# Modélisations pour le contrôle de l'irrigation pour la réutilisation des eaux usées

**Antoine Haddon**[1] Jérôme Harmand[1] Alain Rapaport[2] Sébastien Roux[2]

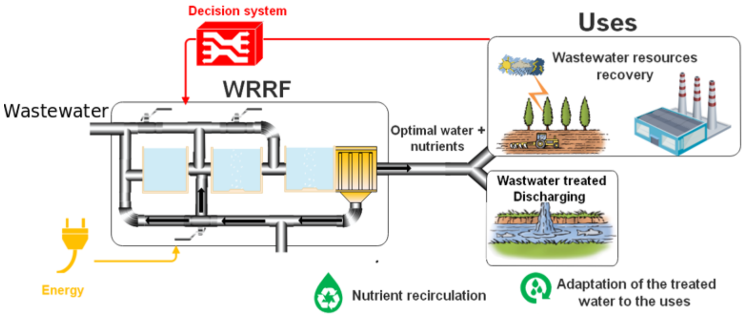
[1]INRAE, Univ. Montpellier, LBE, Narbonne, France

[2]INRAE, Univ. Montpellier, MISTEA, Montpellier SupAgro, France

AG du réseau REUSE INRAE 2021

18 - 20 Octobre 2021

# Wastewater Reuse for Agriculture




## Integrated Reuse chain

- Adapting wastewater treatment to benefit from nutrients
- Dynamic irrigation and fertilization requirements as setpoints for wastewater treatment

# Decision support in Agriculture

- Decision support methods
  - Irrigation : evapotranspiration model, from weather data compute water losses from soil
  - Fertilization : mass balance model, compute gains and losses from mineralization, fixation, crop uptake, immobilization, leaching.

- Current developments
  - Dynamic crop models
  - Compute crop inputs from optimization problems

Controls :
Irrigation Volume [mm]
Nutrients concentration
(Mineral Nitrogen [mg/L])

$\longrightarrow$ Crop Model $\longrightarrow$

Costs and Rewards :
Biomass [T/ha]
Irrigation and fertilisation costs
Enviromental costs
(N leached [kg/ha])

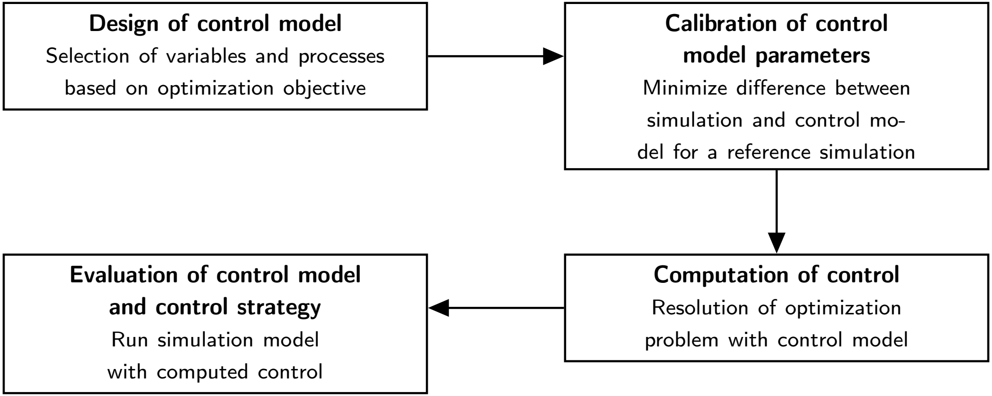
# Crop models for decision support

- **Simulation model**
  - Computer model, unclear mathematical structure, 'Black Box'
  - Detailed representation, extensively validated
  - Limited use for decision support, evaluation of scenarios
  - Examples : STICS, APSIM, DSSAT
- **Control model**
  - For decision support, specific to an objective
  - Reduced systems, limited domain of validity
  - Dynamical systems, suited for resolution of optimization problems

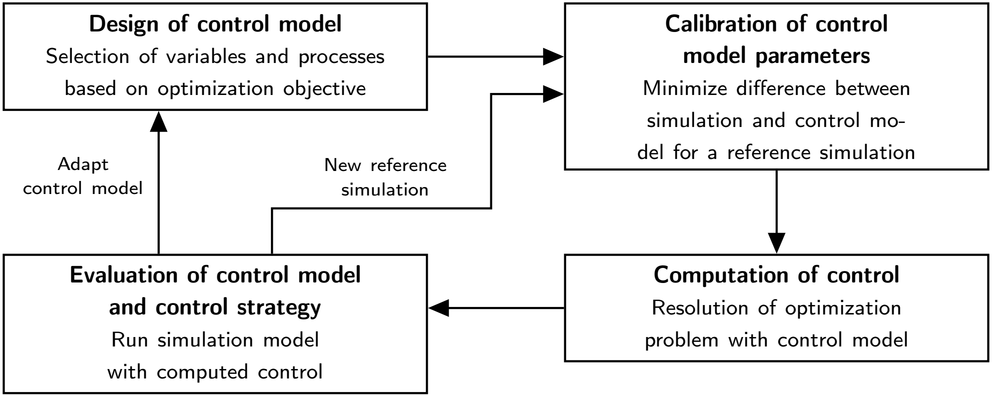
## Double Modelling Method

- Control model as a local approximation of simulation model
- Solve optimization problem using control model
- Evaluate controls and control model with simulation model

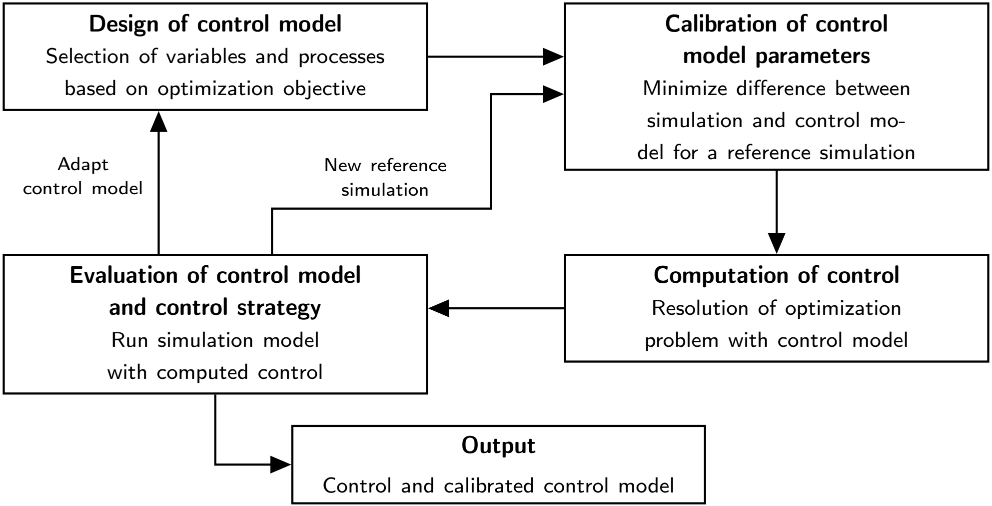
# Double Modelling



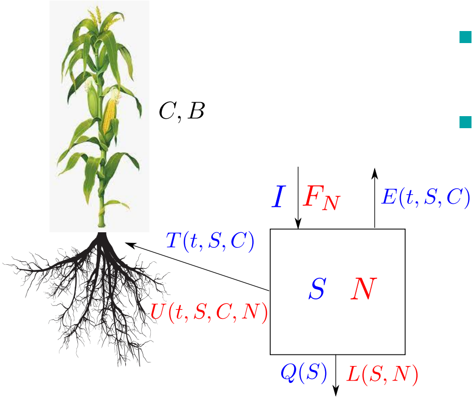
# Double Modelling



# Double Modelling

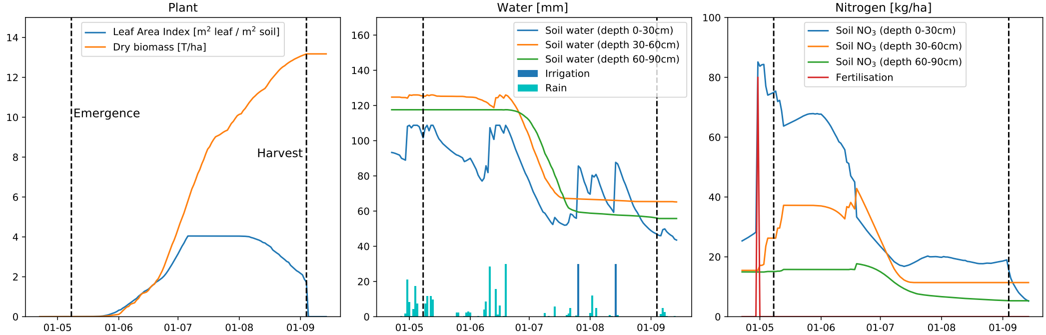


# Control model



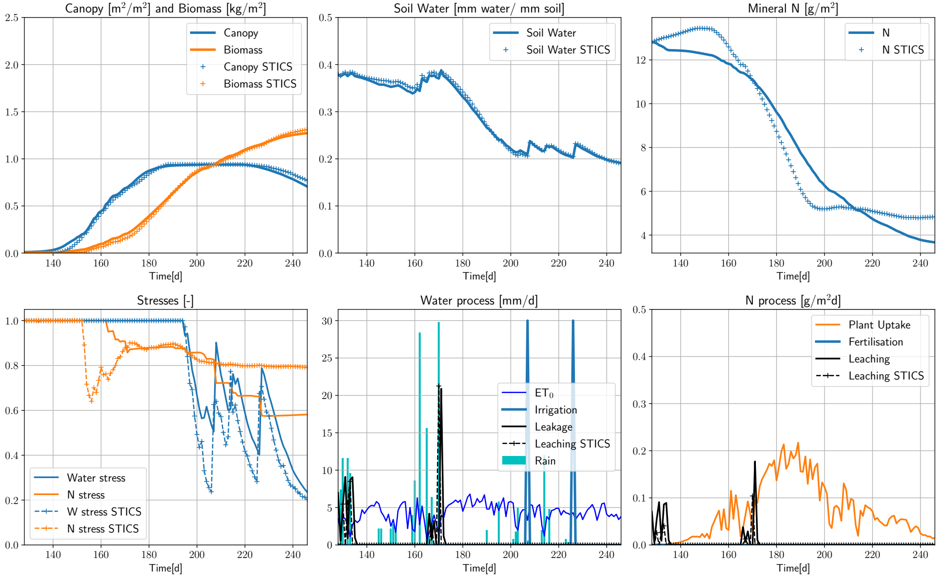

- Focus on essential processes : water and nutrient balance of soil-crop system
- Homogeneous representation of soil and plant
  - Soil water : $T$ crop transpiration , $E$ evaporation, $Q$ leakage
  - Soil Mineral Nitrogen : $U$ crop uptake, $L$ leaching
  - Canopy Cover : fraction of ground shaded by crop, logistic growth with water stress $K_S$, nitrogen stress $K_N$ and impact of weather
  - Crop Biomass : growth proportional to water and N uptake
- Weather : Rain $R$, Reference evapotranspiration $ET_0$
- Controls : irrigation [mm/d] and N concentration of irrigation water [g/L]

# Reference Simulation from STICS



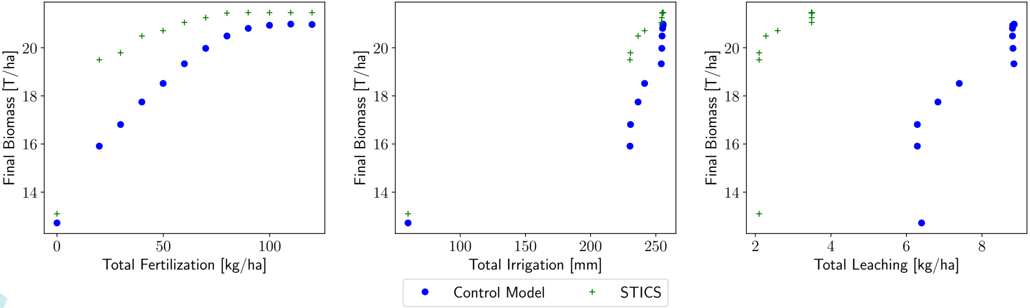

- STICS model
  - Detailed representation of soil-crop system
    - Soil divided 1 cm layers, root density, carbon, water and nitrogen balances
    - Crop above-ground biomass, harvested organs mass, 12 development stages
    - Crop management, micro-climate
  - Generic crop model, 600+ parameters and options
  - Parameters calibrated for 34+ crops

# Calibration of control model to reference simulation



# Optimization of reuse irrigation

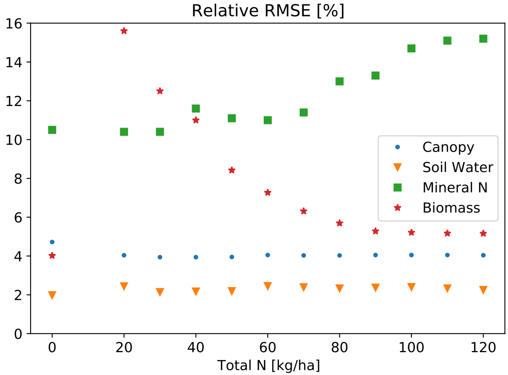
- Constrained Optimal control
  - Maximize final Biomass
  - Constraint on total Nitrogen added through irrigation
  - Excess irrigation or N leaching causes N losses : solution efficient in irrigation and avoid N leaching
  - Change the upper bound on total N to explore the trade-offs between objectives



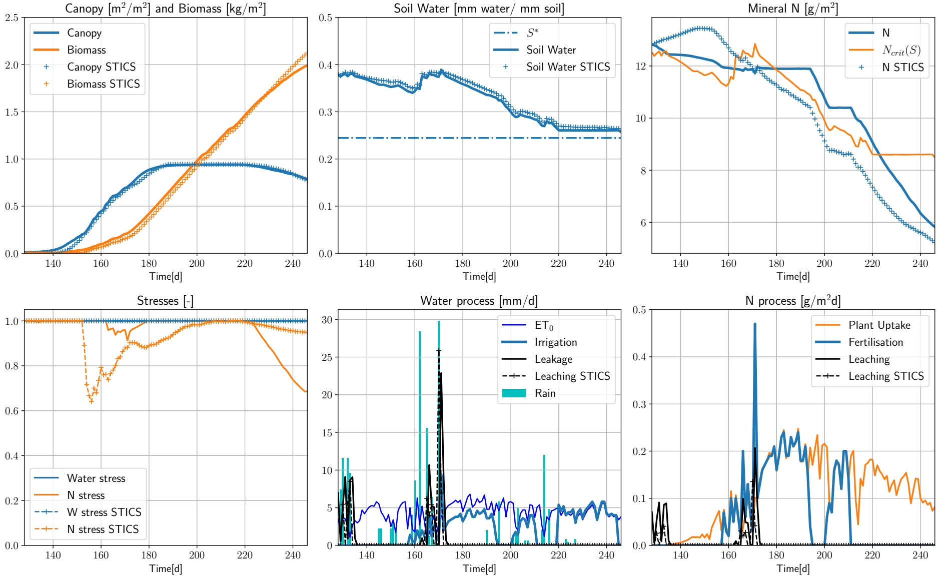
# Control Model Evaluation

- Control model reproduces well STICS simulations for various controls with single set of parameters
  $\Longrightarrow$ Can identify the trade offs between different objectives

- Output of method is also the control model and calibrated parameters
  $\Longrightarrow$ Mechanistic model provides insight on control problem

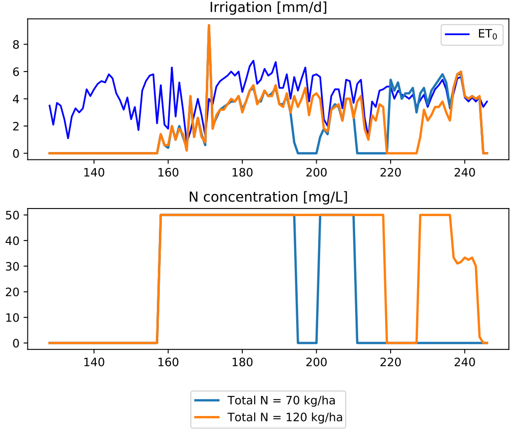


# Optimal Reuse for 70 kg/ha



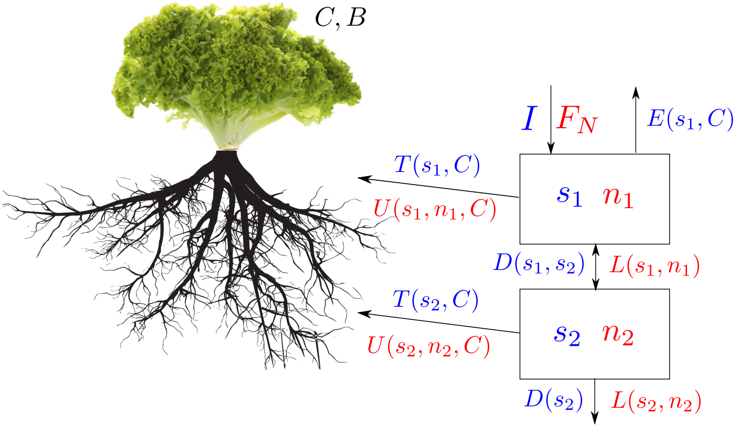
# Controls

- Control aims at avoiding stress, follows plant uptake
  $\Longrightarrow$ Importance of calibrated stress level parameters : optimal controls maintain system at or above these levels
  $\Longrightarrow$ Possibility of feedback control



# Perspectives

- Limited complexity models also better suited for link with measurement data
- Adapt model to objective : represent spatial heterogeneity from drip irrigation



Merci pour votre attention !