Study of STICS behavior in response to climate change in wheat crops

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Égalité
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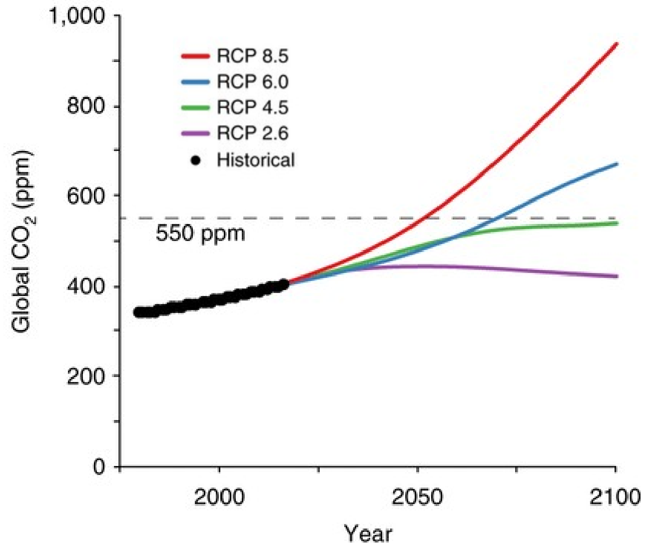
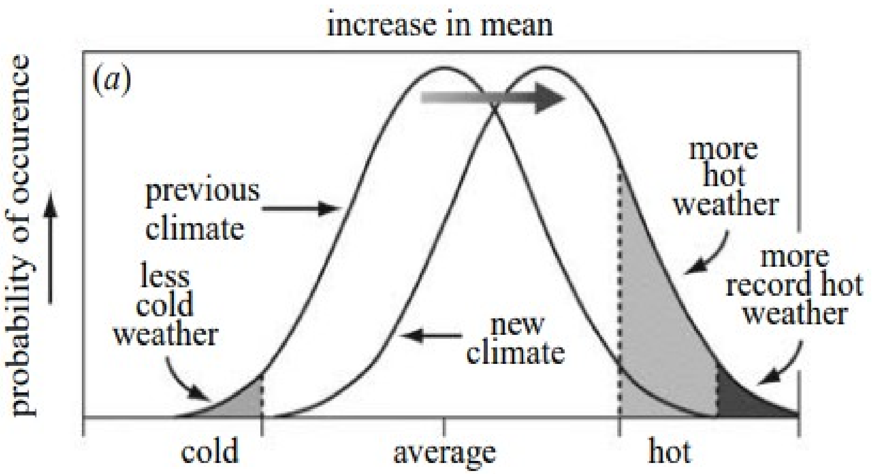
Effects of climate change on wheat crops

- Climate change = combination of variables
  - Increase in CO_2 340 ppm (1980) → 415 ppm (2020) → 540-970 ppm (2100)
  - Increase in temperatures +2-4°C in 2100
  - Intensification of thermal and water stress
- Understand the effects on wheat growth and production
  - Limited experiments
  - Use of crop models
- Issue of model validity
  - Little validation on experimental data
  - Diversity of implementation of CO2 effects (AgMIP CO2, D. Cammarano)



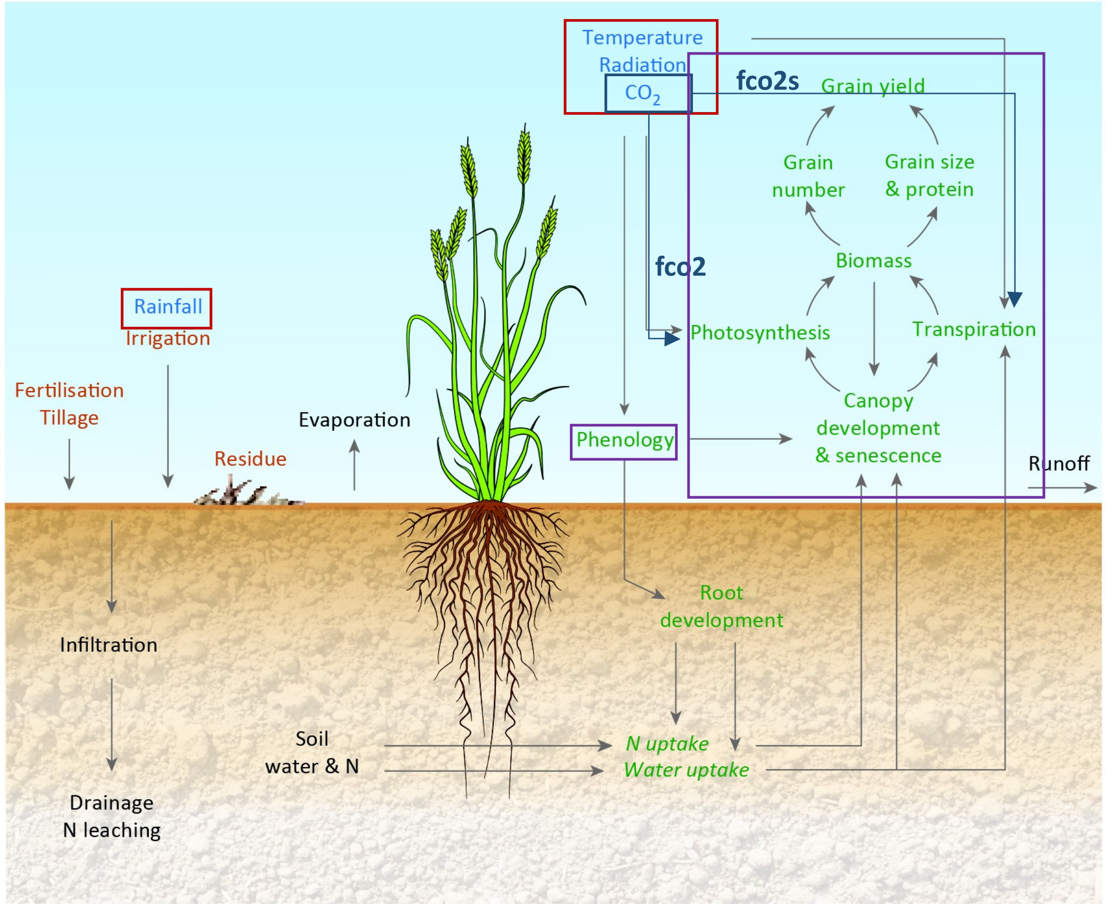


Research question : Better understand the behavior of our models in response to climate change for wheat crops

→ STICS ?

Sensitivity analysis approach

Input variability
- Homogeneous variations (CO2, temperature)
- Specific stress (temperature, drought)



Structural variability
- CO2 processes
  - Increased RUE

$$fco2 = 2 - exp\left(log(2 - \mathbf{alphaCO2}_P) \cdot \frac{CO2(t) - 350}{600 - 350}\right)$$

  - Decreased conductance

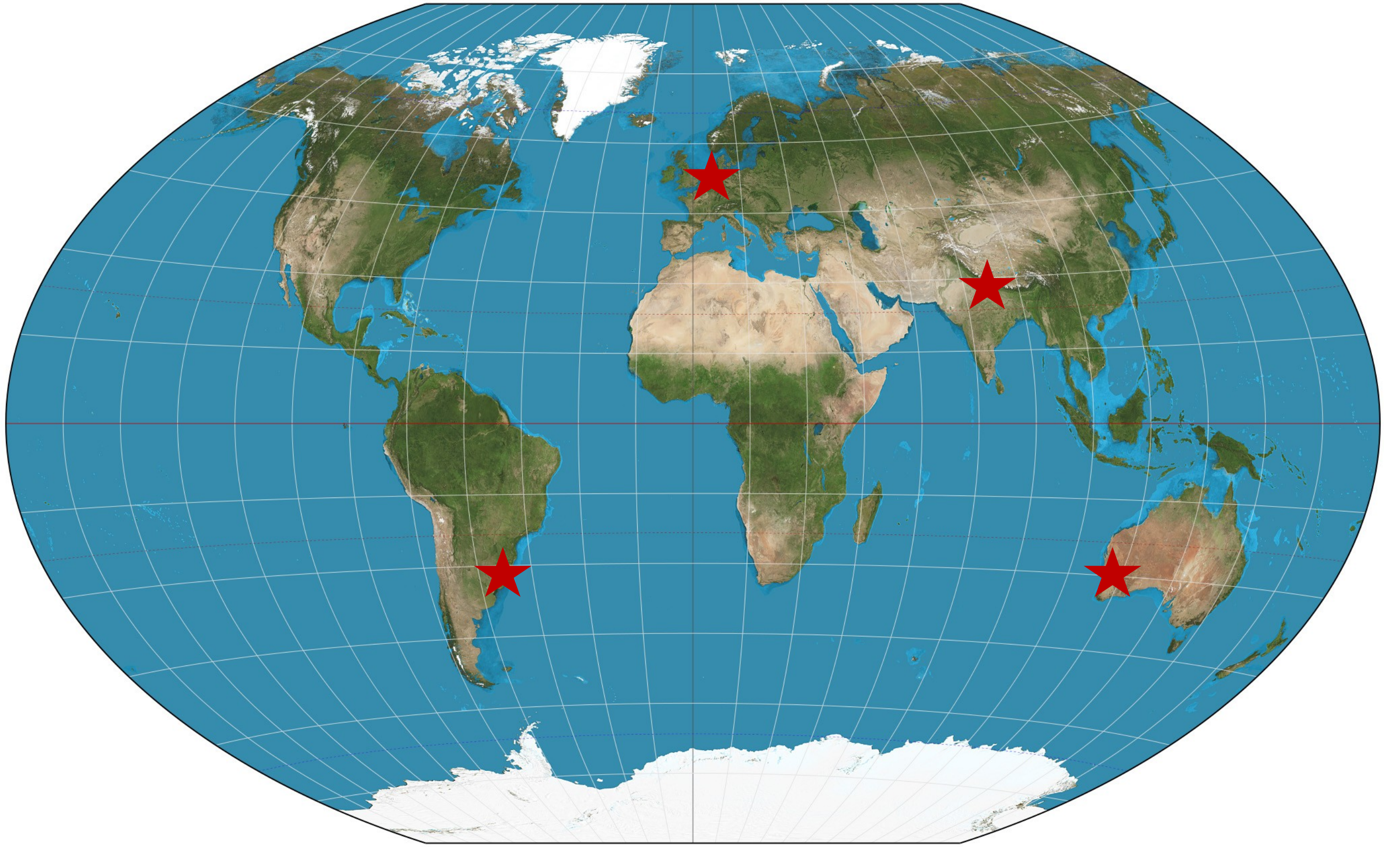
$$fco2s = 1 + 0.77\left(1 - \frac{fco2}{2.5}\right) \cdot \left(1 - \frac{CO2}{330}\right)$$

- Parameters
  - CO2 (sensitivity)
  - Temperature (development, LAI, stress RUE and grain filling)
  - Water (stress on development, LAI, RUE and senescence)

Sensitivity analysis approach

Simulation framework

- 4 contrasted sites (Asseng et al., 2013)
  - Netherlands
  - India
  - Argentina
  - Australia
- Data on soil, cultivar parameters and crop management
- Climate data 1980-2010
- Preliminary calibration



Sensitivity analysis approach

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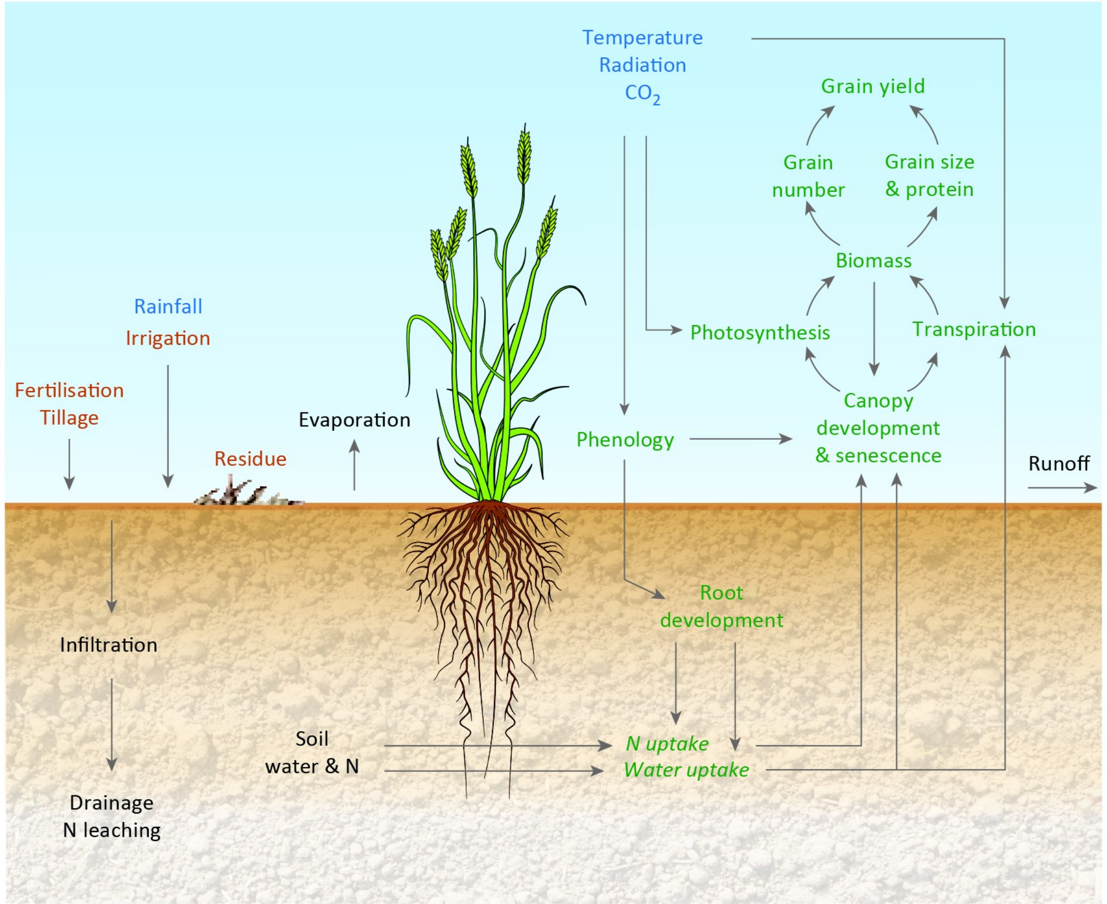

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Climatic sensitivity analysis

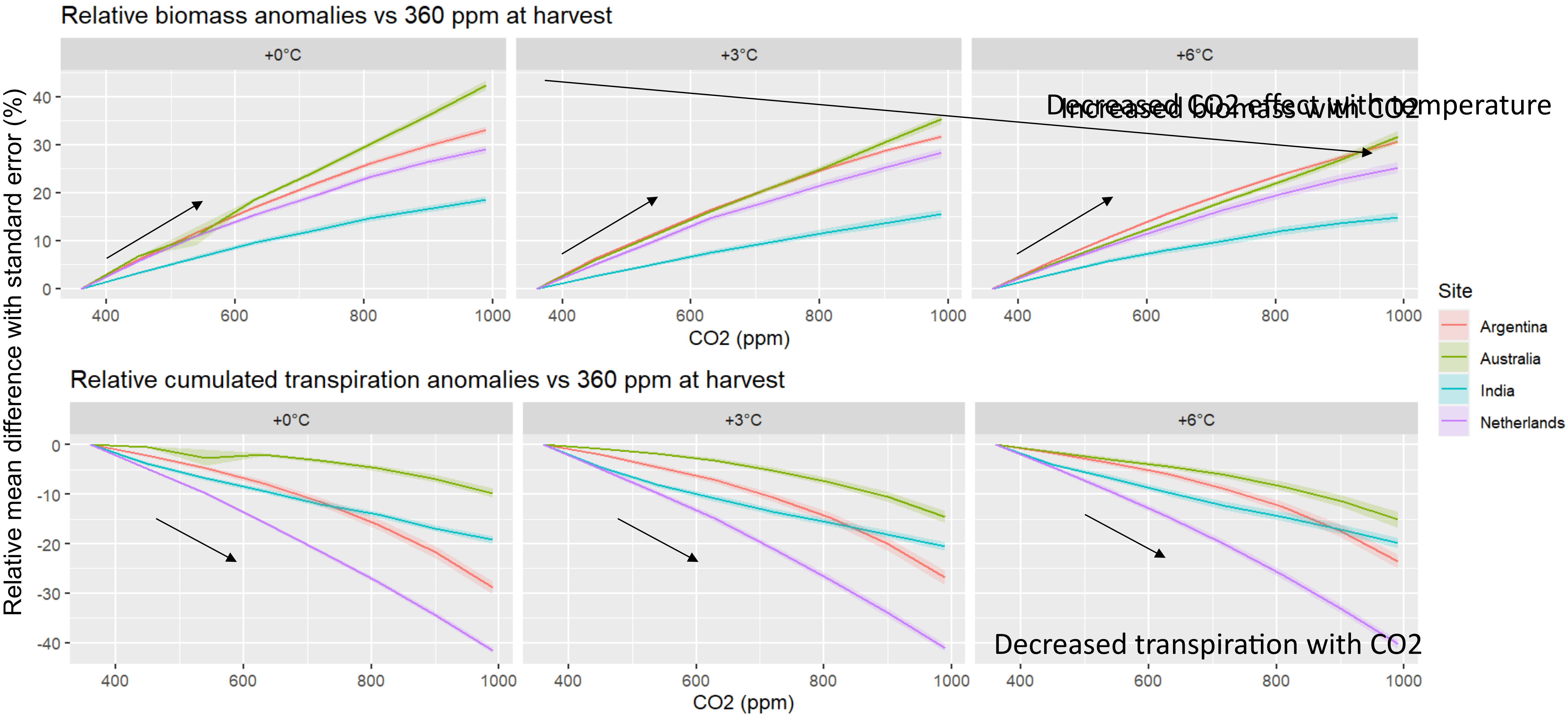
Protocole

- CO_2 → homogeneous variations 350-1000 ppm
- Temperature
  - Homogeneous increase (+0 to +6°C) on mean temperatures
  - Variation thermal stress at flowering → modulation of duration and intensity
- Water
  - Variation water stress at flowering → modulation of duration and intensity

Preliminary results

- Reduced sensitivity analysis with AgMIP CO_2 (B. Dumont, P. Aubry) on 4 sites 1980-2010
- Homogeneous climatic variations
  - CO_2 360-990 ppm
  - Temperatures +0, +3 and +6°C

Climatic sensitivity analysis

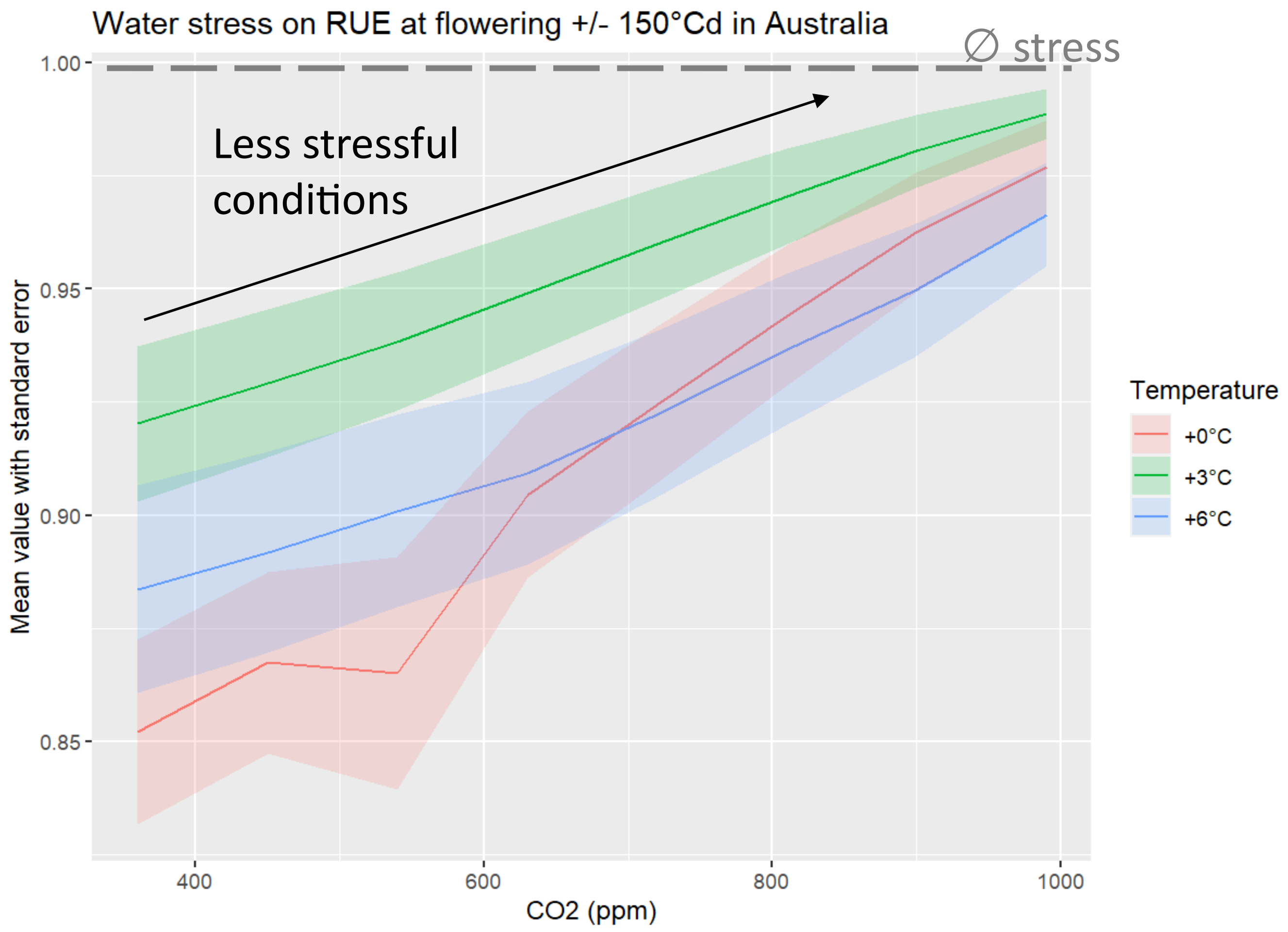


Climatic sensitivity analysis

Stress indicators on RUE at flowering

- Water
  - Australia reduction of water stress with CO2
  - Little variation for the other sites (0.998-1)
- Thermique
  - Little variation (0.95-0.99)

→ Need to simulate specific stress to generate stressful conditions



Sensitivity analysis approach

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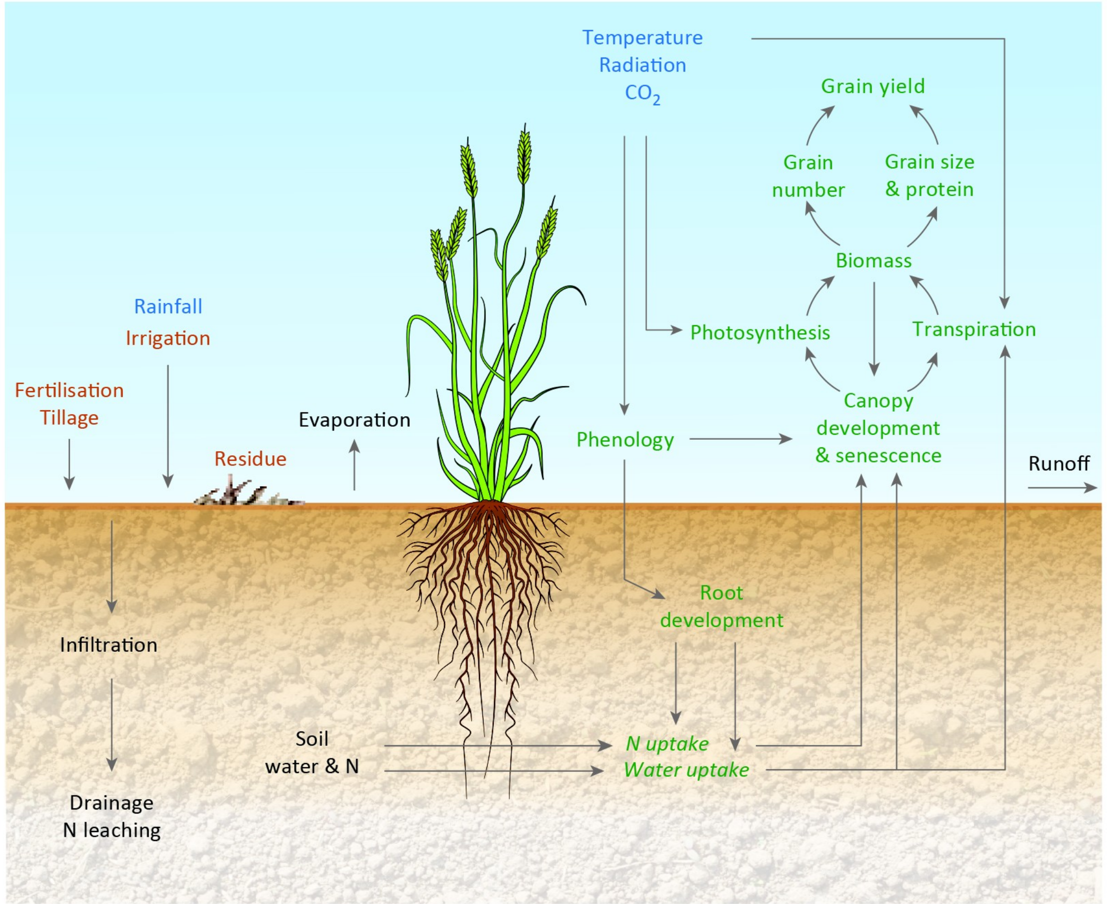

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Structural sensitivity

CO2 effects

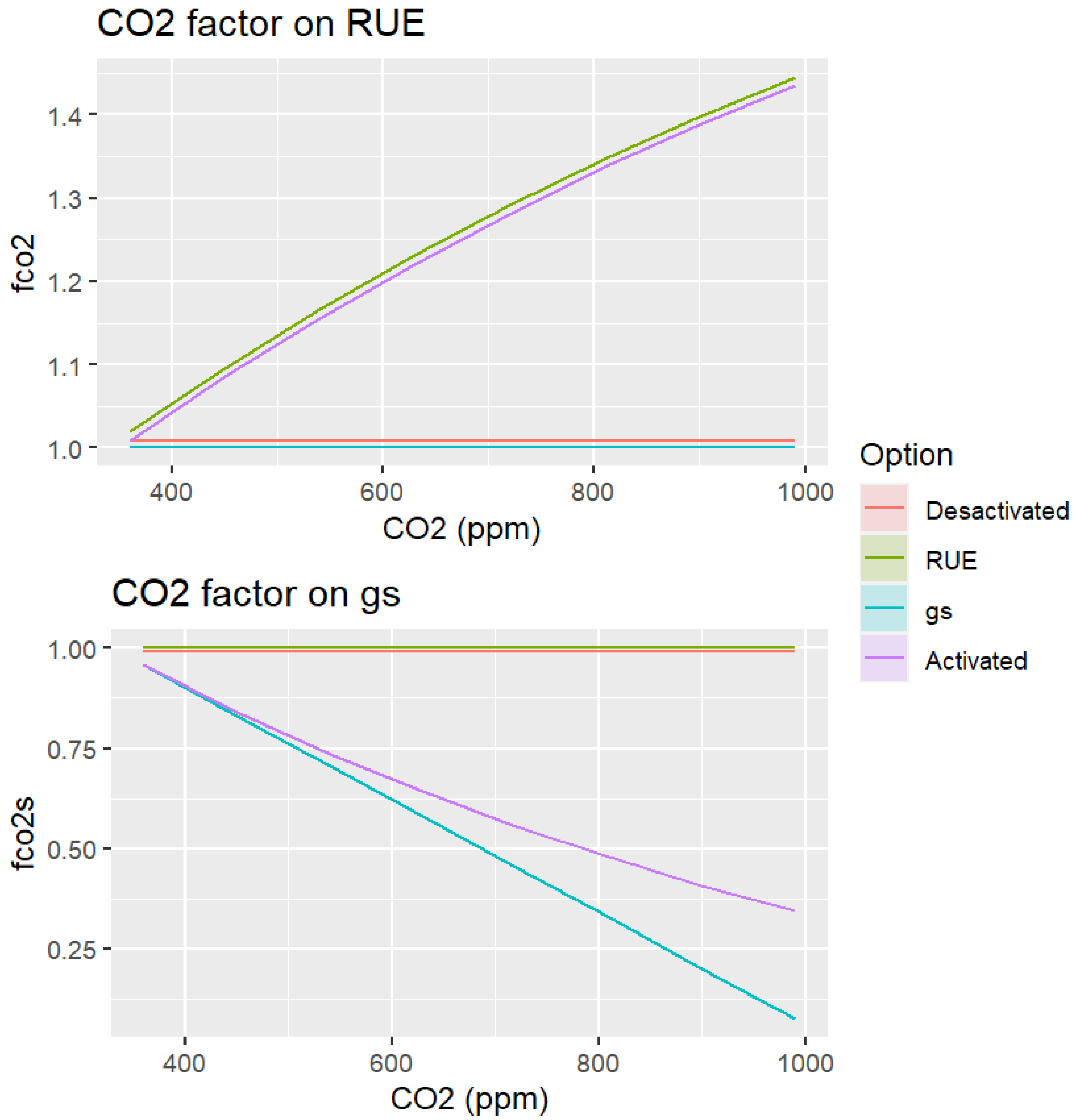
Sequential activation of CO_2 effects

- Desactivated → ∅
- RUE
- Conductance (gs)
- Activated → RUE + gs

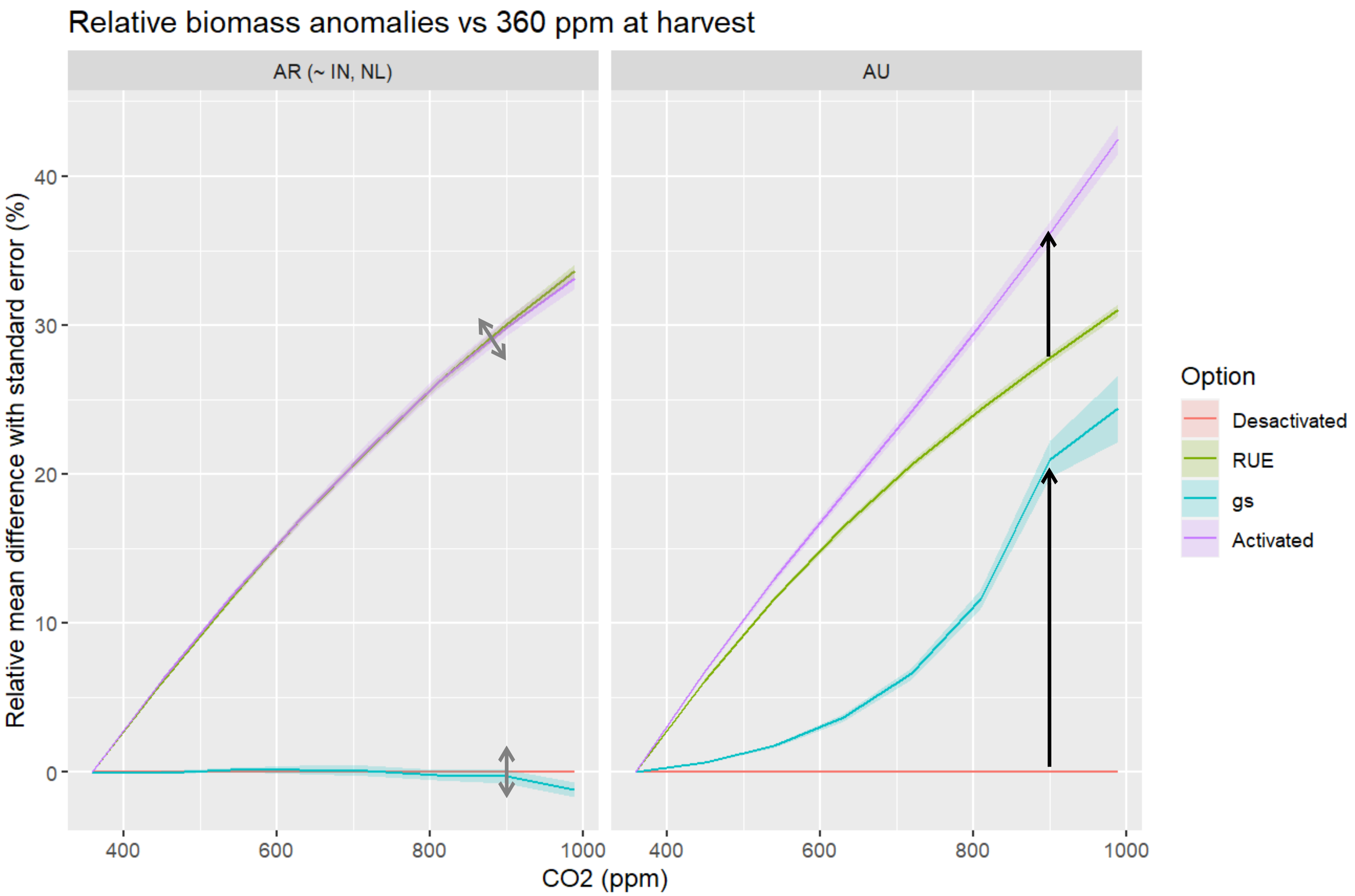
Variation of CO_2 factors

- RUE (fco2) → only depending on CO_2
- gs (fco2s) → depending on CO_2 and fco2

→ What effects on biomass at harvest ?



Structural sensitivity analysis

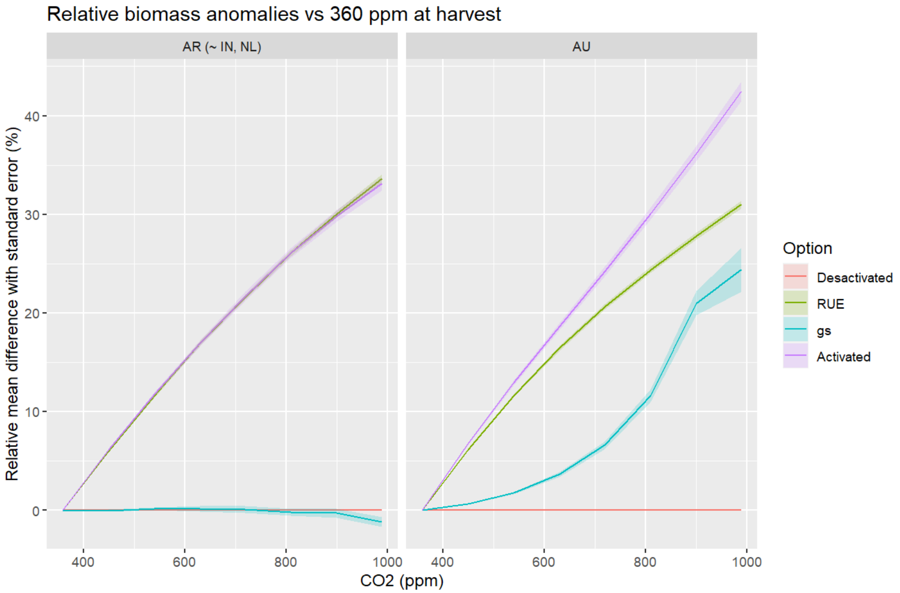


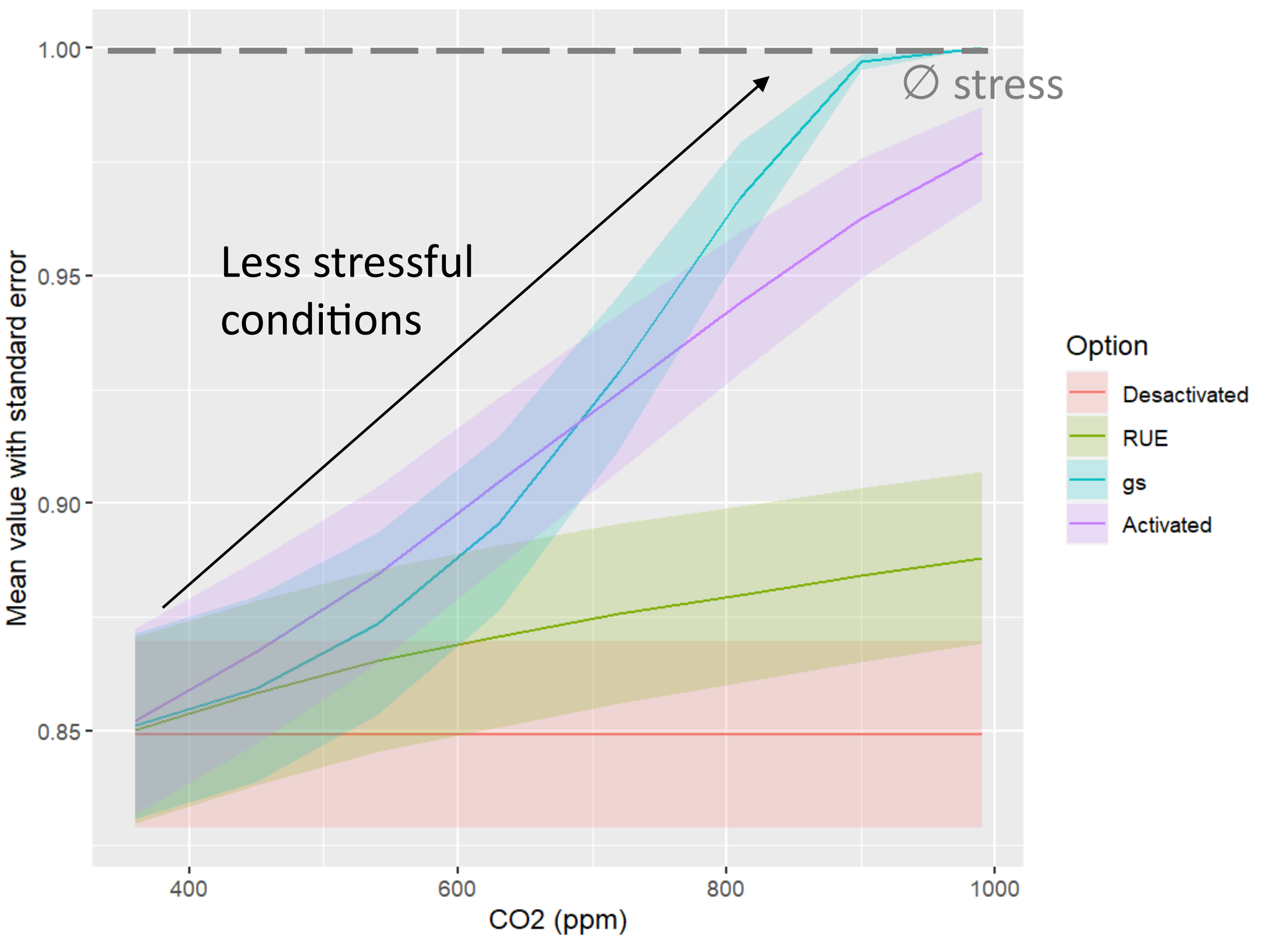
Increased biomass with CO2 linked to the RUE effect

- In Argentina, India and Netherlands
  - Weak effect of the gs option on biomass
- In Australia
  - Important impact of the gs option compared to « Desactivated » and « Only RUE »

→ Why ?

Structural sensitivity analysis





- Moderate water stress in Australia (0.85 at 360 ppm) → decreased transpiration with CO_2 allow to reduce water stress on RUE and increase biomass
- No water stress elsewhere → no impact of decreased transpiration on biomass

The effect of CO_2 on conductance impacts biomass in situations with water stress, even moderate.

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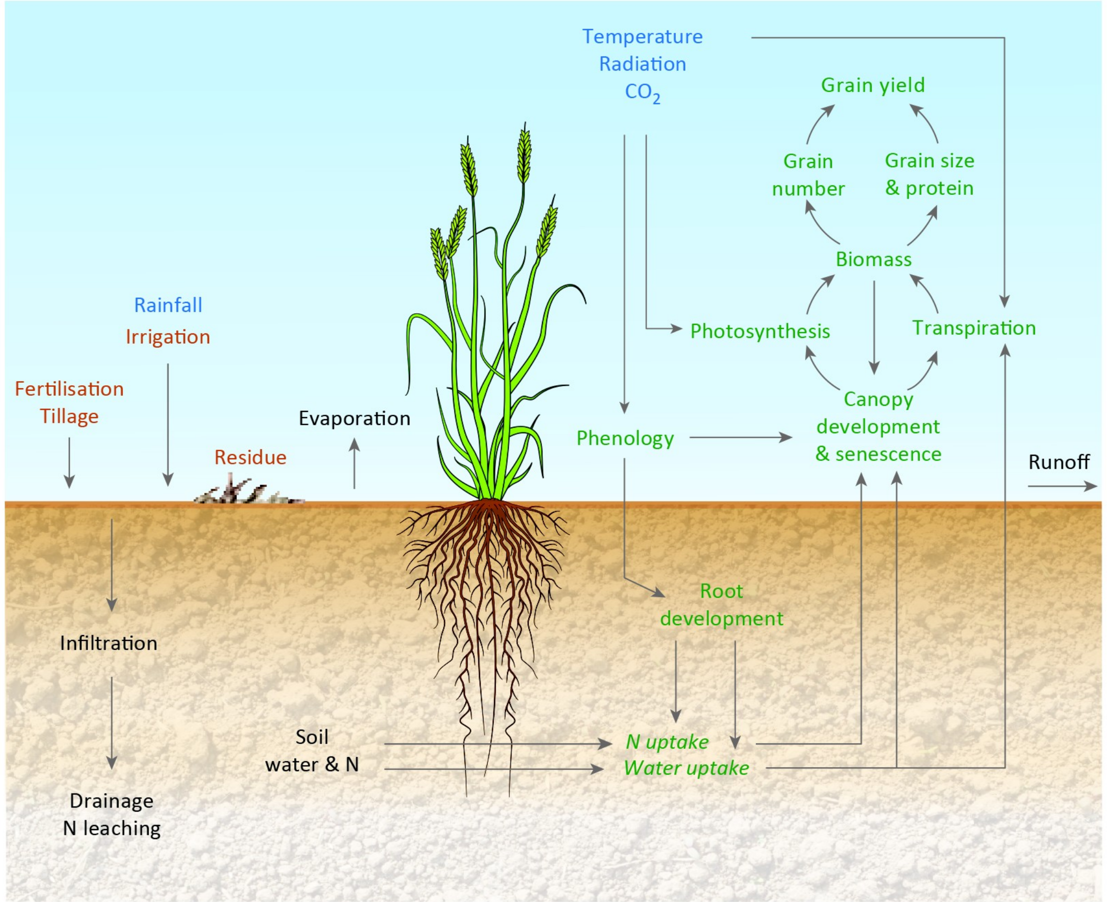

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Structural sensitivity analysis

Model parameters

Joint variation of STICS parameters linked to climatic variables

- Choice of parameters (~14)
  - CO_2 → sensitivity to CO_2 alphaCO2
  - Temperature → development (tdmax, tcxstop), LAI (tcmax), stress on RUE (temin, teopt, teoptsbis, temax) and grain filling (tminremp, tmaxremp)
  - Water stress (swfacmin, psisto, psiturg, rsmin)
- Choice of variation ranges for identified parameters
- Study at different CO_2 concentrations 350, 700 et 1000 ppm for 4 sites 1980-2010

Conclusion and perspectives

Multi-sensitivity analysis

- Better understand the behavior of STICS in response to climate change
- Prioritise climatic variables and identify their interaction effects
- Link these climatic interactions to the structure of the model to better question its functioning

Perspectives

- Development of sensitivity analysis methodology (collab. S. Buis) and implementation of multi-simulations (SIWAA, collab. P. Chabrier)
- Apply the same multi-sensitivity analysis protocole to APSIM (K. Chenu, A. Severini) to compare the two models