Evaluation of forest canopy damage using airborne videography

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ABSTRACT

A recently commissioned airborne video system, based on that developed by the US Forest Service, is being used to document canopy damage caused by introduced animals, insects and disease in both exotic and indigenous forests in New Zealand. The system has a number of attributes which make it attractive for management scale monitoring and assessment of forest health problems, although its limitations must also be recognised.

In this study the effects of light quality, system setup and swath width on image quality were reviewed. Imagery already obtained for a range of forest types and canopy damage suggested that the system produces outstanding results for some objectives, but may have little application for others.

NZFRI Ltd experience during 1993-94 indicated the following positive features of the system: ability to subsample within overall coverage using a remote controlled zoom lens; high-quality imagery obtainable under a wide range of light conditions; inclusion of audio information with the video track, and ease of imagery transfer into a computer environment. However, swath width is limited by the required level of resolution, and subsampling must be carefully preplanned. Lower tree crown information is likely to be unreliable.

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INTRODUCTION

The evaluation and introduction of an integrated airborne video image acquisition system as part of the Forest Health Group's research programme at NZFRI, (Hosking *et al.*, 1992) has generated interest from resource managers, in particular those responsible for exotic and indigenous forests. The technology is seen to fill a niche between the high resolution of conventional aerial photography and the gross mapping capabilities of satellite imagery.

The strengths and weaknesses of video imagery are discussed by Pywell and Myhre (1990) and Hosking *et al.*, (1992) and revolve around the issues of flexibility, cost, and resolution. Airborne video imagery can be obtained under a wide variety of weather conditions, can be viewed and modified during acquisition, is relatively cheap to acquire once the hardware is in place, and can be imported directly into an image processing environment. Resolution is an order of magnitude poorer than that obtained by aerial photography and therefore less suitable for the generation of base maps. Recognition of strengths and weaknesses of the technology is essential when selecting applications and generating imagery. In this paper, the 1993-94 experience gained by the New Zealand Forest Research Institute Ltd in monitoring forest canopy damage by video imagery is reviewed.

BACKGROUND

The use of remotely-sensed data as part of the information base of geographic information systems (GIS) has increased during the past decade as land managers gradually accept GIS as their primary planning and management information tool. The wide range of remotely sensed information available, and its forestry applications, is reviewed by Howard (1991). The key to success in utilising remotely sensed information is matching the application with the most appropriate technology. Satellite information, for example, is well suited to resource mapping of large areas (White *et al.*, 1993), but limited by resolution, frequency of coverage, and post-acquisition availability. It is not suitable for the precisely-timed, high-resolution assessment required for monitoring forest health. Synthetic aperture radar (SAR) shows great promise as a remote sensing tool, but is costly, requires a high level of technical expertise for its operation (Milne 1993), and needs specialists to interpret the imagery.

Video imagery is a less sophisticated technique for remote sensing, but offers advantages in cost, availability and ease of interpretation providing that resolution and image distortion are acceptable. The linking of video imagery and associated global positioning system (GPS) data with image rectification and mosaicing software (Bobbe *et al.*, 1993, Evans 1992, Graham 1993) has overcome some of the disadvantages of video imagery as a mapping tool. A range of video systems has been applied to resource monitoring, including panchromatic, colour, multi-spectral and multi-camera techniques (Mausel *et al.*, 1992). A United States Department of Agriculture Forest Service system used by NZFRI was specifically designed to utilise commercially-available components and to act as a workhorse in resource monitoring, rather than advance new frontiers in remote sensing.

METHODS

Equipment

Components of the aircraft image acquisition system are described in detail in Pywell and Myhre (1990). The equipment presently in use by the Forest Health Group includes an S-VHS video camera, video recorder, video monitor, power inverter, power junction box, caption generator and GPS unit as well as a camera mount, equipment rack and necessary cabling. The system is operated from a Cessna 180 aircraft through a standard large-format camera hatch with power provided by direct feed from the aircraft. The aircraft's communication system is used, with cockpit conversation being recorded on the video tape.

Image Acquisition

Of a total of 136 segments of imagery obtained during 1993-94, 26 were specifically related to canopy condition and covered a range of forest types under different flying conditions and varying swath widths (Table 1). Zoom subsampling, using a remote-controlled lens, was included in many runs, and a variety of camera shutter speeds and filter combinations were explored.

Image Evaluation

The normal method used in image evaluation was direct on-screen viewing of both individual frames and split frame comparisons. Dual frames were obtained from a video printer which also provided postcard size polaroid prints. The prints were used during ground verification. Stereo pairs can also be produced for use in evaluating images.

Verification

Hard copy from the video printer was used in the field to determine feature differentiation and exact swath width for representative runs in most of the vegetation types (Table 1).

Location	Forest Type	Canopy	Damage Type	Swath Width (m)	Sky Conditions
Kaingaroa	P. radiata	Even	None	1850	Clear
Kaingaroa	P. radiata	Even	None	100	Clear
Kaingaroa	P. radiata	Even	None	1000	Clear
Kaingaroa	P. radiata	Even	None	70	Clear
Kaingaroa	P. radiata	New plantings	Tree mortality	1000	Clear
Kaingaroa	P. radiata	New plantings	Tree mortality	70	Clear
Kaingaroa	P. radiata	Even	None	1850	Clear
Tongariro	P. radiata	Young trees	Weed invasion	2000	Overcast
Tongariro	P. radiata	Young trees	Weed invasion	100	Overcast
Kaingaroa	P. radiata	Individual trees	UMCY*	500	Clear
Kaingaroa	P. radiata	Individual trees	UMCY	190	Clear
Kaingaroa	P. radiata	Individual trees	UMCY	90	Clear
Te Puke	P. radiata	Even-steep gully	Wind	800	Clear
Rotoehu	P. radiata/Eucalypt	Even	Tree mortality	1000	Overcast
Rotoehu	P. radiata/Eucalypt	Even	Tree mortality	70	Overcast
Rotoehu	Mixed Broadleaf	Irregular	Tree mortality	290	Overcast
Onaia	Mixed Broadleaf	Very irregular	Defoliation	500	Part Cloud
Onaia	Mixed Broadleaf	Very irregular	Defoliation	100	Part Cloud
Hunua	Rata/Broadleaf	Emergent crowns	Possum	150	Clear
Te Aroha	Rata/Broadleaf	Very irregular	Possum	200	Clear
Minginui	Rata/Tawa	Irregular	Possum	300	Overcast
Minginui	Rata/Tawa	Irregular	Possum	30	Overcast
Tongariro	Totara/Broadleaf	Emergent crowns	Possum	2000	Clear
Tongariro	Totara/Broadleaf	Emergent crowns	Possum	100	Clear
Waipapa	Podocarp	Very irregular	None	250	Clear
Homunga Bay	Pohutukawa	Single Trees	Possum	200	Clear

* Upper mid-crown yellowing

TABLE 1 - Video imagery collected during 1993-94

RESULTS

Light Quality

The single most important factor affecting image resolution in the assessment of canopy damage was found to be light quality. Irregular canopies created light wells and side shading which modified light penetration. For plantation conifers, such as radiata pine, light quality had a limited effect on light penetration, but in most other situations it determined the difference between usable and unusable imagery.

All indigenous forest areas from which imagery was obtained had irregular, very irregular, or emergent crown canopies (Table 1). Light quality, as affected by cloud cover, was the overriding influence on image resolution. The deep shade of light wells and dark shadows cast by emergent crowns obscured detail when the image was normally exposed. The amount of deep shadow was increased by low sun angles especially on hill slopes falling away from the sun. Full sun accentuated damage in emergent crowns, e.g. in possum-damaged northern rata at Hunua and defoliated totara on Mt Tongariro.

In general, full cloud cover enhanced the resolution of imagery of indigenous forests. The diffuse light penetrated light wells and reduced lateral shadows cast by emergent trees. It also allowed the recording of more natural colour and more consistent distinction between the crowns of individual species. Diffuse light reduced the brightness of highlights (e.g. those produced by patches of bare land) and decreased contrast in the overall scene. The most important constraint on the availability of diffuse light is the fact that the ceiling for some cloud types commonly occurring over New Zealand is 3000-4000 ft (900-1200 m). An altitude of 4000-8000 ft (1200-2400 m) above ground level is required for wide swath coverage. In the absence of zoom subsampling, diffuse light does not compensate for the decreased resolution associated with wide swath width and there is no need for overcast conditions to be associated with high flying.

The worst sky condition for image acquisition, irrespective of forest type, was found to be partial cloud. This was due to the image being alternately affected by diffuse and direct light. Although usable imagery was obtained in such circumstances in the Onaia area, constant adjustment of the lens iris was necessary to prevent over- and under-exposure.

Even with diffuse light, detail below 4-6 m in the upper tree crown could not be obtained in *P. radiata* plantations. Dense shadow resulting from the close planting of narrow crowned conifers could not be penetrated.

Canopy Architecture

Image resolution was strongly affected by the interaction between individual tree or stand canopy architecture and image acquisition variables, e.g. sun angle and light quality. Images of forests dominated by species carrying foliage on the outer surface of spreading crowns are much easier to interpret than those recording the deep narrow crowns of many coniferous forest trees. In New Zealand, the former are typified by mixed broadleaf forests and some podocarp species, while the latter are largely represented by *Pinus radiata* plantations.

If canopy damage is to be monitored or assessed by airborne video imagery, the damage must be visible from above and adequate resolution must be achievable at an acceptable swath width. Defoliation of individual trees by insects, disease and introduced animals can be easily assessed in indigenous broadleaf species, but radiata pine poses more of a problem. Damage to the lower or mid crown by agents such as *Dothistroma pini* is masked by the upper crown branches and foliage. Leader death in individual trees was often invisible even in 200 m swath widths. Individual tree death, or damage affecting groups of trees, can be reliably assessed and mapped. The technology is well suited to canopy conditions involving larger areas of forest, such as crown colour changes caused by nutrient deficiency or wind damage.

Swath Width

Swath width was critical to the achievement of image acquisition objectives. In many cases the swath width was too wide to give the required resolution, or too narrow to provide coverage representative of the area in question. Swath widths of less than 100 m were of limited use and zoom subsampling was considered to be more satisfactory if small areas were to be examined. Indigenous forest gross canopy damage at the individual tree level could usually be classified into four classes (healthy, damaged, severely damaged and dead) at swath widths between 200 m and 400 m. Where detailed imagery with ground verification was required, two levels of continuous coverage were found to be the most useful, e.g. an easily-located 200 m swath width within a 1000 m overview.

Maintenance of a consistent swath width was difficult in steep terrain, and contour flying was used to minimise variation. The effect of terrain on swath width was least at wide swath widths and greatest at narrow swath widths, and swath width variability increased with decreasing altitude above ground level.

Zoom Subsampling

Use of the remote controlled zoom lens to subsample within wider coverage required careful planning. There was a tendency to zoom too frequently and to use excessive magnification. Zoom subsampling is suitable for formal assessment of canopy damage covering large areas where the rate of subsampling can be carefully determined. Canopy damage in indigenous forests is often discontinuous and clumped and requires continuous narrow swath coverage for effective assessment. Full zoom imagery proved very useful for ground location of sites of particular interest. Hard copy of frames progressing from wide angle to full zoom facilitated the location of individual trees.

GPS and Flight Planning

The integration of GPS to provide on-screen navigation information greatly enhanced the ability to refly specific flight lines. At the flight-planning stage, way points were loaded into the GPS receiver for the beginning and end of each run. This simplified location of the start of each run in unfamiliar territory and reduced ferrying time between runs. The GPS position shown on screen was that of the aircraft and not necessarily the ground location of the centre of the on-screen image. For this reason, a GPS unit of high accuracy will not be required until errors caused by aircraft tip and tilt can be reduced. For the evaluation exercise a Trimble Pathfinder Basic + receiver was used without differential correction, giving an estimated positional accuracy of ±150 m, which was considered adequate. The GPS information could be used to identify segments of imagery on VCRs with inadequate frame counters.

Post Processing

Processing was limited to on-screen analysis of individual frames or tape segments, and the use of hard copy from a video printer to take into the field for verification. The use of an editing VCR was essential for location of imagery on tapes and for freeze-frame viewing. The video printer allowed multi-image comparison on screen, so that different parts of a run, or different runs, could be compared directly. The ability to view images side by side is one of the most important aspects of the use of airborne video technology in canopy damage assessment. It is more valuable than automatic image-processing because it allows sensitivity to the wide range of knowledge and discrimination expected from an experienced assessor.

DISCUSSION

A number of constraints have been identified in the application of airborne video techniques to tree canopy damage evaluation. Crown architecture and light quality were shown to influence resolution, while the position, contrast and extent of canopy damage determined the level of detail which could be extracted from the imagery. The study suggested that airborne video imagery is suitable for relatively coarse classification of damage into a few classes. Identification of subtle differences in crown condition, or monitoring of gross recovery or deterioration over time may be possible using split screen images. This level of detail is often ideally suited to the pragmatic requirements of forest managers.

The study reinforced the importance of clearly defined objectives for specific image acquisition, in particular maximum swath widths and desirable sky conditions. Decisions about analysis of imagery are best made before image acquisition, since requirements for image processing may differ from those for simple on-screen analysis.

Successful application of airborne video imagery within both research and management programmes is dependent on tailoring image acquisition to the individual problem. While an appreciation of the capabilities and limitations of the technology is an essential starting point, best results can only be obtained by experimenting with the most relevant variables as part of an applications trial.

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