Strategic management of the highly invasive *Buddleja davidii* within New Zealand in a changing climate

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Summary *Buddleja davidii* Franchet is a very high impact exotic weed that competes strongly with forest plantations in New Zealand. While it is currently restricted mainly to the North Island, a large proportion of the area identified for future forest expansion is in eastern and southern regions of the South Island where the weed is presently relatively scarce. Using a process-oriented climatic niche model (CLIMEX), we project increases in climatic suitability for the weed under climate change to be greatest in these eastern and southern regions of the South Island. As *B. davidii* predominantly colonises disturbed areas, the likely future increases in plantation area in this region can be expected to promote the spread of *B. davidii*. Various climate-change adaptation strategies that could be implemented to reduce the spread of *B. davidii* are discussed.

Keywords *Buddleja davidii*, butterfly bush, climate change, CLIMEX, invasive alien species, spread, weed risk.

INTRODUCTION

In plantation forestry, competition from weeds is the most important risk affecting establishment success and consequent tree growth and survival (Richardson 1993). Without management of competing vegetation, tree survival on most sites would be very low, and the yield of the surviving trees would be dramatically decreased (Wagner *et al.* 2006). The degree of weed competition strongly depends on the type of weed. Tall woody plants retard tree growth more than grasses and herbaceous species (Richardson *et al.* 1996) and are generally more difficult to control, often requiring repeated management treatments.

Maps describing the potential distribution of key high-impact weed species under climate change projections could be useful to land managers for assessing the risks of expanding into new areas or converting to plantation forestry. As climate strongly influences plant distribution and abundance, such maps may provide a useful indication of the effects of climate change on species range boundaries. We propose that determining the intersection of potentially suitable areas for high impact weeds with regions designated for future plantations, provides a useful basis for evaluating potential vegetation management risks.

As well as being widely regarded as an attractive garden plant *Buddleja davidii* Franchet is also a highly invasive species that competes strongly with other species in native ecosystems and plantation environments. In Europe, *B. davidii* poses such a significant conservation management threat that it has been identified as the highest priority target for biological control (Sheppard *et al.* 2006). Similarly, in the extensive plantations common in the central North Island of New Zealand, *B. davidii* retards tree growth more than any of the other major co-occurring weed species (Richardson *et al.* 1996). It has been rated by forest managers as the most problematic weed species within this region (Watt *et al.* 2008).

In this paper we consider how changes in the potential distribution of *B. davidii* under climate change are likely to overlap with current and planned forest plantations in New Zealand. This information was then used to identify strategies to mitigate the potential impact of *B. davidii* on future plantations.

MATERIALS AND METHODS

The CLIMEX model The CLIMEX modelling package (Sutherst *et al.* 2007) was used to model the current and future potential distribution of *B. davidii* using a previously developed model (D.J. Kriticos unpublished data). CLIMEX version 3 (Sutherst *et al.* 2007) is a dynamic climate model integrating weekly growth and survival (stress) responses of a species to temperature and soil moisture into an annual index of climatic suitability, the Ecoclimatic Index (EI). The EI ranges from 0 for locations where the species cannot persist to 100 for optimal locations.

Climate change scenarios Six climate change scenarios were used to project the potential distribution of *B. davidii* under climate change. These scenarios were developed from three Global Climate Models (GCMs) each run using two standard International Panel on Climate Change (IPCC) scenarios, representing medium (A1B) and high (A2) emissions, drawn from the set of standardised emissions scenarios (IPCC 2007). Selected GCMs included CSIRO Mark 3.0 (CSIRO, Australia), NCAR-CCSM (National Centre for Atmospheric Research, USA) and MIROC-H (Centre for Climate Research, Japan).

Estimating areas for potential afforestation Land area in New Zealand suitable for future plantations was identified using the selection process and criteria described in detail by Hall *et al*. (2009). Briefly, the selection of areas for afforestation was undertaken using GIS analysis and a range of datasets that included elevation, slope and land use layers. Areas excluded were highly productive land (e.g. arable land; based on land use classification and land use), developed areas (e.g. cities), existing plantations, indigenous forest area and the Public Conservation Land administered by the Department of Conservation.

Using the most conservative scenario a total of 0.83 million (M) hectares was identified in New Zealand as suitable for future plantations. Of this area, substantial areas were located in Canterbury (0.34 M ha), Otago (0.32 M ha) and Southland (0.051 M ha). Within these three regions there are currently 0.26 M ha of existing plantations.

RESULTS

Current climate projections of potential distribution based on ecoclimatic suitability show most of the North and South Island to be suitable for *B. davidii* (Figure 1a). Regions that are unsuitable for *B. davidii* are located at high altitude adjacent to the main axial ranges in the South Island (Figure 1a). There are large tracts of land (tens of thousands of square kilometres) suitable for *B. davidii* within the south-east of the South Island (Figure 2a) where *B. davidii* is currently scarce (Figure 1a). Under current climate the ecoclimatic index declines with region latitude (Figure 2b).

Under climate change the potential distribution of *B. davidii* increases markedly in the South Island (Figures 1b, 2a). Similarly increases in ecoclimatic index under climate change increase with latitude (Figure 2b). For all regions within the South Island expansion was lowest under the CSIRO model, intermediate under the MIROC-H model (Figure 1b) and highest under the NCAR model. There was little

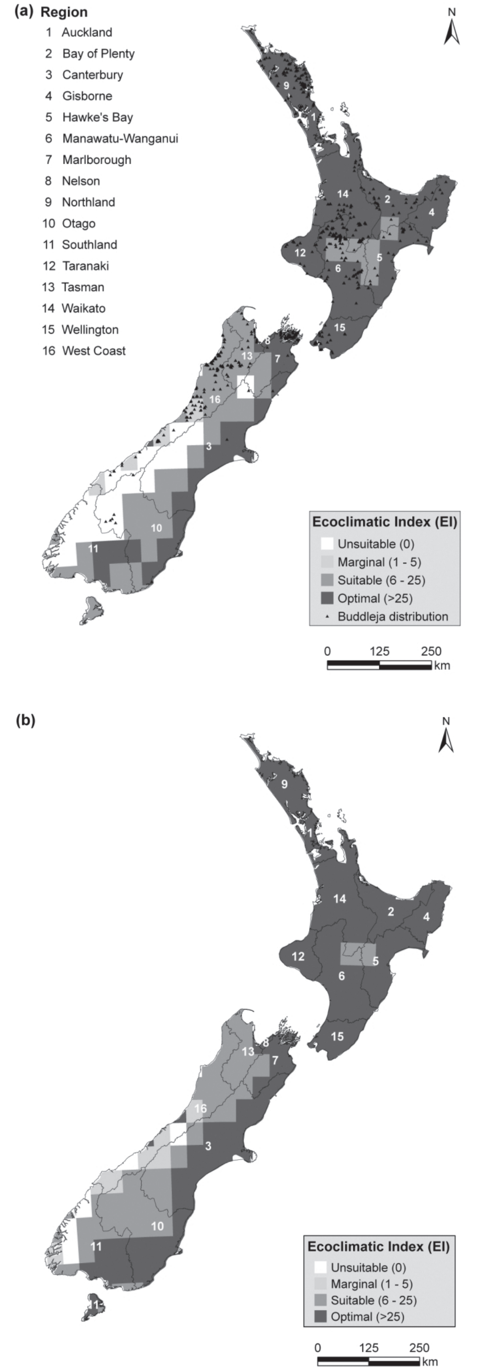

Figure 1. Ecoclimatic index for *Buddleja davidii* by region, under (a) current climate and (b) future climate projected by the mid-range MIROC-H AIB scenario. Also shown on Figure (a) is the current distribution of *B. davidii* (solid triangles).

variation in projected potential distribution between emission scenarios within each model.

DISCUSSION

Examination of the present distribution of *B. davidii* clearly shows that there are sparse populations of the species in eastern and southern regions. Given that the current plantation estate of 0.26 M ha could potentially expand by 0.71 M ha, a control line (see Figure 3) is likely to be of significant use in reducing spread rates and impacts to plantations.

Results show that *B. davidii* could grow well in areas of Canterbury, Southland and Otago under current climate. Under future climates, model projections show that the area of climate suitability within eastern South Island is likely to markedly increase. As *B. davidii* colonises disturbed sites, such as newly prepared forest sites and river flats, any new afforestation within the eastern and southern South Island is at risk of invasion.

The risk of *B. davidii* expanding its range into eastern and southern regions of the South Island of New Zealand is likely to be increased by planned changes in land use. Eastern and southern regions within the South Island are presently characterised by agricultural land with vigorous grass species that have been shown to out-compete *B. davidii* (Tran Hop unpublished data). In the absence of effective control measures, the disturbance associated with establishment of forest plantation mosaics is likely to exacerbate the rate of spread and abundance of *B. davidii* within this region. This has previously occurred in other regions where plantations constitute a high proportion of the land area (e.g. Bay of Plenty).

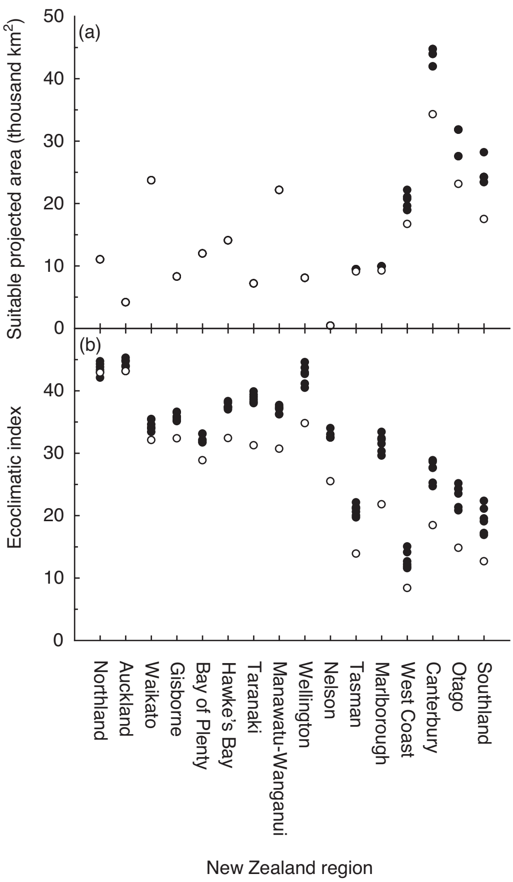

Figure 2. (a) Area projected to be suitable and (b) ecoclimatic index for *Buddleja davidii,* by region, under current climate (open circles) and projected future climate (filled circles), run using the six described scenarios (see Materials and methods). Regions are sorted from left to right in order of increasing latitude.

Figure 3. Map of New Zealand, showing the proposed control line (black) and the current distribution of *Buddleja davidii* (black triangles). The control line follows the regional boundaries of West Coast and Tasman and bisects Marlborough along a major road (State Highway 63). Region numbers shown on the figure follow the names given in Figure 1a.

The arrival of *B. davidii* in forests around Nelson has already prompted the Tasman District Council to list *B. davidii* as an invasive pest. This status prevents it from being sold in nurseries under Sections 52 and 53 of the Biosecurity Act and helps to contain it through boundary control. However these precautions have come too late for forest growers in the upper South Island who are now faced with the costly control measures associated with this weed, where it is becoming more problematic every year.

Other South Island regions would benefit from taking early steps to prevent the southward spread of *B. davidii*. In areas where *B. davidii* is presently rare, local eradication may be a cost-effective management option. The plant is not just a problem for forest growers – it can also invade conservation areas. It colonises any areas of soil disturbance, so river flats are particularly vulnerable.

Adaptation strategies that could be implemented to reduce the spread of *B. davidii* are: (1) including the weed in New Zealand's National Pest Plant Accord to prevent its sale and propagation nationwide; (2) preventing spread of the species across a South Island 'control line', that geographically separates infested regions on the west coast and northern regions of the South Island from the sporadically-occupied areas in eastern and southern areas; (3) including it as a target for eradication in the Regional Pest Management Strategies (RPMS) of all eastern and southern territorial authorities in the South Island, and in particular, Marlborough, to reduce the risk of spread from naturalised populations into North Canterbury; and (4) invoking a nationally coordinated response through the National Interest Pest Response process.

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