CentraleSupelec
Séminaire UQSay #08

The role of uncertainty analysis to assess risk of biological invasion

David Makowski
INRAE
david.makowski@inrae.fr

Risk of biological invasion

Risk that an harmful organism present in an area A **enters**, **establish** and **spread** in an area B (where the organism is absent) and has some negative **impacts**.


Autriche
Hongrie
France
Suisse
Slovénie
Croatie
Golfe de Gascogne
Monaco
Italie
Andorre
Portugal
Espagne
Mer
Tyrrhénienne
Gibraltar
Olive tree


Xylella fastidiosa
Olive tree
France
Autriche
Suisse
Monaco
Italie
Andorre
Portugal
Espagne
Gibraltar
Golfe de Gascogne
Mer
Tyrrhénienne


Xylella fastidiosa
France
Autriche
Suisse
Golfe de Gascogne
RISK?
Monaco
Italie
Andorre
Mer
Tyrrhénienne
Gibraltar
Olive tree

Many sources of uncertainty in biological invasion risk assessment

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 assessment 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

Fusarium oxysporum f. sp. Cubense
An invasive species with potentially high impact on bananas

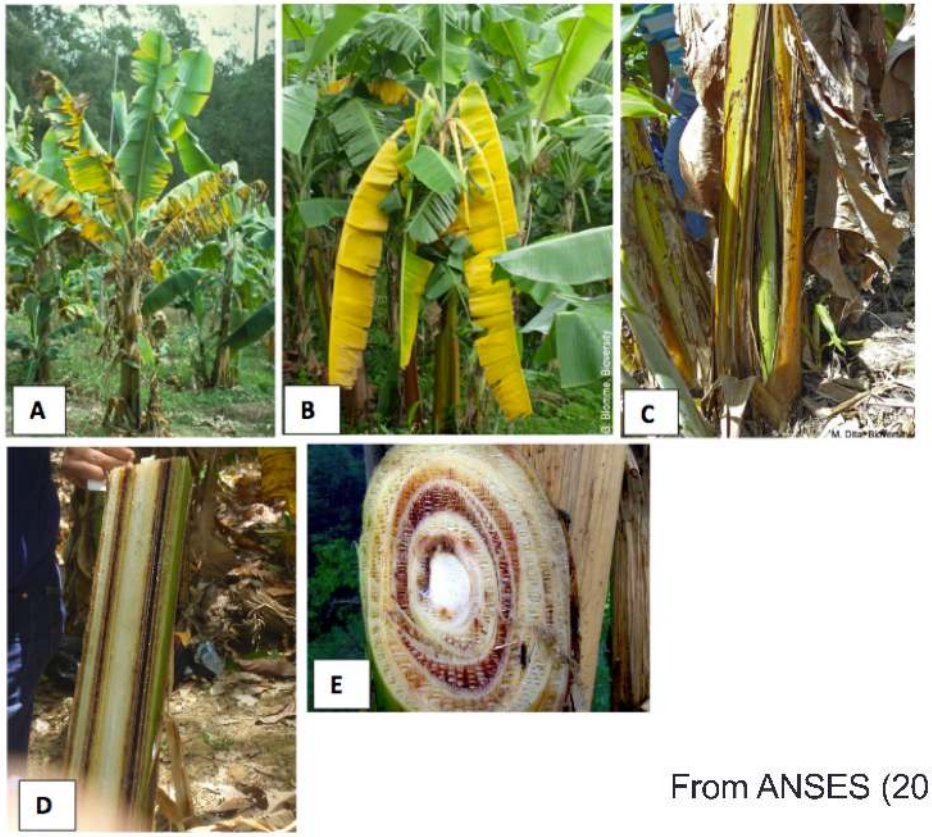
Fusarium

↓

Soil

↘ ↗

Roots



From ANSES (2018)

Photos A et C, Altus Viljoen ; Photos D et E, Yolande Chilin-Charles ; Photo B, Guy Blomme (Bioversity)

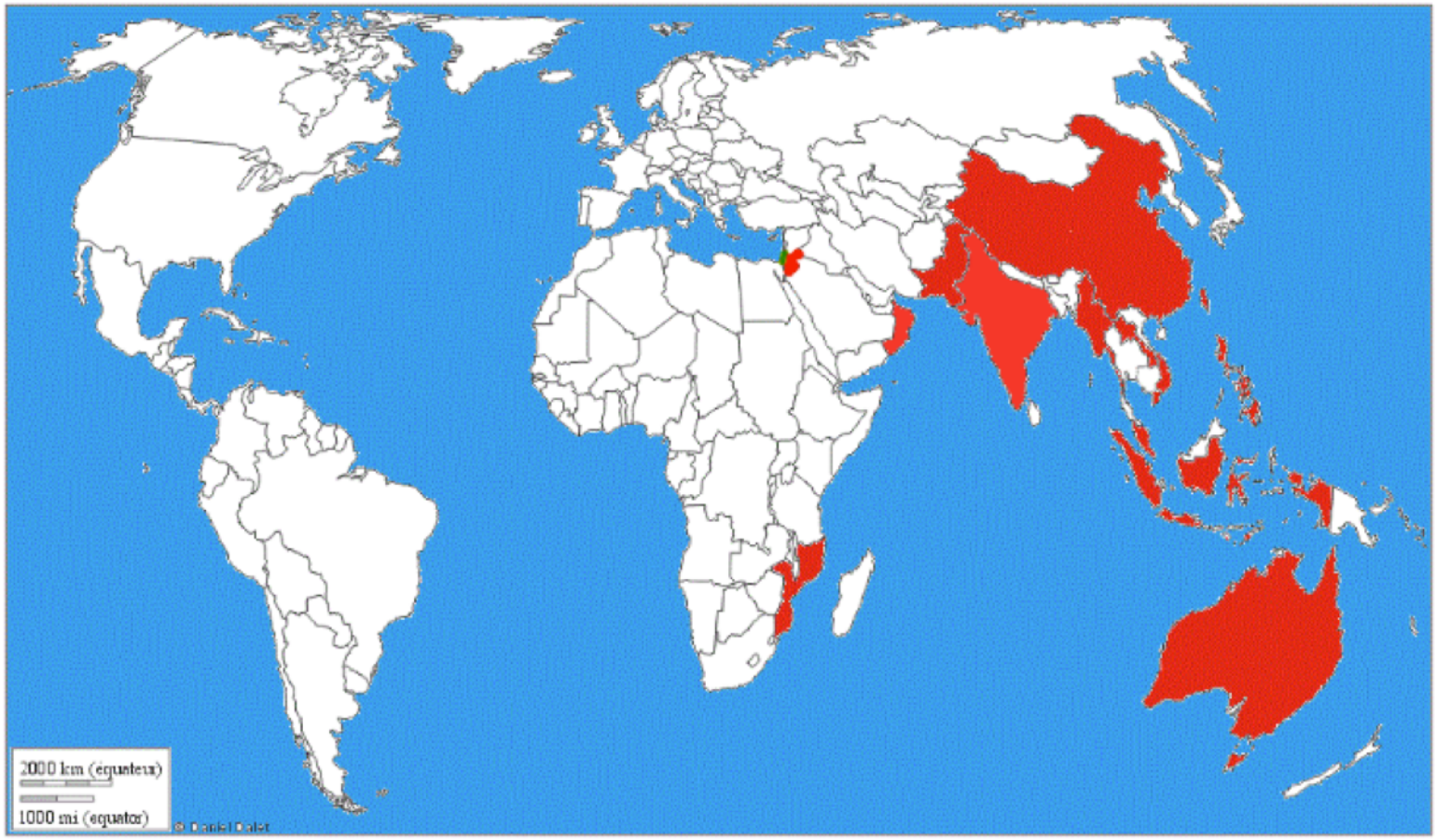
Fusarium oxysporum f. sp. Cubense
An invasive species with potentially high impact on bananas

Race TR4 is very harmful

« TR4 is decimating Cavendish monocultures [the main banana cultivar] in southern Asia and would affect 85% of global production were it disseminated more widely. »

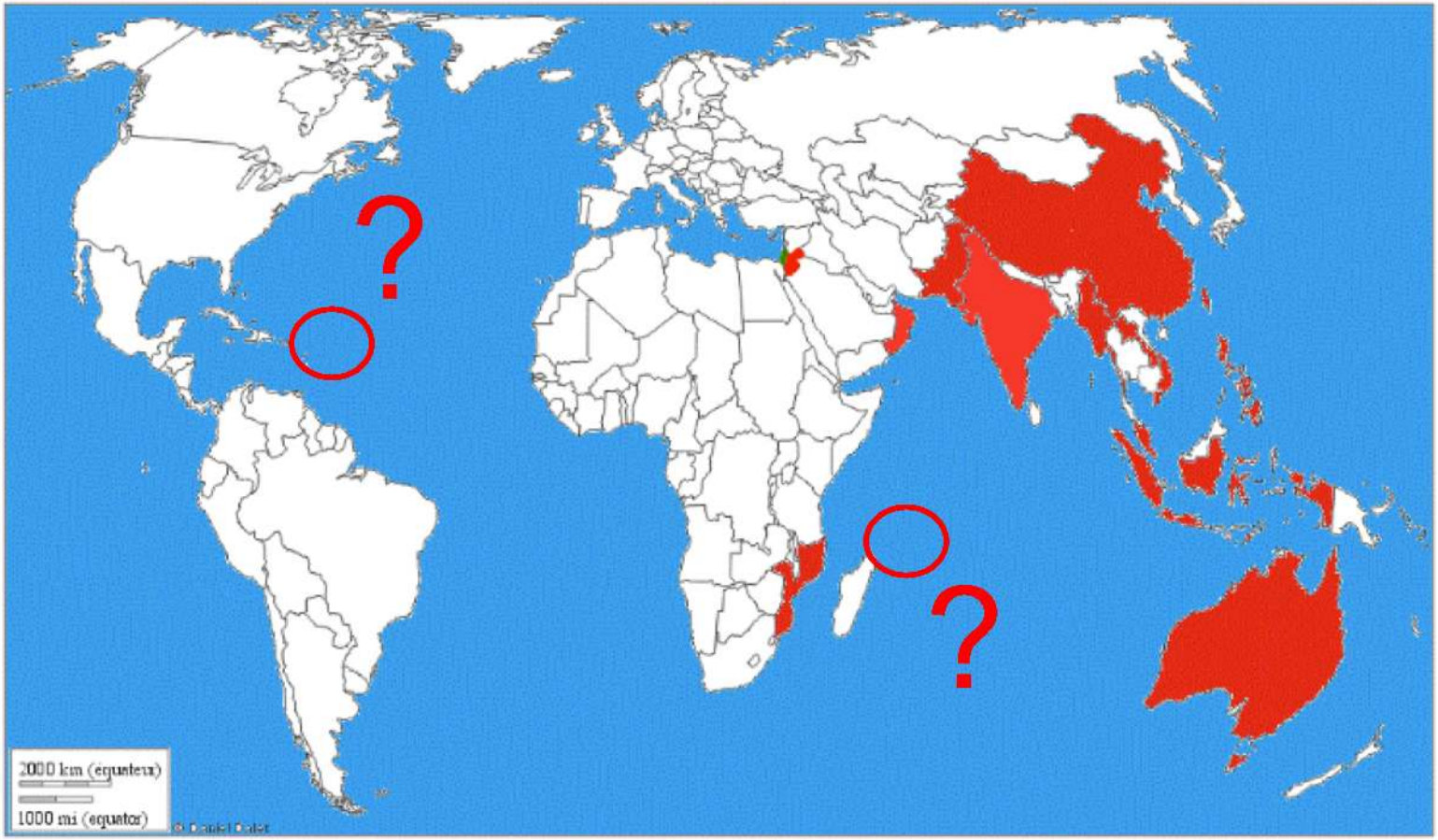
Ploetz and Chruchill (2011) 10.17660/ActaHortic.2011.897.73

Fusarium oxysporum f. sp. Cubense
An invasive species with potentially high impact on bananas



Presence of **race TR4** (from ANSES, 2018)

What is the level of risk for the French oversea departements?



anses
agence nationale de sécurité sanitaire
alimentation, environnement, travail

Connaître, évaluer, protéger

Risque phytosanitaire portant sur *Fusarium oxysporum f. sp. cubense* pour les départements d'outre-mer

Avis de l'Anses
Rapport d'expertise collective

Août 2018 | Édition scientifique

Entry

Establishment

Spread

Impact

Entry

Pathways from the origins (soil, vitroplants, tourisms etc.)
Incidence of the pathogen where it is present
Methods of control

Establishment

Spread

Impact

Entry

Establishment

Climatic conditions
Vectors
Detection techniques
Speed of dissemination
…

Spread

Impact

Entry

Establishment

Spread

Impact

Disease control efficacy
Prices
Sociological conditions
Sensitivity of cultivars…

Entry

Establishment

Spread

Impact

Many sources of uncertainties !

Different attitudes towards uncertainty

- Ignore it
- Qualitative uncertainty analysis
- Quantitative uncertainty analysis

Different attitudes towards uncertainty

- **Ignore it**
- Qualitative uncertainty analysis
- Quantitative uncertainty analysis

« Ignore it »
An untenable position for scientists

Kuhn (1962) : « *the discovery begins with the awareness of an anomaly* »

Anne Fagot-Largeault : the researcher's ethics are based on « respect for the facts and lucidity on the degree of validity of the results ».

EFSA (2016) : « *assessors need to inform decision-makers about scientific uncertainty when providing their advice* »

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 [illegible]?

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

anses
agence nationale de sécurité sanitaire
alimentation, environnement, travail

Prise en compte de l'incertitude en évaluation des risques : Revue de la littérature et recommandations pour l'Anses

Rapport d'étape

Saisine n°2015-SA-0090

EFSA Journal

SCIENTIFIC OPINION

Guidance on Uncertainty in EFSA Scientific Assessment

EFSA Scientific Committee[1, 2]

European Food Safety Authority (EFSA), Parma, Italy

anses
agence nationale de sécurité sanitaire
alimentation, environnement, travail

Prise en compte de l'incertitude en évaluation des risques : Revue de la littérature et recommandations pour l'Anses

Rapport d'étape

Saisine n°2015-SA-0090

EFSA Journal

SCIENTIFIC OPINION

Guidance on Uncertainty in EFSA Scientific Assessment

EFSA Scientific Committee[1, 2]

European Food Safety Authority (EFSA), Parma, Italy

Different attitudes towards uncertainty

- Ignore it
- Qualitative uncertainty analysis
- Quantitative uncertainty analysis

Different attitudes towards uncertainty

- Ignore it
- **Qualitative uncertainty analysis**
- Quantitative uncertainty analysis

anses
agence nationale de sécurité sanitaire
alimentation, environnement, travail

Connaître, évaluer, protéger

Risque phytosanitaire portant sur *Fusarium oxysporum f. sp. cubense* pour les départements d'outre-mer

Avis de l'Anses
Rapport d'expertise collective

Août 2018 | Édition scientifique

Item	Risk level	Uncertainty
Entry	Very likely	Moderate
Establishment	Very likely	Low
Spread	High	Low
Impact	Very high	Low

from ANSES (2018)

Item	Risk level	Uncertainty
Entry	Very likely	Moderate
Establishment	Very likely	Low
Spread	High	Low
Impact	Very high	Low

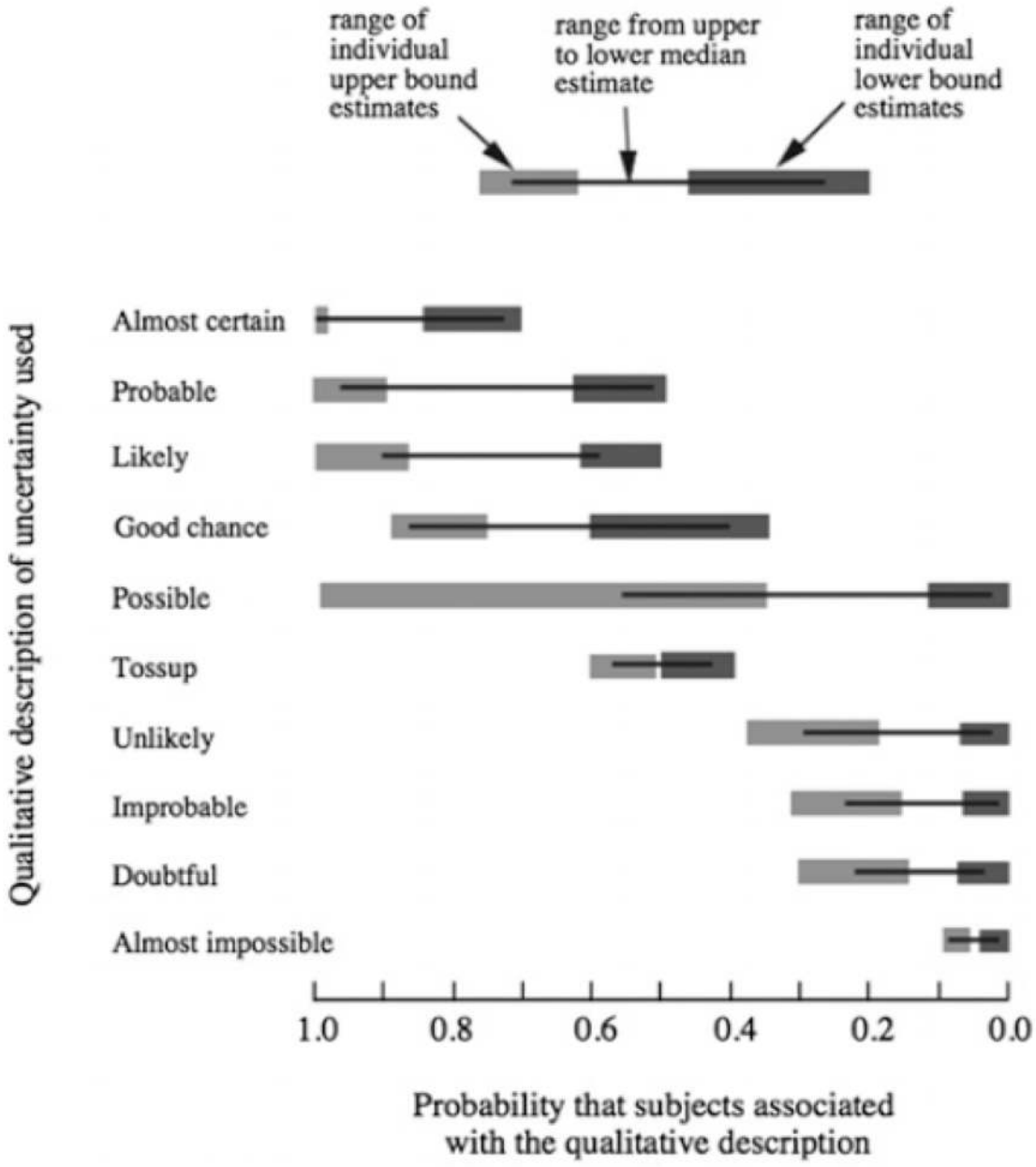
	Risk level	Uncertainty
Natural spread by insects	Very low	Low
Natural spread by water	Moderate	Low
Natural spread by soil	Low	High
Human spread by soil (intentional)	Moderate	High
Human spread by plants	High	Low
Human spread by irrigation	High	Low

from ANSES (2018)

« Qualitative Uncertainty Words Are Not Sufficient »

Morgan (2014)

Different experts have different interpretations of qualitative ratings



from Morgan (2014)

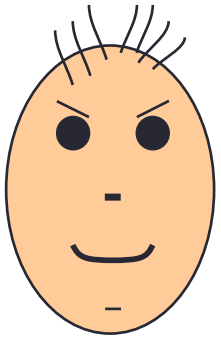
How to make expert-based uncertainty analysis more reliable?

Probabilistic expert elicitation

- Elicitation consists in carrying out a **synthesis of the knowledge of an expert (or a group of experts)** on a quantity of interest for which there is an uncertainty due to a lack of available data.

- The result of an elicitation is in the form of a **probability distribution** reflecting the **expert's knowledge** and level of **uncertainty**.

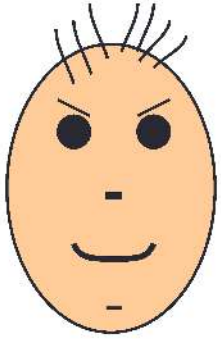
What is the probability of entry?



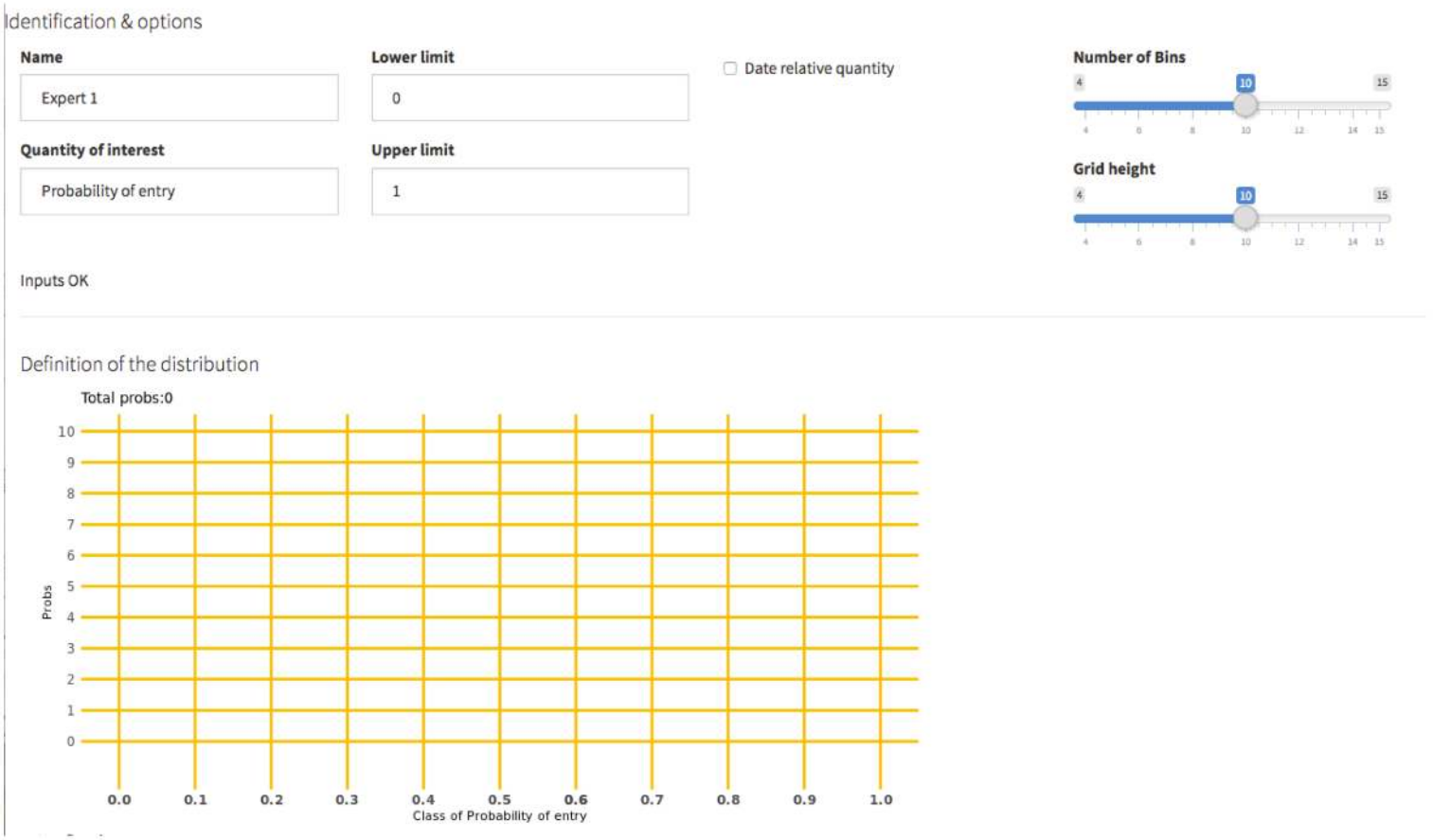
Expert 1

https://licite.fr/licite/

What is the probability of entry?

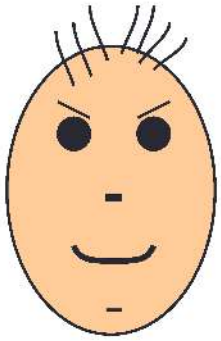


Expert 1



https://licite.fr/licite/

What is the probability of entry?



Expert 1

Identification & options

Name: Expert 1

Lower limit: 0

Date relative quantity

Quantity of interest: Probability of entry

Upper limit: 1

Inputs OK

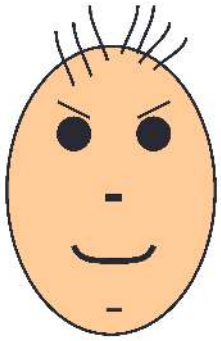
Number of Bins

Grid height

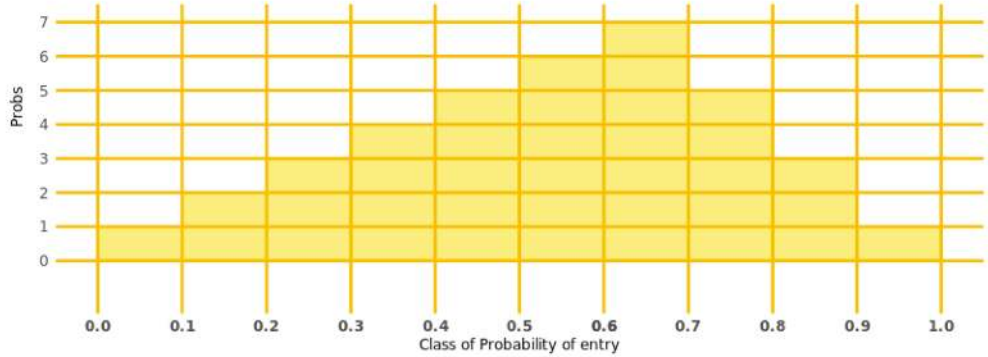
Definition of the distribution

https://licite.fr/licite/

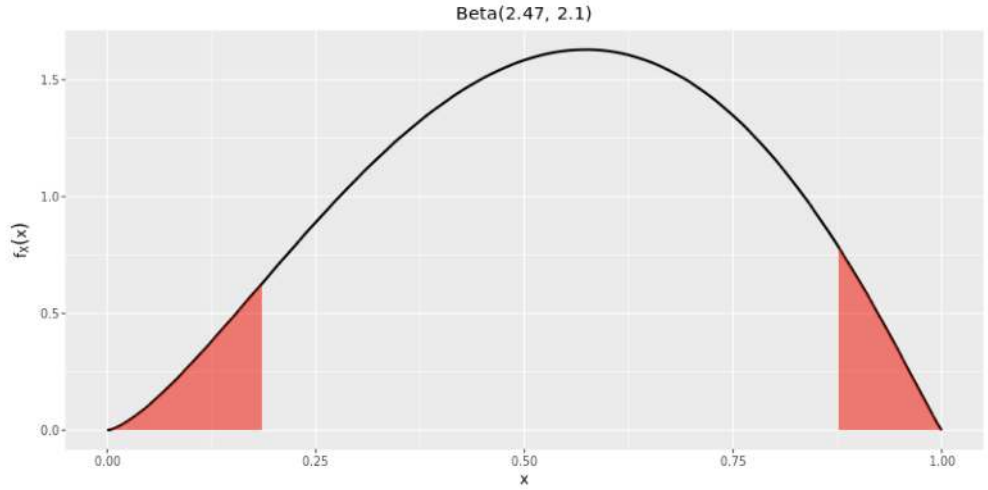
What is the probability of entry?



Expert 1



Fitted



Fitting

- ○ Normal
- ○ Student t
- ○ Gamma
- ○ Log normal
- ○ Log Student t
- ○ Beta
- ◉ Best fitting
- ○ Hist

☑ Show fit

☑ Spread end probs over empty bins

lower feedback quantile

0,05

upper feedback quantile

0,95

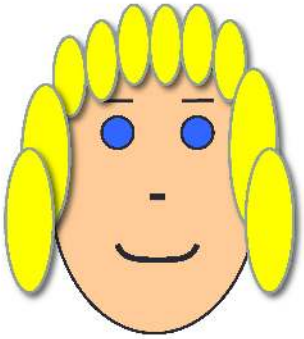
Save elicitation in a file

Quantile values for each distribution law

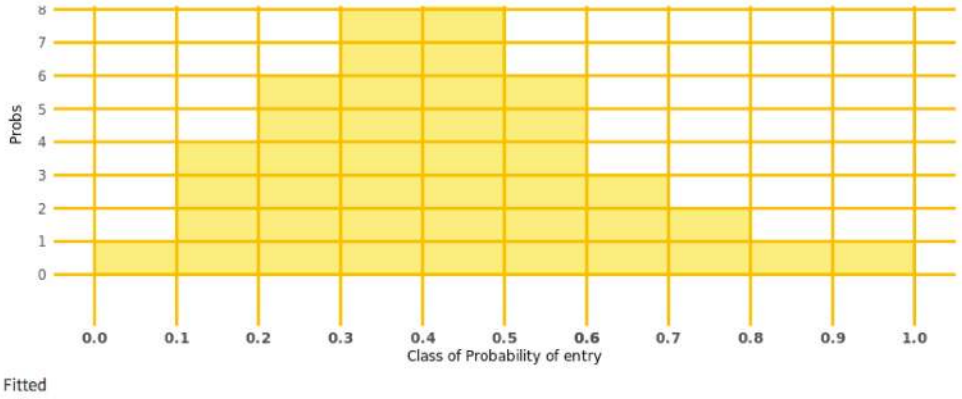
	Normal	Student-t	Gamma	Log normal	Log Student-t	Beta
0.05	0.17	0.11	0.24	0.26	0.23	0.18
0.95	0.92	0.99	0.99	1.04	1.20	0.88

https://licite.fr/licite/

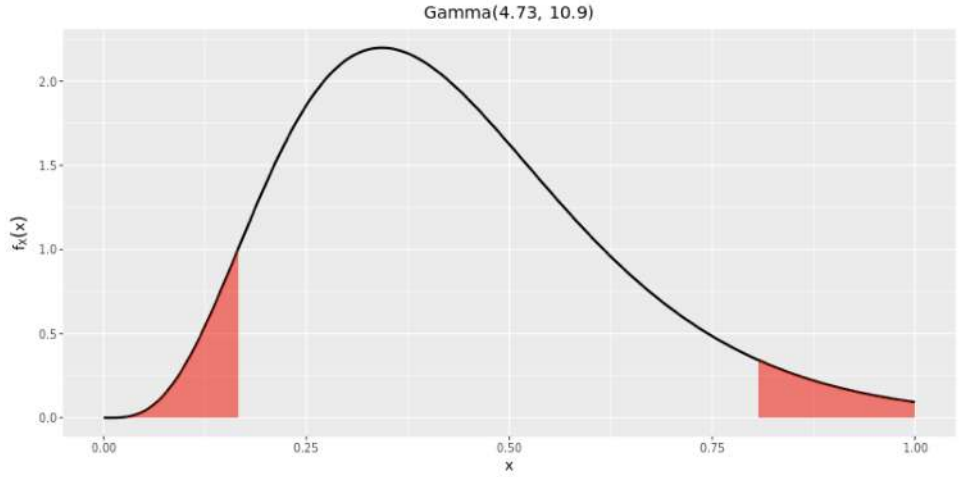
What is the probability of entry?



Expert 2



Fitted



Fitting

- Normal
- Student t
- Gamma
- Log normal
- Log Student t
- Beta
- Best fitting
- Hist

- Show fit
- Spread end probs over empty bins

lower feedback quantile

0,05

upper feedback quantile

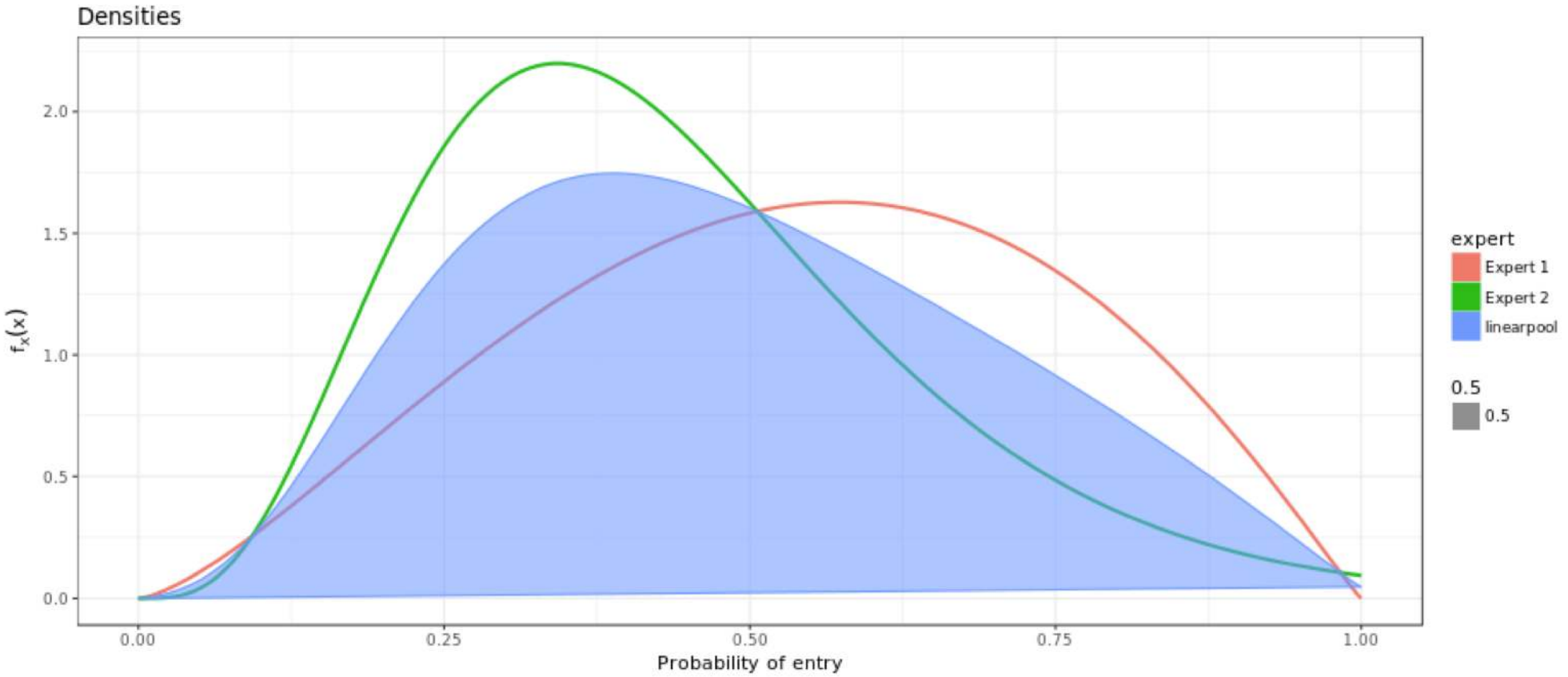
0,95

Save elicitation in a file

Quantile values for each distribution law

	Normal	Student-t	Gamma	Log normal	Log Student-t	Beta
0.05	0.10	0.05	0.17	0.19	0.17	0.14
0.95	0.73	0.79	0.81	0.85	0.96	0.74

https://licite.fr/licite/



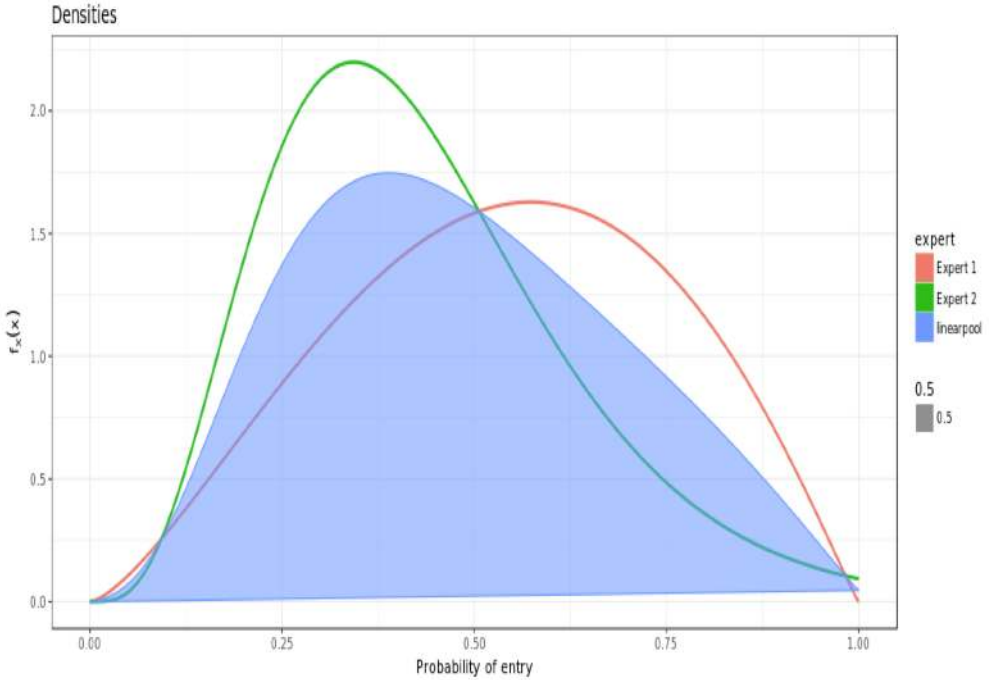
Linearpool : mean = 0.48, variance = 0.04

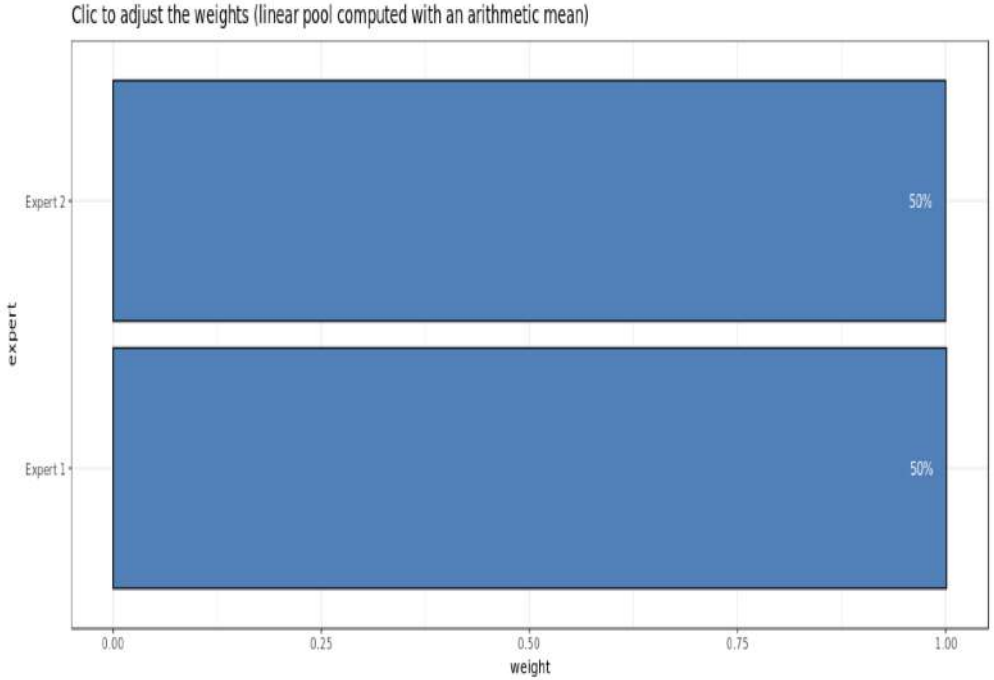
Define x	$P(X \leq x)$	Define $q = P(X \leq x_q)$	quantile x_q
0.5	0.55	0.5	0.47

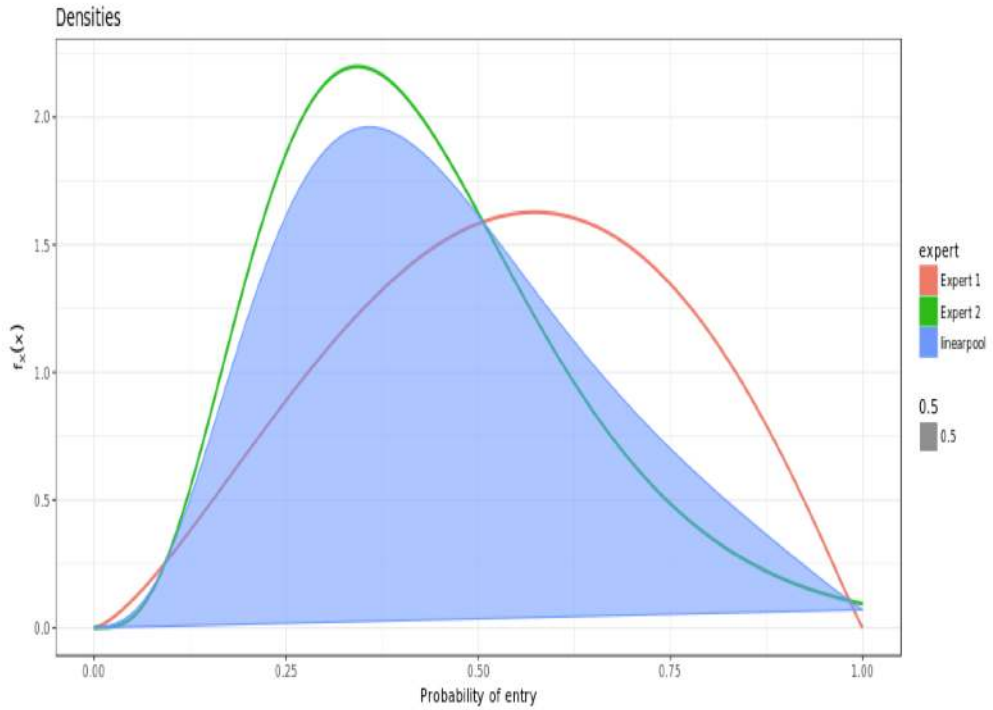
Densities

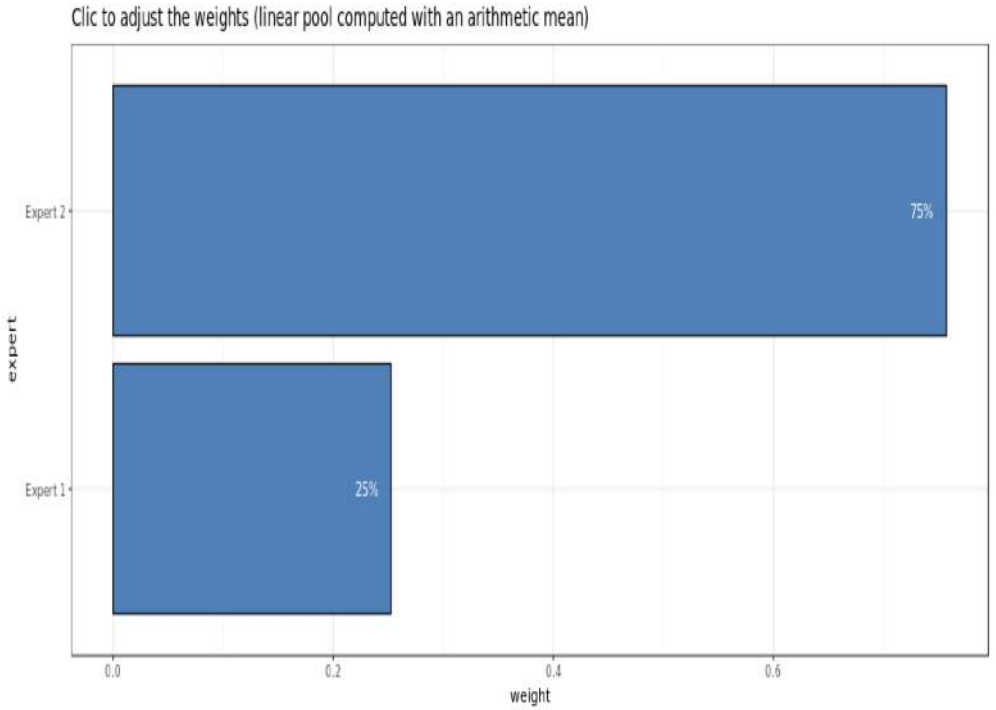
Linearpool sample (1e+05)

https://licite.fr/licite/


Densities
2.0
1.5
1.0
0.5
0.0
$f_x(x)$
0.00
0.25
0.50
0.75
1.00
Probability of entry
expert
Expert 1
Expert 2
linearpool
0.5
0.5


Clic to adjust the weights (linear pool computed with an arithmetic mean)
Expert 2
Expert 1
50%
50%
expert
0.00
0.25
0.50
0.75
1.00
weight


Densities
2.0
1.5
1.0
0.5
0.0
$f_x(x)$
0.00
0.25
0.50
0.75
1.00
Probability of entry
expert
Expert 1
Expert 2
linearpool
0.5
0.5


Clic to adjust the weights (linear pool computed with an arithmetic mean)
Expert 2
Expert 1
expert
75%
25%
0.0
0.2
0.4
0.6
weight

Different attitudes towards uncertainty

- Ignore it
- Qualitative uncertainty analysis
- **Quantitative uncertainty analysis**

Probabilistic uncertainty analysis

i. Identification of uncertainty sources

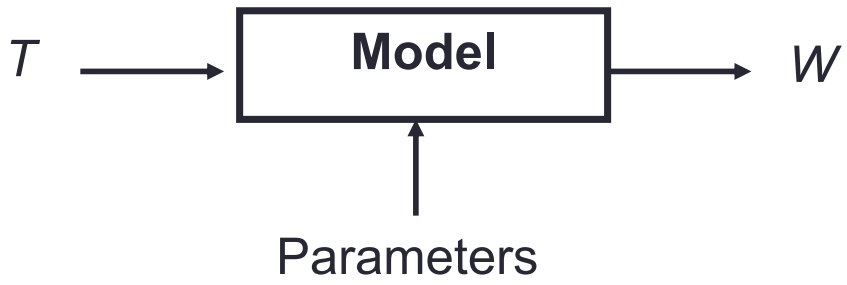
ii. Description of uncertainties using probability distributions

iii. Propagation of uncertainties through **a quantitative model** to obtain the distribution of the output of interest

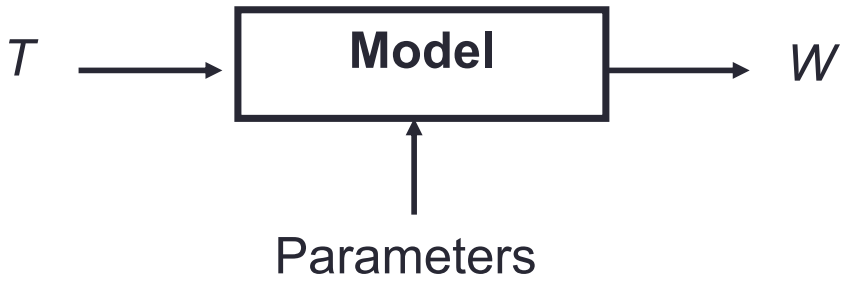
iv. Communication of results

Model computing the wetness duration requested for fungal infection

(Magarey *et al.*, 2005)



W = requested wetness duration (h)
T = man air temperature (° C)



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

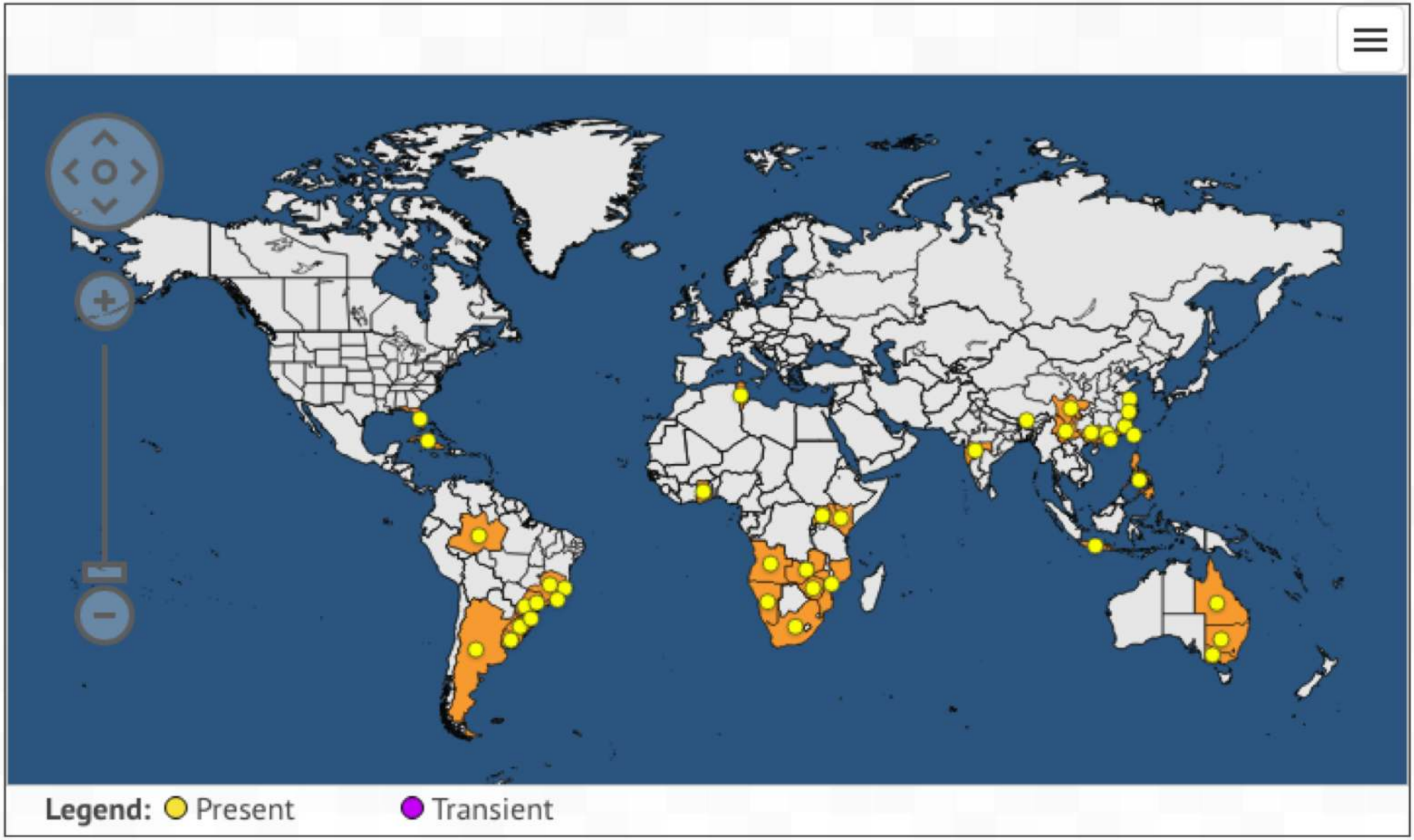
$$f(T) = \left(\frac{T_{\max} - T}{T_{\max} - T_{opt}} \right) \left(\frac{T - T_{\min}}{T_{opt} - T_{\min}} \right)^{\left(T_{opt} - T_{\min}\right) / \left(T_{\max} - T_{opt}\right)}$$

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

Citrus black spot
Phyllosticta citricarpa

Distribution

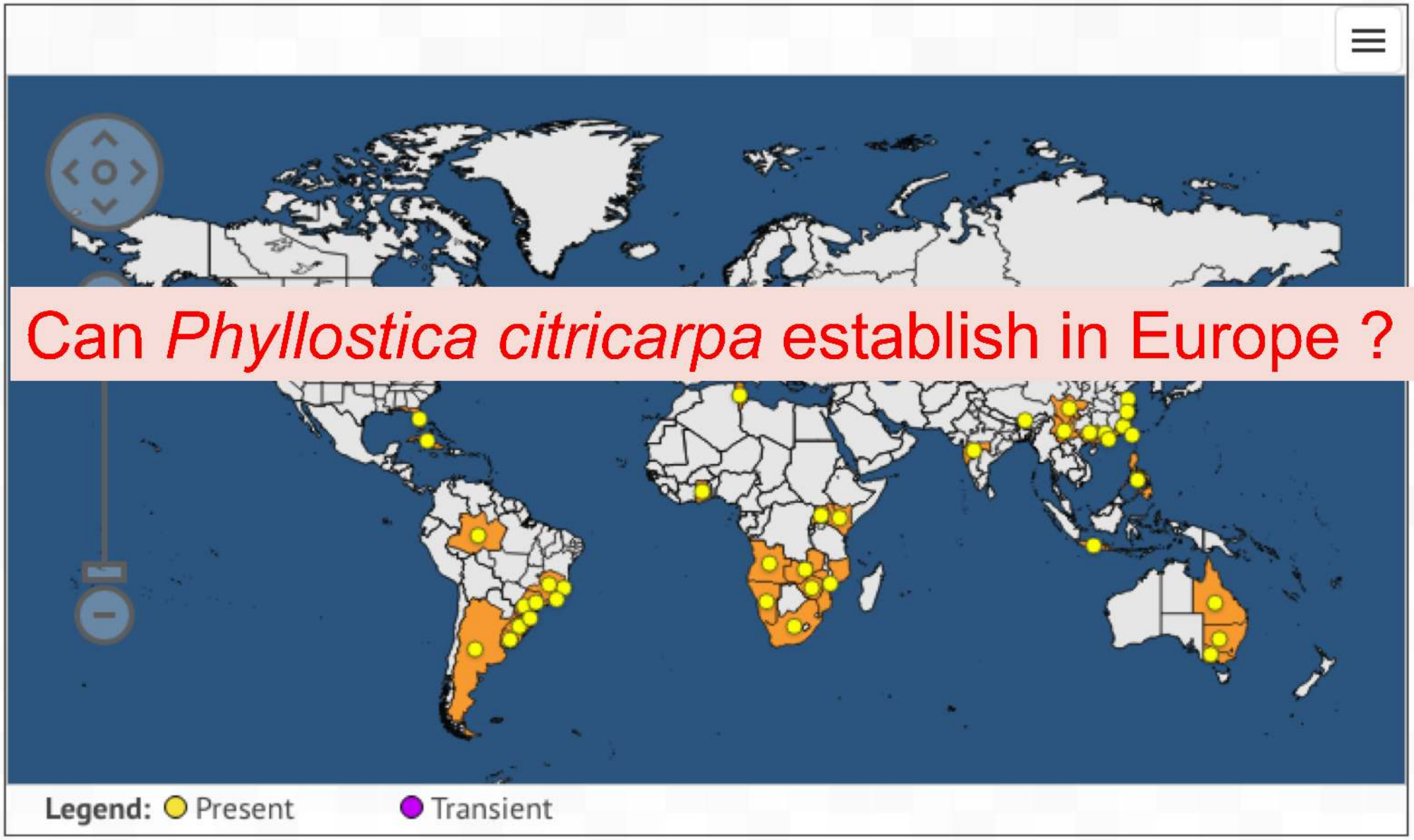
Last updated: 2020-01-24



https://gd.eppo.int/taxon/GUIGCI/distribution

Distribution

Last updated: 2020-01-24



Can *Phyllostica citricarpa* establish in Europe ?

https://gd.eppo.int/taxon/GUIGCI/distribution

European Food Safety Authority

EFSA Journal 2014;12(2):3557

SCIENTIFIC OPINION

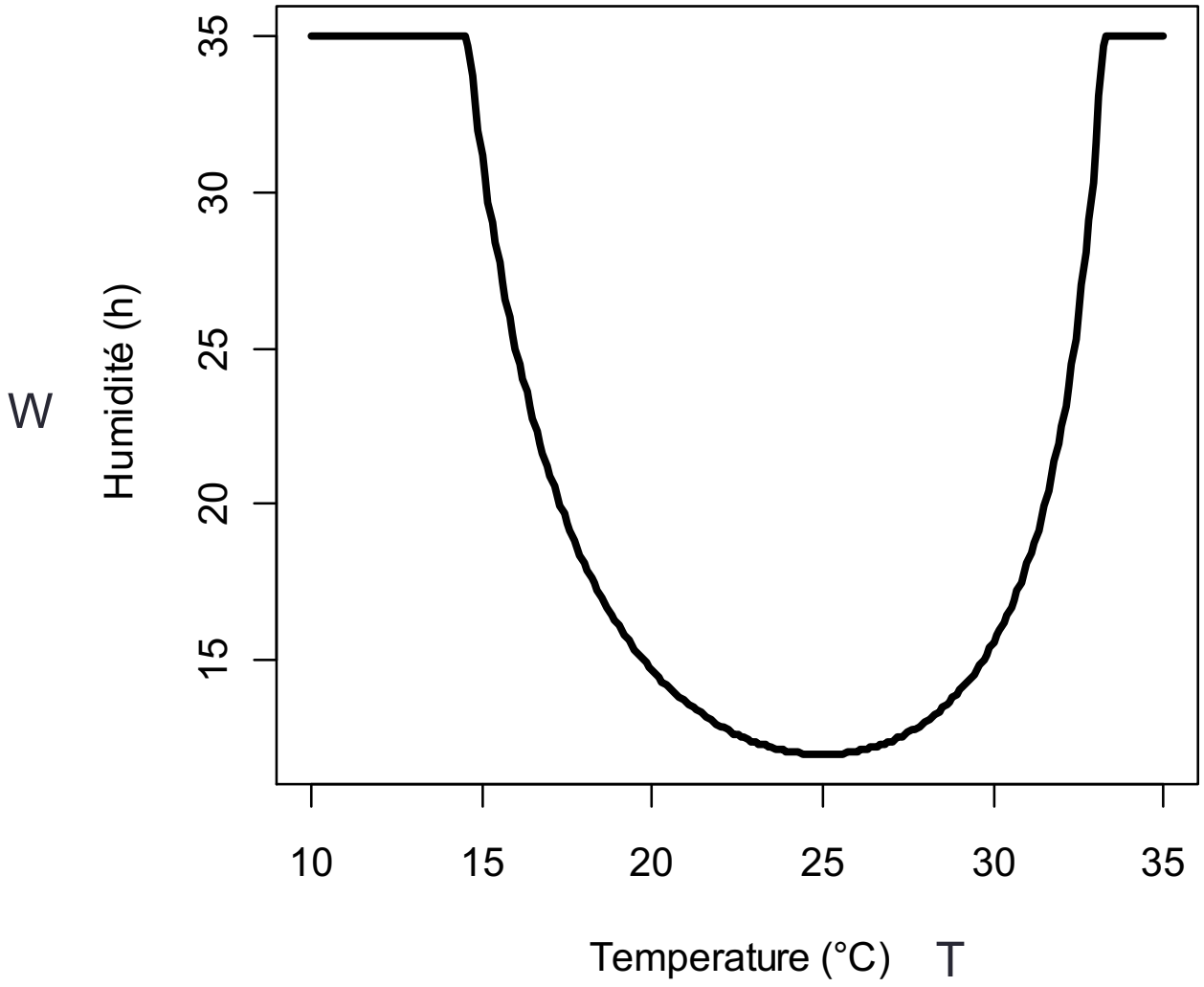
Scientific Opinion on the risk of *Phyllosticta citricarpa* (*Guignardia citricarpa*) for the EU territory with identification and evaluation of risk reduction options[1]

EFSA Panel on Plant Health (PLH) [2,3]

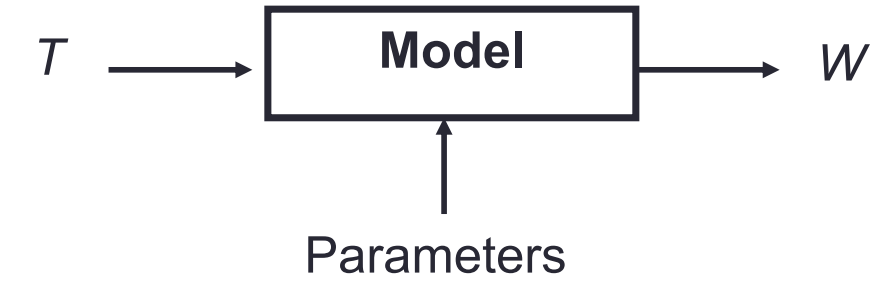
European Food Safety Authority (EFSA), Parma, Italy

Simulated values of W with estimated parameter values for pycnidiospores of *Phyllosticta citricarpa*

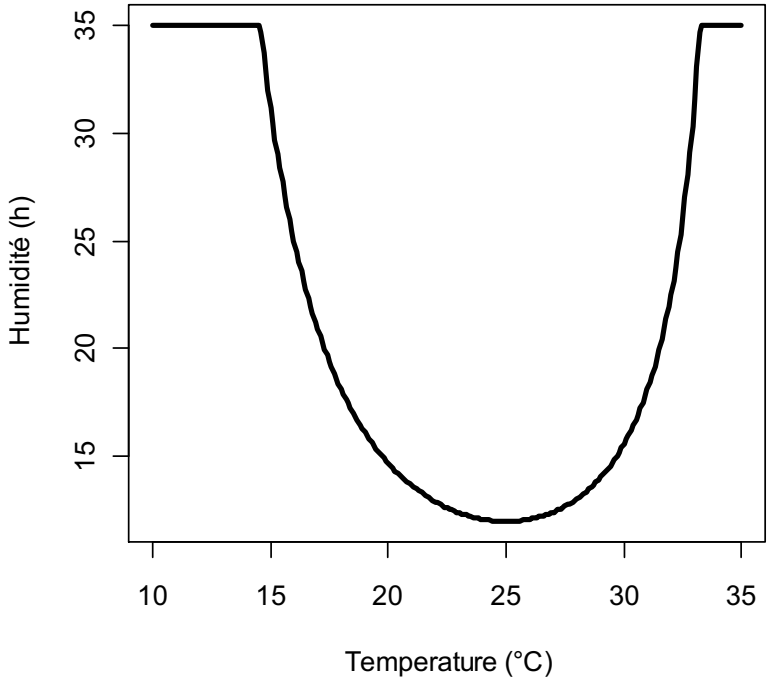
Tmin= 10 • C, Topt= 25 • C, Tmax=35 • C, Wmin=12 h, Wmax= 35 h

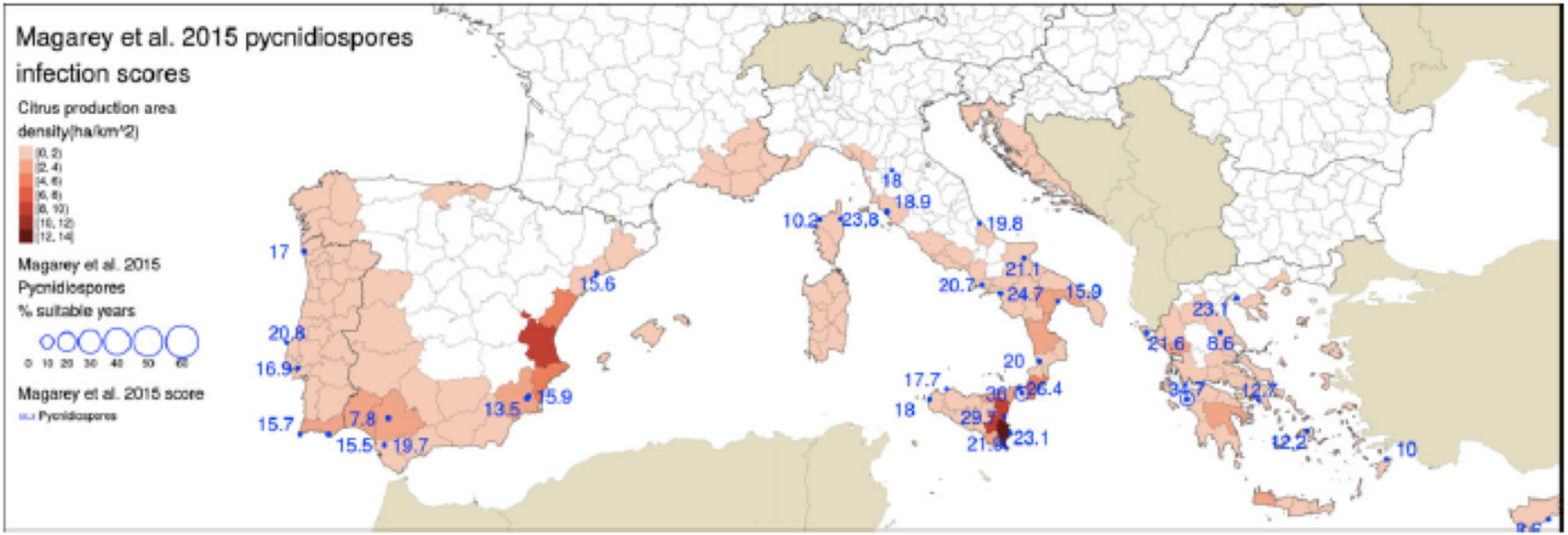


10° C < T < 35° C



Tmin= 10 ° C, Topt= 25 ° C,
Tmax=35 ° C, Wmin=12 h, Wmax= 35 h





Densité d’agrumes en Europe et proportions d’années favorables aux infections

https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2014.3557

Probabilistic uncertainty analysis

i. Identification of uncertainty sources

ii. Description of uncertainties using probability distributions

iii. Propagation of uncertainties through **a quantitative model** to obtain the distribution of the output of interest

iv. Communication of results

Probabilistic uncertainty analysis

i. **Identification of uncertainty sources**
   - **Parameters**
   - **Input variables**
   - **Equations**

ii. Description of uncertainties using probability distributions

iii. Propagation of uncertainties through **a quantitative model** to obtain the distribution of the output of interest

iv. Communication of results

Incertainties in parameter values

Ranges of parameter values defined by the experts of the « Panel on Plant Health EFSA » (2008)

		Min	Max
Tmin	(° C)	10	15
Topt	(° C)	25	30
Tmax	(° C)	32	35
Wmin	(h)	12	14
Wmax	(h)	35	48

Probabilistic uncertainty analysis

i. Identification of uncertainty sources

ii. Description of uncertainties using probability distributions

iii. Propagation of uncertainties through **a quantitative model** to obtain the distribution of the output of interest

iv. Communication of results

Probabilistic uncertainty analysis

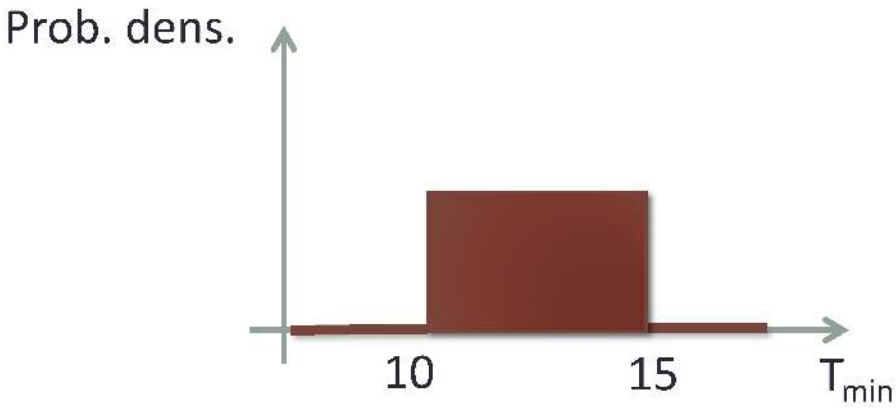
i. Identification of uncertainty sources

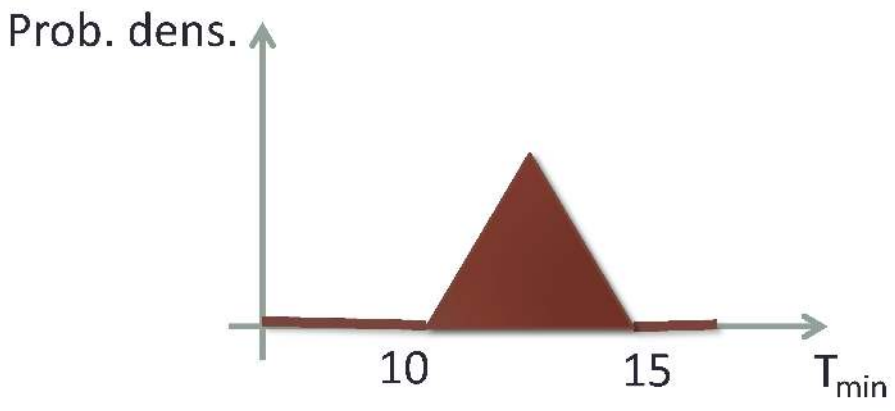
ii. **Description of uncertainties using probability distributions**

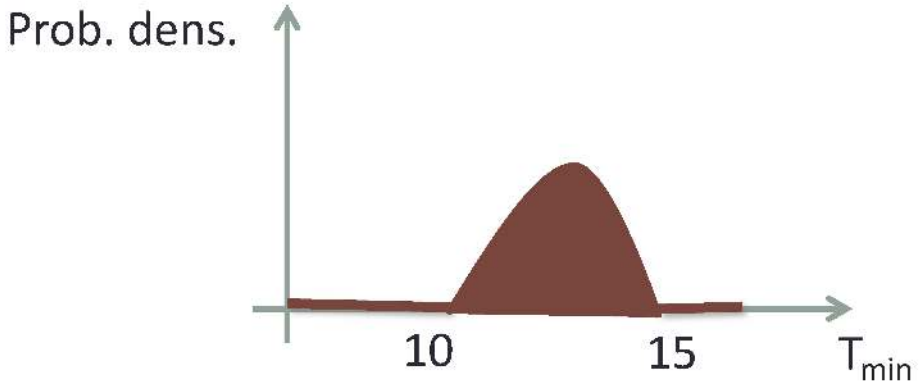
iii. Propagation of uncertainties through **a quantitative model** to obtain the distribution of the output of interest

iv. Communication of results

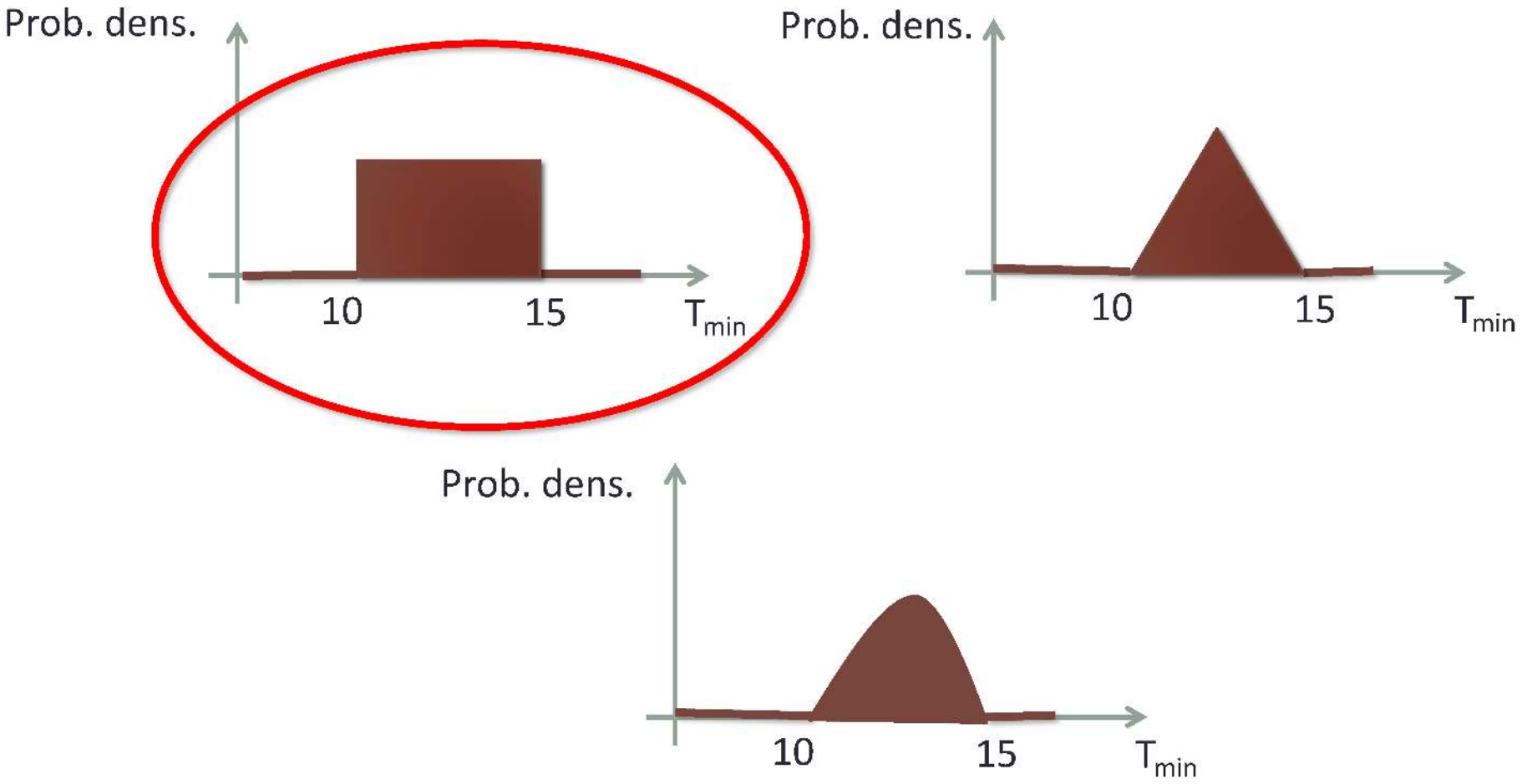
Description of uncertainties using probability distributions





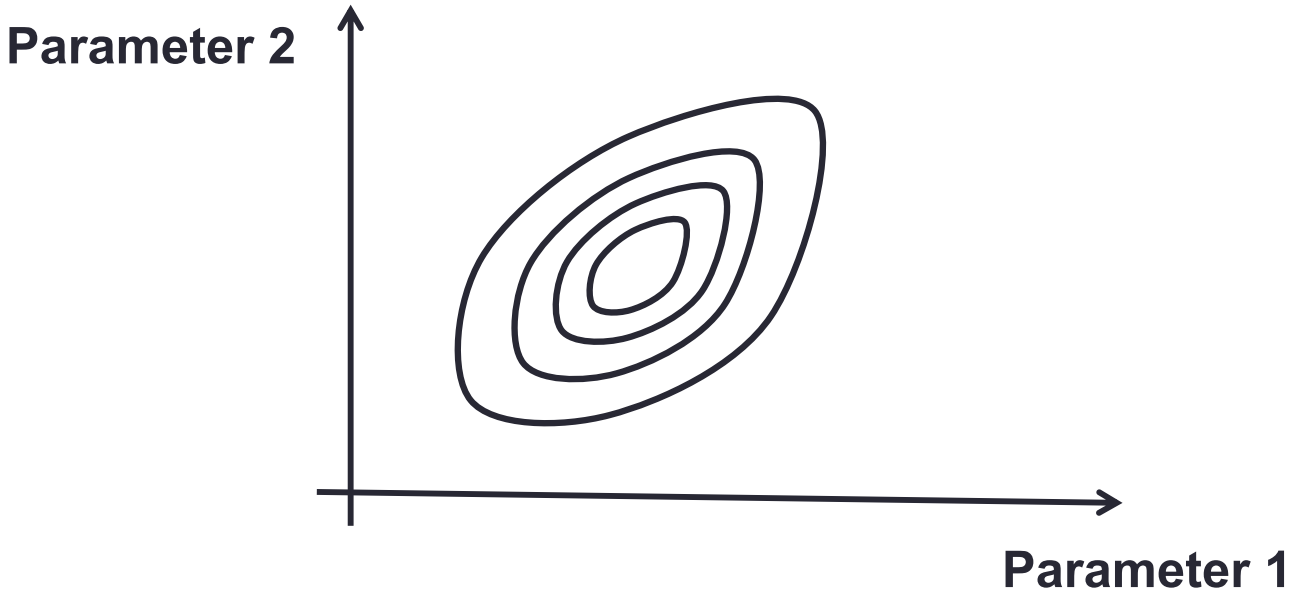


Description of uncertainties using probability distributions

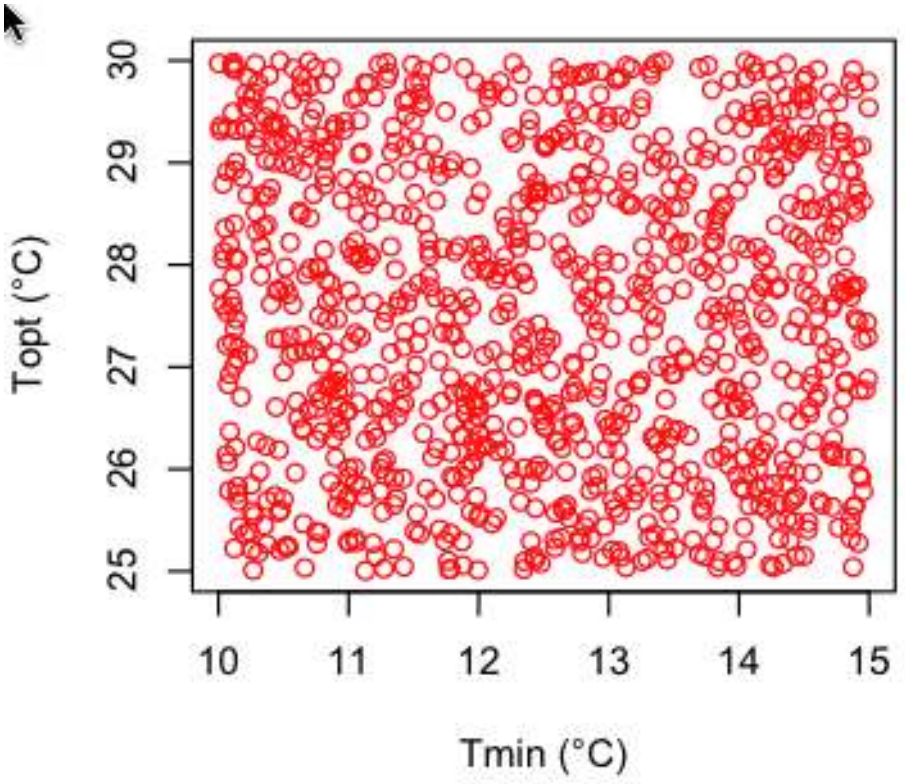


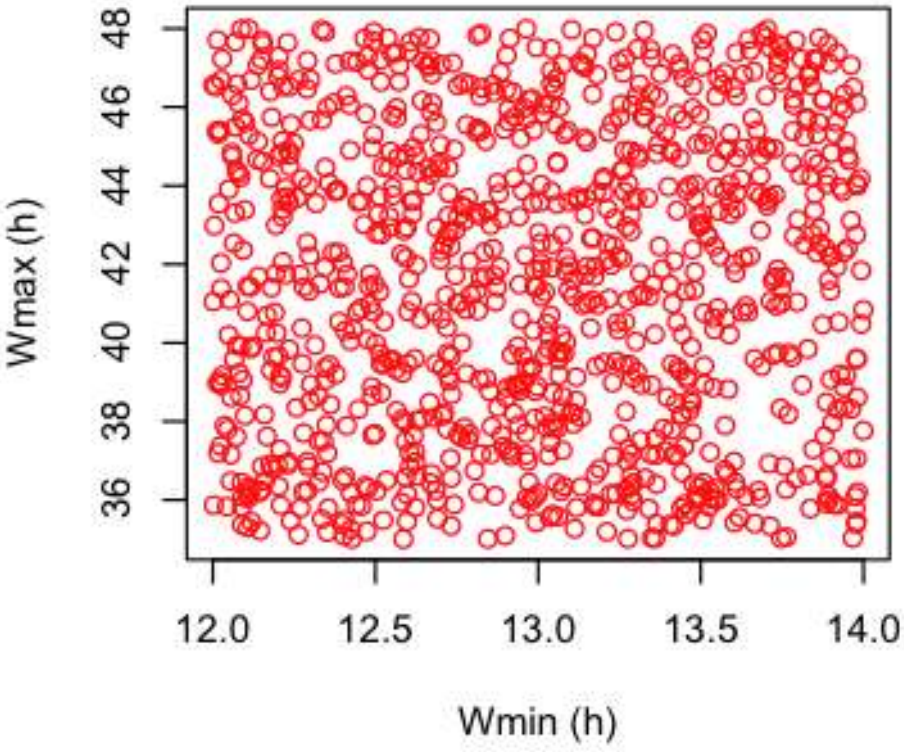
Description of uncertainties using probability distributions

Independent or correlated parameters?

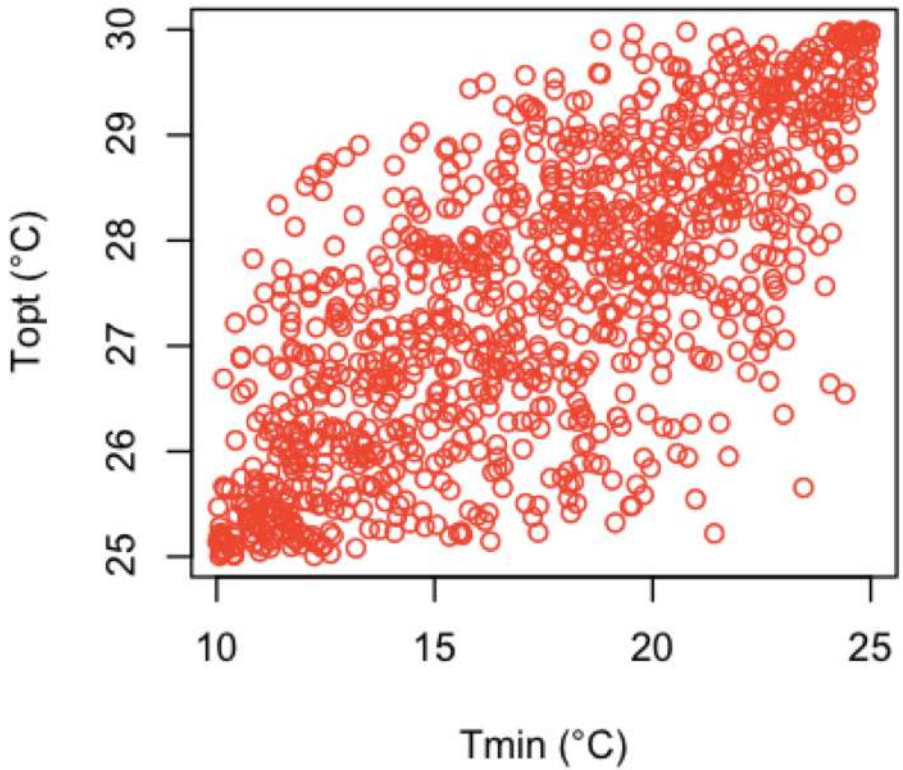


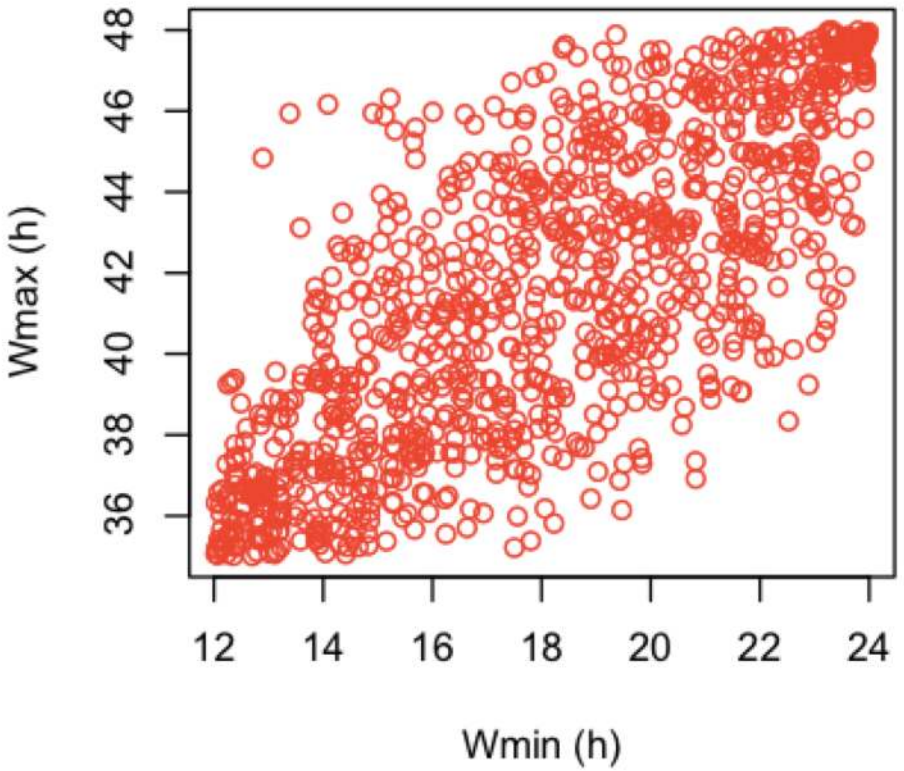
N=1000 (uniform & independent)





N=1000 (uniform & correlated, +0.75)





Copula; a powerful tool to deal with non-independent variables

Let F be a p-dimensional distribution function with margins $F_1, \ldots, F_p$.

Sklar (1959) first showed that there exists a p-dimensional copula C such that for all x in the domain of F,

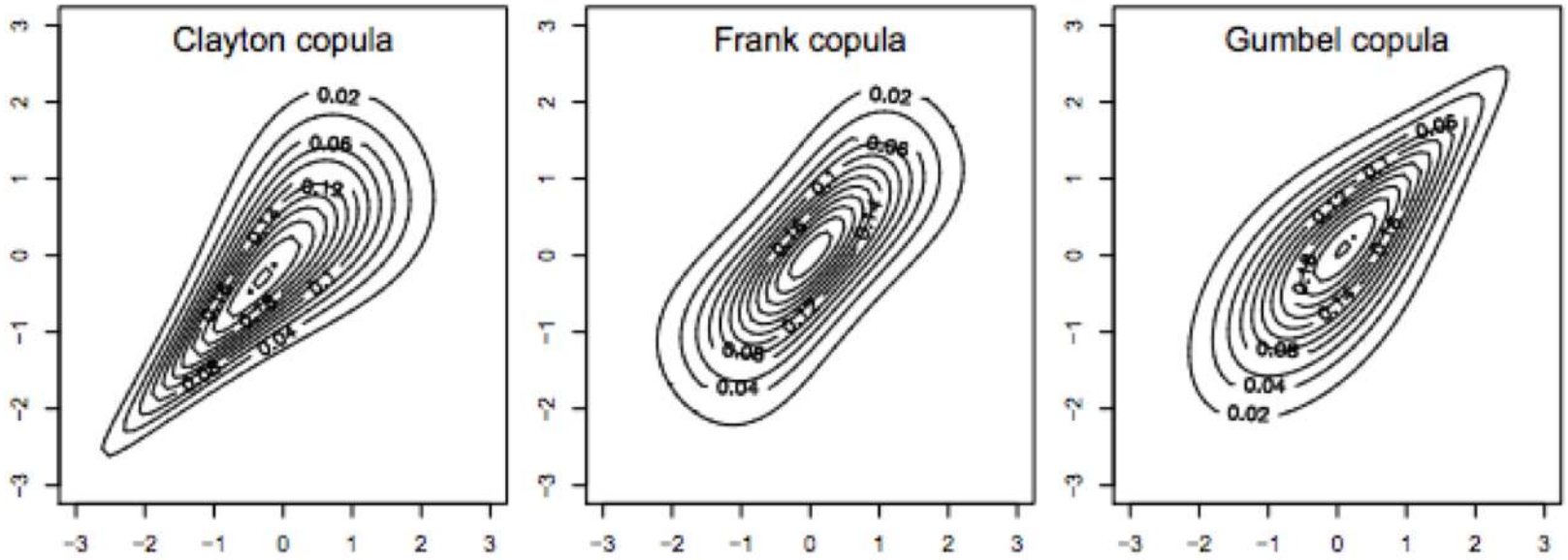
$$F(x_1, \ldots, x_p) = C\{F_1(x_1), \ldots, F_p(x_p)\}.$$

FELIX SALMON BUSINESS 02.23.09 12:00 PM

Recipe for Disaster: The Formula That Killed Wall Street

David X. Li's Gaussian copula function as first published in 2000.

Copula; a powerful tool to deal with non-independent variables



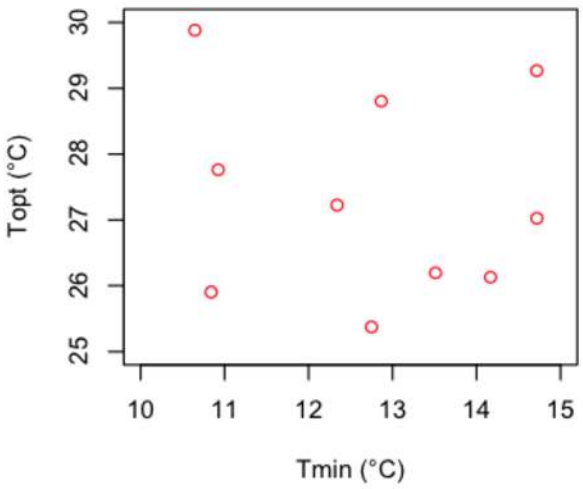
Probabilistic uncertainty analysis

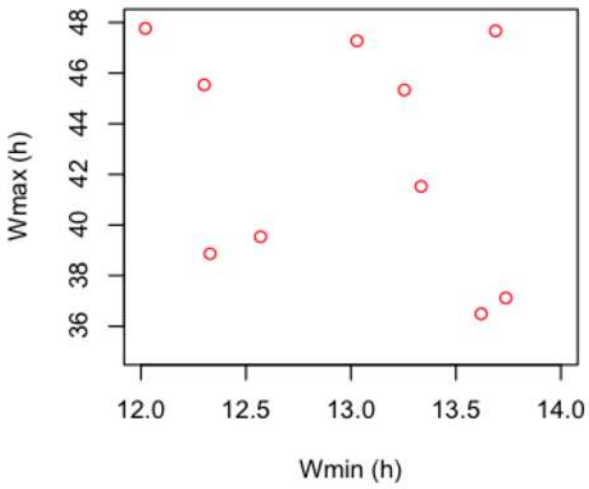
i. Identification of uncertainty sources

ii. Description of uncertainties using probability distributions

iii. Propagation of uncertainties through a quantitative model to obtain the distribution of the output of interest

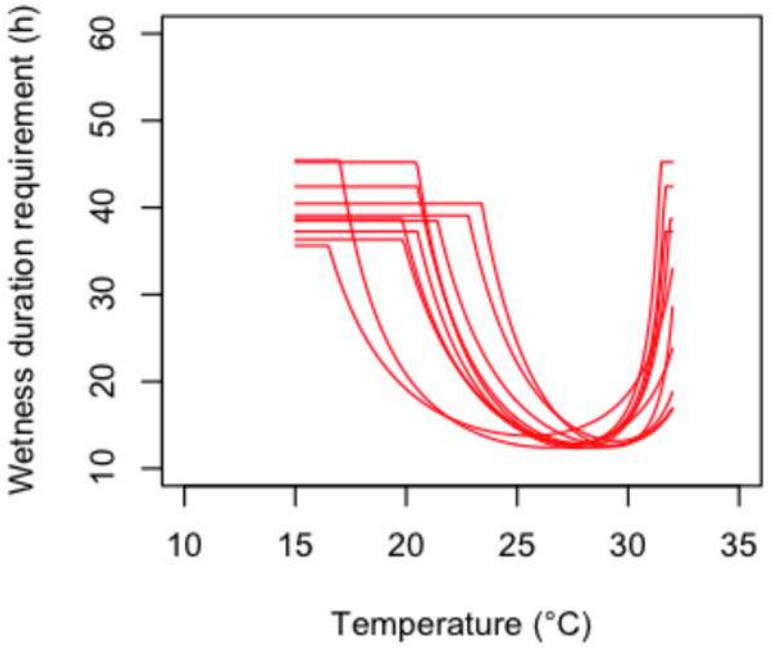
iv. Communication of results

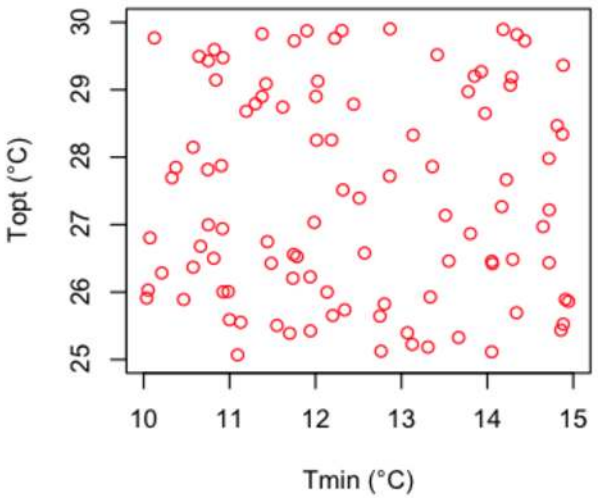

Topt (°C)
25
26
27
28
29
30
10
11
12
13
14
15
Tmin (°C)

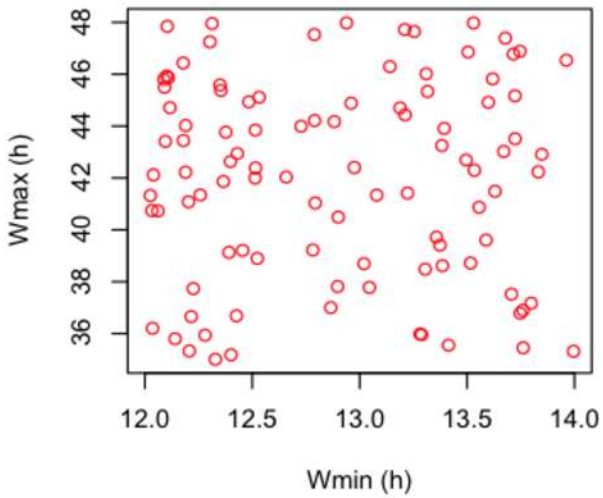

Wmax (h)
36
38
40
42
44
46
48
12.0
12.5
13.0
13.5
14.0
Wmin (h)

Model

N=10

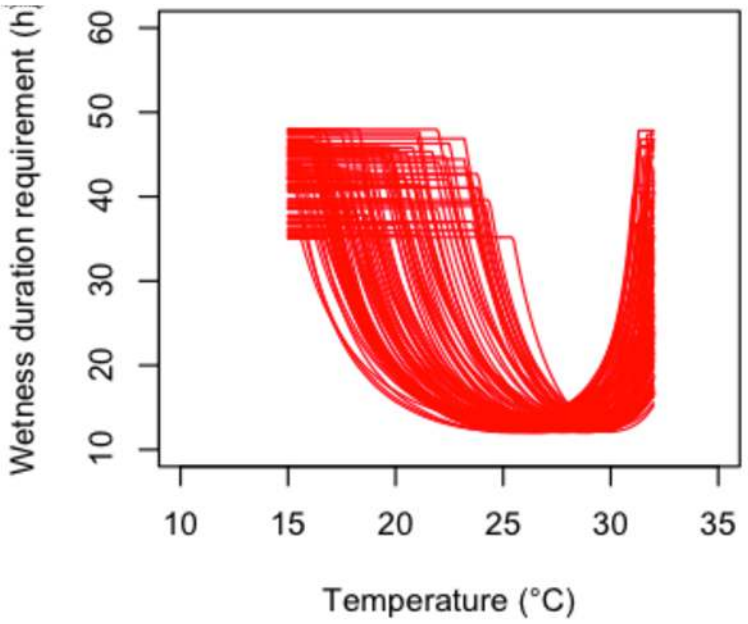

Wetness duration requirement (h)
10
20
30
40
50
60
10
15
20
25
30
35
Temperature (°C)

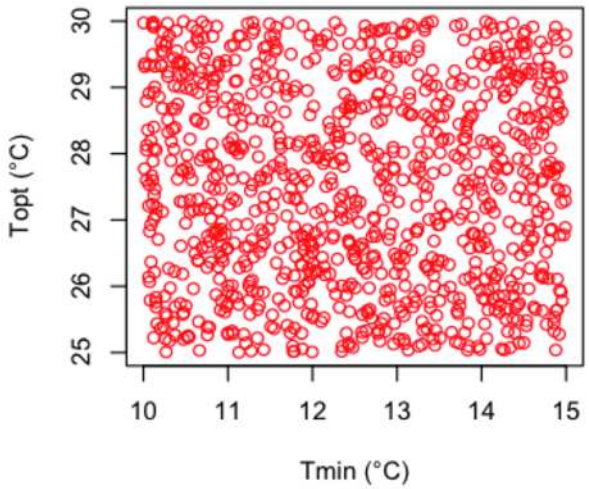

Topt (°C)
25
26
27
28
29
30
10
11
12
13
14
15
Tmin (°C)

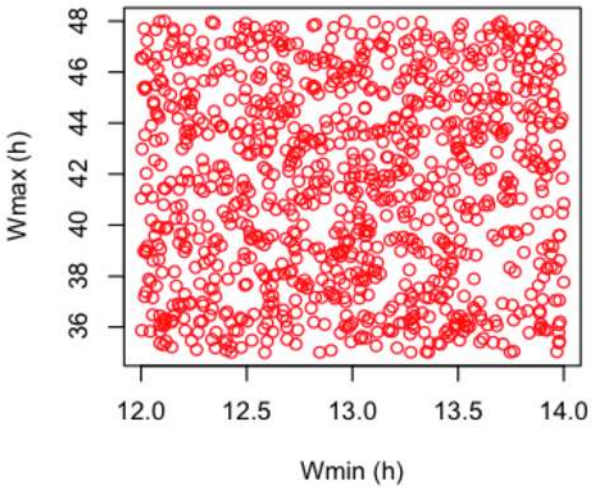

Wmax (h)
36
38
40
42
44
46
48
12.0
12.5
13.0
13.5
14.0
Wmin (h)

Model

N=100

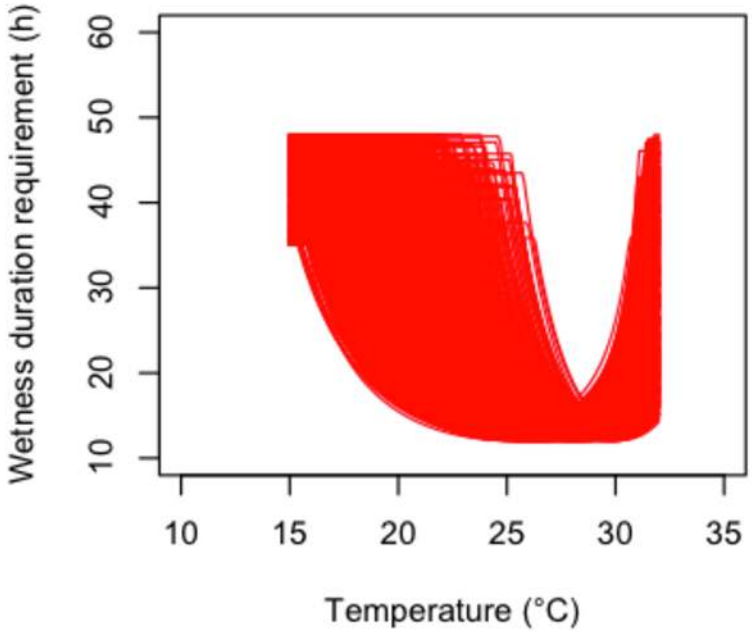

Wetness duration requirement (h)
10
20
30
40
50
60
10
15
20
25
30
35
Temperature (°C)


Topt (°C)
25
26
27
28
29
30
10
11
12
13
14
15
Tmin (°C)

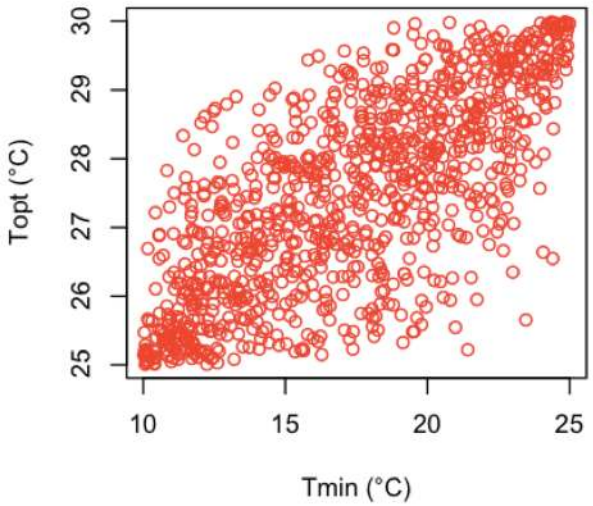

Wmax (h)
36
38
40
42
44
46
48
12.0
12.5
13.0
13.5
14.0
Wmin (h)

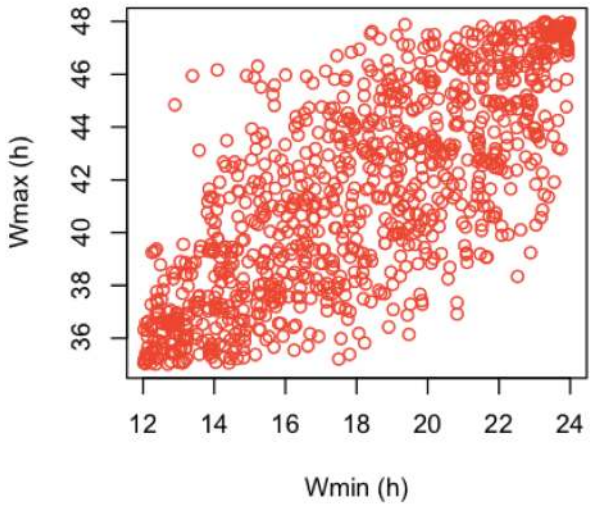
Model

N=1000


Wetness duration requirement (h)
10
20
30
40
50
60
10
15
20
25
30
35
Temperature (°C)

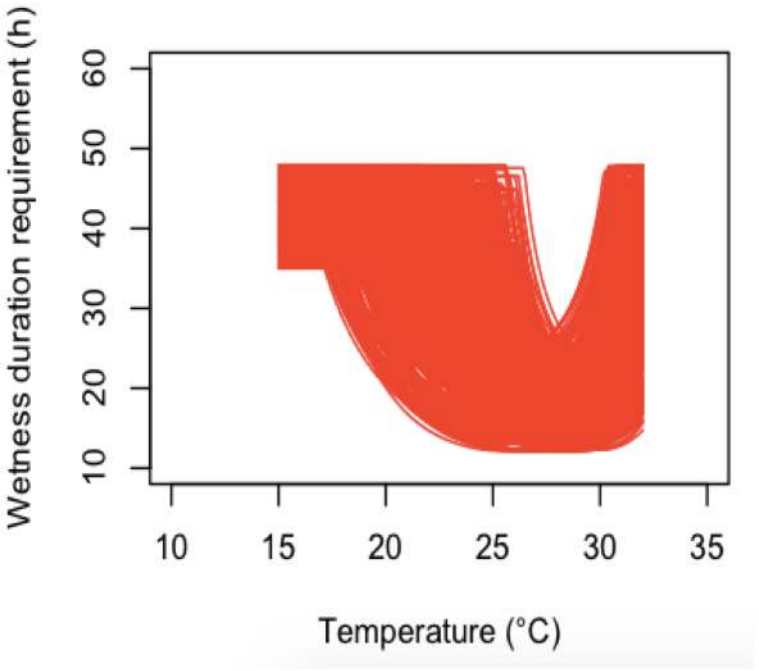
Non-independent distributions (+0.75)





Model

N=1000



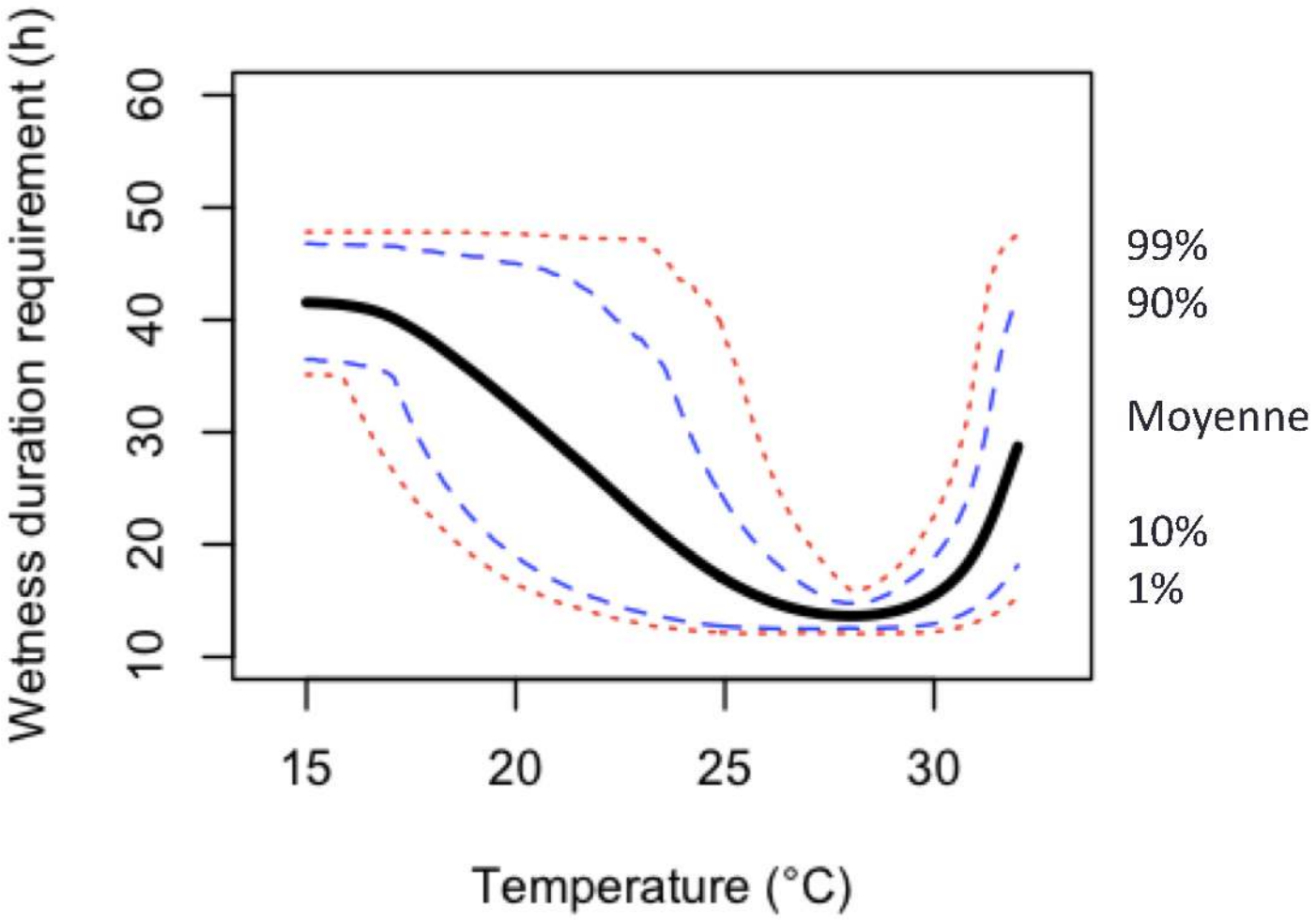
Probabilistic uncertainty analysis

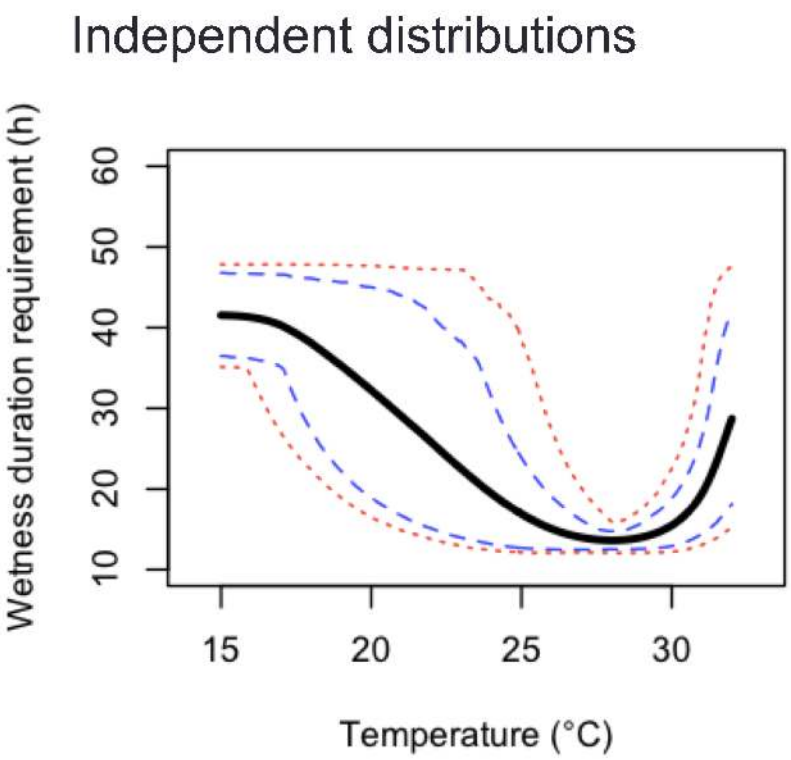
i. Identification of uncertainty sources

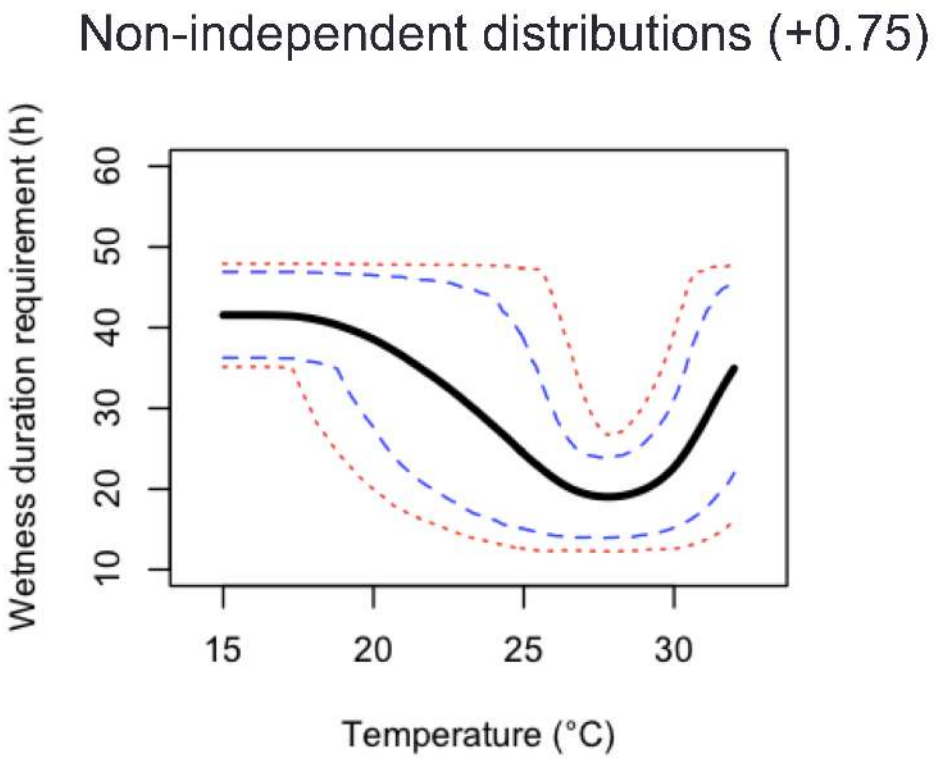
ii. Description of uncertainties using probability distributions

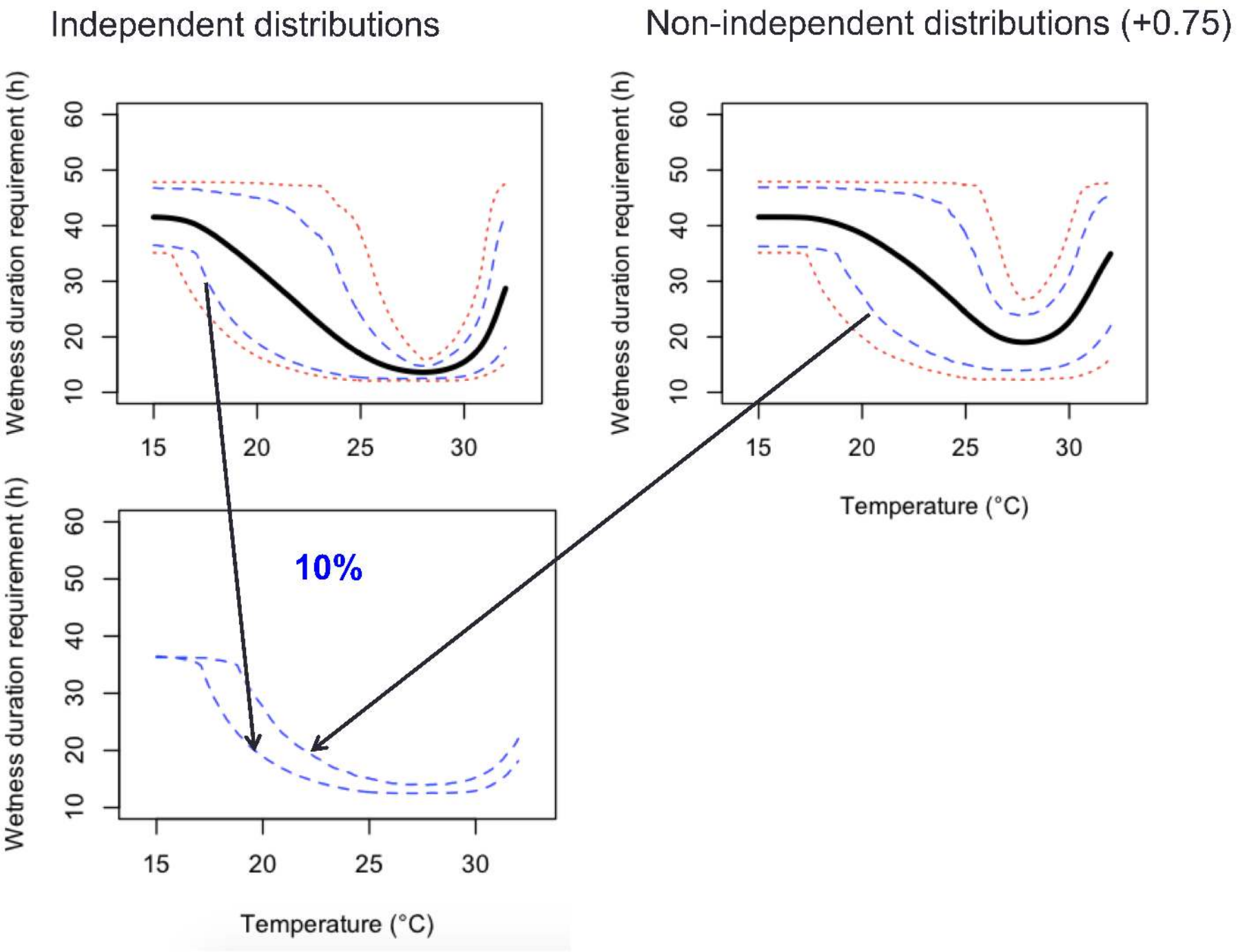
iii. Propagation of uncertainties through **a quantitative model** to obtain the distribution of the output of interest

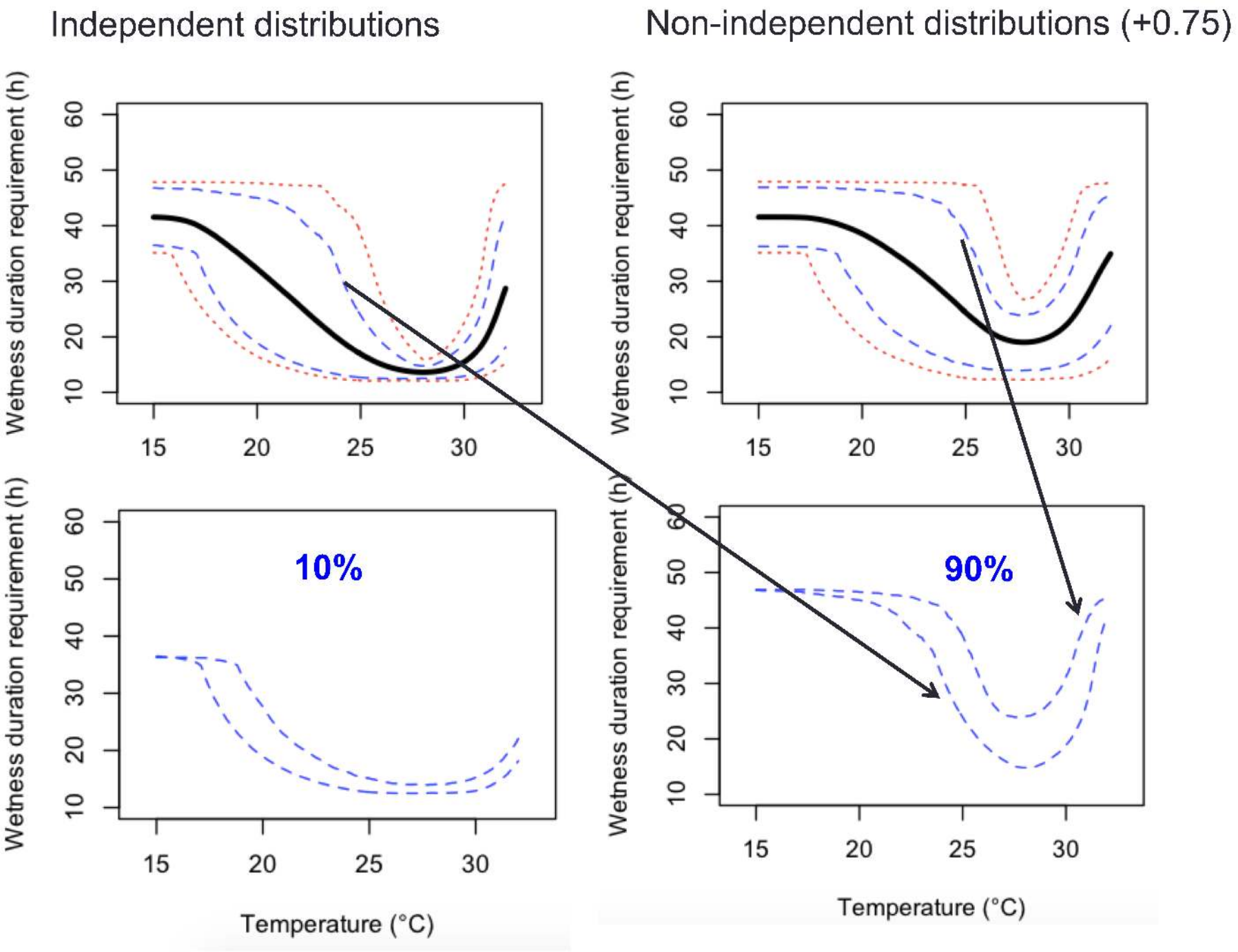
iv. Communication of results


Wetness duration requirement (h)
10
20
30
40
50
60
15
20
25
30
Temperature (°C)
99%
90%
Moyenne
10%
1%


Independent distributions
Wetness duration requirement (h)
10
20
30
40
50
60
15
20
25
30
Temperature (°C)


Non-independent distributions (+0.75)
Wetness duration requirement (h)
10
20
30
40
50
60
15
20
25
30
Temperature (°C)


Independent distributions
Non-independent distributions (+0.75)
Wetness duration requirement (h)
10
20
30
40
50
60
15
20
25
30
Temperature (°C)
10%


Independent distributions
Non-independent distributions (+0.75)
Wetness duration requirement (h)
10
20
30
40
50
60
15
20
25
30
10%
90%
Temperature (°C)

Different attitudes towards uncertainty

- Ignore it
- Qualitative uncertainty analysis
- Quantitative uncertainty analysis

Advantages of probabilistic uncertainty analysis

- Transparent
- Quantitative
- Combine several sources of uncertainties
- Allow sensitivity analysis

Critical issues

- Carefully define probability distributions
  - Eliciting expert knowledge
  - Classical statistical methods
  - Bayesian statistical methods
  - Copulas

- Deal with computation times
  - Efficient coding/parallelization
  - Meta-modelling (use of emulators)

L'incertitude des événements, toujours plus difficile à soutenir que l'événement même

The uncertainty of events, always more difficult to sustain than the event itself

Jean-Baptiste Massillon ; Maximes et pensées (1742)