Spatial assessment of Red Needle Cast observations

Mark Kimberley, Barbara Hock and Ian Hood

Date: August 2016

Milestone No: Milestone 1.7

Report No: ND-T012

supported by forestgrowers commodity levy

PUBLIC REPORT INFORMATION SHEET

Report Title	Spatial assessment of Red Needle Cast observations
Authors	Mark Kimberley, Barbara Hock and Ian Hood
ISBN No.	
Scion Publication No.	
Sidney Output Number	
Signed off by	Mike Watt
Date	August 2016
Copyright	

Spatial assessment of Red Needle Cast observations

Mark Kimberley, Barbara Hock and Ian Hood

August 2016

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1

1.1 The Problem 1
1.2 This Project 1
1.3 Key Results 1
1.4 Final Conclusions and Implications of Results 1
1.5 Further Work 1

Introduction 2

Methods 2

Results 5

Conclusions 8

Further Work 9

Acknowledgments 9

References 9

EXECUTIVE SUMMARY

1.1 The Problem

Red needle cast (RNC), caused by *Phytophthora pluvialis*, is a problematic disease of radiata pine. This research compared climate data with red needle cast observations, to determine if there are climatic factors relating to disease presence and severity.

1.2 This Project

Records of RNC were extracted from the Forest Health Database. Altogether, 539 observations were available for modelling. To establish the population profile for the environmental variables a 1km point grid with random origin was created over New Zealand exotic plantation forest estate, resulting in 20,356 points. Monthly climate data based on 30-year normals were extracted for all the observation and forest points.

The mean and 10th and 90th percentiles of each climate variable were calculated for the RNC observations and for the underlying population, and compared graphically.

The RNC and forest data were then combined into a single dataset with presence of RNC disease coded as 1 (for the RNC observations) and as 0 (for the forest population data). Various regression models were fitted using presence of RNC as the dependent variable and the monthly climate data as independent variables.

All analyses were restricted to North Island data only. RNC observations were recorded throughout the North Island, but only in some northern areas of the South Island. This suggests that the pathogen has not yet spread to all susceptible forests in the South Island meaning that regression models using climate data in the South Island could produce misleading results.

1.3 Key Results

Charts of means and upper and lower percentiles of each climate variable in the RNC data and the forest population data showed no evidence of any difference in climate between locations where RNC is recorded and locations sampled from the population of plantations in the North Island. The best fitting regression models for predicting presence of RNC from climate variables explained no more than 6% of the variation. These results indicate that in terms of average climate, the disease is equally likely to be observed anywhere within the North Island exotic plantation forest estate.

1.4 Final Conclusions and Implications of Results

It appears that there are no combinations of average climate conditions that limit the incidence of RNC within North Island radiata pine forests.

1.5 Further Work

Data could be segregated by year and RNC severity analysed against the actual weather by year. It is recommended that field sampling and recording should be conducted in a more systematic fashion making it more suited to modelling against climate data. Given the weaknesses inherent in field observational data, another approach that should be explored is develop methods of monitoring the disease using remote sensing technologies.

INTRODUCTION

Red needle cast (RNC) caused by *Phytophthora pluvialis*, is a problematic disease of radiata pine in New Zealand (Dick et al. 2014). This research compared climate data with red needle cast observations to determine if there are climatic factors relating to disease presence and severity. Should some factors be significant in regard to the presence or the severity of red needle cast, this could assist in a targeted approach to controlling the disease.

Existing records of the disease from the Forest Health Database (Forest Protection Group) indicate where the disease has been found and how severe was the outbreak. Scion holds a comprehensive set of environmental surfaces that can be explored for the outbreak locations. The datasets are at a national level making possible a countrywide assessment of potential environmental influences (the independent variables of the model).

The aim of this study was to determine whether incidence of RNC could be linked to climate data, and if so, to produce a national map (GIS layer) describing areas at higher risk from the disease.

METHODS

RNC observations

Records of RNC were extracted from the Forest Health Database with the assistance of members of the Forest Protection Group. These consisted of 256 collection records confirmed as RNC in the laboratory by the presence of *P. pluvialis* (including its previous designation, *Phytophthora* aff. *pseudosyringae*) together with a large number of inspection records determined in the field by trained observers. The reliability of the inspection records was further endorsed by parsing and removing from subsequent assessment any in which RNC could not be supported from the site visit details, leaving a balance of 390 inspection records.

All observations were imported into GIS to check the stored coordinates and if possible location-based errors were corrected. Missing locations were added when they could be identified from the location descriptions or the inspector's field notes. Altogether 542 records were successfully imported into GIS from both database sources. However a further three locations were situated outside the extent of the environmental variables described below hence were unavailable for analysis.

Altogether, 539 observations were available for spatial modelling. Of these, 333 had severity codes (severe, high, medium, low, trace) and 241 had a quantitative order of magnitude for either severity percentage or incidence percentage. As the number of observations with both percentages set was comparatively low (76) a consistent severity class across all descriptors was developed (high, medium, low) with all observations assigned to one of these classes by Scion experts (Figure 1). Of the RNC observations, 92% were in the North Island and almost all South Island observations were in the Nelson and Marlborough regions (Figure 2).

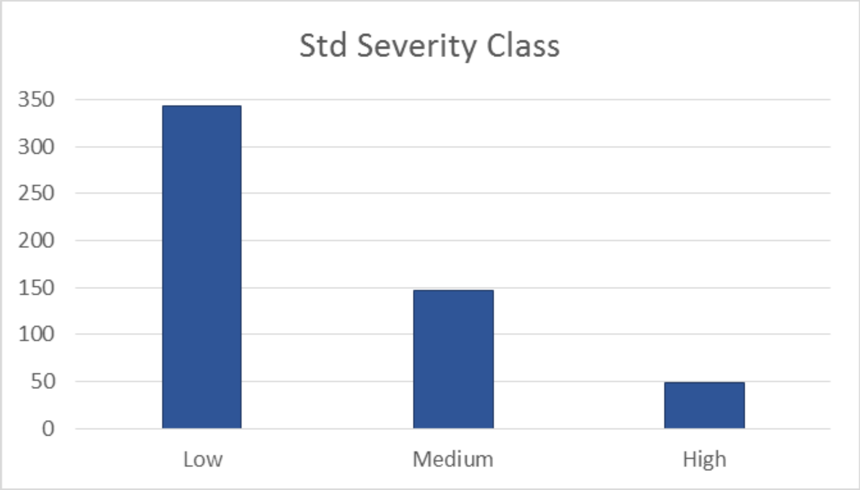


Figure 1: Number of RNC observations by severity level.

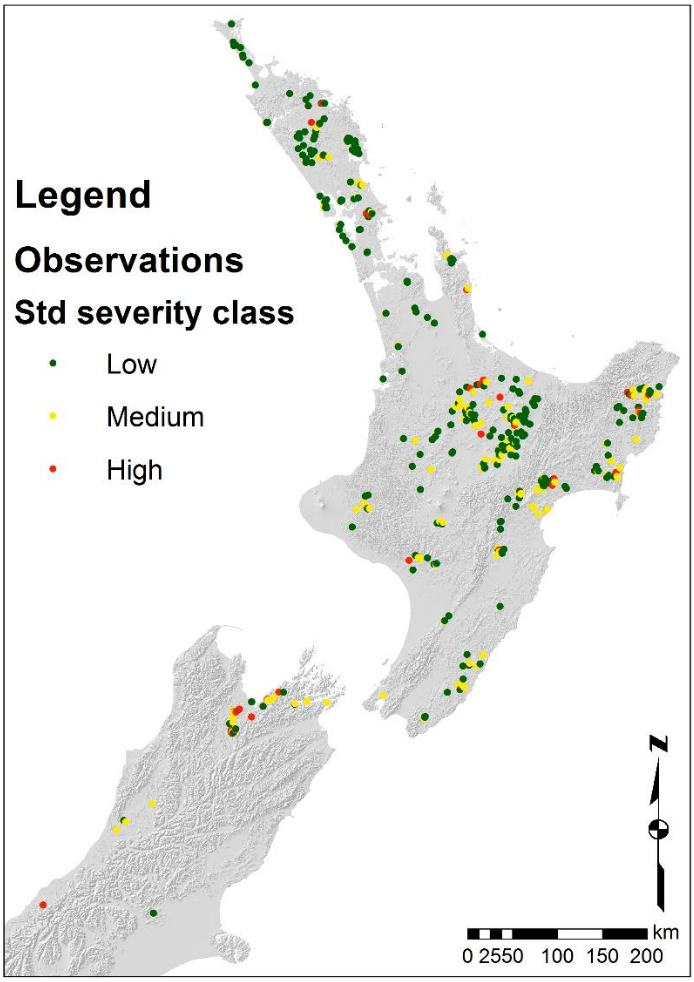


Figure 2: Map showing observations of RNC categorised by their severity level.

Forest population data

To establish a population profile for the environmental variables a 1km point grid with random origin was created over all New Zealand exotic forests, resulting in 20,356 points.

Environmental data

Monthly climate data based on 30-year normal (Wratt et al. 2006) and basic topological data (Ollivier 2015) were extracted for all the RNC observations and forest points (Table 1).

Table 1: Environmental data per observation and forest grid point.

Source	Data type	Layers
NIWA	Total rainfall	Annual and monthly at 500m resolution
	Rain days	
	Average daily temperature	
	Average daily maximum temperature	
	Average daily minimum temperature	
	Sunshine hours	
	Solar radiation	
	Average wind speed	
	Potential evapotranspiration	
	Growing degree days (base 10ºC)	
	Relative humidity	
	Heating degree days (for 18 ºC)	
	Days of soil moisture deficit	
	Average earth temperature at 10cm	
LINZ	Elevation	150m resolution
	Slope	

Modelling

RNC observations were plotted by month for each year to determine months of peak occurrence. The lack of observations from the South Island (Figure 2) suggests there is a possibility that the pathogen has not yet spread to all susceptible locations there. Another possibility is that the pathogen has spread further in the South Island than the observations suggest, but disease has not been recorded. It must be acknowledged that the records used in this analysis are not systematically acquired but are in a sense “ad hoc”, and it is possible RNC is more widespread than the observations suggest, although if it is present further south in the South Island it would be surprising if it had not been reported.

If the lack of observations in the South Island is due to the pathogen not having spread throughout its potential range, modelling the incidence of RNC against South Island climate data could produce misleading results. Until the pathogen is found and has had time to produce disease, conclusions cannot be drawn on whether climate is limiting its distribution. On the other hand, Figure 2 shows that RNC has dispersed widely in the North Island. Because of this, modelling the incidence of the disease against climate data in the North Island may indicate whether there are climatic conditions that limit the occurrence of the disease in any part of the island. Therefore, all analyses were restricted to the North Island data only.

An initial exploratory analysis was performed to determine whether the distribution of each climate variable differed between locations where RNC has been observed and compared with all North Island plantation forests. Means and 10^{th} and 90^{th} percentiles were calculated for the RNC observation data, and the forest population data, and compared graphically.

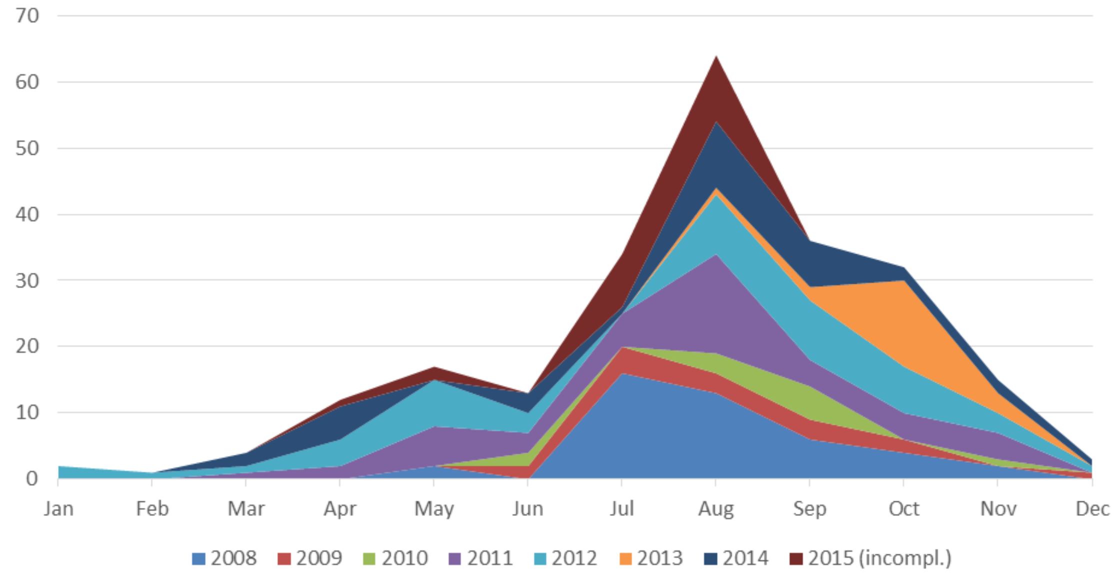
RNC observations and forest data were then combined into a single dataset with presence of RNC coded as either 1 (for the RNC observations) or 0 (for the forest population data). Various regression models were then fitted using presence of RNC as the dependent variable and the monthly climate data as independent variables.

All statistical analyses were performed using Microsoft Excel and SAS Version 9.3.

RESULTS

Figure 3 shows confirmed records of *P. pluvialis* by month the sample was taken and by region in successive years for every year between 2008 and 2015. Most observations occurred during winter months with only a few over the summer period (Figure 3(a)). Records were obtained in most North Island regions in most years but only in the northern South Island (Figure 3(b)). The earliest observations in 2008 were recorded in Northland, Gisborne, Taupo and Bay of Plenty, with the pathogen then found in other North Island regions from 2010. The pathogen was first confirmed in the Wairarapa as late as 2013. This was the penultimate North Island region to be affected, with the first record in Wellington made in 2015. The pathogen was found in Nelson as early as 2010, with some records made in the following year in Marlborough and Buller, but it has yet to be recorded in other parts of the South Island.

(a)



(b)

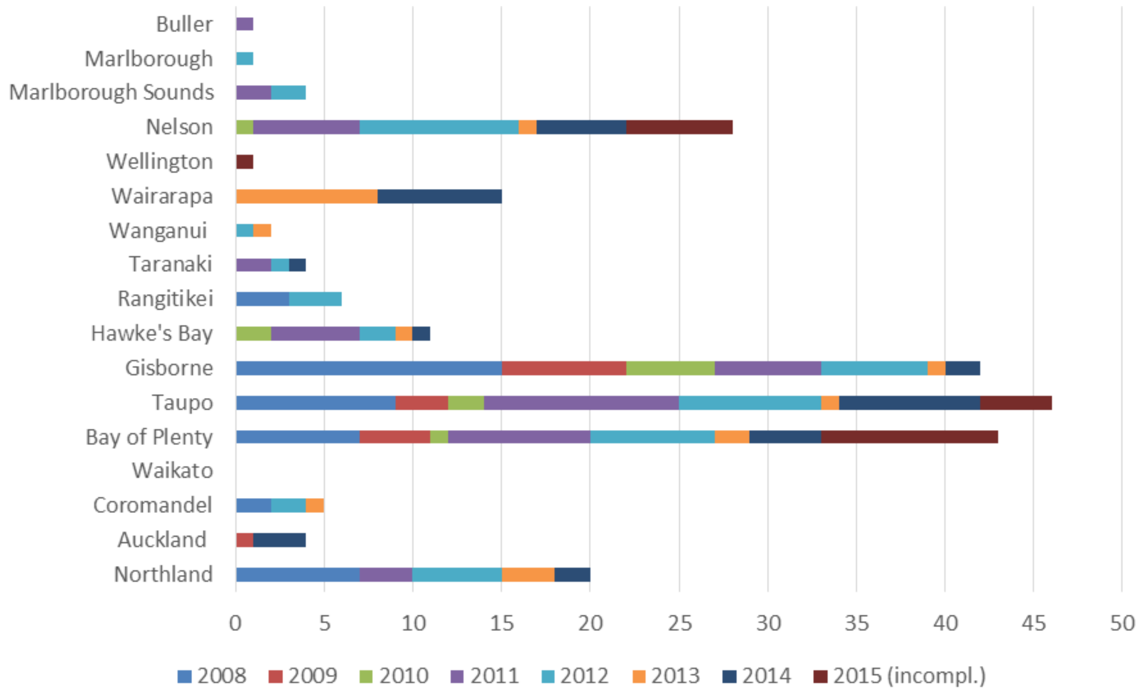


Figure 3: (a) Records of *P. pluvialis* in the Forest Health database by month and year, and (b) Number of records of *P. pluvialis* in the Forest Health database by Crosby region and year.

Monthly averages of climate variables, along with their 10th and 90th percentiles, are shown for North Island locations where RNC was recorded (all records, collection and inspection), for the North Island exotic plantation population, in Figure 4. The charts show very little difference in means of climate variables, or in the upper and lower limits of climate variables, between RNC locations and the North Island population.

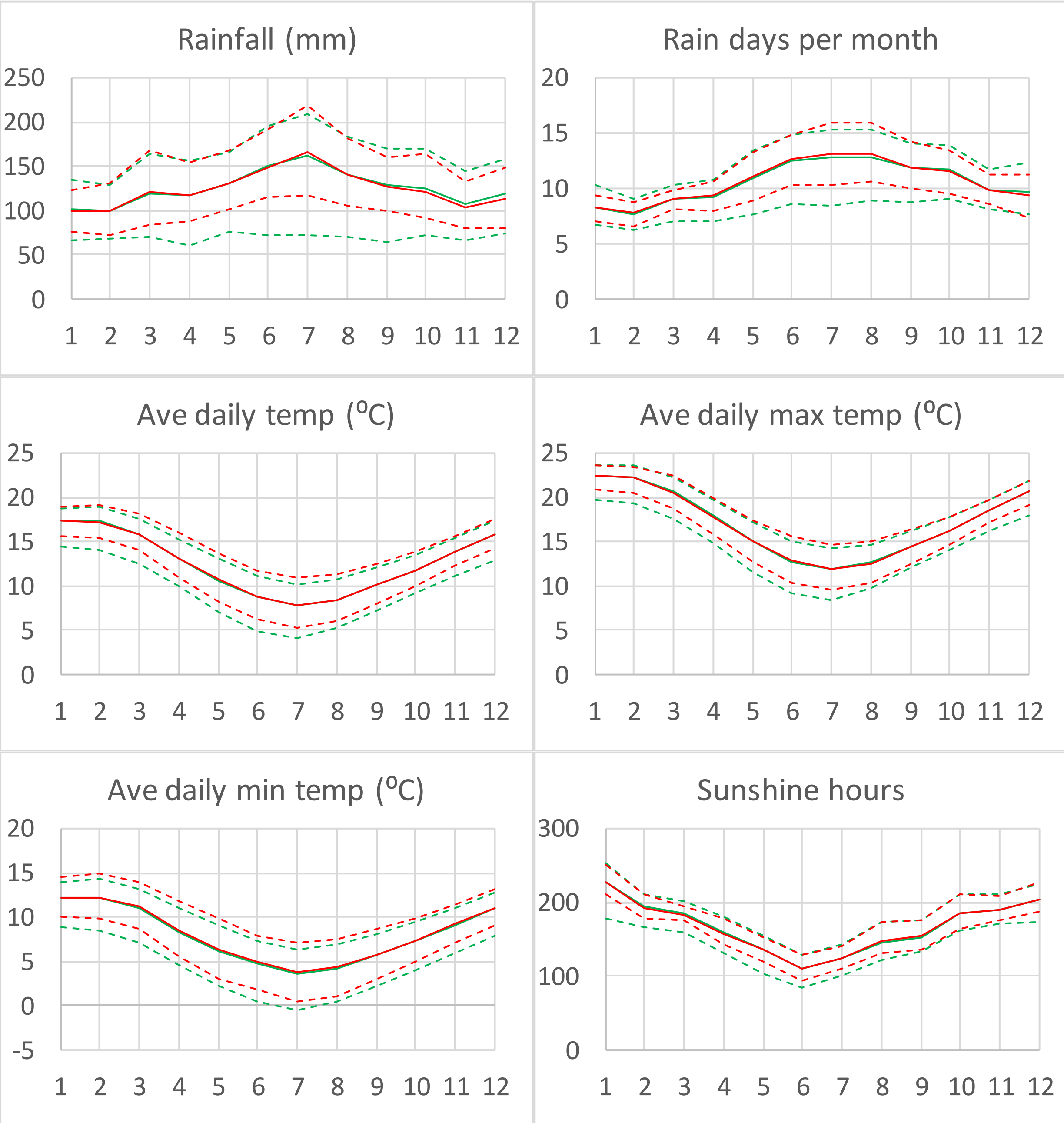


Figure 4: Monthly mean (solid lines), and 10th and 90th percentiles (lower and upper dashed line respectively) for all North Island plantation forests (green lines) and for sites where RNC disease was observed (red lines), for several climate variables.

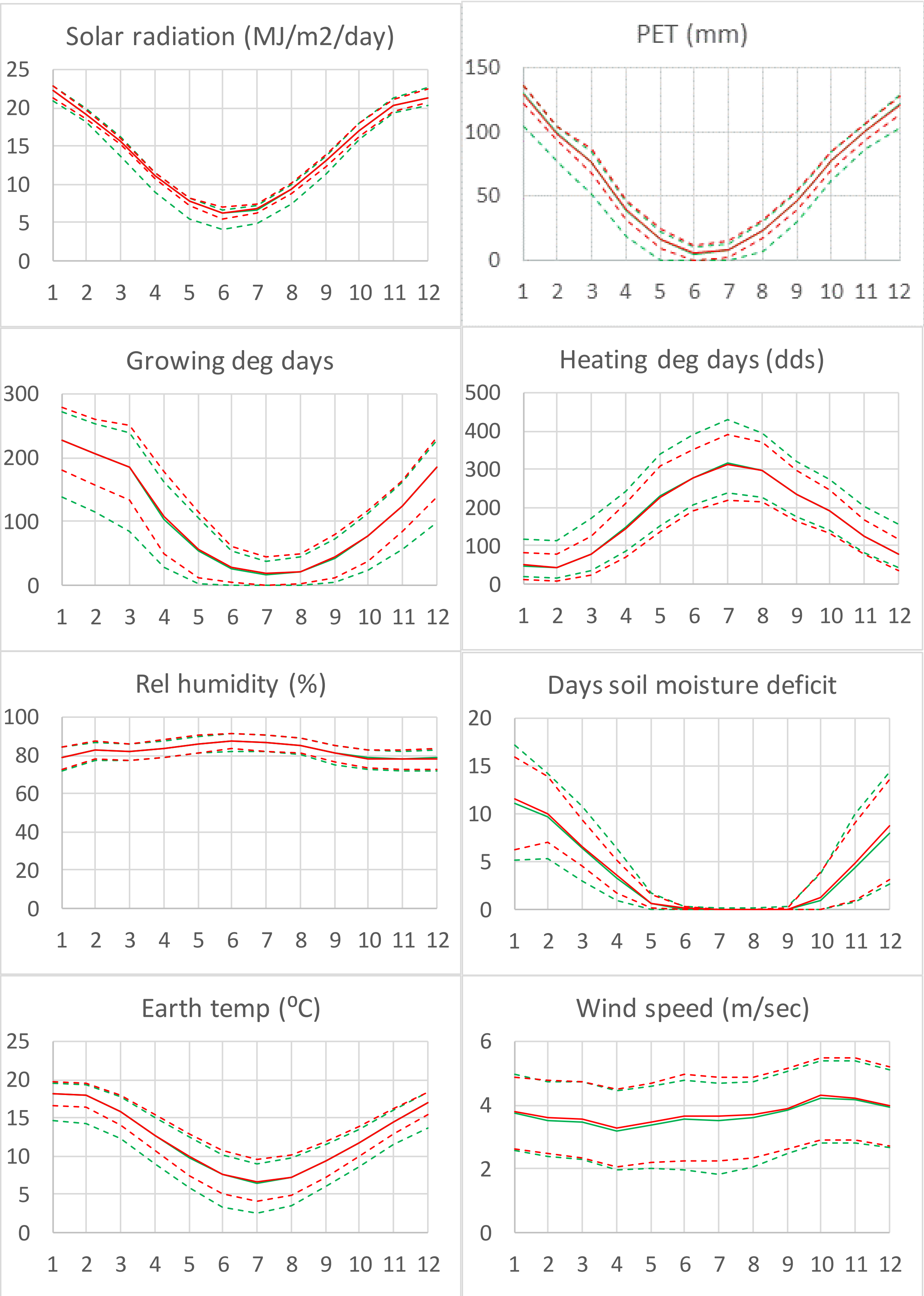


Figure 4 (continued): Monthly mean (solid lines), and 10th and 90th percentiles (lower and upper dashed line respectively) for all North Island plantation forests (green lines) and for sites where RNC disease was observed (red lines), for several climate variables.

Various regression models were developed to predict presence of RNC as a function of monthly climate data based on 30-year normals. However, none of these models explained a useful percentage of the variation. The independent variable best predicting presence of RNC was solar radiation in June which was positively related to presence of RNC, but only explained 3% of the variation.

Multiple regression models provided no worthwhile improvement in model performance (Table 2). For example, the best fitting multiple regression model with 5 independent variables had an R^2 of only 6%. When presence of RNC was restricted just to the medium and high severity classes, regression models were even poorer, and models predicting presence of the high severity class were poorer still.

Table 2: Maximum percent variance explained by multiple regression models using increasing numbers of independent variables.

Number of independent variables	Dependent variable		
	Presence of RNC in any severity class	Presence of RNC in medium or high severity classes	Presence of RNC in the highest severity class
1	3	1	0
2	4	2	1
3	5	3	1
4	5	3	1
5	6	3	1

An alternative regression modelling approach, which is often successfully used when there are large numbers of highly correlated predictors, is Partial Least Squares Regression (PLS regression). With this approach, successive linear combinations of the predictors called factors are derived, in such a way that the factors explain both response and predictor variation. However, PLS regressions performed no better than multiple regressions, explaining only a few percent of the variation in presence of RNC (Table 3).

Table 3: Percent variance accounted for by partial least squares factors.

Number of extracted PLS factors	Dependent variable		
	Presence of RNC in any severity class	Presence of RNC in medium or high severity classes	Presence of RNC in the highest severity class
1	2	1	0
2	3	2	1
3	4	2	1
4	5	3	1
5	5	3	1

These results show that average climatic conditions in locations where RNC has been observed in the North Island almost perfectly mirror the distribution of climate variables across all North Island plantation forests. They suggest that the disease is not limited by any combination of mean climate conditions found in the North Island exotic forest plantation estate.

CONCLUSIONS

It appears that there are no combinations of average climate that limit the incidence of RNC disease within North Island radiata pine forests.

FURTHER WORK

The existing data could be segregated by year and RNC severity analysed against the actual weather present within in each year. NIWA has key daily weather data interpolated across New Zealand at a 5km resolution (Tait et al. 2006). Of particular interest may be years with higher levels of red needle cast severity or where the weather differed significantly from the 30-year normals.

The analysis undertaken in this study is based on an assumption that field observations are sufficiently objective to allow inferences to be made about the absence of the disease. In other words, the assessment of the presence and severity of red needle cast assumes that all occurrences have been recorded or observed to a sufficient sampling standard. It is recommended that field sampling and recording should be conducted in a systematic fashion to ensure that these assumptions are met.

Given the weaknesses inherent in field observational data, another approach that should be explored is to develop methods of monitoring the disease using remote sensing technologies.

ACKNOWLEDGMENTS

The Forest Growers Trust Levy and the Forest Protection core purpose funding is acknowledged for funding this project as part of the Needle Disease Strategy.
Lindsay Bulman and Beccy Ganley for guiding the data review. Rodrigo Osorio and Judy Gardner for assistance with the locations of observations.

REFERENCES

Dick, MA, Williams, NM, Bader, MK, Gardner, JF, & Bulman, LS. (2014). Pathogenicity of *Phytophthora pluvialis* to *Pinus radiata* and its relation with red needle cast disease in New Zealand. New Zealand Journal of Forestry Science, 44, 6. doi:10.1186/s40490-014-0006-7.

Wratt, D. S., Tait, A., Griffiths, G., Espie, P., Jessen, M., Keys, J., Ladd., M., Lew, D., Lowther, W., Mitchell, N., Morton, J., Reid, J., Reid, S., Richardson, A., Sansom, J. & Shankar, U. (2006). Climate for crops: integrating climate data with information about soils and crop requirements to reduce risks in agricultural decision-making. *Meteorological applications*, 13(04), 305-315.

Ollivier, K. (2015). Corax Topo 2015: LINZ Topo Vector and Raster (Version 17) www.ollivier.co.nz

Tait, A., Henderson, R., Turner, R., & Zheng, X. (2006). Thin plate smoothing spline interpolation of daily rainfall for New Zealand using a climatological rainfall surface. *International Journal of Climatology*, 26(14), 2097-2115.