The contribution of STICS to modelling the impacts of weeds and climate change on crop production and biodiversity in FLORSYS

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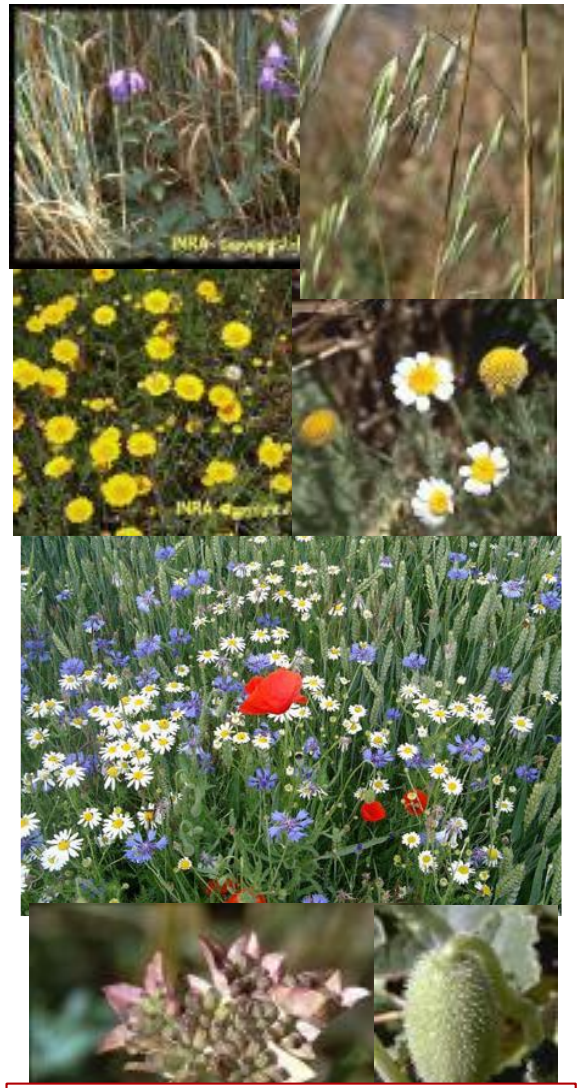
XIVth STICS seminar, 17-19 March 2026, organized by ULiege-GxABT & INRAE

Liebman & Gallandt (1997)

Combinations of partially efficient & interacting techniques



Many diverse species

(Jauzein 1995, Mamarot et Rodriguez, 2013)

Oerke (2006) Journal of Agricultural Science

Crop production
- Grain / Biomass
- Energy

Weed harmfulness
- Yield loss
- Field infestation
- …

LOSS

Weed benefits Biodiversity
- Species richness
- Species eveness
- Trophic resources for birds, bees…

Marshall et al (2003) Weed Research

Multi-criteria evaluation

We need models!

Liebman & Gallandt (1997)

Many diverse species

(Jauzein 1995, Mamarot et Rodriguez, 2013)

Oerke (2006) Journal of Agricultural Science

Crop production
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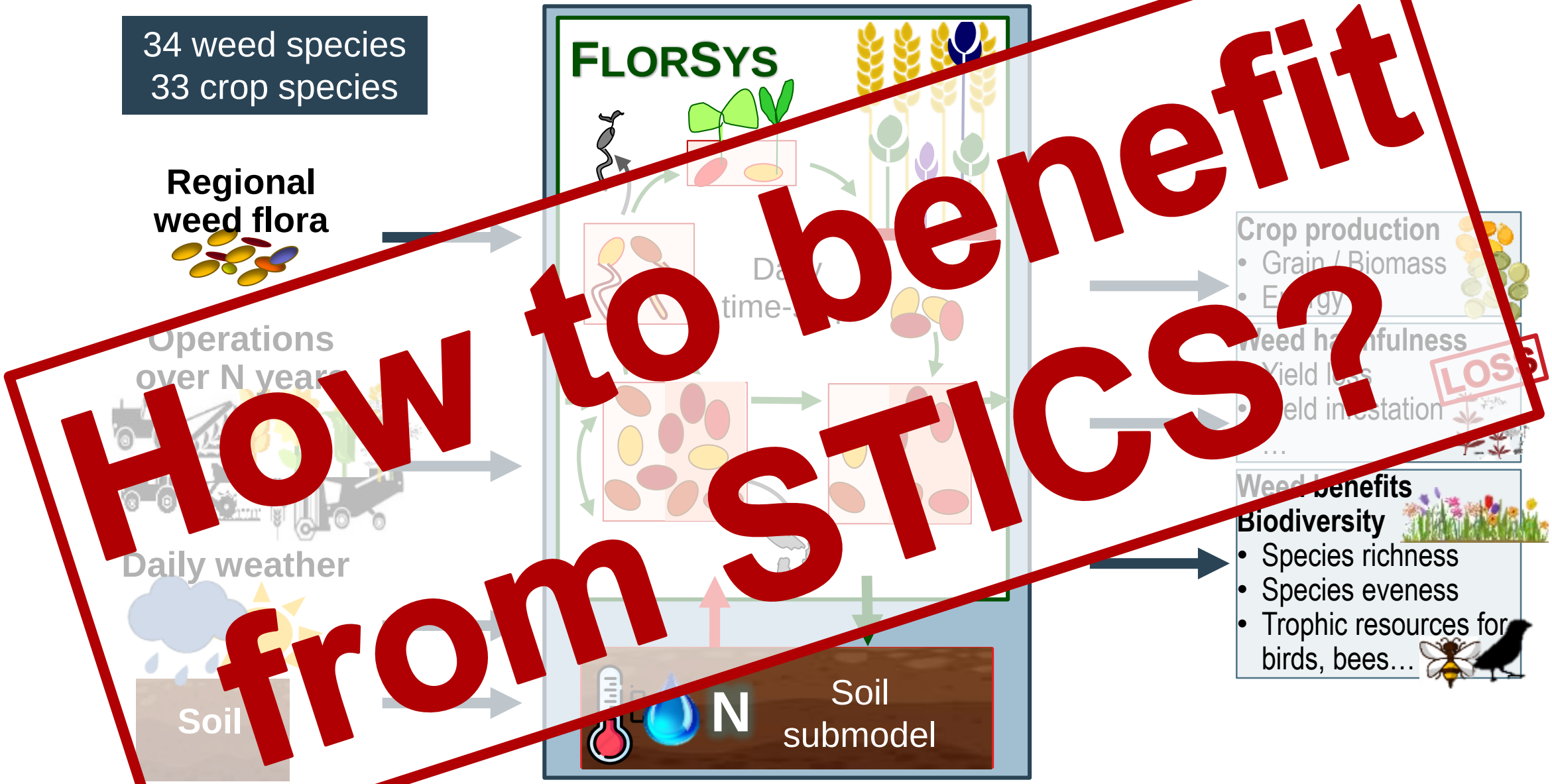
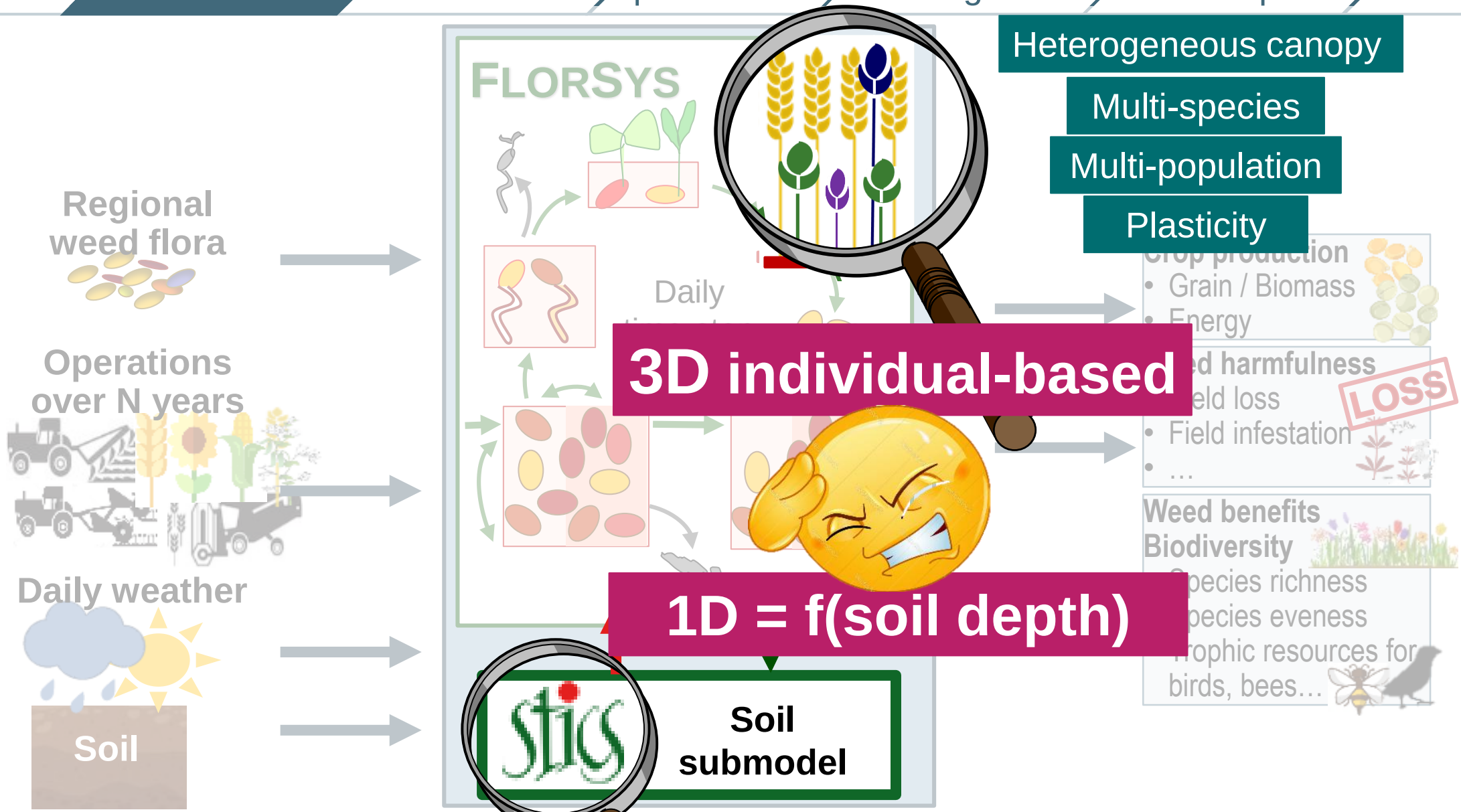
Multi-criteria evaluation

34 weed species
33 crop species



How to benefit from STICS?

Colbach et al (2014) Eur J Agron, Colbach et al (2021) Field Crops Research, Gardarin et al (2012) Ecol Modelling, Mézière et al (2015) Ecological Indicators, Munier-Jolain et al (2013) Ecol Modelling, Pointurier et al (2021) Ecol Modelling



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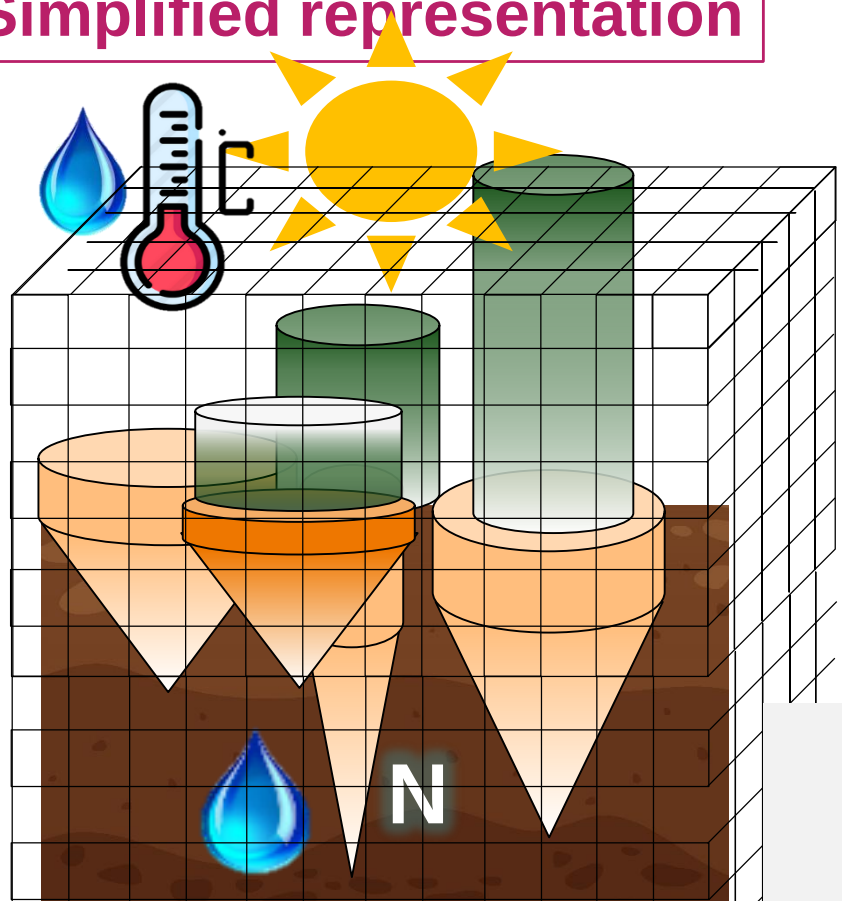
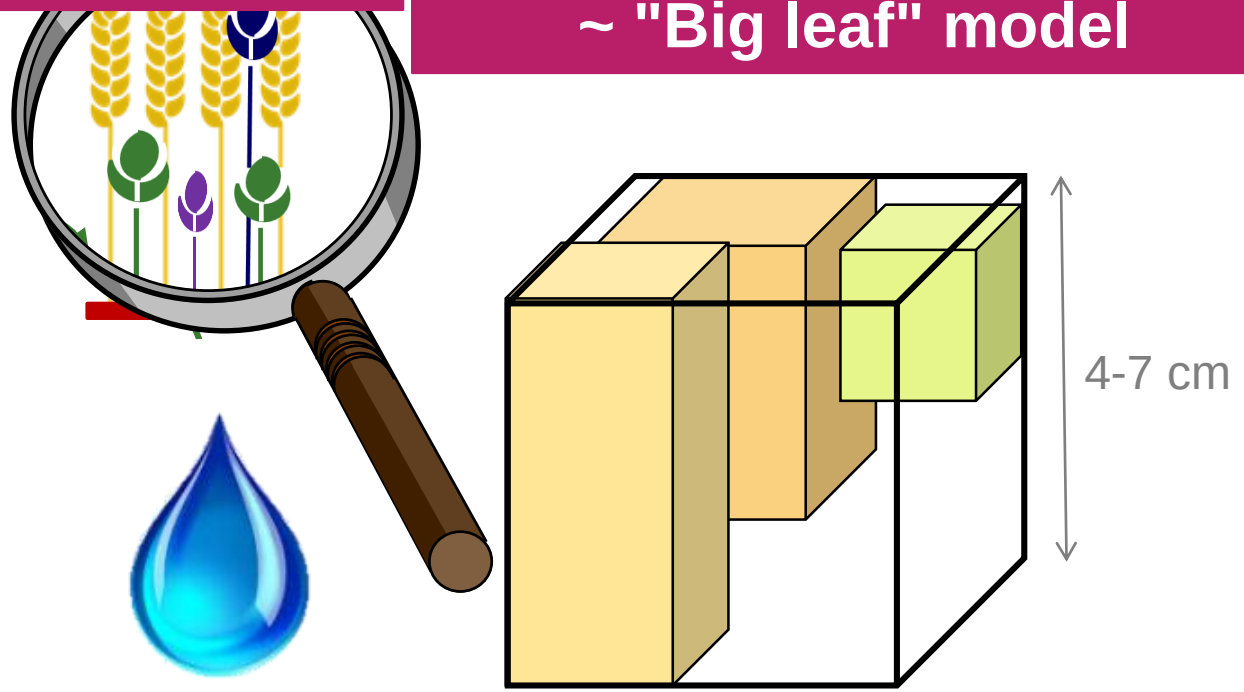
Plant position
Simplified representation



FSPM × Crop model

Competition for resources
~ "Big leaf" model

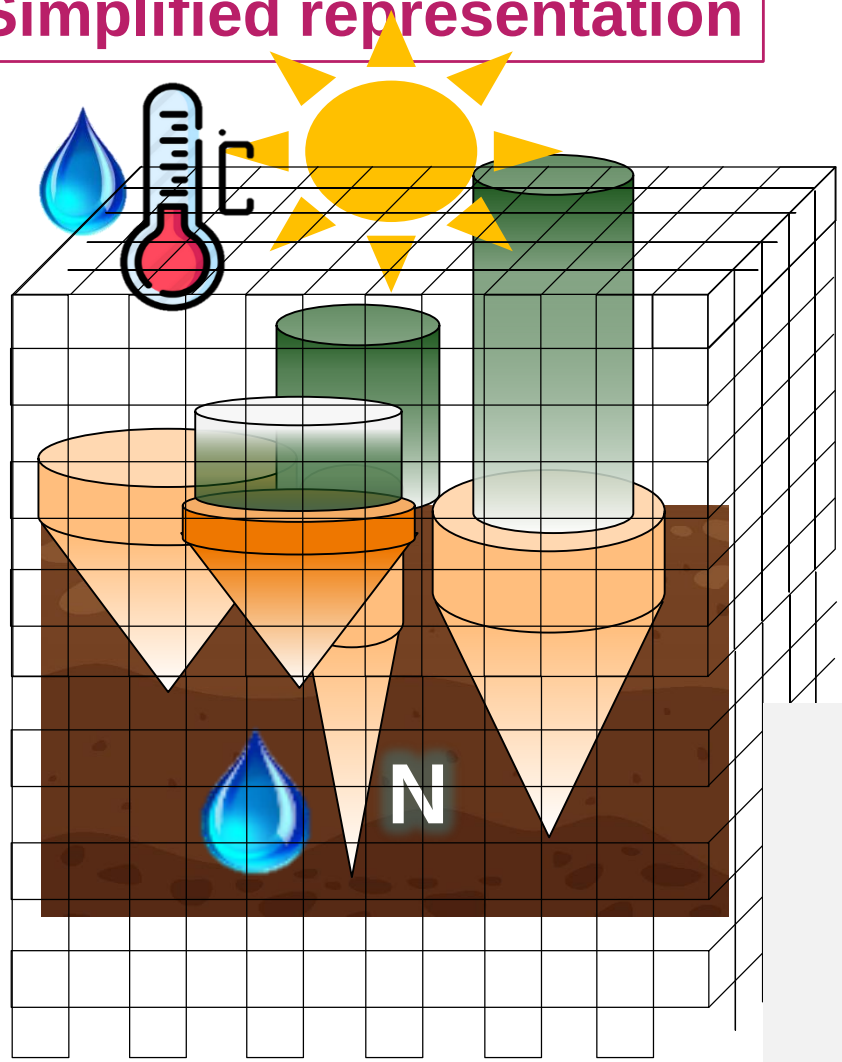


$$\text{H2O takeup of plant in voxel} = \text{available g H2O in voxel} \times \frac{(\text{g root biomass of plant in voxel} \times \text{species takeup potential per g root} \times \text{g H2O demand of plant in voxel})}{\sum(\text{plant root biomass plant area in voxel} \times \text{species takeup potential} \times \text{plant H2O demand in voxel})}$$

Munier-Jolain et al (2013) Ecological Modelling
http://dx.doi.org/10.1016/j.ecolmodel.2012.10.023
Moreau et al (2021) Field Crops Research
https://doi.org/10.1016/j.fcr.2021.108166

Cournault et al (submitted) European Journal of Agronomy

Plant position
Simplified representation



Competition for resources
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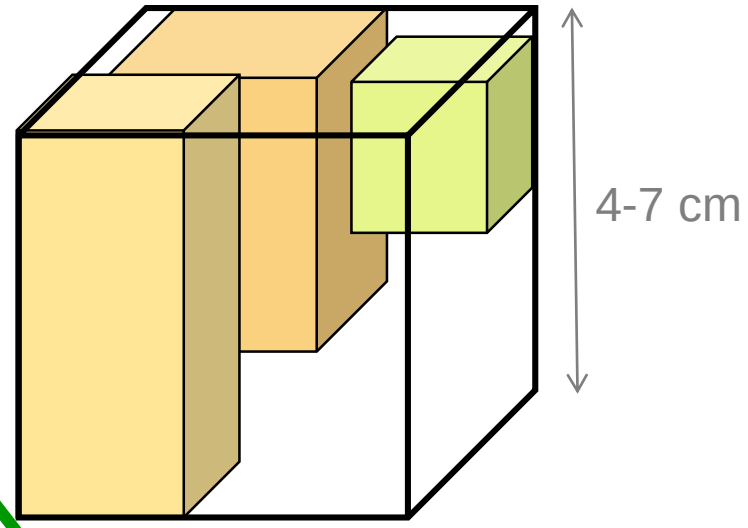

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?

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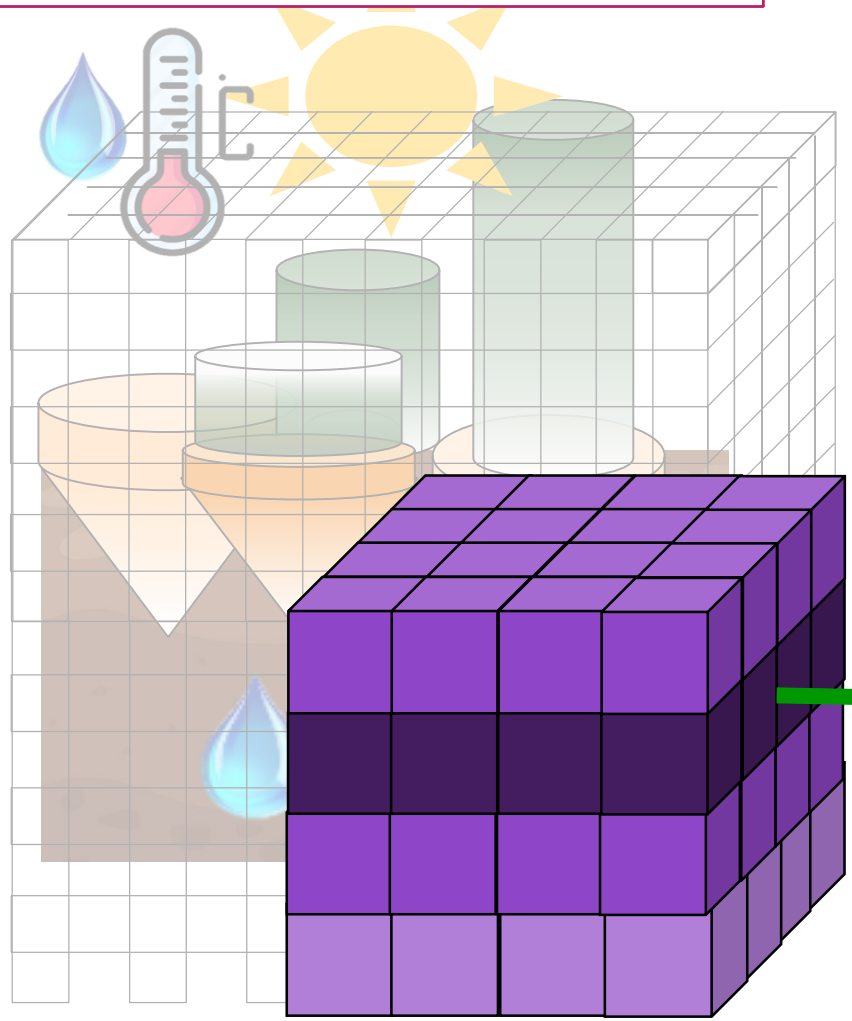

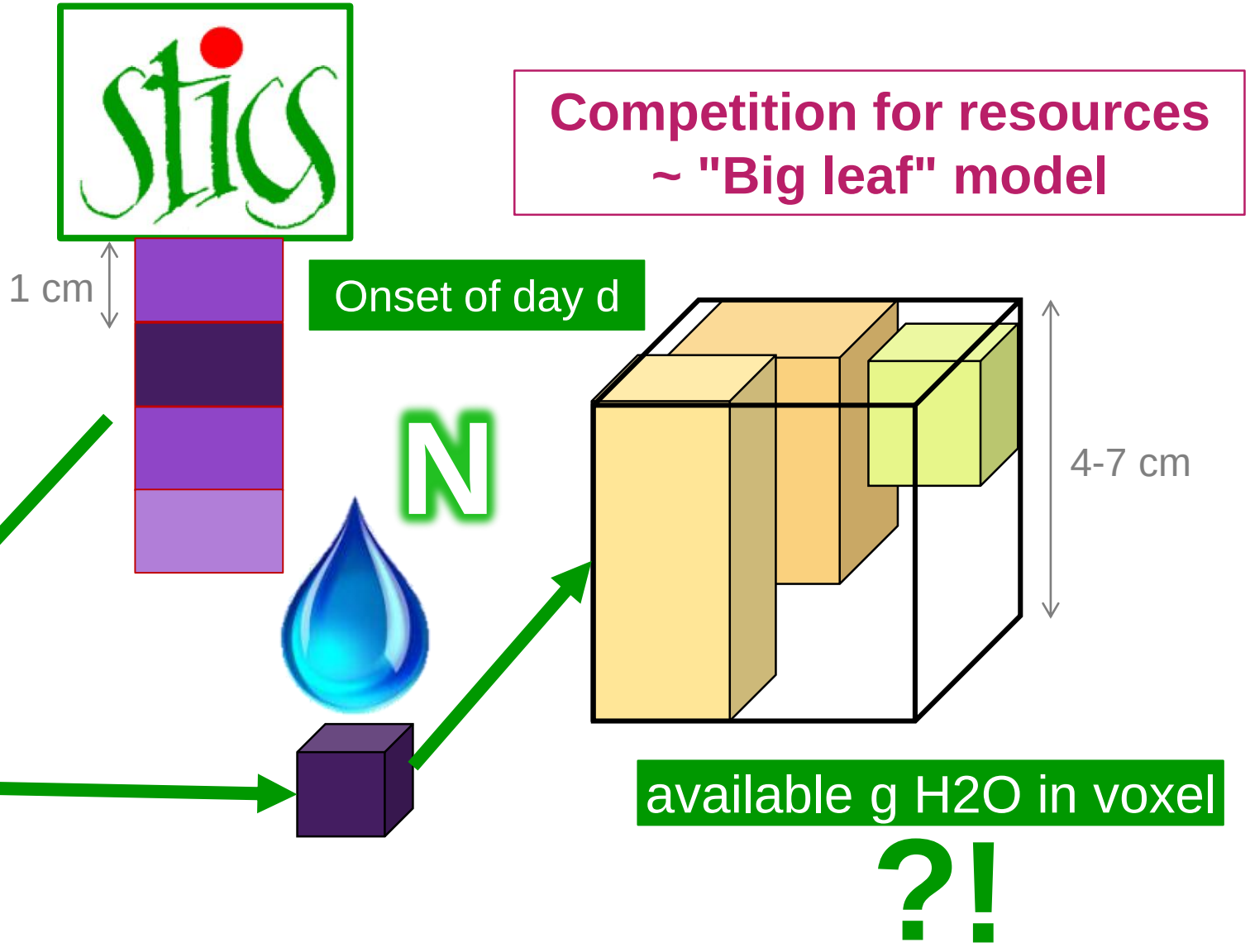

Competition for resources
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Moreau et al (2021) Field Crops Research https://doi.org/10.1016/j.fcr.2021.108166
Cournault et al (submitted) European Journal of Agronomy

Plant position
Simplified representation

Competition for resources
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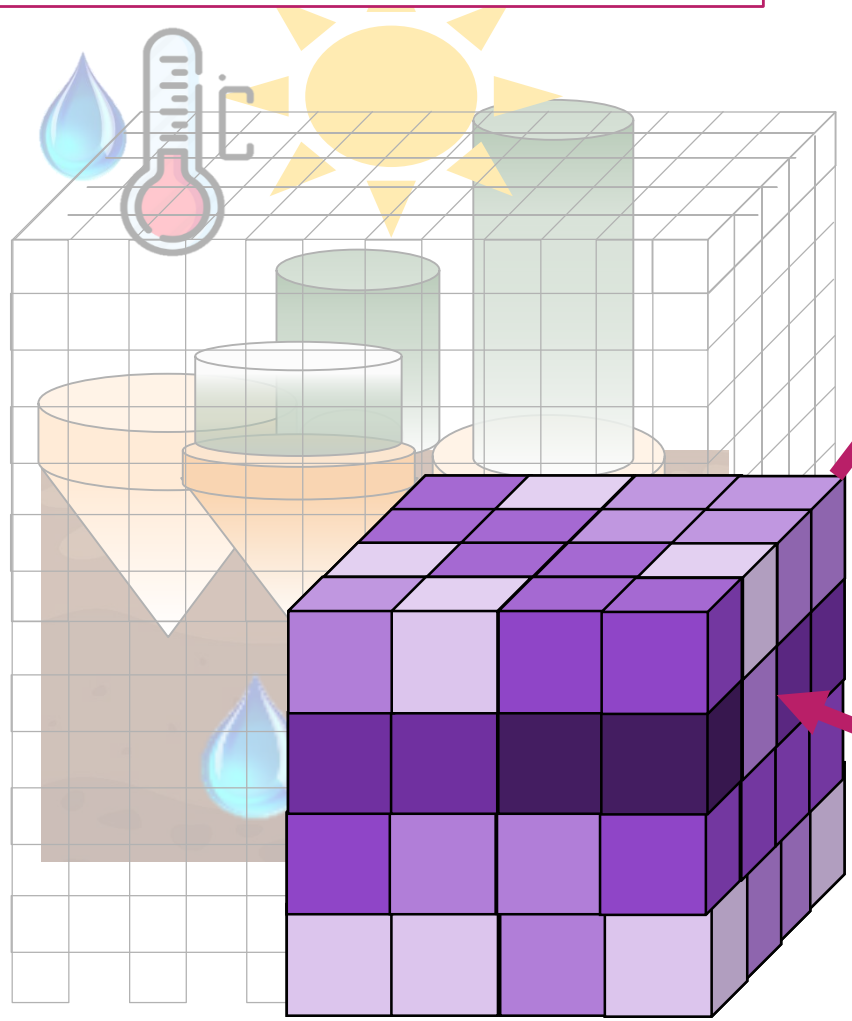
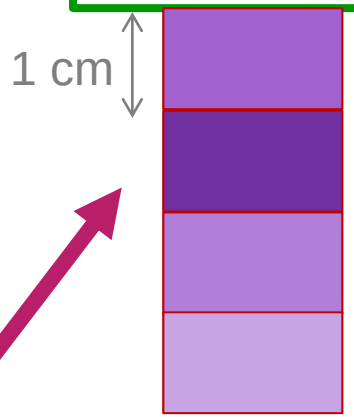
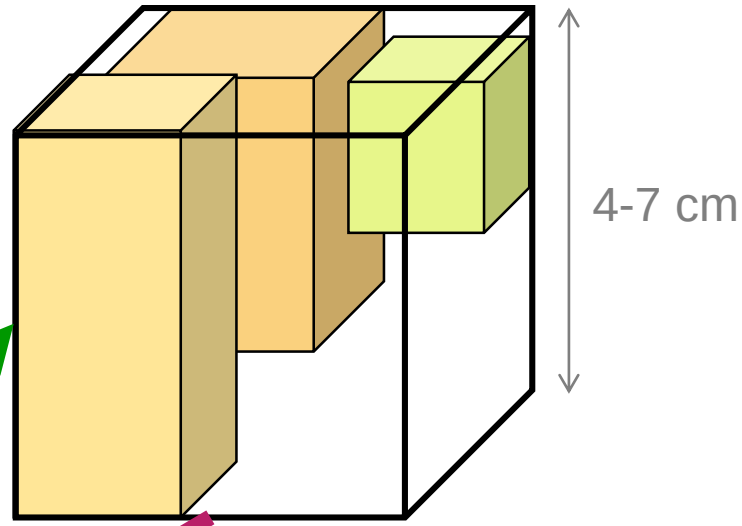




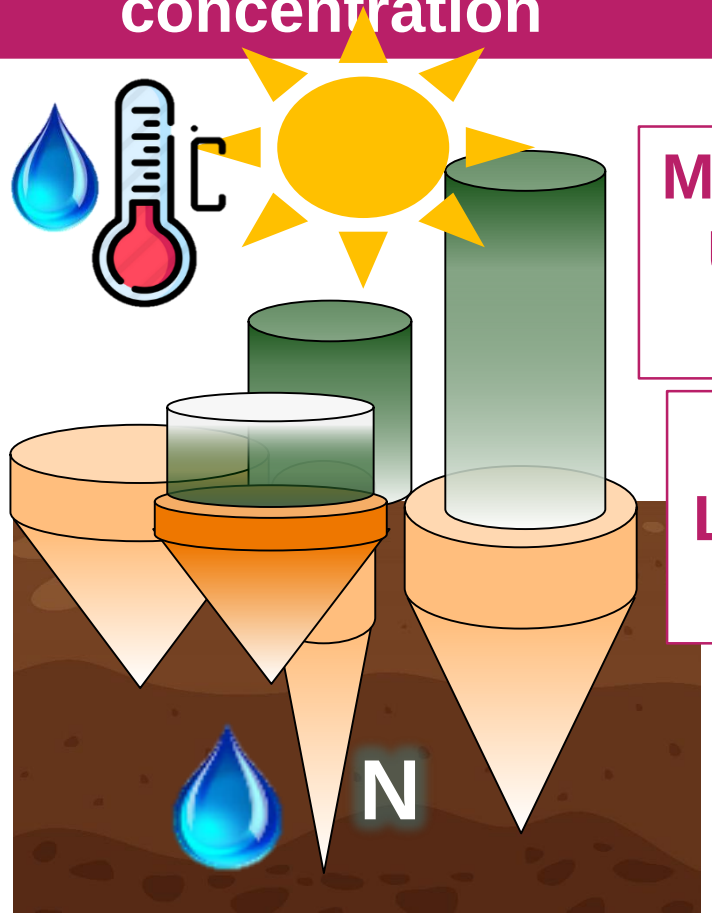


Competition for resources

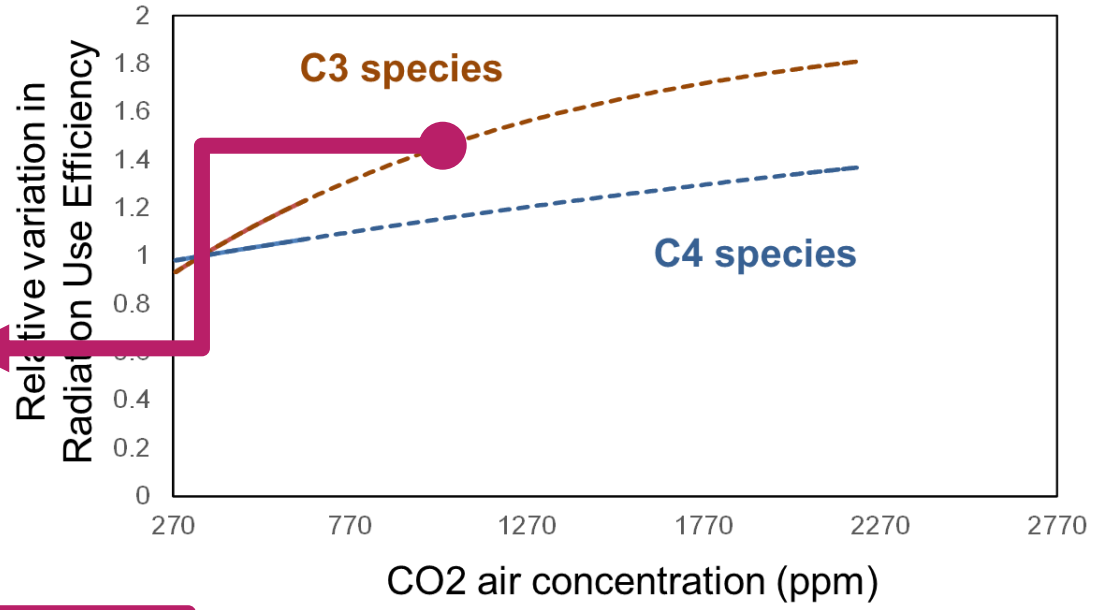
End of day d

Moreau et al (2021) Field Crops Research https://doi.org/10.1016/j.fcr.2021.108166
Cournault et al (submitted) European Journal of Agronomy

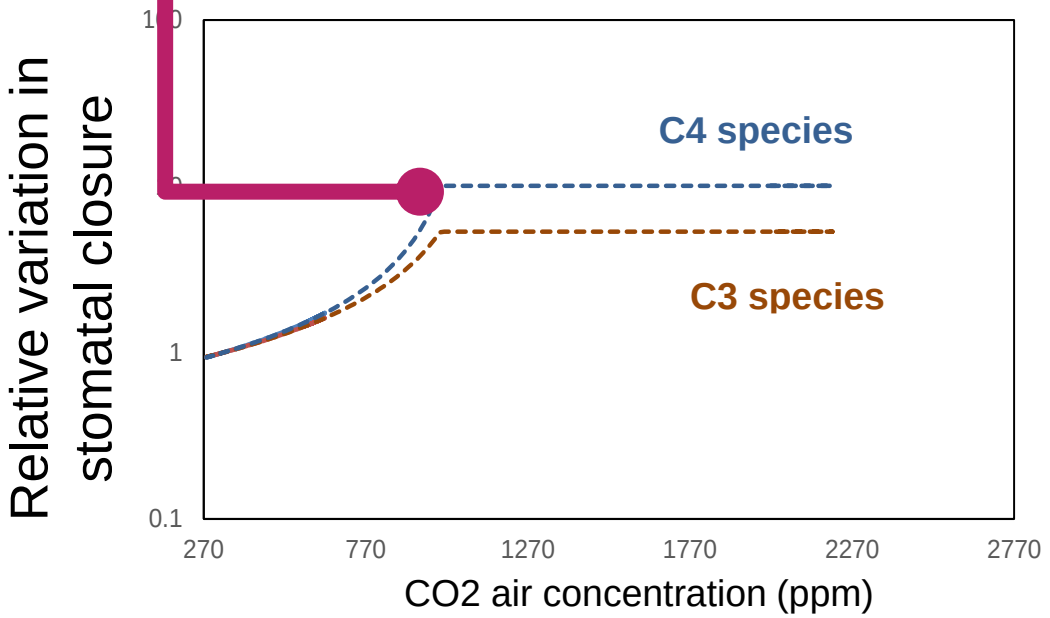
Effect of elevated CO2 concentration



Multiplies Radiation Use Efficiency in FLORSYS



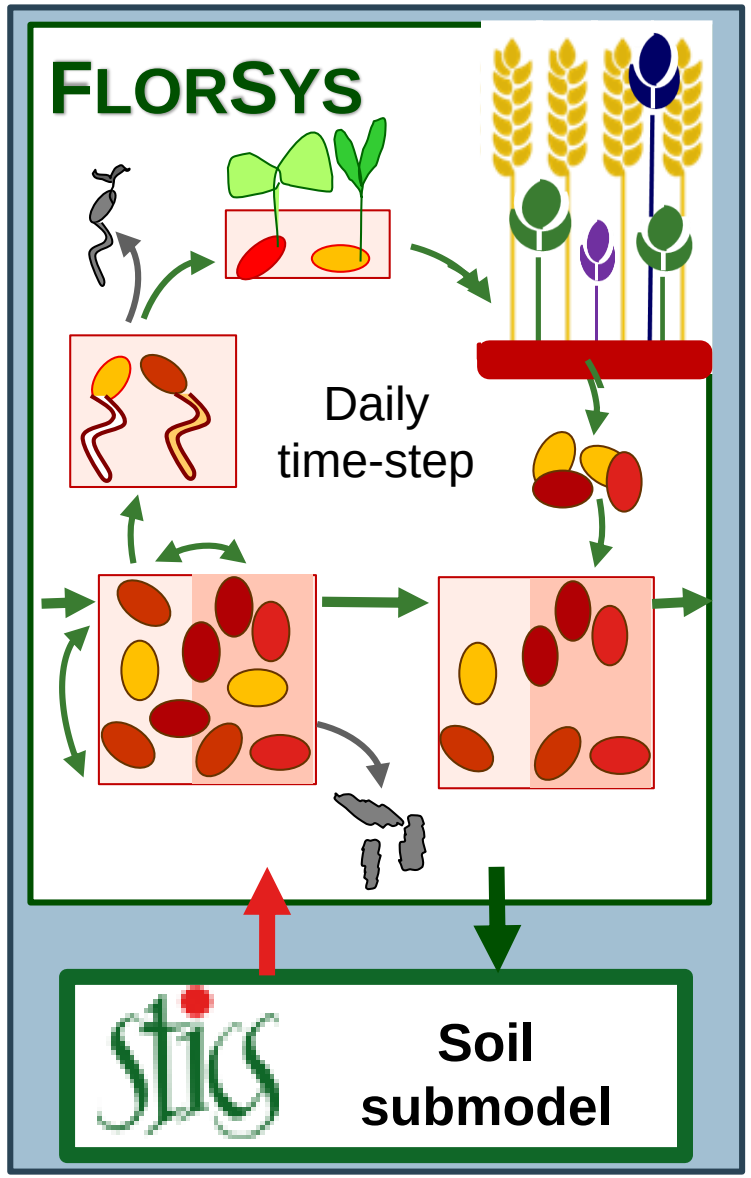
Divides Leaf transpiration in FLORSYS



Colbach et al (in prep)

Crop parameters

- Base temperature
- Temperature thresholds for photosynthesis
- Temperature thresholds for frost damage



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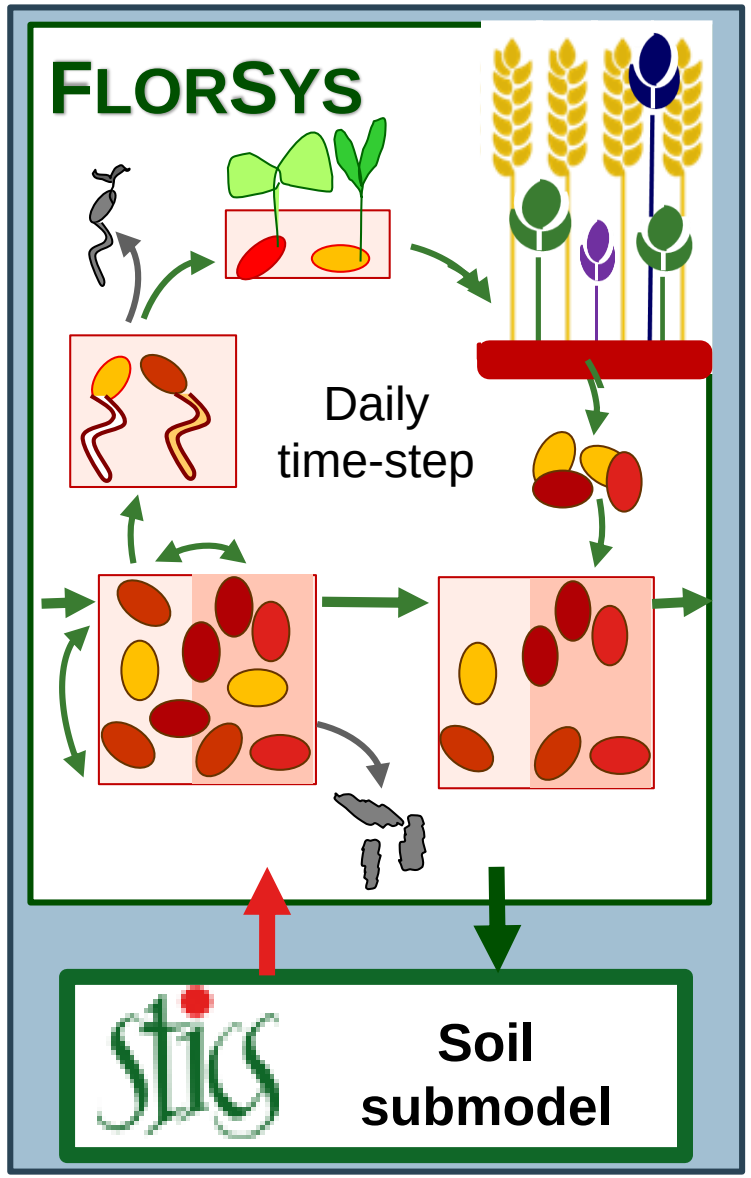


Weed parameters

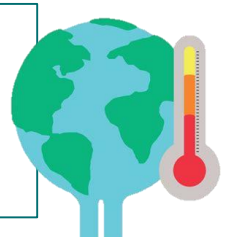
- **Similar crop species**
- Genus or Monocots vs dicot
- Emergence season
- C3 vs C4

Colbach et al (2014) Eur J Agron, Colbach et al (2021) Field Crops Research, Gardarin et al (2012) Ecol Modelling, Mézière et al (2015) Ecological Indicators, Munier-Jolain et al (2013) Ecol Modelling, Pointurier et al (2021) Ecol Modelling

Simulation plan

- 32 weed species
- 15 locations
- 3 soil types
- 36 tillage dates
- 10 weather years

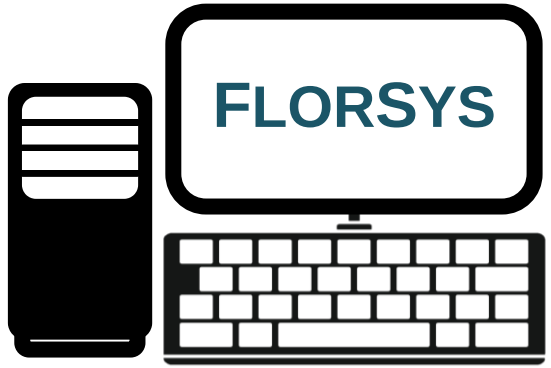
Climate
- Past: 1980–1990
- Recent: 2010–2020

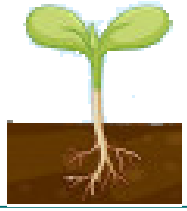


1 year

Nota bene
- No crops
- No seed production
- No competition

Impact of climate change on weed emergence patterns





Emergence per 10-day

1˙036˙800 1-year scenarios

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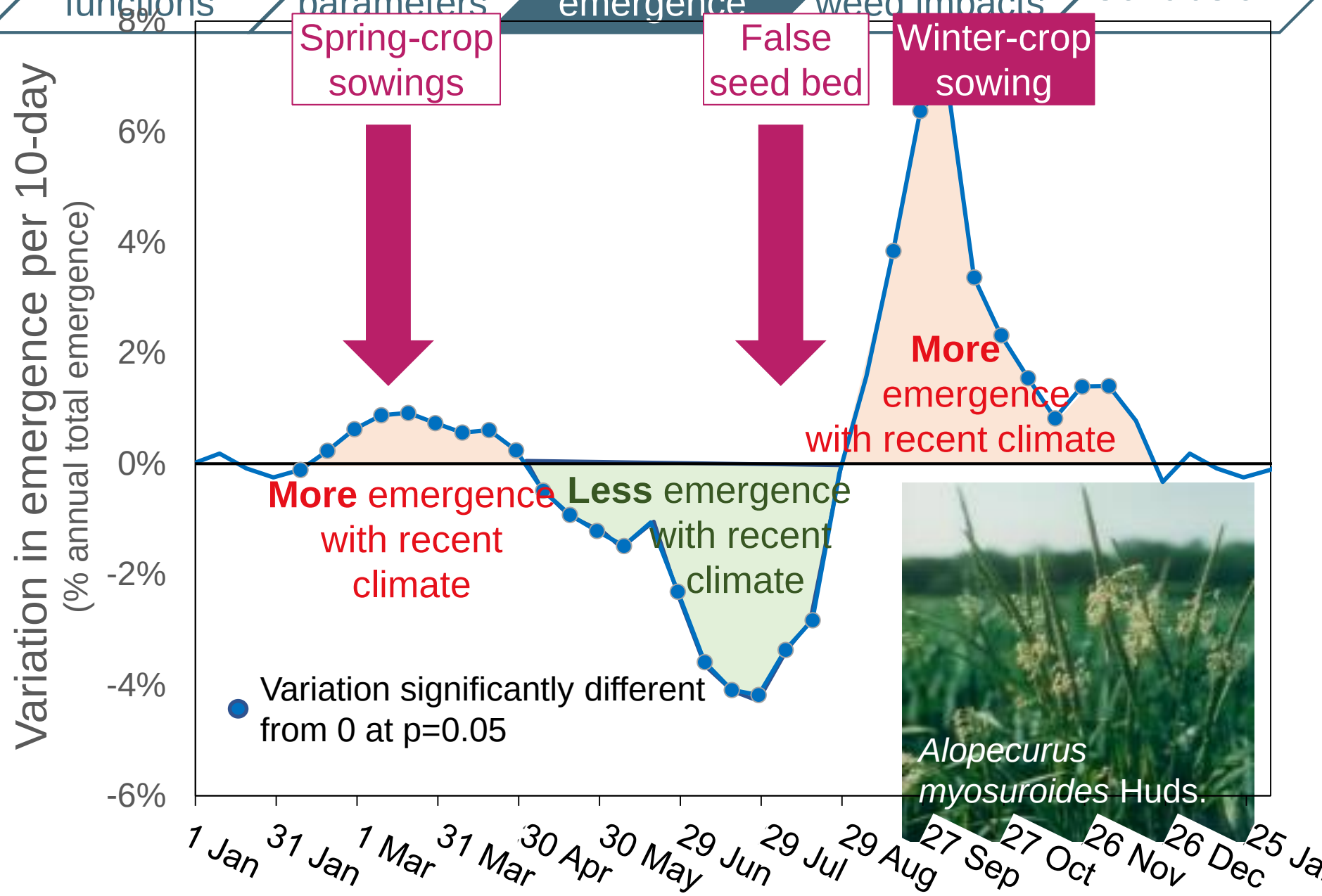


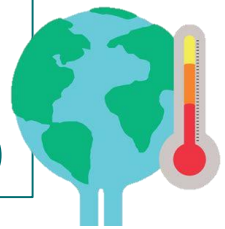
Simulation plan

- 10 cropping systems
- 10 weather series

× Soil resources
- Unlimiting
- Competition

× CO2 concentration
- Constant (350 ppm)
- Measured

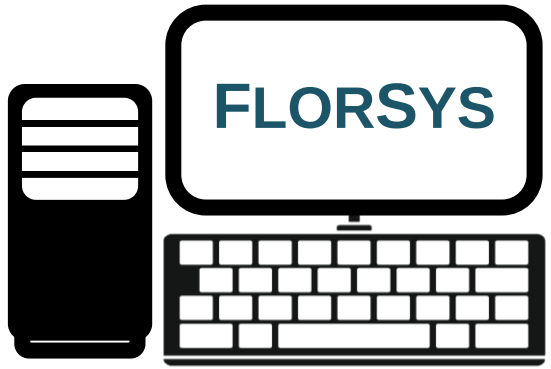
× Climate
- Past: 1950-1980
- Recent: 1990-2020



30 years

Impact of climate change on weed dynamics & impacts

- 800 30-year scenarios
- 24000 years



Crop production
- Grain / Biomass
- Energy

Weed harmfulness
- Yield loss
- Field infestation
- …

Weed benefits Biodiversity

- Species richness
- Species eveness
- Trophic resources for birds, bees…



….but reduces crop biomass more than weed bic mass

Simulation factor	Wild plant biodiversity		Functional biodiversity				Crop yield		Weed harmfulness	
	Species richness	Species evenness	Bird food offer	Bee food offer			Weed-free	Weedy	Yield loss	Field infestation
Soil resources §	0.99	0.68	0.77	0.32			0.63	0.75	0.68	0.89

Competition for soil resources reduces both potential yield and weed biomass

1 = no change, ns variation not signficantly different from 1 at p= 0.05

Estimated marginal means after analysis of variance = f(10 cropping systems, with with without soil-resource competition, constant vs measured CO2, past vs recent climate, weather repetition, time, double interactions)

§ average over all climates, CO2 and cropping systems





Simulation factor	Wild plant biodiversity				Functional biodiversity				Crop yield				Weed harmfulness			
	Species richness		Species evenness		Bird food offer		Bee food offer		Weed-free		Weedy		Yield loss		Field infestation	
Soil resources §	0.99		0.68		0.77		0.32		0.63		0.75		0.68		0.89	
Increasing CO2 $	0.96		1.02	ns	0.92		0.73		1.39		1.53		0.87		0.74	

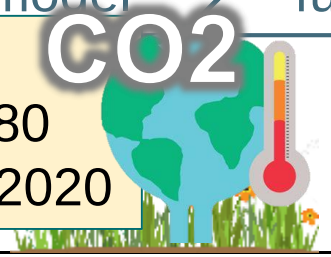
Crops benefit more than weeds

1 = no change, ns variation not signficantly different from 1 at p= 0.05

Estimated marginal means after analysis of variance = f(10 cropping systems, with with without soil-resource competition, constant vs measured CO2, past vs recent climate, weather repetition, time, double interactions)

§ average over all climates, CO2 and cropping systems
$ limiting soil resources, average over all climates and cropping systems

Climate change
- Past: 1950-1980
- Recent: 1990-2020



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Climate change &	0.99	ns	0.97	ns	1.04		1.01	ns	1.06		1.05		0.97		1.10	

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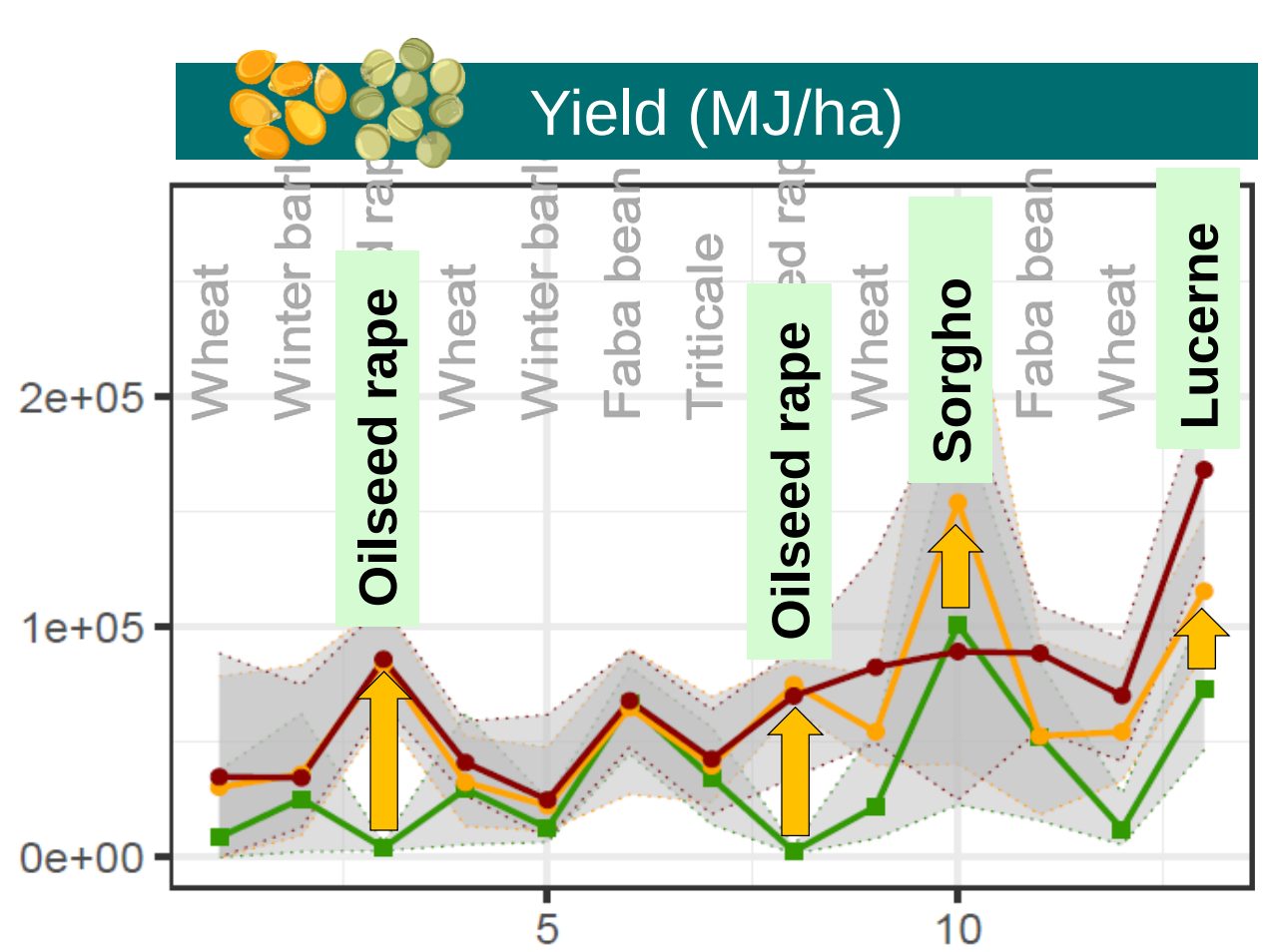
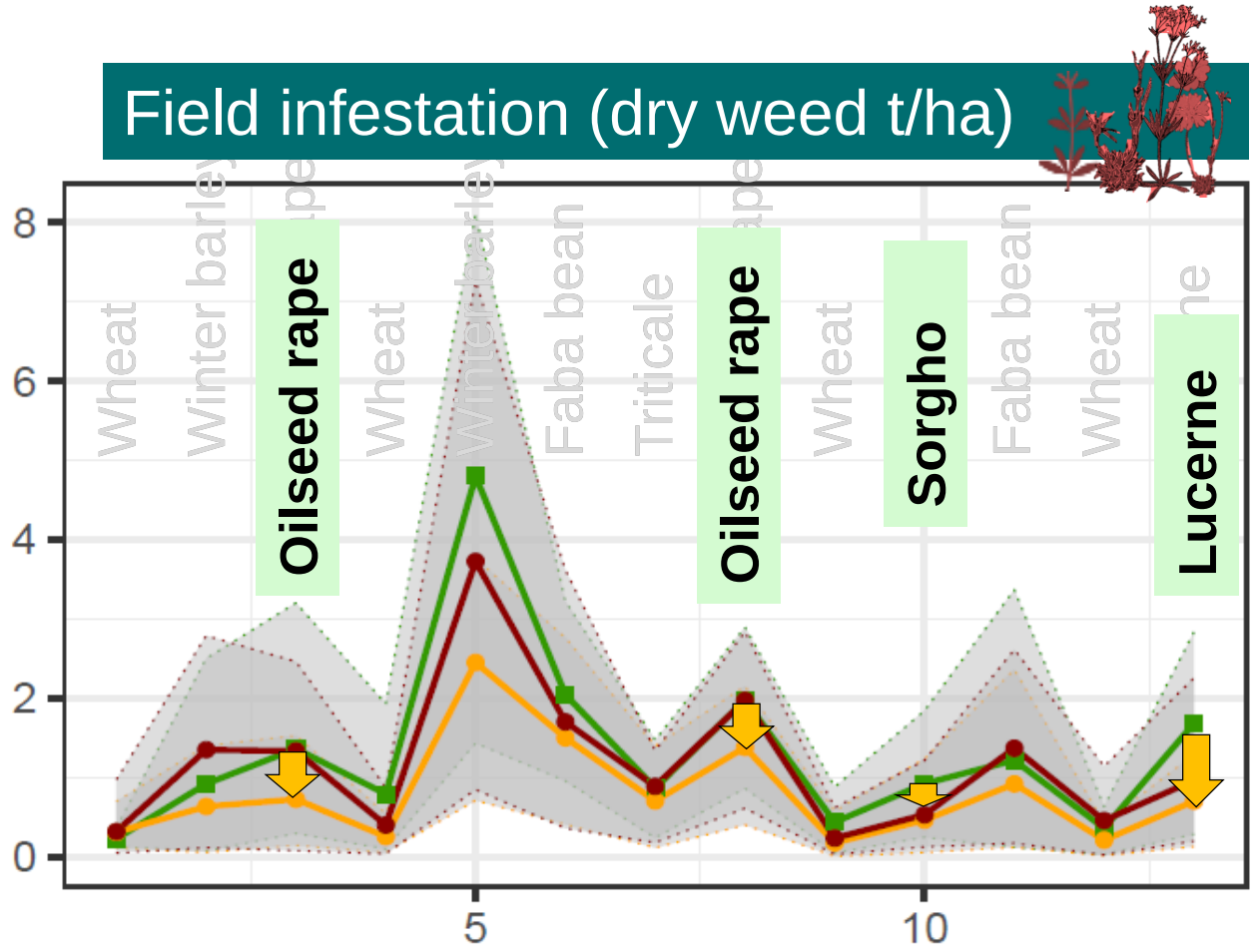
Estimated marginal means after analysis of variance = f(10 cropping systems, with/without soil resource competition, constant vs measured CO2, past vs recent climate, weather ...s)

§ average over all climates, CO2 and cropping systems
$ limiting soil resources, average over all climates and cropping systems
& limiting soil resources, average over all cropping systems

Climate change cancels out crop benefits and favours weeds





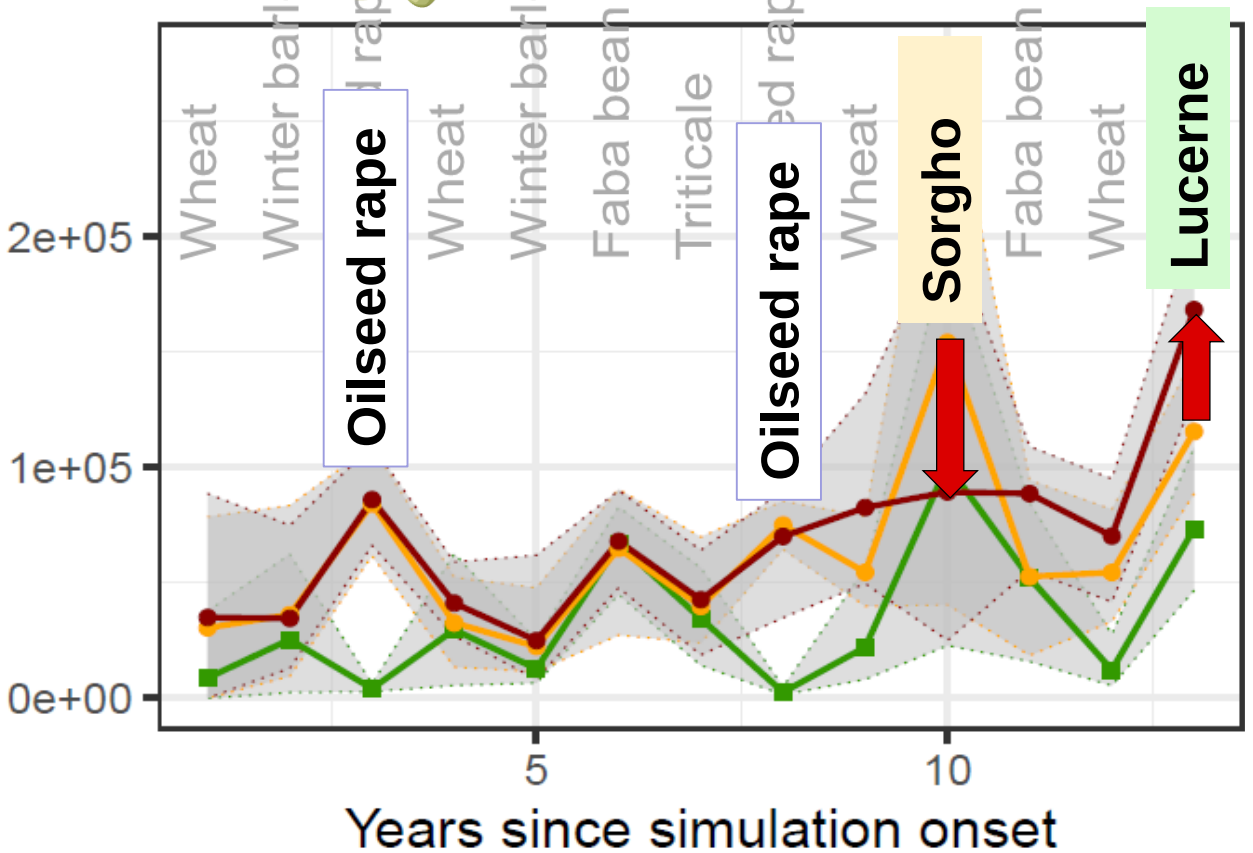
Constant CO2 – Past climate 1950–1980

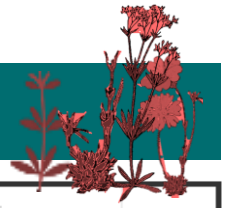
CO2 Measured CO2 – Past climate 1950-1980

CO2 Measured CO2 – Recent climate 1990–2020

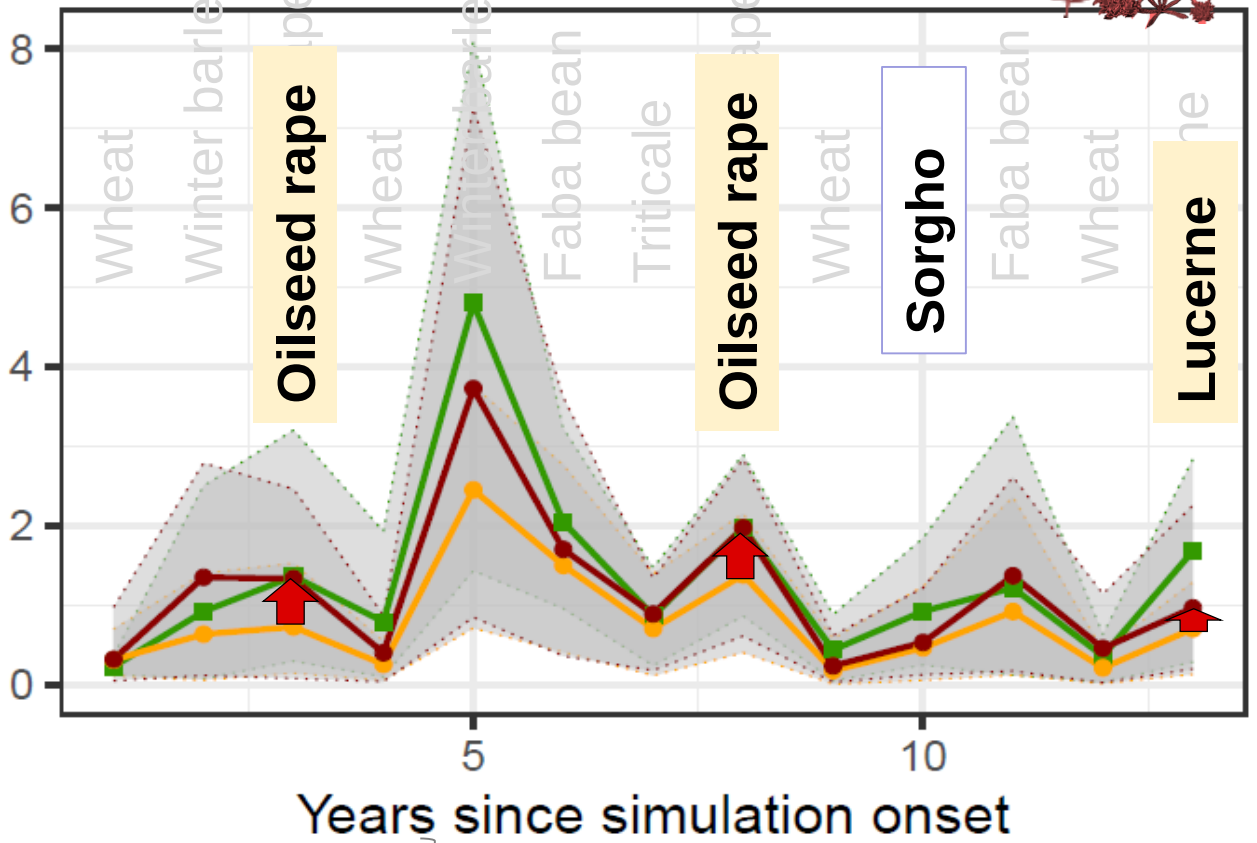
Limiting soil resources

Yield (MJ/ha)





Field infestation (dry weed t/ha)



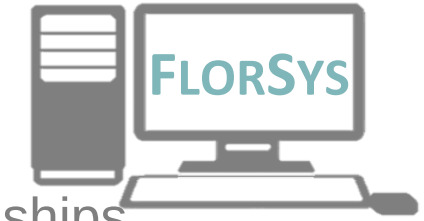
CO2 — Constant CO2 – Past climate 1950–1980

CO2 — Measured CO2 – Past climate 1950-1980

CO2 — Measured CO2 – Recent climate 1990–2020

Limiting soil resources

- **A generic model for heterogeneous multispecies canopies**
  - Generic plant representation
  - Parameters taken from other models and/or estimated with functional relationships



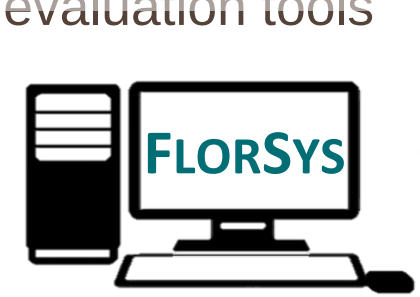
Essential to accompany agroecological transition

- Essential to juggle with the many techniques, objectives, conditions
  → Determine flexible rules adapted to local conditions
- Decision support tool DECIFLORSYS based on random forests
  → Co-designed with stakeholders
- From multicriteria weed evaluation to multicriteria cropping-system evaluation
  → need and connect several evaluation tools

DEXiPM ARABLE CROPS For sustainability

What next

- Parameterize more species
- Submodel allelopathy
- Simulate DEPHY cropping systems
  →technical & biological drivers of climate-resilient weed management



ÉCOPHYTO DEPHY | RÉDUIRE ET AMÉLIORER L'UTILISATION DES PHYTOS

- Special edition of "Innovations Agronomiques" on our project https://ciag.hub.inrae.fr/revue-innovations-agronomiques/volume-101-avril-2025
- Replay on a conference: https://ciag.hub.inrae.fr/les-carrefours-de-l-innovation/copraa
- Web site with our models and decision support systems: https://florsys.hub.inrae.fr/

- Colbach, N., Cavan, N., Flament, M., Maillot, T., Moreau, D., Pernel, J., Queyrel, W., Villerd, J., 2025. La complémentarité des outils d'accompagnement des acteurs pour la gestion des adventices économe en herbicides. Innovations Agronomiques 101, 119-134. https://dx.doi.org/10.17180/ciag-2025-vol101-art11
- 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 261, 108006. https://doi.org/10.1016/j.fcr.2020.108006
- Colbach, N., 2020. How to use a “virtual field” to evaluate and design integrated weed management strategies at different spatial and temporal scales. In: Chantre, G.R., González-Andújar, J.L. (Eds.), Decision Support Systems for Weed Management. Springer International Publishing, Cham, Switzerland, pp. 227-248.
- 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. https://doi.org/10.1111/wre.12112