CONIFEROUS REGENERATION SURVEYS USING COLOR INFRARED AERIAL PHOTOGRAPHY

Warren B. Cohen
Marshall D. Ashley
College of Forest Resources
University of Maine at Orono
Orono, Maine 04469 USA

ABSTRACT

Forest managers need an accurate and economical method of surveying conifer regeneration in disturbed areas. Large scale color infrared aerial photography can provide a method that's less expensive and gives a synoptic view which allows a more complete survey than can be conducted on the ground. In this study three scales of photography were obtained over three categories of regenerating sites. The scale of 1:1200 overestimated field stocking by 5.8 percent in clearcuts 0-2 years old and by 6.0 percent in clearcuts 5-15 years old. The scale of 1:3600 underestimated stocking by 18.6 percent and 24.7 percent on the same two regeneration categories. For overtopped stands where the seedlings were considerably taller than in the other two categories, field stocking was underestimated by only 5.4 percent using the 1:3600 photography and overestimated by 2.2 percent using a scale of 1:12,000. This points out the relationship between photo scale and seedling recognition which a forest manager should consider when planning an aerial regeneration survey. Regardless of the photo scale used in this study, a regression analysis facilitated the placement of regenerating stands into one of three broad stocking categories (understocked, partially stocked, and fully stocked) with as much as ninety percent accuracy. This can reduce the need for field surveys considerably through limiting them to the partially stocked category.

INTRODUCTION

Regeneration programs on commercial forestland are greatly increasing the workload of the forest manager. This is a result of the large amount of forest land which is deforested annually by both harvesting operations and natural disasters. Some of this land will regenerate naturally to an acceptable number and distribution of desirable tree species while the remainder won't. An accurate, timely, and economically feasible method is needed that will allow a manager to assess the stocking of regeneration in these deforested areas. Such assessments can provide the manager with the information needed to determine whether silvicultural treatments should be initiated to insure a suitably stocked stand of trees at some acceptable rotation age. Once developed, this method can be utilized for subsequent monitoring to ascertain stand conditions at other critical stages of development.

This project was supported by federal McIntire-Stennis funds, Great Northern Paper Company, and the University of Maine Cooperative Forestry Research Unit.

The research described here was conducted in Northern Maine where softwood species are the primary source of forest products. The use of large scale color infrared aerial photography for assessing conifer regeneration stocking is studied.

BACKGROUND

Ground Surveys

Regeneration stocking assessments have traditionally been accomplished using a ground survey. With such a survey each regenerating site must be visited and systematically sampled. Kaltenberg (1978) tested the accuracy and precision of the three basic field sampling methods now in use; fixed area rules, distance rules, and polyareal rules. Each method characterizes a regenerating site by seedling density, stocking, or both.

Seedling density is expressed as an average number of trees per unit area (OMNR, 1981). According to Grant (1951) seedling density isn't a reliable guide to the status of regeneration. Two sites can be equally populated, yet one may be well stocked and the other poorly stocked depending on the distribution of the seedlings. A more representative measure is the proportion of an area having the potential of being covered by tree crowns at some specified age (Kaltenberg, 1978). This is commonly known as stocking. Kaltenberg found that fixed area measurements generally provided the most accurate representation of both seedling distribution and density.

In today's financial climate it's impractical to assess every regenerating site using an intensive ground survey (OMNR, 1981). Such ground surveys are too time consuming and expensive. Also, some of the land to be surveyed is inaccessible by roads, and when road access is possible the field work is limited to the summer months when other field work also needs to be done.

Aerial Surveys

Aerial regeneration surveys provide an appealing alternative to the ground survey. Some of the advantages of regeneration stocking assessments using aerial photography are discussed here. The aerial vantage point offers a more complete sampling and evaluation scheme that is accurate, precise, and economically feasible (Butler, 1983 and Goba et al., 1982). Photo interpretation can take place any time of the year leaving the summer months open for other field work (Ball and Kolabinski, 1979). Insect and frost damage, and other similar problems can be quickly and easily identified allowing prompt corrective action to be initiated (Nelson, 1977).

Relative Costs of Aerial Surveys

Ground surveys can account for a significant proportion of the overall cost of forest management (Swantze, 1957 and Kirby and van Eck, 1973). The results may be statistically sound, but an examination of the plots and ground traversed between them only provides a rough estimate of the true stocking conditions (Swantze, 1957). The regeneration between the traversed strips is often as much as ninety percent of the total area and is never surveyed.

The cost of photographic assessments is substantially lower (Nelson, 1977), often running well under five percent of stand establishment costs (Ball and Kolabinski, 1977). If a 70 millimeter or 35 millimeter camera is available the photo acquisition can potentially be conducted by in-house personnel, even further reducing the cost of the survey. Meyer (1973) presents suggestions on the use of 35 millimeter cameras for aerial photography and describes a camera mount designed for use with light aircraft.

Established Regeneration and Photo Scale

A seedling's visibility on aerial photography is closely related to its height (Nelson, 1977). The forest manager should first decide what height seedling is acceptable as an established seedling (one that is likely to survive and be harvested as a crop tree), then choose a photo scale that will allow an interpreter to consistently identify these seedlings at some acceptable level of accuracy (Ball and Kolabinski, 1979 and Smith, 1964). In this way a forest manager can be confident that almost all established seedlings will be visible on the photography.

Survey Methodology

The first step in a photo regeneration survey is normally a stratification of regeneration into stocking categories (Swantze, 1959 and Goba et al., 1982). Under most circumstances three broad categories of regeneration can be delineated on the photography; understocked, partially stocked, and fully stocked. If a photo scale is chosen that allows most established seedlings to be detected, then the stratification process can be expected to be an accurate representation of general stocking conditions.

After stratification each strata can be surveyed with the aid of a stocking template (Goba et al., 1982). If during this process any major stocking discrepancies within a strata are detected, restratification is necessary. This results in a detailed and precise representation of true stocking conditions. A ground survey need only be conducted on the partially stocked stands where more detail is needed before a treatment decision can be made (Bernstein, 1974, Canadian Forestry Service, 1975, and Butler, 1983). Here, a double sampling technique can be employed which combines photo counts and field counts in a regression analysis. This type of analysis may require as few as one ground plot for every ten photo plots (Canadian Forestry Service, 1975).

Aerial Photo Parameters

When planning an aerial photo survey several factors must be considered. These include film type, photo scale, photo season, film exposure, and weather conditions. Taking these factors into consideration assures successful acquisition of quality photography.

Various films have been tested for their relative success in regeneration surveys (Smith, 1964, Bernstein, 1974, Kirby and van Eck, 1973, Meyers, 1961, and Schaefer, 1978). Color infrared film was found to be superior for making these surveys.

Scales of photography tested and proven successful range from 1:200 to 1:16,000 (Haapala and Newmann, 1972, Shutov et al, 1978, Kirby, 1982, Schaefer, 1978, Hoppus, 1983, Butler, 1983, Ball and Kolabinski, 1979, Thompson, 1976, Nelson, 1977, Smith, 1964, Goba et al., 1980 and 1982, Kirby and van Eck, 1973, and Meyer, 1961). With a few exceptions the accuracies obtained were greater than eighty percent, with most being between ninety and one hundred percent.

The photos should be obtained during the short period of time in spring or fall when deciduous vegetation is dormant and there's no snow on the ground. At this time the infrared reflectance of the conifer regeneration is in maximum contrast with other materials on the ground (Swantze, 1957, Smith, 1964, Kirby and van Eck, 1973, Nelson, 1977, Kirby, 1980, and Goba et al, 1980 and 1982). Weather conditions are also critical when color infrared film is used. Essentially cloud-free conditions are required, and the sun's elevation should be such that tree shadows are minimized and there's enough illumination to properly expose the film (Goba et al, 1980 and 1982).

DATA COLLECTION

Three categories of conifer regeneration were used in this study; areas clearcut for up to two years (0-2), areas clearcut for five to fifteen years (5-15), and areas severely disturbed by fire and thereafter reestablished by hardwoods which now overtop to conifer regeneration (overtopped).

Eight study sites were chosen in Northern Maine. Kodak Aerochrome Color Infrared Type 2443 film in a nine inch format was used to obtain two scales of photography for each category. Scales of 1:1200 and 1:3600 were obtained for the 0-2 year and 5-15 year categories, while 1:3600 and 1:12,000 were obtained for the overtopped category. The photography was taken in early spring before bud-break.

Photo Survey

On the 1:3600 scale photography each site was stratified into stands of similar stocking density based solely on appearance. Though there was no effort to break the strata by exact percent stocking, the categories of understocked (0-39%), partially stocked (40-69%), and fully stocked (70-100%) were used as guidelines. Other considerations in the stratification process were the spatial distribution of seedlings, apparent soil differences, and contrast of the seedlings to their background. All stratified stand boundaries were then transferred to the other scale of photography covering the site.

The combined percent stocking of spruce and fir was determined for each stratified stand with the aid of a stocking template designed by the Ontario Centre for Remote Sensing. There was no pine regeneration present on any of the study sites. The template consists of one hundred rectangular shaped quadrats clustered in groups of ten, each cluster being randomly distributed to correspond with the clustered nature of spruce and fir regeneration in this region. The template was designed to cover four hectares (ten acres), with each quadrat representing one mil-acre (1/1000 acre) at photo scale.

Therefore, for each photo survey the size of the template was matched to the nominal scale of the photography. For all sites the smaller scale photography was surveyed first. The sampling intensity on each site was one hundred mil-acre quadrats for each four hectares (ten acres).

Field Survey

A field survey was conducted so that the accuracy of the photo survey could be determined. A systematic spacing of three chains on line by three chains between lines was used for plot center locations. Each plot was circular and four mil-acres in size. By dividing the plot into four quadrants of equal size the plot tally was on a mil-acre basis allowing it to be directly compared to the photo survey. A plot was tallied as stocked if a spruce or fir seedling greater than six inches in height was present within it. The average height of all seedlings six inches and greater for the four plot cluster was also recorded.

DATA ANALYSIS METHODS AND RESULTS

A total of thirty stands were stratified from the eight study sites. The percent stocking from surveys of the two scales of photography and a field survey yielded ninety observations. An analysis of variance was performed on this data to see if there were significant differences between the photo and ground estimates of stocking. Each age category was analyzed separately since the scales of photography weren't the same for each category.

The results of the analysis of variance indicated a significantly different stocking level was estimated depending on the kind of survey employed for all but the overtopped age category. The interpretation of the 1:1200 photography resulted in overestimates relative to the field survey of 5.8 percent and 6.0 percent for the 0-2 year and 5-15 year age categories respectively. The 1:3600 photography interpretations underestimated field stocking by 18.6 percent and 24.7 percent respectively for the same age categories. Table 1 illustrates the results of a Duncan's Multiple Range Test showing that only the estimates obtained with the 1:3600 photography were significantly different from the field estimates.

The apparent reason the 1:3600 photo estimates weren't significantly different from field estimates for the overtopped category was seedling heights. The heights were substantially taller in this age category than in the other two categories causing underestimates of field stocking which averaged only 5.4 percent low. The trees were even tall enough to be accurately detected on the 1:12,000 photo scale. The photo estimates using this scale were only 2.2 percent greater than indicated by the field survey.

A regression analysis was also conducted on the data. From this analysis a regression equation and graph were developed for each of the six combinations of photo scale and age category used in this study (Figure 1). The predicted field stocking can be read from each graph directly for any observed photo stocking. The equations can be used in lieu of the graphs with the same result. Ninety-five percent confidence limits for the predicted stocking are also shown.

Comparisons were made between the predicted and the observed field stocking using the stocking categories described earlier; understocked (0-39%), partially stocked (40-69%), and fully stocked (70-100%) (Table 2). 30.4 percent of all observations using the 1:1200 photography were misclassified. Predicted stocking values obtained from regression analysis reduced the percent misclassified to 17.4. The 40.0 percent of misclassified observations using the 1:3600 photography was reduced to 13.3 percent by regression. Regression analysis had no effect on the percent misclassified using the 1:12000 photography. The model for these regressions was:

$$\hat{Y} = b_0 + b_1 X_1 + b_2 X_2$$

where:

$\hat{Y}$ is the predicted field stocking
X_1 is the photo stocking
X_2 is the age category

Of the nine misclassified observations after regression three were very close to observed field values, the reason for misclassification being a function the 40 percent category boundary. One observation had an observed field stocking of the 40.6 percent and a predicted field stocking of 39.0 percent. Another had an observed value of 39.3 percent and a predicted value of 42.0 percent. The third had an observed field stocking of 40.6 percent and a predicted value of 35.3 percent. If these observations aren't considered to be misclassified, then the average percent misclassified over all the observations is reduced from 15.0 percent to 10.0 percent.

SUMMARY AND CONCLUSIONS

Three different scales of color infrared photography were tested for their accuracy in determining the percent stocking of regenerating spruce and fir stands in Maine. The interpretation of 1:1200 scale photos resulted in overestimates of field stocking by 5.8 percent on clearcuts up to two years old and by 6.0 percent on clearcuts up to five to fifteen years old. For the same two age categories interpretation on 1:3600 photography resulted in underestimates of field stocking by 18.6 percent and 24.7 percent respectively. The photo scale of 1:3600 was also tested on overtopped stands along with a scale of 1:12000. For these stands the seedlings were tall enough to be accurately and consistently detected on both scales. The 1:3600 photo underestimated stocking by 5.4 percent, whereas the 1:12000 photos overestimated stocking by 2.2 percent.

The consistency with which each photo scale estimated stocking within an age category made it possible to develop graphs and equations that allow an interpreter using the same photo scale and age categories to accurately predict stocking from photo surveys. As each photo interpreters skills, photo scales used, and age categories chosen varies, a manager conducting aerial photo surveys should do a study similar to that conducted here. This will allow graphs, equations or tables to be developed which are tailored to unique situations.

Age Class	Measurement Method	Mean Percent Stocking
0 - 2	Field	38.6
	1:1200	44.4
	1:3600	20.0*
5-15	Field	55.8
	1:1200	61.8
	1:3600	31.1*
overtopped	Field	29.8
	1:3600	24.4
	1:12000	32.0

Table 1. Mean percent stocking levels for each age class and type of measurement. Stocking means with an * are significantly different from the field measurements at the 5% level.

Photo Survey			Misclassified Photo Observations			
			Photo Stocking		Predicted Stocking	
Photo Scale	Age Category	Number of Observations	Number	Percent	Number	Percent
1:1200	0-2	8	2	25.0	1	12.5
	5-15	15	5	33.3	3	20.0
		23	7	30.4	4	17.4
1:3600	0-2	8	1	12.5	0	0.0
	5-15	15	10	66.6	3	20.0
	overtopped	7	1	14.3	1	14.3
		30	12	40.0	4	13.3
1:12000	overtopped	7	1	14.3	1	14.3
		7	1	14.3	1	14.3
Totals		60	20	33.3	9	15.0

Table 2. Comparison of misclassified photo observations before and after regression analysis.

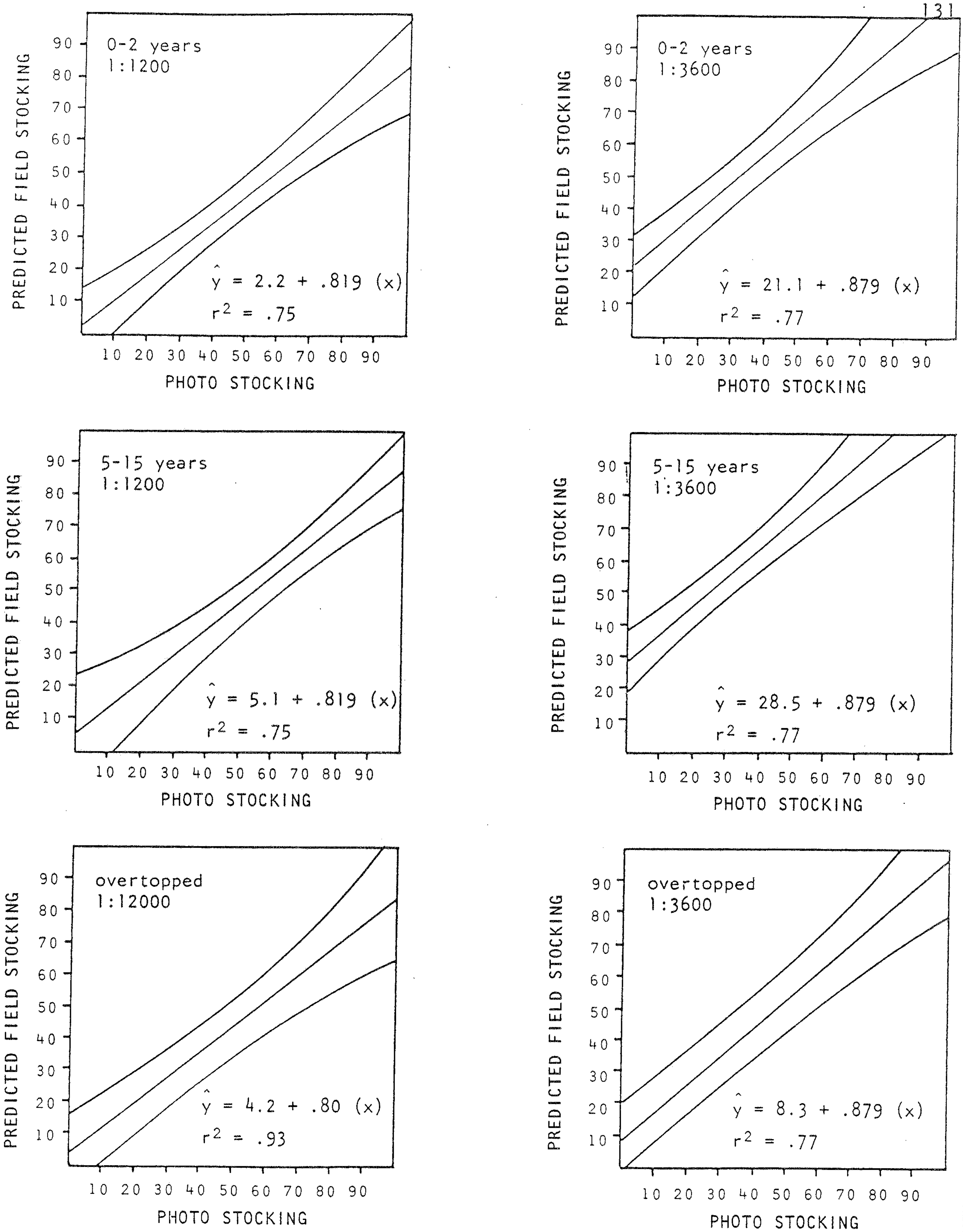

Figure 1. Predicted field stocking and its 95 percent confidence limits for observed photo stocking using three scales of photography on three regeneration age categories.

The research done here shows that large scale color infrared photograhy can be used to accurately determine field stocking on sites regenerating to spruce and fir in the Northeastern United States. A forest manager can determine from the photos the percent stocking of a stand and then place it in a relative stocking category with predetermined percentage boundaries. If the three broad categories of understocked, partially stocked, and fully stocked are chosen, only the partially stocked stands will need checking in the field. In combination, photo plots and field plots can provide the manager with the detail needed to decide how these questionable stands should be treated.

ACKNOWLEDGEMENTS

The authors would like to thank Professor William Soule, Jr. of the Department of Mathematics at the University of Maine at Orono for his advice on the statistical analysis used in this study.

REFERENCES

Ball, W.J. and V.S. Kolabinski. 1979. An Aerial Reconnaissance of Softwood Regeneration on Mixedwood Sites in Saskatchewan. Information Report NOR-X-216. Northern Forest Research Centre, Canadian Forestry Service, Edmonton, Alberta.

Bernstein, David A. 1974. Are Reforestation Surveys with Aerial Photography Practical? Photogrammetric Engineering, Vol. 40, No. 2, pp. 69-73.

Butler, Mark. 1983. Regeneration Surveys from the Air Using Large Scale Aerial Photography. Woody Points, Vol. 12, No. 1, April, 1983.

Canadian Forestry Service. 1975. A Place for Aerial Photography in Regen Surveys? Forestry Report, Vol. 4, No. 4, p. 6. Northern Forest Research Centre, Canadian Forestry Service, Edmonton, Alberta.

Goba, N.L., et al. 1980. Integration of Remote Sensing Technology with Assessment of Coniferous Regeneration Success. Canada - Ontario Joint Forest Research Committee, Remote Sensing Symposium, October, 1980. Proceedings, pp. 147-159.

Goba, N.L., et al. 1982. An Instruction Manual on the Assessment of Regeneration Success by Aerial Survey. Ontario Centre for Remote Sensing, Ministry of Natural Resources.

Grant, J.A.C. 1951. The Relationship Between Stocking and Size of Quadrat. University of Toronto Bulletin, Chapter 7, pp. 16-21.

Haapala, F.H. and P.O. Newmann. 1972. Determining Stocking of Conifer Reproduction with Large Scale Color Infrared Aerial Photography. DNR Report, Department of Natural Resources, Washington.

Hoppus, Michael Leeman. 1983. Accurate Aerial Forest Regeneration Surveys in Mountainous Terrain Using a 35-mm Camera. A Paper Presented in Partial Fulfillment of Master of Science Degree, University of Idaho.

Kaltenberg, Michael Charles. 1978. Evaluation of Regeneration Sampling Methods: A Monte Carlo Analysis Using Simulated Stands. State of Washington, Department of Natural Resources, Olympia.

Kirby, C.L. 1980. A Camera and Interpretation System for Assessment of Forest Regeneration. Information Report NOR-X-221. Northern Forest Research Centre, Canadian Forestry Service, Edmonton, Alberta.

Kirby, C.L. and P.I. van Eck. 1973. Forest Regeneration Sampling from the Air. Forestry Report, Vol. 3, No. 3, p. 8. Northern Forest Research Centre, Canadian Forestry Service, Edmonton, Alberta.

Meyer, Merle P. 1973. Operating Manual - Montana 35MM Aerial Photography System (1st Revision). ARSL Research Report 73-3. Institute of Agriculture Remote Sensing Laboratory, College of Forestry, University of Minnesota, St. Paul.

Meyers, B.J. 1961. Stocking Assessment In Young Pine Plantations Using 70MM Aerial Photography. Australian Forest Research, Vol. 6, No. 3, pp. 35-42.

Nelson, Harold A. 1977. Assessment of Forest Plantations From Low Altitude Aerial Photography. 11th International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, April 25-29, 1977. Proceedings, pp. 1515-1522.

Ontario Ministry of Natural Resources. 1981. Regeneration Survey Manual for Ontario. Forest Resources Group, Toronto, Ontario, Canada.

Schaefer, Eugene Louis. 1975. Remote Sensing for Determination of Seedling Survival. Symposium, Remote Sensing for Vegetation Damage Assessment, February 14-16, 1978, Seattle, Wash. Proceedings, pp. 465-495.

Shutov, I.V., et al. 1978. Evaluating Regeneration of Spruce and Pine in Young Broadleaved Stands. Lesnoe Khozyaistvo, No. 6, pp. 53-55.

Smith, Carl W. 1964. Specialized Photography an Aid to Planting Inventory. General Reforestation. Western Forestry and Conservation Association, Portland, Oregon.

Swantze, H. 1957. Photogrammetric Methods in Reforestation Surveys. Photogrammetric Engineering, Vol. 23, No. 4. pp. 789-790.

Thompson, E.J. 1976. Optimum Photo-plot Size for Estimating Stocking in Young Pine Plantations. Australian Forest Research, Vol. 7, pp. 47-51.