Recreating the invasion of exotic conifers in New Zealand

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Summary In little over 100 years, the extent of exotic conifers in New Zealand has progressed from isolated seedlings to occupy about 15% of the land area. Currently about half the area is commercial forestry dominated by two species with the balance comprising commercially worthless stands or scattered individuals of ten species that have largely self-established. Wilding conifers are now regarded as significant environmental weeds. Despite warnings of weed threats for 50 years, and sustained management for 40 years, the area occupied by wilding stands continues to increase.

I used three techniques to recreate the invasion and estimate the rate of increase each decade. The strengths and weaknesses of each technique are discussed along with departures from generalised invasion curves. Though much uncertainty remains, recreating a historic invasion has many uses. Spread rates can be used to predict future spread, understand impacts of investment and control strategies and lobby for operational funding.

Keywords Wilding conifers, invasion, spread.

INTRODUCTION

The conifer element of the indigenous vegetation of New Zealand comprises no species of Pinaceae but many have been introduced for forestry, amenity plantings, windbreaks and erosion control. Self-established seedlings of exotic conifers were first noted in the late 1880s (Smith 1903) and by 2015, 26 species have been recorded as naturalised.

The environmental weed potential of exotic conifers has long been recognised (Beauchamp 1962) and today these species are known as wilding conifers and affect around 1.7 million ha (Greenaway *et al*. 2015). Illustrating this dramatic invasion has been difficult as data have not been consistently collected. In this investigation, I compared three methods for graphically recreating the invasion of wilding conifers.

MATERIALS AND METHODS

Published national estimates of wilding conifer infestation area were compiled and the quoted area occupied was plotted against time.

Regional estimates of infestation area were collated from published and unpublished reports. Estimates of area were standardised by defining presence in 1 km^2 cells. Estimates were grouped by regions, and summarised by decades to 1995 then five yearly to 2015. I included areas where establishment was assisted (usually by aerial seeding) if the area is now considered an unmanaged stand. Where information was missing for any time period, a linear relationship was assumed. Categories of density were derived based on stems per ha. Where density information was not available, the ratio of sparse, moderate and dense stands was assumed using 2014 ratios.

Electronic records of specimens of the 12 most common wilding conifer species and 12 native beech and podocarp tree species that are common in montane forests were obtained from four national herbaria. Native and exotic species specimen locations were overlaid with a 10 × 10 km grid based on the NZTM projection. I plotted the cumulative number of cells occupied against time to create an invasion curve (*sensu* Delisle *et al*. 2003).

Finally, I calculated the total land area that could potentially be invaded by wilding conifers by summing the vulnerable land classifications in the Land Cover Database (LCDB) version 4.1. I used a criteria modified from an earlier report (North and Ledgard 2005).

RESULTS

Published estimates area for the area of wilding conifers were obtained from seven publications and a start point of 1 ha in 1895 was assumed. The resultant invasion curve depicts extremely rapid rise in affected area from the late 1990s (Figure 1).

In addition to the national figures, over 70 reports contained valuable, but highly variable observations and information on wilding conifers throughout New Zealand. The summarized estimates of invasion extent are illustrated in Figure 2.

A total of 290 useable herbarium records were obtained for wilding conifers, but 3418 records were obtained for the 12 native montane forest species. For wilding conifers, a period of increased recordings appeared in the late 1980s (Figure 3). A similar period was observed for native species in the 1970s. When the slopes of the logged cumulative area occupied were compared, the slope for exotic conifers was significantly steeper than for native montane species.

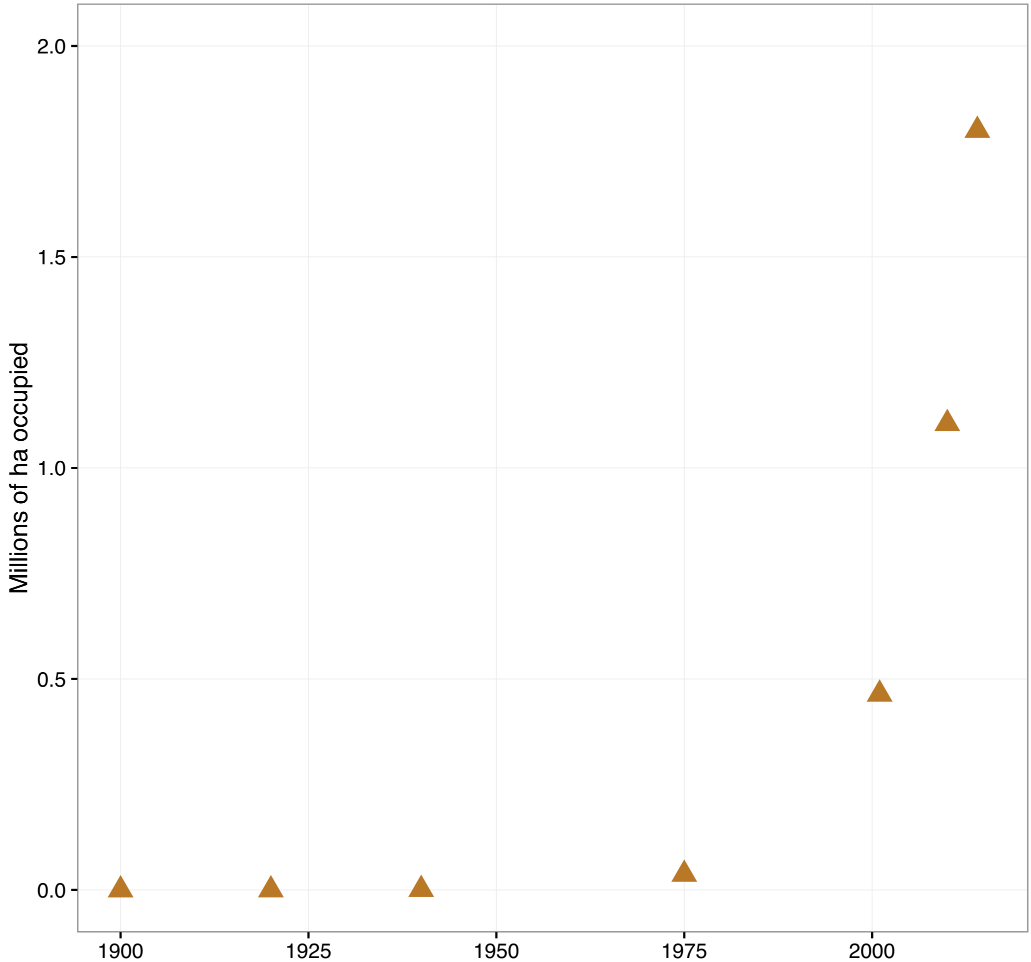

Figure 1. Approximate area occupied by wilding conifers using only published national estimates.

Using summed area of vulnerable lands, a figure of 7.3 million ha was derived as a possible upper limit for wilding conifer invasion.

DISCUSSION

Simply relying on published numbers of area infested has several problems. Firstly, the threat of wildings was debated from 1930 to 1970 and estimates did not include ongoing deliberate establishment for erosion control. Secondly, early estimates typically excluded very sparse wildings. The lower level of infestation for inclusion was typically one tree per ha. Stephens (2003) described the lightest level of infestation 0.001% cover. This equates to 0.1, 1 m^2 individuals per ha. In search and destroy operations from helicopters, operators frequently report densities below one plant per ha. It is now clear that although least some areas were prone to very sparse long distance spread by the 1960s (Buckley *et al*. 2005) and surveillance over very large areas is required because dispersal over distances of 10 km or greater is regularly observed.

Collating information from a large number of reports was very time-consuming and a large number of assumptions were required. However, I believe this is the most accurate reconstruction possible of the methods tested here. The total area fits a 6% growth model (Greenaway *et al*. 2015), but in some areas

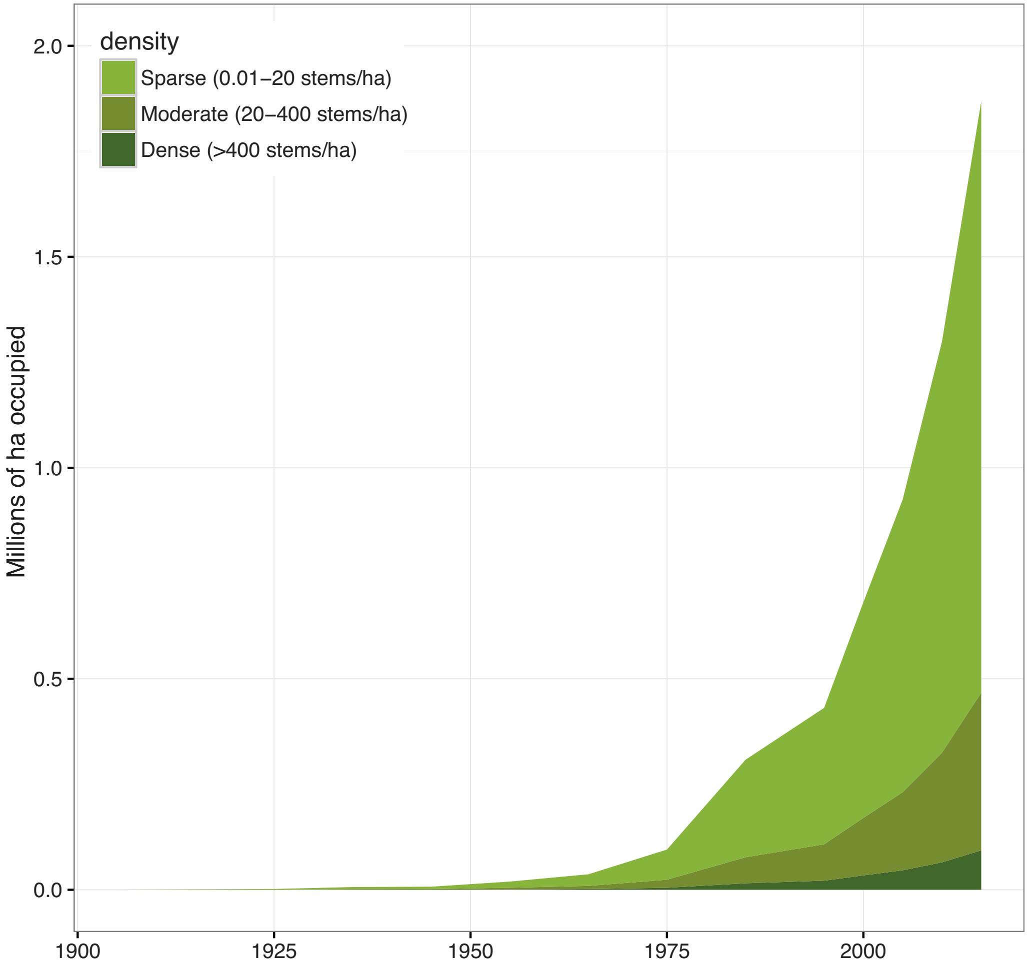

Figure 2. Approximate area occupied by wilding conifers in New Zealand using standardised regional reports.

and decades there is likely to have been significant departure from this.

Inclusion of some deliberately established areas of exotic is contentious (Dodet and Collet 2012), but I believe it is justified because such areas were never intended as commercial forestry, and are major contributors to wilding spread today. Exclusion of such stands initially, results in almost instantaneous expansion which is misleading. As well as promoting establishment, human intervention has also limited conifer growth through sustained control in some areas.

Using 2014 ratios of sparse, moderate and dense infestations in all eras was done out of necessity. As applied, such ratios fits with likely rates of progression of stands from sparse to moderate and ultimately dense infestations. It is possible that environmental changes such as changes in herbivore densities, mycorrhizal facilitation, or control intensity may have altered the rate of progression with time. However this level of complexity was not examined in any detail.

The estimates for area occupied here are significantly larger than the best estimate of area occupied using a remote sensing approach (Paul 2013). The main difference is likely to be related to the lower threshold of wilding conifer density I used for an area to be affected. The quality of images currently available for remote sensing does not allow reliable detection of small trees. Manual searching typically

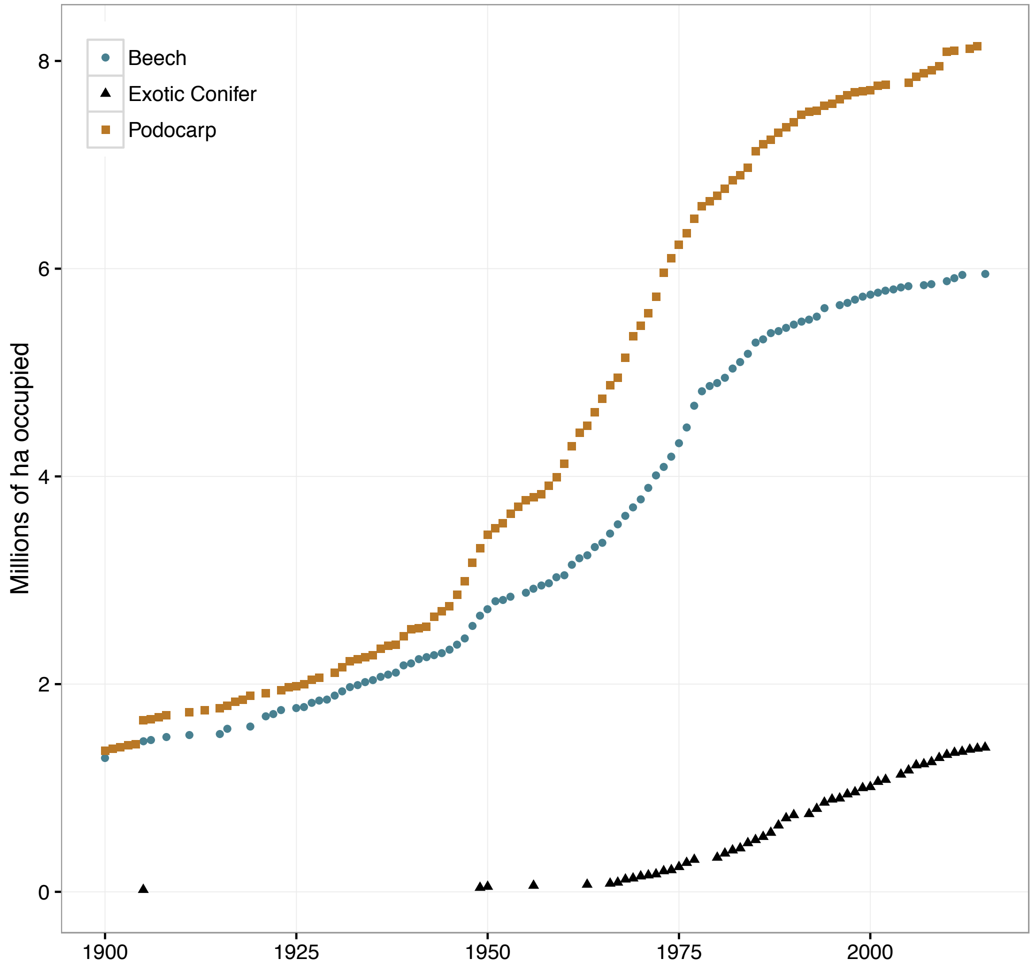

Figure 3. Approximate area occupied by wilding conifers and native tree species in New Zealand, using herbarium specimen occupancy of 10 × 10 km cells.

results in detection of smaller individuals, many more detections per ha, and a much greater overall area.

The increased collection of herbarium specimens of exotic conifers in the late 1980s coincides with the production of a major update to the published exotic flora (Webb *et al*. 1988) and is observed in other groups of exotic plants. Herbarium specimens are only a small fraction of presence records for New Zealand weeds (Howell and Terry 2016) so care needs to be taken when inferring distributions from specimens alone. However, comparison of collections of exotic conifers and montane native trees is informative. The methodology of Delisle *et al*. (2003) indicates that wilding conifers are spreading rapidly but comparing slopes on logged data penalises more widespread species. It seems likely that reductions in the collection rate of native species can be partly attributed to lack of interest in hundreds of specimens of the same species.

The potential area that could be invaded by wilding conifers of 7.3 million ha equates to approximately 30% of the land area of New Zealand. Using a spread model of 6% from 2015, this figure could be reached in as little as 30 years. However, it is likely that a logistic model will provide a better fit, as vulnerable land will become increasingly geographically isolated. Similarly, interventions to clear and maintain wilding-free areas will delay colonisation in some places. There are significant ecological, social and financial costs associated with continued spread of wilding conifers – it remains to be seen to what extent wilding conifers can be contained.

ACKNOWLEDGMENTS

Larry Burrows (Landcare Research) compiled the first figure of wilding conifer extent from published papers in 2013 that prompted this investigation. The Ministry for Primary Industries (MPI) funded national collection of data in 2014 on the extent of wilding conifer infestations. Nick Ledgard (Scion) authored many detailed reports on the status and management options for wilding conifer infestations for over 30 years. Kelvin Lloyd and Des Smith (Wildlands Consultants) have refined the classification of the categories of LCDB v. 4.1 that are vulnerable to wilding conifer invasion.

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