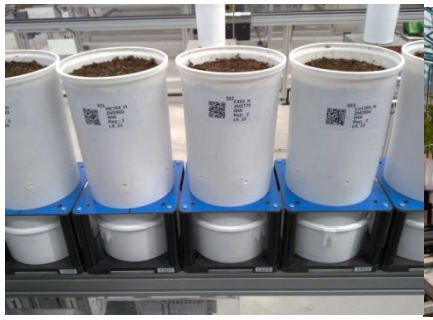
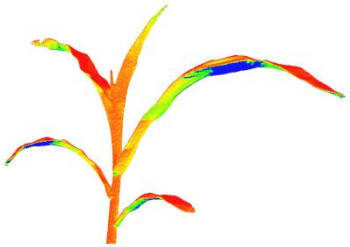
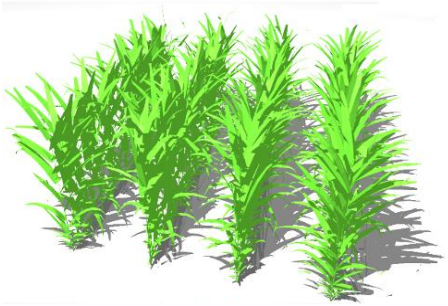
Workflows d'analyse d'image Pour le phenotypage





Christian Fournier

cirad

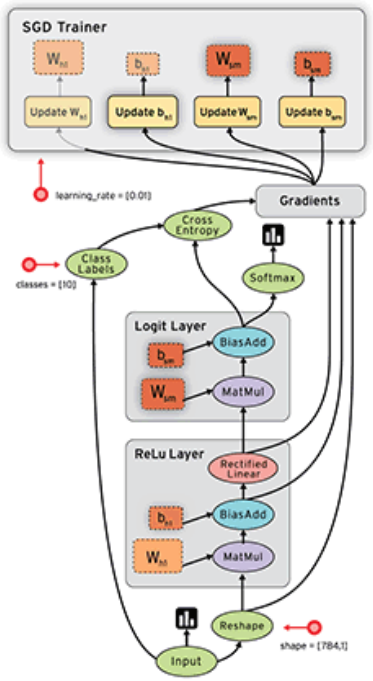
informatics mathematics Inria

Laboratoire d'Ecophysiologie des Plantes Sous Stress Environnementaux lepse Montpellier

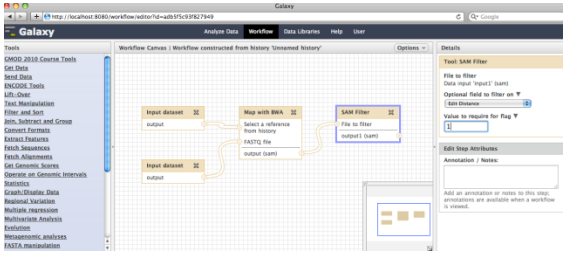
INRA SCIENCE & IMPACT

OpenAlea

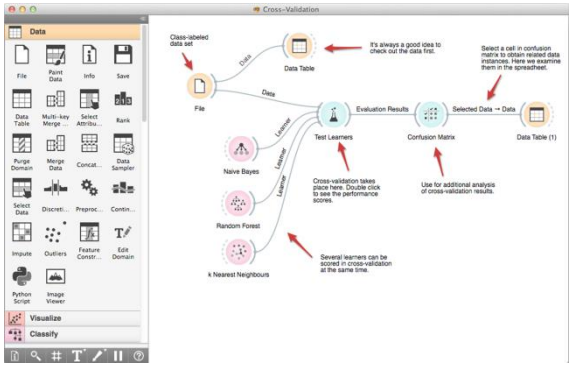
Workflow Systems



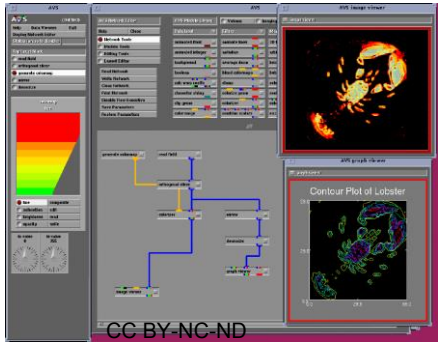
Tensorflow (Google), Abadie 2016



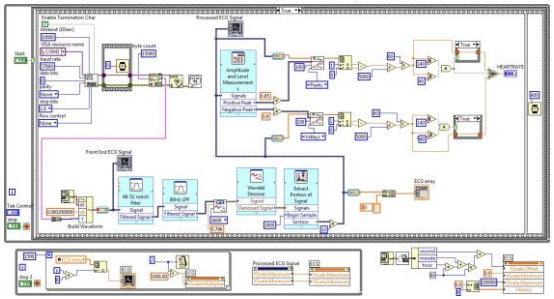
Galaxy, Goecks, 2010



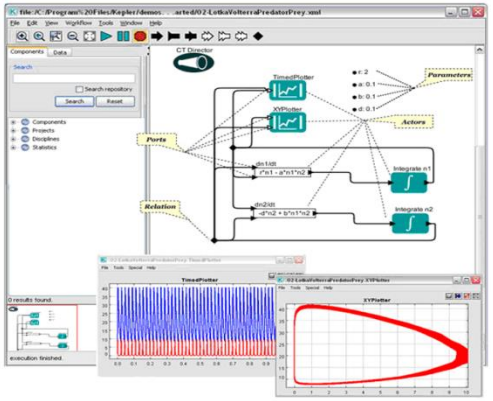
Orange, Demšar, 2004



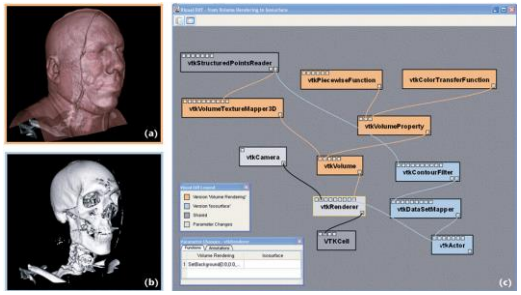
AVS, IEEE CG&A, Upson 1989



LabView, Whitley, 2001



Kepler, Ludäscher, 03



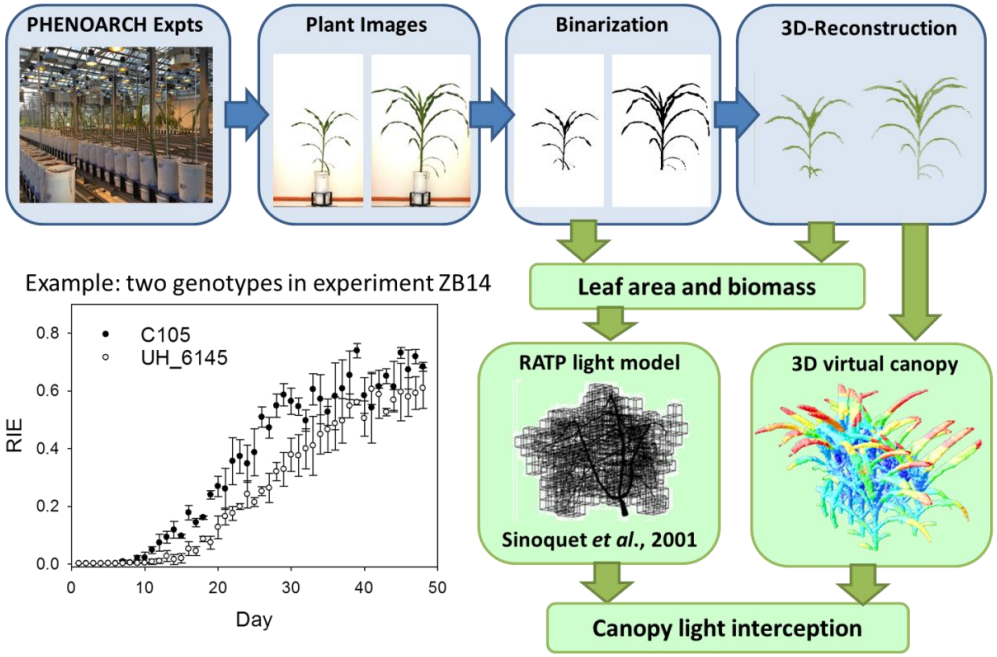
VisTrails, Callahan, 2006

Snakemake, Köster, 2012

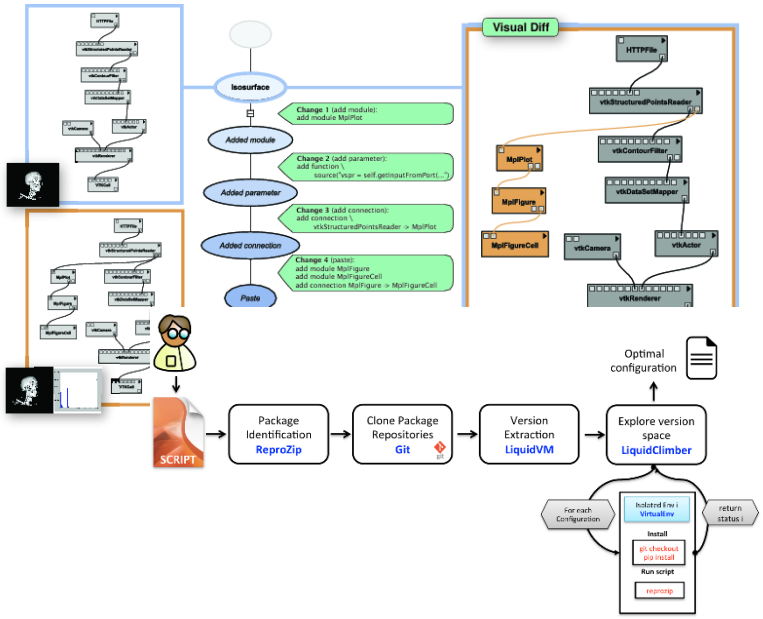
Services of Scientific Workflow Systems

Findable Accessible Interoperable Reusable

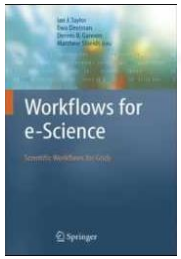
Modular, Evolutive and traceable specification of data processing pipelines



Capture of provenance (processing history, data lineage)

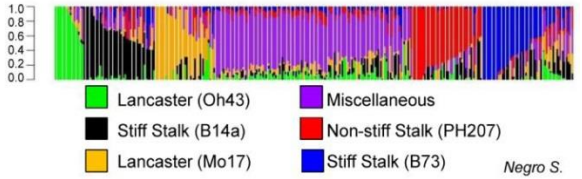


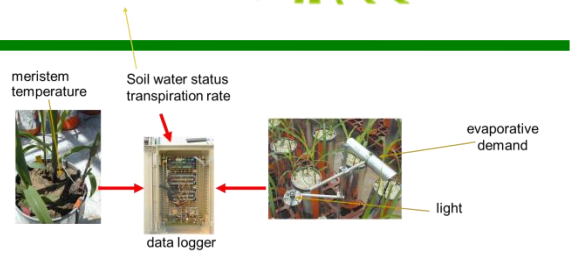
Distributed computing

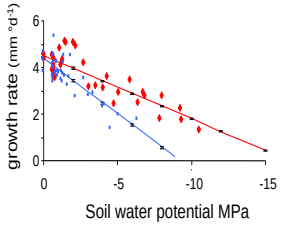


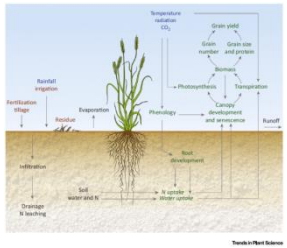
Sasha, Pradal, Cohen-Boulakia, Valduriez

Phenomics@LEPSE





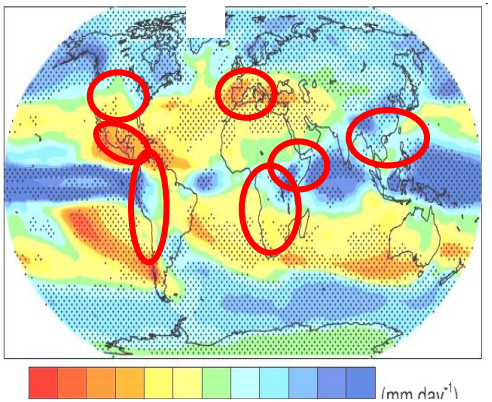




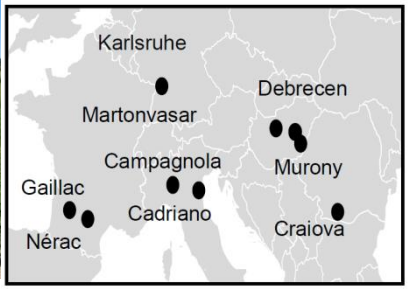
Screening of phenotypic variability in controlled/ greenhouse conditions

Ecophysiology & modelling of response traits integration in crop models

Model assisted phenotyping

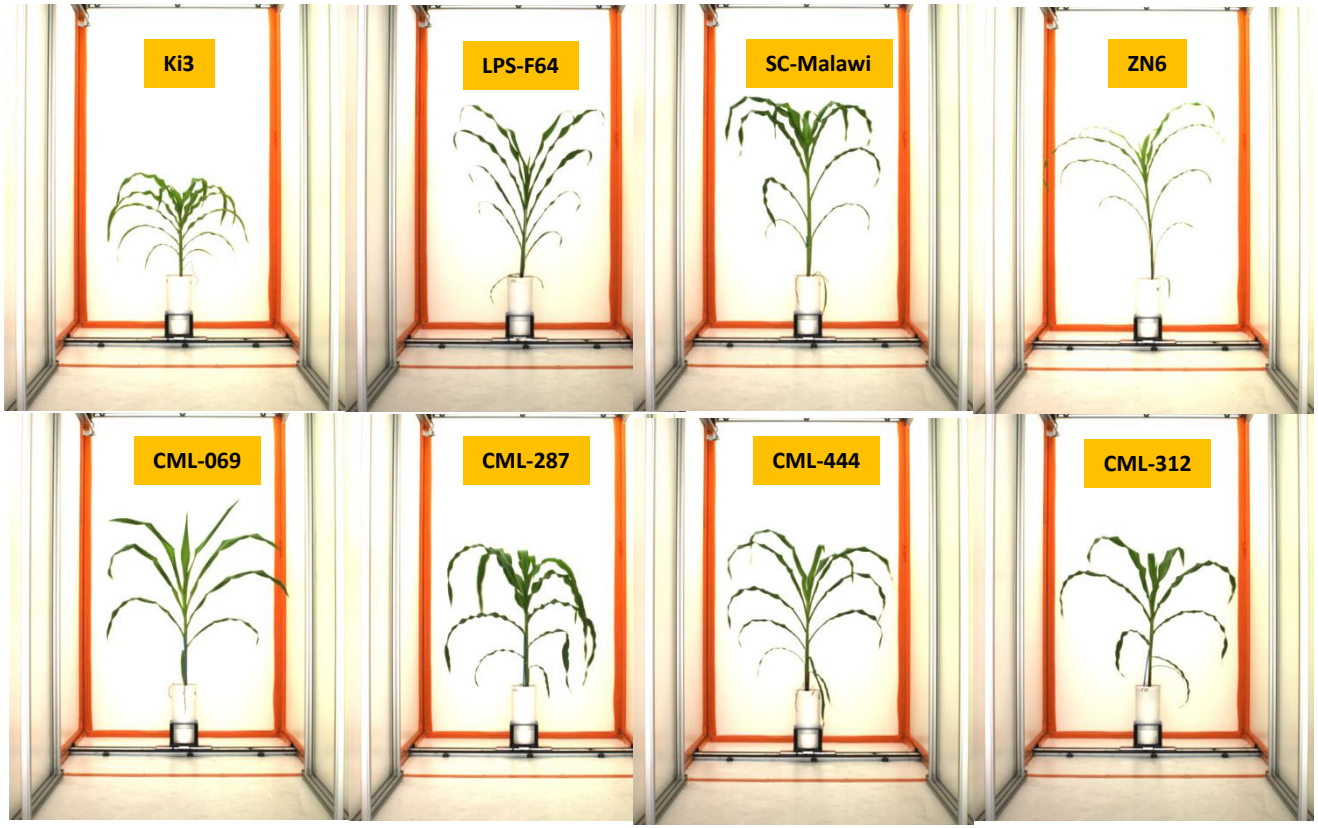


Genomic prediction of adapted genotypes for Current and future environments



Check / calibrate field prediction in multi-site genetic trial

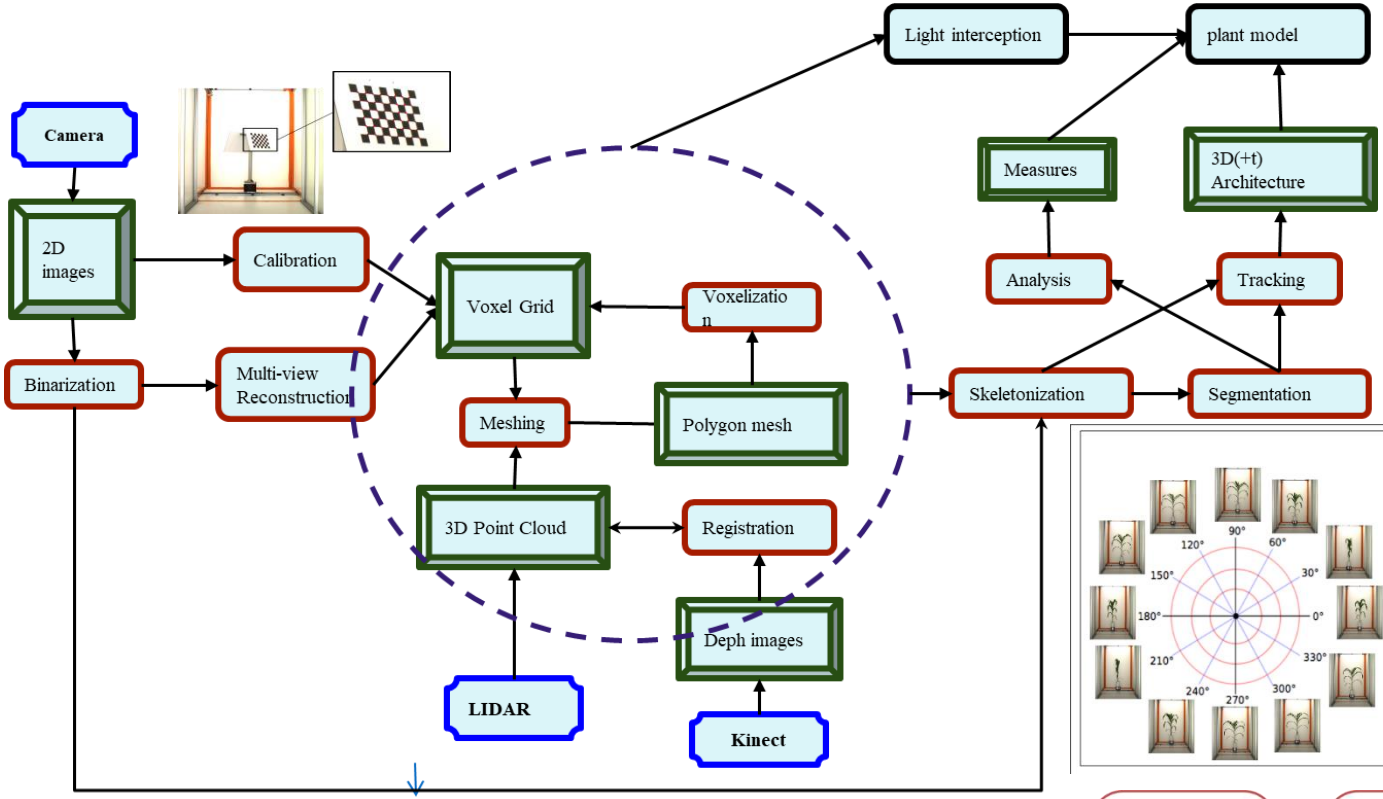
What part of the ‘phenoarch’ phenotypes can be use to predict behavior in the field ?

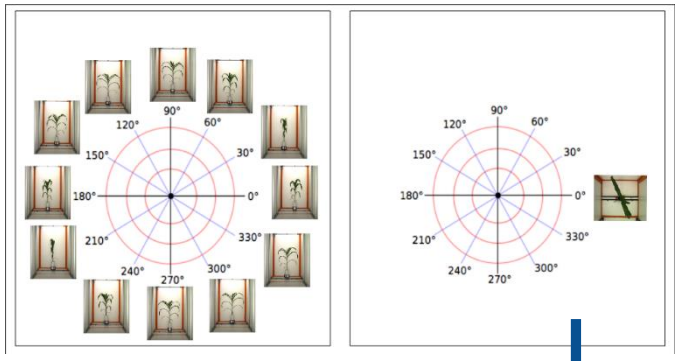


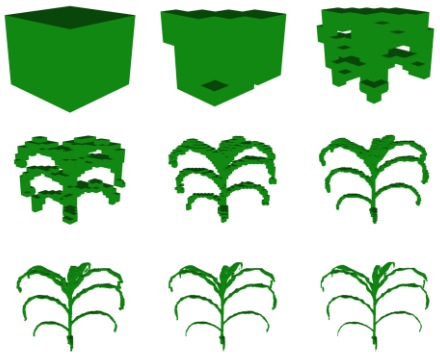
+ weighting
+ manual leaf counts

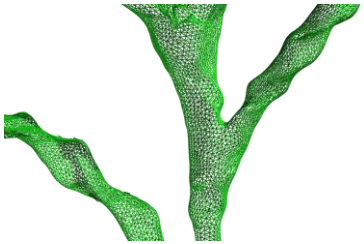
=> Dissection in traits

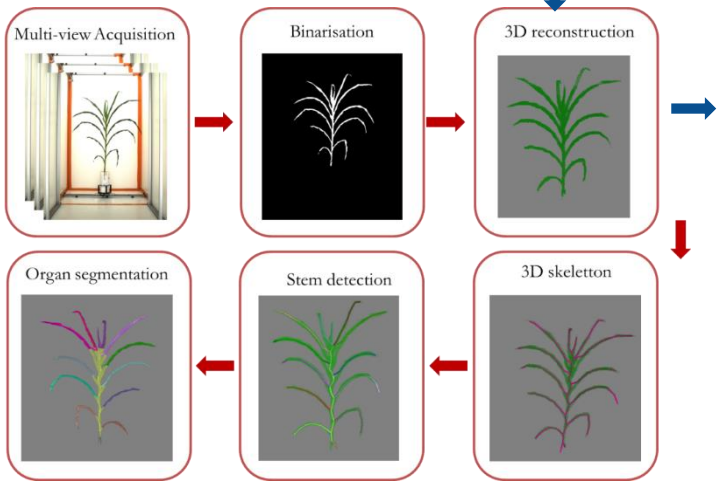
Image Workflows @ phenoarch







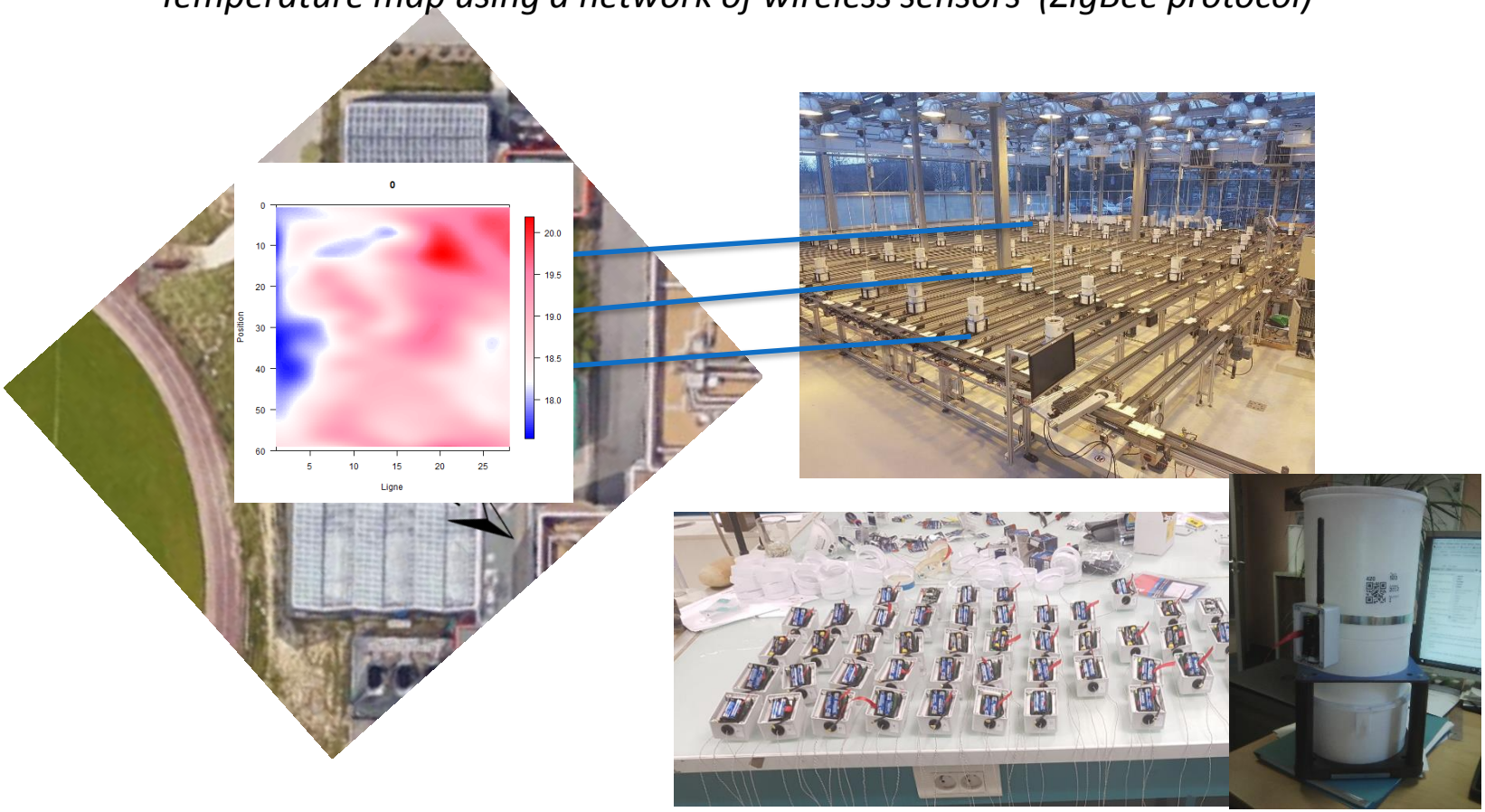


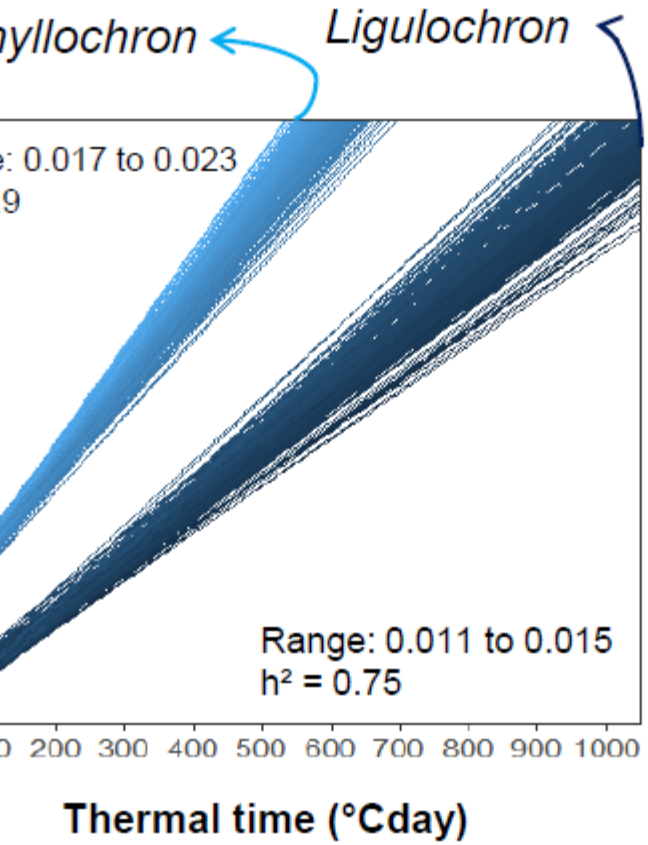


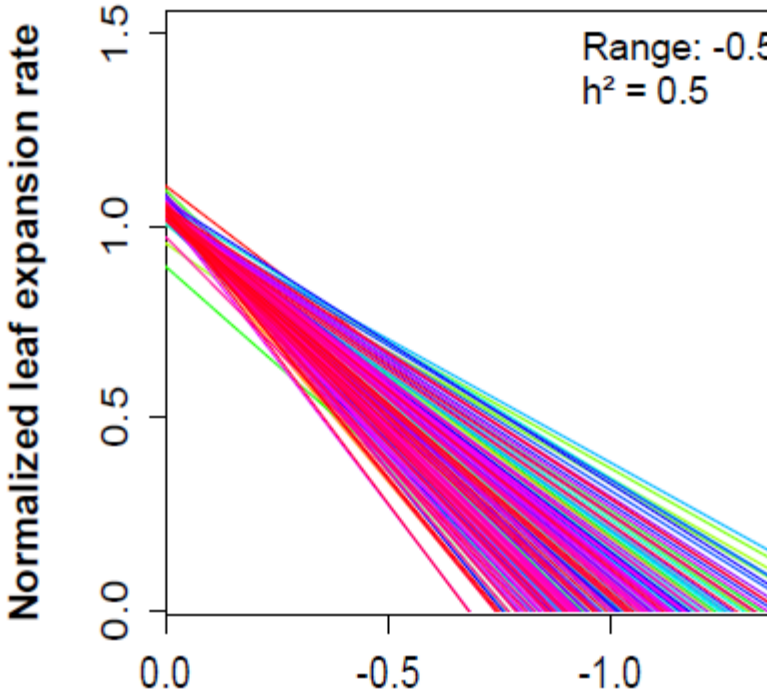
Artzet et al. 2019

Temperature maps: network of sensors

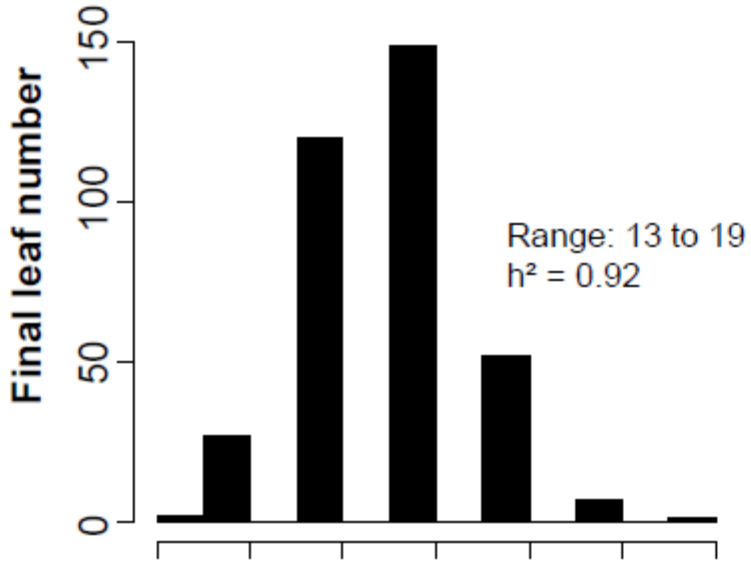
Temperature map using a network of wireless sensors (ZigBee protocol)





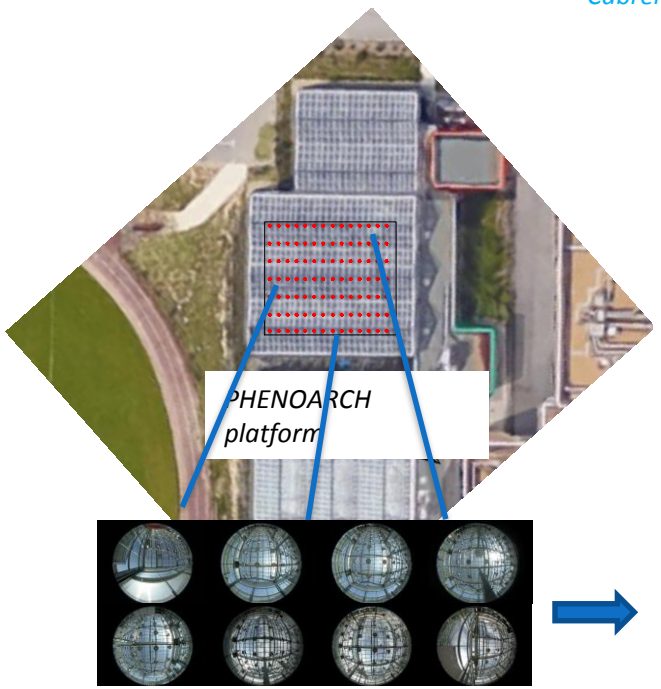


its/model parameters
owed high heritability

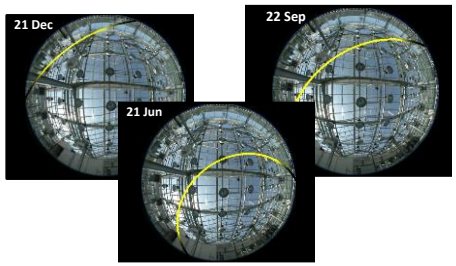


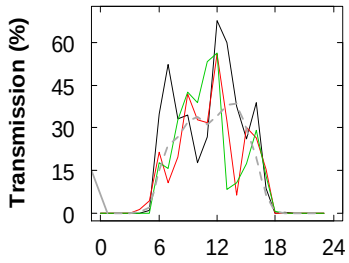
A method for estimating local light availability in the greenhouse (IPPS 2016, Mexico)

Cabrera-Bosquet et al. 2016 New Phyt



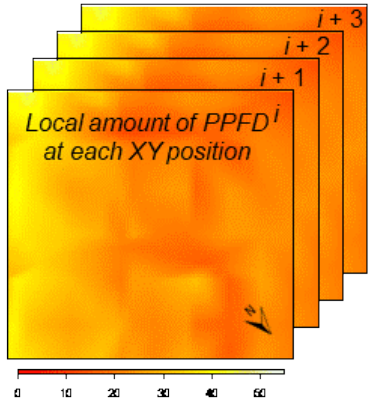
Sun paths





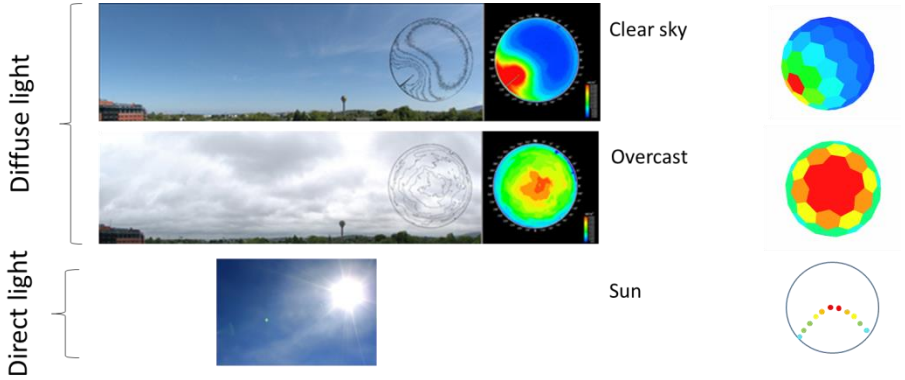
Every hour every day of year

Daily local light maps



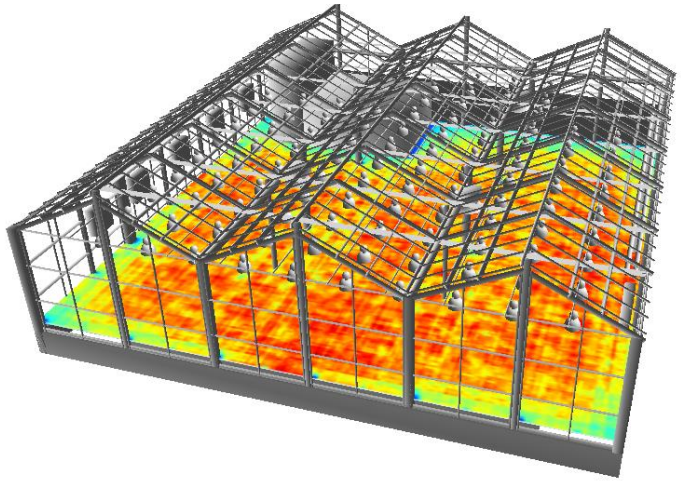
Incident light map within greenhouse using FSPM tools

Sky luminance model



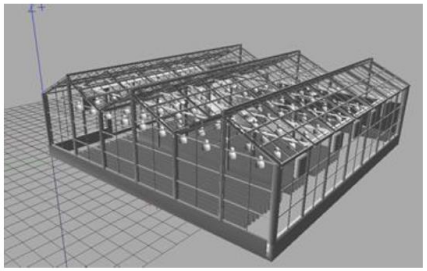
https://github.com/openalea-incubator/astk

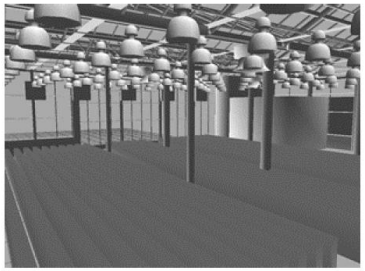
Raytracing



https://github.com/openalea-incubator/caribu

GreenHouse reconstruction





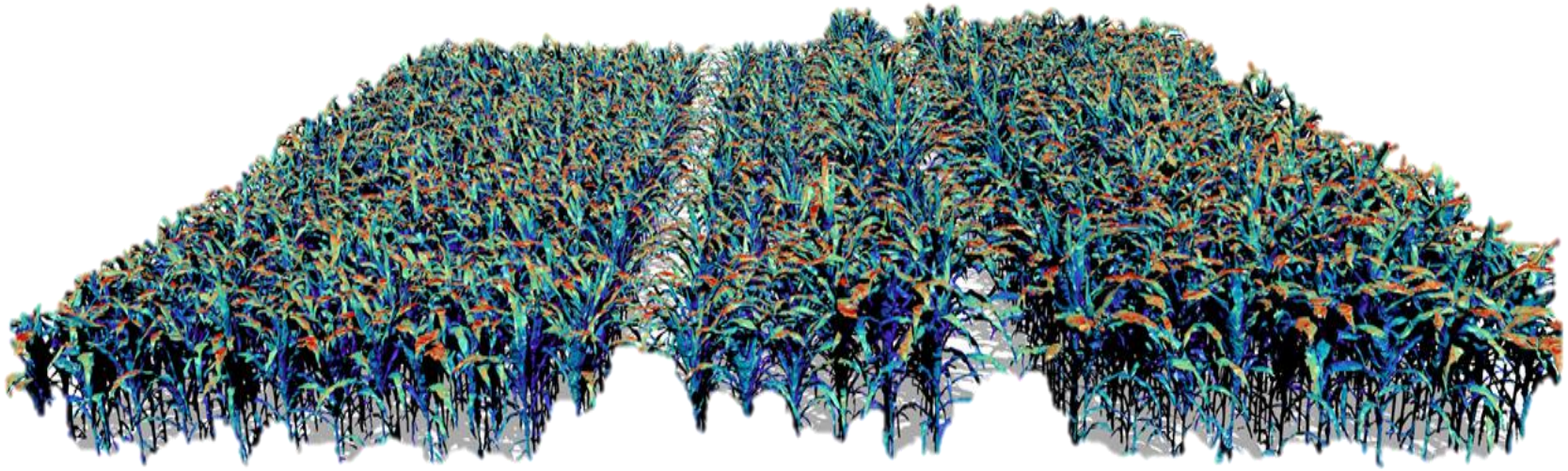
https://github.com/openalea/plantgl

OpenAlea

Rouet, Fournier (ongoing)

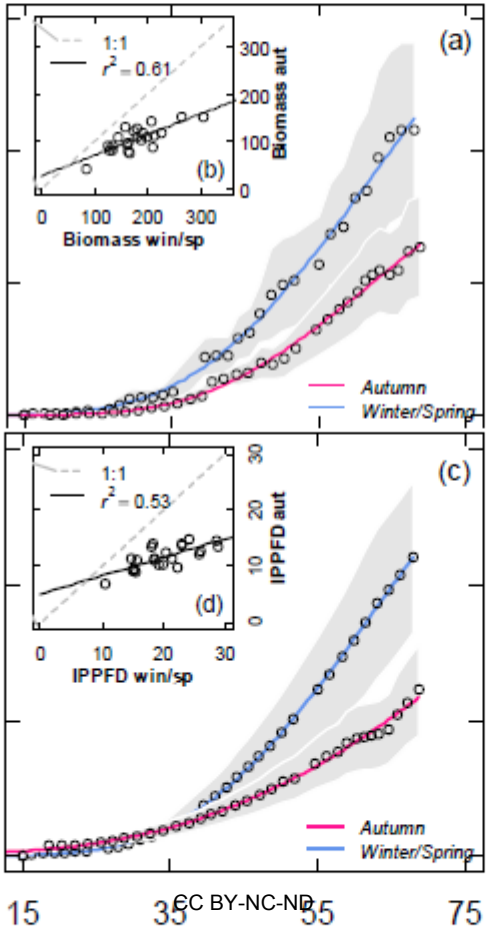
Virtual canopy illumination

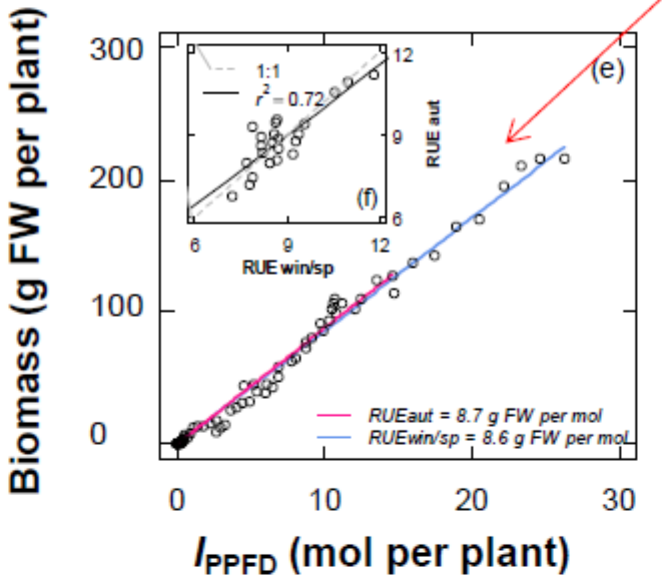
Artzet et al. 2019

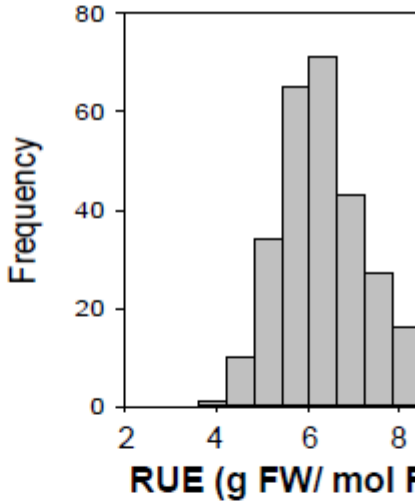


OpenAlea

$$Biomass = \int Incident\ light \times Intercepted\ light \times RUE$$





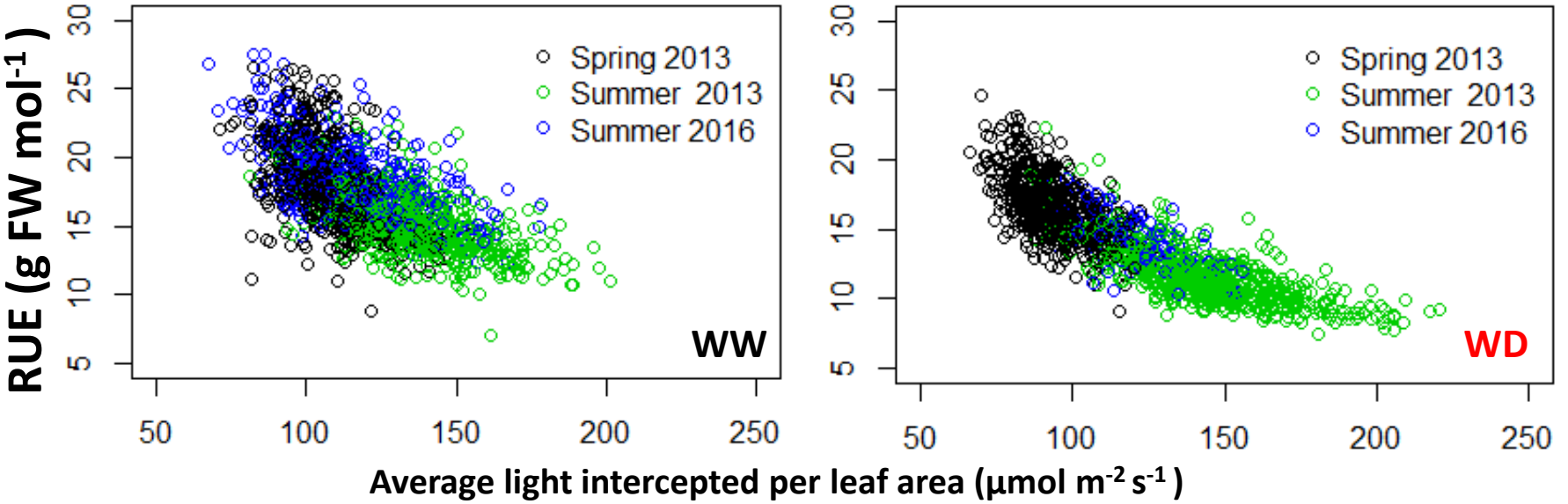


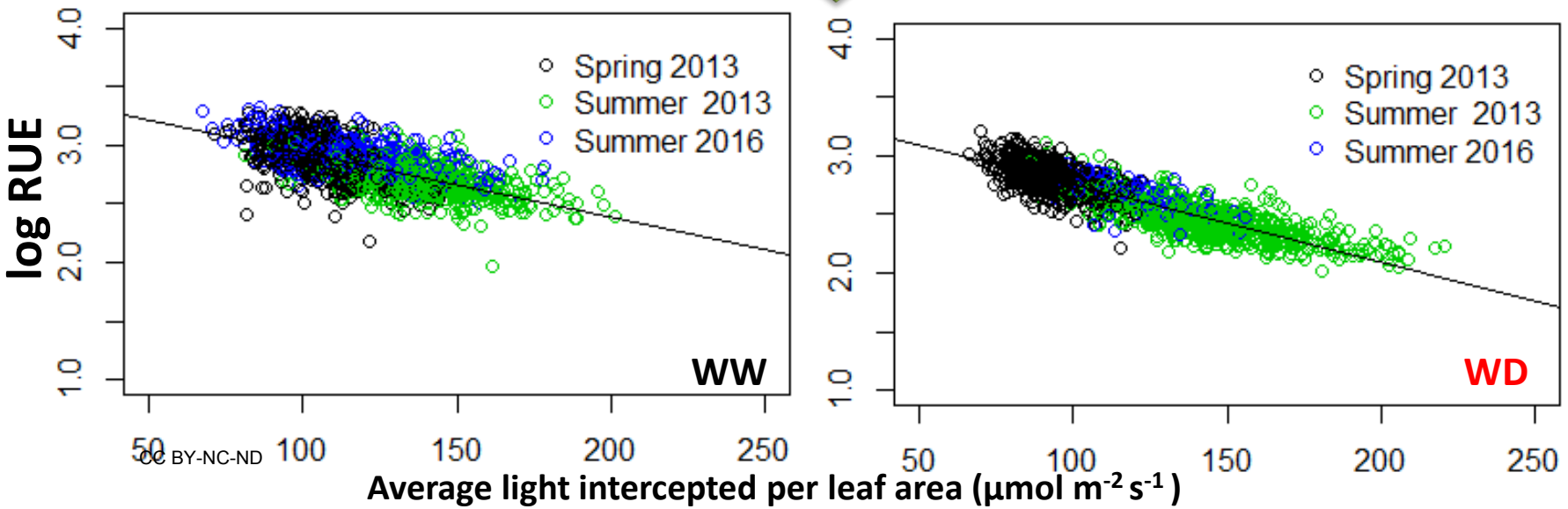
Cabrera-Bosquet et al., 2016_*New Phytologist*

Tsu-Wei Chen (LEPSE,

15 35 55 75

Dependency of RUE on light



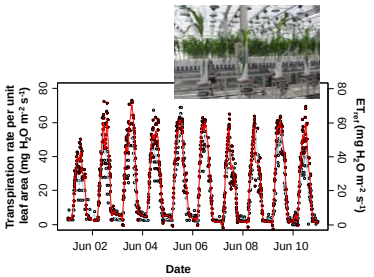


Combining experiments and environments (and scales)

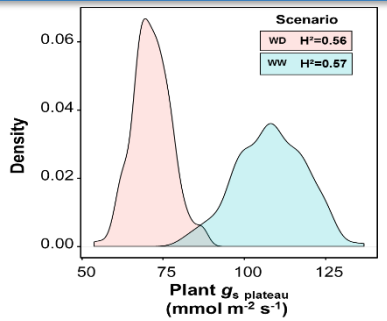
A method for high throughput estimation of maize **stomatal conductance**, based on transpiration, leaf area and micro-meteorological conditions (Alvarez Prado *et al*. *PCE* 2018)

Stomatal conductance from water flux in 250 genotypes
(**Inversion of Penman-Monteith's equation**):

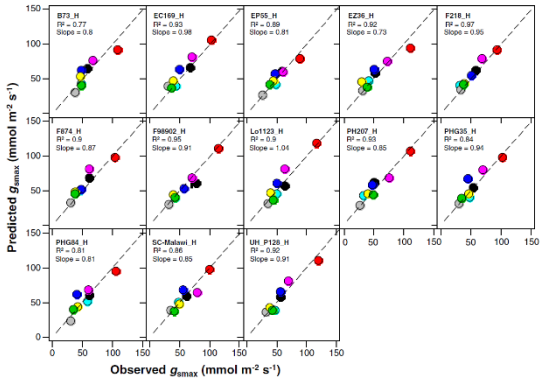
$$g_s = g_a \, Tr \, l \, g \, / ((s \, Rn + r \, Cp \, VPD \, g_a - Tr \, l \, (s + g)))$$



Genotypic variability and heritability of stomatal conductance

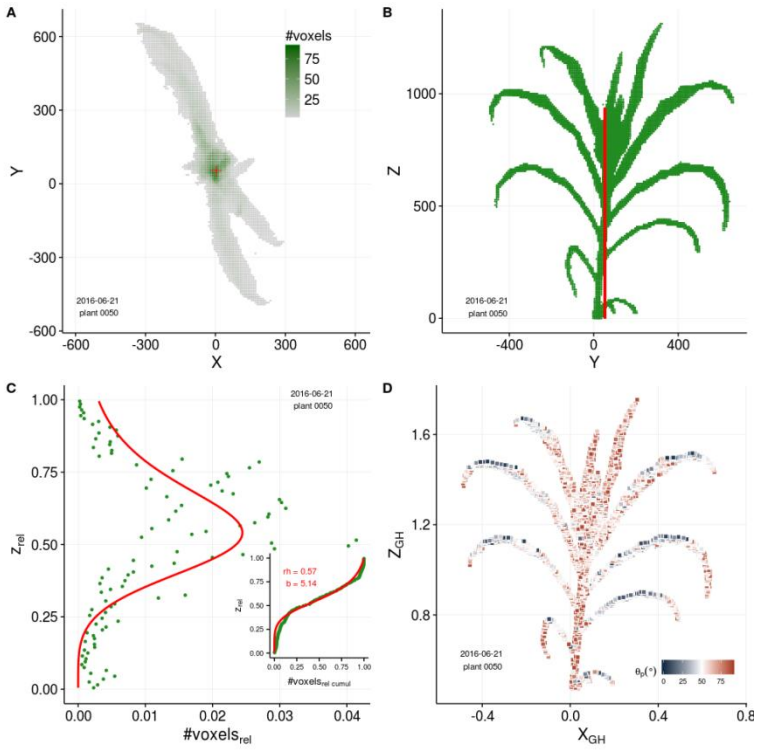


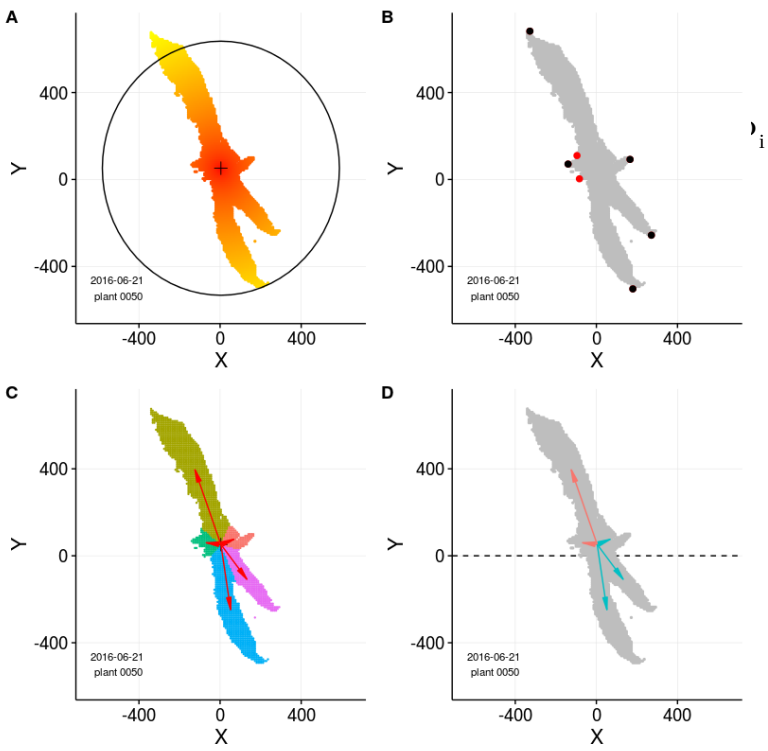
Genetic dissection of g_s
and **prediction** by considering detected QTL and local micrio-environmental conditions



S. Alvarez Prado

Disecting CI with architectural traits (R. Perez PCE 2019)





Symbols	Units	Traits	Type of area distribution
LA	m^2	Plant leaf area	-
h_{stem}	cm	Stem height	vertical
θ	degrees	Plant inclination index	vertical & horizontal
rh_{PAD}	-	Plant relative height where half plant leaf area is reached	vertical
b_{PAD}	-	Distribution of leaf area along plant height	vertical
radius	cm	Plant radius	horizontal & vertical
σ_{az}	degrees	azimuths dispersion	horizontal
Δ_{row}	degrees	azimuth deviation from row	horizontal

EP72

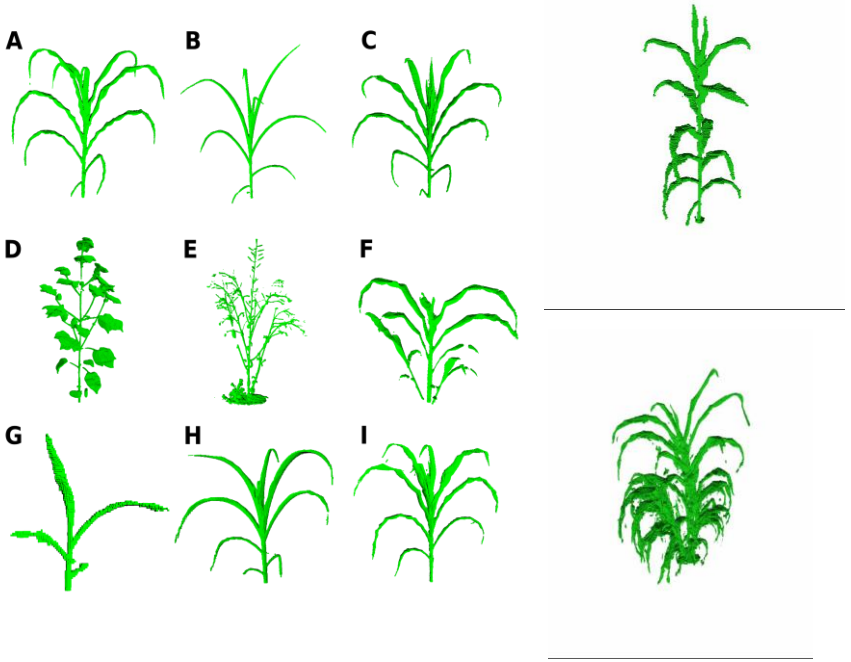
HMV5325

3D reconstruction pipelines

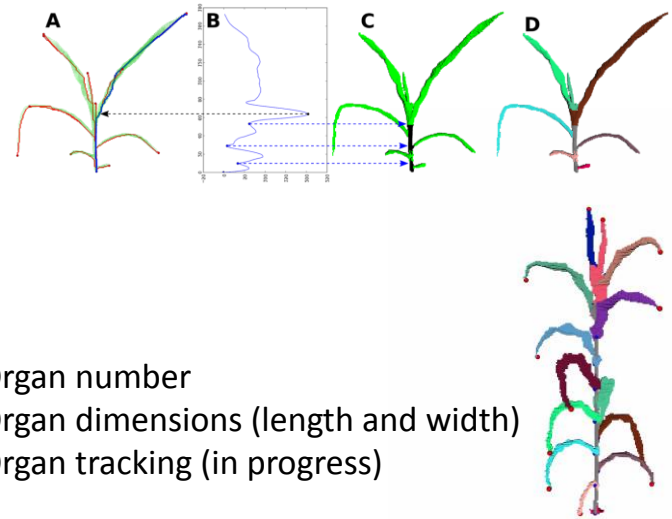
***Phenomenal**: An automatic open source library for 3D shoot architecture reconstruction and analysis for image-based plant phenotyping*

Artzet et al. 2019

3D geometric multi-view reconstruction => multi-species

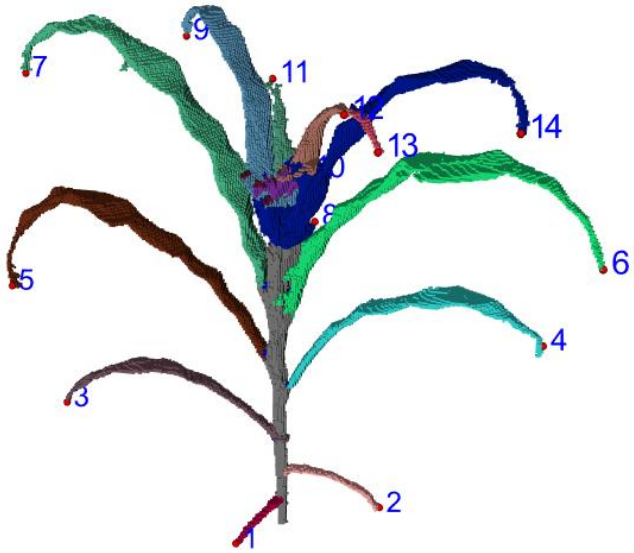


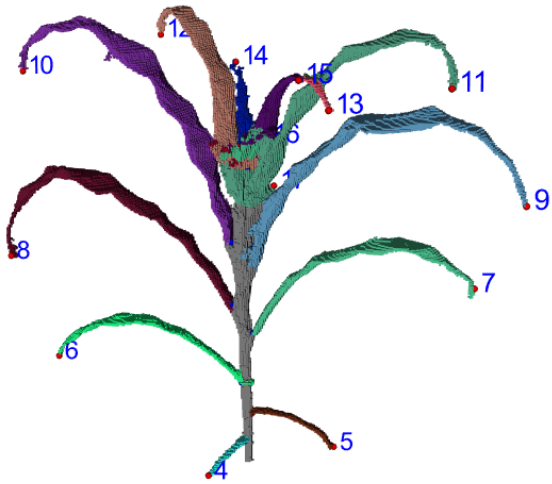
3D reconstruction of plant architecture (topology and geometry)



- Organ number
- Organ dimensions (length and width)
- Organ tracking (in progress)

Model assisted pipeline !





Phenomenal output Fit FSPM model (ADEL) Anotated output

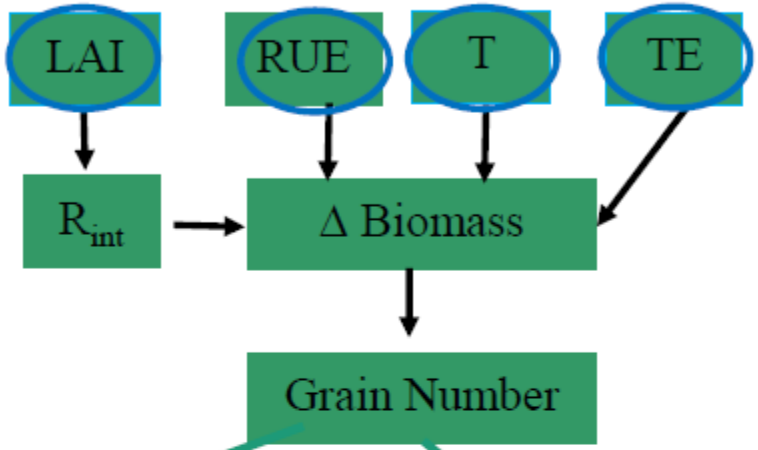
Fournier et al, IcropM

Prediction of grain number combining gen
prediction with dynamic models

Genomic prediction

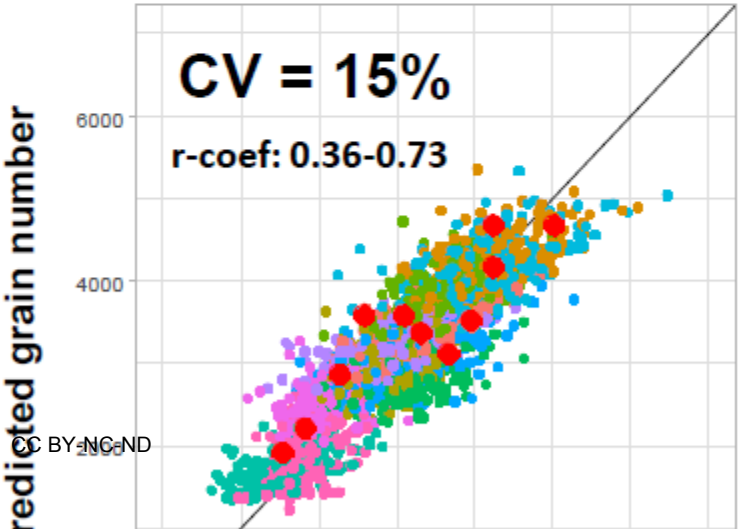
Model parameters/Traits

APSIM

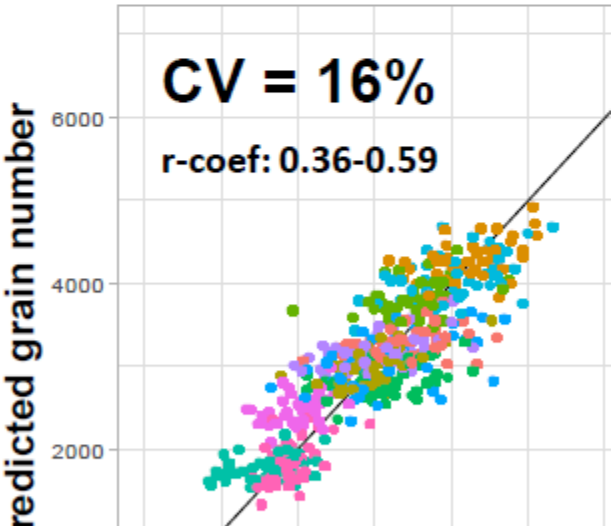


Climatic ar
field

[G, E] *Training Set*

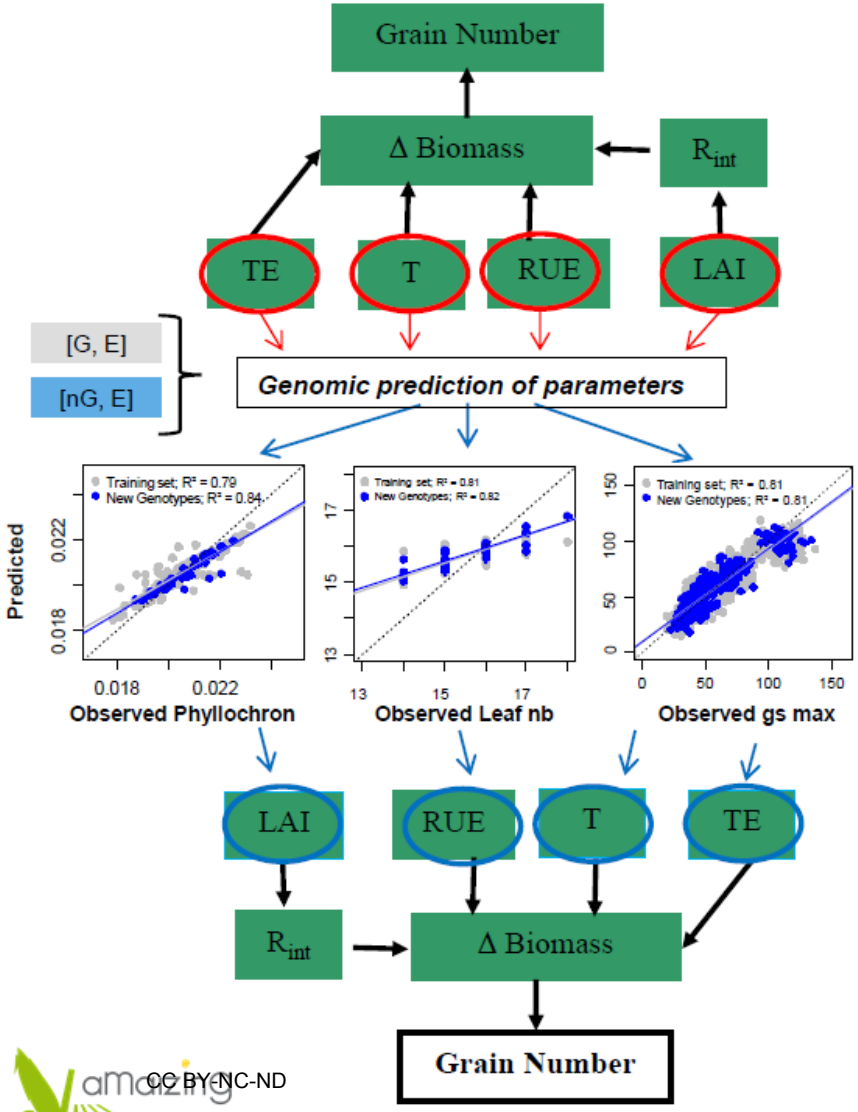


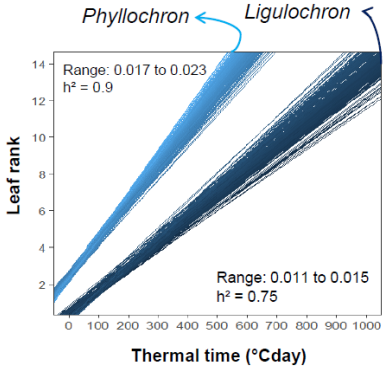
[nG, E] *New genot*

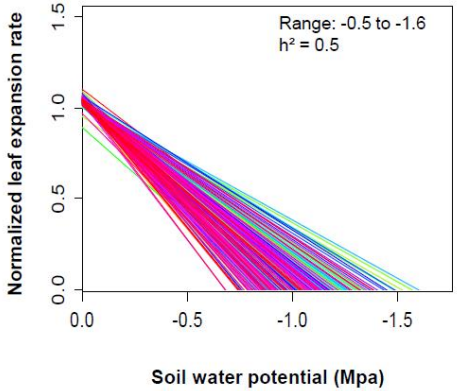


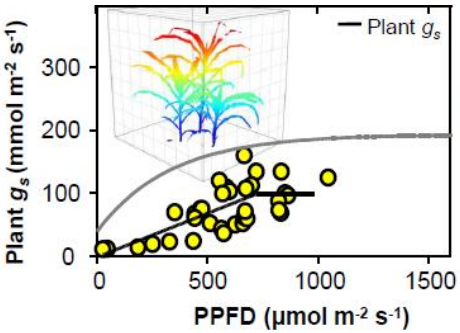
Genomic prediction of responses

Dynamic model: prediction of parameters



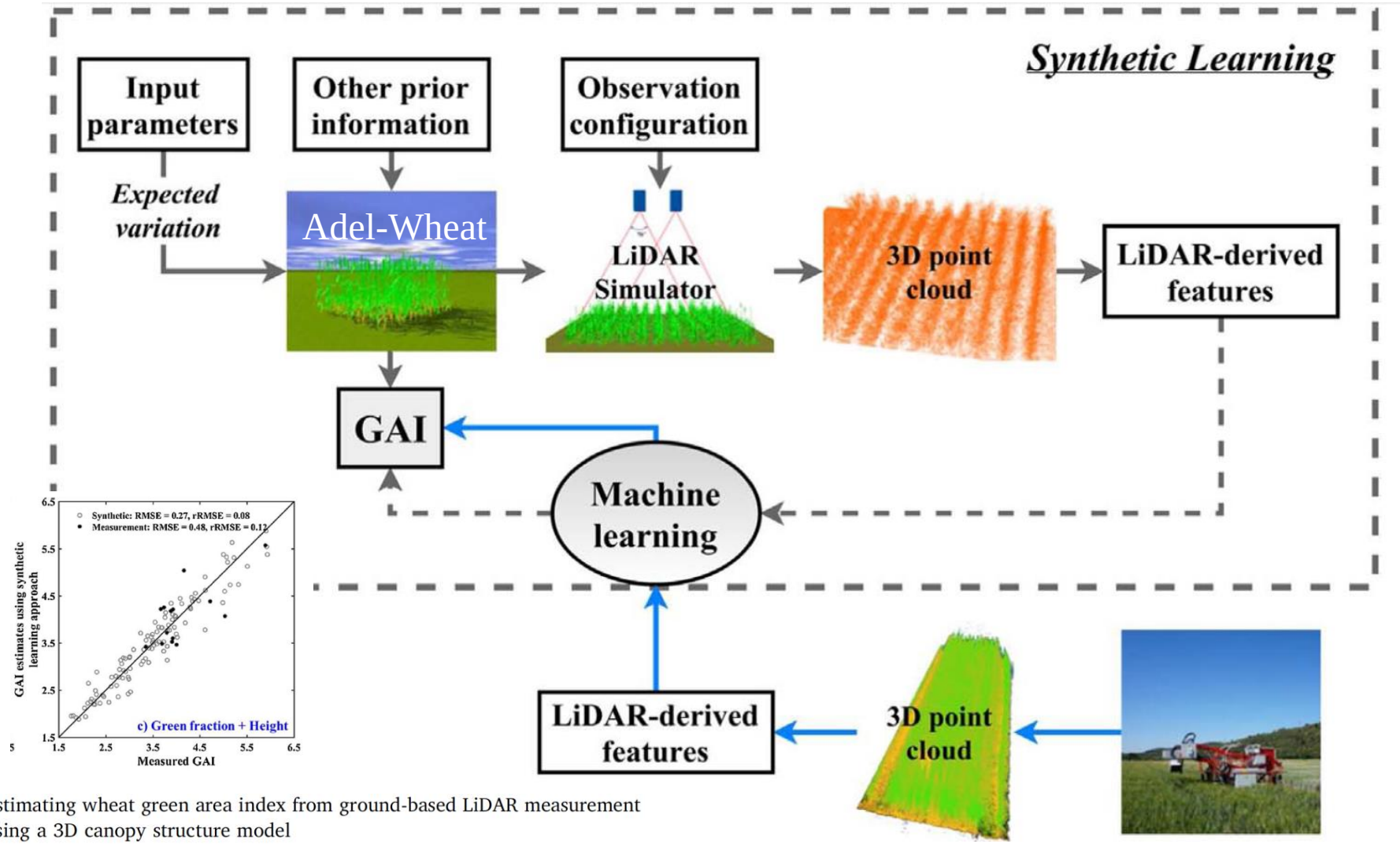






Alvarez Prado et al 2017 *Plant Cell Environment*

Predict, (machine) learn & estimate



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

Shouyang Liu[a,*], Fred Baret[a], Mohamed 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]

Summary

Model assisted phenotyping for HT automated acquisition

- Field
- Platform

Plant phylloclimate

- Simulation local environnent
- New co-variables

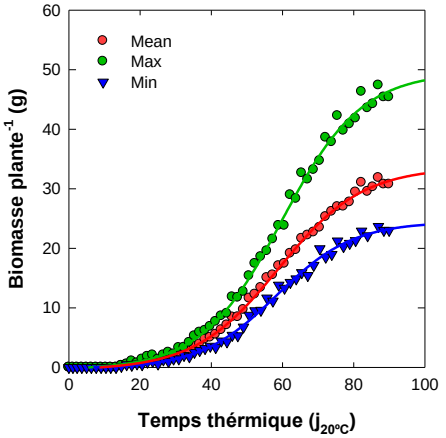
Dissecting plant responses

- Test/validate FSPM process model <-> 'productive FSPM'
- Extract traits / response traits

Gene to phenotype upscaling

- Extend / Link to crop models

Plant growth analysis

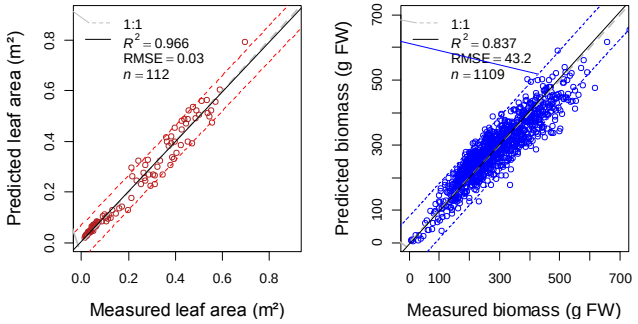


RGB image | Green pixel separation | Image descriptors

Estimation of Plant Growth over time

Combination of 0°, 90° and Top view:
Projected Leaf Area, Convex Hull Area, Minimum Enclosing Circle, Minimum Enclosing Rectangle, etc…

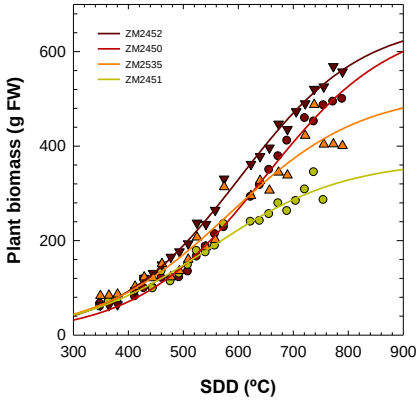
Multiple Linear Regression with Measured Plant Biomass and leaf area



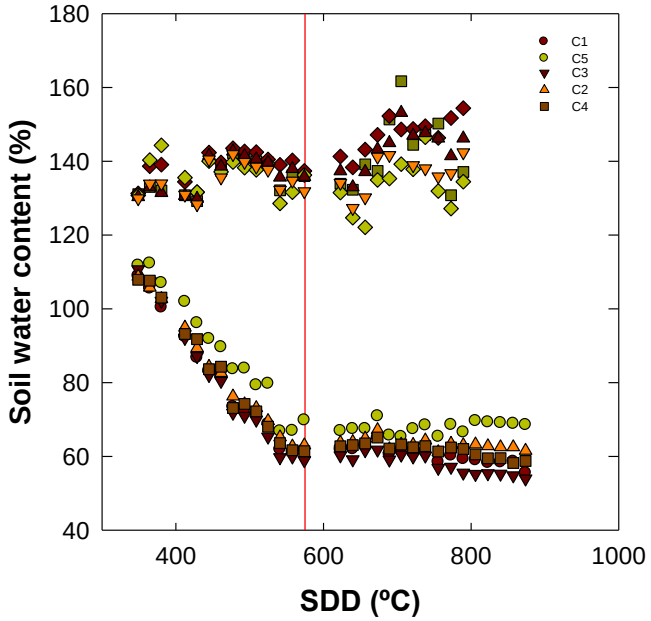
Control of irrigation

Weigth plants + pots

Irrigate for constant SWC

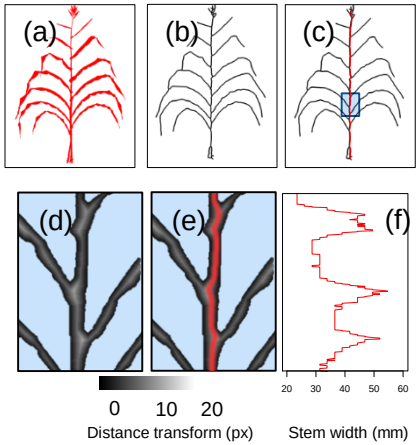


Estimate biomass

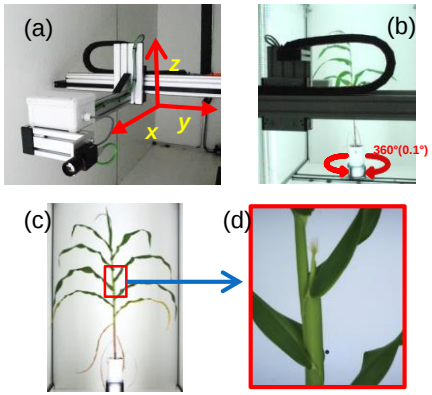


High-troughput method to track silk growth in maize

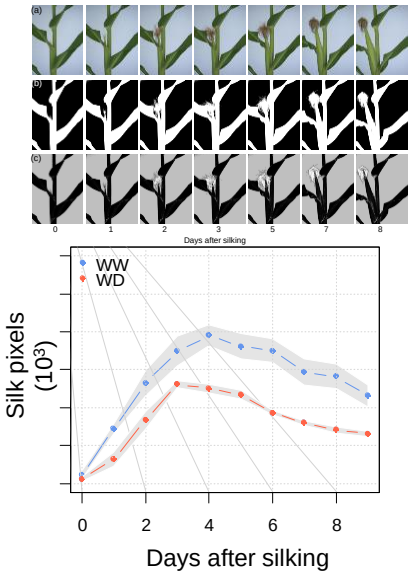
1. Detection of ear position



2. 'XYZ' robot camera



3. Machine learning and dynamic analysis of silk growth



Brichet *et al. Plant Methods* (2017) 13:96
DOI 10.1186/s13007-017-0246-7

Plant Methods

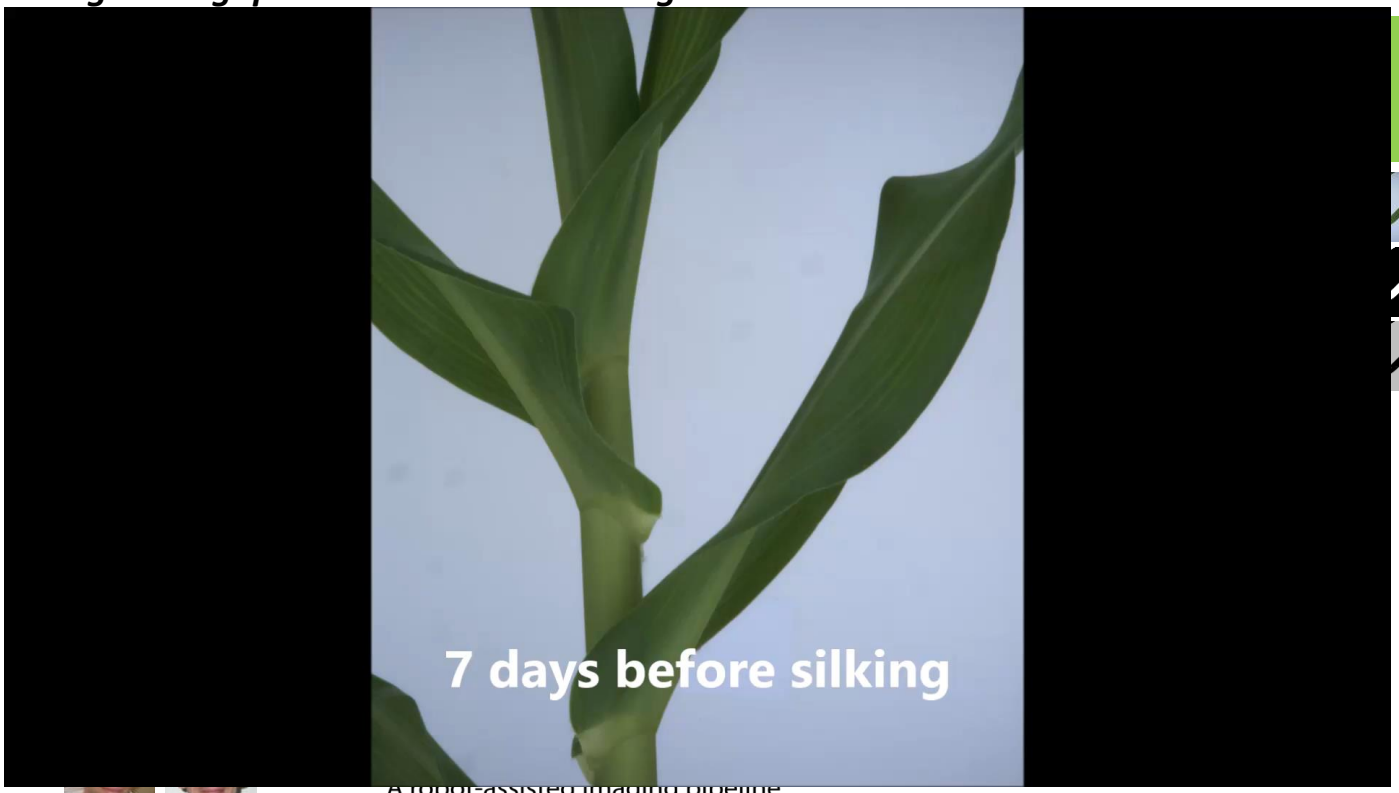
METHODOLOGY Open Access

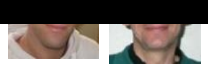
A robot-assisted imaging pipeline for tracking the growths of maize ear and silks in a high-throughput phenotyping platform

Nicolas Brichet[1], Christian Fournier[1,2], Olivier Turc[1], Olivier Strauss[3], Simon Artzet[1,2], Christophe Pradal[2,4,5], Claude Welcker[1], François Tardieu[1] and Llorenç Cabrera-Bosquet[1*]

Brichet et al. 2017 Plant Methods

High-troughput method to track silk growth in maize





A robot-assisted imaging pipeline
for tracking the growths of maize ear and silks
in a high-throughput phenotyping platform

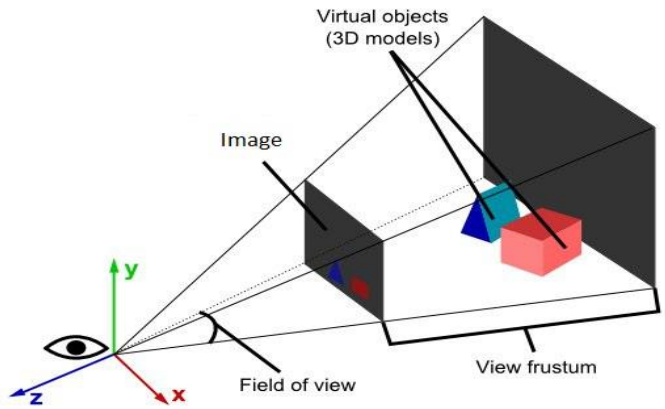
Nicolas Brichet[1], Christian Fournier[1,2], Olivier Turc[1], Olivier Strauss[3], Simon Artzet[1,2], Christophe Pradal[2,4,5], Claude Welcker[1], François Tardieu[1] and Llorenç Cabrera-Bosquet[1*]

Brichet et al. 2017 Plant Methods

Camera Calibration & multiview reconstruction

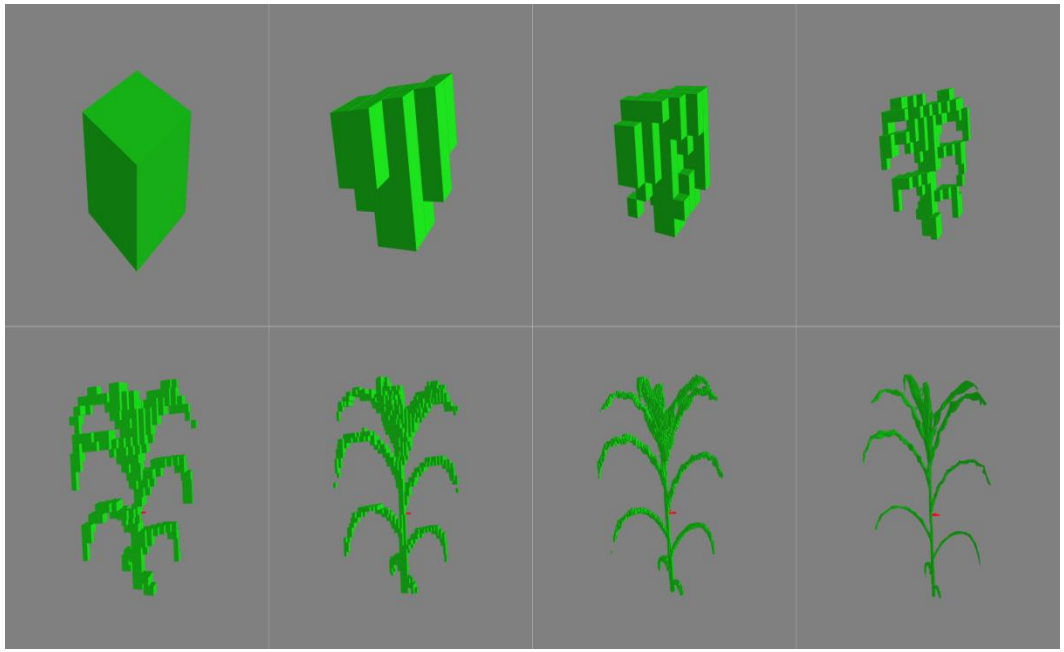
Calibration of the camera

- OpenCV chessboard detection + fiting of moving pinhole camera along a rotation axis
- Projection function

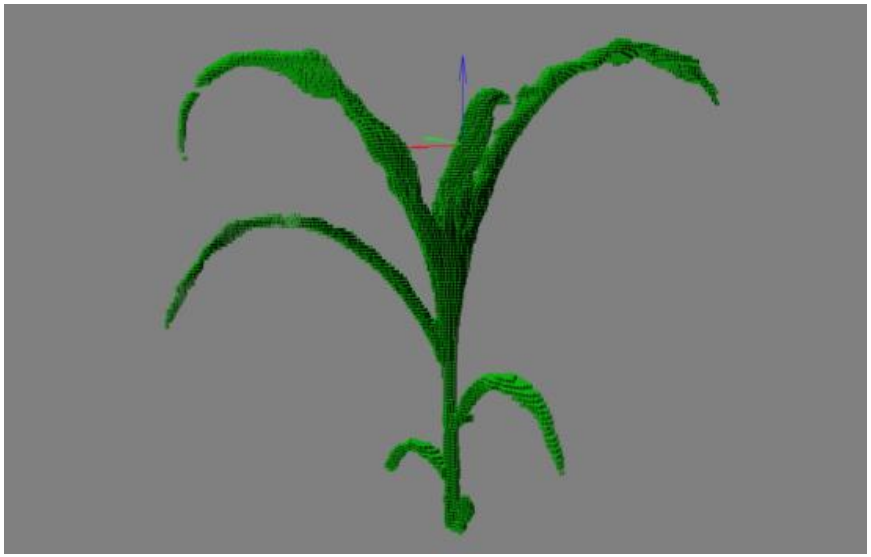


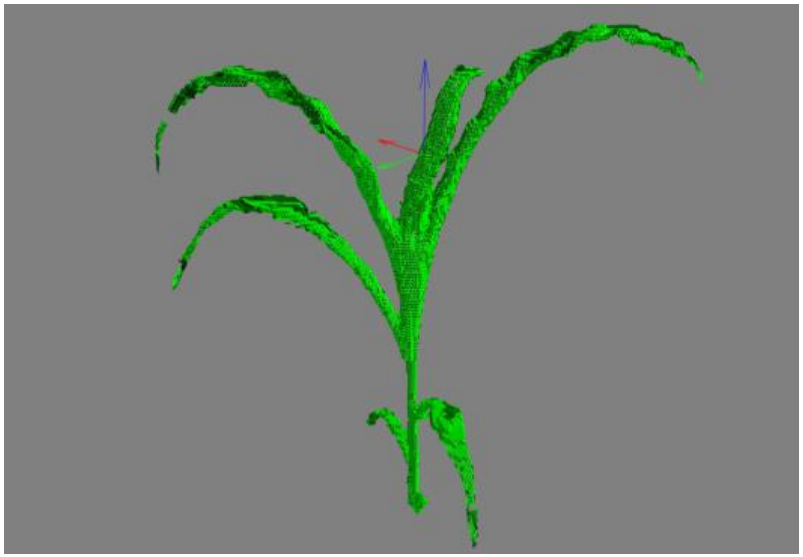
Iterative space carving for 3D reconstruction

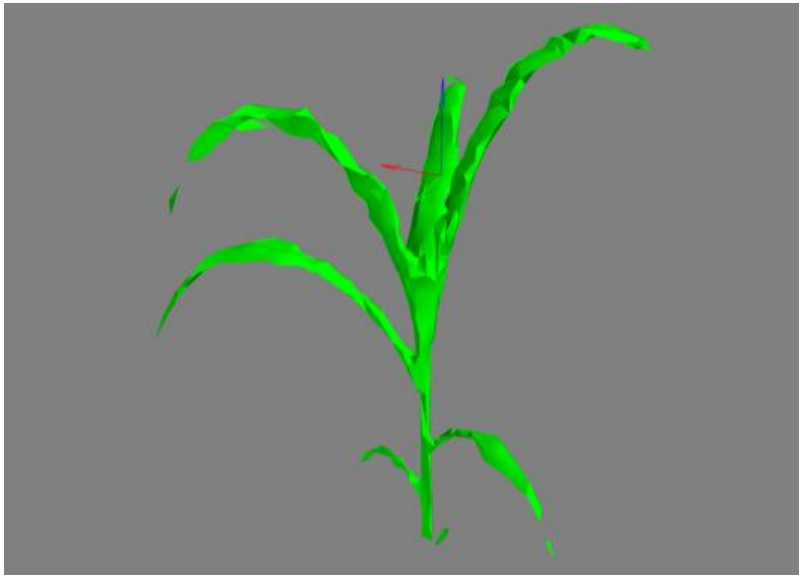
- Defines a voxel of the size of the scene.
- Iterative octree subdivision
- Keep voxel projected on segmented object



Surface reconstruction & Mesh decimation







3D Skeleton

3D thinning

A 3D 6-subiteration thinning algorithm for extracting medial lines of Kalman Palagyi and Attila Kuba

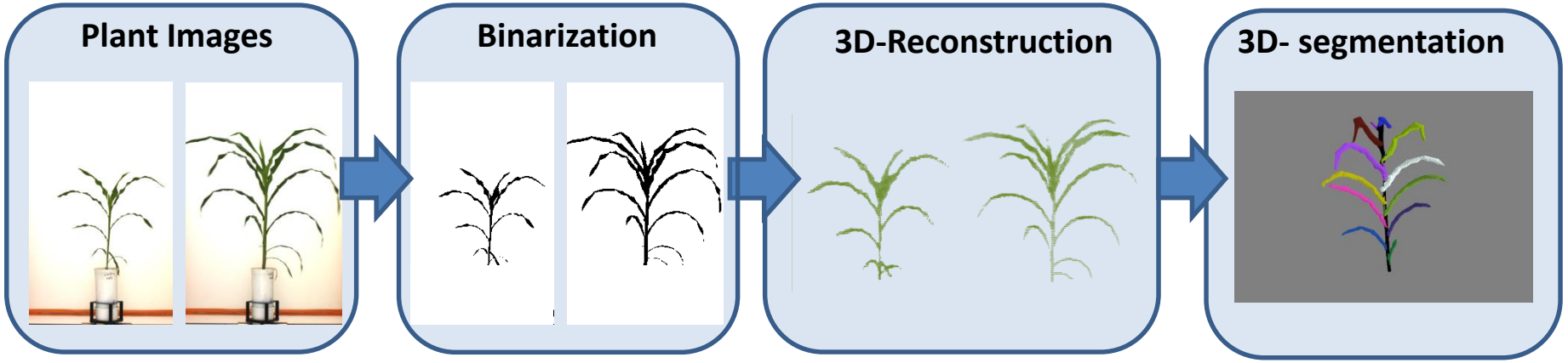
Space colonization

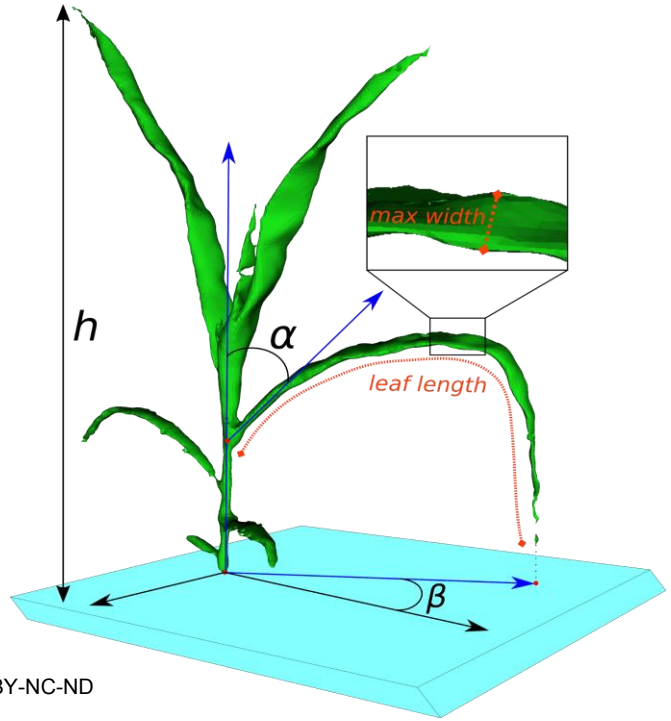
Implementation of Xu et al. 07 method for main branching system (space colonisation clustering)

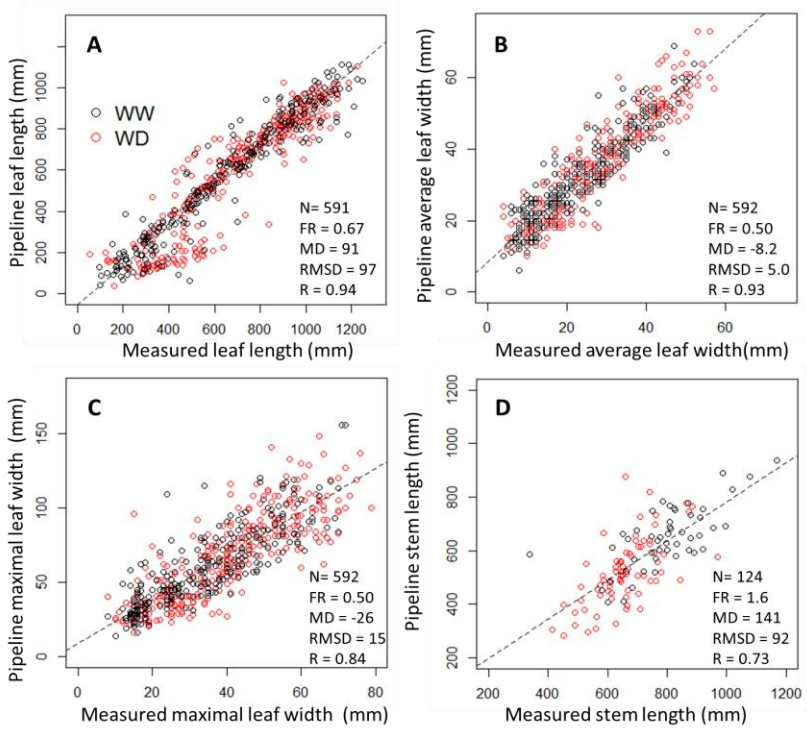
Longest shortest path

voxel cloud graph shortest path transform (networkx) + interative simplification with planar intersection along longest paths

Model assisted measurement of plant development

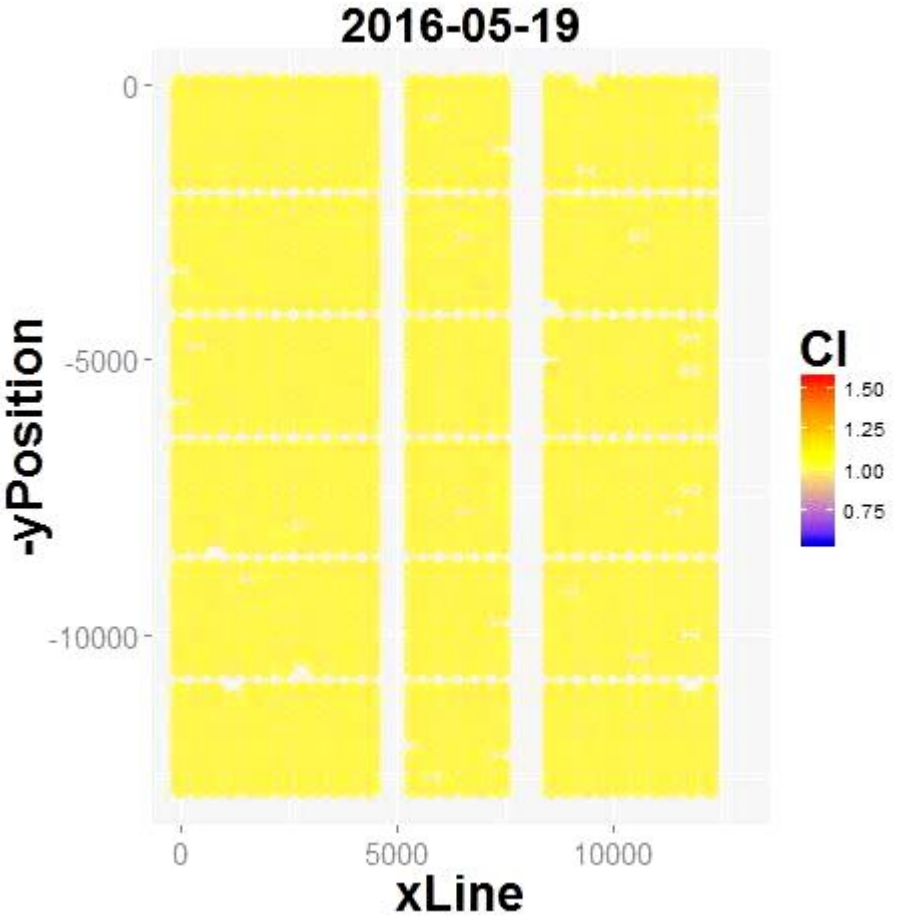






What influences RIE?

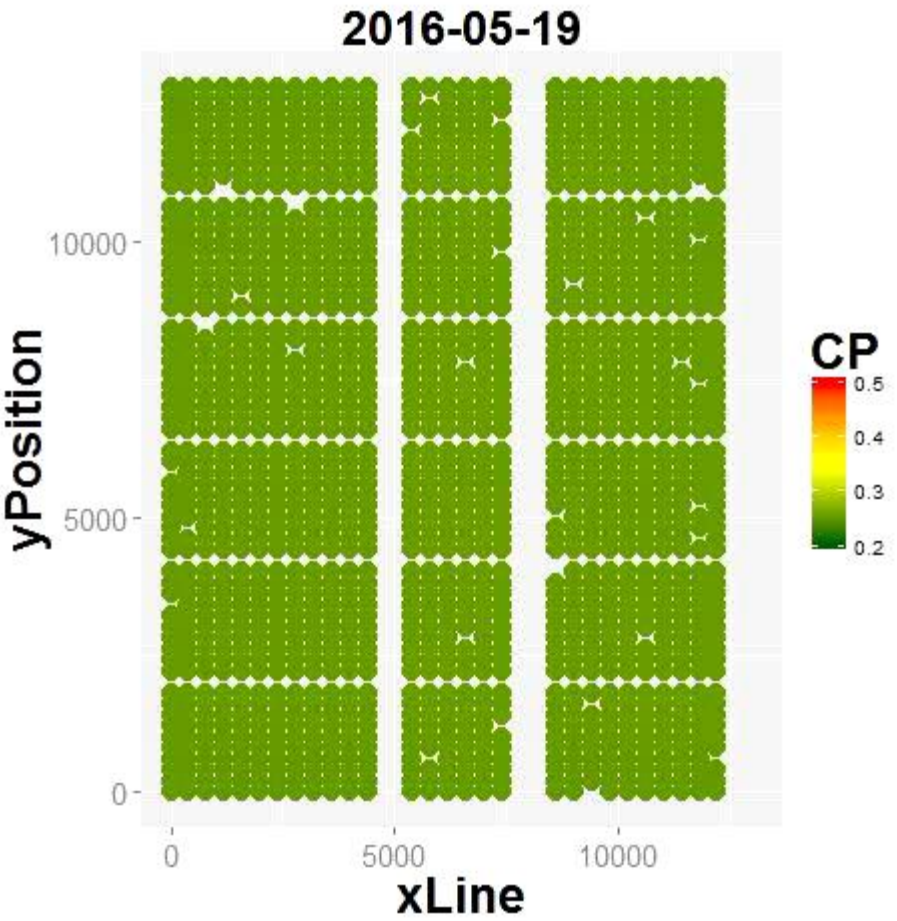
Competitiveness index (CI)



Blue: low competitiveness

Red: high competitiveness

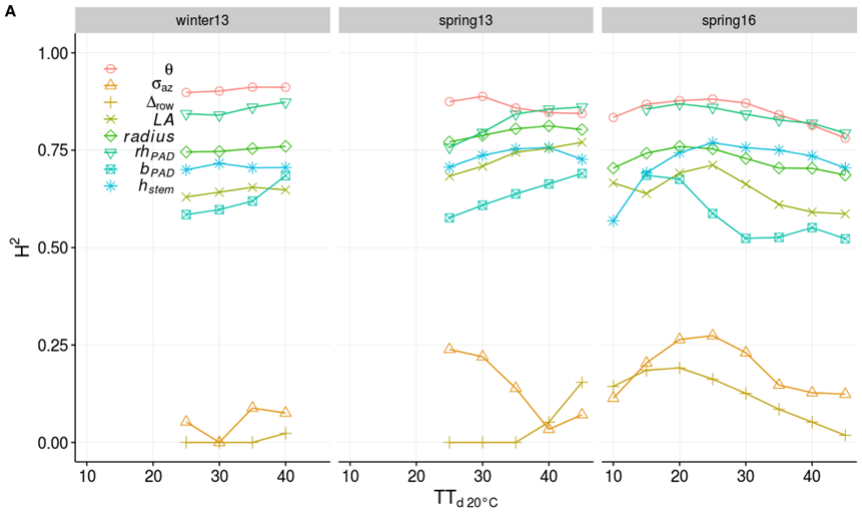
Competition pressure (CP)

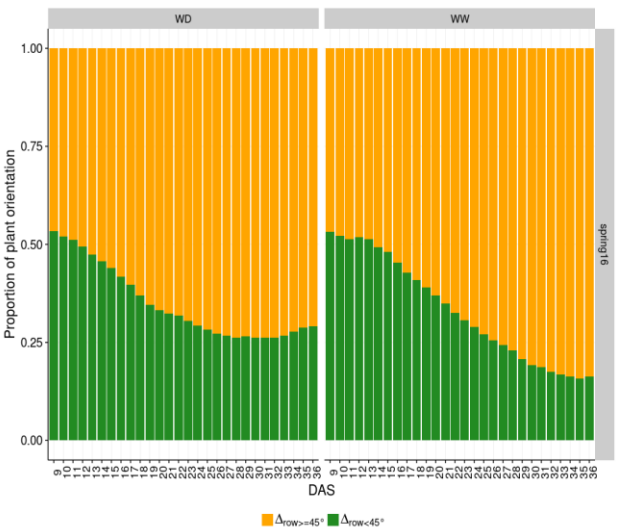


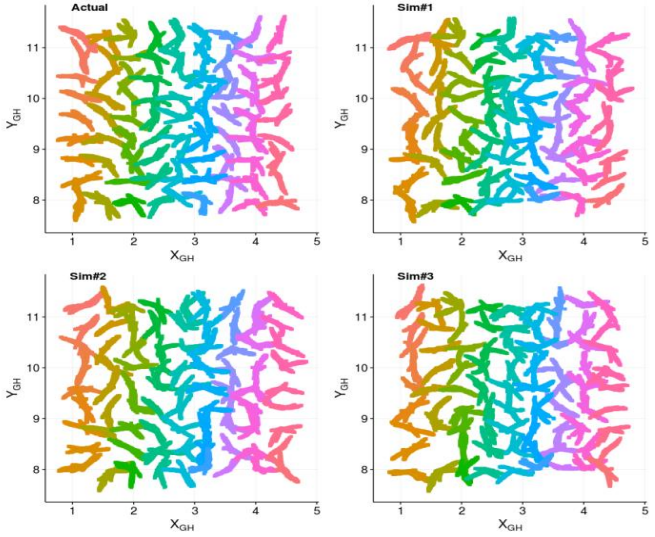
gree: low competition pressur

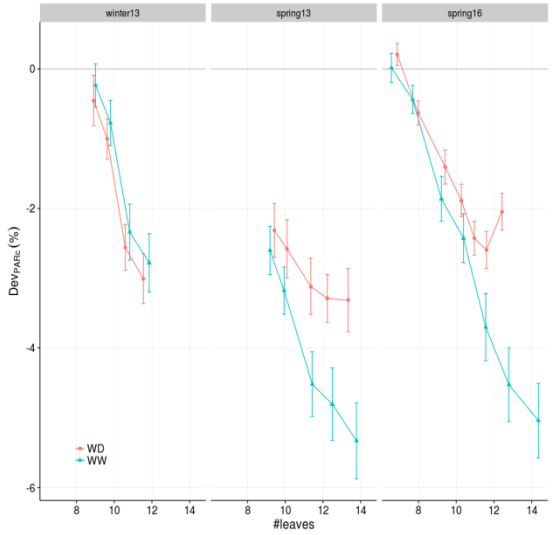
Red: high competition pressur

Disecting CI with architectural traits (R. Perez ongoing)









Current direction

Phenotyping architectural development

- Organ detection / tracking
- Adel developmental model = f(T, Light, Water)

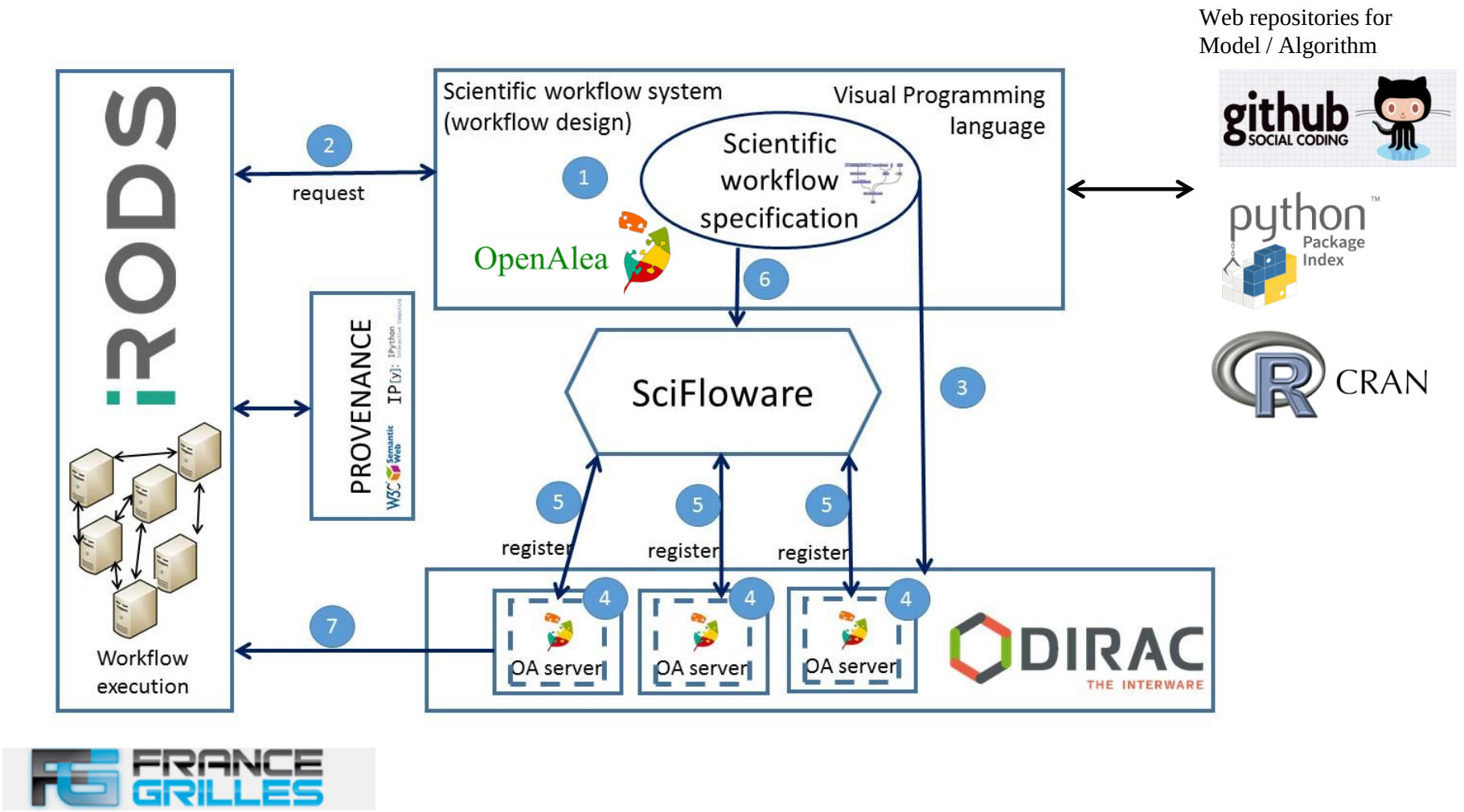
Functional phenotyping

- FSPM transpiration model

Linking Crop and FSPM models

- Shared processes
- Upscaling models
- Mixed FSPM –Crop models

M3P/Phenome solution: InfraPhenoGrid



Pradal C, Artzet S, Chopard J, Dupuis D, Fournier C, et al. (2016) InfraPhenoGrid: A scientific workfow infrastructure for plant phenomics on the Grid. Future Generation Computer Systems (in press).