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

2 IPCC Website, November 2015
Pest and disease modelling in the commercial plantation forestry context

- 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/timber quality
- Estimate of cost of potential damage
- Estimate of cost of management interventions

Integration of uncertainties
Choosing appropriate action
Probability of damage occurring

Ecological envelopes (pest/pathogen and host)

Scenario testing
*Climate change*

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
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)
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)

The model

**Probability of occurrence (%)**

**Ranking of predictors**

**Measure of Accuracy**

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

**AUC=0.94**

**Variable contribution**

- 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

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*Provincial boundaries
Leptocybe invasa
Value
Risk: High
Risk: Low*
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

Measure of Accuracy

Probability of occurrence (%)

Ranking of predictors

AUC=0.90

False Positive Rate

True Positive Rate

Variable contribution

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
FUTURE CLIMATE CHANGE SCENARIO
2080-2100

Probabilty of occurrence (%)

AUC=0.89

False Positive Rate

True Positive Rate

Variable contribution

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
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 management interventions

Estimate of cost of potential damage

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

Clone-site matching
Biological control
Chemical control

Decision making under uncertainty

Cost analysis: losses vs intervention
Practical use of the risk model

• Identification of potential “hot spots”

• Prioritisation of *Selitrichodes neserii* (biocontrol) release sites

*Photo: Dr Stefan Nesser*
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)
Thank you