DIGITAL AIRBORNE AND SATELLITE DATA FOR EVALUATING SPRUCE BUDWORM DAMAGE IN QUEBEC

J. Beaubien
Laurentian Forest Research Centre
Canadian Forestry Service
Sainte-Foy, QC, Canada G1V 4C7

P. Laframboise
Ministère de l'Energie et des Ressouces du Québec
Centre québécois de coordination de la télédétection
Sainte-Foy, QC, Canada G1N 4H9

ABSTRACT

Since 1970, northeastern North America has experienced a spruce budworm (Choristoneura fumiferana (Clem.)) outbreak that has had an important influence on management of Quebec's fir/spruce forests. Landsat MSS, high altitude CIR aerial photography, and medium scale photography have low capabilities for detecting spruce budworm damage level. The potential of higher spatial and/or spectral resolution digital data for detecting, mapping, and quantifying cumulative defoliation, needed for spraying protection programs and stand harvesting schedules, was studied. In November 1983 and August 1984, a Deadalus 1260 and a MEIS II (Multi-Detector Electro-Optical Imaging Scanner) collected multispectral digital data. Ground resolutions were 20 and 10 m, and 5.6 and 2.8 m. From these data, future SPOT multispectral and panchromatic imagery was simulated. A Landsat TM scene of May 18, 1984, was also acquired. Various enhancement techniques for discriminating damage levels were investigated. Principal component enhancements of SPOT simulated multispectral data gave the best results for producing imageries that can be used as an additional tool in the traditional sketch-mapping from small aircrafts. The amount of dead crowns or tops inside stands can be evaluated. The study continues to determine the optimum spectral band combinations from the sets of data for enhancing or classifying damage levels.

INTRODUCTION

Since 1970, northeastern North America has experienced a spruce budworm (Choristoneura fumiferana (Clem.)) outbreak that has an important influence on management of fir/spruce forests in Quebec. Spruce budworm, the most important destructive forest insect in Quebec, affects the valuable pulpwood species: balsam fir (Abies balsamea (L.)) and spruces, mainly white spruce (Picea glauca (Moench) Voss). The economic impact is important; tree mortality covers 12 million hectares, and, since early 1970, over 22 million hectares of forest were sprayed in an effort to control this pest.

Information is needed on the amount and location of budworm damage for planning stand management or spray strategies. Current methods, estimating damage over large areas, rely on aerial visual surveys and various types of ground surveys. These are the only methods operational. They are costly and time consuming, and partially fill present needs. Recent remote sensing tools may have the potential for a more rapid and accurate assessment.

Color and chiefly color infrared (CIR) aerial photographs were investigated for evaluating spruce budworm damage. Ashley (1976) concluded normal color, summer imagery, scales 1:15 840 and larger, was the best for evaluating current defoliation when the affected needles are brown and still held on branches by the budworm's webbing. Heavy cumulative (current and past) defoliation was identified on CIR, scales 1:31 680 and larger, whereas moderate and light defoliations were not detected at any scales ranging from 1:9 900 to 1:63 360. Beaubien (1975) also found that only very severe damage of one year feeding or more could be identified on high-altitude (1:60 000) CIR photographs. Color variations due to certain stand characteristics (density, age, site quality) prevented the detection of lighter damage.

Satellite imagery acquired on a systematic and repetitive basis is theorically a powerful tool to monitor changes in forest canopy. Landsat-MSS data with a resolution of 80 m have low capabilities for evaluating levels of insect damage. However, in coniferous stands, tree mortality was delineated over large areas of pure or nearly pure stands (Beaubien and Daus 1977).

Higher resolution data were studied through airborne MSS data. Leckie and Gougeon (1981), using 19 and 4.5 m data, concluded that classification of total defoliation levels was difficult in mixed stands and in stands of varying density, hardwood component and crown closure affect stand signatures. However, four (4) levels of total defoliation were classified in dense fir/spruce stands by a supervised classification of 4.5 m resolution data, with misclassification error of approximately 25 percent. Nelson et al. (1984) used airborne data to simulate Landsat TM data for delineating boreal forest cover types in Maine where coniferous stands were heavily damaged by spruce budworm. As data were obtained October 12, 1981, when leaf drop was beginning, mixedwood and conifer severe defoliation was confused with hardwoods. They suggested a data acquisition in August for an overall (cumulative defoliation) tree condition evaluation.

Remote sensing has not proved its effectiveness to replace traditional sketch-mapping from small aircrafts. Each year large areas of forest susceptible to defoliation by spruce budworm have to be surveyed to plan protection programs or stand harvesting schedules. The best known tools are medium to large scale aerial photographs, but their yearly acquisition is too costly. This is also true for airborne MSS data if their capability was proven. Satellite data have the operational capability to be used over large areas, probably as a supplementary tool to current methodology.

A study was initiated to determine the potential of higher spatial and/or spectral resolution digital data, particularly TM and future SPOT data, for detecting, mapping, and quantifying cumulative defoliation.

STUDY AREA

The study area is in the Pohenegamook Lake area, about 170 km NE of Quebec City and 40 km SE of the St. Lawrence River. This low relief, rolling area is covered by mixed coniferous stands: balsam fir, white spruce and black spruce (Picea mariana (Mill.) B.S.P.), and also some pure, black spruce stands. Hardwood and mixedwood stands are abundant; white birch (Betula papyrifera Marsh.) and trembling aspen (Populus tremuloides Michx.) prodominate.

Spruce budworm has been in the area for more than ten years. Most balsam fir and white spruce that have not been sprayed are severely or completely defoliated. Yearly spraying preserved a few patches. Consequently the study turned out to be more an evaluation of the proportion of dead trees or dead tops inside stands, than an evaluation of defoliation levels.

DATA ACQUISITION

A Deadalus 1260 and a MEIS II (Multi-Detector Electro-Optical Imaging Scanner) collected multispectral digital data over the area in November 1983 and August 1984. Therefore data collected in two seasons, with and without leaves, could be studied. Flight altitudes of 8 000 m and 4 000 m gave ground resolutions of 20 and 10 m, and 5.6 and 2.8 m for both dates. Coincidental color IR aerial photographies were acquired on both flights. Future SPOT multispectral imagery was simulated from Deadalus data, panchromatic channel from MEIS-II data (Saint and Podaire 1982). Geometric corrections and resampling produced 10 m images, overlaying MSS and panchromatic data. A normalization was applied to attenuate the effect of scanning angles. A Landsat TM scene of May 18, 1984, was also acquired.

METHODOLOGY

The objective was to investigate the effectiveness of various enhancement techniques and to determine the optimum spectral band combinations from these sets of data for enhancing or digitally classifying levels of cumulative damage. Recent major problems with our image analysis system limited the projected analysis to the production of enhancements: stretches, band ratios, and mainly principal component transformations (PCT) on SPOT simulated multispectral data and a TM scene.

A first PCT general enhancement using Beaubien's (1984) method was produced from Deadalus autumn and summer raw data (bands 0.55-0.60, 0.77-0.90, 1.55-1.75 µm) and was used as source documents for two reconnaissance samplings from a helicopter, the first in summer and the second in autumn 1984. Each observation was accompanied by an oblique 35 mm color slide carefully located on the printed enhancements. Ground sample plots were also established. In spring 1985, a second PCT enhancement oriented only on conifers (healthy and damaged) was produced from SPOT simulated multispectral data of both acquisition dates. The imageries were used for a third reconnaissance flight and additional ground samplings. The ground-truth data enabled to set final enhanced images by modifying the histograms of the component digital values. Only the two first components were used, the third one being too dependent of the scanning varying angles. Using the Taylor (1974) color space, the first component was loaded on a "brightness" axis, the second on a red-green axis and the first was repeated on a blue-yellow axis.

A TM scene of May 1984 was also enhanced by PCT, studied and compared with preceeding results.

PRELIMINARY RESULTS

All enhancements were analyzed through ground-truth data and by interpreting the CIR aerial photographs. The following is a summary of the preliminary results:

- severe cumulative defoliation (1/3 of the upper crown and over) or tree mortality was observed on each set of data;
- only amount of dead crowns inside stands could be evaluated, not defoliation level;
- on winter (autumn) images, damages are over-estimated in some stands because of the high density of leafless hardwood branches;
- on summer images, damages tend to be under-estimated in mixed-stands, some dead crowns hiding behind hardwood leaves;
- principle component enhancements from SPOT MSS data, viewed through Taylor's color space, gave the closer picture of stand conditions;
- because of the prodominance of radiometric variation along scan lines on the third component, only the first two components were usable from SPOT data;
- the best image for conifer defoliation detection extracted from the TM scene was obtained by using the three first components viewed through the standard color space (red, green, blue), originating from spectral bands 2 (green), 3 (red), 4 (near infrared), and 5 (middle infrared 1). As suggested by Nelson et al. (1984), bands 1 (blue), 3, 5, and 7 (middle infrared 2) were tried but with less success. Other combinations have to be tested;
- SPOT summer data gave the best results. Dead tops in stands (conifers, mixed dominated by conifers or mixed dominated by hardwoods) could be evaluated according to three approximate percentages: 25-50 percent, 50-75 percent, and more than 75 percent; and,
- SPOT winter imagery was preferable to separate black spruce from balsam fir.

CONCLUSIONS

Current methods to quantify adequately spruce budworm damage must be improved. Satellite imagery with it's repetitive coverage should be seriously investigated as a possible tool to facilitate the task of forest managers. Because of their poor resolution, Landsat-MSS data have low capabilities for insect damage appraisal except for large areas of pure to nearly pure severely affected stands. Landsat-TM or future SPOT imagery may have the potential of producing valuable information.

Partial results are encouraging, at least as a valuable additional tool to the present eyeball evaluation. Principle component enhancements produced from SPOT simulator data allowed us to evaluate the percentage of dead conifer tops in forest stands according to three classes: 25-50 percent, 50-75 percent, and more than 75 percent. This is valuable information to guide a more detail survey or to plan a spraying program. Up to now the results from TM data analysis are not so conclusive; they locate the highest concentrations of dead tops. One should notice that the overall results allow only an approximate evaluation of the proportion of dead tops in the forest canopy, not an appreciation of defoliation levels among trees. In dense stands, dead tops and killed trees are impossible to differentiate from data of this resolution.

Data acquired in summer seem more convenient than those acquired in winter, hardwood naked branches have the effect of exagerating damage. On the other hand, hardwood leaves hide a certain amount of dead branches, this varies with stand characteristics.

Considering the common heterogeneity of forest cover and the numerous factors affecting it's spectral response, defoliation is an additional confusing factor not easy to characterize. It is felt that interpretation of digitally enhanced images is the only way of extracting the needed information on spruce budworm damages. This study will continue with the main objective to select better spectral band combinations to improved enhancements. Digital classification will be also tested.

Methodology based on satellite data will not give more than an approximate estimation of severe cumulative damage to conifers within stands. For current defoliation evaluation, aerial data must be acquired during a short period (2-3 weeks) when dead needles remain on branches. Presently, the chance of obtaining a satellite image in a so short period is slight. To obtain levels of total defoliation among conifer stems, data of much higher resolution will have to be acquired: in the order of 1 m for digital data. Those data will be convenient for sampling; they will be too costly to cover large areas as presently needed in Quebec. The principal anticipated limitation of this methodology will probably be the poor availability of satellite images for the desired areas and dates.

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REFERENCES

Ashley, M.D. 1976, Spruce Budworm Damage Evaluations Using Aerial Photography: Photogrammetric Engineering and Remote Sensing, Vol. 42, pp. 1265-1272.

Beaubien, J. 1975, High-Altitude Colour-IR Photographs for Evaluating Spruce Budworm Damage in Quebec: Proceedings 3rd Canadian Symposium on Remote Sensing, Canadian Aeronautics and Space Institute, Ottawa, Ontario, pp. 281-283.

Beaubien, J. and S.J. Daus 1977, Le traitement numérique des données de Landsat pour la cartographie: Proceedings 4th Canadian Symposium on Remote Sensing, Canadian Aeronautics and Space Institute, Ottawa, Ontario, pp. 19-26.

Beaubien, J. 1984, Une méthode de rehaussement d'images Landsat pour la classification du couvert végétal: Proceedings 8th Canadian Symposium on Remote Sensing, Canadian Aeronautics and Space Institute, Ottawa, Ontario, pp. 559-566.

Leckie, D.G. and F.A. Gougeon 1981, Assessment of Spruce Budworm Defoliation Using Digital Airborne MSS Data: Proceedings 7th Canadian Symposium on Remote Sensing, Canadian Aeronautics and Space Institute, Ottawa, Ontario, pp. 190-196.

Nelson, R.F., R.S. Latty and G. Mott 1984, Classifying Northern Forests Using Thematic Mapper Simulator Data: Photogrammetric Engineering and Remote Sensing, Vol. 50, pp. 607-617.

Saint, G. and A. Podaire 1982, Méthodes de simulation radiométrique et leur représentativité: Comptes rendus du colloque sur le système SPOT d'observation de la terre, Association québécoise de télédétection, Sainte-Foy, Québec.

Taylor, M.M. 1974, Principle component color display of ERTS imagery: Proceedings 2nd Canadian Symposium on Remote Sensing, Canadian Remote Sensing Society, Ottawa, Ontario, pp. 295-314.