Which models for which objectives of IPM under the context of Climate Change?

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endure
diversifying crop protection

Summer School 2016

The role of IPM in mitigating pest development under climate change–modelling approaches

OUTLINE

1) Which objectives of modelling for IPM?
2) Examples of modelling approaches
3) Examples of simulation model outputs on pest dynamics under Climate Change
4) Discussion

3 levels of de-intensification in agroecosystems (role of IPM)

Efficiency

Substitution

Redesign

Hill and MacRae (1995

Réseau Mixte Technologique
Systèmes de
Culture Innovants

A wide range of objectives for modelling for crop protection

- Warning systems
- Decision Support System for chemical or biological control
- Design of agroecosystems less susceptible to pests
- Design of strategies to preserve cultivar resistances (or pesticide efficacy)
- Design of landscape management strategies to limit pest development
- Design of control strategies throught crop architecture management
- Design of ideotypes
- Yield loss analysis
- Invasive species analysis
- Analysis of the effects of climate change on pest development
- Assess various performances of IPM strategies
- Design sampling strategies
- …

Aubertot. 2015. 2nd PURE international conference. Poznan, Poland

OUTLINE

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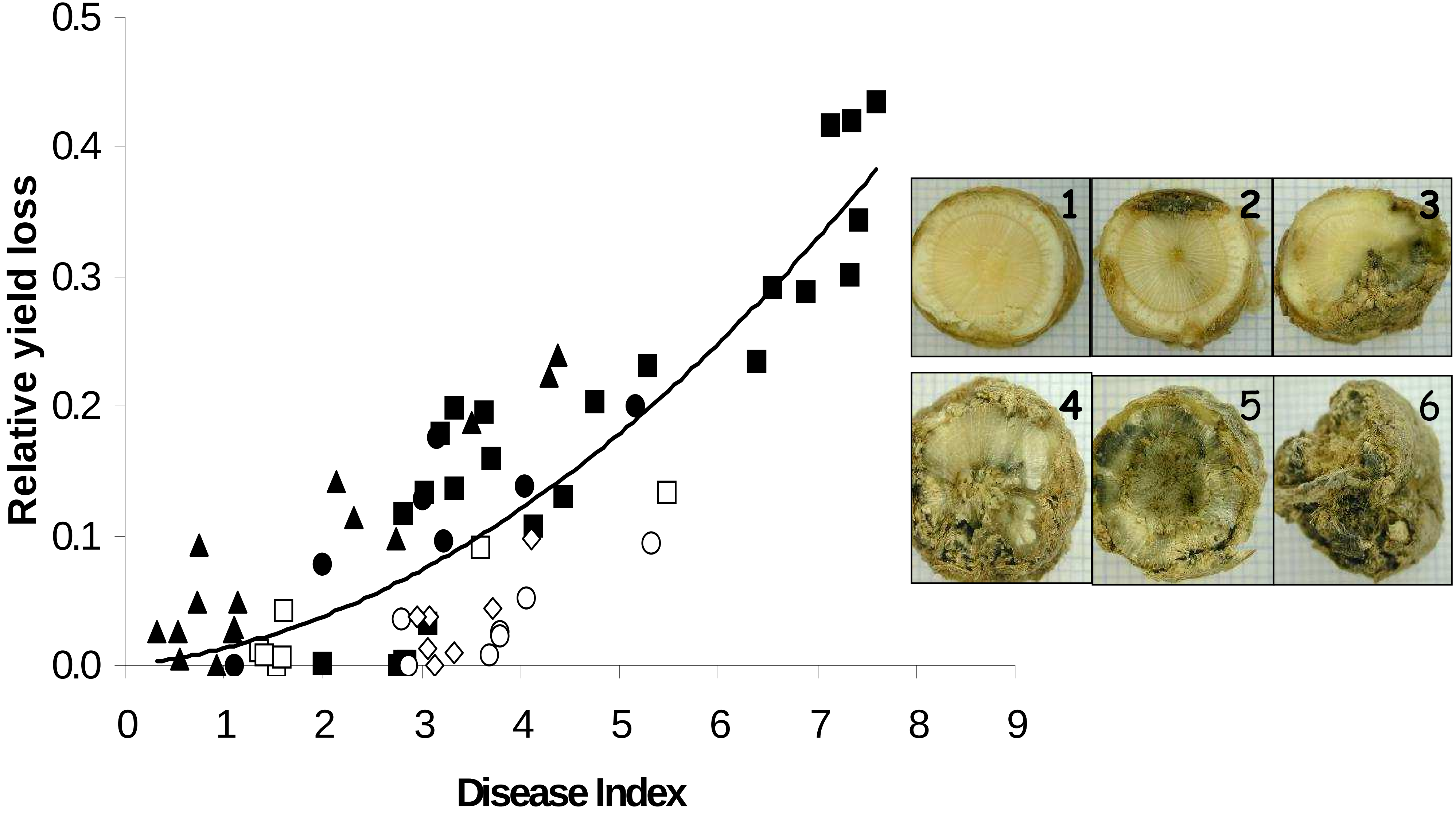
Modelling to quantify issues: crop loss quantification

Example 1/3

Example of single point damage model:

polynomial regression (phoma stem canker on oilseed rape)



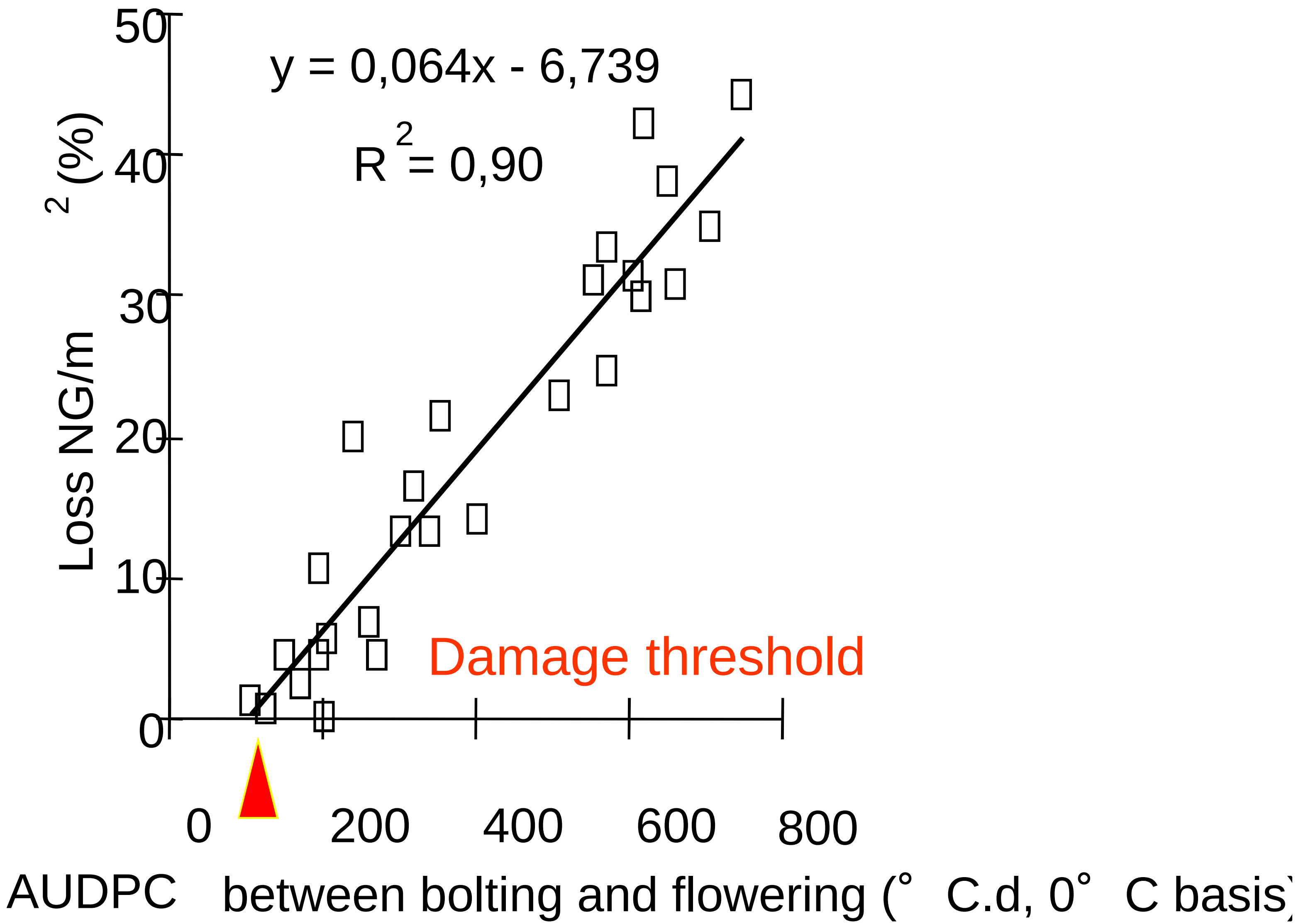
Aubertot et al, 2004

Modelling to quantify issues: crop loss quantification

Example 2/3

Example of damage model integrated over time:

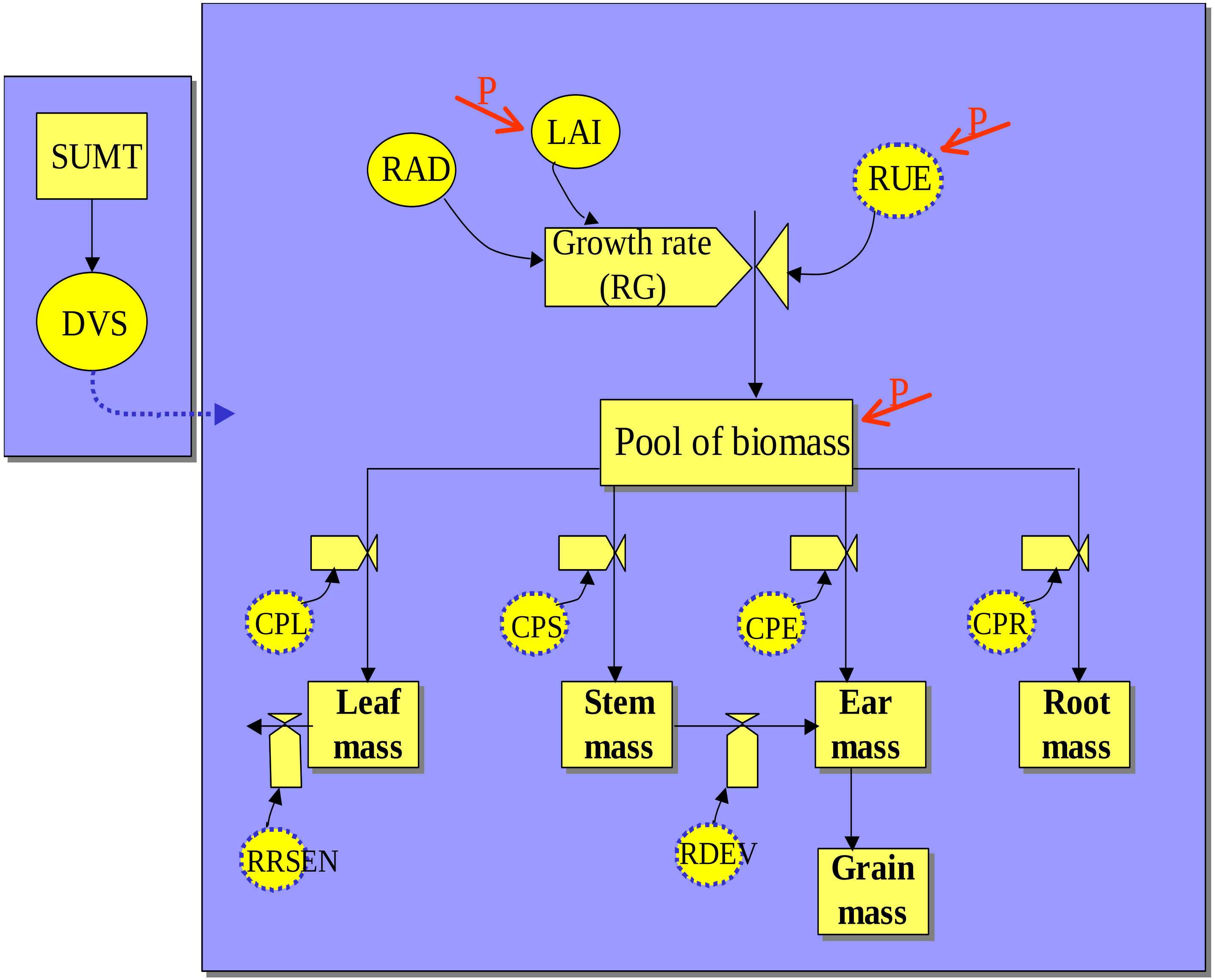
an AUDPC model (Schoeny, 1999)



Modelling to quantify issues: crop loss quantification

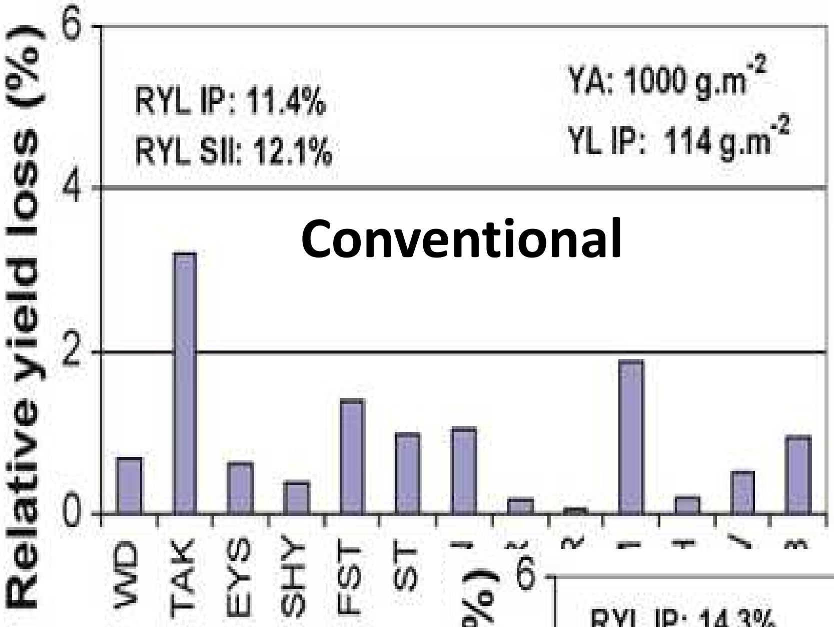
Example 3/3

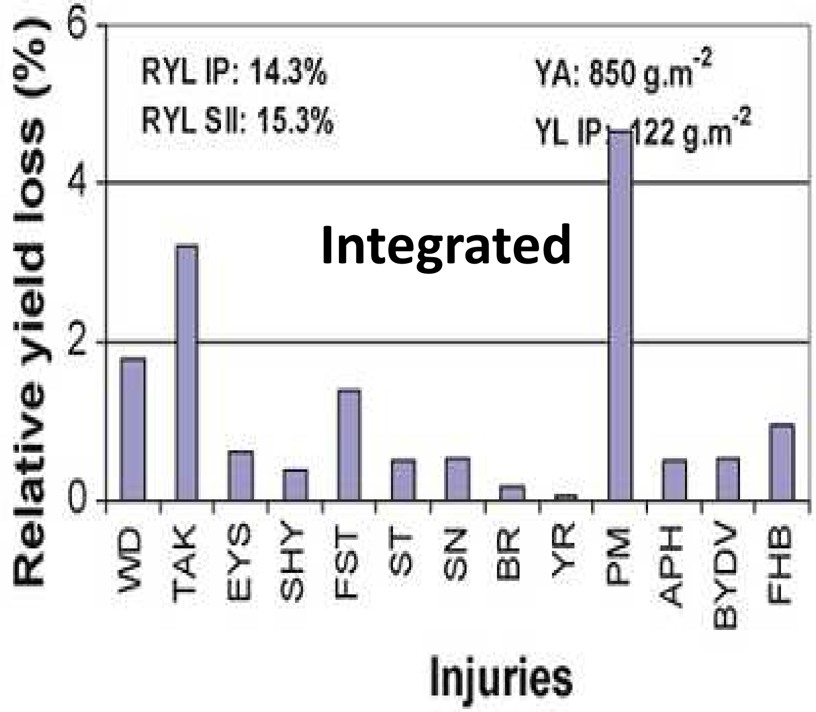
Example of a dynamic damage model adressing an injury profile (Wheatpest)

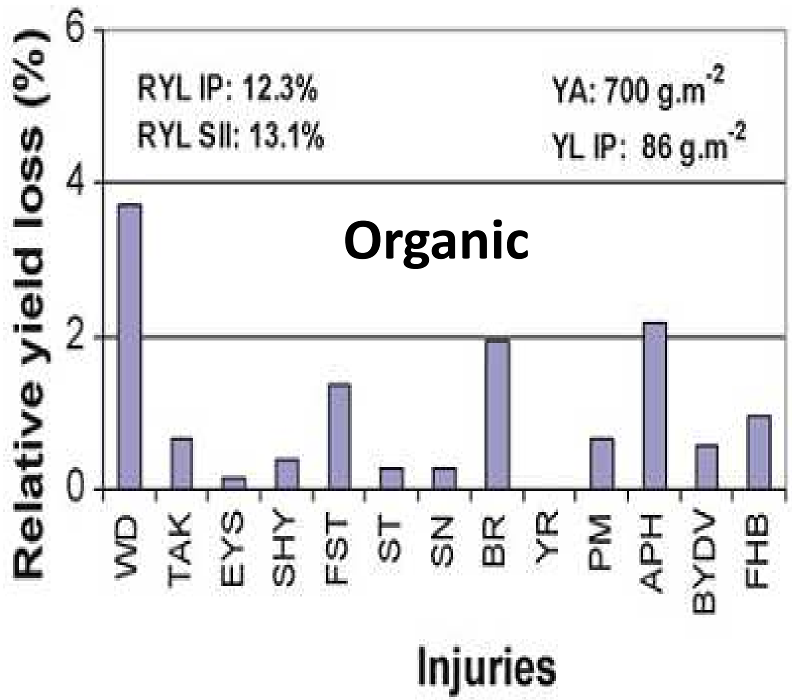


Willocquet et al, 2008

Wheatpest output examples

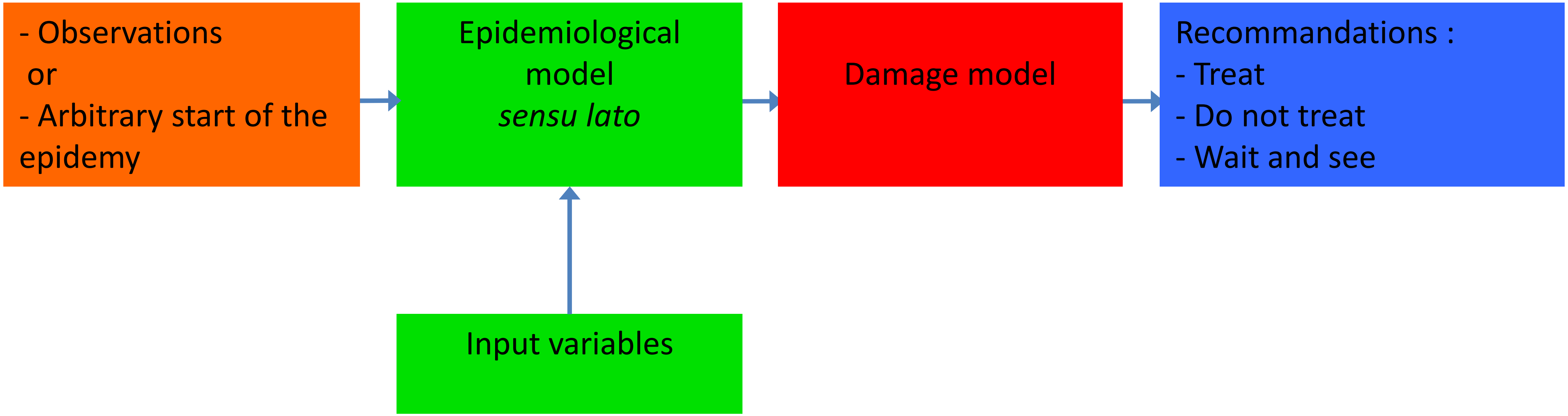






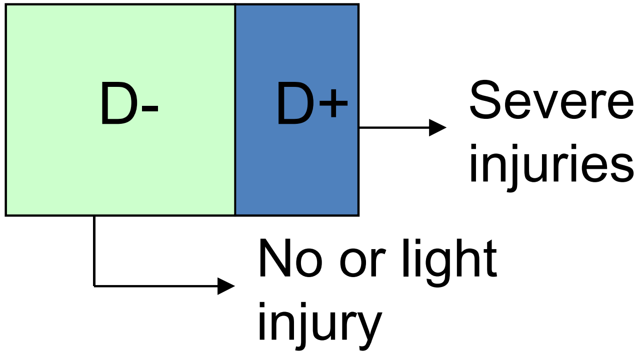
Willocquet et al, 2008

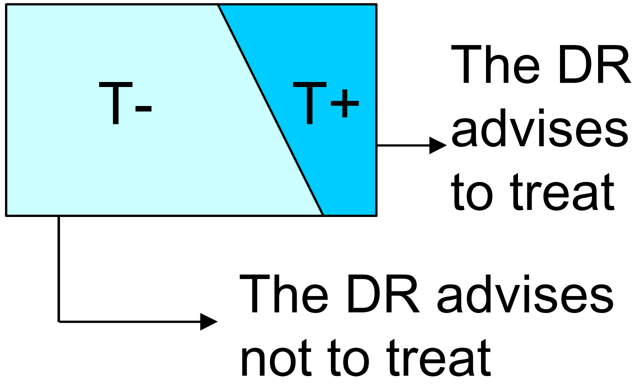
Modelling to help decision making for treatments (E)



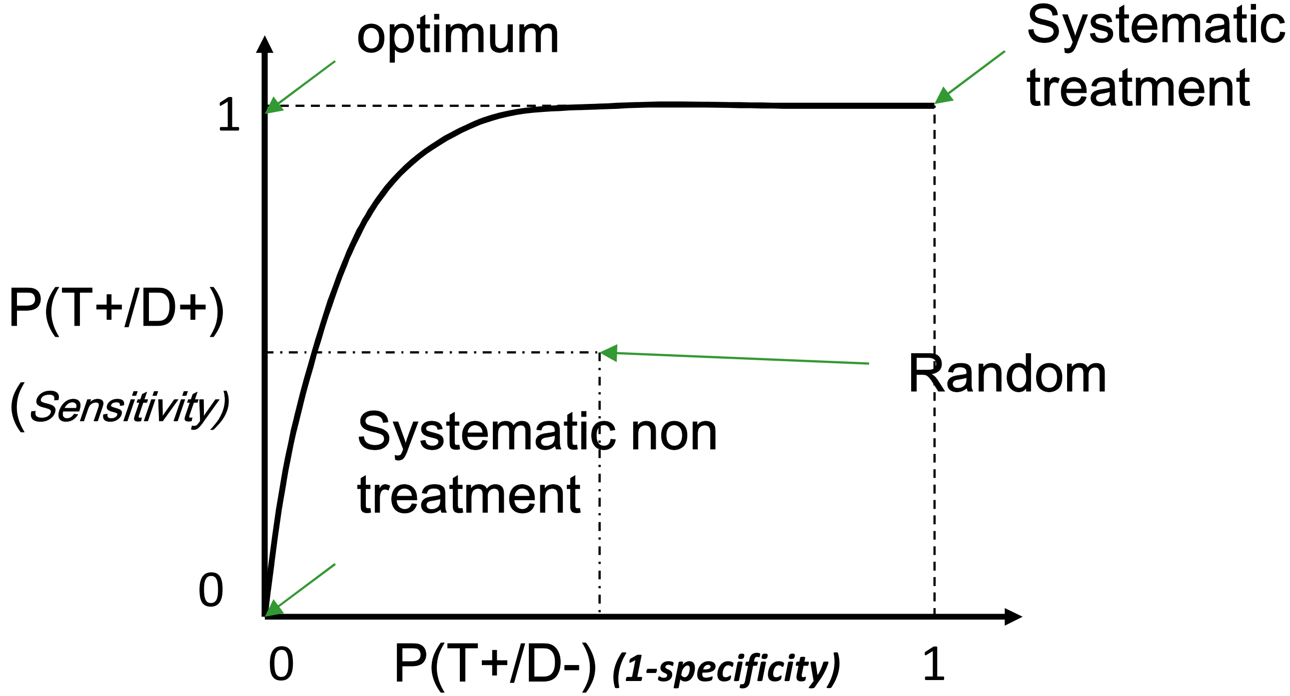
Aim: to select decision rules limiting severe injuries on sclerotinia on oilseed rape (INRA/CETIOM collaboration)

2 tools: risk grid & petal sampling

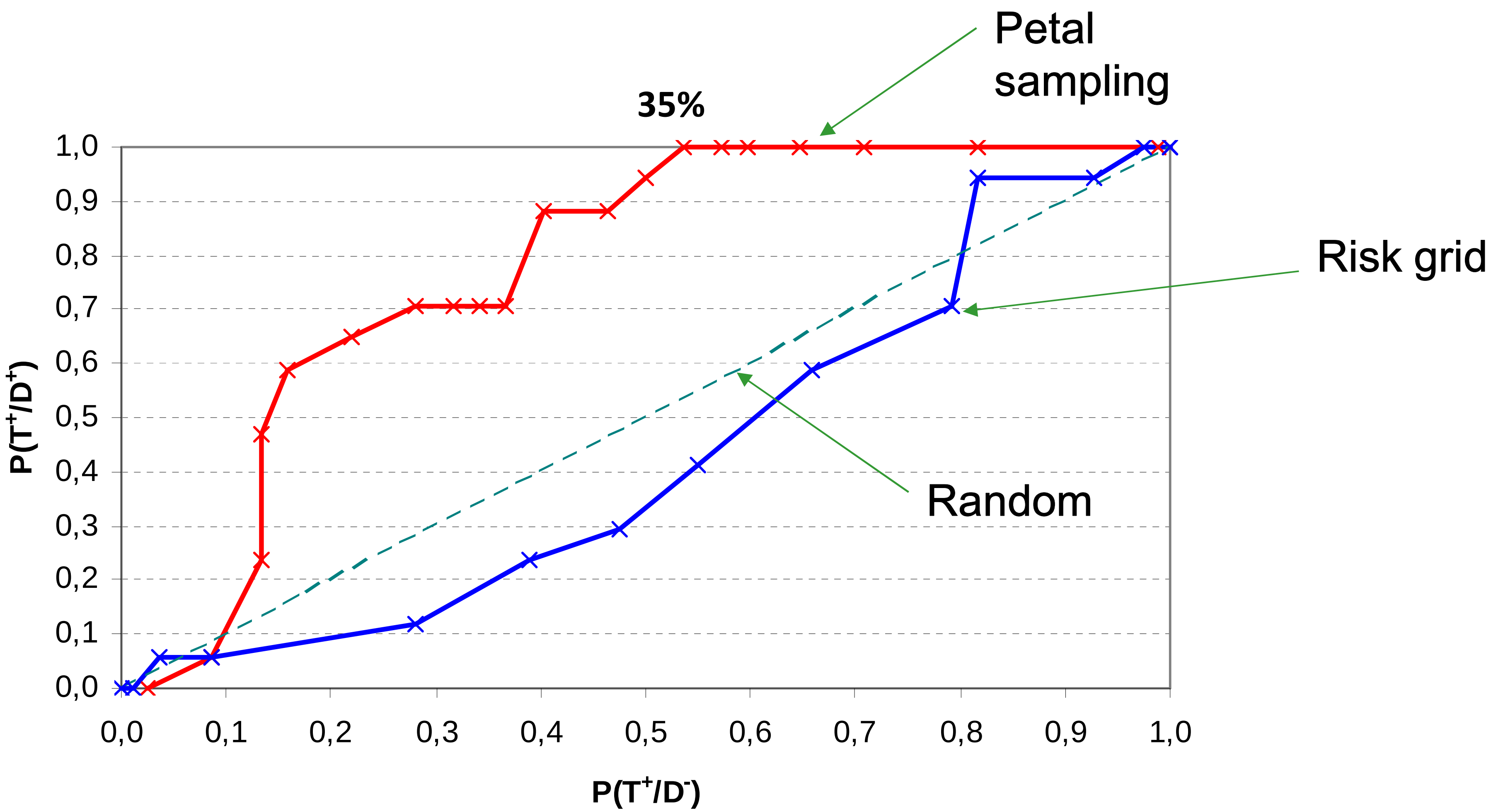




P(T+/D+), P(T+/D-)



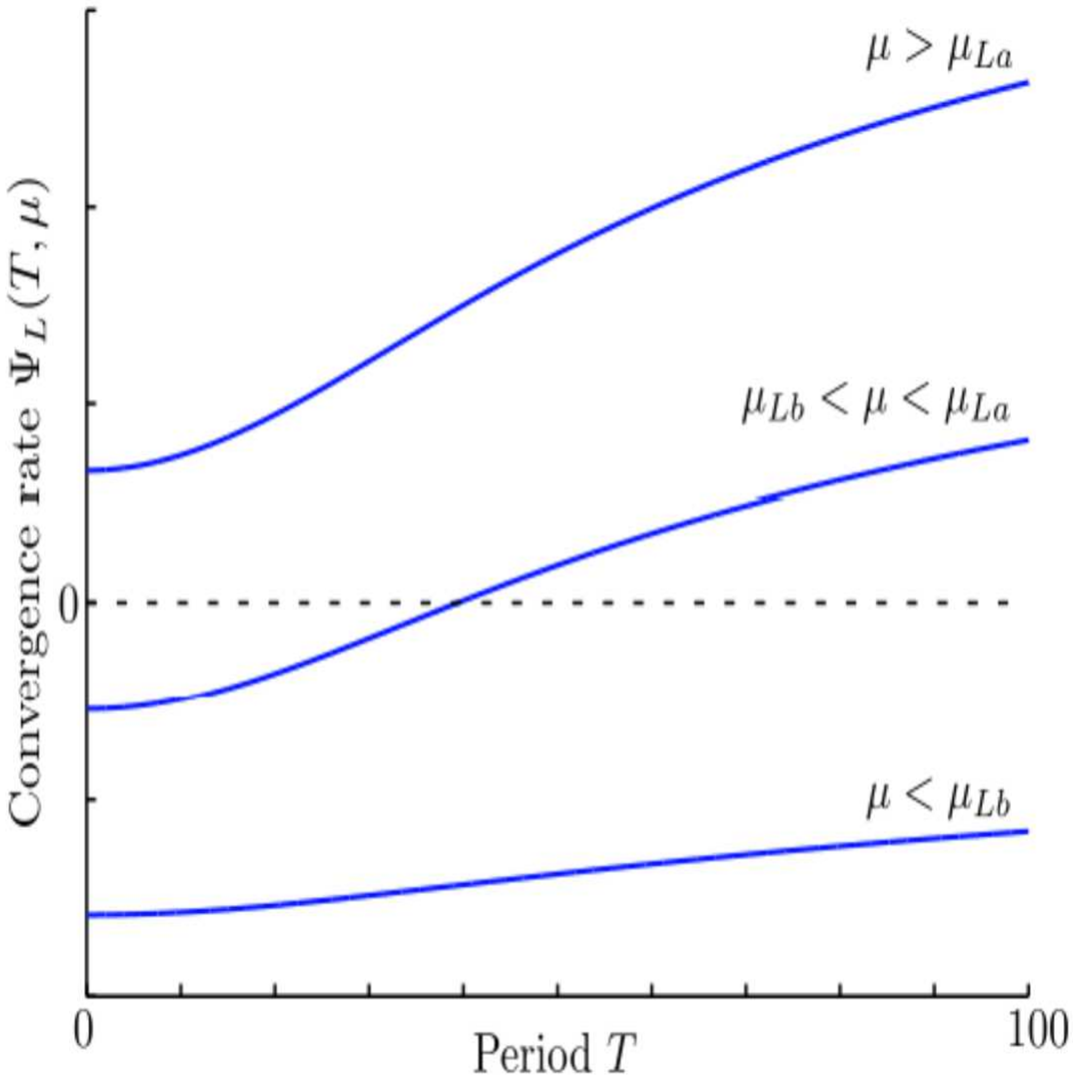
YUEN et al., 1996
HUGHES et al., 1999



Makowski et al., 2004

Modelling to help decision making for treatments (S)

Optimisation of biological control
Use of theoretical predator-prey model – system of differential equations (including the Allee effect)



Bajeux, Grognard, Mailleret. 2014

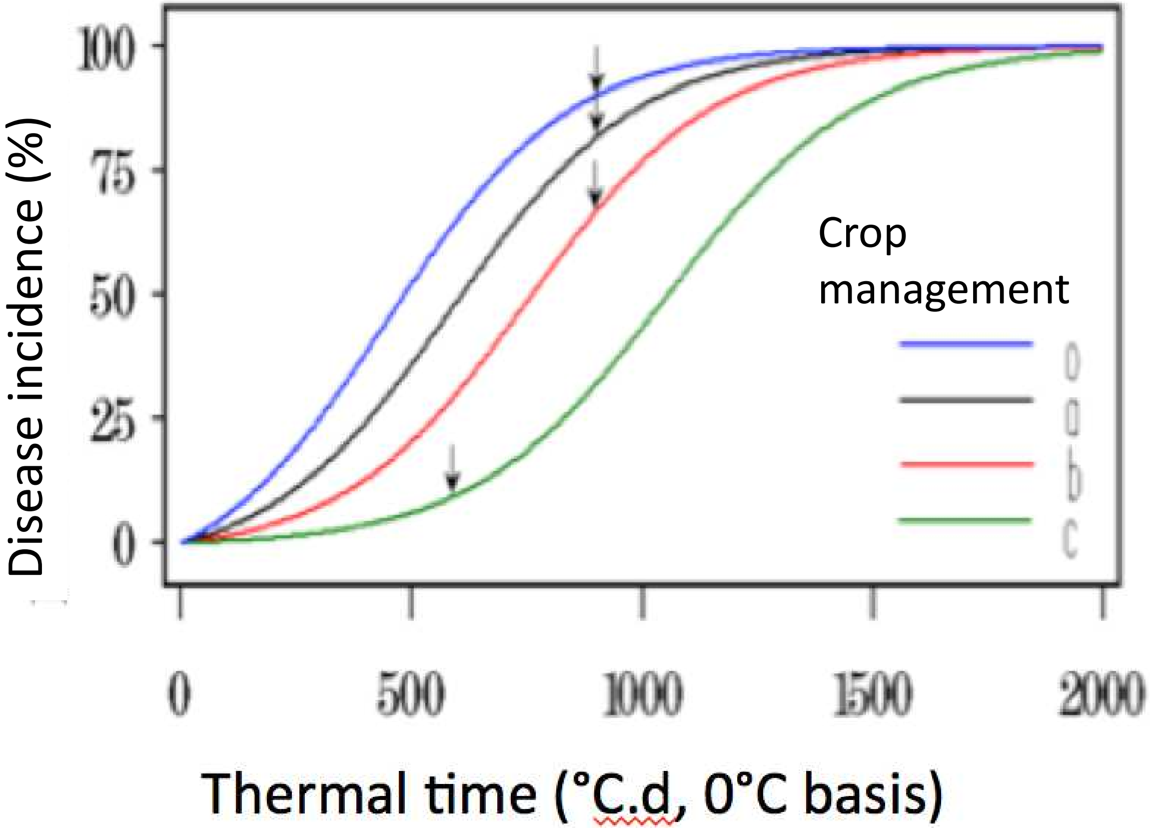
Modelling to help re-design cropping systems (R)

Example 1/2

Simple epidemiological model (Prof. C Gilligan) adapted by Colbach et al. to take-all on wheat

$$y = \frac{1 - e^{-(c_1 + c_2)t}}{1 + \frac{c_2}{c_1} e^{-(c_1 + c_2)t}}$$

	O	a	b	c
DS	10/10	10/10	10/10	10/11
NP (m²)	350	240	225	225
N dispo (kg/ha)	300	270	225	225



Modelling to help re-design cropping systems (R)

Example 2/2

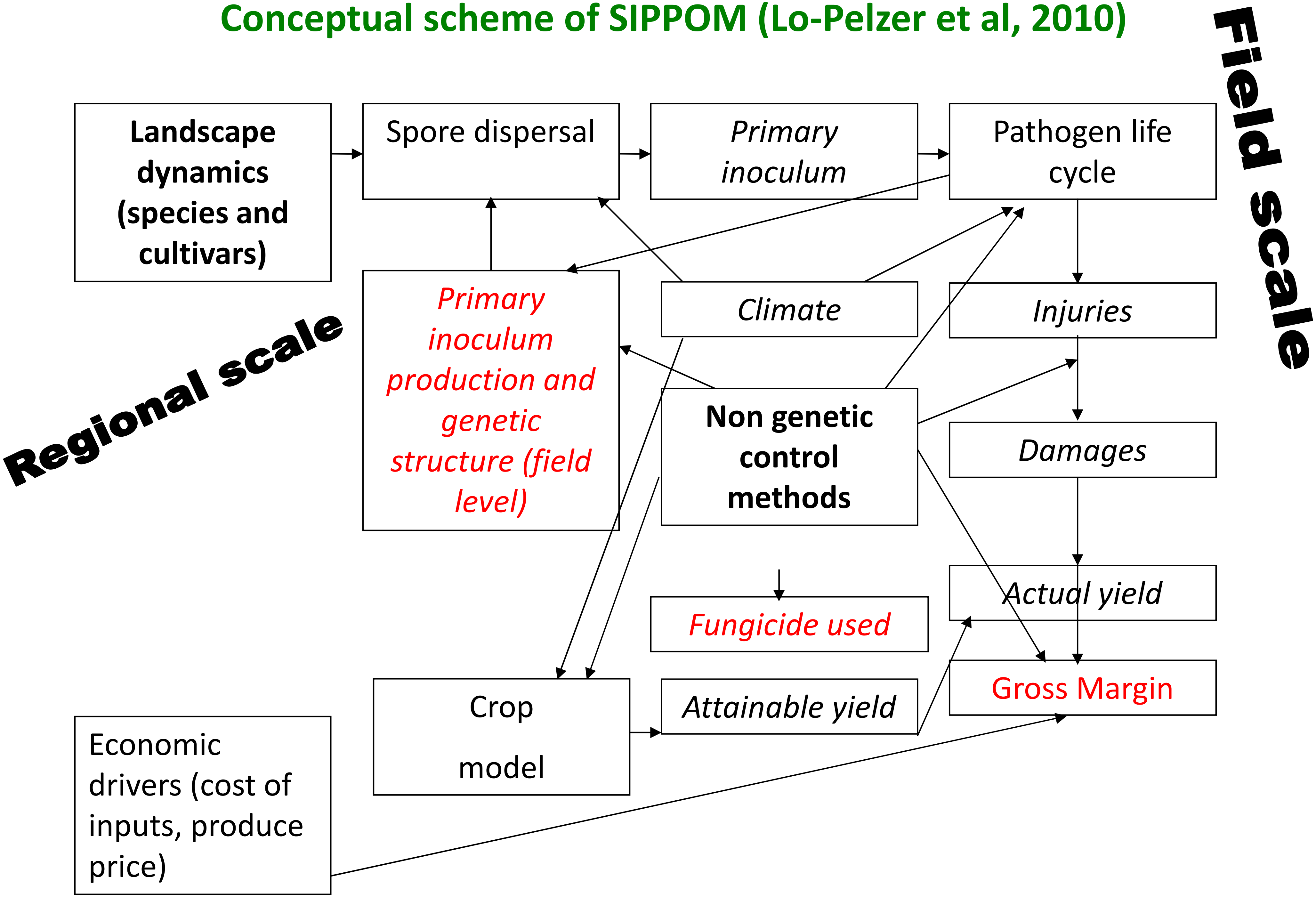
How to design sustainable management strategies of phoma stem canker on oilseed rape?

→ Combining genetic control, cultural control and chemical control if need be

- Ascospore dispersal: disease management at the landscape level
- Need to ensure the durability of crop protection strategies
- Assessment multicriteria

→ Need for an integrated modelling approach

Conceptual scheme of SIPPOM (Lo-Pelzer et al, 2010)



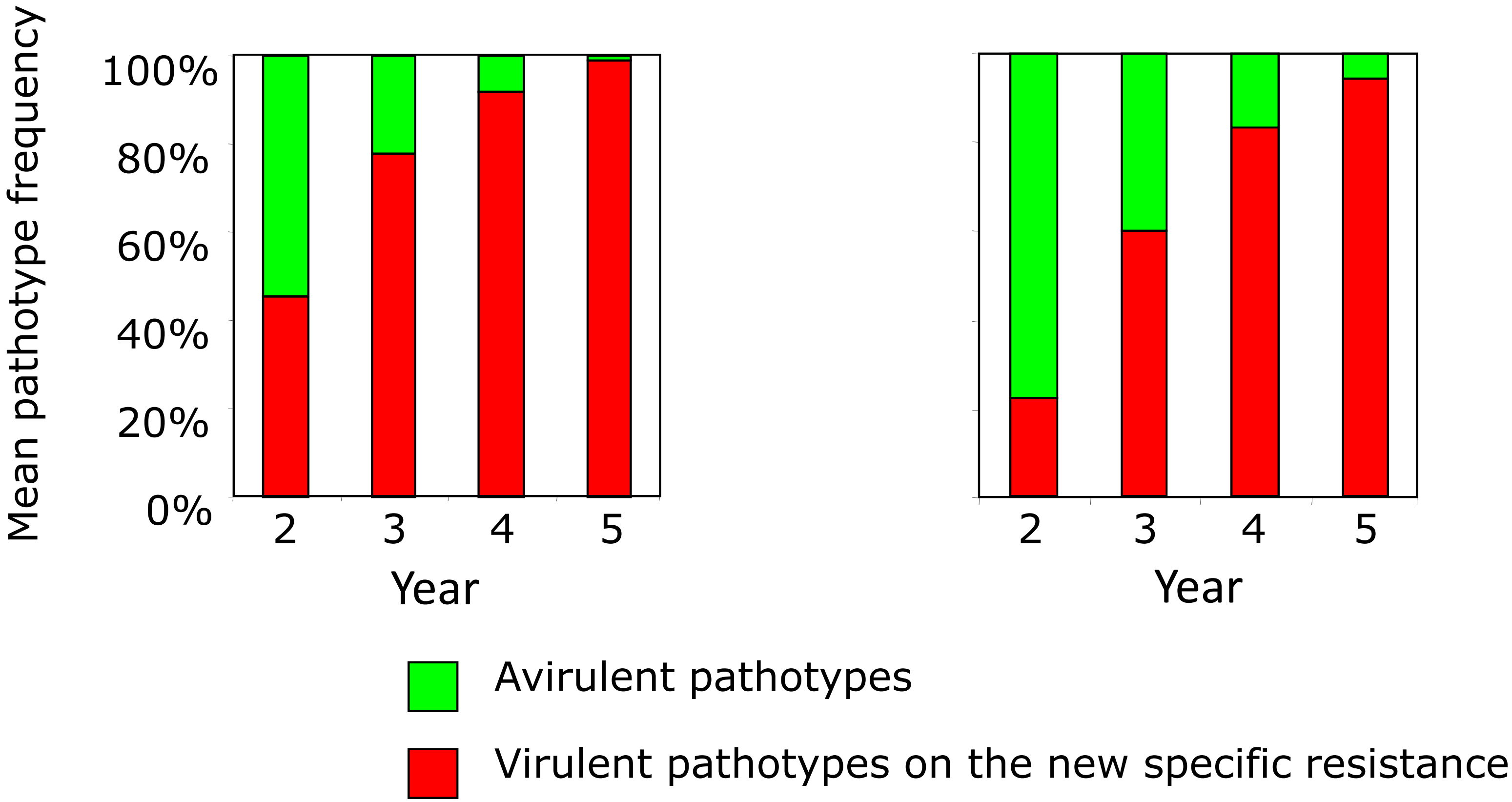
Simulated outputs on resistance durability

Scenario 1

- 50 % fields with specific resistance
- 50 % fields with a susceptible cultivar
- Intensive Crop Management with simplified tillage for all fields

Scenario 2

- 50 % fields with specific resistance associated to integrated crop management with ploughing
- 50 % fields with a susceptible cultivar associated to Intensive Crop Management with simplified tillage



OUTLINE

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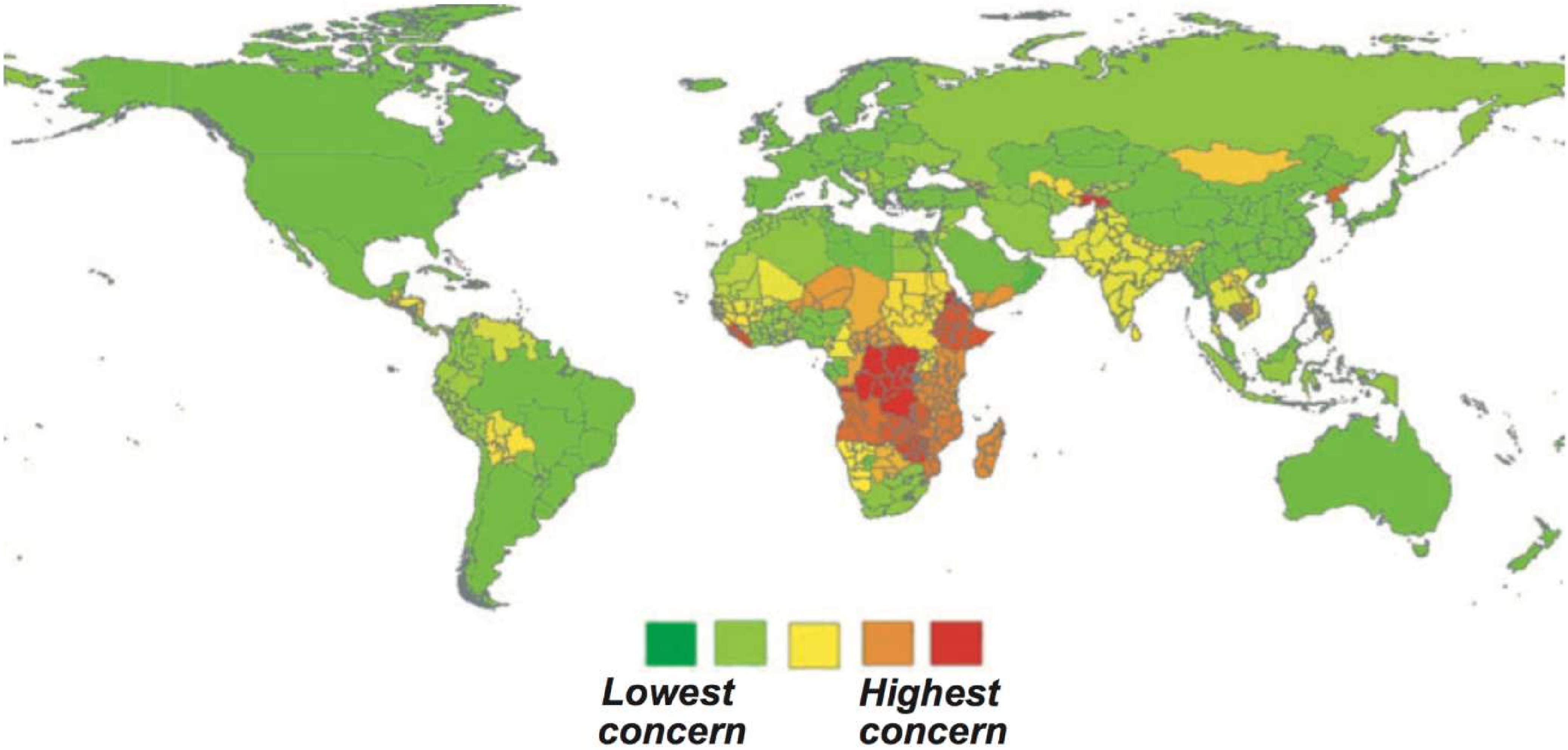
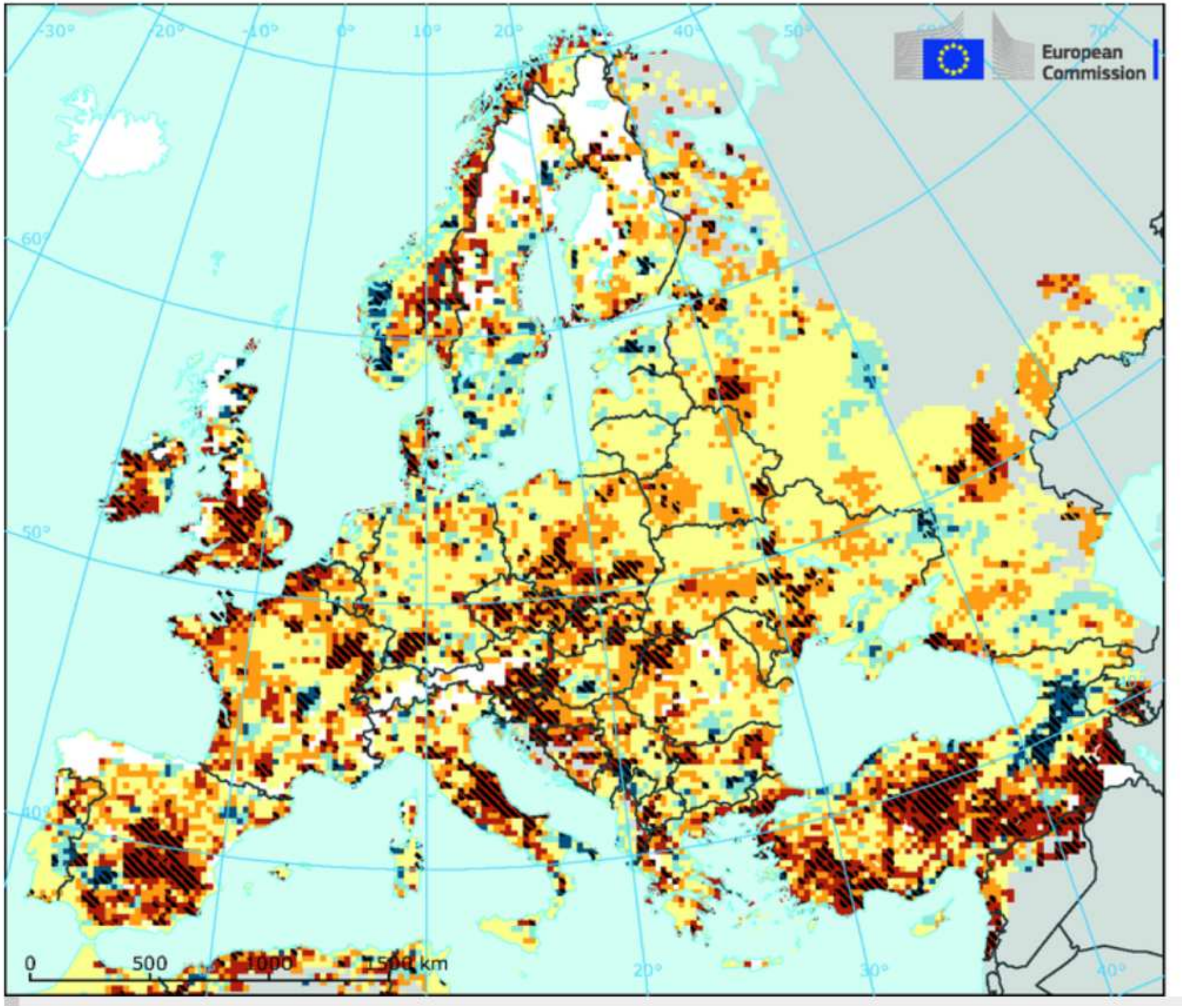
Identification of food insecurity hotspots based on hunger, food aid and dependence on agricultural gross domestic production statistics from FAOStat and WRI; 2001–2003



Chakraborty and Newton (2011). Plant pathology.

Change in the number of frost-free days per year



European Environment Agency

2014

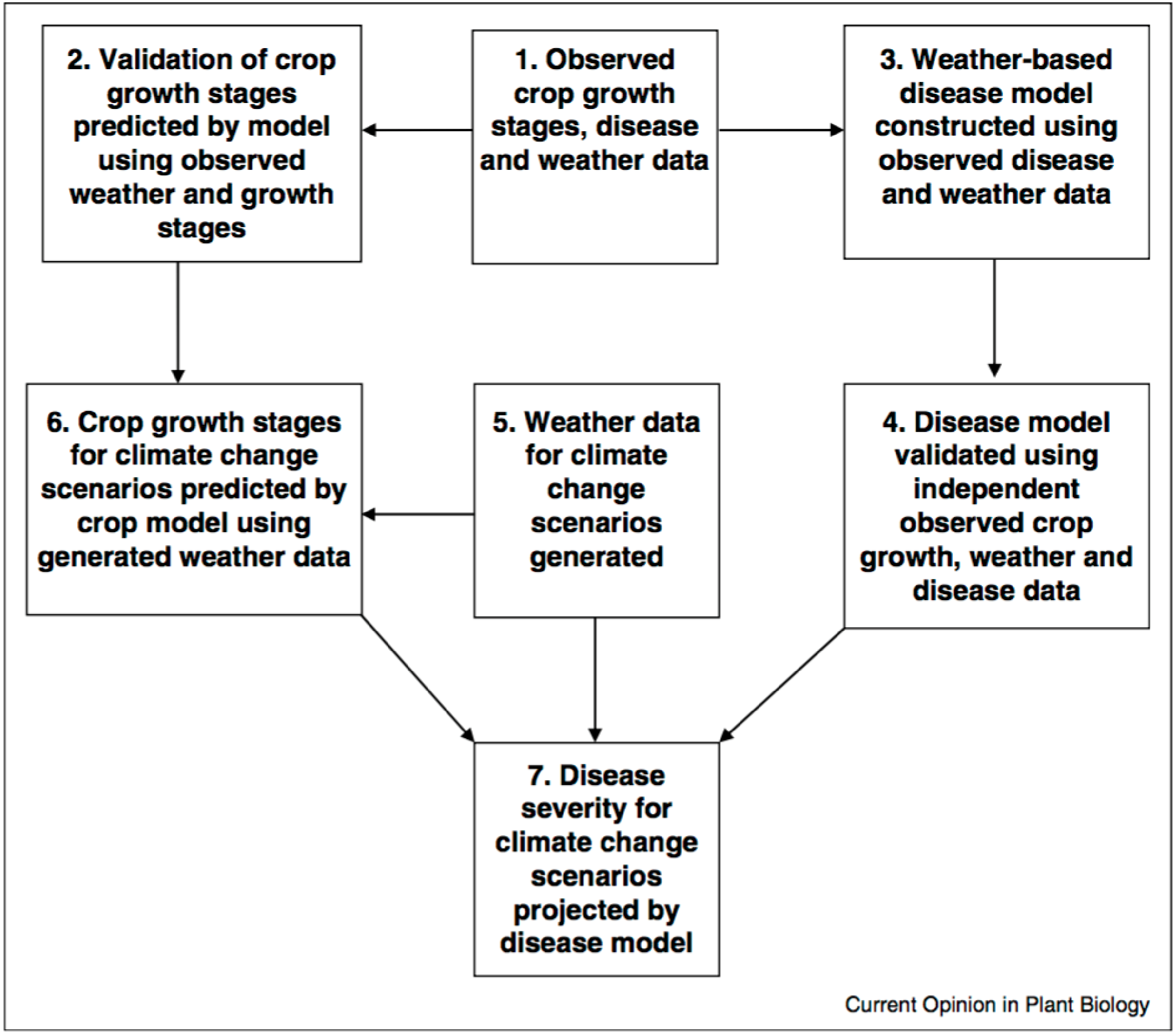
Plant pathogens

Table 1

Climate change impacts on crop disease studies published between January 2014 and January 2016

Pathogen group	Disease	Pathogen	Model components	Comments	Reference
Fungi	Various diseases on various hosts	*Fusarium oxysporum* f. spp.	Two GCM → CLIMEX	Climate change impacts on global distribution of a pathogenic species complex.	[68]
Fungi	Fusarium head blight on wheat	*Fusarium* spp.	One GCM → simulated weather + crop model + disease model.	Climate change impacts in China.	[21]
Fungi	Fusarium head blight on wheat	*Fusarium culmorum*	11 GCM ensemble + anthesis model + mycotoxin model.	Climate change impacts on mycotoxin levels in Scotland.	[32*]
Fungi	Brown rust on wheat	*Puccinia recondita*	15 GCM → simulated weather + disease model.	Climate change impacts in Luxembourg.	[24]
Fungi	Six soil-borne fungi: three affecting cereals, three affecting spring-sown herbaceous crops	*Fusarium nivale* *Fusarium culmorum* *Bipolaris sorokiniana* *Pythium ultimum* *Sclerotinia minor* *Macrophomina phaseolina*	One GCM + soil conditions model + disease model.	Climate change impacts in Europe.	[69]
Fungi Bacteria	Leaf blast on rice Leaf blight on rice	*Magnaporthe oryzae* *Xanthomonas oryzae* pv. *oryzae*	One GCM → simulated weather + crop model + disease model.	Climate change impacts in Tanzania. Same disease can increase in severity in some areas and decrease in others.	[19]
Fungi Bacteria	Leaf blast on rice Leaf blight on rice	*Magnaporthe oryzae* *Xanthomonas oryzae* pv. *oryzae*	One GCM → simulated weather + disease model.	Climate change impacts in South Korea.	[26*]
Fungi Bacteria	Leaf blast on rice Leaf blight on rice	*Magnaporthe oryzae* *Xanthomonas oryzae* pv. *oryzae*	11 GCMs and ensemble → simulated weather + disease model.	Climate change impacts in South Korea.	[31]
Fungi Oomycetes	Phoma stem canker on oilseed rape Brown rust on wheat Net blotch on barley Downy mildew on grape Potato late blight	*Leptosphaeria maculans* *Puccinia recondita* *Pyrenophora teres* *Plasmopara viticola* *Phytophthora infestans*	One GCM → simulated weather + infection model.	Climate change impacts in France for five foliar pathogens.	[17**]
Oomycetes	Downy mildew on grape	*Plasmopara viticola*	One GCM → simulated weather + crop model + disease model.	Climate change impacts in France.	[25]
Oomycetes	Potato late blight	*Phytophthora infestans*	3 GCM → monthly means + crop model + disease model.	Global climate change impacts.	[20]
Oomycetes	Potato late blight	*Phytophthora infestans*	Weather data + 3 disease models.	Not strictly a climate change impact paper but a comparison of different disease models.	[70]

Newbery et al. 2016. Current Opinion in Plant Biology



Newbery et al. 2016. Current Opinion in Plant Biology

Weeds

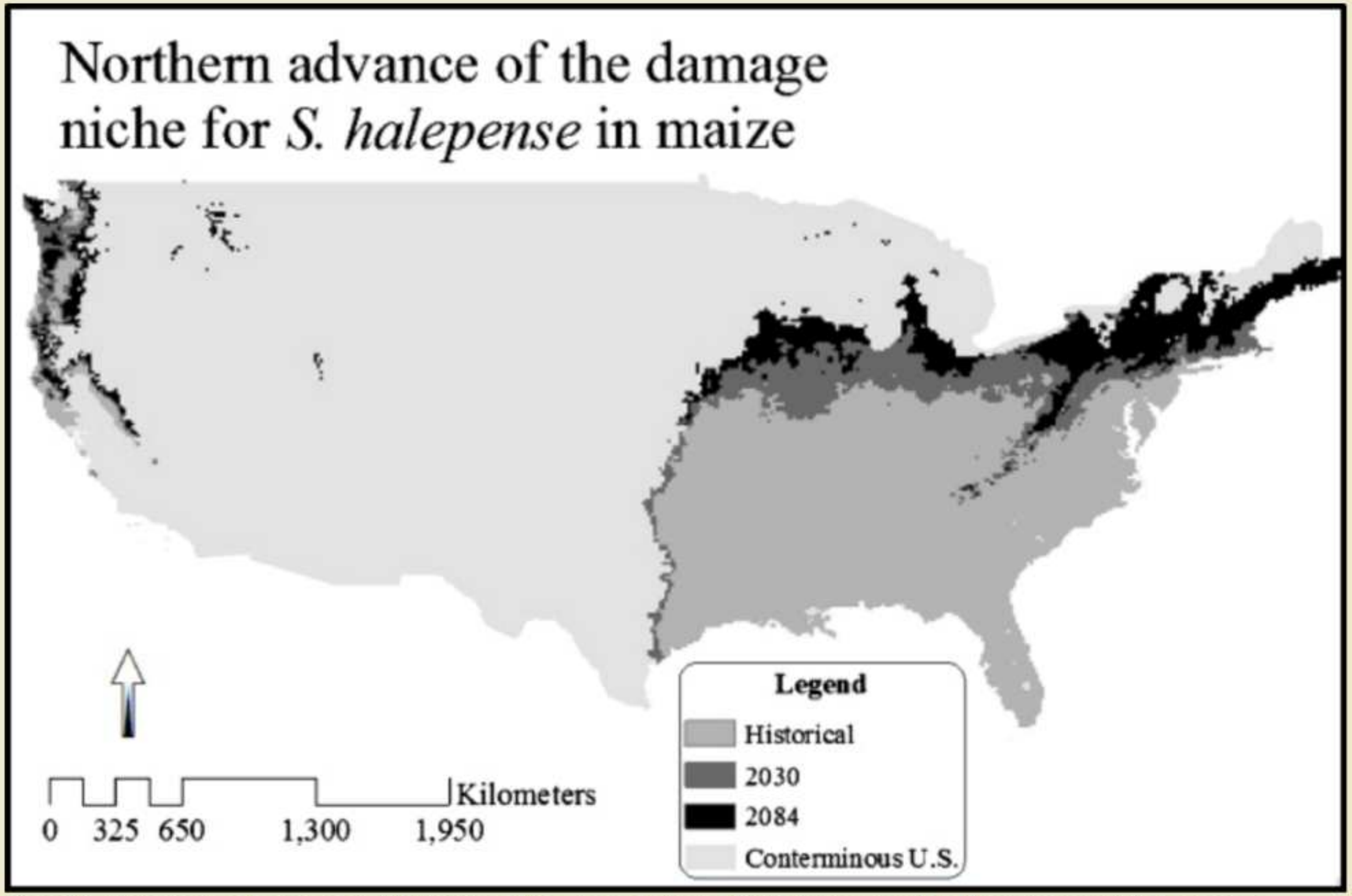
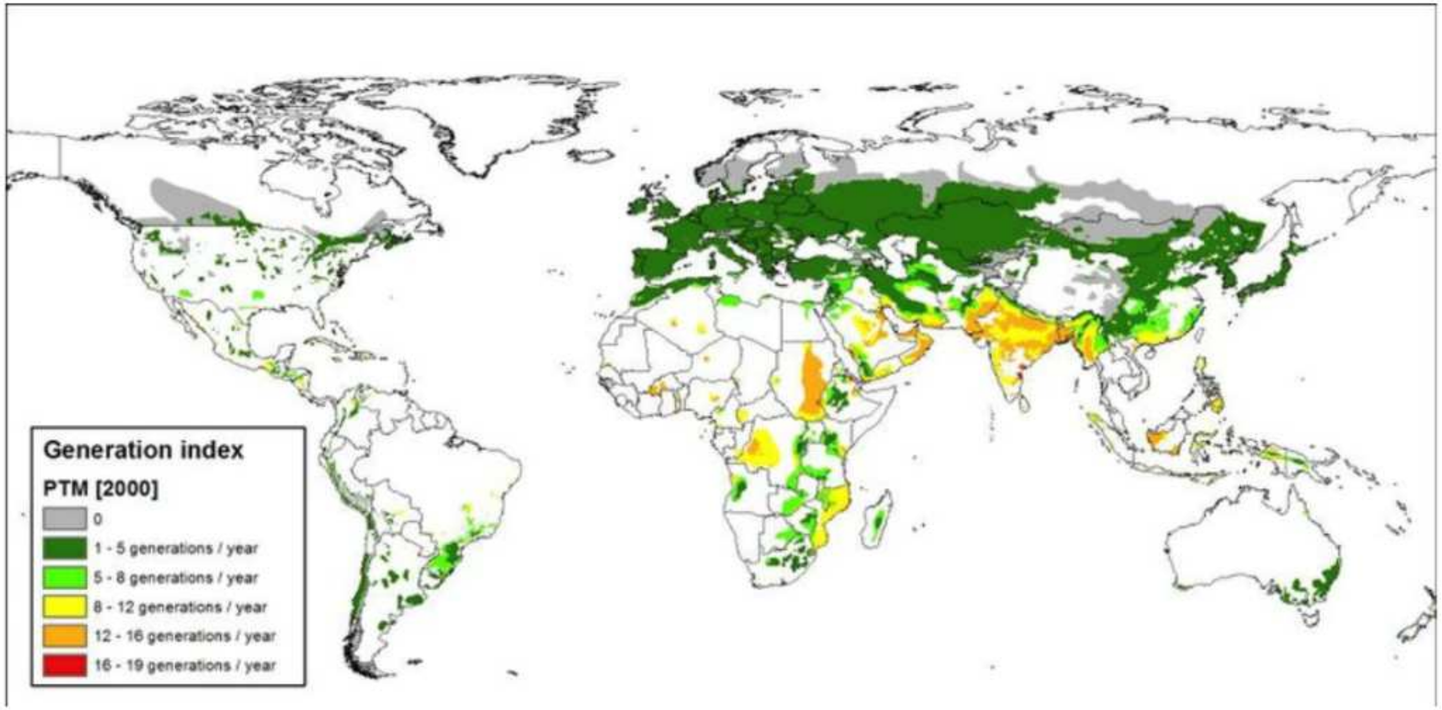


Figure 2. Historical and projected distribution of the damage niche for S. halepense in U.S. maize cropping systems. Projections are for climatology centered on 2030 and 2084 under a "business-as-usual" GHG emission scenario. Towards the end of the century, the damage niche for S. halepense may experience a pole-ward advance of approximately 200-600 km north of present-day boundaries [14].

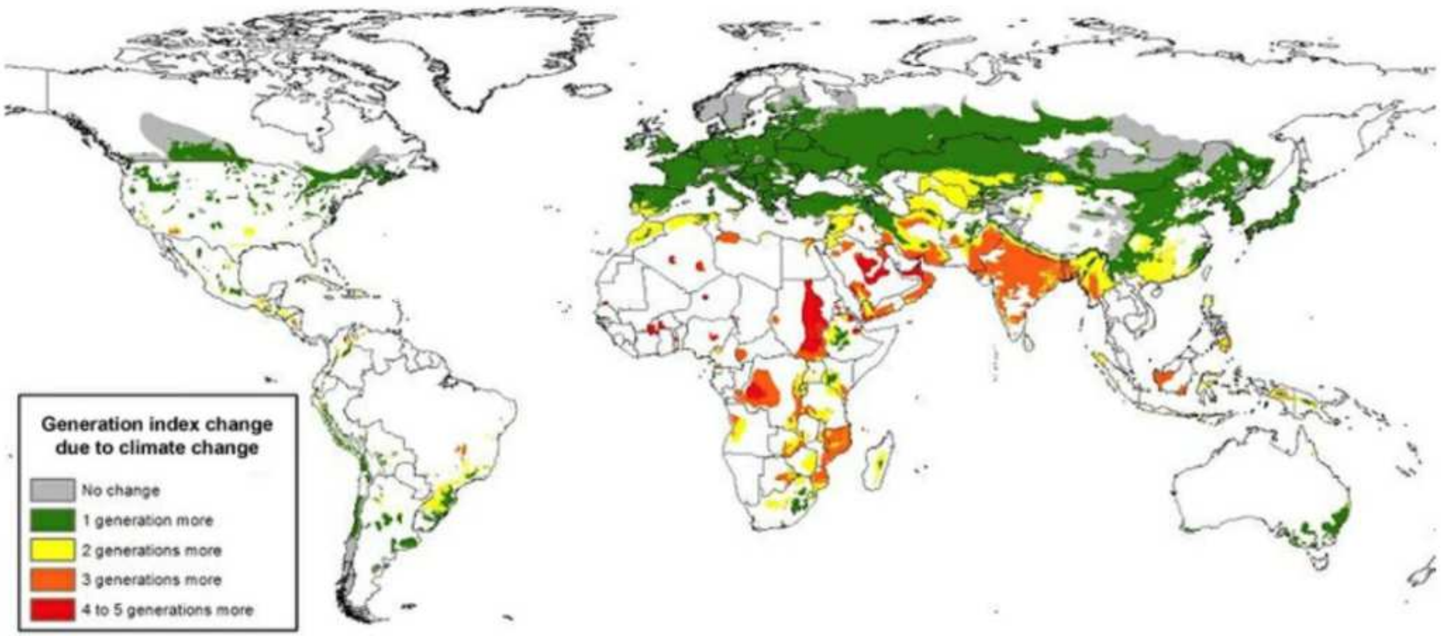
McDonald, A., S. Riha, et al. (2009). "Climate change and the geography of weed damage: Analysis of U.S. maize systems suggests the potential for significant range transformations." Agriculture, Ecosystems & Environment.

Animal pests

Climate change scenarios for the potato tuber moth, Phthorimaea operculella:



Generation index (generations/ year) under present temperature conditions



Change in numbers of generations per year by 2050 using the atmospheric general circulation model

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Discussion

1) Can the current damage models correctly represent the impact of Climate Change on crop losses?

2) Can the current simulation studies on the impact of Climate Change on pests be correct?

1) There is a wide range of modelling approaches available. Most important are the underlying conceptual models (cf. presentation on conceptual modelling)

2) Simulation models can be useful to IPM, but they are associated to uncertainties, and have limited domains of validity. They have to be combined with other sources of knowledge such as expert knowledge and technical references.