The Potential Use of Remote Sensing for Forest Vegetation Management:

Synopsis of a North American Workshop

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Abstract

Forest managers require accurate and timely information describing vegetation conditions on cutover areas to assess vegetation development and prescribe the corrective actions necessary to achieve management objectives. Needs for this information are increasing, as traditional timber production objectives are broadened to include other forest values, such as biological diversity, wildlife habitat, and landscape ecology. Data collected by field survey are often costly, subjective, and of low spatial or temporal coverage. To explore potential applications of remote sensing, a three-day workshop was held in Sault Ste. Marie, Ontario, Canada, in December 1995. Participants generally concurred that, among currently available sensors, aerial photographs offer the most suitable combination of characteristics for vegetation management decision making, including high spatial resolution, stereo coverage, a range of image scales, a variety of film, lens, and camera options, versatility, and moderate cost. Experience and results from related studies suggest that data for crop and non-crop density, cover, height, and spatial distribution may be acquired from aerial photographs and used to assess the relative dominance of crop and non-crop vegetation greater than 0.5 m tall. Other remote sensing technologies, such as digital frame cameras, airborne video, space- and airborne imaging spectrometers, synthetic aperture radar, and lasers, offer unique features that may prove useful in forest vegetation management applications with further testing and refinement. Additional research priorities defined include the development of computer-based classification and interpretation algorithms for digital image data, investigation of relationships between image measures and physical measures, such as leaf-area index and biomass, and investigation of remote sensing applications in partial cutting systems. Surveys that require very detailed information on smaller plants (less than 0.5-m tall) and/or individual or rare plant species are not likely to be supported by current remote sensing technologies.

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1. Introduction

Nearly 90% of Canada's 236 million ha of nonreserved productive forest lands are public or "Crown" lands and fall under the jurisdiction of one of its 10 provinces or 2 territories. Approximately 1 million ha of these forests are harvested annually, largely by clearcut methods (Canadian Council of Forest Ministers, 1996). Individual cutover sizes have ranged from 5 to 250 ha, but regulations in several provinces now limit size to less than 100 ha. About half of all areas clearcut are site prepared and planted, with the remainder being left to regenerate naturally. Woody and herbaceous vegetation establishes rapidly and can fully occupy most sites within one or two growing seasons (more than 80% of sites being typical of the Boreal Forest Region). Invading plant species play important roles in maintaining site stability, water quality, nutrient cycling, and wildlife populations, but they can seriously compete with timber-producing species for light, moisture, and nutrients.

Forest vegetation management (FVM) is that part of silviculture directed at manipulating the rate and course of early plant succession to achieve a forest stand of a particular composition, structure, and form, within a specified period of time (Wagner, 1994). FVM requires timely, quantitative data that describe the relative size, composition, distribution, and condition of regenerating vegetation on forest cutovers. These data are needed from a timber-management perspective and, increasingly, for broader concerns such as biological diversity, wildlife habitat, and landscape ecology. Evolving forest management legislation and computer-based decision support systems are creating additional data demands.

Data required for FVM decision making are frequently collected by field survey methods that range from simple visual observations to the installation of field plots for measurement of variables such as vegetation height, cover, and health. Sites may be located 50 km or more from a forest manager's base of operations and, given a large number of cutovers, high costs, subjectivity, and low spatial and temporal coverage can significantly limit decision-making effectiveness (Tappeiner and Wagner, 1987). New data acquisition methods are needed to deliver extensive, objective, multi-dimensional, spatially accurate, and cost-effective data for FVM decision making and monitoring.

To assess the scientific, technical, and practical issues facing the development and application of remote sensing in FVM decision making and monitoring, over 50 remote sensing, FVM, and forest industry experts from Canada and the United States met in Sault Ste. Marie, Ontario, December 6-8, 1995 (Appendix). This workshop, hosted by the Ontario Ministry of Natural Resources (Vegetation Management Alternatives Program) and the Canadian Forest Service, included reviews of the full range of currently available remote sensors (satellite and airborne optical, radar, and laser-based sensors) and problem-oriented working-group discussions. Discussion focused on building consensus about developing a suitable remote sensing system for current and future implementation, and on establishing future research directions and priorities. The following briefly summarizes the conclusions reached.

2. Forest Vegetation Management Data Requirements

During early stand development (up to 10 years following harvest), vegetation surveys are conducted to gather data and information that describe forest vegetation problems that are, or may become, an obstacle to achieving forest management objectives. Two questions often asked by forest managers are: 1) is the development of early-seral vegetation on a successional trajectory consistent with management objectives, and 2) what vegetation treatments, if any, are required to redirect succession toward the desired course and rate? Data used to describe vegetation conditions (the relative abundance, dominance, and distribution of crop and non-crop plants) include measures of density (trees/ha) or cover, height, stocking, and condition. When detailed species information is gathered, these data may be further used to calculate measures of species diversity, identify the presence of rare and endangered plants, understory plants, and/or describe temporal changes in the vegetation. In the future, descriptors of vegetation conditions may be augmented by more sophisticated measures such as biomass, horizontal distribution, and physiological status.

FVM treatment prescriptions involve the integration of vegetation conditions with site characteristics, operational constraints (proximity to water courses, human habitation, etc.), and knowledge-based factors (management objectives, available treatments, economics, etc.). Prescriptions are commonly developed for cutovers as large as 250 ha, however, the high cost of FVM treatments and environmental pressures are making within-cutover prescriptions (perhaps as small as 5 ha) more desirable.

3. Application of Existing Technologies

While various remote sensing technologies offer unique features with potential for applications in FVM, workshop participants were most confident in recommending the traditional aerial camera and film. Recommendations were based on aerial photography being a proven technology with established mensurational techniques and a wide range of acquisition equipment in current operation. Recent improvements in aerial camera and film technologies have resulted in images that contain the highest spatial resolution of any of the current remote sensing technologies (Light, 1996). This feature is necessary for FVM applications that require images which resolve a high degree of detail. There also have been some successful applications of aerial photography to aspects of FVM, including measurements of crop and non-crop plants on research plots (Pitt and Glover, 1996), regeneration assessment (Hall and Aldred, 1992), and free-to-grow surveys (Hunter and Associates, 1983).

The general consensus among workshop participants was that a sequence of aerial photographs taken at strategic points during the regeneration phase may meet several FVM data requirements:

1. The first set of photographs, taken during leaf-off conditions immediately following harvest, would consist of 23-cm format, colour infrared (CIR), at scales of 1:10,000 to 1:20,000 (depending on cutover size and frequency). Photo scale should be small enough to provide complete coverage of one or more cutovers and large enough to provide adequate spatial detail for accurate depletion mapping and areal stratification for pre-establishment planning. CIR film should enhance the visibility of advanced conifer regeneration, as well as the presence of wet areas, water

courses, potential frost pockets, rock outcrops, excessive slash loads, and high-use wildlife and recreation areas, that are important for prescription formulation.

2. The second set of photographs, taken during leaf-on conditions between age 2 and 5, would consist of supplementary 23-cm or 70-mm format, normal colour, at scales of 1:5,000 to 1:10,000 (depending on cutover size). These photographs should provide complete coverage of individual cutovers and, combined with air or field reconnaissance, permit the identification and mapping of areas requiring thinning, supplemental planting, or release. Similar photographs taken toward the end of the regeneration period (between age 5 and 10) should serve to verify and document whether management objectives have been achieved.
3. To verify the strata and prescriptions in 2) and/or collect quantitative data, a combination of supplementary 1:500-scale, stereo photographs (taken in sampling mode) and field plots is recommended.

New-generation 23-cm format aerial cameras with high resolution (90-100 line pairs mm^{-1}) lenses, forward motion compensation, angular motion stabilization, and integrated geo-positioning and exposure-control systems (Fent et al., 1995; Light, 1996) are available for the best results in 1) and 2), above. Fixed-base or sequential systems employing 35-mm or 70-mm cameras, as described by Spencer and Hall (1988), may be used to obtain large-scale, stereo, sampling photographs. An additional camera, equipped with a shorter focal length lens than the sample camera(s), can be used to obtain simultaneous images at a scale of 1:2,000 to 1:4,000 to facilitate vegetation stratification and/or the post-flight recovery of selected photo plots in the field (Kirby, 1980).

The literature and experience suggest that crop and non-crop evaluations of vegetation percent cover, density, height, stocking and condition may be made with reasonable confidence from 1:500-scale photographs for plants greater than 0.5 m tall. Through multi-phase sampling (Pitt et al., 1996), biomass and leaf-area index might be inferred from these variables. Field sampling remained a key component in suggested strategies, due to the need for verification and also because not all FVM requirements can be met by current remote sensing technologies (e.g., detailed species diversity evaluations, presence of rare and endangered plants, and small (<0.5 m) or understory plants).

The recommended sequence of aerial photography would provide 1) a flexible, spatial framework for the direction and allocation of data collection and silviculture efforts, 2) a reliable means of extrapolating sample data to similar areas of interest, 3) relatively continuous monitoring of cutover areas throughout the regeneration period, 4) a permanent record of management activities that may be referenced at any time in the future, and 5) up-to-date hard-copy images for field use. Since field sampling and silviculture costs are high, it is estimated that the ability to allocate these efforts to specific areas of need may largely offset the costs of photo acquisition.

4. Research and Development Directions

In the past, foresters have largely been able to meet their FVM data requirements by employing seasonal labor and quick visual surveys. With evolving forest management legislation and computer-based decision-support systems creating greater demands for tangible data, foresters must now seek alternative options for data collection and information processing. Escalating silvicultural costs are also making within-cutover prescriptions more attractive, but the planning of these may only be practical with a remotely-sensed overview. Although remote sensing has existed for many years in various forms, the approach proposed above is the result of research and experience derived from workshop discussions. Subsequent research should include verification and demonstration of its capabilities in an operational trial.

Arguably, aerial photographs cannot be used to satisfy all FVM data requirements and, given new and evolving technologies, may not offer the most efficient source for particular types of data. Further research is needed to improve upon the proposed approach by incorporating the unique features of other technologies. Digital frame cameras, for example, are poised to displace traditional cameras in aerial photography, bringing to the art all of the advantages of direct digital images (e.g., real-time viewing of results, high sensitivity to object radiance, wide dynamic range, and computer manipulation, analysis, and storage of images, etc.). Airborne video offers a low-cost alternative to tracking photography for the location of large-scale sample plots and, as spatial resolution increases, may offer a medium for the acquisition of sample data as well. Both of these technologies have proven potential in narrow-band multispectral imaging in addition to traditional colour and colour infrared formats (King, 1995). Laser profilers and lidar may be used to obtain quantitative information on vegetation height and vertical distribution, complementary to the main sensor. Smaller-scale overviews may be facilitated in the future by new high resolution satellite imagery (anticipated to have spatial resolutions from 1 to 3 m panchromatic and 4 to 15 m multispectral (Fritz, 1996)), cloud-penetrating airborne or spaceborne radar, and high spectral-resolution line-imaging sensors such as CASI and MEIS.

In preparation for the imminent digital era, research is needed to 1) explore spectral signatures and other image measures for young crop and non-crop plants, 2) adapt and develop auto-interpretation techniques based on crown shape, spectral reflectance (e.g., Gougeon, 1995), texture, and pattern recognition, 3) continue development of techniques for dealing with radiometric distortion, 4) streamline the integration of image capture and GPS, 5) refine film selection, exposure, processing parameters, timing, and photo scales for specific FVM applications, 6) investigate the relationship between image measures and physical measures, such as leaf-area-index and biomass, and 7) investigate remote sensing applications in partial cutting systems. It is recommended that a network of remote sensing experts, FVM specialists, and forest managers be assembled to implement these recommendations and coordinate future research.

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References

Canadian Council of Forest Ministers. 1996. Compendium of Canadian forestry statistics 1993, National Forest Database. Natural Resources Canada, Industry, Economics and Programs Branch, Ottawa, Ontario, Canada. K1A 0E4. 202 p.

Fent, L., R.J. Hall, and R.K. Nesby. 1995. Aerial films for forest inventory: optimizing film parameters. *Photogrammetric Engineering and Remote Sensing,* **61**(3): 281-289.

Fritz, L.W. 1996. The era of commercial Earth observation satellites. *Photogrammetric Engineering and Remote Sensing,* **62**(1): 39-45.

Gougeon, F.A. 1995. A crown-following approach to the automatic delineation of individual tree crowns in high spatial resolution aerial images. *Canadian Journal of Remote Sensing,* **21**(3): 274-284.

Hall, R.J., and A.H. Aldred. 1992. Forest regeneration appraisal with large-scale aerial photographs. *Forestry Chronicle,* **68**(1): 142-150.

Hunter and Associates. 1983. Free-to-grow evaluation compiled from large scale photo sampling. Prepared for the Ontario Ministry of Natural Resources, Cochrane District. 2695 North Sheridan Way, Ste. 120, Mississauga, Ontario, Canada. L5K 2N6. 11 p.

King, D.J. 1995. Airborne multispectral digital camera and video sensors: a critical review of system designs and applications. *Canadian Journal of Remote Sensing,* Special Issue on Aerial Optical Remote Sensing, **21**(3): 245-273.

Kirby, C.L. 1980. A camera and interpretation system for assessment of forest regeneration. Canadian Forest Service, Northern Forest Research Centre, Information Report NOR-X-221. 8 p.

Light, D.L. 1996. Film cameras or digital sensors? The challenge ahead for digital imaging. *Photogrammetric Engineering and Remote Sensing,* **62**(3): 285-291.

Pitt, D.G., and G.R. Glover. 1996. Measurements of woody plant attributes from large-scale aerial photographs. *New Zealand Journal of Forestry Science* (in press).

Pitt, D.G., G.R. Glover, and R.A. Jones. 1996. Two-phase sampling of woody and herbaceous plant communities using large-scale aerial photographs. *Canadian Journal of Forest Research,* **26**(4): 509-524.

Spencer, R.D., and R.J. Hall. 1988. Canadian large-scale aerial photographic systems. *Photogrammetric Engineering and Remote Sensing,* **54**(4): 475-482.

Tappeiner, J.C., II, and R.G. Wagner. 1987. Principles of silvicultural prescriptions for vegetation management. In *Vegetation Management for Conifer Production.* Edited by J.D. Walstad and P.J. Kuch. John Wiley and Sons Inc., New York. p. 399-429.

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