FLORSYS Training session
A virtual field to experiment cropping systems

To evaluate weed dynamics and impacts on crop production and biodiversity

Nathalie Colbach

Agroécologie, INRAe, Institut Agro, Univ. Bourgogne Franche-Comté, 21000 Dijon

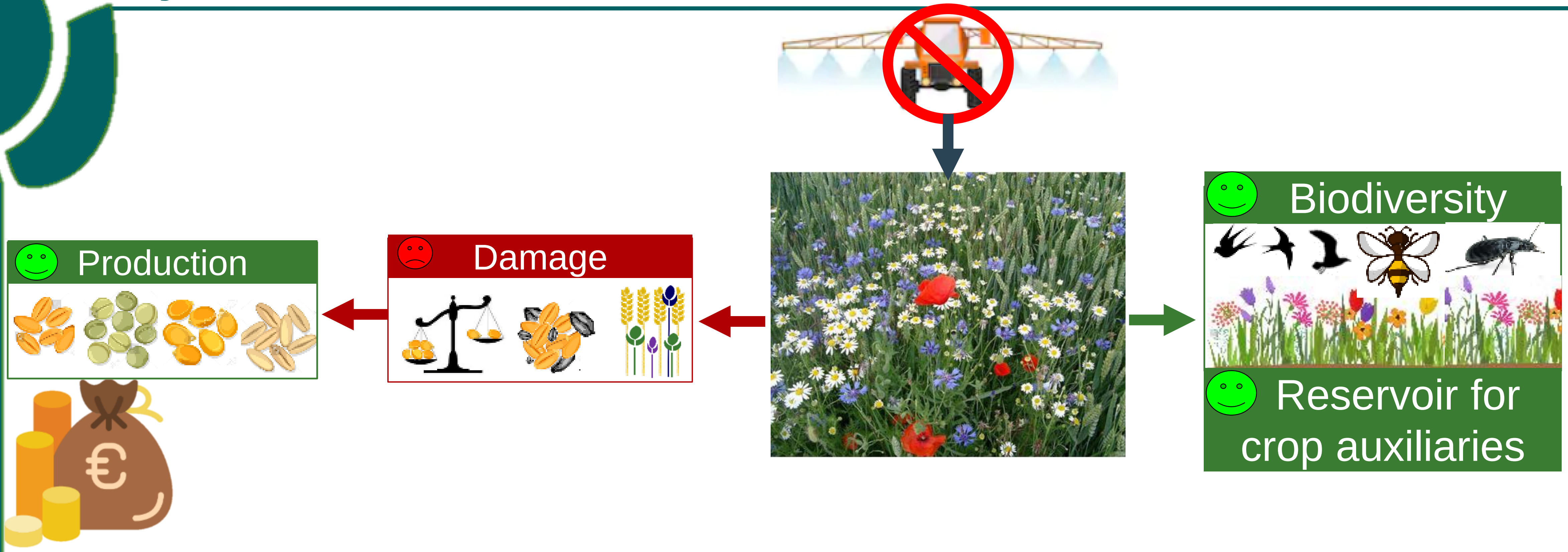
Nathalie.Colbach@inrae.fr

Plan | Today's presentation

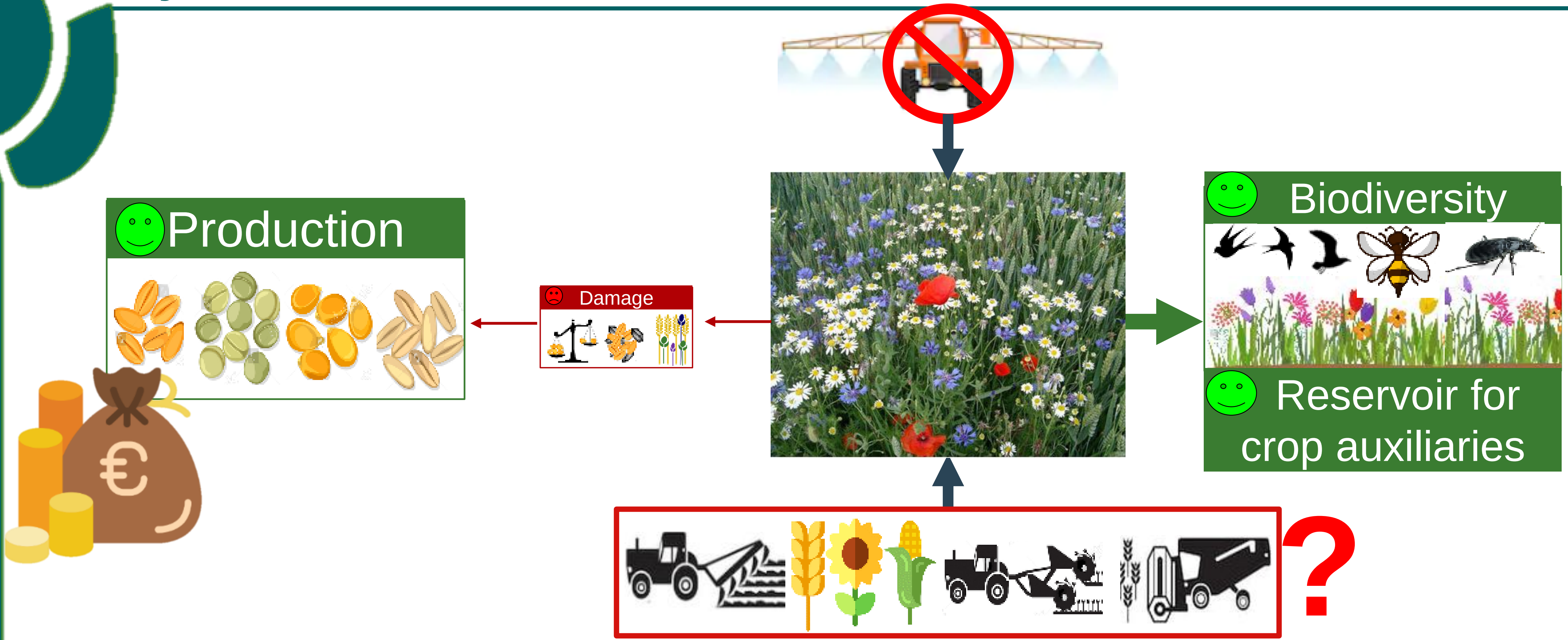
1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. Effets des techniques culturales
4. Le reste: indicateurs, paysage
5. Évaluation du modèle
6. Examples d'utilisation
7. Comment faire tourner le modèle?

1. Model objectives & structure
2. Details of life cycle
3. Effects of management techniques
4. What else? Indicators, landscape
5. Model evaluation
6. Examples of model use
7. How to run the model?

Why weeds?


Production
Damage
Biodiversity
Reservoir for crop auxiliaries

Why weeds?



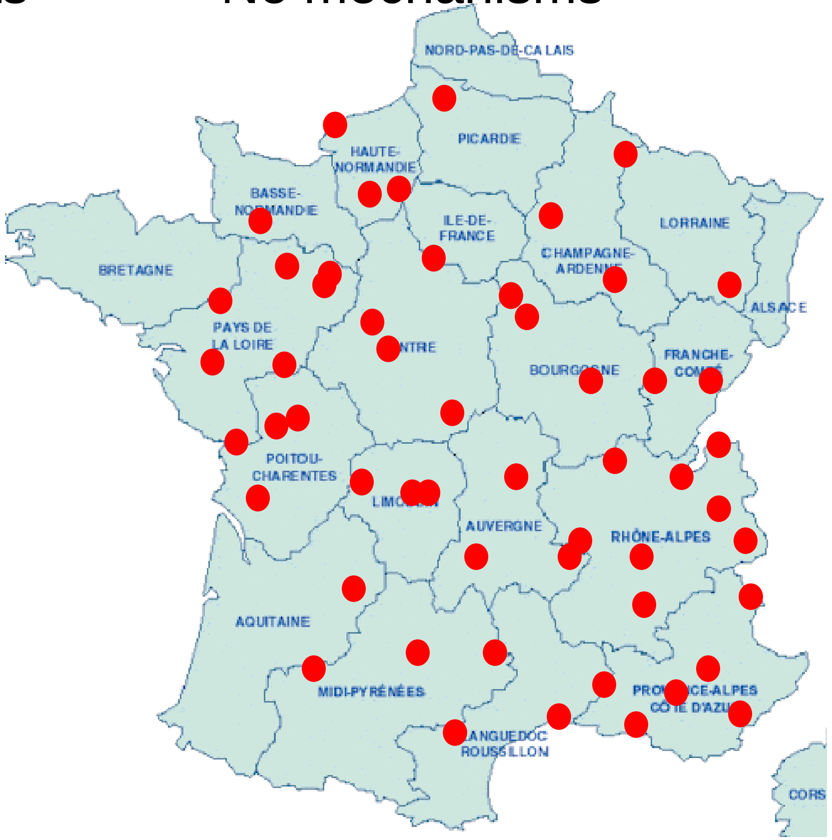
Replace **1 simple** & **efficient** technique
by **combinations** of **partially** efficient & **interacting** techniques

How to evaluate cropping systems

Field trials
- Expensive
- Few years
- Few situations
- Few repetitions
- Many measurements

Survey
- Expensive
- One-time „Snapshot"
- Many situations
- Few repetitions
- No mechanisms

Models
- Cheaper
- Long-term simulations
- Many situations
- Many repetitions
- Sensitivity to parameters ⇨ Understand processes



What are models?

- **Definition of "model"**

  "Simplified representation of a process or a system, in order to describe, explain or predict it"

- **Model = Tool to…**
  - Organise research
  - Synthesize and quantify knowledge
  - Support decisions

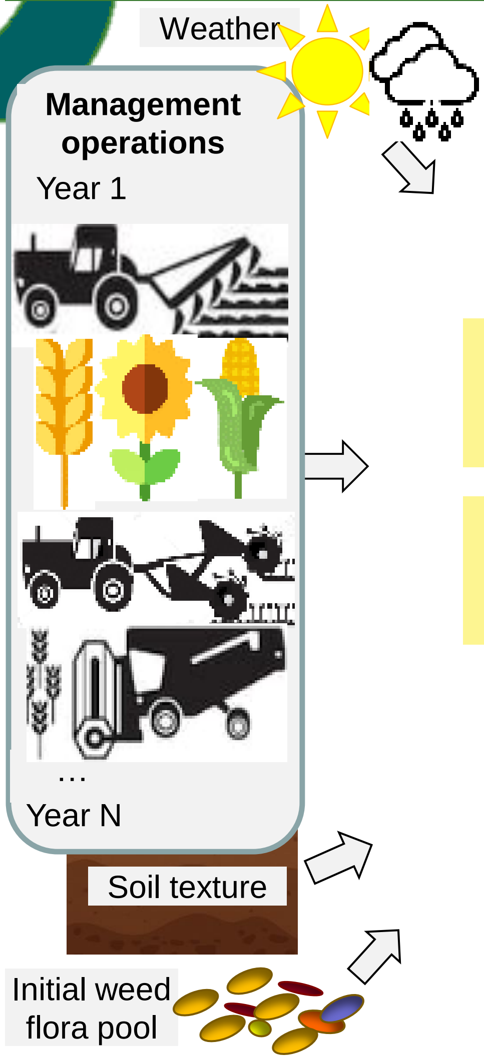
- **Different types of models/tools**

Research models
- Use/simulations:
  Researchers, technical institutes
- Advice based on simulations:
  Farmers, legislators

Decision support systems
- Use/simulations:
Researchers, technical institutes
Participatory workshops
Farmers, legislators

The virtual field FLORSYS

Inputs chosen by user

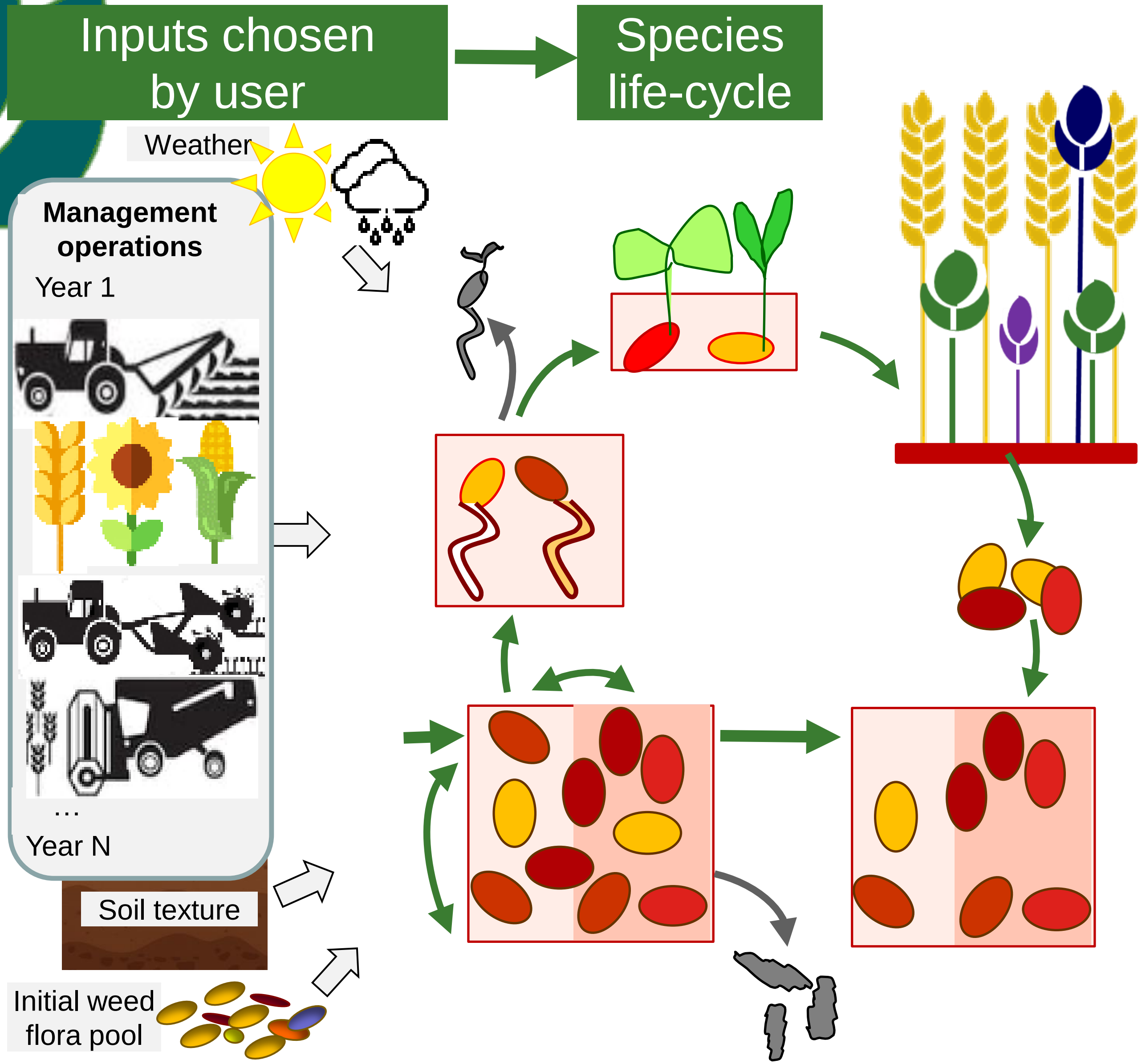


Detailed list of operations ~ records from experimental station or farmer‘s field

Detailed description of pedoclimate ~ virtual field

Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Colbach et al. (2014) Soil Till Res; Weed Res; Colbach et al (2017) Ecol Indic; Colbach et al (2020) Field Crops Res; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res; Mézière et al 2015 Ecol Indic; Moreau et al (2020) Eur J Agon; Pointurier et al 2021 Ecol Mod

The virtual field FLORSYS



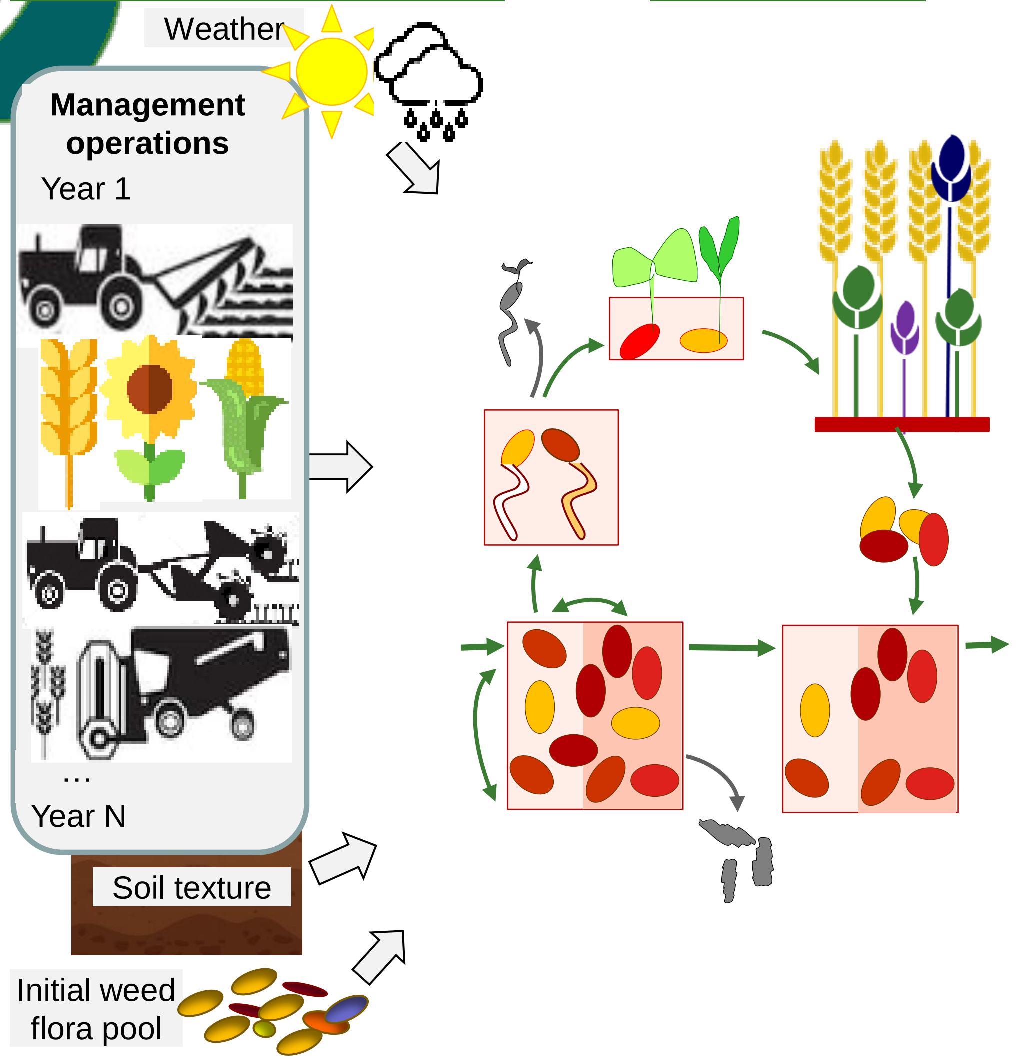
Mechanistic description
Daily time-step
Multi-annual simulation

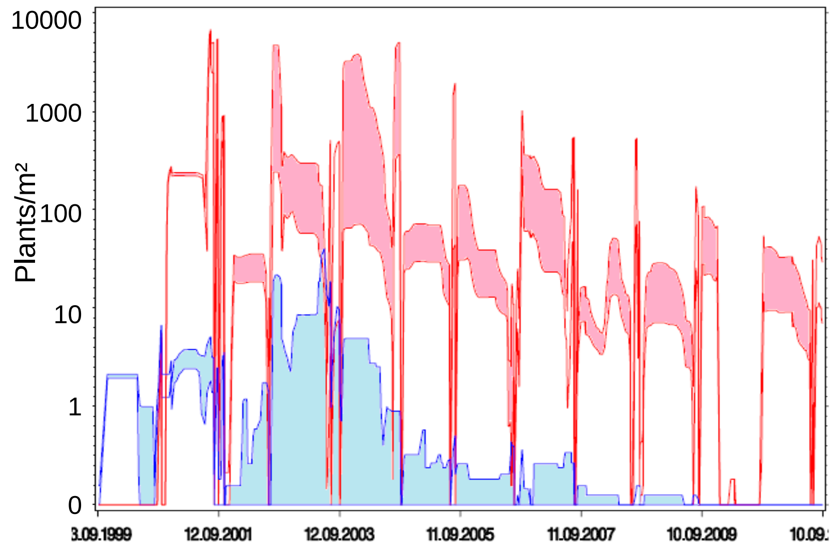
Annual species

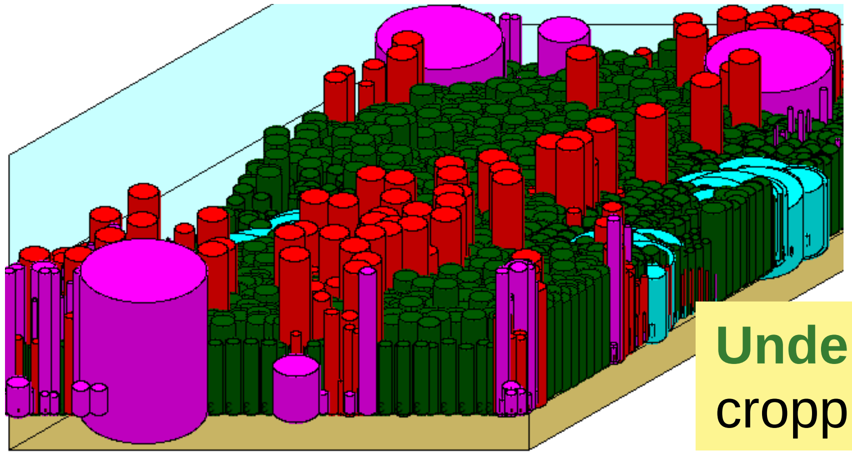
Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Colbach et al. (2014) Soil Till Res; Weed Res; Colbach et al (2017) Ecol Indic; Colbach et al (2020) Field Crops Res; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res; Mézière et al 2015 Ecol Indic; Moreau et al (2020) Eur J Agon; Pointurier et al 2021 Ecol Mod

The virtual field FLORSYS

Inputs chosen by user → **Species life-cycle** → **Detailed outputs on weeds and crops**







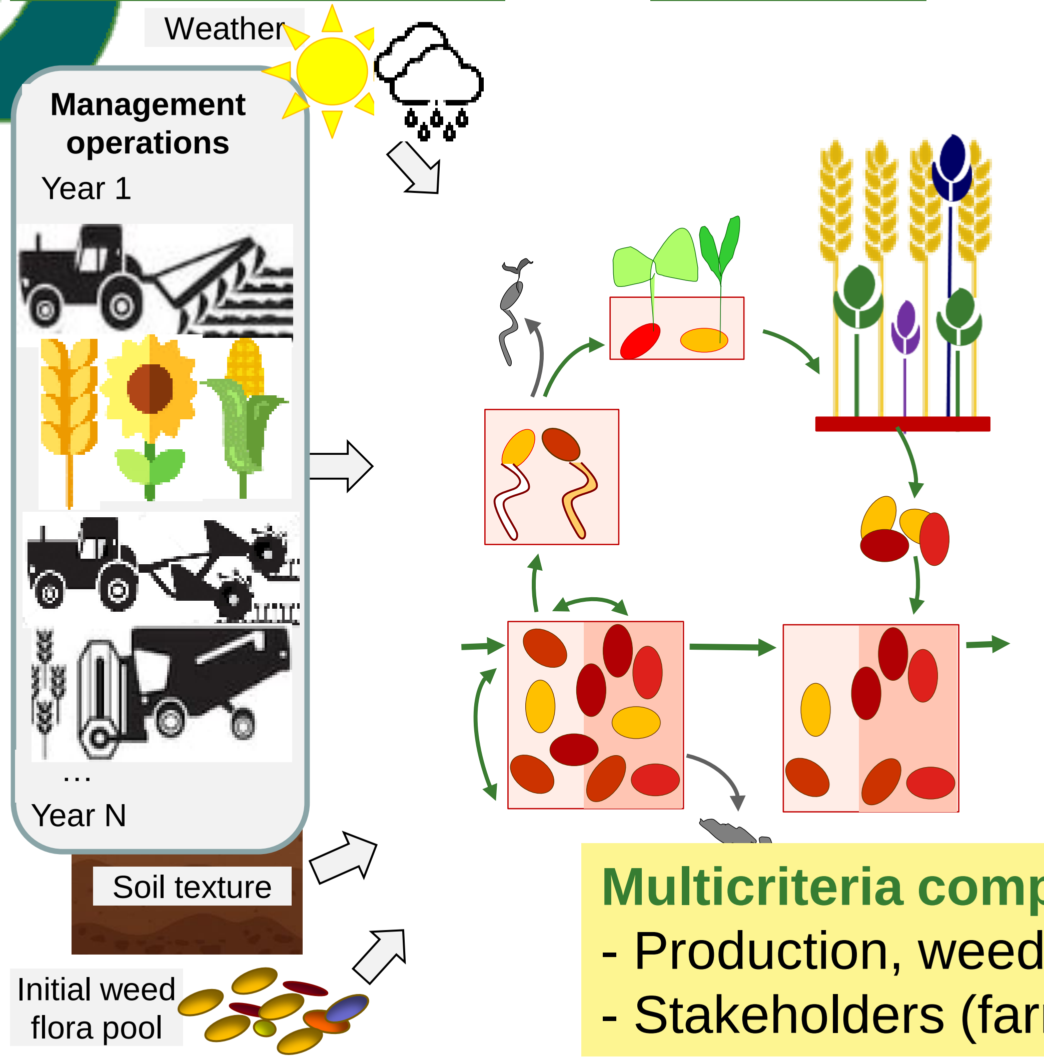
Virtual measurements
- crop & weed, soil
- Per day, in 3D

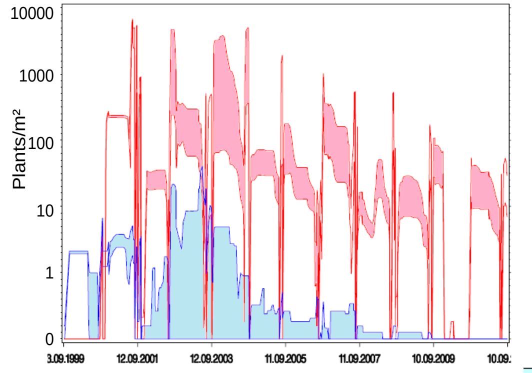
Understand and diagnose
cropping techniques & systems

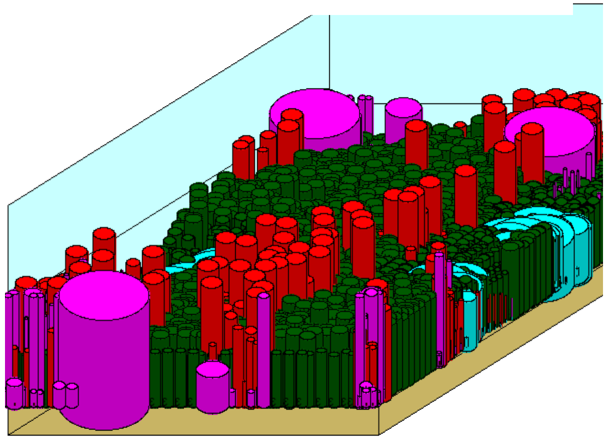
Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Colbach et al. (2014) Soil Till Res; Weed Res; Colbach et al (2017) Ecol Indic; Colbach et al (2020) Field Crops Res; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res; Mézière et al 2015 Ecol Indic; Moreau et al (2020) Eur J Agon; Pointurier et al 2021 Ecol Mod

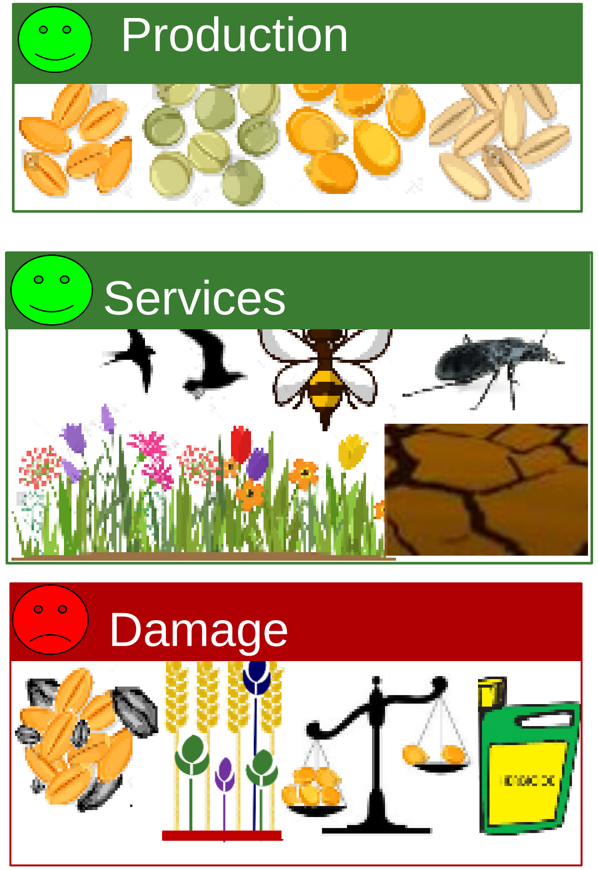
The virtual field FLORSYS

Inputs chosen by user → Species life-cycle → Detailed outputs on weeds and crops → Weed impact indicators









Multicriteria comparison of cropping systems
- Production, weed (dis)services
- Stakeholders (farmers, ecologists etc)

Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Colbach et al. (2014) Soil Till Res; Weed Res; Colbach et al (2017) Ecol Indic; Colbach et al (2020) Field Crops Res; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res; Mézière et al 2015 Ecol Indic; Moreau et al (2020) Eur J Agon; Pointurier et al 2021 Ecol Mod

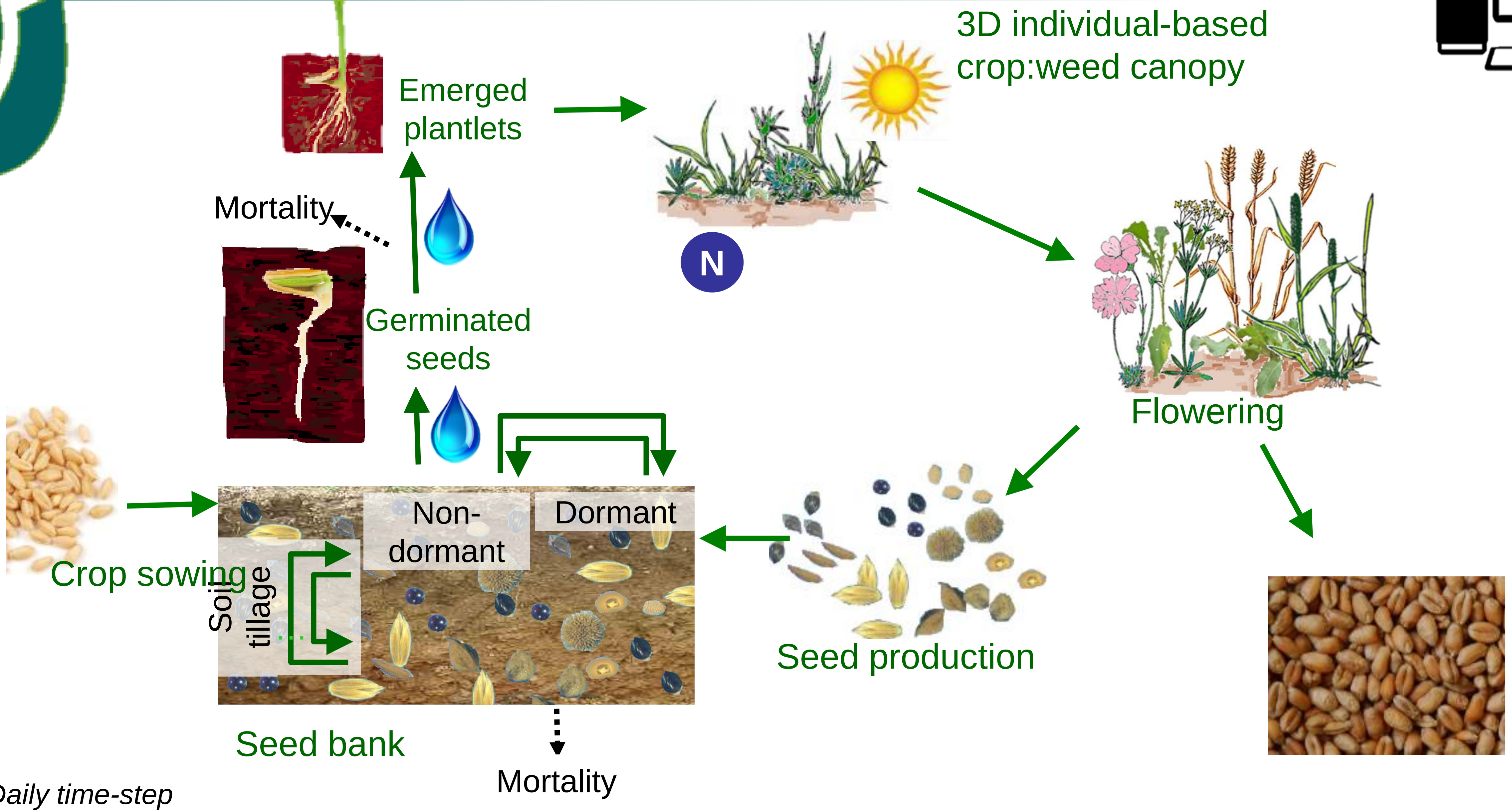
Plan

1. Objectifs du modèle & structure
2. **Détails du cycle de vie**
3. Effets des techniques culturales
4. Le reste: indicateurs, paysage
5. Évaluation du modèle
6. Examples d'utilisation
7. Comment faire tourner le modèle?

Today's presentation

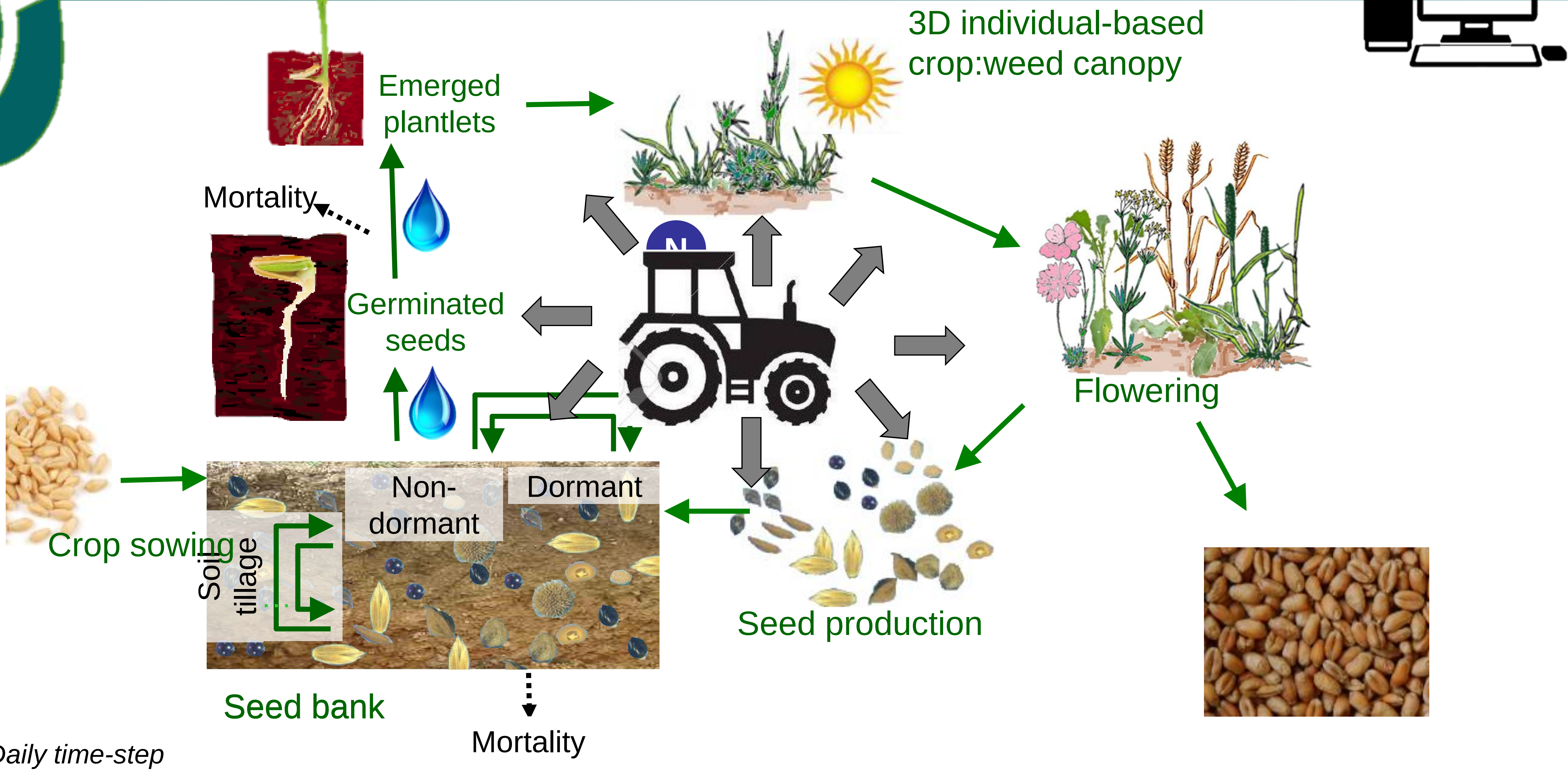
1. Model objectives & structure
2. **Details of life cycle**
3. Effects of management techniques
4. What else? Indicators, landscape
5. Model evaluation
6. Examples of model use
7. How to run the model?

The annual life-cycle of crops and weeds in FLORSYS



Daily time-step

The annual life-cycle of crops and weeds in FLORSYS



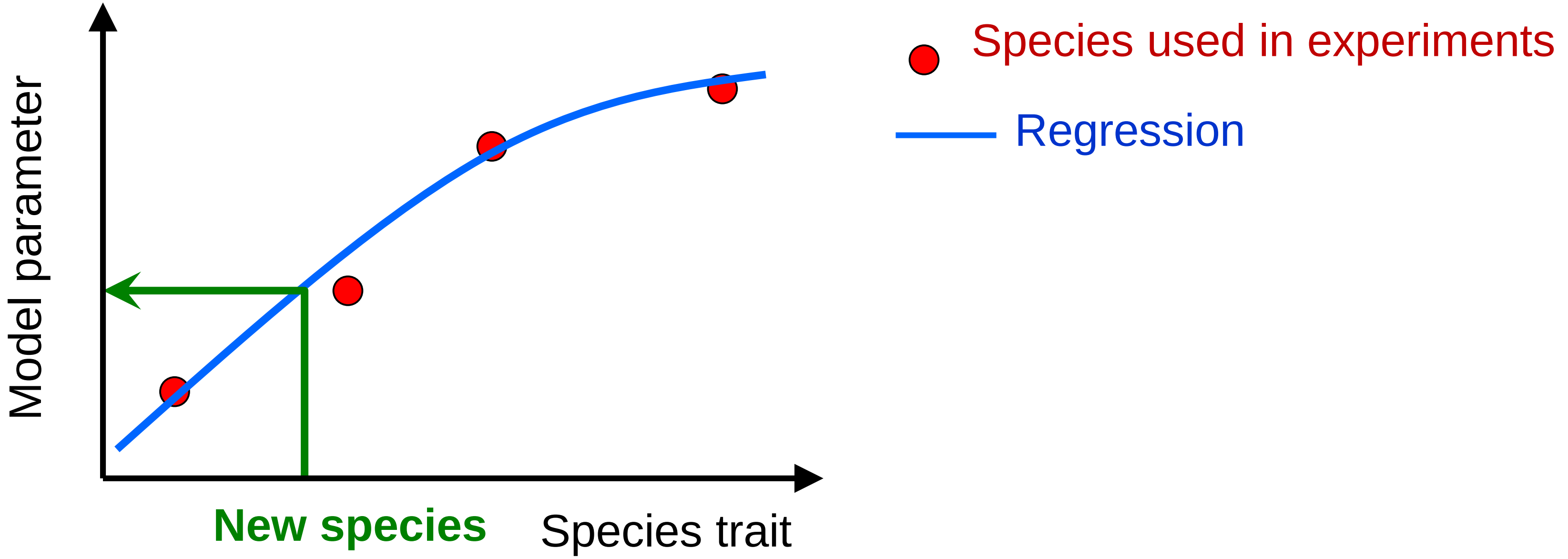
Daily time-step

Parameterize from easily measured species traits

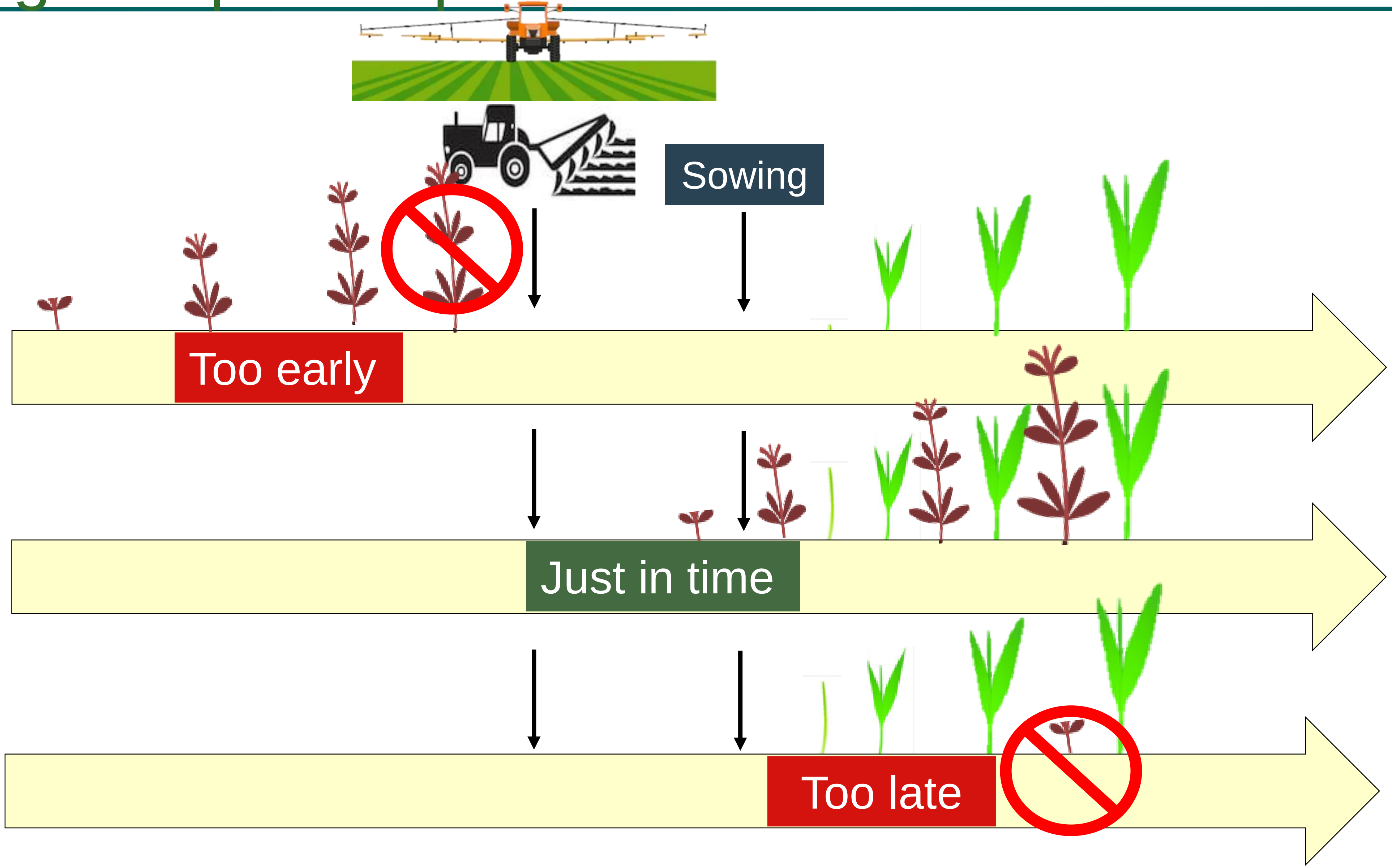
Gardarin et al 2012 Ecol Modelling

Principle

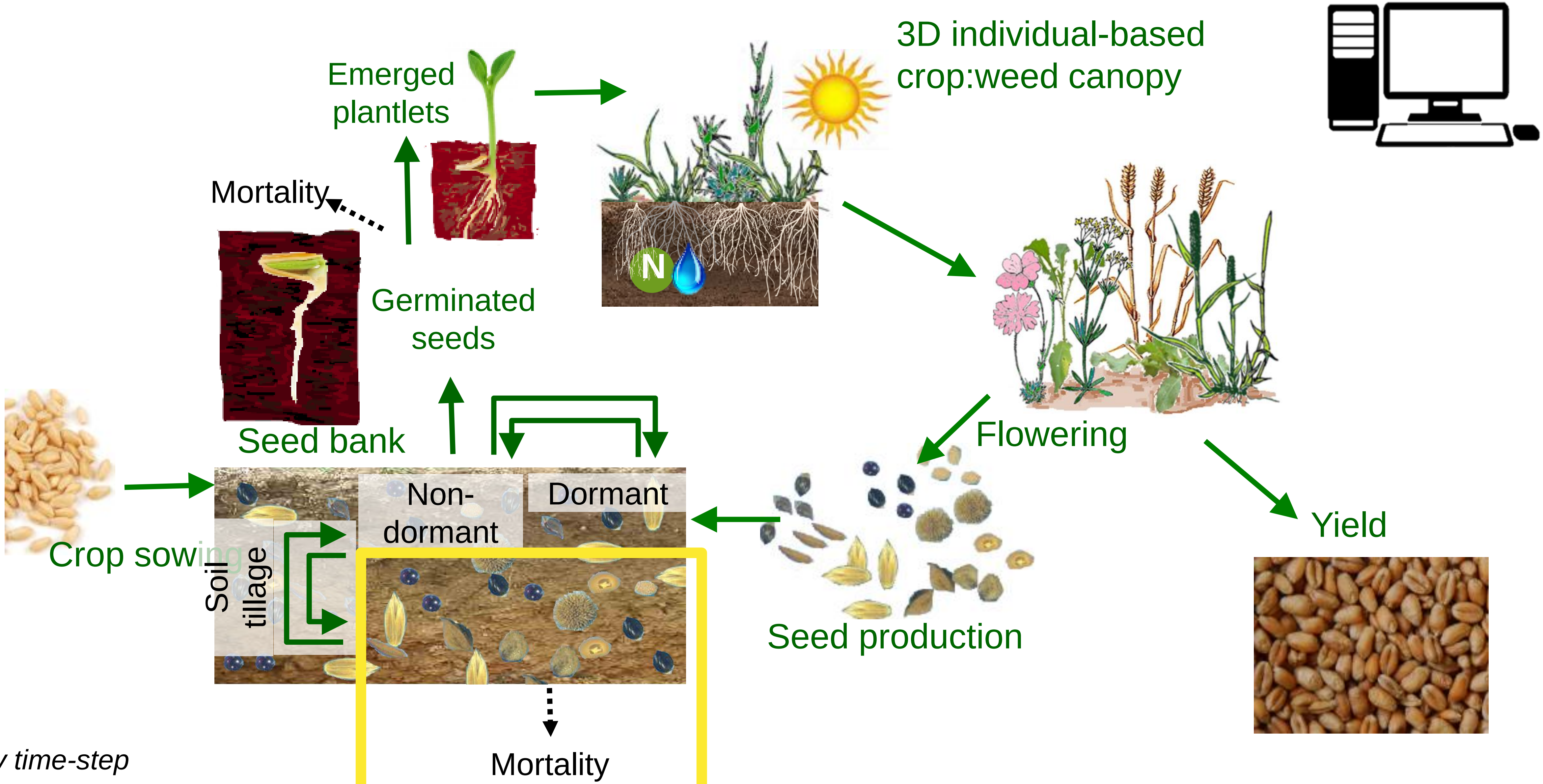
- 230 parameters per species/variety
- Parameters predicted from
  - Species traits = morphological, physiological or phenological characteristics measured at the individual scale (Violle *et al.*, 2007)
    AND easily measured
  - Expert knowledge



Timing trumps competition



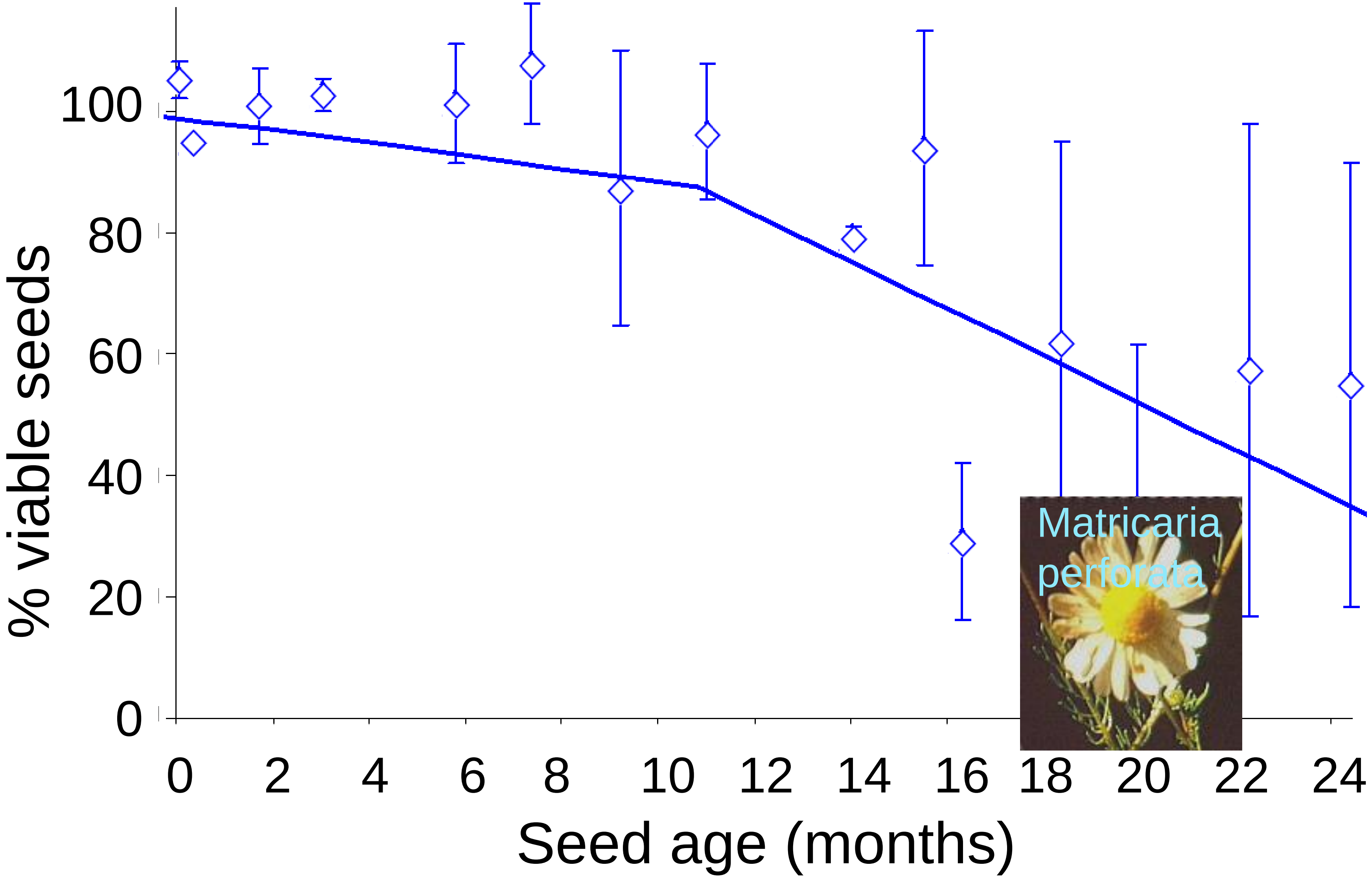
A generic life-cycle for annual crops and weeds



Daily time-step

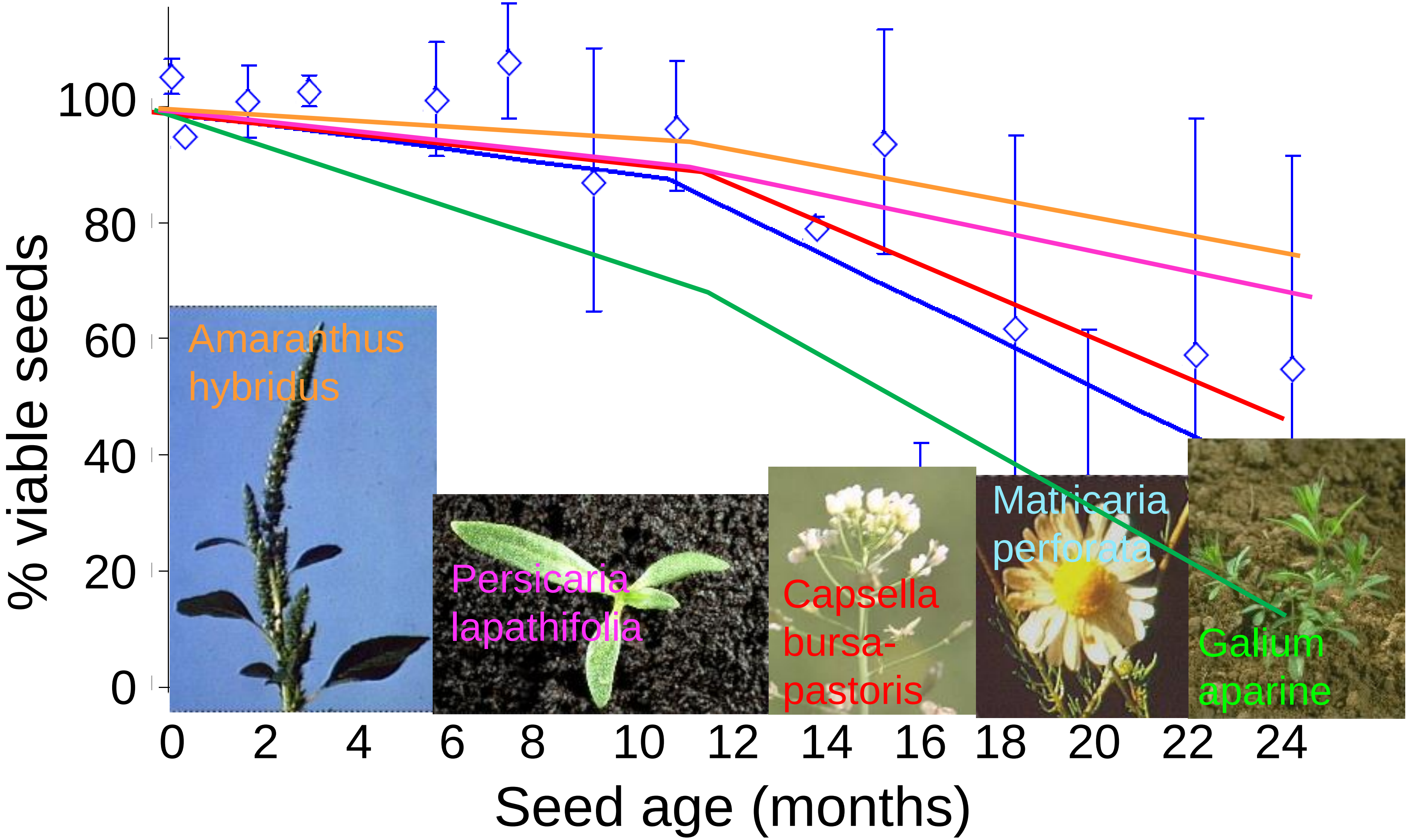
Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Colbach et al. (2014) Soil Till Res; Weed Res; Colbach et al (2017) Ecol Indic; Colbach et al (2020) Field Crops Res; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res; Mézière et al 2015 Ecol Indic; Moreau et al (2020) Eur J Agon; Pointurier et al 2021 Ecol Mod

Seeds disappear over time



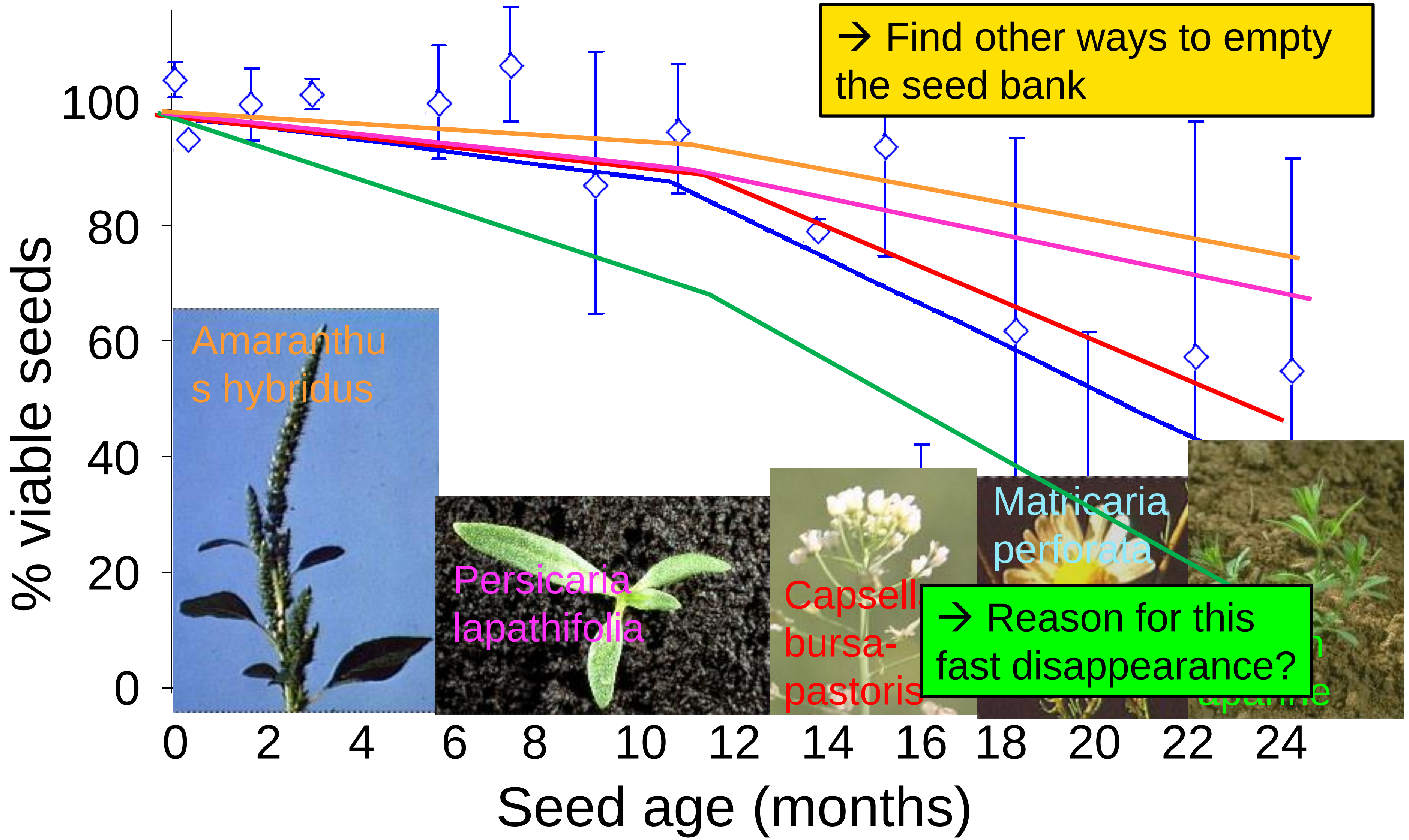
Gardarin et al. (2010) Seed Sci Res

Mortality rate = f(species)



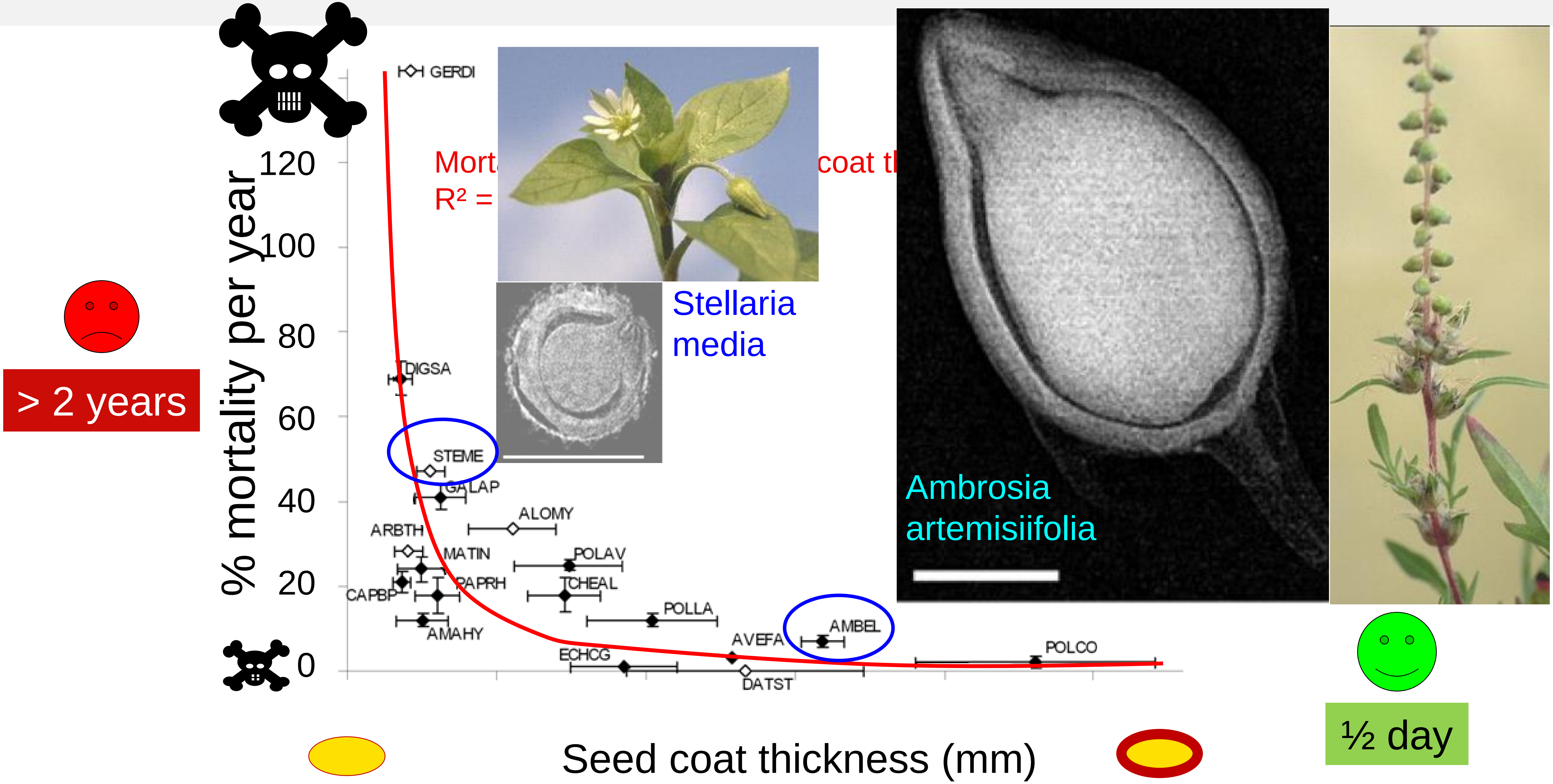
Gardarin et al. (2010) Seed Sci Res

Mortality rate = f(species)



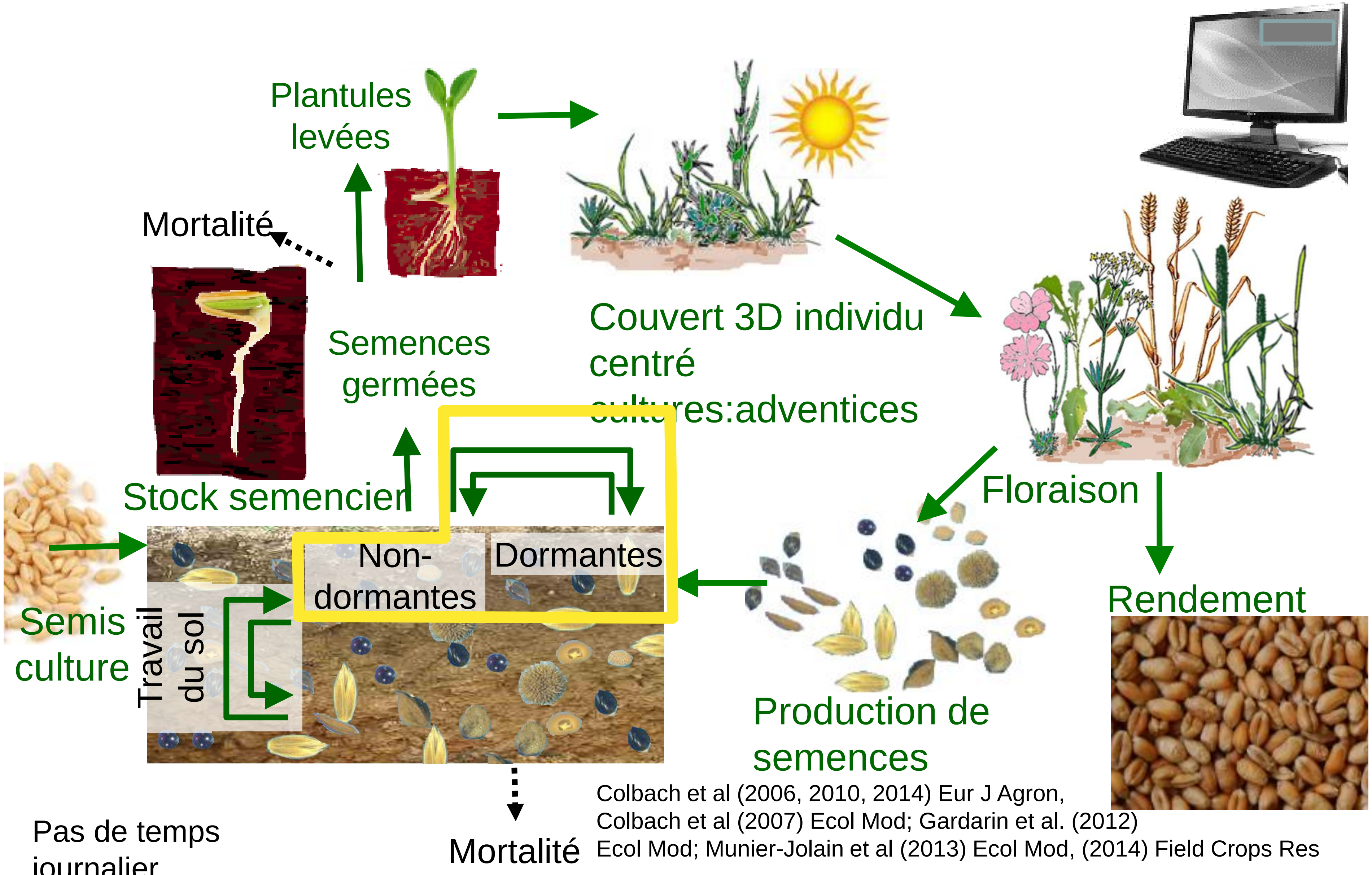
Gardarin et al. (2010) Seed Sci Res

Seed coats protect the embryo



Gardarin et al. (2010) Seed Sci Res

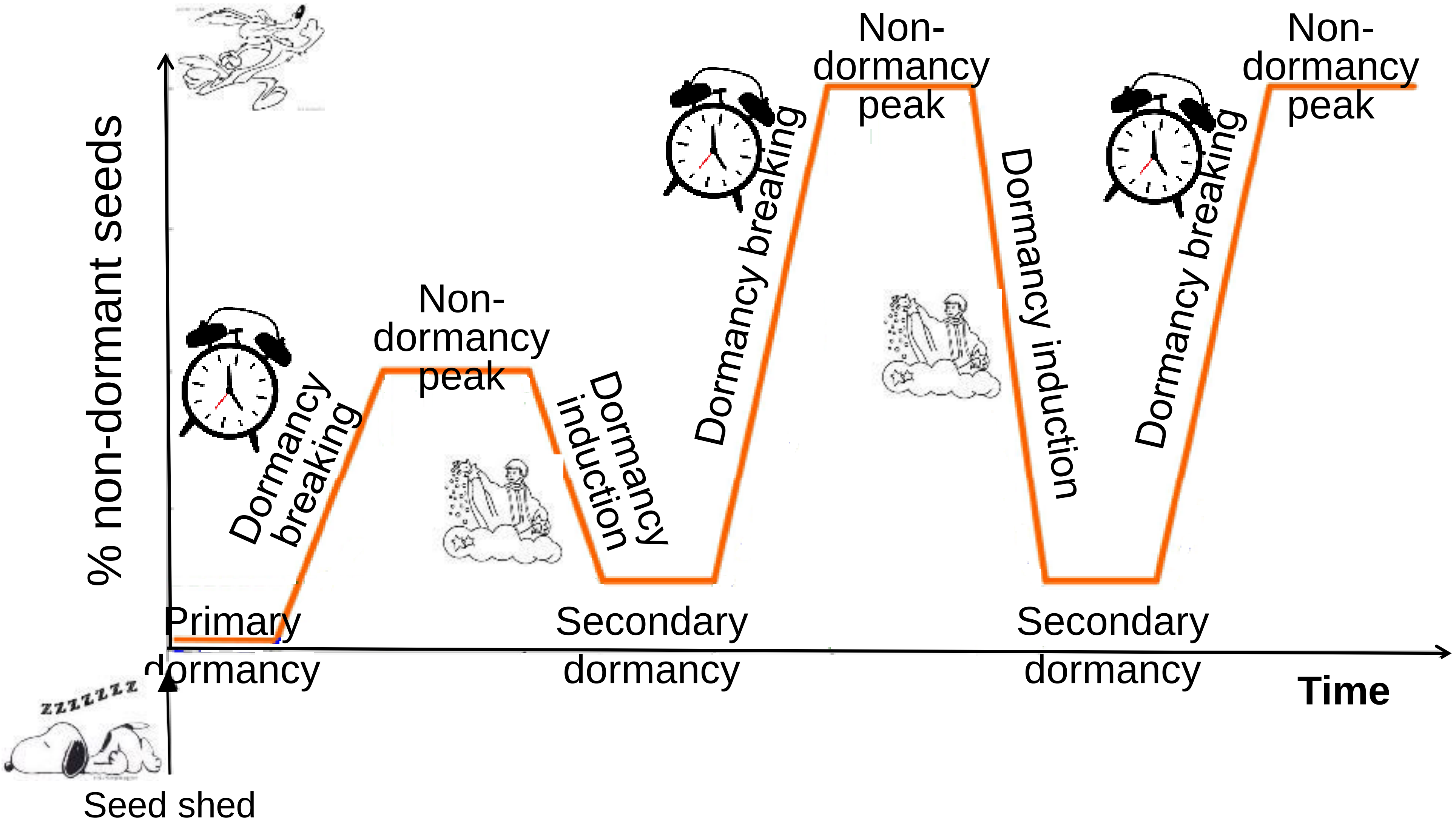
Le cycle de vie générique pour adventices et cultures annuelles



Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res

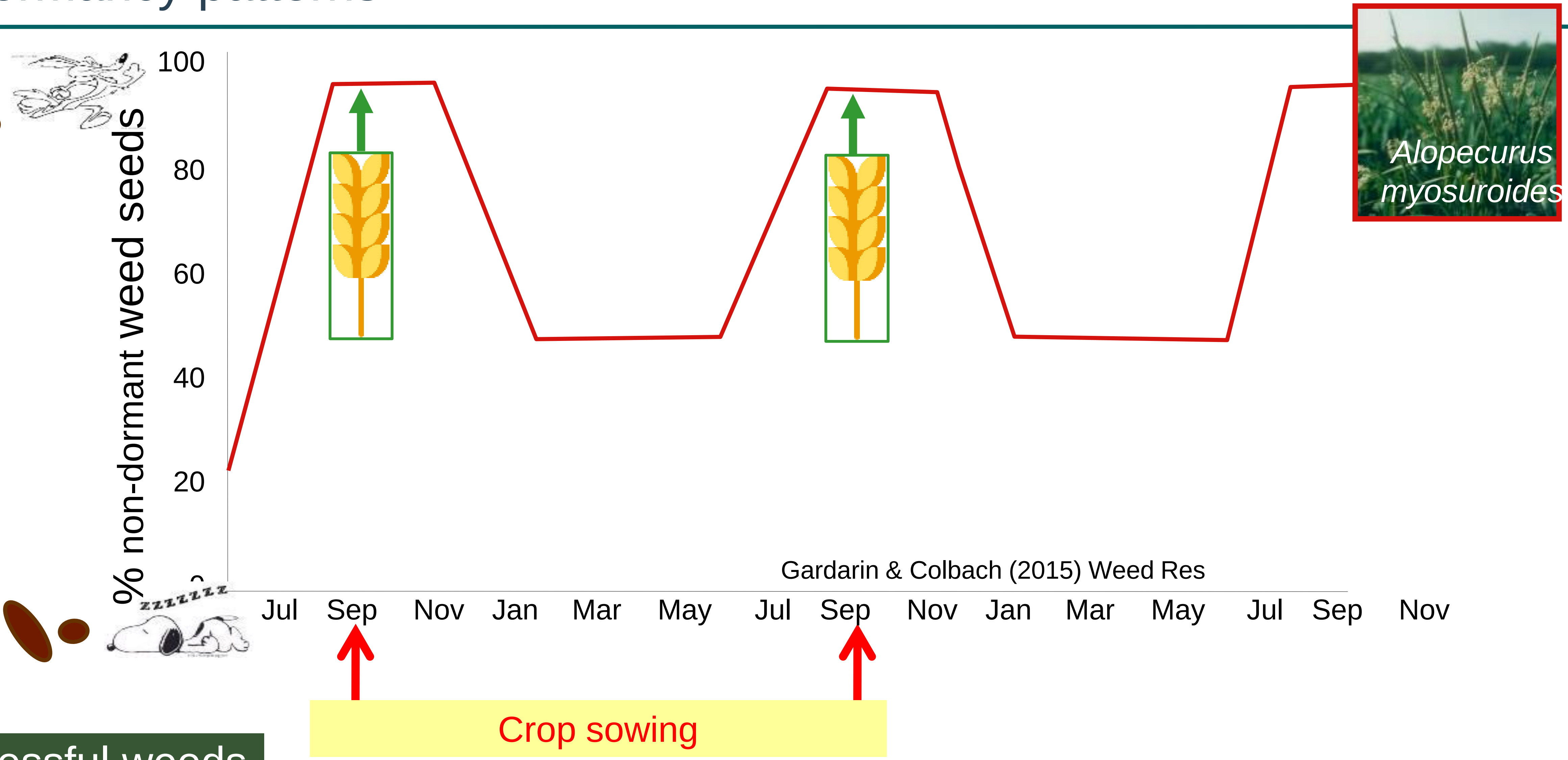
Pas de temps journalier

Dormancy determines emergence season



Gardarin & Colbach (2015) Weed Res

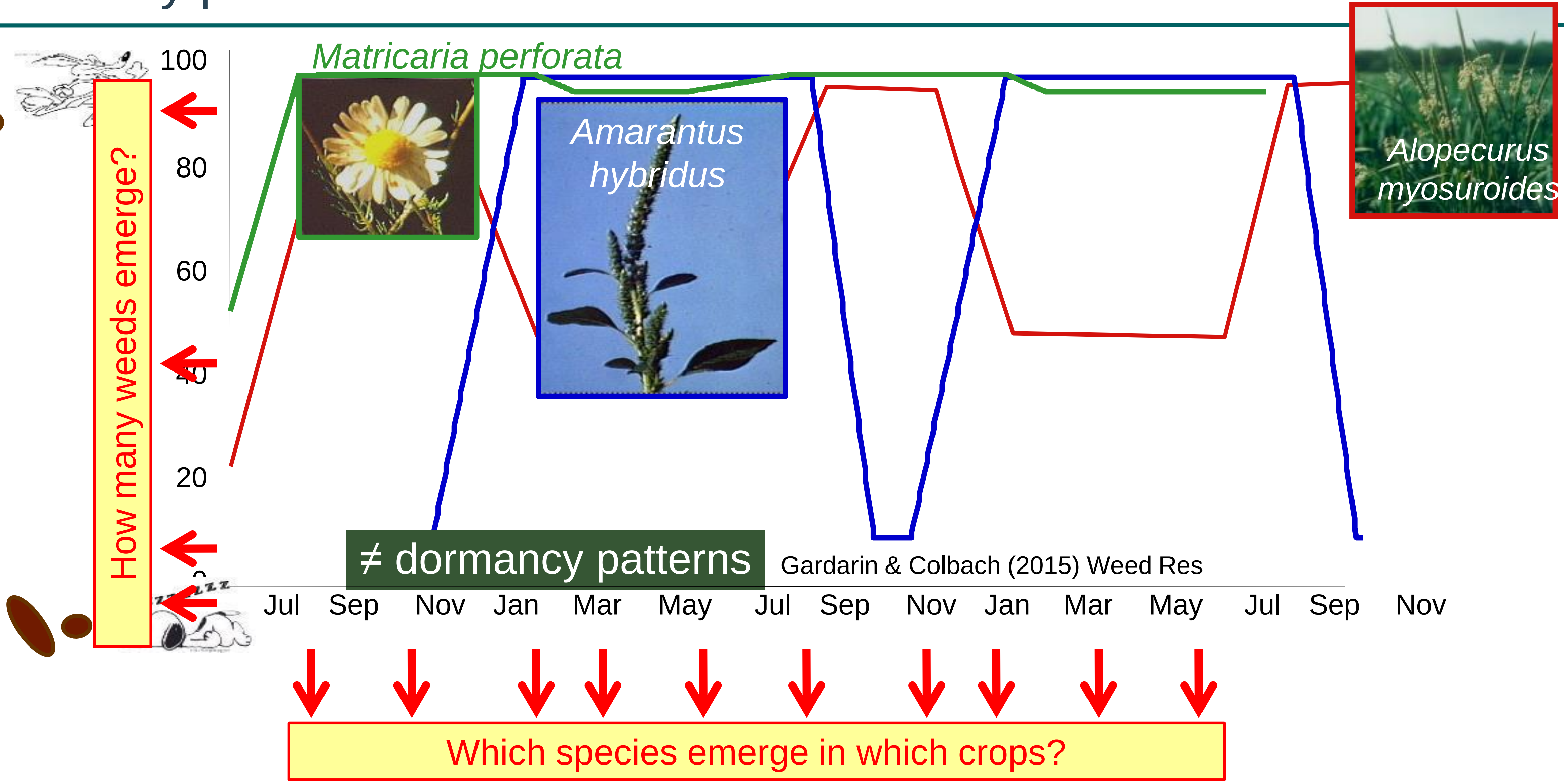
Dormancy patterns



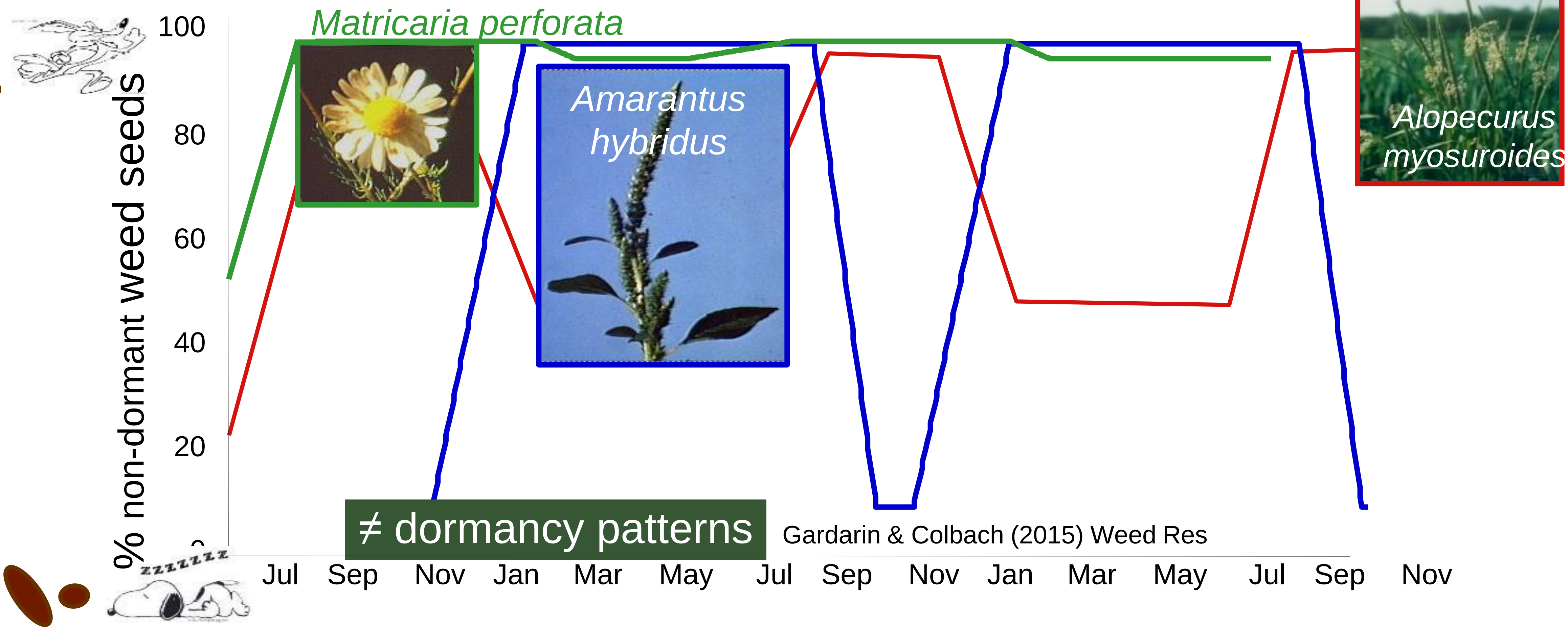
Successful weeds mimic crops

Barrett (1983) Economic Botany; Fried et al (2008) Agric Ecosyst Environ; Neve et al (2009) New Phytol
…

Dormancy patterns



Dormancy patterns



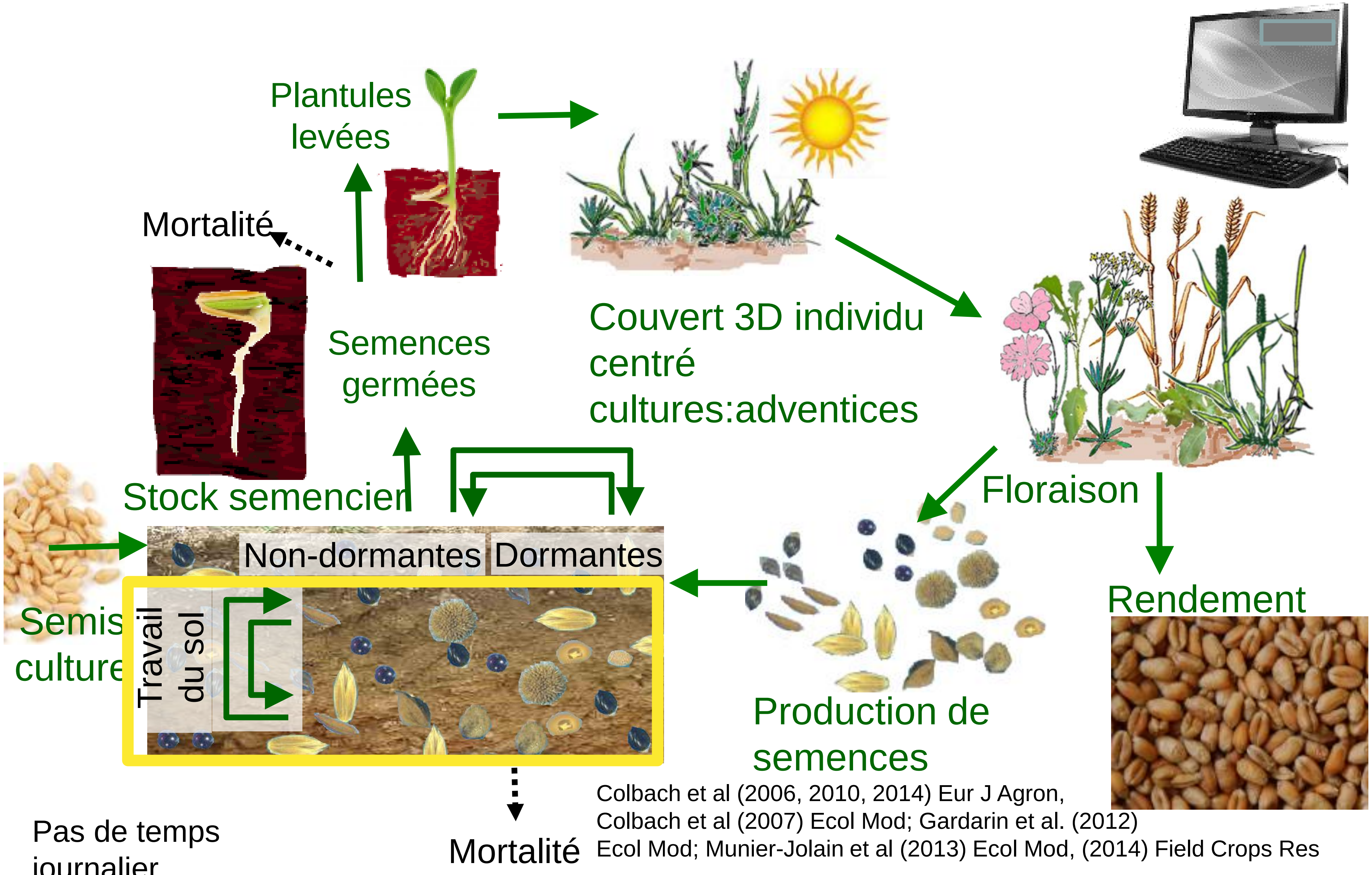
Crop diversification ↗ Weed diversity

Neyret et al (2020) Agric Ecosyst Environ
Jastrzebska et al (2019) Agronomy-Basel

Crop diversification ↘ Weed pressure

Weisberger et al (2019) PLOS ONE
Adeux et al (2019) Agron Sustain Dev

Le cycle de vie générique pour adventices et cultures annuelles



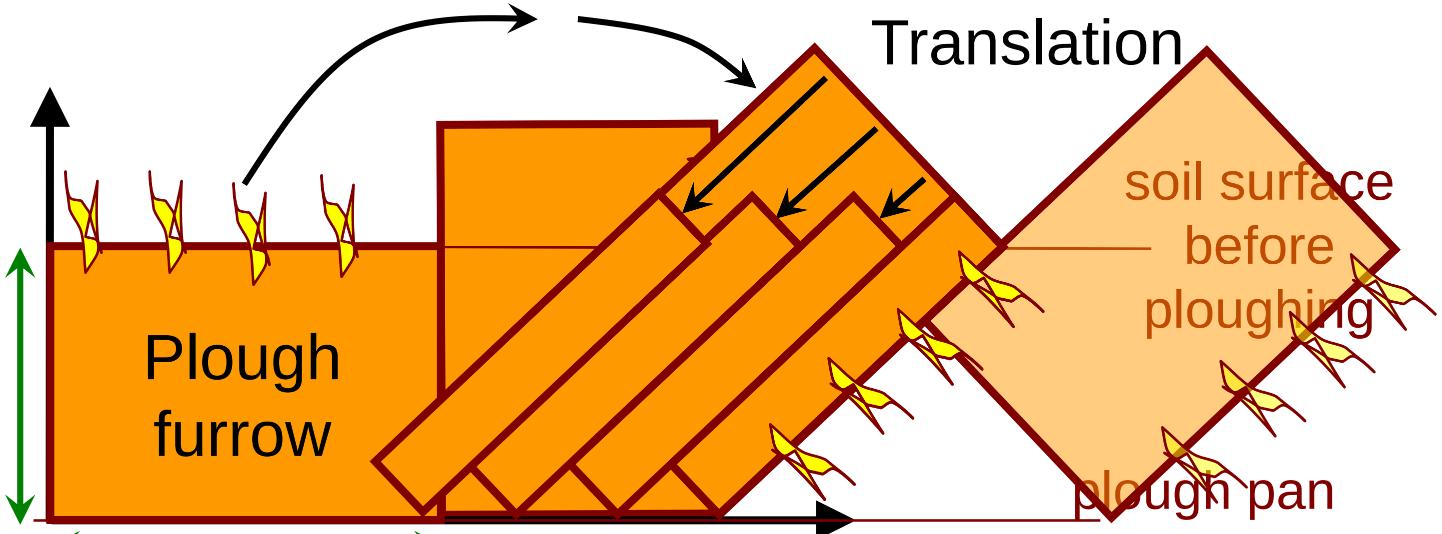
Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res

Pas de temps journalier

Weed seed burial: example of model adaptation

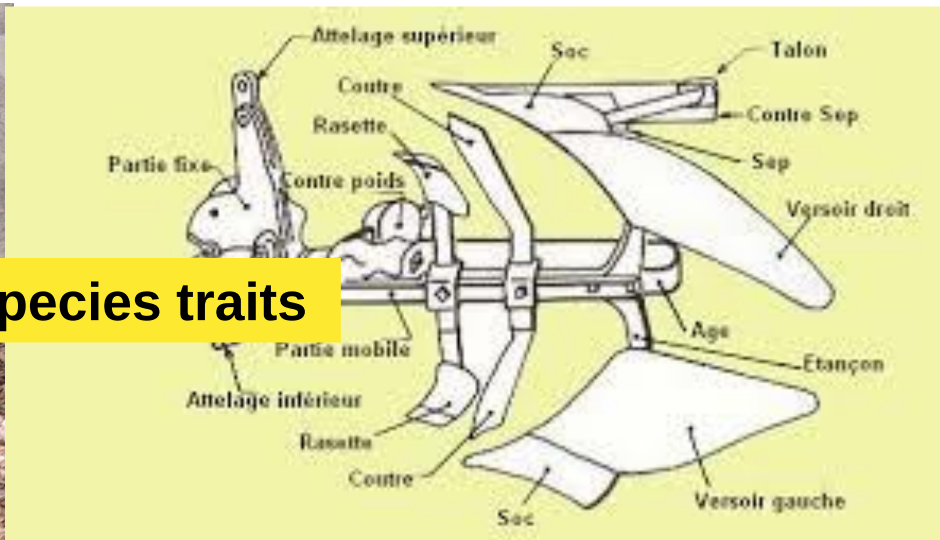
Existing model = SISOL (Roger-Estrade et al. 2001)

(view perpendicular to the tractor motion)



ploughing width

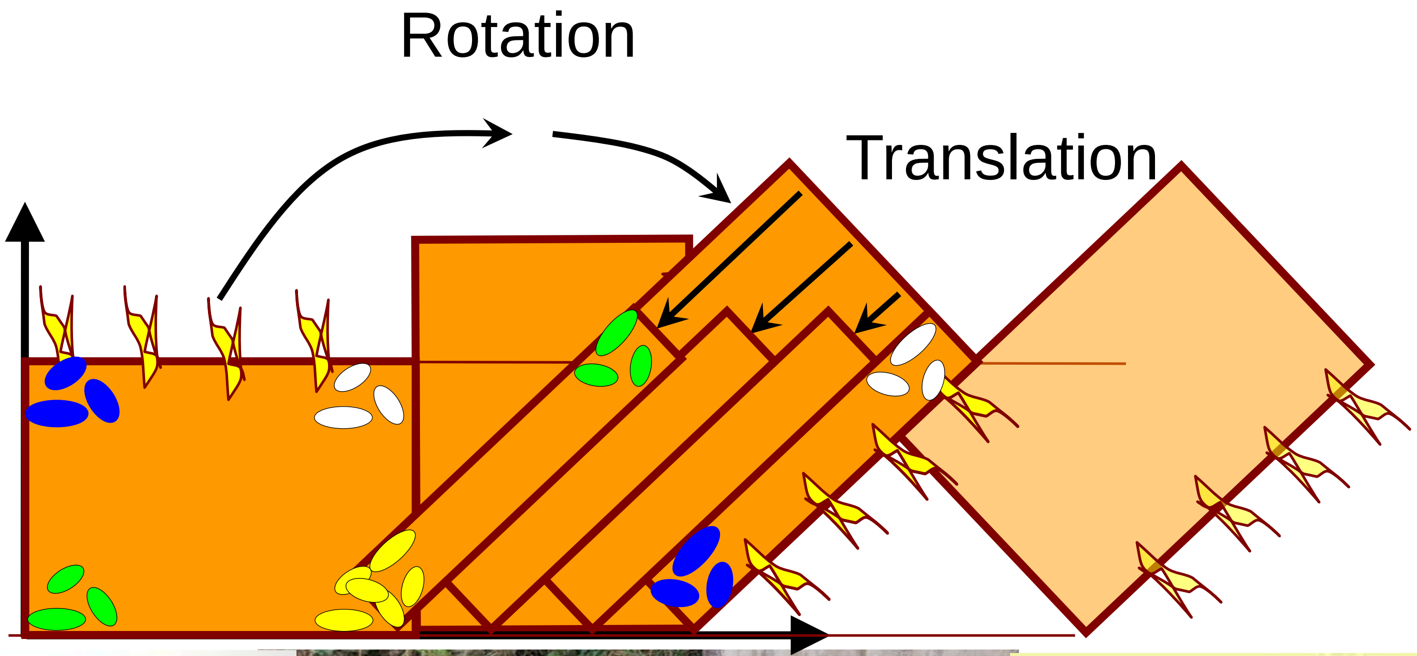
+ soil structure

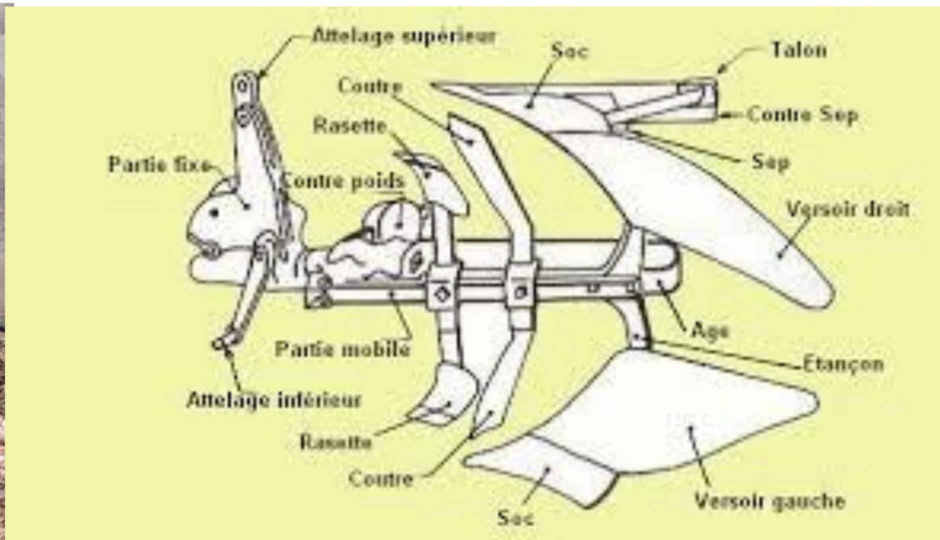


Process independent of species traits

Les mouvements de semences pendant le labour

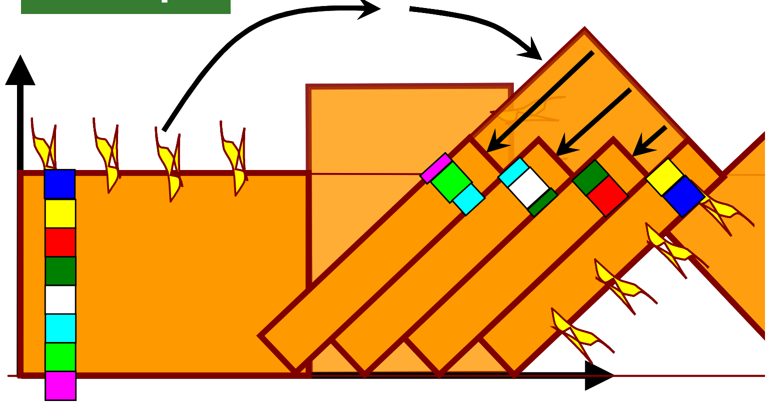
(view perpendicular to the tractor motion)



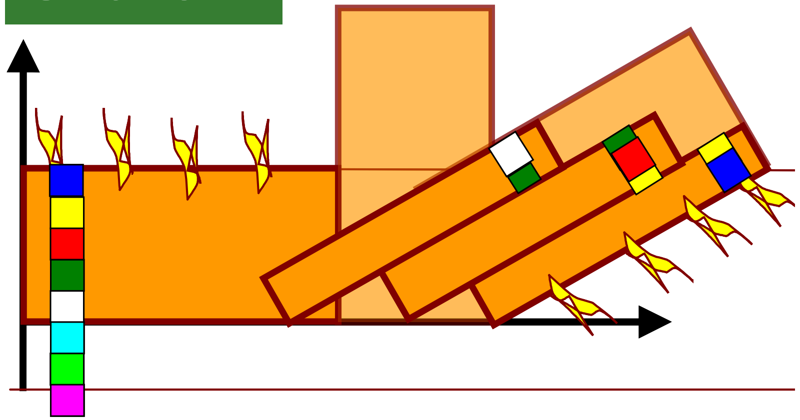


Variability in ploughing effects

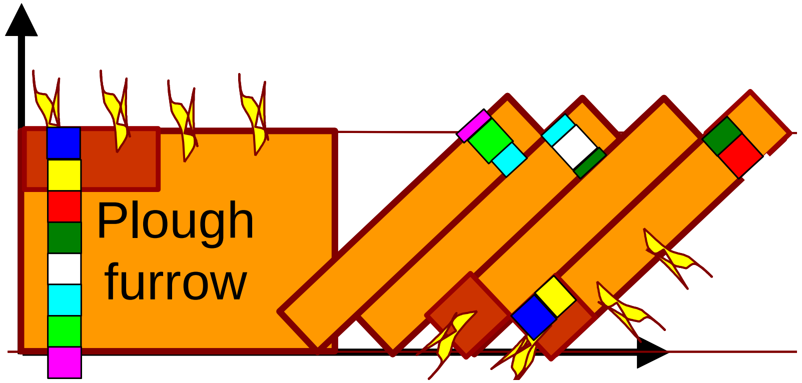
Deep

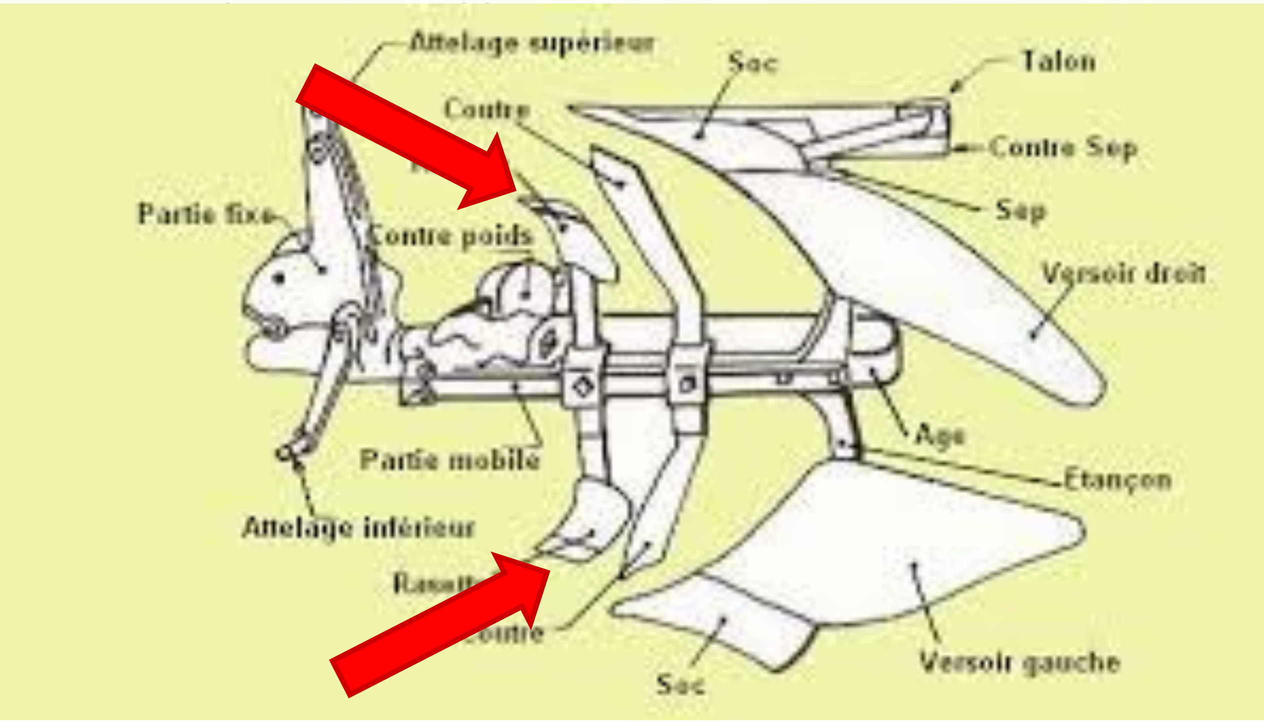


Shallow



Skim-coulter



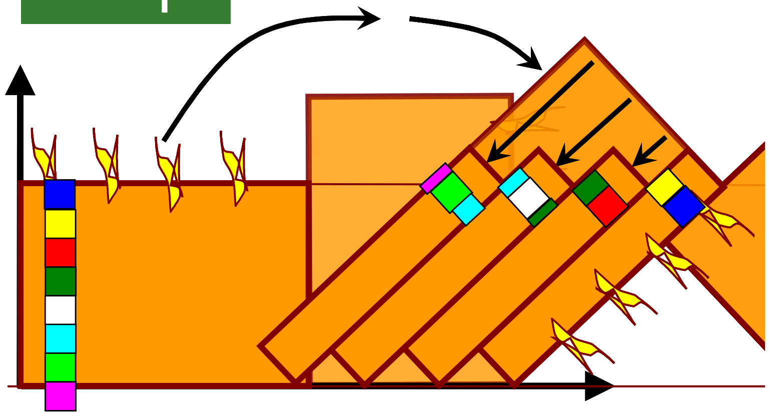


Addition of a skim-coulter:
- better burial of superficial seeds
- more exposure of intermediate seeds

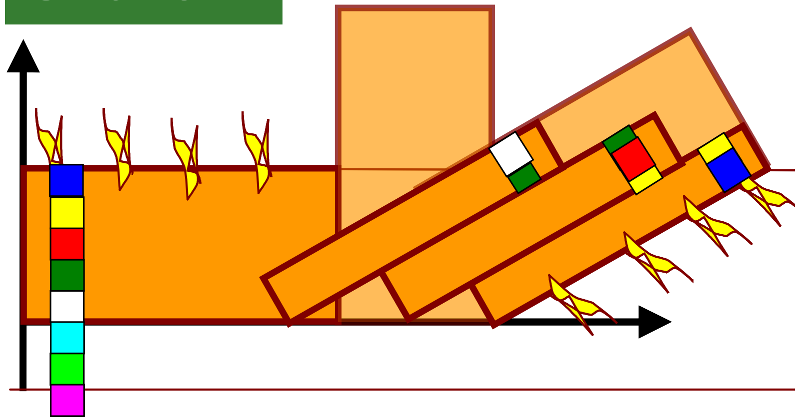
Colbach et al. 2000, Roger-Estrade et al., 2001

Variability in ploughing effects

Deep

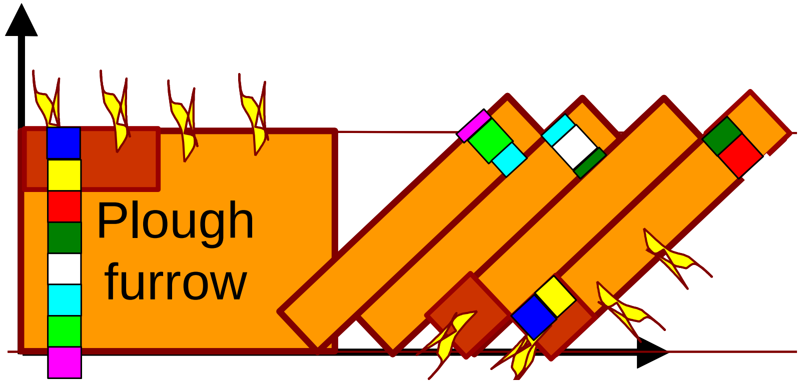


Shallow



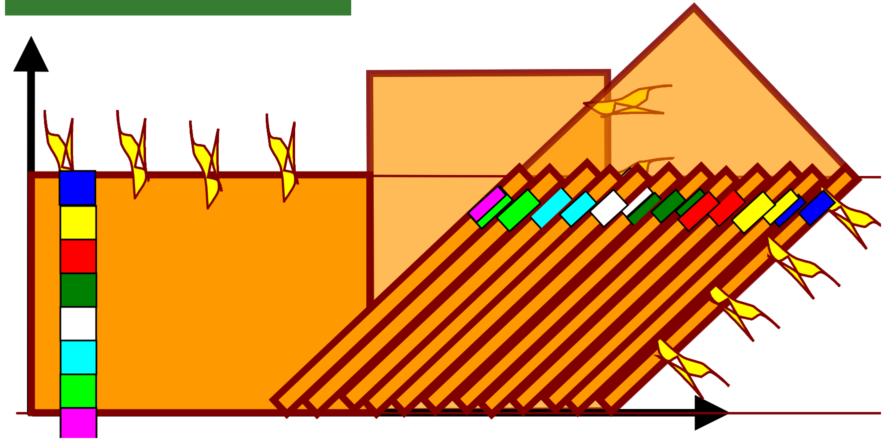
More shallow ploughing:
- more deeper seeds left undisturbed
- seeds less well buried

Skim-coulter



Addition of a skim-coulter:
- better burial of superficial seeds
- more exposure of intermediate seeds

Fine earth



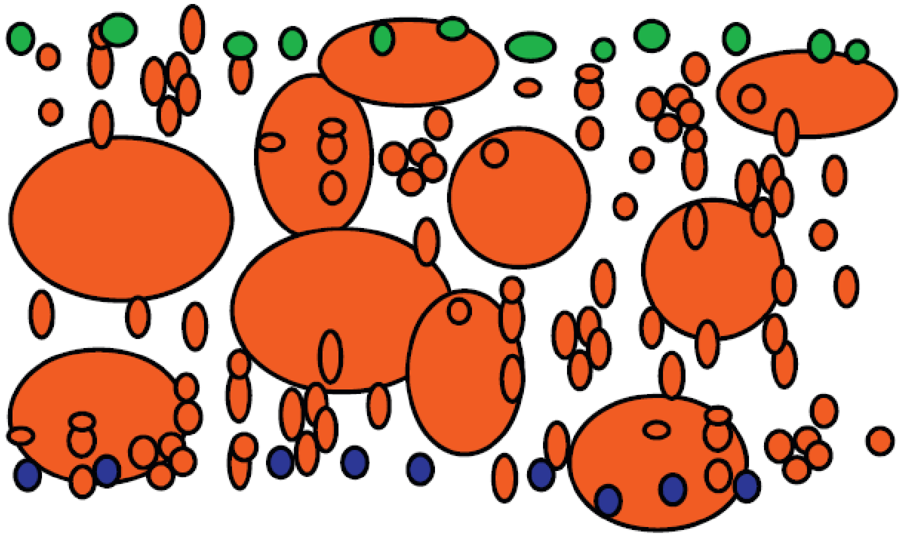
Fine earth structure:
- seeds are less exposed to light

Colbach et al. 2000, Roger-Estrade et al., 2001

Seed movements depend on tool and structure

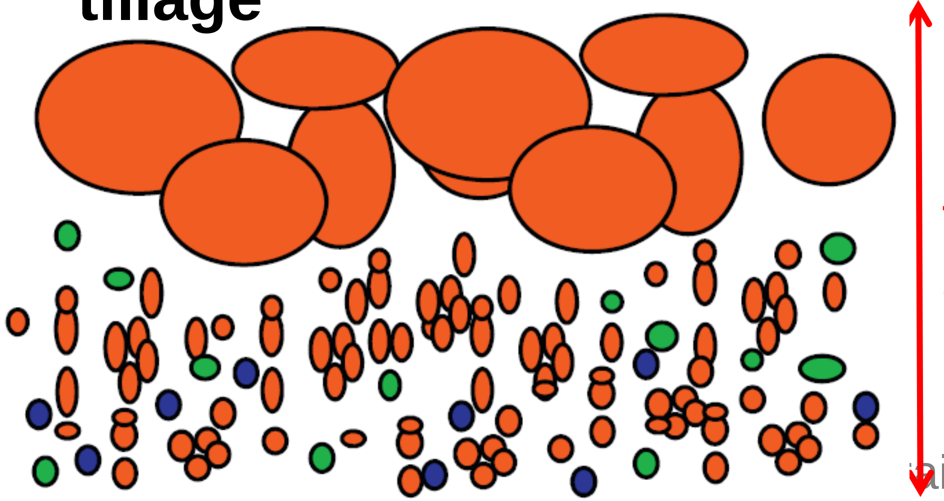
A. Before tillage

Colbach N., Busset H., Roger-Estrade J., Caneill J., 2014 - Predictive modelling of weed seed movement in response to superficial tillage tools. *Soil & Tillage Research, 138, 1-8.*



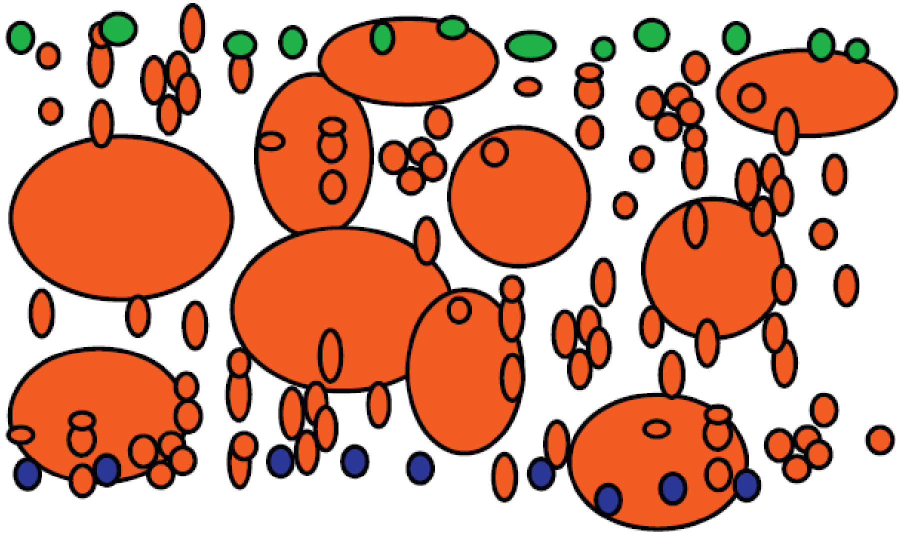
Seeds that were initially on soil surface
Seeds that were initially buried deeply
Soil clod
Fine earth

B. After non-fragmenting tillage



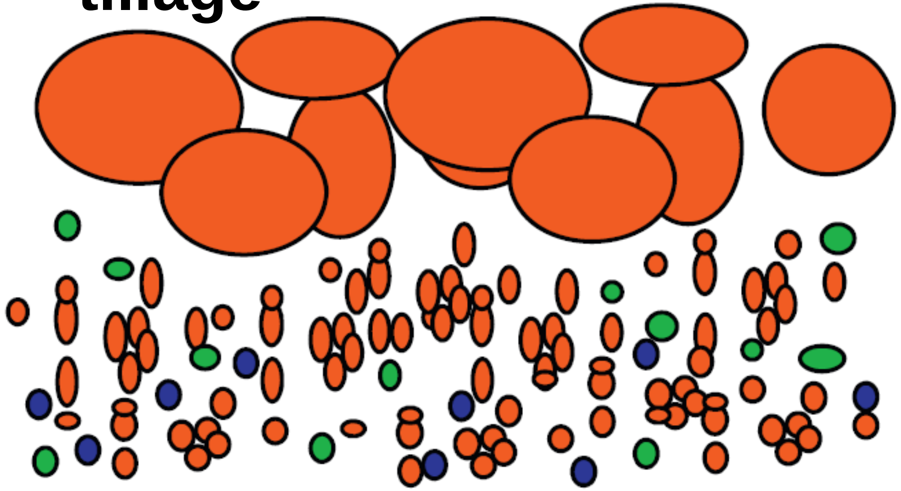
Seed movements depend on tool and structure

A. Before tillage

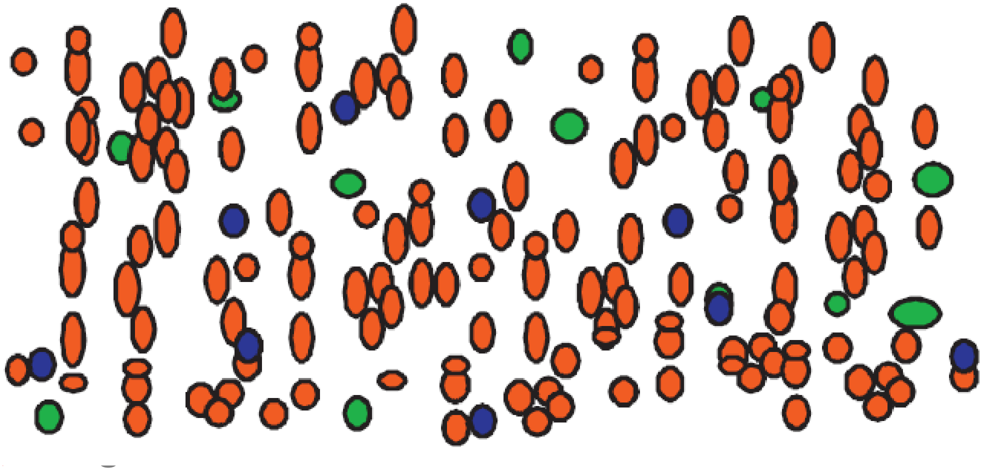


Colbach N., Busset H., Roger-Estrade J., Caneill J., 2014 - Predictive modelling of weed seed movement in response to superficial tillage tools. *Soil & Tillage Research, 138, 1-8.*

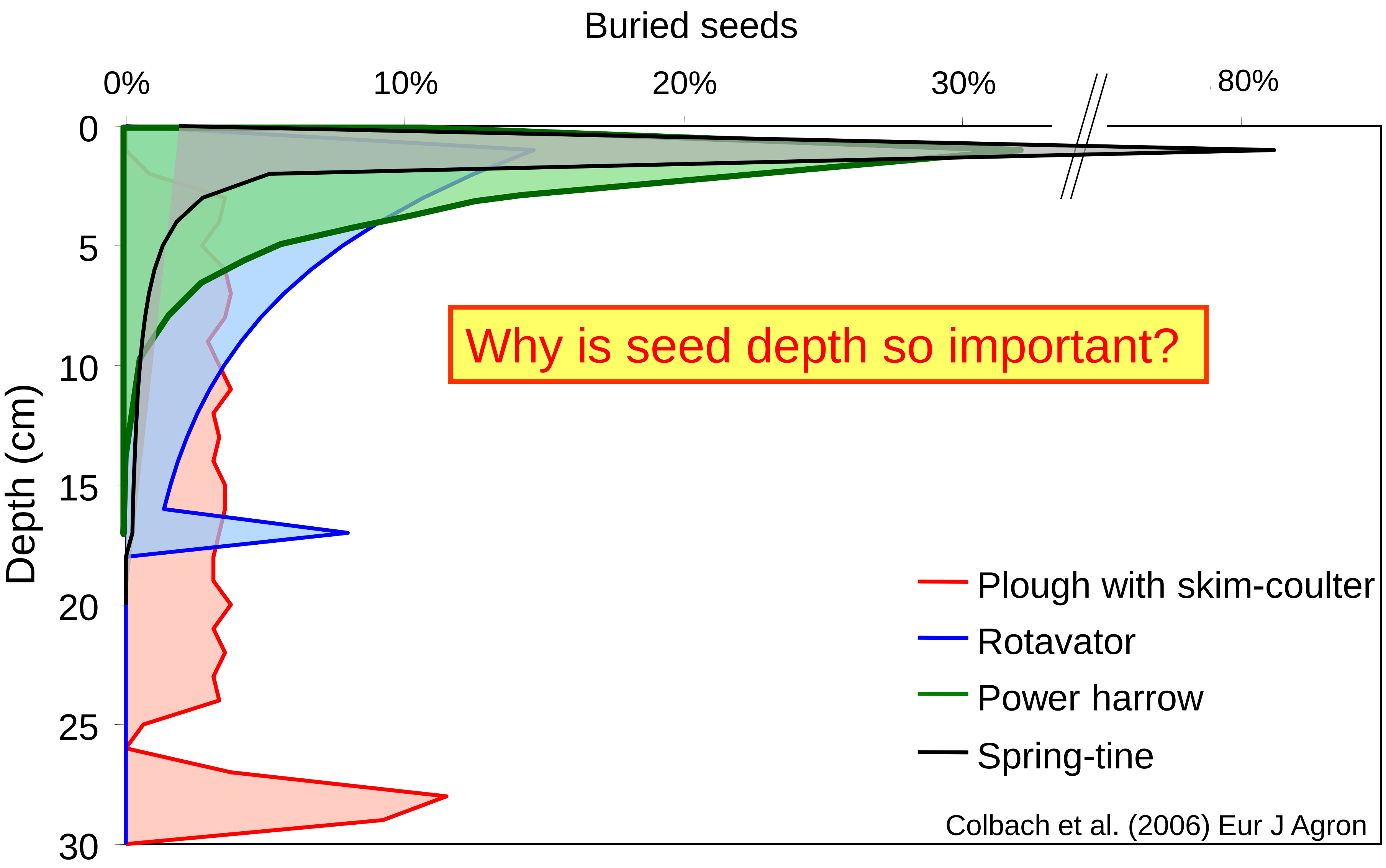
B. After non-fragmenting tillage



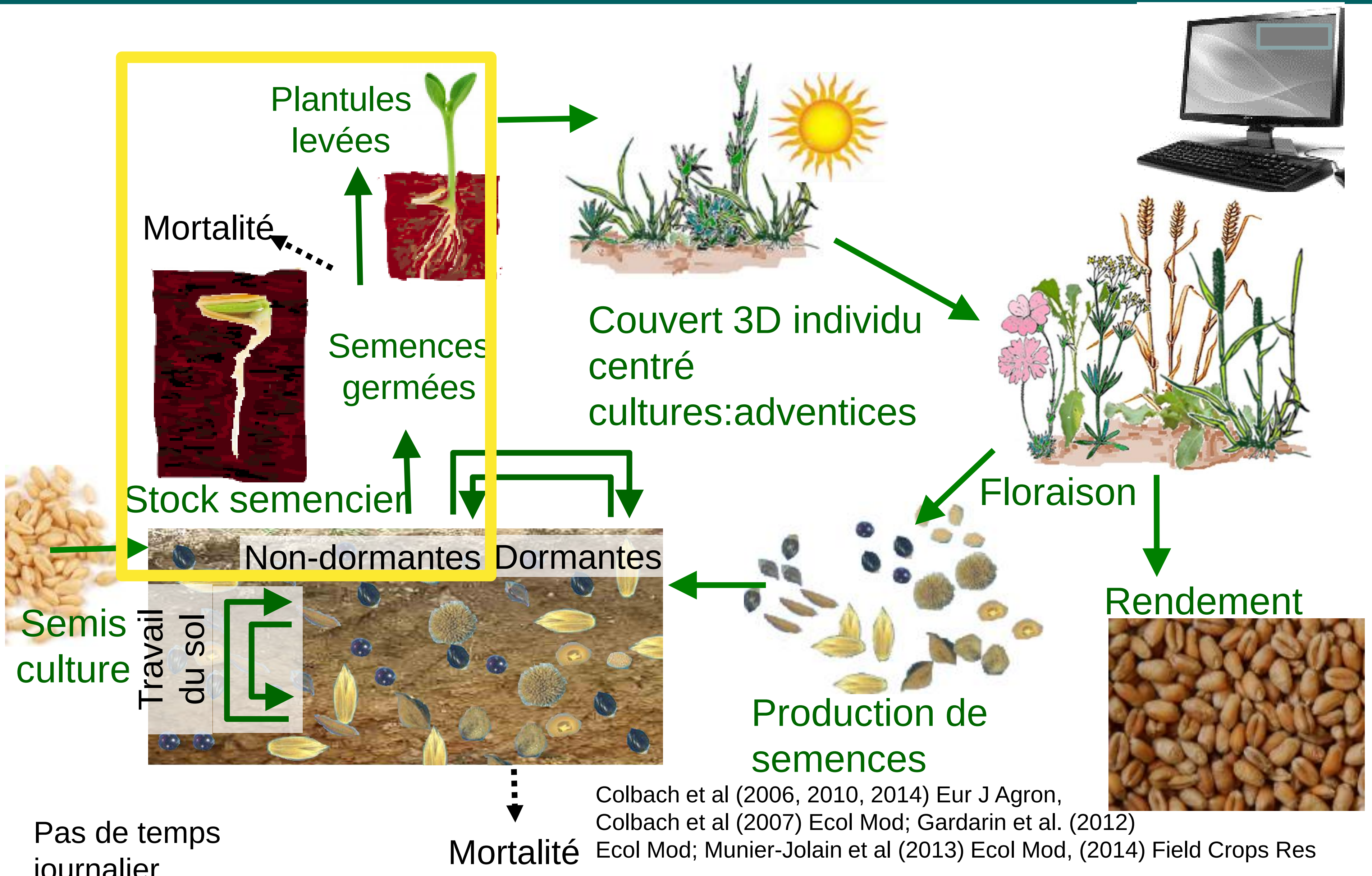
C. After highly fragmenting tillage



Diffferent tools lead to different seed profiles

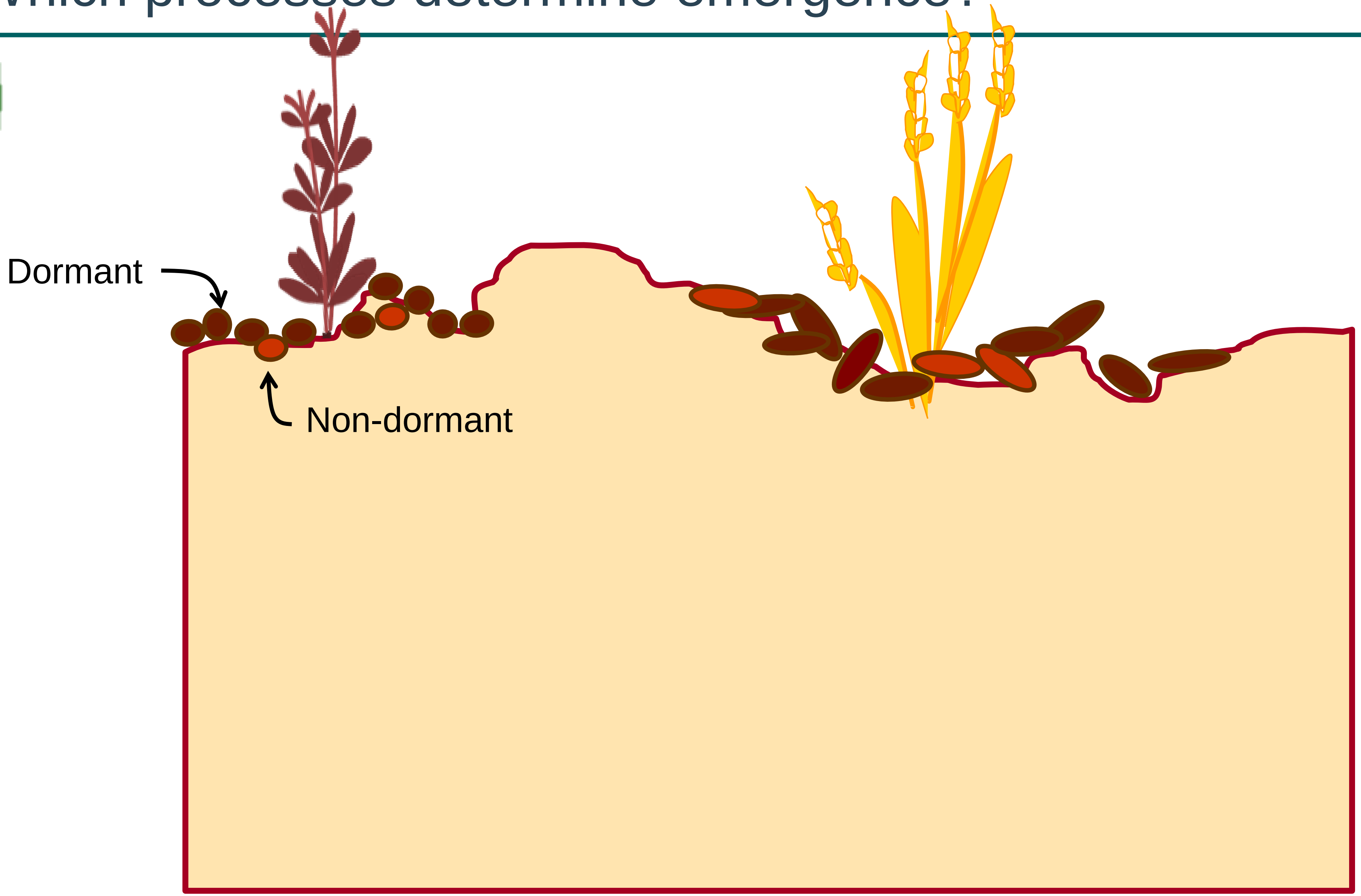


Le cycle de vie générique pour adventices et cultures annuelles



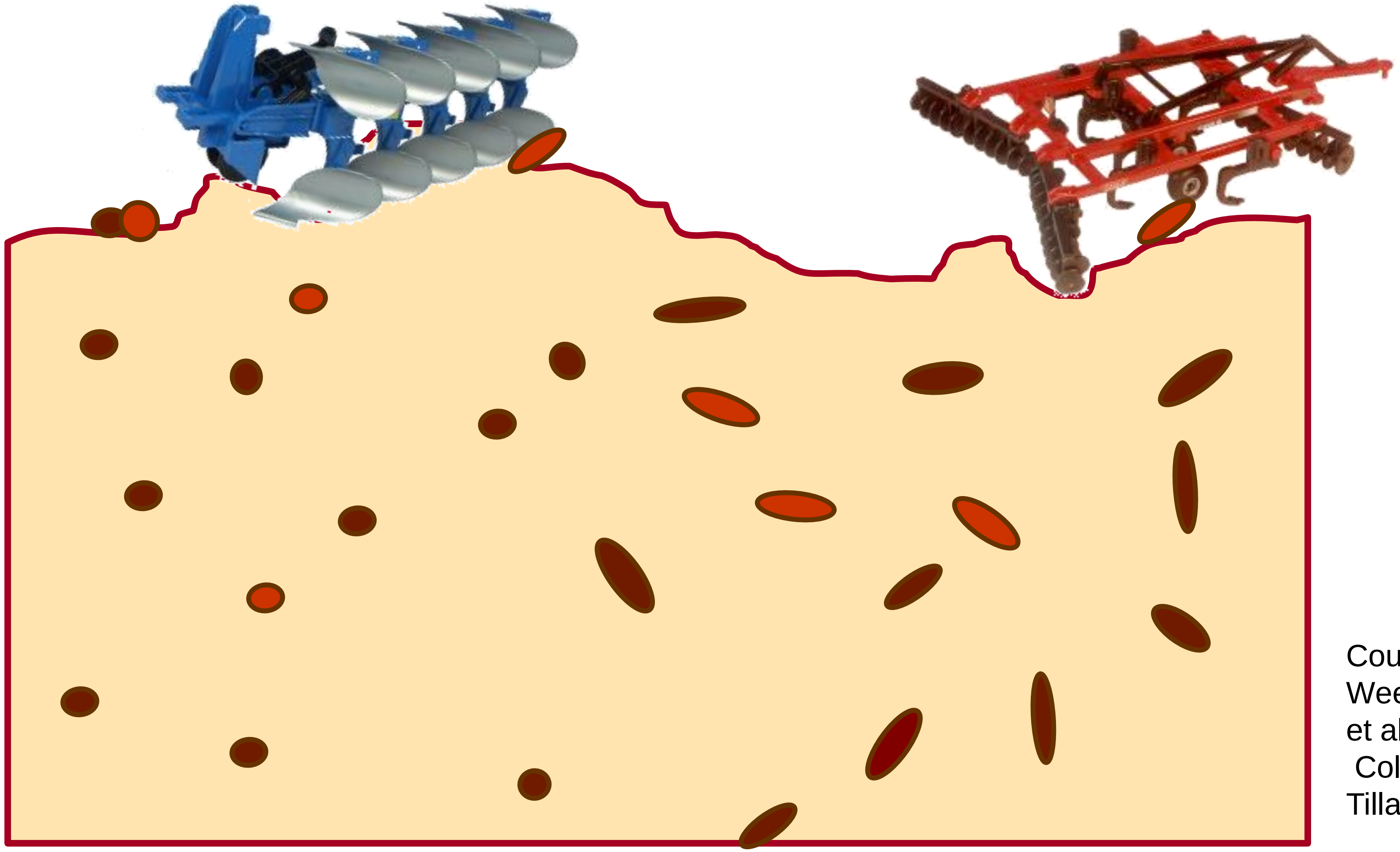
Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res

Which processes determine emergence?



Which processes determine emergence?

Burial

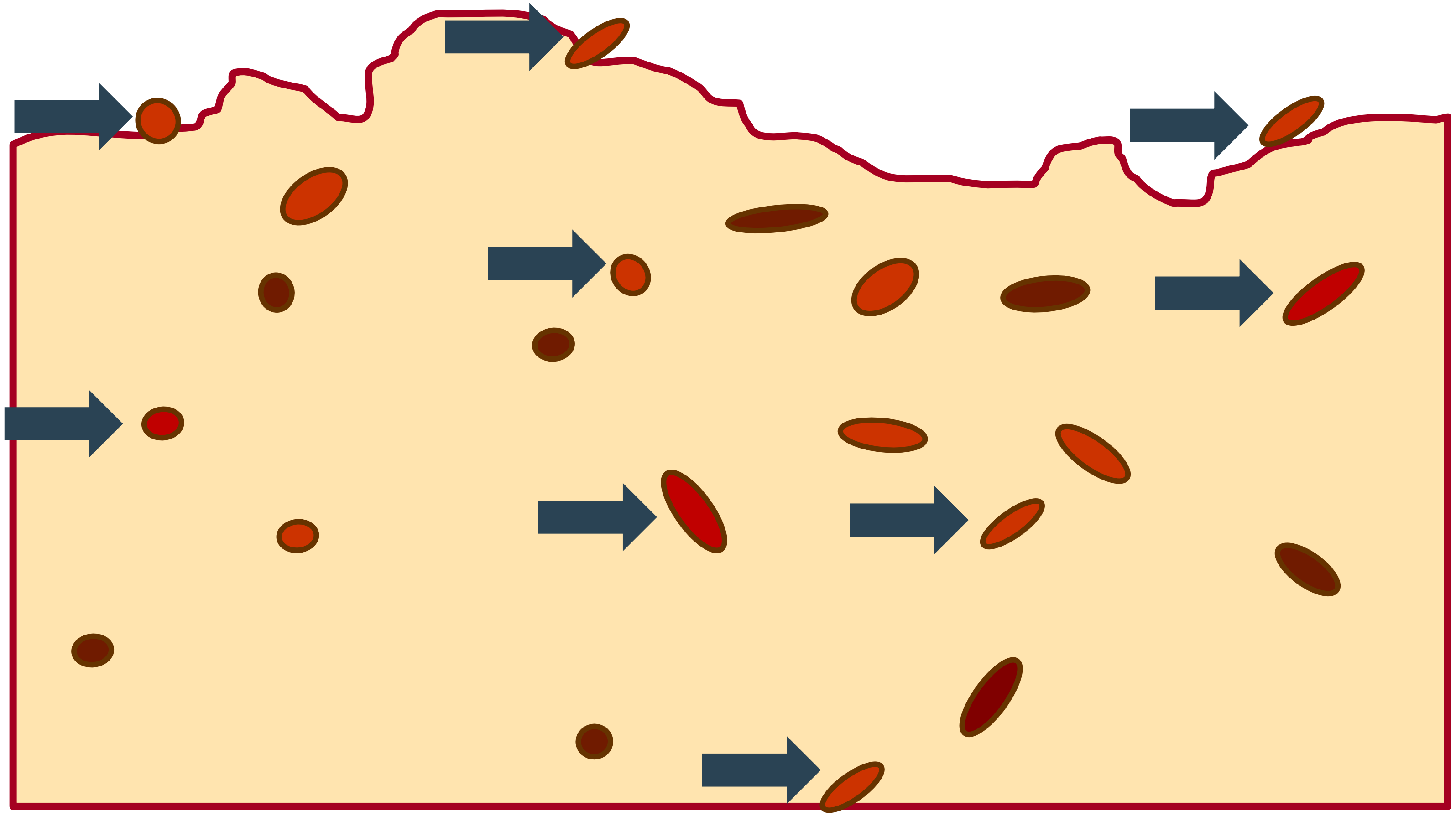


Cousens & Moss (1990) Weed Res; Roger-Estrade et al (2001) Soil Tillage Res; Colbach et al (2014) Soil Tillage Res

Which processes determine emergence?

Burial

Dormancy breaking



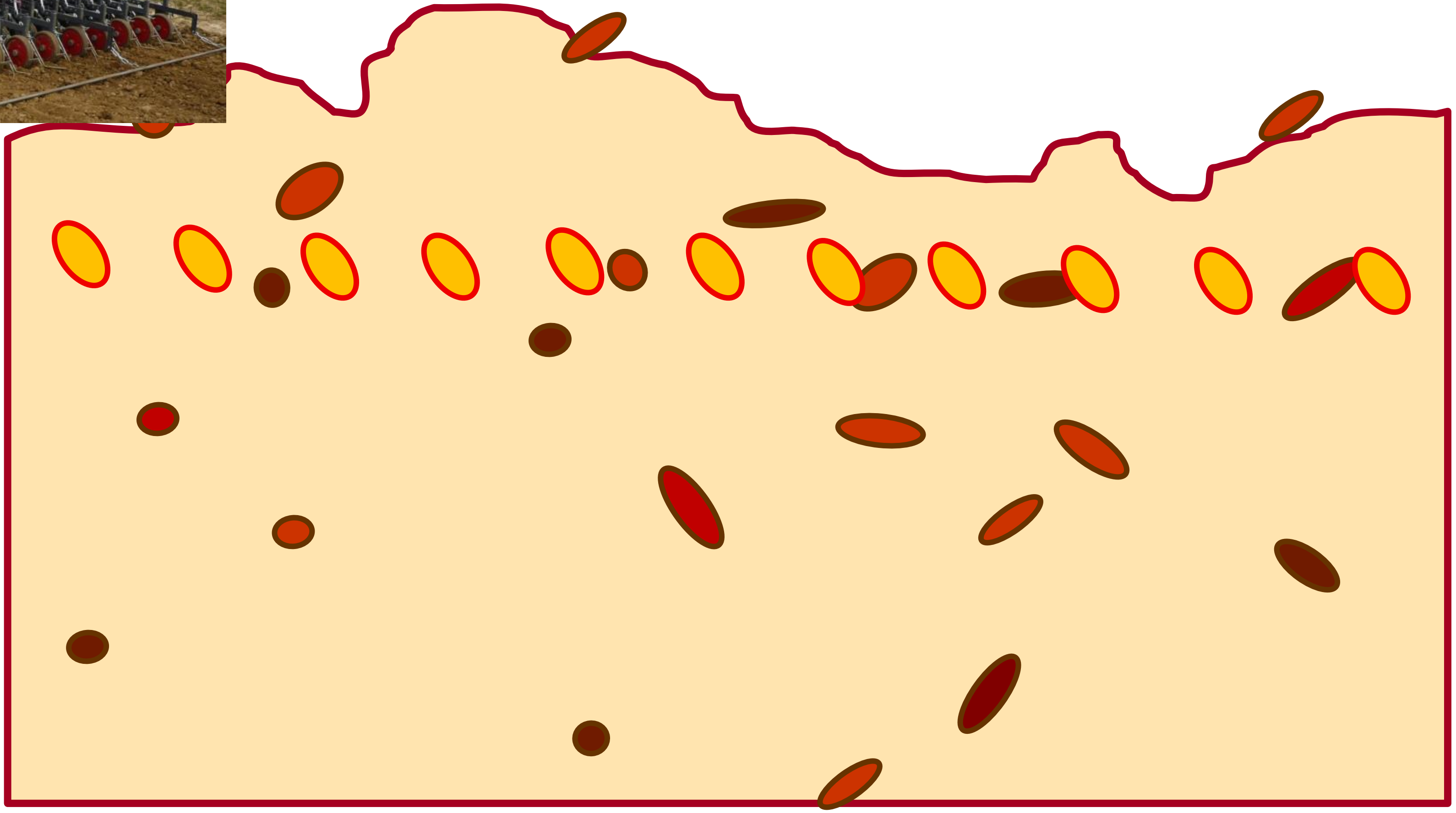
Gardarin & Colbach (2015) Weed Res; Wagmann et al (2012) Ann Botany; Batlla & Benech-Arnold (2007) Crop Protection; Conn et al (2006) Weed Sci; Batlla & Benech-Arnold (2006) Seed Sci Res; Baskin & Baskin (2004) Seed Sci Res …

Which processes determine emergence?

Burial

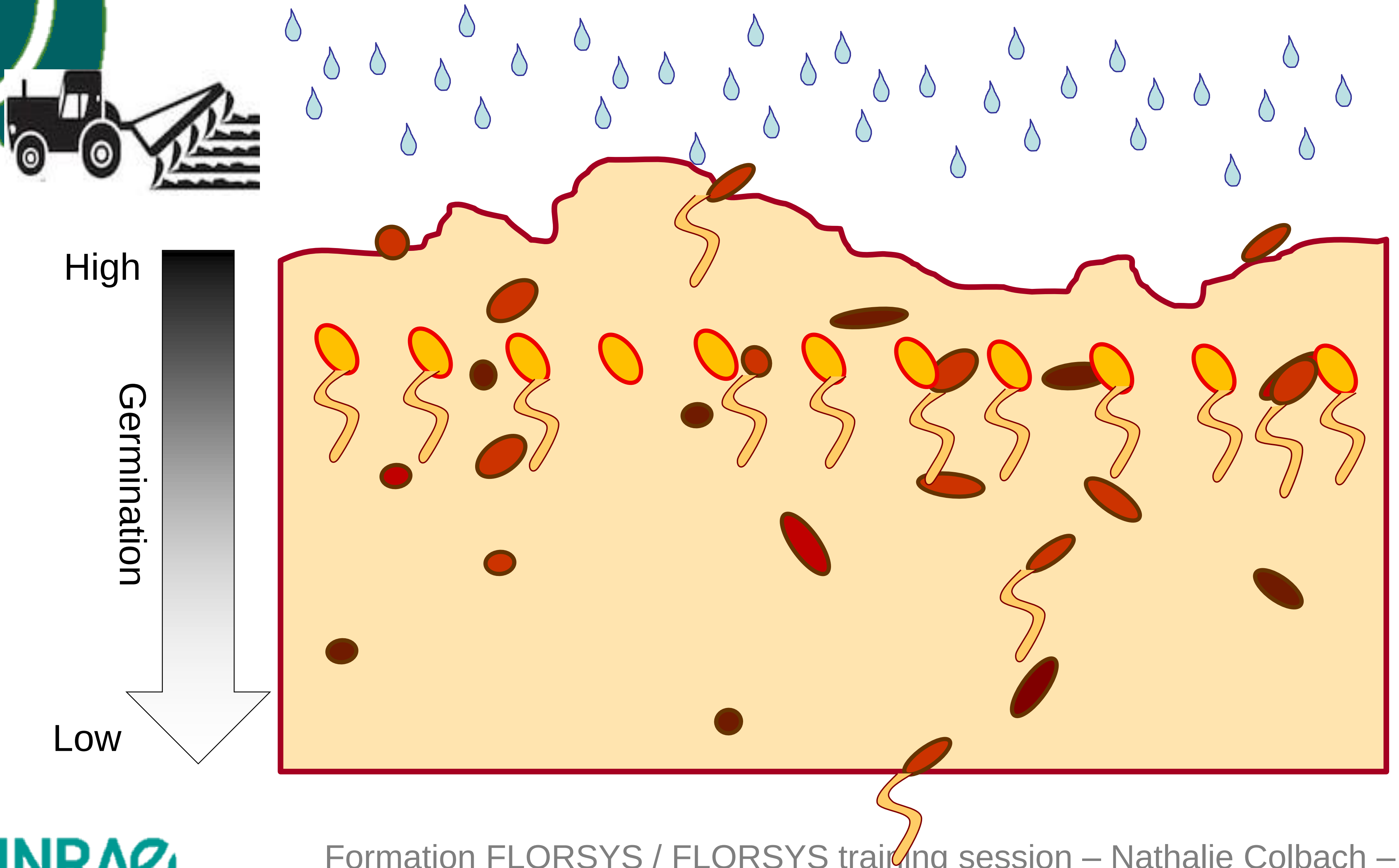
Dormancy breaking

Sowing



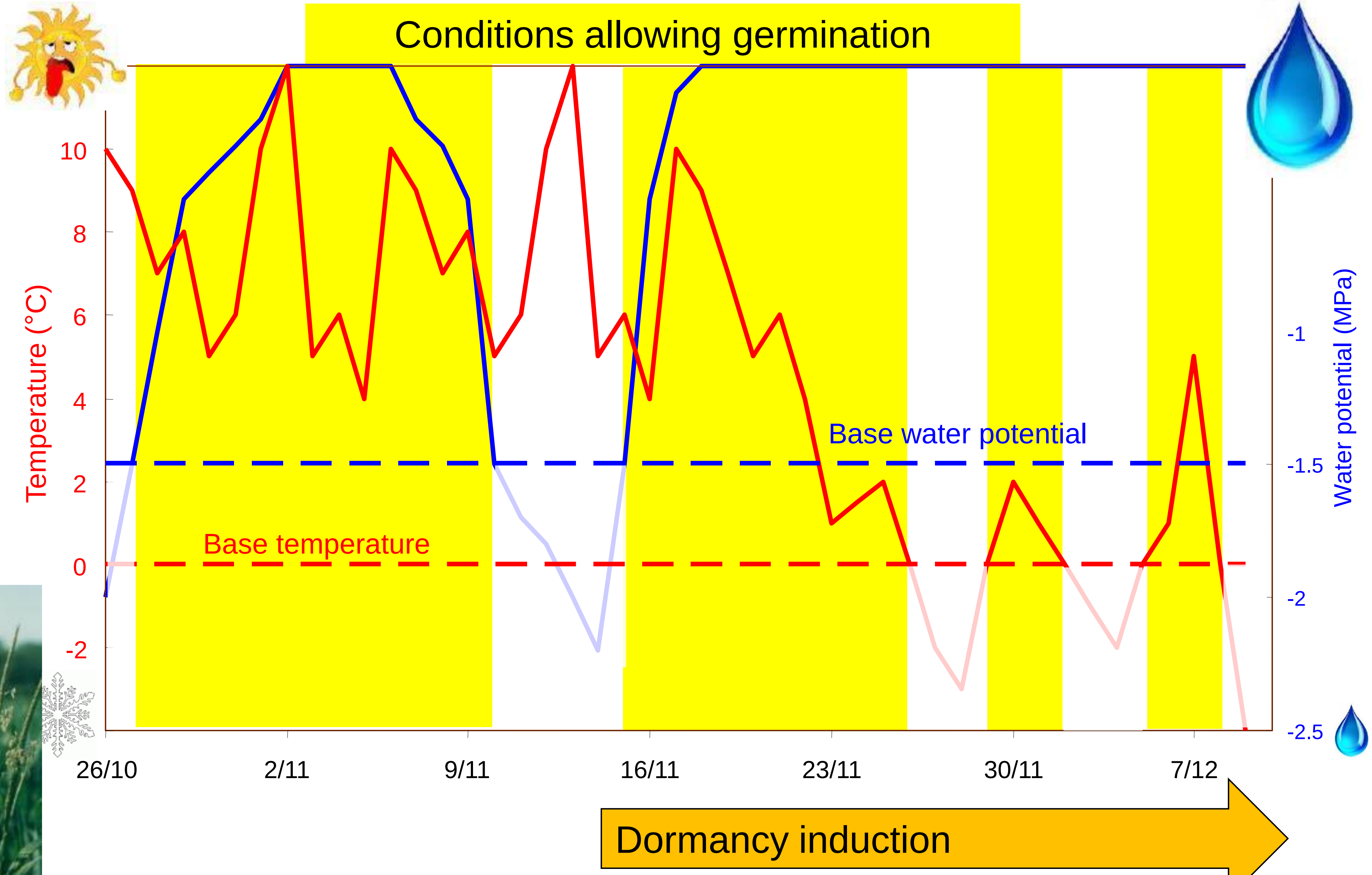
Which processes determine emergence?

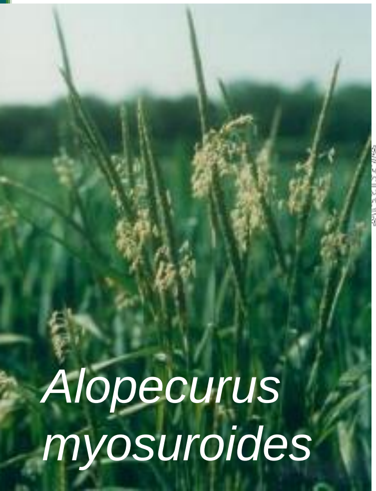
- Burial
- Dormancy breaking
- Sowing
- **Germination**



Dürr et al (2001) Soil Science Society of America Journal; Colbach et al (2006) Eur J Agron; Gardarin et al (2012) Ecol Modelling

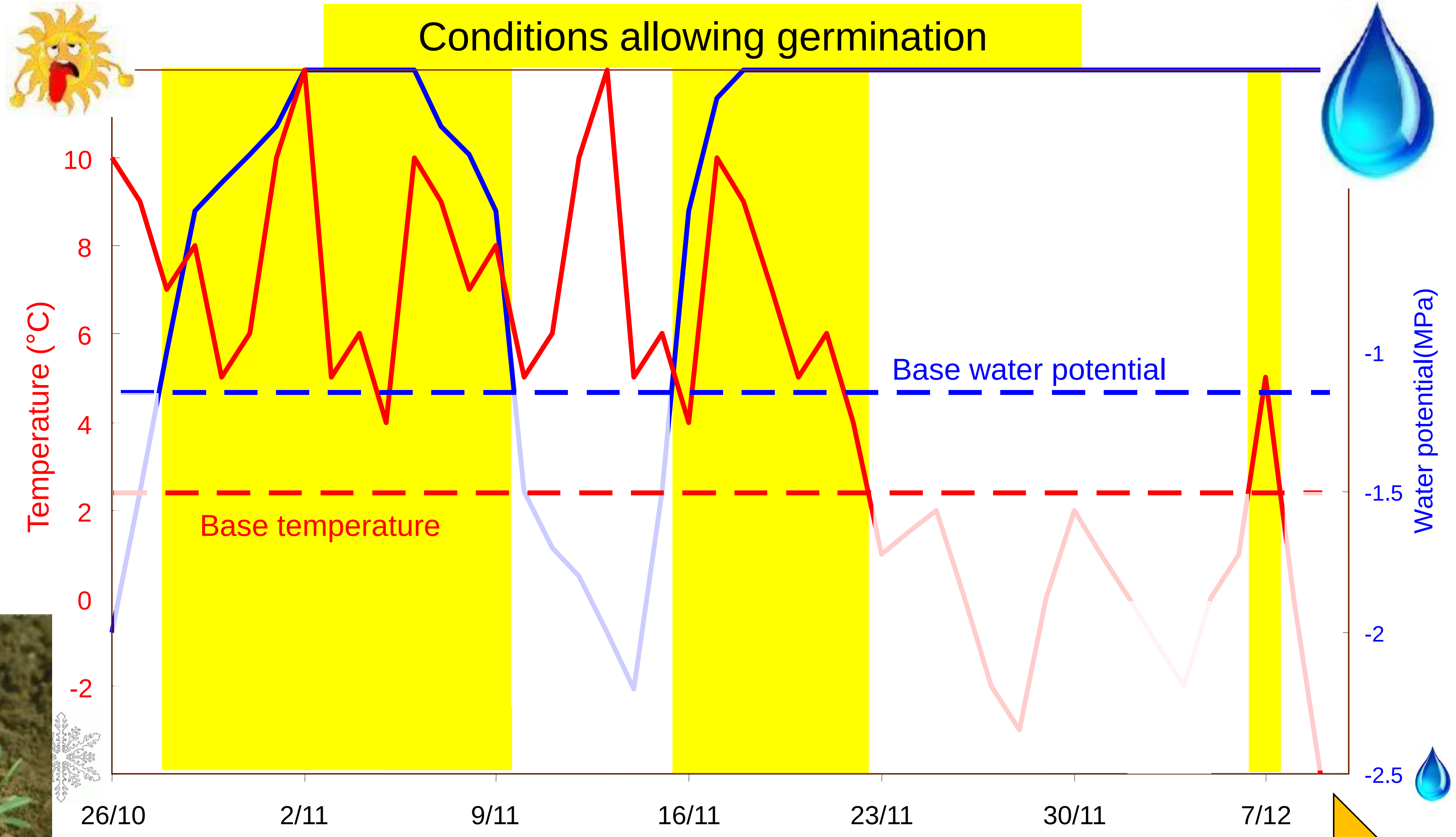
Germination: From potential season to actual date





Alopecurus myosuroides

Germination: From potential season to actual date



Dormancy induction

Which processes determine emergence?

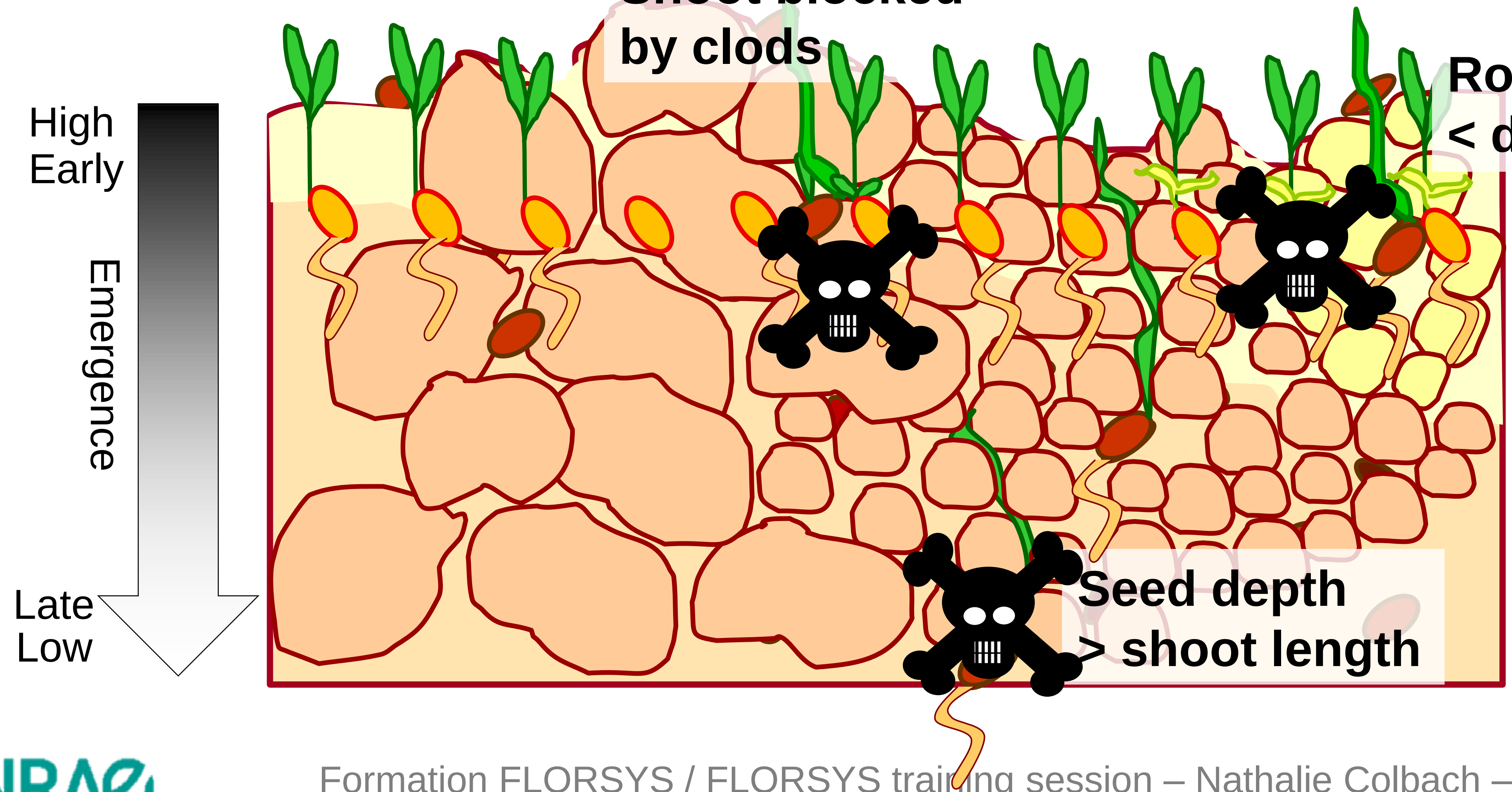
Burial

Dormancy breaking

Sowing

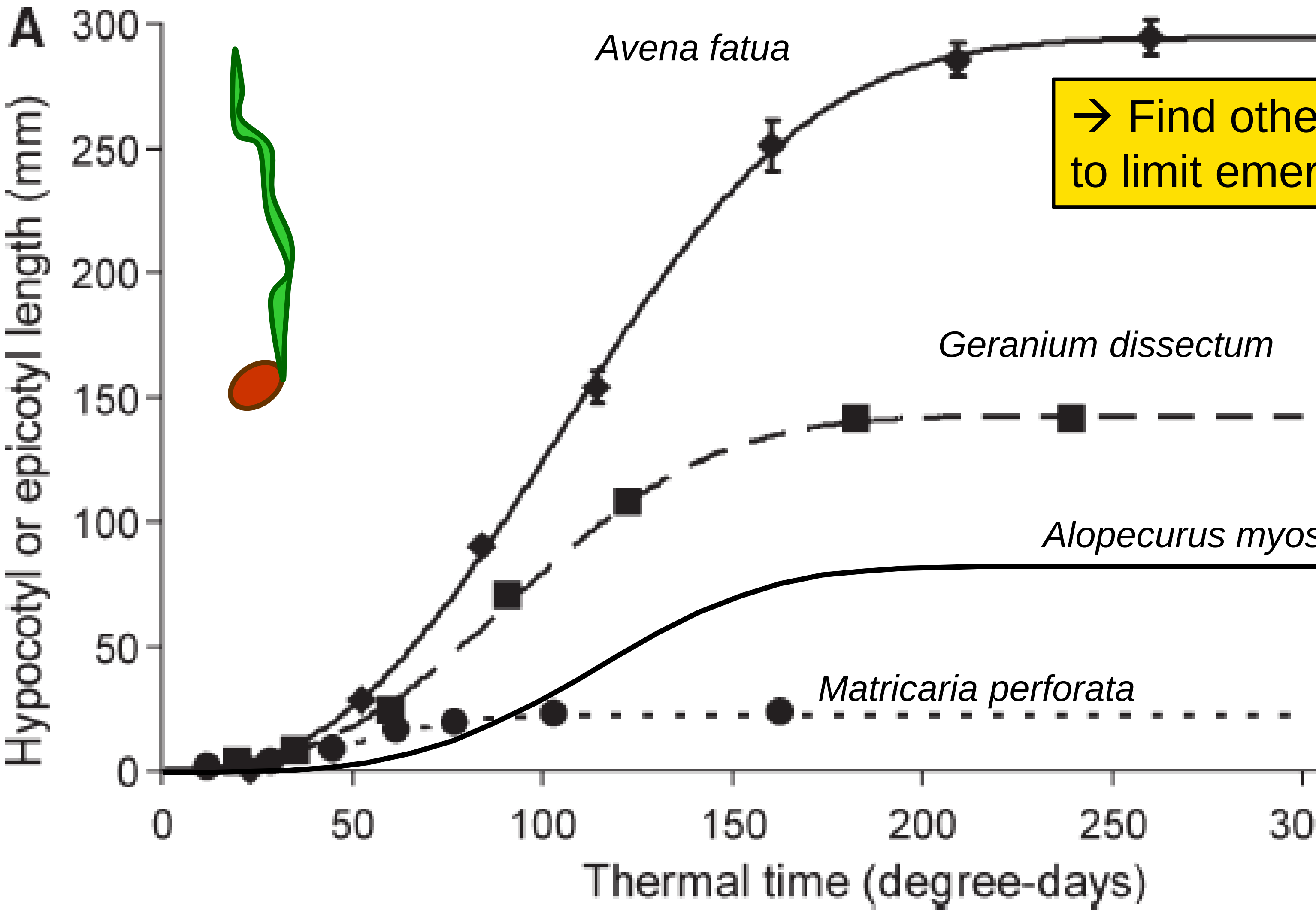
Germination

Seedling mortality



Dürr et al (2001) Soil Science Society of America Journal; Colbach et al (2006) Eur J Agron; Gardarin et al (2012) Ecol Modelling

Croissance pré-levée (sans photosynthèse)

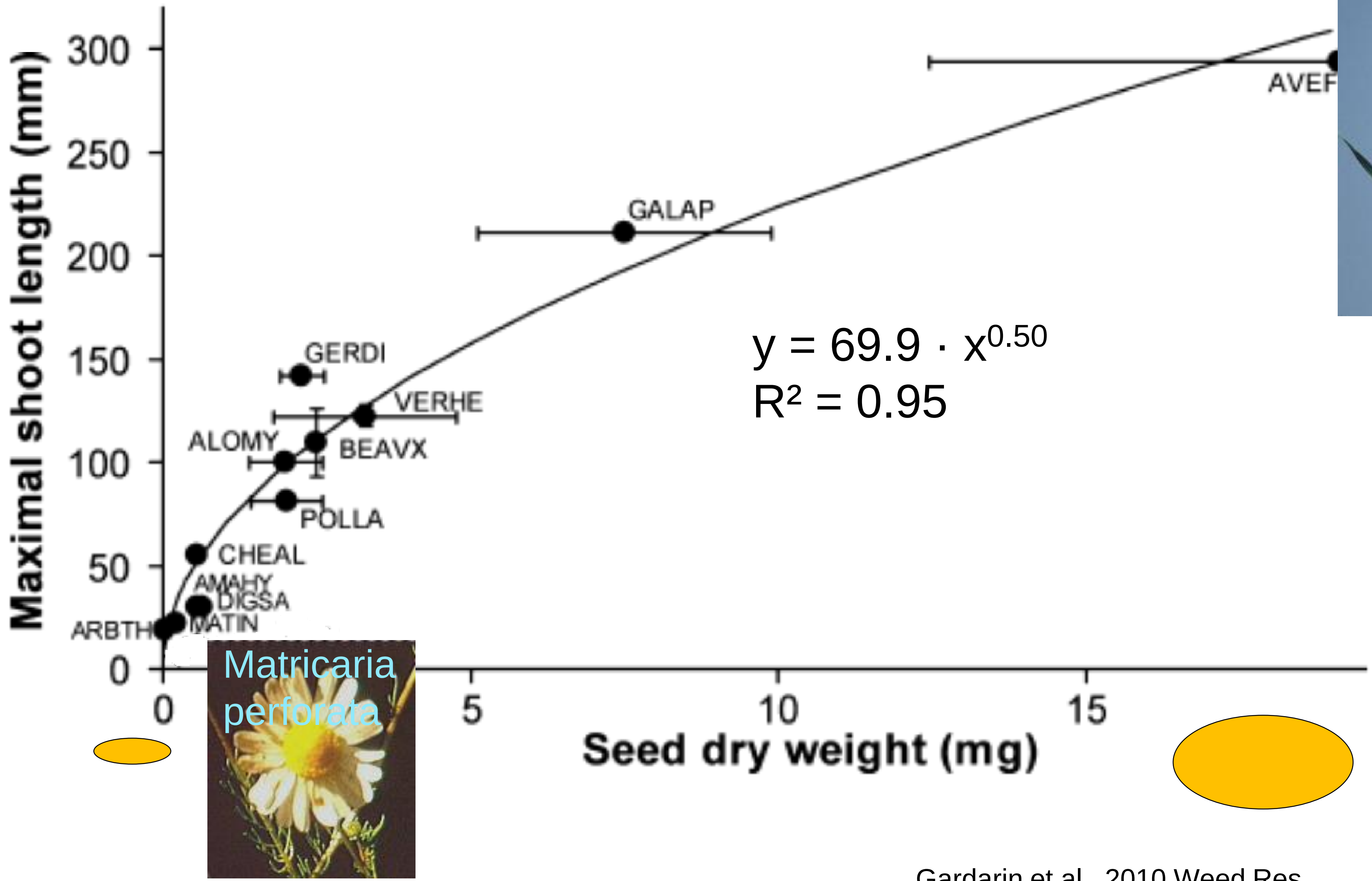


→ Find other ways to limit emergence

→ Bury to limit emergence

Gardarin et al., 2010 Weed Res
Colbach et Dürr 2003 Weed Res

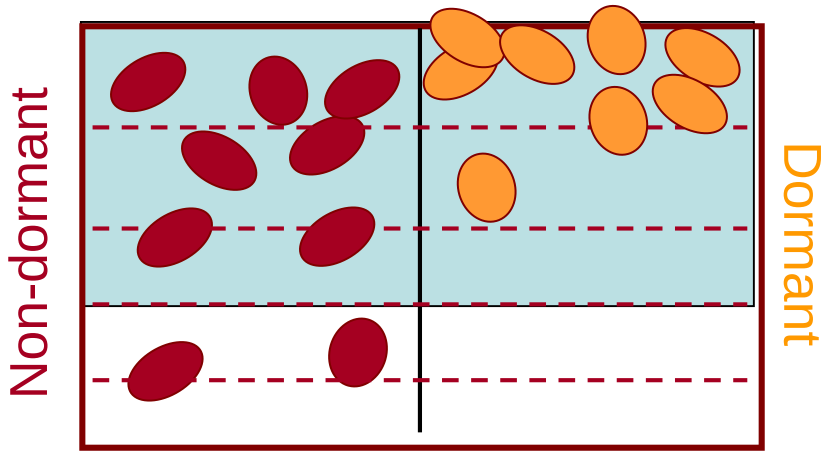
Big is beautiful



$$y = 69.9 \cdot x^{0.50}$$
$$R^2 = 0.95$$

Gardarin et al., 2010 Weed Res

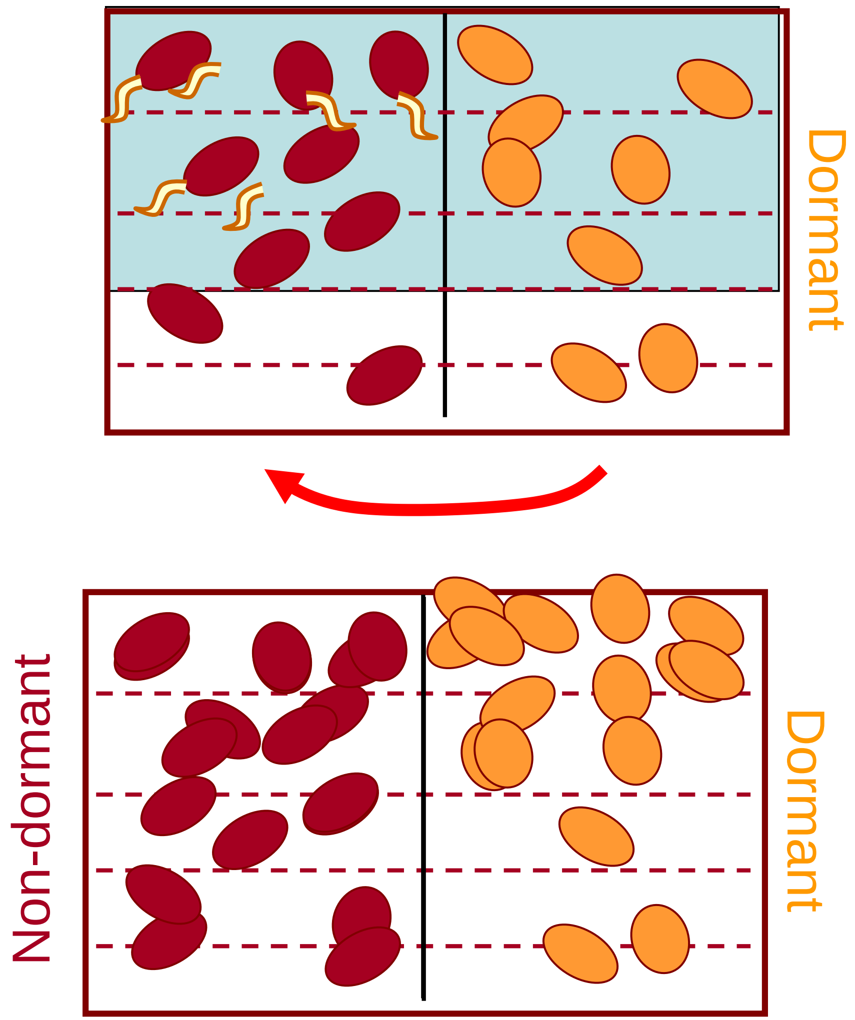
Tillage ⇨ seed germination



(Colbach et al., 2006a, b)

Tillage in moist soil conditions
- moves seeds

Tillage ⇨ seed germination



(Colbach et al., 2006a, b)

Tillage in moist soil conditions
- moves seeds
- breaks dormancy
- stimulates germination
- germination ⇘ with depth

Tillage in dry soil conditions
- only moves seeds

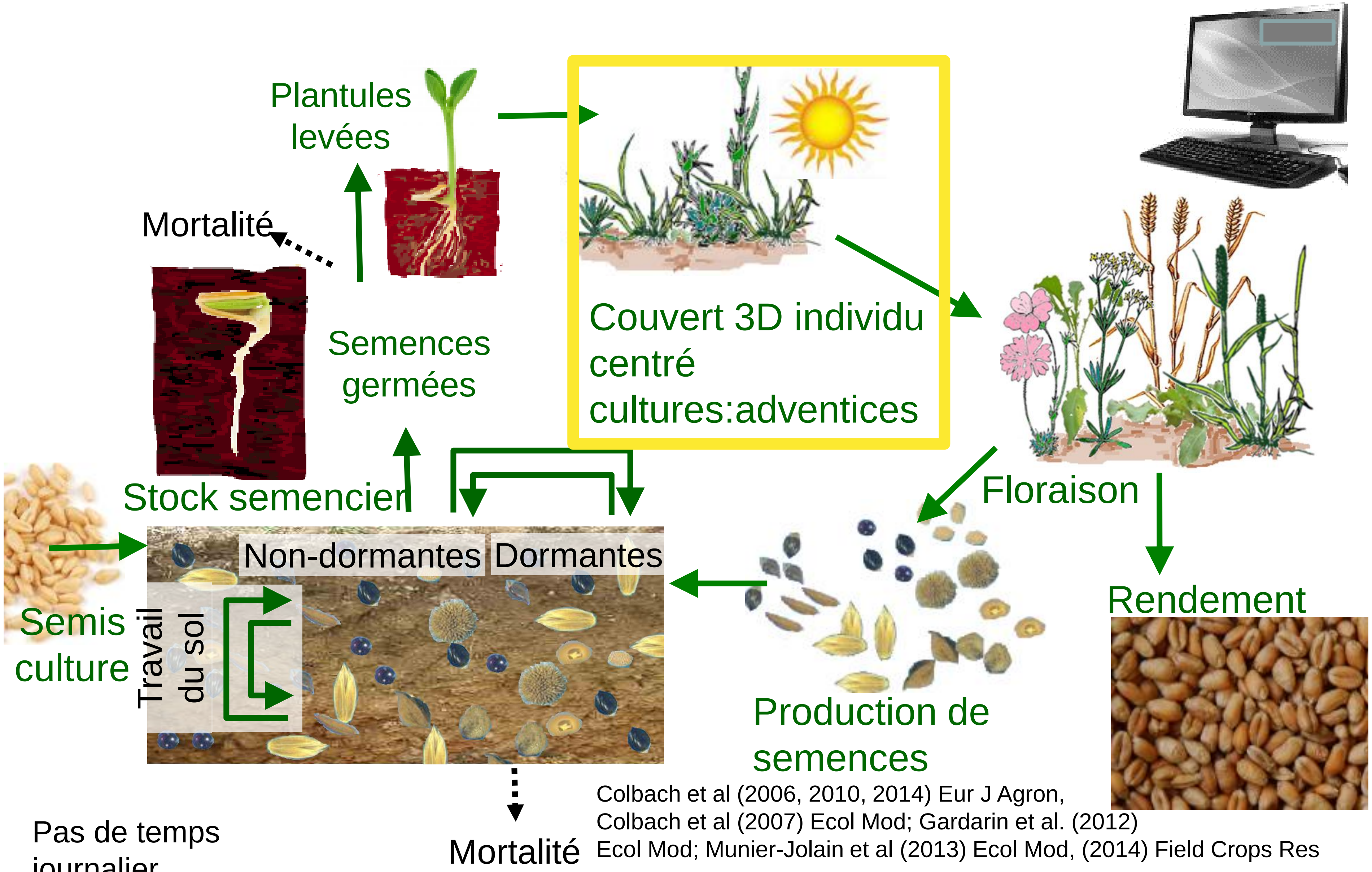
Optimize tillage for weed management

Objective = control harmful weeds

- Optimize tillage **date**
  - False seed bed ⇨ empty weed seed bank
    ⇨ till in moist conditions
  - Prepare soil for crop sowing ⇨ limit weed emergence
    ⇨ till in dry conditions

- Optimize tillage **depth**
  - False seed bed ⇨ empty weed seed bank
    ⇨ till superficially
  - Prepare soil for crop sowing ⇨ limit weed emergence
    ⇨ till deeply and/or invert soil if dry soil
    ⇨ till superficially if moist soil

Le cycle de vie générique pour adventices et cultures annuelles

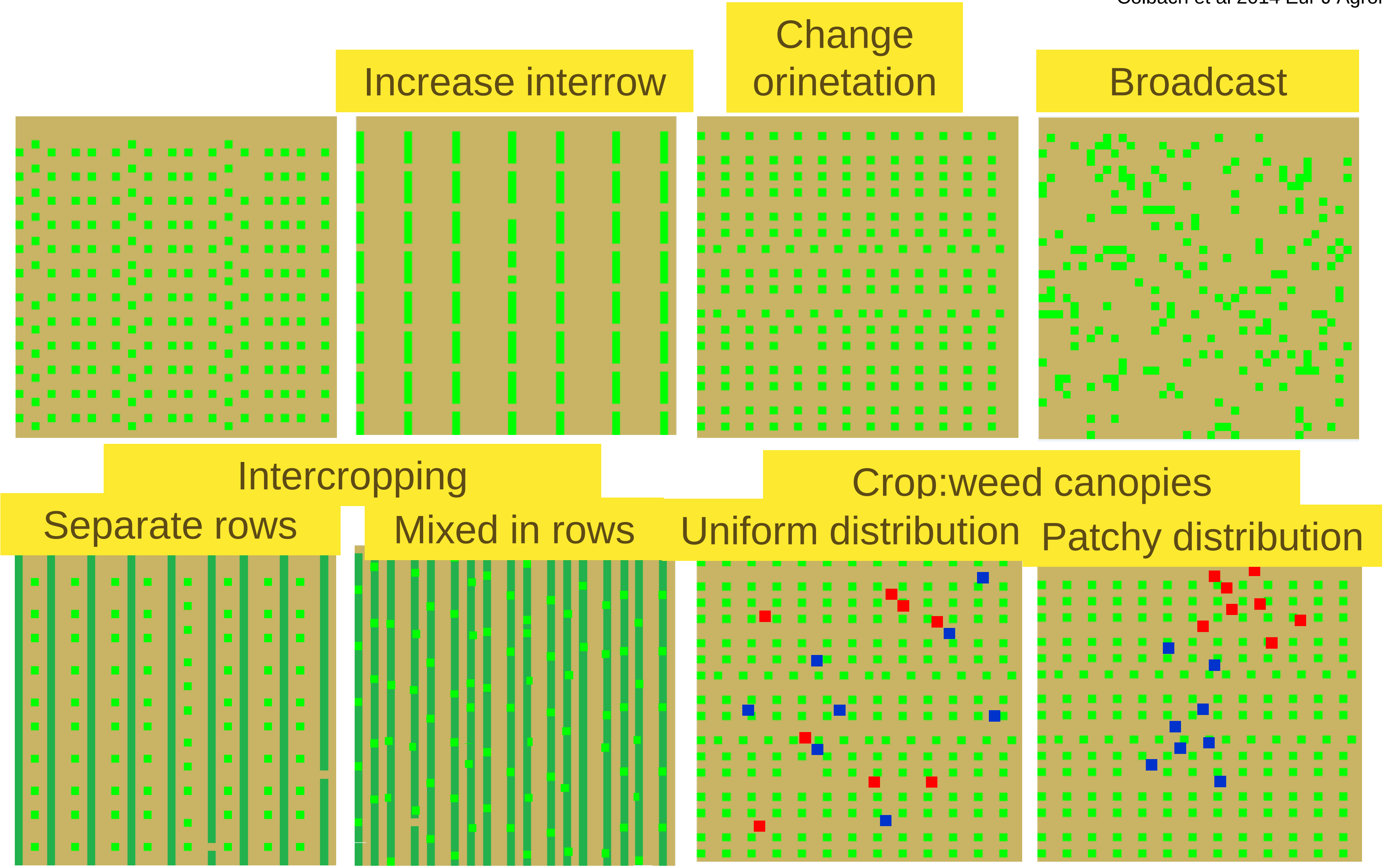


Pas de temps
journalier

Colbach et al (2006, 2010, 2014) Eur J Agron,
Colbach et al (2007) Ecol Mod; Gardarin et al. (2012)
Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res

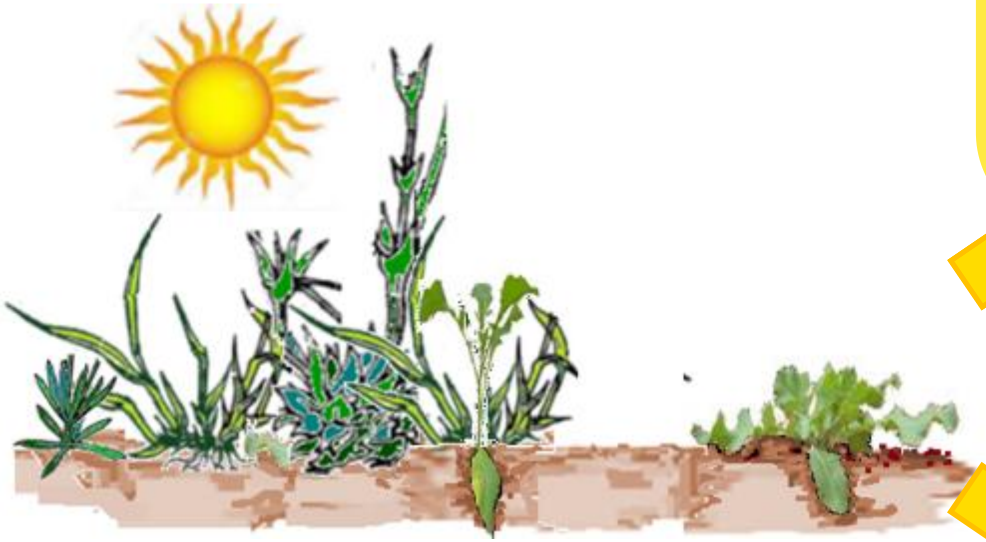
Canopies are heterogeneous

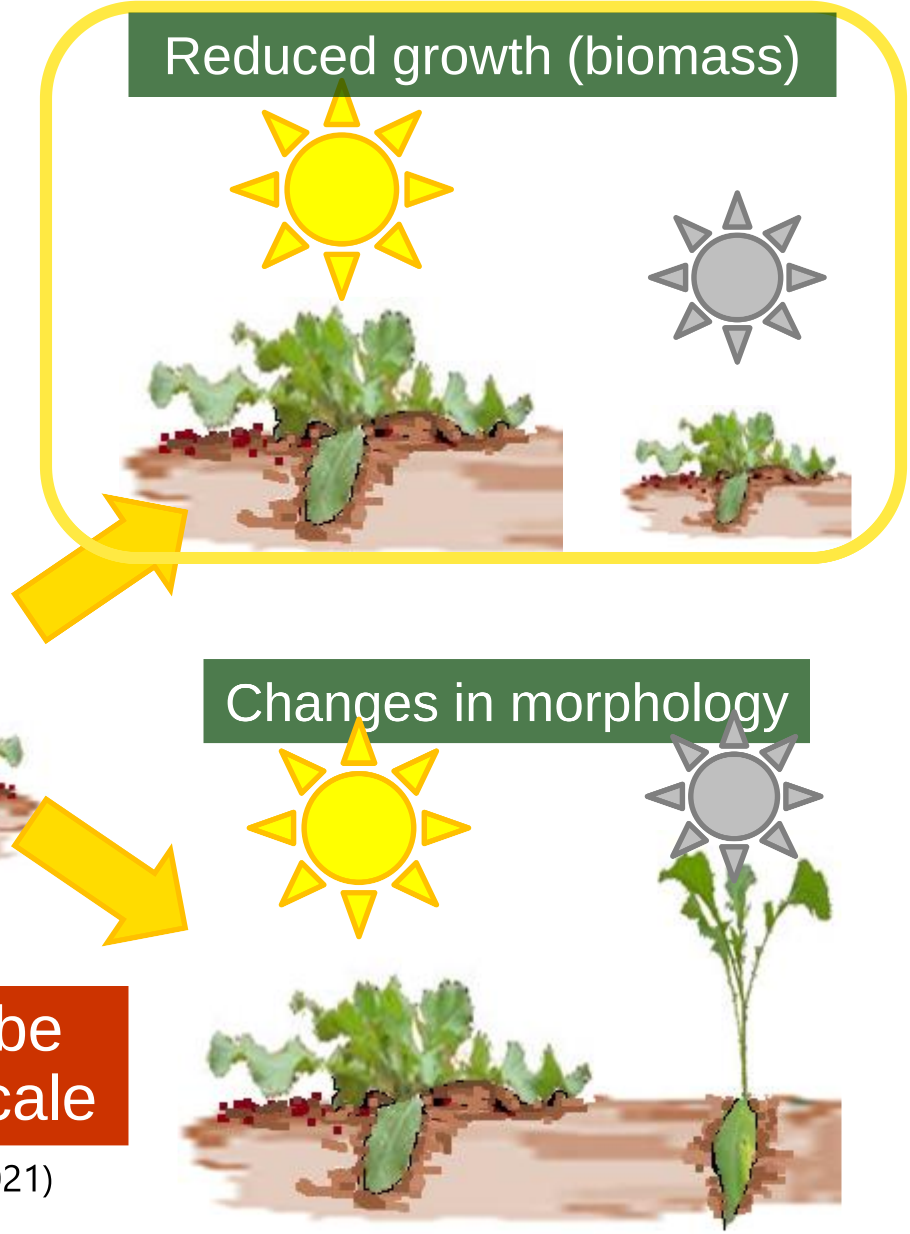
Colbach et al 2014 Eur J Agron



Heterogeneous canopies = diverse neighbours

Available light varies inside heterogeneous canopies



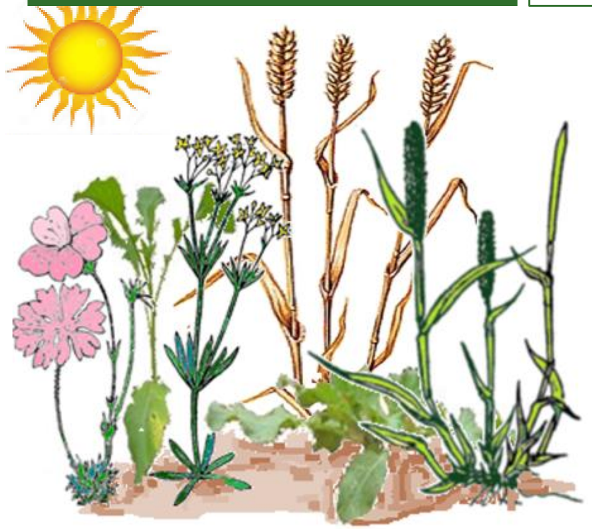


Crop-weed competition must be investigated at the individual scale

Renton (2013) Pest Management Sci; Colbach et al (2021) Field Crops Res

Plant-plant interactions – Competition for resources

Competition for light = most important competition in temperate arable cropping systems



Multispecies heterogeneous canopies
- Crop:weed
- Intercrops

For each plant – daily

$$\Delta biomass = PARa \cdot \varepsilon_b \cdot c_p - respiration$$

PARa → Absorbed light = f(plant morphology, neighbour carnopy)

ε_b → =f(species)

c_p → =f(temperature)

respiration → biomass

Munier-Jolain et al 2013, 2014; Colbach et al 2014 Eur J Agron

Plant-plant interactions – Competition for resources

Competition for light

For each plant – daily

Δbiomass = PARa · ε_b · c_p - respiration

biomass

=f(temperature)

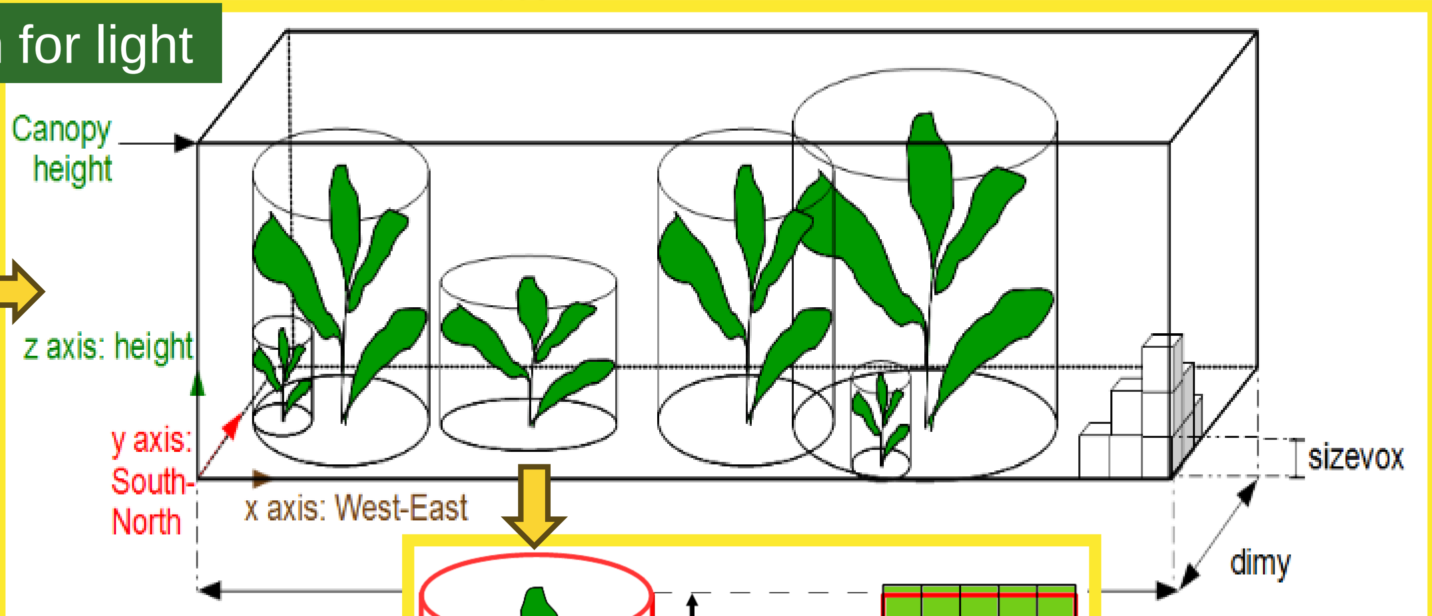
Absorbed light
= f(plant morphology,
neighbour carnopy)

=f(species)

Munier-Jolain et al 2013, 2014; Colbach et al 2014 Eur J Agron

How to model the canopy and light interception?

Competition for light



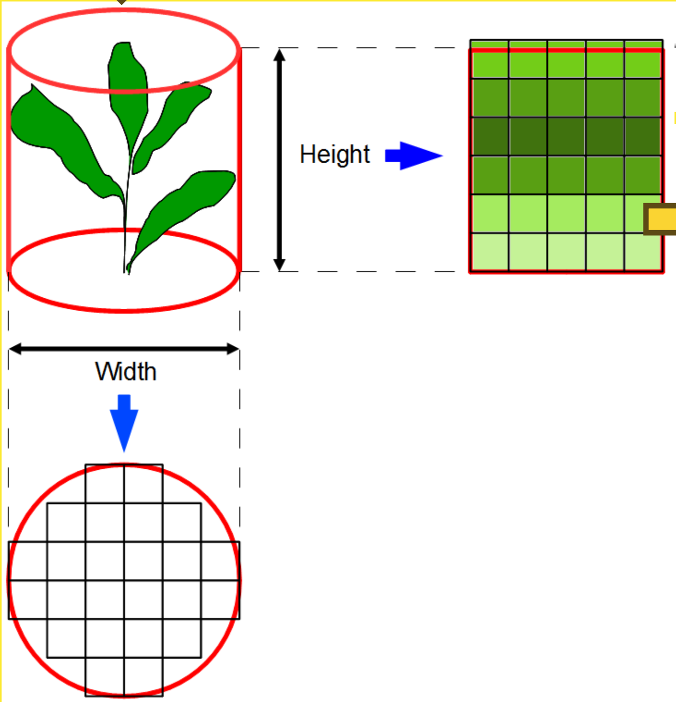
For each plant and day

Δbiomasse = PARa · ε_b · c_p - res

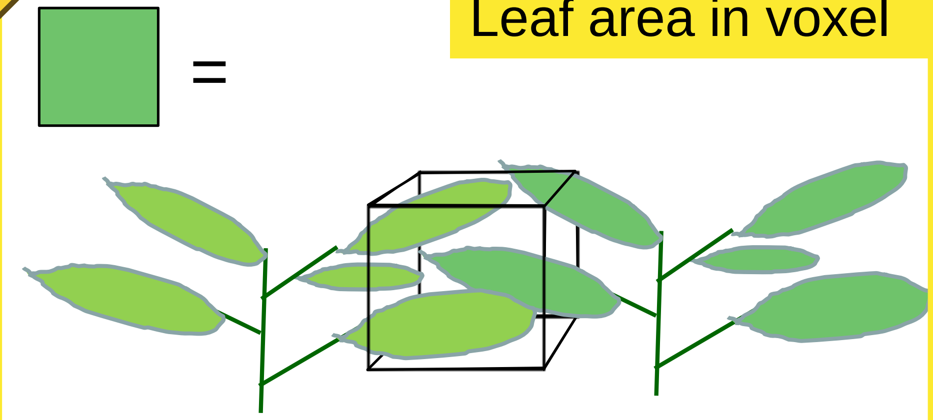
Absorbed radiation = f(plant morphology, neighbour canopy)

=f(species)

=f(t

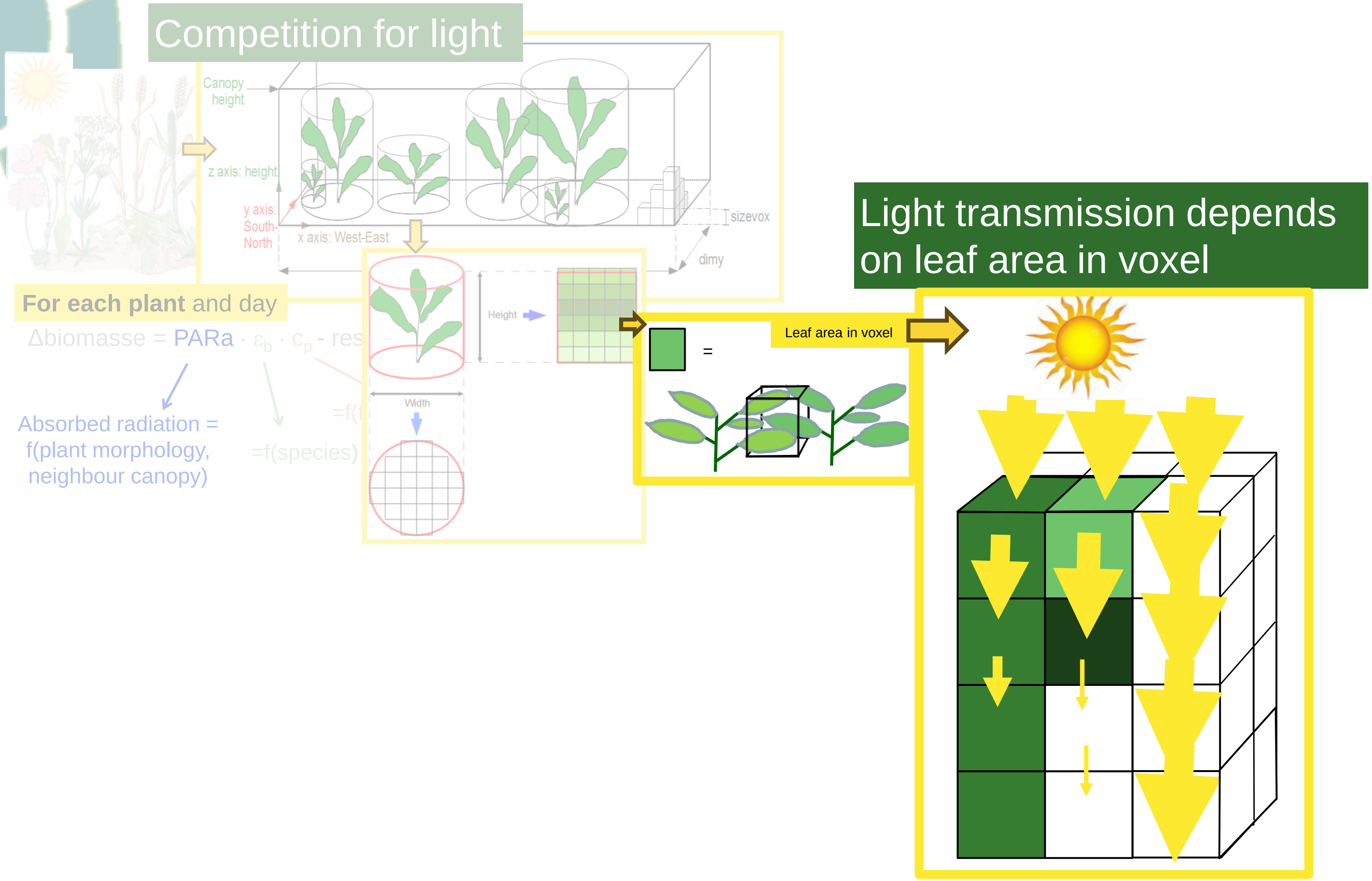


Leaf area in voxel



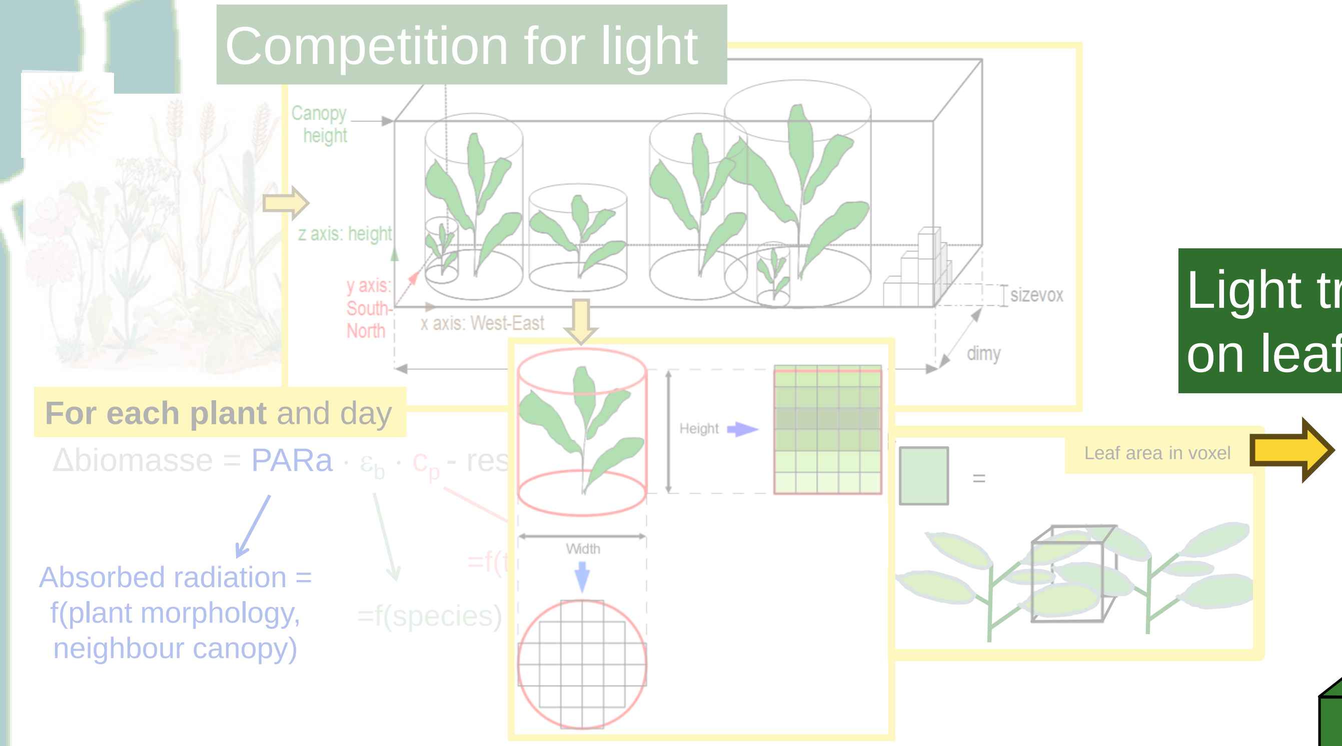
Munier-Jolain et al 2013, 2014; Colbach et al 2014 Eur J Agron

How to model the canopy and light interception?

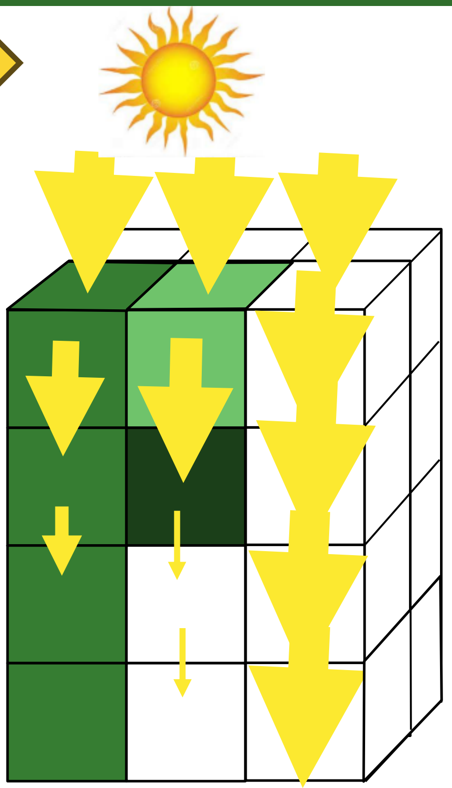


Munier-Jolain et al 2013, 2014; Colbach et al 2014 Eur J Agron

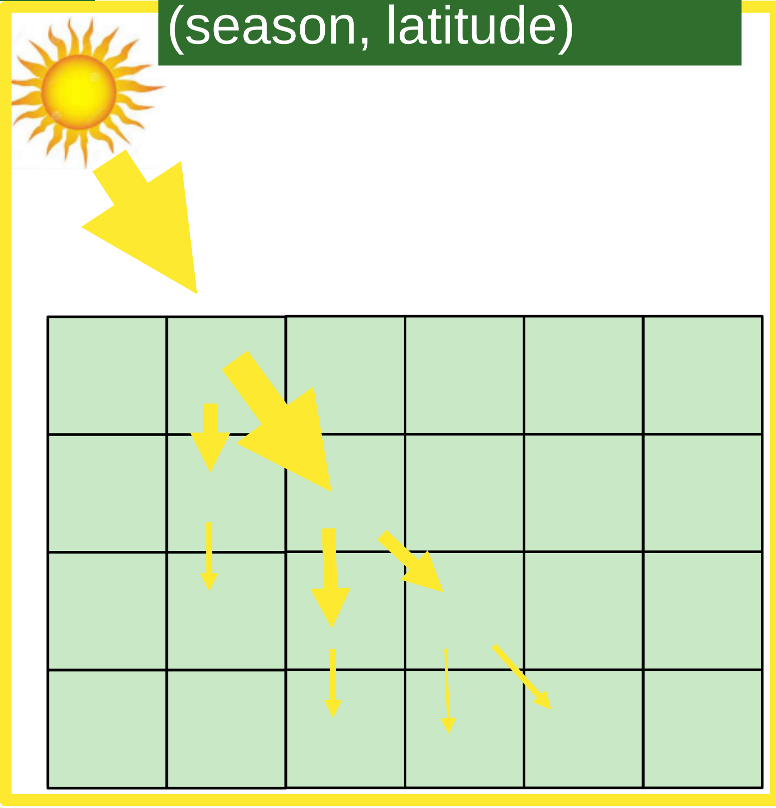
How to model the canopy and light interception?



Light transmission depends on leaf area in voxel



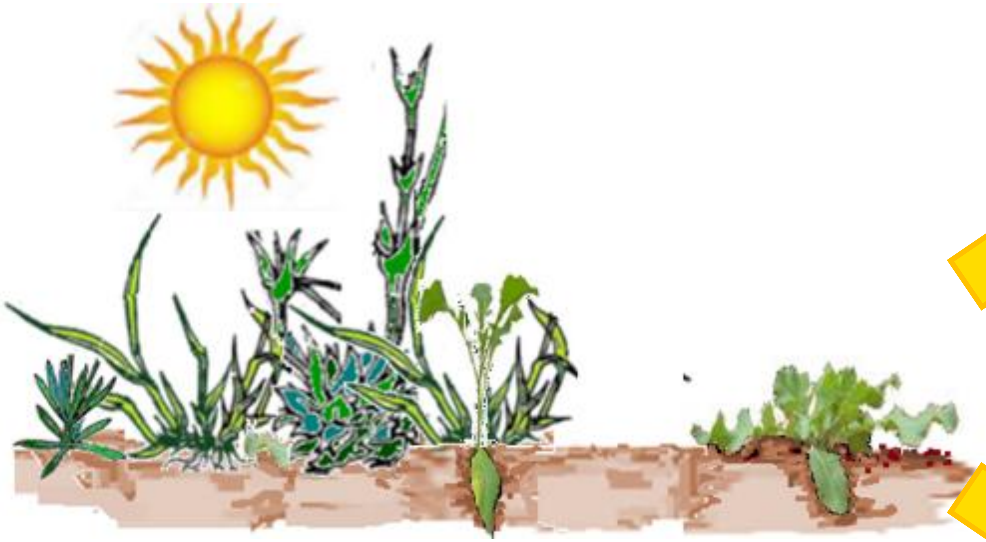
Light transmission depends on sun height (season, latitude)

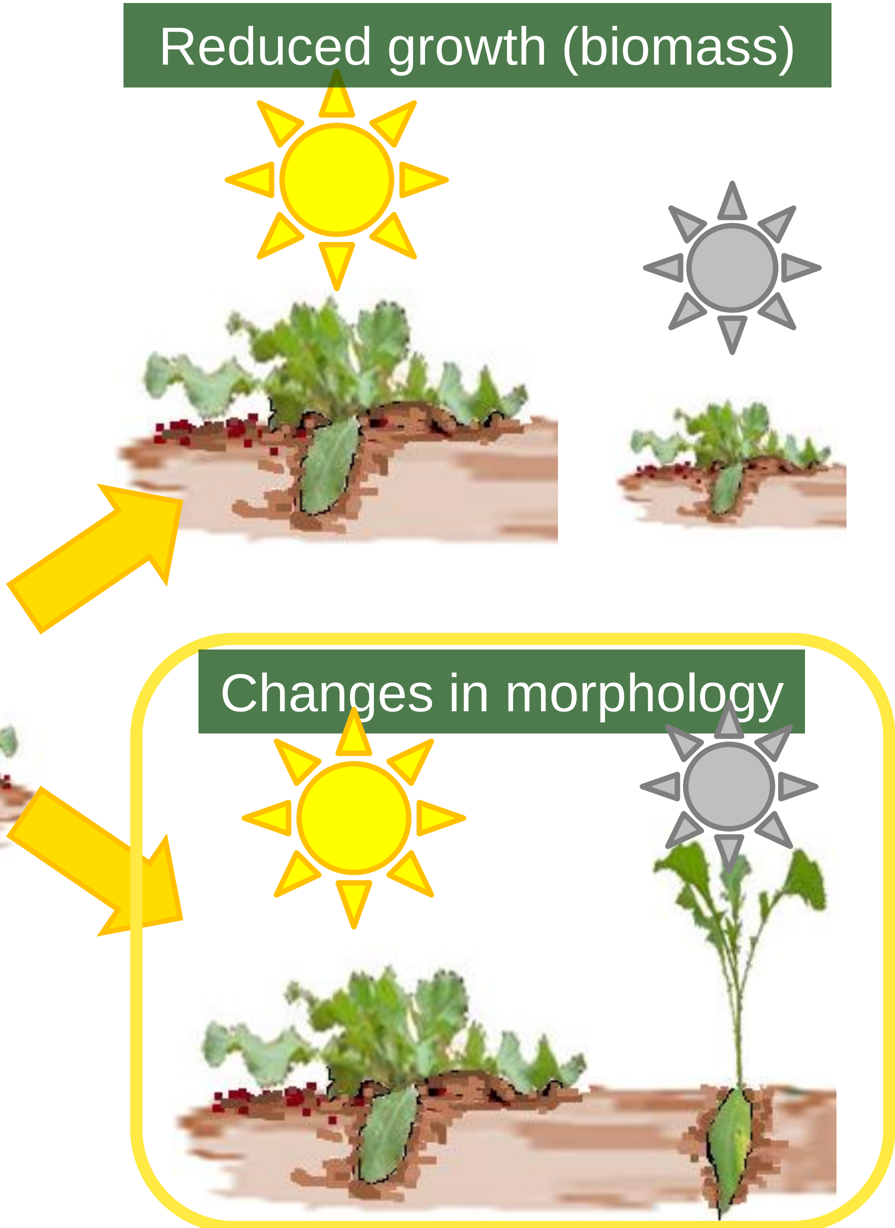


Munier-Jolain et al 2013, 2014; Colbach et al 2014 Eur J Agron

Heterogeneous canopies = diverse neighbours

Available light varies inside heterogeneous canopies

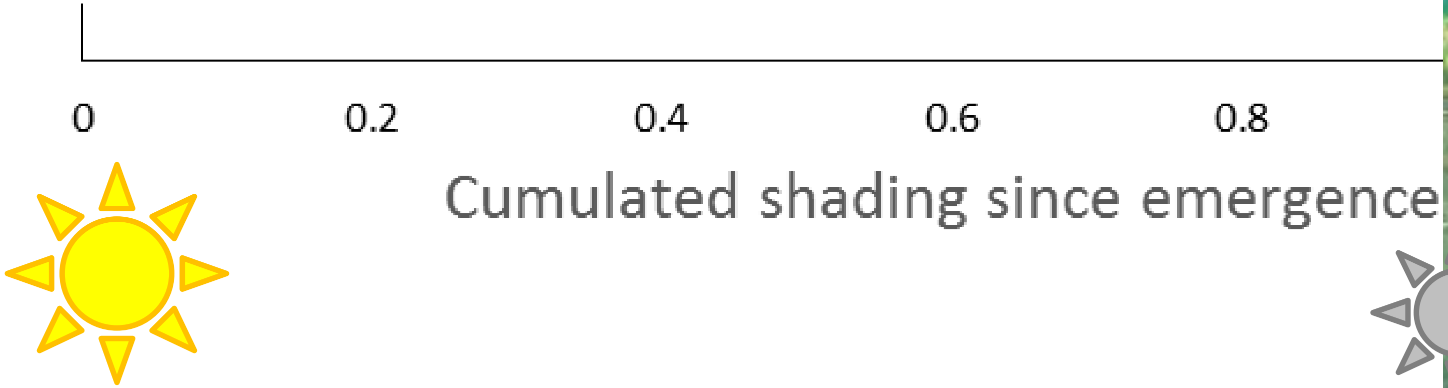




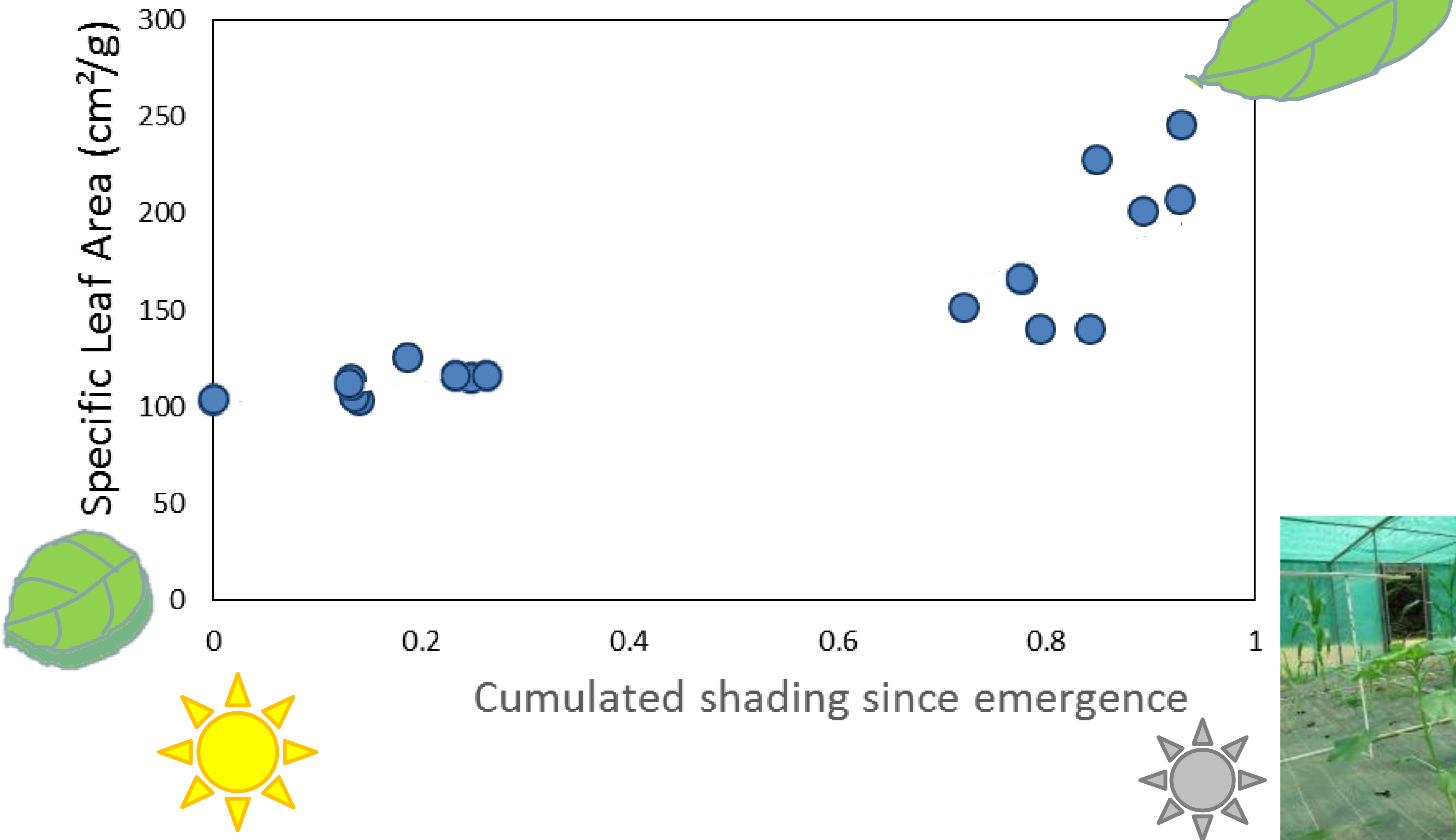
Concept for shading response – Experiment on individual plants in garden plots

Colbach N., Moreau D., Dugué F., Gardarin A., Strbik F. & Munier-Jolain N. (2020) The response of weed and crop species to shading. How to predict their morphology and plasticity from species traits and ecological indexes? European Journal of Agronomy 121, 126158, https://doi.org/10.1016/j.eja.2020.126158

Munier-Jolain N. M., Collard A., Busset H., Guyot S. H. M. & Colbach N. (2014) Investigating and modelling the morphological plasticity of weeds in multi-specific canopies. Field Crops Research 155, 90-98, http://dx.doi.org/10.1016/j.fcr.2013.09.018

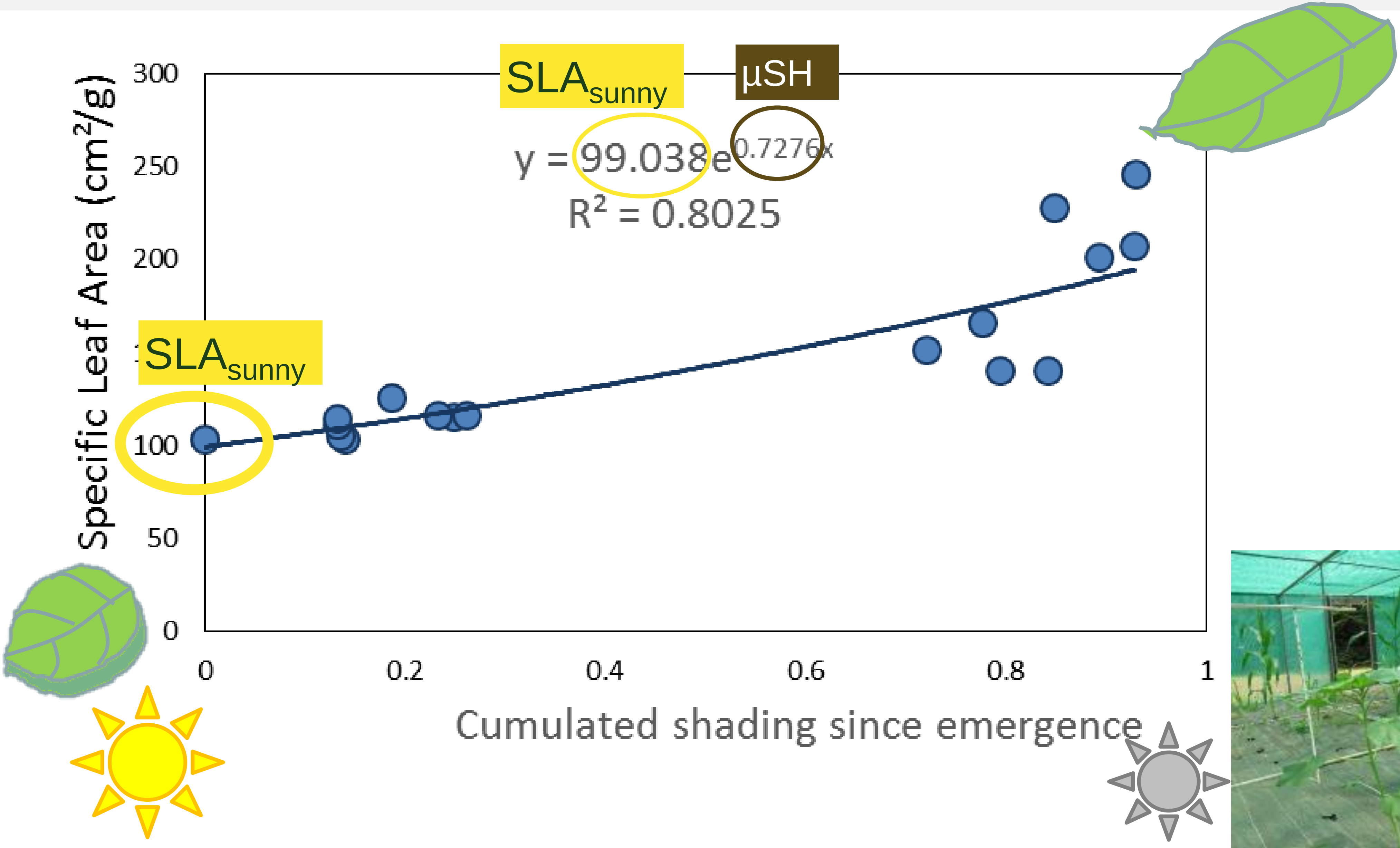


Concept for shading response – Experiment on individual plants in garden plots



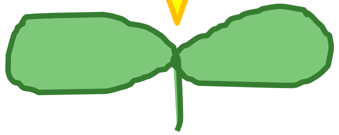
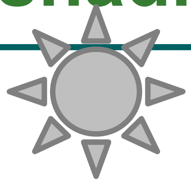
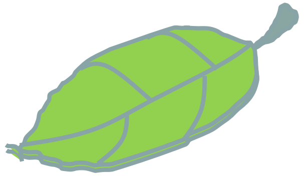
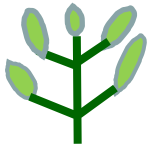
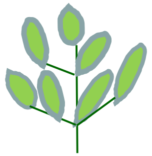
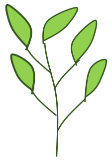
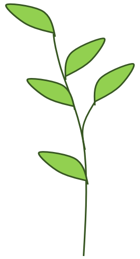
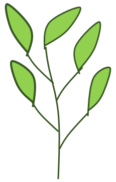
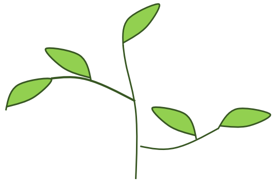
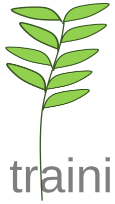
Colbach et al (2020)Eur J Agron, Munier-Jolain et al (2014) Field Crops Res

Concept for shading response – Experiment on individual plants in garden plots

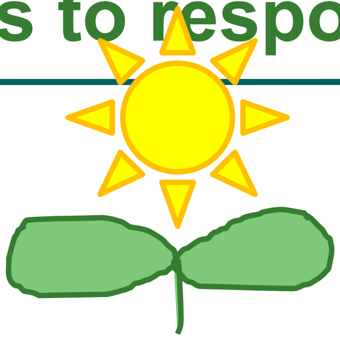


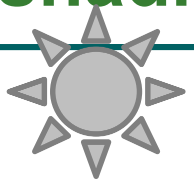
Colbach et al (2020)Eur J Agron, Munier-Jolain et al (2014) Field Crops Res

≠ strategies to respond to shading

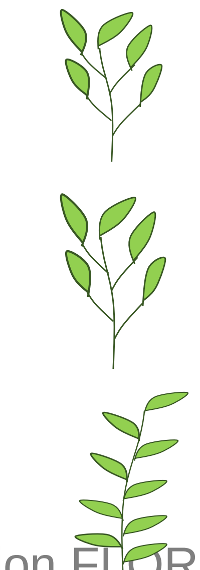
	 	Initial leaf area RGR		Grow fast after emergence → occupy space before any other
Specific leaf area		SLA μ_SLA		Larger & thinner leaves → intercept more light
Leaf biomass ratio		LBR μ_LBR		More leaf biomass → intercept more light
Height biomass ratio		HM b_HM μ_HM		Taller plants → Grow above neighbours
Width biomass ratio		WM b_WM μ_WM		Wider plants → Escape neighbours
Median leaf area height		RLH b_RLH μ_RLH		Leaf area at canopy top → Get closer to light

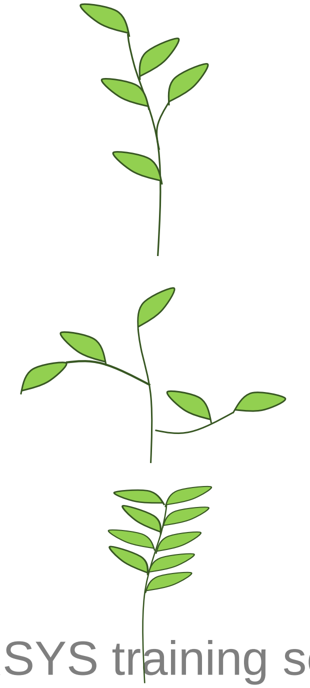
≠ strategies to respond to shading





	Initial leaf area RGR	Grow fast after emergence → occupy space before any other
Specific leaf area	SLA	Larger & thinner leaves …re light
Leaf biomass ratio	μ_LBR	…ss → intercept more light
Height biomass ratio	HM b_HM μ_HM	Taller plants → Grow above neighbours
Width biomass ratio	WM b_WM μ_WM	Wider plants → Escape neighbours
Median leaf area height	RLH b_RLH μ_RLH	Leaf area at canopy top → Get closer to light





Occupy space early & fast
- Early post-emergent growth
- Potential morphology (if no neighbours)

≠ strategies to respond to shading

Initial leaf area
RGR

Grow fast after emergence
→ occupy space before any other

Specific leaf area

Larger & thinner leaves
...e light

Occupy space early & fast
- Early post-emergent growth
- Potential morphology (if no neighbours)

Leaf biomass ratio

μ_LBR

...ss
→ intercept more light

React to shade
- Increase light interception area
- Shift leaves to avoid shade

Height biomass ratio

μ_HM

...lants
...w above neighbours

Width biomass ratio

WM
b_WM
μ_WM

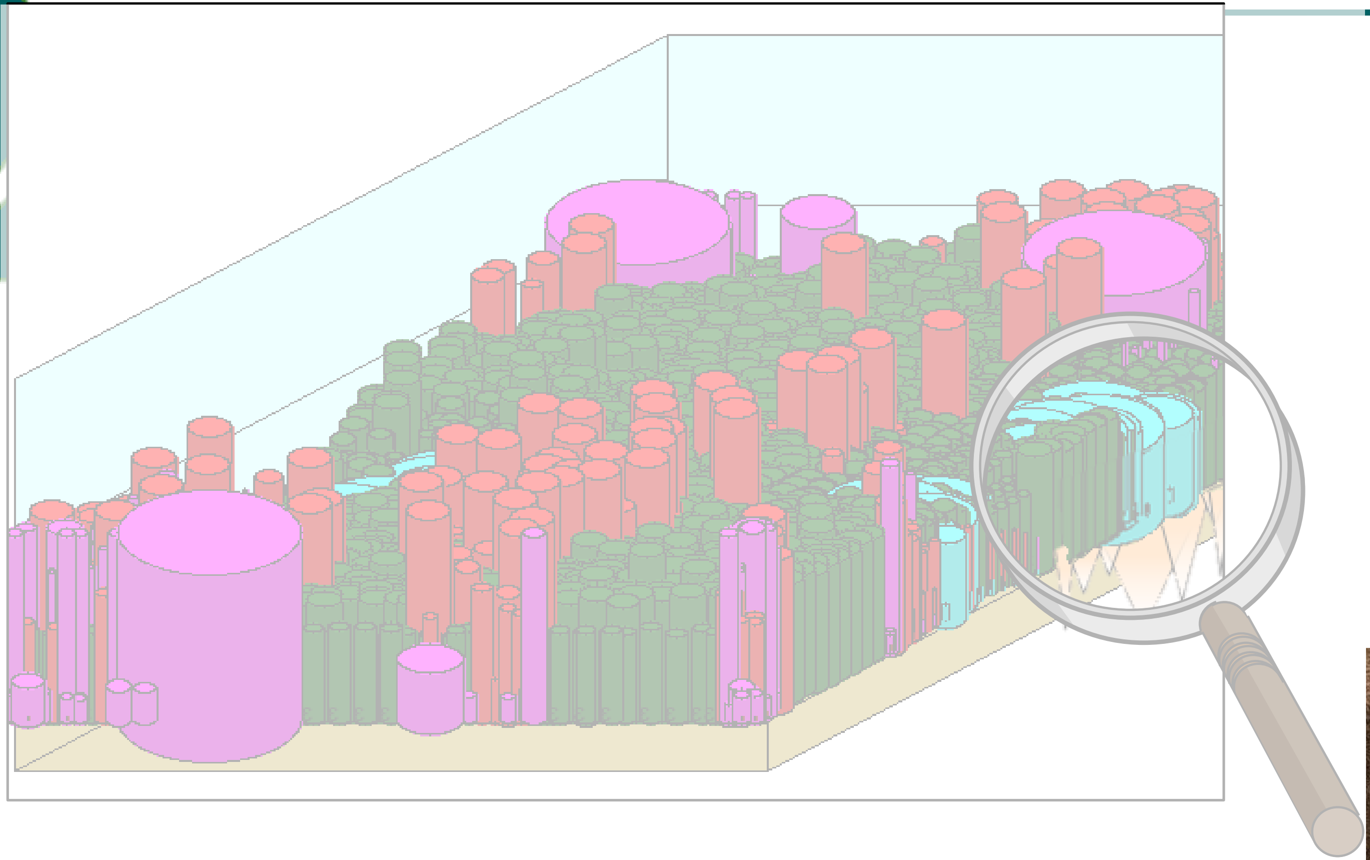
Wider plants
→ Escape neighbours

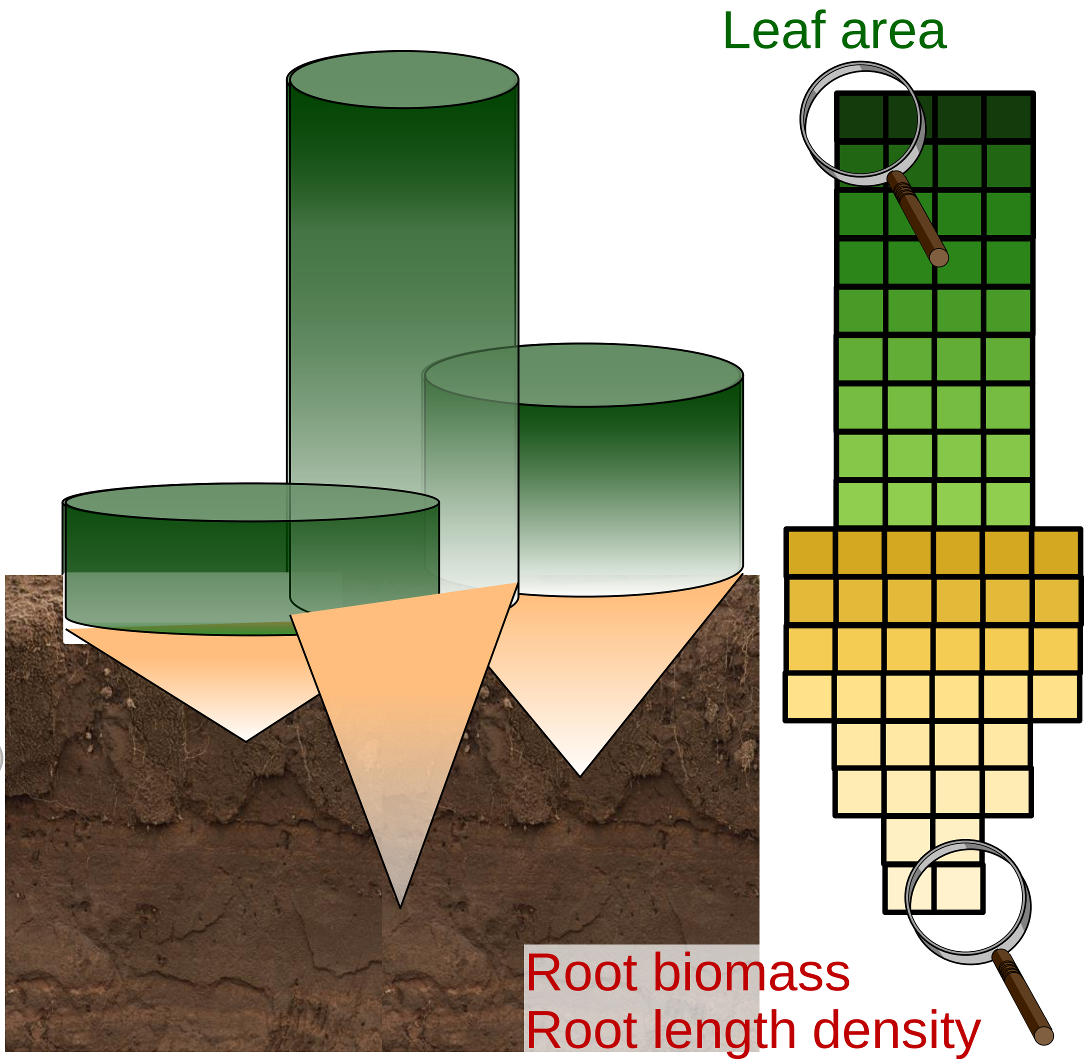
Median leaf area height

RLH
b_RLH
μ_RLH

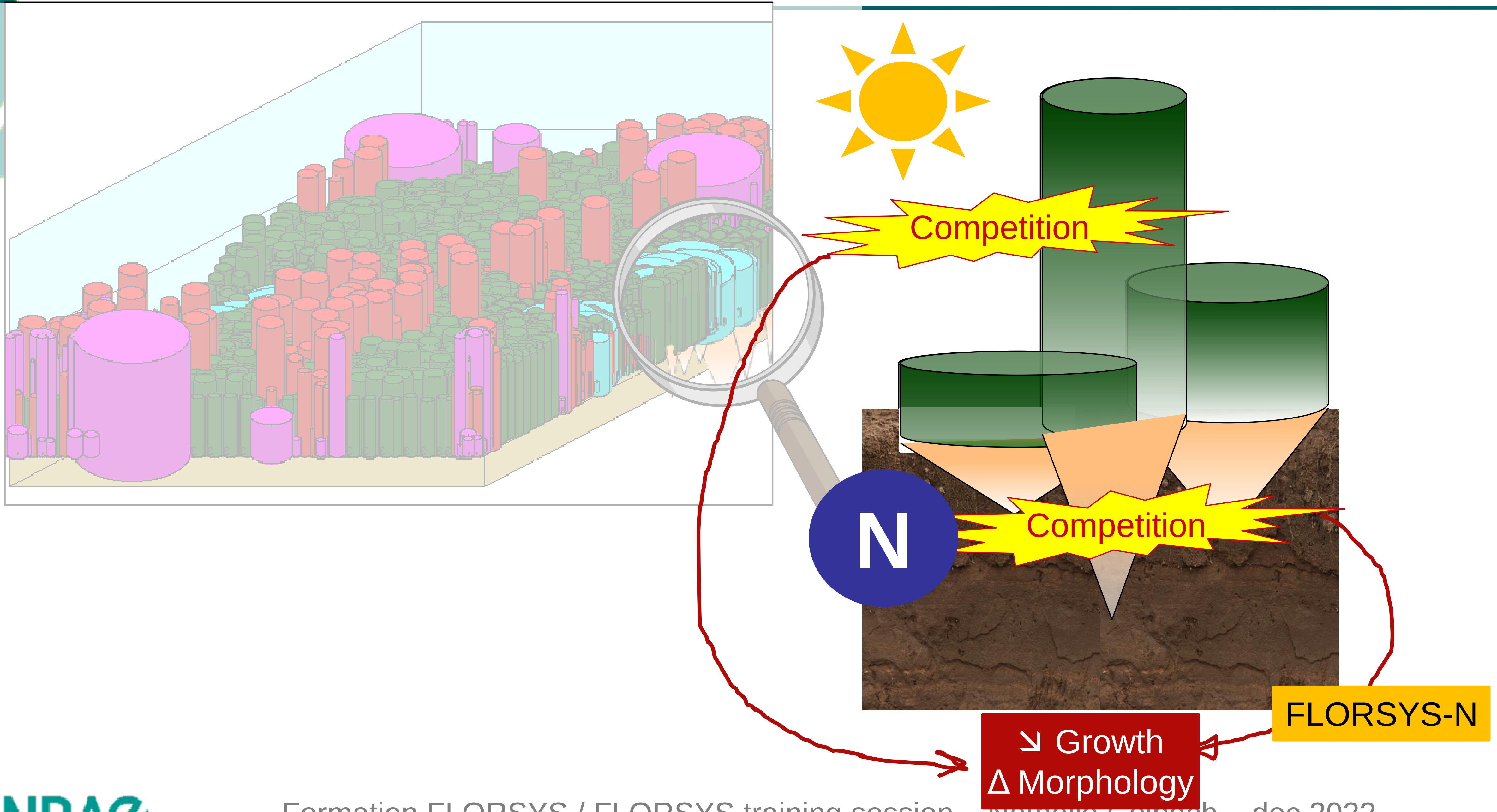
Leaf area at canopy top
→ Get closer to light

Plant-plant interactions: summary

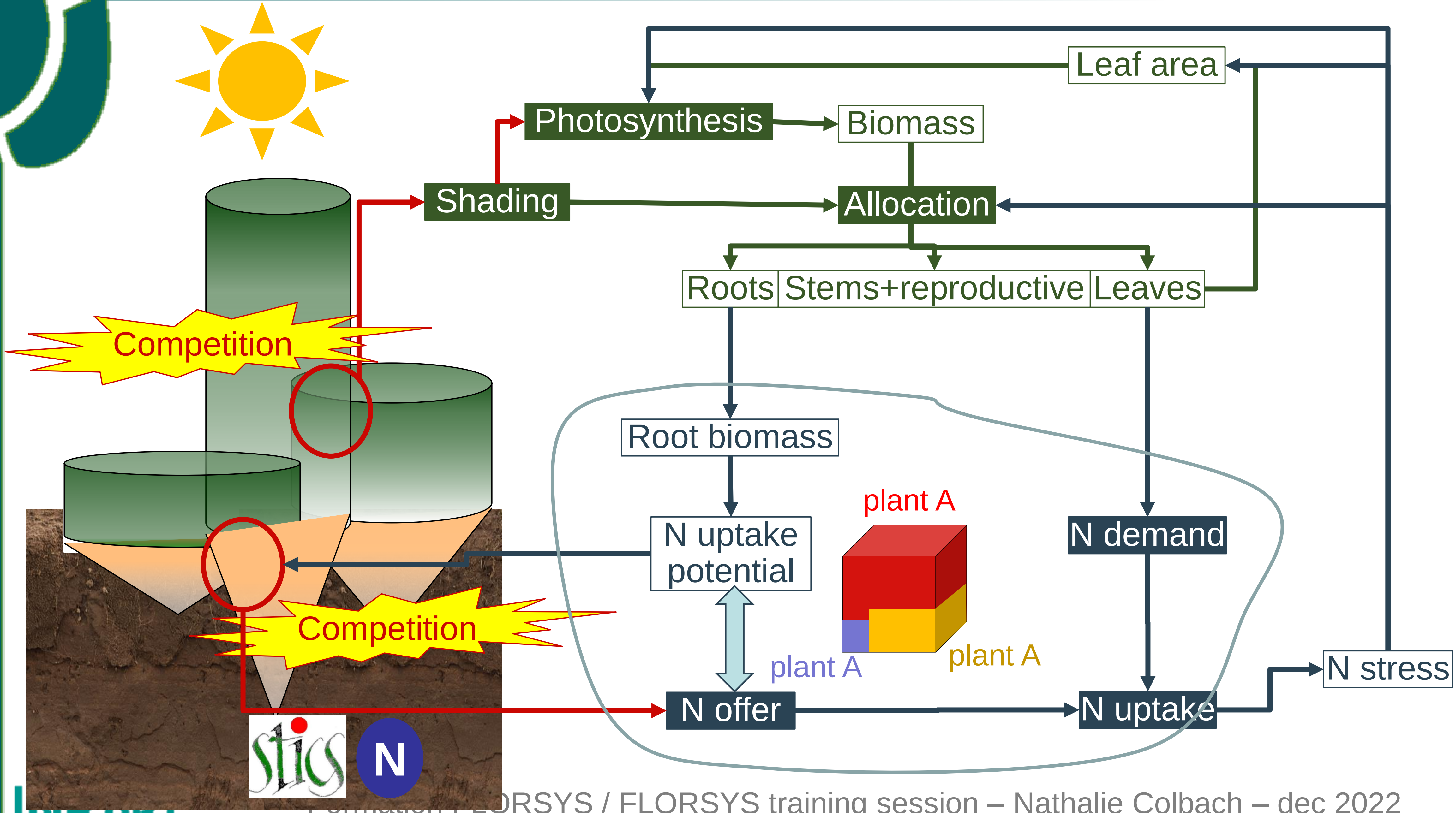




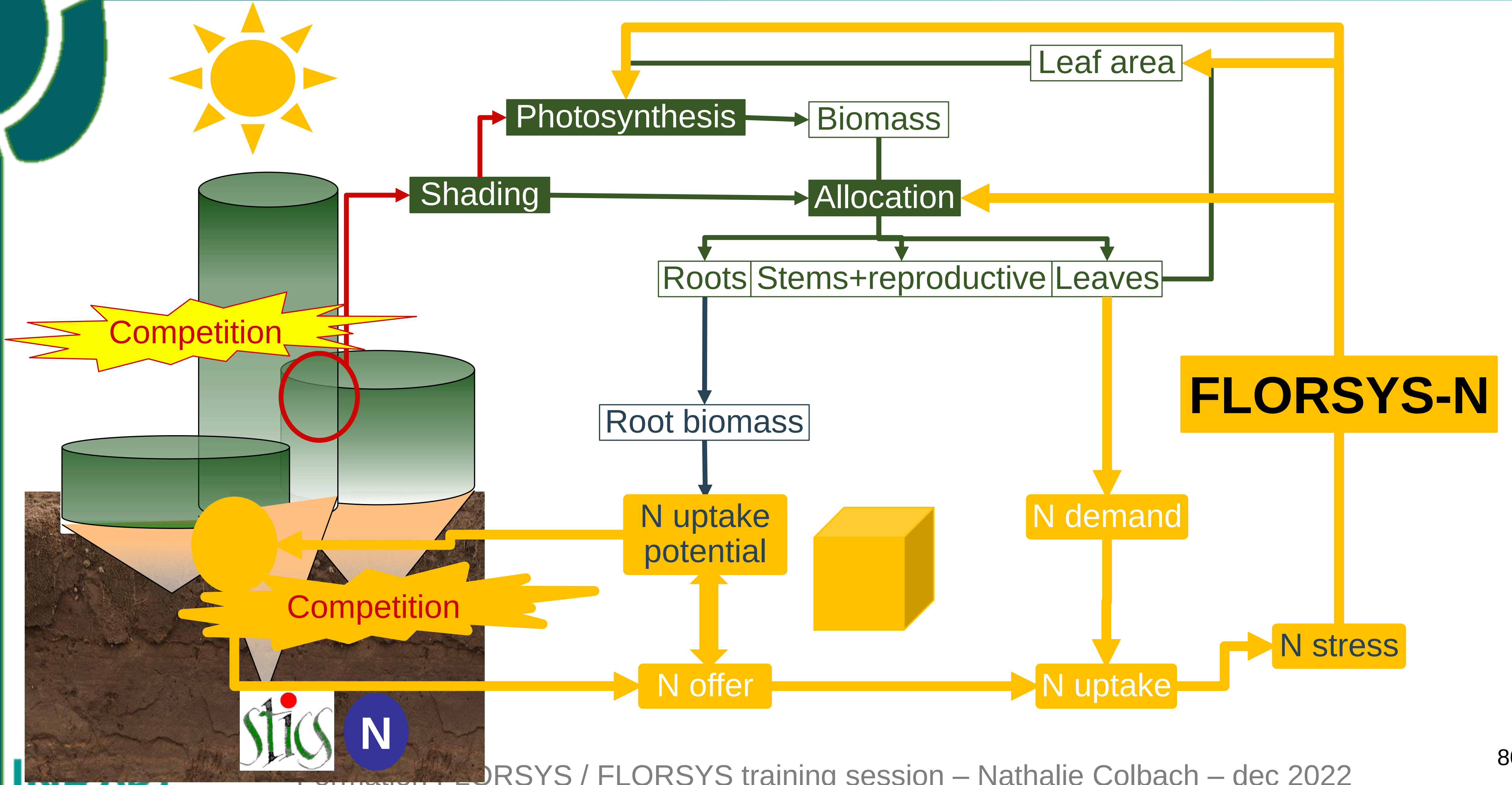
Plant-plant interactions: summary



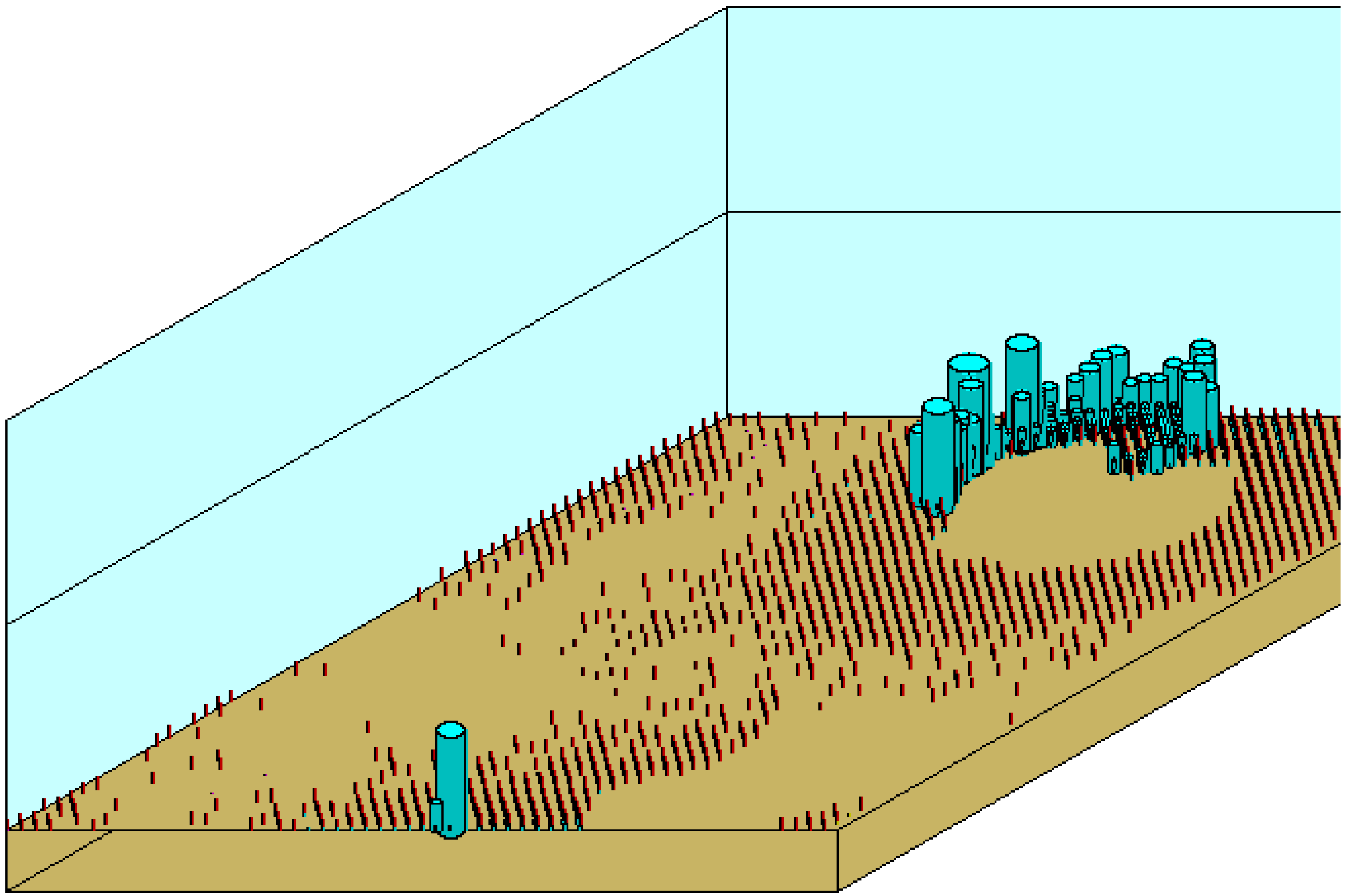
Plant-plant interactions: summary



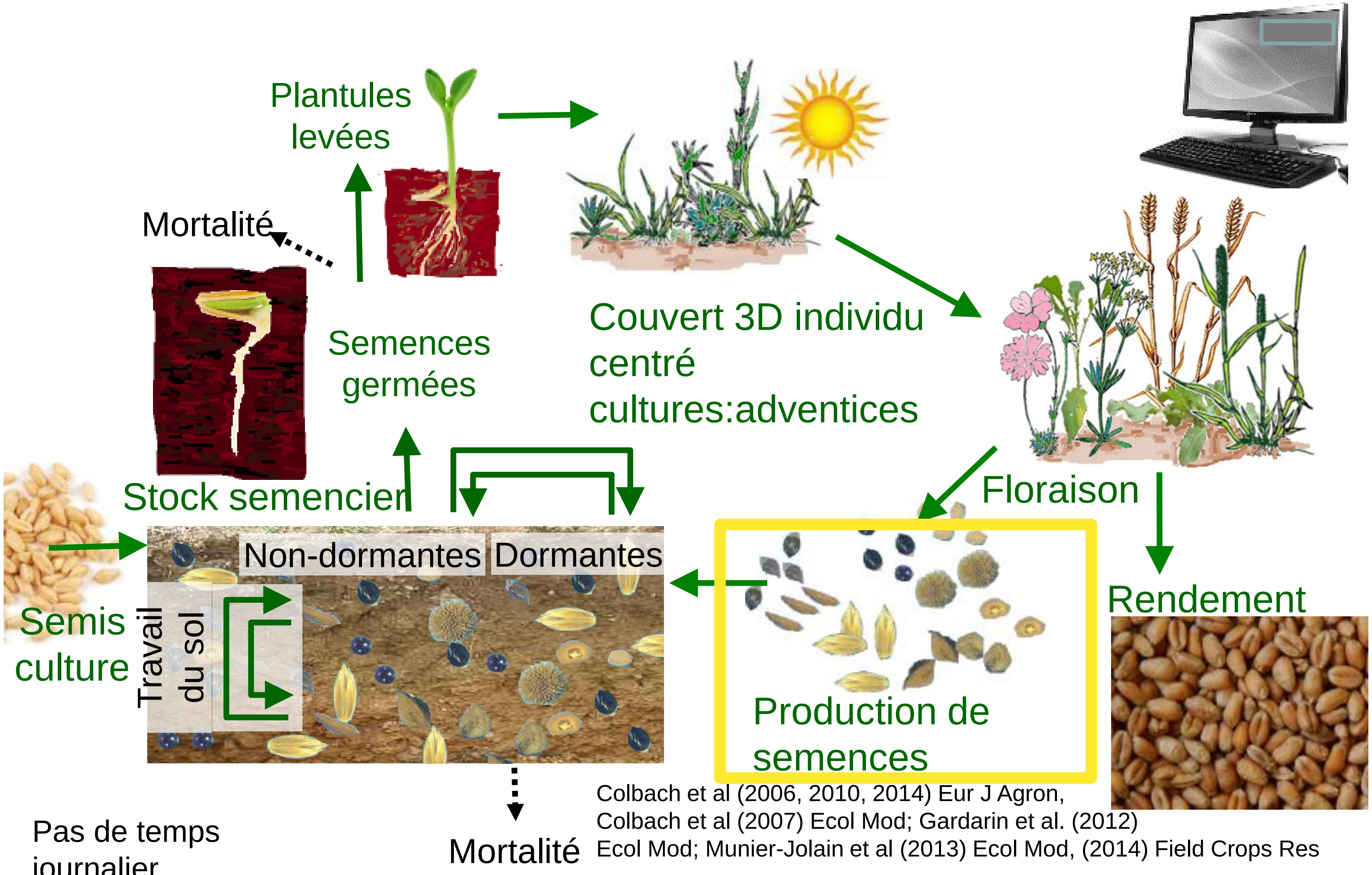
Interactions plante:plante – synthèse



Croissance pendant une saisons (simul)



Le cycle de vie générique pour adventices et cultures annuelles



Pas de temps journalier

Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res

Seed production

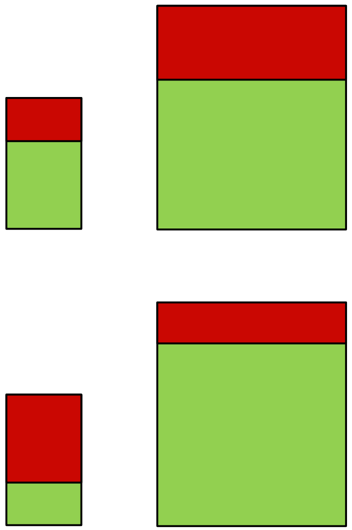
- When a mature plant dies
  - because of old age = f(phenology submodel)
  - becaue of operations (herbicides, tillage etc) or weather events (frost)
- Seed biomass

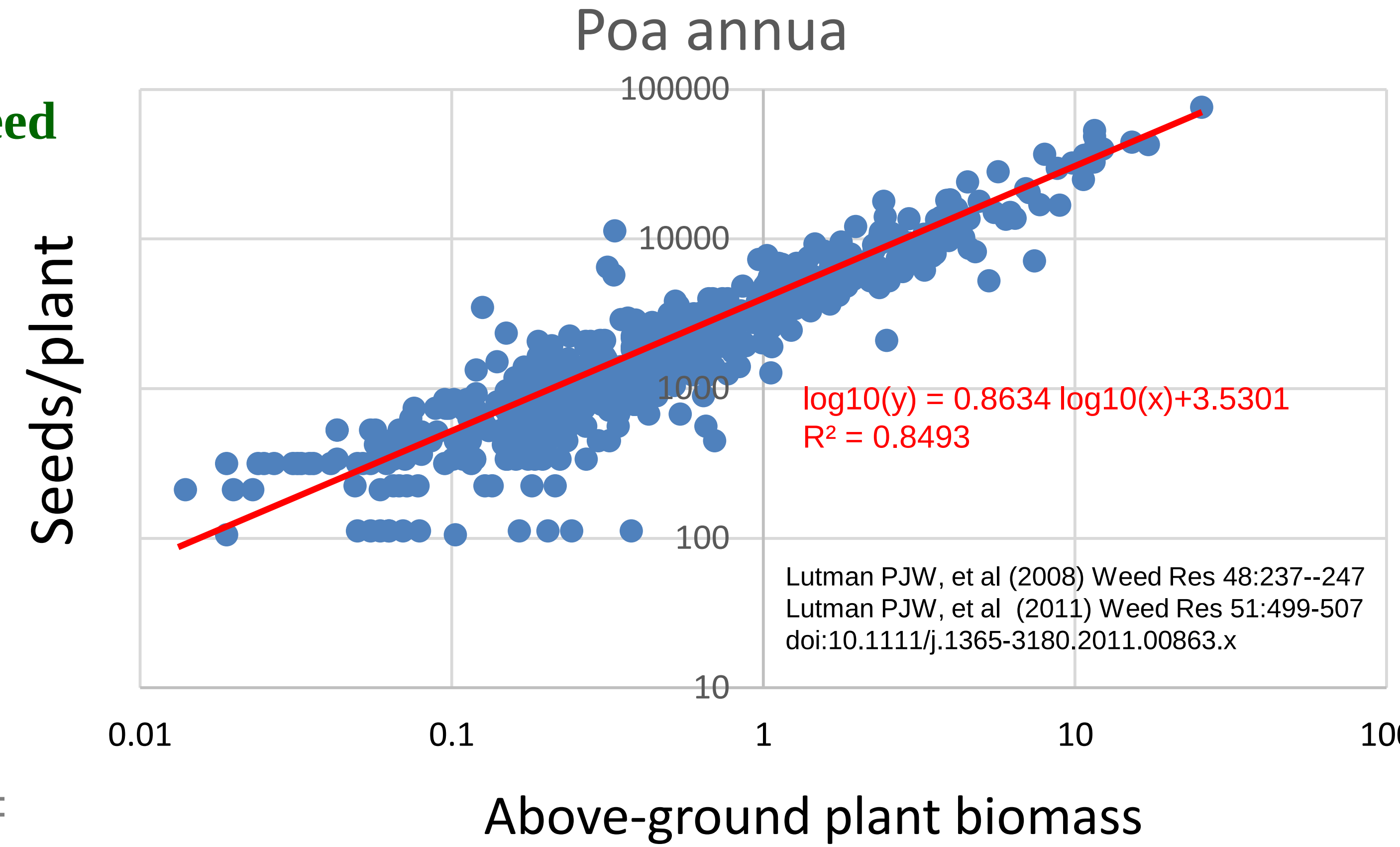
  = **"harvest index"** · above-ground biomass^b · degree of maturation
- Number of seeds

  = seed biomass / **mass of one seed**

b = 1

b < 1





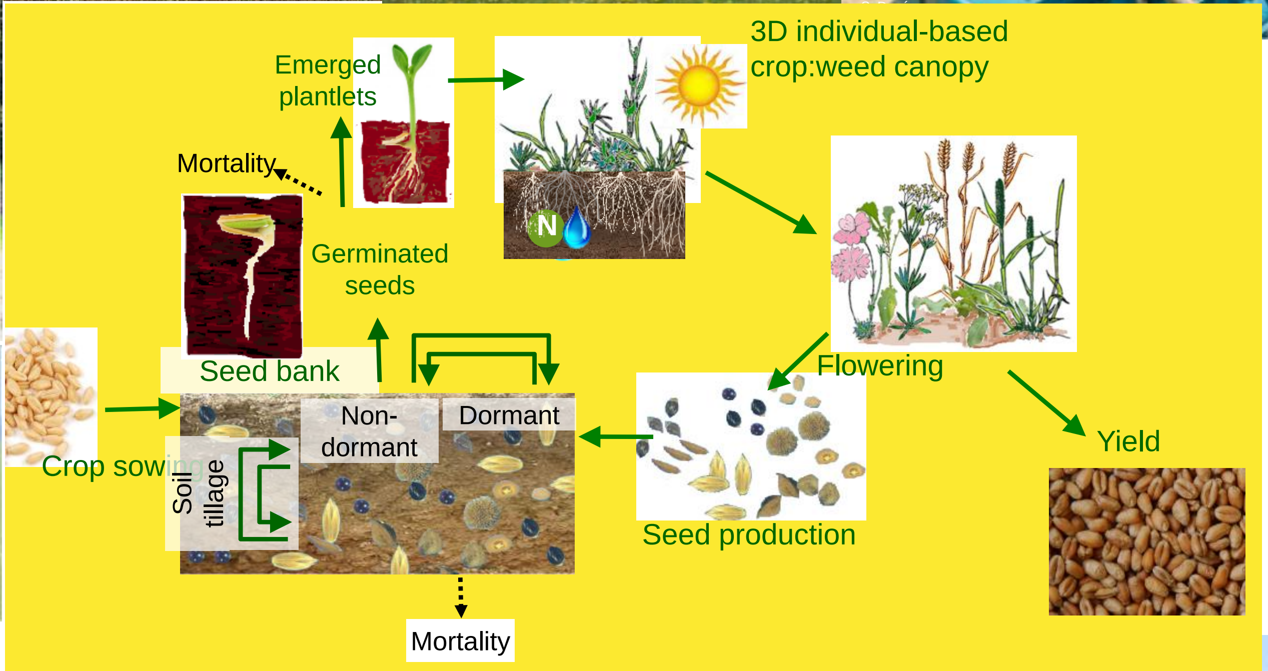
Plan

1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. **Effets des techniques culturales**
4. Le reste: indicateurs, paysage
5. Évaluation du modèle
6. Examples d'utilisation
7. Comment faire tourner le modèle?

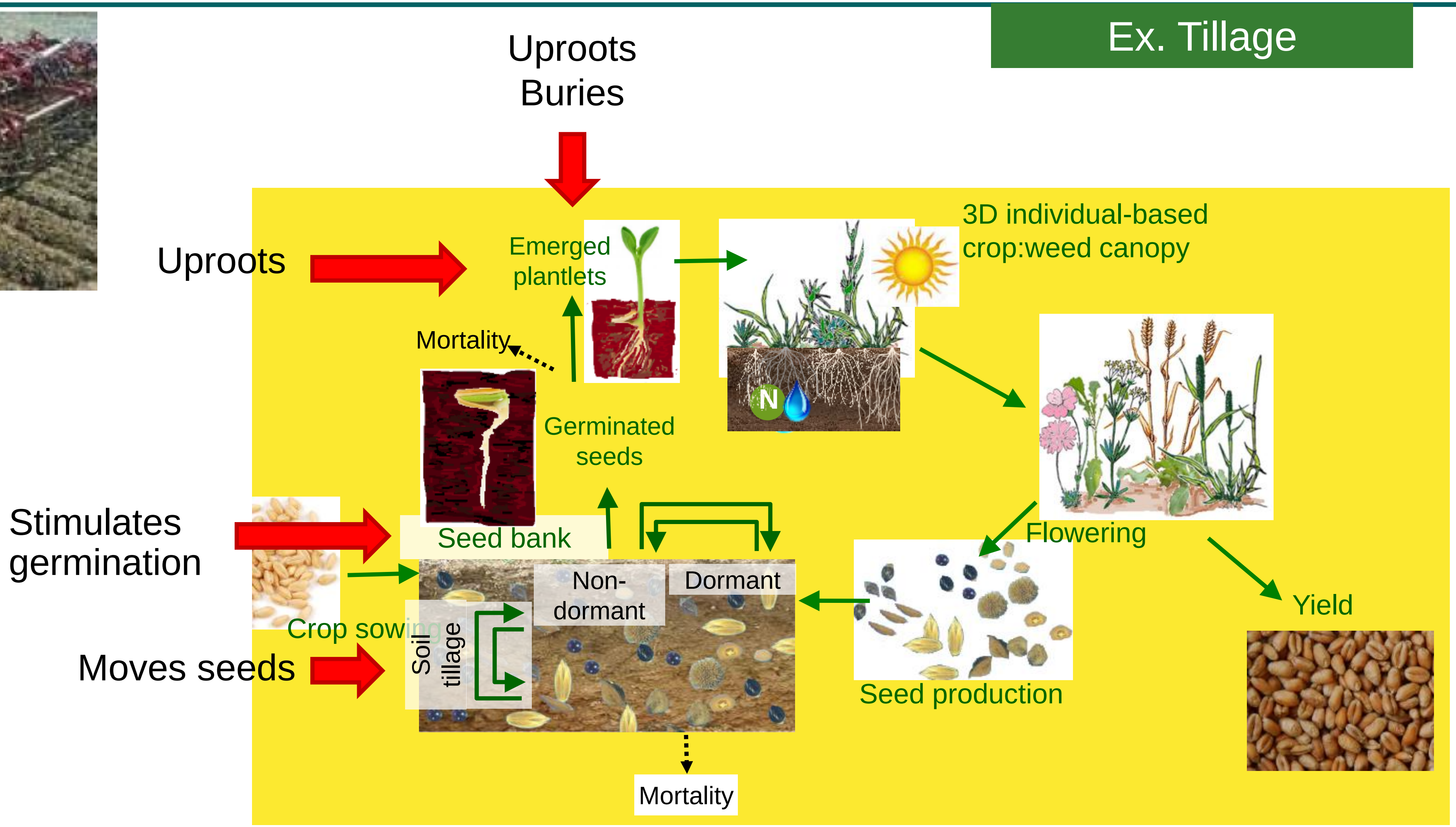
Today's presentation

1. Model objectives & structure
2. Details of life cycle
3. **Effects of management techniques**
4. What else? Indicators, landscape
5. Model evaluation
6. Examples of model use
7. How to run the model?

Disturbances due to management operations



Disturbances due to management operations

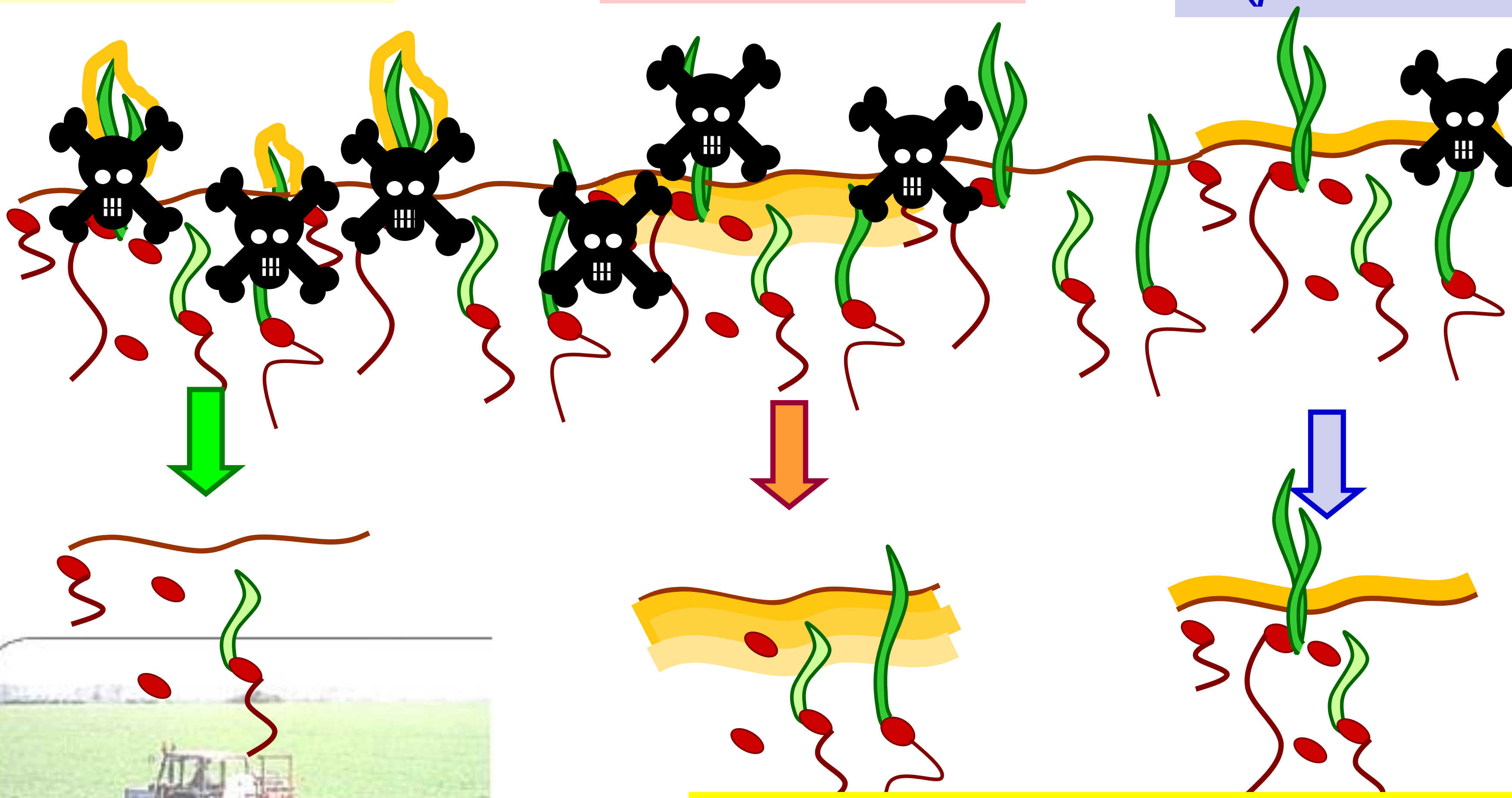


=f(tool, depth, speed) + f(soil moisture, structure) + f(species, stage)

Colbach et al (2006, 2010, 2014) Eur J Agron, Colbach et al (2007) Ecol Mod; Gardarin et al. (2012) Ecol Mod; Munier-Jolain et al (2013) Ecol Mod, (2014) Field Crops Res

FLORSYS: effect of herbicides (i/iv)

Foliaire *(foliar)* | Racinaire *(root)* | Pseudo-racinaire *(pseudo-root)*

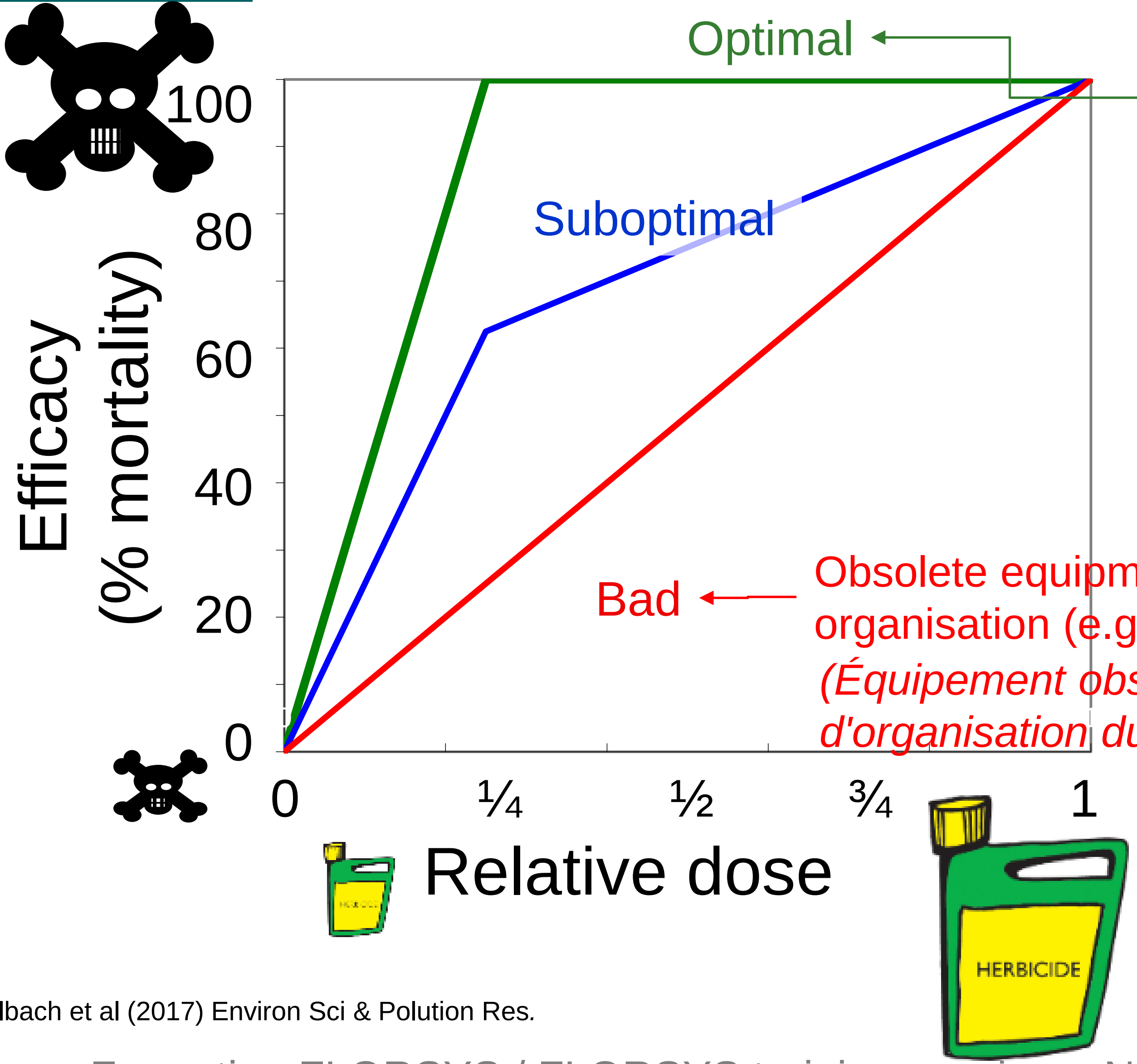


Persistants pendant plusieurs jours/semaines
(persist for several days/weeks)

n, N.M., Dulout-Dalbiès, A., Doré, T., 2010. Assessing non-chemical weeding strategies through a *lopecurus myosuroides Huds.) dynamics. European Journal of Agronomy 32 205-218.*

Herbicides (ii/iv)

Dosage & equipment



Excellent equipment, no constraint for work organisation

(Bon équipement, pas de contrainte sur l'organisation du travail)

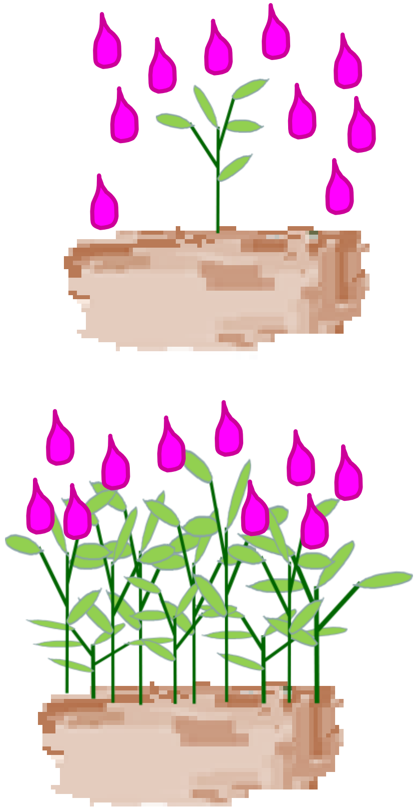
Obsolete equipment, constraints for work organisation (e.g., dairy cows)

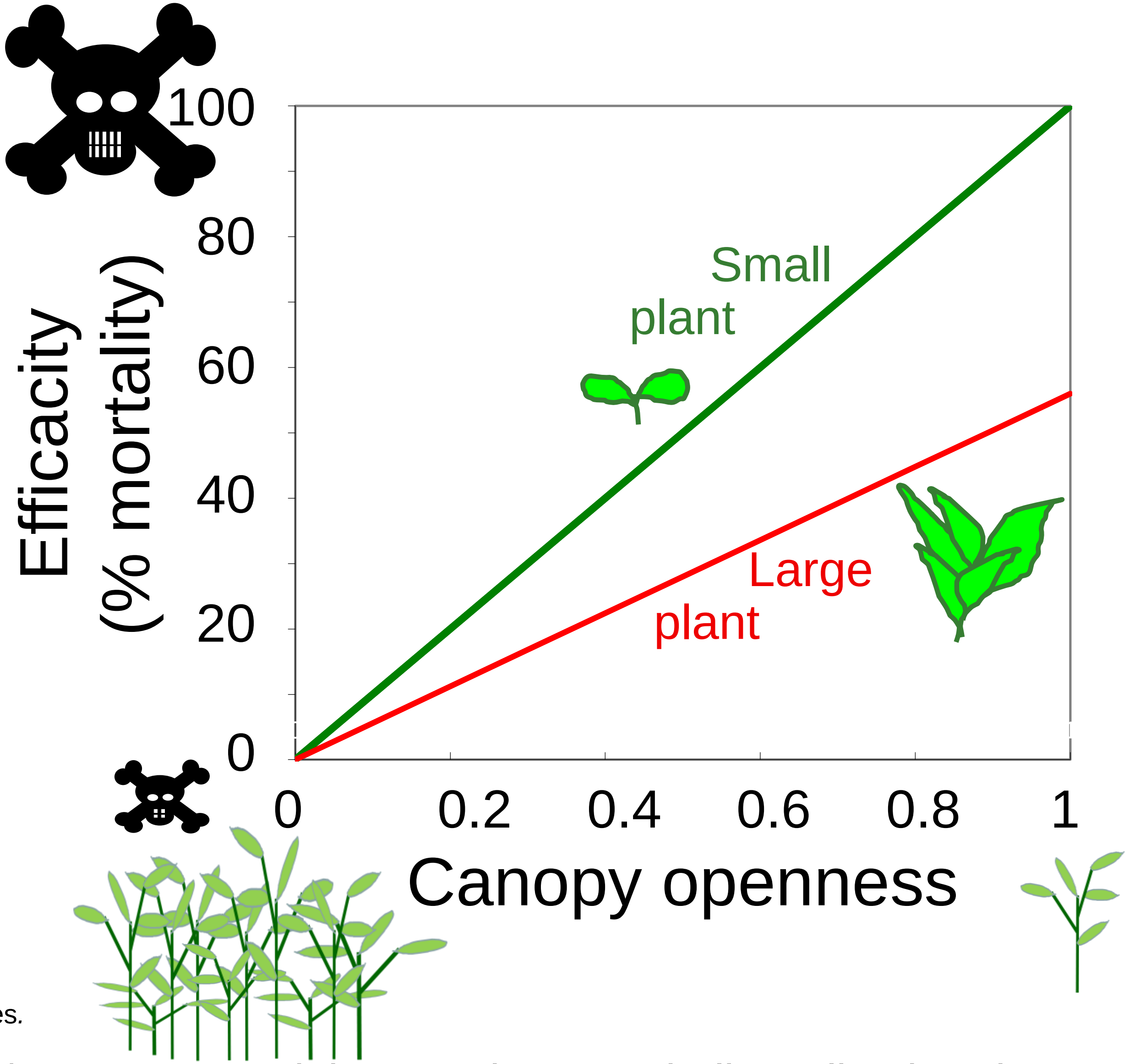
(Équipement obsolete equipment, constraints d'organisation du travail (ex. vaches laitières))

Colbach et al (2017) Environ Sci & Polution Res.

Herbicides (iii/iv)

Canopy density and weed stages

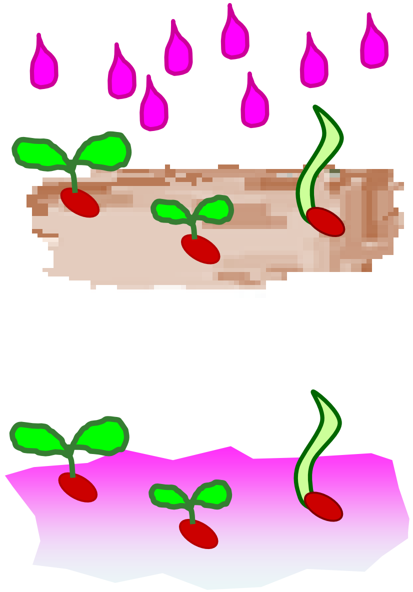




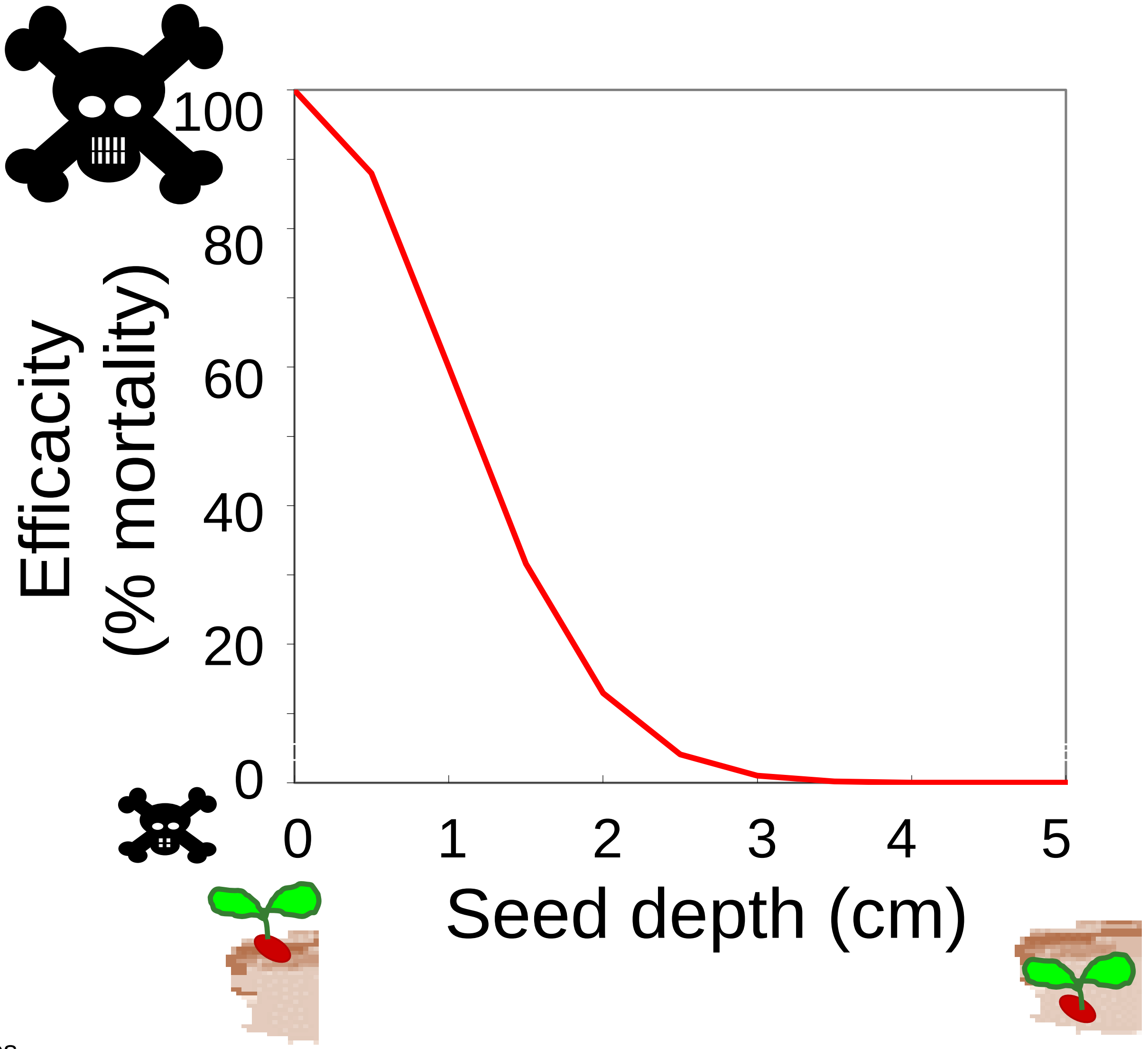
Colbach et al (2017) Environ Sci & Polution Res.

Herbicides (iv/iv)

Penetration into soil



Herbicide concentration decreases with depth



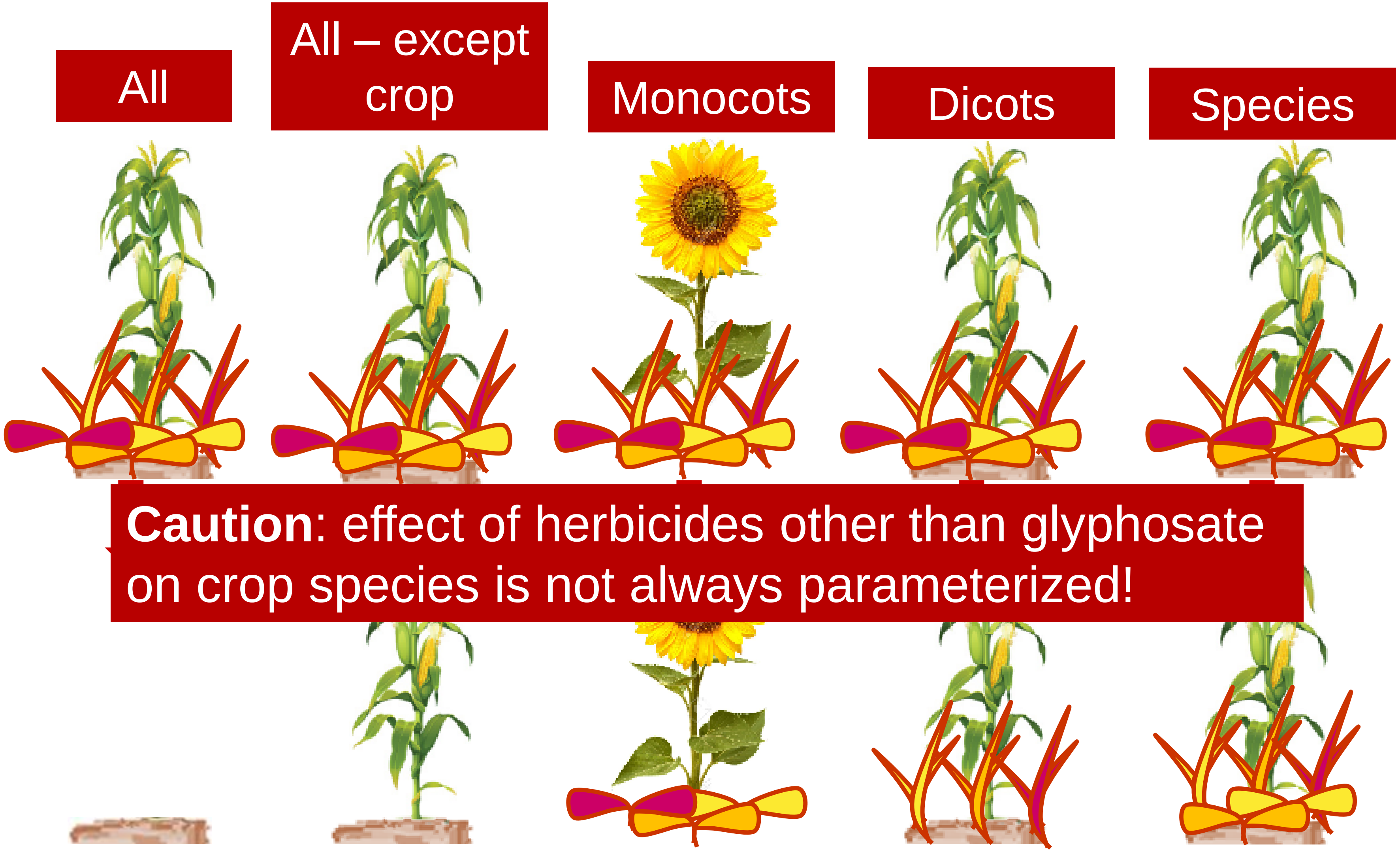
Colbach et al (2017) Environ Sci & Polution Res.

Herbicides (synthesis)

	Foliar	Root	Pseudo-root
Target	All emerged plants	Plants with superficial roots	Emerging plants
When	Treatment day D	Day D and subsequent days/weeks	
Umbrella effect	+	+++	++

Herbicides – not so simple after all

Spectrum

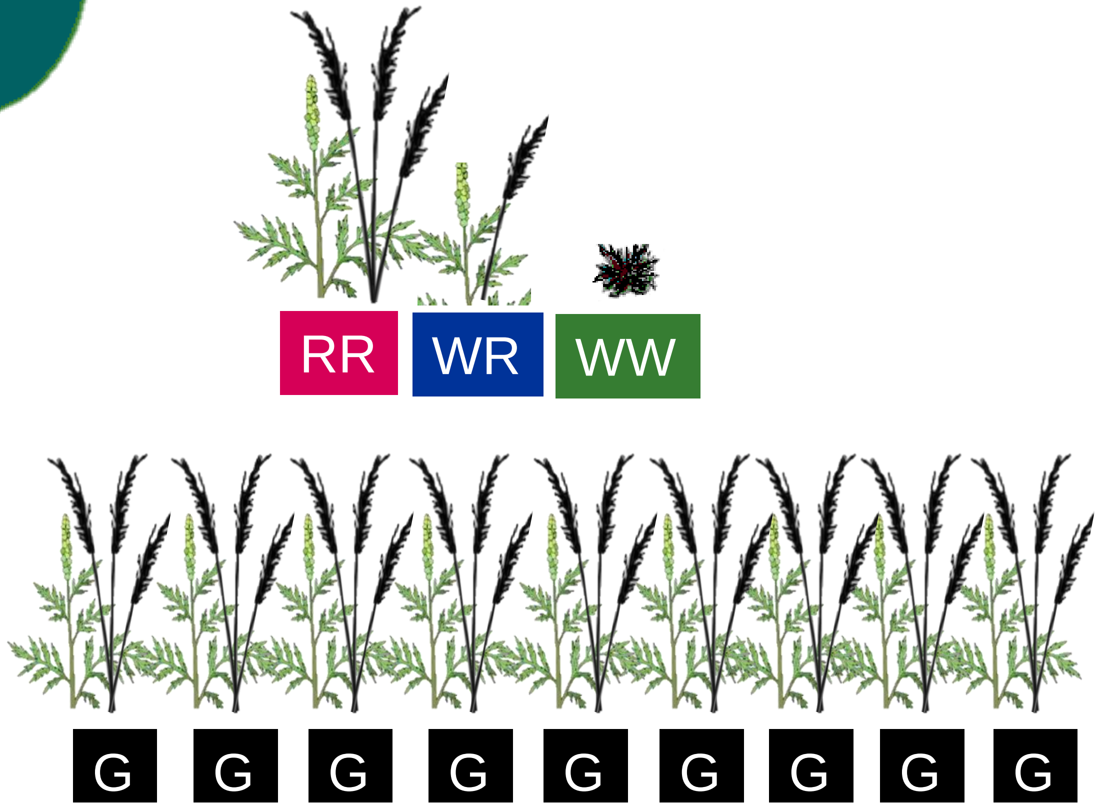


Caution: effect of herbicides other than glyphosate on crop species is not always parameterized!

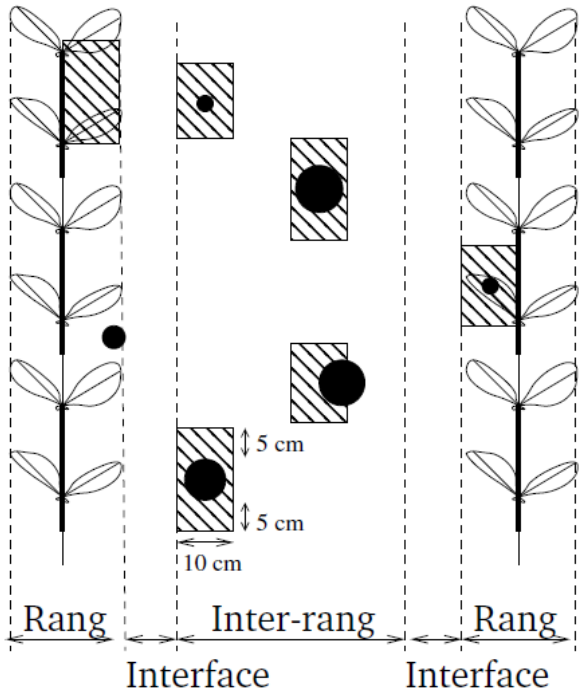
Colbach et al (2017) Environ Sci & Polution Res.

What else is there for herbicides?

- Herbicide resistance in weeds



- Site-specific spraying



Ask for more information if interested

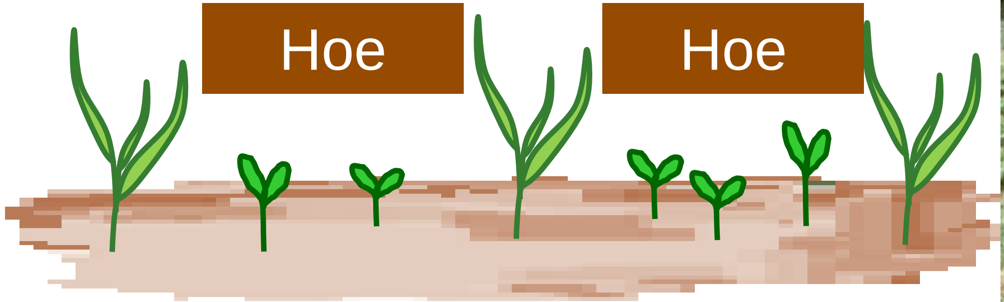
Mechanical weeding (i)

Tilled area

Harrow

Hoe

Hoe



Rotary hoe

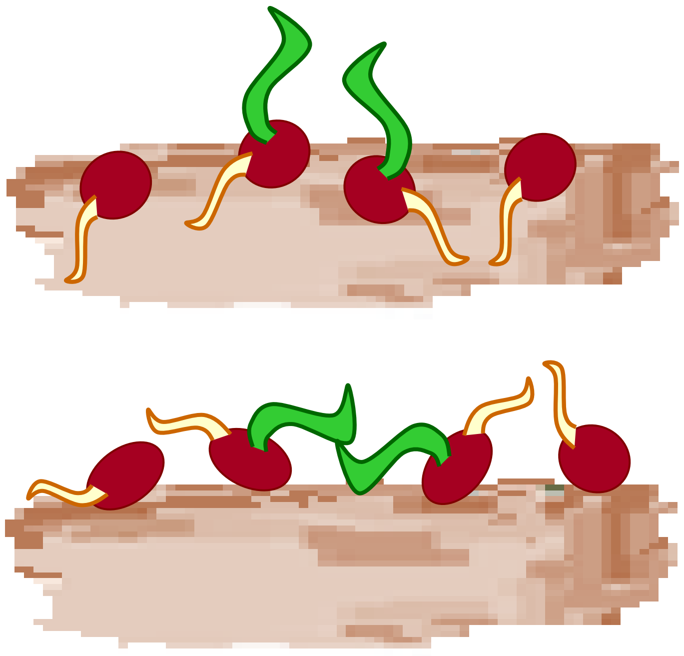
Rotary hoe

Caution: the larger the voxel edge size, the more imprecise plant location, zone size and effects on weeds

Mechanical weeding(ii)

Uprooting

Colbach et al (2010) *Eur J Agron*
Kurstjens et al (2000) Weed Res



0% — Uprooting — 100%

10 cm — Plant height — 0 cm

0 cm — Tillage depth — 5 cm

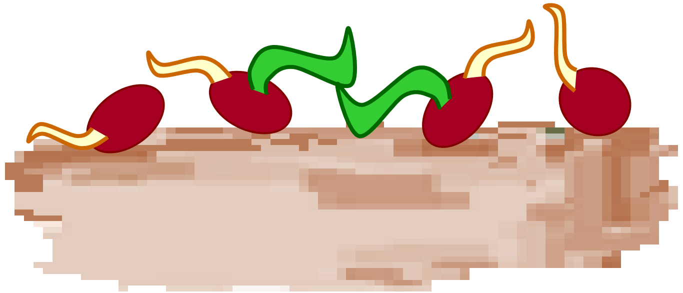
0 km/h — Tillage speed — 12 km/h

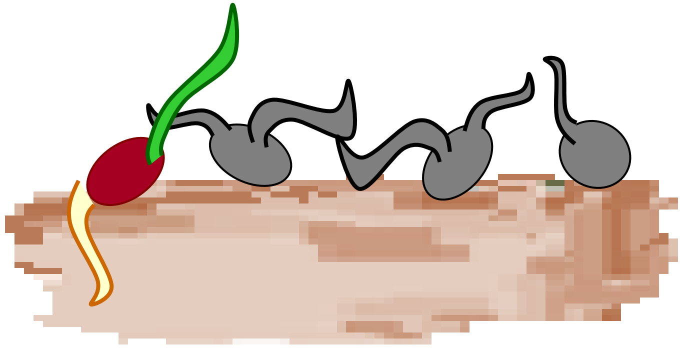
Dry — Soil — moist

Mechanical weeding(iii)

Mortality

Colbach et al (2010) *Eur J Agron*
Kurstjens et al (2000) Weed Res



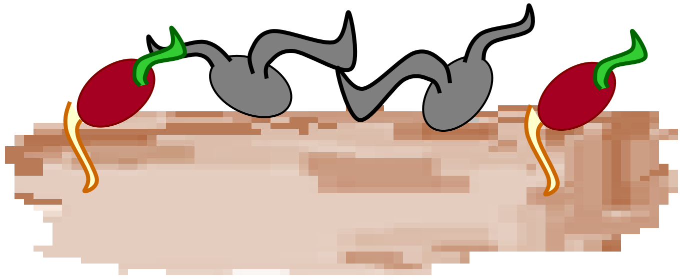


0%	Mortality	100%
0 cm	Plant height	2 cm
0 cm	Tillage depth	10 cm
0 km/h	Tillage speed	14 km/h
moist	Soil	dry

Mechanical weeding(iv)

Plant burial + growth reduction

Colbach et al (2010) *Eur J Agron*
Kurstjens et al (2000) Weed Res



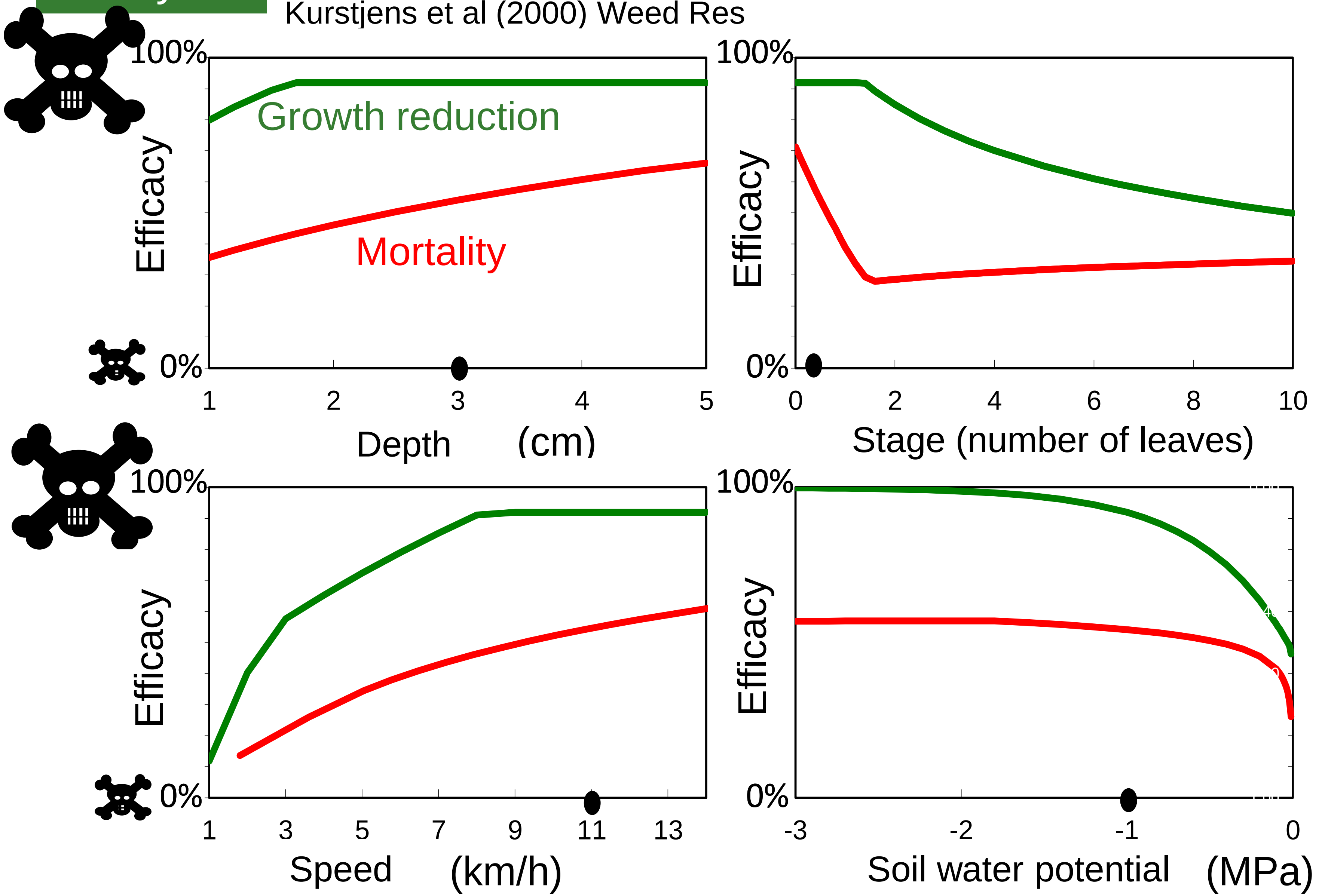
0%	Burial	100%
0 cm	Plant height	10 cm
0 cm	Tillage depth	10 cm
0 km/h	Tillage speed	14 km/h
moist	Soil	dry

Mechanical weeding(v)

Finally...

Colbach et al (2010) *Eur J Agron*
Kurstjens et al (2000) Weed Res

(example of ryegrass)

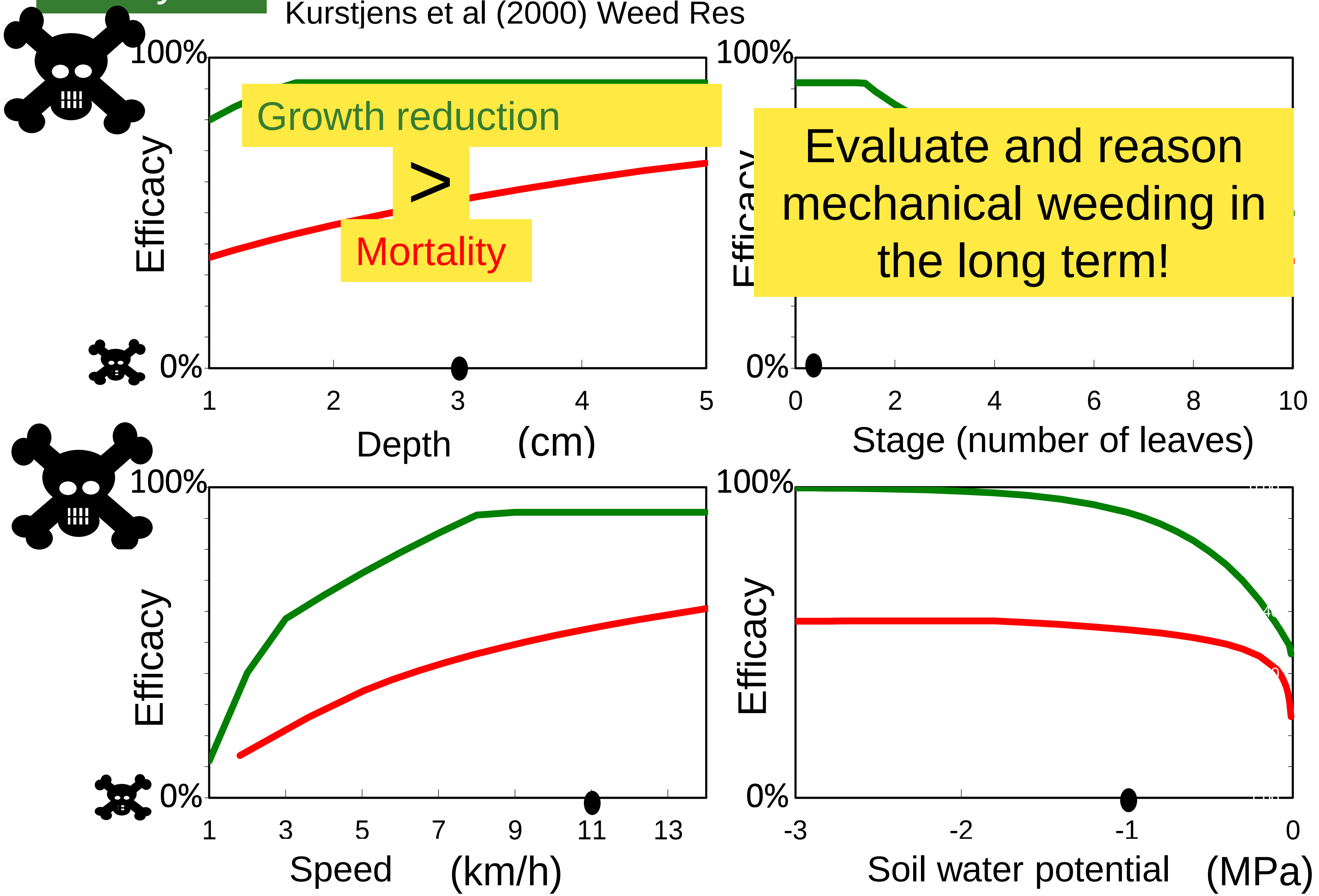


Mechanical weeding(v)

Finally...

Colbach et al (2010) *Eur J Agron*
Kurstjens et al (2000) Weed Res

(example of ryegrass)



Effect of management techniques – Synthesis

Intermediate effect		Effect on weeds			
Tillage & mechanical weeding (effects depend on tool, speed, soil moisture, soil structure)					
		Dormancy	Germination	Pre-emergent seedling mortality	
↘ soil compaction				↘	
Moves seeds		↘ (in moist soil layers, inverting tools)	↗ (in moist soil layers)		
Buries seeds = f(soil structure)	No burial			↗ (if summer drought)	
	Shallow burial		↗ (better water absorption)		
	Deep burial		↘ (insufficient O_2, too much CO_2 & soil weight)	↗ (insufficient seed reserves)	
Uproots & buries seedlings		↗ plant mortality and ↘ plant biomass of survivors			
Crop species and variety (including cover crops, mixtures undersown …)					
Choice of cultivation techniques		See effects of techniques			
Sowing season		↗ weed species that are non-dormant at sowing season			
Shading		↘ photosynthesis & biomass and ↗ etiolation			
Sowing date					
Crop emergence date		The earlier the weed seedlings emerge relative to the crop, the better they survive			
Date of last tillage or herbicide		The later the last tillage, the more weed seeds have germinated already and are killed by tillage/herbicide			
Sowing density					
↗ shading		↘ photosynthesis & biomass and ↗ etiolation			
Variability in shading in canopy		Irregular sowing → canopy gaps → weeds grow and reproduce better			
Herbicides					
Mode of entry		Unemerged seedlings	Emerging plants	Emerged plants	Duration of action
	Leaves	No effect	No effect	Kills	~1 day
	Roots	Kills (shallow roots)	Kills (shallow roots)	Kills (shallow roots)	Several days or weeks
	Meristem	No effect	Kills	No effect	
Dosage		↗ efficiency (particularly if bad conditions/material)			
Canopy density		↘ efficiency			
Weed size		↘ efficiency			
Mowing & harvesting operations					
Cuts plants and ↘ biomass The older the plants at mowing and the less biomass remains & the more plants die					
Manure					
Adds layer on soil surface		~ shallow seed burial by tillage (see above)			
Can include weed seeds		↗ soil seed bank			
Irrigation					
↗ soil moisture	↗ weed seed germination				
	Interacts with techniques whose effects depends on soil moisture (tillage, mechanical weeding, soil compaction)				
All (except crop/variety choice & irrigation)					
↗ soil compaction via wheel traffic		↗ Pre-emergent seedling mortality			
All destructive operations					
		Seed rain if mature weed plants are killed			

Effect of management techniques – Synthesis

Intermediate effect		Effect on weeds		
Tillage & mechanical weeding (effects depend on tool, speed, soil moisture, soil structure)				
		Dormancy	Germination	Pre-emergent seedling mortality
↘ soil compaction				↘
Moves seeds		↘ (in moist soil layers, inverting tools)	↗ (in moist soil layers)	
Buries seeds = f(soil structure)	No burial			↗ (if summer drought)
	Shallow burial		↗ (better water absorption)	
	Deep burial		↘ (insufficient O2, too much CO2 & soil weight)	↗ (insufficient seed reserves)
Uproots & buries seedlings		↗ plant mortality and ↘ plant biomass of survivors		

Mode of entry		Unemerged seedlings	Emerging plants	Emerged plants	Duration of action
	Leaves	No effect		Kills	~1 day
	Roots	Kills (shallow roots)			Several days or weeks
	Meristem	No effect	Kills	No effect	
Dosage		↗ efficiency (particularly if bad conditions/material)			
Canopy density		↘ efficiency			
Weed size		↘ efficiency			
Mowing & harvesting operations					
Cuts plants and ↘ biomass The older the plants at mowing and the less biomass remains & the more plants die					
Manure					
Adds layer on soil surface		~ shallow seed burial by tillage (see above)			
Can include weed seeds		↗ soil seed bank			
Irrigation					
↗ soil moisture	↗ weed seed germination				
	Interacts with techniques whose effects depends on soil moisture (tillage, mechanical weeding, soil compaction)				
All (except crop/variety choice & irrigation)					
↗ soil compaction via wheel traffic		↗ Pre-emergent seedling mortality			
All destructive operations					
		Seed rain if mature weed plants are killed			

Effect of management techniques – Synthesis

Intermediate effect		Effect on weeds		
Tillage & mechanical weeding (effects depend on tool, speed, soil moisture, soil structure)				
		Dormancy	Germination	Pre-emergent seedling mortality
↘ soil compaction				↘
Moves seeds		↘ (in moist soil layers, inverting tools)	↗ (in moist soil layers)	
Buries seeds = f(soil structure)	No burial			↗ (if summer drought)
	Shallow burial		↗ (better water absorption)	
	Deep burial		↘ (insufficient O2, too much CO2 & soil weight)	↗ (insufficient seed reserves)
Uproots & buries seedlings		↗ plant mortality and ↘ plant biomass of survivors		

Crop species and variety (including cover crops, mixtures undersown …)	
Choice of cultivation techniques	See effects of techniques
Sowing season	↗ weed species that are non-dormant at sowing season
Shading	↘ photosynthesis & biomass and ↗ etiolation
Sowing date	
Crop emergence date	The earlier the weed seedlings emerge relative to the crop, the better they survive
Date of last tillage or herbicide	The later the last tillage, the more weed seeds have germinated already and are killed by tillage/herbicide
Sowing density	
↗ shading	↘ photosynthesis & biomass and ↗ etiolation
Variability in shading in canopy	Irregular sowing → canopy gaps → weeds grow and reproduce better

Manure		
Adds layer on soil surface		~ shallow seed burial by tillage (see above)
Can include weed seeds		↗ soil seed bank
Irrigation		
↗ soil moisture	↗ weed seed germination	
	Interacts with techniques whose effects depends on soil moisture (tillage, mechanical weeding, soil compaction)	
All (except crop/variety choice & irrigation)		
↗ soil compaction via wheel traffic		↗ Pre-emergent seedling mortality
All destructive operations		
		Seed rain if mature weed plants are killed

Effect of management techniques – Synthesis

Intermediate effect		Effect on weeds		
Tillage & mechanical weeding (effects depend on tool, speed, soil moisture, soil structure)				
		Dormancy	Germination	Pre-emergent seedling mortality
↘ soil compaction				↘
Moves seeds		↘ (in moist soil layers, inverting tools)	↗ (in moist soil layers)	
Buries seeds = f(soil structure)	No burial			↗ (if summer drought)
	Shallow burial		↗ (better water absorption)	
	Deep burial		↘ (insufficient O2, too much CO2 & soil weight)	↗ (insufficient seed reserves)
Uproots & buries seedlings		↗ plant mortality and ↘ plant biomass of survivors		
Crop species and variety (including cover crops, mixtures undersown …)				
Choice of cultivation techniques		See effects of techniques		
Sowing season		↗ weed species that are non-dormant at sowing season		
Shading		↘ photosynthesis & biomass and ↗ etiolation		
Sowing date				
Crop emergence date		The earlier the weed seedlings emerge relative to the crop, the better they survive		
Date of last tillage or herbicide		The later the last tillage, the more weed seeds have germinated already and are killed by tillage/herbicide		
Sowing density				
↗ shading		↘ photosynthesis & biomass and ↗ etiolation		
Variability in shading in canopy		Irregular sowing → canopy gaps → weeds grow and reproduce better		

Herbicides					
Mode of entry		Unemerged seedlings	Emerging plants	Emerged plants	Duration of action
	Leaves	No effect		Kills	~1 day
	Roots	Kills (shallow roots)			Several days or weeks
	Meristem	No effect	Kills	No effect	
Dosage		↗ efficiency (particularly if bad conditions/material)			
Canopy density		↘ efficiency			
Weed size		↘ efficiency			

Irrigation		
↗ soil moisture	↗ weed seed germination	
	Interacts with techniques whose effects depends on soil moisture (tillage, mechanical weeding, soil compaction)	
All (except crop/variety choice & irrigation)		
↗ soil compaction via wheel traffic		↗ Pre-emergent seedling mortality
All destructive operations		
		Seed rain if mature weed plants are killed

Effect of management techniques – Synthesis

Intermediate effect		**Effect on weeds**		
Tillage & mechanical weeding (effects depend on tool, speed, soil moisture, soil structure)				
		Dormancy	Germination	Pre-emergent seedling mortality
↘ soil compaction				↘
Moves seeds		↘ (in moist soil layers, inverting tools)	↗ (in moist soil layers)	
Buries seeds = f(soil structure)	No burial			↗ (if summer drought)
	Shallow burial		↗ (better water absorption)	
	Deep burial		↘ (insufficient O2, too much CO2 & soil weight)	↗ (insufficient seed reserves)
Uproots & buries seedlings		↗ plant mortality and ↘ plant biomass of survivors		
Crop species and variety (including cover crops, mixtures undersown …)				
Choice of cultivation techniques		See effects of techniques		
Sowing season		↗ weed species that are non-dormant at sowing season		
Shading		↘ photosynthesis & biomass and ↗ etiolation		
Sowing date				
Crop emergence date		The earlier the weed seedlings emerge relative to the crop, the better they survive		
[illegible]		[illegible]		
All (except crop/variety choice & irrigation)				
↗ soil compaction via wheel traffic		↗ Pre-emergent seedling mortality		
All destructive operations				
		Seed rain if mature weed plants are killed		

Mowing & harvesting operations		
Cuts plants and ↘ biomass The older the plants at mowing and the less biomass remains & the more plants die		
Manure		
Adds layer on soil surface	~ shallow seed burial by tillage (see above)	
Can include weed seeds	↗ soil seed bank	
Irrigation		
↗ soil moisture	↗ weed seed germination	
	Interacts with techniques whose effects depends on soil moisture (tillage, mechanical weeding, soil compaction)	

Effect of management techniques – Synthesis

Intermediate effect		Effect on weeds		
Tillage & mechanical weeding (effects depend on tool, speed, soil moisture, soil structure)				
		Dormancy	Germination	Pre-emergent seedling mortality
↘ soil compaction				↘
Moves seeds		↘ (in moist soil layers, inverting tools)	↗ (in moist soil layers)	
Buries seeds = f(soil structure)	No burial			↗ (if summer drought)
	Shallow burial		↗ (better water absorption)	
	Deep burial		↘ (insufficient O2, too much CO2 & soil weight)	↗ (insufficient seed reserves)
Uproots & buries seedlings		↗ plant mortality and ↘ plant biomass of survivors		

Intermediate effect	Effect on weeds
Crop species and variety (including cover crops, mixtures undersown …)	
Choice of cultivation techniques	See effects of techniques
Sowing season	↗ weed species that are non-dormant at sowing season
Shading	↘ photosynthesis & biomass and ↗ etiolation
Sowing date	
Crop emergence date	The earlier the weed seedlings emerge relative to the crop, the better they survive
Date of last tillage or herbicide	The later the last tillage, the more weed seeds have germinated already and are killed by tillage/herbicide
Sowing density	
↗ shading	↘ photosynthesis & biomass and ↗ etiolation
Variability in shading in canopy	Irregular sowing → canopy gaps → weeds grow and reproduce better

Herbicides					
Mode of entry		Unemerged seedlings	Emerging plants	Emerged plants	Duration of action
	Leaves	No effect		Kills	~1 day
	Roots	Kills (shallow roots)			Several days or weeks
	Meristem	No effect	Kills	No effect	
Dosage		↗ efficiency (particularly if bad conditions/material)			
Canopy density		↘ efficiency			
Weed size		↘ efficiency			

Mowing & harvesting operations	
Cuts plants and ↘ biomass The older the plants at mowing and the less biomass remains & the more plants die	
Manure	

All (except crop/variety choice & irrigation)	
↗ soil compaction via wheel traffic	↗ Pre-emergent seedling mortality
All destructive operations	
	Seed rain if mature weed plants are killed

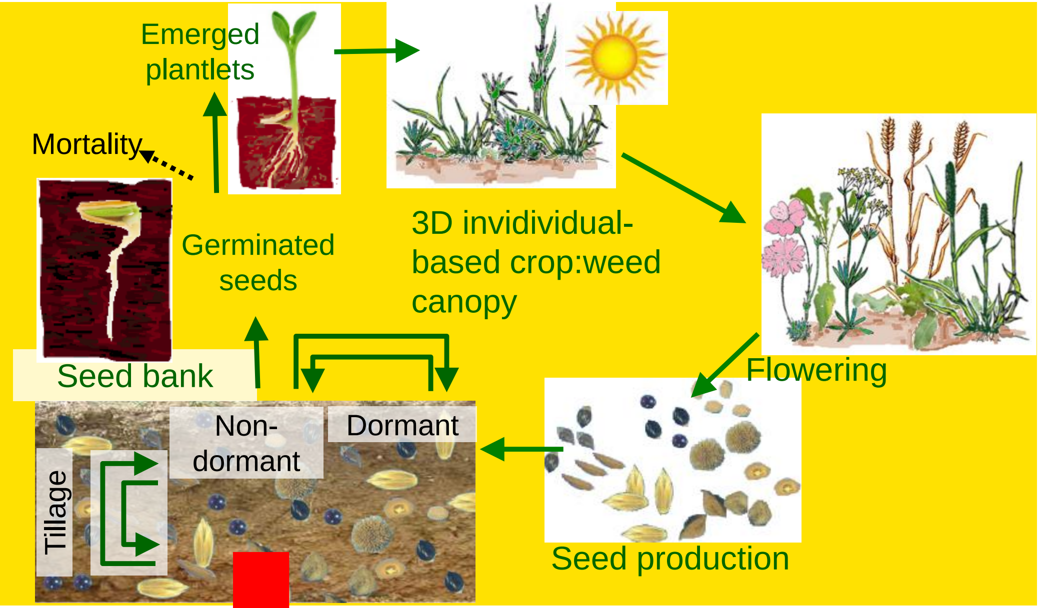
Plan

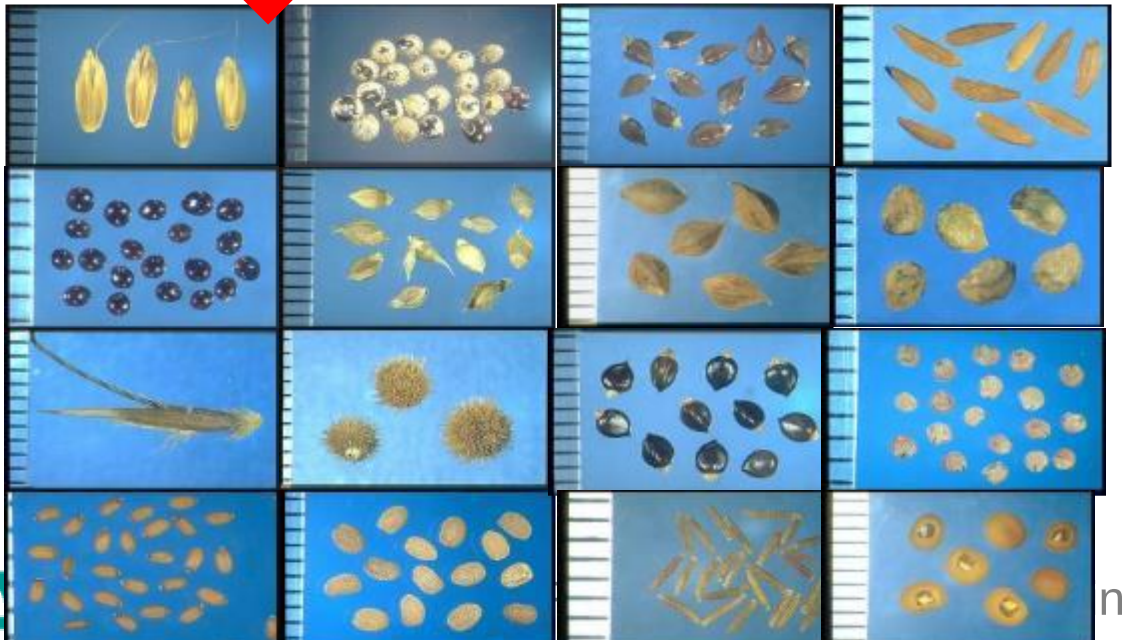
1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. Effets des techniques culturales
4. **Le reste: indicateurs, paysage**
5. Évaluation du modèle
6. Examples d'utilisation
7. Comment faire tourner le modèle?

Today's presentation

1. Model objectives & structure
2. Details of life cycle
3. Effects of management techniques
4. **What else? Indicators, landscape**
5. Model evaluation
6. Examples of model use
7. How to run the model?

FLORSYS Evaluate the effect of weed flora





What is the effect on crop production and on biodiversity?

Weed-related services and dys-services

Weed impact indicators

Crop production	
Yield	
Energy production	

Output of growth submodel

Harmfulness	
Direct	Yield loss
	Harvest pollution
Technical	Harvesting problems
Sociological	Field infestation
Indirect	Promoting parasites & pathogens
Ecotoxicological	Herbicide use intensity

≠ simulation with vs without weeds

Benefits	
Plant biodiversity	Species richness Species evenness
Trophic resources for	Farmland birds Carabids Pollinators
Reduction of environmental impacts	Nitrate leaching Pesticide transfer Erosion

Weed-related services and dys-services

Weed impact indicators

Crop production	
Yield	
Energy production	
Harmfulness	
Direct	Yield loss
	Harvest pollution
Technical	Harvesting problems
Sociological	Field infestation
Indirect	Promoting parasites & pathogens
Ecotoxicological	Herbicide use intensity
Benefits	
Plant biodiversity	Species richness
	Species evenness
Trophic resources for	Farmland birds
	Carabids
	Pollinators
Reduction of environmental impacts	Nitrate leaching
	Pesticide transfer
	Erosion

Trait-based principle

Community-weighted mean (CWM)

CWM= $\sum_{i=1}^{n} p_i * trait_i,$

$$I = \sum_{d \in \text{period of interest}} \sum_{w} V_{wd}\, trait_w$$

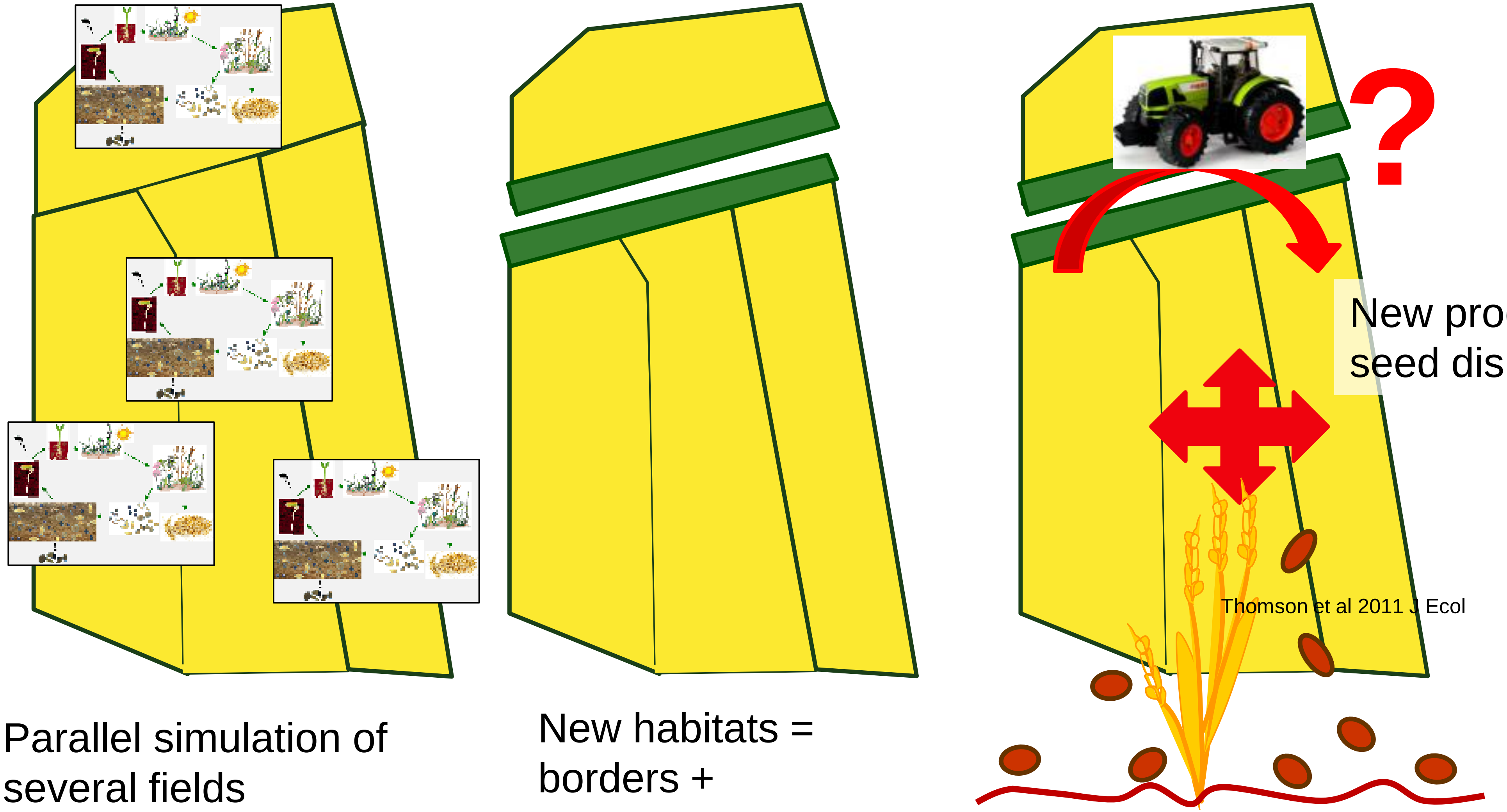
Example

[April,Sept]

Seeds/m² on soil surface

Seed lipid content (g/g)

Upscale from field to landscape



Parallel simulation of several fields

New habitats = borders + flower/grass strips

(CaliFLoPP, Bouvier et al 2009)

Colbach et al 2001 Agric Ecosys Environ
Colbach et al submitted Agric Ecosyst Env

Ask for more information if interested

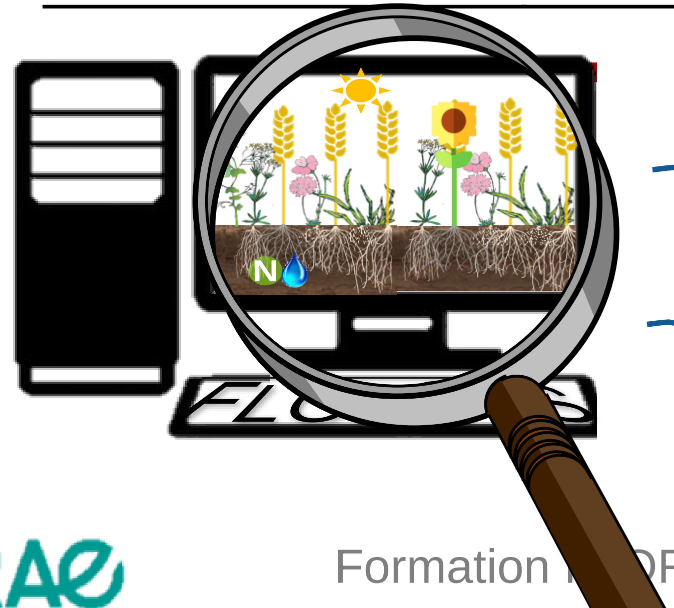
Plan | Today's presentation

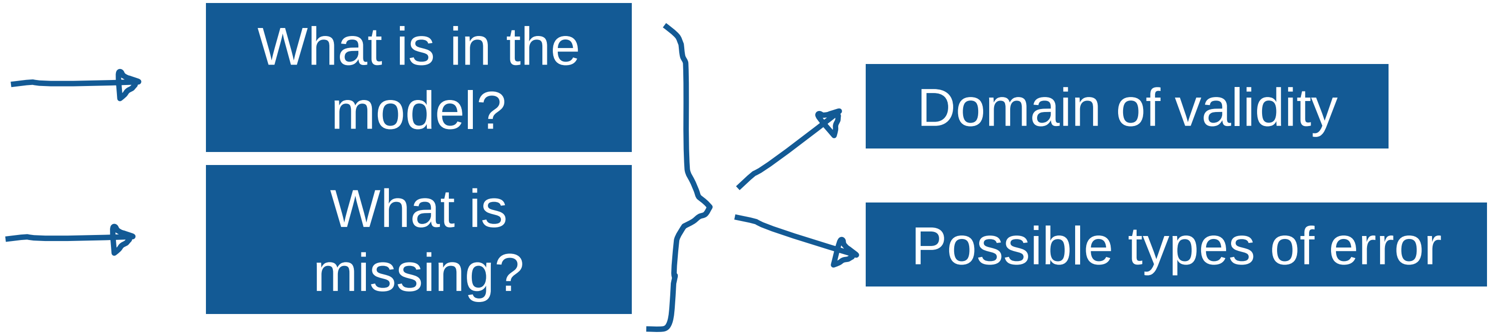
1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. Effets des techniques culturales
4. Le reste: indicateurs, paysage
5. **Évaluation du modèle**
6. Examples d'utilisation
7. Comment faire tourner le modèle?

1. Model objectives & structure
2. Details of life cycle
3. Effects of management techniques
4. What else? Indicators, landscape
5. **Model evaluation**
6. Examples of model use
7. How to run the model?

Evaluation (i) Limit domain of validity based on model structure

Processus	What is well predicted	Limits of domain of validity
Reproduction	32 annual weed species	No perennial weeds (which are frequent in permanent no-till)
Water availability	Temperate climate Irrigated fields	Overestimates drought-sensitive species
N availability	Well fertilised fields	Underestimates oligotrophic species if lack of N
Phenology	Burgundy Latitude	Shift in timing of flowering for species sensitive to photoperiod





Evaluation (ii) Compare simulations to independent field observations

Objective

- Domain of validity, prediction error
- What must be added or improved in the model?

Principle

- Compare simulations to independent field observations

Steps

- Critical processes/stages in specific short-term experiments (choose factors, measure many variables)
  Emergence dynamics, light penetration into canopy, seed movements during tillage etc
- Multi-annual dynamics in long-term field experiments (few situations, well monitored)
- Annual snapshots in farm field surveys (Biovigilance-Flore data base) (many situations, partial data)

Colbach, N., Biju-Duval, L., Gardarin, A., Granger, S., Guyot, S. H. M., Mézière, D., Munier-Jolain, N. M., Petit, S., 2014. The role of models for multicriteria evaluation and multiobjective design of cropping systems for managing weeds. Weed Research 54, 541–555.

Pointurier O., Moreau D., Pagès L., Caneill J. & Colbach N. (2021) Individual-based 3D modelling of root systems in heterogeneous plant canopies at the multiannual scale. Case study with a weed dynamics model. Ecological Modelling 440, 109376, https://doi.org/10.1016/j.ecolmodel.2020.109376

Colbach N., Bertrand M., Busset H., Colas F., Dugué F., Farcy P., Fried G., Granger S., Meunier D., Munier-Jolain N. M., Noilhan C., Strbik F. & Gardarin A. (2016) Uncertainty analysis and evaluation of a complex, multi-specific weed dynamics model with diverse and incomplete data sets. Environmental Modelling & Software 86, 184-203, http://dx.doi.org/10.1016/j.envsoft.2016.09.020

How to evaluate a model with field observations? (i)

Observations

Field trial (or famers' fields)
Several consecutive years

Several contrasting cropping systems

Cropping system type (Dijon)	Crop diversity (12 years)			Tillage	Mechanical weeding
	Species/cultivars (number)	winter crops	Cover crops (years)		
Reference	4	100%	8%	Superficial	No
IWM-simplified	18	77%	39%	Superficial or none	No
IWM-intermediate	10	63%	8%	Mouldboard ploughing	No
IWM-complete	8	55%	0%	Mouldboard ploughing	Yes
IWM-no herbicide	12	63%	16%	Mouldboard ploughing	Yes

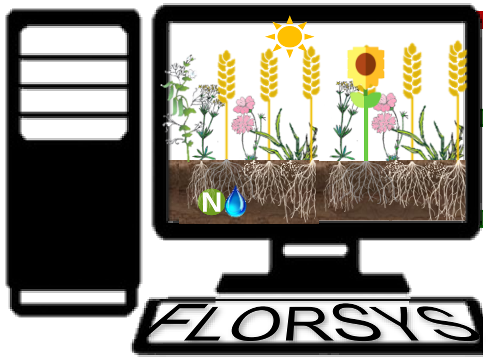
INRAE

Colbach, N., Bertrand, M., Busset, H., Colas, F., Dugué, F., Farcy, P., Fried, G., Granger, S., Meunier, D., Munier-Jolain, N. M., Noilhan, C., Strbik, F., Gardarin, A., 2016. Uncertainty analysis and evaluation of a complex, multi-specific weed dynamics model with diverse and incomplete data sets. Environmental Modelling & Software 86, 184-203.

How to evaluate a model with field observations? (ii)

Simulations & statistics

Inputs
- Detailed field history
- Initial weed seed bank
- Soil texture
- Weather data



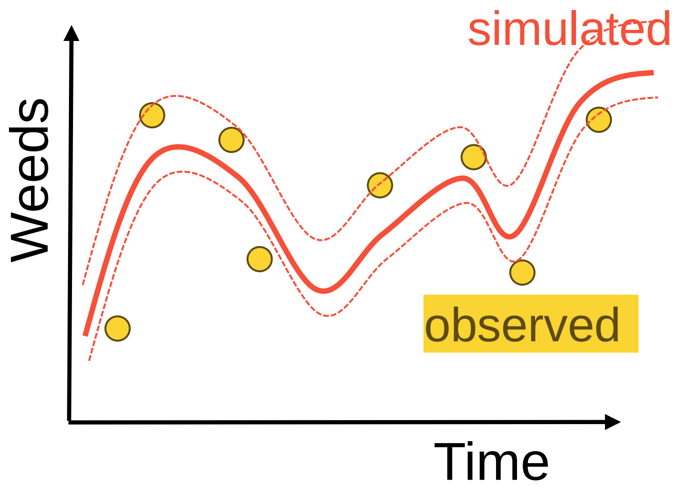
Observed
- Weed plant density
- Weed biomass
- Weed seed bank
- Crop biomass
- Crop yield

Compare (statistics)

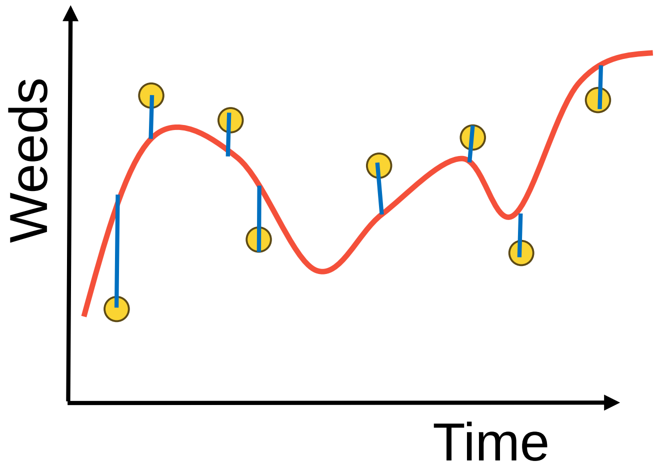
Simulated
- Weed plant density
- Weed biomass
- Weed seed bank
- Crop biomass
- Crop yield

How to evaluate a model with field observations? (iii)

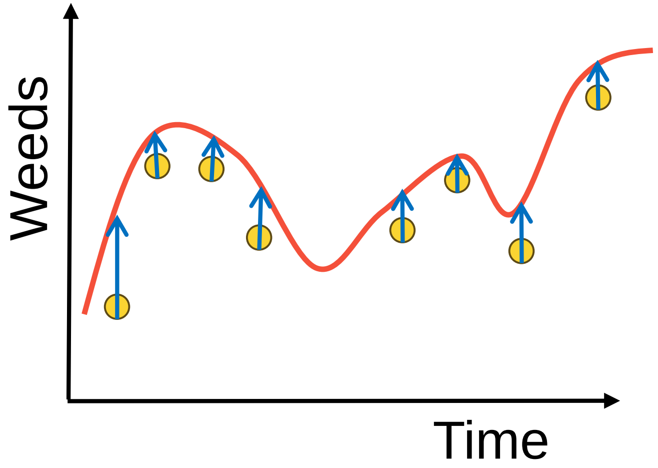
Dynamics % observations in simulated interval



Prediction error = mean of |



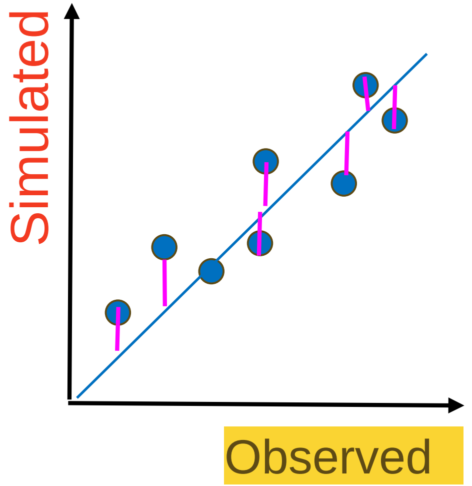
Bias Over or underestimation?



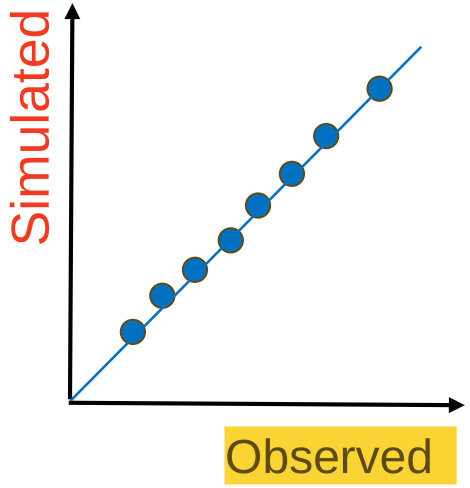
Colbach, N., Bertrand, M., Busset, H., Colas, F., Dugué, F., Farcy, P., Fried, G., Granger, S., Meunier, D., Munier-Jolain, N. M., Noilhan, C., Strbik, F., Gardarin, A., 2016. Uncertainty analysis and evaluation of a complex, multi-specific weed dynamics model with diverse and incomplete data sets. Environmental Modelling & Software 86, 184-203.

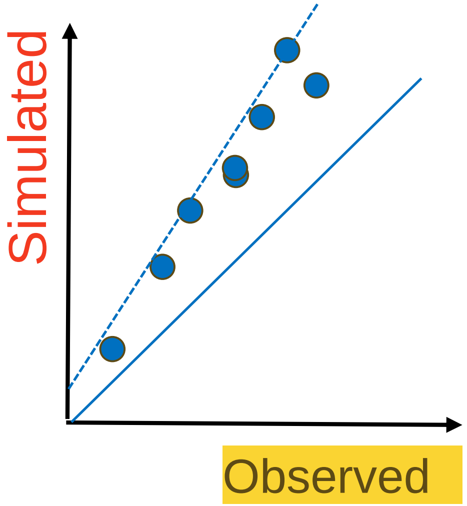
How to evaluate a model with field observations? (iv)

Modelling efficiency = 1 – mean of |

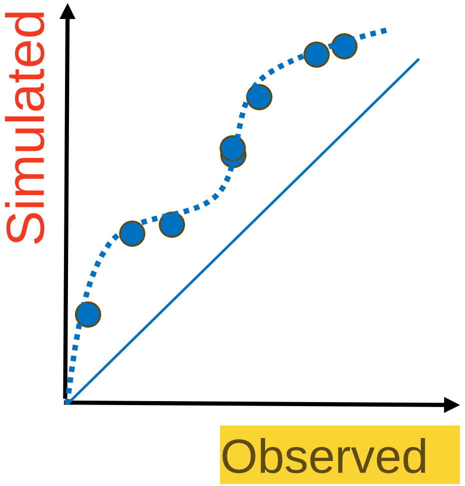


Ideal world…

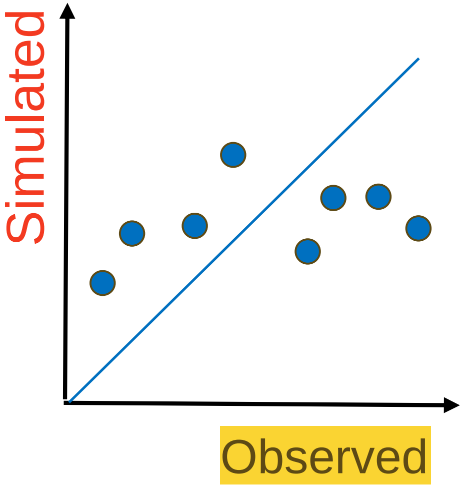




Correct relative prediction



Correct ranking



Wrong!

Colbach, N., Bertrand, M., Busset, H., Colas, F., Dugué, F., Farcy, P., Fried, G., Granger, S., Meunier, D., Munier-Jolain, N. M., Noilhan, C., Strbik, F., Gardarin, A., 2016. Uncertainty analysis and evaluation of a complex, multi-specific weed dynamics model with diverse and incomplete data sets. Environmental Modelling & Software 86, 184-203.

Evaluation (iia) Individual processes / stages

Set-up specific well-monitored experiments on key submodels

Process	What is well predicted	Limits of domain of validity	
Emergence flushes after seed rain, rain or tillage	Date, density	Emergence overestimated if seedling loss due to diseases	Colbach et al 2006 EJA
Light penetration into heterogeneous canopies	Photosynthetically active radiation in different layers	Except cloudy winter days	Munier-Jolain et al 2013 FCR
Seed movements during mouldboard ploughing	Seed depth	Except if ploughing depth > distance between plough shares	Colbach et al 2000EJA, Roger-Estrade et al 2001 STR
Seed bank survival	Order of magnitude, ranking of situations	Overestimates seed density on soil surface in permanent no-till	Colbach et al 2006 EJA

- **Experiment with key factors = input variables:**
  soil structure x burial depth x burial time x pre-burial rainfall
- **Measurements to check that target conditions were reached**
  e.g. soil temperature & moisture, soil structure, seed depth…
- **Measurements of output variables**
  e.g. weekly emergence, seed survival…

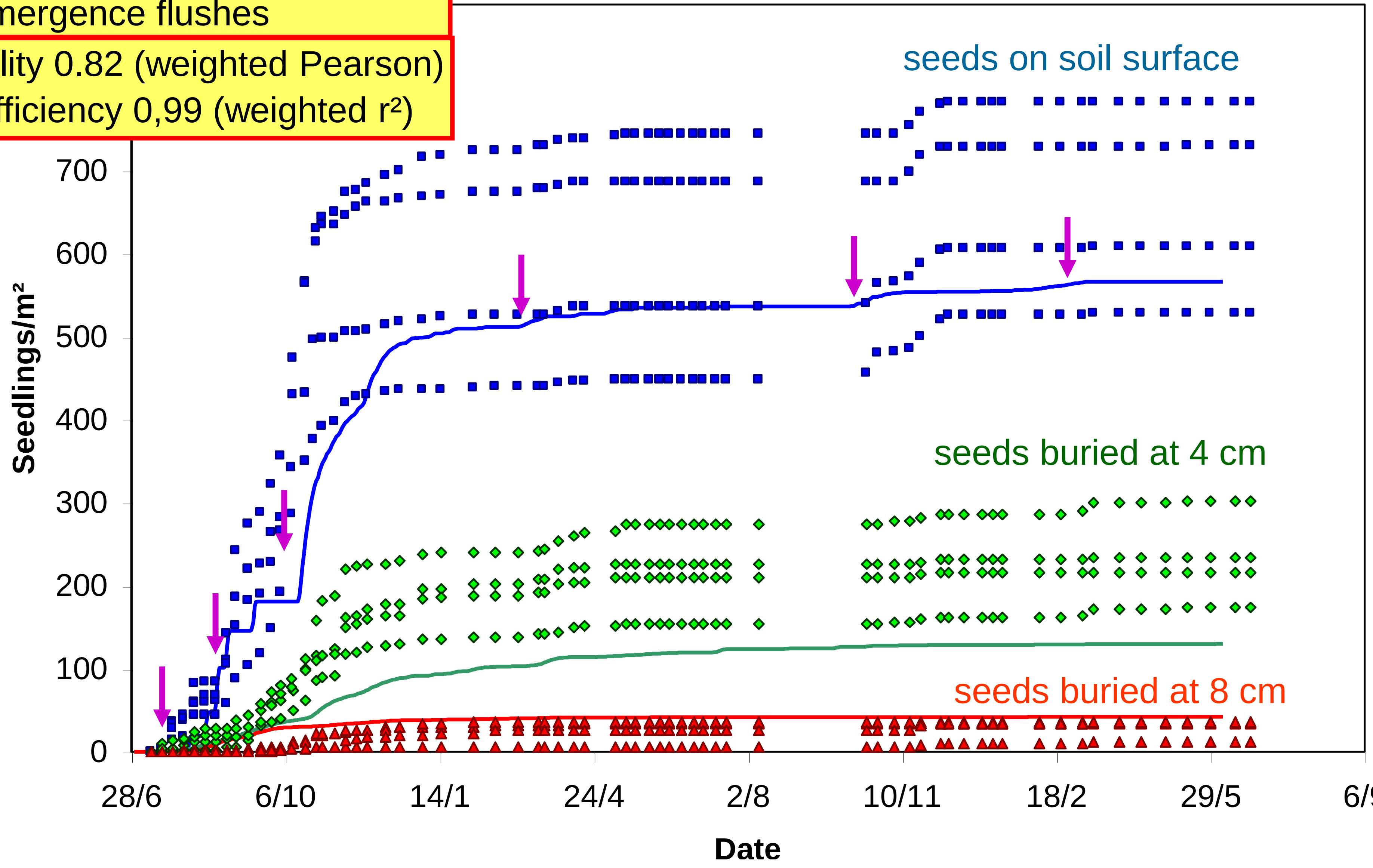
Evaluation: critical stage = emergence

Seeds buried immediately after maturity – fragmented soil structure

Timing of emergence flushes

Ranking ability 0.82 (weighted Pearson)

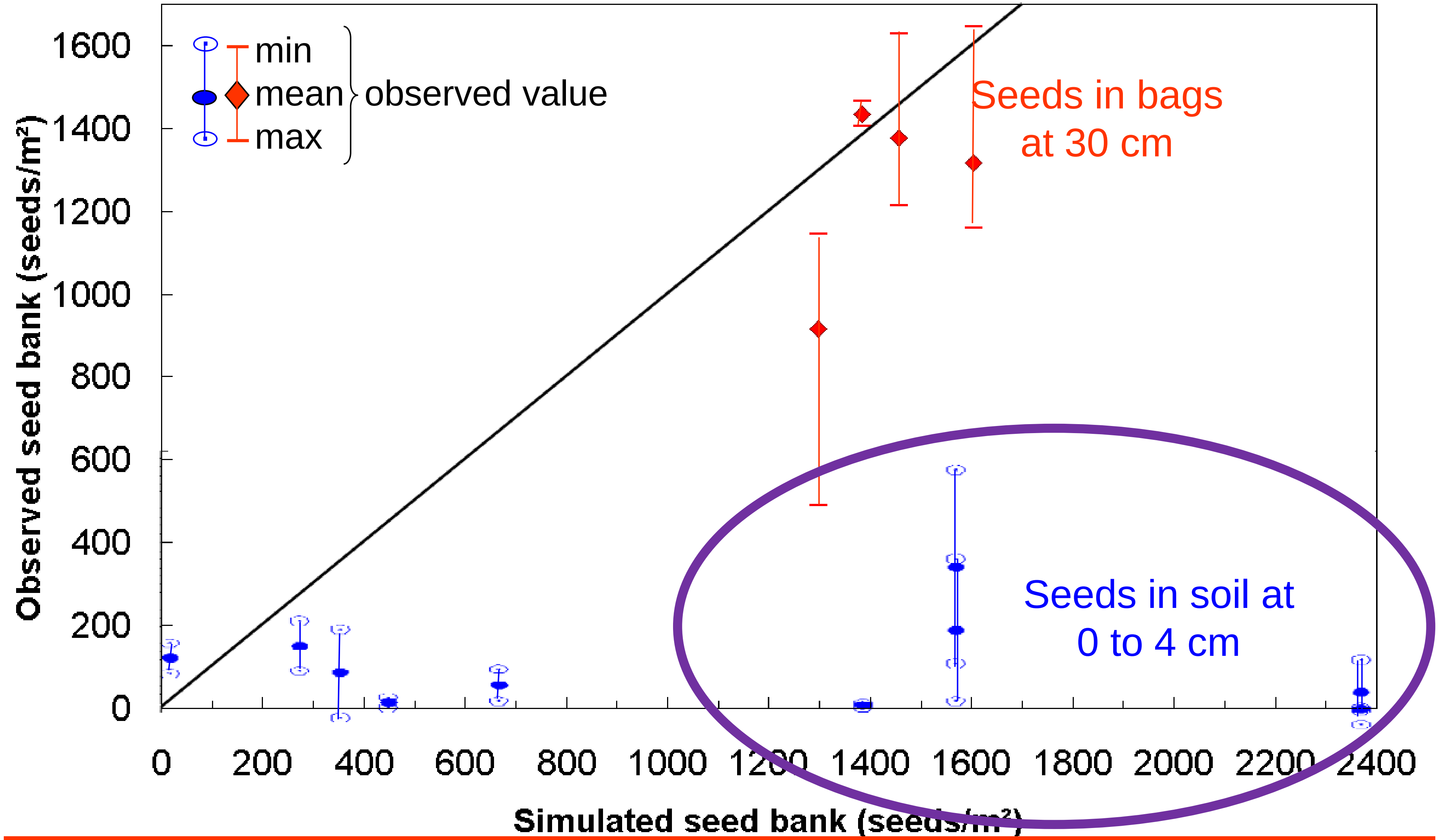
Modelling efficiency 0,99 (weighted r²)



Colbach, N., Dürr, C., Roger-Estrade, J., Caneill, J., 2005. How to model the effects of farming practices on weed emergence. Weed Res. 45, 2-17.

INRAE

Prediction of surviving seed bank



Missing process = mortality process for seeds close to surface

Colbach, N., Dürr, C., Roger-Estrade, J., Caneill, J., 2005. How to model the effects of farming practices on weed emergence. Weed Res. 45, 2-17.

Evaluation (iia) Individual processes / stages

Set-up specific well-monitored experiments on key submodels

Process	What is well predicted	Limits of domain of validity	
Emergence flushes after seed rain, rain or tillage	Date, density	Emergence overestimated if seedling loss due to diseases	Colbach et al 2006 EJA
Light penetration into heterogeneous canopies	Photosynthetically active radiation in different layers	Except cloudy winter days	Munier-Jolain et al 2013 FCR
Seed movements during mouldboard ploughing	Seed depth	Except if ploughing depth > distance between plough shares	Colbach et al 2000EJA, Roger-Estrade et al 2001 STR
Seed bank survival	Order of magnitude, ranking of situations	Overestimates seed density on soil surface in permanent no-till	Colbach et al 2006 EJA

- **Experiment with key factors = input variables:**
  soil texture x soil structure x ploughing depth x plough options x initial seed position
- **Measurements to check that target conditions were reached**
  e.g. soil structure, tillage depth …
- **Measurements of output variables**
  e.g. seed depth, lateral seed displacement, soil movements, soil fragmentation …

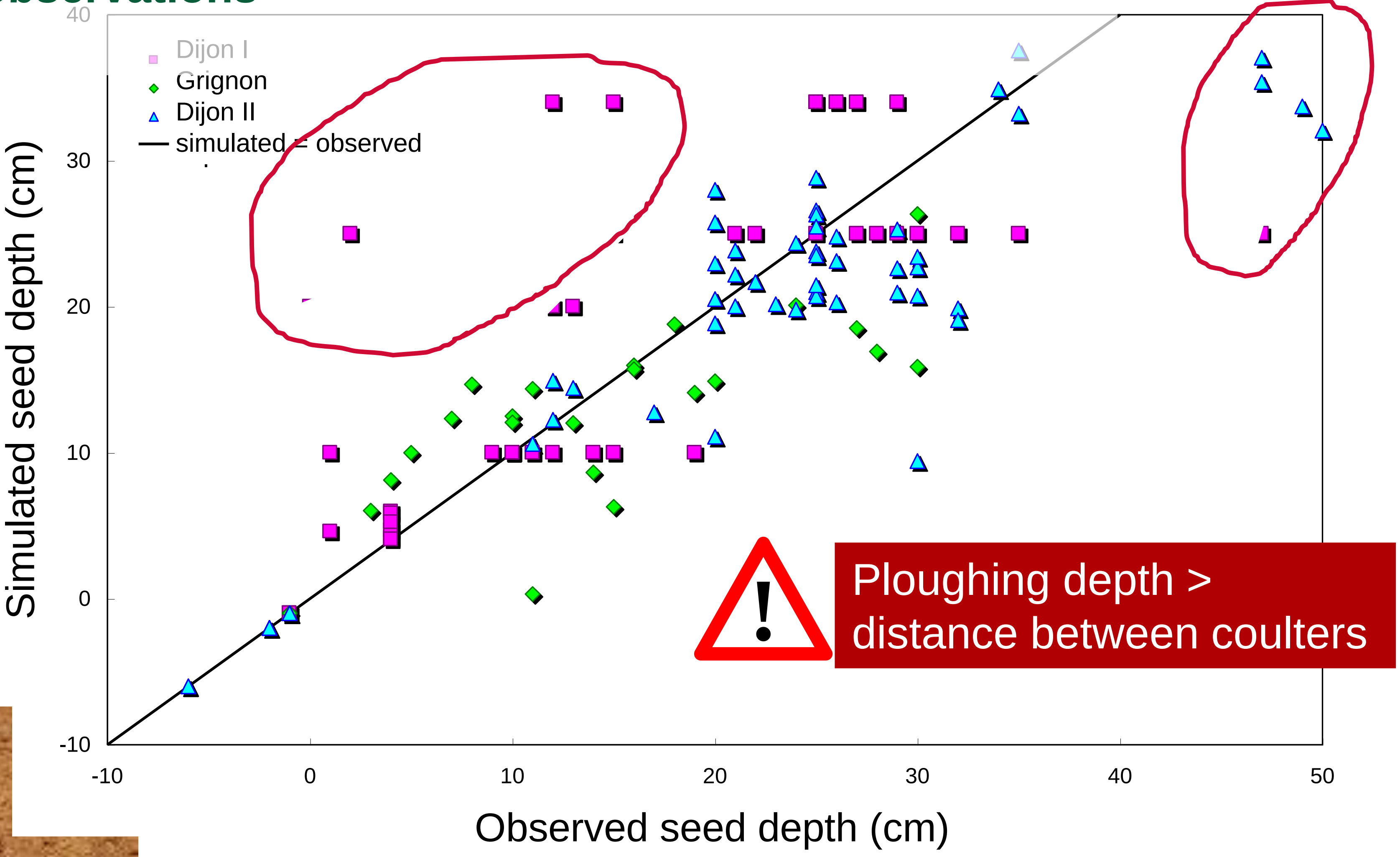
Evaluate ploughing submodel

Set-up specific well-monitored experiments on key submodels

- **Compare predictions vs observations**

  e.g. seed depth

Visual analysis



Colbach et al 2000 EJA, Roger-Estrade et (al 2001 STR)

Evaluate ploughing submodel

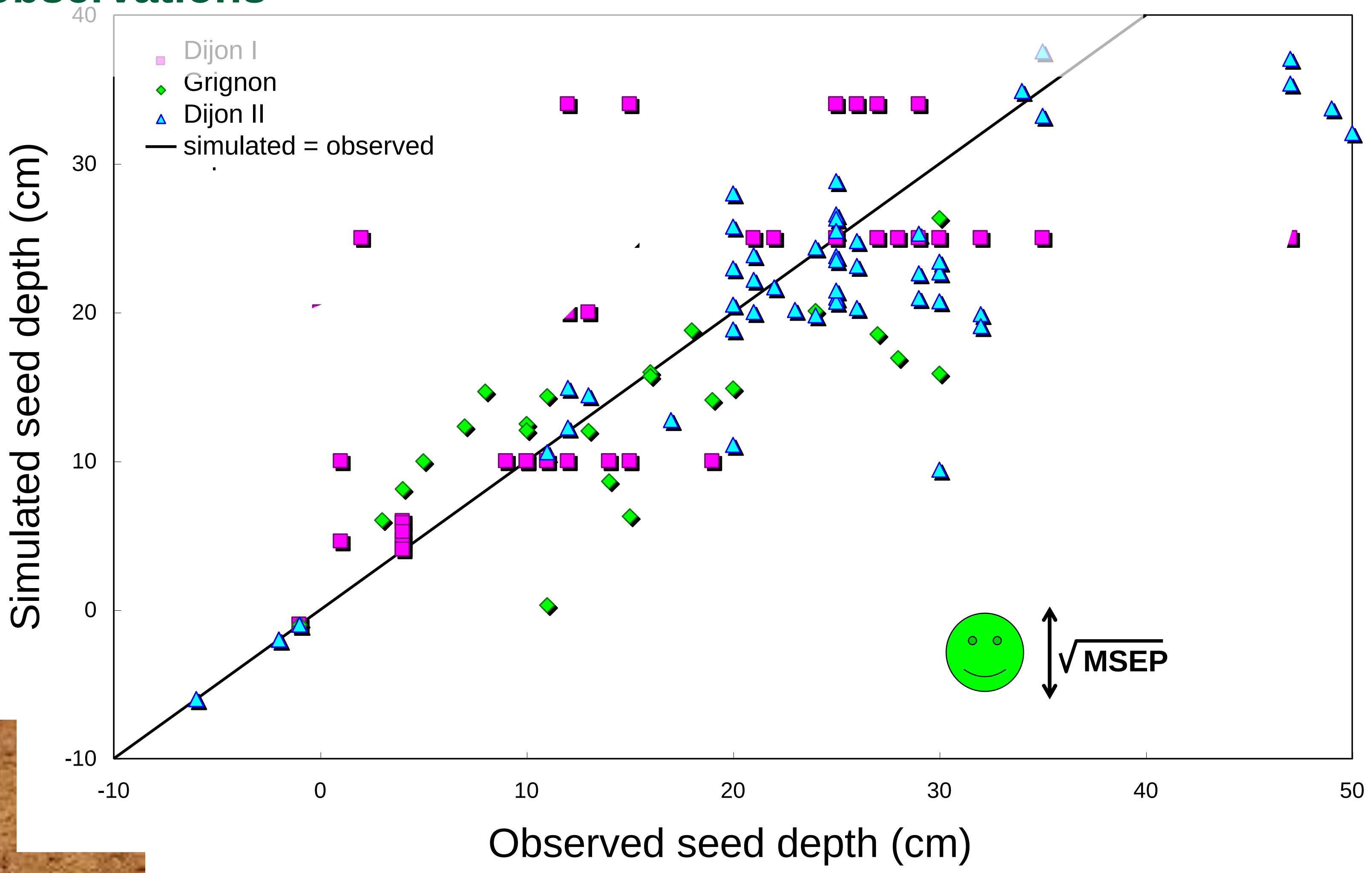
Set-up specific well-monitored experiments on key submodels

- **Compare predictions vs observations**

e.g. seed depth

Visual analysis

Prediction error



Colbach et al 2000 EJA, Roger-Estrade et (al 2001 STR)

Evaluate ploughing submodel

Set-up specific well-monitored experiments on key submodels

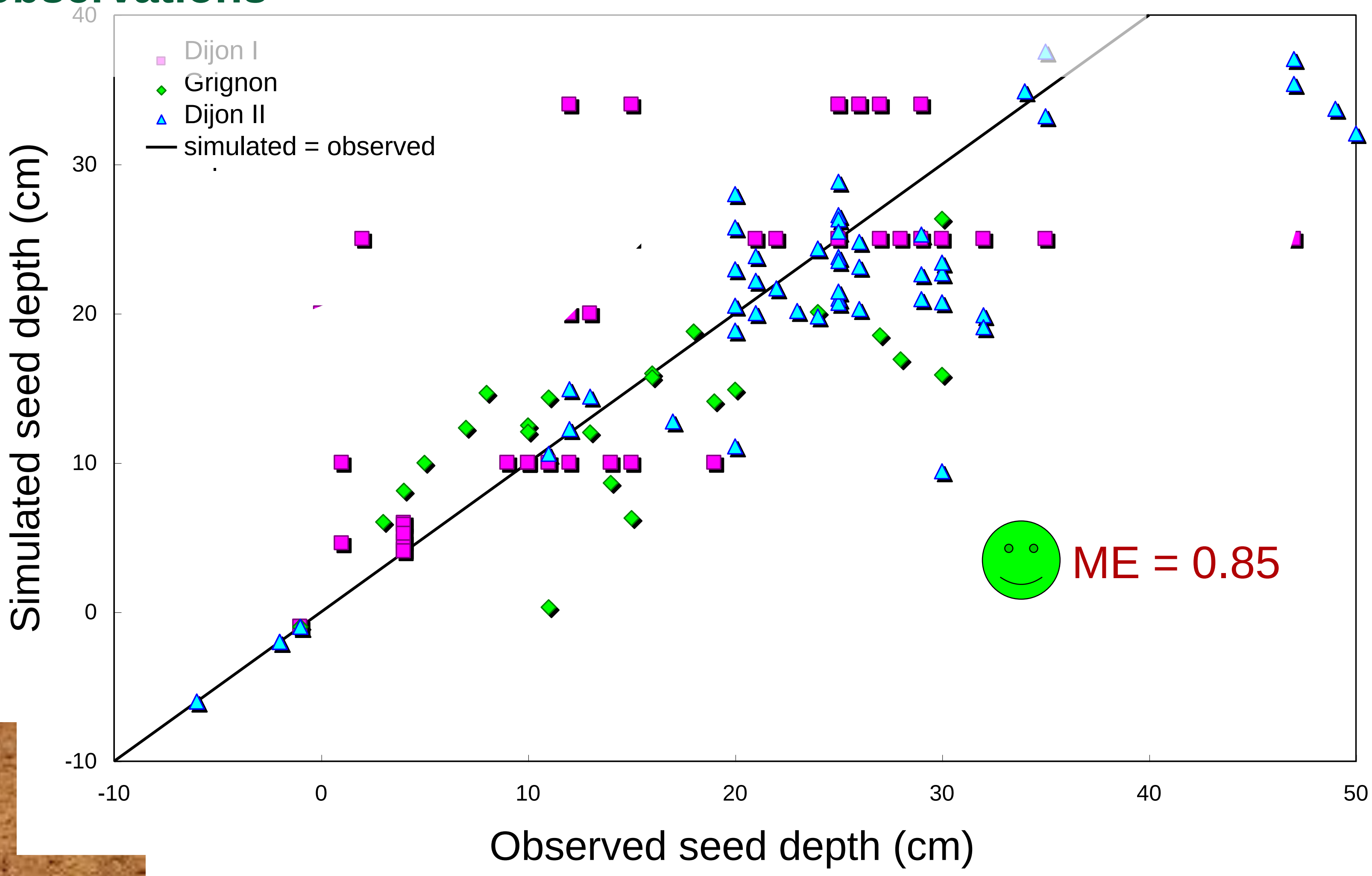
- **Compare predictions vs observations**

e.g. seed depth

Visual analysis

Prediction error

Modelling efficiency

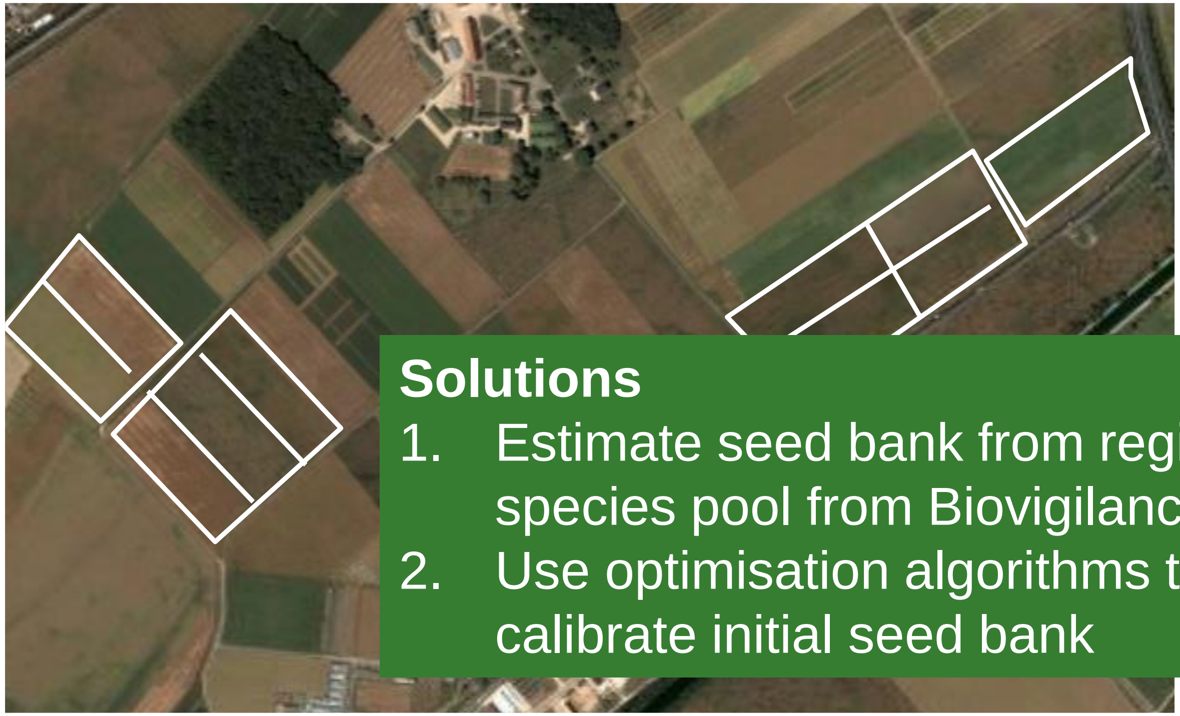


Colbach et al 2000 EJA, Roger-Estrade et (al 2001 STR)

Evaluation (iib) Evaluate multi-annual dynamics

- With existing well-documented multiannual cropping system trials
  - **Main key drivers = input variables**
    rotation x tillage strategies x herbicide intensity x …
  - **Measurements of initial condition**
    e.g. weed seed bank …
  - **Measurements of output variables several times / year over many years**
    e.g. weed density, biomass, seed bank … crop biomass, yield …

Colbach et al 2016 EMS
Maillot, Forestier, Colbach … in prep



3 locations

- Dijon-Epoisses
- Versailles-Lacage
- Toulouse-Auzeville

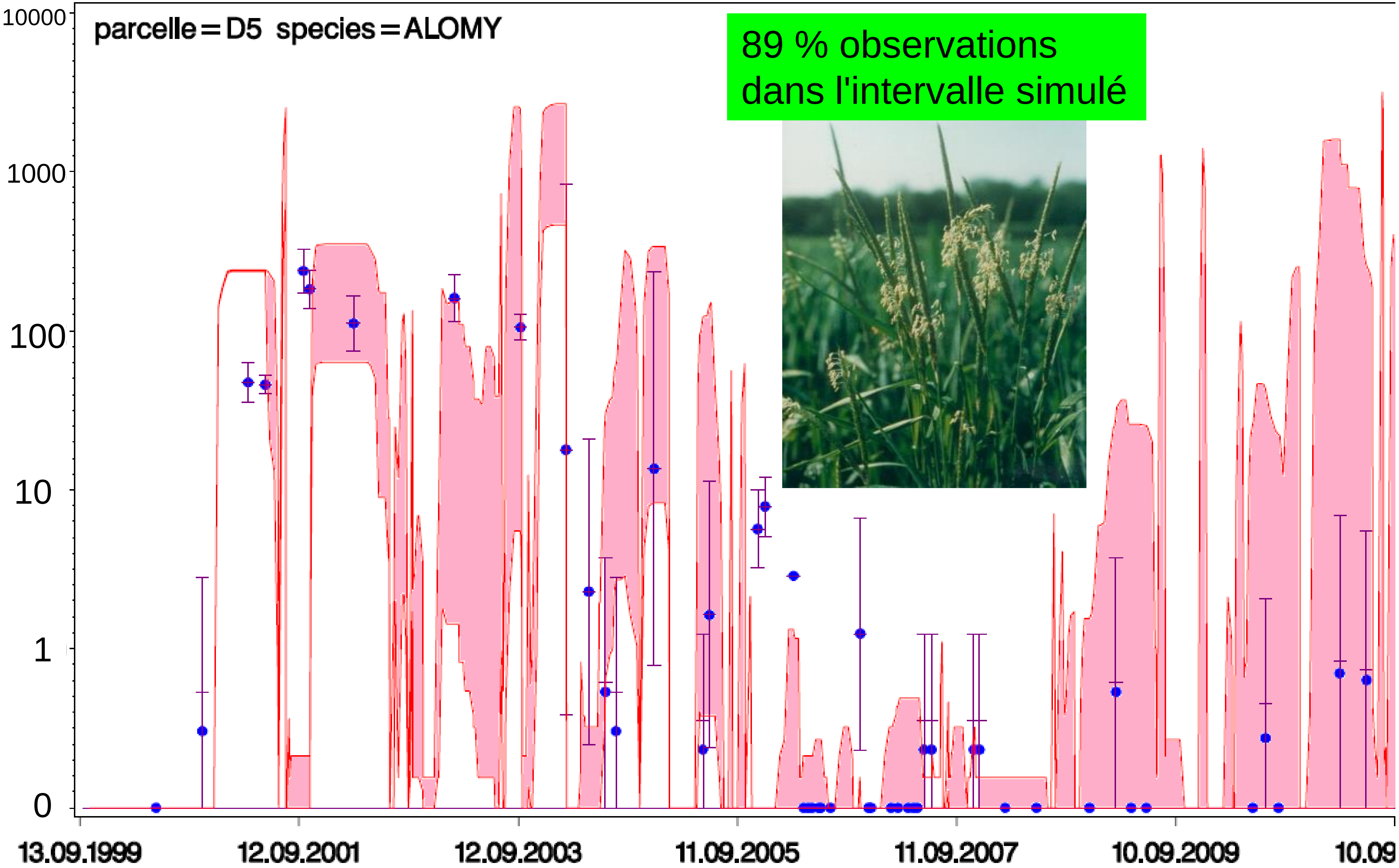
No initial seed bank measurement

Difficult to conclude
if prediction ≠ observation

Solutions

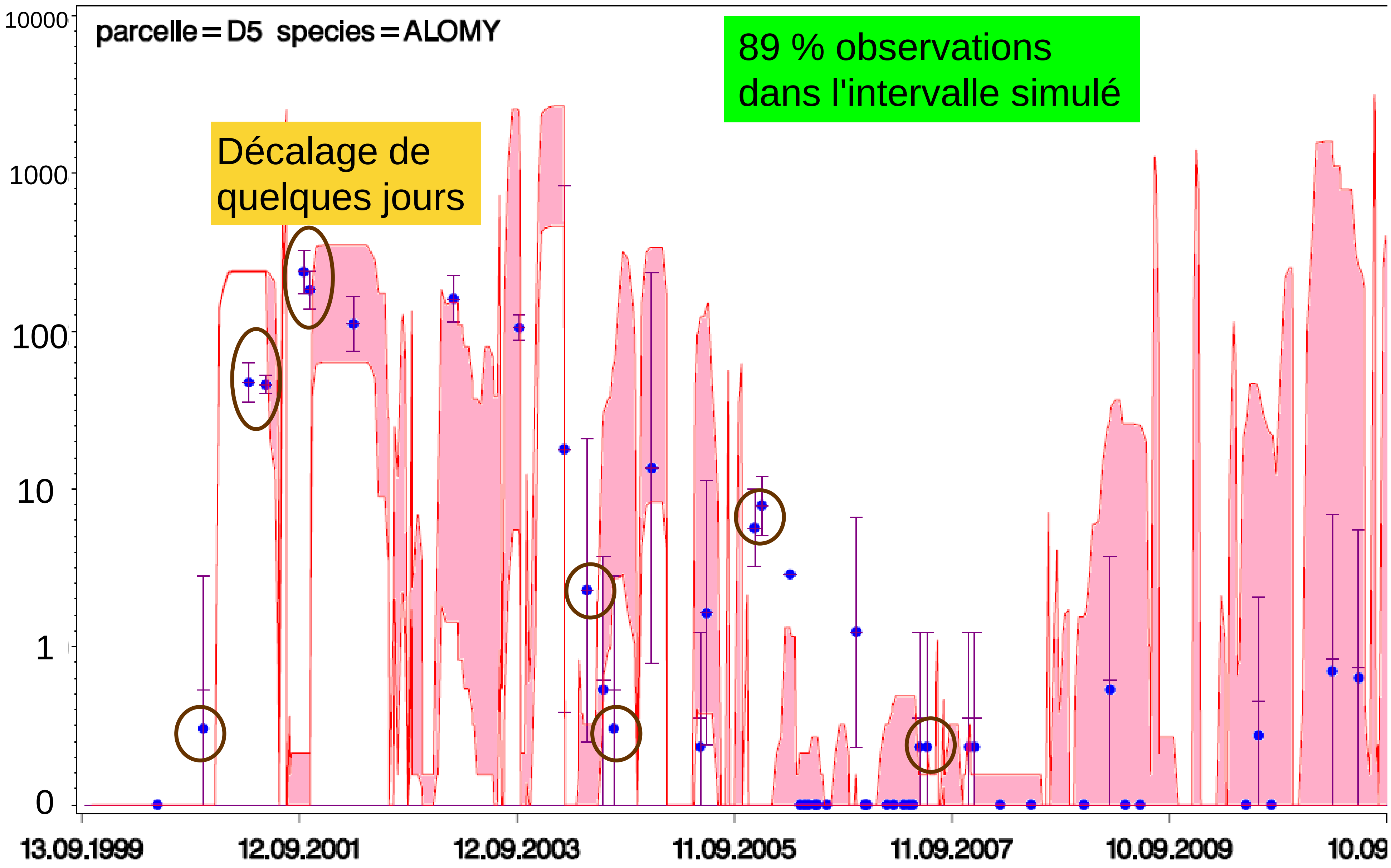
1. Estimate seed bank from regional species pool from Biovigilance-Flore
2. Use optimisation algorithms to calibrate initial seed bank

Dynamique par espèce adventice

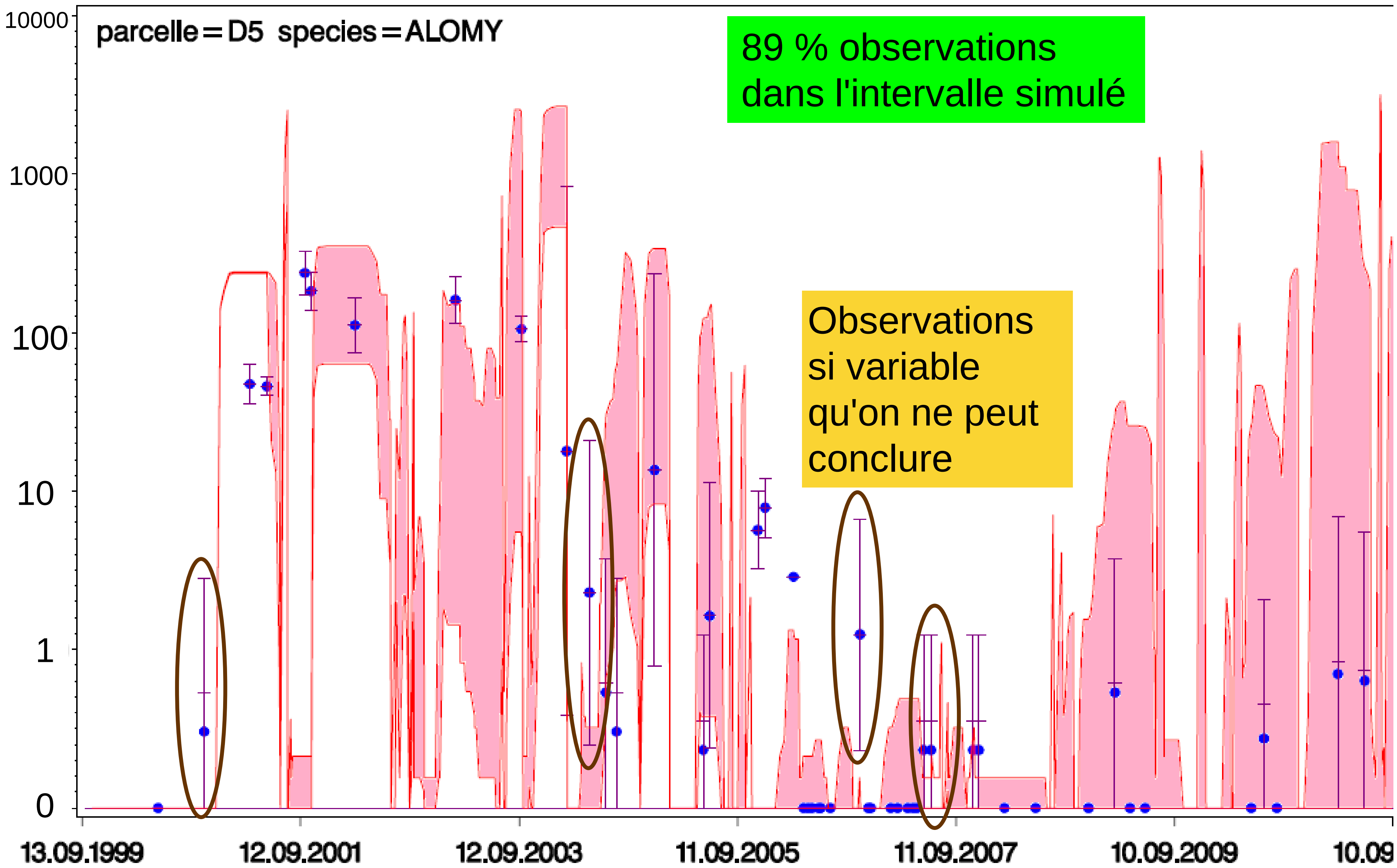


89 % observations dans l'intervalle simulé

Dynamique par espèce adventice



Dynamique par espèce adventice



Evaluation – FLORSYS – Synthesis Dijon trial

Variable	Species scale	Temporal scale	Relative bias (%) [§]	Relative prediction error (%) [$]	Proportion of correctly predicted observations				
					Average values		Daily dynamics [x]		
					Prop [&]	In terms of	Correct	Over-estimated	Under-estimated
Crop yield (t/ha)	Species	Day	-8%	110%	0.42	Absolute values			
Crop biomass (g/m^2)	Species	Day	-2%	~0	0.59	Rank			
Weed seed bank (seeds /m^2)	Sum	Day	15%	~0	-0.08	Rank			
	Species	Day	7%	74%	0.51	Rank			
Weed biomass (above-ground) (g/m^2)	Sum	Multiannual mean	206%	~0	0.13	Rank			
	Species	Multiannual mean	17%	~0	0.55	Rank			
	Sum	Day					0.24	0.68	0.08
	Species	Day					0.79	0.14	0.07
Weed plants /m^2	Sum	Multiannual mean	154%	228%	0.65	Relative values			
	Species	Multiannual mean	17%	148%	0.67	Rank			
	Sum	Day					0.34	0.55	0.11
	Species	Day					0.86	0.10	0.04

- Ranks better than predict absolute values
- Predicts better per species than summed over all species
- Predicts better per rotation than per day

Consistent with model objective = rank cropping systems

Evaluation of FLORSYS

Advice for using the model

- Ranks better than predict absolute values
- Predicts better per species than summed over all species
- Predicts better per rotation than per day

Consistent with model objective = rank cropping systems

Ideas for improving the model

- Total weed densities underestimated
  → add new weed species types
- Seed bank overestimated in direct-sown fields
  → introduce seed predation
- Above-ground biomass overestimated, yield of nitrophilic crops overestimated
  → introduce N competition and below-ground biomass
- Weeds flower too early in Southern France
  → introduce photoperiod effect on phenology

Colbach, N., Bertrand, M., Busset, H., Colas, F., Dugué, F., Farcy, P., Fried, G., Granger, S., Meunier, D., Munier-Jolain, N. M., Noilhan, C., Strbik, F., Gardarin, A., 2016. Uncertainty analysis and evaluation of a complex, multi-specific weed dynamics model with diverse and incomplete data sets. Environmental Modelling & Software 86, 184-203.

Plan

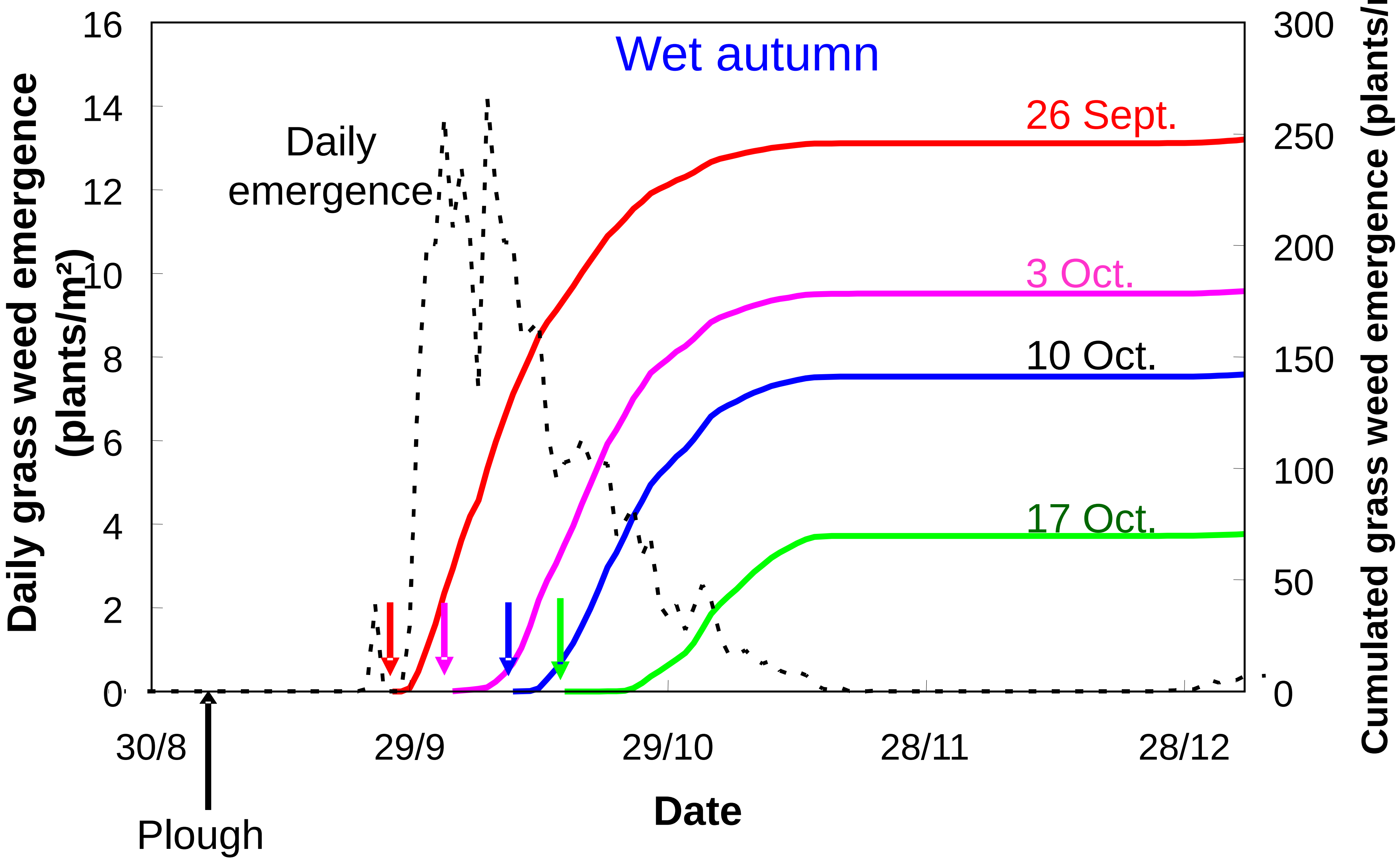
1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. Effets des techniques culturales
4. Le reste: indicateurs, paysage
5. Évaluation du modèle
6. **Examples d'utilisation**
7. Comment faire tourner le modèle?

Today's presentation

1. Model objectives & structure
2. Details of life cycle
3. Effects of management techniques
4. What else? Indicators, landscape
5. Model evaluation
6. **Examples of model use**
7. How to run the model?

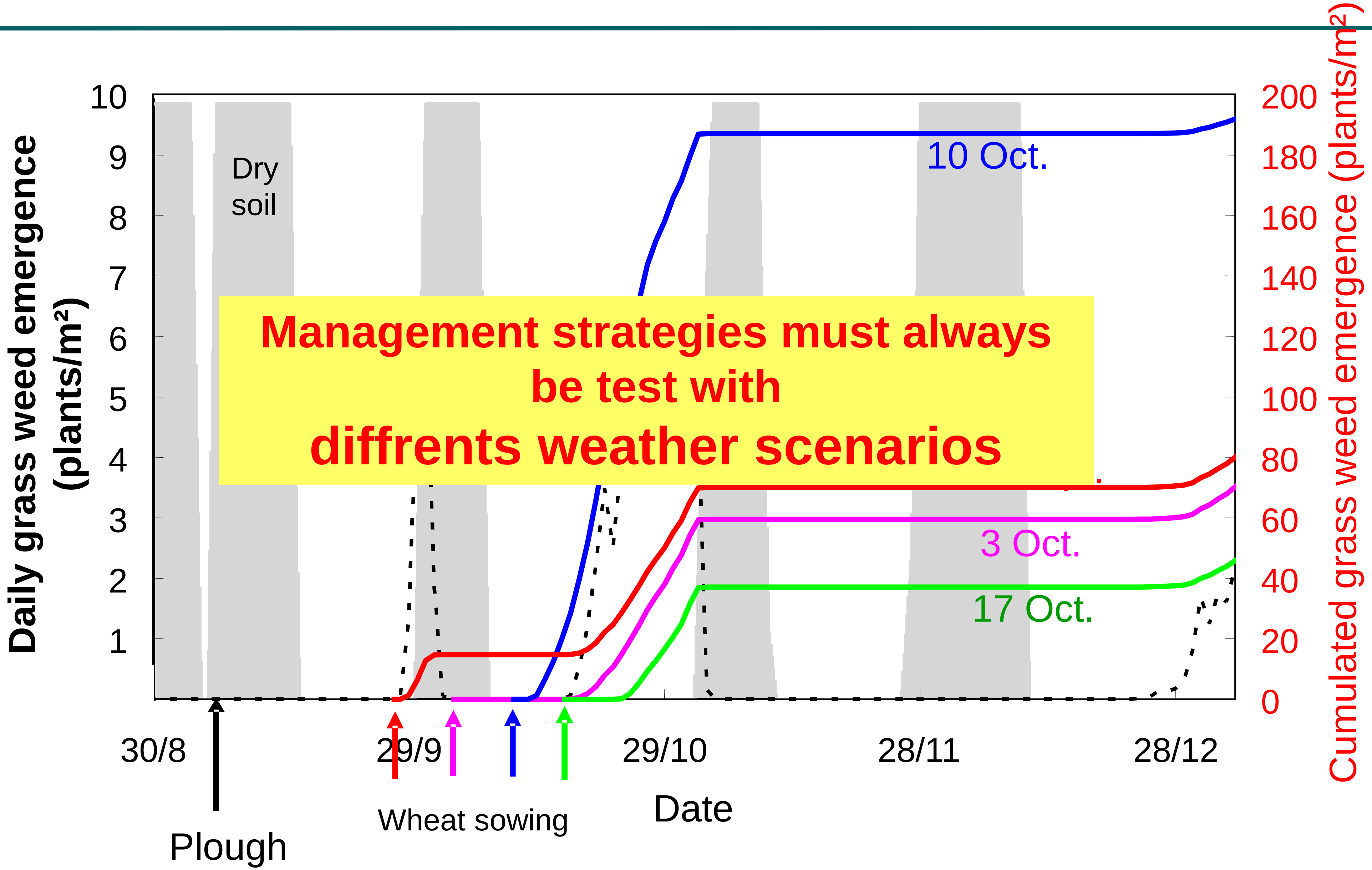
- **Optimize one technique at annual scale**
- Optimize one technique in the short term
- Evaluate farmers' practices at the cropping-system scale
- Evaluate innovative cropping systems
- Work with farmers

Optimise the sowing date of winter wheat



Colbach N., Dürr C., Roger-Estrade J. & Caneill J. (2005) How to model the effects of farming practices on weed emergence. Weed Research 45, 2-17

Optimise the sowing date of winter wheat



Management strategies must always be test with diffrents weather scenarios

Colbach N., Dürr C., Roger-Estrade J. & Caneill J. (2005) How to model the effects of farming practices on weed emergence. Weed Research 45, 2-17

Optimise the sowing date of winter wheat

Initial sowing date (26 Sept)	Effect of delaying wheat sowing by 1 week			
	Northern France		Burgundy	
	% weather repetitions where weed emergence		% weather repetitions where weed emergence	
	Decreases by ≥ 10%	Increases by ≥ 10%	Decreases by ≥ 10%	Increases by ≥ 10%
3 Oct.	7	7	14	14
10 Oct.	7	0	0	7
17 Oct.	7	7	0	7
24 Oct.	14	7	50	0
31 Oct.	57	0	64	0
7 Nov.	50	0	71	0

Colbach N., Biju-Duval L., Gardarin A., Granger S., Guyot S. H. M., Mézière D., Munier-Jolain N. M., Petit S., 2014 - The role of models for multicriteria evaluation and multiobjective design of cropping systems for managing weeds. *Weed Research, 54, 541–555.*

Plan

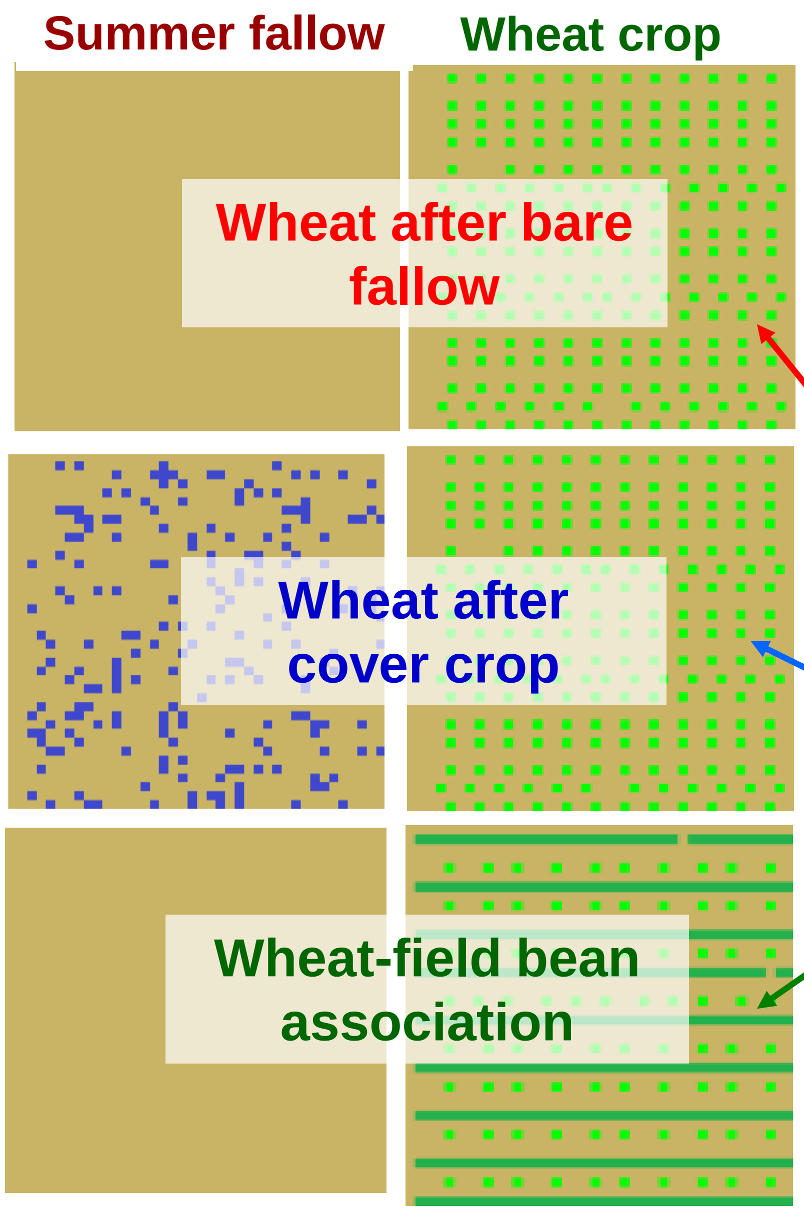
1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. Effets des techniques culturales
4. Le reste: indicateurs, paysage
5. Évaluation du modèle
6. **Examples d'utilisation**
7. Comment faire tourner le modèle?

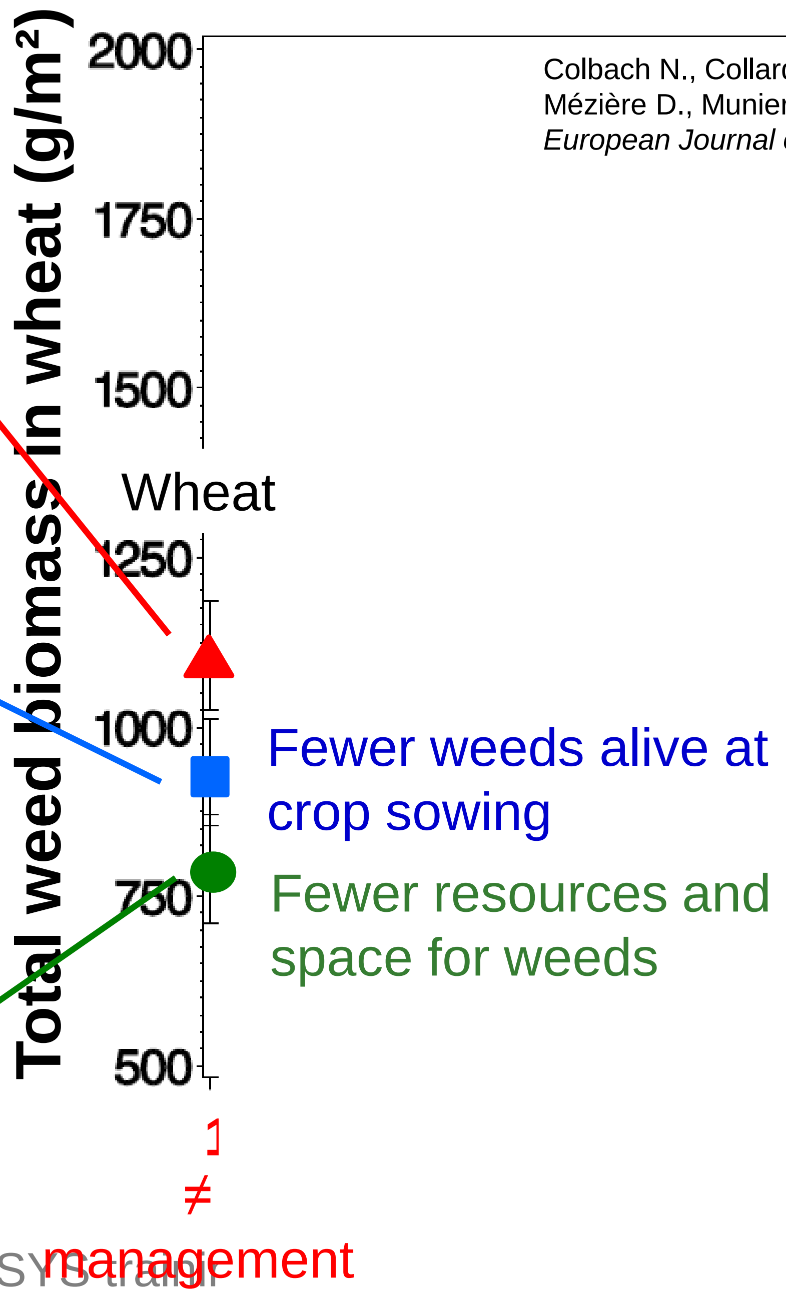
Today's presentation

1. Model objectives & structure
2. Details of life cycle
3. Effects of management techniques
4. What else? Indicators, landscape
5. Model evaluation
6. **Examples of model use**
7. How to run the model?

- Optimize one technique at annual scale
- **Optimize one technique in the short term**
- Evaluate farmers' practices at the cropping-system scale
- Evaluate innovative cropping systems
- Work with farmers

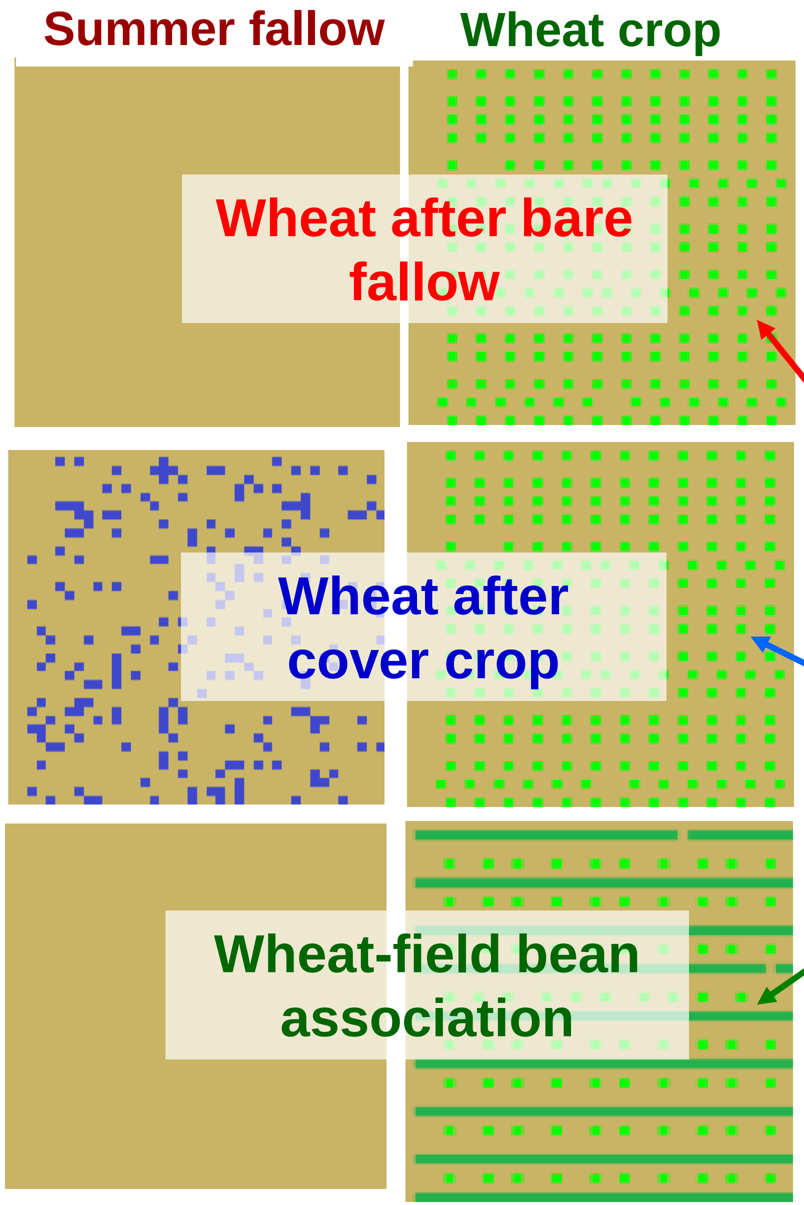
Optimise wheat sowing pattern

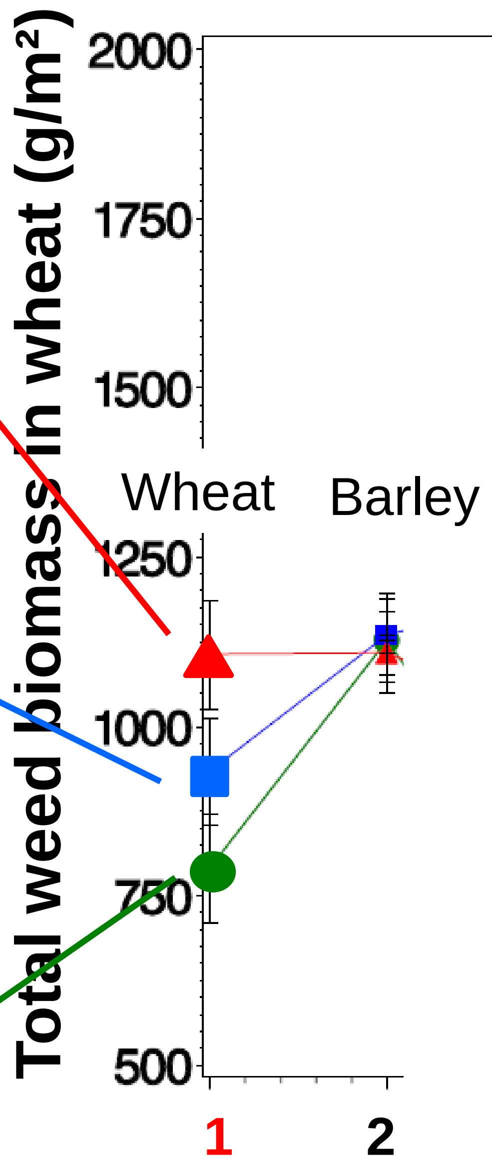




Colbach N., Collard A., Guyot S. H. M., Mézière D., Munier-Jolain N. M., 2014 -. *European Journal of Agronomy, 53, 74-89.*

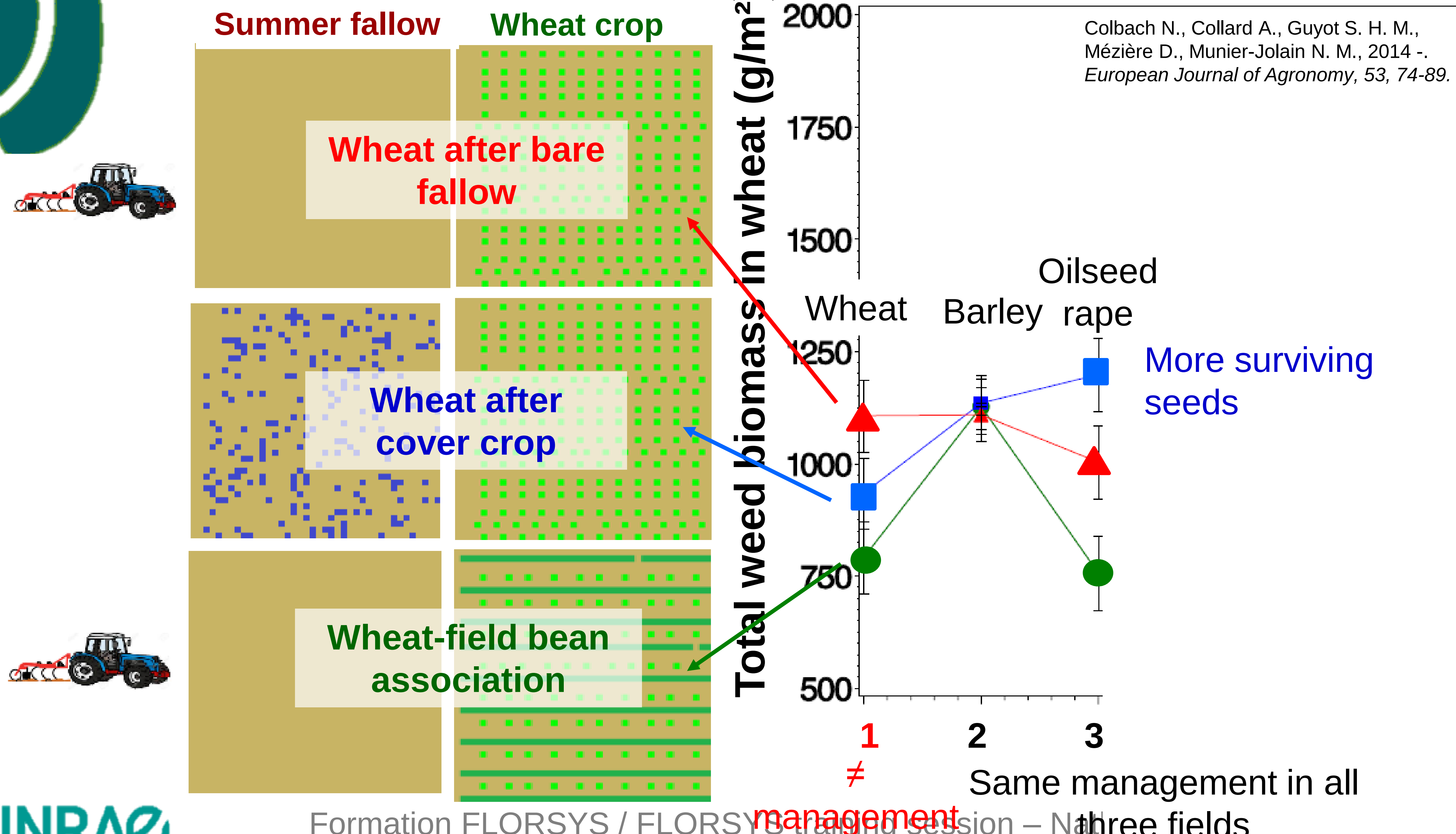
Optimise wheat sowing pattern



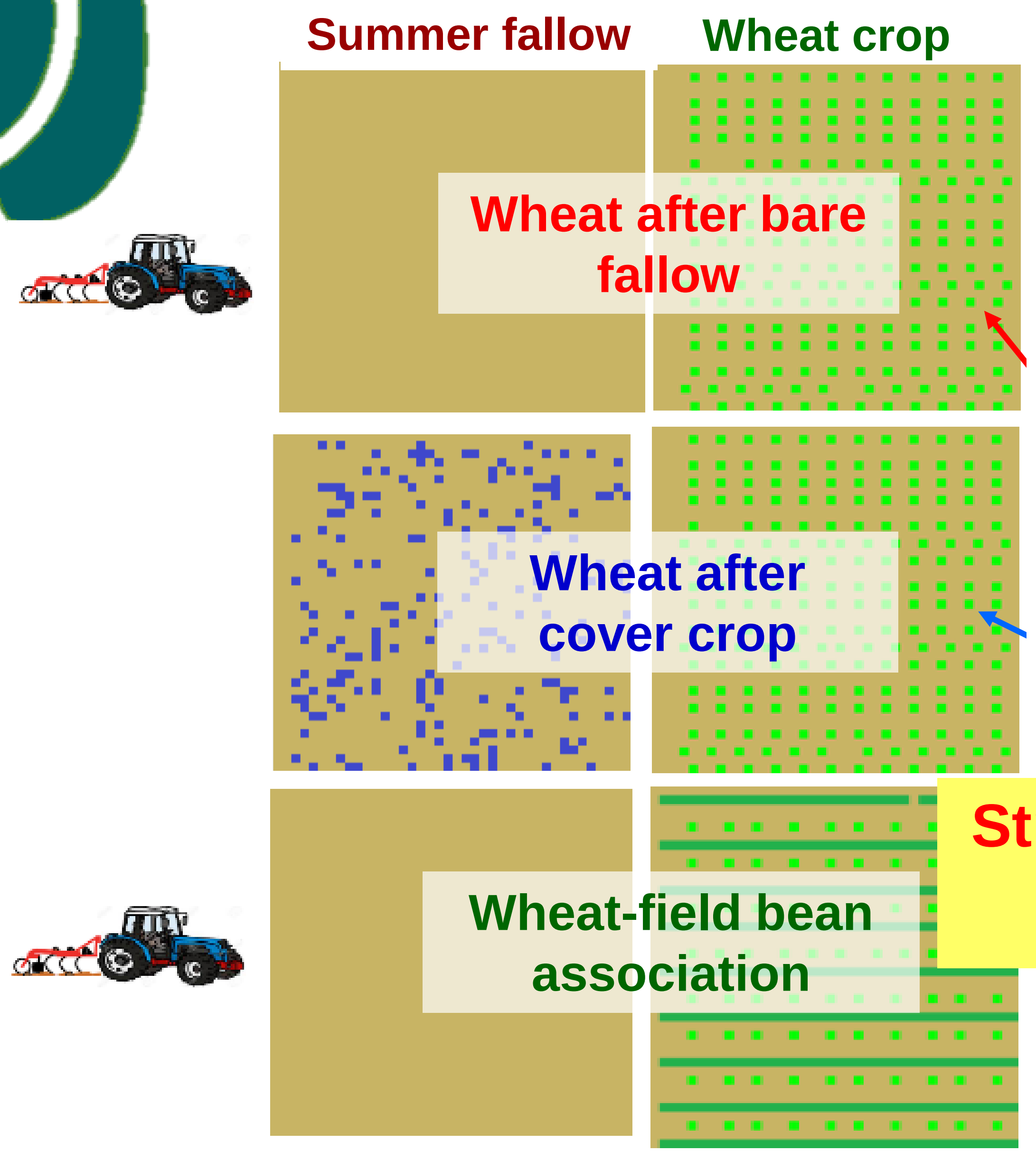


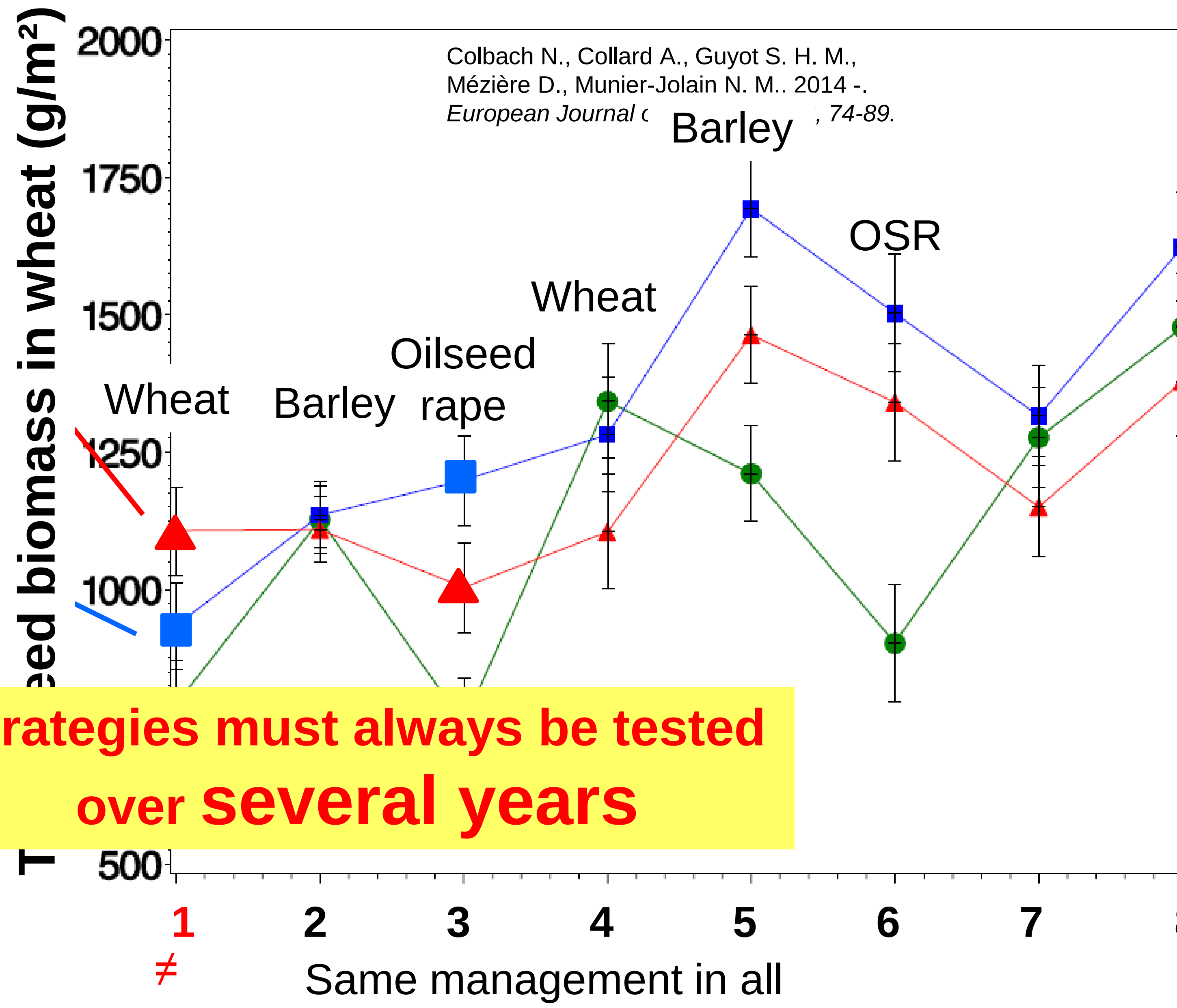
Colbach N., Collard A., Guyot S. H. M., Mézière D., Munier-Jolain N. M., 2014 -. *European Journal of Agronomy, 53, 74-89.*

Optimise wheat sowing pattern



Optimise wheat sowing pattern





Strategies must always be tested over several years

Plan

1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. Effets des techniques culturales
4. Le reste: indicateurs, paysage
5. Évaluation du modèle
6. **Examples d'utilisation**
7. Comment faire tourner le modèle?

Today's presentation

1. Model objectives & structure
2. Details of life cycle
3. Effects of management techniques
4. What else? Indicators, landscape
5. Model evaluation
6. **Examples of model use**
7. How to run the model?

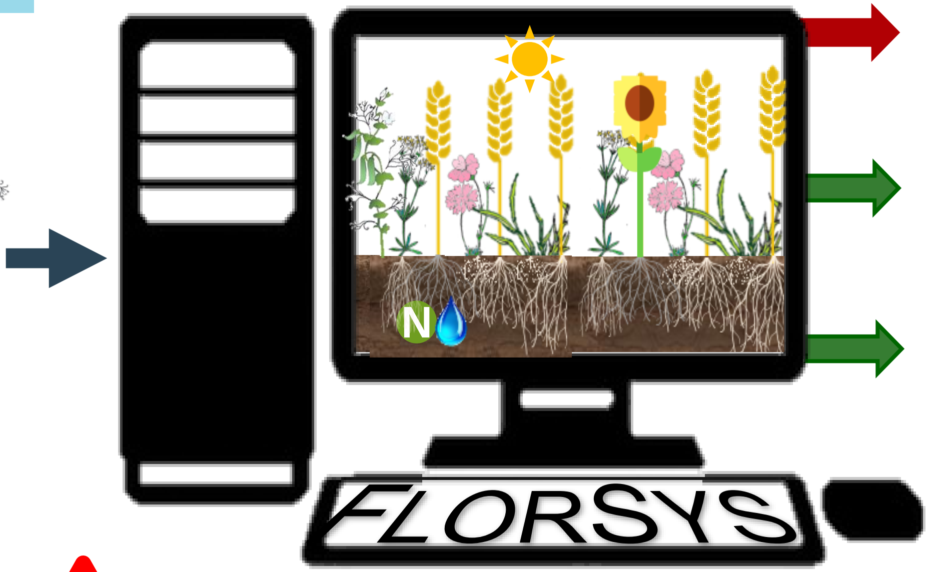
- Optimize one technique at annual scale
- Optimize one technique in the short term
- **Evaluate farmers' practices at the cropping-system scale**
- Evaluate innovative cropping systems
- Work with farmers

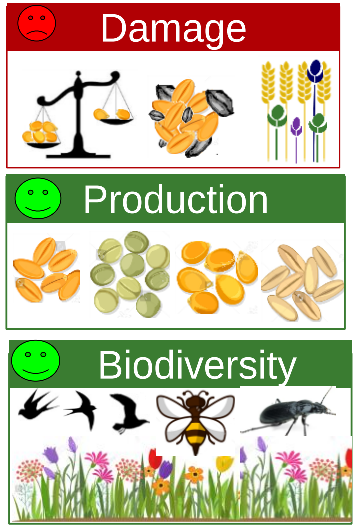
Evaluate farmers' practices

7 regions

25 annual weed species

275 cropping systems



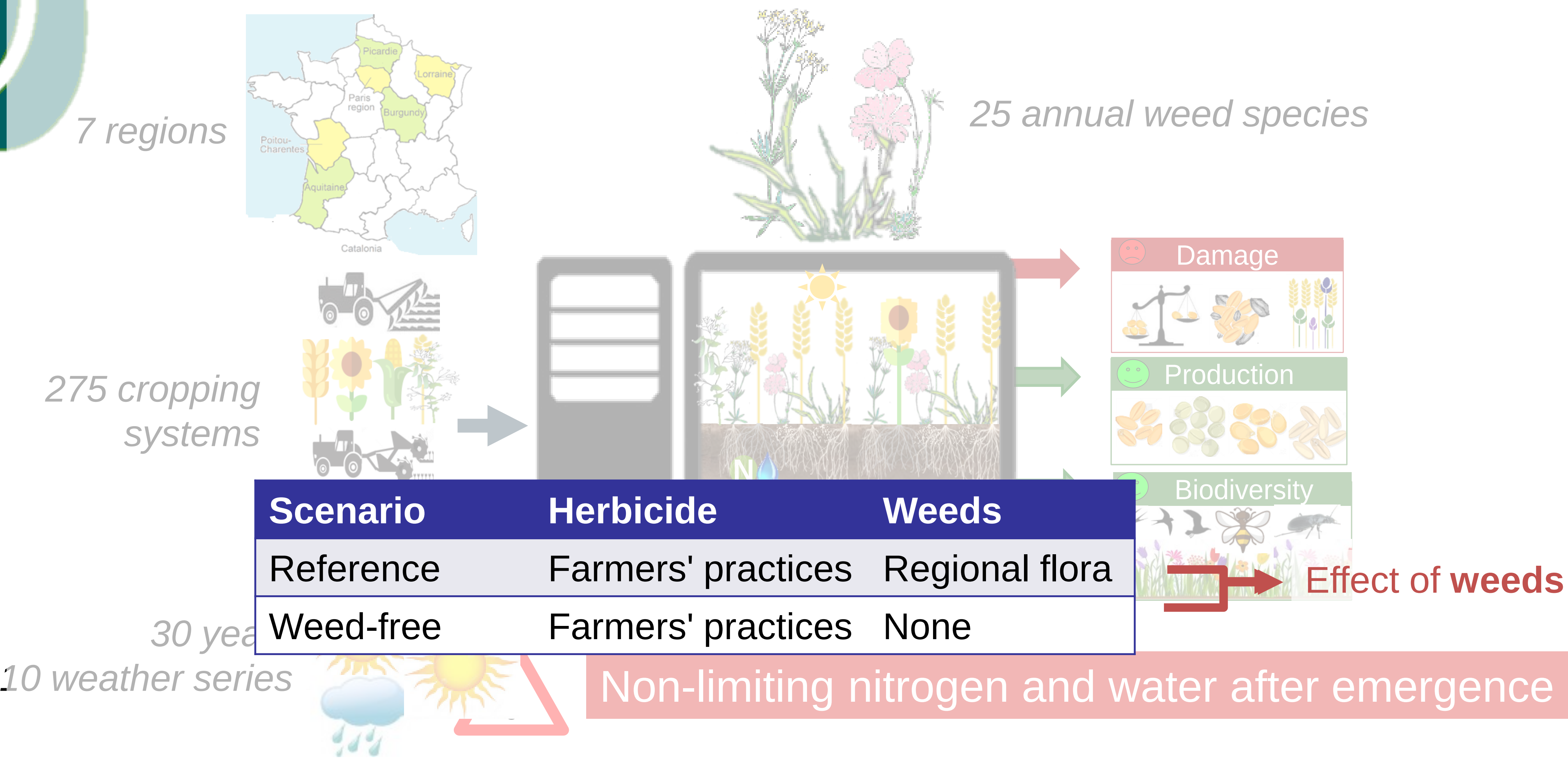


30 years
10 weather series

Non-limiting nitrogen and water after emergence

Colbach et al (2018) Eur J Agron, Colbach et al (2019) Field Crops Res

Evaluate farmers' practices

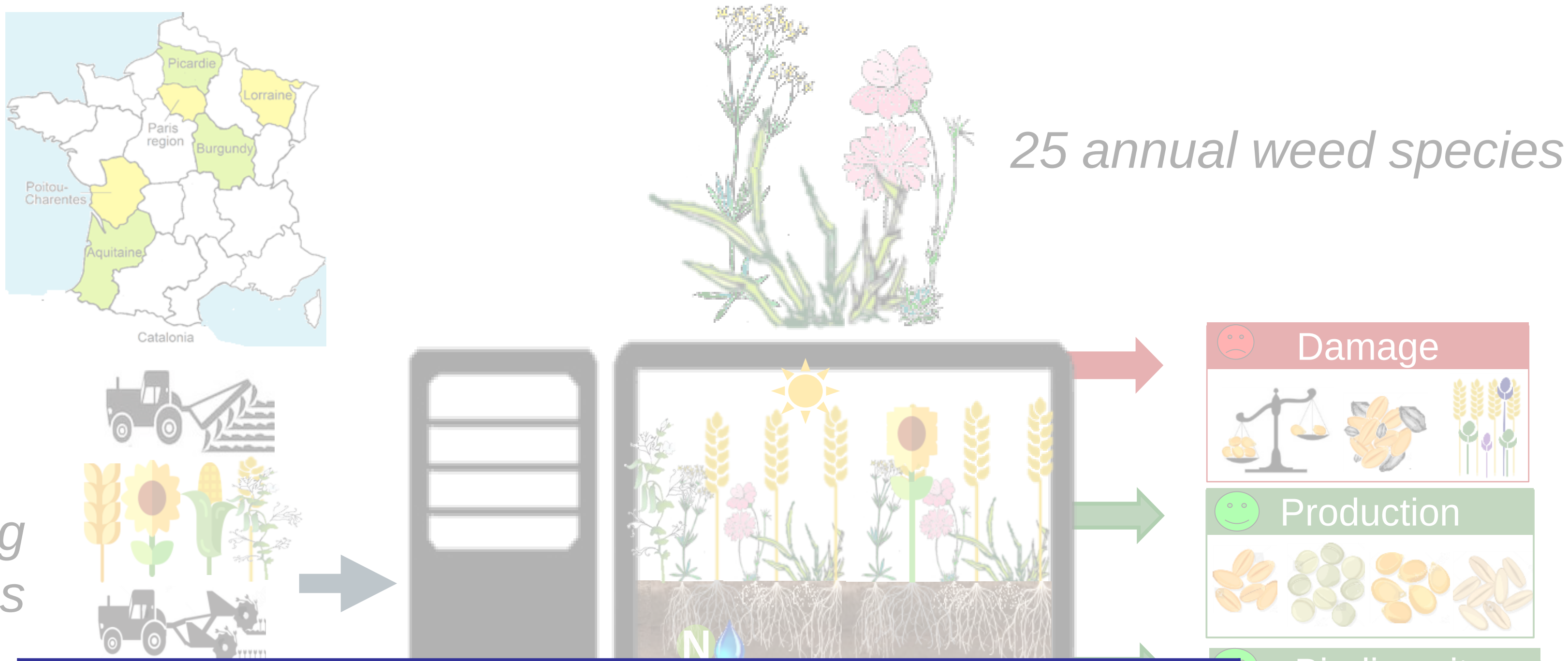


Scenario	Herbicide	Weeds
Reference	Farmers' practices	Regional flora
Weed-free	Farmers' practices	None

Non-limiting nitrogen and water after emergence

Colbach et al (2018) Eur J Agron, Colbach et al (2019) Field Crops Res

Evaluate farmers' practices



30 yea…
10 weather seri…

…ater after emergence

Scenario	Herbicide	Weeds
Reference	Farmers' practices	Regional flora
Weed-free	Farmers' practices	None
Herbicide-free	None	Regional flora

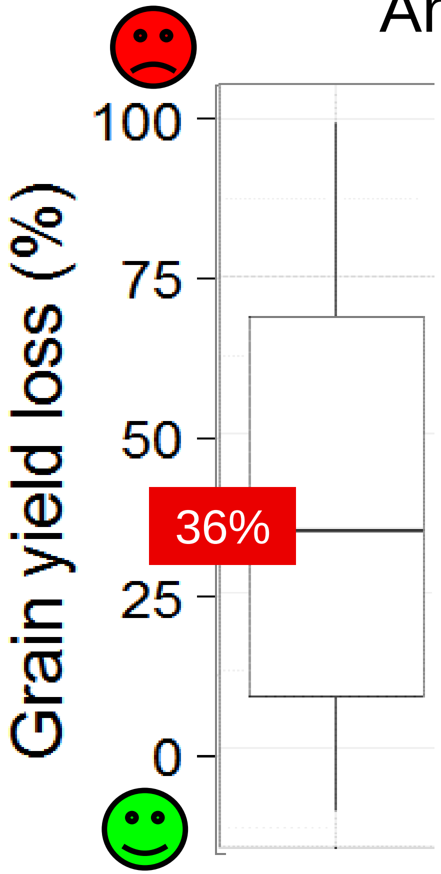
Effect of **weeds**

Effect of **herbicides**

Colbach et al (2018) Eur J Agron, Colbach et al (2019) Field Crops Res

Weeds reduce crop production

Annual scale



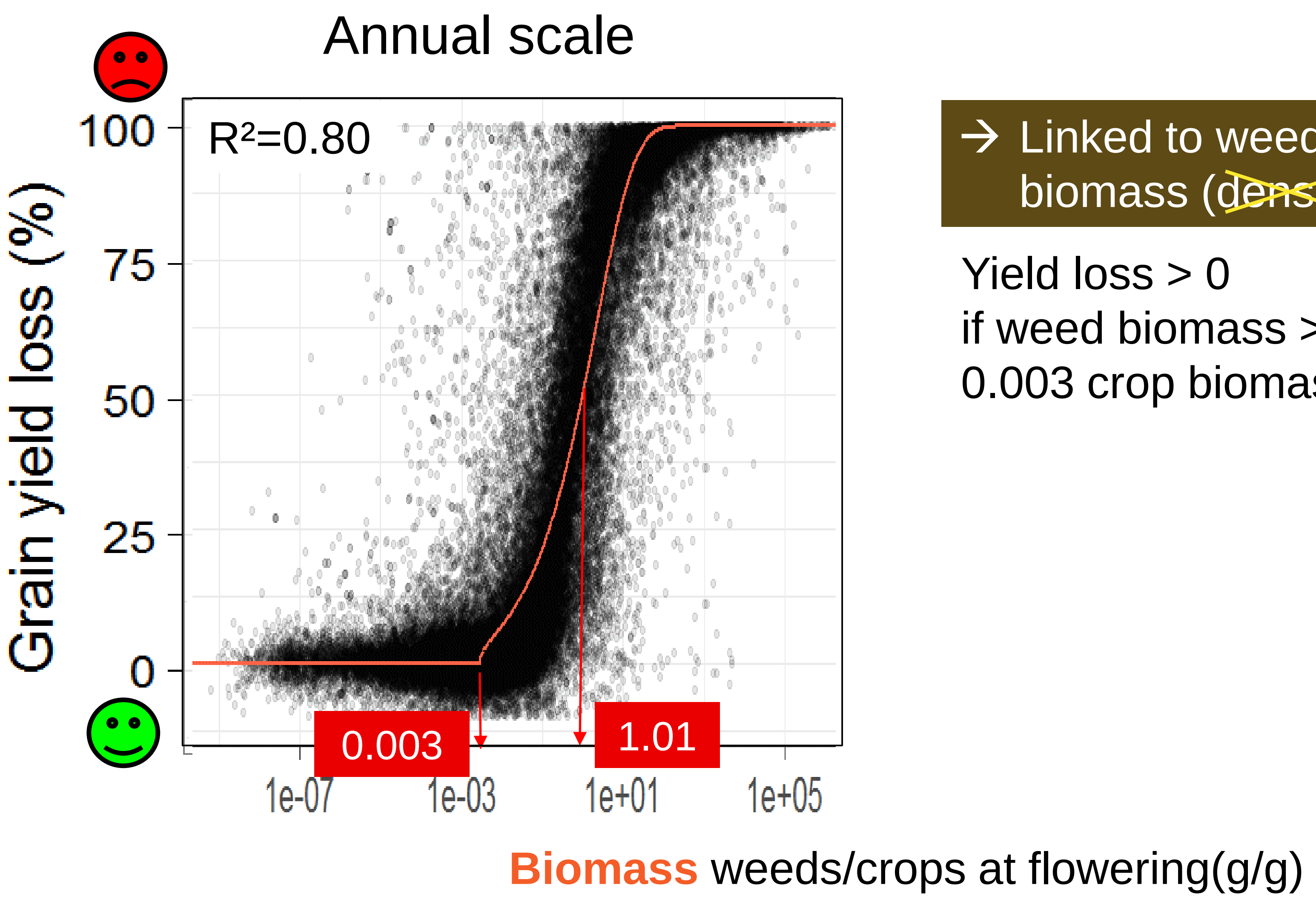
→ Yields loss >> 0

(Colbach & Cordeau 2018 EJA)

Yield loss (%) =

$$\frac{100\ (\text{Yield without weeds} - \text{yield with weeds})}{\text{Yield without weeds}}$$

Find a weed indicator linked to crop yield loss

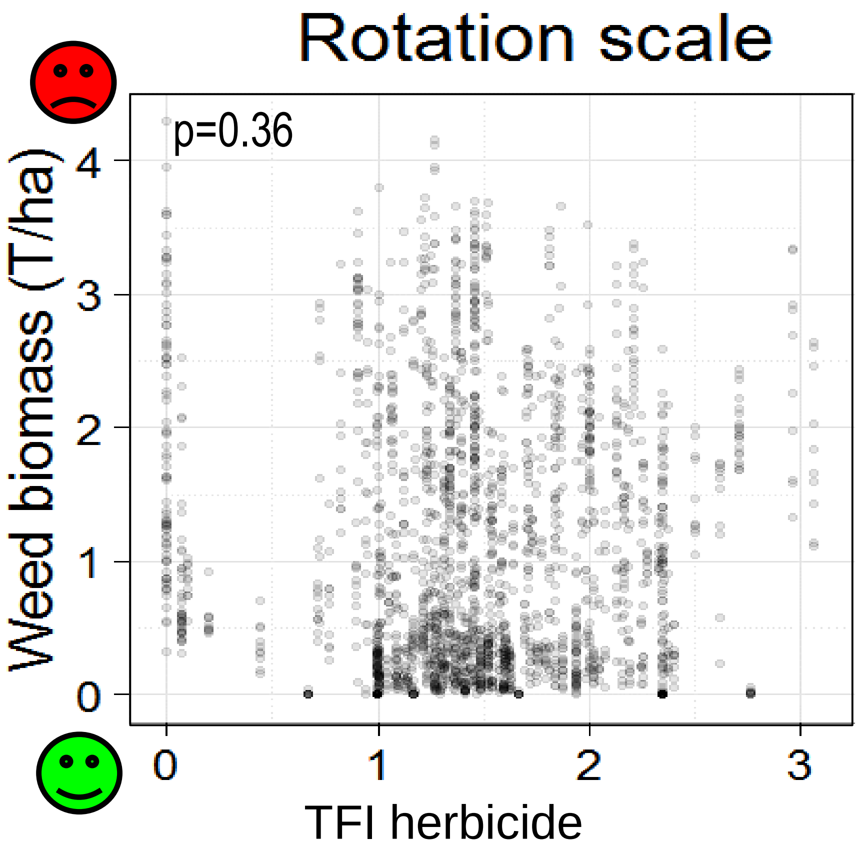


→ Linked to weed biomass (~~density~~)

Yield loss > 0
if weed biomass >
0.003 crop biomass

(Colbach & Cordeau 2018 EJA)

Weeds do not depend on farmers' herbicide use intensity

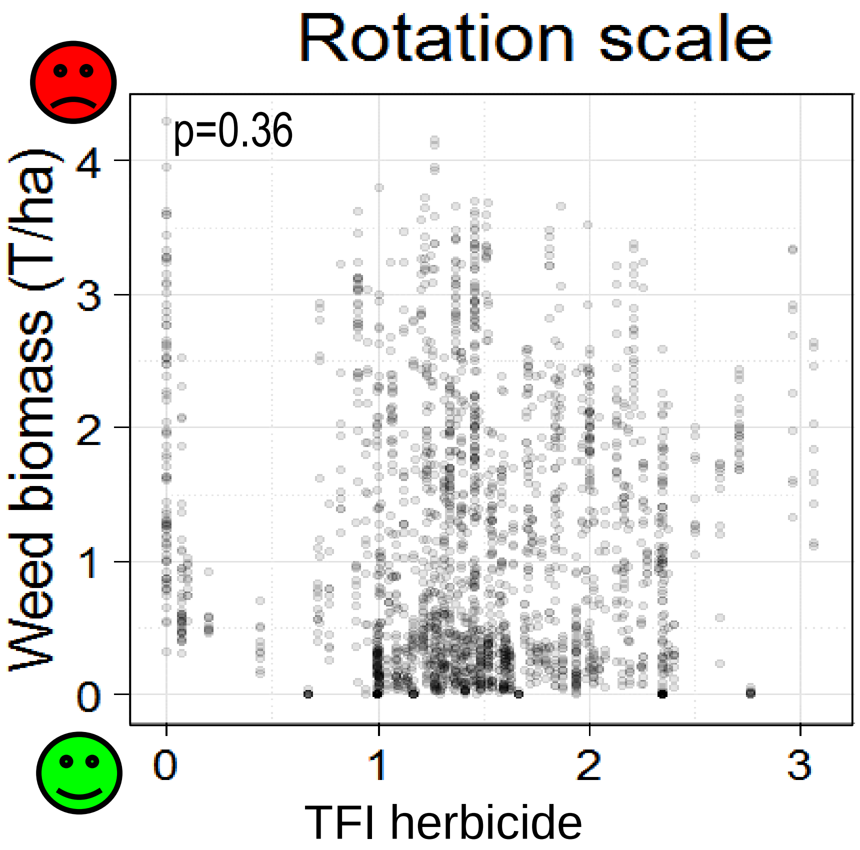


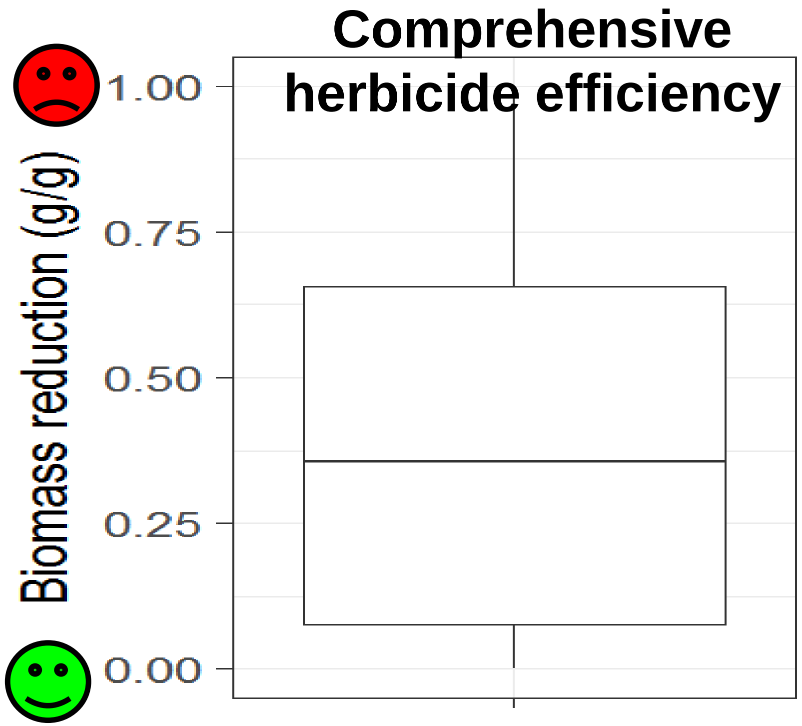
TFI = treatment frequency index
= *number of herbicides at full dosage sprayed over whole field per year*

→ No link with herbicide use intensity

(Colbach & Cordeau 2018 EJA)

Weeds do not depend on farmers' herbicide use intensity



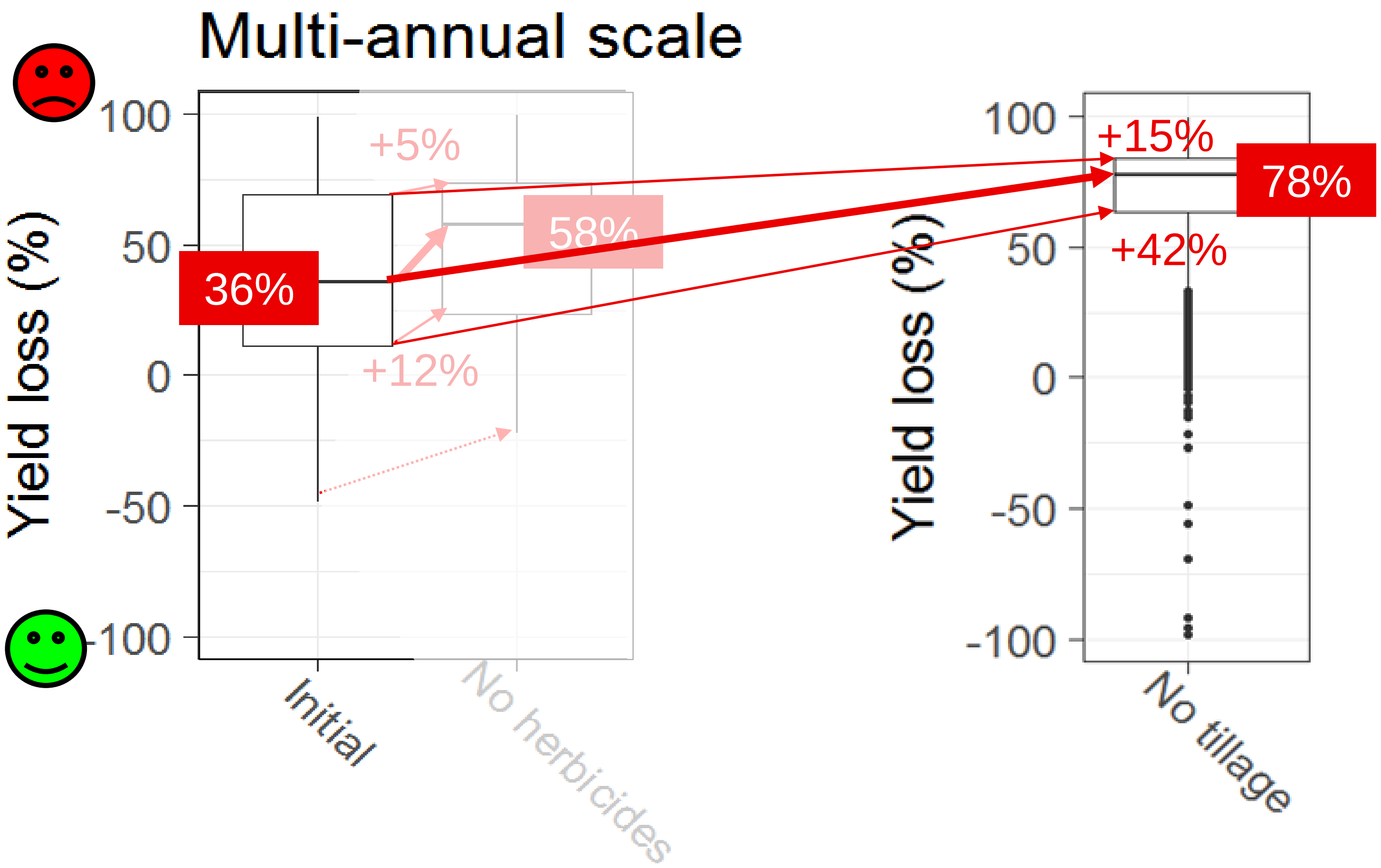


Weeds at flowering – simulations with vs. without herbicides with same weed flora before the herbicide treatment

→ No link with herbicide use intensity
→ Even though herbicides are efficient

Farmers compensate reduced herbicide use with other measures

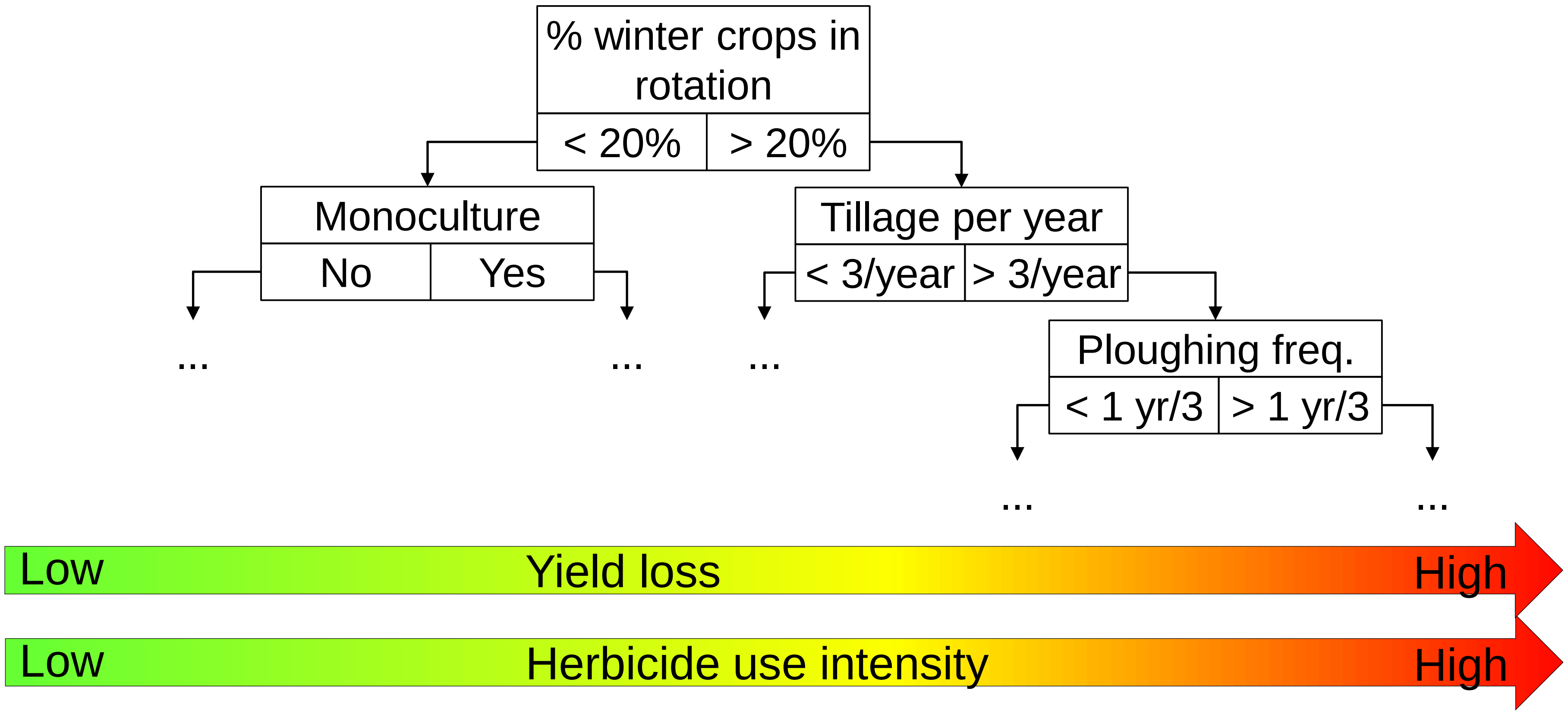
When herbicides are deleted ...



→ Loss increases if herbicides taken out without compensation
→ + visible at rotation vs annual scale

→ Even stronger effect if tillage is deleted

Which practices to reconcile reduced herbicide use with reduced weed-borne yield loss?



Reconcile low yield loss & low herbicide use

Main features of the 3 best strategies (lowest yield loss AND lowest herbicide use)
Identified via data mining of simulated data

Strategy S1
Maize monoculture
No cover crop.
No false seed bed Tillage depth 12-24 cm
Plough < 1 yr/2
1.3-3 herbicides/year (reduced dosage) Same every year
0.25-1.6 mechanical weeding/year, dep. on year
Only possible in some regions, risk of herbicide resistance

→ Very different strategies!

Colbach & Cordeau (2018) Eur J Agron;
Colbach et al (2021) Field Crops Res

Reconcile low yield loss & low herbicide use

Main features of the 3 best strategies (lowest yield loss AND lowest herbicide use)
Identified via data mining of simulated data

Strategy S1	Strategy S2	Strategy S3
Maize monoculture	25-75% spring crops 25-75% winter crops Rotation > 4 crops	36-65% spring crops 15-44% winter crops 20-49% grass
No cover crop.	Cover crop	Rare cover crop
No false seed bed Tillage depth 12-24 cm	> 3.4 superficial tillage/year (> 2 false seed bed/year)	
Plough < 1 yr/2	Plough Oct-Mar > 1 yr/5	Plough Oct-Mar >1 yr/3
1.3-3 herbicides/year (reduced dosage) Same every year	1.3-2.1 herbicides/year (reduced dosage) Depends on year	Nothing in common
0.25-1.6 mechanical weeding/year, dep. on year		Nothing in common
Only possible in some regions, risk of herbicide resistance	More complicated, more operations	

→ Very different strategies!

Colbach & Cordeau (2018) Eur J Agron;
Colbach et al (2021) Field Crops Res

Que peut-on faire encore? What else is possible?

- Identifier des combinaisons de traits de culture/variété optimaux
(au lieu de techniques culturales optimales)

- Identify optimal crop/variety traits
(instead of optimal management techniques)

Colbach N., Gardarin A. & Moreau D. (2019) The response of weed and crop species to shading: which parameters explain weed impacts on crop production? Field Crops Research 238, 45-55, https://doi.org/10.1016/j.fcr.2019.04.008

Que peut-on faire encore?

- Identifier des combinaisons de traits de culture/variété optimaux
  (au lieu de techniques culturales optimales)
- Identifier les traits adventices sélectionnés par les techniques
- Identifier les traits adventices qui déterminent les (dys)services

What else is possible?

- Identify optimal crop/variety traits
  (instead of optimal management techniques)
- Identify weed traits selected by management techniques
- Identify weed traits that drive (dys)services

Which traits are selected?

- RLQ + 4th corner analysis - principle

R matrix — PCA

Field	Practices			
	Rot-ation	Plough	...	Har-vest
A	CBO	1/3		181
B	M	1/1		265
...				
N	MW	2/2		222

L matrix — CA

Field	Species			
	S1	S2	...	Sn
[illegible]	43	5		[illegible]
B	1	[illegible]		[illegible]
...				
N				2

PCA — Q matrix

Traits	Species			
	S1	S2	...	Sn
Mass	2.3	1		0.3
Height	40	15		6
...				
Clade	M	D		D

RLQ

Pearson correlations

Traits	Practices			
	Rot-ation	Plough	...	Har-vest
Mass	0.34	-0.34		0.11
Height	0.01	-0.44		0.78
...				
Clade	0.76	0.20		-0.05

Chessel, D., Dufour, A. B., Thioulouse, J., 2004. The ade4 package. I. One-table method. R News 4 4, 5-10.

Which traits are selected?

- RLO + 4th corner analysis - principle

R matrix

Field	Practices			
	Rot-ation	Plough	...	Har-vest
A	CBO	1/3		181
B	M	1/1		265
...				
N	MW	2/2		222

L matrix

Field	Species			
	S1	S2	...	Sn
A	43	5		1
B	1	22		65
...				
N	0	3		2

Q matrix

Traits	Species			
	S1	S2	...	Sn
Mass	2.3	1		0.3
Height	40	15		6
...				
Clade	M	D		D

Surveyed cropping system practices

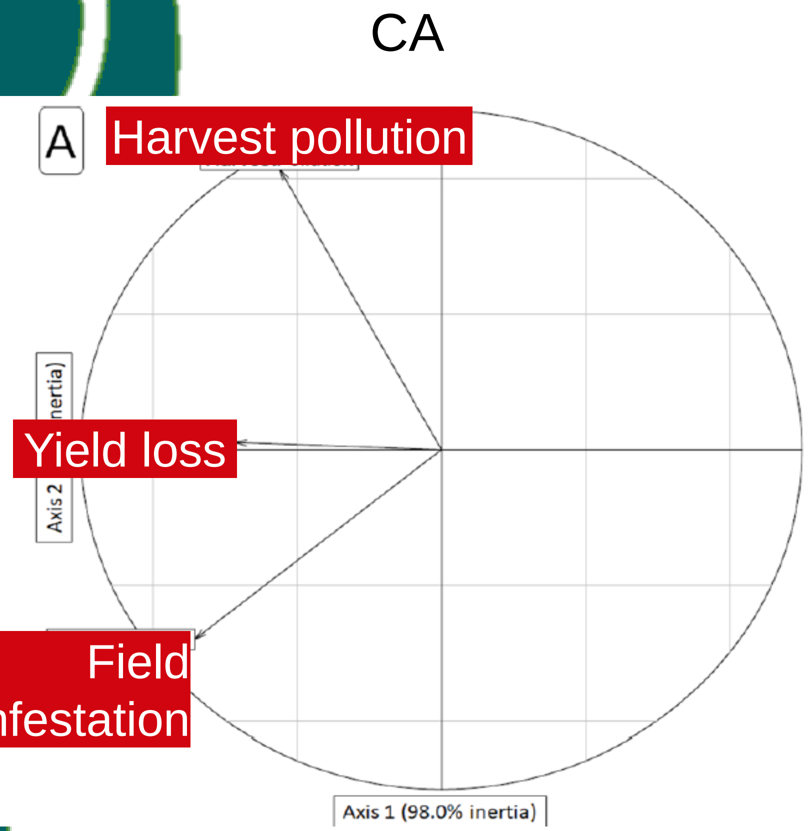
Simulated weed species densities

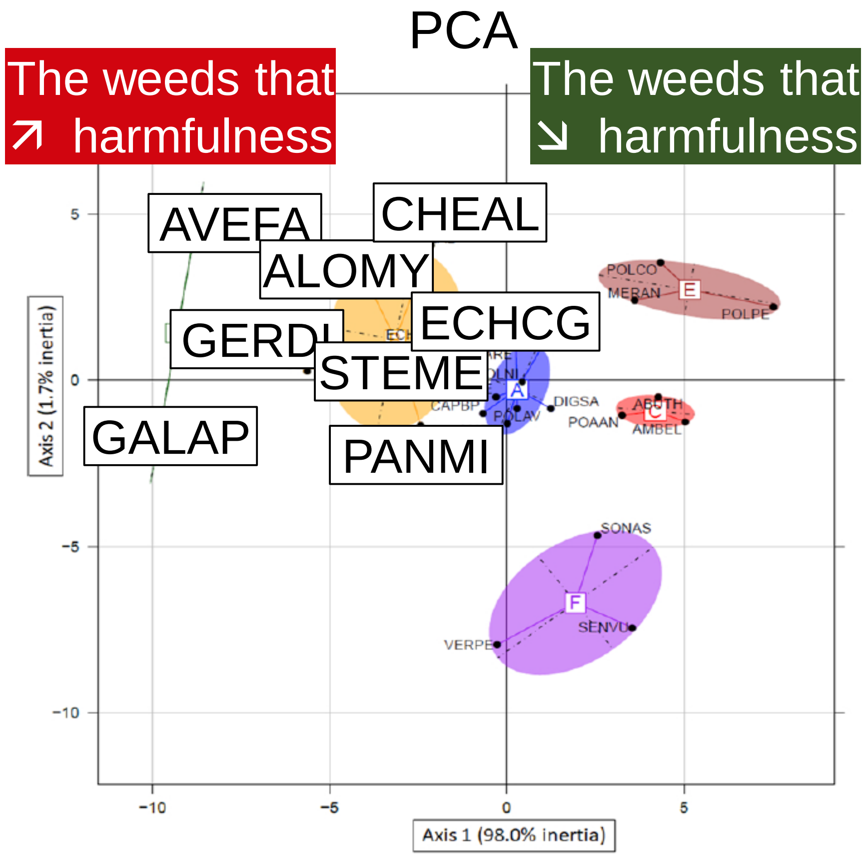
Species traits from FLORSYS data base

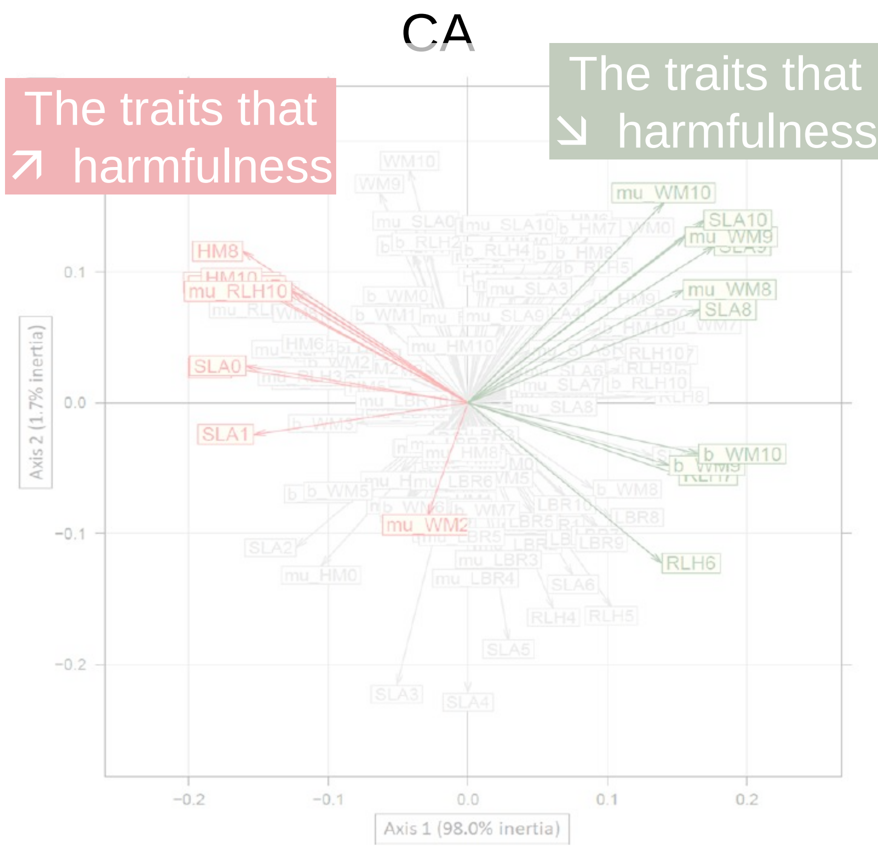
Simulated weed-impact indicators

Colbach, N., Darmency, H., Fernier, A., Granger, S., Le Corre, V., Messéan, A., 2017. Simulating changes in cropping practices in conventional and glyphosate-resistant maize. II. Effect on weed impacts on crop production and biodiversity. Environ Sci Pollution Res 24, 13121-13135.

The weed species and traits → damage to crop production

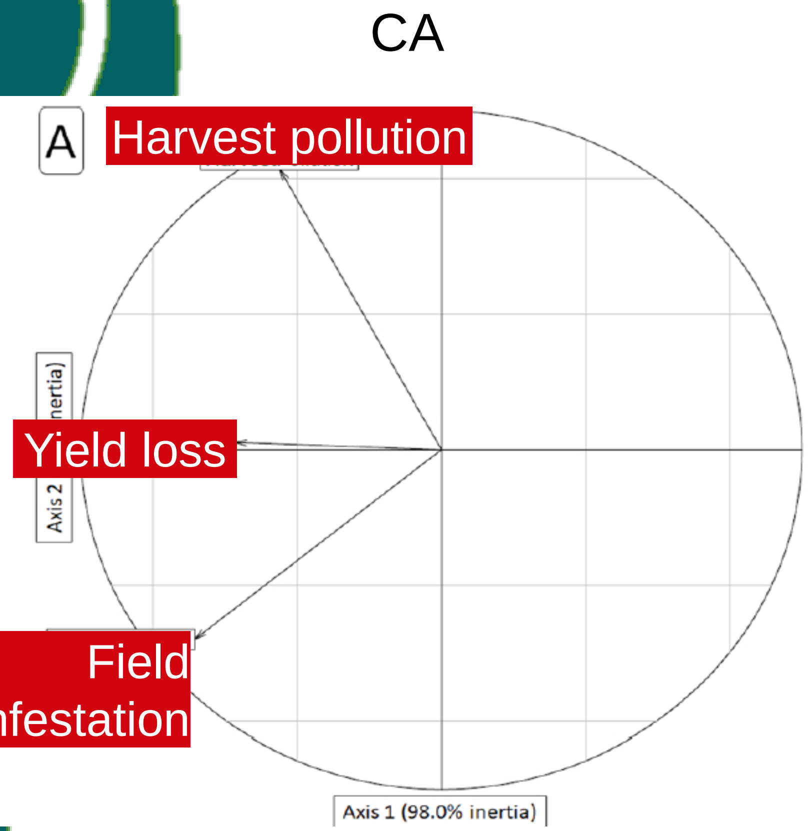


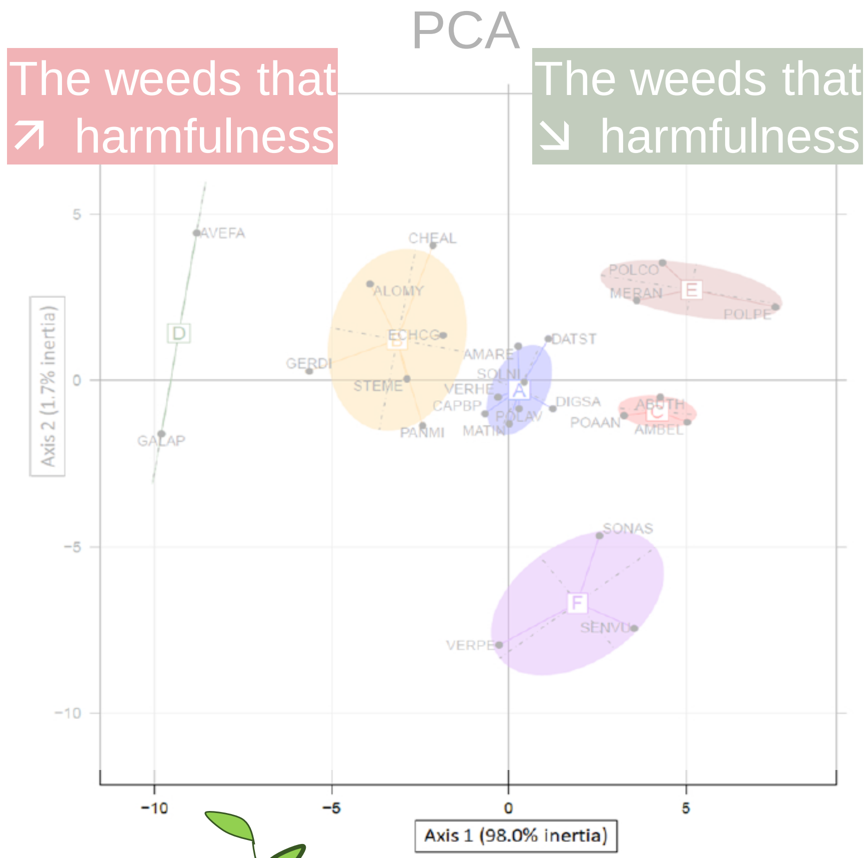


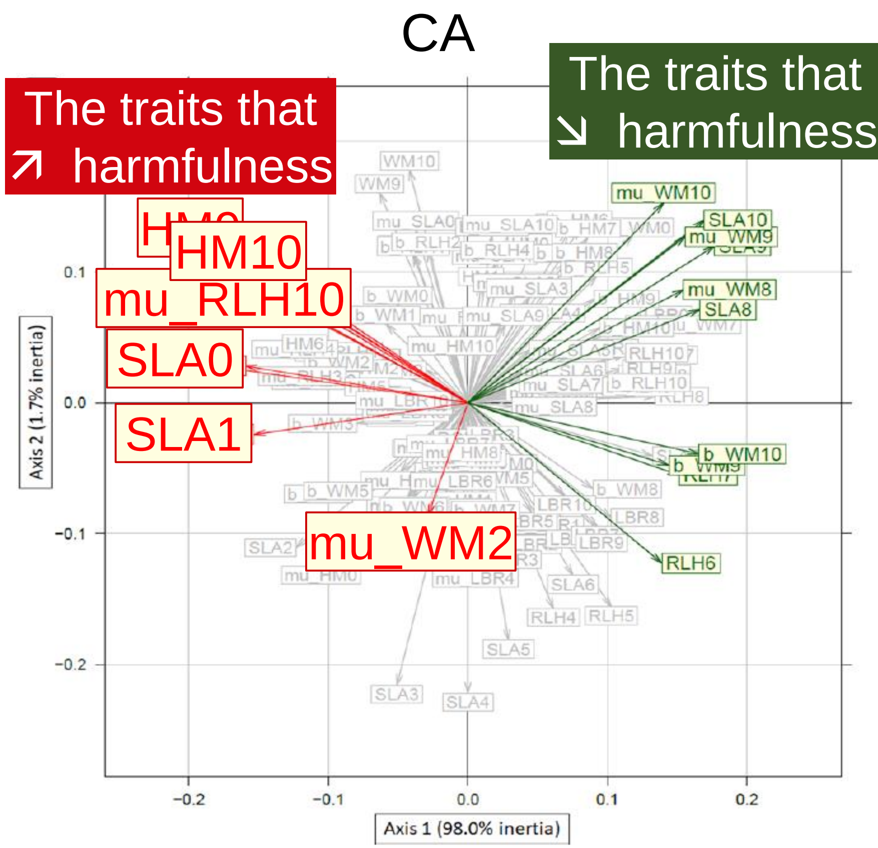


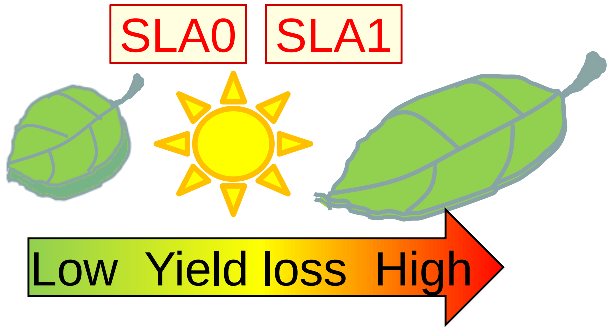
Colbach N, Gardarin A and Moreau D, The response of weed and crop species to shading: which parameters explain weed impacts on crop production? *Field Crops Research 238, 45-55*

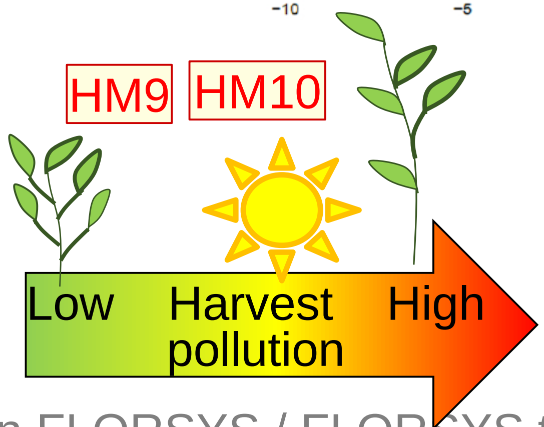
The weed species and traits → damage to crop production

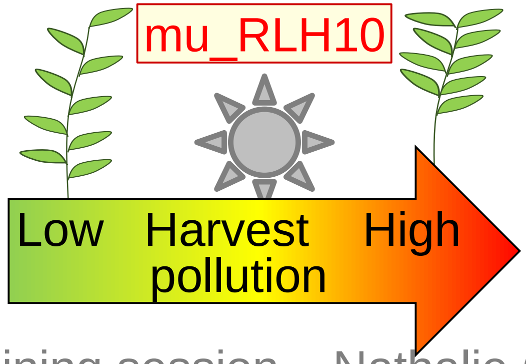


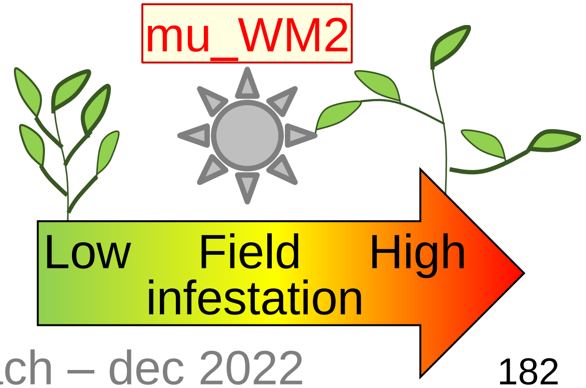










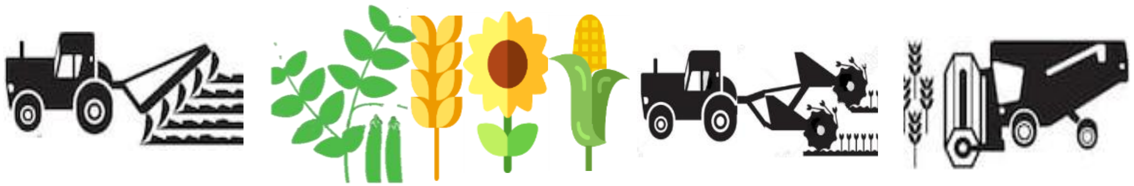


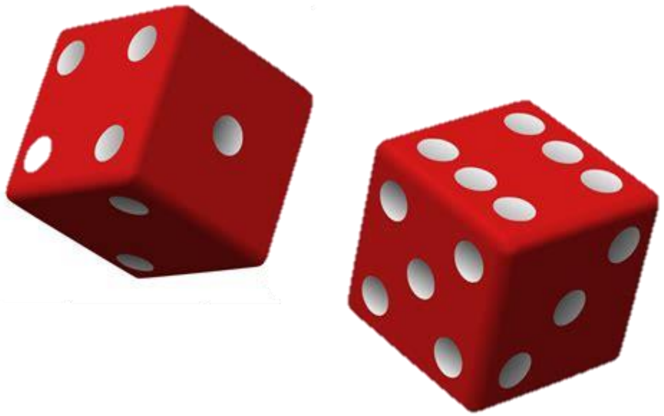
Que peut-on faire encore?

- Identifier des combinaisons de traits de culture/variété optimaux
(au lieu de techniques culturales optimales)
- Identifier les traits adventices sélectionnés par les techniques
- Identifier les traits adventices qui déterminent les (dys)services
- Explorer des systèmes de culture et variétés virtuelles

What else is possible?

- Identify optimal crop/variety traits
(instead of optimal management techniques)
- Identify weed traits selected by management techniques
- Identify weed traits that drive (dys)services
- Explore virtual cropping systems or varieties





Plan

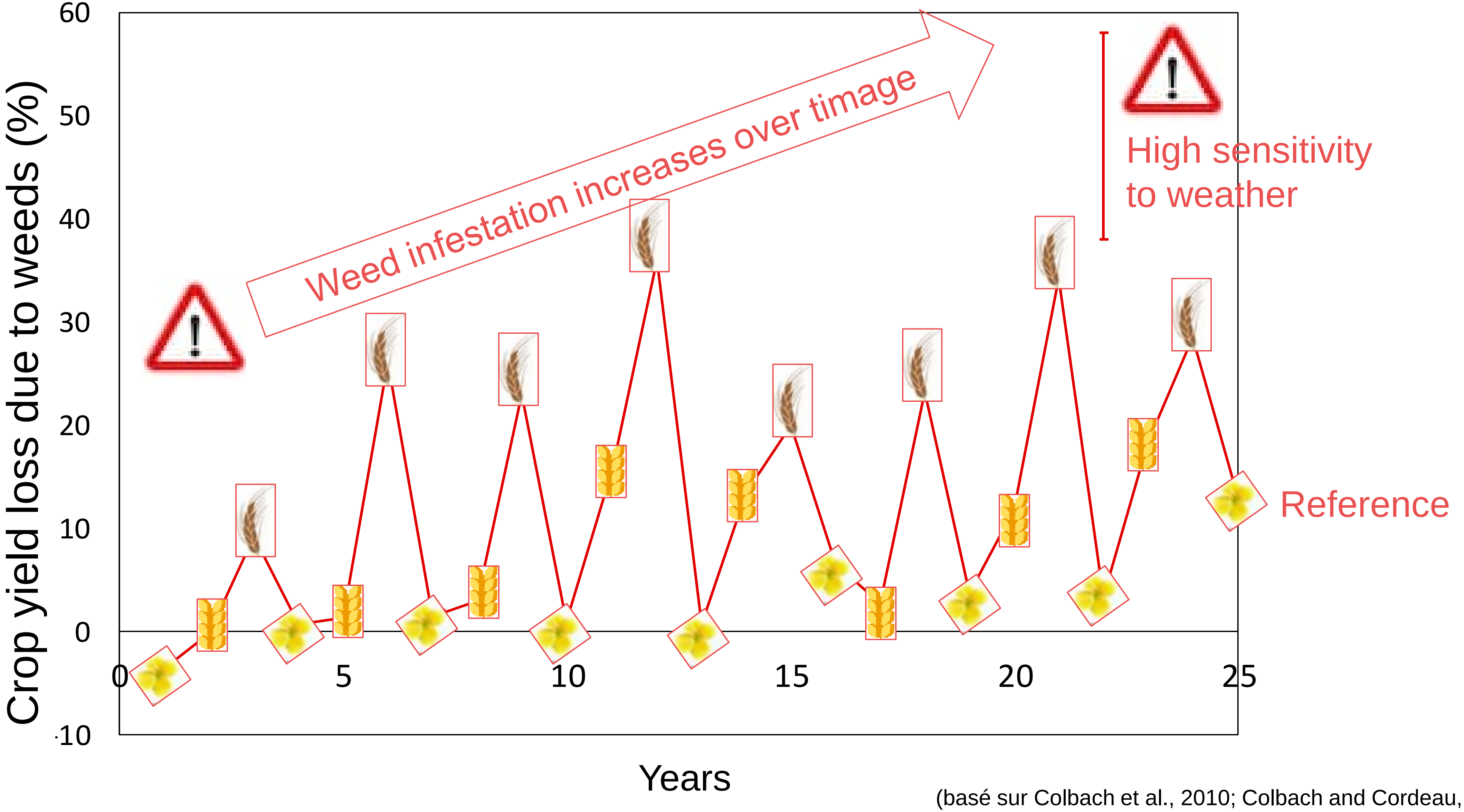
1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. Effets des techniques culturales
4. Le reste: indicateurs, paysage
5. Évaluation du modèle
6. **Examples d'utilisation**
7. Comment faire tourner le modèle?

Today's presentation

1. Model objectives & structure
2. Details of life cycle
3. Effects of management techniques
4. What else? Indicators, landscape
5. Model evaluation
6. **Examples of model use**
7. How to run the model?

- Optimize one technique at annual scale
- Optimize one technique in the short term
- Evaluate farmers' practices at the cropping-system scale
- **Evaluate innovative cropping systems**
- Work with farmers

Evaluate croppping systems proposed by advisors

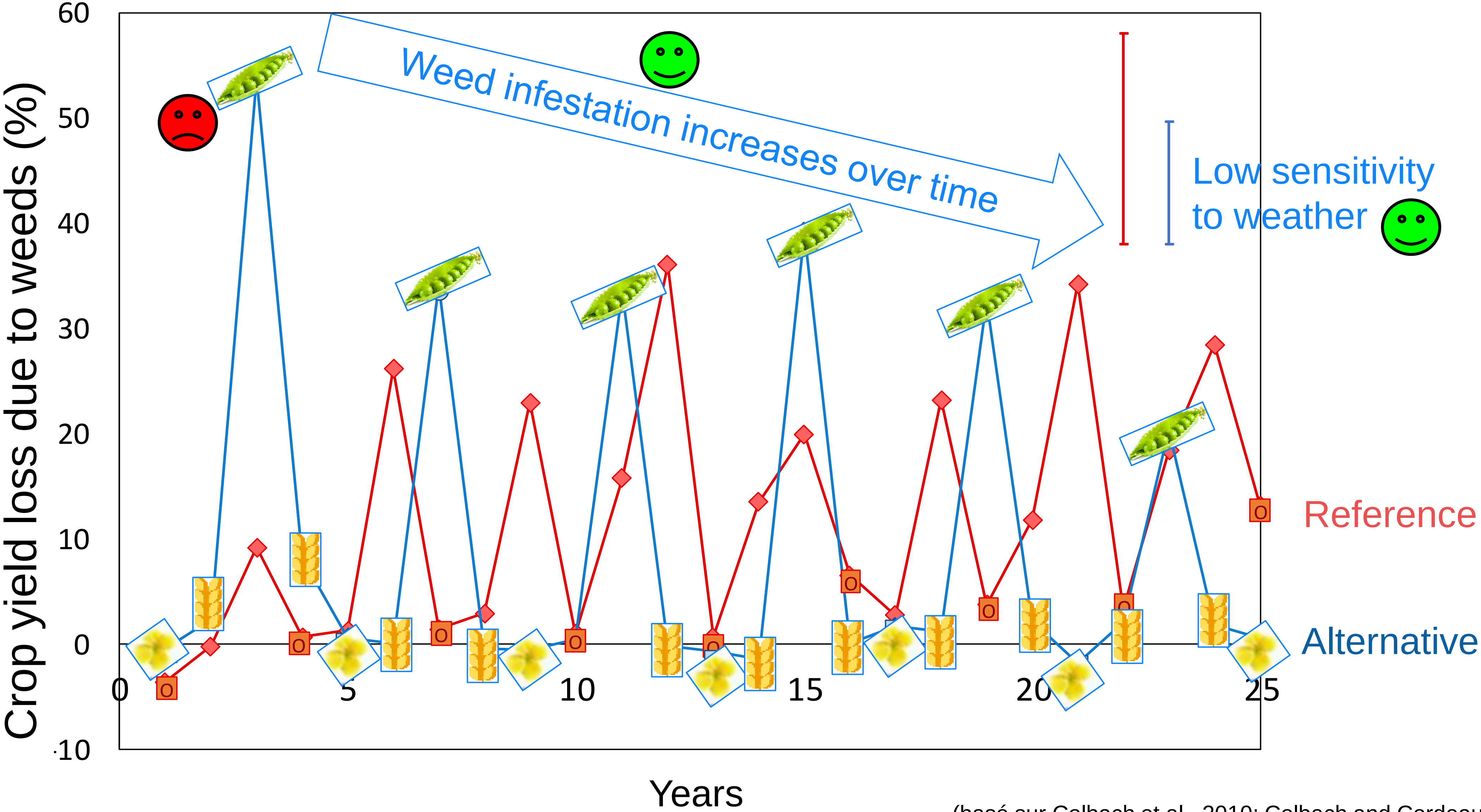


(basé sur Colbach et al., 2010; Colbach and Cordeau, 2018b)

FLORSYS

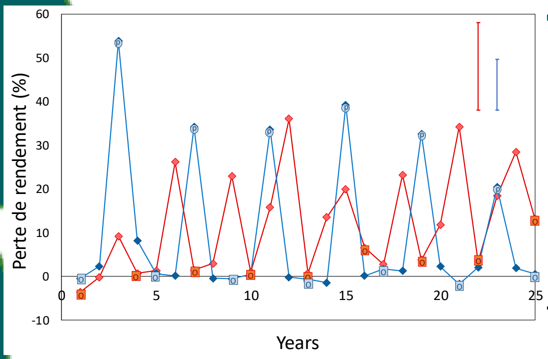
INRAE

Evaluate croppping systems proposed by advisors



(basé sur Colbach et al., 2010; Colbach and Cordeau, 2018b)

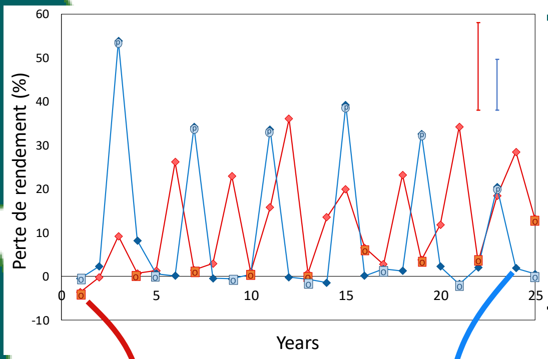
Evaluate croppping systems proposed by advisors



Système de culture	Biodiversité: Richesse spécifique sauvage	Biodiversité: Offre trophique aux abeilles	Production (MJ/ha)	Nuisibilité pour la production: Perte de rende-ment (%)	Nuisibilité pour la production: Contami-nation de récolte	Nuisibilité pour la production: Salisse-ment du champ	Usage d'herbi-cides (IFT§)
CBO labour	11.35 c	1.06 ba	69391 b	11.87 a	2.70 a	0.24 ba	1.72 b
CBO sans labour	10.19 d	1.04 ba	68695 b	12.55 a	2.83 a	0.29 a	1.79 a
CBpB labour	11.99 b	1.00 b	95980 a	10.54 a	1.81 b	0.14 c	1.39 d
CBpB sans labour	12.22 ba	1.03 ba	96804 a	9.50 a	1.82 b	0.14 c	1.57 c
CBtBo labour	12.59 a	1.10 a	98957 a	4.36 b	1.97 b	0.18 bc	1.12 f
CBtBo sans labour	12.43 ba	1.06 ba	98955 a	4.19 b	1.94 b	0.18 bc	1.38 e

FLORSYS

Evaluate croppping systems proposed by advisors



Référence

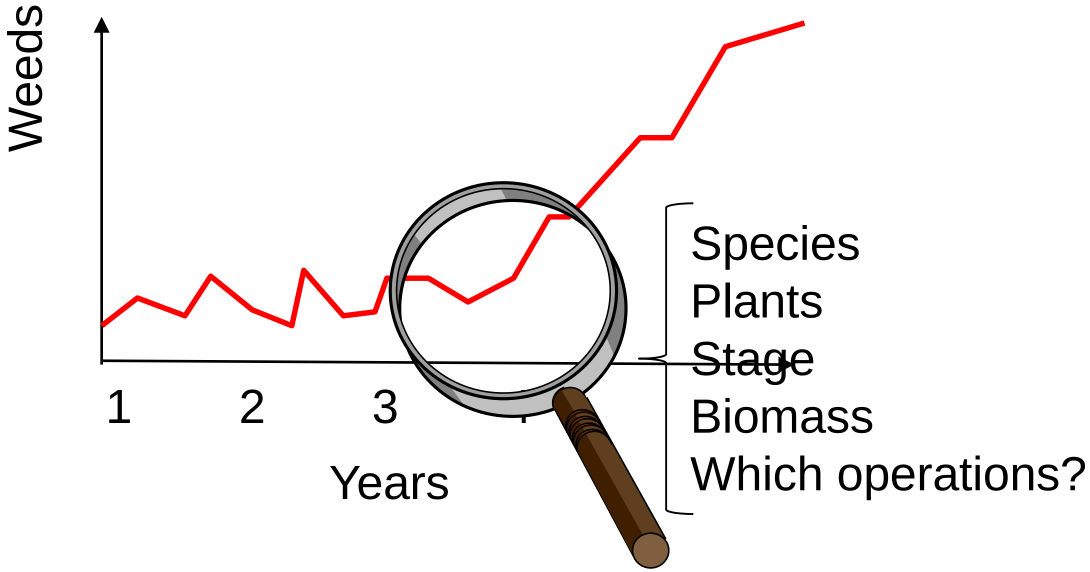
Alternative

Système de culture	Biodiversité: Richesse spécifique sauvage	Biodiversité: Offre trophique aux abeilles	Production (MJ/ha)	Nuisibilité pour la production: Perte de rende-ment (%)	Nuisibilité pour la production: Contami-nation de récolte	Nuisibilité pour la production: Salisse-ment du champ	Usage d'herbi-cides (IFT§)
CBO labour	11.35 c	1.06 ba	69391 b	11.87 a	2.70 a	0.24 ba	1.72 b
CBO sans labour	10.19 d	1.04 ba	68695 b	12.55 a	2.83 a	0.29 a	1.79 a
CBpB labour	11.99 b	1.00 b	95980 a	10.54 a	1.81 b	0.14 c	1.39 d
CBpB sans labour	12.22 ba	1.03 ba	96804 a	9.50 a	1.82 b	0.14 c	1.57 c
CBtBo labour	12.59 a	1.10 a	98957 a	4.36 b	1.97 b	0.18 bc	1.12 f
CBtBo sans labour	12.43 ba	1.06 ba	98955 a	4.19 b	1.94 b	0.18 bc	1.38 e

FLORSYS

Que peut-on faire encore? *What else is possible*

- **Diagnosis**
  (events, techniques, species that drive performance)



Que peut-on faire encore? *What else is possible*

- **Diagnosis**
  (events, techniques, species that drive performance)

- **Probabilities of success or failure → risk**

Pearson correlations for each repetition: indicator vs year since simulation onset

Harmfulness indicator: % repetitons for each system with correlation > 0 at $p<0.05$
Benefit indicator: % repetitons for each system with correlation < 0 at $p<0.05$

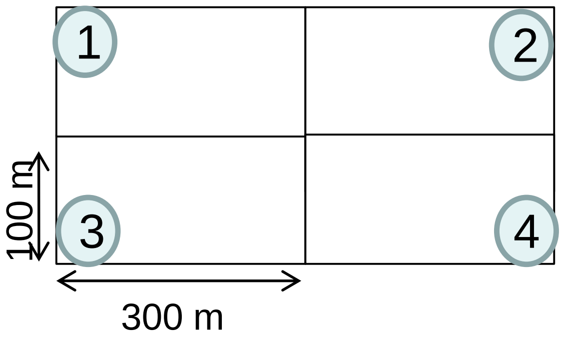
Risk of deterioration	*Weed contribution to biodiversity*		*Crop production*	*Weed harmfulness for crop*	
	Species richness	*Bee food*		*Yield loss*	*Field infestation*
D Reference	**0.5**	**0**	**0.6**	**0.6**	**0.9**
D IWMnoPlough	0	0	0	0	0.1
D IWMnoMechW	0.1	0.2	0.3	0.4	0.5
D IWMall	0.2	0.1	0.3	0.1	0.1
D NoHerbicides	0.1	0	0.1	0.2	0.6

Que peut-on faire encore? *What else is possible?*

- **Diagnosis**
  (events, techniques, species that drive performance)
- **Probabilities of success or failure → risk**
- **Travailler à l'échelle de l'îlot de parcelles**

- Partage vs séparation des terres pour concilier production et biodiversité
  - Colbach N., Cordeau S., Garrido A., Granger S., Laughlin D., Ricci B., Thomson F. & Messéan A. (2018) Landsharing vs landsparing: How to reconcile crop production and biodiversity? A simulation study focusing on weed impacts. Agriculture, Ecosystems & Environment 251:203-217, https://doi.org/10.1016/j.agee.2017.09.005

Field mosaic



Plan

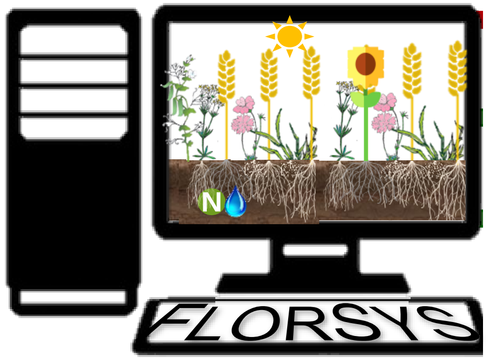
1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. Effets des techniques culturales
4. Le reste: indicateurs, paysage
5. Évaluation du modèle
6. **Examples d'utilisation**
7. Comment faire tourner le modèle?

Today's presentation

1. Model objectives & structure
2. Details of life cycle
3. Effects of management techniques
4. What else? Indicators, landscape
5. Model evaluation
6. **Examples of model use**
7. How to run the model?

- Optimize one technique at annual scale
- Optimize one technique in the short term
- Evaluate farmers' practices at the cropping-system scale
- Evaluate innovative cropping systems
- **Work with farmers**

Boucle de conception-évaluation *Design-evaluation loop*



Cropping system[§]	Crop diversity over 12 years: Species & cultivars (number)	Crop diversity over 12 years: % winter crops	Crop diversity over 12 years: % years with cover crops	Herbicide use (TFI[$])	Yield (MJ/ha)		Weed impact: Yield loss		Weed impact: Field infestation		Weed impact: Bee food		Weed impact: Wild species richness	
Reference	4	100%	8%	**1.6**	**63563**	a	**50.9**	b	**1.63**	b	**2.3**	b	**17.9**	b
IWM-simplified	18	77%	39%	1.7	51067	b	58.4	a	2.3	a	2.42	b	16.5	c
IWM-intermediate	10	63%	8%	0.8	54443	b	55.3	ab	1.85	b	2.74	a	18.6	a
IWM-complete	8	55%	0%	0.7	67402	a	40.9	c	1.46	c	2.05	c	15.9	d
IWM-no herbicide	12	63%	16%	0.1	69077	a	50.5	b	1.6	bc	2.1	c	18.2	ab

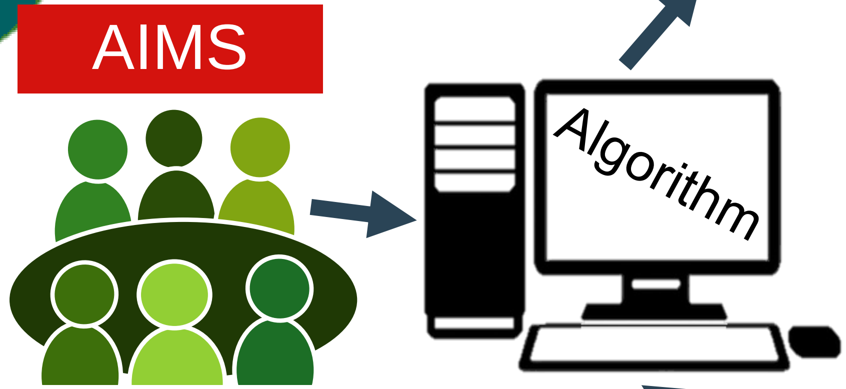
Colbach N., et al. (2021) The FLORSYS crop-weed canopy model, a tool to investigate and promote agroecological weed management. Field Crops Research 261:108006, https://doi.org/10.1016/j.fcr.2020.108006

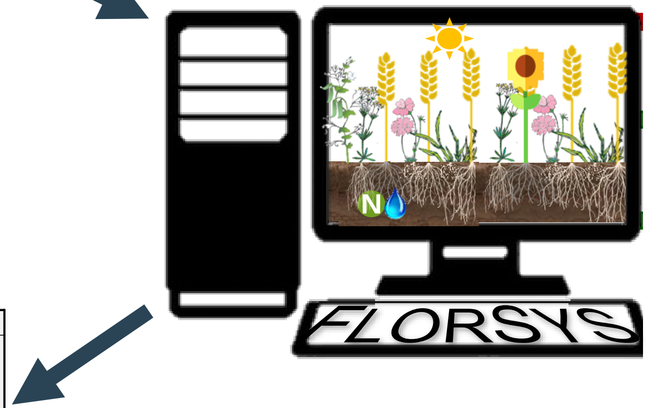
Queyrel W., et al. (2020) Combining expert knowledge and models in participatory workshops with farmers to design sustainable weed management strategies. *In: XVIe ESA, Sevilla, Spain, 49*

Van Inghelandt et al. (2019) Combiner expertise et modèles en ateliers de co-conception de systèmes de culture pour une gestion durable des adventices : apports méthodologiques et perspectives. *In: N. Colbach, F. Angevin, C. Bockstaller, B. Chauvel, C. Denieul, D. Moreau, B. Omon, D. Pellet, A. Rodriguez, L. Trannoy, S. Volan & F. Vuillemin, editors. Gestion des adventices dans un contexte de changement - Séminaire CoSAC Paris, France, 39-41*

Cavan N., et al. (2019) Utilisation du modèle FLORSYS comme outil d'aide à la conception de systèmes de culture innovants performants pour la gestion durable des adventices : exemple d'un groupe DEPHY Ferme de l'Eure. Agronomie, Environnement & Société:131-144, https://agronomie.asso.fr/aes-9-2-15

Algorithmes d'optimisation *Optimisation algorithms*





Cropping system§	Crop diversity over 12 years			Herbi-cide use (TFI$)	Yield (MJ/ha)		Weed impact							
	Species & cultivars (number)	% winter crops	% years with cover crops				Yield loss		Field infestation		Bee food		Wild species richness	
Reference	4	100%	8%	**1.6**	**63563**	a	**50.9**	b	**1.63**	b	**2.3**	b	**17.9**	b
IWM-simplified	18	77%	39%	1.7	51067	b	58.4	a	2.3	a	2.42	b	16.5	c
IWM-intermediate	10	63%	8%	0.8	54443	b	55.3	ab	1.85	b	2.74	a	18.6	a
IWM-complete	8	55%	0%	0.7	67402	a	40.9	c	1.46	c	2.05	c	15.9	d
IWM-no herbicide	12	63%	16%	0.1	69077	a	50.5	b	1.6	bc	2.1	c	18.2	ab

Colbach N., et al. (2021) The FLORSYS crop-weed canopy model, a tool to investigate and promote agroecological weed management. Field Crops Research 261:108006, https://doi.org/10.1016/j.fcr.2020.108006

Maillot T., et al. . (2019) Conception de systèmes de cultures par algorithmes d'optimisation. *In: N. Colbach, F. Angevin, C. Bockstaller, B. Chauvel, C. Denieul, D. Moreau, B. Omon, D. Pellet, A. Rodriguez, L. Trannoy, S. Volan & F. Vuillemin, editors. Gestion des adventices dans un contexte de changement - Séminaire CoSAC Paris, France, 32-35*

Perthame L. (2020) Analyse et modélisation du rôle de la compétition pour l'azote dans la régulation des adventices. *PhD Thesis, Université de Bourgogne Franche-Comté, Dijon, France. p.*

Un peu de lecture sur FLORSYS et la conception de systèmes de culture pour la gestion agroécologique des adventices

- Colbach N., Colas F., Cordeau S., Maillot T., Queyrel W., Villerd J., Moreau D. (2021) The FLORSYS crop-weed canopy model, a tool to investigate and promote agroecological weed management. Field Crops Research, https://doi.org/10.1016/j.fcr.2020.108006
- Colbach N., Cordeau S., Queyrel W., Maillot T., Villerd J., Moreau D. (2019) Du champ virtuel au champ réel - ou comment utiliser un modèle de simulation pour diagnostiquer des stratégies de gestion durables des adventices? Agronomie, Environnement et Sociétés 9, 111-128 https://agronomie.asso.fr/aes-9-2-14
- Colbach N. (2020) How to use a “virtual field” to evaluate and design integrated weed management strategies at different spatial and temporal scales. *in G. R. Chantre and J. L. González-Andujar, editors. Decision support systems for weed management. Springer, 227-248*

- https://www6.inrae.fr/ciag/Revue/Volumes-publies-en-2020/Volume-81-Decembre-2020
- *https://www.projet-cosac.fr/Page-d-accueil/Actualites/Seminaire-final-de-CoSAC-les-31-Janvier-et-1er-fevrier-2019*

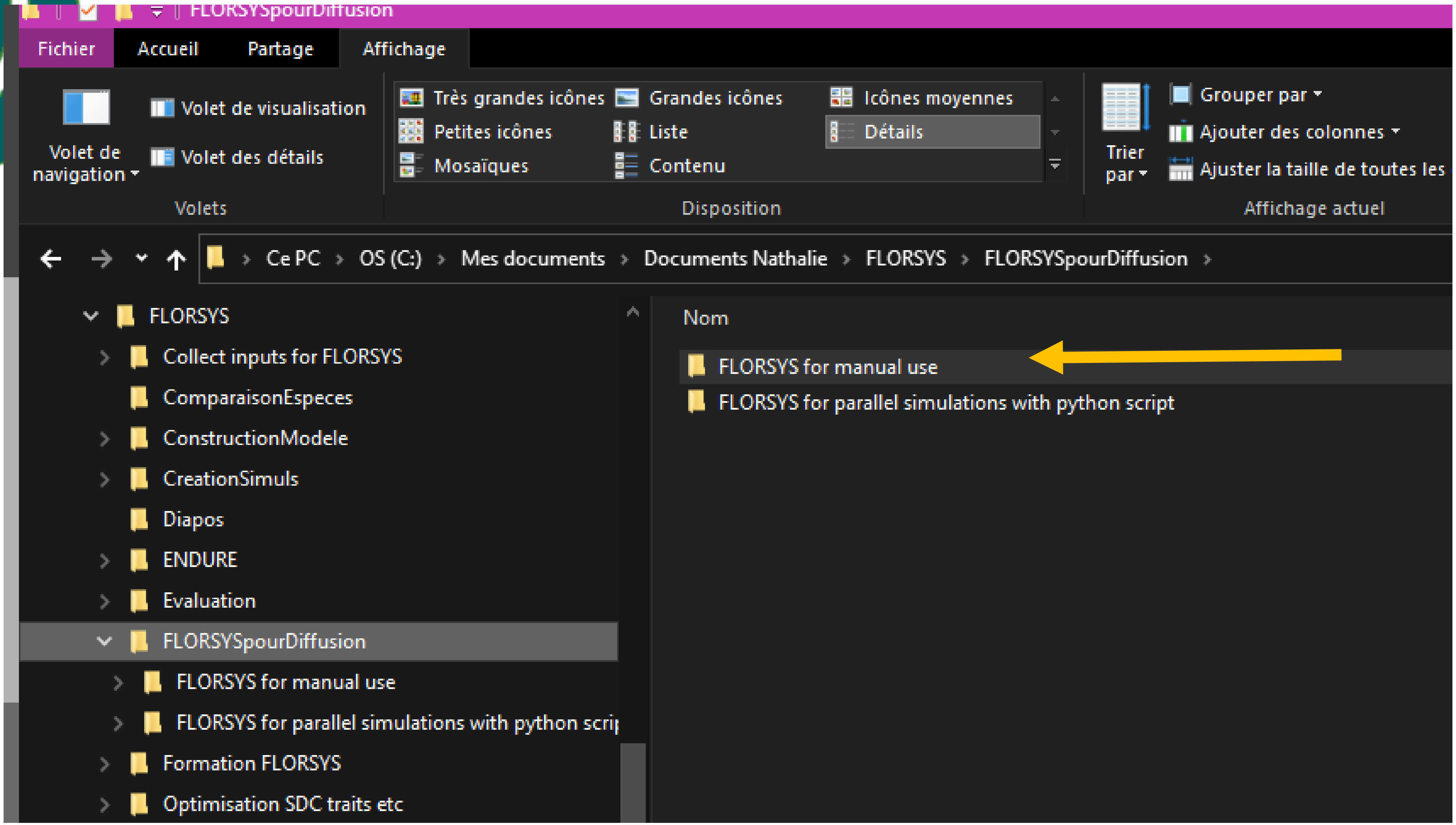
Plan

1. Objectifs du modèle & structure
2. Détails du cycle de vie
3. Effets des techniques culturales
4. Le reste: indicateurs, paysage
5. Évaluation du modèle
6. Examples d'utilisation
7. **Faire tourner le modèle…**

Today's presentation

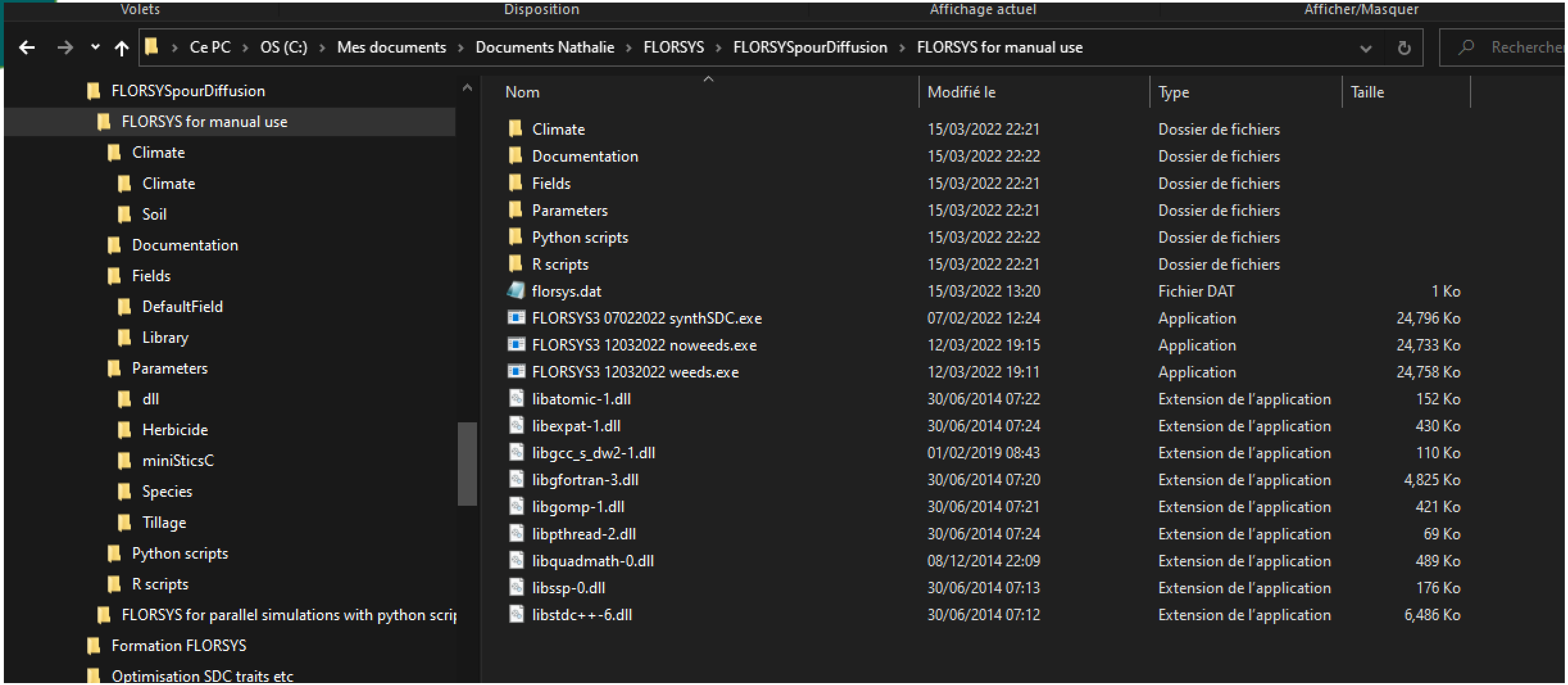
1. Model objectives & structure
2. Details of life cycle
3. Effects of management techniques
4. What else? Indicators, landscape
5. Model evaluation
6. Examples of model use
7. **How to run the model?**

Utiliser FLORSYS en manuel *Manual use of FLORSYS*

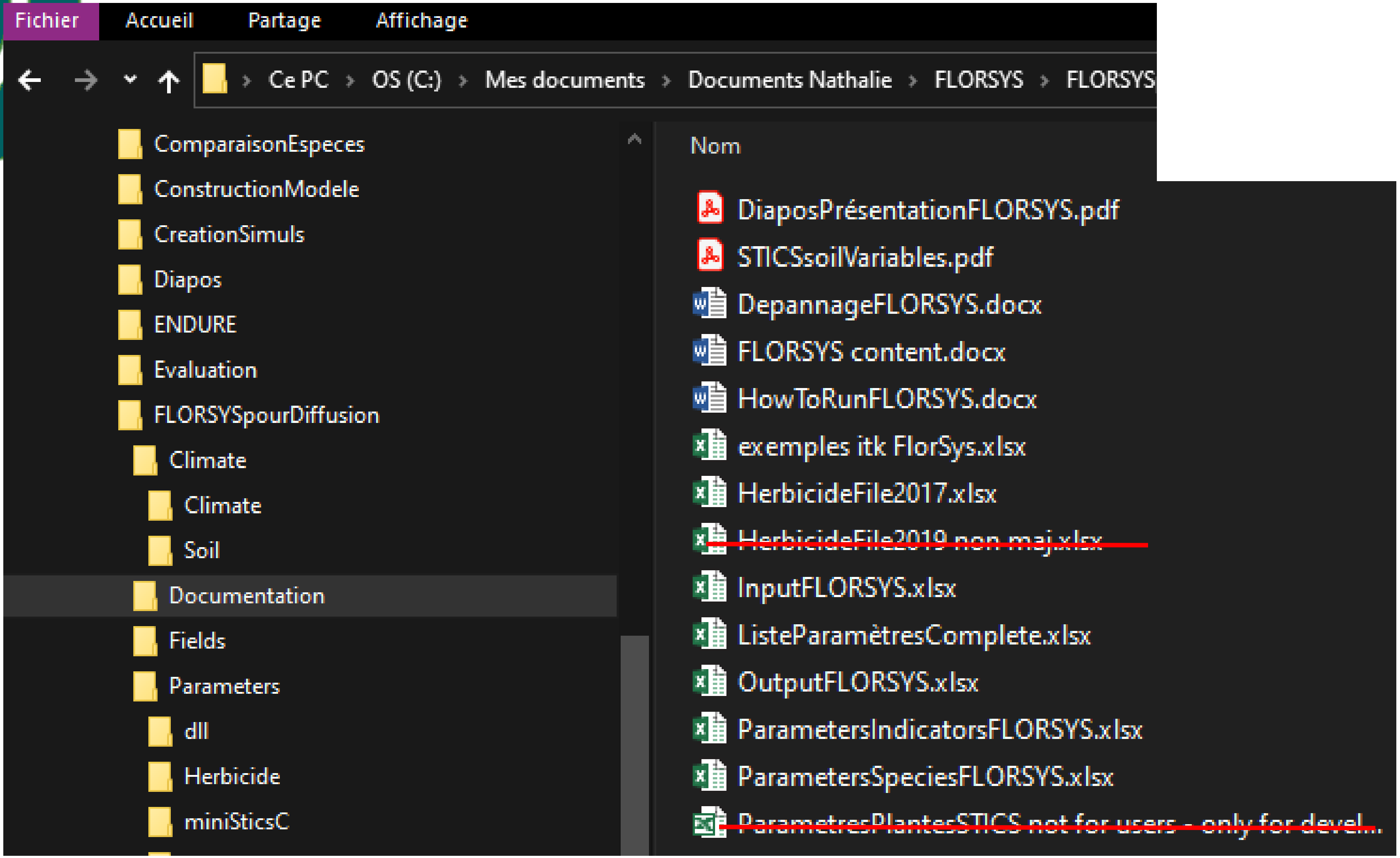


Le logiciel — *The software*

- Le répertoire FLORSYS
- The FLORSYS directory

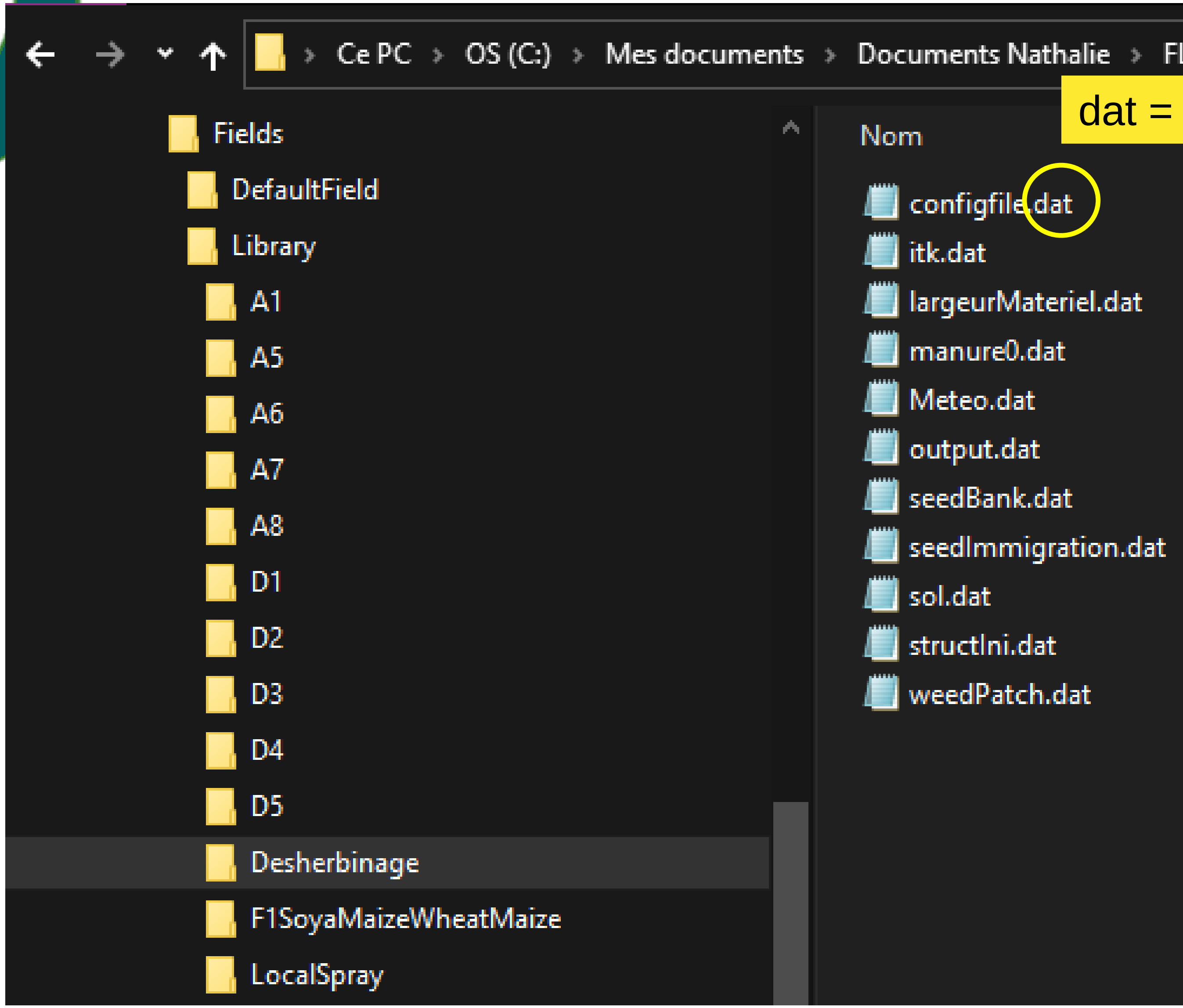


La documentation *The manual*



Préparez une simulation — *To prepare a simulation*

Le répertoire de simulation = parcelle virtuelle • *The simulation directory = virtual field*



dat = fichier d'entrée — dat = Input file

Lieu	*Location*
Système de culture	Cropping system
(*largeur matériel*)	(*equipment width*)
(semences dans fumier)	(seeds in manure)
Liste fichiers météo	*List of weather files*
Choix des sorties	*Choice of output files*
Stock semencier initial	Initial weed seed bank
Immigration semences	*Weed seed immigration*
Texture etc du sol	Soil texture etc
(Structure intiale du sol)	(Initial soil structure)
Répartition adventices	*Weed plant distribution*

Nom de fichier fixe (fichier optionnel) — *File name is fixed* (optionnal file)

Préparez une simulation

- Règles de priorité
  1. Fichiers dans répertoire de simulation
  2. Si absent,
     - DefaultField pour les entrées (*.dat)
     - Parameters/Species pour les paramètres (*.par)

Prepare a simulation

- Priority rules
  1. File in simulation (field) directory are read first, if there are any
  2. If missing,
     - DefaultField for inputs (*.dat)
     - Parameters/Species for parameters (*.par)

Préparez une simulation — *Prepare a simulation*

Examples & explications dans inputFLORSYS.xlsx

Fichier texte — *Text file*

Peut être préparé dans excel et copié dans un fichier texte

Can be prepared in excel and copied into text file

itk.dat - Bloc-notes

Fichier Edition

```
20200125

DATEPREVIOUSHARVEST     181     1
PREVIOUSCROP    ORGEH
DURATION        30      PERIODS
HERBICIDETECHNICITY     SUB_OPTIMUM

PERIOD  1_COLZA 182     1
ORIENTATION     NS
NEXT    SOWING  237     1       NO      30      0       YES     YES
        1
        COLZA   PRIMARY 50      2               NONE
NEXT    FERTILIZATION   32      2       70      50
NEXT    FERTILIZATION   60      2       100     50
NEXT    HERBICIDE       273     1       CLERAVIS        2       L/HA    LOCAL ROW 5
NEXT    MECHANICALWEEDING       273     1 BINEUSE       12      INTERROW        0.7     2

NEXT    HARVEST 196     2       0.2     YES     1       COLZA   0

PERIOD  2_BLEH  197     2
ORIENTATION     NS
NEXT    SOWING  293     2       NO      12      0       YES     YES
        1
        BLE!CEZANNE     PRIMARY 320     2       NONE    FUNGICIDE       NO
NEXT    HERBICIDE       289     2       ROUNDUP 1.5     L/HA    GLOBAL
NEXT    HERBICIDE       60      3       ATLANTISWG      0.25    kg/HA   GLOBAL
NEXT    HERBICIDE       60      3       FIRST   1.5     L/HA    GLOBAL
NEXT    HERBICIDE       60      3       Primus  1.5     L/HA    GLOBAL
NEXT    FERTILIZA
NEXT    FERTILIZA
NEXT    FERTILIZATION   120     3       30      50
NEXT    HARVEST 20
REPEAT
```

Version, ne pas y toucher — *File version, do not modify*

Durée simulation — *Simulation length*

1 période = 1 itinéraire technique
Peut durer plusieurs années

1 period = 1 crop management
Can cover several years

Exemples dans le répertoire Documentation

Examples in Documentation directory

END = toutes les périodes sont listées, ou REPEAT = répéter les périodes listées

END = all periods are listed, or REPEAT = repeat the listed periods to cover simulation length

Préparez une simulation — *Prepare a simulation*

- Fichier système de culture (nom défini dans configFile.dat)
  Cropping system file (name identified in configFile.dat)

Exemples & explications dans Documentation/inputFLORSYS.xlsx
Examples & explanation in

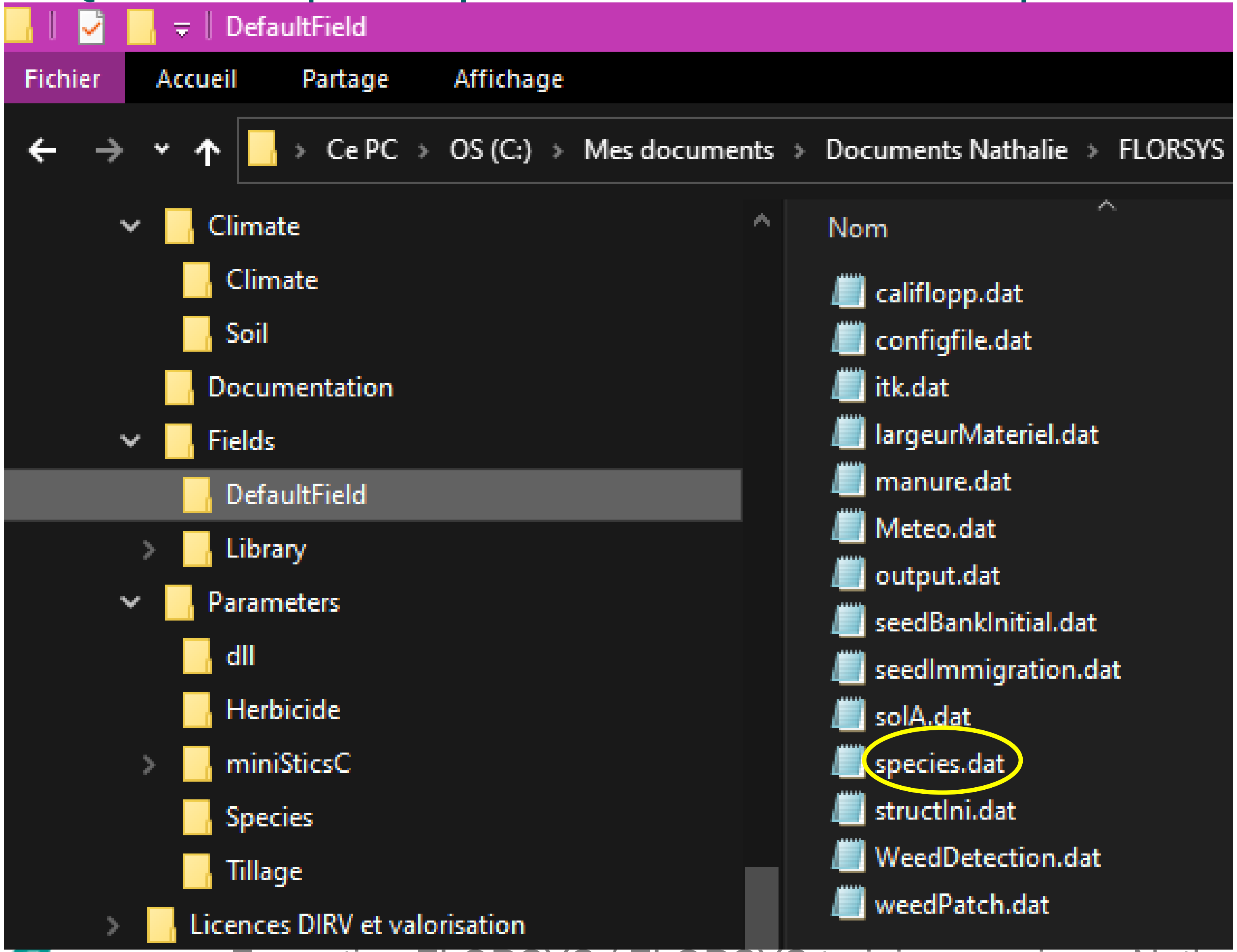
PERIOD	1_COLZA		182	1					
ORIENTATION		NS							
NEXT	SOWING		237	1	NO	30	0	YES	YES
		1							
	COLZA	PRIMARY		50	2		NONE		
NEXT	FERTILIZATION		32	2	70	50			
NEXT	FERTILIZATION		60	2	100	50			
NEXT	HERBICIDE		273	1					
	CLERAVIS		2	L/HA	LOCAL	ROW	5		
NEXT	MECHANICALWEEDING			273	1				
	BINEUSE		12	INTERROW		0.7	2		
NEXT	HARVEST		196	2	0.2	YES	1	COLZA	0

Mots-clés structurant la lecture
Nom d'opération
Autres mots-clés
DDD YYYY
Cultures listées dans species.dat etc

Key words to guide FLORSYS when reading
Operation name
Other key words
DDD YYYY
Crops listed in species.dat etc

Préparez une simulation — *Prepare a simulation*

- Quelles espèces peuvent être simulées: species.dat



The crop & weed species that can be simulated are in species.dat

Préparez une simulation *Prepare a simulation*

- Quelles espèces peuvent être simulées: species.dat
  The crop & weed species that can be simulated are in species.dat

20200122 Version, ne pas y toucher *File version, do not modify*

EntirelyParameterizedSpecies canBeDispersed WeedSpeciesToBeSimulatedInCurrentSimulation

ABUTH	**1**	**1**
ALOMY	**1**	**1**
AMARE	**1**	**1**
AMBEL	**1**	**1**
AVEFA	**1**	**1**
CAPBP	**1**	**1**
CHEAL	**1**	**1**
DATST	**1**	**1**
GALAP	**1**	**1**
GERDI	**1**	**1**
LOLMU	**1**	**1**
MATIN	**1**	**1**

…

END

Les espèces doivent être décrite dans les fichiers paramètres

All species listed here are described in the parameter files

Mots-clés structurant la lecture ***Keywords to guide FLORSYS***

Autres mots-clés ***Other keywords***

Les espèces paramétrées

- Liste complète dans Documentation/ParametersSpeciesFLORSYS.xls / EPPO codes
- 34 espèces de grande culture
  - 18 espèces de rente + 16 espèces de couvert
  - 26 annuelles + 7 pérennes
  - 16 légumineuses, 9 graminées, 9 autres
  - Plusieurs variétés pour pois (7), blé (3), féverole (2)
- 32 espèces adventices annuelles
  - 9 graminées, 22 autres
  - 3 génotypes RLC (RR, WR, WW) x 9 génotypes RNLC
  - 16 automnales, 16 printanières/estivales

The current parameterized speciea

- *Complete list in Documentation/ParametersSpeciesFLORSYS.xls / EPPO codes*
- *34 arable crop species*
  - *18 cash crop + 16 cover crops*
  - *26 annual + 7 perennial*
  - *16 legume, 9 grass, 9 other*
  - *Several varieties for pea (7), wheat (3), faba bean (2)*
- *32 annual weed species*
  - *9 grass, 22 other*
  - *3 genotypes TSR (RR, WR, WW) x 9 genotypes NTSR*
  - *16 winter, 16 spring/summer*

Préparez une simulation — *Prepare a simulation*

Les caractéristiques de la parcelle — *Field characteristics*

– configFile.dat

Version, ne pas y toucher

File version, do not modify

```
20180202
LATITUDE[DEGREES]      47.321999
CROPPING_SYSTEM_FILE           itk.dat
TOOL_WIDTH_FILE        largeurMateriel.dat
SOIL_CLIMATE_FILE(ROOT)_OR_STICS_OPTION  STICS
WEATHER_FILE(ROOT)     dijonMeteo
INITIAL_SEEDBANK_FILE          seedBank.dat
SOIL_TEXTURE_FILE      sol.dat
FIELD_SAMPLE_DIMENSIONS        4 2
VOXELS_SIZE    7.000000        7.000000
PLANT_DENSITY_MAX      5000
WEATHER_OPTIONS        LIST
```

dijonMeteoYYYY.dat
…
dijonMeteoZZZZ.dat
In Climate/Climate

Dans le répertoire de simulation

In simulation directory

LIST → meteo.dat avec liste d'années météo à utiliser
TRUE → utilise les années météo du fichier système de culture
RANDOM …→ tirage au hasard d'années météo

LIST → meteo.dat with weather records to use
TRUE → use the weather years from cropping system file
RANDOM …→ random choice of weather records

Mots-clés structurant la lecture

Autres mots-clés

Keywords to guide FLORSYS

Other keywords

Préparez une simulation — *Prepare a simulation*

Les caractéristiques de la parcelle — *Field characteristics*

– Sol.dat (nom listé dans configFile.dat) — *(name listed in configFile.dat)*

Version, ne pas y toucher

```
20110315

structure_initiale_sol        structIni.dat
conditions_humidités_initiales      SEC
texture_du_sol_ALS(0-100)           36      58      6
cailloux(0-100)    4
profondeur_du_sol         90


sol_STICS(0_si_nouveau_sol)         0

…
```

File version, do not modify

Dans le répertoire de simulation
Ou TERRE_FINE MOTTEUX TASSE

On a des exemples

La suite = fichiers sol STICS

Mots-clés structurant la lecture — ***Keywords to guide FLORSYS***

Autres mots-clés — ***Other keywords***

Préparez une simulation *Prepare a simulation*

Les caractéristiques de la parcelle *Field characteristics*

– seedBank.dat (nom donné dans configFile.dat) *(name listed in configFile.dat)*

numberOfSpecies				29
ABUTH	**0**	0	0	0
ABUTH	**1**	0	365	0
ABUTH	**1**	1	365	0
ABUTH	**1**	2	365	0
ABUTH	**1**	3	365	0
ABUTH	**1**	4	365	0
ABUTH	**1**	5	365	0
ABUTH	**1**	6	365	0
ABUTH	**1**	7	365	0
ABUTH	**1**	8	365	0
ABUTH	**1**	9	365	0
ALOMY	**0**	0	0	6.493407254
ALOMY	**1**	0	365	0.649340725
ALOMY	**1**	1	365	0.649340725
…				

Mots-clés structurant la lecture — ***Keywords to guide FLORSYS***

Autres mots-clés — ***Other keywords***

Espèces listées dans species.dat etc — *Weed species listed in species.dat etc*

On a des exemples + méthodes pour créer des stocks à partir de données de flore régionale

Examples + methods to create seed banks from regional flora observations are available

Préparez une simulation *Prepare a simulation*

Les caractéristiques de la parcelle *Field characteristics*

– seedImmigation.dat

Version, ne pas y toucher *File version, do not modify*

```
20120121
ABUTH  0            RANDOM
ALOMY  0.064934073  RANDOM
AMARE  1.144113503  RANDOM
AMBEL  0            RANDOM
AVEFA  0.038950326  RANDOM
CAPBP  1.93958918   RANDOM
CHEAL  0.999778577  RANDOM
…
END
```

Mots-clés structurant la lecture ***Keywords to guide FLORSYS***

Autres mots-clés ***Other keywords***

Espèces listées dans species.dat etc *Weed species listed in species.dat etc*

On a des exemples + méthodes pour créer le fichier à partir de données de flore régionale

Examples + methods to create file from regional flora observations are available

Préparez une simulation *Prepare a simulation*

Les caractéristiques de la parcelle *Field characteristics*

- weedPatch.dat

On a des exemples

Examples available

20150908							
durationOfFixedPatches		0					
Species	Distribution	PatchNumber	Type	Size	NumberManagement	InitialPatchX	Y InitialPatchSize
ALL	PATCH	3	HEIGHT	95	CONSTANT		
END							

Version, ne pas y toucher *File version, do not modify*

20150908							
durationOfFixedPatches		0					
Species	**Distribution**	**PatchNumber**	**Type**	**Size**	**NumberManagement**	**InitialPatchX**	**Y Initi**
ALL	**PATCH**	1	**HEIGHT** 95		**CONSTANT**		
ALOMY	**PATCH**	3	**HEIGHT** 95		**CONSTANT**		
END							

20150908							
durationOfFixedPatches		0					
Species	**Distribution**	**PatchNumber**	**Type**	**Size**	**NumberManagement**	**InitialPatchX**	**Y Initi**
ALL	**UNIFORM**						
END							

Mots-clés structurant la lecture | **Autres mots-clés** | Espèces listées dans species.dat etc

Keywords to guide FLORSYS | ***Other keywords*** | *Weed species listed in species.dat etc*

Préparez une simulation *Prepare a simulation*

- Choisir les variables de sortie *Choose output files*

```
20181210
Synthese            1
Indicators          1
SeedBank            0
SoilStructure       1
GerminationDates            1
Germination         1
Emergence           1
WeedPopulations             1
WeedSeedProduction          1
WeedBiomass         0
OUT_CROP_WEED_STATS         1
…

NumberOfDates 2
123     1995
225     1996
END
```

```
…
NumberOfDates FREQUENCY 15
END
```

⚠

+ on demande sortie,
+ lente est la simulation!

The more output files are required, the longer the simulation takes!

Lancer une simulation (ou une liste) *Run a simulation (or a list of)*

- Préparez les fichiers d'entrée
- Lister les parcelles à simuler dans florsys.dat

- *Prepare input files*
- *Lister fields to simulate in florsys.dat*

florsys.dat - Bloc-notes

Fichier Edition Format Affichage Aide

```
20140101

NEXT 10 ./Fields/Library/A1/
NEXT 10 ./Fields/Library/A5/
NEXT 10 ./Fields/Library/A6/
NEXT 10 ./Fields/Library/A7/
NEXT 10 ./Fields/Library/A8/

NEXT 10 ./Fields/Library/D1/
NEXT 10 ./Fields/Library/D2/
NEXT 10 ./Fields/Library/D3/
NEXT 10 ./Fields/Library/D4/
NEXT 10 ./Fields/Library/D5/

NEXT 10 ./Fields/Library/F1SoayMaizeWheatMaize/
NEXT 10 ./Fields/Library/LocalSpray/
NEXT 10 ./Fields/Library/Desherbinage/

END
```

Version, ne pas modifier

File version, do not modify

Nombre de répétitions

Number of repetitions

Chemin depuis l'emplacement de l'exe

(Peut aussi être donné en absolu C:/Simulation/Champ/A1/)

Path from where the exe is

(Complete paths are also accepted C:/Simulation/Champ/A1/)

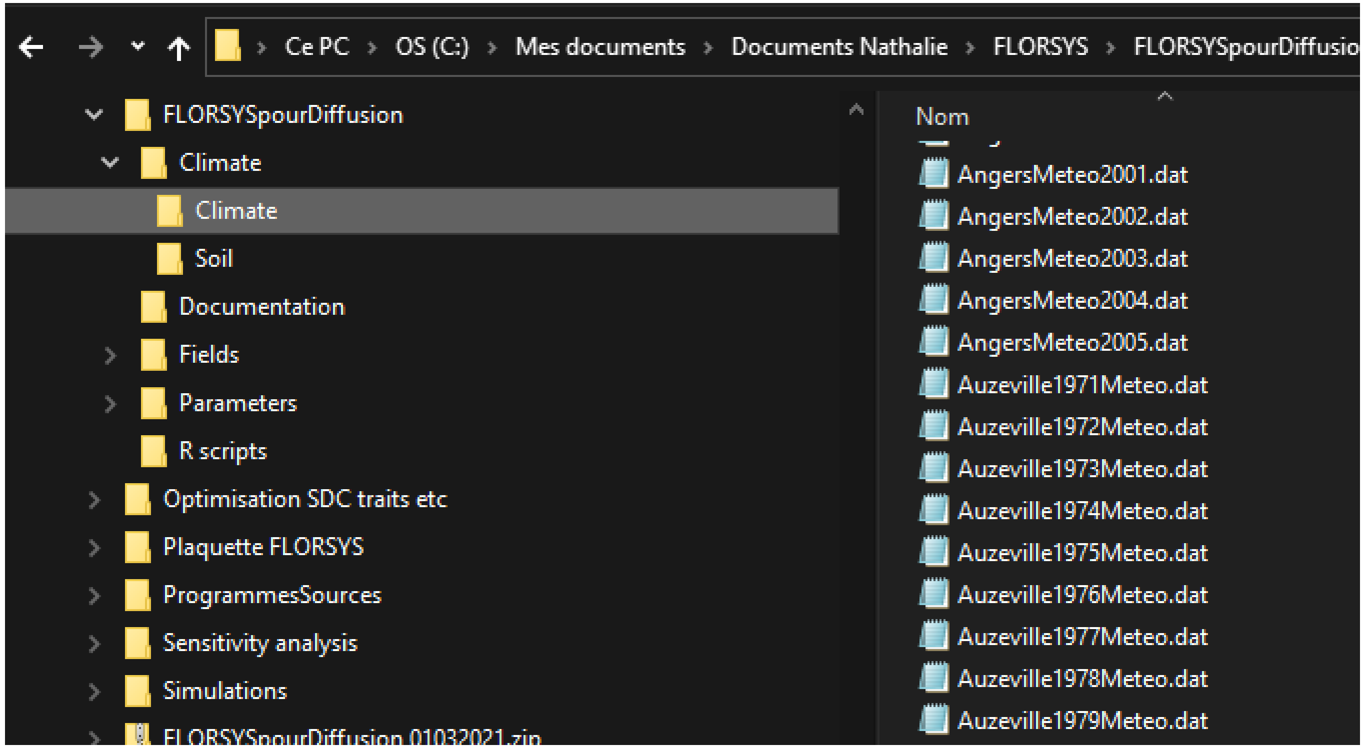
Tout ce qui est après END est ignoré

Everything after END is ignored

Actual weather or randomised list? Meaning of repetitions? (i)

Objective = compare simulations to field observations

- Use "real" weather corresponding to the dates covered by the cropping system file
- Climate/Climate locationYear1.dat – locationYearN.dat if field history runs from year1 to yearN
- configFile.par: WEATHER_OPTION TRUE
- Florsys.dat: R=10 repetitions (only stochastic effects)



Actual weather or randomised list? Meaning of repetitions? (ii)

Objective = evaluate (actual or prospective) cropping systems

- Use randomised weather series (always the same for each system) → complete experimental plan with blocks
- Climate/Climate: all locationYearX.dat with X listed in meteo.dat
- configFile.par: WEATHER_OPTION LIST
- Meteo.dat: R series of N+1 weather years (chosen randomly or consecutive)
- Florsys.dat: R=10 repetitions (stochastic + weather effects)

*Meteo.dat - Bloc-notes

Fichier Edition Format Affichage Aide

```
2006
2006
2001
2002
2000
2004
2002
2006
2003
2006
2003

NEXT
2006
2003
2002
2006
2006
2003
2003
2003
2004
2002
2003

NEXT
2001
2005
2002
2001
2005
2006
2002
2000
```

*Meteo.dat - Bloc-notes

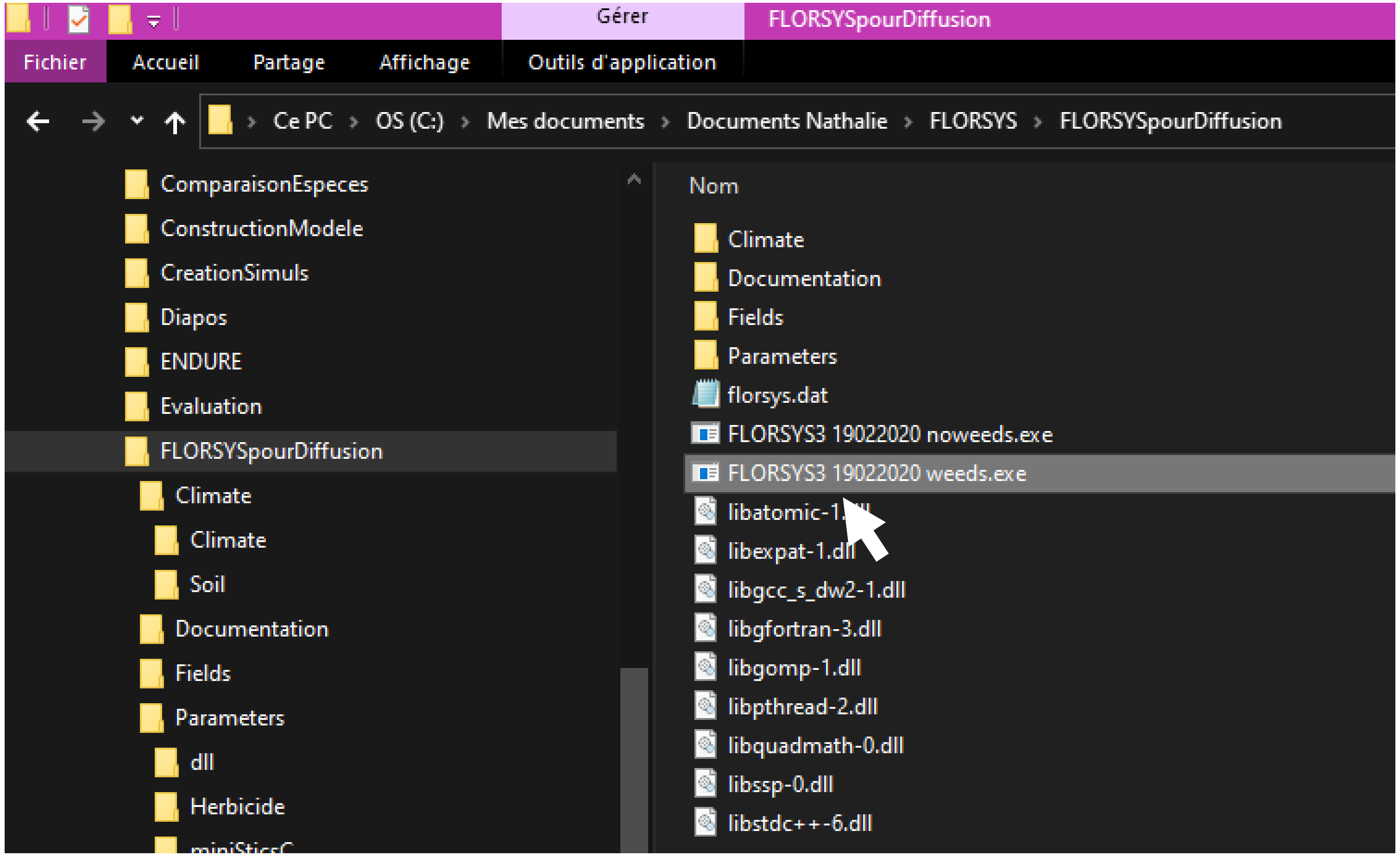
Fichier Edition Format Affichage Aide

```
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

NEXT
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

NEXT
2003
2004
2005
2006
2007
2008
2009
2010
```

Lancer une simulation — *Run a simulation*

- Préparez les fichiers d'entrée
- Lister les parcelles à simuler dans florsys.dat
- **Double-cliquer sur le fichier exe**

- *Prepare input files*
- *Lister fields to simulate in florsys.dat*
- ***Double-click on exe file***



Les différentes versions *The different FLORSYS versions*

Actuellement *Currently*

- FLORSYSddmmyyyy weeds.exe
- FLORSYSddmmyyyy noweeds.exe
- … noherbicides.exe
- … onlyGLY.exe
- … notill.exe
- … PHERA.exe
- …N.exe

En cours de développement *Work in progress*

- … predation.exe

Lancer une simulation / *Run a simulation*

- Préparez les fichiers d'entrée
- Lister les parcelles à simuler dans florsys.dat
- Double-cliquer sur le fichier exe
- **Une fenêtre apparaît**

- *Prepare input files*
- *Lister fields to simulate in florsys.dat*
- *Double-click on exe file*
- ***A window opens***

"C:\Mes documents\Documents Nathalie\FLORSYS\ProgrammesSources\Sources depuis Renater\branches\NC_dev\FLORSYS.3\bin\Release\FLORSYS3....

```
Reading herbicide parameter file.....SUCCESS
./Parameters/Herbicide/PesticidesIndicators.par
%%%%%%%%% rotationPattern %%%%%%%%%%%%
ablength 2
%%%%%%%%% irrigation: vecDiffBetweenPreviousPeriod %%%%%%%%%%%%
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0
synthItk.prn written
synthItkPerCrop.prn written
181     dominating species UNKNOWN -> ABUTH

FlorsysStics 2226 > forceVegetation > species ABUTH crop
182 183 184 185 186 187 188 189 190 191         dominating species ABUTH -> CHEAL

FlorsysStics 2226 > forceVegetation > species CHEAL crop
192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208     dominating species CHEAL -> SOLNI

FlorsysStics 2226 > forceVegetation > species SOLNI crop
209 210 211 212 213 214 215 216 217 218         dominating species SOLNI -> DIGSA

FlorsysStics 2226 > forceVegetation > species DIGSA orge
219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237
-----------------
SOWING
sowing 0/0 -> nbpl really sown=400 (every seed)
(mix 1/1)(sown_crop 1/1)
SOWING DONE
-----------------

238 239 240 241 242 243 244 245 246 247
```

Fin de simulation — *End of simulation*

- Si tout s'est bien passé — *If everything goes well*

```
"C:\Mes documents\Documents Nathalie\FLORSYS\ProgrammesSources\Sources depuis Renater\branches\NC_dev\FLORSYS.3\bin\Release\FLORSYS3....
 _______________

  FLORSYS.3 2019
 _______________


Your operating system is : Windows
Florsys input files updates


ATTENTION: Des divergences entre simulations et observations sont probables et normales, surtout si
- le fichier mÚtÚo ne correspond pas Ó la mÚtÚo pendant l'essai
- les dates des interventions (notamment du travail du sol) sur le terrain et dans la simulation ne sont pas exactement
les mÛmes
- la simulation n'a pas ÚtÚ initialisÚe avec un stock mesurÚe avant l'essai
- la simulation concerne une pÚriode plus longue que l'essai
- l'essai a ÚtÚ soumis Ó des facteurs limitants (sÚcheresse, manque d'azote, maladies etc) autres que les adventices
Voir la notice sur les limites du modÞle et l'interprÚtation des rÚsultats

-----------------------------
ALL THE SIMULATIONS ARE OVER.
-----------------------------


----------------------
NO ERROR was reported.
-------------------------

PRESS ENTER TO QUIT
```

Fin de simulation — *End of simulation*

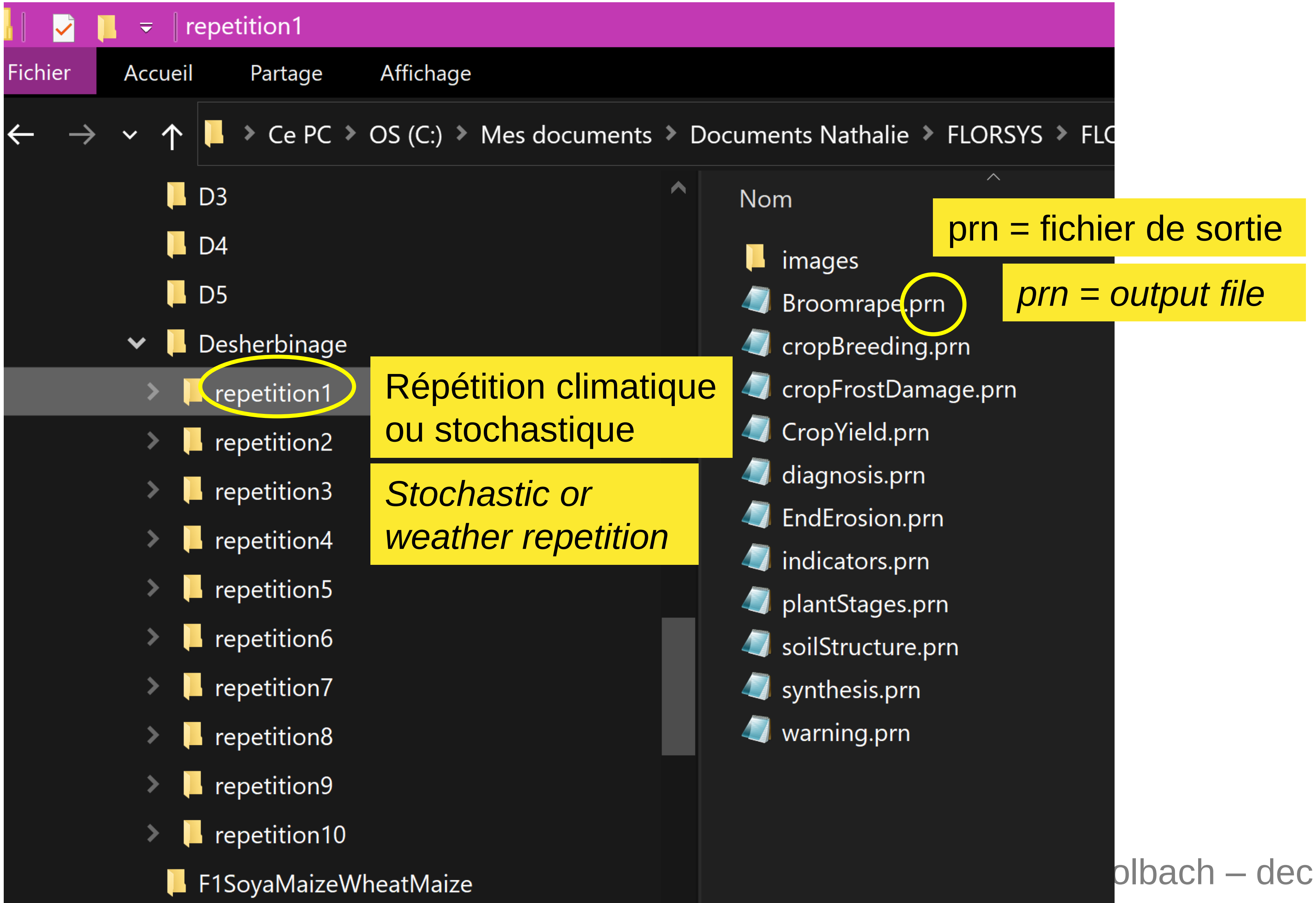
- Cherchez l'erreur — *Looking for errors*

"C:\Mes documents\Documents Nathalie\FLORSYS\ProgrammesSources\Sources depuis Renater\branches\NC_dev\FLORSYS.3\bin\Release\FLORSYS3....

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
FlorsysSimulation - while reading input files
CRITICAL ERROR IN SIMULATION "./Fields/A1/"
Error = "In force_mkdir,
Florsys WIN32 cannot create the directory ./Fields/A1/repetition1/.
Close any open output files or open output directories.".
This simulation fails and the next one (if any) will begin.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!




ATTENTION: Des divergences entre simulations et observations sont probables et normales, surtout si
- le fichier mÚtÚo ne correspond pas Ó la mÚtÚo pendant l'essai
- les dates des interventions (notamment du travail du sol) sur le terrain et dans la simulation ne sont pas exactement
les mÛmes
- la simulation n'a pas ÚtÚ initialisÚe avec un stock mesurÚe avant l'essai
- la simulation concerne une pÚriode plus longue que l'essai
- l'essai a ÚtÚ soumis Ó des facteurs limitants (sÚcheresse, manque d'azote, maladies etc) autres que les adventices
Voir la notice sur les limites du modÞle et l'interprÚtation des rÚsultats

-----------------------------
ALL THE SIMULATIONS ARE OVER.
-----------------------------


---------------------------------------------------------------------
CAUTION: critical errors occurred in at least one of the simulations.
Please read the error.prn file for further information.
---------------------------------------------------------------------

PRESS ENTER TO QUIT
```

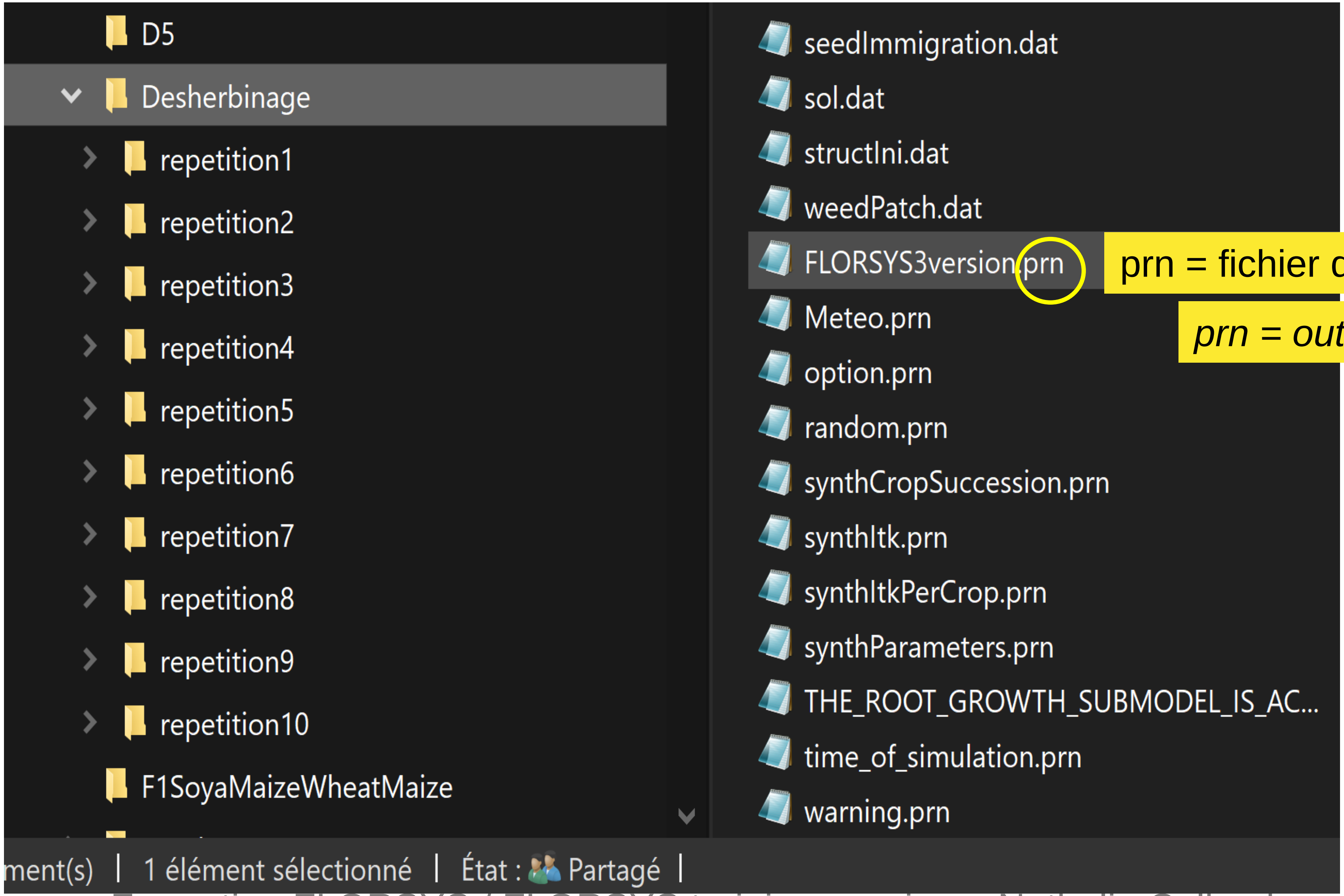
Les sorties — *Output files*

- Les sorties par répétition — *Output per repetition*



Les sorties / *Output files*

- Les sorties globales / *Global outputs*



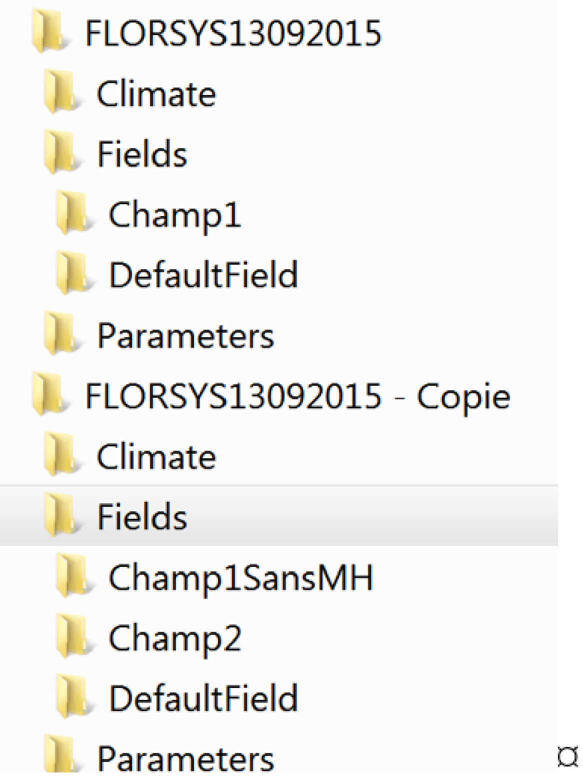
prn = fichier de sortie

prn = output file

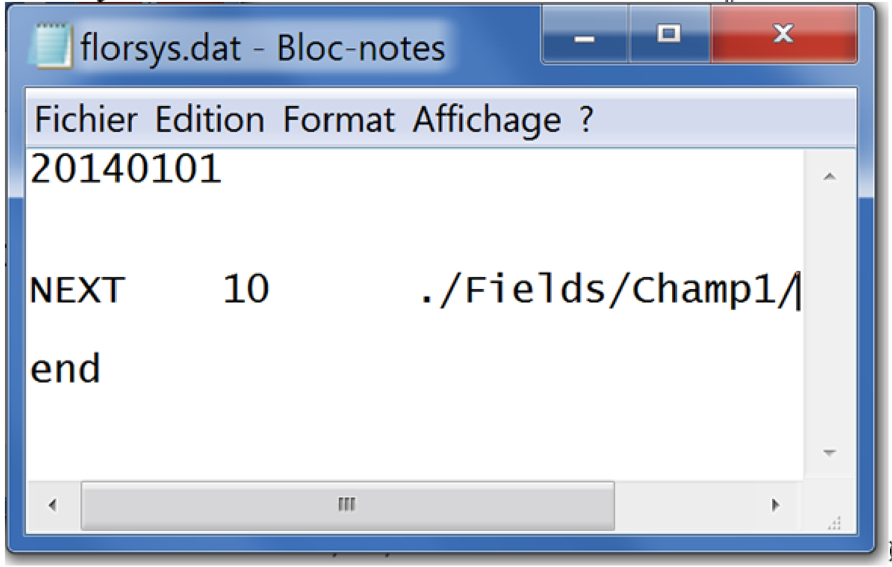
How to run a great number of simulations? (i)

Parallelise manually

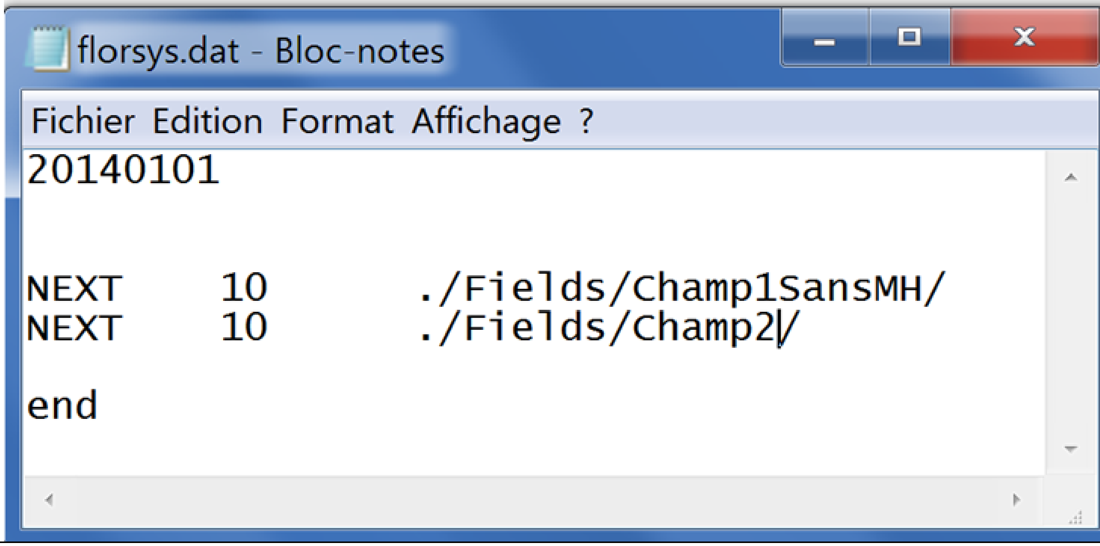
- Create X FLORSYS directories ("clones")
- Distribute the virtual fields to simulate among the Fields directories of the different FLORSYS clones



Florsys.dat file for FLORSYS13092015

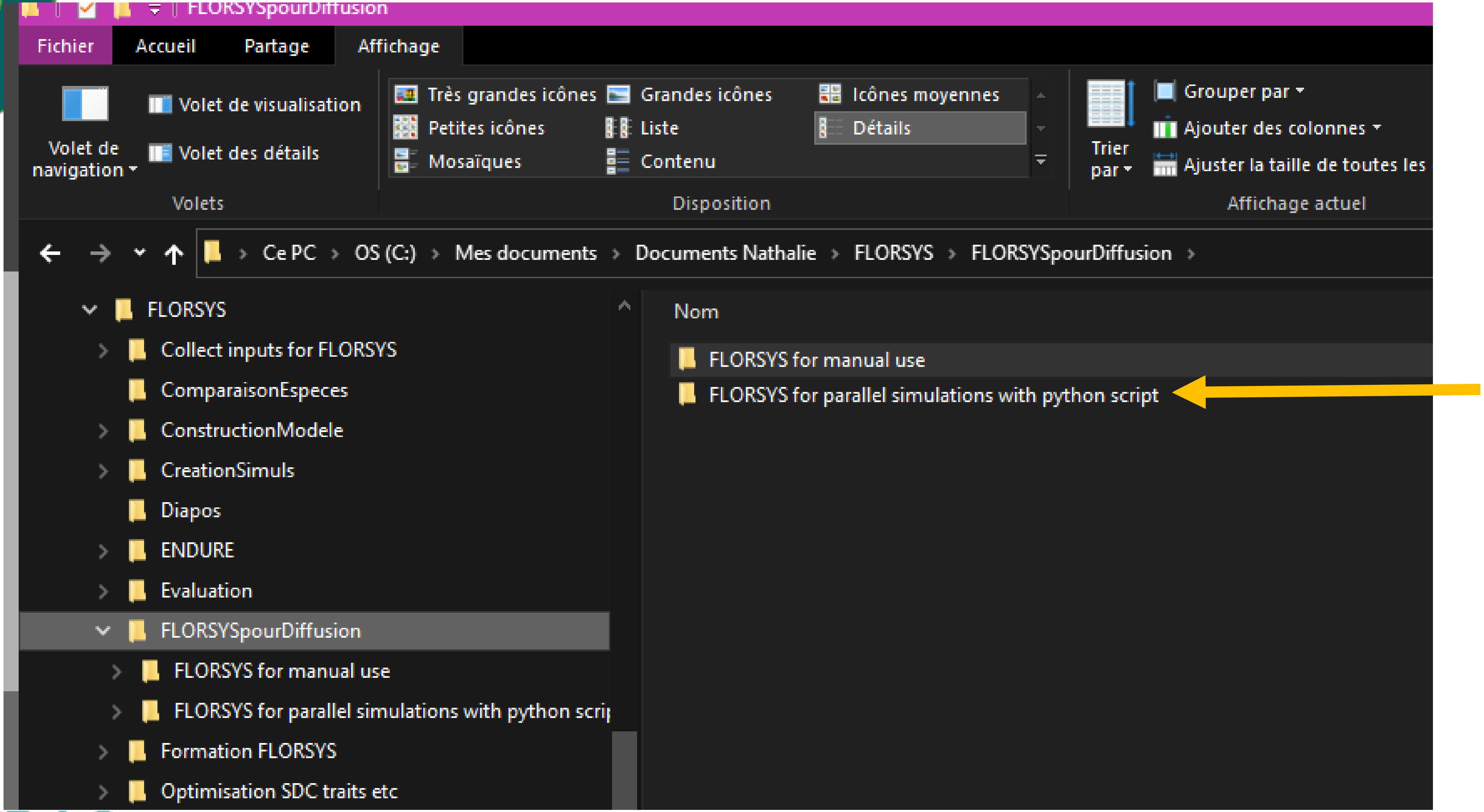


Florsys.dat for FLORSYS13092015 – Copie



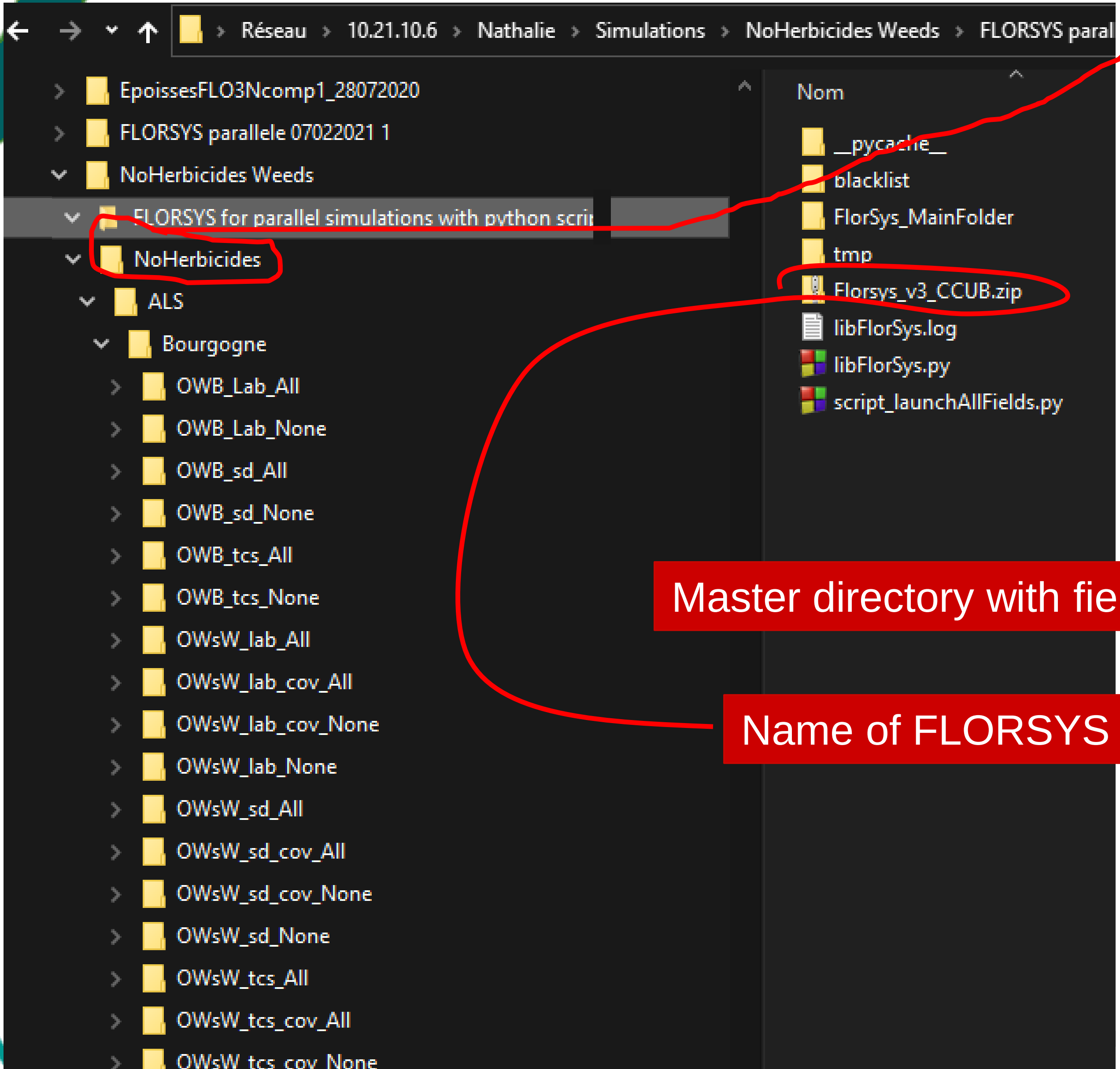
Utiliser FLORSYS en parallélisation automatique

Use the automatic FLORSYS parallelisation



How to run a great number of simulations? (ii)

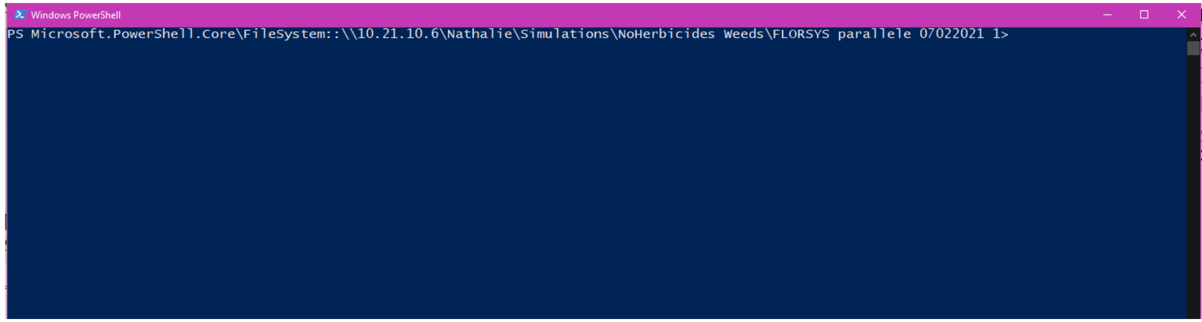
Parallelise with Python script



Master directory with fields

Name of FLORSYS exe in this zip

- Put all field directories to be simulated in a single master directory
- Open a powerShell window (shift-right-click droit in FLORSYS for parallele simuations)



- Type python command to run: python script_launchAllFields.py "./../NoHerbicides/" –e "FLORSYSddmmyyyy.exe" –n 50 –r 10

Nb repetitions

Number of FLORSYS clones (must be < number of logical processors)

What to do in case of problems (this will surely happen!)

- Look in the manual
  - FAQ in HowToRunFLORSYS.doc
  - Dépannage.doc
- In case of total dispair ☺
  - FLORSYSteam@inrae.fr with
    - Needed: The field-directory (zipped)
    - If possible: The FLORSYS directory (zipped)
  - We will answer (but not immediately…)

Quels cas particuliers voulez-vous traiter?

Quels systèmes tester?

Des cas particuliers?

What particular case studies do you have?

- *Which systems do you want to test?*
- *Particular situations?*