Modelling for the design and assessment of IPM solutions

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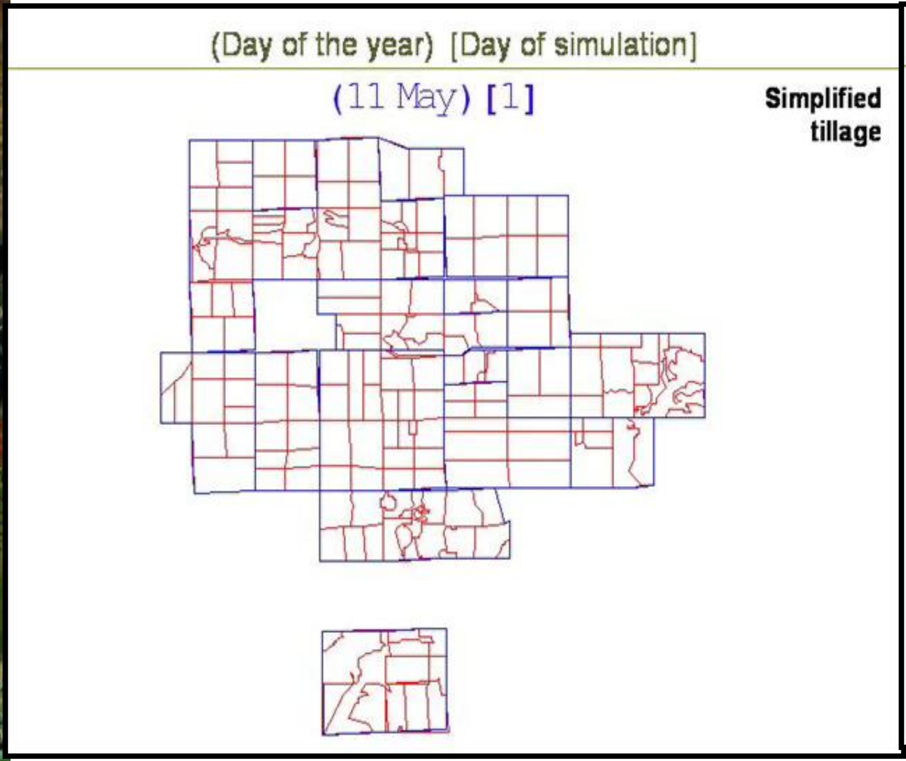
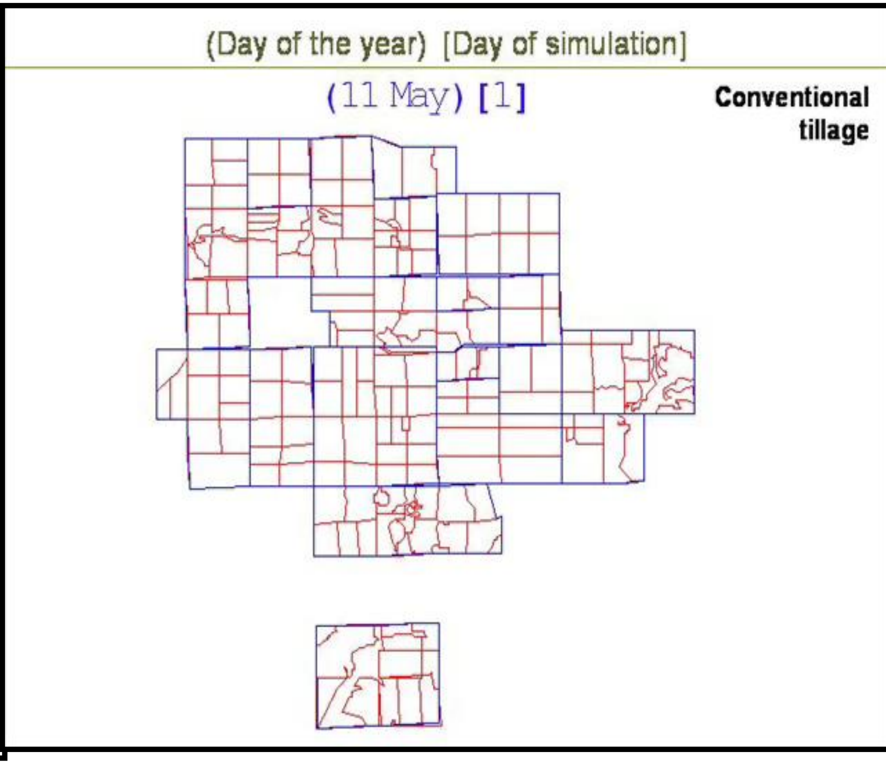
A wide range of objectives for modelling

- 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
- Yield loss analysis
- Invasive species analysis
- Analysis of the effects of climate change on pest development
- Assess various performances of IPM strategies
- Teaching, communicating
- …

Videos to raise farmers’ awareness about the impact of their cropping practices at the landscape level





Aubertot et al, 2006

A wide range of modelling technics…

- Conceptual modelling
- Set of differential equations
- Set of difference equations
- Agent based models
- Statistical models
- Networks
- Matrices
- Qualitative modelling
- …

Main outputs from WP1 with regards to modelling

- UNISIM (N Holst, AU): a collaborative modelling platform to design domain specific language-based models
- DEXIPM (Pelzer et al, INRA): an *ex-ante* and *ex-post* aggregative multicriteria assessment tool of IPM strategies
- SYNOPS (J Strassmeyer et al, JKI): a multi-level pesticide risk assessment tool
- PREMISE (Hennen et al, DLO): multi-level pesticide risk assessment tool (spatial scale, use of indicators)
- X-PEST and IPSIM (Aubertot, Robin et al): multiple pest modelling
- Optimisation technics (Sabbadin et al, INRA): Matlab toolbox for GMDP (and other approaches)

Injury Profile SIMulator. : wheat case study

Aubertot and Robin, 2013

Issues

- To enhance agroecosystem sustainability

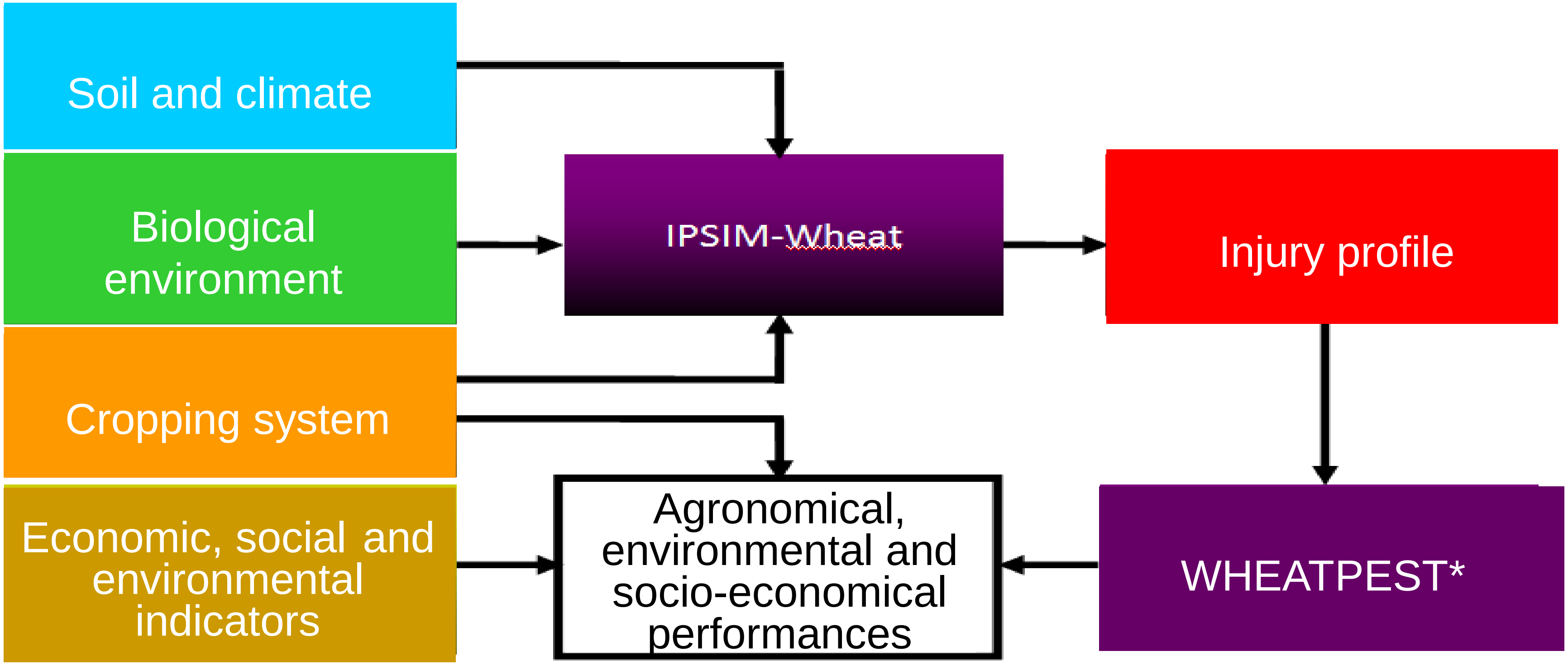
- Methodological innovation for the design and assessment of IPM-based cropping systems

Objectives

- Development of a generic modelling platform to design qualitative models that predict injury profiles

- To enhance vertical and horizontal integration of IPM

Conceptual framework of the approach



Soil and climate

Biological environment

Cropping system

Economic, social and environmental indicators

IPSIM-Wheat

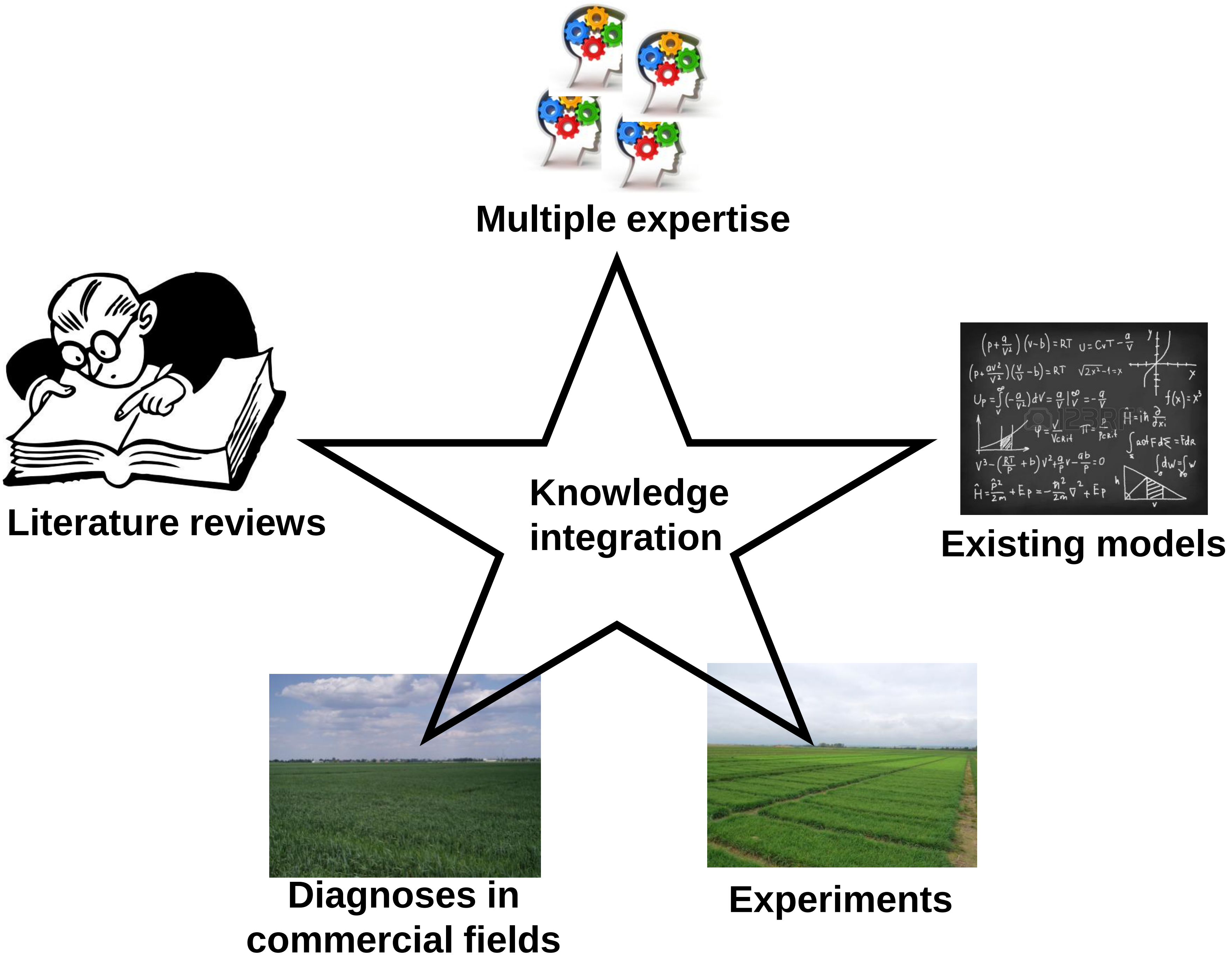
Injury profile

WHEATPEST*

Agronomical, environmental and socio-economical performances

*Willocquet et al, 2008

No available dataset that describes simulteanously cropping practices, soil&climate, injury profiles!



Multiple expertise

Literature reviews

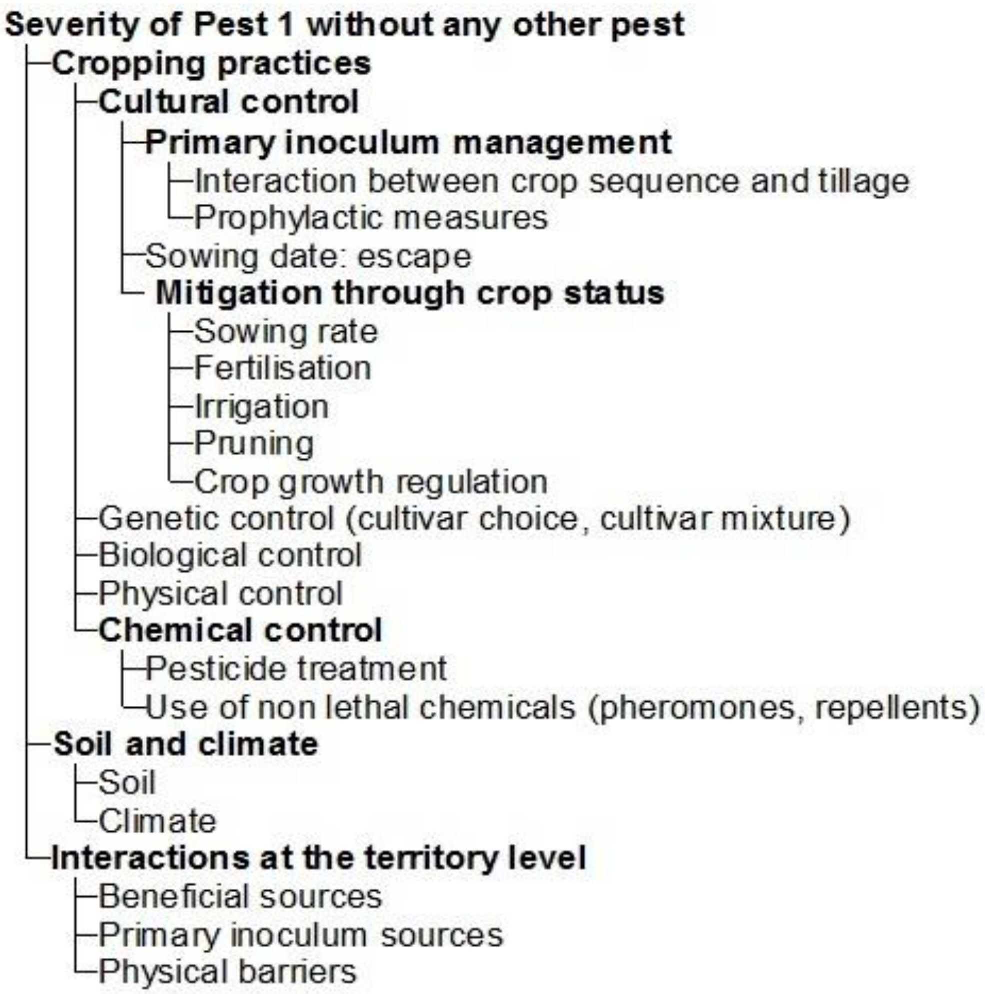
Knowledge integration

Existing models

Diagnoses in commercial fields

Experiments

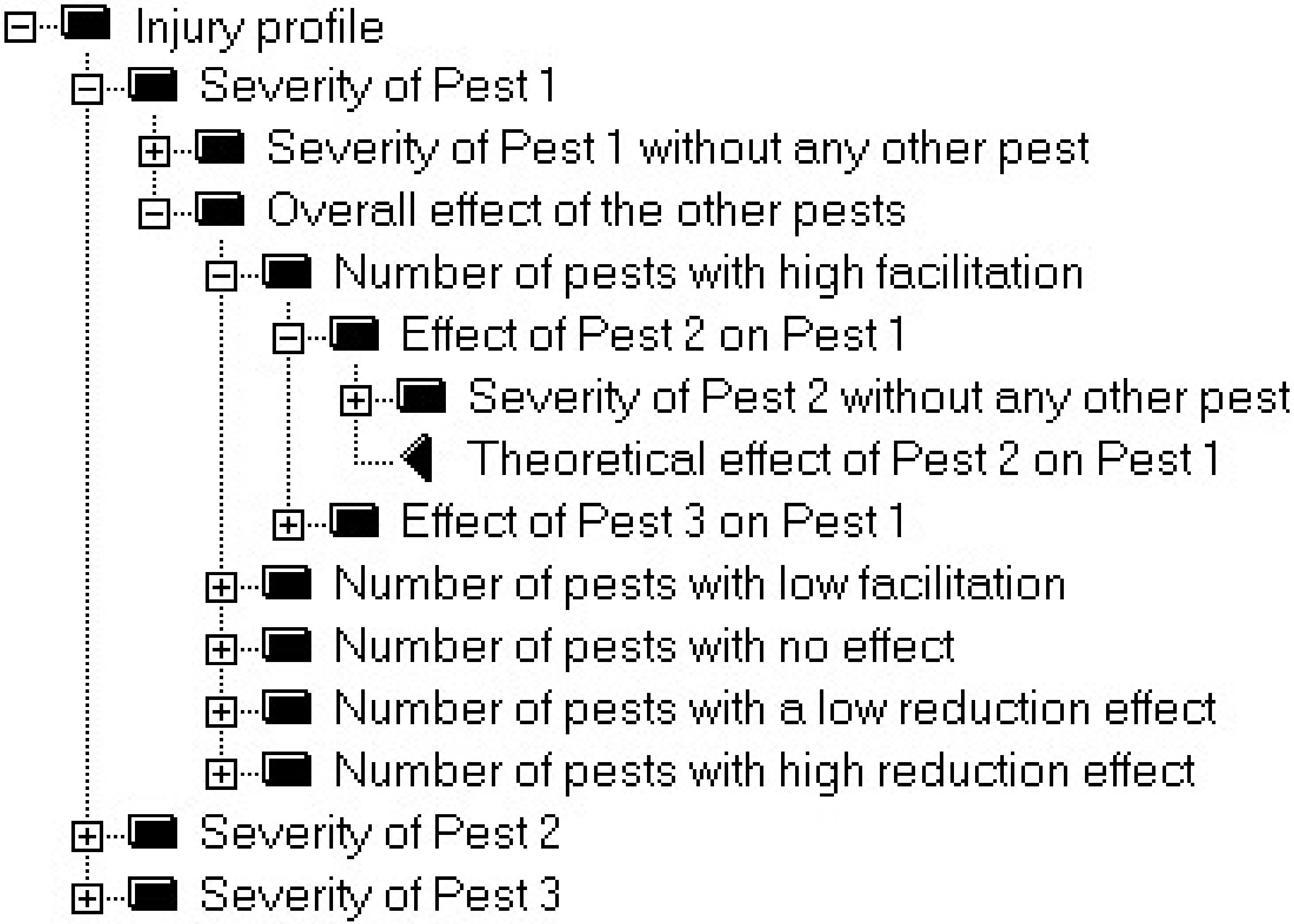
A hierarchical deterministic bayesian network to predict the severity of a single pest (use of DEXi; Bohanec, 2014)



Severity of Pest 1 without any other pest
- **Cropping practices**
  - **Cultural control**
    - **Primary inoculum management**
      - Interaction between crop sequence and tillage
      - Prophylactic measures
    - Sowing date: escape
    - **Mitigation through crop status**
      - Sowing rate
      - Fertilisation
      - Irrigation
      - Pruning
      - Crop growth regulation
  - Genetic control (cultivar choice, cultivar mixture)
  - Biological control
  - Physical control
  - **Chemical control**
    - Pesticide treatment
    - Use of non lethal chemicals (pheromones, repellents)
- **Soil and climate**
  - Soil
  - Climate
- **Interactions at the territory level**
  - Beneficial sources
  - Primary inoculum sources
  - Physical barriers

Aubertot and Robin, 2013

Combination of individual pest models to predict an injury profile (with interactions)



- Injury profile
  - Severity of Pest 1
    - Severity of Pest 1 without any other pest
    - Overall effect of the other pests
      - Number of pests with high facilitation
        - Effect of Pest 2 on Pest 1
          - Severity of Pest 2 without any other pest
          - Theoretical effect of Pest 2 on Pest 1
        - Effect of Pest 3 on Pest 1
      - Number of pests with low facilitation
      - Number of pests with no effect
      - Number of pests with a low reduction effect
      - Number of pests with high reduction effect
  - Severity of Pest 2
  - Severity of Pest 3

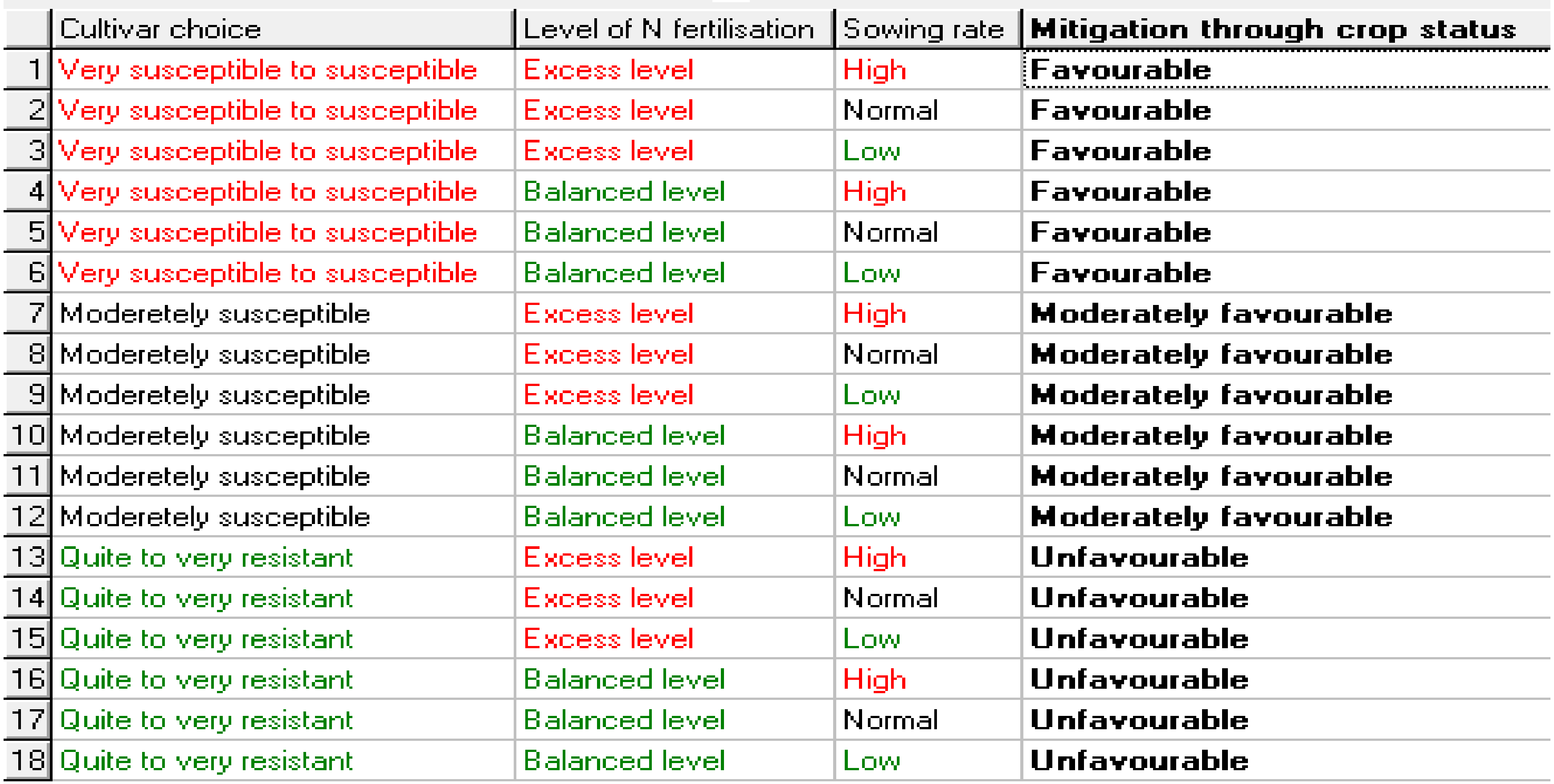
Aubertot and Robin, 2013

Definition of aggregating tables using international literature and expert knowledge

Factor	Direction of the effect	Intensity of the effect	Impact on eyespot development	References
Tillage	+/-	++	Contradictory results. For some authors, reduced soil tillage decreased eyespot infection. For others, eyespot was often more severe after ploughing than after non-inversion tillage.	[1-14, 29, 40]
Preceding and pre-preceding crop	+	++	Preceding and pre-preceding host crops are known to favour eyespot. However, the interaction between tillage and the crop sequence has to be taken into account.	[4, 9, 14-21, 29, 40, 59]
Sowing date	+	++	Eyespot has always been reported to be more severe in early sown crops.	[4, 14, 15, 17, 20-21, 40]
N fertilisation rate	+	+	High nitrogen availability generally favoured the disease. However these results were questioned.	[15, 20]
Sowing rate	+	+	Prevalence was increased by high plant density and/or low shoot number per plant.	[15, 17, 20]
Cultivar choice	+	+++	The use of varieties with resistance could obviate the need for fungicide.	[4, 21, 22]
Cultivar mixture	0	0	No significant difference was found between the disease level in mixtures and the mean of disease level of the mixture components in pure stands.	[23-25]
Climate	+	++	Eyespot strongly depends on climate. Infections require periods of at least 15 h with T° between 4°C and 13°C and HR>80% (from October to April).	[13, 20, 26-29]

Robin et al, 2013

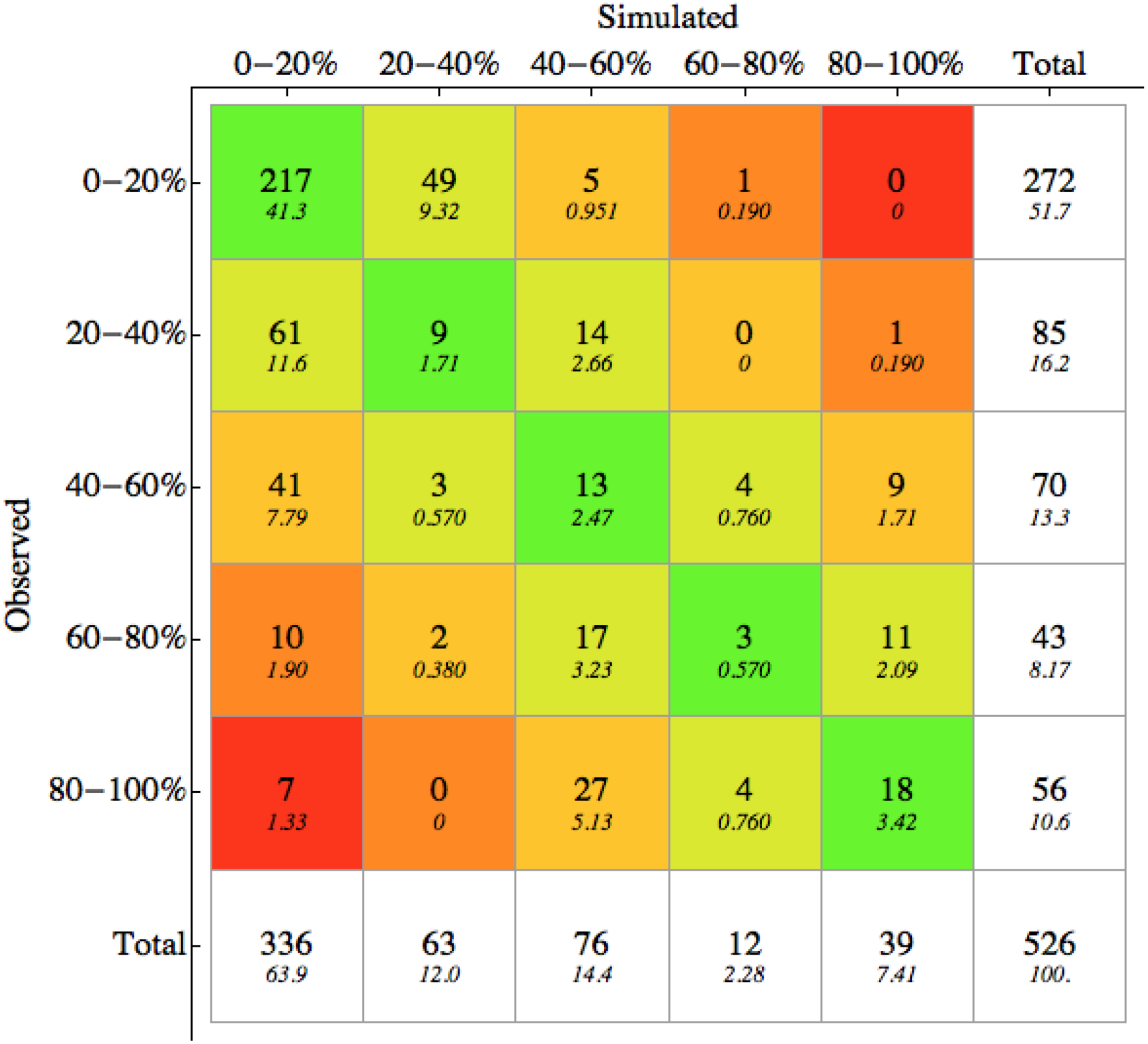
Example of an aggregative table



	Cultivar choice	Level of N fertilisation	Sowing rate	**Mitigation through crop status**
1	Very susceptible to susceptible	Excess level	High	**Favourable**
2	Very susceptible to susceptible	Excess level	Normal	**Favourable**
3	Very susceptible to susceptible	Excess level	Low	**Favourable**
4	Very susceptible to susceptible	Balanced level	High	**Favourable**
5	Very susceptible to susceptible	Balanced level	Normal	**Favourable**
6	Very susceptible to susceptible	Balanced level	Low	**Favourable**
7	Moderetely susceptible	Excess level	High	**Moderately favourable**
8	Moderetely susceptible	Excess level	Normal	**Moderately favourable**
9	Moderetely susceptible	Excess level	Low	**Moderately favourable**
10	Moderetely susceptible	Balanced level	High	**Moderately favourable**
11	Moderetely susceptible	Balanced level	Normal	**Moderately favourable**
12	Moderetely susceptible	Balanced level	Low	**Moderately favourable**
13	Quite to very resistant	Excess level	High	**Unfavourable**
14	Quite to very resistant	Excess level	Normal	**Unfavourable**
15	Quite to very resistant	Excess level	Low	**Unfavourable**
16	Quite to very resistant	Balanced level	High	**Unfavourable**
17	Quite to very resistant	Balanced level	Normal	**Unfavourable**
18	Quite to very resistant	Balanced level	Low	**Unfavourable**

Robin et al, 2013

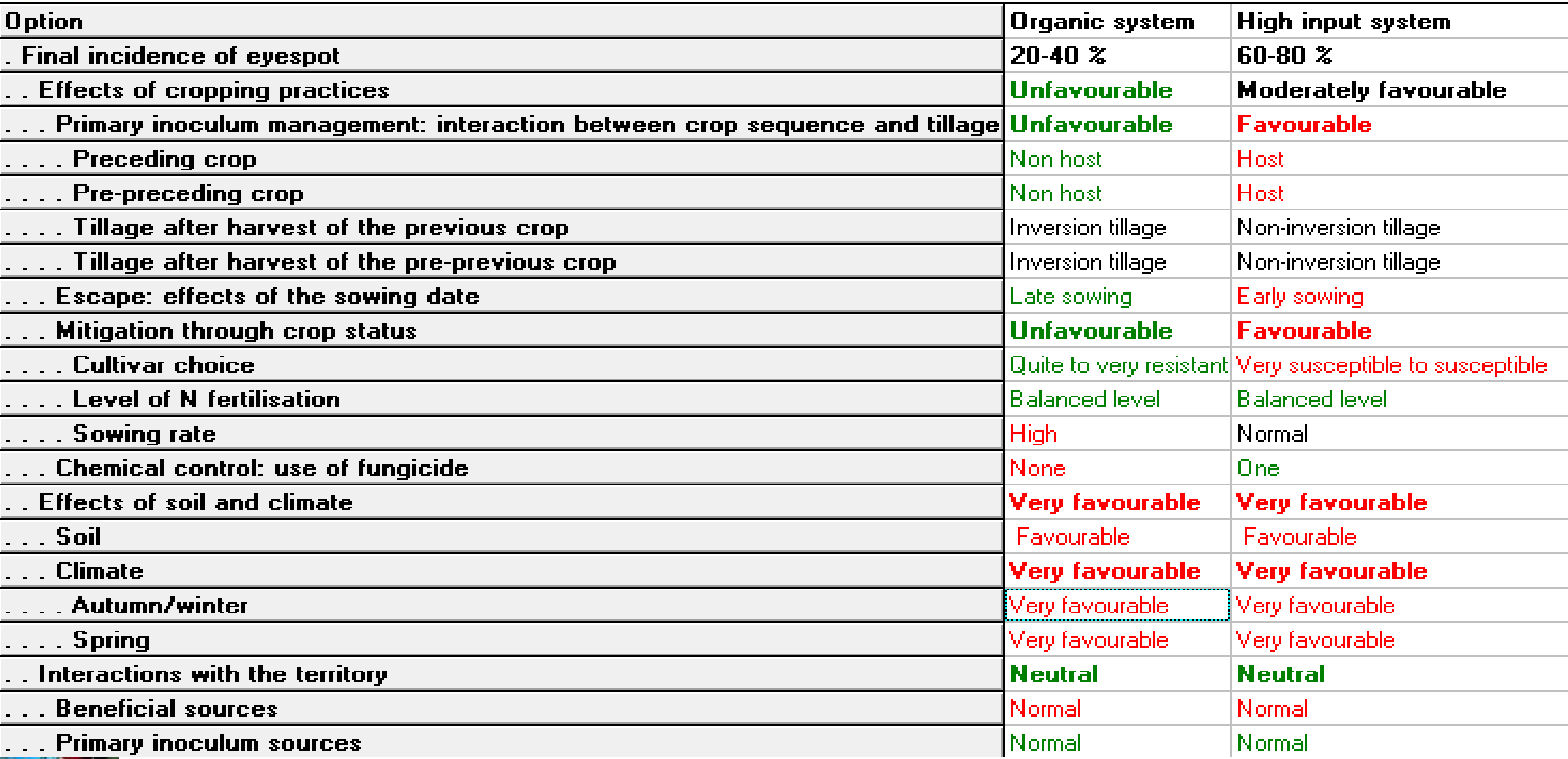
Evaluation of the predictive quality of IPSIM-Wheat-Eyespot



	Simulated					
Observed	0–20%	20–40%	40–60%	60–80%	80–100%	Total
0–20%	217 *41.3*	49 *9.32*	5 *0.951*	1 *0.190*	0 *0*	272 *51.7*
20–40%	61 *11.6*	9 *1.71*	14 *2.66*	0 *0*	1 *0.190*	85 *16.2*
40–60%	41 *7.79*	3 *0.570*	13 *2.47*	4 *0.760*	9 *1.71*	70 *13.3*
60–80%	10 *1.90*	2 *0.380*	17 *3.23*	3 *0.570*	11 *2.09*	43 *8.17*
80–100%	7 *1.33*	0 *0*	27 *5.13*	4 *0.760*	18 *3.42*	56 *10.6*
Total	336 *63.9*	63 *12.0*	76 *14.4*	12 *2.28*	39 *7.41*	526 *100.*

Accuracy=0.49
QWKappa=0.61

Example of simulations (eyespot)



Option	Organic system	High input system
. Final incidence of eyespot	20-40 %	60-80 %
. . Effects of cropping practices	**Unfavourable**	**Moderately favourable**
. . . Primary inoculum management: interaction between crop sequence and tillage	**Unfavourable**	**Favourable**
. . . . Preceding crop	Non host	Host
. . . . Pre-preceding crop	Non host	Host
. . . . Tillage after harvest of the previous crop	Inversion tillage	Non-inversion tillage
. . . . Tillage after harvest of the pre-previous crop	Inversion tillage	Non-inversion tillage
. . . Escape: effects of the sowing date	Late sowing	Early sowing
. . . Mitigation through crop status	**Unfavourable**	**Favourable**
. . . . Cultivar choice	Quite to very resistant	Very susceptible to susceptible
. . . . Level of N fertilisation	Balanced level	Balanced level
. . . . Sowing rate	High	Normal
. . . Chemical control: use of fungicide	None	One
. . Effects of soil and climate	**Very favourable**	**Very favourable**
. . . Soil	Favourable	Favourable
. . . Climate	**Very favourable**	**Very favourable**
. . . . Autumn/winter	Very favourable	Very favourable
. . . . Spring	Very favourable	Very favourable
. . Interactions with the territory	**Neutral**	**Neutral**
. . . Beneficial sources	Normal	Normal
. . . Primary inoculum sources	Normal	Normal

Partial conclusion

☹

- **Lack of precision**
- **Subjectivity when defining aggregating tables**
- **No explicit representation of underlying mechanisms**
- **Static models**
- **Threshold effects**

☺

- **Lack of precision**
- **Combination of various sources of knowledge**
- **Fair predictive quality without calibration**
- **Transparent**
- **Very easy to develop and to present**
- **Great for communicating and teaching**
- **Better vertical and horizontal integrations in IPM**

Conclusion

- Modelling is a key tool with regard to various aspects of IPM, especially, integration
- Conceptual models not only generate simulation models, but also experiments and diagnoses of commercial fields
- They certainly need to be revised
- Modelling techniques also need developments in order to handle higher levels of complexity for IPM design and assessment