be seen as too great for some land owners and managers in the high country.

The Resource Management Act has been the target of much criticism and praise since it came into law in 1991. It is acknowledged that it is new far-reaching legislation, which has most people struggling to come to terms with what is required and how it is to be achieved. The reality is that a huge implementation task has been placed with regional and district councils, and that first-up cases testing its meaning are likely to be more time-consuming and expensive than in the future. These test cases will have a major influence on future RC land-use decisions, which, in turn, should be less costly once the ground rules are clearer.

Suggestions have been made for reducing the time and costs presently involved in gaining an RC for forestry. These involve early recognition of the need to meet environmental concerns, seeking long-term approval for integrating forestry over whole farms or groups of farms, and considerate consultation between all affected parties. In this way just one RC application may be needed for all planting, costs can often be shared, problem areas can be identified at the outset, and compromise can be more readily attained. The consequence should be less discord, lower individual costs and better overall environmental outcomes.

References

Belton, M.C. and N.J. Ledgard. 1991. A study of the spread of trees in the Canterbury high country. New Zealand Mountain Lands Institute 'Review 48', P.O. Box 56, Lincoln University. 41-50.

Davis, M.R. 1991. Increased nutrient availability in topsoils under conifers in the South Island high country. New Zealand Journal of Forest Science 21, 165-179.

Fahey, B. 1994. The effect of plantation forestry on water yield in New Zealand. New Zealand Forestry 39(3), 18-23.

Fisher, D. 1992: The resource management legislation of 1991: a judicial analysis of its objectives: Resource Management. Booker and Friend Ltd, Wellington, New Zealand. 42 p.

Harris, B. 1993. Sustainable management as an express purpose of environmental legislation: the New Zealand attempt. Otago Law Review 8(1), 31-76.

Hughes, H.H.R. 1991. Sustainable use for the dry tussock grasslands in the South Island. Parliamentary Commissioner of the Environment, P.O. Box 10-241, Wellington, New Zealand. 105 p.

Ledgard, N.J. 1994. A form for assessing the risk of conifer spread in the South Island high country. New Zealand Forestry 39(1), 26-27.

Martin, G. 1994: South Island High Country Review: final report from the working party on sustainable land management. Commissioned by the Ministers of Conservation, Agriculture and Environment, Wellington, New Zealand. 184 p.

Ministry of Forestry. 1994. South Island high country forestry design. Ministry of Forestry, P.O. Box 25022, Christchurch, NZ. 36 p.

O'Connor, K.F. 1994. High country land use: what are the issues for 1994? What relevance has forestry? New Zealand Forestry 39(4), 2-5.

Perkins, H.C. and A. 1993: Environmental Planning in New Zealand. Palmerston North, Dunmore Press. 199 p.

Development of a large-scale, aerial photography technique to assess the severity of Upper Mid-Crown Yellowing (UMCY) in *Pinus radiata* trees

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ABSTRACT

A number of photographic variables were evaluated for assessing Upper Mid-Crown Yellowing in Pinus radiata D. Don trees. These included comparing: vertical and oblique photography, several image scales, different camera look-angles, two film types, various light conditions, mono versus stereo imagery and fixed wing versus helicopter camera platforms.

As a result of this work, a technique has been developed and used operationally for surveying the extent and severity of UMCY in several forests. The method is based upon colour, oblique stereo photography taken from a helicopter flying at approximately 100 m above the canopy. A Global Positioning System (GPS) is used to navigate to the photo-site and a radar altimeter for determining the required flying height.

A methodology was also developed to quantify the severity of UMCY, when viewed on the stereo-photographs. This involves assessing approximately 30 trees per stereopair using a four-point classification. The results obtained are converted to a compound value for each photo-site which can be used to map the distribution of UMCY throughout a compartment or forest.

The methodologies described could have application for assessing other disorders in tree crowns.

KEYWORDS

Aerial photography; Forest health assessment; GPS; *Pinus radiata;* Upper Mid-Crown Yellowing.

INTRODUCTION

The symptoms of UMCY vary from yellowing of needles in the upper section of the crown, to premature needle loss. They can include twig die-back and, in severe cases, branch death. This disorder affects many stands of *Pinus radiata* in New Zealand and is thought to be related to a nutritional imbalance (Beets, Payn & Jokela, 1993). Although the severity of a tree's UMCY symptoms can be assessed by an observer standing on the ground (Beets *et al.*, 1991), this approach becomes impractical when undergrowth restricts movement, when the canopy is closed or when the information is required on a forest scale. For these situations, use of aerial photography is more appropriate because it can provide high resolution images using proven technology and many sites can be visited in a short space of time.

OBJECTIVES

The objective of this study was to develop a practical remote

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sensing method for assessing UMCY, in *Pinus radiata*, across a stand or forest.

Two basic approaches were evaluated: vertical and oblique aerial photography.

APPROACH ONE: VERTICAL PHOTOGRAPHY TAKEN FROM A FIXED-WING AIRCRAFT

Method

A series of runs of vertical, natural colour, aerial photographs were taken over several forest compartments known to contain trees showing UMCY symptoms. The photographs had scales ranging from 1:1800 to 1:10,000 and were taken as stereoscopic pairs with a 55 mm format Hasselblad camera mounted in a Cessna 180 aircraft.

Results

Whilst UMCY symptoms could be discerned on the vertical photographs that had scales larger than about 1:5000, it was not possible to accurately assess the severity of the condition. This result was not unexpected in view of the fact that the branches in the mid-crown, where the UMCY symptoms occur, were often overtopped by healthy green foliage (see Figure 1). Due to this limitation, vertical photography was considered unsuitable for assessing UMCY and was eliminated from further consideration.

In order to obtain the large photo-scales required to discern the UMCY symptoms, very low-flying heights were necessary, combined with slow ground speeds to minimise image motion (blurring) in the photographs. Because a fixed-wing aircraft is not a suitable camera-carrying platform for these situations, a helicopter was used for subsequent developmental work.

APPROACH TWO: OBLIQUE PHOTOGRAPHY TAKEN FROM A HELICOPTER

Method

A series of runs of oblique aerial photographs was taken over a number of stands containing trees showing UMCY symptoms. The photographs were taken from a helicopter at a range of scales using a purpose-designed camera mount (see Figure 2). This mount consisted of a tripod with a head modified to accommodate two, parallel mounted 55*55 mm format cameras, the firing mechanisms of which were linked through an intervalometer[1]. Although the cameras were positioned only 30 cm apart, use of the intervalometer and the forward movement of the helicopter, allowed the effective distance between them to be increased. The percentage of overlap of the photographs, and the resulting stereoscopic perception of depth, could therefore be controlled.

The range of conditions investigated for the oblique photography included:

- Photo-scales ranging from 1:500 to 1:10,000[2].
- Camera look-angles of 35° and 45°.
- Natural colour and colour infra-fred film emulsions (Kodak VPS III, type 5026, and Kodak Aerochrome type 2443, respectively) processed to negative[3].
- Overcast and cloud-free skies.
- Effective camera separations ranging from 30 cm to 10 m.

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[1] A device designed to enable an electrical signal to be delayed by a predetermined amount.

[2] Because the scale of an oblique photograph decreases from foreground to background, the value used is the one across the centre of the frame.

[3] The 5026 film was developed and printed by NZ Aerial Mapping, Hastings. The 2443 film was developed and printed by Landcare Research Ltd, Palmerston North.

The 2443 film is normally processed to a positive, however, in order to give it a wider exposure latitude (Zsilinszky *et al.* 1985) and to make it more comparable with the negative film 5026, it was processed to a negative for this study.

Figure 3 is an example of the type of oblique imagery obtained during the study. It is a stereogram showing a stand containing a number of trees exhibiting UMCY symptoms and allows a comparison to be made between their appearance on natural colour and colour infra-red film.

The oblique negatives were enlarged 4x then hand printed to maintain consistency in colour balance. The prints were examined, with the aid of a mirror stereoscope, by two interpreters who had experience assessing UMCY symptoms in the field, and by the authors.

Results

The photographs provided a clear view of the upper part of the tree's crown and were found to be ideally suited for scoring UMCY. The results of the evaluation of the various sets of oblique images are given below:

Photo-scale

It was clear at an early stage of this examination that selecting a suitable photo-scale was one of the most critical factors affecting the suitability of images from which UMCY could be accurately assessed. While the smallest negative scale at which the symptoms could be seen was about 1:4000, they were more obvious when the scale was 1:2000 or larger. The optimum negative scale was found to be approximately 1:1000. This scale provided sufficient resolution to enable the trees to be scored with relative ease and also gave enough coverage for approximately 30 trees to be assessed per stereopair. This number was selected on the basis of foliage sampling work carried out by Knight (1978) and a study into the genetic variability of UMCY affected trees carried out by Beets *et al.,* (1996). A sample of this size should provide a mean UMCY score for a site accurate to better than +/– 20% of the mean value at the 0.05 probability level.

Look-angle

The look-angle of the imagery was found to have an important influence on the photo-interpreter's ability to discern UMCY symptoms. From an examination of the various images, it was found that the optimum look-angle was approximately 45°. At lower angles, there was an increased likelihood that the symptoms would be hidden by the crowns of adjacent trees. At higher angles, the symptoms were frequently hidden by the healthy crown on the top of the tree.

Natural colour v. *colour infra-red film*

When photographs were taken in full sunlight conditions, the UMCY symptoms could be seen equally well on both the natural colour and colour infrared prints. However, when the photographs were taken under partial cloud, the natural colour prints were found to be more suitable because, in the areas of cloud shadow, the images of the trees, although underexposed, still contained sufficient information to allow their UMCY symptoms to be discerned and scored. For the colour infrared prints, however, the infrared emission in the cloud shadow areas was much lower and was insufficient to allow suitable images to be formed on the film. This effect is explained by the greater absorption of infrared radiation by the water vapour in clouds, and its lower atmospheric scattering compared to the shorter wavelength visible light (Jensen, 1986).

Overcast v. *sunlit conditions*

When the natural colour photographs taken on overcast days were compared with those taken in full sunlight, it was observed that it was easier to discern the UMCY symptoms on the former, because the lack of harsh shadows allowed more in-crown detail to be seen.

Camera separation/stereoscopy

One of the most important factors that enabled an interpreter to discern UMCY symptoms on the oblique photographs was the ability to view them stereoscopically. Only then was it possible to clearly discriminate between the foliage of one crown and another. The camera separation required to achieve the optimum stereoscopic effect was found to be 5 m. This was obtained through a physical camera separation of 30 cm, a one second interval between the triggering of the cameras and a forward movement of the helicopter of ~ 10 knots.

It should be noted that it was not possible to use a single camera to obtain the stereo-photographs because the motorised film advance mechanism was too slow to permit the second image to be taken in time.

DEVELOPMENT OF A METHOD FOR SCORING UMCY FROM STEREO IMAGES

Once the aerial photographs had been obtained, the following technique, outlined by Thorn *et al.*, (1995), was developed to score the imaged trees for UMCY:

A stereo pair of the photographs was placed under a mirror stereoscope and a sheet of clear acetate film laid over one photograph. Thirty trees (if possible), located in the centre of the stereo-overlap, were identified and marked on the acetate. Each sample tree was then assessed according to the UMCY scoring system shown in Table 1. If any tree appeared to be suffering from severe *Cyclaneusma minus* or had any other physical or health problem, it was not scored.

Table 1: The UMCY severity classes, their description and corresponding UMCY value, based upon scoring *Pinus radiata* from stereo oblique aerial photographs.

UMCY severity class	Description	UMCY value
A	Healthy green upper crowns with good needle retention.	1
B	Yellowing of older needles (usually two- but possibly one-year-old) visible in the upper crown. Some thinning of needles in the central portion of the upper crown may be present.	3
C	As for B, but with a hollow zone (as a result of needle loss and twig death) occupying up to half or more of the width of the upper crown.	5.5
D	As for C, but with dead primary branches (from a single primary branch to entire whorls) in the UMCY zone.	7.5

The scoring system presented in Table 1 is a modification of the eight severity classes used by Beets and Jokela (1994) to assess UMCY from the ground. When scoring UMCY from the aerial photographs, it was necessary to reduce the number of severity classes to four because fine detail, such as secondary twig death and small amounts of needle yellowing used to differentiate trees in the 8 class system, could not be clearly identified.

In Table 1, a score of A is equivalent to the usual A+ described by Beets and Jokela (1994), B is equal to an A- to B-, C equals C+ to C- and D equals D+ to D-. The UMCY values in the above table have been adjusted accordingly.

The number of trees in each UMCY severity class was recorded for each pair of the scored stereo images. The percentage of trees in each UMCY class was then calculated (the total number of trees did not include unclassifiable trees such as those suffering from severe *Cyclaneusma*).

For each stand of trees, represented by a stereo-pair of photographs, an UMCY value was calculated as follows:

UMCY stand value = ((%A x 1) + (%B x 3) + (%C x 5.5) + (%D x 7.5)) / 100

The resulting data could then be used to map the incidence (percentage of trees affected by UMCY) and severity of UMCY across a forest estate.

THE RECOMMENDED PROCEDURE FOR UMCY SURVEYS

From the results of the study described above, the key elements of a remote sensing procedure for providing images for scoring the incidence of UMCY in the canopies of approximately 30 *Pinus radiata* trees per photo-site were identified as:

- A helicopter as the imaging platform.
- Two medium format cameras, mounted parallel and 30 cm apart.
- Natural colour film (e.g. Kodak VPS III, type 5026).
- A camera look-angle of approximately 45°.
- A print scale at the photo-centre of approximately 1:250 derived using a 150 mm focal length lens, a flying height above the canopy of approximately 100 m and a negative enlargement of 4x to 22 cm square.
- Overcast sky conditions but scattered cloud or cloud-free conditions would also be acceptable.
- Stereo-imagery with an air-base of approximately 5 m.

The variability in tree height that occurs across a forest, and the undulating nature of many types of terrain, can make it difficult to consistently maintain the optimum 100 m flying height above the canopy. It is recommended, therefore, that the aircraft be equipped with a radar altimeter in order to provide the pilot with an independent height reference. Experience has shown that this method works well on all but the most undulating sites. In these instances it becomes necessary to be guided by the coverage shown in the camera mount's viewfinder.

To facilitate the task of navigating from site to site, it is essential that a Global Positioning System (GPS) be used. The grid coordinates of the photo-points may be obtained from a map, then, after being converted to the WGS 84 datum, entered into the GPS receiver as 'waypoints'. During the aerial survey, the receiver provides the pilot with a display showing the distance and bearing to the next waypoint. This information is updated every few seconds and enables the helicopter to be flown directly to the site.

The GPS can also be used to calculate the actual location of the photo-point. About five GPS coordinates, beginning the instant the photographs are taken, are recorded as the helicopter continues in a straight line along its flight path. After post processing, the data identifies the location of the helicopter, to within 2-5 m[4], and shows its heading. When this information is combined with the look-angle of the cameras and the helicopter's flying height, the coordinate of the actual photo-point can be estimated.

[4] This figure relates to the Trimble pathfinder Basic Plus GPS used in this study.

Figure 1. A *Pinus radiata* tree exhibiting UMCY symptoms.

Figure 2. The camera mount, designed for taking oblique, stereo aerial photographs, installed in a helicopter.

Although the symptoms of UMCY are at their peak in spring, it is considered that the best time to photograph affected trees is in November or December. By this time, needles which are yellow because of infection by the fungus *Cyclaneusma minus,* have been cast (Bulman 1993).

The severity of UMCY in the photographed trees then needs to be quantified. Using the approach described above, an experienced interpreter can score 30 trees in approximately 15 minutes. In order to avoid eye strain, the maximum amount of time that should be spent doing this work is about four hours per day.

CONCLUSION

A remote sensing procedure has been developed that enables an assessment to be made of the incidence of UMCY across stands of *Pinus radiata* trees. The resulting images, based on large-scale, oblique, stereo aerial photography, enable the foliar discolouration in the tree's crowns to be easily seen and scored.

For the approximately 1100 stereopairs of photographs taken to date, the average direct cost (helicopter + film + printing) was approximately $NZ100 per pair and the average time to fly to and photograph each site was four minutes.

The procedure has been used successfully by two major forestry companies in New Zealand to carry out surveys over nearly 250,000 ha of their forest estate. One of these surveys is described in Thorn *et al.*, (1995). The results enabled forest maps to be produced showing the distribution of UMCY, and facilitated research into the relationship between the incidence and severity of the crown disorder and environmental factors.

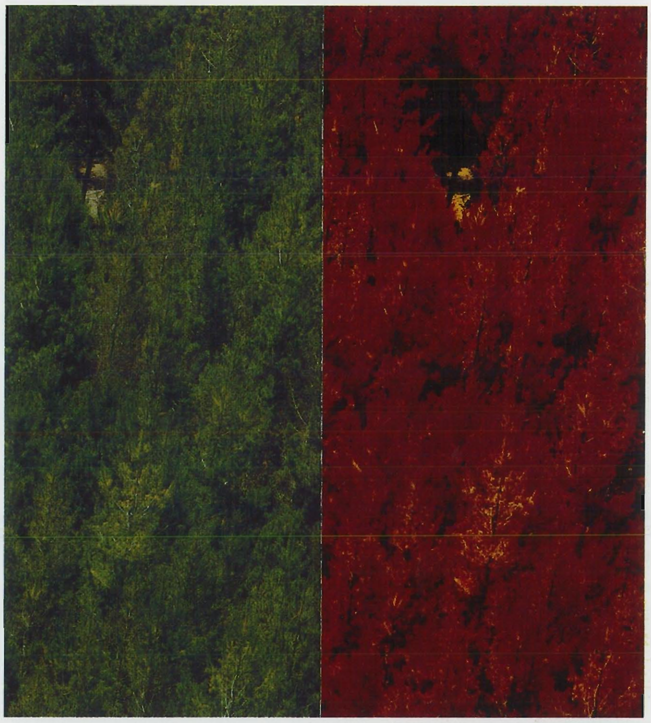
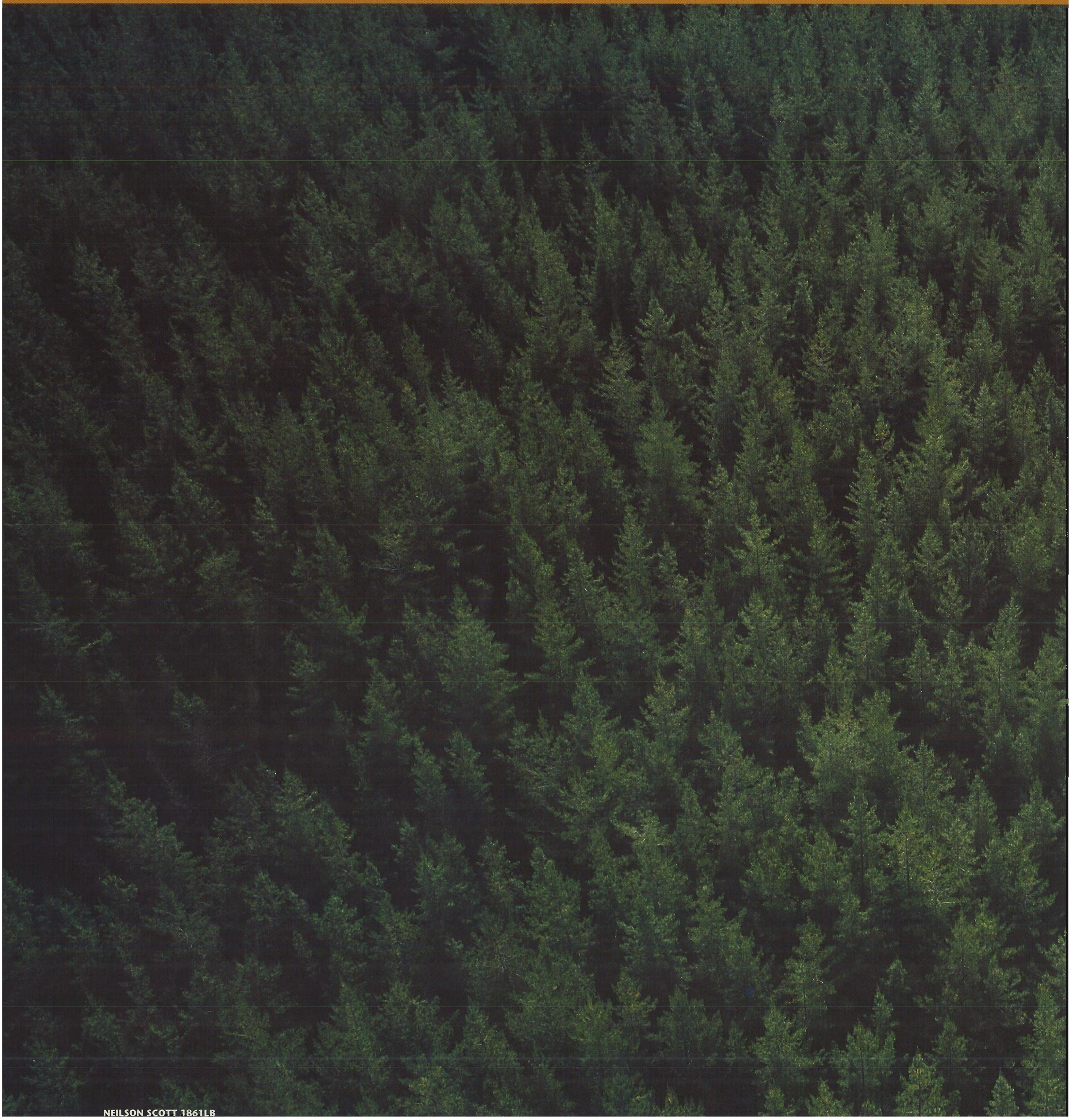


Figure 3. A stereogram (left image normal colour, right image colour infrared) of a stand of trees, some of which show UMCY symptoms. The look angle was 35° and the print scale at the centre of the images approximately 1:400.

FUTURE WORK

It is recognised that, in stands where there is considerable short-range variability in the expression of UMCY, the scores obtained from a limited number of photographs may not be representative of the stand as a whole unless the variation is captured by a higher sampling intensity. A development of the current approach is therefore under investigation. A video camera will be installed between the film cameras and used to provide a sequence of images during the fly-by and photo-sampling of the site.

If you **think** this looks
wait until **you see**



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Although the resolution of these images will not be high enough to enable UMCY to be scored directly from them, their quality should be such that it will be possible to ascertain whether or not the photographs are representative of the surrounding area.

ACKNOWLEDGEMENTS

This work was supported by the NZ Forest Industry's UMCY Multi-Client Research Group and the Foundation for Research Science and Technology. The main developmental work was carried out in collaboration with the Forestry Corporation of New Zealand.

The authors would like to acknowledge the contribution made by Bronwyn Rodgers and Peter Beets to the UMCY scoring and data analysis.

REFERENCES

Beets, P., S. Carson, M. Dick, A. Singh, M. Skinner and I. Hunter. 1991: Mid-crown yellowing – on the increase. What's New In Forest Research No. 206. Ministry of Forestry, Forest Research Institute, Rotorua.

Beets, P. N., T.W. Payn, and E.J. Jokela. 1993: Upper mid-crown yellowing (UMCY) in *Pinus radiata* forests. NZ Forestry 38(2): pp 24-28.

Beets, P.N., E.J. Jokela. 1994: Upper mid-crown yellowing in *Pinus radiata:* some genetic and nutritional aspects associated with its occurrence. NZ J. For. Sci., 24(1): pp 35-50.

Beets, P.N.; G.R. Oliver, and M.O. Kimberley. 1996: Genotypic versus environmental variation in Upper Mid-Crown Yellowing in *Pinus radiata* stands. NZ J. For. Sci.: (in press).

Bulman, L. 1993: *Cyclaneusma* needle-cast and *Dothistroma* needle blight in NZ pine plantations. NZ Forestry, 38(2): pp 21-24.

Jensen, J.R. 1986: Introductory digital image processing: A remote sensing perspective. Prentice-Hall, Englewood Cliffs, NJ 07632, page 97.

Knight, P.J. 1978: Foliar concentrations of ten mineral nutrients in nine *Pinus radiata* clones during a 15-month period. NZ J. For. Sci. 8(3): pp 351-368.

Thorn, A.J., P.N. Beets, S.T. Olykan, L.A. Morris. 1995: Recent developments in assessment of nutrient deficiencies in *Pinus radiata* using colour imagery. NZ Forestry, 40(2): pp 33-37.

Zsilinszky, V.R., D.I. Ross, D. Klimes. 1985: The capabilities of colour infrared film as a negative. Photogrammeteria, (4) pp 179-192.

Participatory planning and management of Pohnpei's watershed and environment: a case study from the Federated States of Micronesia

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ABSTRACT

The loss of indigenous forests and biodiversity on the island of Pohnpei in the Federated States of Micronesia is of national and regional concern and of international interest. The country is dependent on the conservation of its natural environment which is one of the most diverse in the pacific.

Early attempts to conserve the island's watershed and environment ended in failure, due to top-down decision-making and inadequate consultation with the stakeholders. Subsequently, a participatory model has evolved which promises to be more acceptable.

In this paper the participatory planning and management processes are described. The strengths of this approach and the prerequisites for the future success of conservation efforts are outlined.

INTRODUCTION

Empowering local people so that they are actively involved in making decisions about their environment is critical in the Pacific islands. Much of the land and coastal resources are customary owned and used, and Governments have little jurisdiction or enforcement authority at village level. Yet, generally there has been a slow appreciation of this and attempts to impose policies often have disastrous results, as Pohnpeians found out.

In Pohnpei, in the north-west Pacific, attempts were made to protect the watershed of the main island by designating the intact forest in the rugged interior and the coastal mangroves. This approach did not work. A different strategy was necessary. So far, participatory planning and management (PPAM) has proved to be a highly successful alternative to the top-down approach.

This paper discusses the history of attempts to conserve the watershed and the island environment. The futility of acting without the support of the local community and traditional chiefs is contrasted with a more holistic model. The central features of this alternative approach is that it is more attuned to the needs of the community and it integrates conservation and development, rather than attempting to preserve resources by statutory designation. A decision-making framework is used to illustrate the different levels of planning and decision-making that is required and to highlight areas that still need to be covered to make planning and management effective.

BACKGROUND

Pohnpei is a tropical volcanic island of approximately 35,500 ha in the Eastern Caroline islands group of the north-west Pacific. The circular island is steep and mountainous, with the highest peak rising to 780 m. It has an average rainfall of 3090 mm, which is thought to exceed 7500 mm in the rugged interior (Pohnpei State Government 1995). Together with six outlying atolls it forms one of the four states of the Federated States of Micronesia.

The rugged mountain interior of Pohnpei is heavily vegetated, comprising several forest types including upland, palm, swamp and dwarf or cloud forest at high elevations. Agroforestry and secondary forest is found at lower elevations and in coastal areas, together with some grass or fern savannah (Raynor 1991). Extensive mangrove forests, up to 4 km wide, fringe the island. The flora is amongst the most diverse in Micronesia, with the upland

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