Forest pest and disease risk modelling for better management: Case study from South African forest plantations

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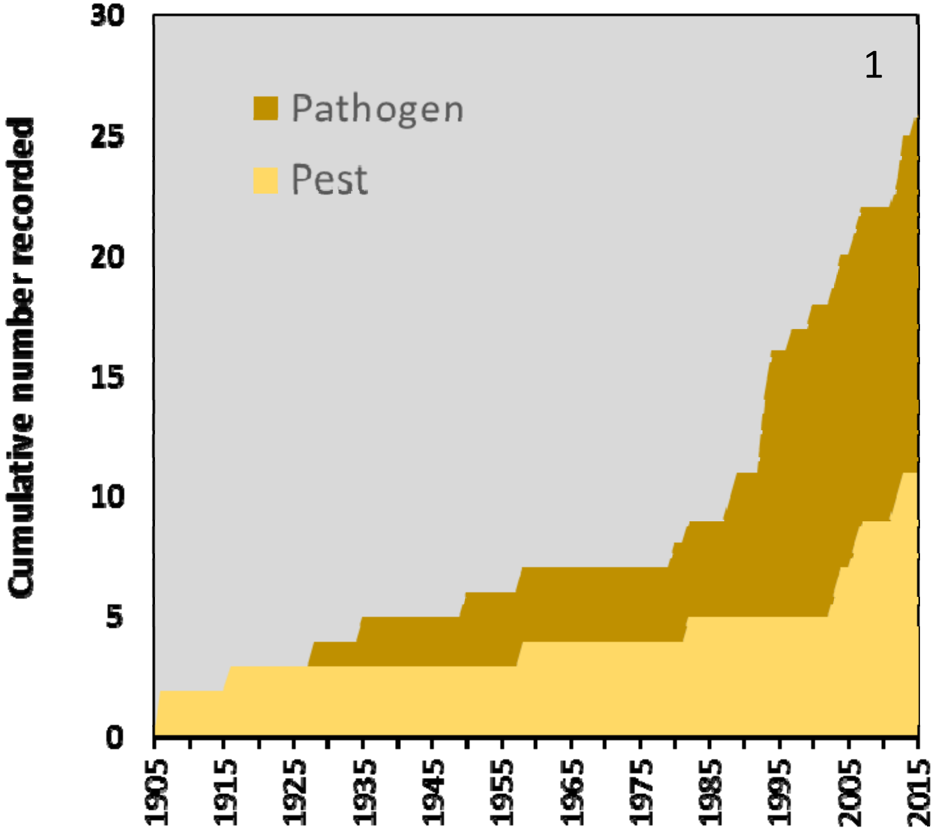
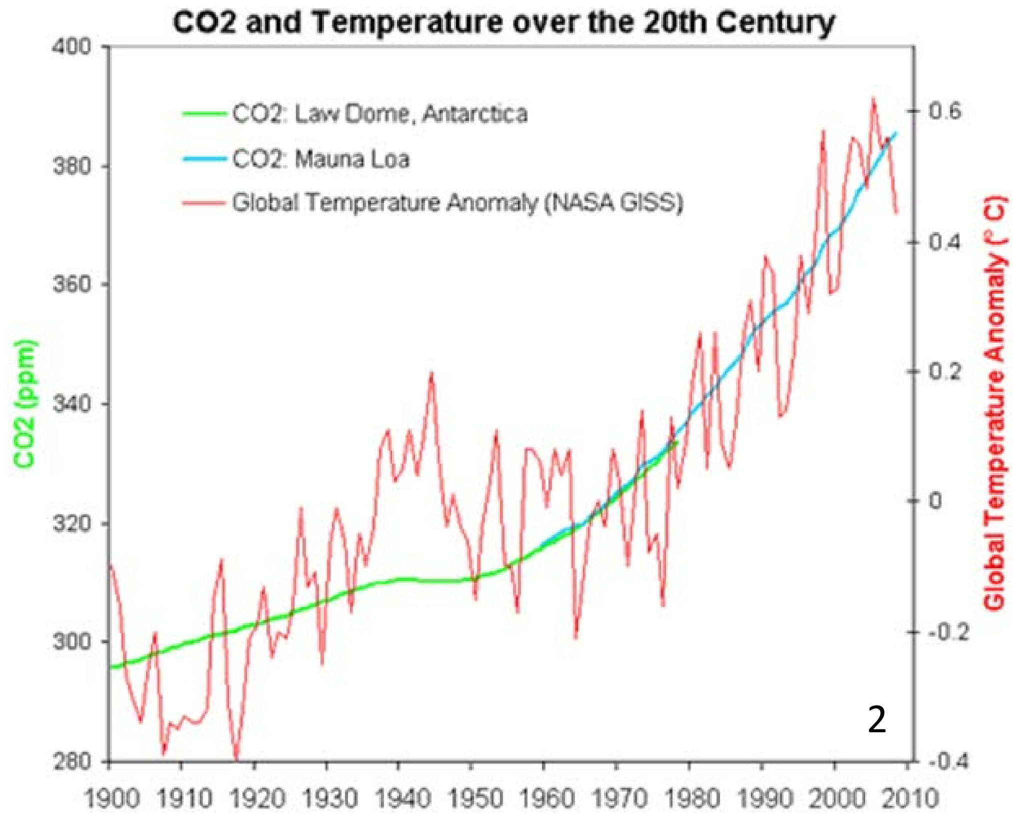
Pests and pathogens: A major threat to plantation forestry in South Africa





1 Adapted from Wingfield et al (2008): Eucalypt pests and diseases: growing threats to plantation productivity. Southern Forests 2008, 70(2): 139-144.

2 IPCC Website, November 2015

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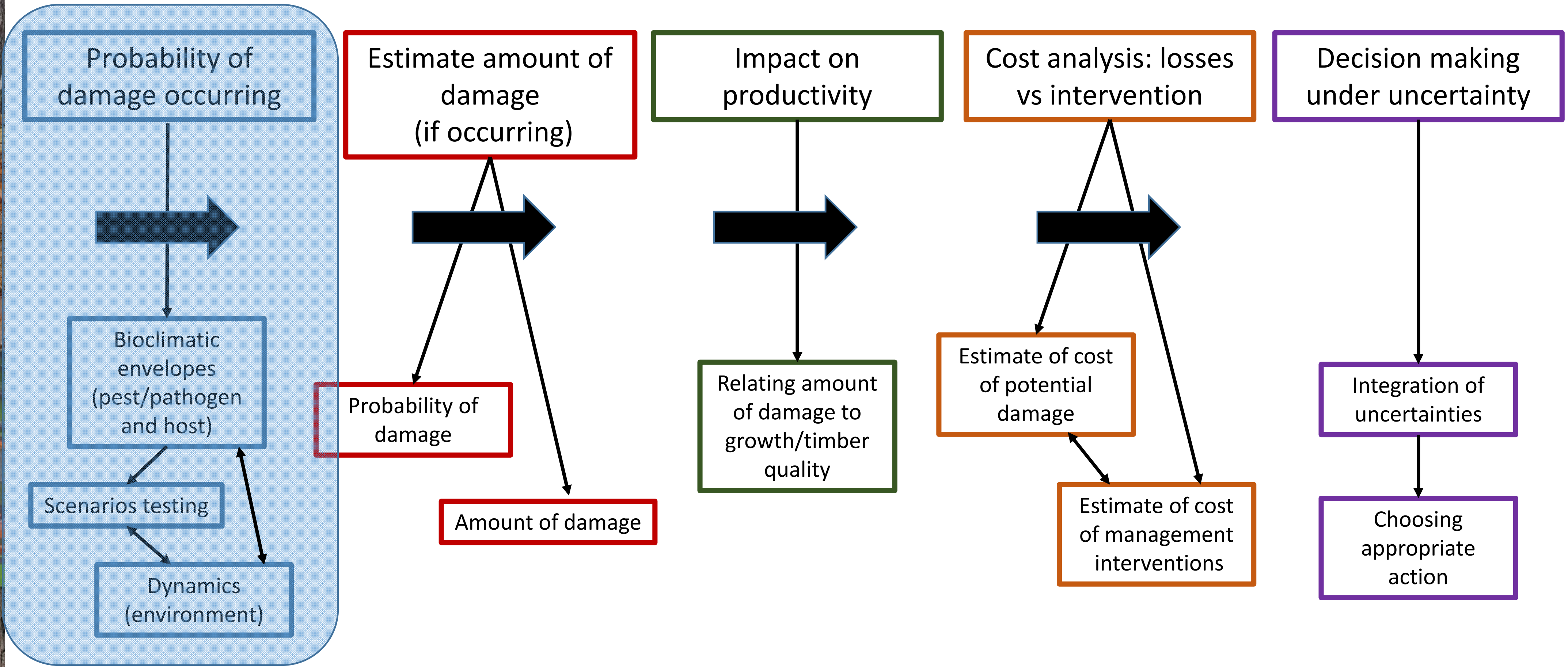
Pest and disease modelling in the commercial plantation forestry context



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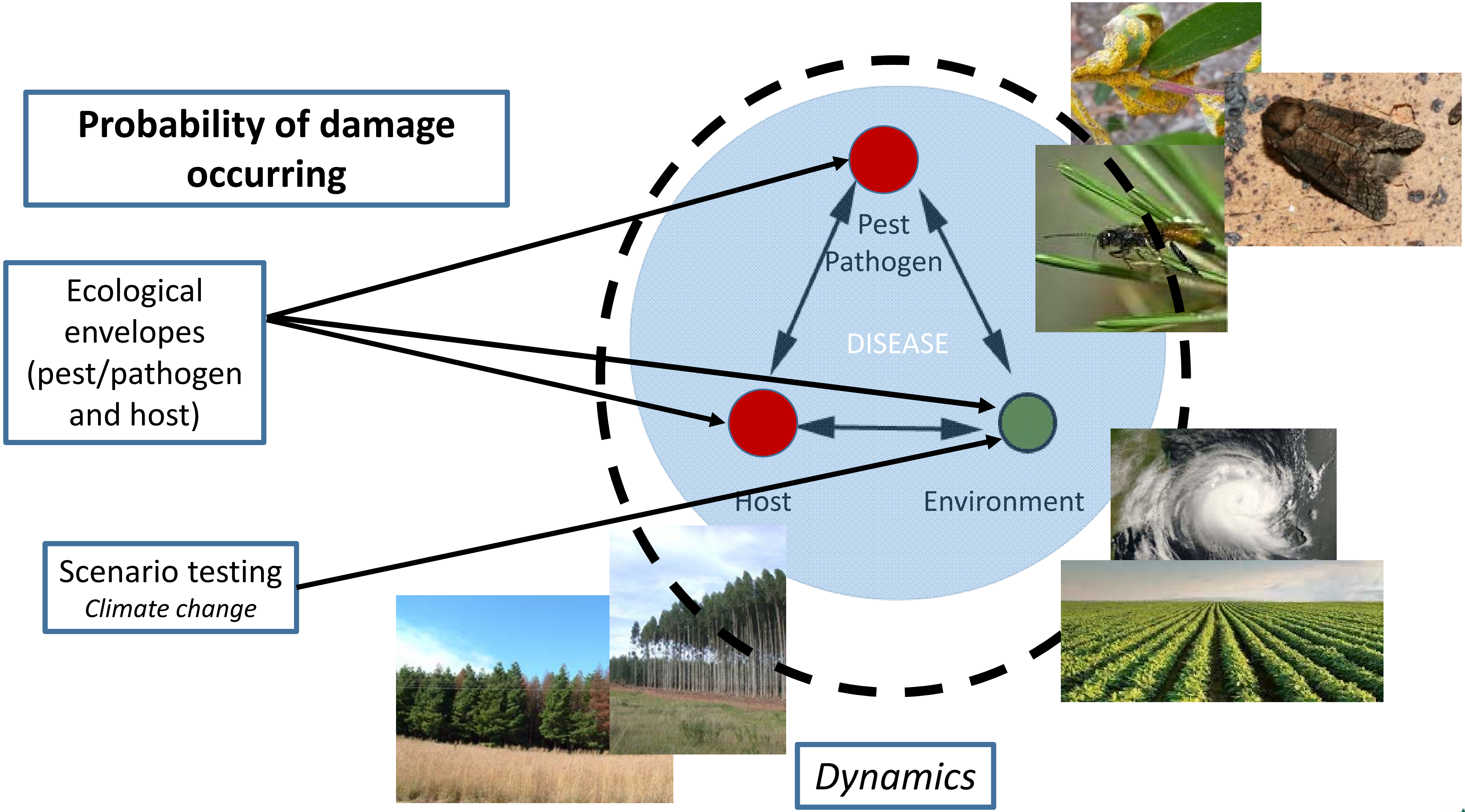

Probability of damage occurring
Ecological envelopes (pest/pathogen and host)
Scenario testing
Climate change
Pest
Pathogen
DISEASE
Host
Environment
Dynamics

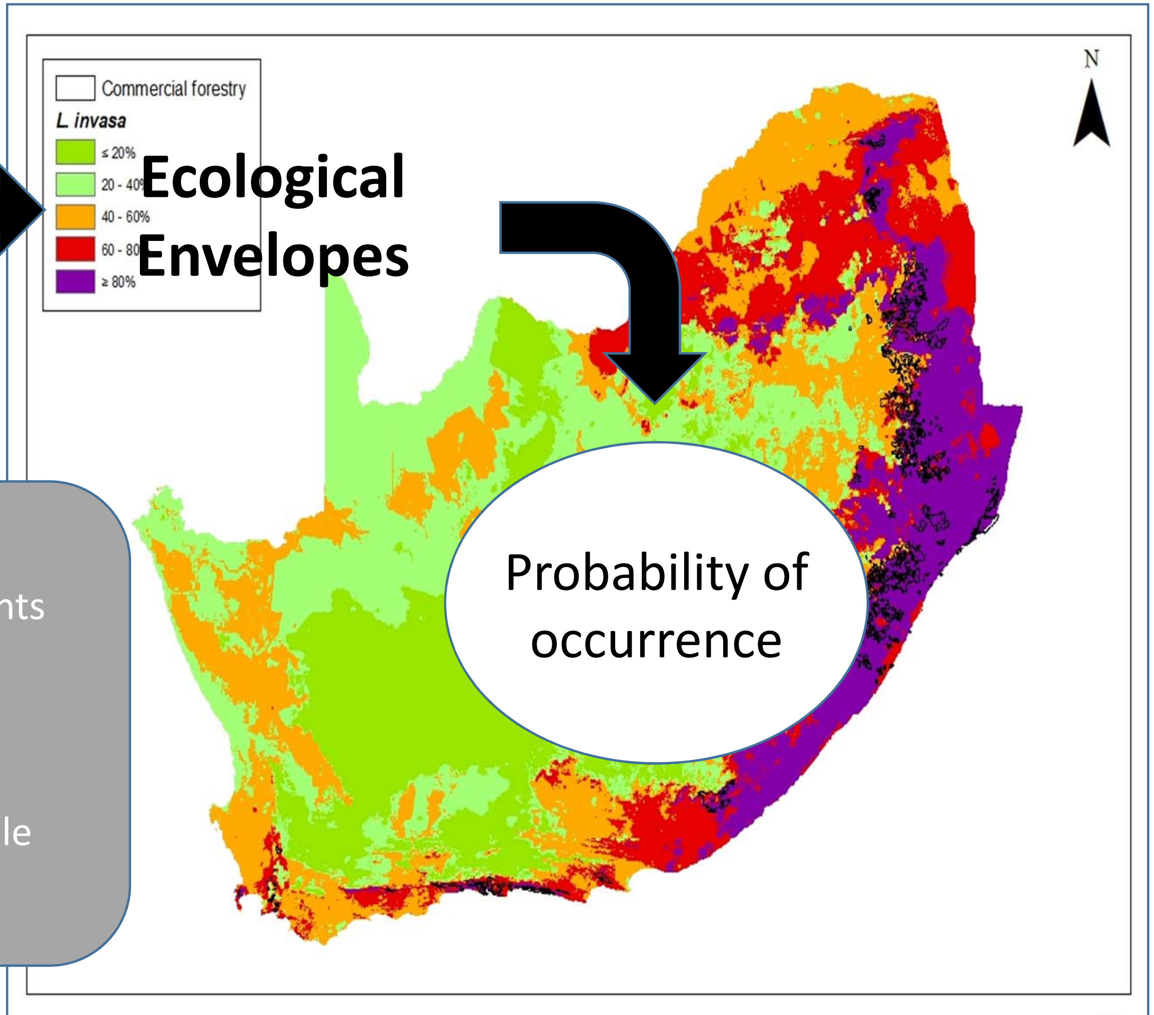
Statistical approaches

Regression-based

Machine learning/black box

Ecological Envelopes

Probability of occurrence



Population dynamics (accounting for phenology)

Non linear response to environment changes

Ecological dynamics

Extreme climate events

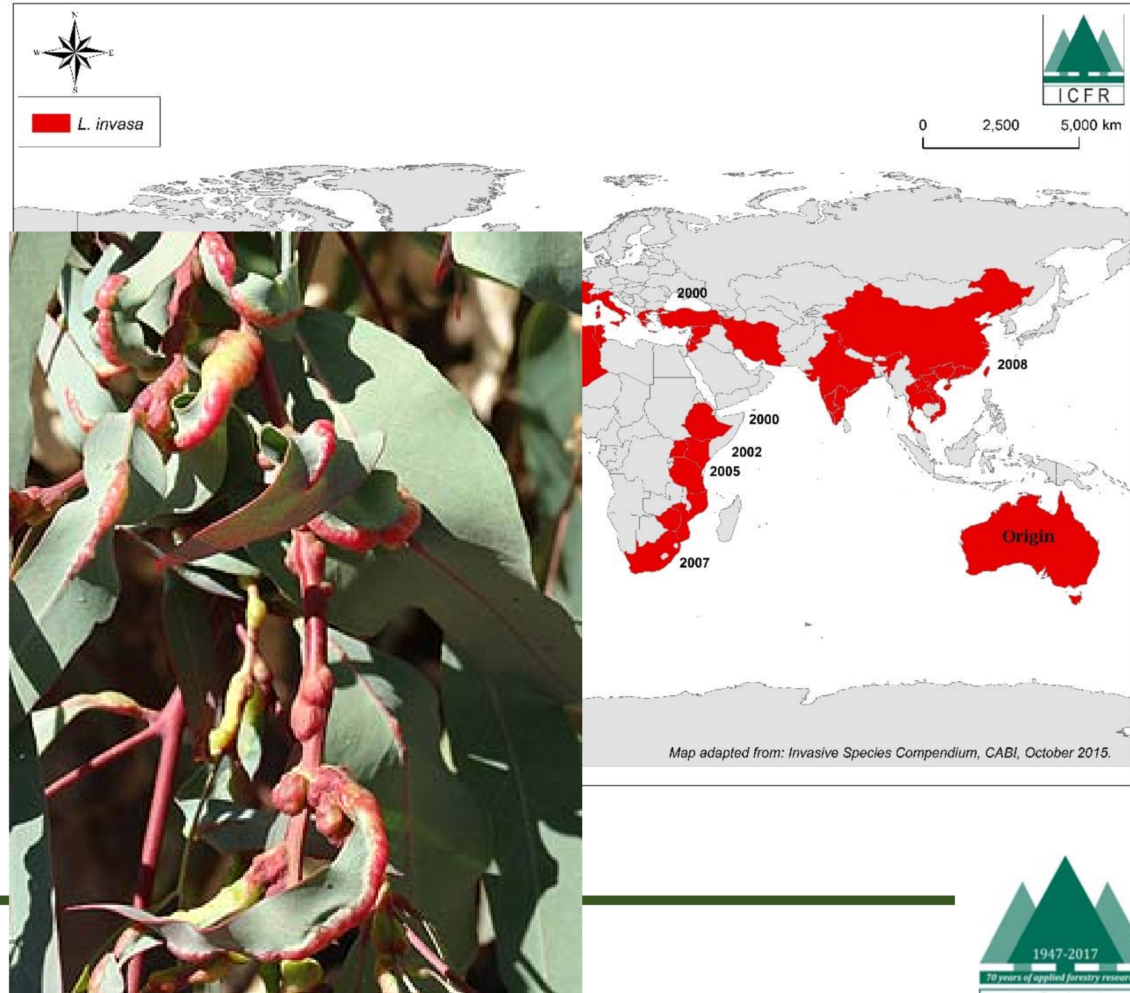
Host susceptibility

Integration of multiple disturbances

A case study

Leptocybe invasa (Eucalypt gall wasp)

- A gall inducing wasp native to Queensland, Australia
- Host: Eucalyptus species (particularly young trees)
- In South Africa since 2007
- Symptoms: Galls on midrib, petioles and stems resulting in stunted growth, dieback, leaf fall and in severe cases tree death



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Modeling technique

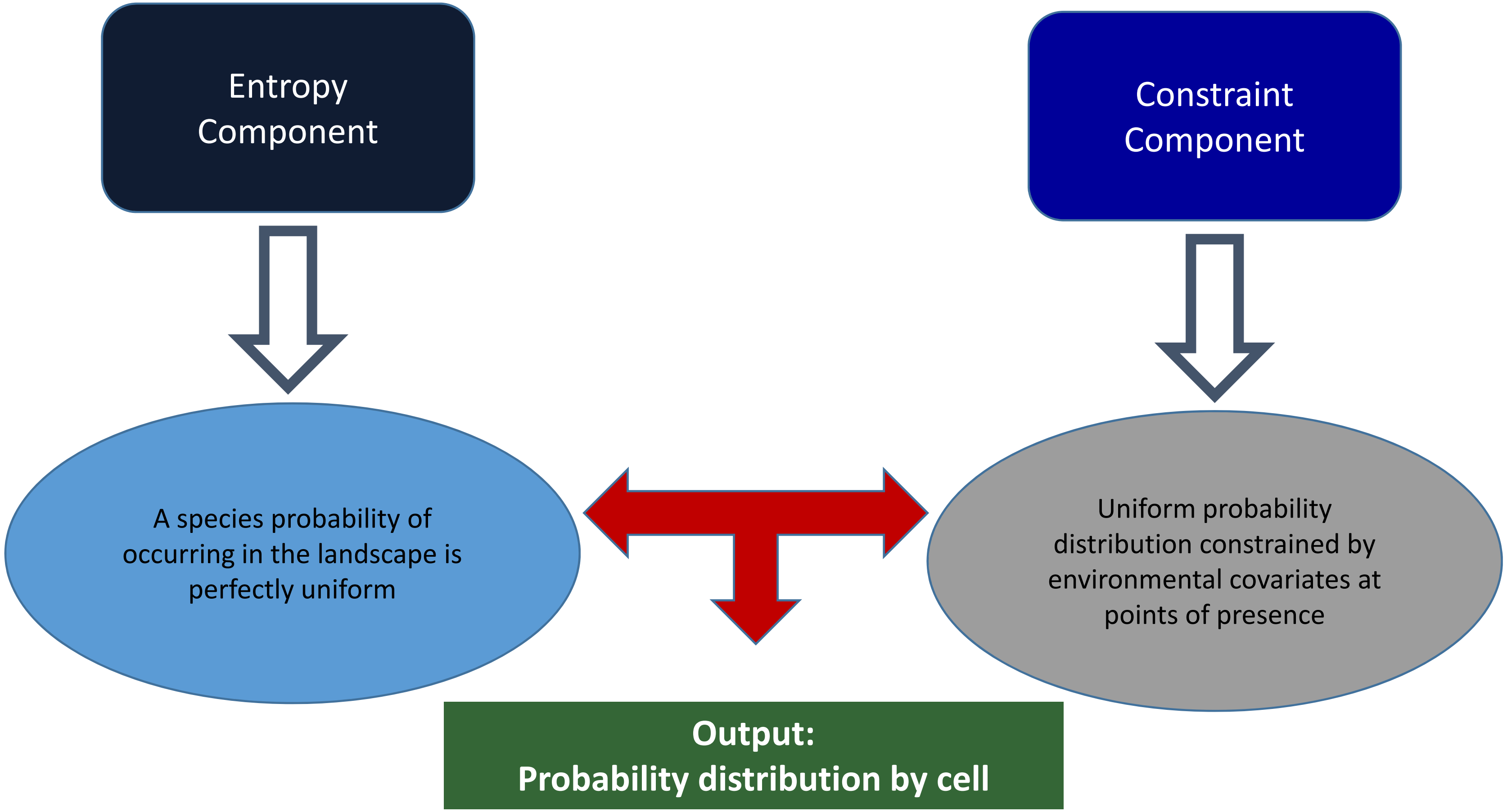
Maxent (Phillips et al 2006), using Dismo package (Hijmans and Elith. 2016)

R environment

Presence data only (unreliable absence data; dispersal constraints…)

- Ecological niche (probability of occurrence)
- Ecological drivers defining habitat suitability
- Future distribution under climate change (scenario testing)

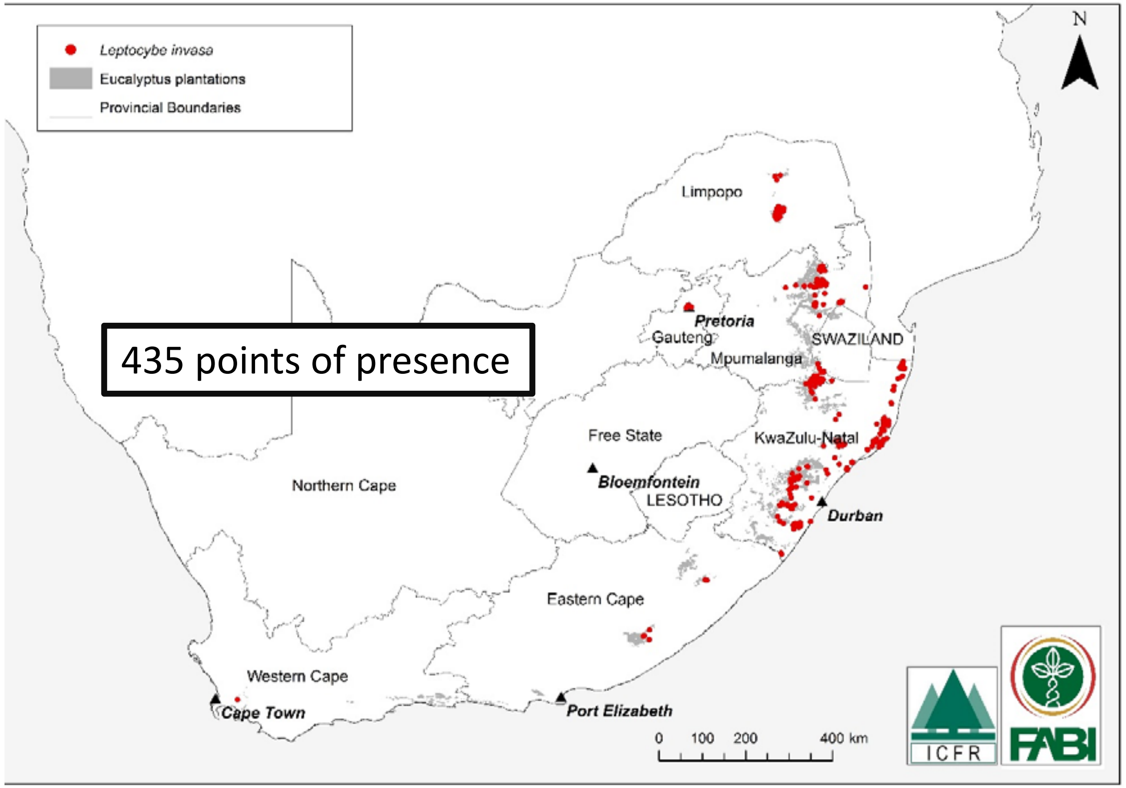
Steven J. Phillips, Robert P. Anderson and Robert E. Shapire.
Maximum entropy modelling of species geographic distributions. 2006. Ecological Modelling 190/3-4, pp231-259


Entropy Component
Constraint Component
A species probability of occurring in the landscape is perfectly uniform
Uniform probability distribution constrained by environmental covariates at points of presence
Output:
Probability distribution by cell

Predictors:

19 Bioclimatic variables (Hijmans et al. 2005)

BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (* 100)
BIO4 = Temperature Seasonality (standard deviation *100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter



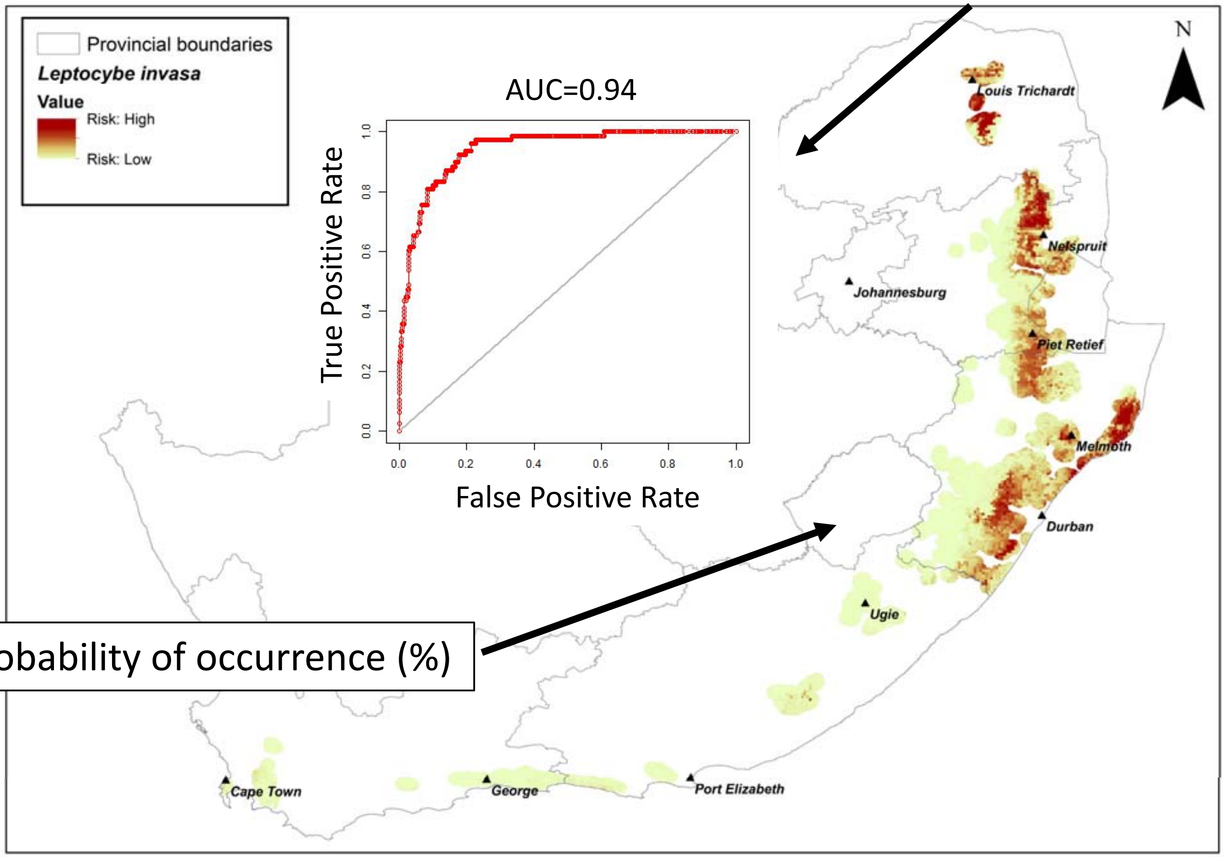
Developed from national climate grids (Dismo, 2016)
Current climate
1 km x 1 km cell (CSIR).
Climate Change scenarios: 1 km x 1 km cell (CSIR)

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology 25(15):1965-1978*

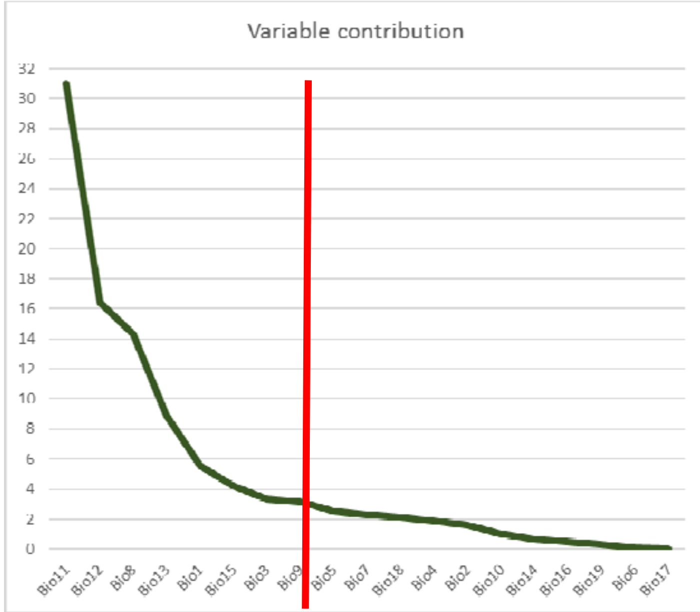
The model

Ranking of predictors

Measure of Accuracy



Probability of occurrence (%)

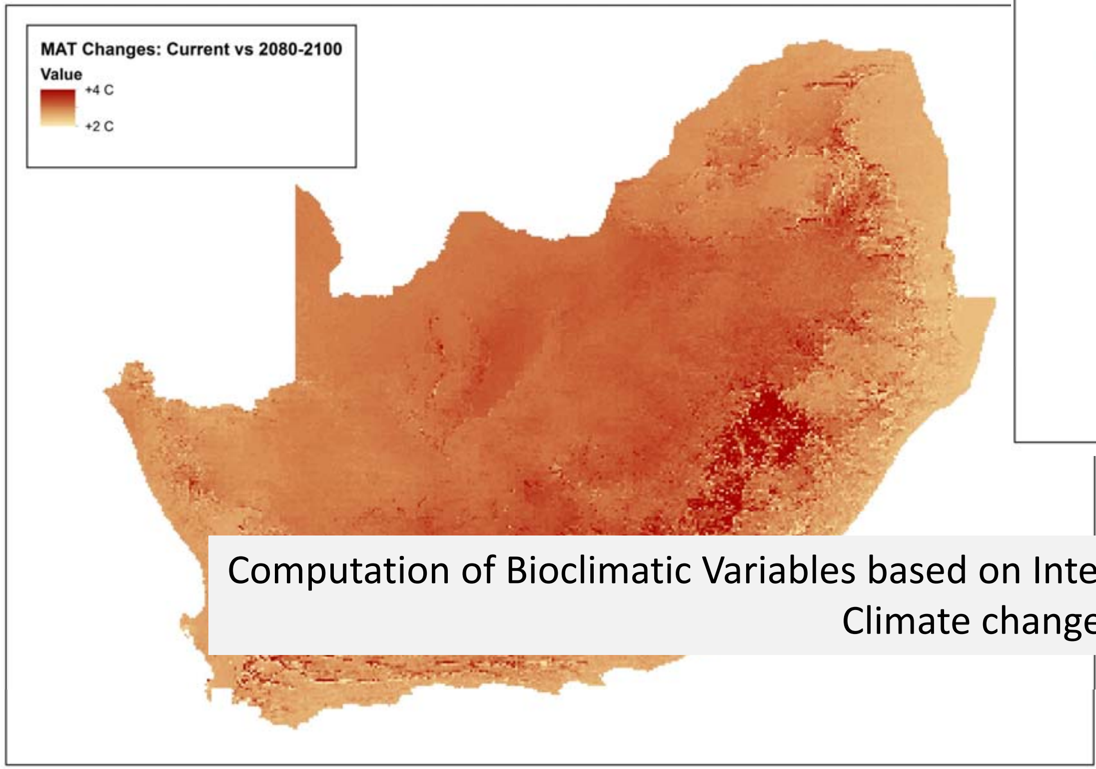


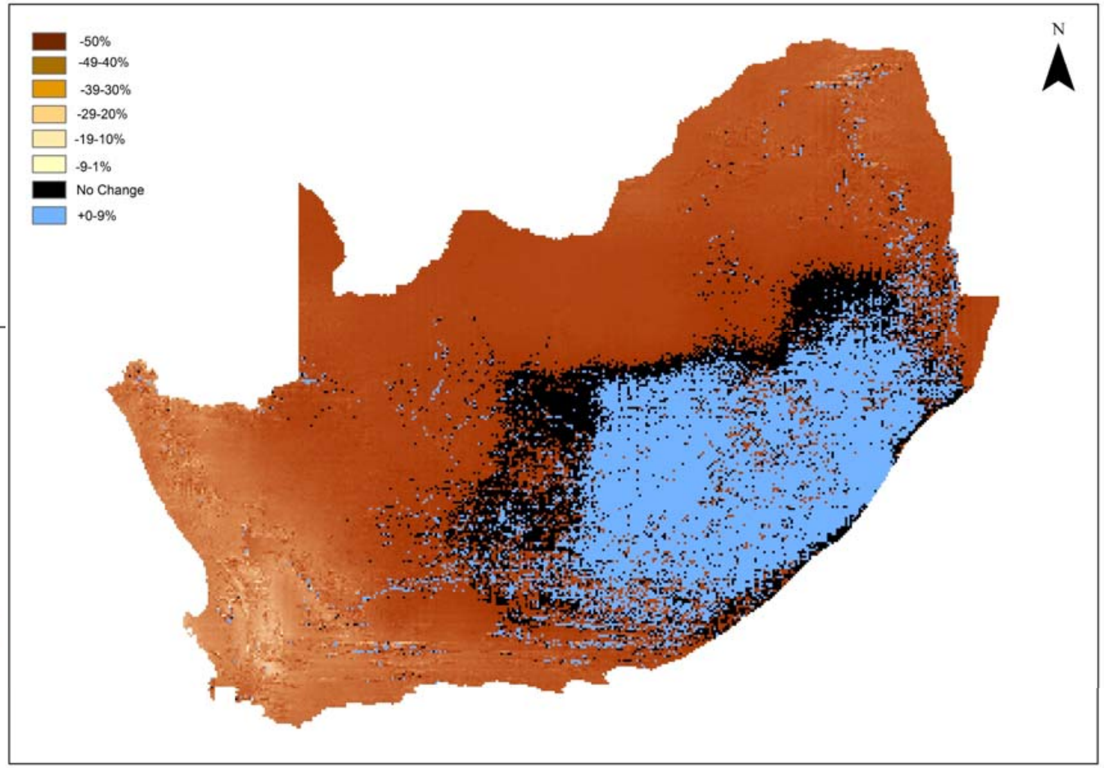
Bio11: Mean Temperature Coldest Quarter
Bio12: MAP
Bio8: Mean Temperature Wettest Quarter
Bio13: Precipitation Wettest Month
Bio1: MAT
Bio15: Precipitation Seasonality (cv)
Bio3: Isothermality*
Bio9: Mean Temperature Driest Quarter

** Mean monthly ((max temp – min temp)/(max temp warmest month – min temp coldest month)) x 100*

Scenario Testing: Climate change

Long Term, A2 (IPCC)
(Regionally downscaled, CSIR)



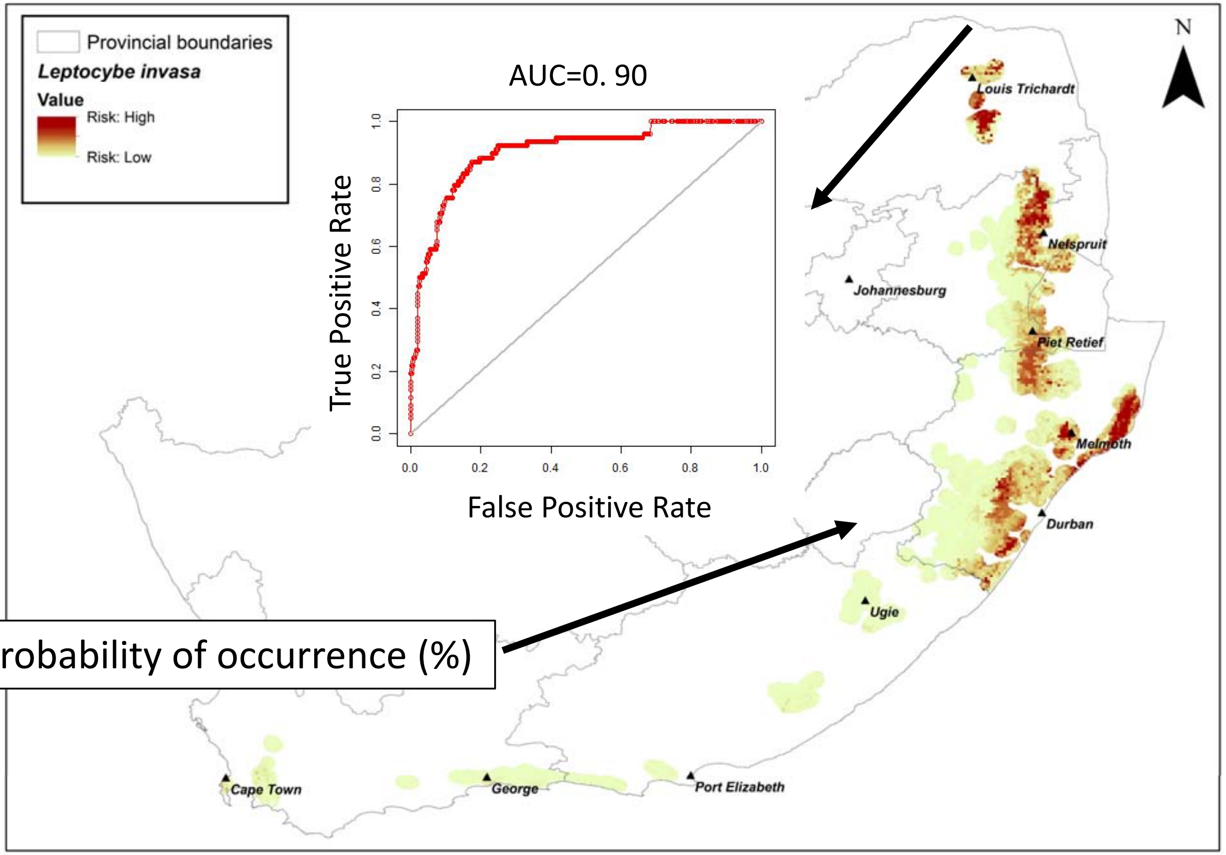


Computation of Bioclimatic Variables based on Intermediate (2050-2060) and Future (2080-2100) Climate change scenarios

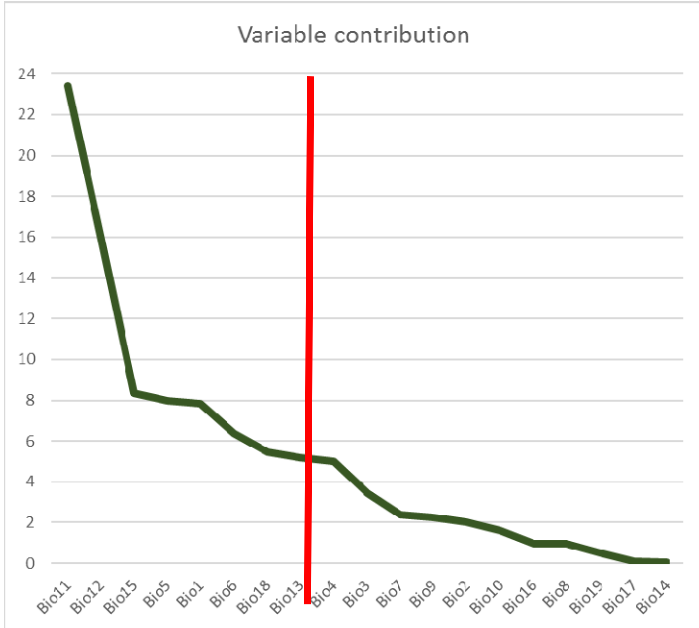
INTERMEDIATE CLIMATE CHANGE SCENARIO 2050-2060

Ranking of predictors

Measure of Accuracy



Probability of occurrence (%)



Bio11: Mean Temperature Coldest Quarter
Bio12: MAP
Bio15: Precipitation Seasonality (cv)
Bio05: Max temperature Wettest Month
Bio1: MAT
Bio6: Min Temperature Coldest Month
Bio18: Precipitation Warmest Quarter
Bio13: Precipitation Wettest Month

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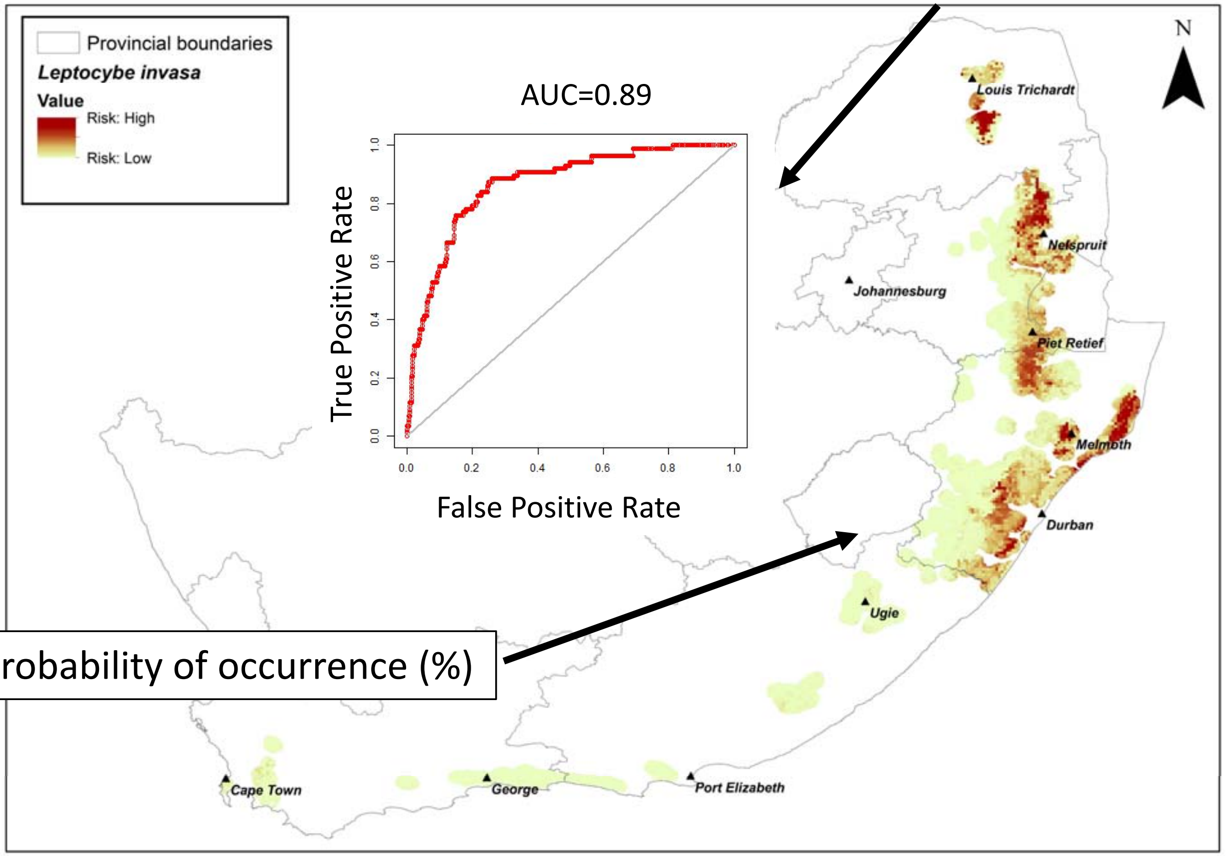
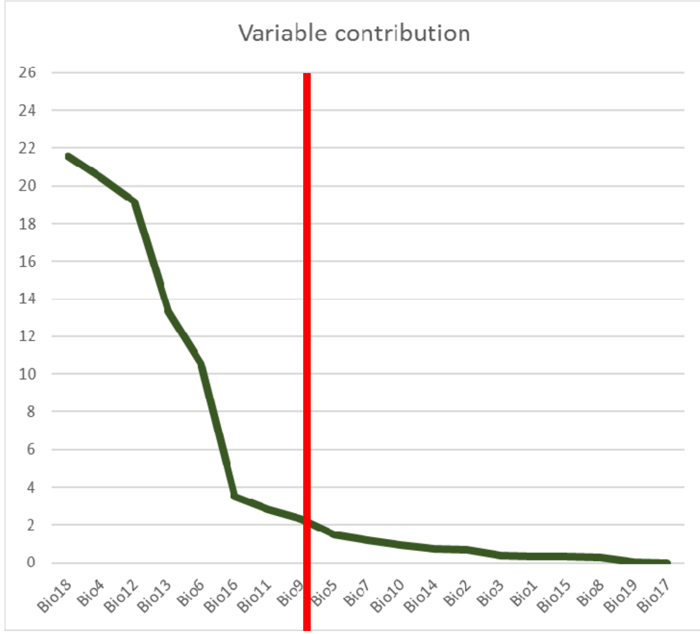
FUTURE CLIMATE CHANGE SCENARIO
2080-2100

Ranking of predictors

Measure of Accuracy



Probability of occurrence (%)



Bio18: Precipitation Warmest Quarter
Bio4: Temperature Seasonality (STD x 100)
Bio12: MAP
Bio13: Precipitation Wettest Month
Bio6: Min Temperature Coldest Month
Bio16: Precipitation Wettest Quarter
Bio11: Mean Temperature Coldest Quarter
Bio9: Mean Temperature Driest Quarter

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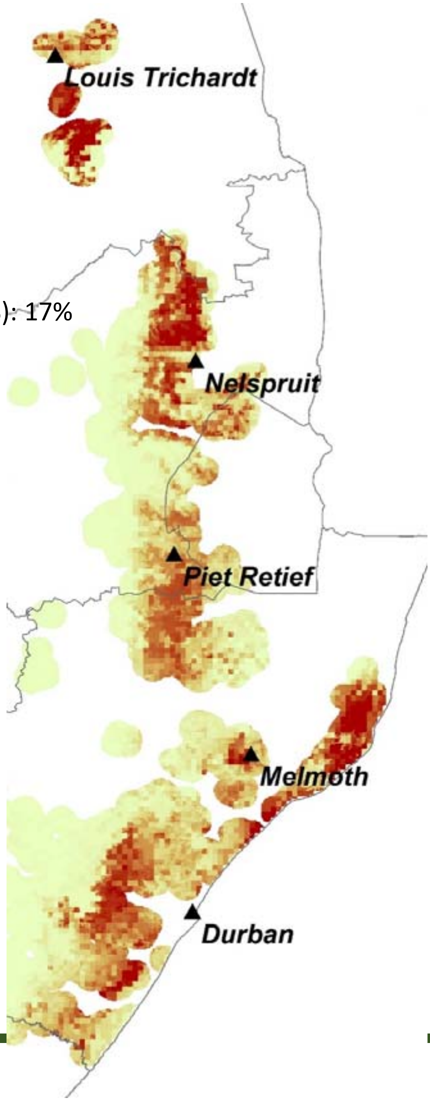
CURRENT

Risk

Low (<30%): 80%

Moderate (31-60%): 17%

High (>60%): 3%



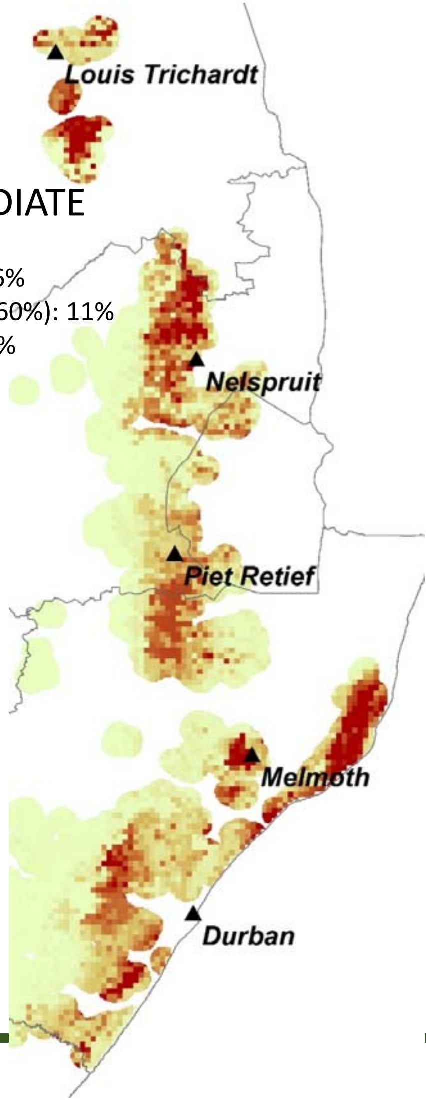
INTERMEDIATE

Risk

Low (<30%): 86%

Moderate (31-60%): 11%

High (>60%): 3%



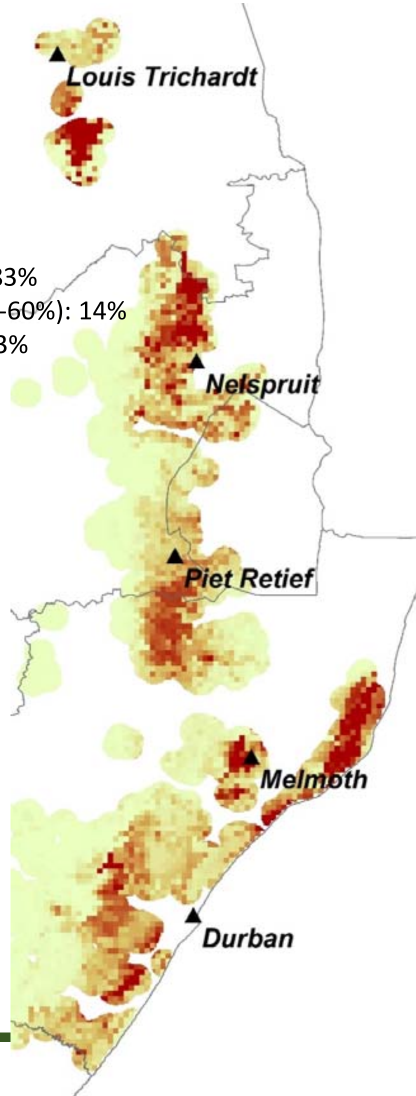
FUTURE

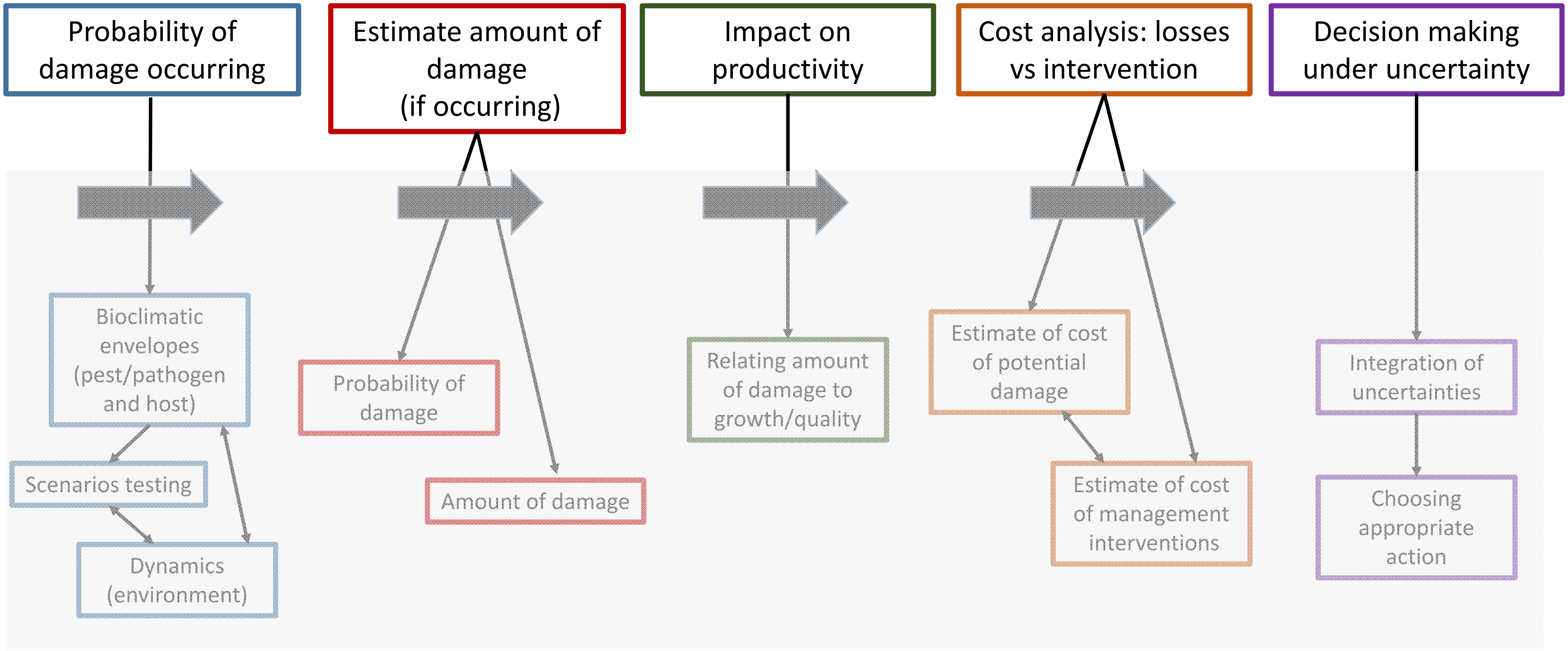
Risk

Low (<30%): 83%

Moderate (31-60%): 14%

High (>60%): 3%




Probability of damage occurring
Estimate amount of damage (if occurring)
Impact on productivity
Cost analysis: losses vs intervention
Decision making under uncertainty
Bioclimatic envelopes (pest/pathogen and host)
Scenarios testing
Dynamics (environment)
Probability of damage
Amount of damage
Relating amount of damage to growth/quality
Estimate of cost of potential damage
Estimate of cost of management interventions
Integration of uncertainties
Choosing appropriate action

The *L. invasa* model in the context of pest management

Probability of damage occurring

Estimate amount of damage (if occurring)

Impact on productivity

Risk model

Field assessments
National monitoring programme

Field trials

Decision making under uncertainty

Cost analysis: losses vs intervention

Clone-site matching

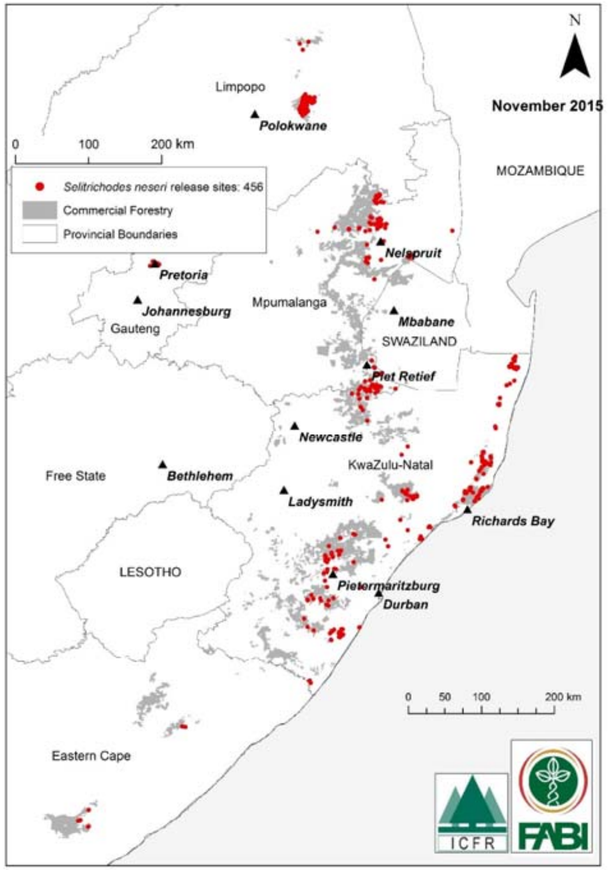
Biological control

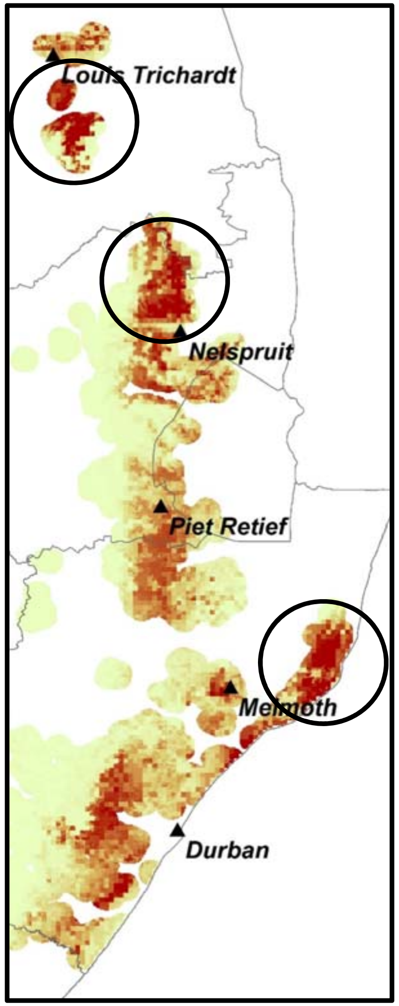
Chemical control

Practical use of the risk model

- Identification of potential "hot spots"
- Prioritisation of *Selitrichodes neserii* (biocontrol) release sites

Photo: Dr Stefan Neser





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Other examples

Puccinia psidii (Eucalypt rust)

Sirex noctilio (woodwasp)

Puccinia psidii (Eucalypt rust)

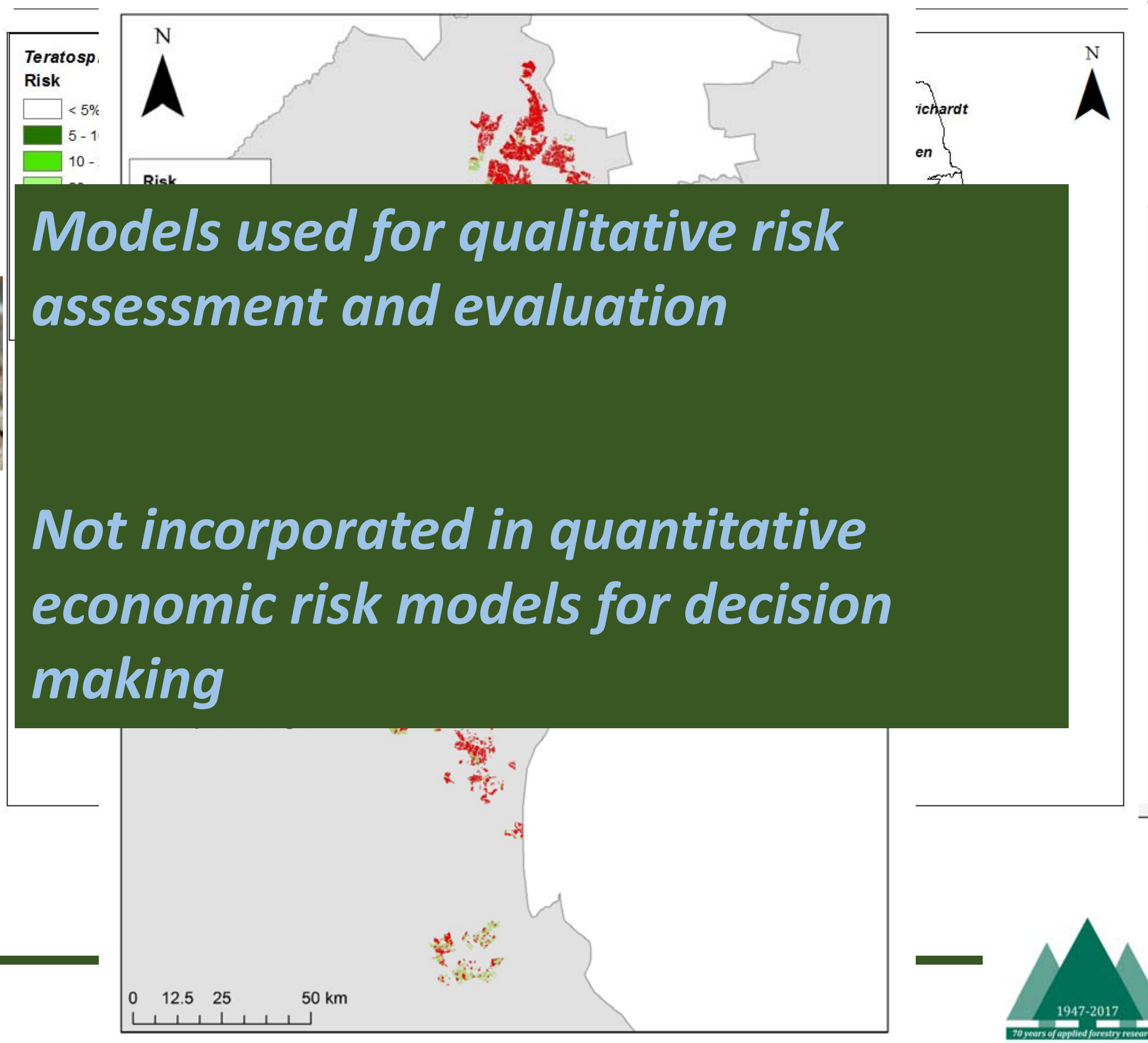
Teratosphaeria destructans

Sirex noctilio (woodwasp)

Papio ursinus (Chacma baboon)

Teratosphaeria destructans

Papio ursinus (Chacma baboon)



Models used for qualitative risk assessment and evaluation

Not incorporated in quantitative economic risk models for decision making

Challenges for the future

- Integration of uncertainty in risk models (dynamic environment; scenarios)
- Integration of other hazards in risk models (other pests/pathogens; weather events, fire..)
- Integration of risk models into quantitative, economic based tools
- Dealing with the issues of scale (tree to landscape)

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Thank you

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