LARGE-SCALE BLACK AND WHITE AND NATURAL COLOR PHOTOGRAPHS FOR THE MEASUREMENT OF TREE CROWN AREAS

R.J. Morton*, R.J. Hall **, R.K. Nesby *** and I. Sutherland ****

ABSTRACT

Tree crown area, measured on large-scale aerial photographs, is a frequently estimated forest inventory variable. There is uncertainty, however, regarding the accuracy to which crown area can be measured on various scales and film types. In order to address this question, a controlled factorial experiment was conducted to test differences in performance between two film types (color, black and white panchromatic), four scales (1:500, 1:1000, 1:2000, 1:3000) and two experienced interpreters. Crown area targets were specially constructed to resemble typical tree crown outlines. The accuracy response variable used in this analysis was the absolute deviation between the known crown target area and the photo-estimate of that target area.

Major differences in accuracy were observed between scales, with minor differences evident between films and interpreters. There were no significant differences between the photo estimates and known target areas using any of the 1:500 or 1:1000 photography, however, the minimum differences were encountered on the black and white 1:1000 photographs.

LA PHOTOGRAPHIE NOIR ET BLANC ET EN COULEURS NATURELLES A GRANDE ECHELLE POUR MESURER LA SUPERFICIE DE CIMES D'ARBRES

RESUME

L'indice de cime, telle que mesuré sur les photographies aériennes à grande échelle, est une variable de l'inventaire forestier qui fait souvent l'objet de calcul. Toutefois, il existe une certaine incertitude concernant l'exactitude avec laquelle l'incide de cime doit être mesuré compte tenu des diverses échelles et des différents types de films utilisés. Pour résourdre cette question, une expérience factorielle contrôlée a été réalisée pour tester les différences de rendement entre deux types de films (couleur, panchromatique noir et blanc), quatre échelles (1/500, 1/1000, 1/2000, 1/3000) et deux interprètes expérimentés. Les cimes cibles ont été spécialement construites de façon à ressembler aux cimes d'arbres typiques. L'exactitutde de la variable de réponse utilisée dans cette analyse a été l'écart absolu entre la superficie connue des cimes cibles et l'évaluation par photographie de la superficie visée.

Les différences de précision ont été importantes entre les échelles mais mineures entre les films et les interprètres. Aucune différence significative n'a été révélée entre l'évaluation des photographies et les zones cibles connues suite à l'utilisation de photographies à 1/500 ou 1/1000; cependant, les photographies en noir et blanc à 1/1000 ont produit les différences les moins grandes.

Keywords/Mots-Clés: large-scale photographs, mensuration, inventory (forest), tree crown area.

* Silvacom Ltd., Edmonton, Alberta
** Canadian Forestry Service, Edmonton
*** Alberta Energy and Natural Resources, Edmonton
**** Alberta Remote Sensing Centre, Edmonton

Morton, R.T.; Hall, R.J.; Nesby, R.K.; Sutherland, I. 1986. Large-scale black and white and natural color photographs for the measurement of tree crown areas. Pages 133-140 in M.D. Thompson and R.J. Brown, editors. Proceedings of the 10th Canadian symposium on remote sensing, May 5-8, 1986, Edmonton, Alberta. Canada Centre for Remote Sensing, Ottawa.

INTRODUCTION

Tree crown areas, as estimated on large-scale aerial photographs (LSP), have been used with estimates of tree height as a predictor of stem diameter and tree volume (Aldred and Sayn-Wittgenstein 1972; Kirby and van Eck 1977; Nielsen et. al., 1979; Jano 1980). The accuracy with which tree crown area measurements can be made is uncertain due to the difficulty in obtaining ground measurements. Crown area is difficult to define from beneath a tree, and it is not known what part of the crown an interpreter sees on the photographs (Paine 1981). Aldred and Sayn-Wittgenstein (1972) addressed the issue and concluded that it was not of serious consequence whether photo-measured crown dimensions were significantly different from ground measurements provided photo measurements were repeatable. Although their study exhibited technical merit, questions remain:

- What is the effect of film type and scale on the accuracy of measuring crown area?
- How accurately can crown area be measured?

The objective of this study was to determine the effects of film, scale, and the additional effects of radar altimeter calibration, and interpreter differences, on the accuracy of measuring crown areas by comparing photo measurements to known target areas.

METHODS

Crown Area Target Construction and Layout

Irregular-shaped targets were constructed to resemble the geometry, in terms of size and shape, of typical tree crowns as viewed on vertical photographs (Figure 1). The targets were digitized to obtain their exact area, which ranged from 0.7 to 7.9 m^2 (Table 1).

Table 1. Areas of Crown Area Targets

Target number	Area (m^2)
1	0.9
3	0.7
5	1.2
16	1.2
17	1.3
18	1.4
19	1.4
21	3.6
22	6.1
23	5.9
24	7.9

The crown area targets were placed in an array (Figure 2) across an open area over which the large-scale aerial photographs were acquired. The spatial arrangement of the targets also provided ground control for radar calibration of the acquired imagery.

Photo Acquisition

LSP were acquired in October, 1985 using Kodak Double-X Aerographic 2405 and Kodak Aerocolor Negative 2445 films. Nominal scales of 1:500, 1:1000, 1:2000, and 1:3000 were acquired sequentially over the crown area targets. Each scale was flown more than once. The photos were acquired using the Canadian Forestry Service aeronautically-approved 70-mm aerial camera system with radar altimeter (Hall 1984) mounted on an Alberta provincial government helicopter. Measurement photos were taken with a Vinten 492 camera and calibrated 152 mm lens. The aircraft speed was varied to ensure that the photogrammetric parameters of overlap (70% nominal), camera cycling, and image motion (not greater than 25 micrometres) across all photo scales were as equal as possible. Focusing shims to maintain sharp focus were utilized as required. Continuous contact prints were produced from which measurements were made.

Photo Scale Calibration

Scale calibration was included as an additional factor in the analysis of accuracy attained on the selected film/scale combinations to address the question:

- Is the accuracy of estimating tree crown areas improved when flying heights, determined by the radar altimeter, are calibrated using ground measurements?

The procedure followed that of Kirby and Hall (1979), and consisted of relating scale check measurements of height above ground in a simple linear regression model. An equation was produced for each of 1:500, 1:1000, 1:2000 and 1:3000. The observations were derived from the range of heights occurring at each scale. Distances between identifiable features, (eg., fallen logs), in addition to the array of targets, provided several observations from which the actual photo-scales were calculated.

Three levels of the calibration factor were recognized in this experiment:

1. radar height above ground (uncalibrated)
2. calibrated radar height above ground

3. actual measured photo scale using ground measurements

Photo Interpretation

Photo measurements were performed using a Zeiss G-2 Stereocord and Hewlett Packard 9825 microcomputer. The measurement software was modified to include radar calibration factors for computations, and tabular outputs to facilitate keypunching and data compilation. The photo measurement procedures were slightly modified from those employed in operational forest inventories and included:

1. Pin-prick and mount stereopair.
2. Digitize fiducial points.
3. Digitize principle and conjugate points at ground level.
4. Digitize dummy plot corners starting with upper left corner and enclosing crown area targets.
5. Establish ground datum by digitizing points within plot area. If there is any significant relief within the plot area, then the ground points should be digitized where the relief breaks.
6. Digitize crown areas.
7. Receive output from printer.

Two experienced photo-interpreters participated in this study. During the interpretation sessions, the interpreters did not observe the results of their photo measurements, and were not informed of target sizes. Interpreter learning bias was therefore minimized to ensure replicated observations were independent. The software modification also eliminated any interpreter variation caused by redigitizing the same crown area target. The computer software performed all area computations for each calibration factor for each crown area target.

Statistical Analysis

A controlled factorial analysis of variance (ANOVA) was performed using the Statistical Package for the Social Sciences on an IBM Personal Computer[1] with the following factors:

1. Film type (2 films: black and white, color)
2. Photo scale (4 scales: 1:500, 1:000, 1:2000, 1:3000)
3. Scale Calibration (3 factors: radar only, calibrated radar, actual measured scale)
4. Interpreter (2 photo interpreters)

[1]Trade names are mentioned for information only.

The actual size of the crown area targets was employed as a covariate in the analysis. The ANOVA design was employed to determine which of the above effects (main effects and interactions) were statistically significant, and therefore capable of influencing photo estimates of crown area.

The response variable was the absolute value of the difference between the photo estimate and the known target area. The analysis therefore negated consideration to high or low trends, since positive and negative differences were considered equally important by taking its absolute value. Results of the ANOVA combined with an analysis of the residuals (estimated minus actual crown area) governed the selection of observations for paired t-tests. These tests were used to determine if the photo estimates of crown area targets were significantly different from their actual areas.

RESULTS AND DISCUSSION

Photo Acquisition

Aerial photographs were acquired on October 2, 4 and 5, 1985, as weather permitted. Photographs were useable and representative of operational photos. A stereopair or triplet generally covered the target array.

Photo Scale Calibration

The following 2 equations were produced (Y = actual height above ground, X = radar height above ground):

1:500, 1:1000
$Y=6.99 + 0.97X$ $r^2=0.9989$ SE=1.52 m
1:2000, 1:3000
$Y=0.34 + 1.01X$ $r^2=0.9988$ SE=2.40m

Both regressions were highly significant and accounted for nearly 100% of the total variation in the height above ground observations.

Statistical Analysis

A comparison of the ANOVA results (Table 2) to the means of the absolute differences between photo estimates and actual areas (Table 3) yielded the following:

1. There was a significant difference in measurement accuracy between films. Estimates using the black and white photographs were significantly closer to known target areas. This may be

attributed to the poorer exposure on some of the color photographs.

2. There was a significant difference in accuracy between photo scales with 1:1000 scale photos exhibiting less error. With the exception of black and white 1:500 photographs, the estimates of crown area were over estimated. This tends to support the operational use of black and white 1:1000 nominal scale photographs for crown area measurements.

3. There was no significant difference between scale calibration factors. Radar altimeter calibration did not contribute to the accuracy of photo measurements, thus concluding that calibration was not required. The radar altimeter performed accurately over the open area where the targets were placed. This result is not necessarily indicative of the need for calibration over forested areas where calibration may be required (Aldred and Lowe 1978; Kirby and Hall 1980).

4. There was a significant difference in the accuracy of target area estimation between the interpreters which may be attributed to inherent human differences in visual acuity, experience and knowledge. Two examples which may affect measurements include the rate of digitizing, and the interpreter's choice for location and number of ground datum points established on the stereomodel during measurement. The role of the interpreter therefore cannot be overemphasized in its contribution to the accuracy produced from employing and comparing different techniques.

5. Two-way interaction effects suggest that photo scale was the major influence on errors associated with crown area measurements. There were no significant three-way and four-way interactions.

The main factors accounted for the greatest portion of the total variance when the variation in crown area target size was considered. The film-scale interaction was the largest of all two-way interactions (Table 2). Paired t-tests were therefore performed for all film-scale combinations with a single scale calibration (radar only) and interpreter (interpreter 1) factor. There was no significant difference between photo measurements and ground targets for black and white or color film at scales of 1:500 and 1:1000 (Tables 4). Measurements from 1:1000 black and white and 1:500 color were closest to ground targets (Table 4).

SUMMARY

This study has addressed the issue of crown area measurement accuracy through the use of specially constructed targets. The effects of film type, photo scale, scale calibration and interpreter were considered using a controlled factorial ANOVA experimental design. The role of the interpreter was significant with film scale having the major effect on accuracy of crown area measurements. There was no significant difference between photo estimates and ground targets at scales of 1:500 and 1:1000. Crown area measurements from large-scale photos are consistent, and are a reasonable estimate of actual areas. Continued use of nominal 1:1000 scale black and white photos is generally recommended for this purpose.

ACKNOWLEDGEMENTS

This study was funded as part of a larger demonstration project by the Alberta Remote Sensing Center of Alberta Environment. the technical assistance of Tom Walsh (Canadian Forestry Service) and Dave Taylor (Alberta Energy and Natural Resources) were critical to this study and is gratefully acknowledged.

REFERENCES

Aldred, A.H. and J.J. Lowe (1978) Application of Large-Scale Photos to a Forest Inventory in Alberta, Environ. Can., Can. For. Serv., For. Manage. Inst., Ottawa, Ont., Inf. Rep. FMR-X-40, 57 pp.

Aldred, A.H. and L. Sayn-Wittgenstein (1972) Tree Diameters and Volumes from Large-Scale Aerial Photographs, Environ. Can., Can. For. Serv., For. Manage. Inst., Ottawa, Ont., Inf. Rep. FMR-X-40, 43 pp.

Hall, R.J. (1984) Use of Large-Scale Aerial Photographs in Regeneration Assessments, Agr. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta., Inf. Rep. NOR-X-264, 31 pp.

Jano, A. (1980) Large-Scale Photography for Forest Inventory: Problems and Limitations, Proc. Workshop on Practical Applications of Remote Sensing to Timber Inventory, Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta., Inf. Rep. NOR-X-224, pp 52-57.

Kirby, C.L. and R.J. Hall (1980) Description and Accuracy Evaluation of the Honeywell Radar Altimeter, Environ. Can., Can. For. Serv., North For. Res. Cent., Edmonton, Alta., Inf. Rep. NOR-X-222, 13 pp.

Kirby, C.L. and P.I. van Eck (1977) A Basis for Multistage Forest Inventory in the Boreal Forest Region, Proc. 4th Canadian Symposium on Remote Sensing, Quebec City, Que. pp 72-94.

Nielsen., U., A.H. Aldred and D.A. Macleod (1979) A Forest Inventory in the Yukon Using Large-Scale Photo Sampling Techniques, Environ. Can. For. Serv., For. Manage. Inst., Ottawa, Ont., Inf. Rep. FMR-X-121, 39 pp.

Paine, D.P. (1981) Aerial Photography and Image Interpretation for Resource Management, John Wiley and Sons, Toronto, Ont., 571 pp.

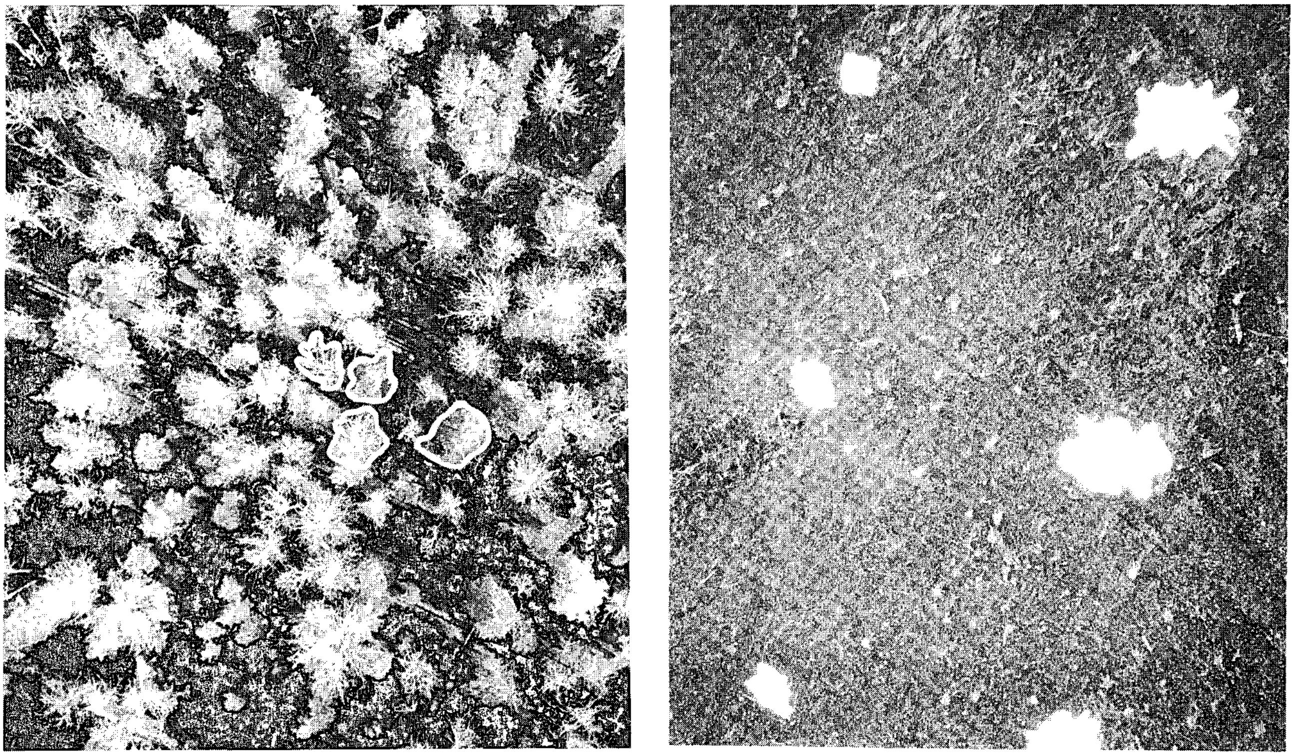

Figure 1. Typical tree crown outlined on aerial photograph (left) compared to shapes of targets constructed.

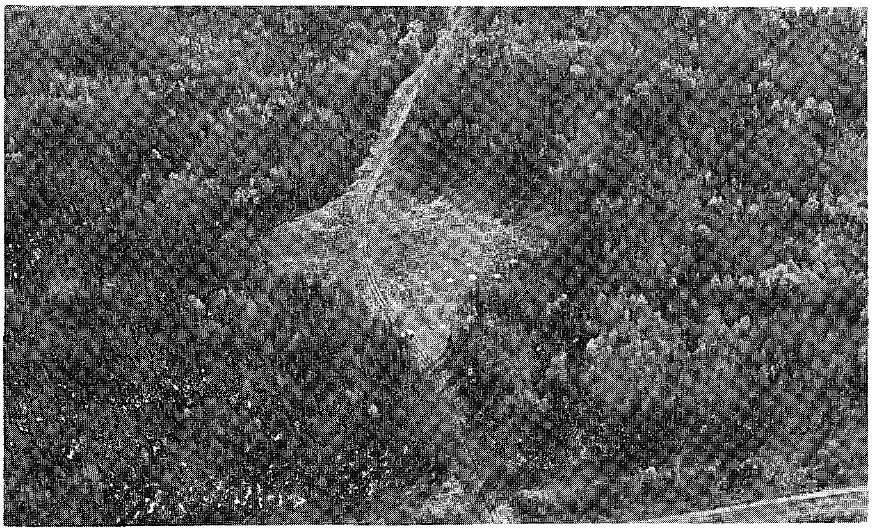

Figure 2. Oblique photograph illustrating configuration of targets in the field.

Table 2: Summary ANOVA Table.

Source of variation	Sum of squares	DF	Mean square	F	Probability level
Covariate					
Crown area targets	181.327	1	181.327	737.324	0.000*
Main effects-total	126.507	7	18.072	73.458	0.000*
Film	1.593	1	1.593	6.474	0.011*
Scale	115.878	3	38.626	157.000	0.000*
Scale calibration	0.124	2	0.062	0.251	0.778
Interpreter	8.913	1	8.913	36.227	0.000*
2-way interactions-total	19.314	17	1.136	4.618	0.000*
Film scale	12.380	3	4.127	16.773	0.000*
Film scale calibration	0.358	2	0.179	0.728	0.484
Film interpreter	0.255	1	0.255	1.036	0.309
Scale scale calibration	0.692	6	0.115	0.469	0.832
Scale interpreter	5.615	3	1.872	7.608	0.000*
Scale calibration interpreter	0.014	2	0.007	0.029	0.972
3-way interactions-total	1.293	17	0.076	0.309	0.997
4-way interactions-total	0.025	6	0.004	0.017	1.000
Explained	328.466	48	6.843	27.814	0.000*
Residual	117.846	479	0.246		
Total	446.312	527	0.847		

*denotes significance at a probability level of 0.05.

Table 3. Mean absolute difference between photo estimates and actual crown area.

Main effects

Film type

Kodak 2405	Kodak 2445
0.81	0.92

Scale

1:500	1:1000	1:2000	1:3000
0.49	0.36	1.07	1.53

Scale Calibration Factor

Radar	Radar Calibration	Actual Measured Scale
0.86	0.88	0.84

Interpreter

Number 1	Number 2
0.73	0.99

Table 4: Mean standard deviation of paired differences and paired T-test results.

Label	Mean	Standard deviation	Paired t-test
Black and white 1:500	-0.86	1.26	n.s.
Color 1:500	0.05	0.35	n.s.
Black and white 1:1000	0.01	0.42	n.s.
Color 1:1000	0.24	0.44	n.s.
Black and white 1:2000	0.74	0.81	*
Color 1:2000	1.06	0.80	*
Black and white 1:3000	0.94	0.72	*
Color 1:3000	0.48	1.18	*

n.s. - Not significant
* - Significant at a probability level of 0.05.