A national weed management decision-support system

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Summary In New Zealand, Regional Councils have the primary governmental responsibility for coordinating the management of weeds and other pests. Similarly, in Australia, it is the States that have this responsibility. In both countries, the national co-ordination and harmonisation of weed control efforts has been a perennial challenge, leading to initiatives such as the Weeds of National Significance in Australia and the National Policy Direction for Pest Management in New Zealand. Further, in both countries, the number of weeds that affect natural and productive ecosystems far exceeds the resources available to manage them such that prioritisation is necessary. In New Zealand, a favourable cost benefit analysis is required for a weed to be considered for inclusion in a Regional Pest Management Plan. The ability of New Zealand's Regional Councils to undertake such analyses has been hampered by a lack of crucial biophysical data regarding the target weed, including its current distribution, potential future distribution and its rate of spread in the absence of control. To redress this, and to facilitate the required nationally consistent approach, scientists from AgResearch and CSIRO have collaborated to develop a platform of five tools: a national weed occurrence database (NWDD) that automatically harvests regional weed occurrence data; a database of CLIMEX models and their projections for New Zealand (CLIMENZ); a weed spread model (MDiG); a spatial weed risk assessment model (WRASP); and a cost benefit model (CBA for regional pest management). In this paper, we illustrate this decision-support system and comment on its adoption by Regional Councils in New Zealand and its contribution to targeting resources to the most deserving weed problems. We then consider how easily it might be extended for use in Australia.

Keywords Biosecurity, weed, cost benefit analysis, CLIMEX, weed risk assessment, spread, spatial occurrence.

INTRODUCTION

New Zealand's *Biosecurity Act 1993* provides for the eradication or effective management of harmful organisms that are present in New Zealand (NZ) through 'Pest Management' (national and regional) and 'Pathway Management' Plans (Ministry for Primary Industries 2016). These plans must be consistent with the National Policy Direction for Pest Management 2015 (NPD) to ensure that they provide for the best use of available resources for New Zealand's best interests, and are aligned with one another when necessary (Ministry for Primary Industries 2015). To this end, the NPD firstly requires, and provides direction for, an analysis of the benefits and costs of a proposed pest management plan. The analyses must quantify the impacts of the pest and the benefits of alternative management options. They must also state assumptions and account for uncertainties. Secondly, the NPD requires that a weed (or other pest) be managed under one of four defined program types (exclusion, eradication, progressive containment, sustained control) (Ministry for Primary Industries 2015).

The ability of New Zealand's Regional Councils to comply with the requirements of the NPD in their Regional Pest Management Plans (RPMP), in particular, regarding the analysis of benefits and costs for the proposed management of a weed species, has been hampered by a lack of availability of crucial biophysical data. This includes the species' current distribution, potential future distribution and its probable rate of spread and impact in the absence of the proposed regional management program. To redress this, and to facilitate the nationally consistent approach and standardised classification of weed management programs specified in the NPD, scientists from AgResearch and CSIRO have collaborated to develop a platform of five tools. Two are currently available. Three require further development for which funding is being sought. In this paper we describe these tools, present usage statistics for one that is currently available (a cost benefit analysis web application), and consider how the latter, and the platform as a whole, might be applied in both New Zealand and Australia.

THE DECISION SUPPORT SYSTEM

Overview The weed management decision support system that we are developing is structured around informing the cost benefit analysis (CBA) required for a weed (or other pest) proposed for inclusion in a Regional Pest Management Plan in New Zealand (Figure 1). The system recognises that the CBA must account for the expected benefits and costs for managing the species of interest under the proposed Program Type (Exclusion, Eradication, Progressive Containment, Sustained Control).

The component WRASP, a spatially explicit weed risk analysis tool, determines which of the four Program Type(s) best suits the species. The costs of the program are determined externally, based on the type and frequency of interventions required to achieve the outcome for the program. The benefits are informed jointly by the three component system tools NWDD, CLIMENZ and MDiG (Modular Dispersal in GRASS). Respectively, they estimate the species' current distribution (ha), potential distribution (ha) and the rate (spread rate) at which the potential distribution is expected to be realised in the absence of the management program. The CBA returns the Net Present Value (NPV) and Internal Rate of Return (IRR) supporting the decision to proceed (or not) with the proposed management program for the species of interest.

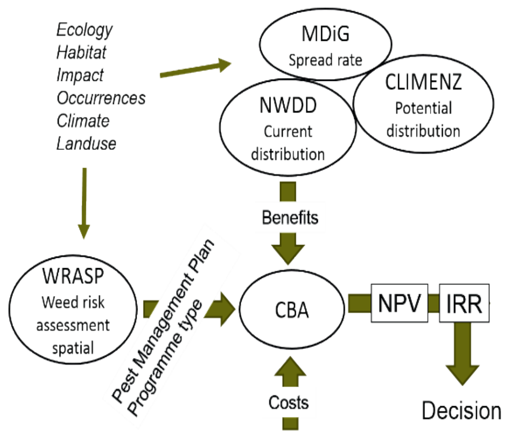

Figure 1. Regional weed management decision support system under development in New Zealand.

NWDD There is significant interest in New Zealand in establishing a National Weed Distribution Database (NWDD) that would automatically harvest weed occurrence data from the disparate databases held by regional councils, Department of Conservation and other organisations (Basse *et al.* 2008). In addition to the many benefits perceived in a recent study (viewing changes in weed distributions, understanding threats, understanding weed spread, improved decision making, long-term archival service for weed distribution data, identifying national priorities for coordinated action) (Cooper *et al.* 2010), a NWDD could provide the data necessary to quantify the current infested area of a weed in a region as required by the CBA tool (Figure 2). A prototype NWDD has been developed, based on the work of Clayson Howell in the NZ Department of Conservation (DoC), which combined NZ data on 180 weeds from several sources – herbaria records, Regional Council databases, DoC databases and personal interviews with biosecurity staff in all Regional Councils. This data set was completed in 2008 and has subsequently been lodged in an online resource under development.

CLIMENZ Climenz, a web-based tool approximates the CLIMEX algorithm (Kriticos *et al.* 2015, Sutherst and Maywald 1985). It allows authorised users to generate high resolution maps for the projected climate suitability of New Zealand for particular taxa under current and future climates (Kean *et al.* 2015). The projections are made from published CLIMEX models of which 118 were available for plants in 2015; models for other weed species can be added when available. The output from CLIMENZ includes land areas (ha) for the species that are climatically Optimal, Suitable, Marginal and Unsuitable. CLIMENZ is available at (http://b3.net.nz/climenz) and these estimates inform the potential infested area parameter in the CBA tool (Figure 2).

MDiG MDiG is a dynamic, stochastic dispersal model that simulates temporally discrete dispersal processes within an open-source GIS system (Neteler and Mitasova 2004). A raster map of the current distribution of a given pest with an appropriate cell size is updated annually through two dispersal processes – local spread (based on knowledge of population boundary movement) and long-distance spread (by sampling from a Poisson probability distribution based on historic distribution data, such as might be obtained from GBIF, http://data.gbif.org/datasets). Newly establishing infestations are restricted to a climatic suitability envelope, obtained from CLIMEX, and a geographic envelope (a GIS layer defining unsuitable habitats such as water bodies for terrestrial species). The model produces a large set of realised distributions from many stochastic replications and thus the output is an occupancy probability map over time. The impact of RPMP actions can be simulated by modifying key parameters such as the success of new infestations, spread rates etc. The model has been applied to two organisms to date, Argentine ant (Pitt *et al.* 2009) and the shrub weed *Buddleja davidii* Franch. (Pitt *et al.* 2011).

WRASP This tool is a spatialised version of the widely-used aspatial Post Border Weed Risk Management tool, PBWRM (Anon. 2006). It allows the risks posed by a weed to be characterised using spatial variables, and indicates the most appropriate type of management program (exclusion, eradication etc.) as a spatial variable. This new spatial system for weed risk assessment has been illustrated using a case study in New Zealand, comparing the results of a spatial and an aspatial analysis of the risks it poses and the logical management program options (Kriticos *et al.* 2018). In the case study, the spatial view of risks revealed locations of higher and lower risk and suitability for management attention that were hidden by blanket, aspatial weed risk scores of the PBWRM system (Kriticos *et al.* 2018). Development of a web-based version of WRASP will help complete the decision support system by adding a tool enabling the user to objectively determine the most suitable management program type for the weed in question.

CBA This tool employs a standard discounted cash flow analysis to calculate the NPV and IRR for the proposed weed management program. It is accessible free of charge at the AgPest website (https://www.agresearch.co.nz/cba/cba.php) and its underpinning logic is described elsewhere (Bourdôt *et al.* 2015). The user begins by setting the species, region, program type to be simulated (exclusion, eradication, progressive containment, sustained control), and the simulation period (up to 100 years). The expected invasion trajectory of the weed in the region in the absence of the program is then set by the input of the three parameters of a logistic spread model (Current area infested (ha), Potential area infested (ha) and Spread rate (ha y^{-1})). These three parameters are informed, respectively by NWDD, CLIMENZ and MDiG. The weed-free earnings expected from the land at risk of invasion, the expected reduction in these earnings due to the weed, the discount rate to be applied, and the probability of success of the program, are then entered. These parameters are then used by the model, along with the defined invasion trajectory, to calculate the present value of the loss prevented in each year of the program. The costs incurred by the proposed program in each year are then entered and the model returns the NPV as the difference between the present value of the losses prevented ($Cost_0$) and the present value of the costs incurred for the management program ($Cost_1$) (Figure 2). The IRR is also calculated, a useful metric for prioritising species for inclusion in a RPMP. All parameters in the CBA tool, apart from the current area infested (which is assumed to be known with certainty), are adjustable using sliders for sensitivity testing, enabling the uncertainties to be addressed as required by the NPD. The results of each analysis are presented on-screen in graphs and in a downloadable report file.

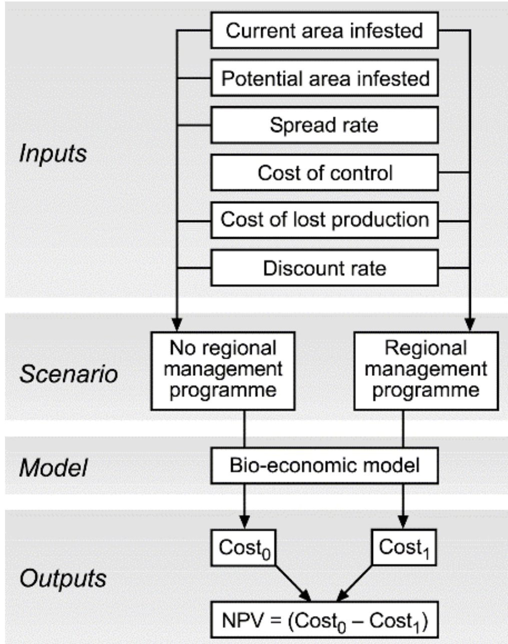

Figure 2. The logic underpinning the CBA model in the system (Bourdôt *et al.* 2015).

ADOPTION

The CBA tool is available to users without restriction whilst CLIMENZ is licensed for use by the New Zealand Ministry for Primary Industries and AgResearch. Whilst the other three supporting tools are yet to be completed, the CBA tool is being used by regional councils throughout New Zealand (Table 1). Usage is increasing with a 30% increase in users and a 220% increase in the number of sessions between 2016 and 2017 following launching in 2015 (Table 1).

Table 1. Usage of the regional weed management CBA web application in New Zealand since launching in 2015. The application is available at https://www.agresearch.co.nz/cba/cba.php

	2016	2017
Users	80	104
Sessions	127	280
Sites	18	18

ADAPTING THE WEED MANAGEMENT DECISION-SUPPORT SYSTEM FOR AUSTRALIA

Conceptually, the Regional Councils in New Zealand and the Australian States are similar in many respects. Of particular interest here is the fact that most post-border biosecurity responsibilities fall on these governance bodies. The system described here could be adapted to the Australian context relatively easily. The NWDD could, for example, easily be extended off the Atlas of Living Australia platform (www.ala.org). Indeed, the concept for the NWDD was drawn from a prototype system developed in Australia for the National Land and Water Audit (Auricht Projects). The CLIMENZ database provides an estimate of the climatic niche for each weed species using CLIMEX models. Because CLIMEX models can be run using globally available climate data, this information could easily be generated for Australia at a suitable spatial resolution to underpin strategic weed management. MDiG is an open-source generic spread modelling platform that can be applied to any jurisdiction. WRASP is presently coded as a model within ARC-GIS, and can be run using whatever geographical data the analyst wishes to use. The CBA tool is inherently independent of jurisdiction, and the results are likely to be universally relevant to decisions involving resource allocation to weed management in situations where there is market failure.

CONCLUSION

Adapting these tools to the Australian context offers potentially significant savings in analytical effort, as well as improvements in the quality of information to support decisions regarding strategic weed management. This system offers the prospect of a robust, defensible, cost-effective system for strategic weed management.

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