OPTIRRIG

Generation, analysis and optimization of irrigation scenarios for crops

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Context of development and contact persons at INRAE

- **INRAE has 14 Scientific Departments**
- Fields of activities and collaborations involved in the development of Optirrig belong mainly belong to the "Water & Agriculture" perimeter in two Departments:

AQUA (~Functioning and evolution of aquatic ecosystems, water and biogeochemical cycles, Head of the Department: mohamed.naaim@inrae.fr)

AGROENV (~Conception and evaluation of agroecosystems ; understanding of the functioning and evolution at different scales of organization, Head of the Department: philippe.hinsinger@inrae.fr)

- Optirrig is developed in Montpellier, in the **Joint Research Unit G-Eau** (~Water management, usages and actors - Director: olivier.barreteau@inrae.fr)
- Optirrig is a product of the **OPTIMISTE team** (Optimisation of the Piloting and Technologies of Irrigation, Minimisation of InputS, Transfers in the Environment - Co-facilitators: severine.tomas@inrae.fr and bruno.cheviron@inrae.fr)

Optirrig as a legal and scientific object

- Partnerships, dissemination and transfers of Optirrig are managed by the **AgroValo team of INRAE Montpellier** (gaspard.lepine@inrae.fr, helene.genty@inrae.fr).
- We receive **legal support** from the Common Service of Contractual Engineering (celine.delmas.juri@inrae.fr) of the **General Direction** for Consortium Agreements and issues of Intellectual Property.
- Optirrig is a **property of INRAE** and a recent deposit of the program has been made (Franch Agency for Programs Protection) APP. Version v2.0 of the software will be deposited as "**collective work**" later in 2020.
- The development of Optirrig is a **collaborative effort** supervised by the permanent staff of the OPTIMISTE team, leaning on fixed-term recruitments to write dedicated modules or address **emerging research questions**.
- Optirrig is written in **R language** but may easily include (or be interfaced with) modules or programs written in other languages.
- Optirrig relies on a parsimonious description of physical processes, compatible with pluridisciplinary approaches and the treatment of emerging questions, clearly focusing on **the generation, analysis and optimization of irrigation scenarios**.

Optirrig in the current Era and in INRAE

- Irrigation for agriculture: 70% of fresh water resources in the world
- Global change: resource deficit and pressure on competing usages
- Need for optimization: plot and regional scales

Study and/or control of biophysical processes
Hydro, Agro, FluidMechs: modeling + metrology

Scale of action ***Scale of management***

Decision-making processes, interdisciplinarity
spatially-distributed modeling

OPTIMISTE — ***Team*** ***JRU*** ***INRAE Departments***

***O**ptimisation of the **P**iloting and **T**echnologies of **I**rrigation*
***M**inimisation of **I**nput**S**, **T**ransfers in the **E**nvironment*

Coupling with multi-agent simulations
Projects with water economists

Coupling with spatially-distributed modelling and remote sensing

Optirrig as an integrating and centralizing tool

- Simplified process representation and assembling
- Optimization of irrigation scenarios... and their consequences
- Thematic opening, emerging and connected questions

Some partnerships, projects and activities

Major groups

β-test 2017-2019
Pioneer, CACG, Maïsadour

CA, consultancy

CA17, CA80
Tests at plot scale
Adour-Amont territory
With economists (S.Loubier)

"Small" projects

ARBRATATOUILLE
Agroforestry (Anduze)

Large structuring projects

[ADEME] RSEau (Aquasys)
Eco-efficiency, OpenFluid, Remote sensing
[FUI] SFR (Veolia)
REUSE, Ferti-irrigation, Nitrogen, Wind Drift
[ADEME] Sun'Agri 3 (Sun'R)
Dynamic agrivoltaic systems
TASCII (CACG)
Agroecological transition, irrigated systems

Education, internships

Water & Agriculture (Master)

Experimental station of Lavalette (Montpeliier)

- Irrigation efficiency
- Combined water and nitrogen stresses
- Agroecology, conservation agriculture
- Dynamic agrivoltaic plot
- Test of irrigation material
- Optirrig on the Pi Raspberry device

+ Emerging questions for Optimiste

Research

INRAE MISTEA JRU
Optimal control for REUSE
CIFRE Thesis (A.Ramos)
Agrivoltaic in Sun'Agri3
Thesis (K.Akakpo)
Agroforestry (Tunisia)
Thesis (B.Richard)
Multi-agent simulations
GR hydrological model
AET at regional scales

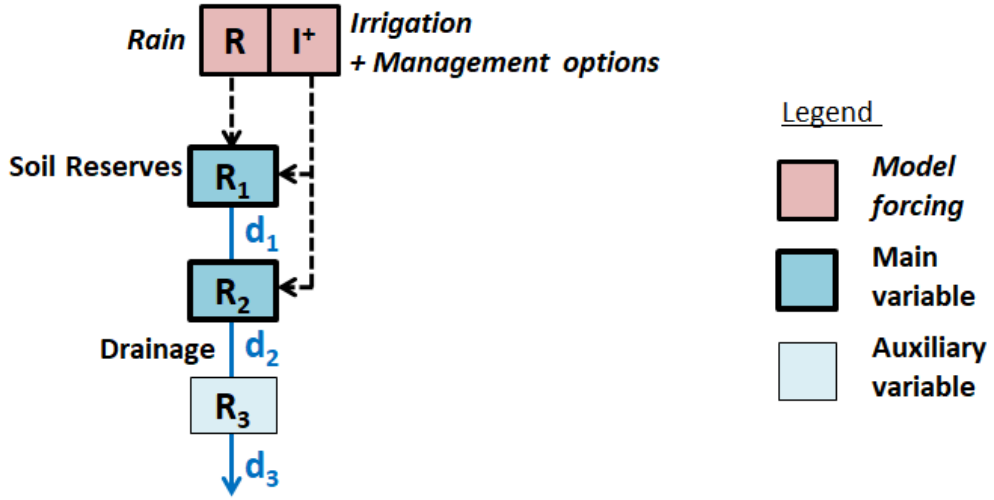
Conceptual scheme of the hydro-agro loop

1. Filling soil water reserves

- Three successive fictitious reservoirs (R1: surface, R2: racines, R3: profond)
- R1-R2-R3 communicate through drainage (no capillary rise)
- Filling occurs through rain or irrigation (inc. surface or subsurface drip irrigation)
- Irrigation strategy is the main control on the soil-plant system (for known crop variety and sowing date)
- Two families of irrigation strategies

  Scheduling type

  Phenomenological type



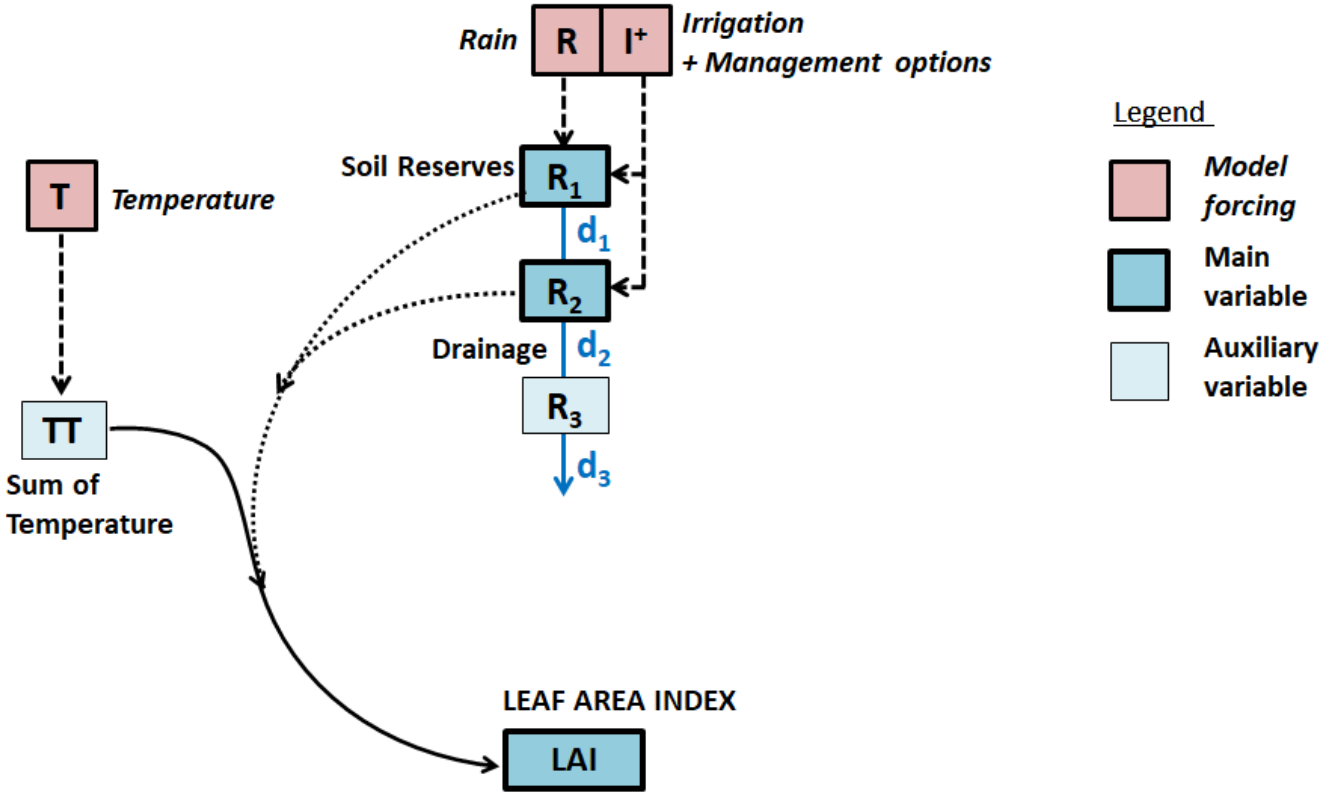
Dates and doses détermined by decision rules that rely on water turns and rain, possibly postponing irrigation. Optirrig knows how to generate such irrigation schedules from meteo data and several types of decision rules.

Dates and doses determined by threshold values of some model variables (soil water reserves, stress) or associated variables (soil water potential) either measured or predicted.

Conceptual scheme of the hydro-agro loop

2. Crop growth

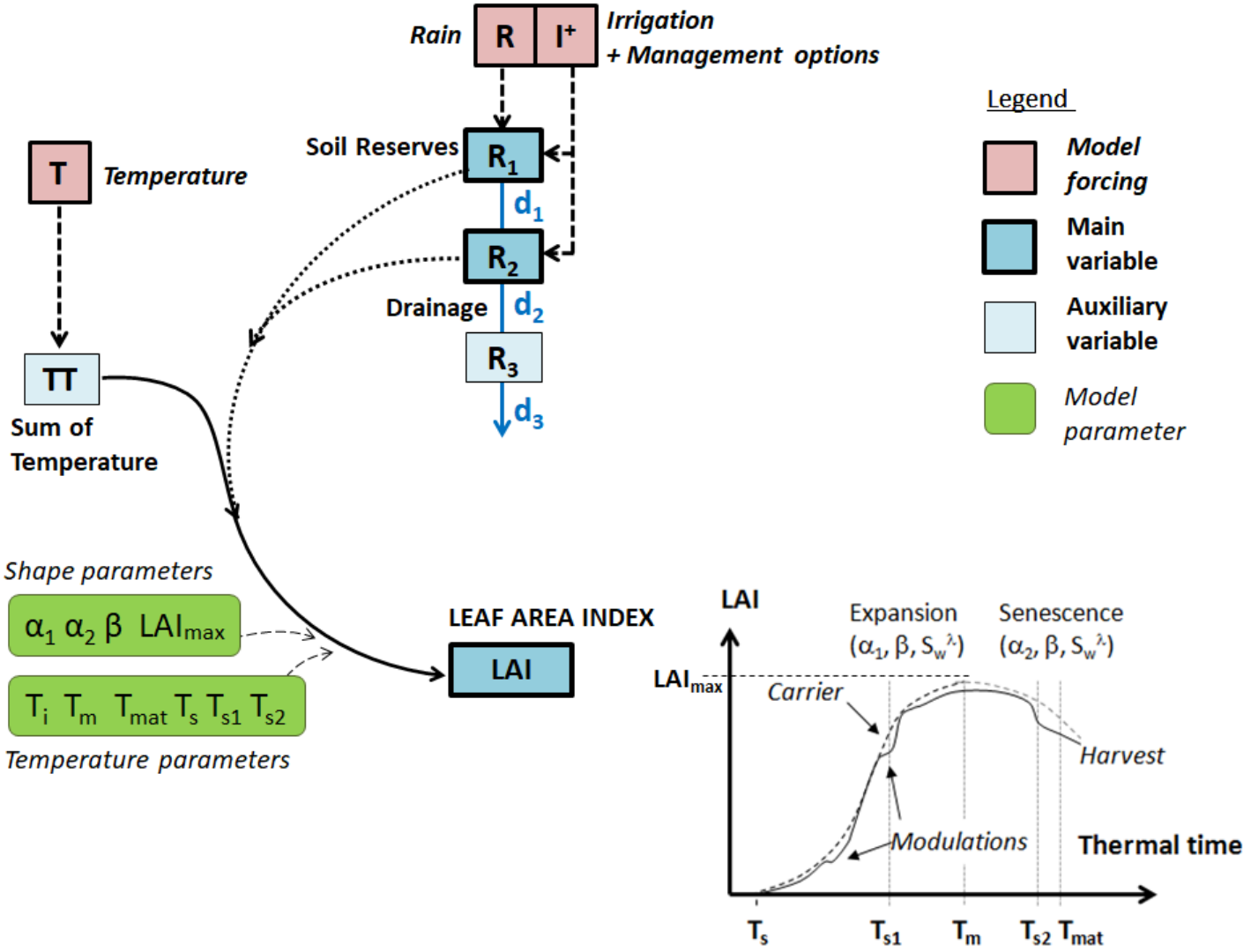
- Optirrig belongs to the "thermal time" type of models
- Crop growth first controlled by the sum of daily-averaged air temperatures since sowing
- Water stress occurs if soil water reserves vanish (next slides) which may affect crop growth
- Leaf Area Index is the key indicator of crop growth
- Leaf Area Index is the ratio of total leaf surface on the projected soil surface



Conceptual scheme of the hydro-agro loop

3. Shape of the LAI curve

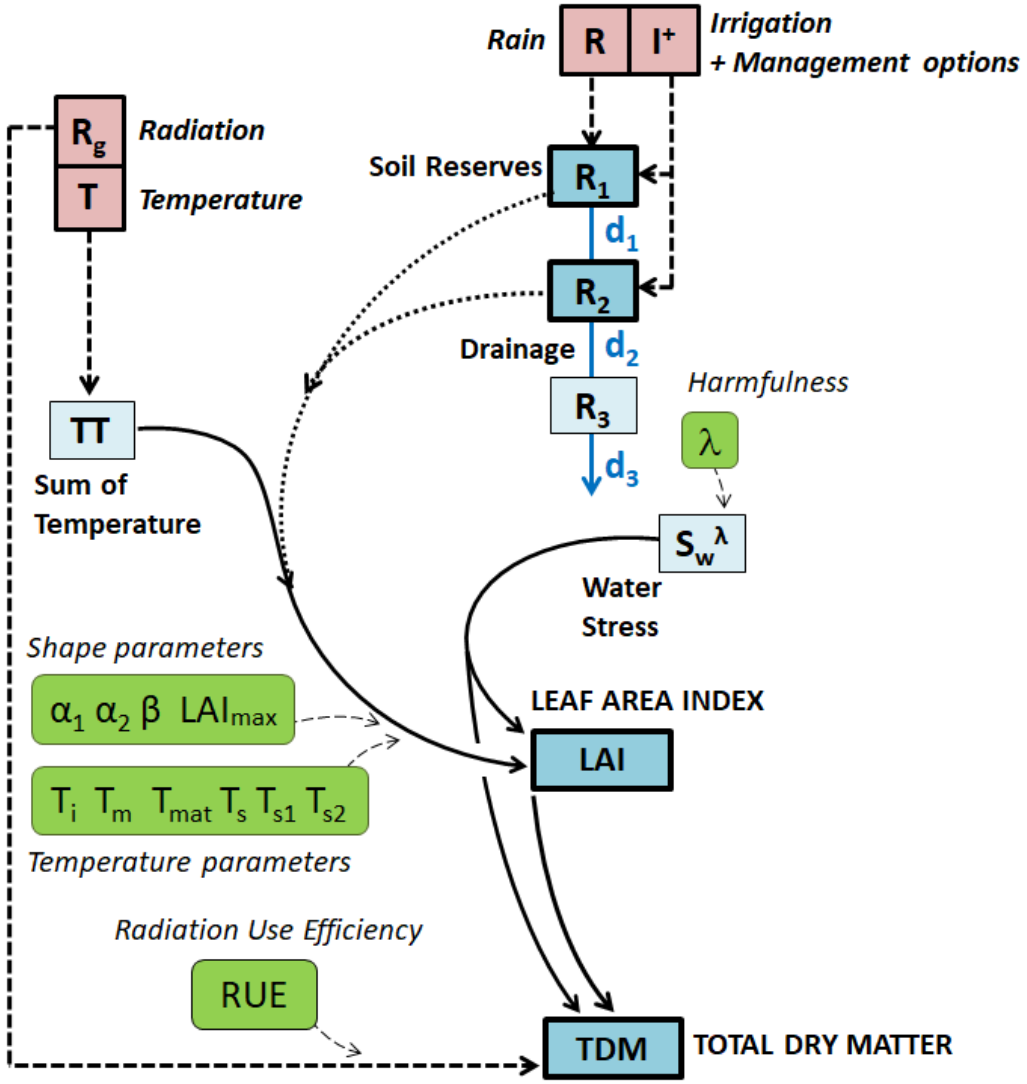
- The Leaf Area Index is a pseudo-sigmoid function (S-shaped curve) of the temperature sum
- Stress episodes delay and hamper crop growths (modulations on the LAI curve)
- The shape of the curve (curvature, inflection pont, scale and spreading) is controlled by crop-specific parameters
- Our database contains the necessary information but most seasonal crops *(fruit trees and grassland soon to be added)*



Conceptual scheme of the hydro-agro loop

4. Biomass production

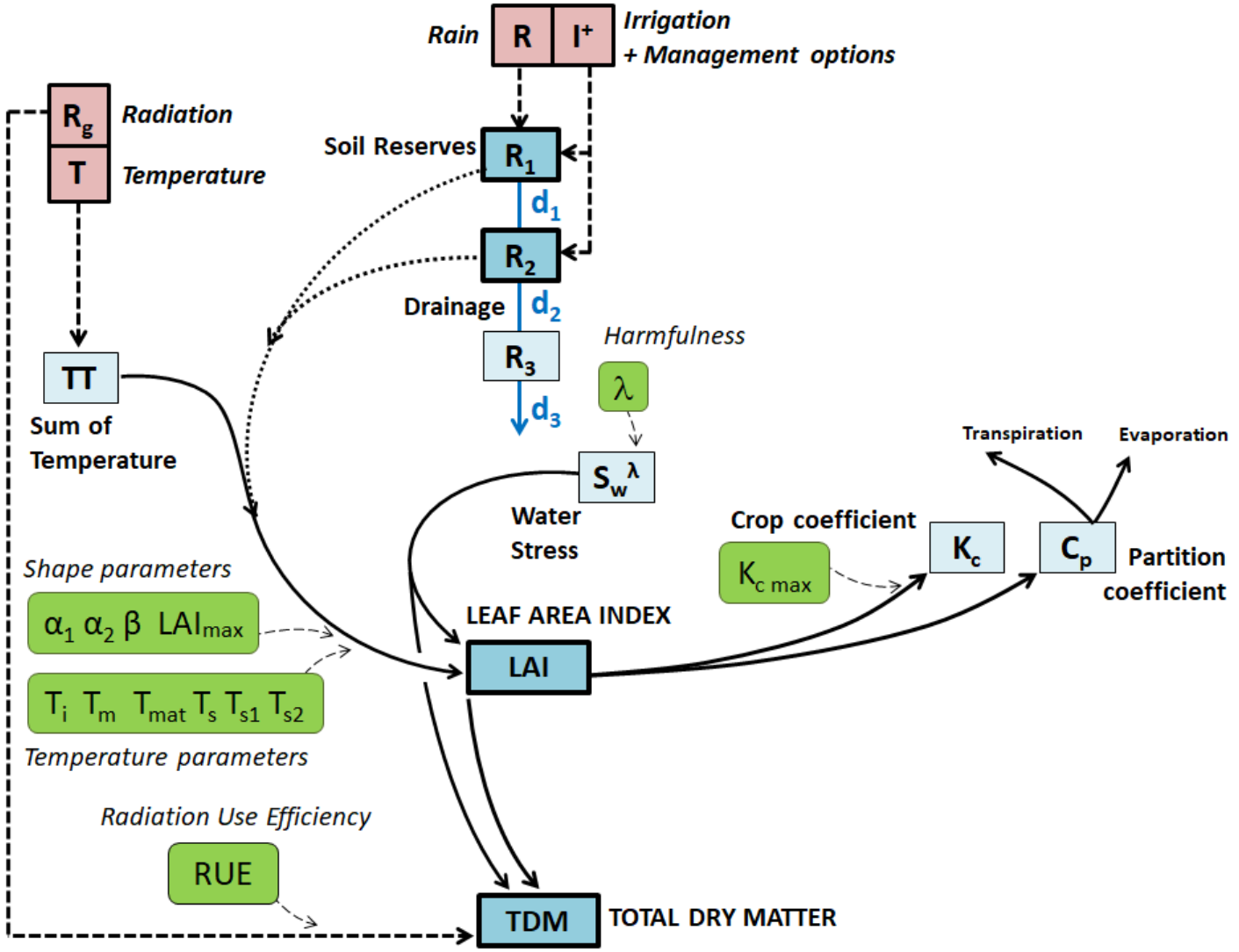
- Biomass is phosynthetized from radiation
- Radiation use efficiency is a crop-specific parameter
- The fraction of radiation intercepted by the crop is a function of the Leaf Area Index
- Water stress has a negative impact on biomass production



Conceptual scheme of the hydro-agro loop

5. Crop coefficient

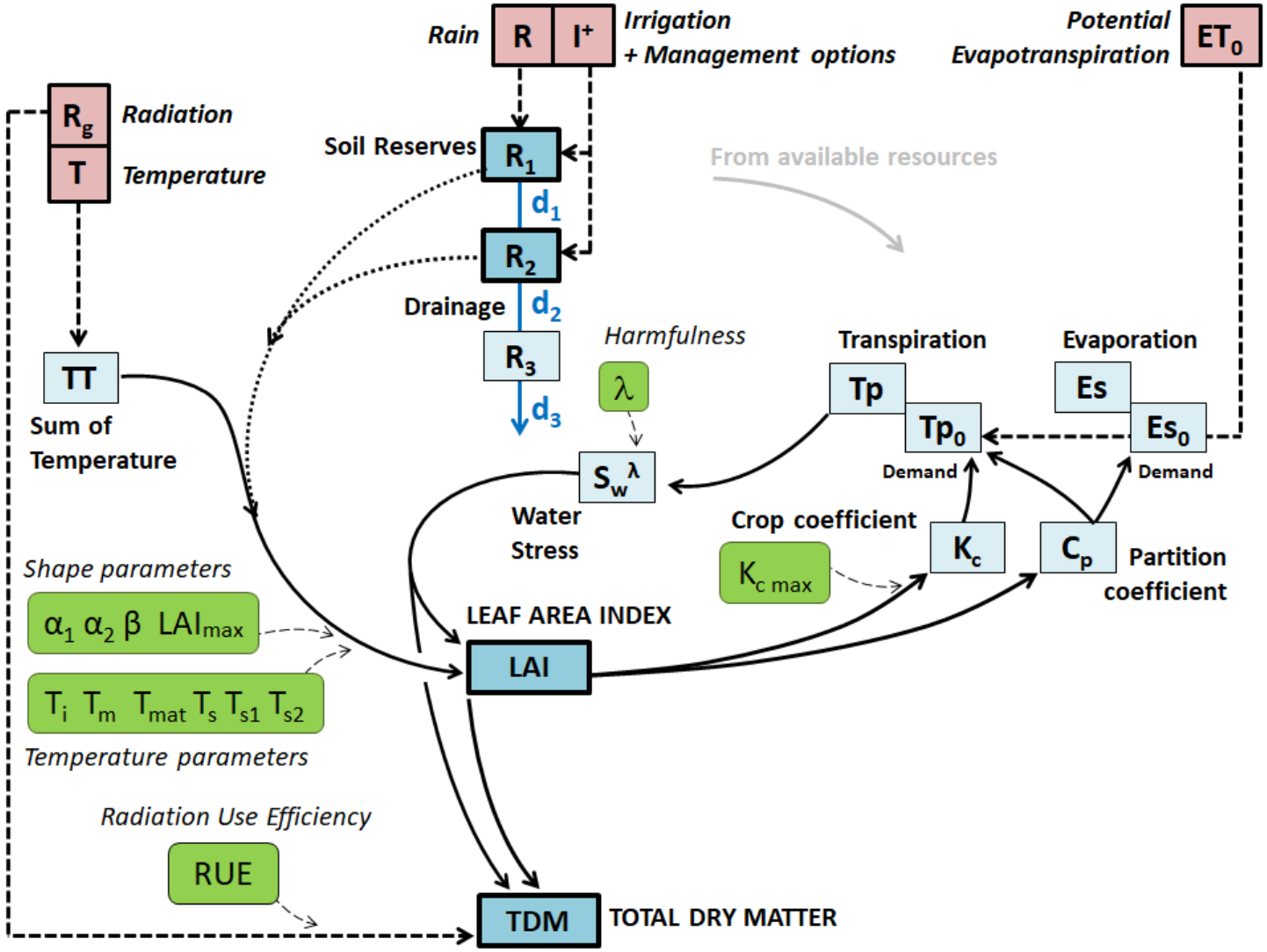
- The crop coefficient describes the capacity of the soil-plant system to evapotranspirate
- The crop coefficient is a function of the Leaf Area Index
- The partition coefficient rules the evapotranspiration demand between soil and plant
- The partition coefficient is a function of the Leaf Area Index
- Transpiration tends to prevail over evaporation for well-developed plants (if enough water is present)



Conceptual scheme of the hydro-agro loop

6. Evapotranspiration

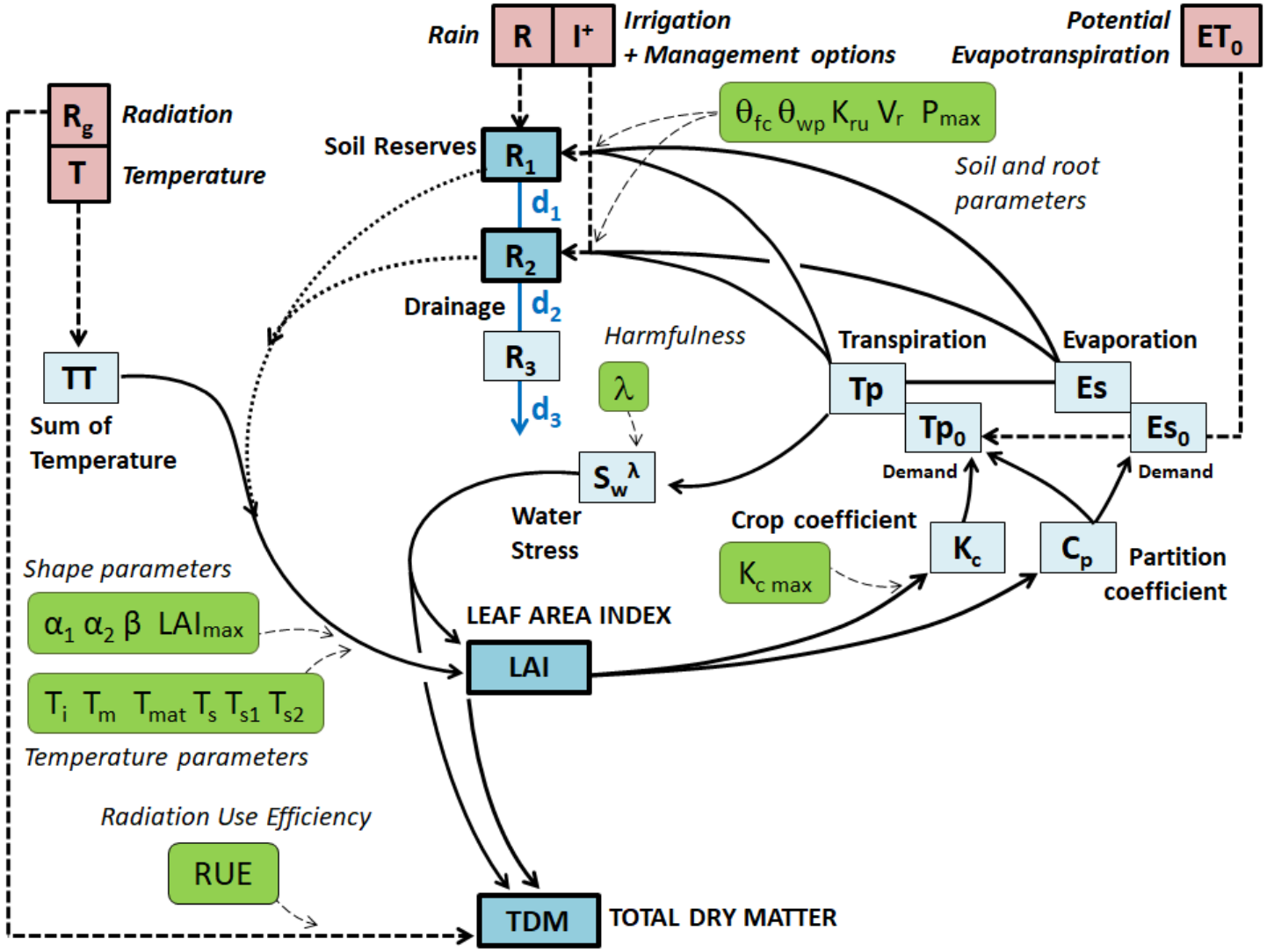
- The transpiration and evaporation demands are calculated from the overall demand, by means of the partition coefficient
- The actual evapotranspiration still depends on the available soil water
- Evaporation is supposed to happen before transpiration when both demands cannot be satisfied at once



Conceptual scheme of the hydro-agro loop

7. Update of soil reserves

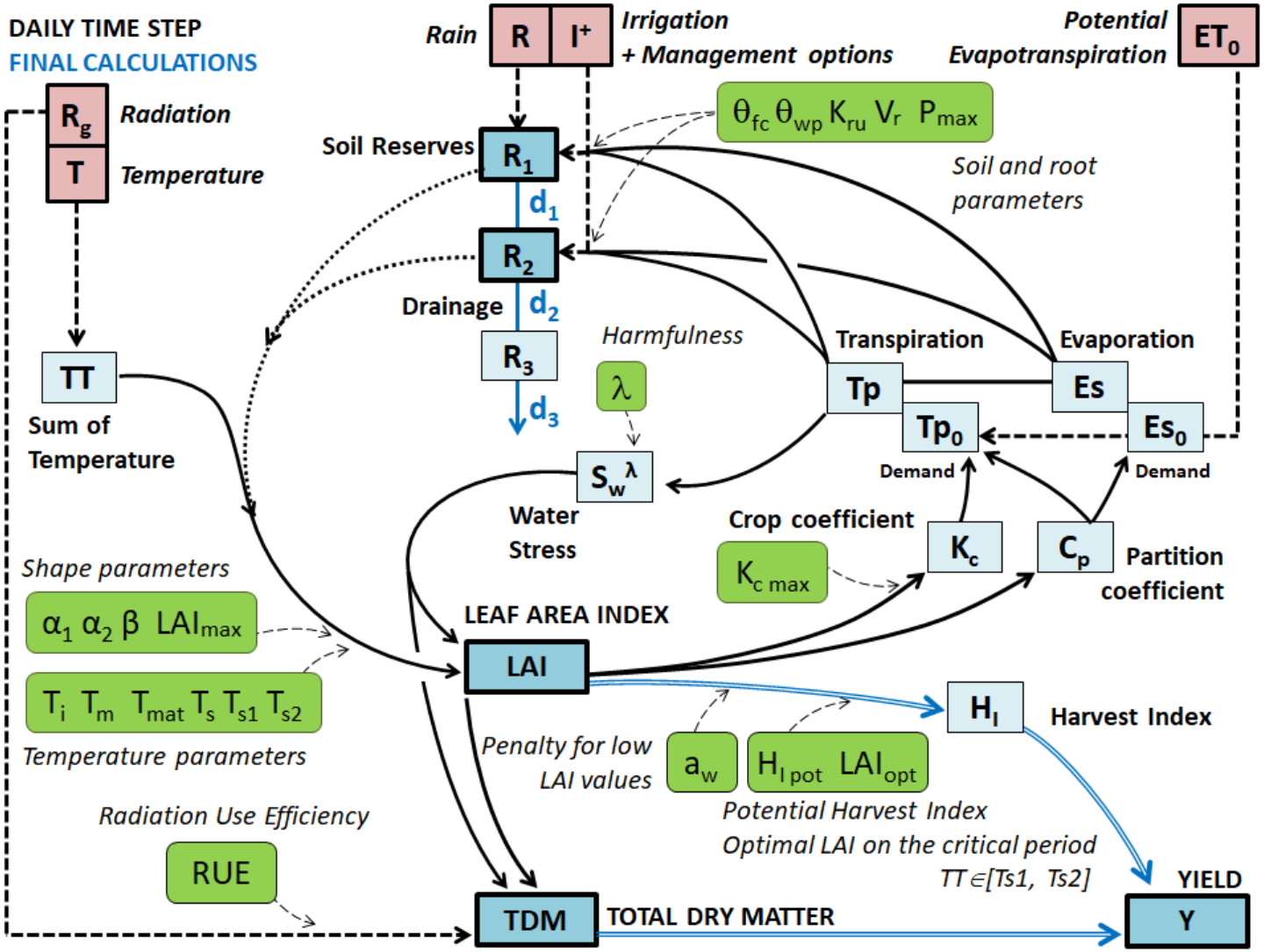
- The calculated actual evapotranspiration allows the update of soil reserves at the end of the time step
- The evapotranspiration deficit creates a stress that impacts Leaf Area Index
- The transpiration deficit creates a stress that impacts biomass production
- The most sensitive parameter for the water budget is field capacity that determines soil available water réserve utile (crucial to measure or guess)



Conceptual scheme of the hydro-agro loop

8. Agricultural yield

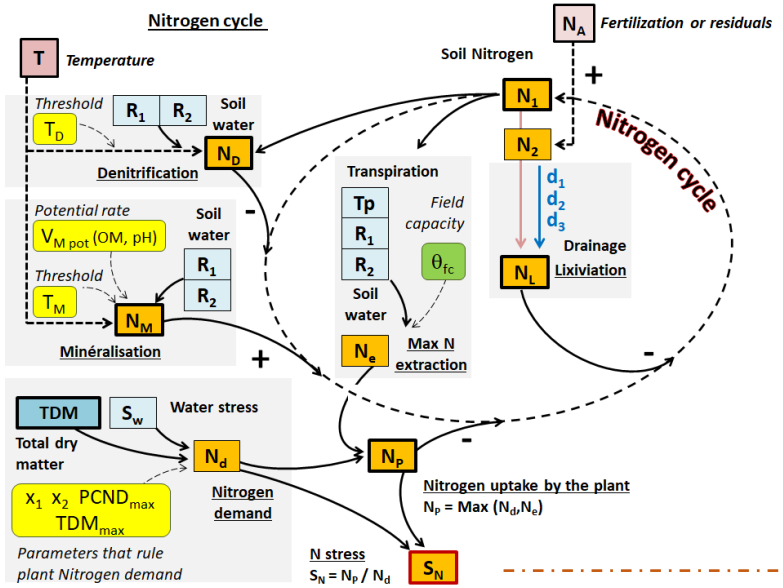
- Yield is calculated as the product between total aerial biomass and the harvest index
- The harvest index is either forced or calculated from the chronicle of Leaf Area Index between selected phenological stages during the season

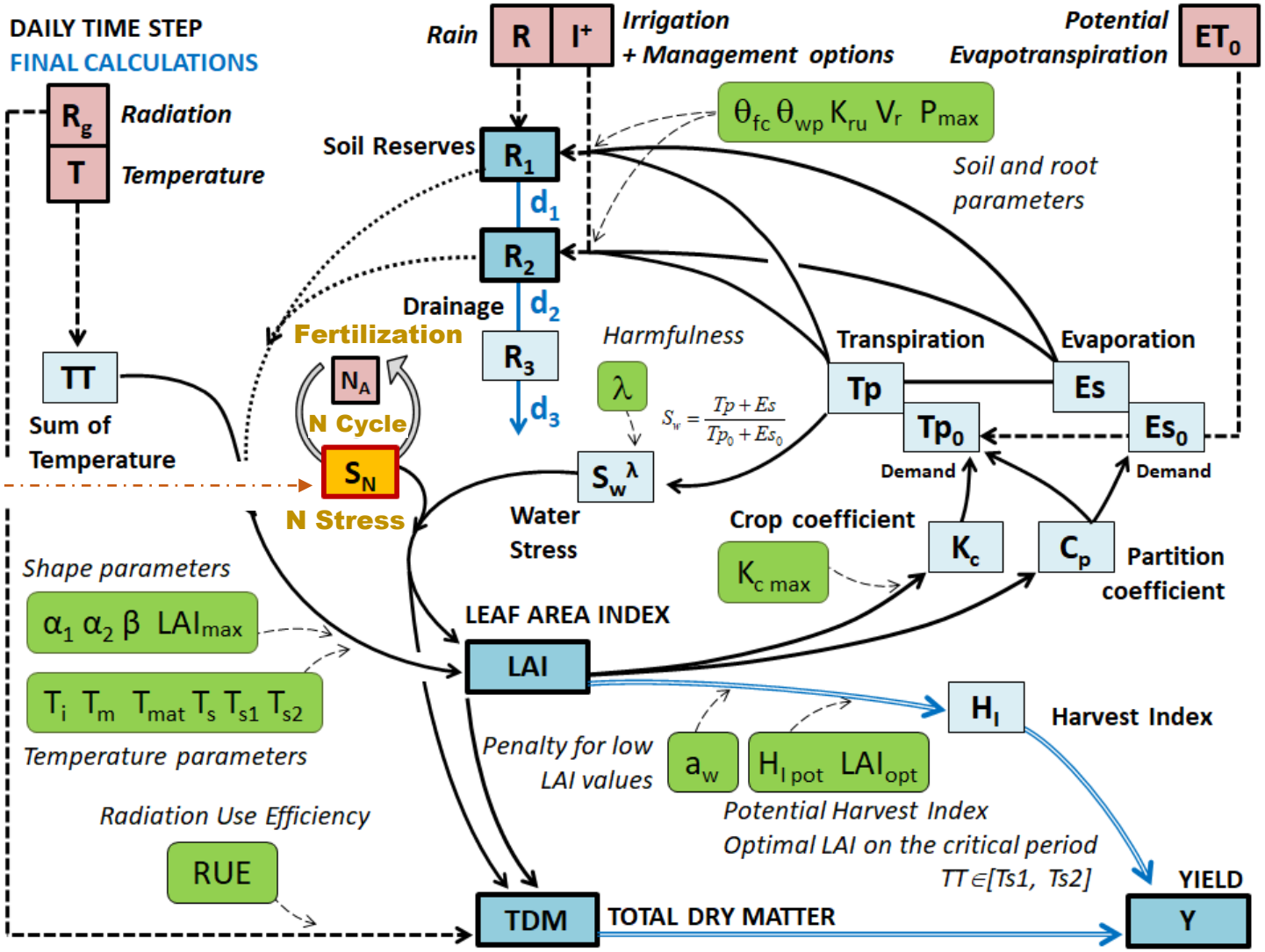


Conceptual scheme of the hydro-agro loop

9. Nitrogen management

- Nitrogen cycle recently added
- For limiting nitrogen conditions
- Results in a nitrogen stress
- Then in combined stresses

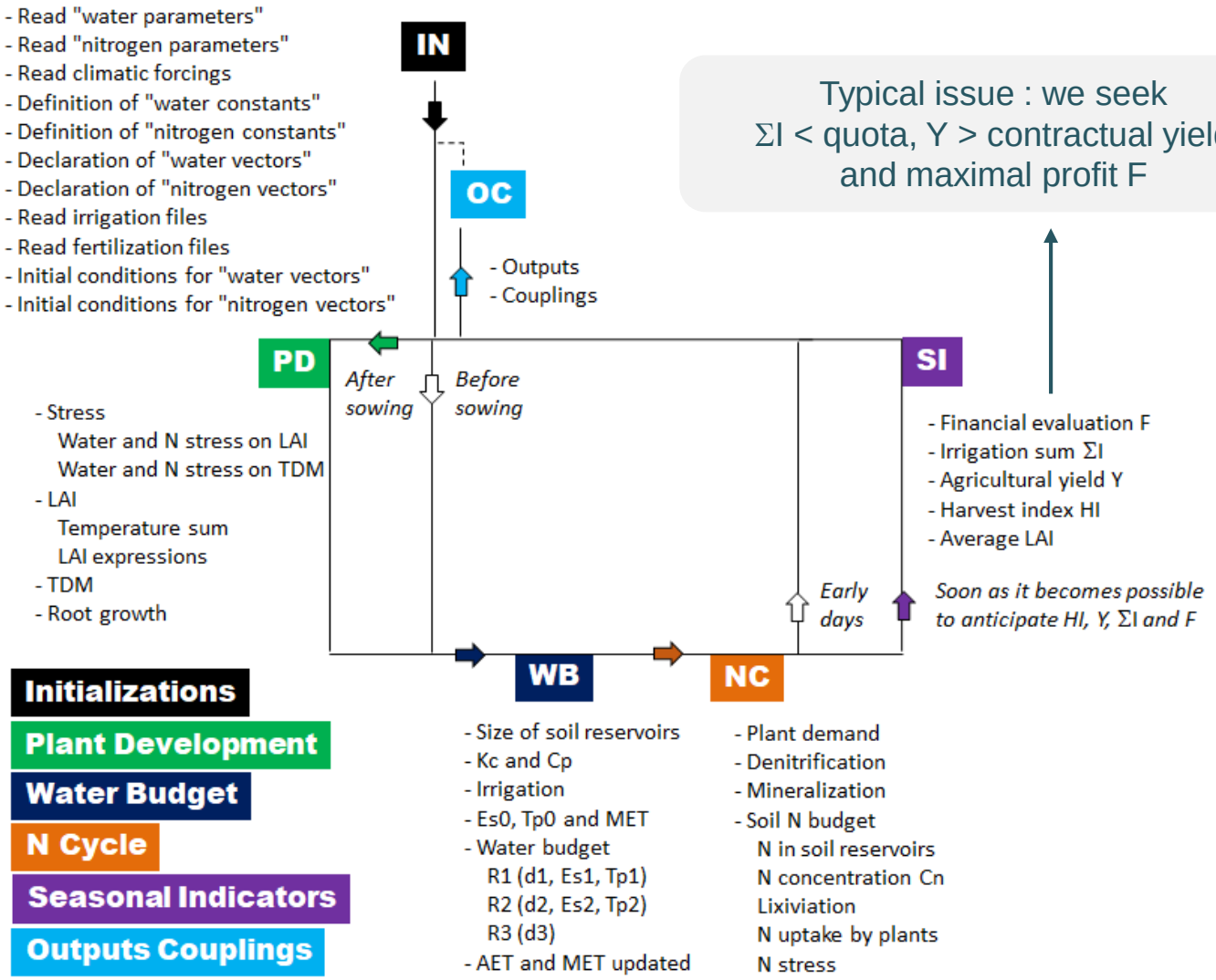




Functional scheme of the hydro-agro loop

A more accurate description of successive calculations

- Indicates families of variables and the main bifurcations
- Indicates the true calculation order for all model variables
- More detailed, accurate and comprehensive than the conceptual scheme
- Inputs and outputs in text format make coupling and interfacing easier
- Graphical outputs in pdf files for all main variables
- This scheme depicts the ref. version (no extra module)



Generation, analysis and optimization of irrigation scenarios

Multiple runs of the hydro-ago loop: Optirrig modes

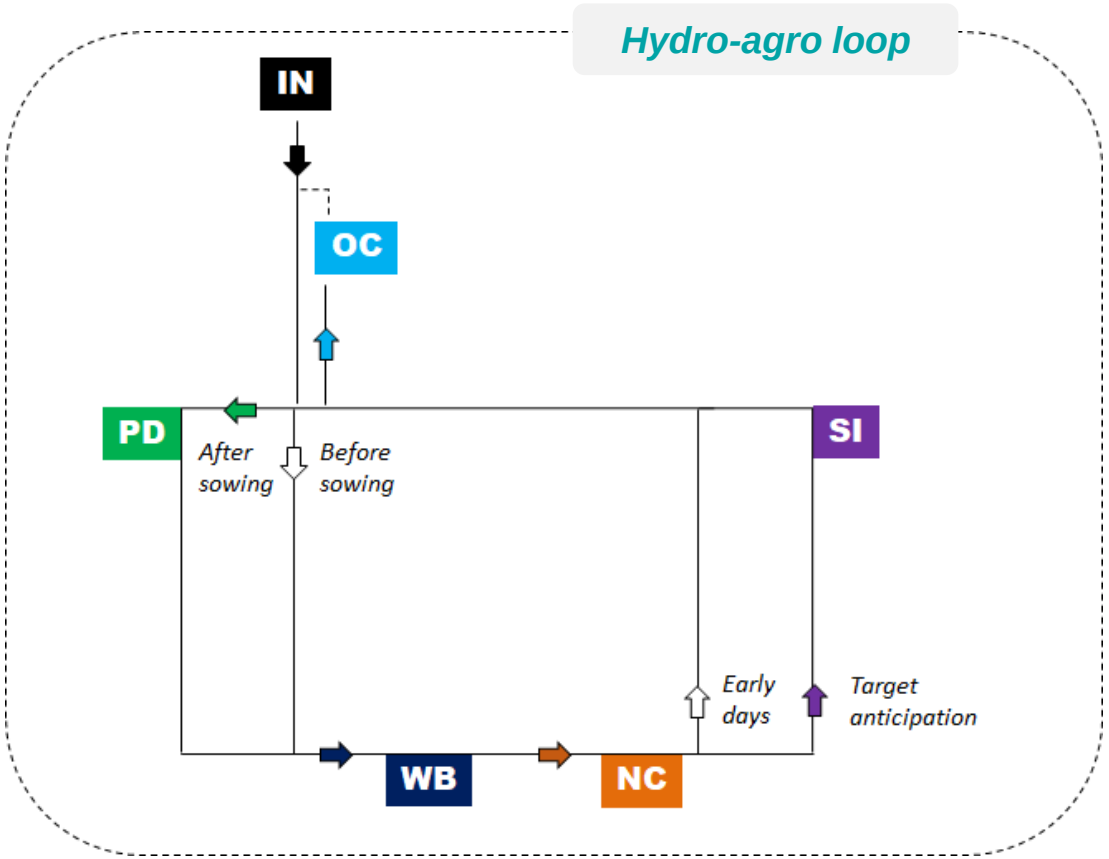
- EXPLORATORY SCENARIOS
- Scénarios of irrigation-fertilisation
- Effects of climatic scenarios
- Various prospectives studies

- NUMERICAL ANALYSIS
- Sensitivity analysis
- Uncertainty analysis*

- CALIBRATION-VALIDATION
- Model fitting
- Fitting of dedicated modules

- OPTIMIZATION
- Ex-post optimization
- Quasi-real time optimization*

Multiple runs
Ad hoc outputs



** On-going development*

Generation, analysis and optimization of irrigation scenarios

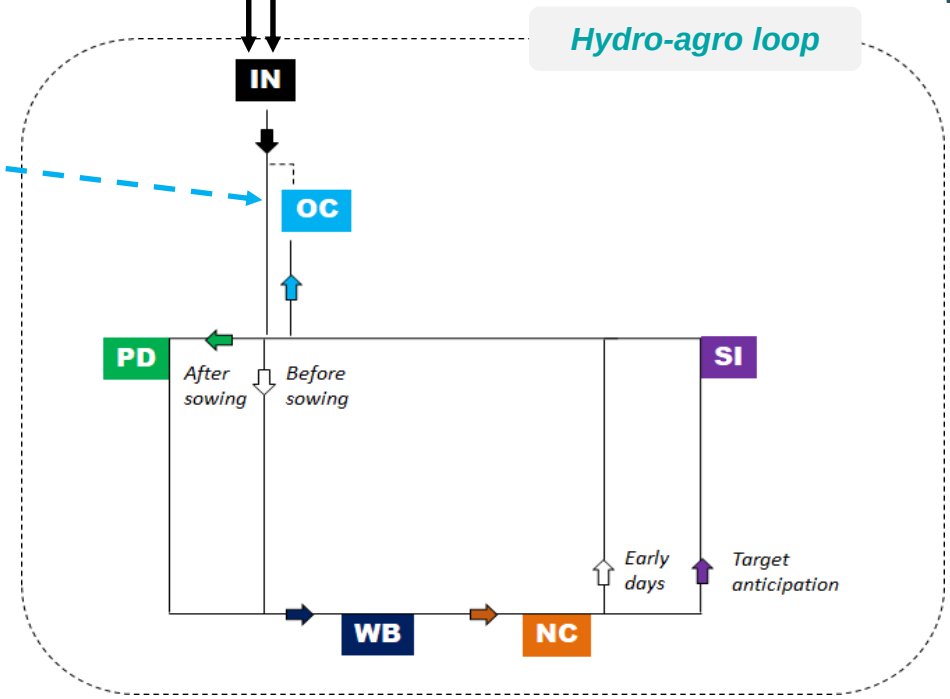
Generic view of contexts and objectives handled by Optirrig

ANTHROPIC CONTROLS
"Scenarios that we decide"

Sowing date and criterion
Irrigation strategy
Fertlization strategy
Harvest date and criterion

DAILY VARIABLES
"What we can measure"

Leaf Area Index, biomass
Reserves, tensiometry
Soil and plant Nitrogen



HYDRO-AGRO-PEDO-CLIMATIC CONTEXT
"What we do not decide"

Climatic forcings (P, Rg, T, ET0)
Resources (water table, rivers...)
Constraints (quota, availaibility...)
Soil and plant parameters

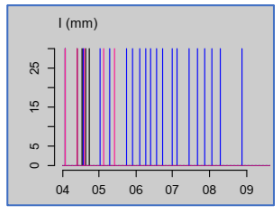
SEASONAL INDICATORS
"What we aim to optimize"

Water and Nitrogen used
Agricultural yield
Performance, efficiency...
Financial profit

Generation, analysis and optimization of irrigation scenarios

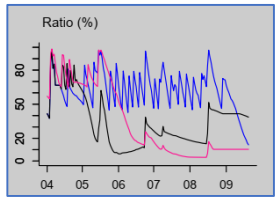
Illustration for three irrigation scenarios

ANTHROPIC CONTROLS
"Scenarios that we decide"



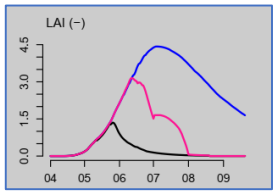
Irrigation chronicles

DAILY VARIABLES
"What we can measure"

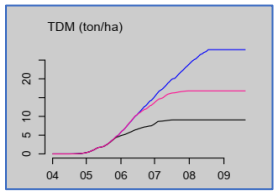


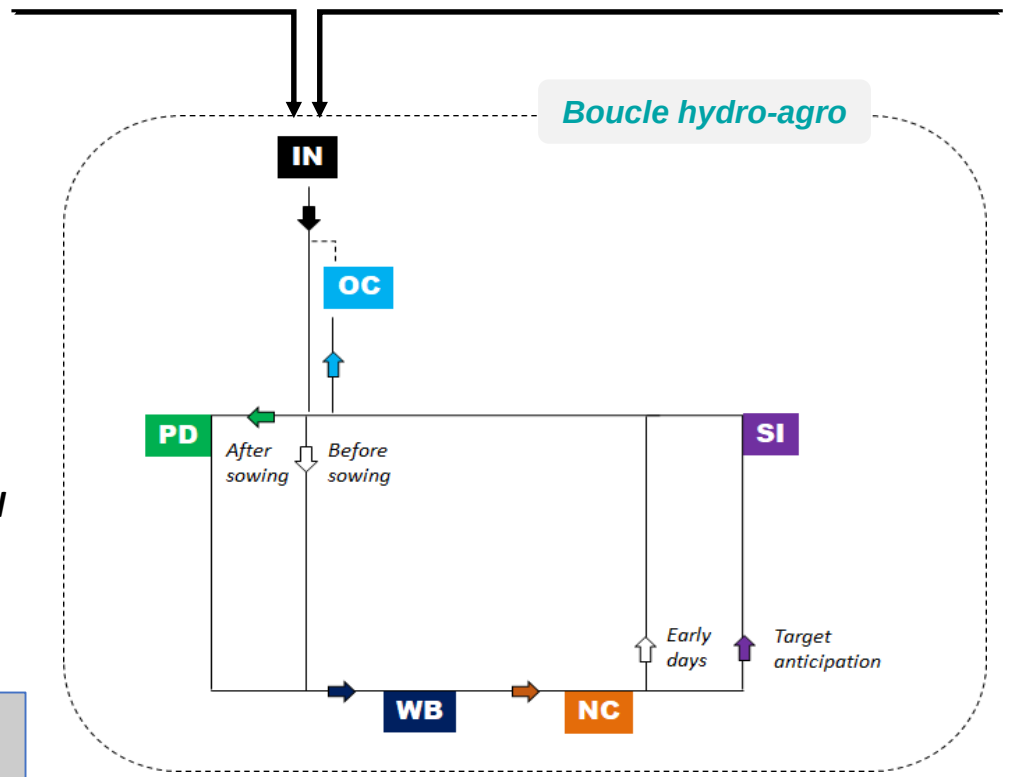
Evolution of soil water reserves

Leaf Area Index



Biomass



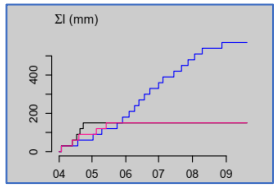


Anticipated agricultural yield

HYDRO-AGRO-PEDO-CLIMATIC CONTEXT
"What we do not decide"

Climatic forcings (P, Rg, T, ET0)
Resources (water table, rivers...)
Constraints (quota, availaibility...)
Soil and plant parameters

SEASONAL INDICATORS
"What we aim to optimize"



Sum of irrigation

Anticipated financial profit