26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Modelling spread of invasive organisms as part of a New Zealand Biosecurity Risk Evaluation Framework

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Abstract: It is critical that New Zealand's (NZ) plant-based industries prepare for incursions of exotic pests, but it is infeasible to prepare for every potential pest species as they are too numerous. To help prioritise threats and support preparedness, a Biosecurity Risk Evaluation Framework was developed to identify species with the greatest potential to establish in NZ and cause significant economic impacts. Here we present one component of that framework, a stochastic geographic automaton, which estimates the rate of spread of a particular pest using climatic data, host distribution records and species-specific estimates of potential spread rates. We give examples of model outcomes for two exemplar insect pests of *Pinus radiata*.

Keywords: *Biosecurity, invasive organisms, spread model, geographic automata*

1. INTRODUCTION

Ongoing incursions of exotic pathogens, pests and weeds are significant threats to New Zealand (NZ)'s plant-based industries. A Biosecurity Risk Evaluation Framework was developed to help proactive industries identify the most important risks to prepare for and mitigate. The framework begins by developing a comprehensive list of all possible hazards to a crop. Species are then ranked, using a statistically-derived semi-automated algorithm, based on likelihood of establishment in NZ. Top ranked species are then taken through spread and impact modelling steps, whereby a hazard's relative rate of spread in NZ and potential economic impacts are estimated. Finally, top ranked species are recommended for industry preparedness. Here we describe the spread modelling step only.

2. METHODOLOGY AND RESULTS

The Biosecurity Risk Evaluation Framework spread model is a stochastic geographic automaton (Torrens & Benenson, 2005), based on a gridded landscape running on an annual timestep, with a hazard's spread modulated by the climate and presence of potential hosts in each cell (Figure 1). A hazard can spread relatively quickly through highly suitable climates with potential hosts, and more slowly or not at all in less suitable climates or where there are no potential hosts. Other factors that influence a hazard's spread are its expected rate of natural dispersal and its propensity for hitchhiking. The probability an uninfested cell will become infested by natural spread decreases with distance from infested locations, and the probability an uninfested location will become infested by hitchhiking increases as the number of infested locations increases.

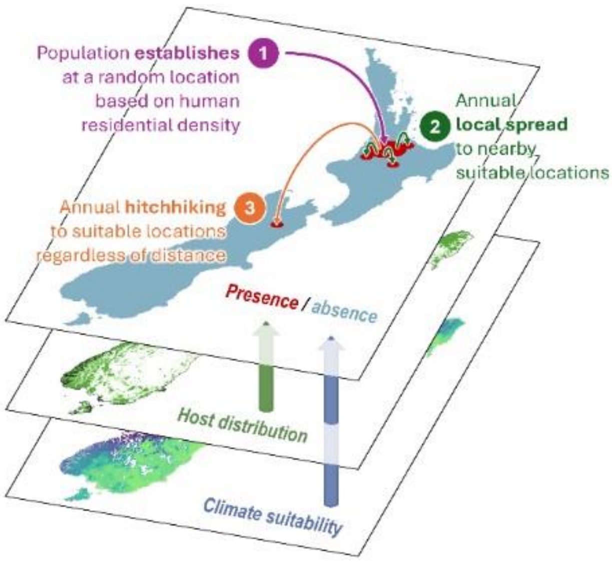

Figure 1 Schematic of the spread modelling method

Therefore, for each organism, three datasets are used in the model: a spatial dataset of climate suitability, a spatial dataset of host plant(s) distribution, and parameters describing the rate of spread. NZ's climatic suitability for the organism is estimated by climate matching (Roige and Phillips 2021) and this in tandem with its host plant distribution defines the species' potential NZ distribution. The climate matching method identifies where a hazard has been observed overseas, the climate where it was observed and how well that climate matches those in NZ. Potential host distribution is derived by considering the pest's host plant range, and the spatial distributions of its hosts are then obtained from the NZ land cover database (Landcare Research NZ Limited, 2020). Estimates of rates of natural dispersal and human-assisted movement are elicited from experts using a systematic elicitation process (Hemming et al. 2018). Natural spread dispersal functions are either the Weibull or negative exponential functions from Nathan et al. (2012), where scale is calculated from the mean spread estimate. While low in detail of species-specific biology, this model provides a generic framework to estimate the spread of multiple species without needing to devote extensive time developing species-specific models.

Each simulation begins with the insect establishing in NZ at a randomly chosen location, weighted by human population density, assuming that it is more likely that arrival and establishment will be related to human activity. For each organism, spread is simulated 500 times. Figure 2 gives the outcomes from the spread modelling step of the Biosecurity Risk Evaluation Framework with two exemplar insect pests of *Pinus radiata*, one fast spreading (A) and the second slow spreading (B).

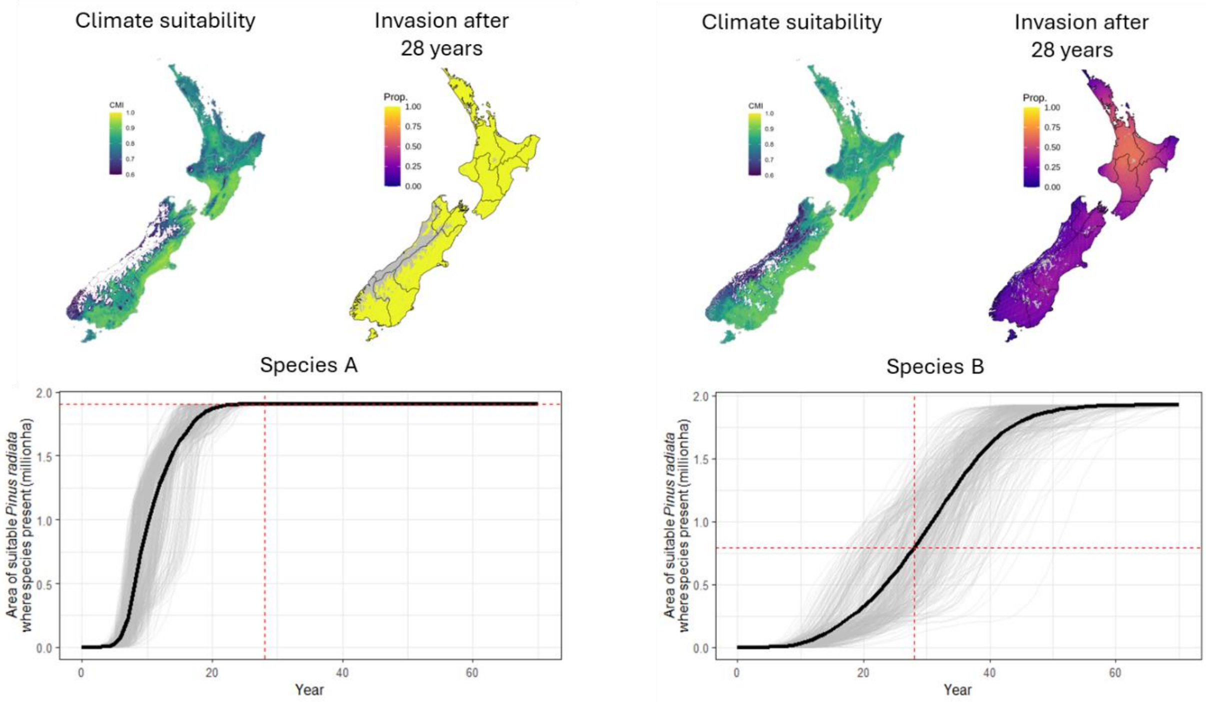

Figure 2 Spread modelling outcomes for two exemplar insect pests of *Pinus radiata*

3. CONCLUSIONS

We present the spread modelling component of the Biosecurity Risk Evaluation Framework, demonstrating its usefulness to estimate different rates of insect spread through NZ based on climatic, host distribution and species-specific rates of potential spread.

ACKNOWLEDGEMENTS

The underlying methodological development was funded by Ministry of Business, Innovation and Employment, NZ, through the Better Border Biosecurity (B3) research collaboration (www.b3nz.org). *Pinus radiata* application was funded by Forest Growers Research.

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