Economic Impact of Cyclaneusma Needle-cast in New Zealand

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EXECUTIVE SUMMARY

Objective

Aerial surveys to assess the incidence and severity of Cyclaneusma needle-cast were carried out in spring 2005 and 2006. The objective was to collect data to allow the economic impact of the disease to be estimated, and to develop a model to predict disease incidence and severity at the microsite level, based on climatic and geographical data.

Key Results

The total financial loss attributable to Cyclaneusma needle-cast over the *P. radiata* estate aged between 6 and 20 years is estimated to be $38 million per annum. This is considerably lower than estimates of over $60 million per annum that were made based on data collected in the mid 1980s.

Attempts to develop a model using climate and topographical data were unsuccessful. It was concluded there were too many confounding factors masking the main factor that affects disease, autumn rainfall. However, general trends were seen in some regions with higher disease seen in East Cape, Bay of Plenty and Westland after a wetter than normal autumn.

Application of Results

Cyclaneusma needle-cast is a damaging disease in some regions on some sites. On disease-prone sites silvicultural control measures should be evaluated.

Further Work

An operational field trial will be established in spring 2009 if a suitable site can be identified and disease is present.

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INTRODUCTION

Van der Pas *et al.* (1984b) estimated that the reduction of revenue at clearfelling increased by approximately $600-$700/ha for each 10% increase in the proportion of trees diseased by *Cyclaneusma*. When 50% of the final-crop trees were diseased the reduction in revenue ranged from $3200/ha to $3600/ha. These losses are probably underestimates, as growth projections for diseased trees were based on a disease history of only 4 years' duration and it was assumed that disease would have no further effect on growth after age 15.

Aerial surveys to assess the incidence and severity of Cyclaneusma needle-cast in fifteen forests throughout New Zealand were carried out from 1983 to 1985. Disease incidence and severity data collected from these surveys indicated that the volume loss in the 15 forests surveyed would have been of the order of 5% per annum for the age classes 6-20 years (Bulman 1988). The 5% per annum figure is an average of all forests surveyed. Volume loss will be much higher for forests on disease-prone locations (e.g. Northland, East Cape, and central North Island). In 2001, a 76 page bulletin was published on the biology of the fungus, and the distribution, economic significance, and control of the disease (Bulman & Gadgil 2001). The distribution and economic impact reports were primarily derived from data collected from aerial surveys done in the 1980s. Since then, the genetics of the host and its silvicultural treatment have changed, and the incidence and severity of the disease may have changed also.

The Forest Biosecurity Research Council and FRST funded a project to survey forests throughout New Zealand for incidence and severity of Cyclaneusma needle cast. The objective was to determine the economic impact of the disease at a national and regional scale and to develop a model to predict disease incidence and severity at the microsite level. Cyclaneusma needle-cast was assessed from the air in forests selected throughout New Zealand.

MATERIALS AND METHODS

Selection and survey

Aerial surveys were carried out at differing intensities in forests throughout most of New Zealand. In high risk regions (i.e. Northland, Auckland, East Cape) all susceptible stands in major forests were assessed. Elsewhere, all susceptible stands in a selection of forests were assessed with the sampling intensity related to risk, i.e. fewer forests were surveyed in Canterbury and Hawke’s Bay than in the central North Island or Coromandel (Figure 1).

Target Pests were contracted to plan and carry out the surveys. Only experienced surveyors were used. In total, five surveyors were used, each being familiar with the forests they surveyed. Surveys were carried out over 2005 and 2006 to allow for annual variation in disease levels. During both years, surveys started first in Northland and progressed southwards to coincide with maximum symptom expression.

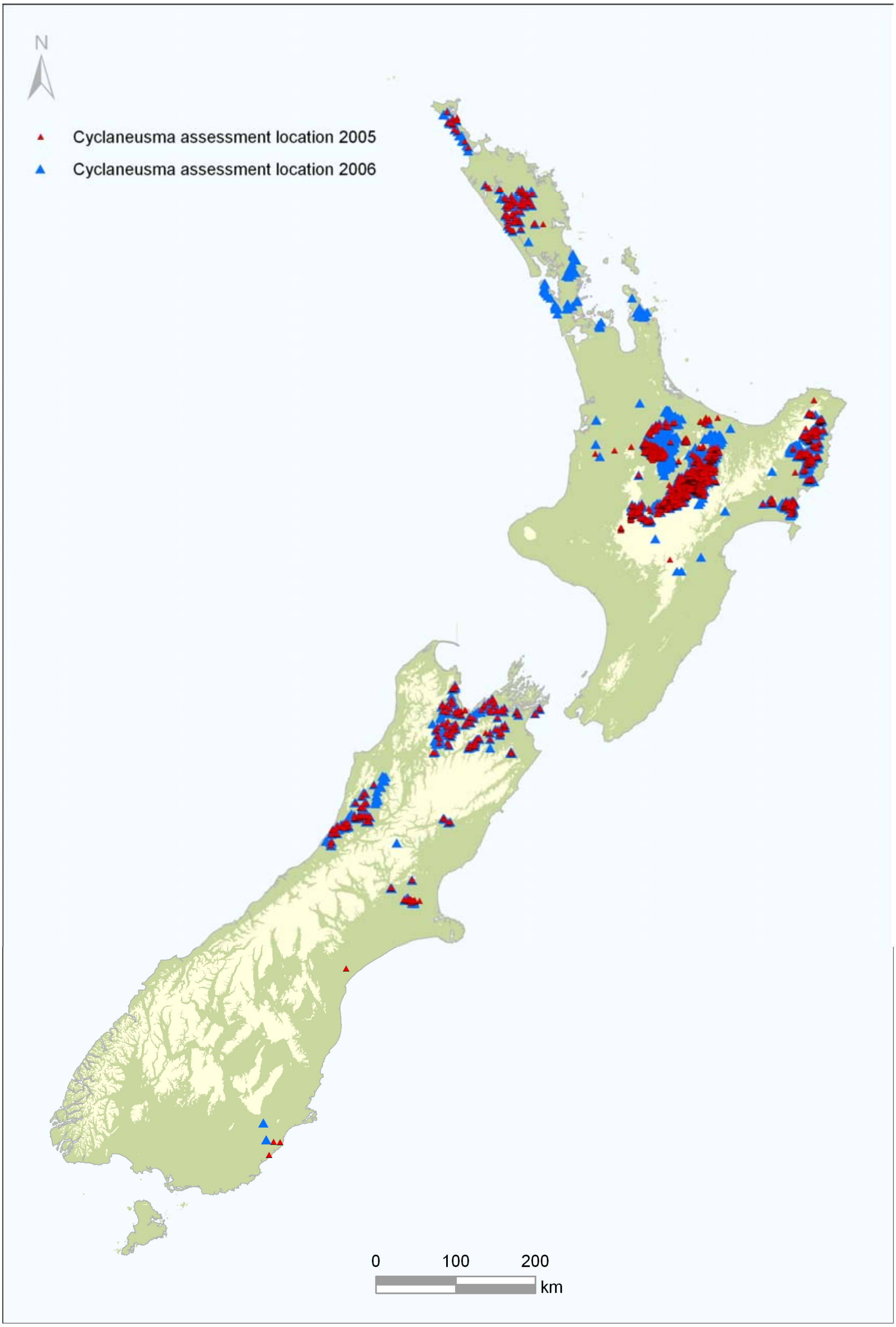

Figure 1 – Cyclaneusma survey locations 2005 and 2006

Assessments

Disease incidence (percentage of trees affected in a stand) and average disease severity (percentage of foliage diseased on affected trees) was assessed and recorded for each stand assessed. Where disease differed significantly within a stand, i.e. because of topography or altitude, different scores were recorded. Planting year was recorded where available.

Data management

Data were entered into Excel data sheets by each surveyor and then checked by Target Pests before being sent to Scion. Location, stand, and establishment year details of sites in the data sheets were then matched with records on the forest health database and where exact matches with location, were achieved NZMG data were copied from the database to the data sheets. This provided NZMG data for approximately 60% of the aerial survey records. The remaining data were collected by examining data individually and taking the location record from the database that provided the closest match. For instance, Golden Downs Forest, compartment 283, 2003 planting was surveyed but that stand was not recorded in the forest health database. In that case, NZMG details recorded for the 1972 planting in compartment 283 were added.

Once NZMG coordinates were gathered for the aerial survey data, GIS was used to determine average autumn rainfall, and actual rainfall in 2005 and 2006, by using splined data for each forest stand assessed. Disease assessments were then related to autumn rainfall and elevation data to determine if any relationships could be found.

Territorial Authority (Appendix I) was determined for every location using GIS, and from that average disease incidence and severity for each Territorial Authority for 2005, 2006, and both years combined was calculated.

Economic loss calculations

Trees aged between 6 and 20 years old were assumed to be susceptible, based on results from Bulman (1988). Area of plantation forest within that age-class as at 1 April 2007 was obtained for each Territorial Authority from Ministry of Agriculture and Forestry (2008).

Volume loss attributable to Cyclaneusma needle-cast can be estimated from the formula:

V = 426D/537

where V is volume loss (%) and D is average disease severity (van der Pas *et al*. 1984c).

An estimate of the annual volume loss for each Territorial Authority was made using total area, average disease severity, and average disease incidence. The volume loss figure was then multiplied by a mean annual increment (taken to be $20m^3$/ha) and a stumpage of $50 to derive loss in dollar terms.

The following procedure was used to estimate loss, using the Gisborne Territorial Authority as an example.

1. Gisborne Territorial Authority has 100,556 ha of susceptible radiata pine with an average disease severity of 21% in 2005.
2. Using the formula V = 426D/537, the percentage volume loss from an average disease severity of 21% is 16.7%.
3. The percentage volume loss of 16.7% was multiplied by 23.9% (the average disease incidence for Gisborne in 2005) to give an annual volume loss figure of 4.0%.
4. The annual volume loss of 4% was multiplied by the susceptible area of 100,556 ha and then by the expected mean annual increment of $20m^3$/ha and stumpage of $50 to give and expected financial loss of $4,160,000 in the Gisborne TA for 2005.

RESULTS

Financial loss

The total financial loss attributable to Cyclaneusma needle-cast over the *P. radiata* estate aged between 6 and 20 years is estimated to be $38 million per annum. Loss in stands younger than 6 years or older than 20 years, or stands growing in regions not surveyed, is considered to be negligible.

Table 1: Estimates of direct losses attributable to Cyclaneusma needle-cast in New Zealand plantation forests (dollar value loss is stated as at the year the study was conducted)

Source	Stumpage used ($/m^3)	Growth loss (%)	Susceptible area (000 ha)	Value loss ($ million)
van der Pas et al. (1984c)*	50	2.3	749	9.1
Sweet (1989)	60	2.3	1,200	13.8
Bulman (1988)*	50	5.0	195	4.9
Bulman (2001b)	50	6.6	763	51.0
Bulman (Unpubl. data 2004)	50	6.6	940	61.0
Bulman (this report)	50	4.5	791	38.0

*van der Pas et al. (1984c) and Bulman (1988) did not estimate financial loss. The estimate was made using their volume loss data, forest area, a stumpage of $50/m^3, and allowance for the different age classes. Loss is not comparable with the three most recent estimates.

Sweet (1989) crudely estimated loss to be $13.8 million after dividing his initial estimate by 3 to allow for compensation in growth, and using a percentage loss figure of 2.3% and an estate area of 1.2 million hectares. Bulman (2001b) estimated loss to be $51 million in the 6- to 20-year-old age-class, based on van der Pas' 1983 data and surveys of 15 forests flown in 1984 and 1985. Bulman revised his annual loss estimates in 2004 to be $61 million, primarily due to an increase in susceptible area.

Volume loss

Volume loss per annum is now estimated to be 4.5%, based on data collected in 2005 and 2006. The percentage loss figure differs from van der Pas *et al.* (1984c), Bulman (1988, 2001b), and Sweet (1989). Van der Pas *et al.* (1984c) estimated that volume lost as a result of Cyclaneusma needle cast was in the order of 2.3% in all ages over the entire estate, based on a survey of nineteen forests undertaken in 1983, and 3.8% in the 11-20 age-class. Bulman (1988) estimated loss to be 5.0% in the 6- to 20-year-old age-class, based on van der Pas' 1983 data and surveys of 15 forests flown in 1984 and 1985. Bulman (2001b) used a loss estimate of 6.6%, but this was calculated by allocating disease risk to regions rather than using empirical data. This approach is likely to overestimate disease levels and thus loss.

Losses due to Cyclaneusma needle cast by wood supply region are shown in Table 2. Losses by Territorial Authority are appended. There was little difference in loss between 2005 and 2006. Not all stands assessed in 2005 were assessed in 2006, and some assessed in 2006 were not assessed in 2005. For instance, in 2005 forests in the Hastings and Auckland Territorial Authorities were not surveyed. Therefore, the total area for both years combined exceeds the total area for each of the individual years.

Table 2 – Wood supply region, disease incidence and severity, susceptible area, and annual financial loss from Cyclaneusma needle-cast

Year	Supply Region	Disease incidence (%)	Disease severity (%)	Area (ha)	Loss (%)	Financial loss
2005	Canterbury	17.7	20.9	39,000	4.3	$1,085,000
	Central North Island	30.3	36.0	294,000	9.0	$24,160,000
	East Coast	23.9	21.0	105,000	4.0	$4,158,000
	Hawke's Bay	7.4	8.4	29,000	0.5	$142,000
	Nelson/Marlborough	20.4	19.2	93,000	3.3	$3,012,000
	Northland	11.8	12.1	84,000	1.1	$863,000
	Otago and Southland	7.3	15.0	51,000	0.9	$444,000
	Southern North Island	30.0	21.0	16,000	5.0	$821,000
	West Coast	12.1	6.7	15,000	0.6	$112,000
Total		**20.7**	**22.1**	**725,000**	**4.6**	**$34,798,000**
2006	Auckland	4.2	4.1	11,000	0.1	$18,000
	Canterbury	10.0	7.5	32,000	0.6	$206,000
	Central North Island	30.9	36.7	294,000	9.5	$24,242,000
	East Coast	30.8	26.3	105,000	6.4	$6,727,000
	Hawke's Bay	25.7	25.0	66,000	5.1	$3,322,000
	Nelson/Marlborough	19.2	18.9	93,000	3.0	$2,627,000
	Northland	9.7	11.6	101,000	1.0	$1,013,000
	Otago and Southland	10.0	1.0	51,000	0.1	$40,000
	West Coast	22.7	20.9	15,000	4.4	$459,000
Total		**20.5**	**21.5**	**768,000**	**4.6**	**$38,655,000**
2005/2006	Auckland	4.2	4.1	11,000	0.1	$18,000
	Canterbury	17.1	21.1	39,000	4.3	$1,056,000
	Central North Island	30.1	34.6	294,000	8.6	$23,185,000
	East Coast	28.7	24.7	105,000	5.6	$5,870,000
	Hawke's Bay	22.0	21.9	66,000	3.9	$2,609,000
	Nelson/Marlborough	19.7	19.0	93,000	3.2	$2,789,000
	Northland	9.7	10.9	101,000	1.0	$947,000
	Otago and Southland	6.4	9.2	51,000	0.5	$238,000
	Southern North Island	30.0	21.0	16,000	5.0	$821,000
	West Coast	21.3	18.9	15,000	3.9	$378,000
Total		**20.4**	**21.6**	**791,000**	**4.5**	**$37,909,000**

Relationships with environmental factors

Severity of Cyclaneusma needle cast is related to weather during the infection period. Spores are produced over the entire year on needles that are cast and fall on the forest floor, but new foliage is resistant to infection for the first six months. Cyclaneusma therefore first infects healthy current needles in April and continue into winter if temperatures reach 10° or more. Most of the infected needles turn yellow and are cast in spring, but some remain green and are not cast. These needles turn yellow during a second and usually less severe period of needle-cast in autumn one year after first becoming infected. It is from this cast that that spores are produced to infect the six-month-old foliage and thus continue the infection cycle.

Attempts to relate disease and weather over the infection period autumn and winter were unsuccessful. There was a mildly positive relationship between disease and elevation and autumn rainfall for data from the East Cape region (Figure 2) but none was found for the central North Island or Westland (Figures 3 and 4).

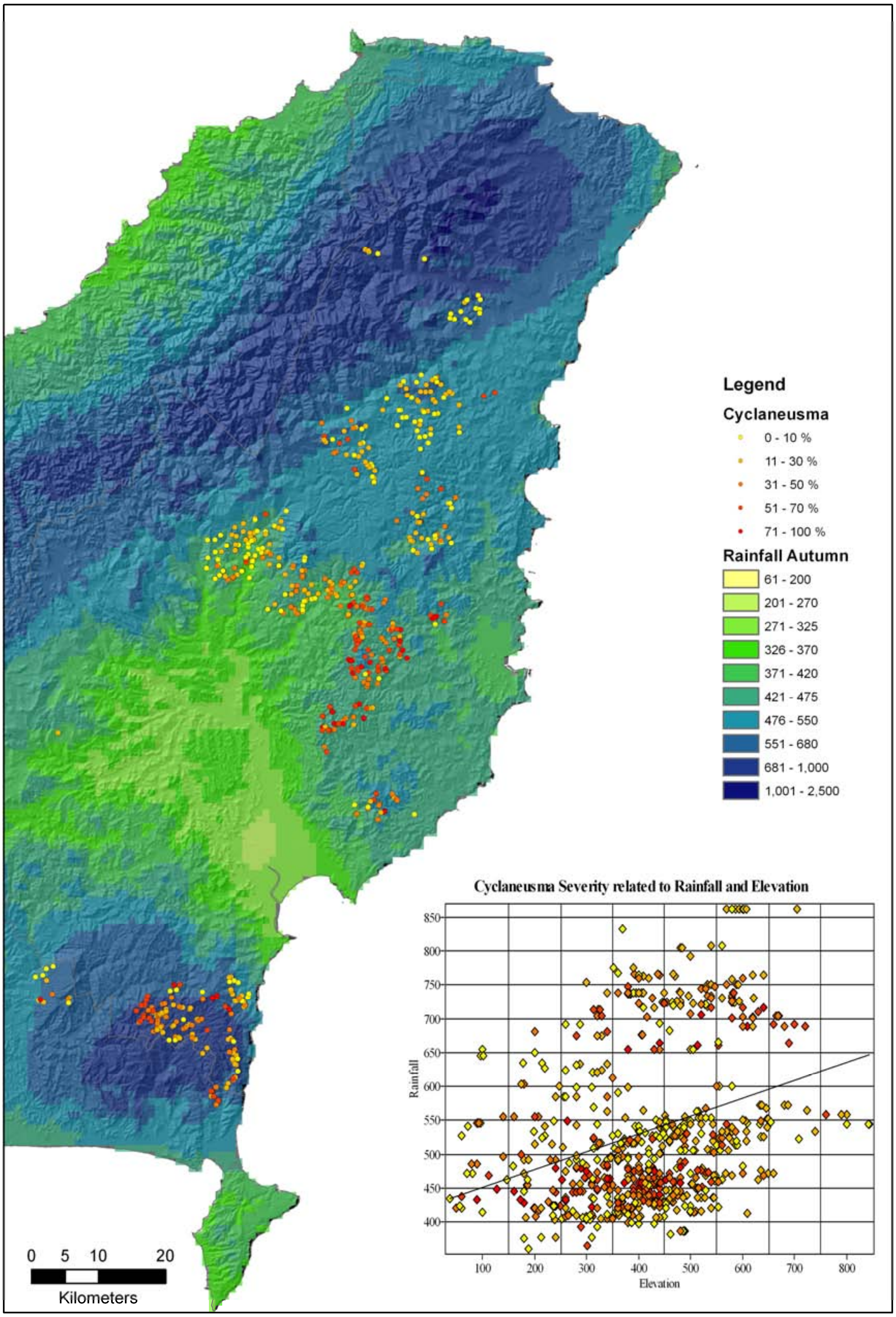

Figure 2 – Cyclaneusma severity related to autumn rainfall and elevation

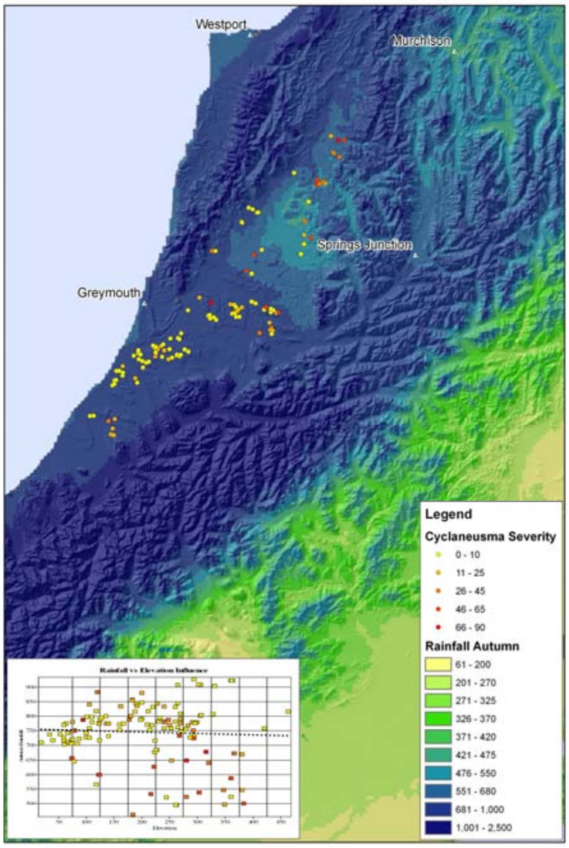

Figure 3 - Westland

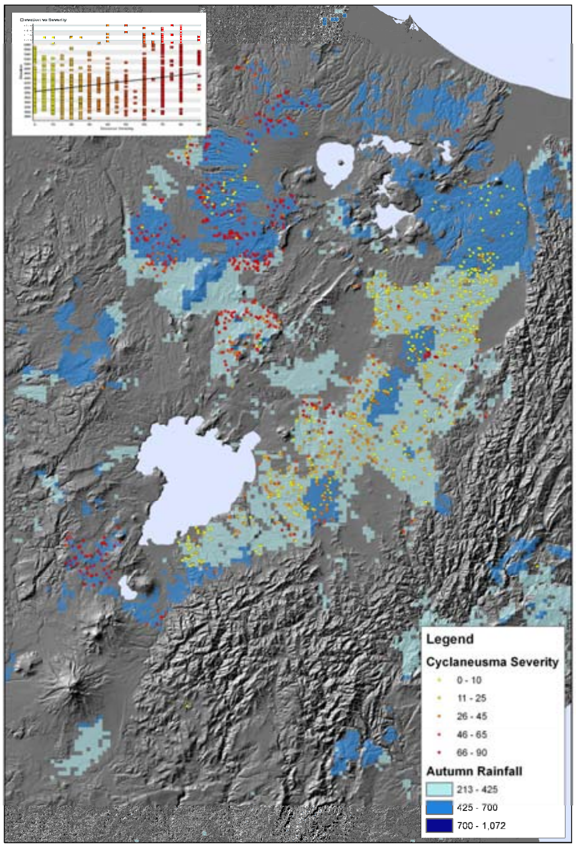

Figure 4 – Central North Island

The East Cape experienced a drier autumn in 2005 than 2006, with average April to June rainfall in 2005 at 460 mm compared with 630 mm in 2006. Neither figure is extreme but 2006 rainfall was significantly above the long term average. Average disease severity on the East Cape in 2005 and 2006 was 21% and 26%, respectively. No statistical relationships were found using data from other regions.

However, general trends were apparent. In 2005, there was record autumn rainfall in parts of the Bay of Plenty (NIWA 2005), followed by extremely high autumn rainfall in 2006 (NIWA 2006). Cyclaneusma needle-cast was high in both 2005 and 2006 with average incidence and severity exceeding 30%. Autumn rainfall was less than 75% of normal in Buller and Westland in 2005, and above normal in 2006 with disease severity in Westland 7% and 19% in the respective years.

DISCUSSION

The level of annual economic loss at under $40 million per annum was unexpected. It was considerably less than most previous estimates. There are two factors that have contributed to the lower estimate. Firstly, Northland had a relatively small susceptible area in 2005 and 2006, compared with the 1980s and 1990s when previous estimates were made. Secondly, and more importantly, disease incidence and severity assessments were lower than those taken in the 1983-85 surveys. These lower levels of Cyclaneusma needle-cast have resulted in a reduction of annual growth loss from 6.6% to 4.5%. It is likely that a number of factors contributed to the lower disease levels compared with the 1980s.

Improved genetics have resulted in trees being less susceptible to Cyclaneusma needle-cast. Historically, in the 1960s, tree breeding assessments for needle cast focused on needle retention. By default, this would have resulted in the elimination of the most susceptible material to Cyclaneusma needle-cast from the breeding programme, provided the trees assessed were growing in a region that favoured the disease. Work specifically directed at Cyclaneusma needle-cast in the genetics area began around 1972 (C. B. Low, pers. comm.), but it wasn't until 1979 that Cyclaneusma needle-cast was assessed on 10-year-old trees in the 588 progeny in the "268" progeny trial (Shelbourne *et al.* 1981). Evaluation of Cyclaneusma needle-cast assessment data from a number of genetics trials showed that there was a wide range of heritability values and genotype/site/assessment timing interactions were complex. It was difficult to determine what amount of genetic control of the disease was possible (Dungey *et al*. 2006). Even so, trees planted in the 1990s are less susceptible to Cyclaneusma needle-cast than those planted in the 1970s because of the elimination of highly susceptible genotypes.

We were not successful in obtaining a meaningful relationship between disease severity and autumn rainfall for all regions, even though Gadgil (1984) showed that autumn rainfall influences disease severity. A relationship was found only with data from the East Cape and even then relationship was weak. Other factors such as stand age, silviculture, planting stock, and site influence disease severity and these may have been confounded with the influence of rainfall. Assessor variation was another source of error. Van der Pas et al. (1984a) found that errors of aerial estimates of Dothistroma needle blight from one observation by one assessor were in the order of 25%. For instance, an estimated disease level of 40% had a standard error of 10%. The use of different assessors may also have contributed to variation.

RECOMMENDATIONS AND CONCLUSIONS

Notwithstanding the difficulties of conducting an aerial survey and collecting and analysing the data, there is no doubt that Cyclaneusma needle-cast is less damaging now than it was in the 1980s. However, it is still a serious disease in some pine plantations. Bulman (2001a) demonstrated that disease increases with altitude and suggested that mist and low cloud prevalent on higher altitude sites contribute to higher inoculum loads and ultimately more severe disease than that seen in lower and drier sites. It is on disease-prone sites that control options such as selective removal of susceptible trees during thinning operations should be evaluated. Research to test such a system is planned in Scion's FRST Biosecurity programme and a field trial will be established in spring 2009 if conditions are suitable.

ACKNOWLEDGMENTS

Target Pest (now SPS Biosecurity) undertook the flying and assessment. Thanks Brent and your team for your efforts with this difficult work. Samantha Alcaraz carried out the initial GIS analysis, ably followed by Lucy Manning.

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Appendix I - Territorial Authority and wood supply region boundaries

Appendix II – Financial loss by Territorial Authority 2005

TA Name	Ave Incidence 2005(%)	Ave severity 2005(%)	Forest Area (ha)	Ave loss (%)	Financial loss
Far North District	11.5	9.1	41670	7.2	$348,286
Whangarei District	12.0	17.0	16546	13.5	$267,768
Kaipara District	12.0	10.2	25437	8.1	$246,992
Western Bay of Plenty District	24.2	23.5	15274	18.6	$688,228
South Waikato District	32.5	39.0	44986	30.9	$4,520,106
Rotorua District	24.7	26.6	34046	21.1	$1,771,848
Whakatane District	30.1	26.8	65118	21.3	$4,171,969
Waitomo District	45.0	49.0	15349	38.9	$2,684,875
Gisborne District	23.9	21.0	104662	16.7	$4,158,218
Taupo District	28.9	28.7	84103	22.8	$5,528,115
Wairoa District	7.4	8.4	28758	6.7	$141,571
Otorohanga District	20.0	46.0	3353	36.5	$244,713
Ruapehu District	37.2	48.5	31807	38.5	$4,550,547
Rangitikei District	30.0	21.0	16421	16.7	$820,683
Nelson City	23.3	20.6	4201	16.3	$159,855
Marlborough District	12.8	11.2	42106	8.9	$480,516
Tasman District	25.0	25.7	46538	20.4	$2,372,008
Buller District	10.0	5.0	2154	4.0	$8,544
Grey District	10.8	8.4	5312	6.7	$38,143
Hurunui District	15.7	8.6	21689	6.8	$231,650
Waimakariri District	7.5	5.2	10052	4.1	$30,920
Westland District	15.7	6.7	7925	5.3	$65,710
Timaru District	30.0	49.0	7050	38.9	$822,215
Clutha District	7.3	15.0	50918	11.9	$444,122
	20.7	**22.1**	**725475**		**$34,797,598**

Appendix III – Financial loss by Territorial Authority 2006

TA Name	Ave Incidence (%) 2006	Ave severity (%) 2006	Forest Area (ha)	Ave loss (%)	Financial loss
Far North District	9.1	11.8	41670	9.4	$356,736
Whangarei District	14.3	15.7	16546	12.5	$294,464
Kaipara District	11.8	14.2	25437	11.3	$339,506
Rodney District	3.4	4.6	17674	3.7	$22,136
Manukau City	3.0	4.0	2088	3.2	$1,988
Thames-Coromandel District	5.3	4.2	8828	3.4	$15,760
Western Bay of Plenty District	37.8	48.9	15274	38.8	$2,237,270
Rotorua District	30.1	23.9	34046	19.0	$1,943,469
South Waikato District	33.5	43.5	44986	34.5	$5,198,485
Otorohanga District	18.9	27.2	3353	21.6	$136,697
Whakatane District	24.7	18.4	65118	14.6	$2,342,314
Gisborne District	30.8	26.3	104662	20.8	$6,726,649
Wairoa District	27.7	25.3	28758	20.1	$1,599,955
Taupo District	29.2	27.4	84103	21.7	$5,330,104
Waitomo District	35.0	56.0	15349	44.4	$2,386,555
Ruapehu District	38.3	48.4	31807	38.4	$4,667,408
Hastings District	23.8	24.6	37130	19.5	$1,722,312
Nelson City	22.1	20.9	4201	16.6	$153,436
Tasman District	22.9	22.8	46538	18.1	$1,925,903
Marlborough District	12.7	12.9	42106	10.3	$548,074
Buller District	33.7	35.4	2154	28.1	$203,964
Grey District	12.9	14.0	5312	11.1	$75,892
Hurunui District	10.0	9.4	21689	7.4	$161,218
Waimakariri District	10.0	5.7	10052	4.5	$45,134
Westland District	21.4	13.3	7925	10.6	$179,508
Clutha District	10.0	1.0	50918	0.8	$40,393
	20.5	**21.5**	**767724**		**$38,655,331**

Appendix IV – Financial loss by Territorial Authority 2005 and 2006

TA Name	Ave incidence (%) 2005 and 2006	Ave severity (%) 2005 and 2006	Forest Area (ha)	Ave loss (%)	Financial loss
Far North District	10.3	10.5	41670	8.3	$358,212
Whangarei District	12.9	16.5	16546	13.1	$279,741
Kaipara District	11.9	11.9	25437	9.5	$287,198
Rodney District	3.4	4.6	17674	3.7	$22,136
Manukau City	3.0	4.0	2088	3.2	$1,988
Thames-Coromandel District	5.3	4.2	8828	3.4	$15,827
Western Bay of Plenty District	36.4	46.2	15274	36.6	$2,034,979
Rotorua District	28.8	24.6	34046	19.5	$1,910,391
South Waikato District	33.1	41.5	44986	32.9	$4,891,531
Otorohanga District	19.0	29.1	3353	23.1	$147,067
Whakatane District	25.9	20.3	65118	16.1	$2,717,530
Gisborne District	28.7	24.7	104662	19.6	$5,869,761
Wairoa District	20.3	19.1	28758	15.2	$885,505
Taupo District	29.0	28.0	84103	22.2	$5,425,021
Waitomo District	31.3	38.5	15349	30.5	$1,464,961
Ruapehu District	37.6	48.4	31807	38.4	$4,593,238
Hastings District	23.8	24.6	37130	19.5	$1,723,012
Rangitikei District	30.0	21.0	16421	16.7	$820,683
Nelson City	22.5	20.8	4201	16.5	$155,742
Tasman District	23.8	24.1	46538	19.1	$2,121,115
Marlborough District	12.8	12.0	42106	9.5	$512,312
Buller District	32.7	34.2	2154	27.1	$190,988
Grey District	12.1	11.8	5312	9.4	$60,221
Hurunui District	12.7	9.0	21689	7.1	$196,198
Waimakariri District	8.8	5.4	10052	4.3	$37,818
Westland District	19.0	10.6	7925	8.4	$126,339
Timaru District	30.0	49.0	7050	38.9	$822,132
Clutha District	6.4	9.2	50918	7.3	$237,834
	20.4	**21.6**	**791195**		**$37,909,482**