MODELS FOR ANALYZING PLANT HEALTH RISK

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Risk

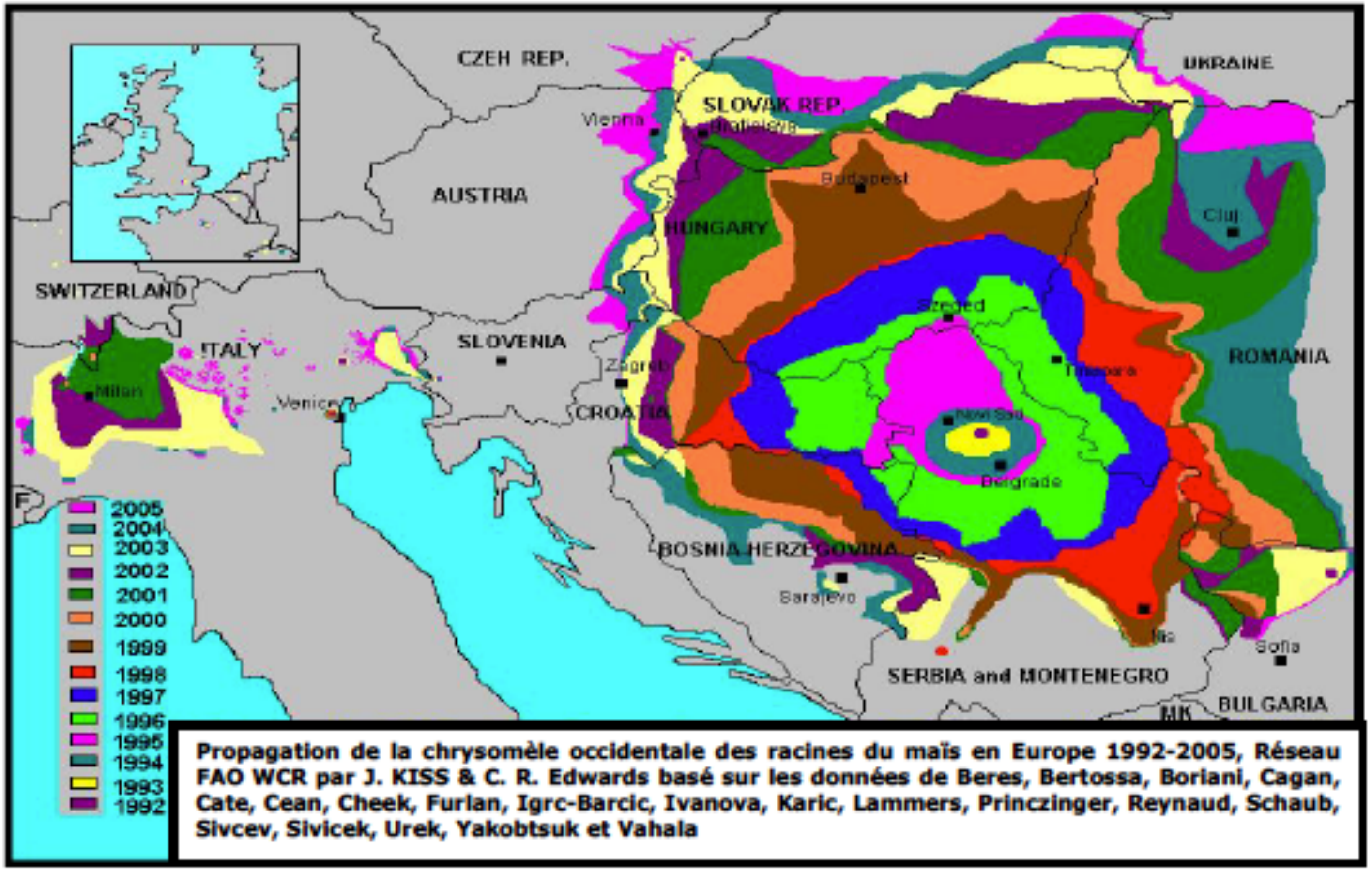
A futur event that may have negative consequences

Risk of biological invasion

Risk that an harmful organism present in an area A enters in an area B (where the pest is absent) and has some impacts

Source : Agpm

Chrysomèle du maïs (*Diabrotica virgifera*)



Propagation de la chrysomèle occidentale des racines du maïs en Europe 1992-2005, Réseau FAO WCR par J. KISS & C. R. Edwards basé sur les données de Beres, Bertossa, Boriani, Cagan, Cate, Cean, Cheek, Furlan, Igrc-Barcic, Ivanova, Karic, Lammers, Princzinger, Reynaud, Schaub, Sivcev, Sivicek, Urek, Yakobtsuk et Vahala

First report of *Xylella fastidiosa* in the EPPO region

- Special Alert -

Octobre 2013

Symptoms of quick decline (complesso del disseccamento rapido dell'olivo) observed in Puglia on olive trees.

All pictures of symptoms on olive trees were kindly provided by Donato Boscia, Istituto di Virologia Vegetale del CNR, UOS, Bari (IT)
Franco Nigro, Dipartimento di Scienze del Suolo, della Pianta e degli Alimenti, Università degli Studi di Bari (IT)
Antonio Guario, Plant Protection Service, Regione Puglia (IT)

Some vectors of grapevine Pierce's disease.

Xyphon fulgida.
J. Clark - University of California, Berkeley (US)

Draeculacephala minerva.
J. Clark - University of California, Berkeley (US)

Graphocephala atropunctata.
A.H. Purcell University of California, Berkeley (US)

Biological invasion results from a succession of events

- Entry of a pest in a given area
- Establishment of a pest in a given area
- Spread of a pest in a given area
- Impact of a pest on some hosts or on the environment

Pest risk analysis aims at analyzing these events

- Currently done by national and international agencies
- ANSES in France, USDA in USA, EFSA and EPPO in Europe
- Resuls of these analyses are used to define official regulations concerning the movements of plant materials
  - Prohibition
  - Test of presence in imported commodities
  - Treatment of commodities

Why could models be useful?

- Computing probability of pest entry in a geographical area
- Computing probability of pest establishment in a geographical area
- Predicting the spread of a pest in a geographical area
- Predicting the impact of a pest on a crop
- Assessing the effectiveness of different methods of pest controls

A great diversity of approaches for assessing risk of invasion

- **Qualitative approaches**

Require risk assessors to choose from categorical ratings *e.g* very low, low, moderate, high, very high

- **Quantitative approaches**

Can be used by risk assessors to obtain numerical quantities (e.g., probabilities)

Qualitative approaches

- Risk rating methods
- Widely used
- Issues related to definition and combination of ratings

EFSA scheme for Pest Risk Analysis (2010)

Availability of suitable hosts or suitable habitats, alternate hosts and vectors in the risk assessment area

1.16. Estimate the number of host plant species or suitable habitats in the risk assessment area (see question 6).

very few, few, moderate number, many, very many

Level of uncertainty:	**Low**	**Medium**	**High**

1.17. How widespread are the host plants or suitable habitats in the risk assessment area? (specify)

very limited, limited, moderately widely, widely, very widely

Level of uncertainty:	**Low**	**Medium**	**High**

USDA Guidelines for Pest Risk Assessments

Sub-elements	Ratings
Quantity imported annually	Low, Med., High 1, 2, 3
Survive post harvest treatment	Low, Med., High 1, 2, 3
Survive shipment	Low, Med., High 1, 2, 3
Not detected at port or entry	Low, Med., High 1, 2, 3
Moved to suitable habitat	Low, Med., High 1, 2, 3
Contact with host material	Low, Med., High 1, 2, 3

Problems related to qualitative approaches

- Ratings not always clearly defined.
- No consensus on method for combining ratings.

Examples of definitions of ratings

Quantity of commodity imported annually
Low (1 point): < 10 containers/year
Medium (2 points): 10 - 100 containers/year
High (3points): > 100 containers/year

from USDA Guidelines

Examples of definitions of ratings

- Negligible = 0 (no potential to survive)
- Low = 1 (potential to survive on a third or less of the range of hosts in the PRA area)
- Medium = 2 (potential to survive on a third to two thirds of the range of hosts in the PRA area)
- High = 3 (potential to survive throughout most or all of the range of hosts in the PRA area)

from Canadian Food Inspection Agency: establishment potential rating guidelines (2002)

Difficult to make generic definitions

Appropriate definitions may depend on pests and areas

No consensus on methods for combining scores

USDA Guidelines for Pest Risk Assessments

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Cumulative risk rating (6-18)

6-9 → Low

10-14 → Med.

15-18 → High

Biosecurity Australia

Plant Pest Risk Analysis Reference Manual

Table 8.4 Matrix of rules for combining descriptive likelihoods — Biosecurity Australia

		Likelihood 2					
		High	**Moderate**	**Low**	**Very (V) low**	**Extremely (E) low**	**Negligible**
Likelihood 1	**High**	High	Moderate	Low	V low	E low	Negligible
	Moderate	Moderate	Low	Low	V low	E low	Negligible
	Low	Low	Low	V low	V low	E low	Negligible
	Very low	V low	V low	V low	E low	E low	Negligible
	E. low	E low	E low	E low	E low	Negligible	Negligible
	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

What is the best method for combining scores?

from Hennen (2007)

Combining scores	Simple	Programming effort	Robust	Objective	Dealing with uncertainty	Relevant (for EPPO)	Sensitive | match knowledge	Complete	Laborious	Reliable	Maintenance	Flexible	Required expert knowledge	Weighted overall score
1 Sum of scores | 2 Arithmetic mean	+	+	+	+	-	o/+	--	-	+	-	+	-	+	5.3
3 Weighted average/sum	+	+	+	o	-	+	o	o	o	+	o	o	-	7.0
4 Maximum	+	+	+	+	-	--	-	-	+	--	+	--	+	3.5
5 Cross the Threshold	+	+	o	+	-	--	o	-	+	-	+	o	o	4.7
6a Mandatory	+	+	o	+	-	--	-	-	+	-	+	--	o	3.5
6b Optional	+	+	+	o	-	-	-	-	+	-	+	-	o	4.5
7 Differentiated scores (Imagine)	--	-	-	-	-	+	++	+	-	o	-	+	--	5.5
8 Fuzzy combinations	-/o	--	o	o	+	+	+	+	-	+	o	+	-	6.4
9 Rule-based Experts Systems	-	--	-	--	+	o	+	o	--	o	--	+	--	3.6
10 Holt (Bayesian)	-/o	o	-/+	o	-	++	-	-	+	-	+	-	+	5.6

A great diversity of approaches for assessing risk of invasion

- **Qualitative approaches**

Require risk assessors to choose from categorical ratings *e.g* very low, low, moderate, high, very high.

- **Quantitative approaches**

Can be used by risk assessors to obtain numerical quantities (e.g., probabilities).

Quantitative approaches

- Many types of models

- Issues related to
  - model choice
  - parameter estimation
  - transparency of complex models
  - uncertainty of the model outputs

A great diversity of models.

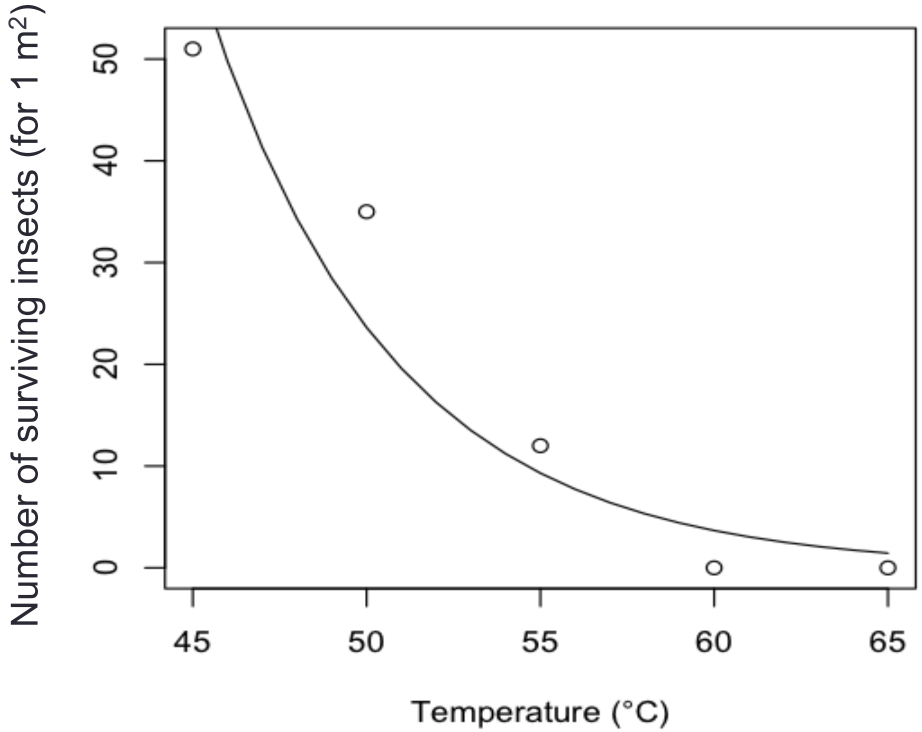
- Statistical models (Poisson, binomial, logistic…)
- Machine learning
- Climate-based systems (NAPPFAST, CLIMEX).
- Pathway models
- Population ecology model (Leslie matrix…)

Important types of generalized linear models

Type	Deterministic part	Stochastic part	R function
Binomial logit	logit link	Binomial distribution	glm(Y~X, family=binomial(link = "logit"))
Poisson log linear	log link	Poisson distribution	glm(Y~X, poisson(link = "log"))
Gaussian linear	Identity link	Gaussian distribution	glm(Y~X, gaussian(link = "identity"))

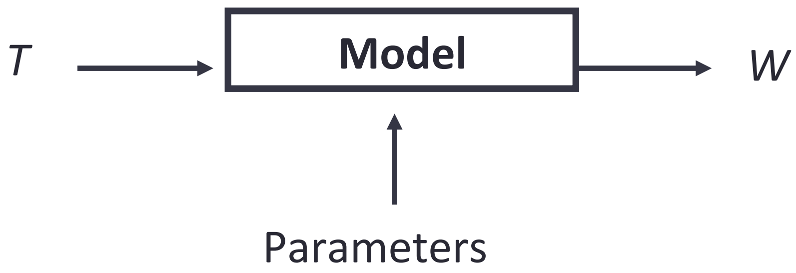
- Consider the experiment of Myers et al. (2009) on the effect of heat treatment on the insect species *Agrilus planipennis*, a pest of ash (a tree species)
- Ash wood were treated at five different temperatures (45, 50, 55, 60, 65°C) during 30 min
- The number of surviving insects were counted after each heat treatments

Temperature	Nb of insects (for 1 m2 of wood)
45	51
50	35
55	12
60	0
65	0



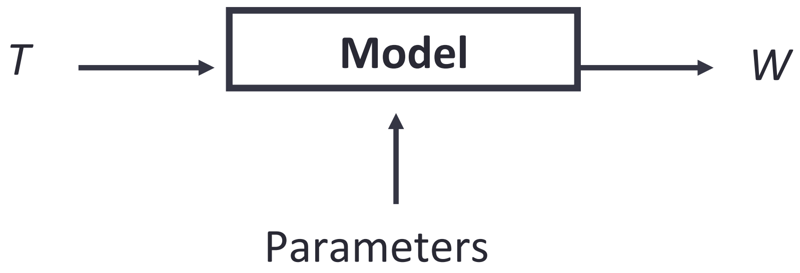
Number of surviving insects (for 1 m²)
0
10
20
30
40
50
45
50
55
60
65
Temperature (°C)

Wetness model (Magarey et al., 2005)



W = leaf wetness duration requirement for successful fungal infection (h

T = average temperature (°C)



$$W = \frac{W_{\min}}{f(T)}, \text{ and } W \le W_{\max}$$

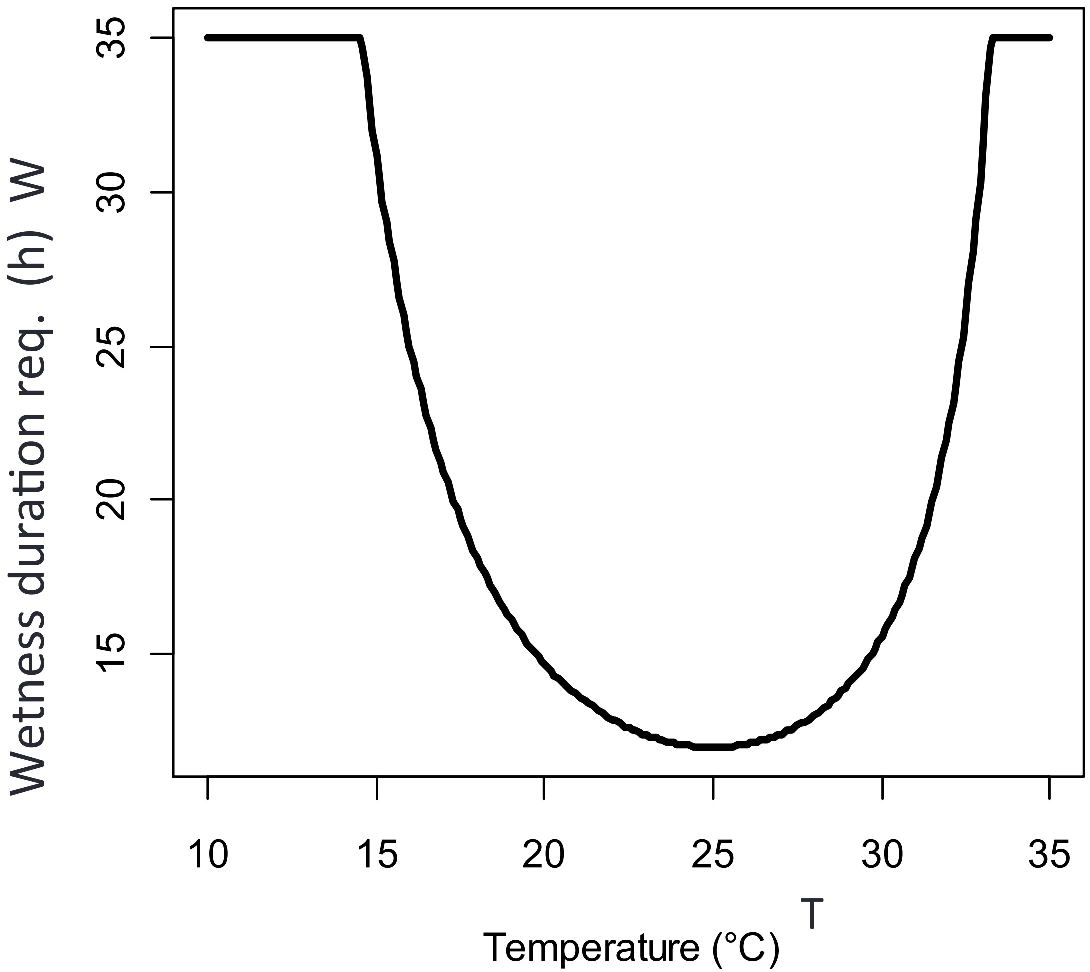
$$f(T) = \left(\frac{T_{\max} - T}{T_{\max} - T_{opt}}\right)\left(\frac{T - T_{\min}}{T_{opt} - T_{\min}}\right)^{(T_{opt} - T_{\min})/(T_{\max} - T_{opt})}$$

Five parameters: T_{min}, T_{opt}, T_{max}, W_{min}, W_{max}

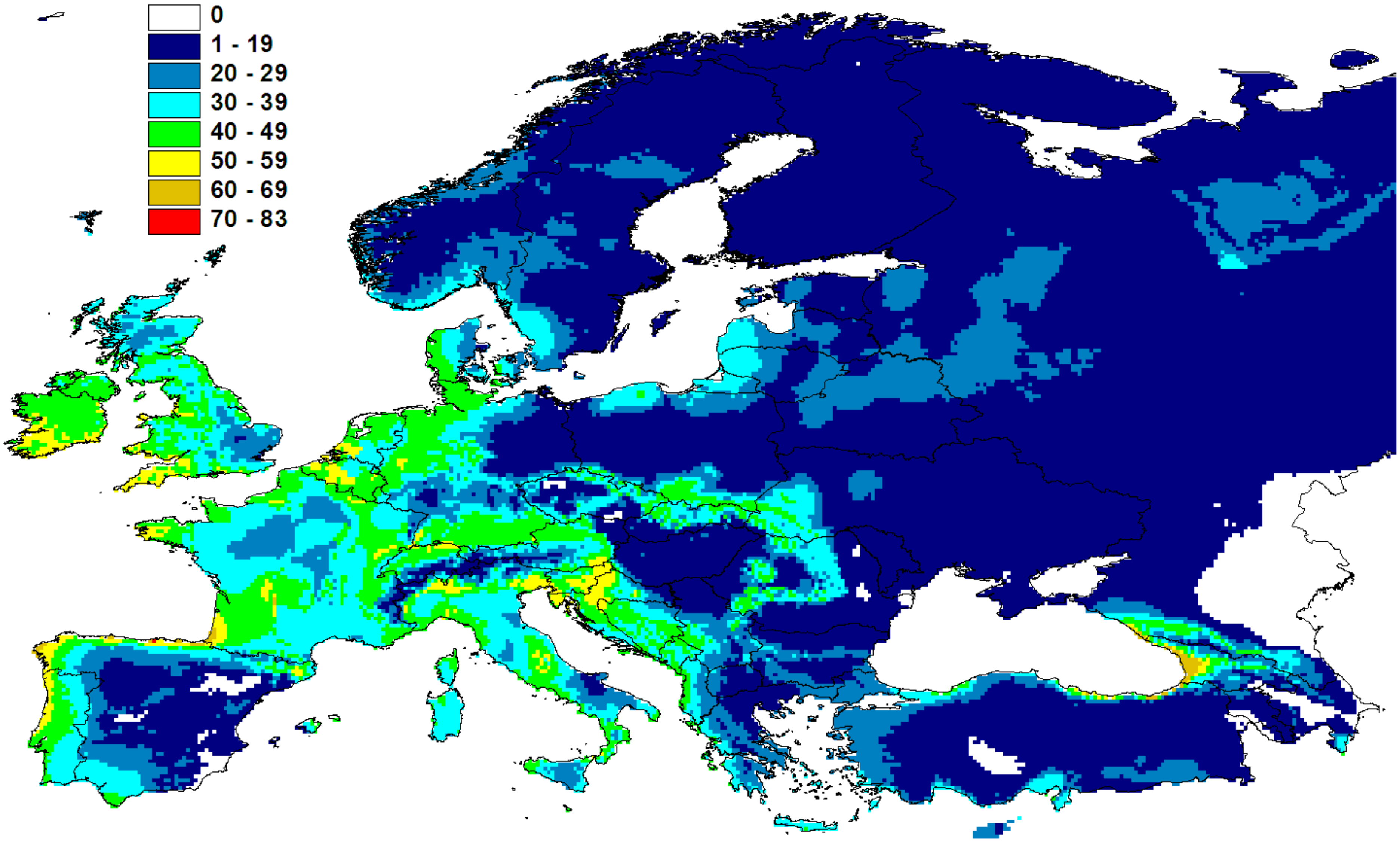
Scientific name:
Guignardia citricarpa
Order: Dothideales, Family: Botryosphaeriaceae
Common Name: Citrus black spot *Guignardia citricarpa* Kiely

Parameter values estimated for pycnidiospores of *Guignardia citricarpa* Kiely , and associated response of *W* to temperature (from EFSA, 2008)

T_{min}= 10 °C, T_{opt}= 25 °C, T_{max}=35 °C, W_{min}=12 h, W_{max}= 35 h



CLIMEX index of establishment suitability for *Phytophthora ramorum*



Estimated probability of establishment of the western corn rootworm (*Diabrotica virgifera virgifera*)

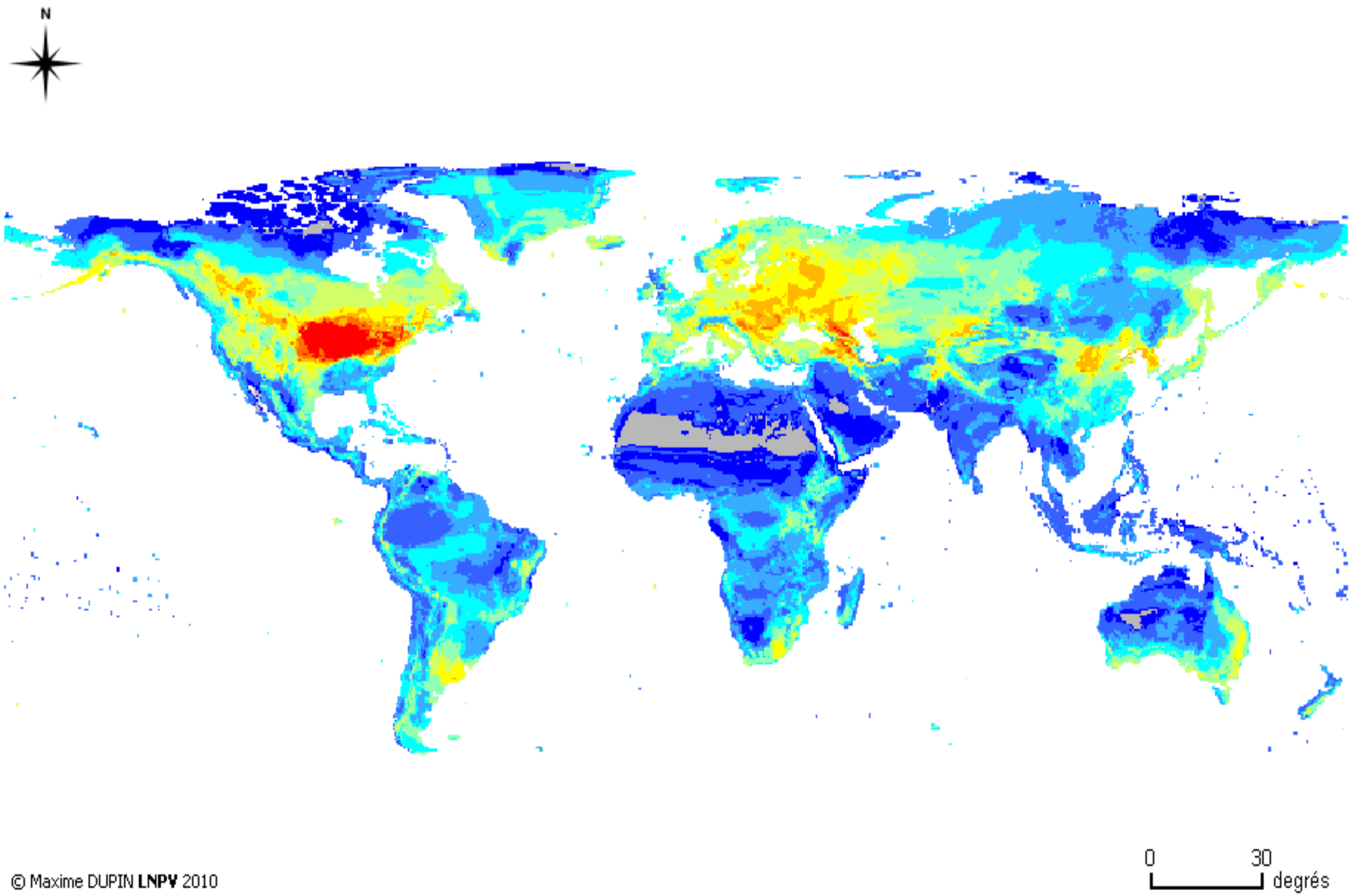


Table 2. Nine models for predicting distribution of the western corn rootworm.

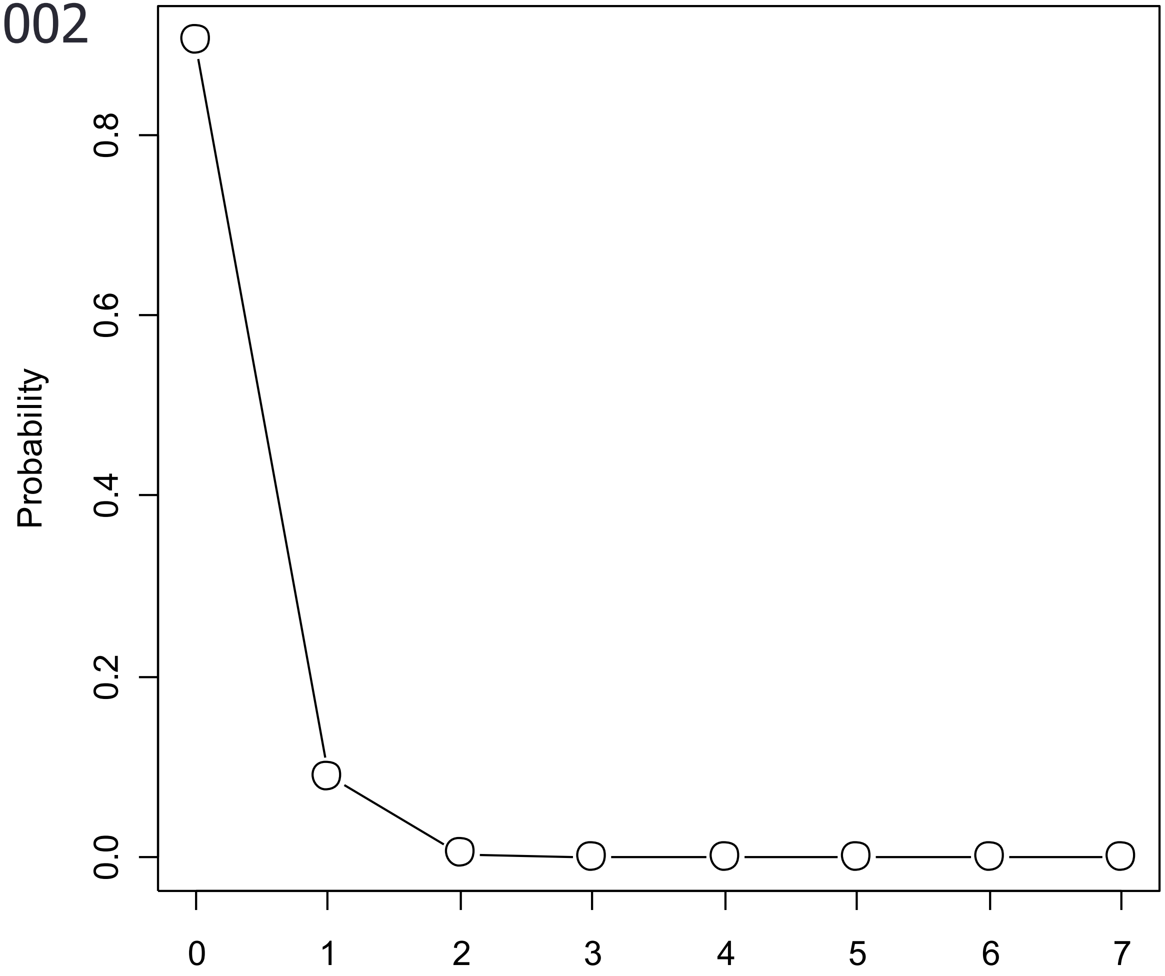
Name	Class of method	Data	Software
BIOCLIM	Envelope model	P	DIVA-GIS v5.2
Envelope Score (ES)	Envelope model	P	openModeller v1.0.9
DOMAIN	Multivariate distance	P	DIVA-GIS v5.2
Environmental Distance (ED)	Multivariate distance	P	openModeller v1.0.9
Climate Space Model (CSM)	Principal components analysis	P	openModeller v1.0.9
DKGARP	Genetic Algorithm for Rule Set Production, desktop version, with the best subset procedure	ppa	openModeller v1.0.9
OMGARP	Genetic Algorithm for Rule Set Production, openModeller version, with the best subset procedure	ppa	openModeller v1.0.9
MAXENT	Maximum Entropy	ppa	Maxent v3.3.1
Support Vector Machine (SVM)	Support Vector Machine	ppa	openModeller v1.0.9

Data needed for model calibration are presence data (p) or both presence and pseudo-absence data (ppa).
doi:10.1371/journal.pone.0020957.t002

Dupin et al. (2011)

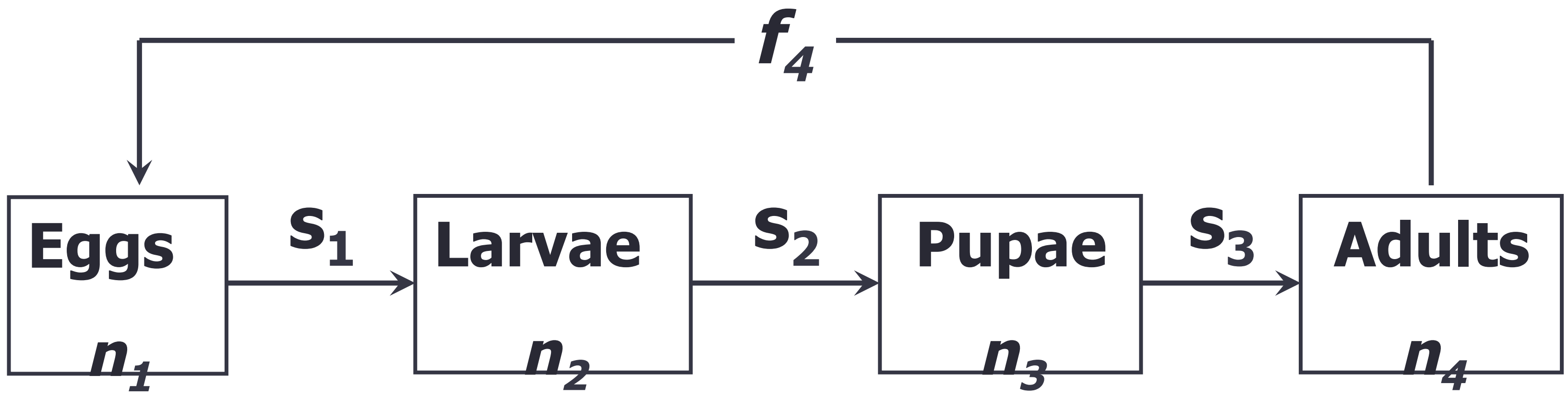
Pathway model for estimating probability of entry

from Stansbury et al., 2002



Number of successful entry of *Tilletia indica* in Australia

Population ecology model for estimating the probability of establishment of the Asian longhorned beetle (*Anoplophora glabripennis*)



from Bartell & Nair (2003).

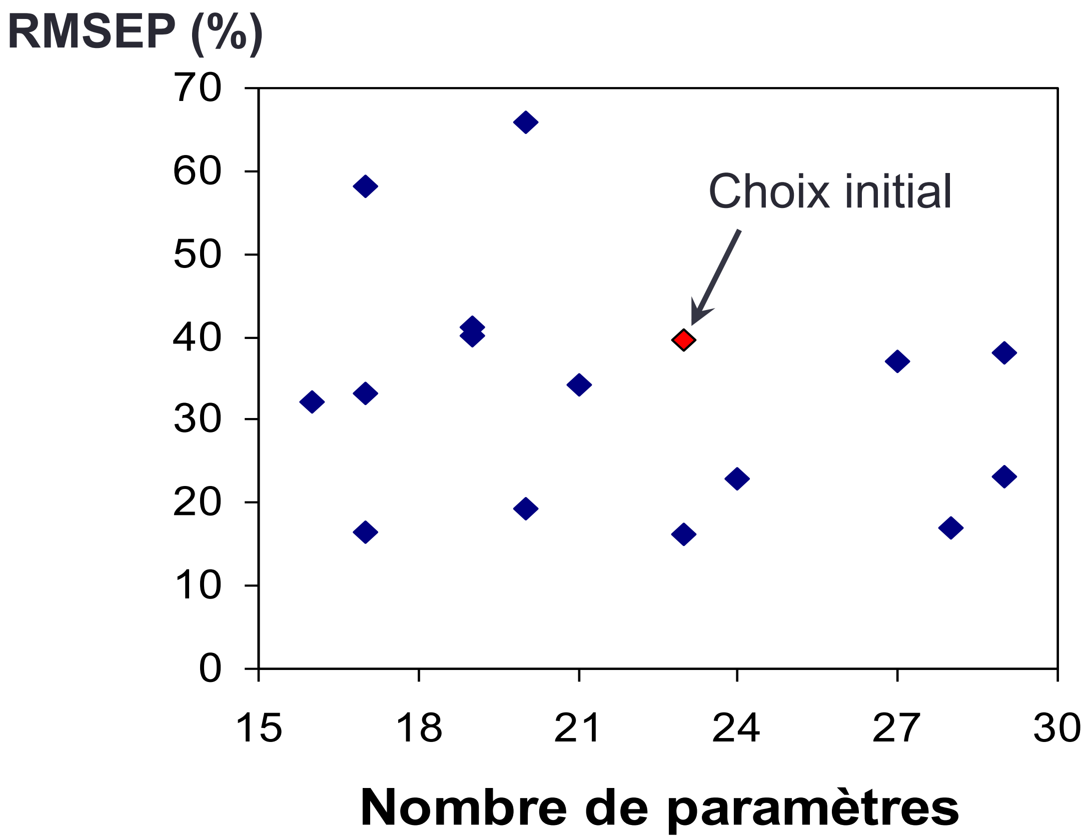
Major problems related to the use of quantitative models

- Model choice
- Parameter estimation
- Transparency of complex models
- Uncertainty of the model outputs

Model choice

- Difficulties in comparing models as:
  - Deep involvement needed to learn how to use all the models and associated softwares
  - Model performance depends on the estimated parameter values
  - Several quantitative criteria could be computed, but each one has its own limitations
  - Need of large amount of reliable data, difficult to find

Evaluation des erreurs de 16 modèles prédisant l'incidence du piétin échaudage du blé



Ennaïfar, Makowski, Meynard, Lucas. 2007.

Major problems related to the use of quantitative models

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Parameter estimation

- Numerous methods
  - Expert knowledge
  - Manual adjustment
  - Frequentist methods
  - Bayesian methods

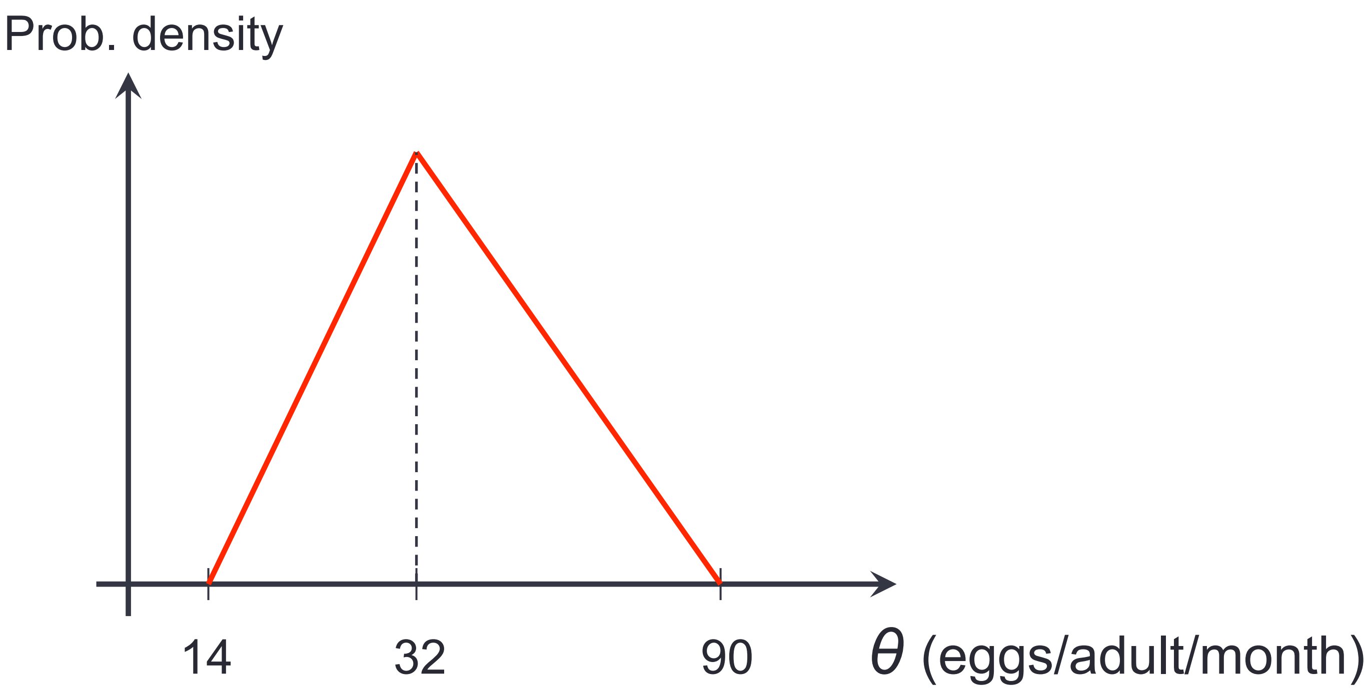
- Influence of experts and of data on model outputs

TABLE 1. CLIMEX parameter values used to model ecoclimatic suitability for *Pyrenophora semeniperda*

Parameter	Description	Value[a]
Temperature		
DV0	Lower temperature threshold for growth	5°C
DV1	Lower optimum temperature	15°C
DV2	Upper optimum temperature	25°C
DV3	Upper temperature threshold for growth	28°C
Moisture		
SM0	Lower soil moisture threshold for growth	0.2
SM1	Lower optimum soil moisture	0.4
SM2	Upper optimum soil moisture	0.8
SM3	Upper soil moisture threshold for growth	1.3
Heat stress		
TTHS	Temperature threshold for heat stress	28°C
THHS	Heat stress accumulation rate	0.0005 $week^{-1}$
Wet stress		
SMWS	Soil moisture threshold for wet stress	1.3
HWS	Wet stress accumulation rate	0.007 $week^{-1}$
Hot–wet stress		
TTHW	Temperature threshold for hot-wet stress	23°C
MTHW	Soil moisture threshold for hot-wet stress	0.2
PHW[b]	Hot-wet stress accumulation rate	0.0101 $week^{-1}$
PDD	Number of degree-days above DV0 necessary to complete one generation	1,100 degree-days

Yonow et al., 2004

Estimation of fecundity rate

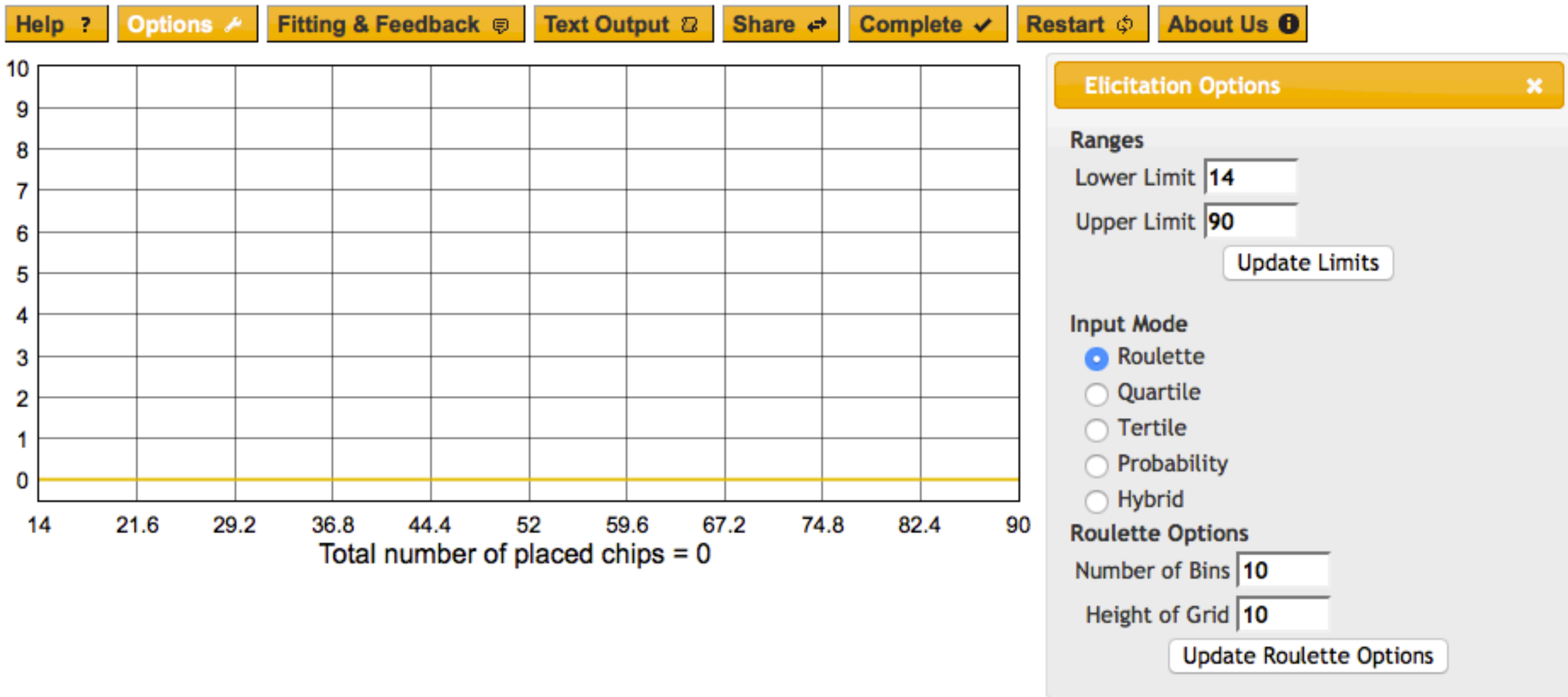


from Bartell & Nair (2003).

Expert elicitation: the MATCH tool

http://optics.eee.nottingham.ac.uk/match/uncertainty.php#

David E. Morris, Jeremy E. Oakley, John A. Crowe, A web-based tool for eliciting probability distributions from experts, Environmental Modelling & Software, Volume 52, February 2014, Pages 1-4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Total number of placed chips = 0
Elicitation Options
Ranges
Lower Limit 14
Upper Limit 90
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Tertile
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Roulette Options
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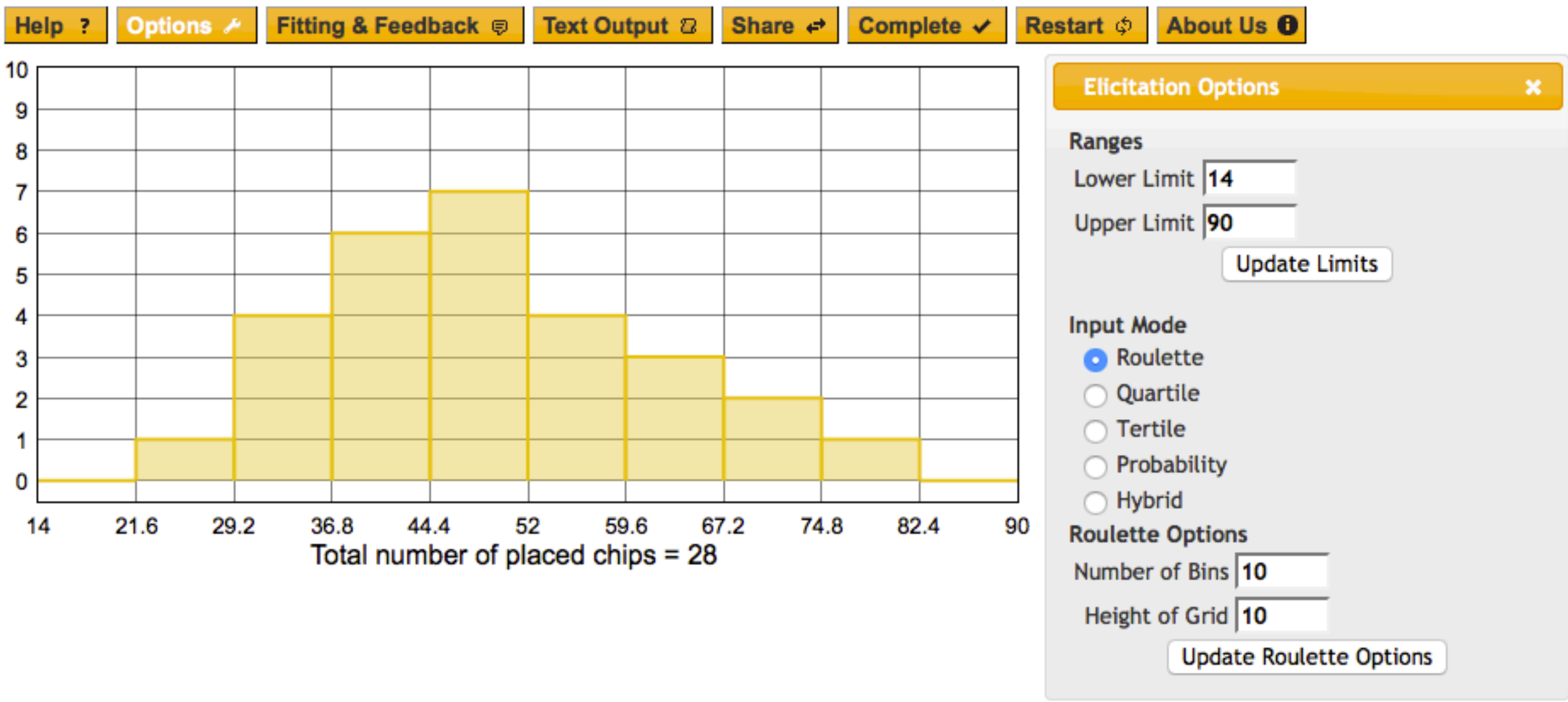
Height of Grid 10
Update Roulette Options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Total number of placed chips = 28
Elicitation Options
Ranges
Lower Limit 14
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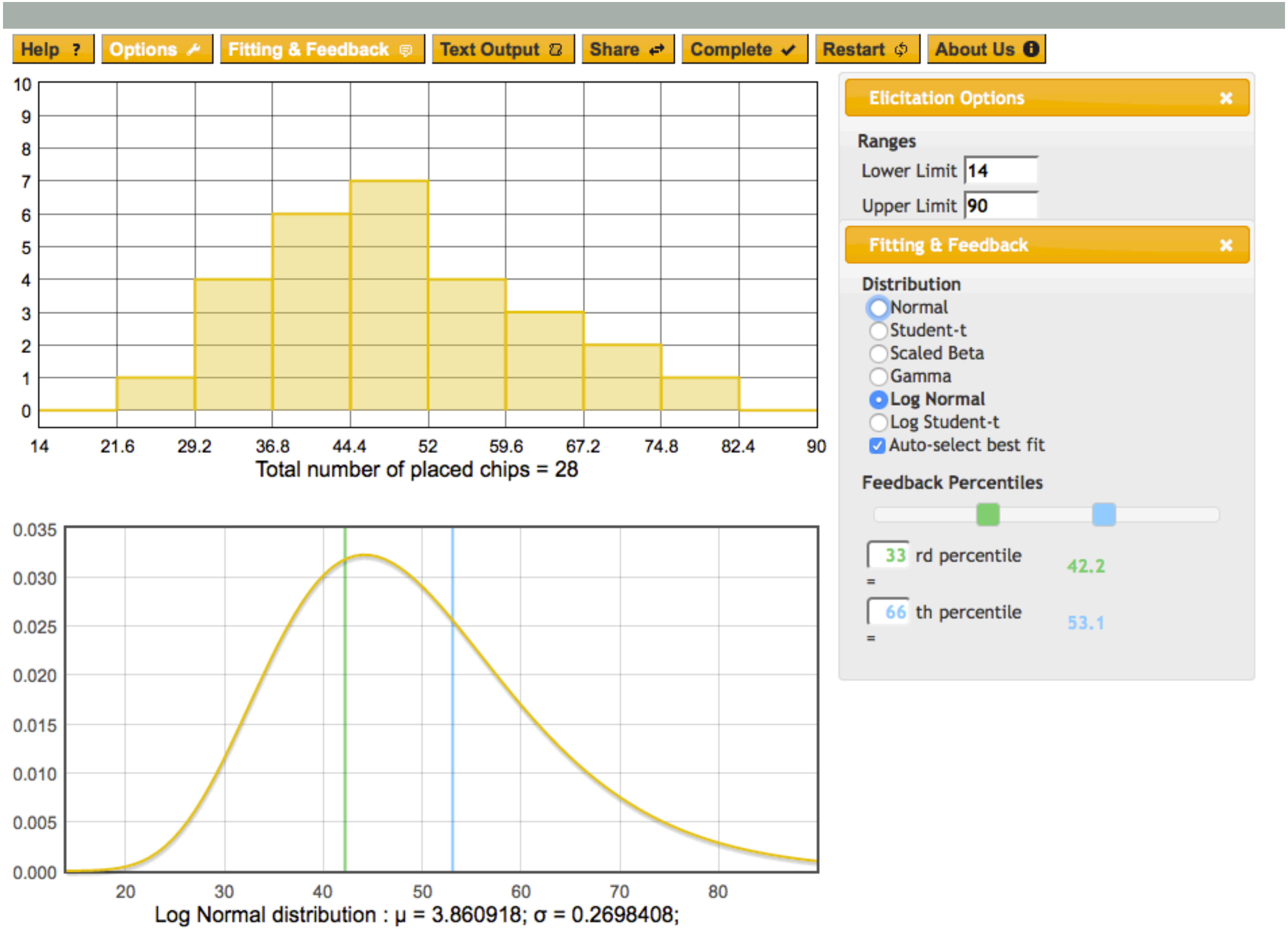
Quartile
Tertile
Probability
Hybrid
Roulette Options
Number of Bins 10
Height of Grid 10
Update Roulette Options


Help ?
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Fitting & Feedback
Text Output
Share
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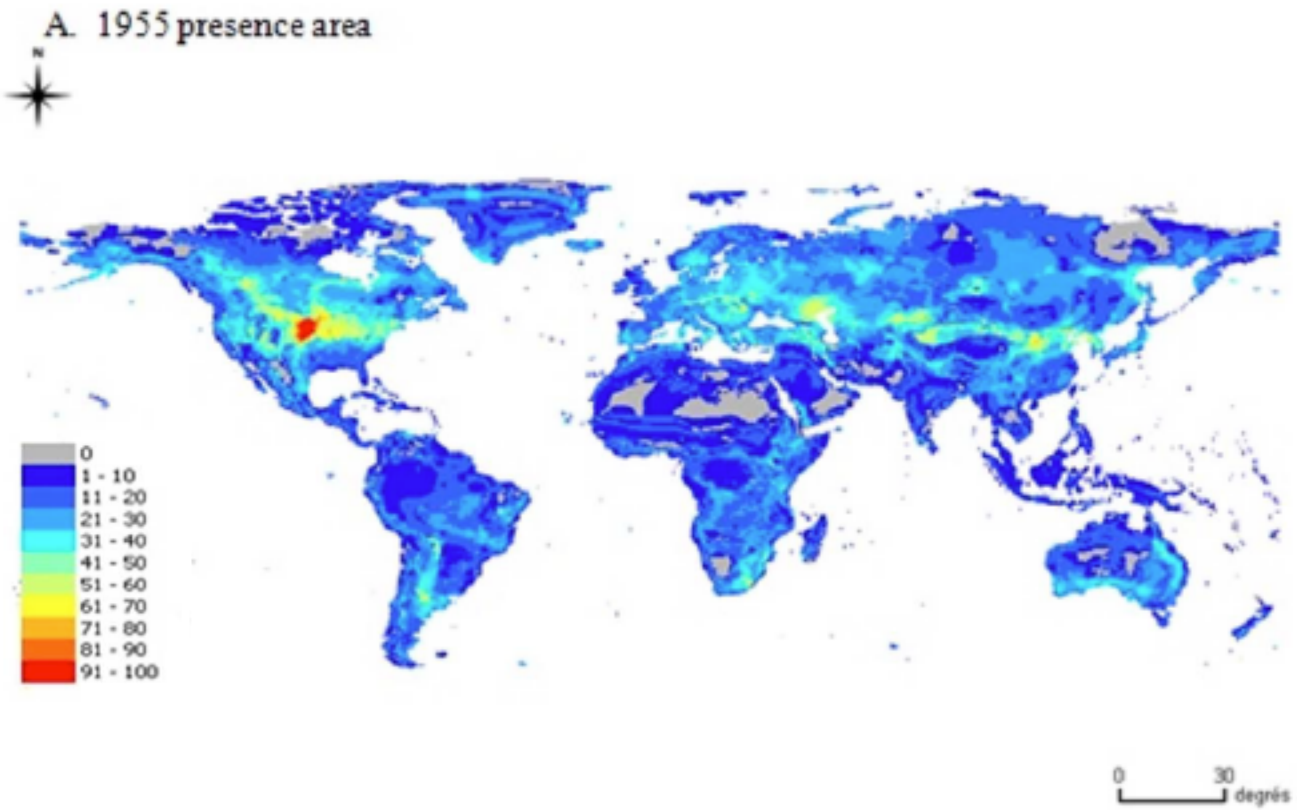
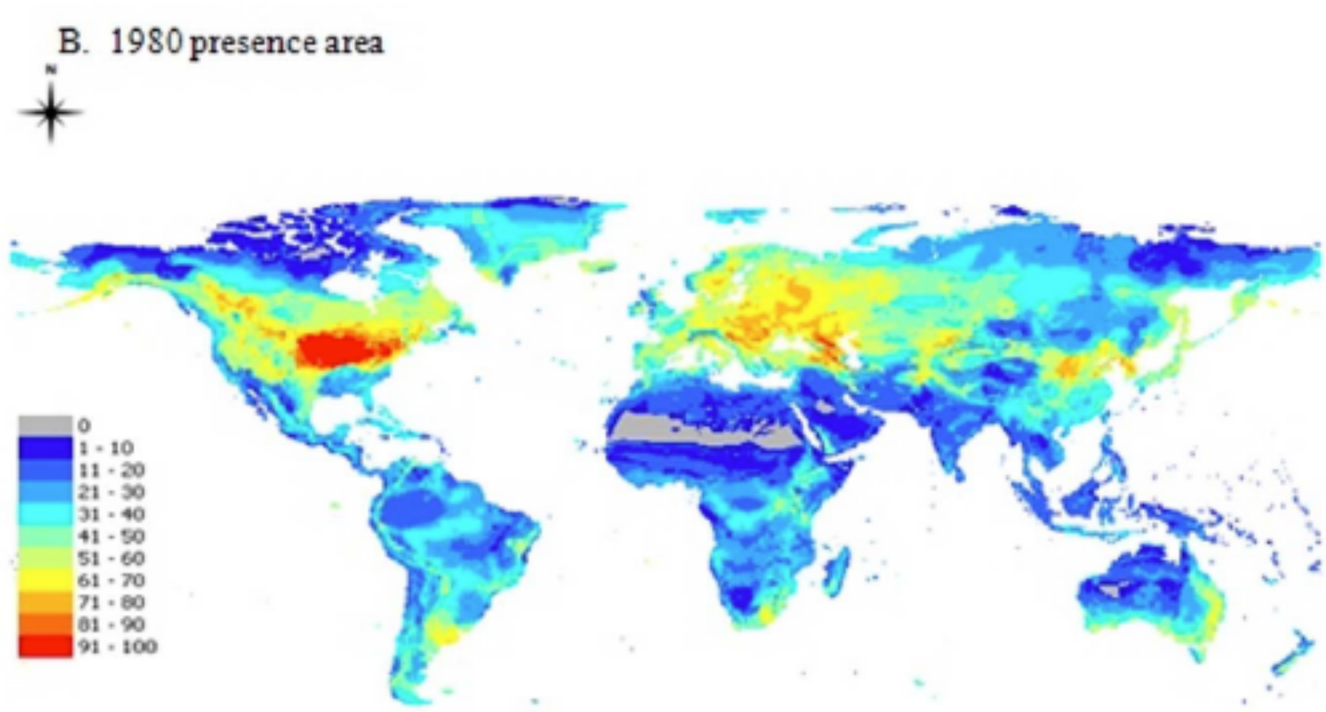
Restart
About Us
Total number of placed chips = 28
Log Normal distribution : μ = 3.860918; σ = 0.2698408;
Elicitation Options
Ranges
Lower Limit 14
Upper Limit 90
Fitting & Feedback
Distribution
Normal
Student-t
Scaled Beta
Gamma
Log Normal
Log Student-t
Auto-select best fit
Feedback Percentiles
33 rd percentile = 42.2
66 th percentile = 53.1

Probability of establishment of *Diabrotica virgifera virgifera*
Model ES fitted to 1955 presence data



Probability of establishment of *Diabrotica virgifera virgifera*
Model ES fitted to 1980 presence data



Major problems related to the use of quantitative models

- Model choice
- Parameter estimation
- Transparency of complex models
- Uncertainty of the model outputs

Analysis of uncertainty

Ten Most Important Accomplishments in Risk Analysis, 1980–2010

Michael Greenberg, Charles Haas, Anthony Cox, Jr., Karen Lowrie, Katherine McComas, and Warner North

As part of the celebration of the 30th anniversary of the Society for Risk Analysis and *Risk Analysis, An International Journal*, a group of your editors engaged in a process to select the 10 most important accomplishments in risk analysis. The article that follows is the product of this process.

Some preliminary decisions were that we would reach out to the full membership for nominations, focus on the period 1980 to 2010, and accept nominations for contributions to theory, methods, and applications. Also, we focused on accomplishments that address health, safety, and the environment, which has been our tradition.(1) All the accomplishments have contributed to answering at least one of the six following risk analysis questions:(2–5)

1. What can go wrong?
2. What are the chances that something with serious consequences will go wrong?
3. What are the consequences if something does go wrong?

TEN MOST IMPORTANT ACCOMPLISHMENTS IN RISK ANALYSIS, 1980–2010

Theory

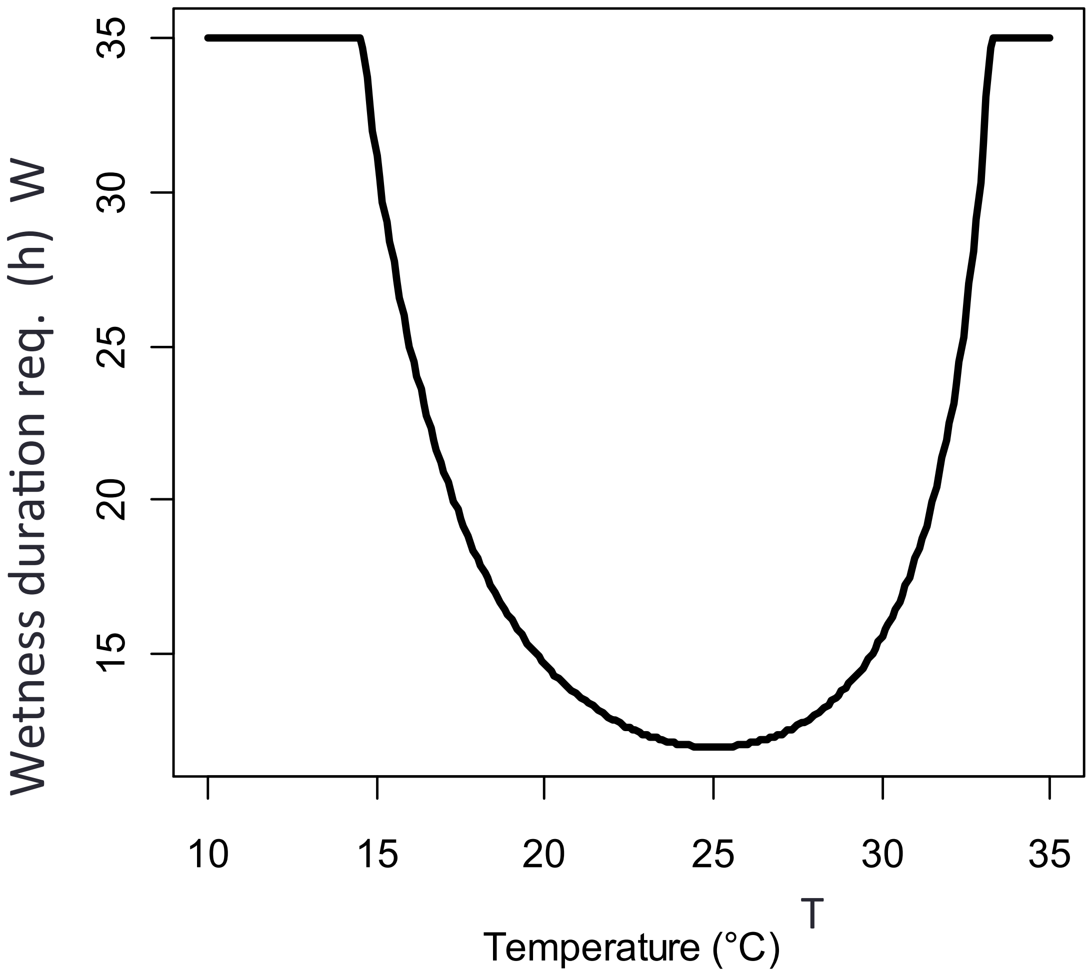
1. Understanding how affect and trust influence risk perception and behavior
2. Recognizing that personal decisions reflect different processes for valuing and combining anticipated and actual losses, gains, delays, and surprises.
3. Developing an environmental justice ethic and frameworks

Methods

4. Using formal uncertainty analysis in risk assessment

Parameter values estimated for pycnidiospores of *Guignardia citricarpa* Kiely , and associated response of *W* to temperature (from EFSA, 2008)

T_{min}= 10 °C, T_{opt}= 25 °C, T_{max}=35 °C, W_{min}=12 h, W_{max}= 35 h



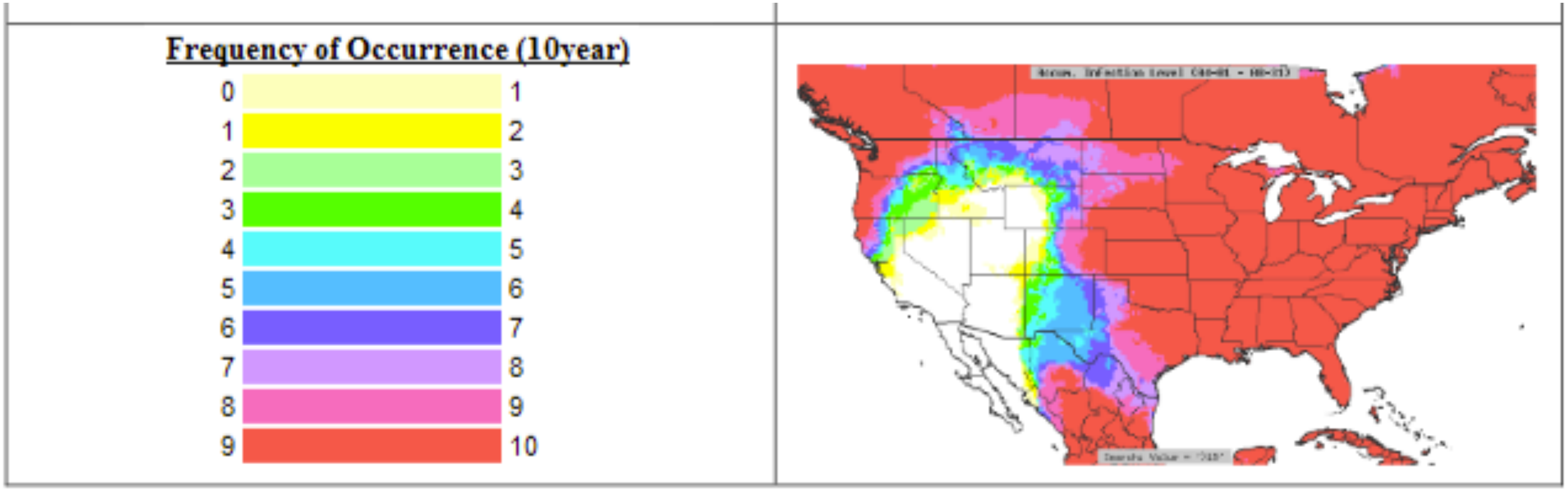


Figure 3B. The probability of more than 15 days suitable for *Guignardia citricapia* pycnidiopsoric infection by continent. (Legend lower left).

Uncertainty about the model parameters

Guignardia citricarpa Kiely

		Min	Max
T_{min}	(°C)	10	15
T_{max}	(°C)	32	35
T_{opt}	(°C)	25	30
W_{min}	(h)	12	14
W_{max}	(h)	35	48

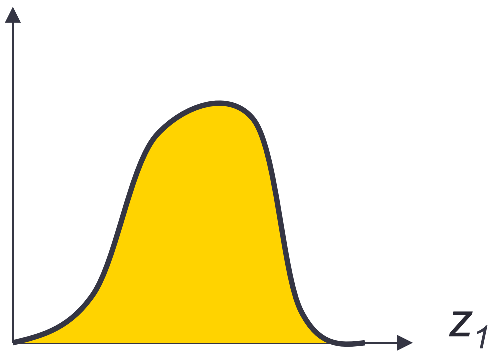
Panel on Plant Health, from EFSA (2008)

Uncertainty analysis

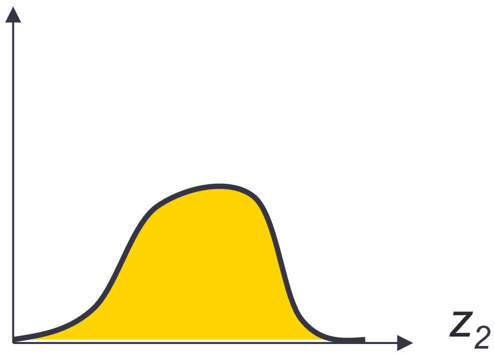
Its purpose is to answer the following question:

« What is the uncertainty about *y*(*z*) resulting from the uncertainty about *z* ? »

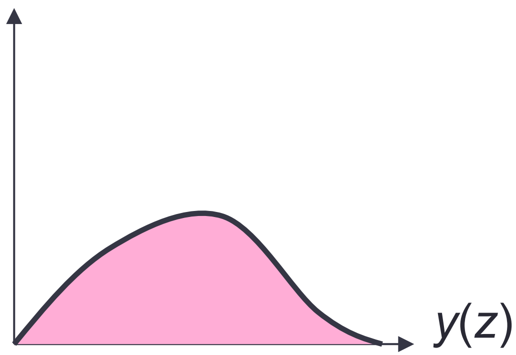
We have



and



We want to compute



How to choose between qualitative and quantitative approaches?

- Advantages and disadvantages of each approach for the assessor, decision makers and stakeholders.
- How to assess the accuracy of different pest risk assessment methods?

Qualitative approaches

- Easy to understand.

- A qualitative PRA can be done quickly.

- Problems of consistency due to
  - inaccurate definitions of ratings,
  - methods used for combining scores.

- Explicit definitions needed.

- Training workshops could be organized to improve the consistency of the assessments made by experts.

- Another option: provide evidences only (no ranking).

Quantitative approaches

- Time and resources can be problematic.
- Model choice is difficult
- Complex models are not transparent
- Data not sufficient. Expert knowledge often required for estimating parameters.
- Uncertainty can be taken into account using probability distributions.
- Models can be used to combine probability of entry and probability of establishment.