beam follows the target as the collimator base is rotated through 360°, parallelism is ensured. The procedure is then repeated for each of the four cameras, by removing the lens and inserting the mirror in the focal plane of each. The camera is rotated round two axes, by pressure plates linked to adjusting screws, (Figure 3) until parallelism is obtained. Deflection of the cameras' optical axes can be reduced to less than 0.1°, using this method developed by the Physics and Engineering Laboratory, DSIR.

The Williamson camera is a large format aerial survey camera manufactured in 1958 and designated the F.95 Mark II (or Eagle IX). It is fitted with a 150-mm Ross lens with a 90° angle of view, and a glass plate (with fiducial marks in the focal plane) against which the film is mechanically pressed. A rechargeable, portable 24 volt gel sel battery pack is used to power the camera and intervalometer (5 to 50 seconds). The Williamson camera mount has been modified to utilize the same mount support bolts as the Wild RC-8 mount, enabling quick interchange of the two cameras.

TABLE 1. 'NORMAL' FILM/FILTER COMBINATIONS USED FOR A TARGET OFTEN PHOTOGRAPHED (SLIP ERODED HILL COUNTRY IN PASTURE, EARLY SUMMER, SUN ANGLE LESS THAN 50°, AND ALTITUDE ABOVE MEAN GROUND LEVEL 1600m)

Camera	Type of Photography*	Film type	Filter	Shutter speed/ aperture setting
Hasselblad	ME	Plus-X (Kodak 2402)	UV/Wratten 12	1/500 f8 / 1/500 f5.6
Hasselblad	ME	Double-X (Kodak 2405)	UV/Wratten 12	1/500 f11 / 1/500 f8
Hasselblad	ME	Tri-X (Kodak 2403)	UV/Wratten 12	1/500 f16 / 1/500 f11
Hasselblad	ME	Colour negative (Kodak 2445)	UV	1/500 f8
Hasselblad	ME	Colour positive (Kodak 2448)	UV	1/250 f8
Hasselblad	ME	Colour infrared (Kodak 2443)	Wratten 12 + CC10M + CC10B	1/250 f8
Hasselblad	MS	Double-X (Kodak 2405)	MS 0 (400–500nm)	1/250 f11
Hasselblad	MS	Double-X (Kodak 2405)	MS 1 (500–600nm)	1/250 f11
Hasselblad	MS	Double-X (Kodak 2405)	MS 2 (600–700nm)	1/250 f11
Hasselblad	MS	Infrared (Kodak 2424)	MS 3 (700–800nm)	1/500 f11
Hasselblad	MS	Infrared (Kodak 2424)	MS 4 (800–950nm)	1/500 f11
Hasselblad	MS	Infrared (Kodak 2424)	MS 5 (700–950 nm)	1/500 f11
Williamson	SE	Plus-X (Kodak 2402)	Wratten 12 + antivignetting	1/200 f8
Williamson	SE	Double-X (Kodak 2405)	Wratten 12 + antivignetting	1/300 f8
Williamson	SE	Tri-X (Kodak 2403)	Wratten 12 + antivignetting	1/300 f11
Williamson	SE	Infrared (Kodak 2424)	Wratten 89B + antivignetting	1/300 f11

* ME-Multi-emulsion
MS-Multispectral
SE-Single emulsion

TABLE 2. FACTORS AFFECTING SPEED/APERTURE SETTING FOR AERIAL PHOTOGRAPHY

Factor	Change in 'normal' settings (Table 1) to expose film correctly			
	Double X-Kodak 2405		Infrared-Kodak 2424	
altitude down to 300 m	open aperture and/or increase shutter speed	½ stop	open aperture and/or increase shutter speed	½ stop
altitude up to 5500 m	close aperture	1 stop	close aperture	1 stop
haze	close aperture	½ stop	close aperture	½ stop
season-mid summer	close aperture	½ stop	close aperture	½ stop
-mid winter	open aperture	1 stop	open aperture	1 stop
time of day-mid-morning	open aperture	½ stop	open aperture	½ stop
-mid-afternoon	close aperture	½ stop	close aperture	½ stop
sun angle above 50°	close aperture	½ stop	close aperture	½ stop
vegetation-healthy	open aperture	½ stop	close aperture	½ stop
-'sick'	close aperture	½ stop	open aperture	½ stop
dry soils and rock outcrops of high reflectance	close aperture	1 stop	close aperture	1 stop
moist/wet features	open aperture	1 stop	open aperture	1-2 stops

N.B. For features of very high contrast (e.g., snow and bare ground) films are over-exposed and under-developed for satisfactory print tonal range.

FILMS AND FILTERS

The range of film types and lens filters is shown in Table 1. For each camera/film/filter combination a 'normal' shutter speed/aperture setting is given for a target often photographed (slip-eroded hill country in pasture, early summer, sun angle less than 50°, and altitude above mean ground level 1600 m). These 'normal' shutter speed/aperture settings for a particular film/filter combination must be subjected to further fine adjustment depending on altitude, time of year, time of day, sun angle, and haze conditions (Table 2).

Whenever possible, the same aperture settings are used on all lenses for multispectral aerial photography. This ensures that each multispectral image has similar lens fall-off characteristics, aiding composite printing. For multispectral interference filters 0, 1 and 2, Double-X (Kodak 2405) film is used in preference to Plus-X and Tri-X (Kodak 2402 and 2403, respectively) to achieve the optimal combination of film speed, resolving power, and granularity. For interference filters 3, 4, and 5 infrared (Kodak 2424) film is used.

Spectral transmittances of the six Spectra Optics interference filters are shown in Figure 4. Interference filters are used in preference to absorption filters, due to their high transmission and sharp cut-off at either end of each spectral band.

PROCESSING AND PRINTING

Film exposure and processing are critical for accurate production of multispectral color composites. A photographic step tablet is exposed on both ends of each black-and-white film to monitor the processing. 70-mm film is processed in a Mafi Universal processor, while 230-mm film is processed in Smith rewind type developing tanks. Kodak DK-50 developer is used for processing infrared film (Kodak 2424) to a gamma of 1.7. Panchromatic films (Kodak 2405 and 2402) are processed to gammas of 1.5 and 1.1, respectively, using Kodak DK-50 developer. Multispectral negative gammas are made as high as possible without placing targets of interest on either the toe or shoulder of the characteristic curve. Color positive (Kodak 2448) and color infrared (Kodak 2443) are processed using Kodak E4 chemicals, while color negative (Kodak 2445) is processed in E4 chemicals and C-22 developer.

Multispectral color composite prints are produced from contact positive or negative trans-

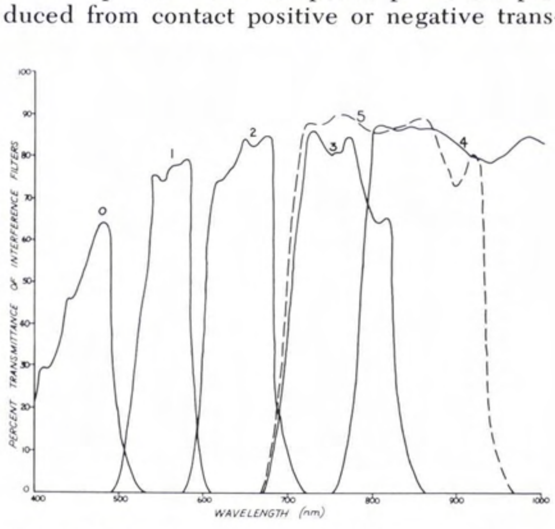

FIG. 4. Spectral transmission of multispectral interference filters 0 to 5.

parencies, made with expanded density ranges to increase discrimination among targets of interest. Up to three contact positives or negatives are successively projected, by a De Vere color enlarger, onto a common registration print, and aligned with it, then exposed through primary separation filters onto color print paper. A computer program is being developed to select the combination of negatives, positives, and filters which gives the greatest visual color enhancement. The production method has been developed from Romijn (1977) and is discussed in detail by Trustrum *et al.* (*in prep*).

The resolutions of processed films from each camera are shown in Table 3. These resolutions are a function of film processing as well as film type and camera parameters. (See Kodak Aerial Exposure Computer R10). They impose practical limits on the interpretation of small objects.

Costs

Table 4 shows the relative costs of photographing a 100 km² area with the two camera systems. Costs associated with pre-flight planning, capital equipment and its depreciation, and overheads are not included. As costs are dependent on photographic scale, the large format Williamson camera is cheaper than the small format Hasselblad cameras, particularly at scales less than 1:20,000 (Figure 5a). The cost advantage of the Williamson camera is markedly reduced if small-scale Hasselblad negatives are enlarged to prints at the required scale. However, the resolution of enlarged Hasselblad prints is less than Williamson contact prints of the same scale, e.g., Williamson 1:5,000 contact prints have a resolution of 0.2 m whereas enlarged Hasselblad 1:5,000 prints (from 1:15,000 negatives) have a resolution of 1.0 m.

The Williamson is less versatile than, and is best used as a complement to, the Hasselblad cameras to survey entire catchments, storm-damaged areas, or river channels, and the Hasselblads to sample these areas at larger scales with a wider range of film types.

Use of Aerial Photography for Assessing Soil Erosion and Catchment Condition

The equipment and techniques outlined in this paper are being used to develop an aerial photographic method of assessing soil erosion and catchment condition in New Zealand's eastern North Island hill country, of which 1400 km² was severely eroded by the winter rains of 1977. Catchments in this region are underlain by unconsolidated, tectonically deformed Tertiary sediments. Intense, local rainstorms alternate with

Table 3. Resolution of Processed Films
Williamson Camera

Photographic scale	Resolution (line pairs/mm)*	Ground Resolution (m)
1:10,000	25	0.4

* Film type : Kodak 2402
Processing : DK-50 developer, 9 minutes at 20°C
Shutter speed : 1/300
Aperture : f8
Ground Speed : 100 knots
Target : High contrast, black-and-white lines (non standard)

Hasselblad Cameras

Photographic scale	Resolution (line pairs/mm)*		Ground Resolution (m)	
	0,1 and 2⁺	3,4 and 5⁺	0,1 and 2⁺	3,4 and 5⁺
1:10,000	25	25	0.4	0.4

⁺ Interference filters

	0,1 and 2 filters	3,4 and 5 filters
* Film type	Kodak 2405	Kodak 2424
Processing	DK-50 developer, 9 minutes at 20°C	DK-50 developer, 9 minutes at 20°C
Shutter speed	1/250	1/500
Aperture	f11	f11
Ground speed	100 knots	100 knots

Target : High contrast black-and-white lines (non standard).

TABLE 4. COMPARISON OF AERIAL PHOTOGRAPHIC SURVEY COSTS FOR A 100 km² AREA

Scale	1:10,000 (Hasselblad) (negative scale)	1:10,000 (Hasselblad) (print scale)	1:10,000 (Williamson) (negative/ print scale)	1:20,000 (Hasselblad) (negative scale)	1:20,000 (Hasselblad) (print scale)	1:20,000 (Williamson) (negative/ print scale)	1:30,000 (Hasselblad) (negative scale)	1:30,000 (Hasselblad) (print scale)	1:30,000 (Williamson) (negative/ print scale)
Number of runs	20	6	6	10	3	3	7	2	2
Number of photographs	800	78	72	210	21	18	105	10	8
Cost of plane,* pilot and crew wages for an area									
a) 100km from base	$750	$390	$310	$430	$300	$220	$360	$230	$230
b) 200km from base	$890	$530	$450	$560	$450	$370	$540	$390	$390
c) 400km from base	$1,160	$810	$730	$820	$730	$650	$820	$700	$700
Cost of film*, processing, printing, and photo technician wages for:									
a) Panchromatic	$640	$ 60	$120	$160	$ 20	$ 30	$ 80	$ 10	$ 10
b) 4 Black-and-white multispectral prints	$2,510	$250		$650	$ 70		$330	$ 30	
c) Color or color infrared	$1,800	$180		$470	$ 50		$240	$ 30	
d) Multispectral color composites (3 band)	$3,700	$360		$970	$100		$460	$ 50	

* Costings are based on the following:

Hire of plane and pilot $79.0/hr without oxygen and $90.0/hr with oxygen. (Assumed use of suitable aircraft at this hire rate for high altitude small scale Hasselblad photography to determine print scale costs).

Cruising speed of plane 120 knots

Photographic speed 100 knots

Wages, $4.00 per hour

Costs for film, chemicals, and papers at standard Kodak rates

All Hasselblad imagery printed on 19 × 19 cm paper (i.e., 3.37 × enlargements); Williamson imagery contact printed.

NZ$

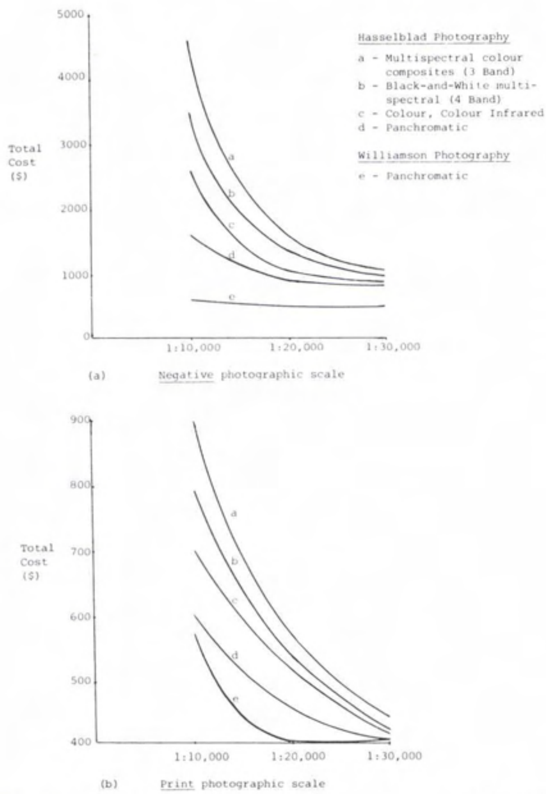

FIG. 5. Aerial survey photographic cost comparison calculated for a 100 km² area situated 200 km from base. (Source: Actual Remote Sensing Group costs, 1978/79.)

long droughts. The terrain is dissected by incised streams, and pocked by slope failures (Figure 6). Assessment of erosion on the ground is hampered by poor vehicle access, high survey costs, the subjectivity of visual inspection, and the absence of permanent photographic records.

FIG. 6. Part of a large format aerial photograph of an area in the Wairarapa, eastern North Island, New Zealand. Photographs such as this are used to assess erosion and catchment condition. Original photographic scale was 1:10,000.

1:5,000 multispectral photographs (Figure 7), taken on transects representative of different land-use capability classes, are used to define the catchment condition and erosion classifications. 1:10,000 panchromatic photographs (Figure 6) are used to extend these classifications to the entire survey area.

The selection of representative transects to photograph with the multispectral cameras, conduct of field work, formulation of the land-use capability, catchment condition and erosion classifications, and systematic interpretation of both small and large format photographs are discussed by Stephens *et al.* (in prep.).

The authors concluded that:

- Aerial photographic assessment of erosion and catchment condition is cheaper, faster, and more accurate than visual assessment on the ground. It also provides a permanent record for future reference.
- Large-format panchromatic photography, due to its cheapness, is the best medium for rapid erosion assessment, by virtue of its adequate detection of bare ground's characteristically high reflectance.
- Multispectral color composite prints are superior to other forms of photography used, as an aid in catchment condition assessment, e.g., detection of old, revegetated erosion scars, determination of pasture grasses' vigor, and assessment of relative soil moisture variations on vegetated and unvegetated sites alike.
- Black-and-white films used for multispectral photography are more stable, and less exposure-critical, than color and color infrared films. They tolerate targets with markedly different reflectances. Yet targets which have subtle differences in reflectance can be given strong color contrasts in the course of color composite printing.
- Small-format multispectral photography is too expensive and time consuming for coverage of large tracts of countryside at the negative scales normally used for large format panchromatic photography. The user must choose between sample coverage by large-scale negatives, or complete coverage by prints enlarged from small scale negatives.

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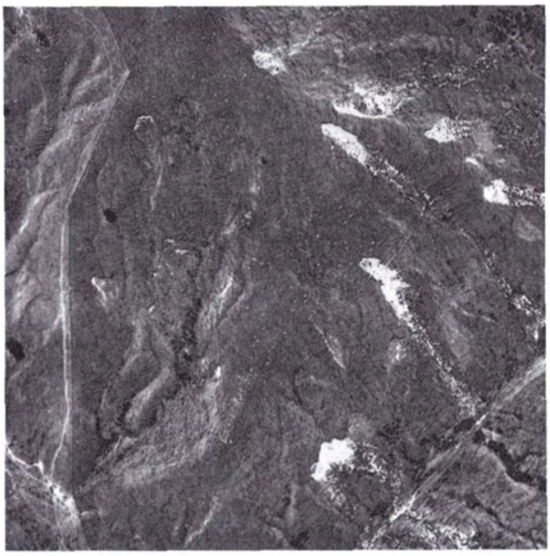

Multispectral Band 1
(500-600nm)

Multispectral Band 2
(600-700nm)

Multispectral Band 3
(700-800nm)

Multispectral color composite
(Bands 1, 2, and 3 combined)

FIG. 7. A color composite and three narrow band multispectral photographs of a scene in the Wairarapa. Erosion and vegetation are enhanced in the color composite, aiding detailed mapping. Original photographic scale was 1:5,000.

early in the program. Mr. J. A. Plank (owner of the Cessna 206) for providing the aircraft and designing and manufacturing the aircraft modifications. Mr. J. Veale, who has been the Group's regular pilot. Miss M. Christensen-Widt, who has been responsible for processing and printing aerial films. Mrs. D. Gilbert and Miss D. Brook for typing the paper. Photographs: Remote Sensing Group, for Figures 5 and 6; Mr. N. A. Trustrum, for Figures 2 and 3; and Mr. P. R. Stephens, for Figure 1.

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