The potential impact of Scotch broom on softwood forestry in Australia

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Summary A CLIMEX model of Scotch broom, (*Cytisus scoparius* (L.) Link) indicates the potential for range expansion of this weed in Australia. Over 97% of the Australian softwood plantation area was found to occur in areas of suitable or optimal climatic suitability for *C. scoparius*. Trees growing in competition with *C. scoparius,* across 24 New Zealand sites, average 51.7% (range 32.8–64.8%) and 23.6% (range 11.0–37.8%) of the height and diameter of trees growing in the absence of plant competition, respectively. Annual rainfall exhibited a moderate positive correlation with relative tree height (height of trees growing in competition with *C. scoparius* compared with those growing weed-free) ($r^2 = 0.37$). If these reductions in *P. radiata* growth and diameter under competition with *C. scoparius* were experienced in Australia, further spread of this weed could seriously impact on site productivity and would add a significant burden to the industry by means of control costs.

Keywords Scotch broom, CLIMEX, *Cytisus scoparius*, impact.

INTRODUCTION

Scotch broom, *Cytisus scoparius* (L.) Link (Fabaceae) is widely distributed throughout the temperate and Mediterranean climatic zones. It is native to western and central Europe, North Africa and Western Asia and is recorded as a specific threat to commercial forestry operations in New Zealand, Australia, the USA and Canada. This weed is already established throughout New Zealand and in many of the commercial forestry regions of Australia and is currently expanding its range in both countries. It is of primary concern during planting as competition between *C. scoparius* seedlings and plantation trees impacts negatively on tree growth, reducing site productivity and, at the worst sites, can lead to premature tree death.

CLIMEX™ (Sutherst and Maywald 1985, Sutherst *et al.* 2007) is a popular computer package for modelling the potential distribution and relative abundance of an organism and undertaking risk assessments. The development of potential distribution maps enables the estimation of the resource area at threat from the species modelled. If knowledge exists as to the nature of the impacts of the modelled species on the assets at risk, then the impacts can be summed, assuming that the potential distribution is realised. This knowledge could provide useful guidance for the development of appropriate weed management strategies, and to prioritise investments in weed management.

In this study we (i) use CLIMEX to determine the potential distribution of *C. scoparius* in Australia; (ii) estimate the area of softwood plantation that could be affected by *C. scoparius* and (iii) calculate the relative impact that *C. scoparius* could have on growth of *P. radiata*.

MATERIALS AND METHODS

The CLIMEX modelling package was used to infer the climatic requirements of *C. scoparius* from its known native distribution in Europe, and to project the potential distribution of the weed in Australia. The details of the model parameters and the development of the *C. scoparius* CLIMEX model are described in Potter *et al*. (unpubl.). The resulting distribution map was then intersected with the location of softwood plantations. From these intersections the total plantation area and plantation area for each category of climatic suitability for *C. scoparius* was calculated. Finally, the indices that describe the response of *C. scoparius* to climate were extracted from the CLIMEX model and used to estimate the likely losses in *P. radiata* height and diameter in the presence of *C. scoparius*.

Impact on growth A hybrid weed competition model (Watt *et al.* 2007) was used to estimate the reduction in tree growth from competition with *C. scoparius*, at 24 New Zealand sites, at which weed-free tree growth was available. At each site potential dominant height of *C. scoparius* was estimated from a relationship with the CLIMEX growth index for this species, as described by Kriticos *et al.* (in prep). Collation of all other variables required to run the hybrid model at each site and parameter determination is fully described in Watt *et al*. (2007).

These calculations defined the relationship between *P. radiata* growth at age three for trees growing with *C. scoparius* relative to the weed-free growth. The relative height of trees with and without weeds was regressed against a range of environmental variables to develop a simple model which could be used to extrapolate estimates of weed impact to Australia.

RESULTS

The potential distribution of *C. scoparius* in Australia (Figure 1) incorporates all locations within the known range of the weed (Figure 2).

This study estimated there was a total of 936,000 hectares of softwood plantation in Australia and the majority of this area was climatically suitable for *C. scoparius* (Figure 1). Of the total area, 80% was classed as suitable with an additional 17% (156,000 ha) falling into the optimal category (Figure 3). Less than 0.4% of the plantation area was apparently unsuitable for the persistence of *C. scoparius*.

Trees growing in competition with *C. scoparius*, across the 24 sites in New Zealand, average 51.7% (range 32.8–64.8%) and 23.6% (range 11.0–37.8%) of the height and diameter of trees growing in the absence of plant competition, respectively.

Annual rainfall was found to have a mild positive correlation with relative tree height (height of trees growing in competition with *C. scoparius* compared with those growing weed-free) (r^2 = 0.37, Figure 4). The relationship between relative tree height and relative tree diameter with a range of other environmental variables and CLIMEX indices was poor (data not presented).

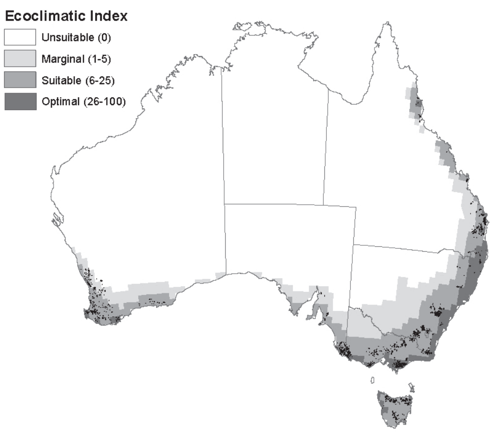

Figure 1. Potential distribution of *Cytisus scoparius* in Australia and the location of softwood plantations (black – source: National Plantation Inventory, Bureau of Rural Sciences).

Figure 2. The known distribution of *Cytisus scoparius* in Australia.

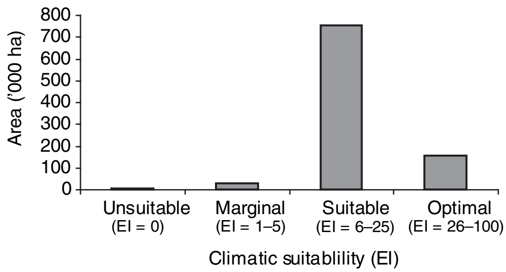

Figure 3. The area of softwood plantation in each category of ecoclimatic suitability (EI) for *Cytisus scoparius* generated by CLIMEX.

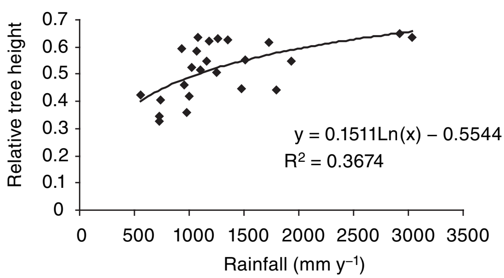

Figure 4. The relative height of *P. radiata* (height of trees growing in competition with *C. scoparius* compared with the weed free tree height) at age three as a function of total annual rainfall.

DISCUSSION

The CLIMEX model of *C. scoparius* clearly indicates the potential for range expansion in Australia as it identifies areas that are climatically suitable for its persistence outside its present known range. Large areas of softwood plantation forestry occur in areas of high climatic suitability for *C. scoparius*, and hence could be at risk of invasion. The estimated reduction in height growth of *P. radiata* under competition with *C. scoparius* compared to a weed-free environment indicates that this range expansion could have a serious impact on site productivity if preventative action and management is not implemented. Of course, other woody weeds growing in similar environments could have a similar impact on tree growth.

C. scoparius is already considered a serious weed in pastoral systems, natural ecosystems and forestry in Australia. However these results indicate that there is potential for range expansion and for further negative impacts to be realised. In New Zealand it has been estimated that the control costs for *C. scoparius* range from NZ\$150–500 hectare^{-1} and the weed costs the forestry industry approximately NZ\$1.31 million year^{-1} (Jarvis *et al.* 2006) in control operations. Hence an increase in *C. scoparius* invasion into softwood plantations in Australia is likely to add a significant burden to the industry by means of lost productivity and control costs.

Weed management plays an important role in forest stand establishment and has a large influence on early plantation tree growth rates. Growth reductions in conifers have been primarily attributed to competition by weeds for water, light and nutrients (Richardson 1993). At dryland sites, competition between *P. radiata* and weeds is primarily for water (Watt *et al.* 2003) and this relationship is reflected in the positive relationship between annual rainfall and relative tree height calculated in this paper.

The estimated impacts of *C. scoparius* on *P. radiata* provide a valuable warning for the Australian forestry industry. The 48.3% average reduction in height was calculated from New Zealand sites ranging in annual rainfall from 557 to 3035 mm year^{-1}. While this encompasses the rainfall range of *P. radiata* plantations in Australia, it is likely to be conservative when applied to Australia, as plantation forests in Australia are on average grown in hotter and lower rainfall environments than those in New Zealand (Richardson 1993).

Another way to adjust this impact calculation for Australia is to utilise annual rainfall data for locations within the potential range of the weed where *P. radiata* are planted. For example, it can be estimated that height reductions in the presence of *C. scoparius* of approximately 57% could be expected in *P. radiata* plantations near Ballarat, Victoria where the annual rainfall is 695 mm year^{-1} or 49% in plantations near Tarraleah, Tasmania where the rainfall is 1166 mm year^{-1}.

In summary, the technique of intersecting climate suitability maps with the distribution of the asset at risk can identify areas likely to be impacted on by a weed in the future. The calculation of weed impact could assist the relevant industry to assess the potential magnitude of the threat and to decide what management strategies may be required and within what time-frame.

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