Climate change impacts on Scotch broom in Australia

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Summary *Cytisus scoparius* is distributed throughout the Temperate and Mediterranean climatic zone. It is widely regarded as a problem species for plantation forests and conservation areas. CLIMEX was used to project the potential distribution of *C. scoparius* in Australia and explore the likely effects of climate change on its distribution. Under current climate, the model projects that there is considerable potential for range expansion both northward along the coastline and inland Victoria, NSW and Western Australia. This expansion may not, however be realised as climate change causes areas of suitable climate to become marginal. Increasing temperatures, for example are likely to reduce the northern range boundary of *C. scoparius* in Australia while there is a concurrent range expansion in south-eastern Australia into areas that are presently too cold.

Keywords CLIMEX, climate change, *Cytisus scoparius*, Scotch broom.

INTRODUCTION

Cytisus scoparius (L.) Link (Fabaceae) is distributed throughout the Temperate and Mediterranean climatic zones and is widely regarded as a problem species for plantation forests and conservation areas. While much is known of the biology and ecology of the species, there has been little previous research into its potential distribution under current and future climatic conditions. Potential distribution maps, developed through climate modelling enable the identification of areas in which the weed may extend its range. When used in tandem with models that describe how the weed impacts on a crop, valuable guidance for land-use planning and the development of cost-effective management strategies can be gained.

Global climate change is projected to increase atmospheric CO_2 concentrations, and to increase temperatures. Projected changes in rainfall are far less certain, with region-specific changes and less agreement amongst the global climate models.

CLIMEX™ (Hearne Scientific, Melbourne, Australia, (Sutherst *et al.* 2007) is a popular tool for projecting the potential distribution of invasive alien species. It can also be used to explore the likely effects of climate change on the potential distribution and relative abundance of the organism being modelled. In this study we use CLIMEX to project the potential distribution of *C. scoparius* under both current and selected future climate scenarios.

MATERIALS AND METHODS

Native and worldwide distribution *Cytisus scoparius* occurs in temperate, Mediterranean and sub-tropical climatic zones, in Australia, New Zealand, Japan, Europe and the United States. It also extends into eastern Europe, Scandinavia, Canada, India, Africa and South America.

The CLIMEX model CLIMEX was used to infer the climatic requirements of *C. scoparius* from its distribution it its native range, and to project its potential distribution in Australia. The CRU CL 1.0 climatology dataset (0.5 degree regular grids of precipitation, mean temperature, diurnal temperature range and vapour pressure for significant land areas from 1961–1990) was used as the current climate dataset.

The climatic requirements of *C. scoparius* were inferred by iteratively fitting the climate response functions in CLIMEX to the known native distribution (Table 1). Growth and stress indices are then combined to provide an overall index of climatic suitability, the Ecoclimatic Index (EI). Details of the development of the *C. scoparius* CLIMEX model are described in Potter *et al*. (unpubl. data). The projections were verified using distribution records from New Zealand and north and South America and the resulting model was validated by comparing the projected distribution of *C. scoparius* with independent observations from Africa, Asia and Australia.

Climate change scenarios The Hadley3 (UK Hadley Centre for Climate predictions and Research Coupled Model #3) global climate model (GCM) was selected from the Intergovernmental Panel on Climate Change (IPCC) database to assess the likely effects of climate change on the potential distribution of *C. scoparius*. This GCM is regarded as a warm, dry model. Details of the generation of this dataset in CLIMEX have been described by Kriticos *et al.* (2006).

The climate scenarios chosen represented two extreme greenhouse gas emissions' scenarios with B1 representing a low emission scenario and A1 a high emission scenario. The B1 and A1 scenarios will hereafter be referred to as the low and high emission scenarios respectively. Rahmstorf *et al.* (2007) has recently shown that the trends in global warming and sea level rise are effectively beyond the upper end of the emissions scenarios considered by the IPCC. Hence, the high emissions scenario used in this study should probably be given more weight as an indicator of future climatic conditions.

RESULTS

The predicted potential distribution of *C. scoparius* in Australia includes all known locations of *C. scoparius* (Figure 1) and projects that it could invade and colonise the east coast of Australia with Rossville in North Queensland its northern limit, extending down the Queensland, New South Wales and Victorian coastlines (Figure 2a). Suitable climate for the species also spreads into inland Victoria, New South Wales and Western Australia. All of Tasmania is of suitable or optimal climate for the species, as well as around Adelaide in South Australia and the south western region of Western Australia.

Under the future climate scenarios there is a poleward shift in the potential distribution of *C. scoparius* in both the low and high emission climate scenarios, with a marked contraction in the areas of optimal climate in all Australian states apart from Tasmania (Figures 2b and c). Under the low emission scenario, the northern range is disjointed with only small areas of suitable climate remaining in northern Queensland. The distribution is also restricted inland of the coast in southern Queensland, New South Wales, Victoria and Western Australia, compared to under current climate. Under the high emission scenario these trends are further intensified, with the northern distribution shifting southward to Bundaberg and a greater area of Tasmania becoming climatically optimal.

Table 1. CLIMEX parameter values used for modelling the distribution of *Cytisus scoparius*. The role and meaning of parameters are described in Sutherst *et al.* (2007).

Index	Parameter	Values[A]
Temperature	DV0	8.5°C
	DV1	18.0°C
	DV2	23.0°C
	DV3	28.0°C
Moisture	SM0	0.1
	SM1	0.95
	SM2	1.5
	SM3	2.5
Cold stress	TTCS	−12.0°C
	THCS	−0.01 Week^{-1}
	DTCS	8.0°C days
	DHCS	−0.00025 Week^{-1}
Heat stress	TTHS	28.0°C
	THHS	0.001 Week^{-1}
Dry stress	SMDS	0.1
	HDS	−0.05 Week^{-1}
Wet stress	SMWS	2.5
	HWS	0.002 Week^{-1}
Annual heat sum	PDD	201.0°C days

[A] Values without units are dimensionless indices.

Figure 1. The known distribution of *Cytisus scoparius* in Australia.

DISCUSSION

It is evident from the results of this study that there is potential for substantial range expansion by *C. scoparius* in Australia under current climate conditions. While the current distribution of this weed already incorporates the majority of the climatically suitable and optimal regions, large areas remain un-infested, particularly inland of the current distribution.

Range expansion north and inland of the current distribution would be of concern as it is likely to impact on agricultural enterprises such as dryland cropping, grazing and forestry. Furthermore, the likelihood of spread and successful establishment of the weed in these areas is high due to activities such as land clearing, cultivation and the re-location of machinery. Similarly, continued spread into natural ecosystems could have far reaching ecological consequences including considerable impacts on vegetation

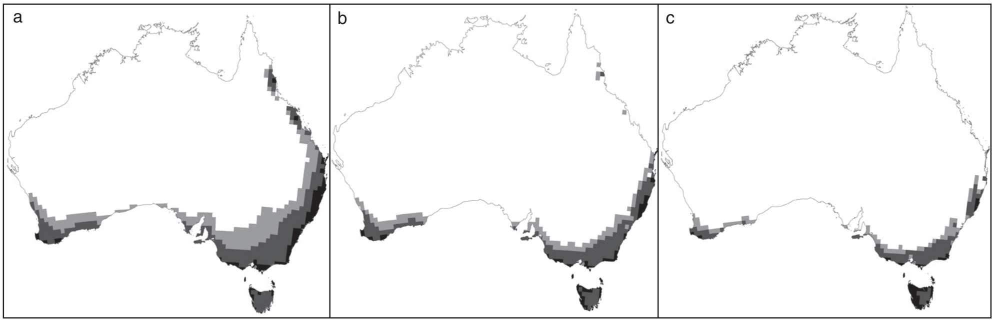

Figure 2. CLIMEX climatic suitability (ecoclimatic index) for *Cytisus scoparius* in Australia under a) current climate, b) Hadley 3, B1 scenario and c) Hadley 3, A1 scenario. Ecoclimatic index – ▭ Unsuitable (EI = 0), ▒ Marginal (1–5), ▒ Suitable (6–25), ■ Optimal (26–100).

succession, local extinction of rare species and an increase in populations of feral animals, native and alien birds (Smith *et al.* 2000)

Under climate change, the northern Australian range boundary is projected to contract southwards (poleward), curtailing its northward invasive spread before it reaches its potential. This is positive news for managers of land in coastal Queensland. However, the improvement in the climatic suitability of invaded sites in south-eastern Australia is sobering, and suggests that efforts at strategically containing the spread of *C. scoparius* in these areas are warranted.

It should also be noted that given that the climatic habitat favoured by *C. scoparius* is similar to that which supports some of our valuable primary industries, any reduction in the area of suitable climate for *C. scoparius* is an indicator of a similar contraction in the area of suitable climate for agriculture, horticulture and forestry. Furthermore, a reduction in the area of suitable climate for *C. scoparius* is likely to lead to a corresponding range expansion for sub-tropical species, including many weeds.

In principle, higher levels of CO_2 should stimulate photosynthesis in C3 plants and suppress photo-respiration making them more water-efficient (IUCC 2007). The CLIMEX model however was not adjusted to include the effects of elevated CO_2 on water use efficiency (WUE) as the relative changes in growth and water use of *C. scoparius* under elevated CO_2 are completely unknown. Nevertheless, any increase in WUE would be expected to increase the favourability of relatively dry sites (Kriticos *et al.* 2003), reducing the degree of coastal range shift under the future climate scenarios.

In summary, the development of potential distribution maps that identify areas in which *C. scoparius* could extend its range under current and future climate scenarios will assist in guiding land- use planning and prioritising control efforts.

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