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A camera and interpretation system for assessment of forest regeneration



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**A CAMERA AND INTERPRETATION SYSTEM FOR ASSESSMENT
OF FOREST REGENERATION**

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ABSTRACT

Spring and fall aerial photography at scales of 1:150 to 1:15 000 was evaluated for assessment of coniferous forest stocking in stands greater than 30 cm in height in Alberta, Saskatchewan, and Manitoba. Two film types were used: Kodak aerocolor negative (2445) and color infrared (2443). Aerial photography with aerocolor negative film at scales from 1:200 to 1:400 was found to be most suitable for assessment of forest regeneration above 30 cm in height. Two Vinten 70-mm cameras were used to obtain the photographs, and a Honeywell radar altimeter provided a digital readout of aircraft height above ground (10-600 m) for accurate ($\pm 3\%$) scale control. Radar heights were recorded on the aerial photographs through the secondary optical system of one of the cameras. Considerable cost reduction in surveys of regeneration greater than 30 cm in height can be achieved by using a multistage sampling design employing two 70-mm cameras with 77- and 280-mm focal length lenses. Timing the aerial photography for early spring and late fall is essential to obtain good contrast of the coniferous seedlings against a background of dead grasses and herbs.

RESUME

L'auteur a étudié des photographies aériennes aux échelles 1:150 à 1:15 000 pour évaluer le degré de densité en conifères dans des peuplements de plus de 30 cm de hauteur de l'Alberta, de la Saskatchewan et du Manitoba. Il a utilisé deux types de films: le film Kodak aérocolor négatif (2445) et le film en couleurs à l'infra-rouge (2443). Les photographies aériennes avec le film aérocolor négatif aux échelles 1:200 à 1:400 se sont avérées les meilleures pour évaluer la régénération forestière au-dessus de 30 cm de hauteur. Deux caméras Vinten de 70 mm ont servi pour les photographies, puis un altimètre radar Honeywell a fourni une lecture numérique de la hauteur de l'aéronef au-dessus du sol (10-600 m) pour contrôler l'échelle avec précision ($\pm 3\%$). Les hauteurs au radar furent enregistrées sur les photographies aériennes au moyen du système optique auxiliaire de l'une des caméras. On peut réduire sensiblement le coût des relevés de régénération dépassant 30 cm en utilisant un plan d'échantillonnage multiple avec deux caméras de 70 mm munies de lentilles à distances focales de 77 et 280 mm. Il est essentiel de photographier par voie aérienne tôt le printemps et tard l'automne pour obtenir un bon contraste entre les semis de conifères et un fond d'herbes et de graminées mortes.

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NOTE

The exclusion of certain manufactured products does not imply rejection nor does the mention of other products imply endorsement by the Canadian Forestry Service.

INTRODUCTION

Forest managers are continually in need of timely and economical information for determining where silvicultural treatment should be applied and, subsequently, how effective it has been. It is estimated that Canada requires up to \$350 million per year to reforest recently cut-over lands and older cuts that have not regenerated (Newnham 1978). These future forests will necessitate better evaluation of silvicultural methods through the use of more efficient and economical assessment techniques than have been possible with ground sampling alone.

This paper describes a camera and interpretation system developed at the Northern Forest Research Centre (NFRC) in Edmonton for the assessment of forest stocking. The camera system incorporates a radar altimeter that had not been tested for large-scale photo sampling. The interpretation system uses a desk-top computer that facilitates plot measurements and their compilation into average stand and stock tables by various forest cover types. In this report, tests of large-scale photo sampling in Alberta, Saskatchewan, and Manitoba are evaluated, and appropriate sampling designs for estimating coniferous stocking on cut-over forest lands are presented.

CAMERA AND INTERPRETATION SYSTEMS

Camera System

A relatively low-cost, highly portable 70-mm camera system with a radar altimeter (Fig. 1) that provides scale data was developed at NFRC and has been in use since 1973. The camera and radar altimeter may be mounted in camera hatches in a variety of aircraft or externally on helicopters. Average installation time is 2 hours or less.

Two types of 70-mm Vinten reconnaissance cameras are used: type 492 has a built-in secondary optical system that permits information such as the altimeter reading and time of exposure to 1/100 s to be recorded on the negative; type 518 has optional image

motion compensation and a higher framing rate of up to 12 frames per second if desired. The cameras have rotating focal plane shutter blinds that provide shutter speeds of 1/1000 or 1/2000 s, depending on the slit width and the cycling rate. Four different focal length lenses may be attached: 44.5, 77.5, 152.9, and 281.9 mm. The magazine can be changed quickly and has a vacuum pressure platen to hold the film flat. It takes a 30-m roll of 70-mm film, which is enough for approximately 500 exposures. The vacuum for the camera is provided by a small pump. In addition, larger-capacity magazines may be obtained if required.

Both Vinten cameras are mounted on a modified A-11-A mount, which fits an aircraft hatch 45 cm or larger in diameter. Quick-release screws permit the cameras to be moved up or down or to be removed completely in flight when lens or filter changes are necessary. L-shaped brackets are available for the Vinten cameras for external mounting. These brackets have proved to be versatile and have been mounted on a number of different types of helicopters. With either mount, vibration is not a problem because of the high shutter speeds of the cameras.

An intervalometer used to control the cameras was designed and built at NFRC (van Eck and Bihuniak 1978). It has a sampling feature that permits one camera to group a number of photographs together, to regulate the time between exposures within the group, and to change the interval between groups. With this feature, both cameras can be used to provide sampling photography. For example, in regeneration assessment one camera with a short 44.5- or 77.5-mm focal length lens photographs the track continuously, while the other camera, equipped with a 281.9-mm focal length lens and using the sampling feature, intermittently takes stereotriplets or longer bursts. These triplets or bursts, which have a scale approximately seven or four times larger than the strip photographs (depending on the ratio of the focal lengths of the lenses used), can be used then as aerial sample plots. Their positions can be located on smaller-scale maps or photographs with the aid of the continuous strip photography.

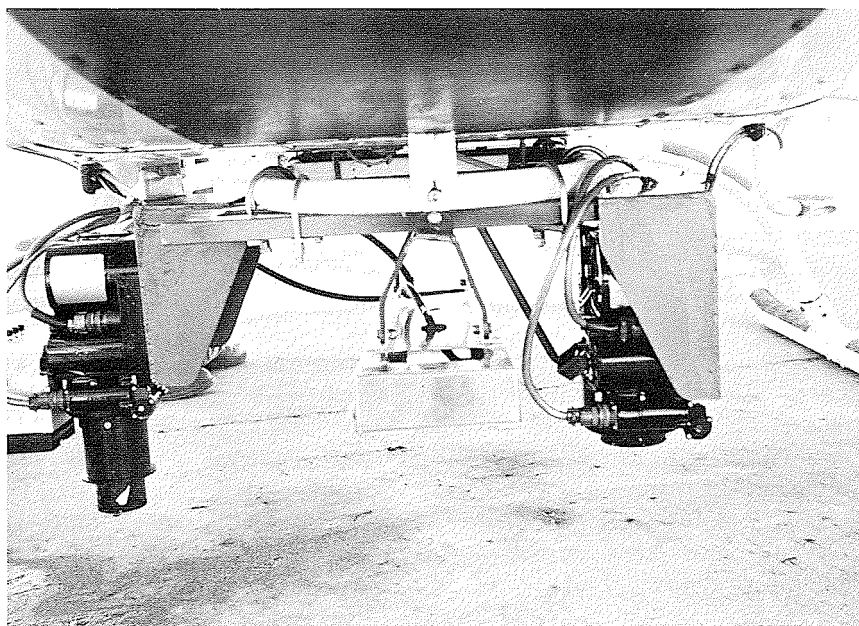


Figure 1. Two Vinten cameras and a radar altimeter mounted on a Bell 206B helicopter.

The cameras, intervalometer, and radar altimeter require 6 A of current at 24 V DC. Power may be supplied by the aircraft or by two Globe 20 A·h, 12 V gel/cell[®] aircraft-approved batteries connected in series. This will operate the system for 2 to 3 hours.

Radar Altimeter

The Honeywell radar altimeter (model AN/APN-194 (v)) is composed of a receiver-transmitter, two antennae, an analog height indicator, and a digital height display on light emitting diodes. This display is recorded on each photograph through the secondary optics of one of the cameras. The radar altimeter is a lightweight (5 kg), high-resolution, short-pulse system, and its advanced design provides for a precision of $\pm 3\%$ or better in estimating aircraft height above terrain from 0 to 600 m (Kirby and Hall 1980). The altimeter is not affected by pitch and roll and is without slant range errors. In addition, it has continuous resolution without step errors, complete immunity to Doppler effect, accurate indication over ice and snow-covered surfaces, and all-weather operation in heavy rain or snow. Operating frequency is 4.3 GHz, with a pulse repetition rate of 8.5 kHz. Peak radiated power is 100 W. The transmission antenna contains the energy within an approximately 35° cone-shaped pattern. Smaller cone shapes may be achieved with a different antenna, if required.

Interpretation System

The measurement of large-scale aerial photo sampling plots has been facilitated by

the interfacing of a Zeiss-Jena Interpretoskop and a Hewlett-Packard 9825A desk-top computer (Fig. 2). The movement of the overhead carriage is measurable in X and Y directions to the nearest 0.25 mm and in the Z direction (parallax measurement) to the nearest 0.01 mm. Measurements of X, Y, and Z can be recorded by the computer at the press of a button. Computer programs have been written to calculate and record individual measurements of tree height, crown area, and tree position and to produce plot maps and stand-and-stock tables for one plot or a group of plots of a given cover type.

METHODS

Three tests were conducted in 1973-78 using large-scale aerial photography for sampling coniferous regeneration on clear-cuts in Alberta and partial cuts in Saskatchewan and Manitoba.

In Alberta, aerial photography of clear-cut areas was obtained in May 1973 and 1978 at 70, 560, and 1200 m above the ground from a Bell 206B helicopter. The aerial photography in Saskatchewan was obtained in May 1975 and 1976 using a Piper Aztec twin-engine aircraft, and in Manitoba it was obtained in October 1974 using a single-engine Otter. The fixed-wing aerial photography was obtained at an altitude of approximately 250 m above ground.

The use of the two-camera system is illustrated in the following technical specifications for aerial photography on a bright, sunny day in May.

	Camera 1	Camera 2
Lens focal length	281.9 mm	77.45 mm
Shutter speed	1/1000 or 1/2000 s	1/1000 s
Intervalometer setting	1/4 or 1/6 s	Variable, to produce 75% overlap
Lens opening	f5.6 or f4.8	f4.5
Film (Kodak)	Aerocolor negative (2445)	Color infrared (2443)
Filter	UV	Wratten 12

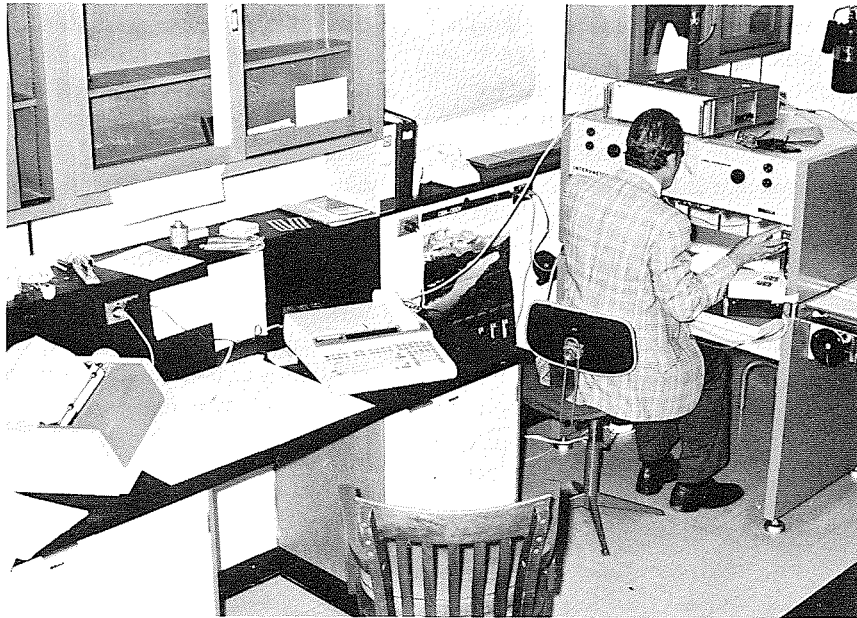


Figure 2. Zeiss-Jena Interpretoskop interfaced with a Hewlett-Packard 9825A desk-top computer for rapid and accurate large-scale photo plot measurement and compilation.

For aerial photography at a scale fraction of 1:250 it is necessary to use a helicopter flying 70 m above ground with a forward speed of 80 km per hour. For scales larger than 1:500 it is possible to use a fixed-wing aircraft with forward speeds of 200 km per hour or faster, depending on the altitude of the aircraft.

Timing of the aerial photography is critical. Photographs were taken in May before green-up of grasses, herbs, and shrubs and leaf-out of poplar (*Populus* spp.) or in October after leaf fall and browning of the grasses. All aerial photography was taken between 10 a.m. and 2 p.m. so that shadows on the ground were at a minimum.

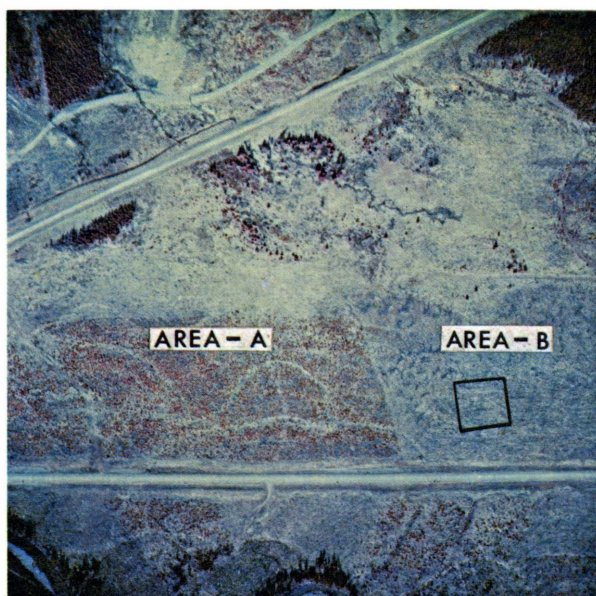
RESULTS

Alberta

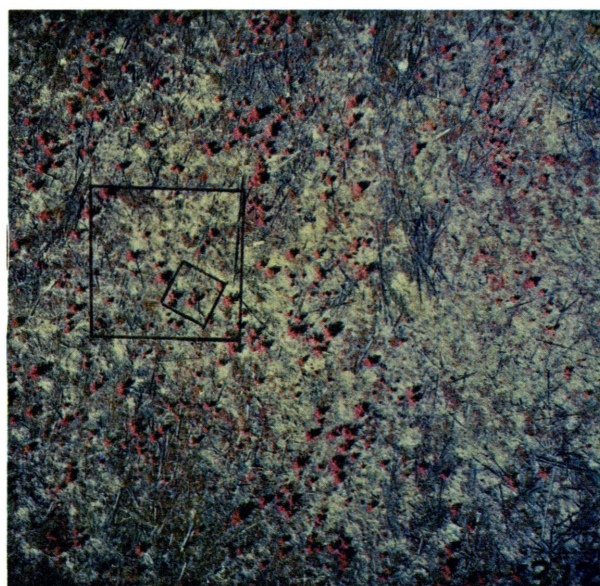
Color infrared photography obtained at 1200 m above the ground (Fig. 3A) was

used for locating and plotting photo sampling strips. At a scale of 1:16 000 it shows regeneration 2 m high and taller but does not indicate regeneration up to 1 m in height. The 1-m-high regeneration is just visible at a scale of 1:2000 (Fig. 3B).

Large-scale photographs in color at a scale of 1:250 and in color infrared at 1:1000 were obtained simultaneously at 70 m above the ground. The 1:250 color photographs (Fig. 3D) were used for sampling at 80-m intervals. Lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) 30 cm and higher is nearly 100% visible except when in clumps or hidden by shadows from stumps or standing trees. Forty percent of the lodgepole pine 15 to 30 cm in size were detected on the color aerial photographs at 1:250 (Fig. 3C). Similar results were obtained with color infrared film, although there was initially some confusion in distinguishing 15- to 30-cm-high lodgepole pine seedlings from bearberry (*Arctostaphylos* spp.), a shrub that also has high infrared reflectance. Once the interpreter



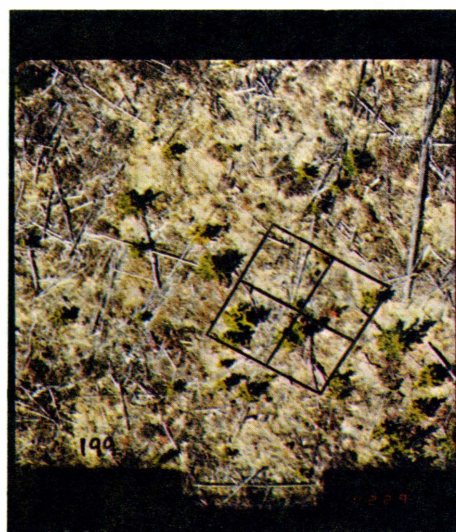
A. Color infrared, original scale 1:16 000. Note that area A lodgepole pine 4 m high are visible, but lodgepole pine 0.5 m high in area B are not detectable on the photograph.



B. Color infrared, original scale 1:1000. The 0.5-m-high lodgepole pine regeneration is now detectable on the photograph. Note the four 2 X 2 m plots that are on the photograph below.



C. Color infrared, original scale 1:250. Lodgepole pine as small as 15 cm in height are detectable. Note that patches of bearberry also appear pink to red in the photograph.



D. Color, original scale 1:250. This aerial photograph was obtained simultaneously with the infrared photography of photo B directly above. Note the four 2 X 2 m plots; stumps 20 cm high may be used as guides for estimating seedling height.

Figure 3. Examples of 70-mm color infrared and color aerial photographs for estimating forest regeneration. A, B, and C photographs enlarged X 1.25.

became aware of this problem, he was able to discriminate between the two.

The complete strip color infrared photo coverage at a scale of 1:1000 also showed lodgepole pine regeneration 30 cm and higher with approximately 80% accuracy.

Manitoba

The aerial photography used in this test was obtained in the fall. One thousand paired ground and photo 2 X 2 m plots showed that only 15% of the spruce seedlings up to 30 cm in height could be identified on the photos. There was nearly 100% detection of spruce seedlings 90 cm high and taller. For stocked 2 X 2 m samples, the photos indicated 10% lower stocking than the ground survey. A regression equation for this survey is shown in Fig. 4, which compares results from ground and photo estimates of 10 clusters of 100 2 X 2 m sampling units.

Saskatchewan

Color aerial photography at 1:500 was obtained in the spring in areas partially cut 10 or more years earlier (Ball and Kolabinski 1979). Photo samples were obtained at 100-m intervals on 90 km of flight lines in five areas. Approximately 880 paired 2 X 2 m photo and ground plots were established. Nine percent of the plots established were not clearly visible because of shadow and were rejected from the sample. Of the remaining 803 2 X 2 m plots estimated to be stocked or not stocked, 90% of the photo plots were correctly identified as to stocking status. Table 1 presents results from the test areas.

CONCLUSIONS AND RECOMMENDATIONS

Large-scale photo sampling (LSP) of coniferous forest regeneration 30 cm and taller is technically possible and may be an economical alternative to ground surveys when access is difficult and costly. Those

areas that appear stocked on large-scale photographs require no further ground checks, as seedlings not visible on the photographs provide a margin of safety. Evaluation of stocking with LSP techniques may reduce regeneration survey costs by eliminating the need for costly ground surveys of areas that obviously are stocked. In addition, LSP could provide a monitoring capability for subsequent mortality or ingress of regeneration. A disadvantage is that differentiation of tree species such as pine, spruce, and fir (*Abies* spp.) less than 90 cm high is not always possible. The main advantages are that a much larger sample may be obtained (up to 100% coverage) and that precise estimates of stocking may be obtained for coniferous regeneration over 30 cm in height.

A two-stage photo sampling design is recommended in which two scales (1:250 and 1:1000) of 70-mm aerial photography are obtained simultaneously. The larger-scale (1:250) color photography is used to sample the regeneration at prescribed intervals. The smaller-scale (1:1000) color infrared photography is used for mapping the clear-cut to indicate unstocked areas, damage situations, and required stratification for subsequent sampling.

The cost of obtaining large-scale aerial photographs will vary with objectives and amount of ferry time required by the helicopter. Assuming ferry time is minimal, approximately \$18 per plot (36 2 X 2 m subplots) would be required at 1979 prices and with a two-stage sampling design as suggested. It appears that large-scale photo sampling techniques may be considerably less expensive than ground sampling, which on the average costs \$4 per 2 X 2 m subplot. Photo sampling techniques are not suitable for estimates of regeneration below 30 cm. They are best suited to large surveys such as that done in Saskatchewan by Ball and Kolabinski (1979). Expensive ground surveys then may be focused on areas obviously not stocked with seedlings 30 cm or greater. Further application of large-scale aerial photography is planned for a survey in the Yukon in 1980.

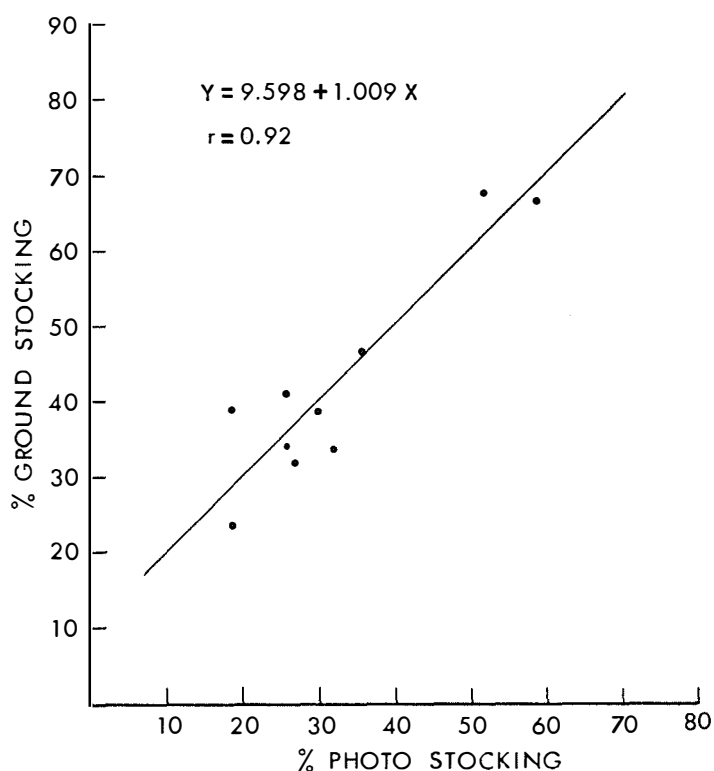


Figure 4. Regression of stocking obtained from 10 paired ground and photo plots (20 X 20 m). Each plot estimate was based on measures from 100 2 X 2 m sub-samples.

Table 1. Comparison of photo and ground measurements of percentage stocking of visible softwood regeneration on six test areas in Saskatchewan

Location	Percent of quadrats stocked			No. of 2 X 2 m quadrats compared
	Photo: visible	Ground: seedlings ≥ 30 cm	Ground: all	
Greenbush	13.6	12.8	18.3	263
Somme	14.2	20.1	23.5	161
McBride Lake	6.3	7.6	11.1	179
Bertwell ¹	0	0	0	40
Armit	65.9	61.6	65.8	160
All	22.8	23.0	27.2	803

¹ There was no apparent softwood regeneration on the ground or on the aerial photographs.

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