A relative invasion threat model for European olive (*Olea europaea* L. ssp. *europaea*) in the Clare Valley, South Australia

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Summary European olive (*Olea europaea* L. ssp. *europaea*) has invaded native vegetation communities in many parts of southern temperate Australia. Originating in the Mediterranean region, European olive has been imported and cultivated for its high oil content. Poor management of cultivated European olive has allowed dispersal into habitats previously free of the species. European olive invasion has led to a significant reduction in native species diversity within a local eucalypt woodland. In response to the threat posed by the expanding olive industry, the South Australian Animal and Plant Control Commission (SAAPCC) developed risk assessment and management guidelines for future olive groves to minimise the risk of escape and spread into surrounding native vegetation. Their model rates the risk of escape, and subsequent threat to native vegetation, of proposed European olive plantations as low, medium, high or very high, based on precipitation, edaphic conditions, surrounding land use, distance to native vegetation and grove management variables.

This paper describes the development of an invasion threat model, incorporating the SAAPCC risk criteria, as well as additional climatic, edaphic and topographic variables, in a GIS environment. The main concern is with the likely success with which European olives can establish and reproduce, as determined by habitat constraints in which a propagule arrives. Output from a Classification and Regression Tree (CART) analysis was used to predict suitable habitat based on current distribution records of adventive (commonly referred to as feral) European olives within the study area. This habitat suitability surface was then combined with distance to native vegetation and land use variables to produce the relative invasion threat surface. This surface, in conjunction with the SAAPCC grove management guidelines, can be used to rapidly assess future applications for olive groves.

Keywords Classification and regression tree, environmental weeds, European olive, *Olea europaea* L. ssp. *europaea*, geographic information systems, predictive modelling, weed risk assessment.

INTRODUCTION

Originating from the Mediterranean region, European olive (*Olea europaea* L. ssp. *europaea*) has been imported into Australia for its horticultural value. The fruit produces high quality flesh and oil. The fruit is also favoured by frugivorous birds, particularly the common starling (*Sturnus vulgaris* L.) (Jupp *et al* 1999), and the European fox (*Vulpus vulpus*) (Paton *et al* 1988), with seeds being dispersed up to several kilometres at a time. Poor management (for example abandonment or crops not harvested) of groves planted 50–150 years ago has led to many serious invasions of European olive into southern temperate eucalypt woodland communities. Diversity of native plant species richness in grey box (*Eucalyptus microcarpa* Maiden) woodland was recently shown to be approximately 50% lower at sites heavily invaded by olives (Crossman in press). The same study also concluded that canopy cover of the overstorey grey box was over 80% lower at invaded sites of the same woodland.

In response to the impacts of olive invasion and the current increase in commercial olive plantings, the South Australian Animal and Plant Control Commission (SAAPCC), in conjunction with industry, NGO and State and Local Government representatives, developed assessment guidelines to minimise threats posed by new olive groves (SAAPCC 1999). A proposed grove is rated as low, medium, high or very high risk, as determined by the location, surrounding land uses and intended management of the grove. However, there is now demand for a more rapid assessment procedure that incorporates the SAAPCC risk variables into a threat [to native vegetation] model that indicates the likelihood that an olive propagule will establish (Paul Jupp SAAPCC, pers. comm.) if it escapes from a poorly managed grove. This threat model can be used in conjunction with proposed grove management strategies to estimate the overall likelihood of olive escape and spread.

This paper presents the methods used to develop a threat model of European olive invasion within the Clare Valley, approximately 120 km north of the Adelaide GPO, South Australia. The study area comprises 184,000 ha of predominantly mixed use agriculture, but also includes intensive horticulture and patches of remnant native vegetation.

METHODS AND MATERIALS

Spatial data Table 1 lists all variables used to produce the threat model. The climatic variables were interpolated using ANUCLIM 5.0 (Houlder *et al* 1999) with a 10 m horizontal resolution digital elevation model (DEM) to estimate climate variables for each grid cell in the DEM. The subset of 10 climatic variables (Table 1) were chosen to represent the full suite of 35 variables available in ANUCLIM. The DEM was also used to calculate the soil wetness index (SWI) from the equation SWI = ln(F/tan(s)) (Hilbert and van den Muyzenberg 1999), where flow accumulation (F) and slope (s) were determined by standard ARC/INFO routines (ESRI 2001). The non-categorical climatic and topographic variables were transformed to a range of 1–255. Distance to native vegetation was generated using the EUCDISTANCE command in the GRID module of ARC/INFO (ESRI 2001). The density of adventive olives was derived from olive distribution and abundance data (n = 10,000 points) supplied by the Lower North Animal and Plant Control Board. A sample (~10%) of this data was field checked and the full dataset was calibrated to reflect true densities. The density data represents stems per 10 m cell. The density data was randomly split 80/20 into training and testing datasets.

Classification and regression trees (CART) All but the last two variables listed in Table 1 were used to calculate a habitat suitability surface based on the theory that a species distribution is limited by climate (Woodward 1987). Accordingly, a species will be restricted to a geographic location in which it can survive and reproduce, as determined by the favourability of variables such as temperature, precipitation, soils, aspect and solar radiation. The variables that describe these conditions, as well as the adventive olive density training data, were input into the CART® 4.0 software package (Steinberg and Colla 1997) to infer relationships between the distribution of olive density and the environmental attributes. CART uses a recursive decision tree to partition similar groups of predictor variables (climatic, edaphic and topographic variables) based on variations in a response variable (olive density). The output was a set of partition rules that reflect variations in olive density.

GIS analysis All GIS analyses were performed in ARC/INFO (ESRI 2001). The outputs from CART were used to create a spatial habitat suitability surface by ranking each predictor variable grouping according to mean adventive olive density. The final habitat suitability surface was reclassified into 10 categories (1 = least suitable; 10 = most suitable). The density test data and habitat suitability surface were analysed for accuracy using SPSS 10.0. To relate distance to native vegetation with risk, the distance to native vegetation dataset (d) was reclassified (DC) into 10 categories (1 = furthest; 10 = closest) using the equation DC = int(10*exp(-0.0005*d)). The negative exponential was used because it is the simplest descriptor of plant dispersal kernels (Willson 1993). The equation was parameterised to reflect SAAPPC (1999) olive dispersal distances. Land use was categorised into five categories based on susceptibility to olive invasion, following the SAAPPC (1999) guidelines (2 = intensive use; 10 = no use). The final threat model was calculated by multiplying habitat suitability, distance to native vegetation and land use. This surface was reclassified into three threat categories based on distance from the mean threat value.

RESULTS

The variables mean annual temperature, minimum temperature of coldest period, mean annual radiation, soil salinity and slope did not feature in the CART output because they did not explain any variation in

Table 1. Variables used as inputs into the threat model.

Type	Name
Climatic	Mean annual temperature
	Mean diurnal range
	Minimum temperature of coldest period
	Mean temperature of warmest quarter
	Mean temperature of coldest quarter
	Annual precipitation
	Precipitation of wettest quarter
	Precipitation of driest quarter
	Annual mean radiation
	Annual mean moisture index
Edaphic	Soil wetness index
	Soil acidity
	Soil fertility
	Soil salinity
	Soil waterlogging
Topographic	Digital elevation model
	Slope
	Aspect
Other	Density of feral European olives
	Land use
	Distance to closest native vegetation

olive density. Figure 1 shows a positive and significant relationship ($r^2 = 0.336$, $P < 0.01$) between the final habitat suitability surface and the olive density test data. Greater levels of habitat suitability are related to greater adventive olive densities. This indicates that the application of CART was successful in predicting the distribution of adventive European olive.

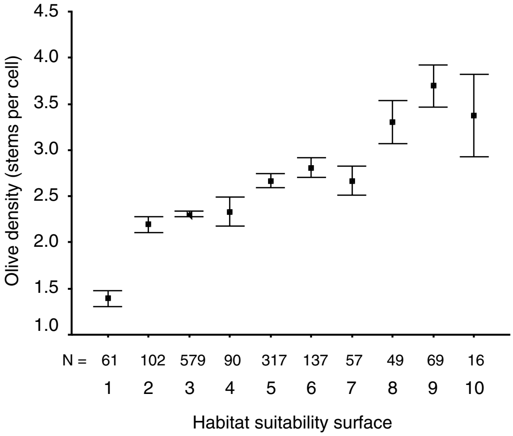

Figure 1. Mean habitat suitability category (1 = least suitable; 10 = most suitable) versus 20% olive density test data. Error bars represent ± 1 SE.

Figure 2 shows (a), the final habitat suitability surface and (b), the threat model. Areas with the highest habitat suitability are concentrated within 15 km south and east of the township of Clare, and across the eastern reaches of the study area. Both areas coincide with zones of higher altitude and precipitation. Importantly, however, the areas of high habitat suitability south of the Clare township contain significant patches of remnant eucalypt woodland. Nearly 62,000 ha (34%) of the study area poses a medium to high threat to native vegetation from European olive invasion (Figure 2b).

DISCUSSION AND CONCLUSION

The habitat suitability and relative threat surfaces provide a tool to aid the Clare and Gilbert Valley Local Government Authority and the Lower North Animal and Plant Control Board with rapid assessments of proposed olive groves. However, these outputs will need to be used in conjunction with proposed orchard management regimes to make a final decision as to the risk that olives will escape from an orchard and subsequent threat the escapes pose to native vegetation.

The habitat suitability surface and threat model does have limitations. The use of adventive olive training data limited to the extent of the study area

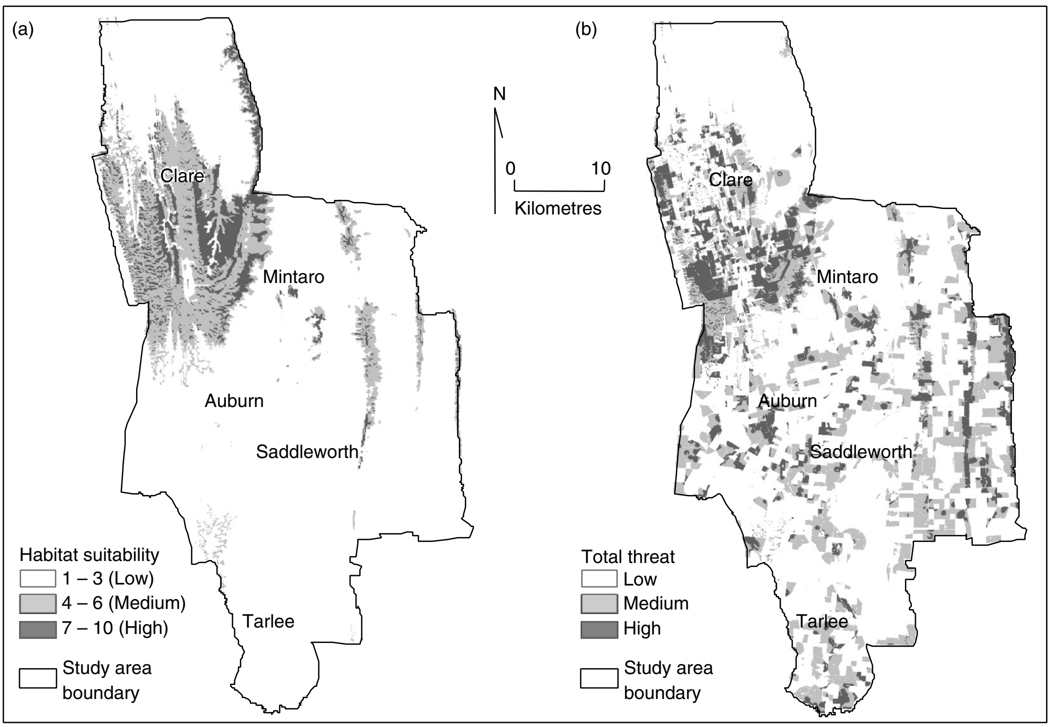

Figure 2. (a) Habitat suitability surface, and (b) final relative threat model, Clare Valley, South Australia.

incorporates bias into the habitat suitability surface and may under-estimate the true extent of highly suitable habitat. Inclusion of adventive olive presence data from locations outside the study area would correct for this bias. Another limitation is that of scale. The usefulness of fine-scale climatic data is limited by the annual variance associated with climate, thereby reducing variation within each variable. Future iterations of the threat model will assess the sensitivity of the outputs to variations in climate, with precision (i.e. cell size) of the climate variables adjusted accordingly.

The methods used in this paper have produced a habitat suitability surface based on the hypothesis that a plant's spatial distribution is limited by a series of edaphic variables. The habitat suitability surface, in conjunction with distance to native vegetation and land use, has been used to derive a relative threat model that rates the site of a proposed olive grove as low, medium or high threat to native vegetation should a propagule escape. As far as I am aware this study is the first attempt to apply the CART data mining technique to environmental weed management. CART is not the only, and may not be the best technique to find patterns in variables influencing weed distribution (Kriticos and Randall 2001). I am currently testing several different techniques, the results of which will be published shortly.

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