Modeling and risk assessment of plant diseases: concepts and examples

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Outline

Disease and epidemics in plants
Concepts on risk assessment and models
Approaches to develop and test models
Examples: soybean and wheat diseases
Diseased plant

Epidemics in plants

“Change in disease intensity in a host population over time and space”

Madden et al. (2007)
Epidemics - epidemiology

Madden et al. (2007)

Epidemics and management

... if, when and where?

Information useful for decision making in disease management
### Decisions in disease management

**Most commonly, the question is...**

**If and when to spray?**

- More “rational” use of pesticides
- Lower (?) production costs
- Lower (?) environmental impact

<table>
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<tr>
<th>Decisions in disease management</th>
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<tbody>
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<td><strong>Other (important!) questions?</strong></td>
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<td>Will an introduced pest establish?</td>
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<td>If so, what is the epidemic potential?</td>
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<td>Where and when to grow a crop?</td>
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<td>Which disease(s) of a crop may increase/decrease in importance?</td>
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Depending on the case...

We need information on the
(more likely, likely or maximum)

RISK

Management action
(short, mid or long term)

Terminology and timeline

- - - - - - - - Risk Assessment / Analysis - - - - - -

Alert / warning

Risk prediction
Forecasting (seasonal)

past Pre-season Season Future... year, decades

Likely to more likely risk Maximum risk
Risk assessment

Models

Have several definitions...
Here, operationally, those providing estimates of RISK

Modeling plant epidemics

Disease models?
Disease is complex (patho)system
Model of the system: complex or simple
Mimic and predict behaviour of the system
Disease model

Modeling

What kind of Models are there

Objective of the study/use?
Information available?
Experience of the modeler?
(Convenient) classification

Empirical/statistical
Mechanistic/simulation

 Complexity ++++

Mechanistic model

Knowledge of disease cycle
Fusarium head blight

Model representation

Flowchart (model)


Model building

Linking submodels (empirically-derived)

\[ HNG = 1 - \exp(-0.0127 \cdot t^{0.4395}) \]
\[ \text{ANT}_{\text{ext}} = 1 - \exp(a \cdot t^b) \]
\[ \text{INF} = 0.001029 \exp(0.1957 \cdot T) \]

\[ \text{GIB2} = \text{ANT} \cdot \text{INF} \cdot \text{GZ} \]

(Del Ponte et al., 2005)
Submodels of the simulation model

\[ H_{NG} = 1 - \exp(-0.0127 \times t^{1.437}) \]

\[ INF = 0.01029 \exp(0.1957 \times T) \]

\[ ANText = 1 - \exp(1.737) \]

Model testing

(Del Ponte et al., 2005)
Model testing

Mechanistic models

Pros and cons
Quantitative review of knowledge
Identify gaps -> new experiments!
Not a black box – extensible
Portability – universal?
When too complex, hard to be practical
Too many input variables can limit adoption
Empirical models

Data

Techniques

Model fitting

Y = ?x₁...

Commercial field
Field trials
Greenhouse
Chambers
Plates

Regression family
Boosted regression
Multivariate
Decision classification trees
Neural networks
Fuzzy logic
Neurofuzzy

Y = response
? = parameter (estimated)
X₁,...,n = predictors

Regression: example

Soybean rust

34 Epidemics (3 seasons and 21 locations)
Regression model

Widely used in warning systems

Marchetti et al. (1976)

Critical period models

INFection-based models

Widely used in warning systems

Mills (1944)
Empirical models

Pros and cons
Simpler models – less predictor variables
Data mining -> new knowledge
Model is as good as the data
Explain well the data – overfitting!
Portability issues

Word of caution ...

Regression:
"when you fix one bug, you introduce several newer bugs."
Examples: our work

**Fusarium head blight**

**Soybean rust**

**Risk assessment**
- historical data

**Risk prediction**
- Real time weather
- Forecast weather
- Risk maps

Risk assessment: example 1

**Fusarium head blight of wheat**

Is the resurge of the disease related to climate variability?

Is there an influence of El Niño events on the risk?

**Methodology**

**Location:** Passo Fudo, RS

**Data**

50 years dataset daily weather data (1957-2006)

**Models**

DSSAT – estimate of flowering date
Disease model (Del Ponte et al., 2005)

**Simulations**

30 planting dates per year (June 1st)
50 years = 1,500 simulations

Del Ponte et al. (2009)

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**Simulation results**

- **<1970**
- **1970 -1989**
- **>1990**

Del Ponte et al. (2009)
Simulation results

[Graph showing the median FHB risk index over sowing dates after June 1st with different periods: 1957-1979, 1980-2006, and all years.]

Del Ponte et al. (2009)

ENSO effects

[Graph showing the frequency distribution of FHB seasonal risk index with different ENSO conditions: "Cold," "Neutral," and "Warm".]

Del Ponte et al. (2009)
Enso effects

Risk assessment: Example 2

1) What is the spatial and temporal variability in soybean rust epidemics?

2) Is the variability affected by ENSO events: El Niño, La Niña years?

Study area – RS State

Rainfall data
daily time-scale
30 years (1978-2009)
24 locations
Time of disease onset

Disease model

Disease model (Del Ponte et al. 2006)

\[ SEV = -2.14 + (0.18 * R_{30}) + (1.28 * RD_{30}) \]

Fonte: www.consórcioantiferrugem.net

Del Ponte et al. (2006)
Simulations

Assumptions

- 31st Jan as detection date
- 28 simulations/year-location (n=720)
- Seasonal risk index = avg 28 simulations

Results

Del Ponte et al. (2011)
Results

Del Ponte et al. (2011)
Results

Risk prediction: example 3

Warning system
Choose location

Choose a heading date
Sisalert – FHB risk

Risk prediction: example 4
Weekly reports of risk

15 reports during 3 growing seasons
2010 to 2012

Geographical risk maps

30-day rainfall grid (CPTEC)
 Severity estimated for each grid cell
 Risk map

Monitoramento de risco climático para ferrugem asiática
de 20 de nov. a 19 de dez. de 2010

Fonte: precipitação observada fornecida pelo CPTEC/INPE. O risco é esti-
nado por modelo climático basado na chuva (Del Ponte et al., 2006).
Geographical risk maps

7-day forecast of rainfall
CPTEC/INPE
ETA (40 x 40 km)

Severity estimated

Risk map

“Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful”

George P. E. Box
Statistician