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Alexandra Jullien, Corinne Robert, Thierry Doré

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Agroecology: biodiversity in agroecosystems to regulate pests and diseases?

Jullien A.¹, Robert C.¹ and Doré T.²

¹*ECOSYS, INRA, AgroParisTech, Université Paris-Saclay, Thiverval-Grignon, France*

²*Agronomie, INRA, AgroParisTech, Université Paris-Saclay Thiverval-Grignon,
France*

alexandra.jullien@agroparistech.fr

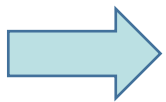
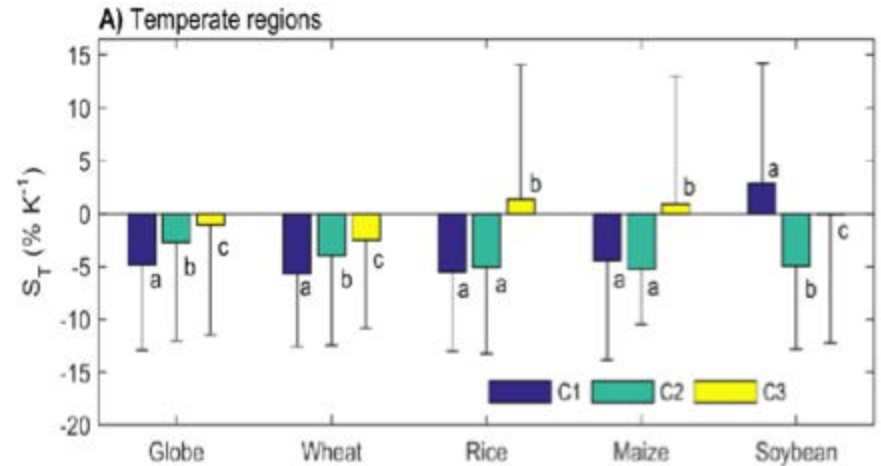
Context

At an international level:

- Yield *plateau*, and prediction of yield loss due to global warming (*Wang et al., in press*),
- Pesticides use is highly controversial due to their effects on environment and human health

At a national level:

- A long lasting reliance on pesticides, which does not drop: the IFT is approximately as high in 2017 as in 2008 (Starting Ecophyto 2018)
- Pesticides arsenal shrinks due to pathogens because of regulations and resistance
- New pests and diseases pop up due to global changes



A need for alternative avenues – Agroecology as a solution ?

Agenda of the talk

- I. Agroecology and biodiversity
 - What is agroecology?
 - The key role of biodiversity in agroecology

- II. Analysing the potential levers and mechanisms of pest and diseases regulation *via* biodiversity

- III. Putting it all together: from mechanisms to agroecosystems including both ecological functioning and agronomic logic?
 - Unknowns
 - Trade-off

Part I

Agroecology and biodiversity

What is agroecology?



A large diversity of key-players ... with a wide range of acceptions for *agroecology*.

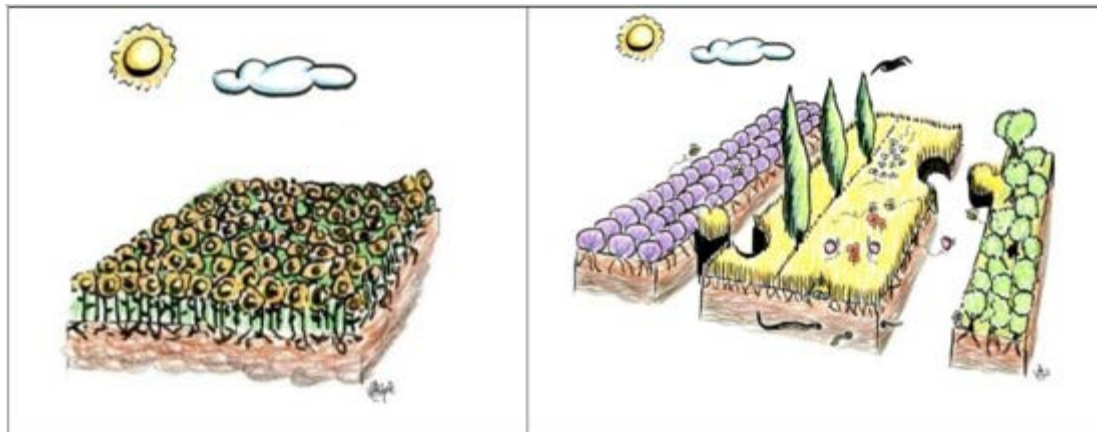
But for all of them, agroecology is a mean to re-create an alliance between agriculture, environment, science and society.

With shared core principles:

- Using **biotic interactions**, **self-regulations** and biodiversity rather than pesticides
- Exploiting non-renewable resources very carefully and **promote their recycling**
- Combining **indigenous** knowledge and **scientific** outputs
- Binding actions at different scales (plot-farm-lanscape-food system) to find solutions **ecologically**, **socially** and **economically** affordable
- Helping **famers** to find their own finely tuned systems



Agroecology : A new view on agroecosystems



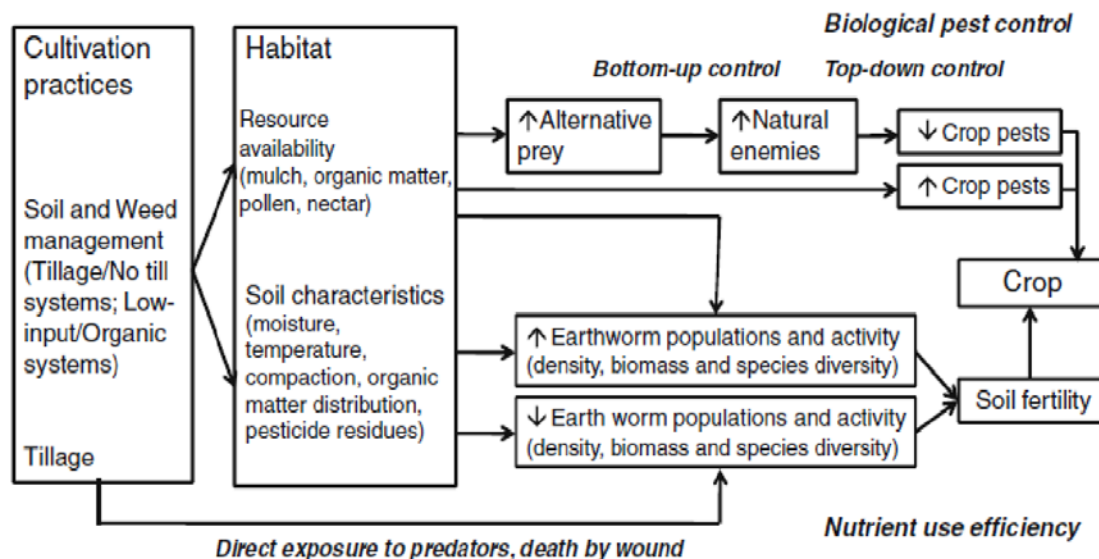
A key expectancy:
promoting self-regulations



An approach:
the agroecosystem seen as
different habitats with organisms
in interaction



A bet:
biodiversity and heterogeneity
are levers to pests and diseases
self-regulation



Médiène et al., 2011

Some star systems in agroecology, which are already disseminating

Conservation agriculture...



Agroforestry...



- Refined by farmers experience and years of empiricism
- Locally conceived and adapted
- Complex and only partially studied by scientists

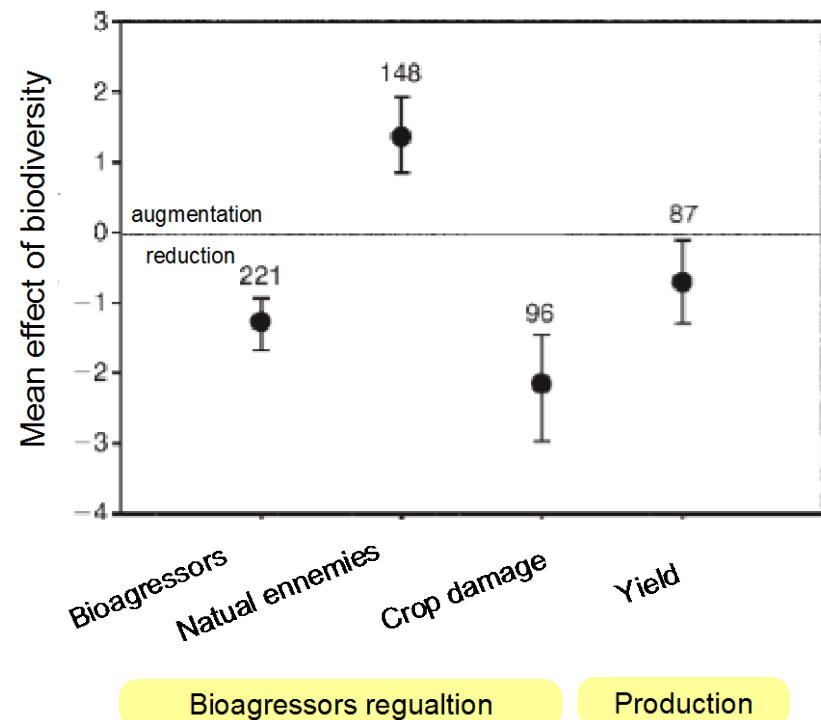
Associations...



=> limits to their generalisation

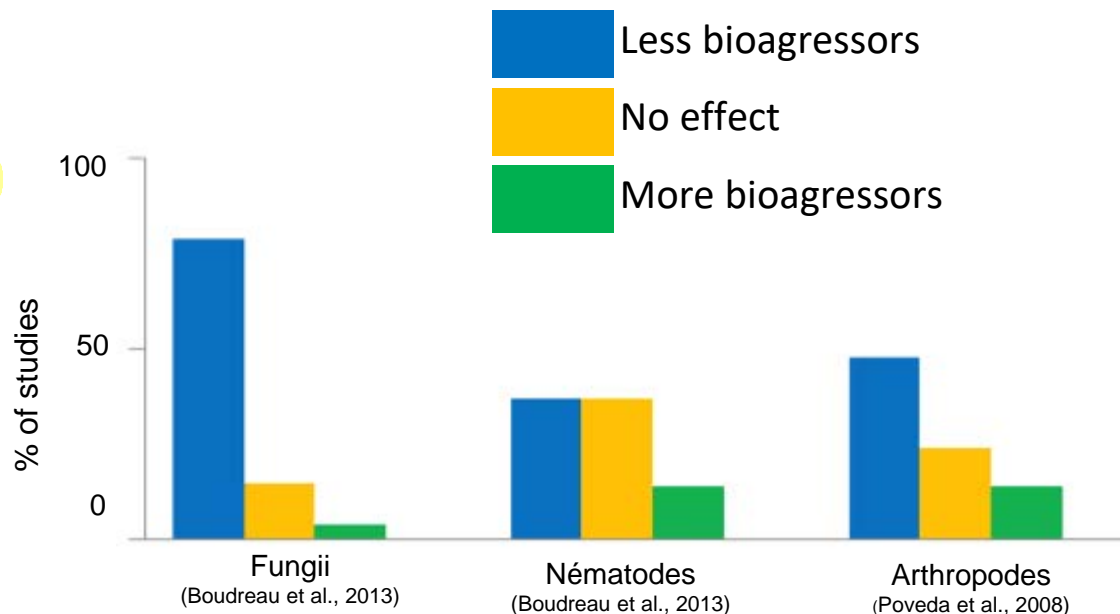


Biodiversité, pests and diseases



- A major positive trend between biodiversity and pest regulation
 - ✓ Fungii (75%) > nematodes and arthropodes
- What are the mechanisms underlying these global trend?
- Why is the effect variable?

Bioagressors regualtion Production



From Letourneau *et al.* 2011
 Boudreau M., 2013
 Poeydebat, 2016

Part II

Potential levers, mechanisms and effects at different scales

Different mechanisms for self-regulation of pests and diseases

Process	Lever
Epidemics and attacks	
Dispersion	Density effect Barrier effect
Infection	Premunition Phylloclimat
Development of pathogens (nutrition, reproduction)	Ressources Predators
Plant response	
Escape, tolerance, compensation	Plasticity of the development
Resistance	Plant defence
Communication	Predators

Letournau *et al.*, 2011; Boudreau, 2013; Vidal *et al.*, 2018

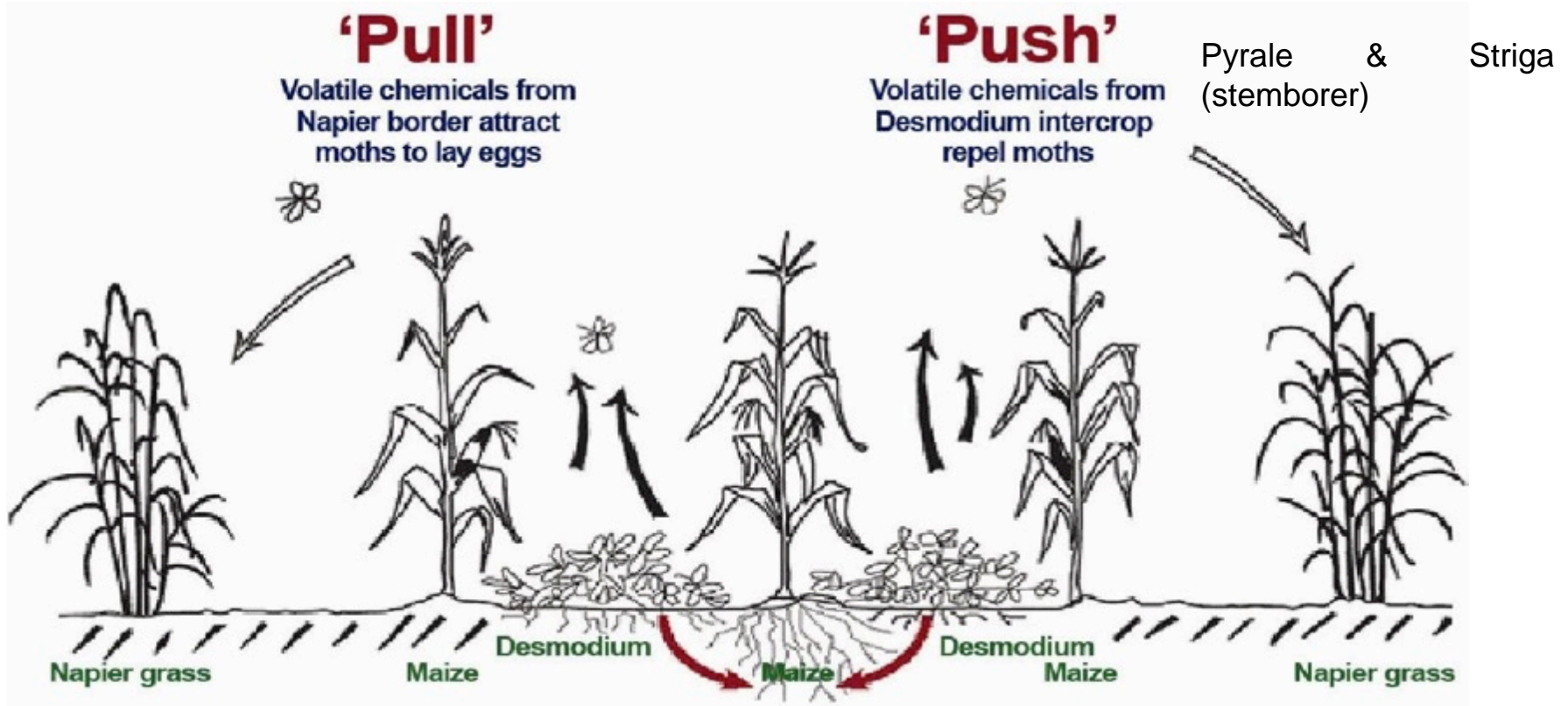
How do **practices and biodiversity** trigger and drive these mechanisms?





Mobilizing plant-plant-organisms communication

Mechanisms of the push-pull effect



<http://www.push-pull.net>

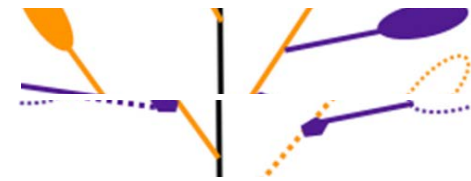
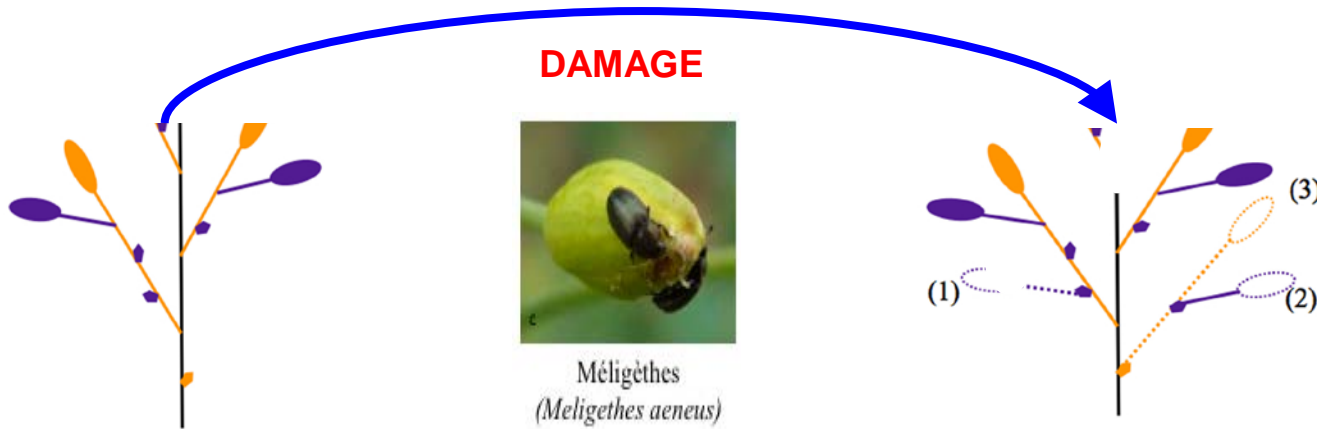


Designing plant architectures for resilient crop

At the plant scale : plant plasticity favours damage compensation

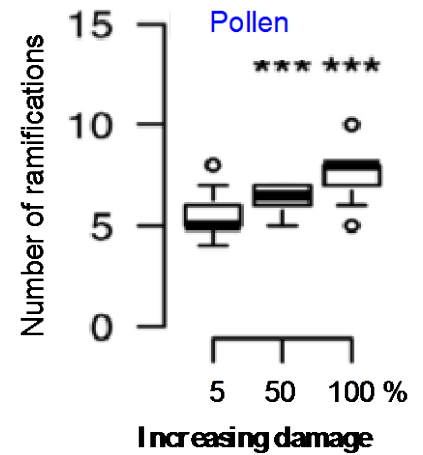


Related to plant capacity to produce secondary and primary branches



Main stem
Terminal inflorescence
New primary axis
New primary inflorescence

	Low branching	High branching
Low damage	Secondary	Secondary
High damage	Secondary	Secondary + Primary



Pinet, 2010
Pinet et al., 2015

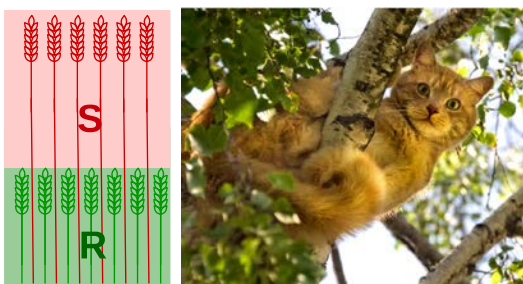


Designing plant architectures in mixed-crops

At the canopy scale : mixing varieties of different heights to reduce epidemics



« Umbrella » effect

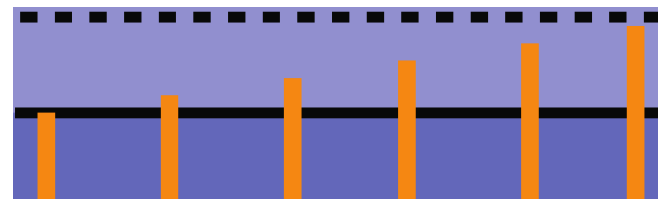
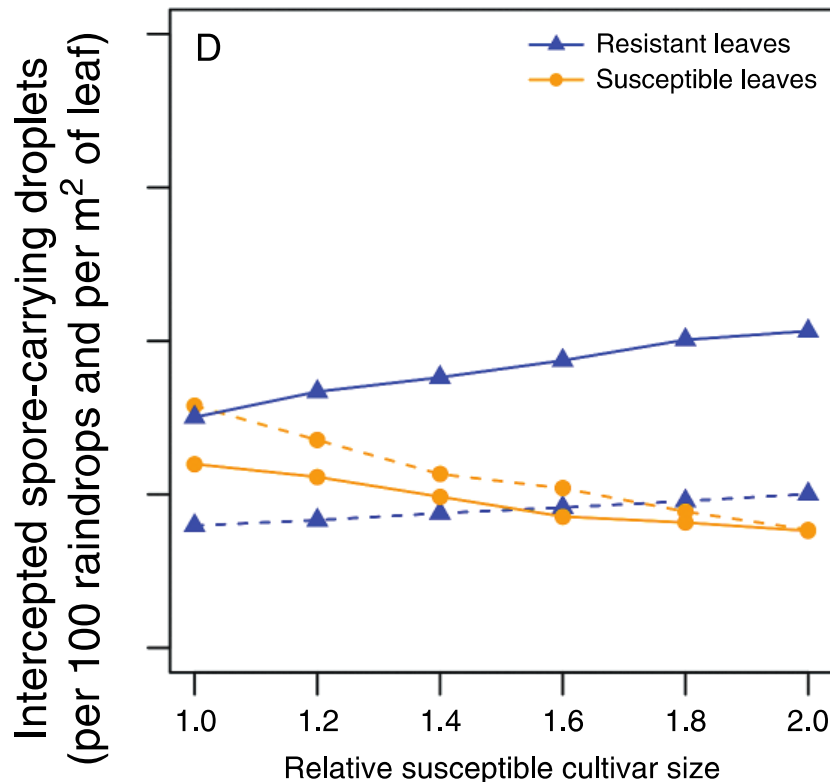


« Perchoir » effect

=> A tall susceptible variety in mixture with a short resistant one will reduce inoculum propagation of septoria tritici by rain splashing

Vidal, 2016
 Vidal *et al.*, 2018, PlosOne
 Vidal *et al.*, 2018 JExpBot

Inoculum interception (fix R height)



Modified *susceptible plant height*
 Fixed *resistant plant height*



Decreasing the **resources** for the pathogens

At the canopy scale : decreasing nitrogen fertilisation decrease epidemics

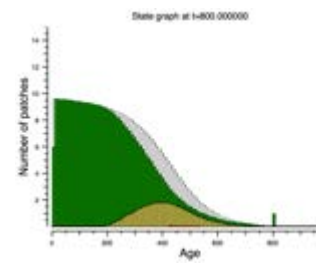
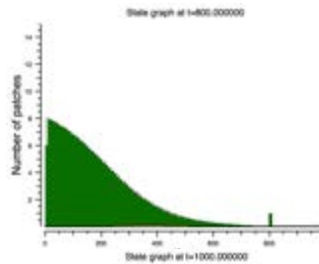
Simulation of canopy growth and leaf rust epidemics for low and high crop fertilisation

Low fertilisation

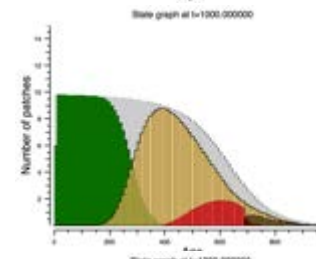
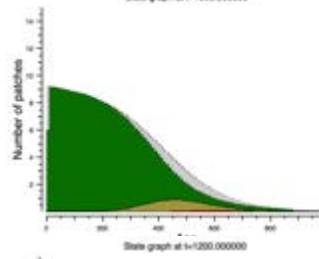
High fertilisation

Legend :
Healthy
Latent
Sporulating
Dead

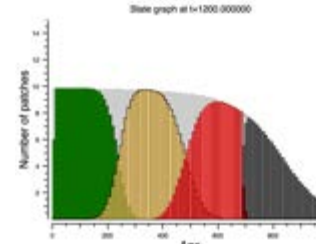
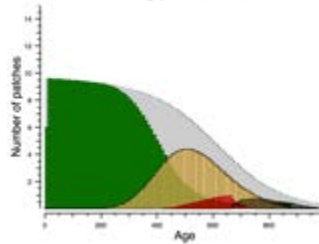
t1



t2



t3



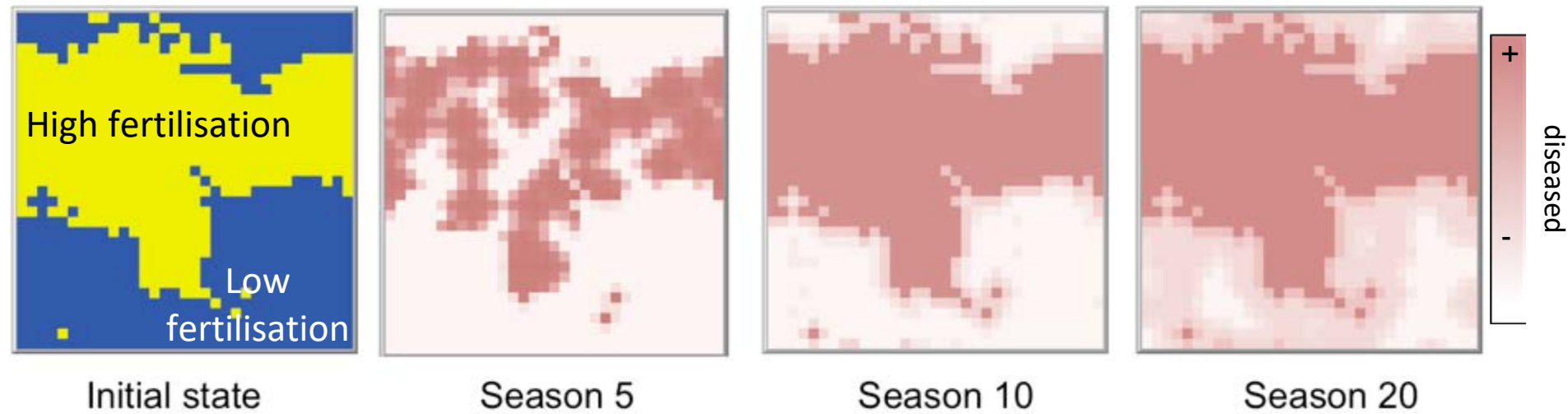
Epidemics is earlier and stronger in high fertilisation

Precigout *et al.*, 2017
Gigot *et al.* in prep

Decreasing the resources for the pathogens

At the landscape scale: resource heterogeneity slows down pathogen colonization

Simulation of landscape colonisation by the leaf rust with heterogeneous fertilisation



- Low fertilisation areas produce few spores and slow down pathogen dispersal in the landscape
- **Heterogeneity in terms of fertilisation slow down landscape colonisation by the pathogen**

Precigout, 2017

Different mechanisms for self-regulation of pests and diseases

Process	Lever	Practices and scale
Epidemics and attacks		
Dispersion	Density effect Barrier effect	Intercropping, Varieties mixture Density Landscape heterogeneity
Infection	Premunition Phylloclimat	Intercropping, Varieties Mixture Density
Development of pathogens (nutrition, reproduction)	Ressources Predators	Crop Fertilisation, Landscape Heterogeneity
Plant response		
Escape, tolerance, compensation	Plasticity of the development	Varieties Species association
Resistance	Plant defence	Varieties Species association (push-pull)
Communication	Predators	Varieties Species association Landscape Heterogeneity

=> **The potential for self-regulation of pests and diseases in agroecosystems is high.**

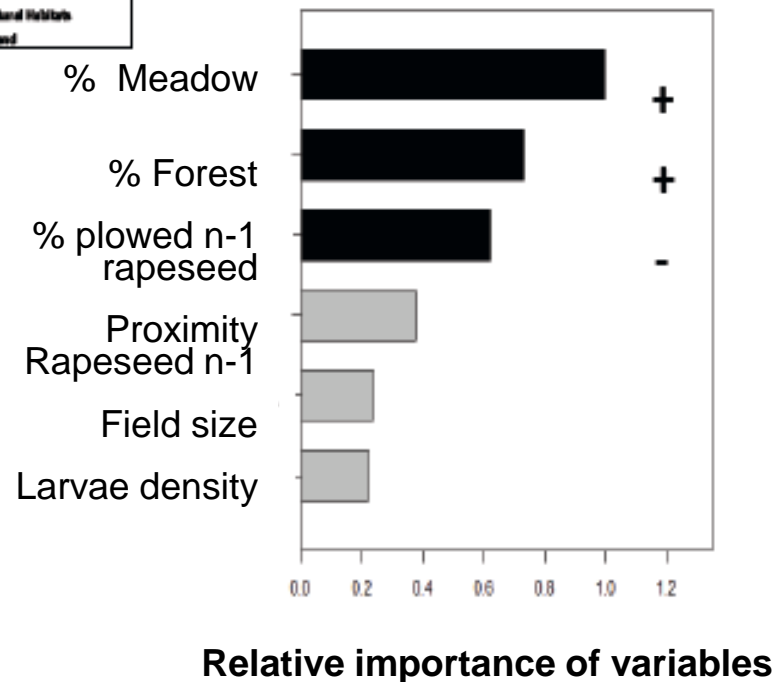
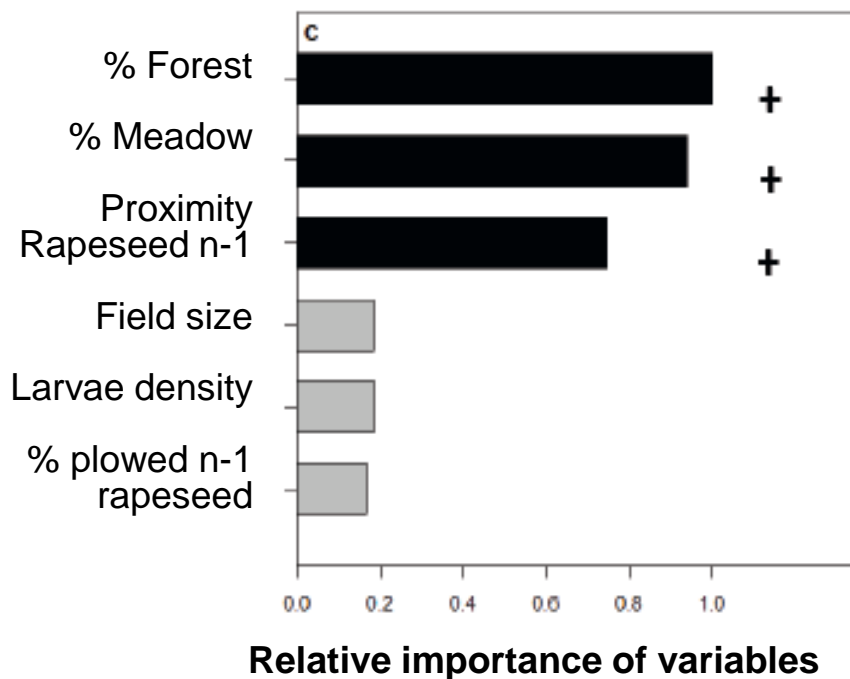
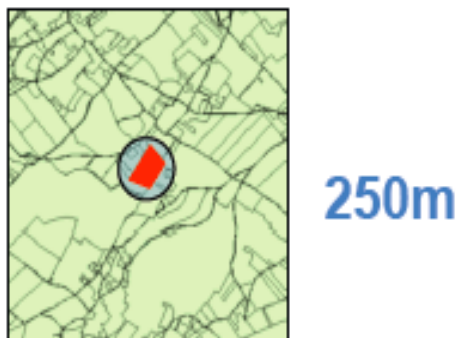
Part III

Putting it all together: from mechanisms to agroecosystems including both ecological functioning and agronomic logic?

Effect of the **landscape** on pollen beetle abundance



Méligèthes
(*Meligethes aeneus*)

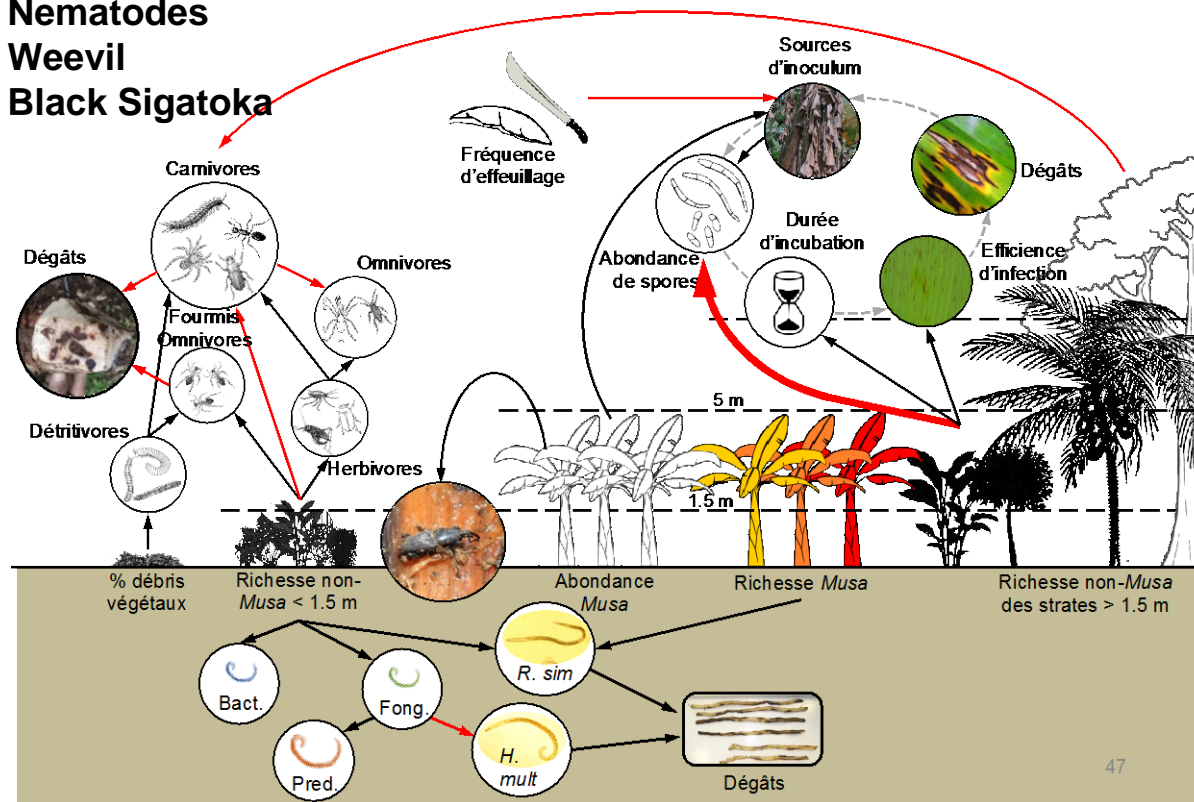


Experimental study on 42 fields selected within contrasted landscapes

Rush *et al.*, 2011, 2012

Complex interactions in the trophic web with unexpected effects

- Nematodes
- Weevil
- Black Sigatoka

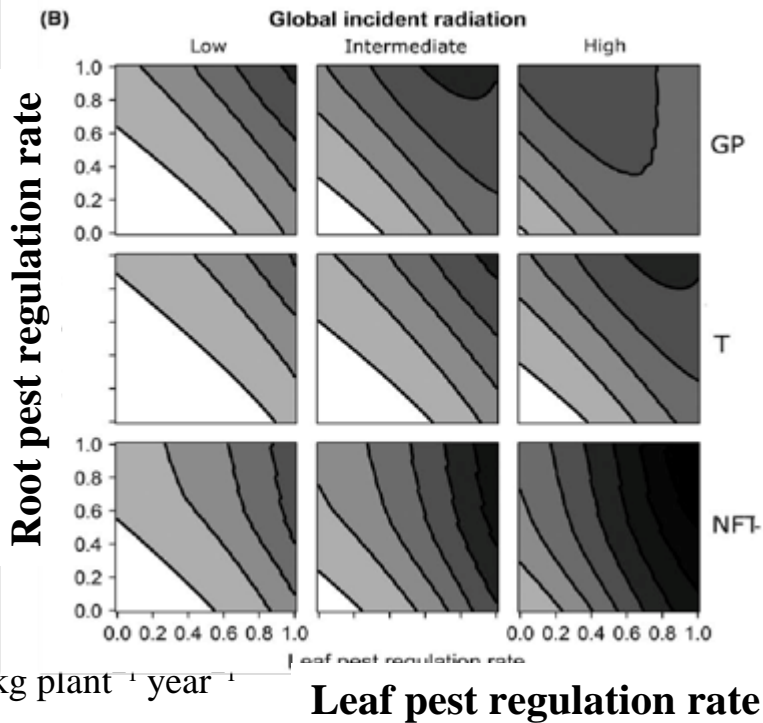
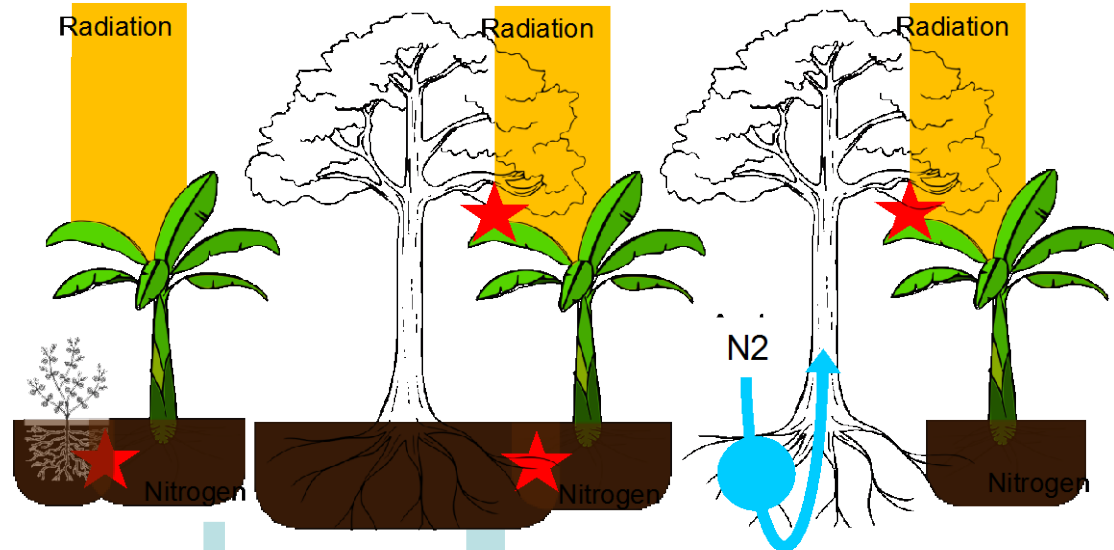


- ⇒ Differential effect of non-Musa species richness according to the trophic behaviour of bioagressors
- ✓ Unfavourable to regulation for a generalists bioagressor like nematodes
 - ✓ Favourable to regulation for a specialist like weevil

D'après Poeyedebat, 2016; 2017

Trade-off between yield and pest regulation

=> The pest regulation effect is necessary to compensate the competition effect of plant mixture



Poeydebat *et al* 2017

Conclusion

Take-home messages

Conclusion

- ⇒ Agroecology and biodiversity offer new avenues for pests and diseases regulation !!
- ⇒ What if agroecology is supposed to largely disseminate... and themselves become a global change? A transition to **a new equilibrium** with a lot of unknowns
 - ⇒ **more or less** pests and diseases? Bioaggressors will adapt!!
 - ⇒ **this may or not lead to yield decrease**
 - ⇒ **...but counterbalanced by reduced inputs and environmental benefits.**
- ⇒ Agroecosystems will be **more resilient** (self-regulation) **this means** with less human control : higher risk
- ⇒ Agroecology purpose not only concerns pest and diseases but also resilience to climate change and autonomy *versus* synthetic inputs (pesticides AND fertilizers)
- ⇒ Scientific approaches on the behaviour of these complex agroecosystems are to be reinforced in order to elucidate them
 - ⇒ **in strong interaction with farmers conceiving these systems on their farms**

Thank you for your attention!

