

Agriculture at the crossroads of IIoT and HPC

**when real-time observation meets simulation to
improve plant proteins and reduce nitrate pollution**

Marion CARRIER

Context : increasing expectations and challenges for Agriculture

Quantitative challenges

- Answer food supply needs in quantity and quality



+ 50% world population in 2050

Environmental challenges

- Reduce environmental impacts (GES, inputs...)
- Enhance biodiversity
- Preserve natural ressources
- Adaptation to climate change



100 millions of tons of nitrates are consumed every year

Agriculture uses 70% of planet water every year



Economic challenges

- Enhance perennity and competitiveness of the food sectors

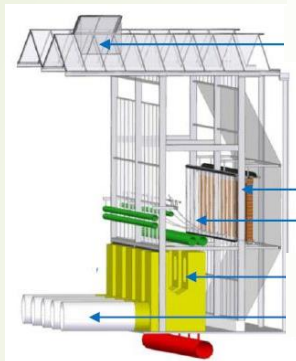


Indian coffee declined by ~30% in 12 years



Context : Embedded IT and precision farming

- Greenhouses : more and more controlled environments



Reduced openings

Air refreshment (pad cooling)

Air heating through thermal exchanges



- Precise sowing, fertilization and irrigation

Precise autoguidance



Variable rate



- Controlled by an adapted decision motor ?

Image of a complex data table, likely a decision support system output, showing various parameters and values.



Context : More and more capacities for crops observation

In situ continuous observation



humidity, temperature...

Manual measurements
Foliar index, nitrogen stresses



Embedded sensors
yield, chlorophyll...



Multiple data
acquisition sensors

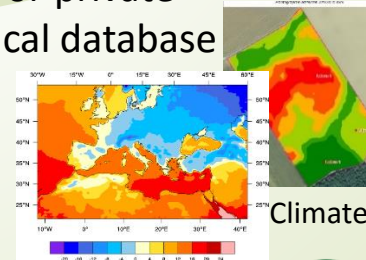
Soil conductance



Optical, radar
imaging



Public or private
historical database

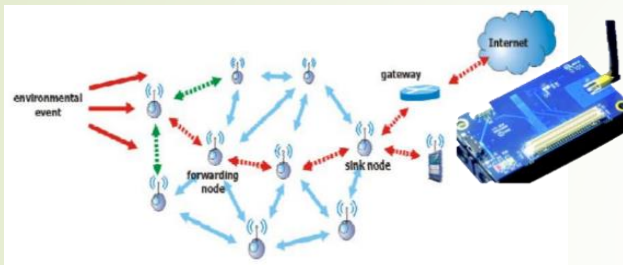


Soil properties
Climate, economy...

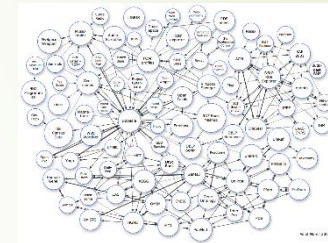
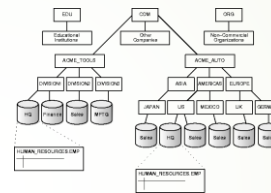
Context: Increasing knowledge in data communication and modeling

➤ Data communication

- Low cost data recuperation



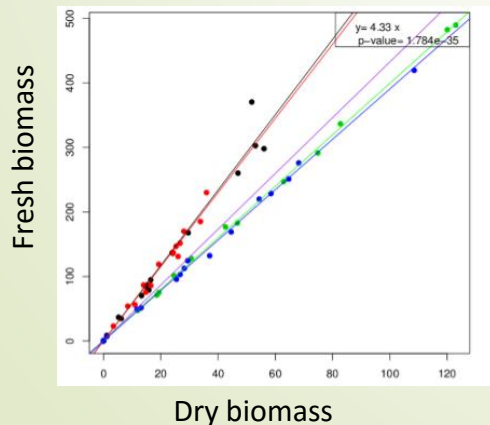
- Data structuration models to visualize and perform utilization of heterogeneous complex datasets



➤ Data models of cropping systems

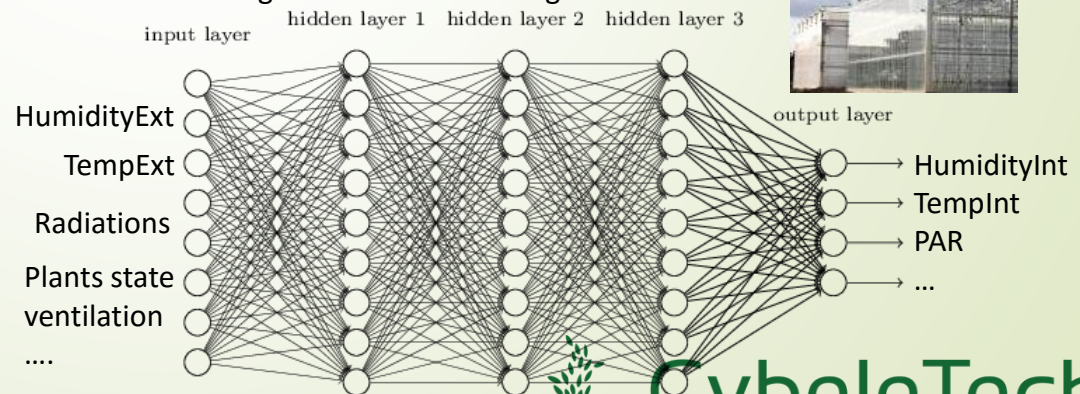
➤ Understanding

Ex : Berries sugar content at harvest for various cepages in same growth conditions



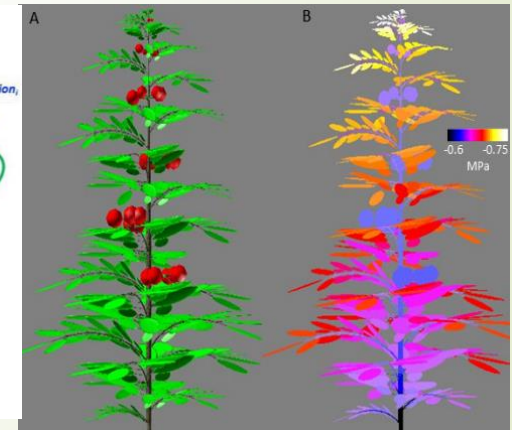
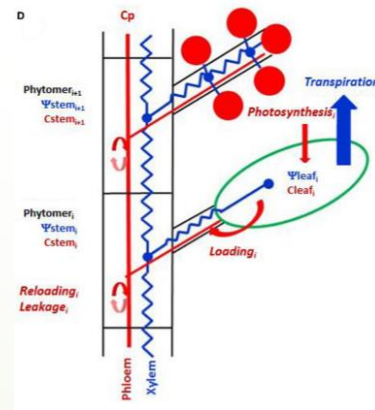
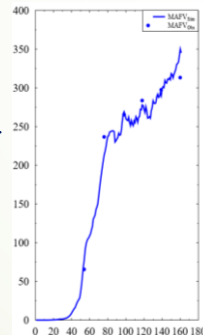
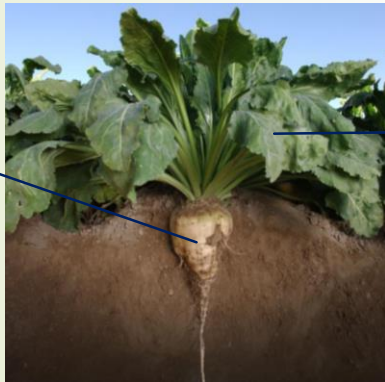
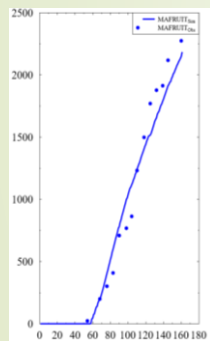
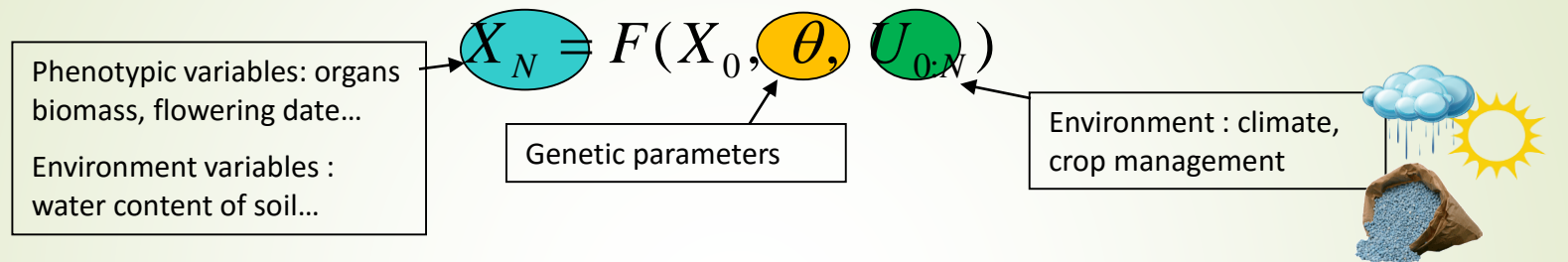
➤ Prediction

ex : NN for greenhouses modelling



Context : Increasing knowledge of crops functioning

- Understanding of plants functioning enables in silico representation of plant growth

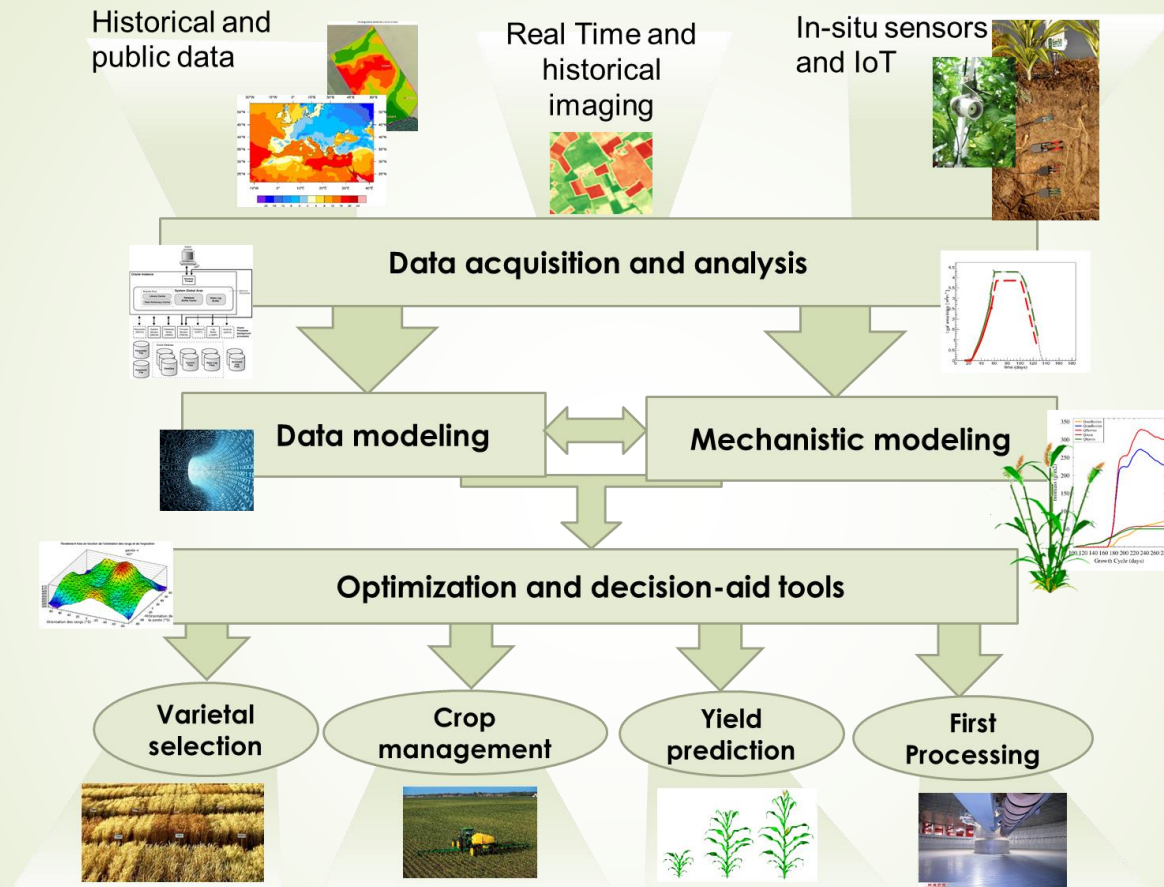


Plant architecture Hydric potential

Baldazzi et al., 2013

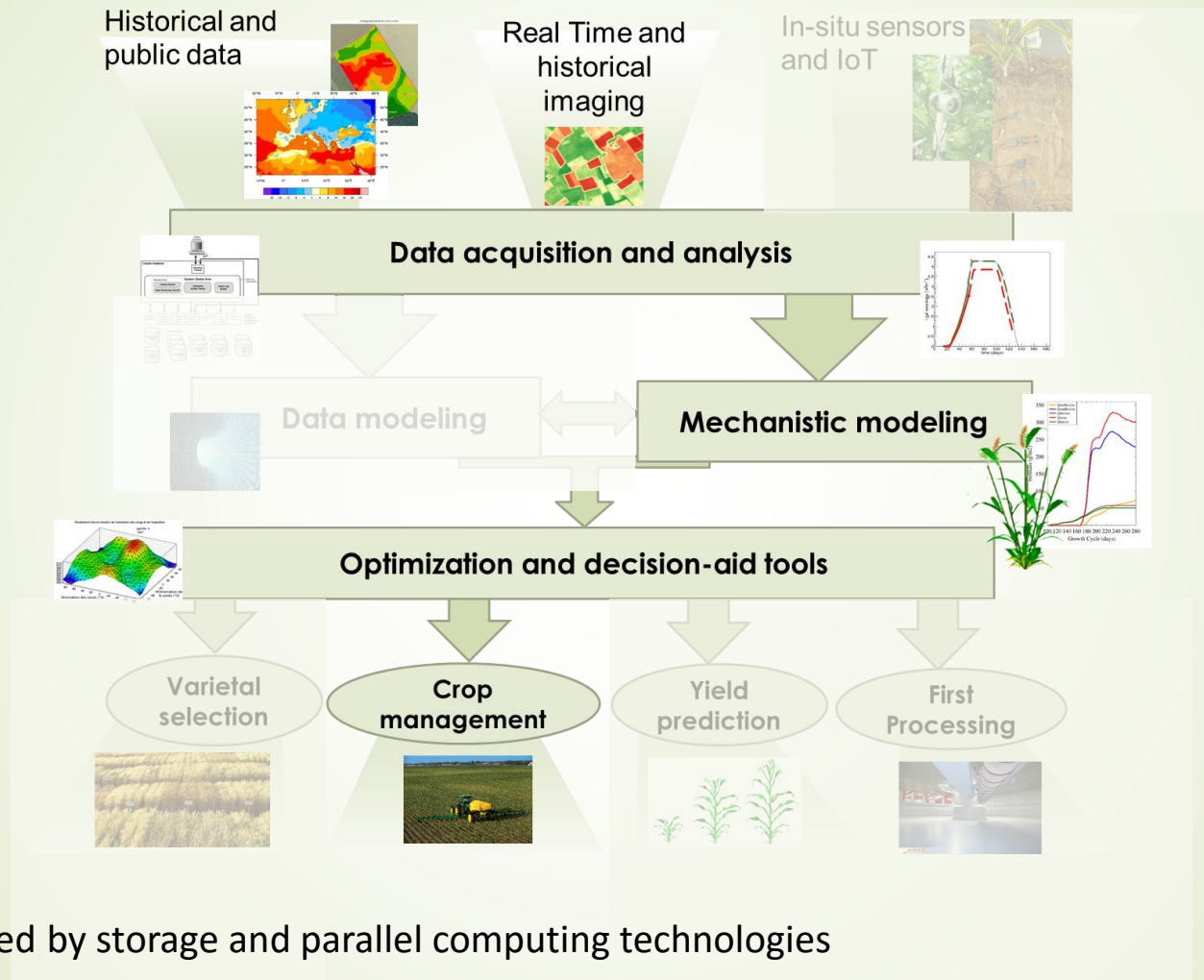
- Enables simulation of plant response to a given environment
- Enables designing Decision Aid Tools

CybeleTech : an integrative approach



- Powered by storage and parallel computing technologies
- Accessible thanks to «cloud computing» and web diffusion tools

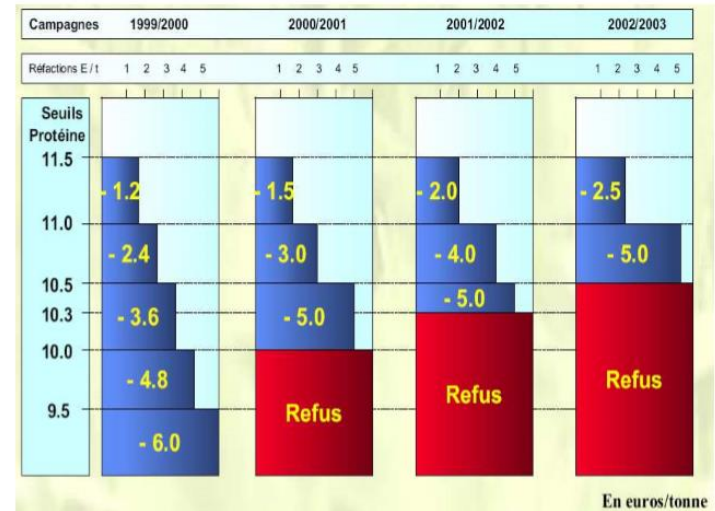
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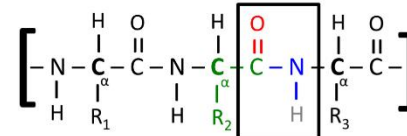
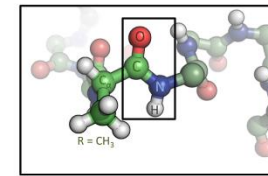
A use case dedicated to
wheat, nitrogen and protein

- A 3 years collaborative project started in 2014
- Dedicated to wheat : major representant of field crops in France and Europe
- Proteins : major qualitative value => major price criteria



Wheat price evolution depending of proteins content,
French agricultural Chamber of Lorraine.

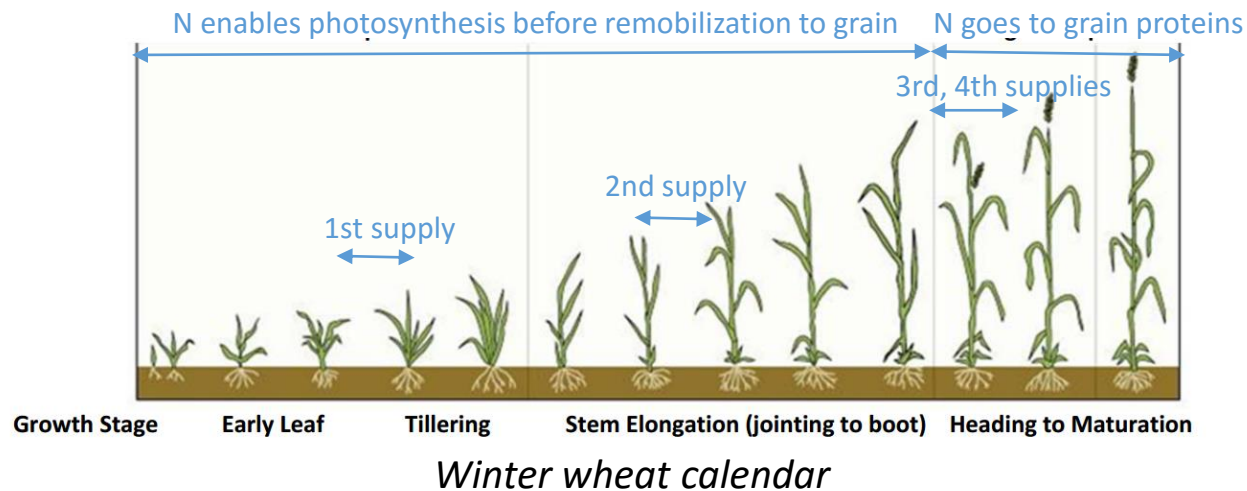
- Protein concentration depends on variety and environment
 - Creation of amino-acids strongly limited by Nitrogen in wheat



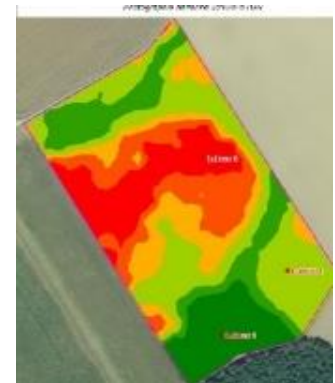


A use case dedicated to wheat, nitrogen and protein

- Nitrogen is the higher cost in wheat production, with seeds
- Its utilization is strongly correlated with plant phenology



- Its absorption depends on soil physical and biophysical properties
- ⇒ **when, where and how much inputs to add to optimize yield (quantity, %proteins) ?**



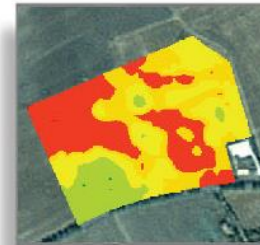
Existing nitrogen positionning tools

- Soil nitrogen measurement
 - + intra-plot exact availability in nitrogen ressource
 - Based on an old measurement (1 month at least)



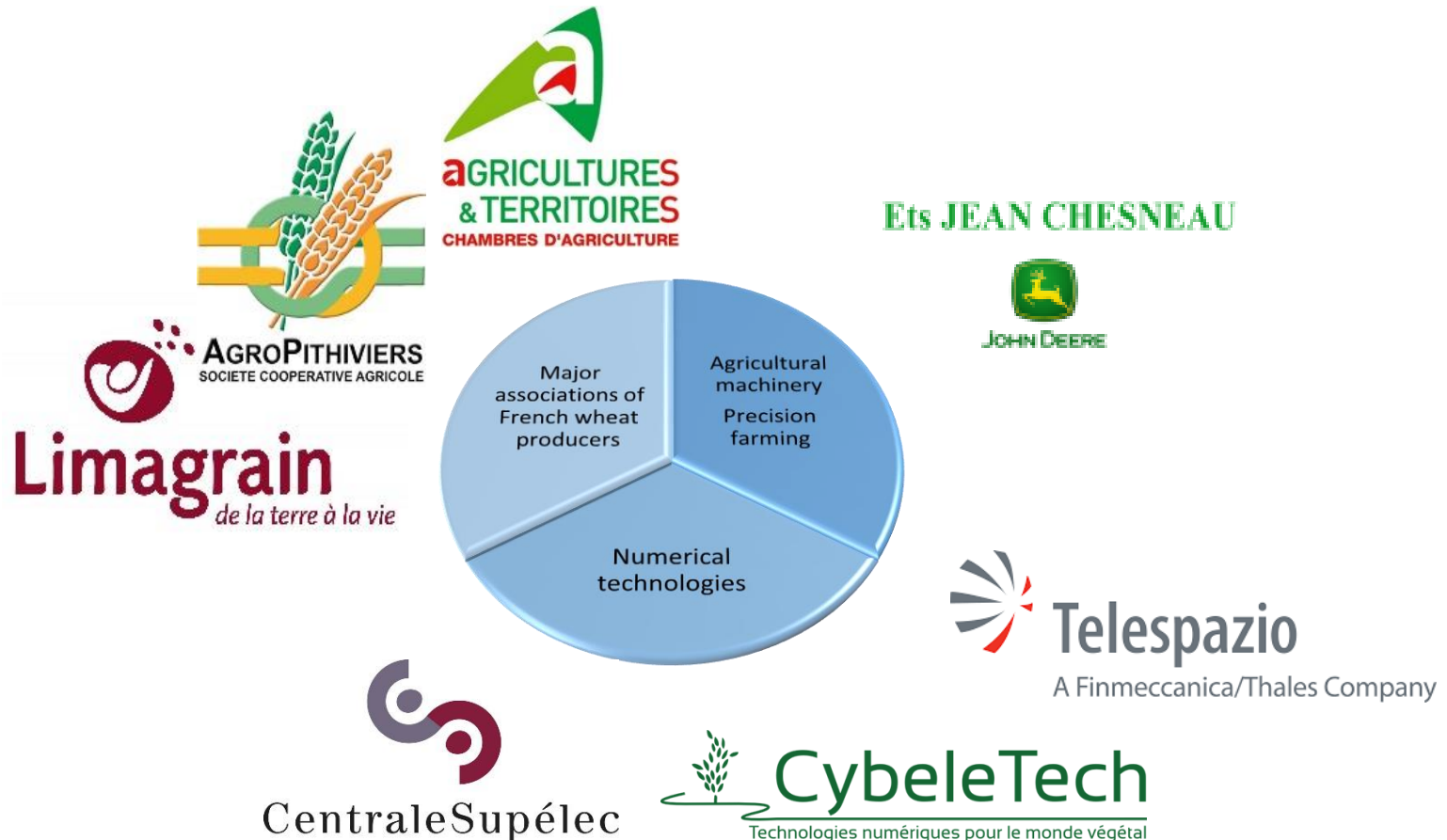
Lab. analysis from soil samples

- Imaging (optical satellite or drone)
 - + intra-plot heterogeneity
 - + consider plant state
 - How to decorrelate nitrogen stress in plant state ?



=> SAS combines wheat growth simulation and real time data acquisition

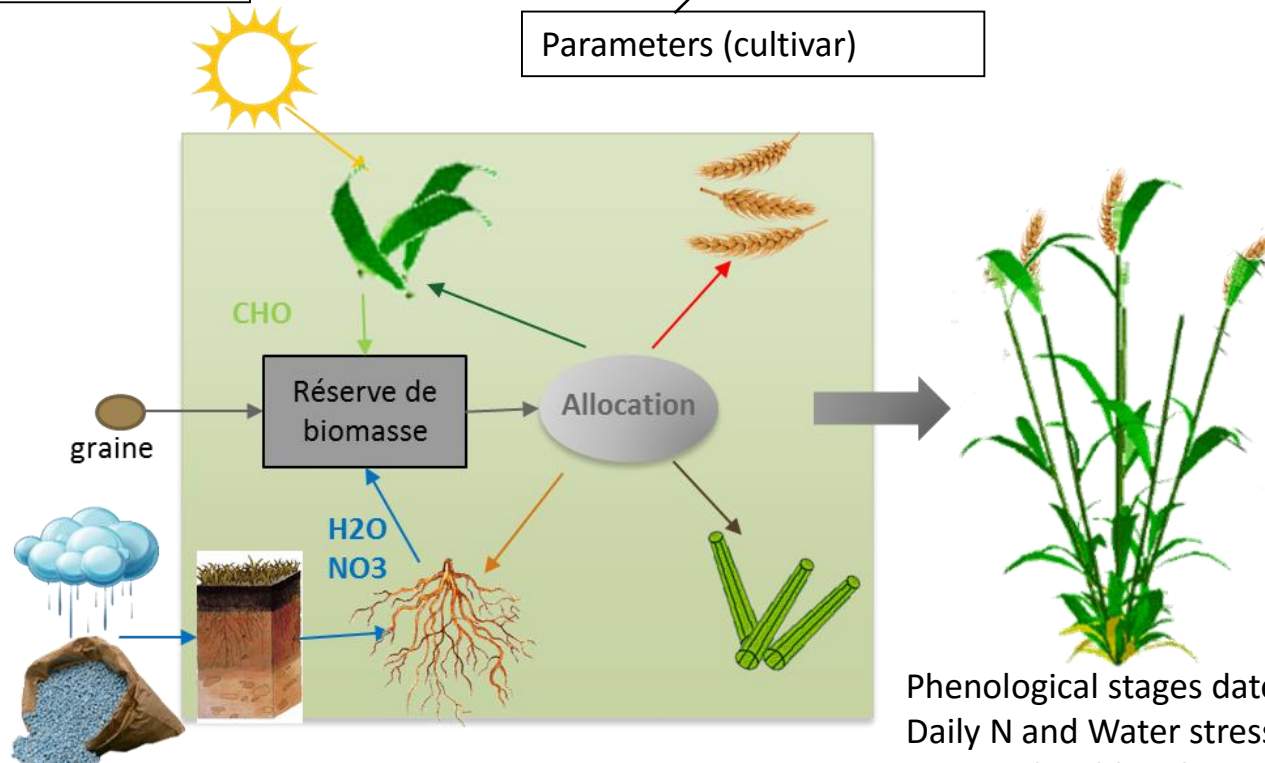
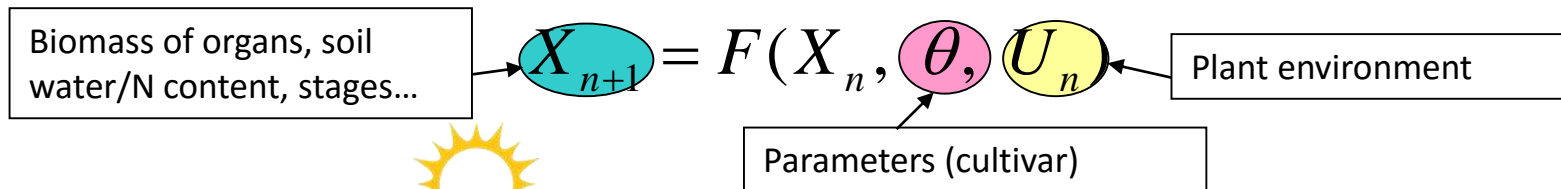
Consortium complementarity



Wheat growth simulation



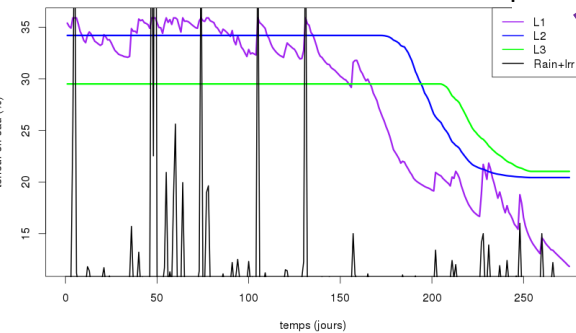
Mechanistic crop modelling



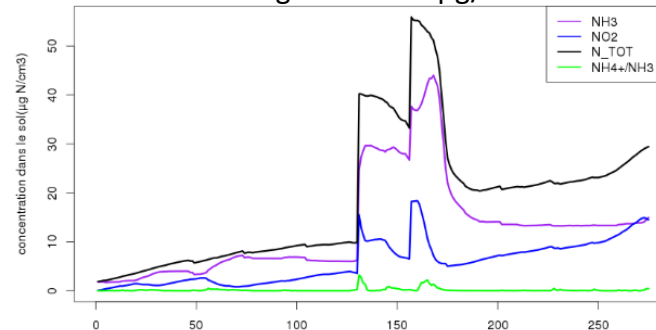
Wheat growth simulation



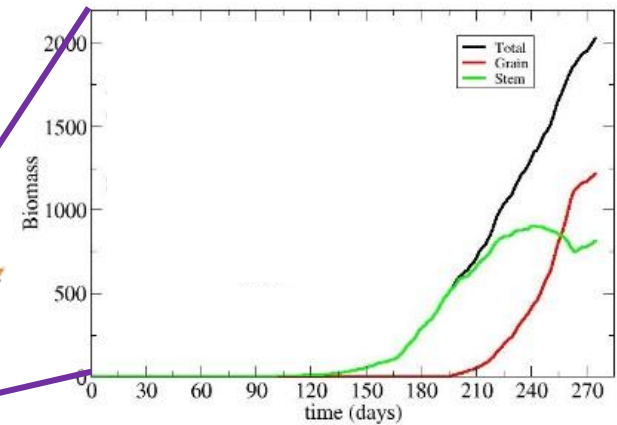
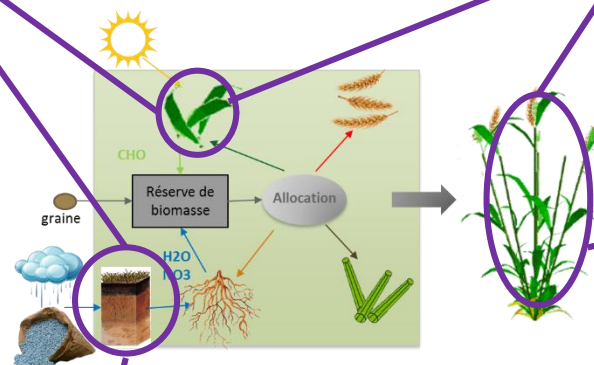
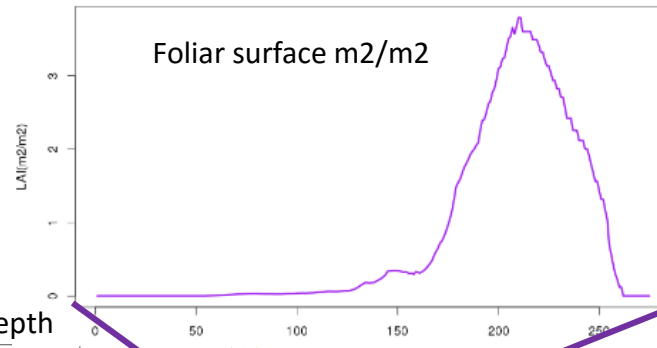
Soil Water content % at various depth



Soil Nitrogen content $\mu\text{g}/\text{cm}^3$



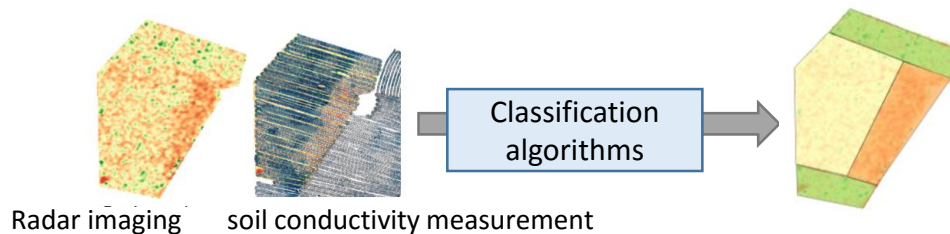
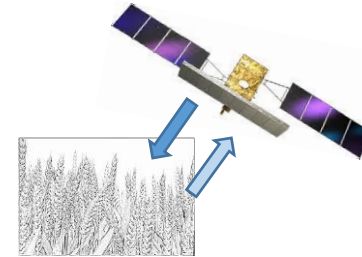
Foliar surface m^2/m^2



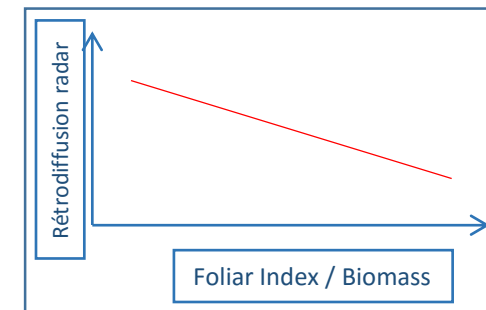
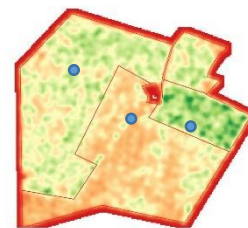
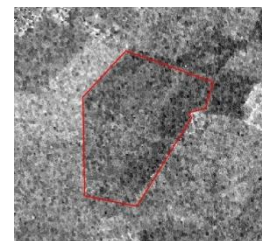
Real Time data acquisition

• « Real Time » Satellite imaging

- Radar \Leftrightarrow any meteorological conditions
- Supported by historical maps
- Relevant intra-plot heterogeneities



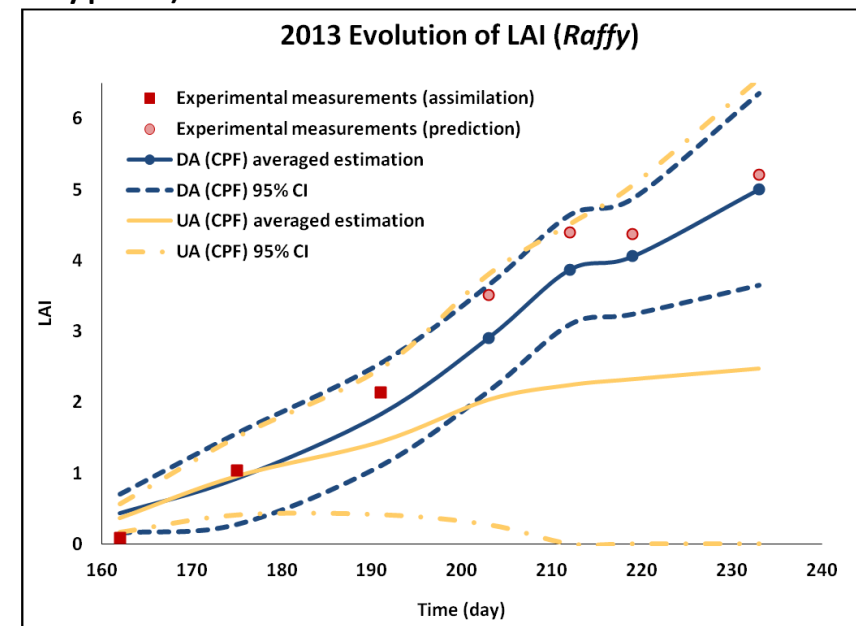
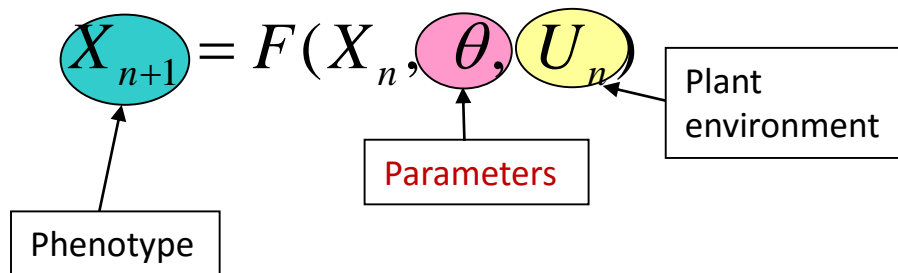
- To calibrate to output instantaneous LAI and/or biomass





Data assimilation techniques

- Data assimilation in plant growth model
 - Correction of plant state prediction
 - Through re-estimation of stochastic processus and/or parameters
 - By fitting « real time » plant status observation
- => Unknown environmental properties (soil type...)
- => Early stages « accidents »



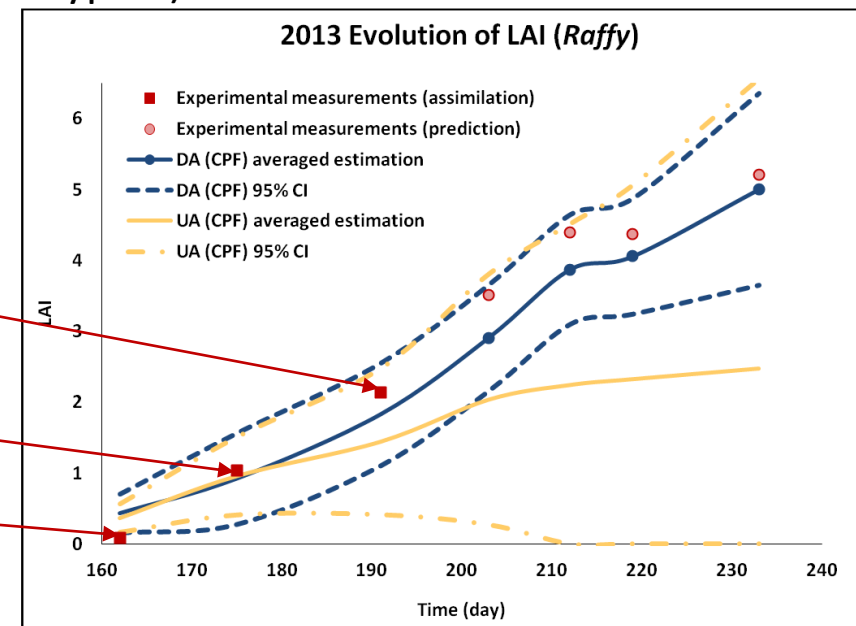
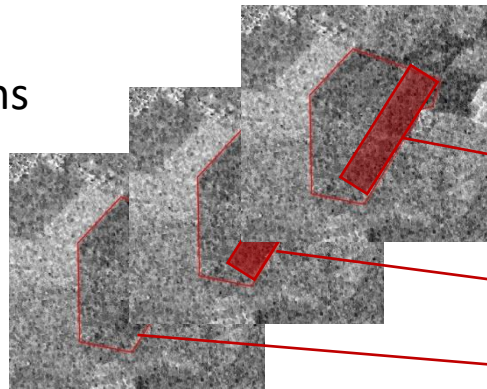
Chen, 2014
Digiplante, Ecole Centrale Paris



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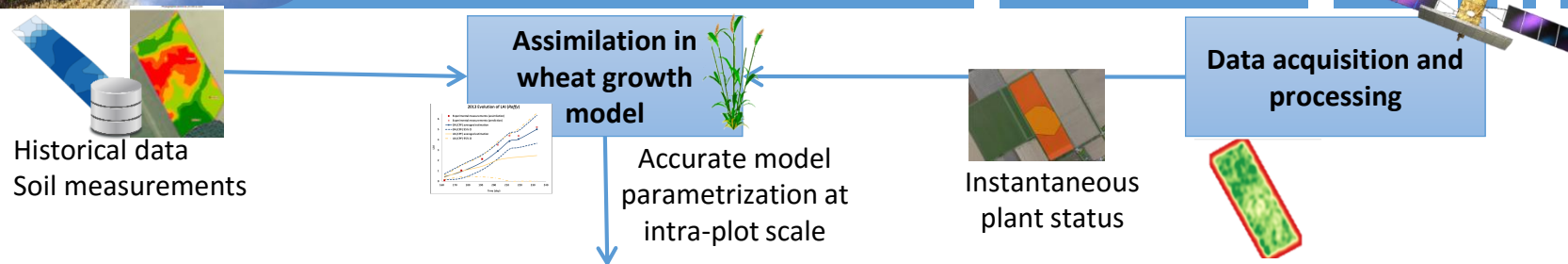
~ 400 000 simulations
~ 1heure CPU



Chen, 2014

Digiplante, Ecole Centrale Paris

Optimisation of production through nitrogen inputs



Optimisation of production through nitrogen inputs

Historical data
Soil measurements

Assimilation in
wheat growth
model

Accurate model
parametrization at
intra-plot scale

Data acquisition and
processing

Instantaneous
plant status

DAT based on potential yield prediction
at intra-plot scale

$$X_N = F(X_0, \theta, U_N)$$

Objectives

Yield, %proteins,
costs...

Levers

Nitrogen application
dates and quantity

User constraints
and objectives

Nitrates legal rates,
inputs types,
sales strategy of
farmer...

Climate data &
scenarii

Informative maps

Potential yield and quality (t/ha)

Abiotic stresses

Intra-plot preconisations
(dates, uN /ha)

End User

End User
embedded system



Conclusion

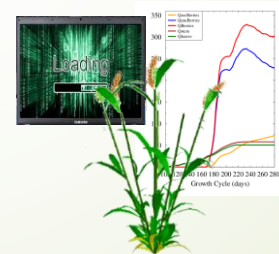
- Food production must adapt and be optimized to face new constraints
 - Economical, social, environmental...

- Thanks to coherent sets of technologies

- Precise crop management tools ⇔

Precise manager

- Accurate tools for crops observation
 - Numerical technologies to represent and aid acting on cropping systems
 - HPC to perform utilization



Thank you !

Questions ?

