

**Remote Sensing Needs Identified During Industry
Consultation**

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Client Report No. 38165

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Industry Consultation**

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Foundation Research Science Technology (FRST)**
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CLIENT REPORT No: 38165

EXECUTIVE SUMMARY

Objective

The objective was to clarify the information and reporting needs of the forest industry through direct consultation.

Key Results

A list of forest health issues was compiled after discussions with industry personnel. Methods to quantify the severity of Dothistroma, Cyclaneusma, weeds, and nutrient deficiencies, and a need for an objective measure of overall forest health condition were the issues rated most significant. Wind damage, Armillaria, and bark beetle mortality were rated very important.

Application of Results

The second stage of this work will be to review and evaluate technologies with the potential to meet needs identified in this paper. Criteria for assessing potential technologies will include their likely effectiveness, cost, and overall acceptability.

Further Work

The next stage will be to determine research priorities and to develop research programmes based on outcomes from this project.



CLIENT REPORT No: 38165

TABLE OF CONTENTS

EXECUTIVE SUMMARY	ii
INTRODUCTION	1
MATERIALS AND METHODS	1
RESULTS	2
Forest pests and other biotic agents	2
Dothistroma needle blight	2
Cyclaneusma needle-cast.....	2
Armillaria.....	2
Hylastes damage	2
Nectria	2
Other pests	3
Possum damage.....	3
Weeds.....	3
Nutrient and physiological disorders.....	3
Nutrient deficiencies	3
PNB (Physiological needle-blight).....	3
UMCY	4
Climatic disorders and other events	4
Drought stress	4
Fire damage.....	4
Frost damage.....	4
Snow damage.....	4
Waterlogging.....	4
Wind damage.....	4
Forest Health Monitoring and Surveillance.....	5
Crown health.....	5
Crown density.....	5
Mortality	5
Nursery surveys.....	5
Pest detection	5
Stocking density/Canopy closure	5
Reporting needs	6
FSC	6
Reports	6
Montreal Process and FAO global forestry resource assessment	6
RECOMMENDATIONS AND CONCLUSIONS	7
APPENDICES.....	9
Appendix A – Individual discussion points from key industry people	9

Contract number	Milestone 1.2.3.3.1
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Location	Rotorua

INTRODUCTION

The importance of forest health related information continues to increase with greater demands for risk management, site-specific management to optimise productivity and minimise costs, and reporting on long-term trends for forest health, pest status, and canopy condition.

At present most forest health-related surveillance is undertaken using standard visual assessments. Recent advances in remote sensing, in particular the use of hyperspectral imagery, has opened up the potential for surveillance of pest and disease impact, nutritional disorders, and weed distribution over extensive land areas. For forestry, potential applications could include the mapping of the incidence and severity of foliage diseases such as *Dothistroma* needle blight, and the distribution of weeds such as gorse and broom. Remote sensing technologies may be able to determine canopy structure and have application with forest condition monitoring. Notwithstanding the potential application of advanced technologies such as hyperspectral imagery and LIDAR, other technologies such as digital photography and visual assessment may also be useful and should not be overlooked.

The FBRC and FRST have co-funded a remote sensing project with the primary objective of determining remote sensing technologies that could be used to assist with forest health issues. The scope of the project is large, forest health and remote sensing, using their broadest definitions, will be evaluated. Firstly, industry needs with regard to forest health issues need to be identified. Then, remote sensing technologies need to be identified and these technologies evaluated with regard to industry needs. This report summarises responses gathered during a series of interviews and discussion with industry representatives, as the first step in providing an outcome for the overall remote sensing project.

MATERIALS AND METHODS

Key industry people involved in forest health issues were interviewed during May and June 2005 (Table 1). Other industry representatives were consulted on an *ad hoc* basis. Their responses were summarised, and points from the key people are appended.

Table 1 – Key Industry Representatives interviewed

Person	Organisation
Nigel Heron	Kaingaroa Timberlands
Wei-Young Wang	PF Olsen and Co
Mark Forward	Weyerhaeuser NZ
Simon Anderson	Carter Holt Harvey Forests
Peter Oliver	City Forest
Paul Lane	Ministry of Agriculture and Forestry
Brendan Murphy	Biosecurity NZ, MAF

RESULTS

A number of significant forest health issues were identified. These are discussed individually below.

Forest pests and other biotic agents

Dothistroma needle blight

This is a significant disease throughout many parts of New Zealand, particularly in the central North Island. There was almost universal agreement that assessment and mapping, leading to a DSS for spray treatment is needed. Infection needs to be assessed at the sub-stand level, in 5% steps if possible. Maps need to be 1:20000 scale. The information obtained from assessments should be able to be transformed so that an area affected, for any specified level, can be calculated. This would enable managers to budget for spray operations and adjust the level of spraying to suit their budget.

Cyclaneusma needle-cast

Needs were similar to those identified for Dothistroma, except spray operations are not carried out for Cyclaneusma. However, disease incidence and severity data would be useful for determining economic impact and for targeting control by silvicultural means. The data may also aid managers to decide if control measures are justified.

Armillaria

This disease was mentioned a few times. There is a need to identify individual tree mortality, and if possible, chronic infection.

Hylastes damage

Identify and map outbreaks and damage (mortality). Identification of seedling mortality would be useful for targeting blanking operations.

Nectria

A significant problem in the lower half of the South Island. Techniques to identify decay in live trees, and cankers on stems, are needed.

Other pests

Swiss needle-cast, and Eucalyptus insect and fungal pests were mentioned but were not high priority.

Possum damage

Population monitoring to determine actual animal numbers rather than damage alone.

Weeds

Need to determine infestation and intensity. Species differentiation is important – i.e. need to be able to identify broom, gorse, etc. The ground cover (area covered by weeds) should be expressed as a percentage, at a stand and block level.

Post-plant release operations (usually second year) are done by helicopter surveys, and are almost presence or absence surveys. Assessment is required for weed control decisions and estimation of planting costs.

Clematis is a hazard at clearfell – can cause trees to hang. Presence is determined by inventory at present.

Nutrient and physiological disorders

Nutrient deficiencies

The identification and determination of nutrient deficiencies was often mentioned. These need to be identified and mapped. There was consensus that a method to identify deficiency before external symptoms (hence damage) was apparent would be beneficial. At present stands are sampled at age 4 (before and after treatment). Accuracy is also an issue - for marginal stands the accuracy from foliage sampling techniques is variable and some stands develop symptoms later than age 4. Remote sensing is needed to provide a more accurate system for estimating marginal deficiencies.

A hand-held analyser for soil and foliage nutrient analysis that provided real time data would reduce costs.

PNB (Physiological needle-blight)

The needs here are the same as for *Cyclaneusma* needle-cast - identification, assessment, and mapping.

UMCY

UMCY is a significant problem in parts of the central North Island and in Nelson. Dieback may not affect wood production but may affect wood quality. Estimates of disease severity over the estate and at stand level are needed.

Climatic disorders and other events

Drought stress

Two respondents considered this to be important, and one considered it not important because it was considered that the climate station network would provide information on whether drought stress is likely to occur. The interaction with shallow soils was mentioned. It would be useful to determine wilt and pre-wilt symptoms.

Fire damage

This was mentioned by only one person, who suggested remote sensing could be used to identify hotspots.

Frost damage

It would be useful to map frost-prone areas, and temperature gradients throughout forested areas in order to target species selection.

Snow damage

Confined to localised areas, but significant. At present quantify by visual means. A technique to quantify broken tops and branches for evaluation and salvage is needed. This applies for wind and possum damage too.

Waterlogging

In some cutover areas waterlogging is a problem. Need to quantify and map for targeting planting.

Wind damage

Need to quantify damage, especially scattered damage. Some problems reconciling inventory data with actual values.

Forest Health Monitoring and Surveillance

Crown health

There was general agreement that a subjective rating of crown health is needed, at the stand and tree level. This would fit in with a ground-based monitoring system. There was high support for the development of a “health index” to provide an overall forest health score at a stand level that was repeatable from year to year. Measurement of stress was also mentioned.

Foliage colour should be measured – used for nutrient status, chlorophyll status (photosynthetic capacity?), and tree health in general.

Any long-term forest health monitoring scheme should ideally tie in with the carbon monitoring plotting system.

Crown density

Remote sensing techniques should deliver an objective means of measuring needle retention and crown transparency. Used to gather baseline data to enable changes in forest health status to be determined.

Mortality

Remote sensing could be used for remapping, identifying areas needing restocking.

Nursery surveys

Remote sensing could deliver a practical solution to nursery surveillance for new pest detection and existing disease surveys.

Pest detection

A remote sensing system tied in with forest health surveillance might detect new pests more quickly – i.e. Nectria. Can remote sensing pick up gall rusts, etc?

Stocking density/Canopy closure

There is a need to reliably estimate canopy closure, as this can affect disease intensity and forest health in general. We need an objective measure of measuring LAI at a stand level.

Reporting needs

FSC

Remote sensing would be useful to gather data for FSC reporting, but at present we do not have NZ standards. The cost may be prohibitive and markets don't require it.

Reports

Annual, or quarterly, forest health reports at the forest level are required. Significant problems need to be identified and reported. Maps at the forest level should be produced. To keep costs down production of reports should be automated and simple.

Montreal Process and FAO global forestry resource assessment

MAF has international requirements to report at a regional or national level. The Montreal Process reports are provided every five years. The FAO global forestry resource assessment reporting needs have been recently broadened to include environment, criteria indicators and processes by forest type. This involves disturbance relating to health and vitality – fire, disease, insect, and abiotic influences.

MAF's main interest would focus on changes over time of diseases that are present and well established, and changes in status of newly established pests, particularly in the changes were destructive.

RECOMMENDATIONS AND CONCLUSIONS

A number of Forest Health issues have been identified during this process. Remote sensing techniques, either now or in the future, may be able to provide information that can address many of these issues. The significant forest health issues identified, and ones where most effort should be spent, are listed below and shown in Table 2.

- Dothistroma
- Cyclaneusma
- Nutrient deficiencies
- Weeds
- Hylastes/seedling mortality
- UMCY
- Wind damage/branch breakage
- Overall forest health score
- Crown density/forest condition monitoring

Other health issues were important and should be considered if resources allow:

- Nursery surveys
- Nectria
- PNB
- Possum damage
- Snow damage

Table 2 – Significant health issues in relation to stand development

					Crop Age				

1-5	6-10		11-15		16-20		21-25		
Hylastes mortality									
Nursery health									
Weeds	Weeds								
- pre- and post-plant	- competition								
Dothistroma	Dothistroma		Dothistroma						
Drought stress	Drought stress		Drought stress						
Nutrient deficiencies	Nutrient		Nutrient						
- pre-symptom	deficiencies		deficiencies						
stress	- visible symptoms		- visible symptoms						
Crown density	Crown density		Crown density		Crown density		Crown density		
Health score	Health score		Health score		Health score		Health score		
Snow damage	Snow damage		Snow damage		Snow damage		Snow damage		
	Nectria		Nectria						
	UMCY		UMCY						
	Cyclaneusma		Cyclaneusma		Cyclaneusma				
	Possum damage		Possum damage		Possum damage		Possum damage		
					PNB		PNB		

Dothistroma is a special case because there is an active aerial spray control programme for this disease. Thus, assessment and reporting needs have to incorporate assessment, mapping, area affected determination, and some type of decision support system for aerial spraying. Cyclaneusma, PNB, and to a certain extent Armillaria

mortality and UMCY, all show foliage symptoms and it is likely that the same remote sensing technologies would be applicable to all these diseases. However, the understanding of factors causing PNB is a prerequisite to defining appropriate monitoring techniques. Possums, wind, and snow all cause branch breakage and damage so they may be able to be evaluated on the same criteria.

Mapping drought stress may be important to indicate tree stress, level of competition from weeds, and interactions with tree health status.

The determination of weed height relative to tree height wasn't specifically mentioned during the interview process, but would be useful.

APPENDICES

Appendix A – Individual discussion points from key industry people

Nigel Heron at Kaingaroa Timberlands, Waiotapu on 10 May 2005

Disease assessment

No need for single tree assessment generally. General needs revolve around mapping disease intensity through a stand. This is because there may be differing disease levels within a stand, i.e., at the sub-stand level.

Dothistroma

Data needs. To categorise infection levels at the stand and sub-stand level. Ideally assess in 5% steps. A disease distribution map should link with a spray decision support system.

Reporting needs. Disease distribution maps generally at a 1:20000 scale. Stand level maps may be required. Also, maps of disease over a specified level would be useful, i.e. 20%, 25%, 30%, etc. This information should be transformed so that area over a specified level, and thus area to be sprayed, can be calculated. At present infection levels obtained from aerial surveys are digitised by hand.

Cyclaneusma

Knowledge of infection levels would be useful for economic impact reports and for decisions on control options. The problem with control by selective thinning is that managers also have to make decisions on pruning. It would be expensive to prune 100% of the crop. Now, thinning is done at age 8 or 9 based on mean top height. It would be useful to know what parts of the estate are prone to *Cyclaneusma*.

Armillaria

Determination of mortality and chronic infection is important. Mapping of individual tree mortality is preferred.

Weeds

Need to determine infestation and intensity. Species differentiation is important – i.e. need to be able to identify broom, gorse, etc. The ground cover (area covered by weeds) should be expressed as a percentage, at a stand and block level.

At present post-plant release operations (usually second year) are done by helicopter surveys, with one look at each stand. They are almost presence or absence surveys. Any weed is significant on the plateau. They are important on hill country too, and justify control operations.

Spacing/canopy closure

A stocking/height formula is used to estimate canopy closure. There is a need to reliably capture this information to enable decisions on thinning rates and timing. Canopy closure influences forest health.

Overall forest health condition

An estimate of overall forest health using some sort of score would be very useful for FSC reporting requirements at the forest level. It would need to overcome seasonal (i.e., *Cyclaneusma* and UMCY) and annual differences.

UMCY and possum damage assessment

Dead tops, dieback, and branch damage may not affect tree growth significantly but may affect wood quality. A means to estimate incidence and severity over the estate would be useful to determine impact and need to control – similar to the *Cyclaneusma* needs.

B deficiency

As with many other disorders, maps of incidence and severity are needed. Remote sensing techniques might pick up deficiencies earlier than foliage sampling – i.e. at age 2 or 3 so fertiliser can be applied earlier. At present stands are sampled at age 4 (before and after treatment). For marginal stands the accuracy from foliage sampling techniques is variable and some stands may develop symptoms at a later stage. So remote sensing is needed to provide a more accurate system for estimating marginal deficiencies.

Forest Health monitoring

Remote sensing could be used to determine needle retention and, possibly, crown transparency. An assessment of canopy condition would be useful in order to provide an overall forest health value.

An objective method for assessments of viewpoint and permanent health plots is needed.

Wei-Young Wang at PF Olsen Ltd, Rotorua on 16 May 2005

New Zealand forests are generally healthy compared with those overseas. We therefore need a very accurate system to identify differences and to quantify disease levels.

PF Olsen is a client-based company and they take the lead from their clients. Forest health reporting is important. Clients require descriptive reports and recommendations for mitigation of significant diseases.

Significant needs were:

Identification and determination of drought stress

Identification and determination of nutrient stress/problems

Weed problems, especially at pre-planting. Required for weed control decisions and estimation of planting costs. Species determination is important.

Mark Forward at Scion, Rotorua on 17 May 2005 (Andrew Dunningham present)

The assessment of foliage colour at the individual tree and group level and is important for:
determination of nutrient status

chlorophyll status

disease/tree health in general for forest condition monitoring

UMCY

UMCY is a significant problem in Nelson. Disease severity and incidence assessment and mapping is required.

Dothistroma and Armillaria

Dothistroma disease incidence and severity assessment and mapping over the entire estate. Armillaria too.

Mortality

Remote sensing could be used for remapping – i.e. mortality and gaps, restocking. Generally one or two stands per year require blanking.

Weeds

Weeds are generally localised and are mapped from the ground. Buddleja, pampas, gorse, broom, and clematis are problems. Clematis is a hazard at clearfell – can cause trees to hang. Presence is determined by inventory at present. The weed gets into water systems, then banks and then tracks and roads. They have gorse and broom exclusion areas. There is a need to differentiate between weeds, i.e. gorse and grass at an early age.

Drought stress

There is an interaction with shallow soils. It may be involved with resin pocket formation. Drought, shallow soils, coastal situation, and P deficiency all contribute to wilting and pre-wilt symptoms.

Nutrient deficiencies

N, P, K, and B deficiencies are the most common. These need to be identified and mapped. At present, they are mapped on a stand basis. The Serpentine belt in Nelson is well recognised. Fertilizer application is sometimes recorded on GPS, but not always. A significant amount of money is spent on fertiliser application.

Waterlogging

In some cutover there are wet areas that need drainage. A remote sensing application to identify these areas would be useful so we could target planting of suitable species in boggy areas. An index of water stress would also be useful.

Forest Condition Monitoring and overall health status

Need an objective means of measuring crown closure, LAI at a stand level. Also colour (greenness), weed competition, crown density, needle length. Stocking and tree counting. A measure of photosynthetic potential is needed. A stress index would be useful for analysis and determination of change in forest health over time.

Fire

Monitoring hotspots.

Possum damage

Population monitoring – determining animal numbers as well as damage.

Wind damage

Quantify damage, especially scattered damage. At present we are having trouble reconciling inventory with actual figures.

Simon Anderson, CHH Forests, by phone, Rotorua on 19 May 2005

Dothistroma

Same requirements as Nigel Heron – assessment, mapping, and links with a DSS. Dothistroma is a significant disease. It is recommended that research effort should be spent on one disease rather than spread effort. There is scepticism that Dothistroma can be determined from the air by remote sensing techniques because of difficulty “seeing” into a stand. Can it be seen from a vertical angle? Accuracy of assessments needs to be so that we can identify individual affected trees.

Cyclaneusma and PNB

Disease levels need to be delineated at stand level, forest level and on a regional basis.

Bark beetle damage

Identify and map outbreaks and damage.

Nutrient deficiencies

Same as previous respondents.

Crown Health

There is a need for an overall rating of crown health, at stand and tree level. Good for identifying patches of disease. Crown closure assessment would be interesting but not too important. Some RS system could be integrated with the forest health condition monitoring system, and might become the primary tool. Transparency and condition are the important things to measure.

Armillaria

Need to identify and assess mortality and chronic infection.

Pest detection

Could we pick up gall rusts and other signatures.

Drought stress

Not important as we have a good network of climate stations that give us such information. A GIS could be used for site specific information.

Nursery surveys

They are quite good at present. Remote sensing would need to deliver a practical solution. This is not a top priority issue.

Other disorders

Swiss needle-cast of Douglas fir, Eucalyptus diseases (leafspots and Paropsis), UMCY

Reporting needs

1. FSC? Waiting for NZ standards. The cost of auditing may be prohibitive and markets don't require it. However, remote sensing applications would be good for FSC reporting.

2. Annual forest health reports at the forests level. *Pinus radiata* is generally very healthy and annual reports are not considered very important in the present format. The Viewpoint plot reports have an action required section but it is unclear if they are followed through. Reports focus on site specific damage (i.e., possum damage – ha affected and the a ground follow-up by a forest supervisor is the recommended procedure. Reports are good for raising the profile of forest health – fire is tangible but forest health isn't. Reporting needs involve cheaper reporting – automated reporting quarterly.

3. Digital photos are useful. Orthophotos for cutover and planning, digital imagery in general used for stocking rate and timing of thinning. Useful if this was automated – i.e. GIS and photo evaluation.

Peter Oliver, City Forests, by phone, Rotorua on 27 June 2005

Nectria

Remote sensing techniques are probably not applicable for *Nectria* as they focus on crown condition. However, techniques to identify decay in the stem of living trees would be useful. Likewise, techniques to identify cankers on stems would be useful, not only for *Nectria*, but for *Diplodia* and cypress cankers too.

Dothistroma and needle-cast.

These have curiosity value at present. Not a big issue now, but may become important so any technology developed may be useful in the future.

Seedling mortality

Hylastes is an issue. We know how to manage it, but it can be a problem if not managed. Identification of seedling mortality would be useful for targeting blacking operations.

PNB

At present this has a small impact, but is present on occasion. Affected trees have been seen dotted through a stand. Techniques to assess incidence and severity, and map, will be useful.

Nutrient deficiencies

UMCY is important, along with others such as B deficiency. It would be good if we could identify deficiencies before the onset of symptoms.

Soil analysis is a large and expensive operation. It is important to develop a better and cheaper way of doing this. A hand-held machine to analyse soil of foliage samples in real time would cut costs significantly.

Climatic events

Frost is important. Useful to map frost-prone areas. It would be interesting to map forests for temperature gradient in summer and winter. We could then target species for specific areas.

Snow damage

Snow damage is significant in some areas.

Wind damage

Wind damage is significant. At present we attempt to quantify damage by eye, but this is not successful. A technique to quantify broken tops and branches objectively would be a significant advance. It would be used for forest evaluation and salvage. Wind and snow damage are big issues.

Forest Health Monitoring

Need a system to assess overall forest condition. A good forest health monitoring system needs to be in place to pick up forest health issues. Nectria would have been picked up sooner if such a system had been in place. The present system is costly. A more efficient and objective system is needed.

It should measure foliage colour and crown density. A ground-based system is needed as well as an aerial system. We need to determine baseline data in order to measure future trends.

Paul Lane, Ministry of Agriculture and Forestry, by phone, Rotorua on 15 July 2005

Montreal Process and FAO

MAF's commitments focus at a higher level than forest management. It has international requirements to report at a regional or national level. The Montreal Process requires reporting of many criteria and reports are provided every five years. The FAO global forestry resource assessment reporting needs have been recently broadened to include environment, criteria indicators and processes by forest type. This involves disturbance relating to health and vitality – fire, disease, insect, and abiotic influences.

MAF's main interest would focus on changes over time of diseases that are present and well established, and changes in status of newly established pests, particularly in the changes were destructive.

Any long-term forest health monitoring scheme should ideally tie in with the carbon monitoring plotting system.

Brendan Murphy, Biosecurity New Zealand, Ministry of Agriculture and Forestry, by phone, Rotorua on 18 July 2005

Pest management

Weeds and wildling pines are a problem for DOC and other stakeholders. A method for mapping the intensity and distribution would be very useful.

Pest detection

Applications would probably be better suited to plantation forests, and less so for ports and other hazard sites where the distribution and composition of host material is so variable. Having said that, a remote sensing technique that could reliably determine host species distribution would have a wide range of uses in various programmes – i.e. pest detection, delimiting surveys, eradication and control campaigns. Host distribution would be useful when planning spraying in urban environments.

Indigenous forest health

Remote sensing technologies are needed to determine change in the health of our indigenous forests over time. This could encompass vegetation changes and changes in health status.

DOC carries out a significant possum control programme. A technology to determine the effectiveness of control operations would be very useful.