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Probabilistic pathway models for risk assessment of plant pest invasions

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► **To cite this version:**

Bob Douma, Monique Mourits, Christelle Robinet, Lia Hemerik, Wopke van Der Werf. Probabilistic pathway models for risk assessment of plant pest invasions. 10. EFSA Anniversary Event, Risk Assessment in Plant Health, Oct 2012, Helsinki, Finland. 67 diapos. hal-02808626

HAL Id: hal-02808626

<https://hal.inrae.fr/hal-02808626>

Submitted on 6 Jun 2020

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Probabilistic pathway models for risk assessment of plant pest invasions



PPM-PIRATES:

Bob Douma (WUR), **Monique Mourits** (WUR), **Christelle Robinet** (INRA), **Lia Hemerik** (WUR), and **Wopke van der Werf** (WUR)



Global trade increases the risk of new plant pathogens



- Increasing international trade leads to new invasions
- Costs associated with plant pathogens estimated to be very large
- Some invasive species may have detrimental effects on natural habitats
- Europe: Douglas-fir beetle

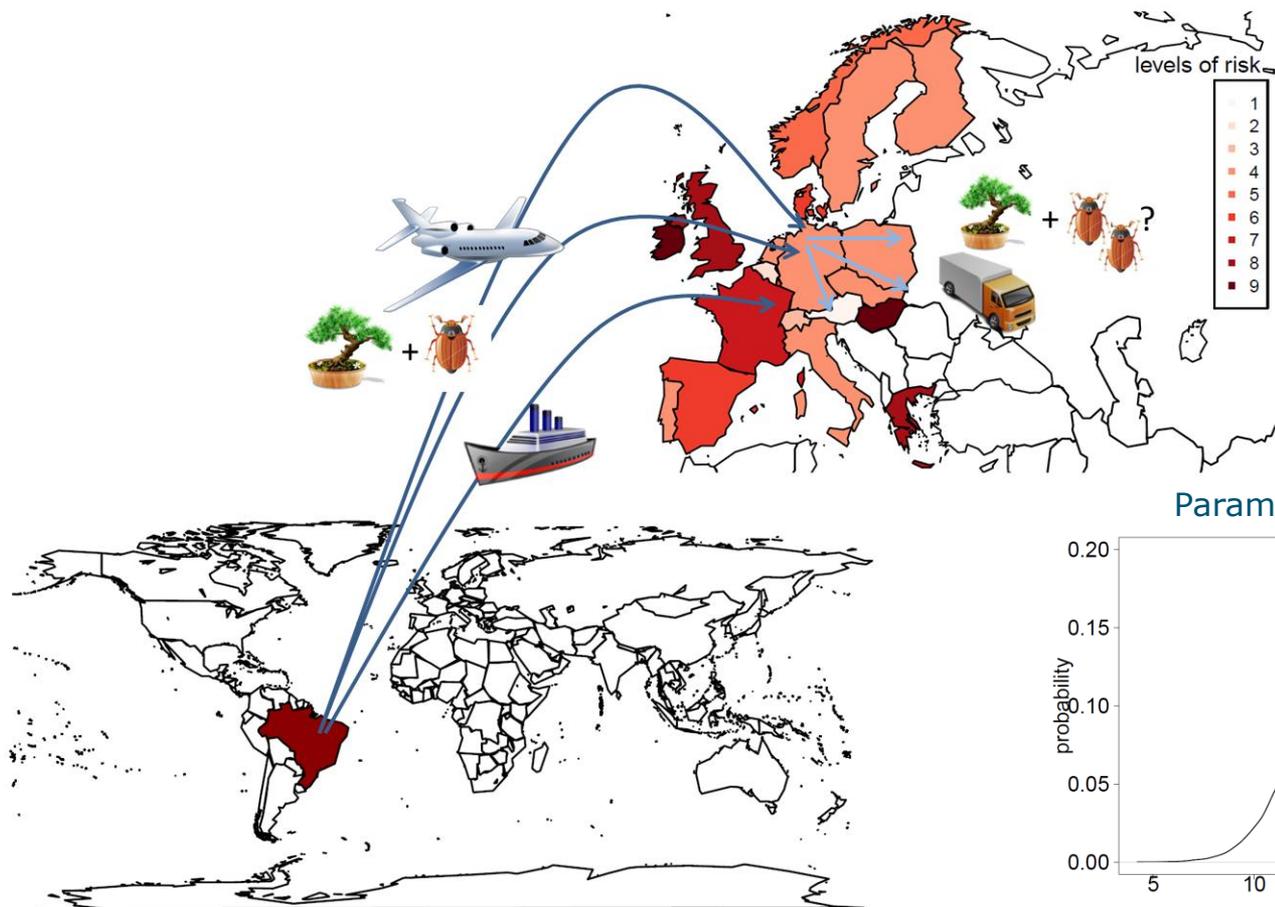


EFSA project – two lots

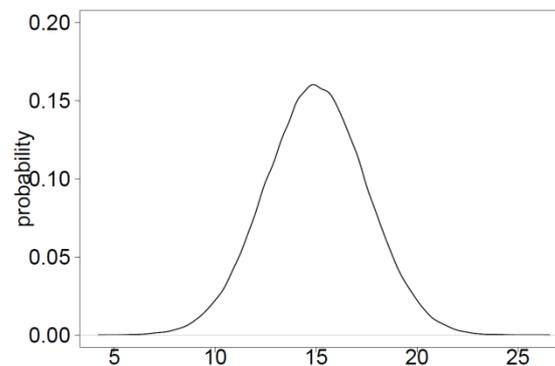


- Lot 1: Edible plant products
 - Conducted by Imperial College and FERA
- Lot 2: Non-edible plant products
 - Conducted by Wageningen University and INRA

How do PPMs work? Graphical summary



Parameter distributions

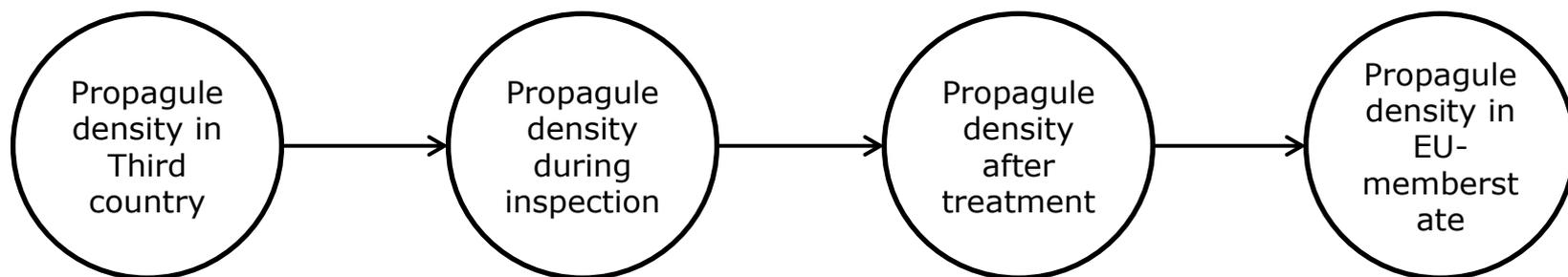


Conceptualisation of the model



- Divide the import process of a pest in nodes; from the source (agro-)ecosystem in the country of origin to introduction into the target (agro-)ecosystem in the EU territory
- Consignment as modeling unit

A sequence of nodes, connected by edges (links):

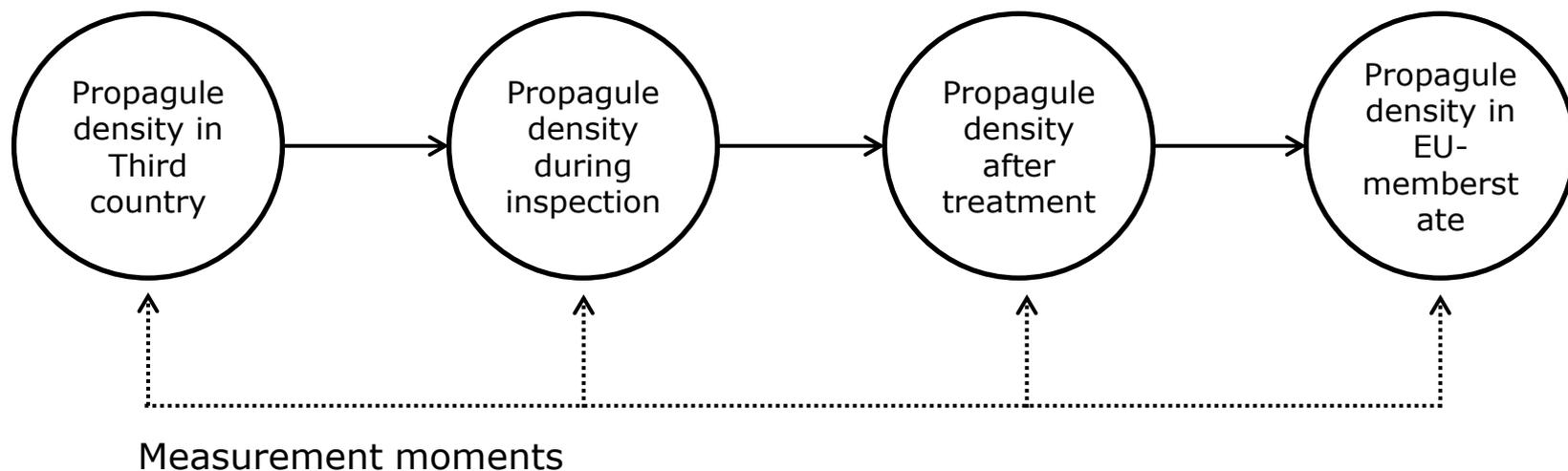


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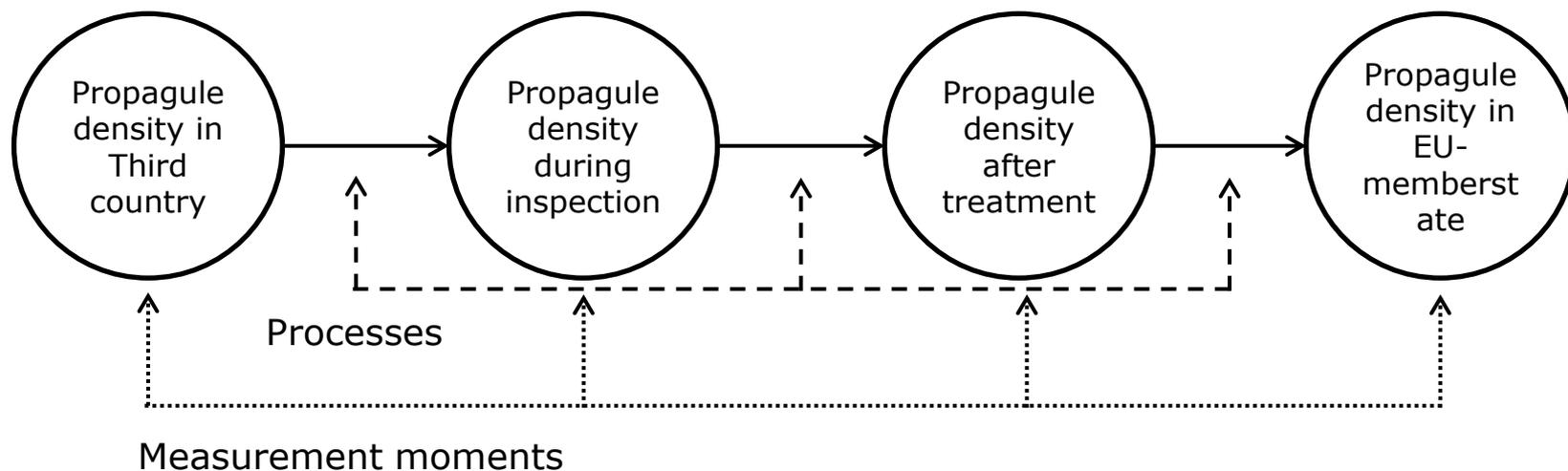


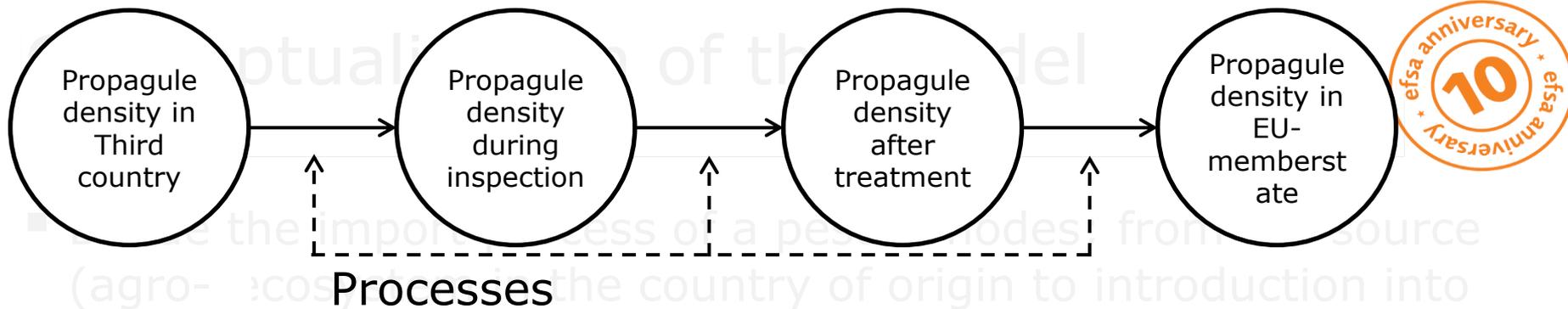
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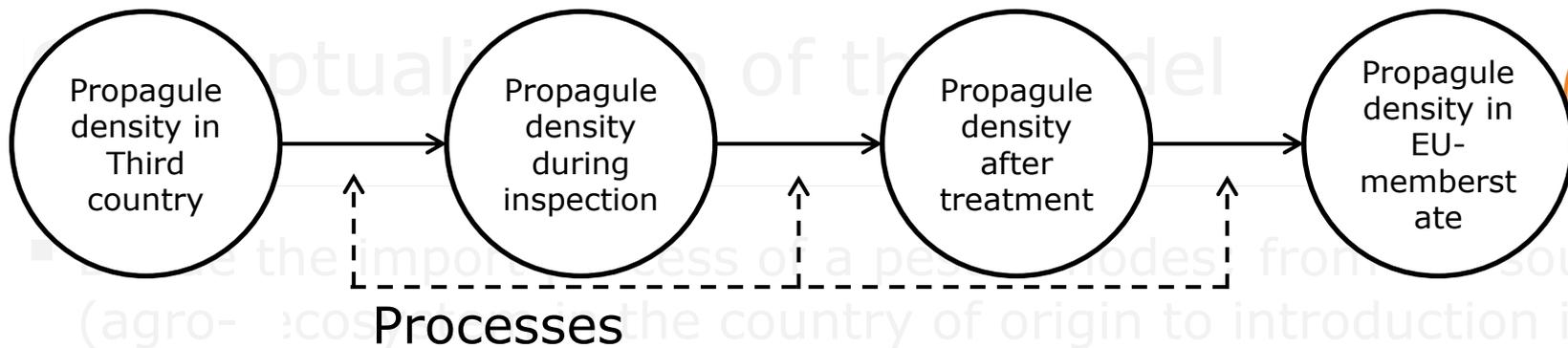




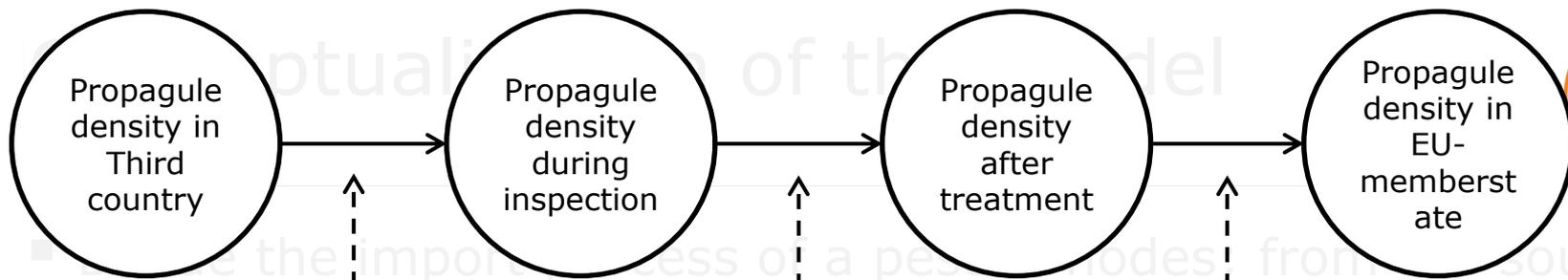
- The importance of a process (nodes) from source (agro-ecosystem) in the country of origin to introduction into the target (agro-)ecosystem in the EU territory

- Consignment as modeling unit

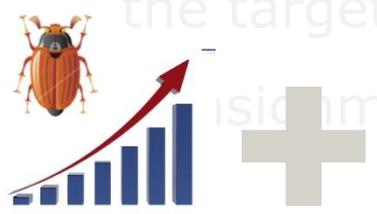
- A sequence of nodes, connected by edges (links):



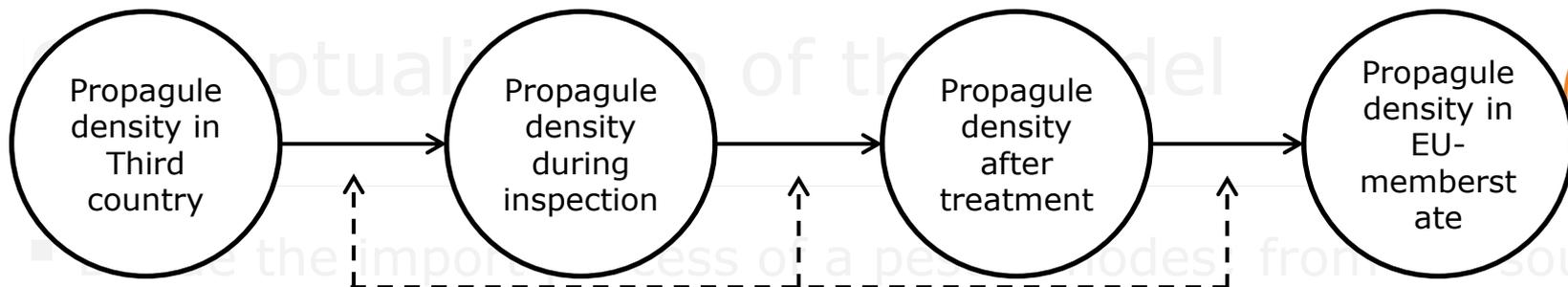
- A sequence of nodes, connected by edges (links):



Processes



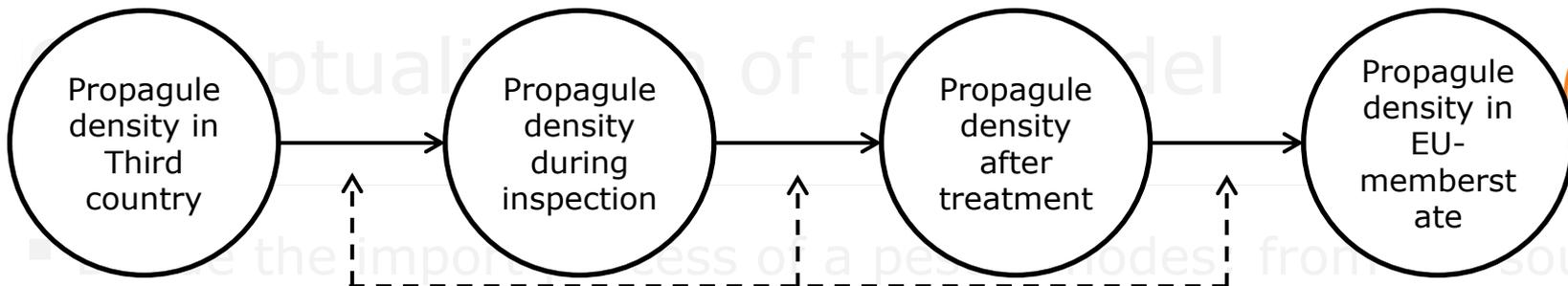
- A sequence of nodes, connected by edges (links):



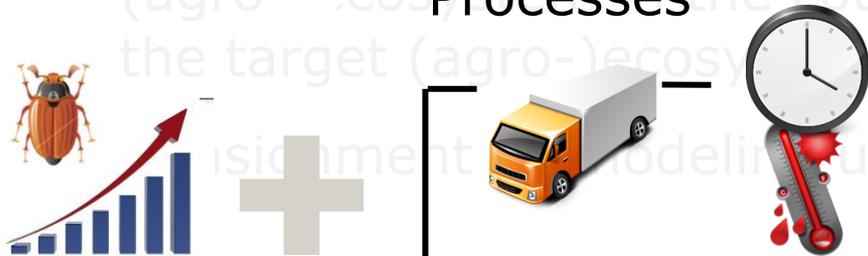
Processes



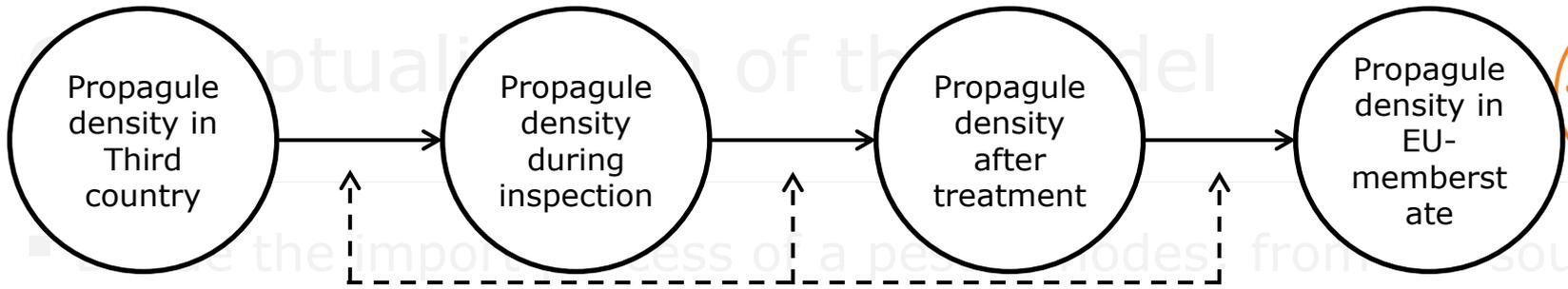
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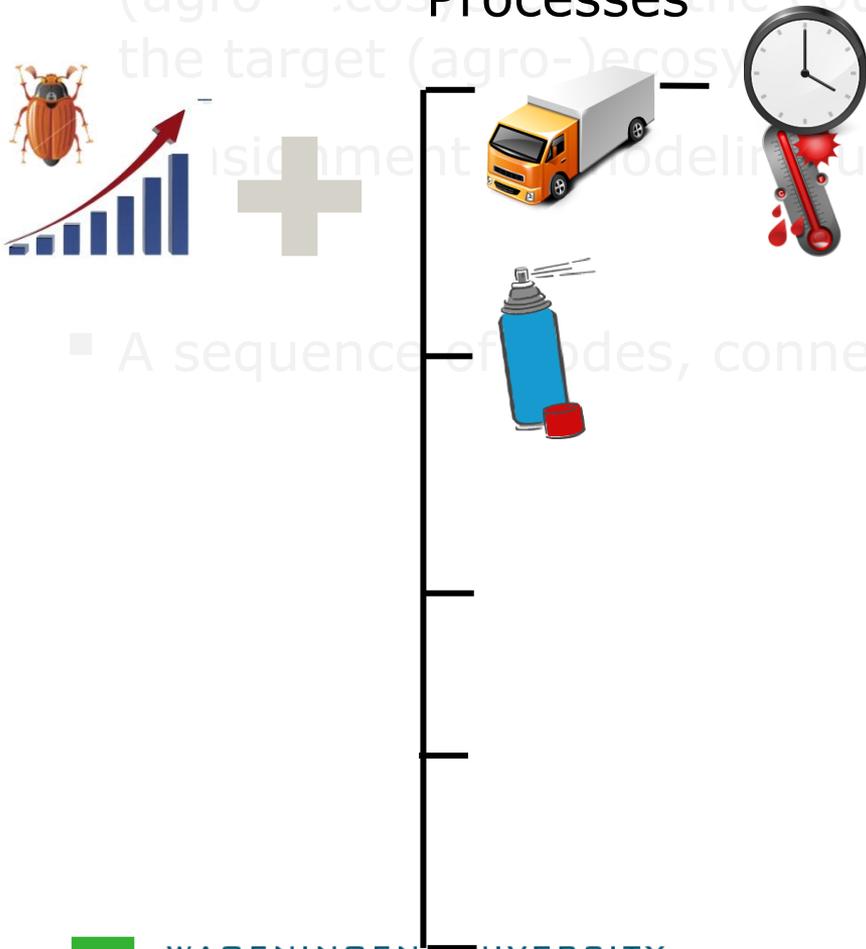
Processes



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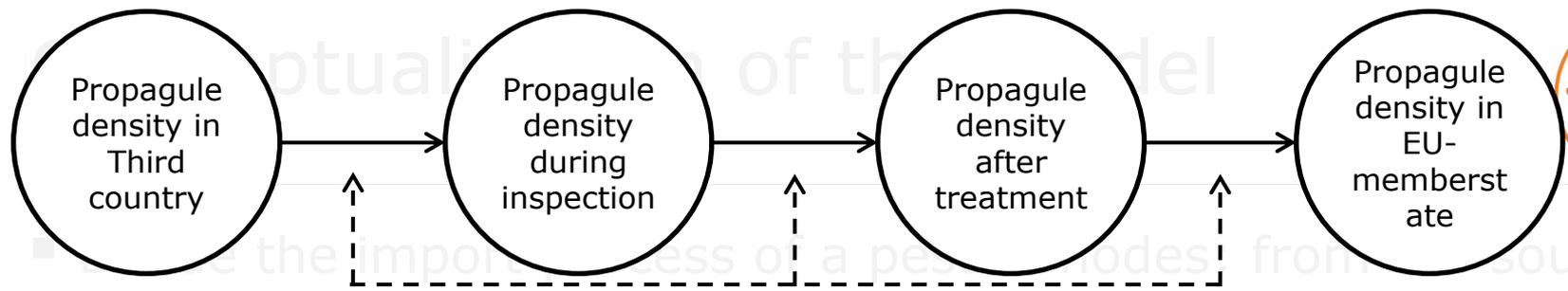


Processes

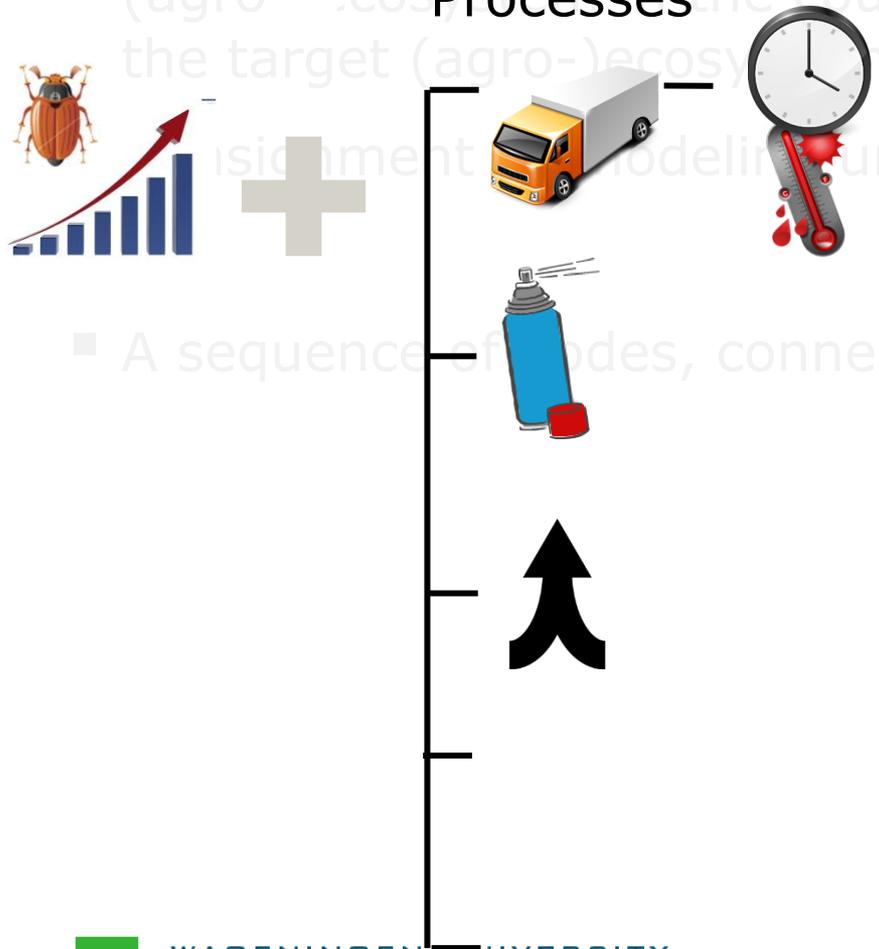


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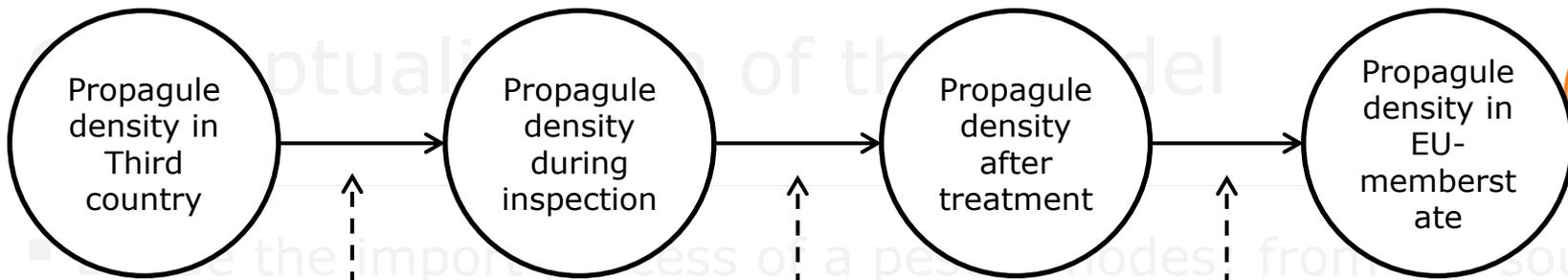




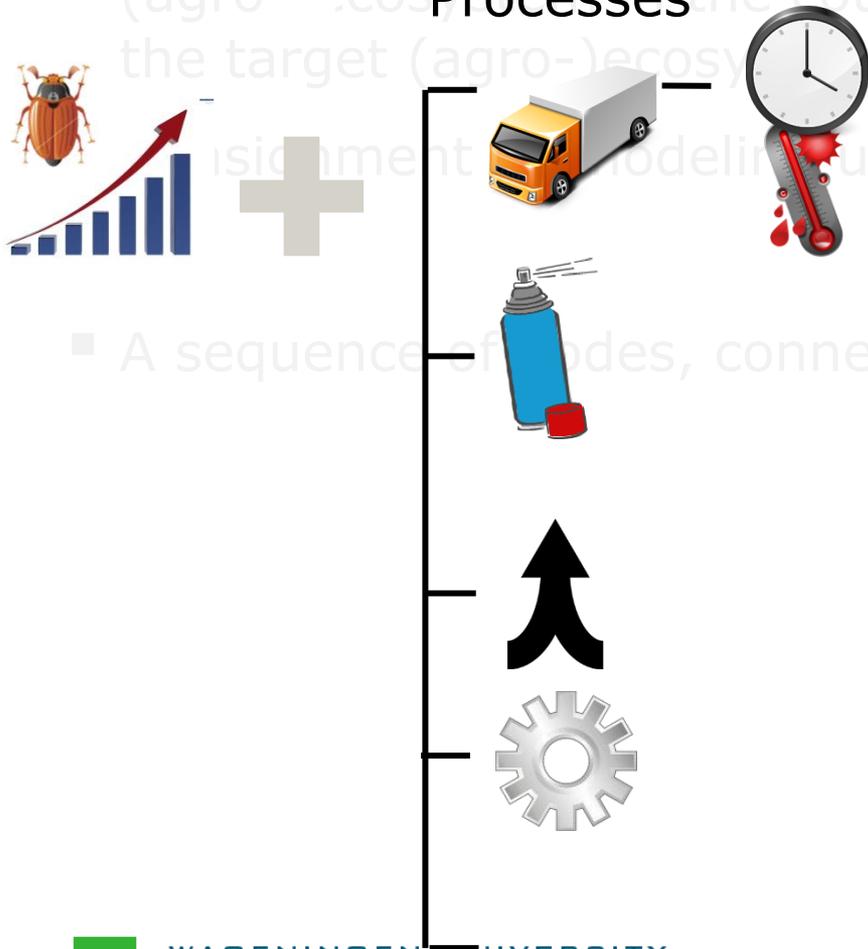
Processes



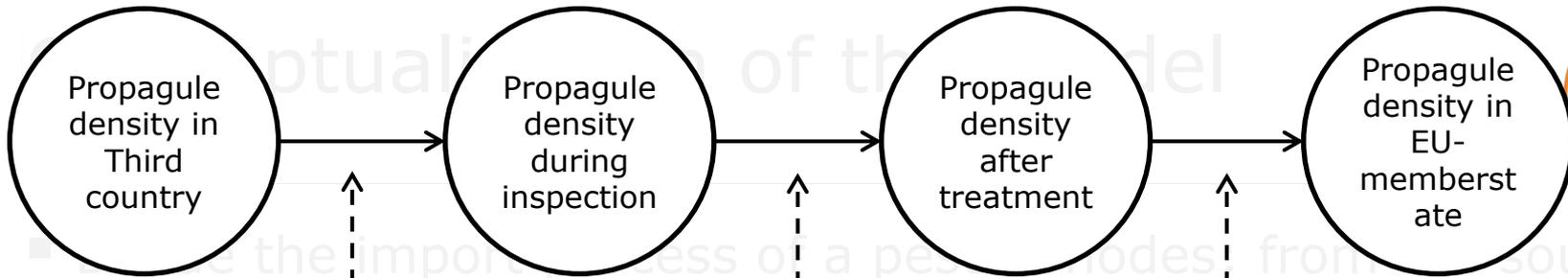
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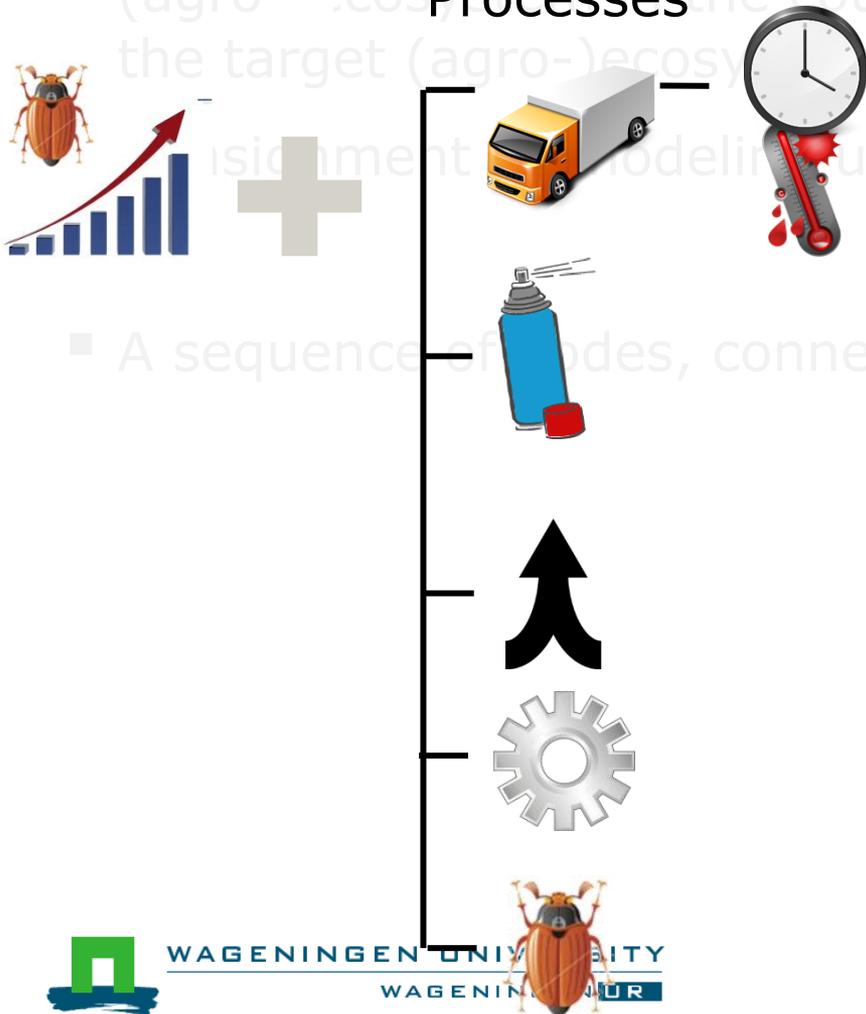
Processes



A sequence of nodes, connected by edges (links):



Processes



■ A sequence of nodes, connected by edges (links):

Conceptualisation of the model



- For each link the (probability distribution) infestation level is updated
- Each process-parameter is defined as a distribution of likely values



Conceptualisation of the model



- For each link the (probability distribution) infestation level is updated
- Each process-parameter is defined as a distribution of likely values
- Output: distribution of propagule density in a given area of an EU memberstate



Conceptualisation of the model



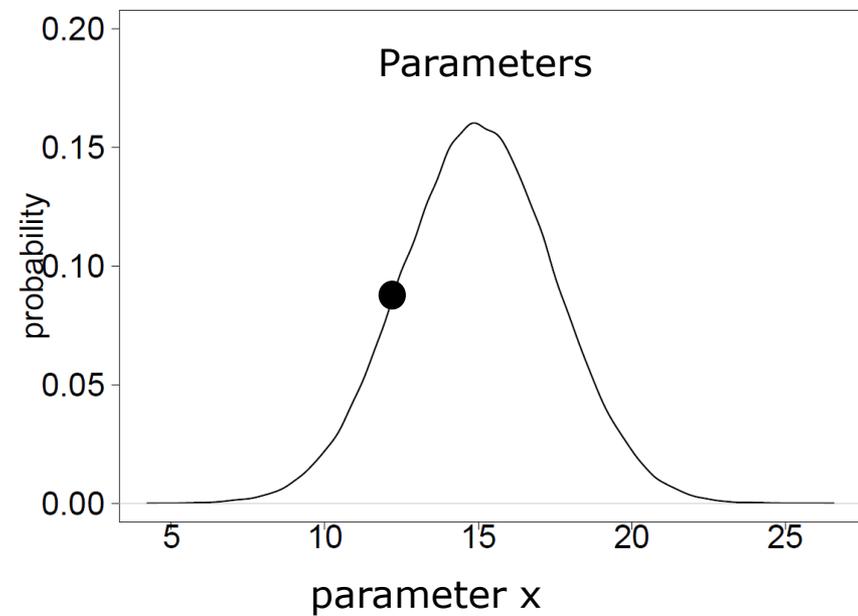
Conceptualisation of the model



Draw from
parameter space
(Monte Carlo)

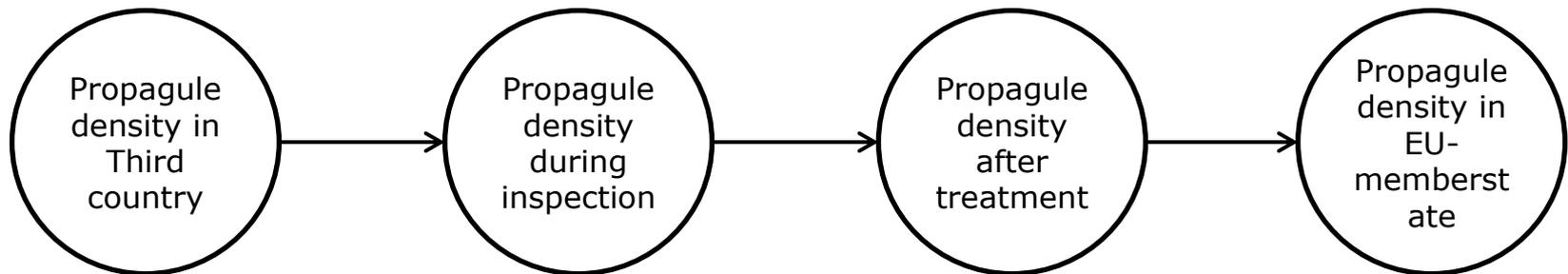
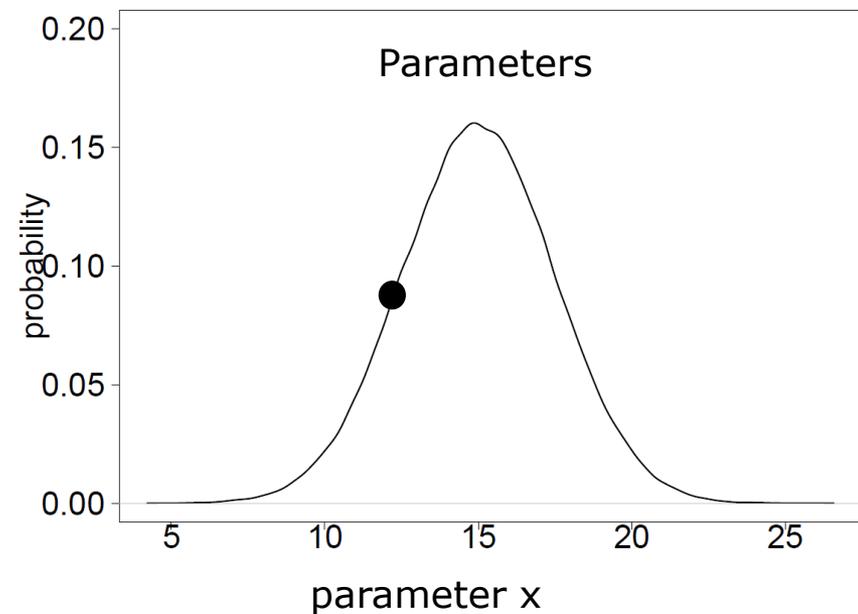
Conceptualisation of t

Draw from
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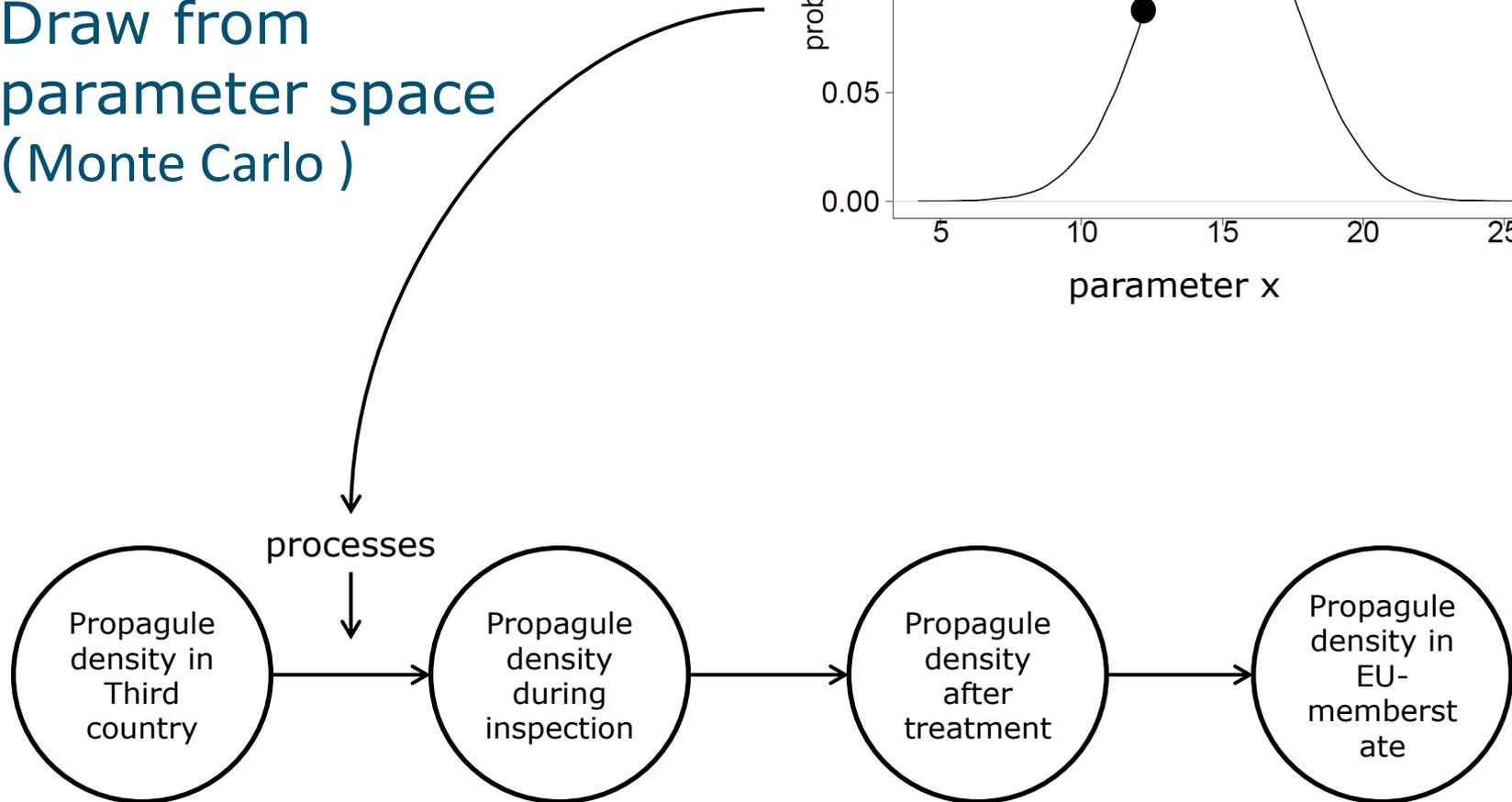
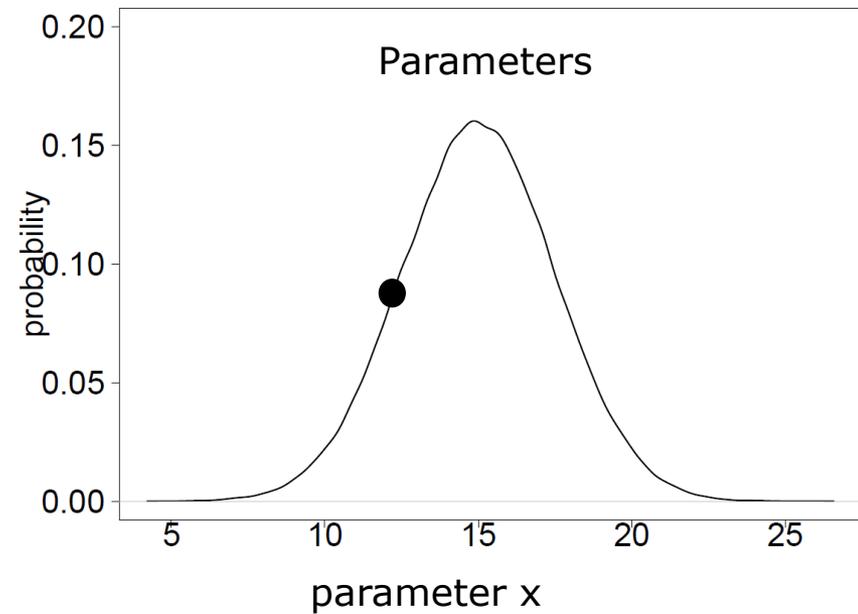
Conceptualisation of t

Draw from
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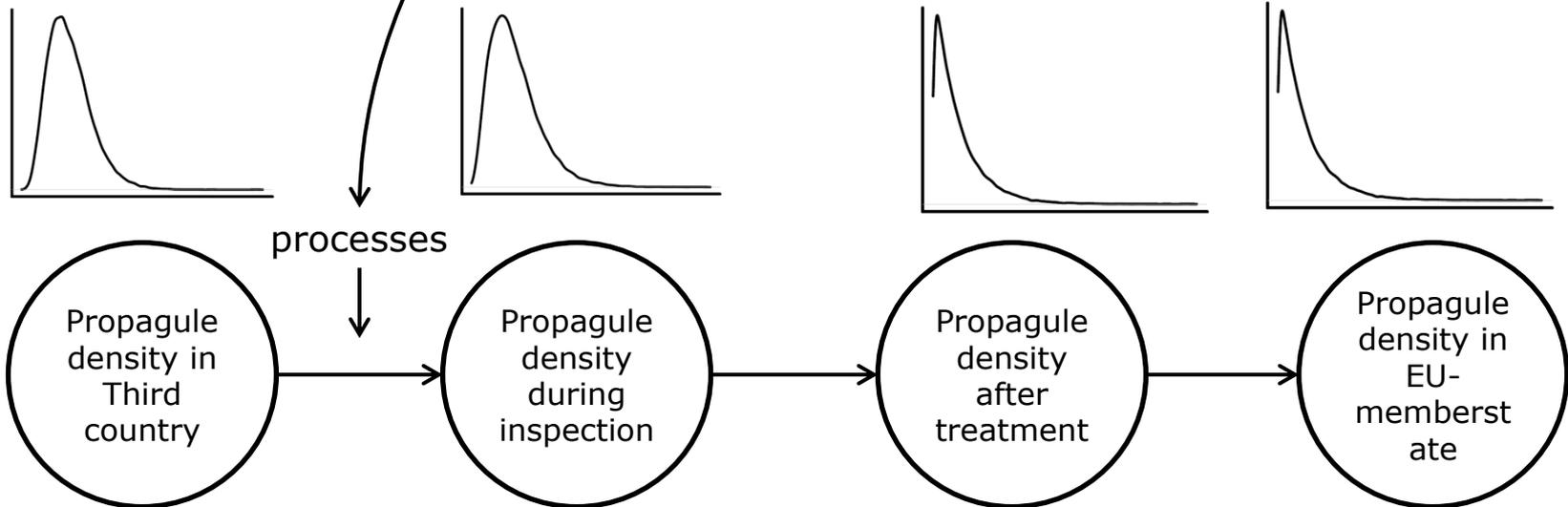
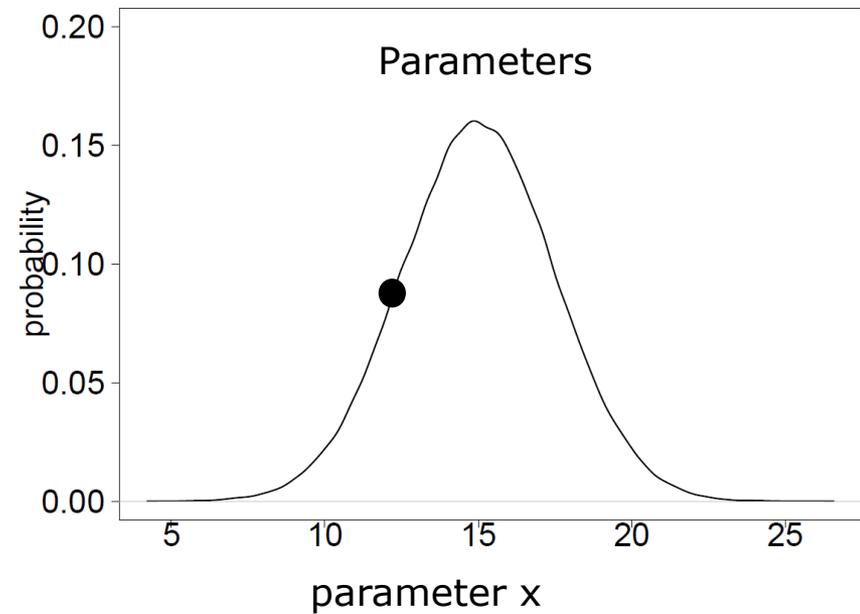
Conceptualisation of t

Draw from
parameter space
(Monte Carlo)



Conceptualisation of t

Draw from
parameter space
(Monte Carlo)



Type of model simulations



	1 realisation	k realisations
1 consignment		
n consignments (population model)		

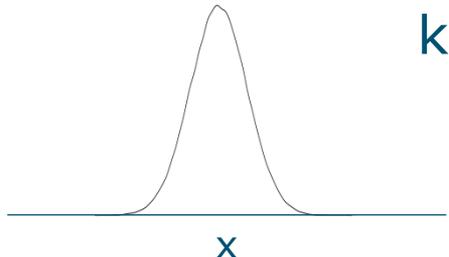
Type of model simulations



	1 realisation	k realisations
1 consignment	1	
	$[x] = \dots$	
n consignments (population model)		

Type of model simulations

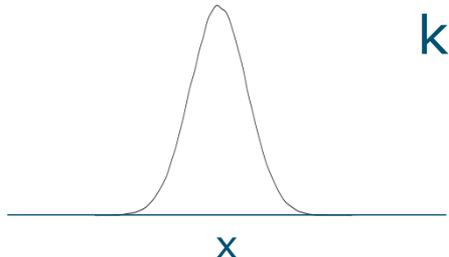


	1 realisation	k realisations
1 consignment	$[x] = \dots$ 1	 k
n consignments (population model)		



Type of model simulations



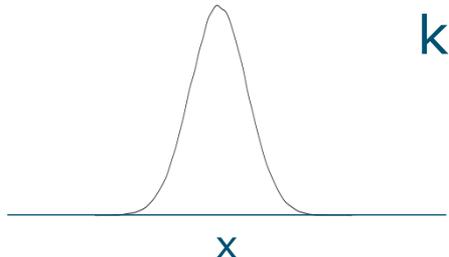
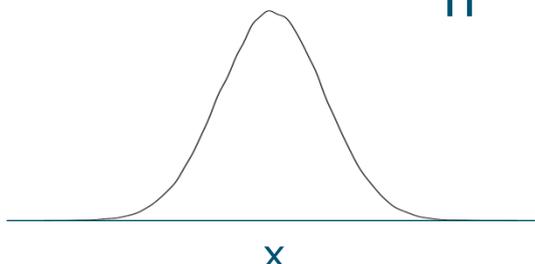
	1 realisation	k realisations
1 consignment	$[x] = \dots$ 1	 k
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Variation in initial conditions

Type of model simulations



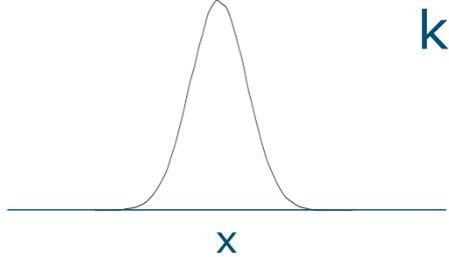
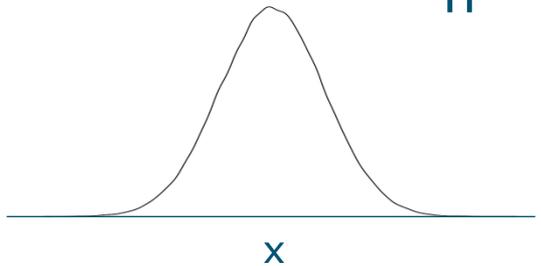
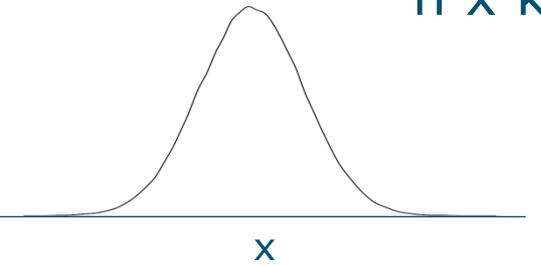
	1 realisation	k realisations
1 consignment	$[x] = \dots$ 1	 k
n consignments (population model)	 n	



Variation in initial conditions

Type of model simulations



	1 realisation	k realisations
1 consignment	$[x] = \dots$ 1	 k
n consignments (population model)	 n	 n x k



Variation in initial conditions

Overview of models to be developed



Generic

Case-studies

Consignment



- 1.
- 2.
- 3.
- 4.
- 5.

- 1.
- 2.
- 3.
- 4.
- 5.

Population



- 1.
- 2.
- 3.
- 4.
- 5.

- 1.
- 2.
- 3.
- 4.
- 5.



Overview of models to be developed



Generic

Case-studies

Consignment



1) Round wood



Population



WAGENINGEN UNIVERSITY
WAGENINGEN



Overview of models to be developed



Generic

Case-studies

Consignment



1) Round wood



Population



2) Wood shavings



Overview of models to be developed



Generic

Case-studies

Consignment



1) Round wood



2) Wood shavings



Population



Overview of models to be developed



Generic

Case-studies

Consignment



1) Round wood



2) Wood shavings



Population



3) Plants for planting



Overview of models to be developed



Generic

Case-studies

Consignment



1) Round wood



2) Wood shavings



3) Plants for planting



Population



Overview of models to be developed

Generic

Case-studies

Consignment



1) Round wood



2) Wood shavings



3) Plants for planting



Population



4) Cut flowers



Overview of models to be developed



Generic

Case-studies

Consignment



1) Round wood



2) Wood shavings



3) Plants for planting



Population



4) Cut flowers



Overview of models to be developed



Generic

Case-studies

Consignment



1) Round wood



2) Wood shavings



3) Plants for planting



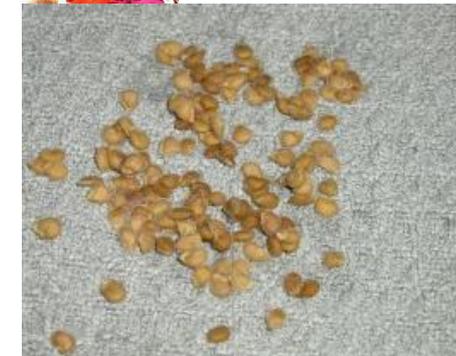
Population



4) Cut flowers



5) Seeds



Overview of models to be developed



Generic

Case-studies

Consignment



1) Round wood



2) Wood shavings



3) Plants for planting



4) Cut flowers



5) Seeds



Population



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WAGENINGEN



Application of PPMs to five case studies



- Douglas fir + *Dendroctonus pseudotsugae*
(douglas fir beetle)

Application of PPMs to five case studies



- Douglas fir + *Dendroctonus pseudotsugae*
(douglas fir beetle)
- Wood shavings + *Bursaphelenchus xylophilus*
(pine wood nematode)



Application of PPMs to five case studies



- Douglas fir + *Dendroctonus pseudotsugae*
(douglas fir beetle)
- Wood shavings + *Bursaphelenchus xylophilus*
(pine wood nematode)
- Bonsai + *Xiphinema americanum*
(nematode)



Application of PPMs to five case studies



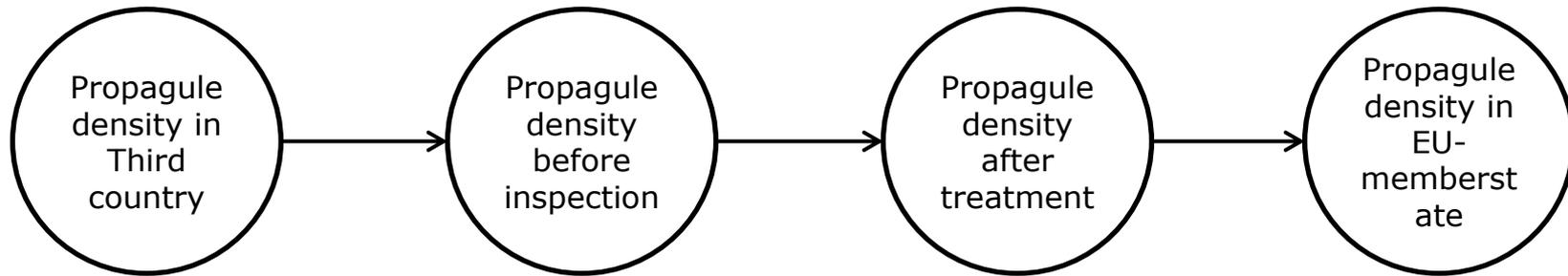
- Douglas fir + *Dendroctonus pseudotsugae*
(douglas fir beetle)
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- Bonsai + *Xiphinema americanum*
(nematode)
- Cut orchid flowers+ *Thrips palmi* (insect)

Application of PPMs to five case studies

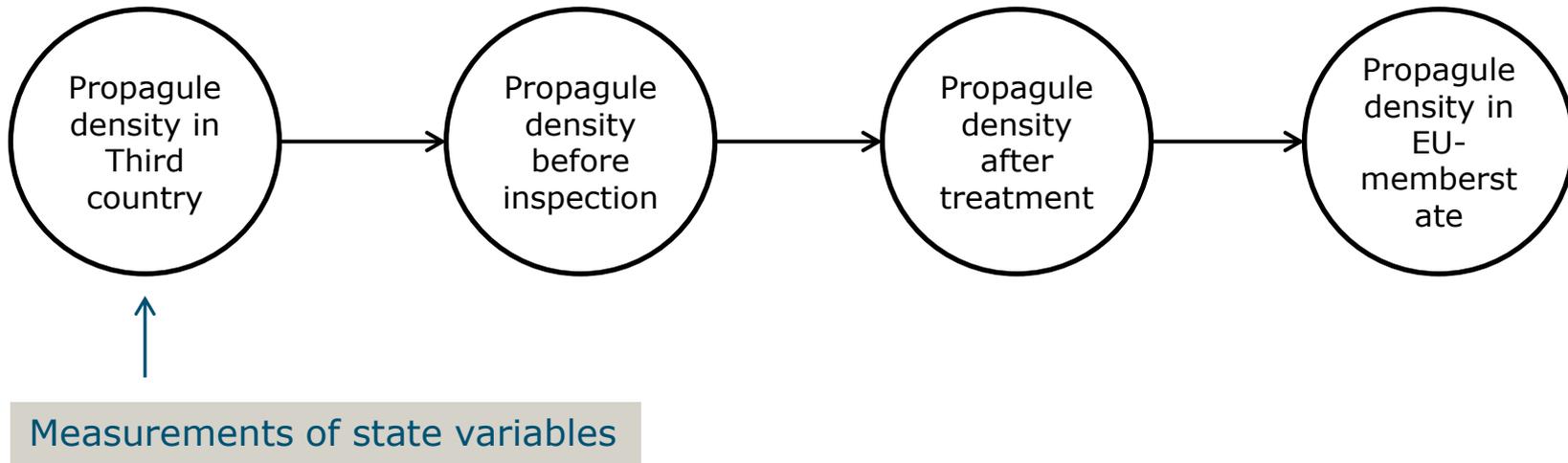


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- Wood shavings + *Bursaphelenchus xylophilus*
(pine wood nematode)
- Bonsai + *Xiphinema americanum*
(nematode)
- Cut orchid flowers + *Thrips palmi* (insect)
- Tomato seeds + PSTVd (viroid)

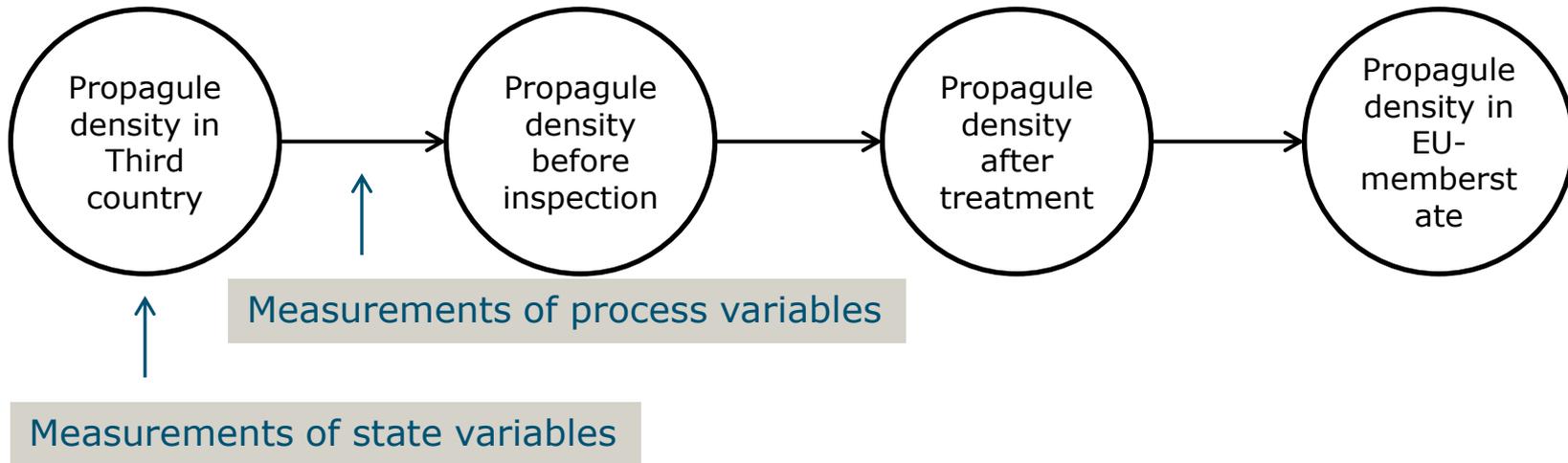
Data requirement of PPMs



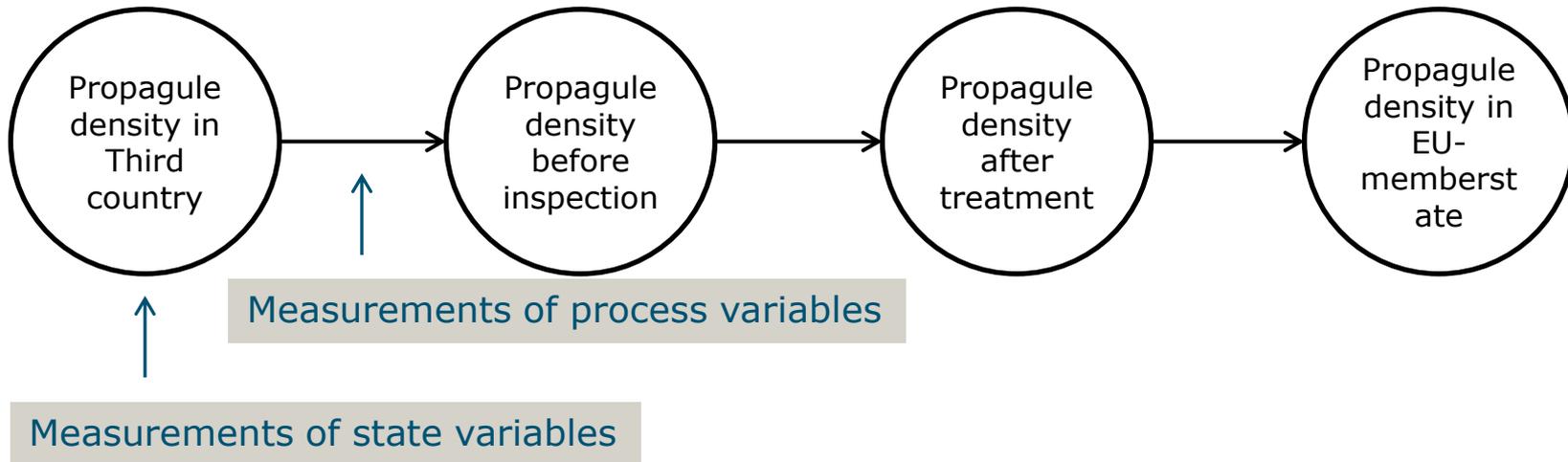
Data requirement of PPMs



Data requirement of PPMs



Data requirement of PPMs



■ Measurements of state variables

- Size of consignments
 - No record of detailed trade statistics
- Consignment infected/not infected
- Number of infected plants per consignments

Strength of approach



- Be explicit about risks at each stage
- To identify worst and best cases for future pest invasion, and visualize what European authorities can do about it
- Scenario analysis:
 - To explore the range of possible outcomes, under multi-parameter (multi-process) variations
 - Identify most (cost-)effective phytosanitary measures and risk reduction options



Sensitivity analysis



Sensitivity analysis:

- Purpose: determine the relationship between process parameters (or structure) and outcomes
- What is the most critical stage during transport?
- Are trade volumes more important than intensity of inspection?

Data requirement of PPMs



- Process data:
 - Biological characteristics of plant pest



Data requirement of PPMs



- Process data:
 - Biological characteristics of plant pest
 - Transport conditions

Data requirement of PPMs



- Process data:
 - Biological characteristics of plant pest
 - Transport conditions
 - Trade volume

Data requirement of PPMs



- Process data:
 - Biological characteristics of plant pest
 - Transport conditions
 - Trade volume
 - Phytosanitary measures (inspection intensity and treatments)
 - Differences in data availability between NPPOs

Data requirement of PPMs



- Process data:
 - Biological characteristics of plant pest
 - Transport conditions
 - Trade volume
 - Phytosanitary measures (inspection intensity and treatments)
 - Differences in data availability between NPPOs
- Standardizing data sources
 - that differ in temporal and spatial resolution
 - from different Plant health agencies

Methodology

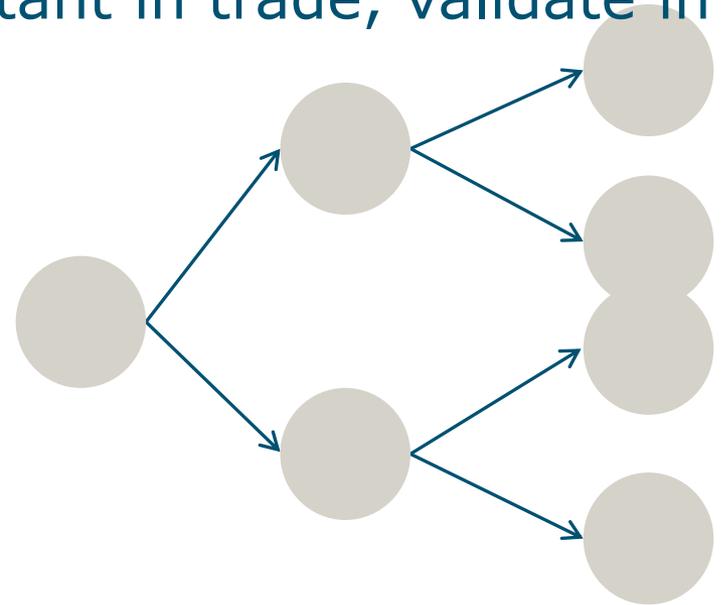


Defining pathways:

- Snow-ball sampling: Experts who recommend other experts
- Start with country (most) important in trade, validate in others

Model complexity:

- Data-driven model development

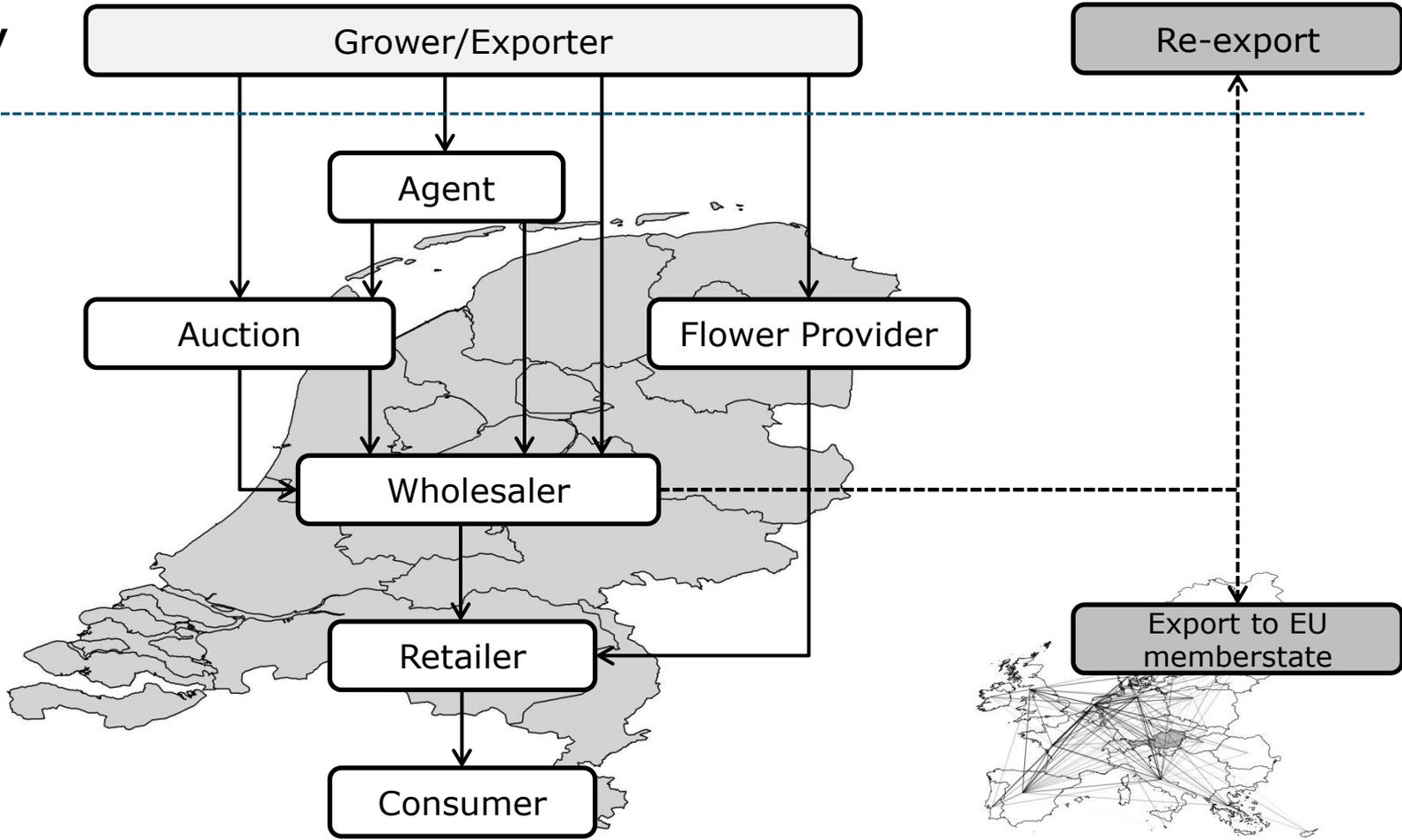


Pathway for cut flowers



Third country

EU

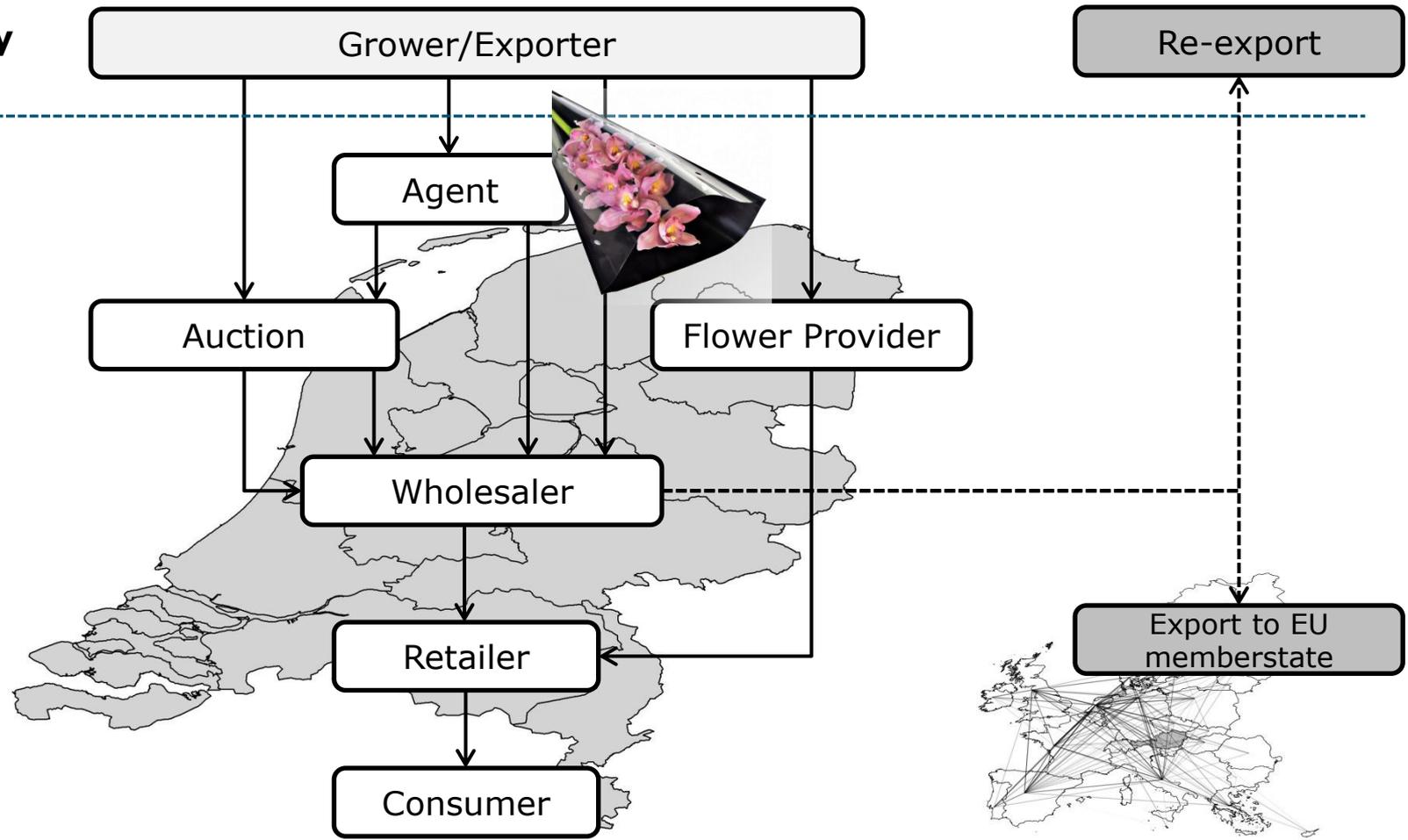


Pathway for cut flowers



Third country

EU

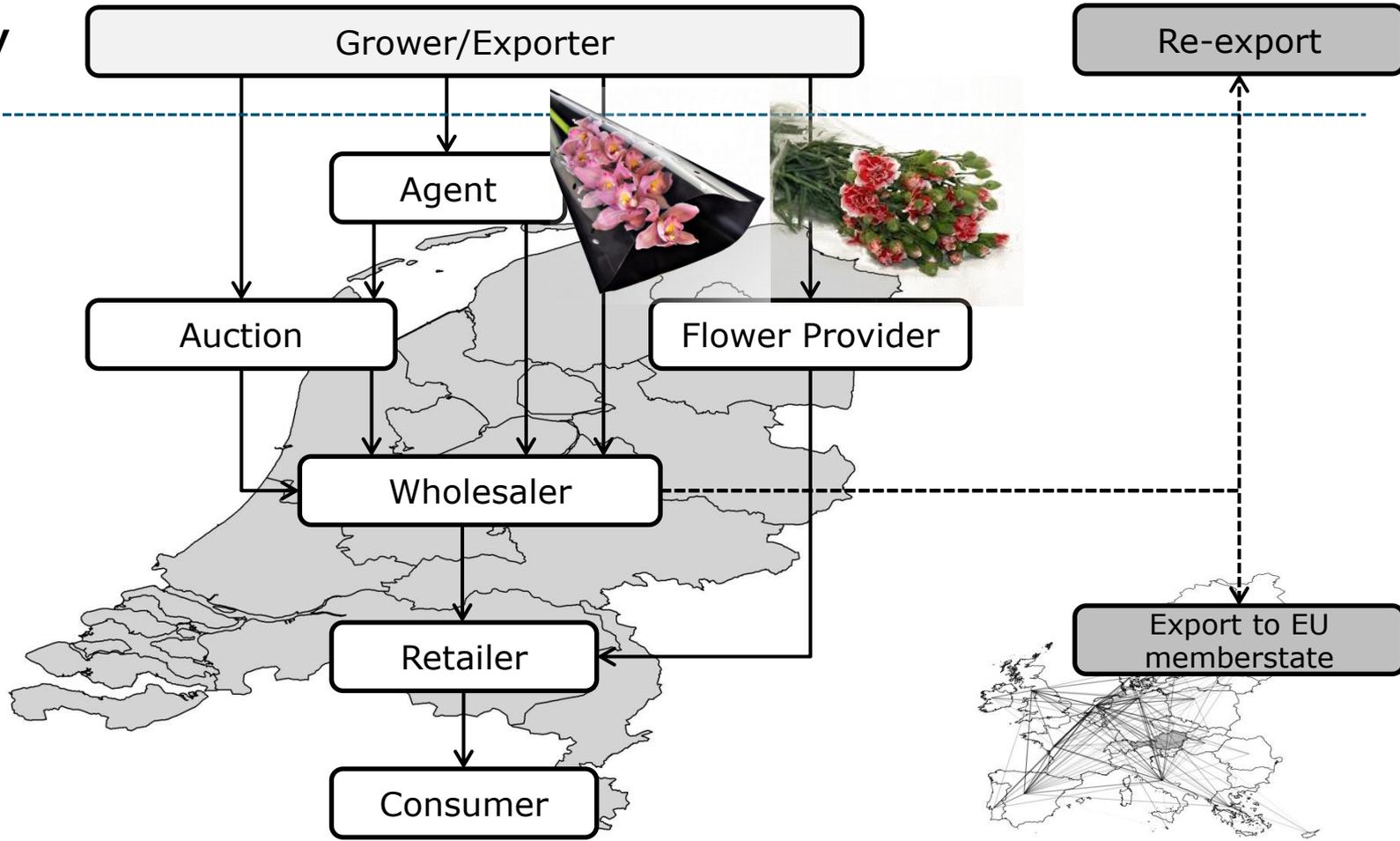


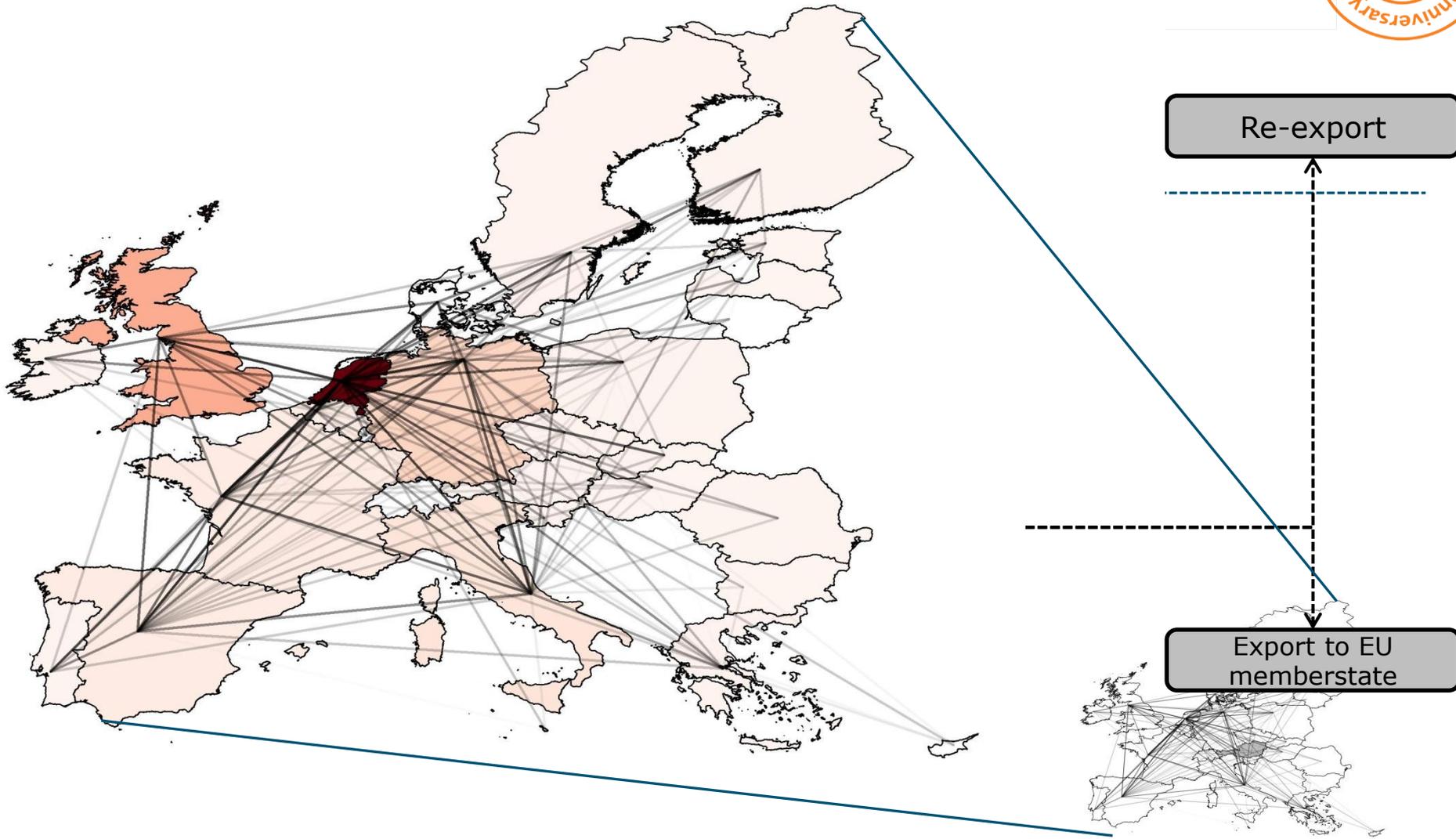
Pathway for cut flowers



Third country

EU





Source: Eurostat



Three ways of transfer to potential host

Two steps with certain probability:

- 1) Infected living cut flowers close to host (monophagous, polyphagous), 2) Pest can disperse to host
- 1) Cut flowers waste close to host, 2) Pest can disperse to host
- 1) Infested transport medium close to host, 2) Pest can disperse to host

- Critical phase but very hard to estimate! Any ideas welcome

User friendly model interface: @Risk

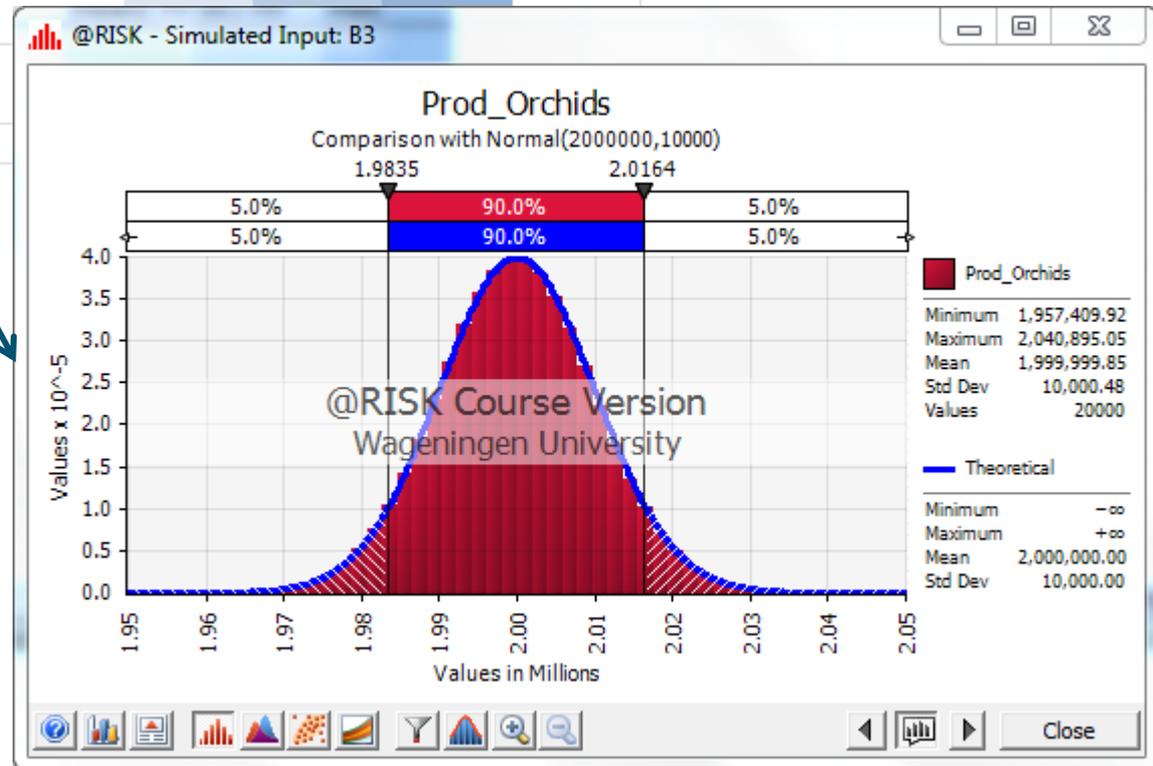


SUM		=RiskNormal(\$E\$3,\$F\$3,RiskName("Prod_Orchids"))						
	A	B	C	D	E	F	G	H
1	Orchids from Thailand				Parameters			
2	Variables	estimate			mean/ mi	sd / ml	max	
3	yearly export orchids (nr/year)	=RiskNormal(\$E\$3,\$F\$3,RiskName("Prod_Orchids"))						
4	proportion affected (%)	0.1			0.1	0.1		
5	% escape detection of PPQ	3.833333			1	3	10	
6								
7								

User friendly model interface: @Risk



	A	B	C	D	E	F	G	H
1	Orchids from Thailand				Parameters			
2	Variables	estimate			mean/ mi	sd / ml	max	
3	yearly export orchids (nr/year)	=RiskNormal(\$E\$3,\$F\$3,RiskName("Prod_Orchids"))						
4	proportion affected (%)	0.1						
5	% escape detection of PPQ	3.833333						
6								
7								



User friendly model interface: @Risk



Example_orchids.xlsx - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View @RISK

Define Distributions Output Function Correlations Model Distribution Fitting Distribution Artist Model Window Iterations 20000 Simulations 1 Start Simulation Analyses Optimizer Browse Results Summary Define Filters Excel Reports Swap Functions

B14 fx =RiskOutput()+\$B\$9

1	O														
2	Va	% escape detection of													
3	ye	PPQ	3.833333			1	3	10							
4	(n	Calculation													
5	pr	infected flowers													
6	(%	(nr/year)	76.66667												
7	%														
8	PP														
9															
10															
11															
12															
13		Output	Value	Mean	Std	CV	1%	5%	10%	25%	50%	75%	90%	95%	99%
14		Infected flowers	76.66667	76.8011	88.6693	1.0018	5.3839	10.5207	14.7665	26.0660	49.8456	94.4835	165.1703	231.0438	425.5645
15															
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@RISK - Output: B14

Infected flowers / Value

5.0% 11 231 5.0%

0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000

-500 0 500 1,000 1,500 2,000 2,500

Infected flowers / Value

Minimum	0.811
Maximum	2,446.95
Mean	76.80
Std Dev	88.67
Values	20000

@RISK Course Version
Wageningen University

Prod_Orchids

Minimum	1,957,409.92
Maximum	2,040,895.05
Mean	1,999,999.85
Std Dev	10,000.48
Values	20000

Theoretical

Minimum	-∞
Maximum	+∞
Mean	2,000,000.00
Std Dev	10,000.00

Quantitative pathway analysis? Is it really worth it?



Feedback,
comments,
ideas,
questions?

All welcome!



Please contact Bob Douma for any use of this presentation
Bob.Douma@wur.nl



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