Model assisted phenomics and phenotype modeling

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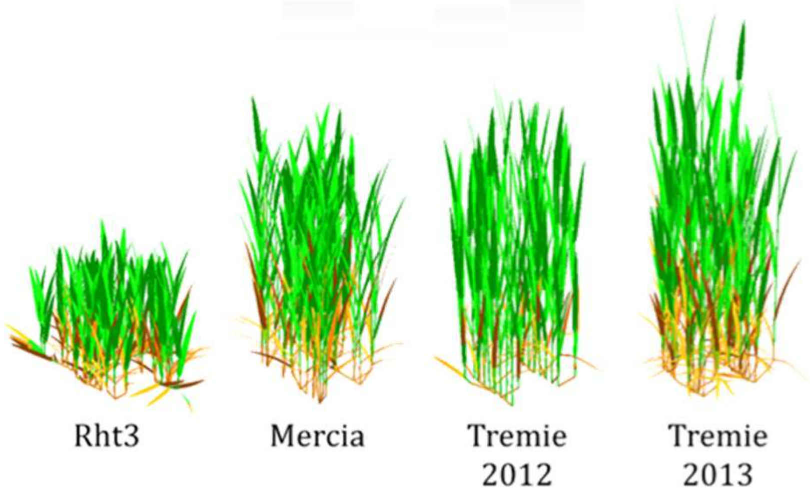
#DigitAg – Modelia Seminar on
Data assimilation

Montpellier, 21 June 2018

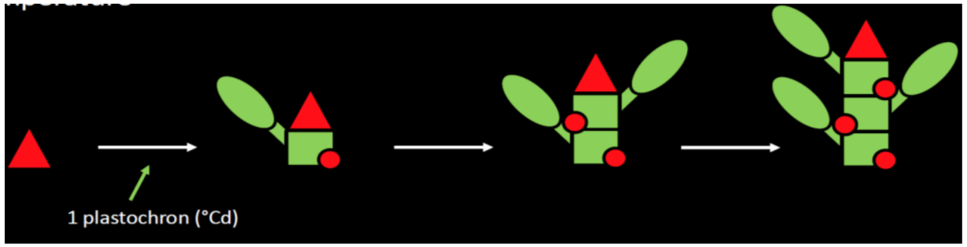
Outline

1. Dynamics models for phenotype modeling
   - Process-based models
   - Functional structural plant models
2. Role of crop modeling in genetics and breeding
3. Interpretation of high-throughput phenotyping data
4. Model assisted phenotyping
5. high-throughput phenotyping data assimilation(parameter estimation)
6. Conclusions

Functional Structural Plant Model (FSPM)



Robert et al., 2017
Garin et al., 2017



Fournier et al., 2003

- Individual based models (behavior of individual plants determine canopies properties)
- Plant architecture is represented in 3D
- Explicit feedback between plant growth and environmental drivers
- Only few functional processes considered

Process-Based Model (PBM)

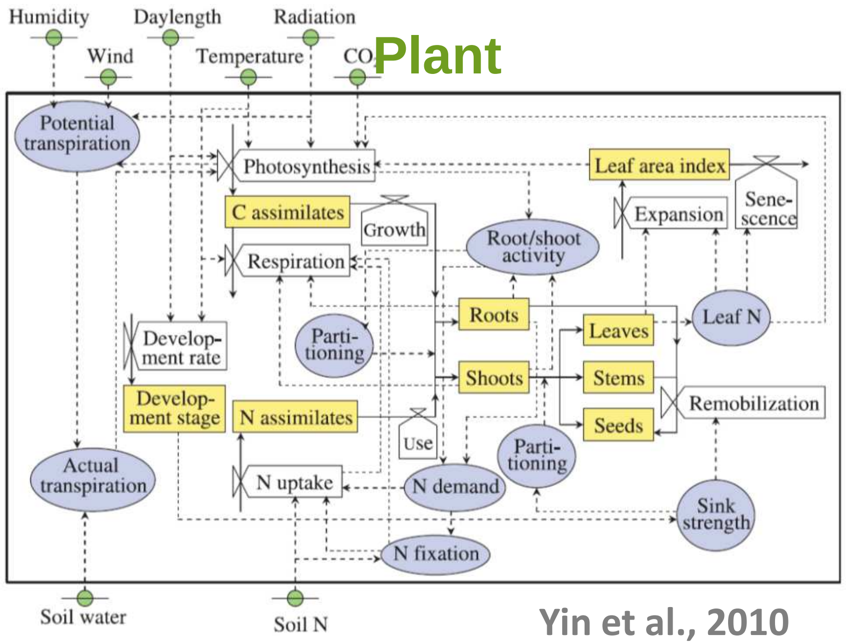
Inputs	Crop model	Simulations

Crop Management
- Sowing date
- N fertilization
- Irrigation
- ….

Soil
- Hydraulic characteristics
- % organic matter
- pH
- ….

Weather
- Temperature
- Radiation
- Precipitation
- ….

Cultivar
- Radiation use efficiency
- Phyollochon
- Potential grain size
- Fruiting efficiency
- ……



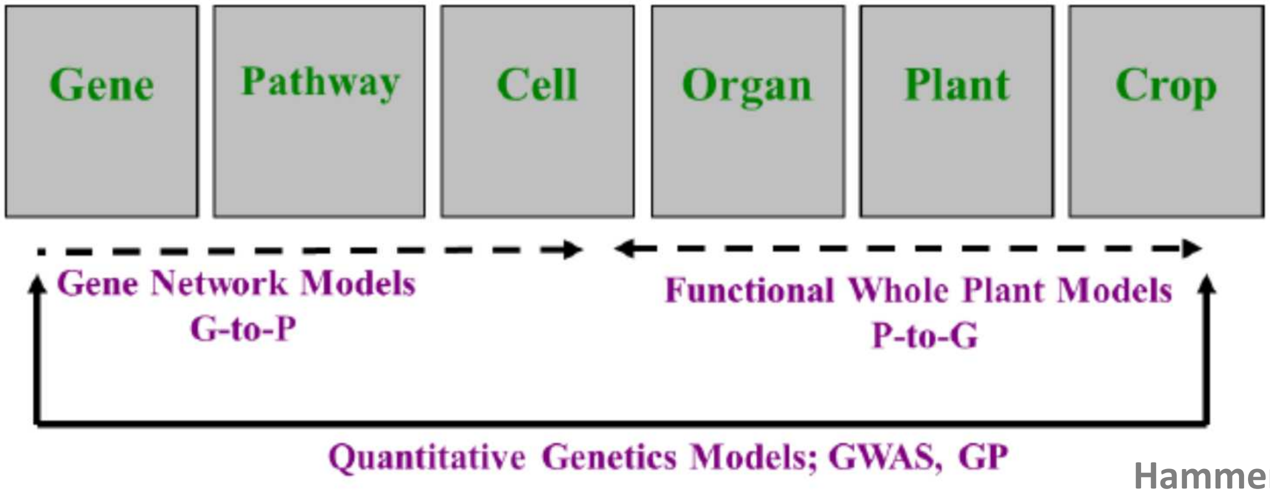
Yin et al., 2010

Simulations:
- Grain yield
- % Proteins
- GPD
- NUE
- WUE
- ….

- ❑ Focus on functional processes and feedbacks (explicit or implicit {emerging properties])
- ❑ Canopy architecture not explicitly considered (canopy = 1D turdbid medium)

Phenotyping distance and prediction

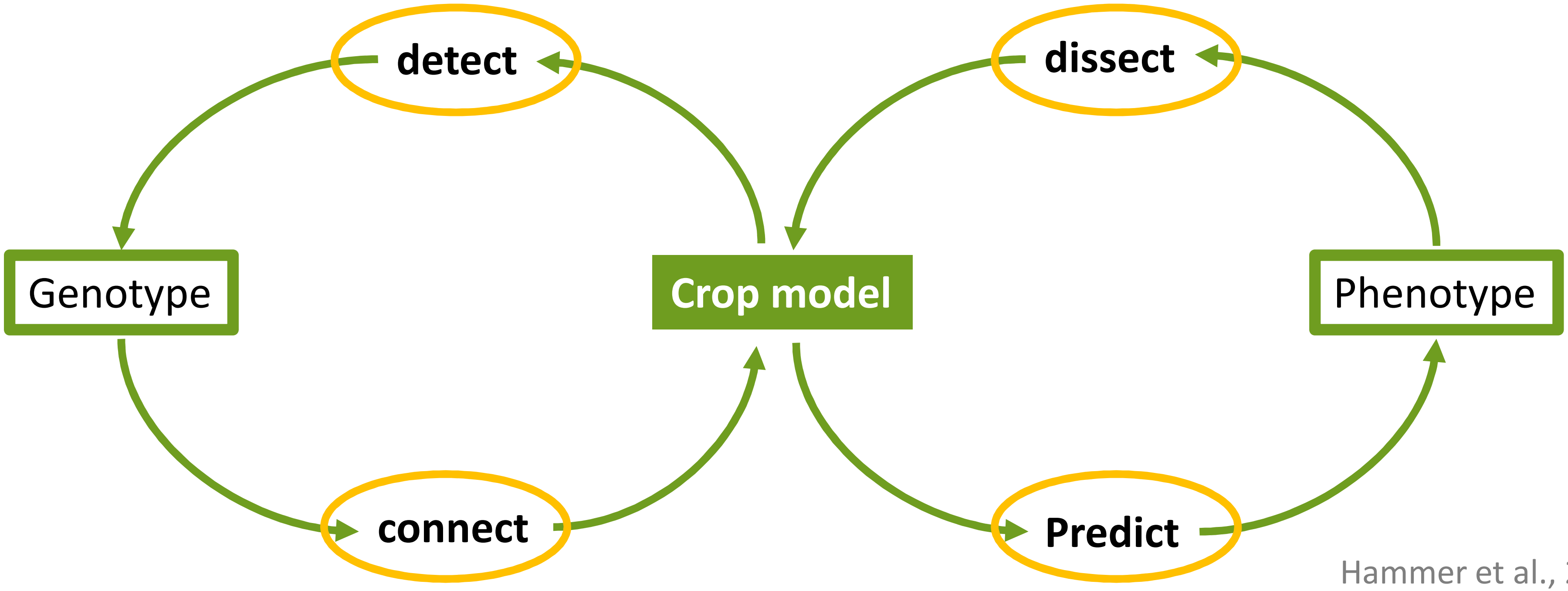
Crossing scales of biological organization confounds prediction



Hammer et al., 2016

- Crop model by integrating traits effect reduce the phenotypic distance
- Genetic analysis should be carried on simple traits and crop model allow scaling to the crop

Role of crop modeling in genetics and breeding



Hammer et al., 2016

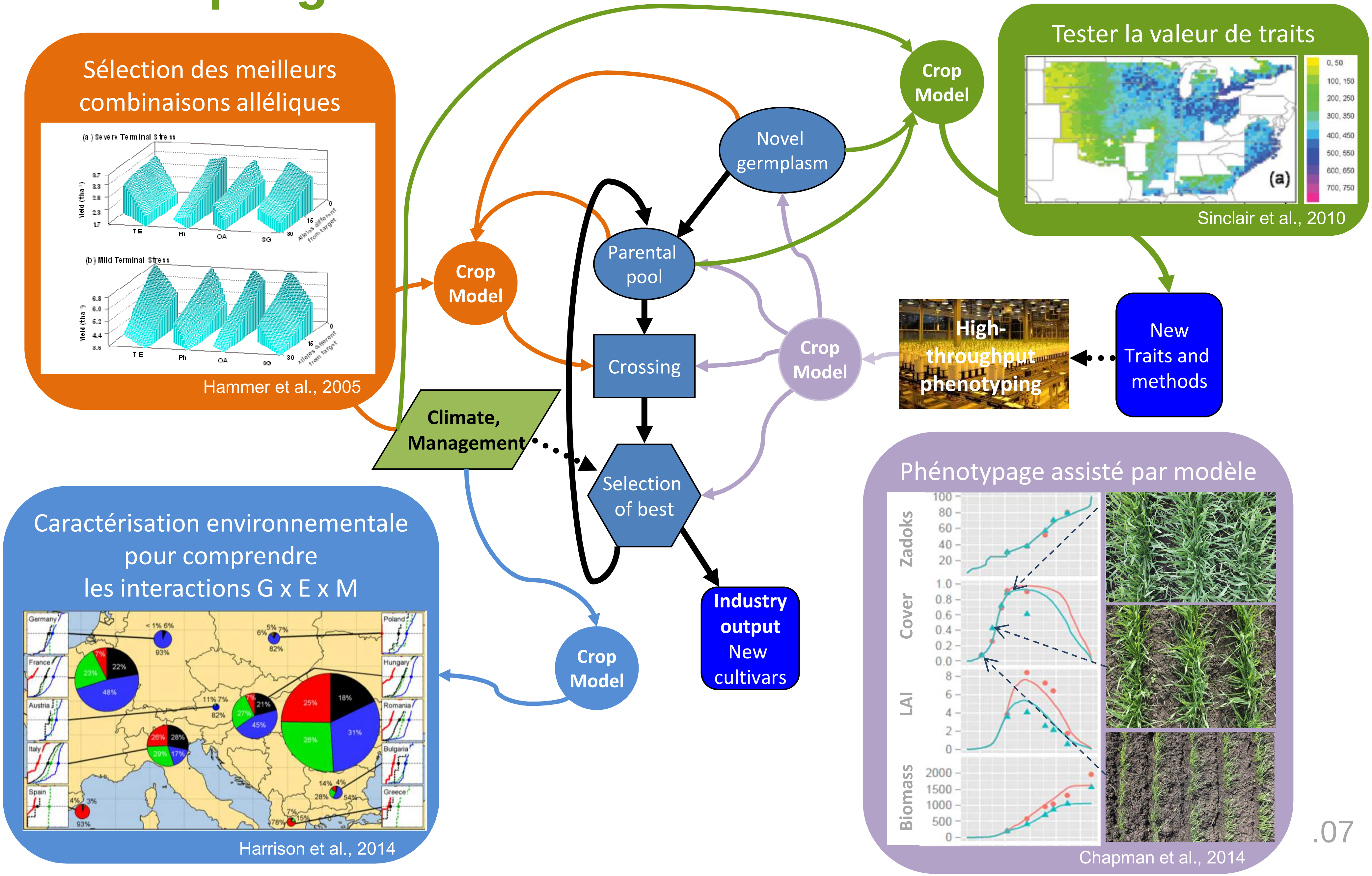
Predict – Trait evaluation in target environments to unravel G x E interactions

Dissect – Understand and simplify complex traits (use of NILs, mutants)

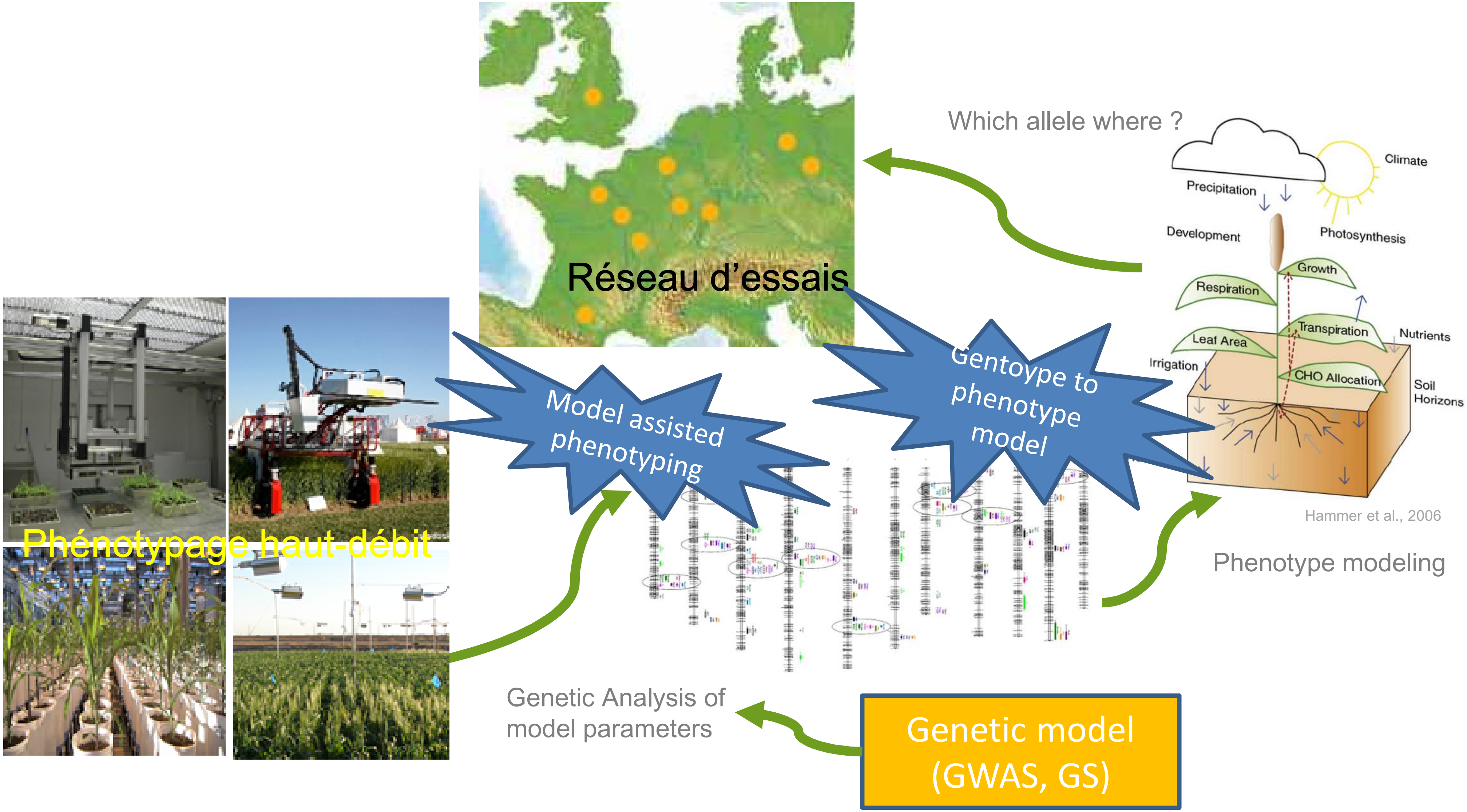
Detect – Inform phenotyping for QTL detection

Connect – Link QTL/genes to crop attributes/processes

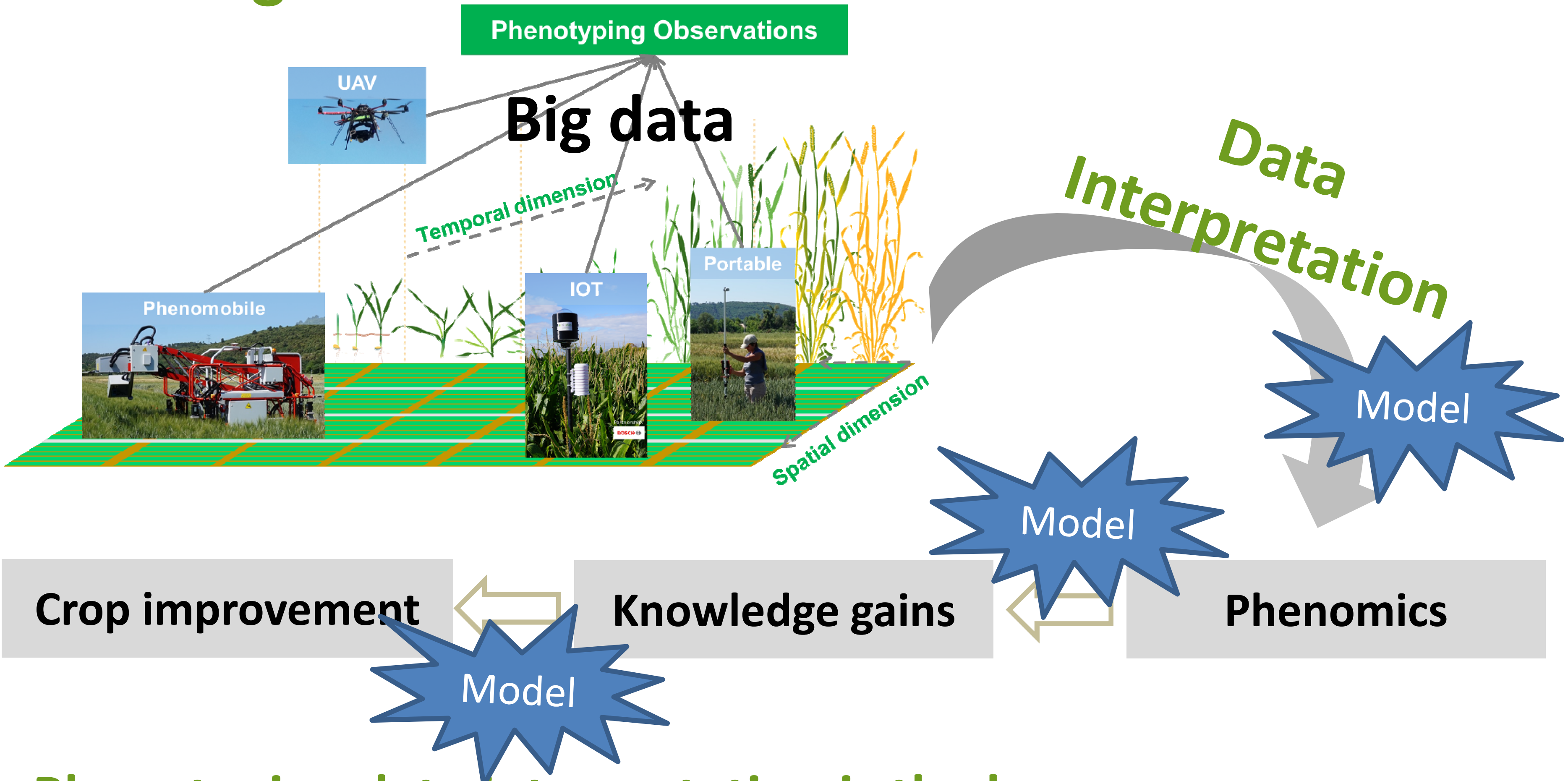
Integration of modeling in a breeding program



QTL/gene-based modeling



High-throughput Phenotyping starts from big data

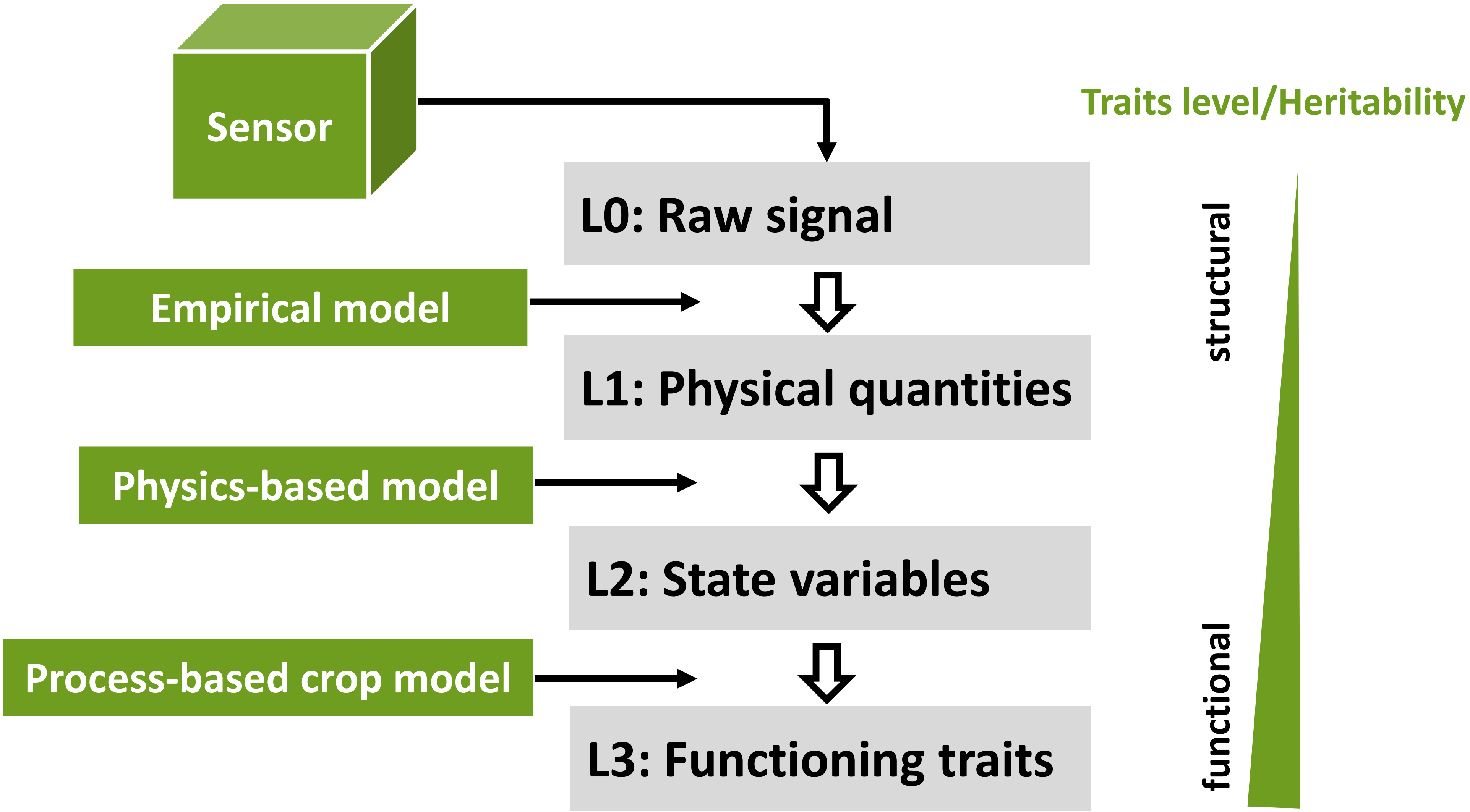


Phenotyping data interpretation is the key

- to transform big data to phenomics
- and finally contribute to the crop improvement

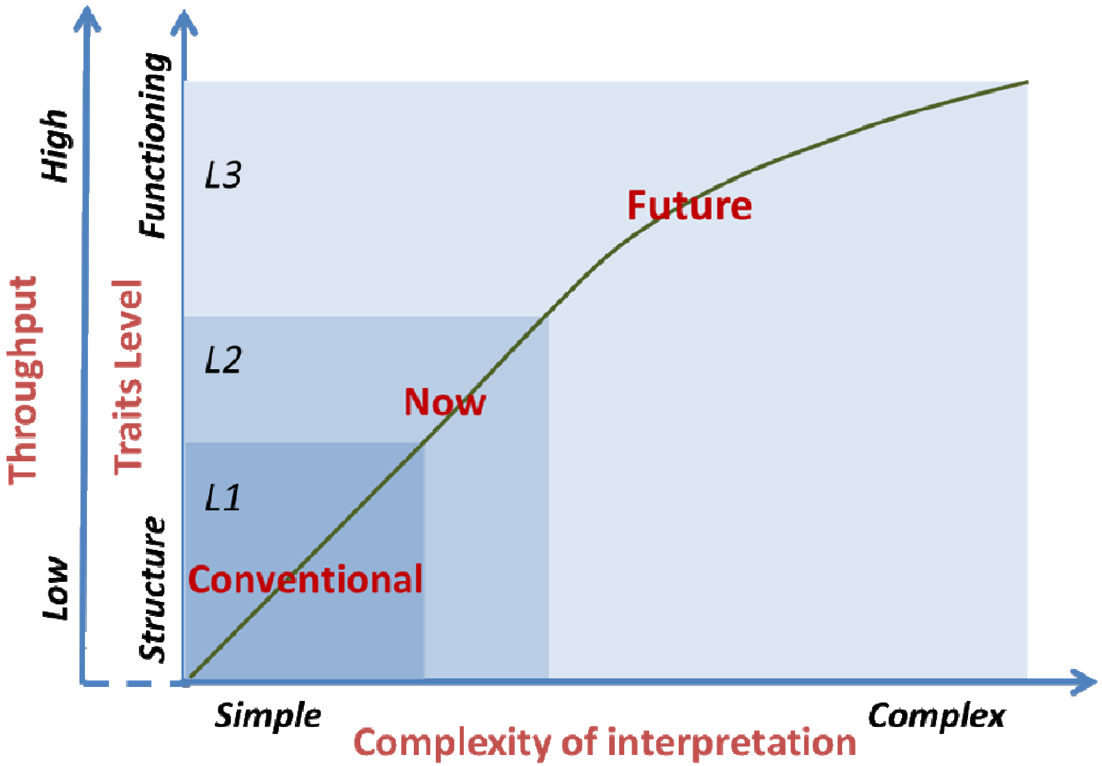
Slide from S. Liu

Levels of Phenotyping data interpretation



Slide from S. Liu

Phenotyping throughput is limited by interpretation



Phenotyping data interpretation:

Goal: maximize the traits' outcome with satisfactory accuracy

Strategy: Optimize the information use from measurements and prior knowledge

Slide from S. Liu

Levels in phenotyping data interpretation

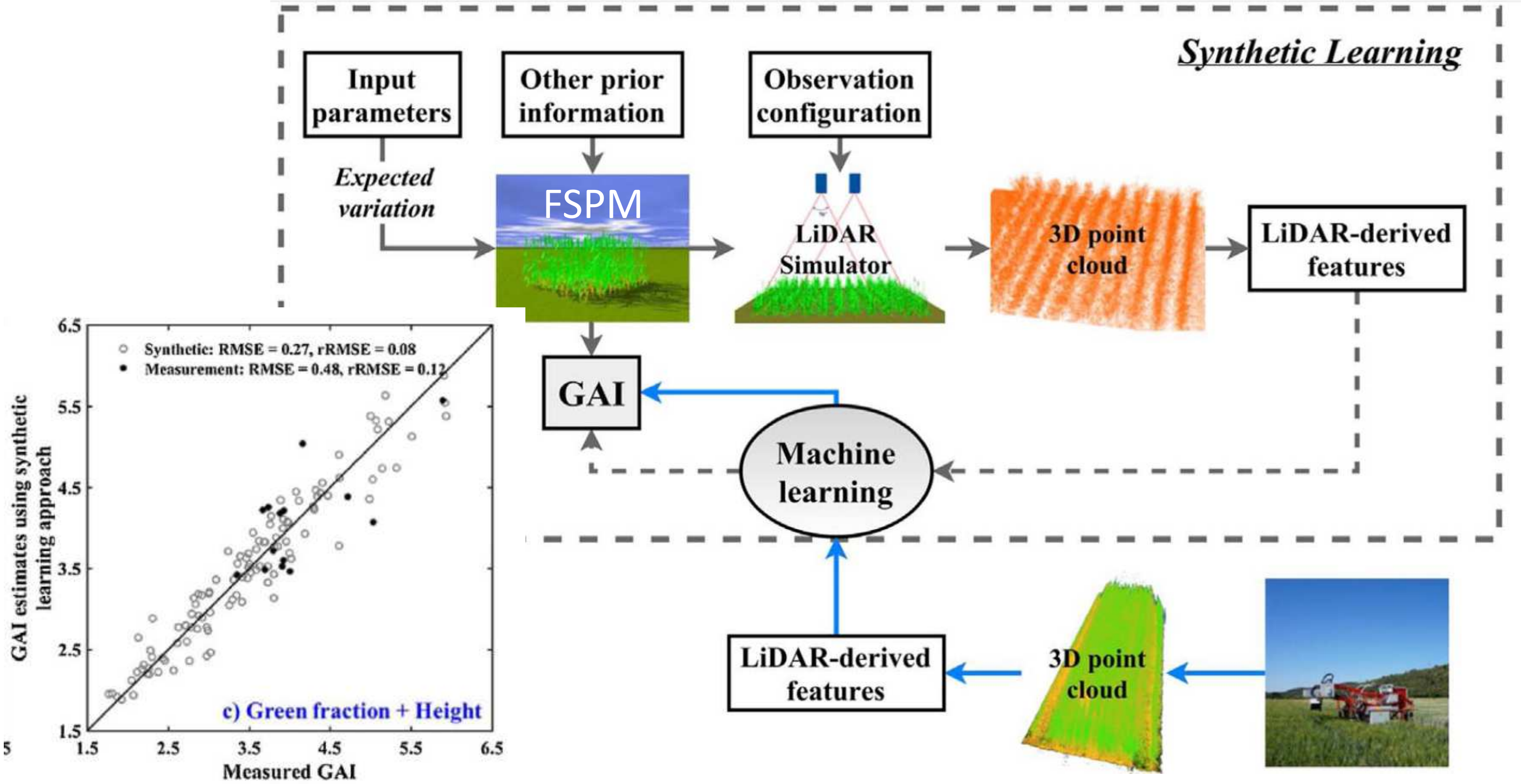
Level	Sensor	Traits	Method
L1	RGB	Plant distribution	Statistic model
		Plant density	Machine learning
		Ear density	Deep learning (Simon Madec)
L2	LiDAR	GAI	**Digital Plant Phenotyping Platform (D3P)**
	Multispectral	Chllorohoyl content	
L3	RGB	3D canopy structure	
		Light interception	

Slide from S. Liu

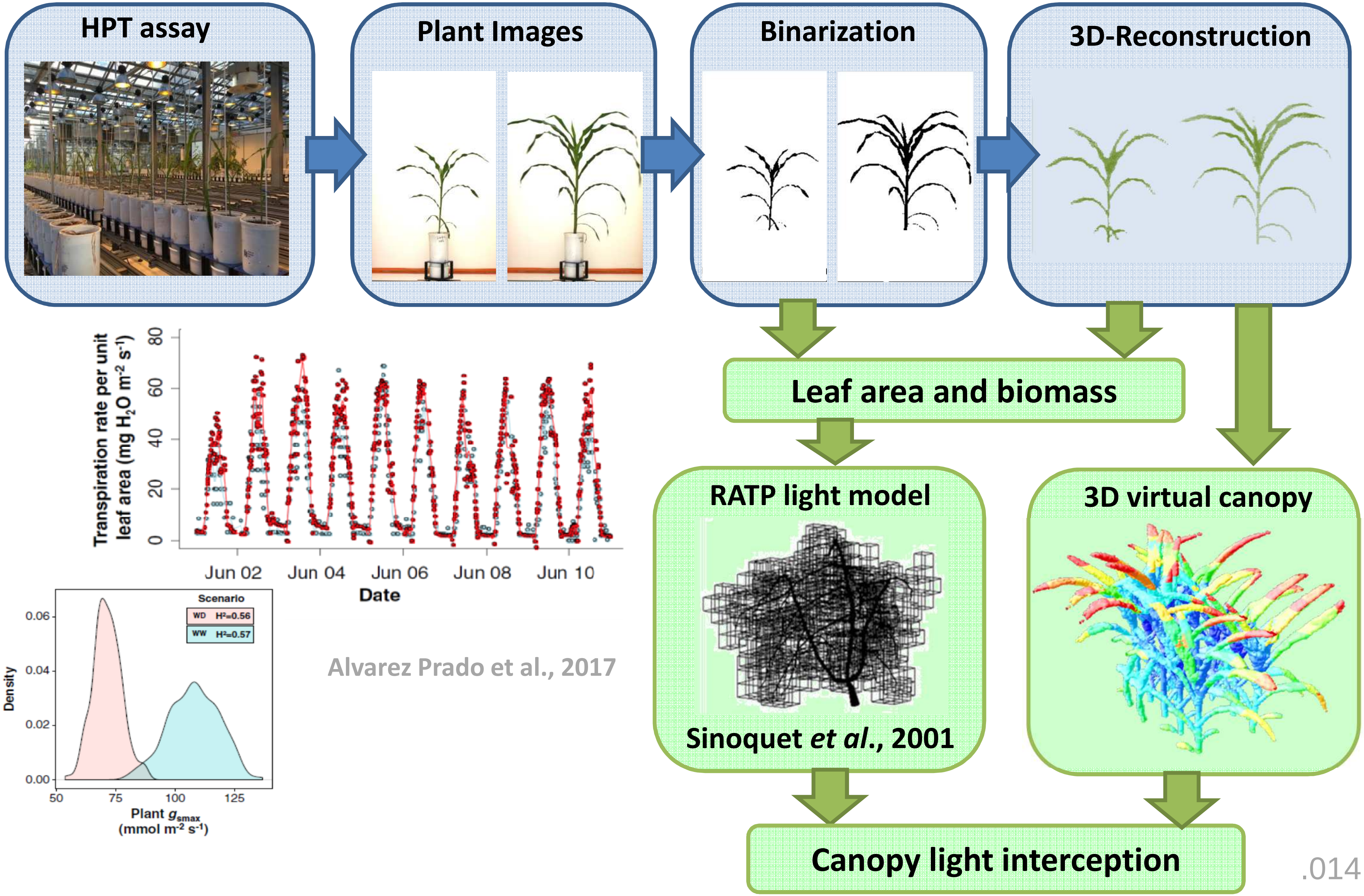
Model assisted field phenotyping

Estimating wheat green area index from ground-based LiDAR measurement using a 3D canopy structure model

Shouyang Liu[a,*], Fred Baret[a], Mariem Abichou[b], Fred Boudon[c], Samuel Thomas[d], Kaiguang Zhao[e], Christian Fournier[f], Bruno Andrieu[b], Kamran Irfan[a], Matthieu Hemmerlé[g], Benoit de Solan[d]



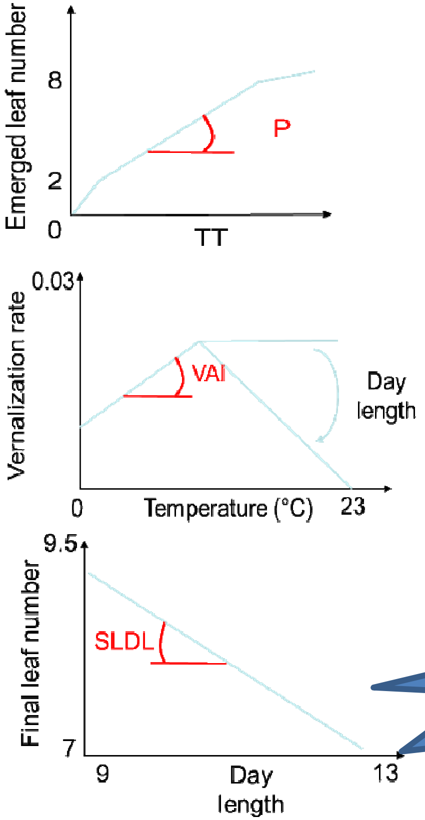
Model assisted platform phenotyping



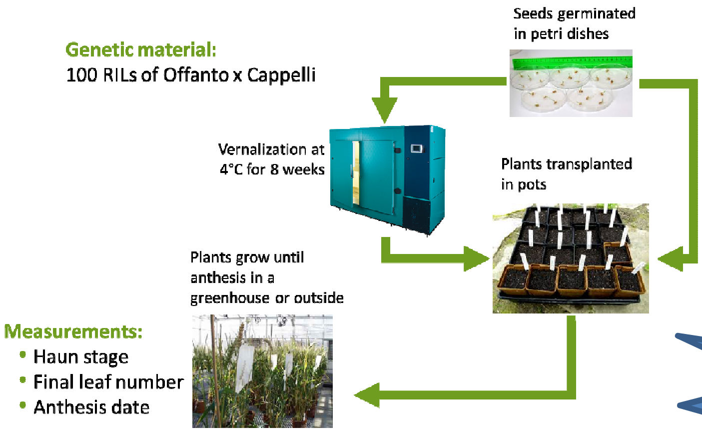
High-throughput data assimilation

Prediction of wheat flowering time

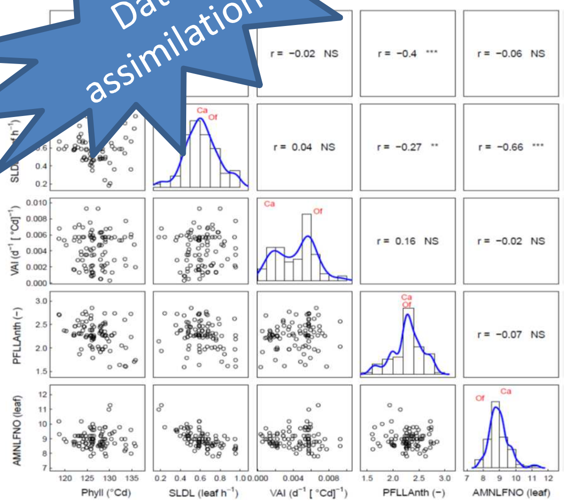
Trait distinction



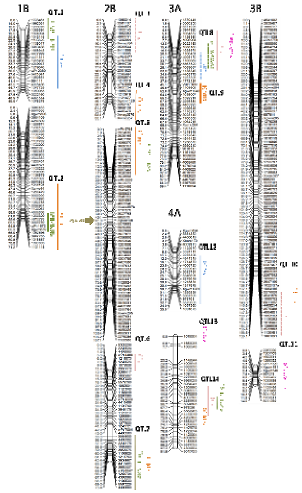
Phenotyping



Data assimilation

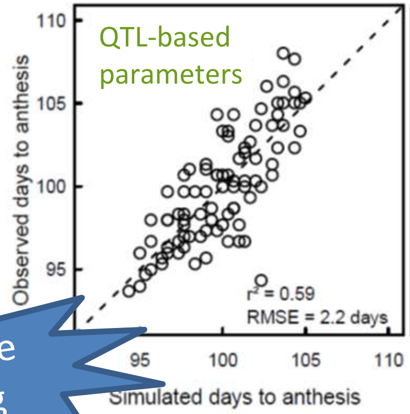


Genetic analysis



$$y_j = \mu + \sum_{i=1}^{n} a_i QTL_{ij}$$

Phenotype prediction (in new environments)

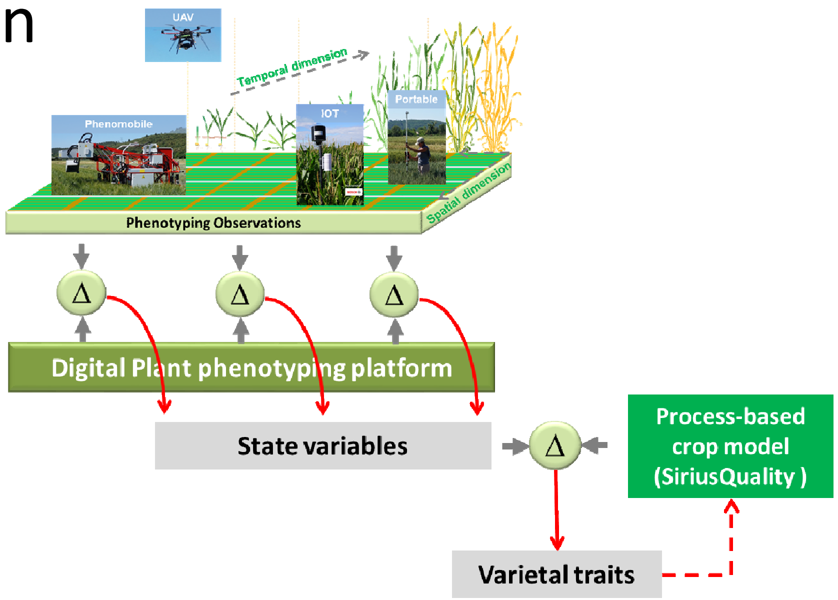


Phenotype modelng

Martre et al., 2018

Conclusions et perspectives

- Phenotyping-oriented crop model are required (biological/physical coherance).
- Phenomics is renewing model development, improvement, and testing.
- To retrieve functional traits Integration of D3P with process-based model is required.
- To develop real time data assimilation for precision agriculture emulators (meta-models) will probably be required (computation time.



Liu, 2016

Thank you for your time

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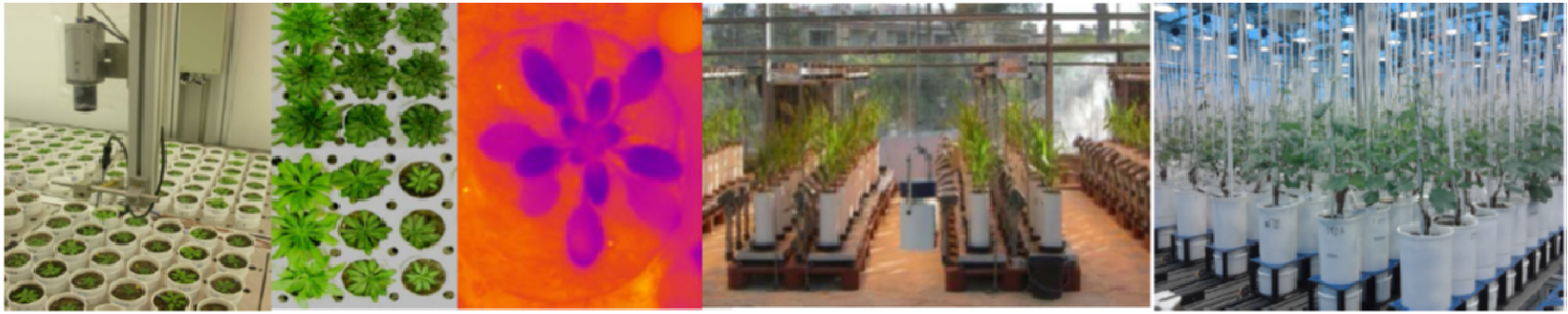

M3P
Montpellier Plant Phenotyping Platforms

lepse Montpellier
Laboratoire d'Ecophysiologie des Plantes sous Stress Environnementaux

www6.montpellier.inra.fr/lepse
www1.clermont.inra.fr/siriusquality