Testing model accuracy when predicting pest susceptibility using expert-driven spatially-explicit models

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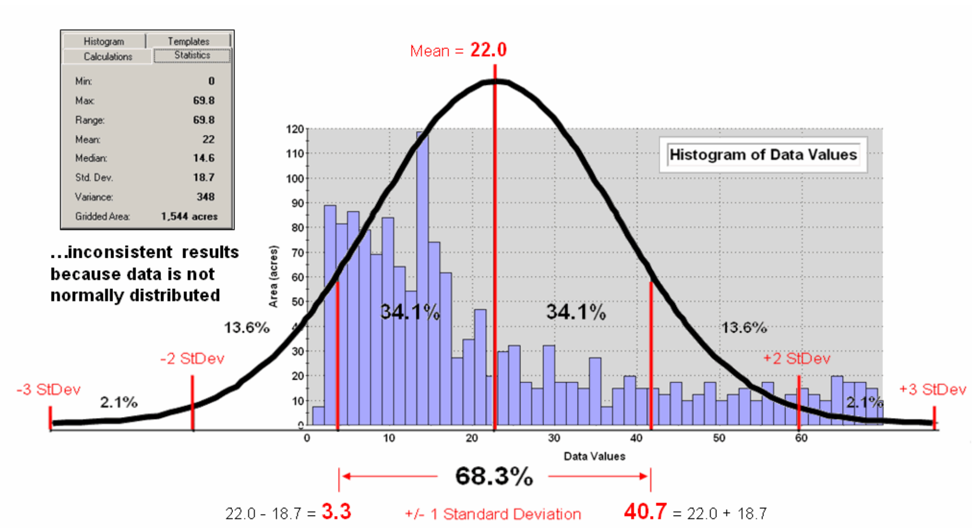
Invasive species and pests

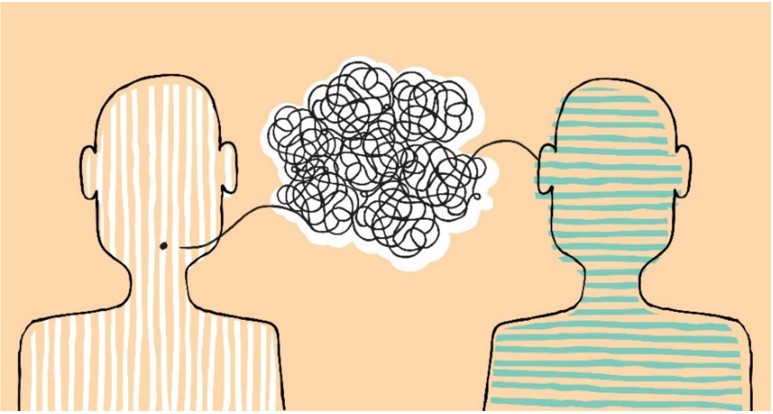
- Invasive species cause significant damage to the environment and economic assets
- Damage to productivity costs the agricultural sector millions of dollars each year.
- Adversely affect ecosystem function, e.g. destruction of habitat, competition
- Reduce agricultural productivity, e.g. crop damage, predation
- Threaten animal and human health and well-being, e.g. disease transmission, adverse human-pest interactions




Effective pest management benefits from scientifically-based recommendations

The problem……..





SCIENCE

COMMUNICATION BREAKDOWN

COMMUNITY

Increasing 'buy-in' for best management practices targeting pests

Modelling economic and environmental costs of pest species with different pest management strategies

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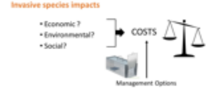
New incentives are needed to encourage increasing adoption of effective strategies to pest management. Quantifying economic impacts of pests may influence solutions and greater participation in broader scale management strategies.



Introduction

Land management is an ongoing process for agricultural and natural environments with the focus on maximum benefit for strategic costs, especially with increasingly limited available resources. Developing models can be an integral part into the understanding of the functioning of a system (Murray *et al.*, 2015). However, management models often fall short in ease of interpretation to end-users, especially if the primary target are land managers without statistical backgrounds. There is a need to convey the information in a manner that promotes interest and a willingness to participate through a sense of community empowerment and inclusivity.

The way to accomplish this is through engaging stakeholders through the entire model-building process. This emboldens ownership of the model from the initial concept to the end-product.

Methodology

- We used a Bayesian Network (BN) to incorporate the model framework consisting of three model components: habitat suitability, management and agricultural production (Figure 1).
- Potential pest impact, a proxy for potential pest density, was determined by experts from suitability of the habitat, a distance threshold and the management activities that are being undertaken. The distance threshold accounted for foraging behaviour within a set distance away from suitable habitat, in this case 100 m for rabbits.
- Agricultural production loss (in percentage) was determined by experts given the potential pest impact and the commodity being produced, both of which can vary seasonally. The experts were asked to identify a production loss range with a mean and standard deviation, to capture the potential variability in loss.

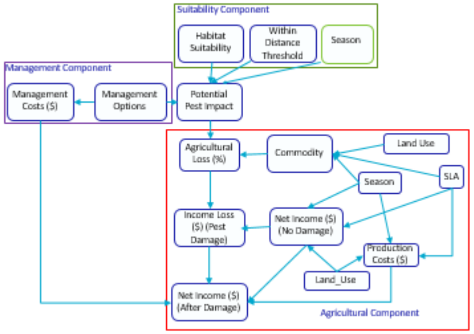


Figure 1. Schematic diagram of economic impact model showing model structure. SLA = Statistical Local Area.

Case study - European rabbit (*Oryctolagus cuniculus*)

- Destroy crops and competes for food with other livestock
- Cause erosion and potential hazards through warren establishment
- Spread invasive weeds & attract introduced predators

Results

- The economic impact model allows the user to choose pest management options, individual agricultural commodities and land use to get an immediate model response as to the effect on the agricultural loss and the resultant income loss.
- The agricultural loss altered with different management scenarios, thereby affecting the income lost from pest damage and ultimately net income (after also accounting for production costs and pest management costs) (Figure 1).
- To really engage the farming community on the impacts of a pest population, scenarios were run for major individual commodities to assess the potential impact on agricultural loss and overall income loss when habitat suitability was high (Table 1).

Table 1: Management scenarios for some example agricultural commodities, given high habitat suitability showing agricultural loss, income loss due to pest damage and net income after damage.

Management Strategy	Average Agricultural Loss (%/ha)	Average Income Loss Pest Damage ($/ha)	Average Income after Damage & Management Costs ($/ha)
No Management	70-90	15,000 – 25,000	0-100
Baiting	30-50	7,000-15,000	5,000-10,000
Integrated Management	0-20	2,000-4,000	10,000-20,000

Managet Implications

- Our spatially-explicit economic impact model is able to give land managers a finer scale understanding of the impact of pests on individual land use categories and commodities.
- The use of scenarios allows land managers to weigh the relative risk of the different management options on the agricultural loss, income loss and resultant net income for each commodity and thereby be more informed to make an economically sound decision towards pest management on their land.
- Pinpointing the proximity of pest habitat to cultivation and conservation will hopefully drive community engagement towards effective integrated management. This tool endeavours to increase community engagement with participation in broad scale pest management planning.

FOR FURTHER INFORMATION

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REFERENCES

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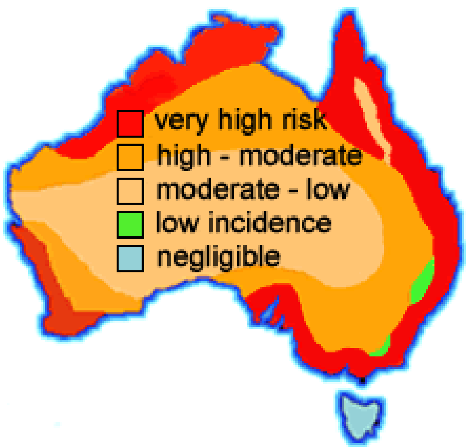
Spatially-explicit risk modelling

- A risk map is a visual representation of the results of an analysis of potential risk within a landscape
- Risk maps allow multiple stakeholders to engage in the process
- Risk maps are not limited by the viewer’s statistical background



Invasive Continuum

Expert elicitation

Benefits:

- One to multiple experts
- Encapsulating broad experiences over and management
- Quick to capture

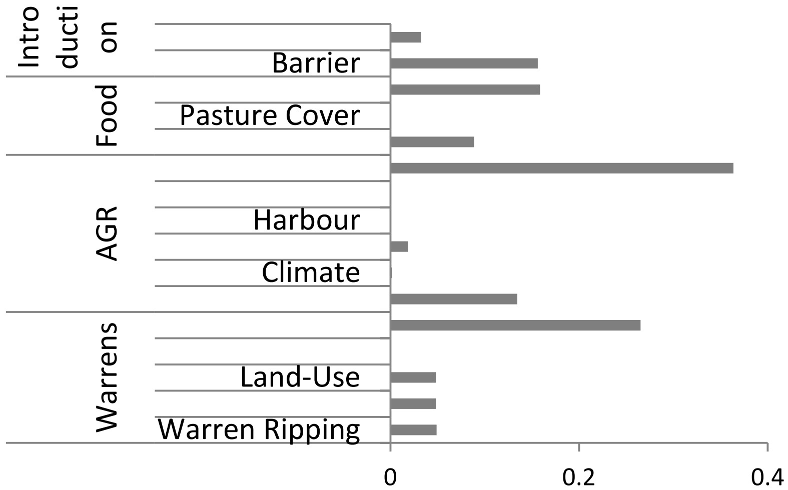
Disadvantages:

- Individual vs group consensus
- Need to monitor for uncertainty
  - Natural variability (individual interpretations)
  - Linguistic uncertainty (confusion on definitions, context…..)
  - Epistemic uncertainty (limited or imperfect knowledge)
  - Anchoring (fixing on a set of beliefs)
  - Optimistic bias (tending toward positive outcomes)
  - Authority bias (being swayed by authority figure)

Predictive modeling: characterizing uncertainty

"Partitioning sources of error"

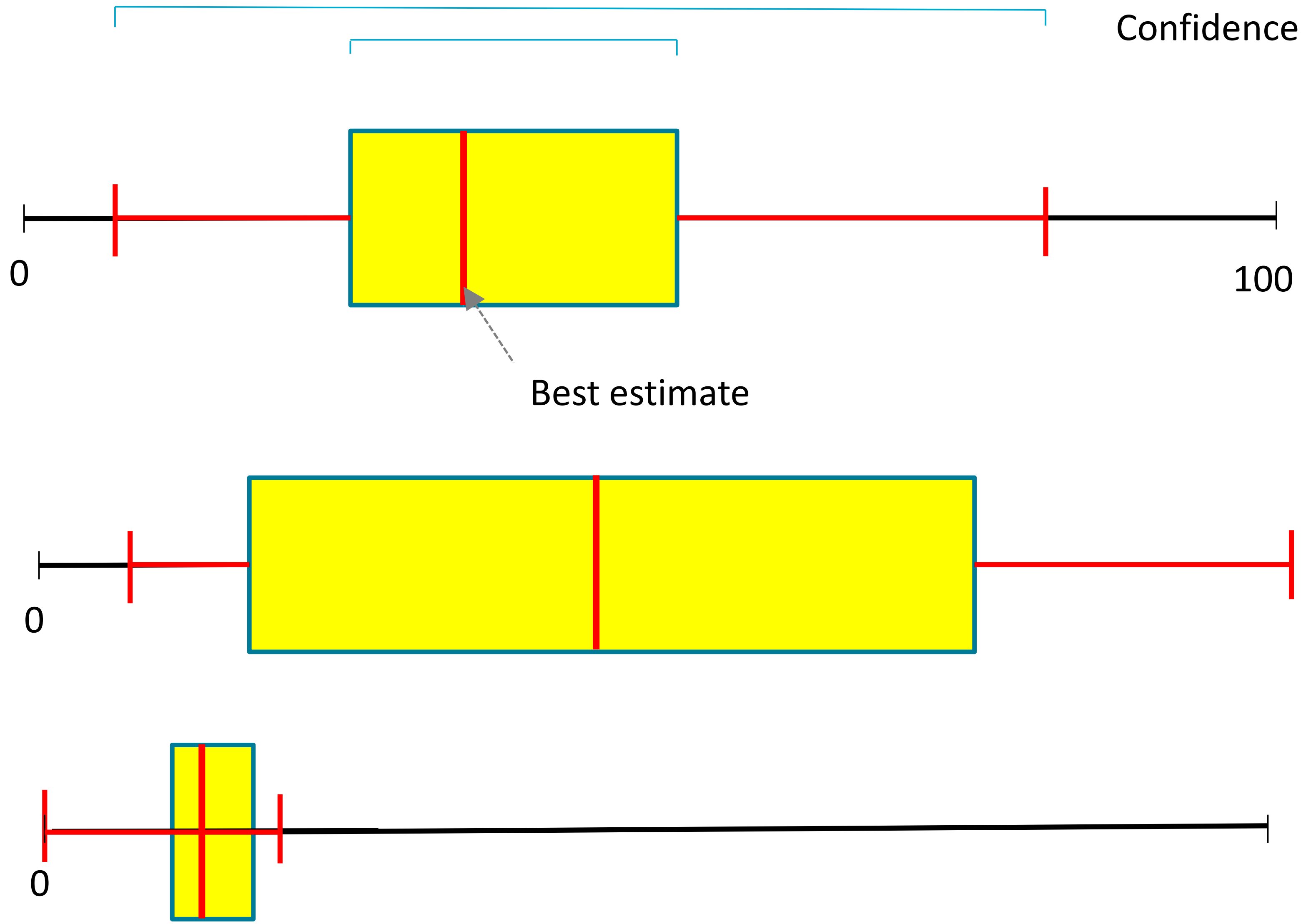
- Which environmental variables are most important? (sensitivity analysis)
- What uncertainty is there in conditional probability estimates?
- How sensitive are predictions to parameter uncertainty?
- Model structure (feedback & validation)

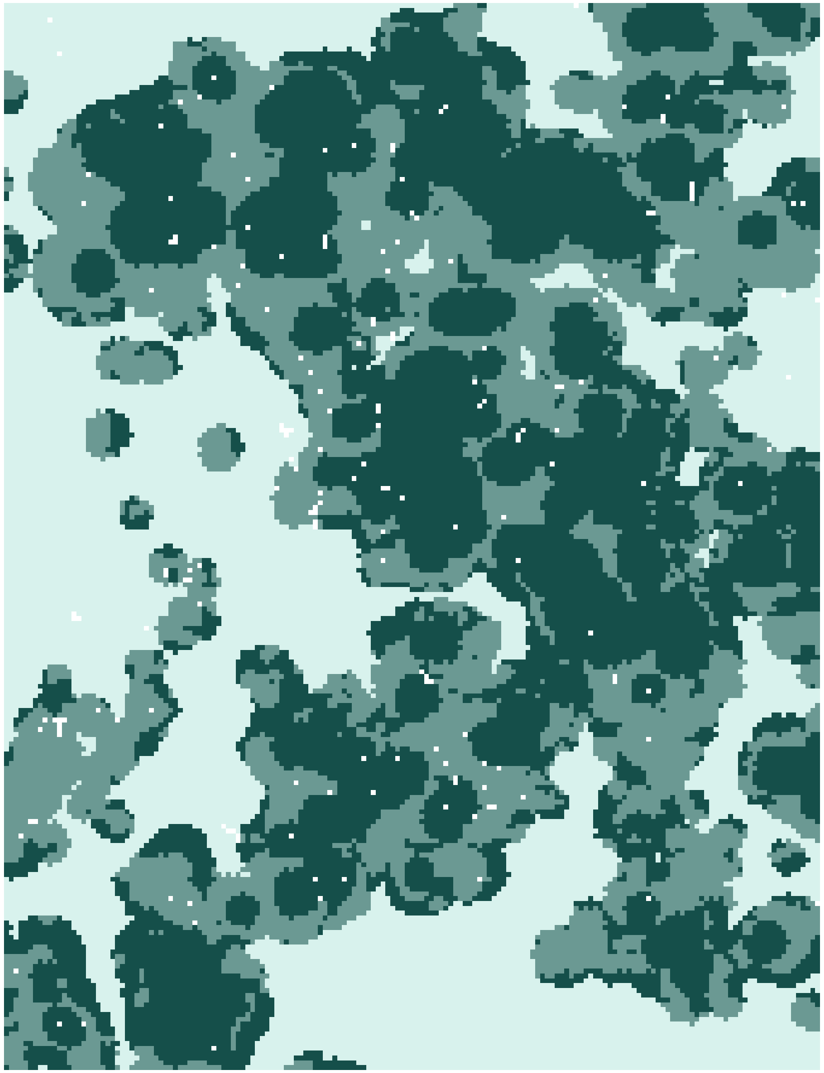
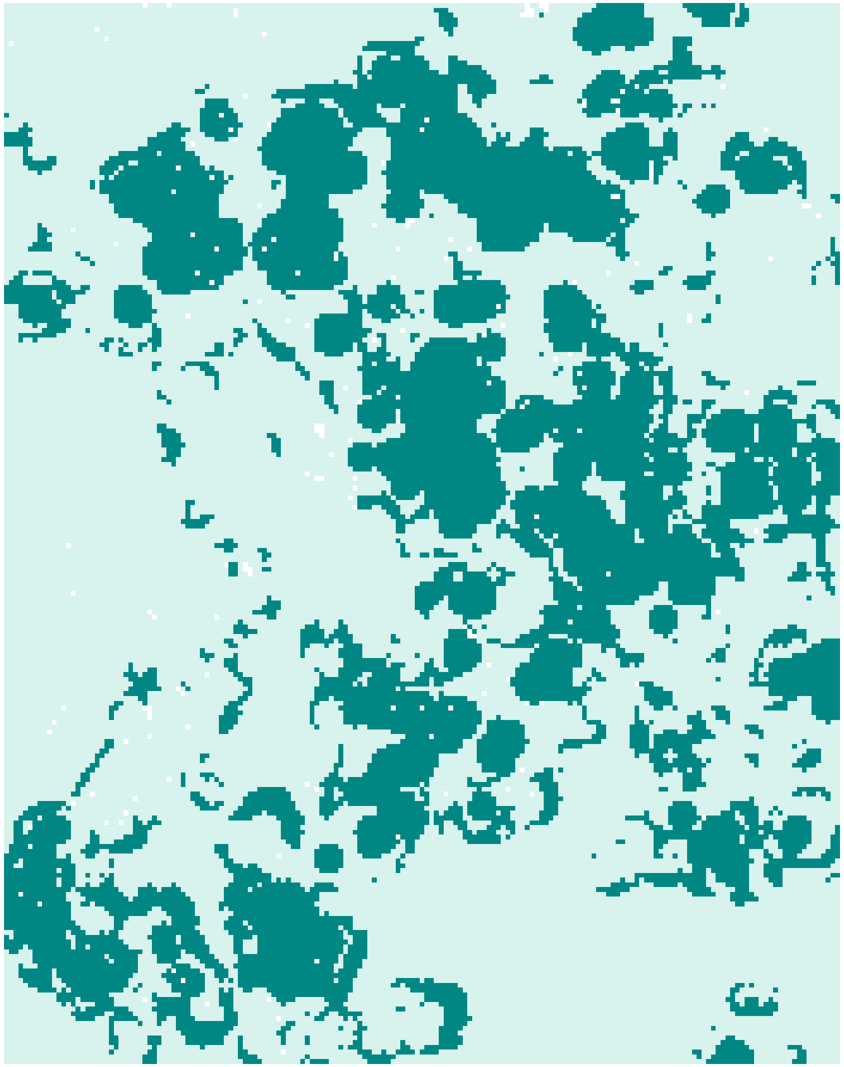



```
Sensitivity of 'Establishment'
Node                Mutual
----                Info

Flood Frequency     0.094
Soil Type           0.074
Ground Cover        0.074
Grazing Management  0.014
```

Environmental Variables		Establishment	
Soil type	Grazing management	High levels	Low levels
Good	Good	90 %	10 %
Good	Poor	30 %	70 %
Poor	Poor	10 %	90 %

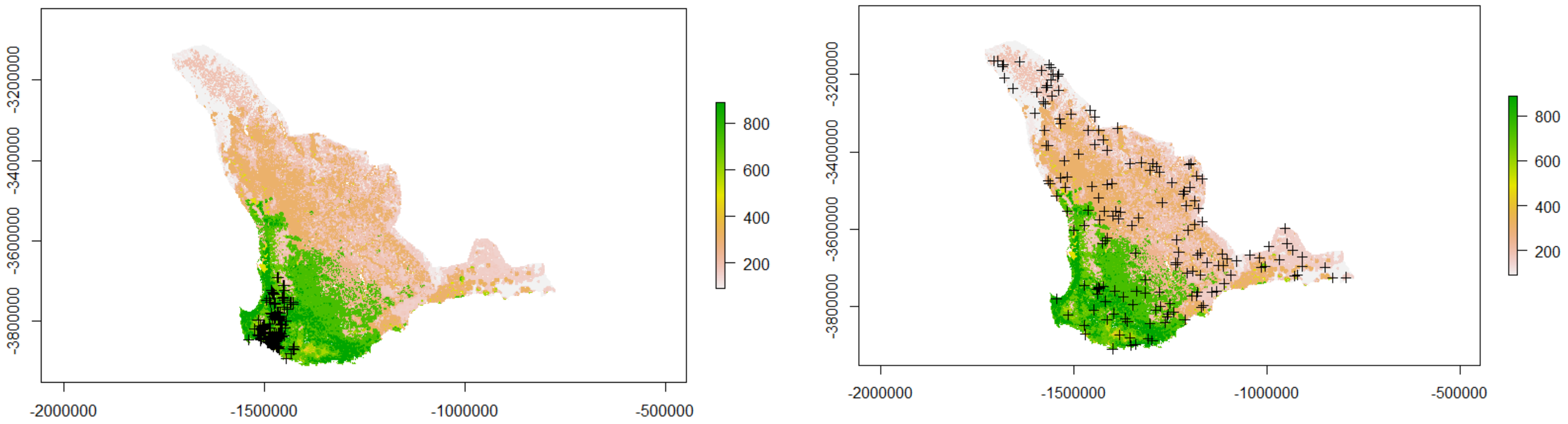

Confidence
0
100
Best estimate
0
0

Validation

<u>Best: </u> balanced data set containing presence/absence covering all environmental gradients

However, we mostly only have access to records of pest presence or damage



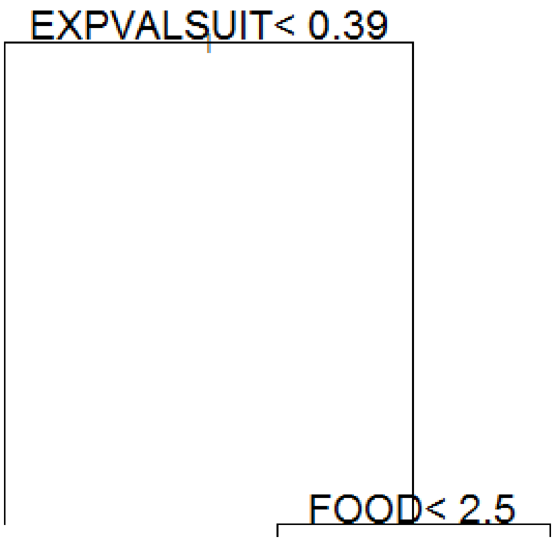
Testing for model accuracy

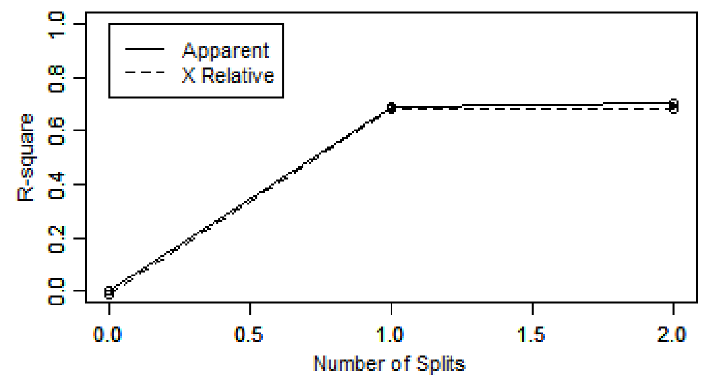
Classification and regression trees

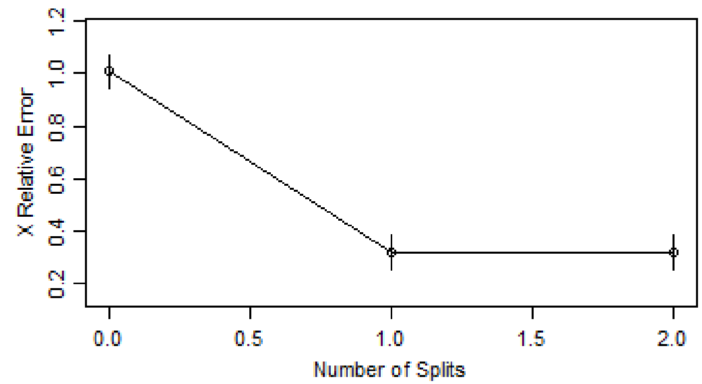
- Robust
- Deals with different data sources

Testing model performance;

- R-squared plot
  - based on the variance explained
  - Comparison of tree size and split accountability against the size of the tree to determine which splits accounted for most of the data when varying the penalties for FP and FN errors.
- Cross-validation plot:
  - 10-fold cross-validation to estimate goodness of fit
  - uses the rsq.rpart function in Rpart.

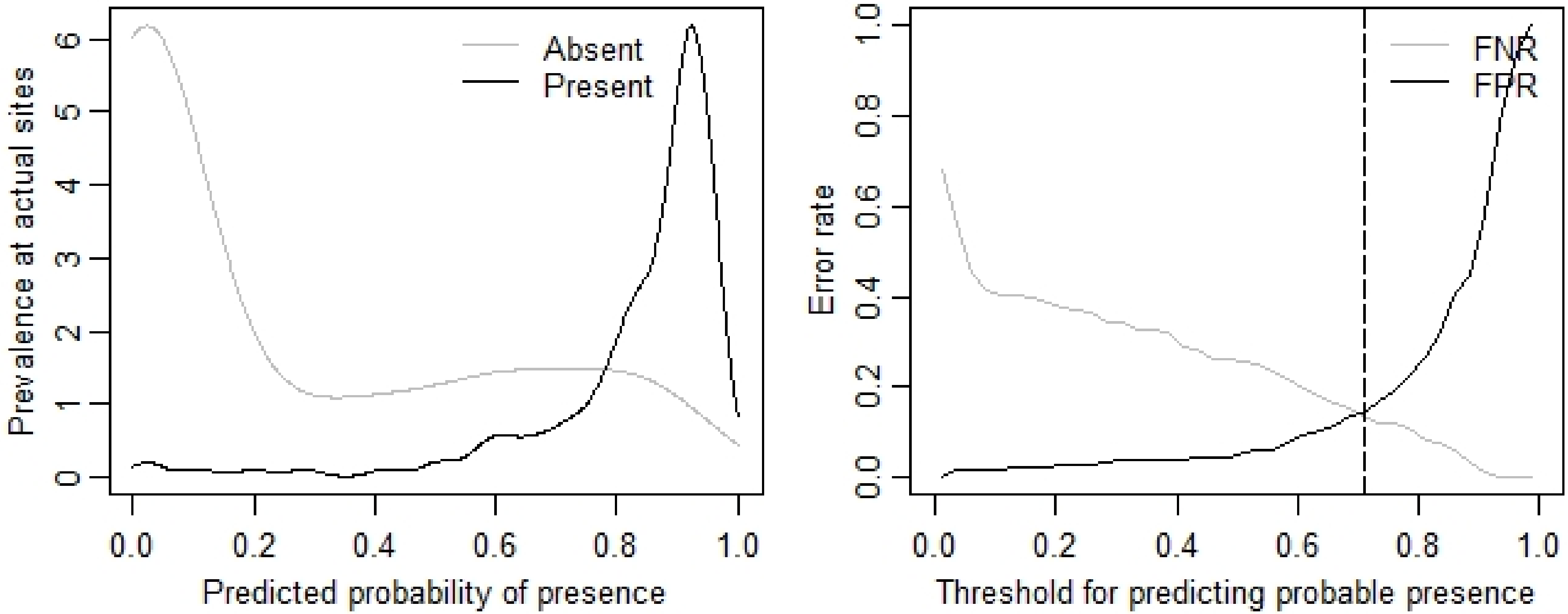






Confusion matrix

- the best model predicts the probability of presence for the species in relation to presence and absence at actual sites (P_{fair}).
- threshold value for predicting the probability of presence where false positive (FP) and false negative (FN) error rates are equal.

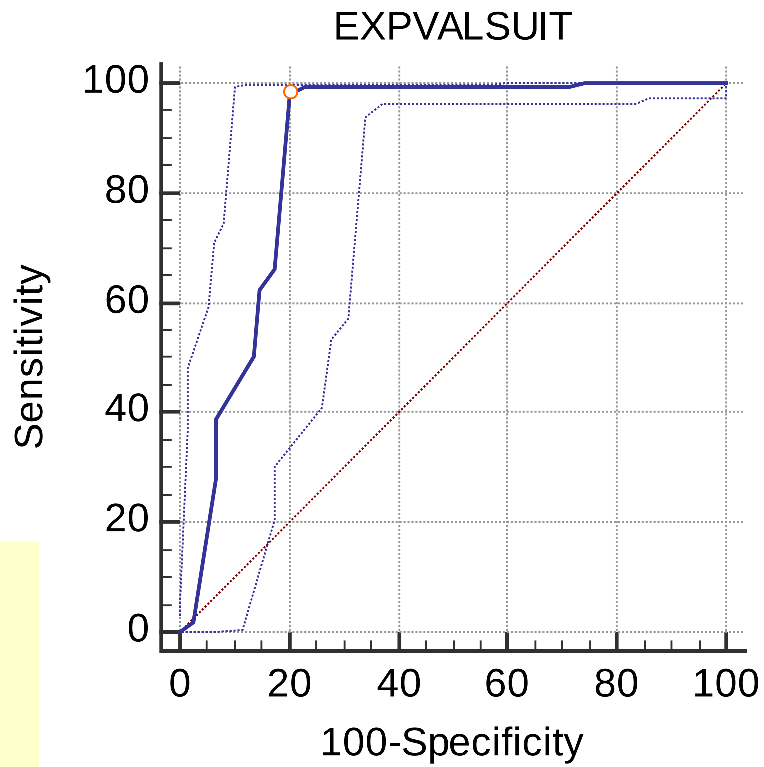


Testing for model discrimination ability

<u>ROC – AUC test</u>

- Sensitivity (true positive rate)
- specificity (true negative rate)
- Values of AUC were considered to reflect poor (0.5–0.7), acceptable (0.7–0.8), excellent (0.8–0.9) or outstanding (>0.9) model accuracy

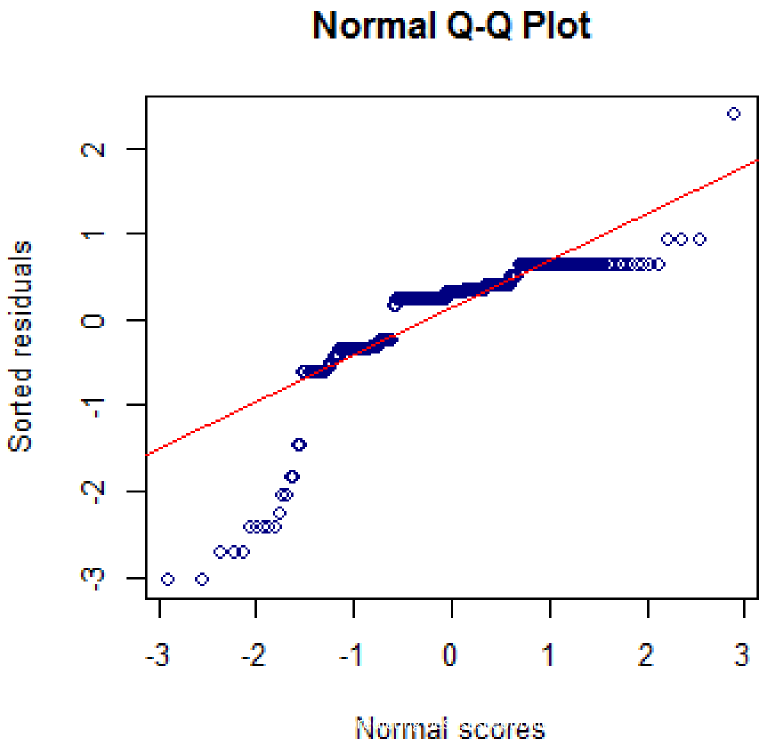
Area under the ROC curve (AUC)	0.878
Standard Error	0.0311
95% Confidence interval	0.833 to 0.915
z statistic	12.162
Significance level P (Area=0.5)	<0.0001

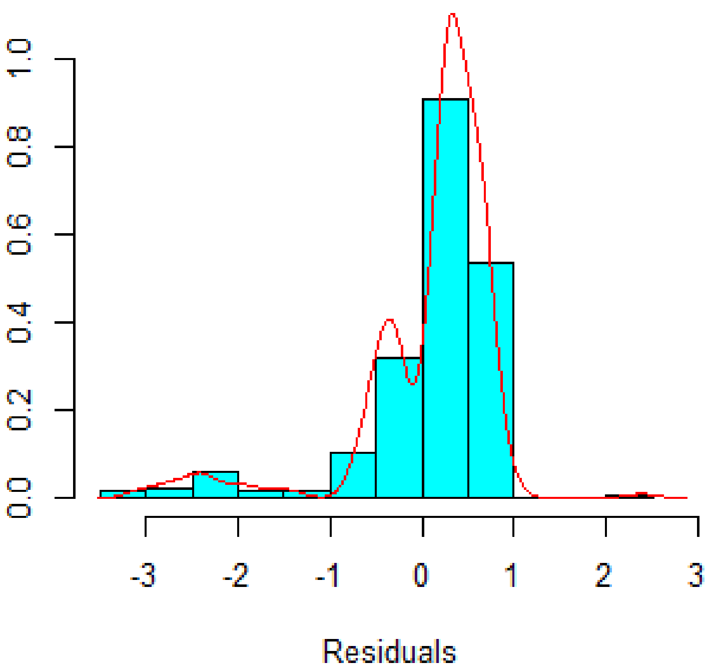


Youden index J	0.7768
Associated criterion	>0.5
Sensitivity	97.95
Specificity	79.73

Generalised Linear Model

	Estimate	Std Error	Z Value	Pr(>|z|)
(Intercept)	-10.9073	2.8151	-3.875	0.000107
Water	1.1101	0.5264	2.070	0.038488
Food	1.2247	0.4329	2.829	0.004665
Shelter	1.5773	0.5078	3.106	0.059837
Seclusion	-0.9141	0.2962	-3.086	0.016845
Expected Value Suitability	10.1305	1.2036	8.417	0.007962





Mapping classification errors

Summary

- All models results should be validated
- Getting the range of belief when collecting expert knowledge can identify the uncertainty around variables
- Pseudo-absences can be used to balance presence-only pest records
- Using a number of different statistical tests and running associated diagnostic plots can be used to assess discriminative ability of model outcomes and see if results are similar.

Thank you

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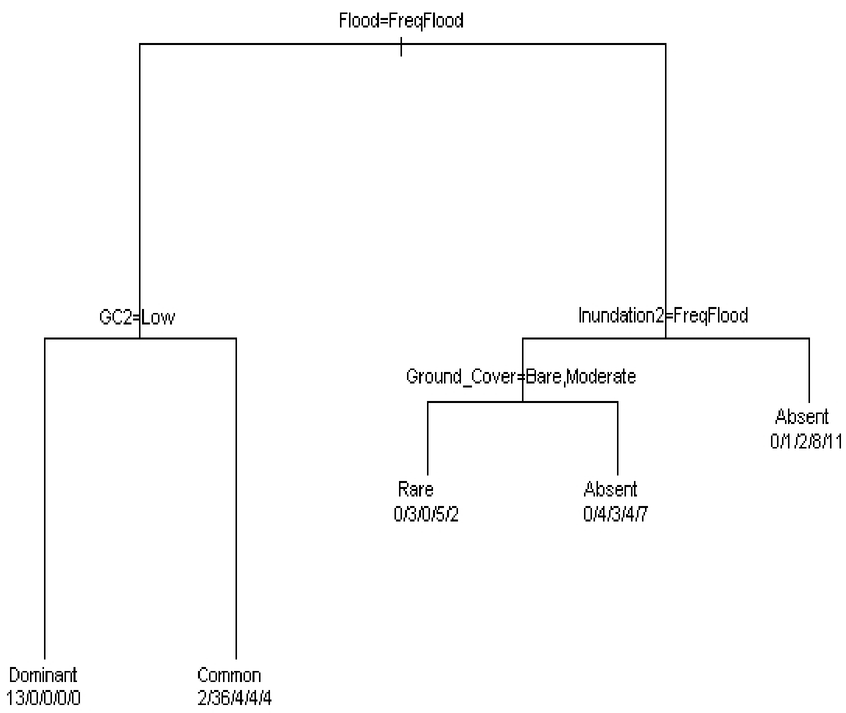
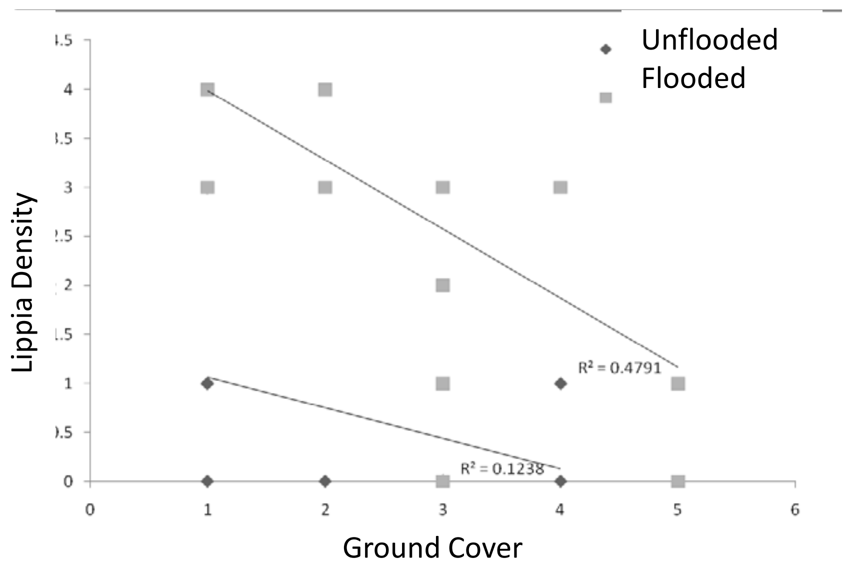
Acknowledging the multiple sources of uncertainty





Model structure ✓✓✓

Parameter estimation ✓✓✓

Validation data ✓ ✓

Environmental layers ✓

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