Extremely high spatial resolution observations for deriving vegetation characteristics: recent advances

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Extremely high resolution imagery is now available from various vectors and sensors

Vectors

Plane/ULM

altitude: 150m-3km
coverage: 5 – 200 km²/h

Drone

altitude: 2m-150m
coverage: 0.5 – 500 ha/h

Robots

altitude: 0.5m - 5 m
coverage: 0.1 - 1 ha/h

IoTs

altitude: 0.5m-3m
coverage: 1m²-5m²

Sensors

RGB camera

Resolution: 10 – 100 Mpix

Multi-spectral camera

Resolution: 0.5 – 2 Mpix

Hyper spectral

Resolution: 0.1 – 0.5 Mpix

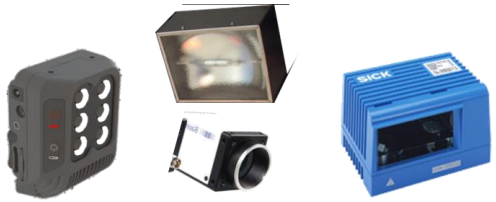
Thermal camera

Resolution: 0.1 - 1 Mpix

LiDAR (scanner)

Resolution: 1 mm – 1 m

The toys we are playing with



Phénomobile

- 150 plot/h

  Several hours between first and last plot sampled
- Little sensitive to wind
- Active measurements

Drone

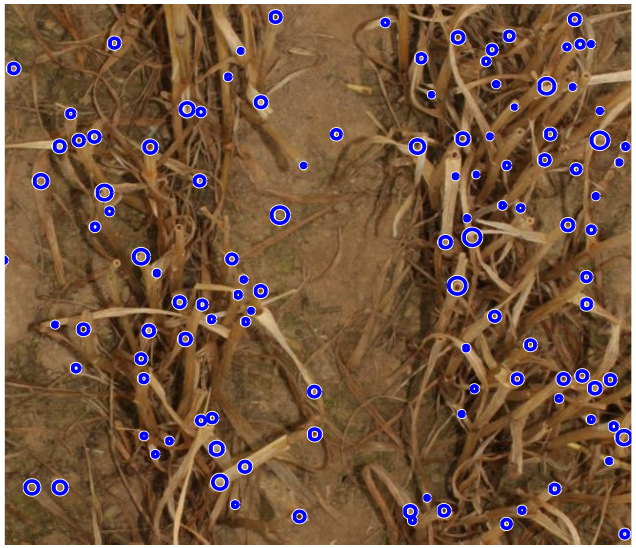
- Throughput: 1000 plot/h

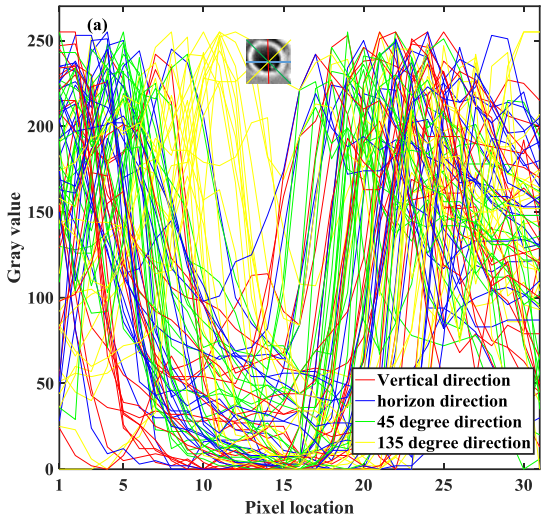
  Almost simultaneous aquisition of the platform
- Sensible to wind
- Passive measurements

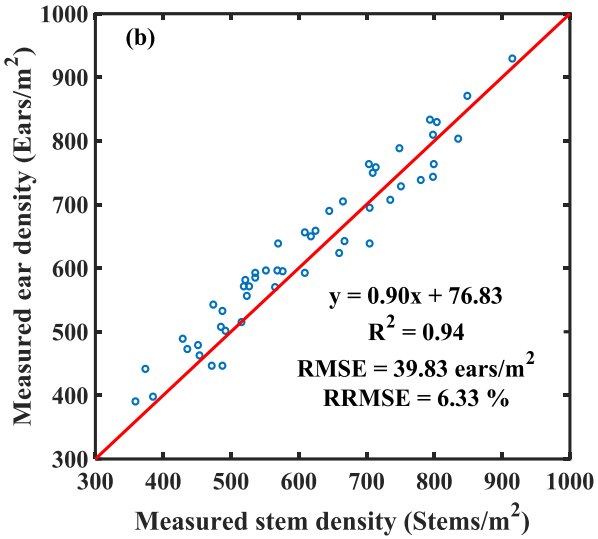
accessing new scales

- **Organ**
  - Leaf
    - Size / orientation
    - Sanitary state
    - Biochemical composition (Chlorophyll / Water contents)
  - Stem
    - Diameter
    - height
  - fruits
- **(Plant)**
  - When not too much overlap between plants:
    - Early stages
    - Low plant density
- **Canopy**
  - Plant/stem density (and sowing pattern)
  - height
  - Green fraction
  - Green area index
  - FIPAR
  - 3D structure

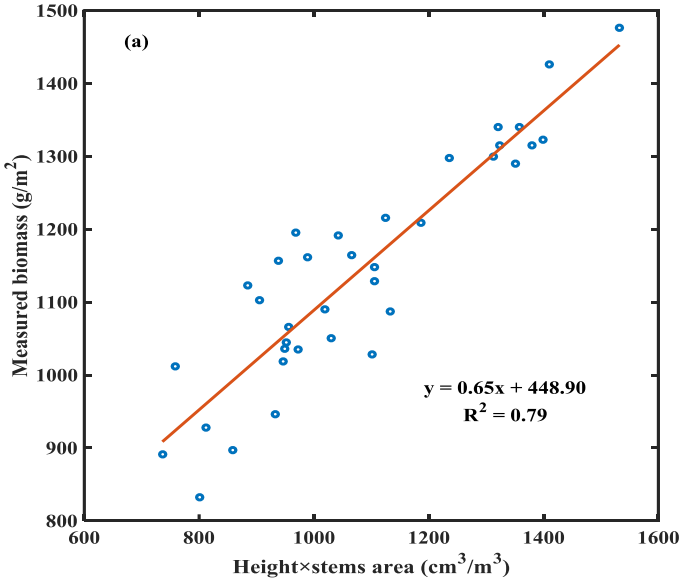
Organ: Stem characterization after harvest







- **The stem density and diameter can be measured with an accuracy better than 10%**
- **When spatial resolution better than 0.2 mm**
- **Biovolume (basal stem area x crop height) highly correlated to total biomass at harvest**



From Jin et al., AFM, 2018

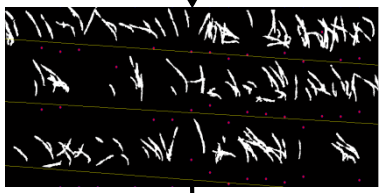
Plant / Canopy: Plant counting & characterization

- Sony α5100
- 60 mm lens
- 3-7 m altitude
- **0.2-0.5 mm resolution**

Images quality equivalent to those taken from ground

Processing Method

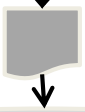
Automatic classification — White balance correction, SVM classification



Iditenfying rows — Distribution of green pixels

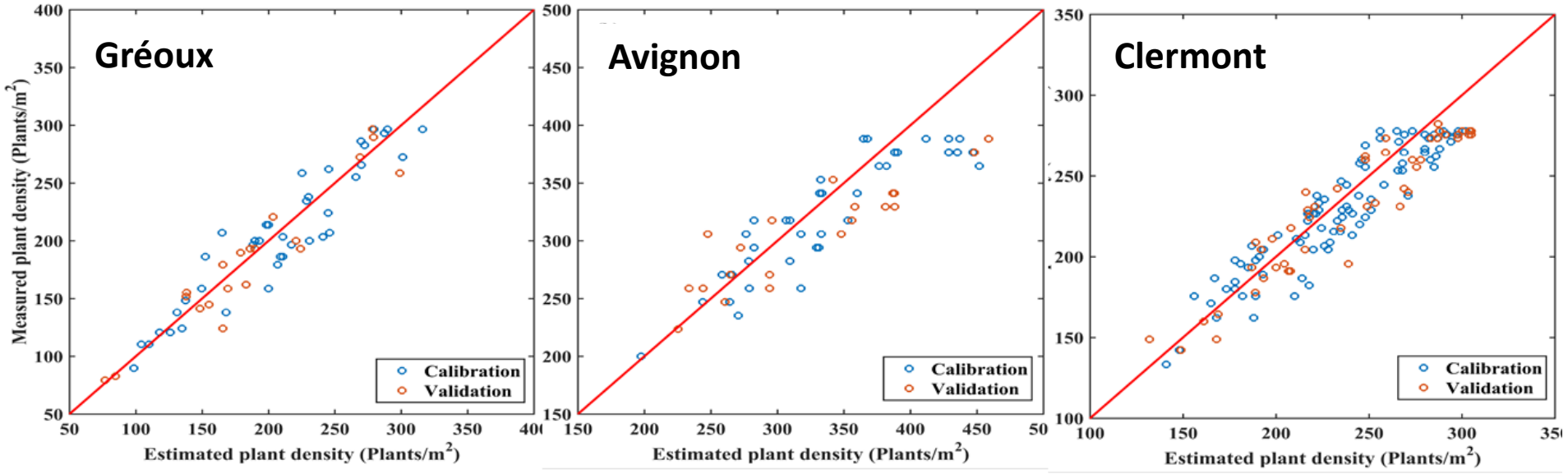
Identifying objects — Cleaning by erosion/dilatation

Objects metrics — Length, width, orientation, size, tips …

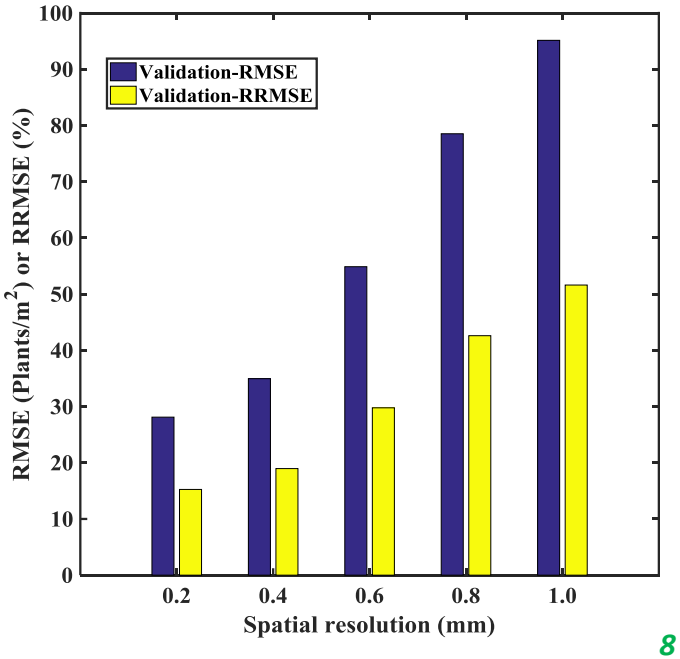


Classifying objects → 1 plant / 2 plants / 3 plants → Actual density

Sample results



- Good performance if density not too high
- Importance of image quality:
  - Resolution (<0.5mm)
  - Crisp (RAW),
  - Orientation with sun (better facing sun)
- Difficulty to maintain low altitude precisely (sonar)
- Difficulty to geolocate the images (RTK/PPK)



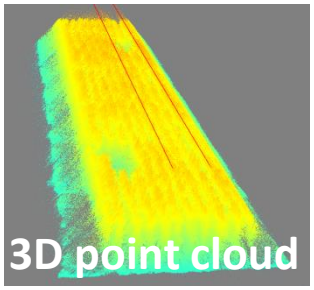
From Liu et al. FPS, 2017

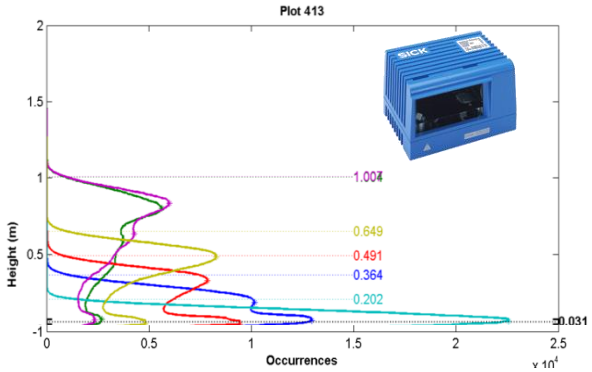
From Jin et al. RSE, 2017

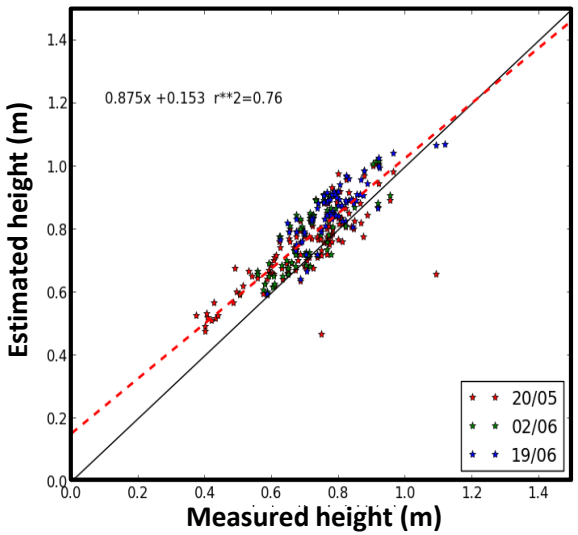
Canopy: plant height (1/2)

LiDAR/Phenomobile

Resolution: 3-5 mm
Throughput: 150 µplot/h
Active measurements

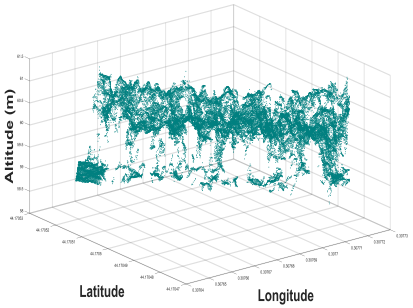


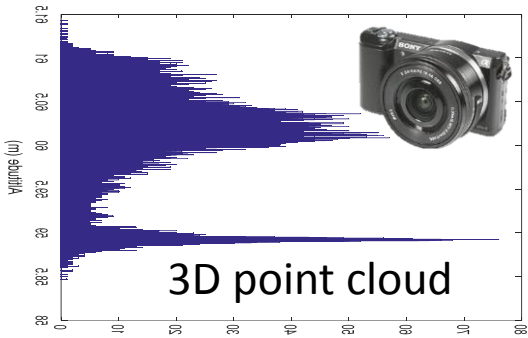


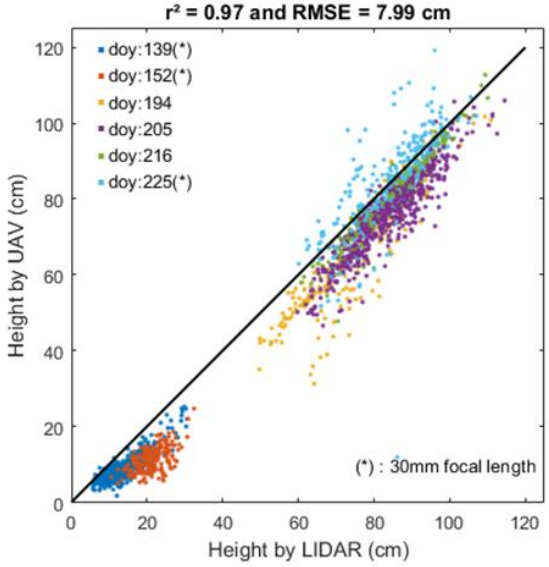


RGB Camera/UAV

Resolution: 10 mm
Throughput: 4000 µplot/h
Passive measurements

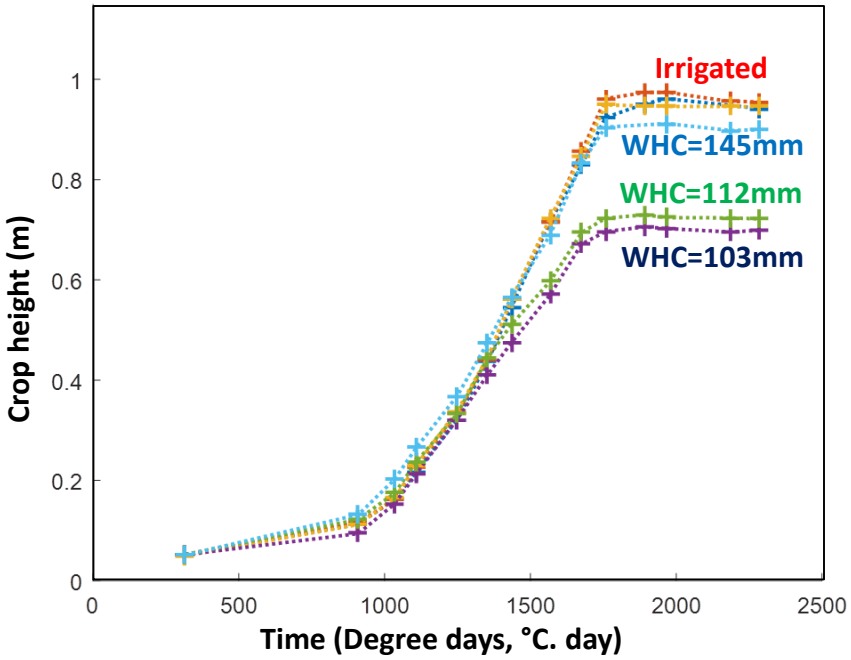


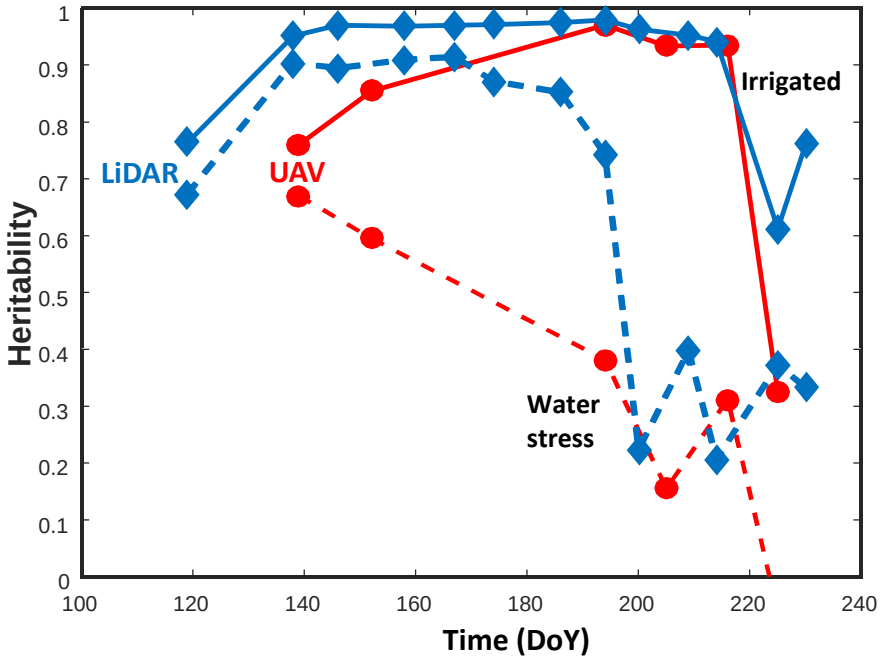


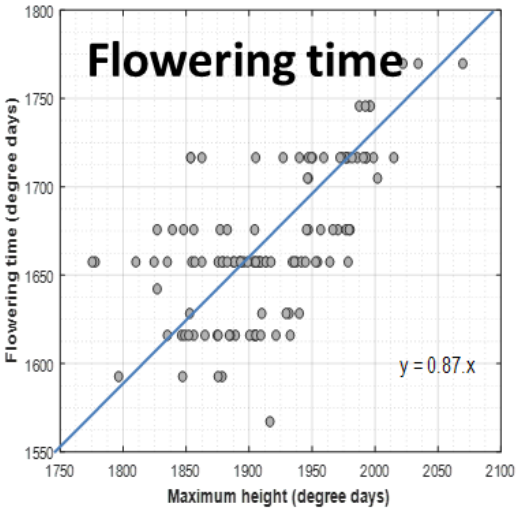


Structure From Motion

plant height: results





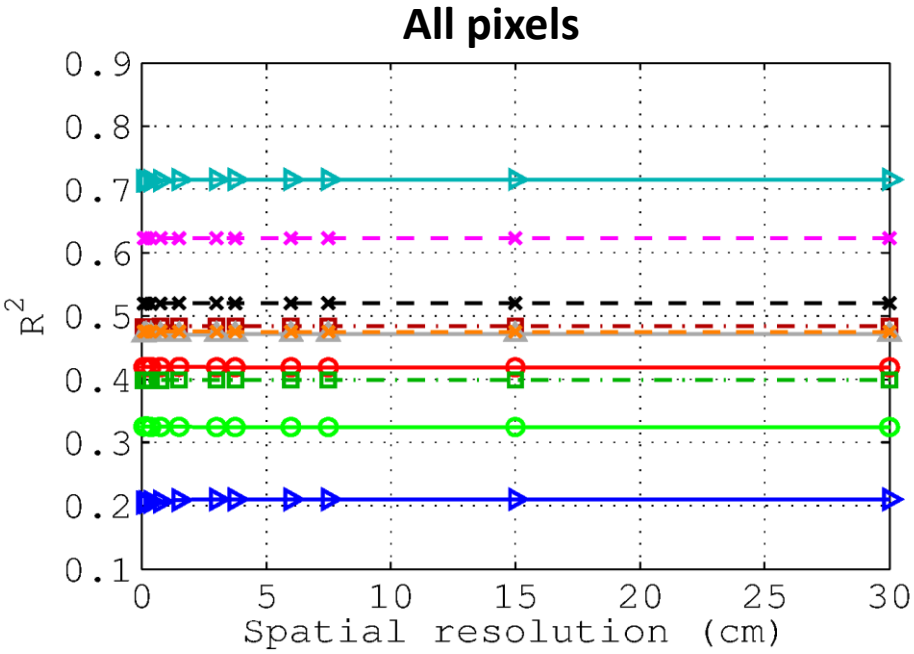


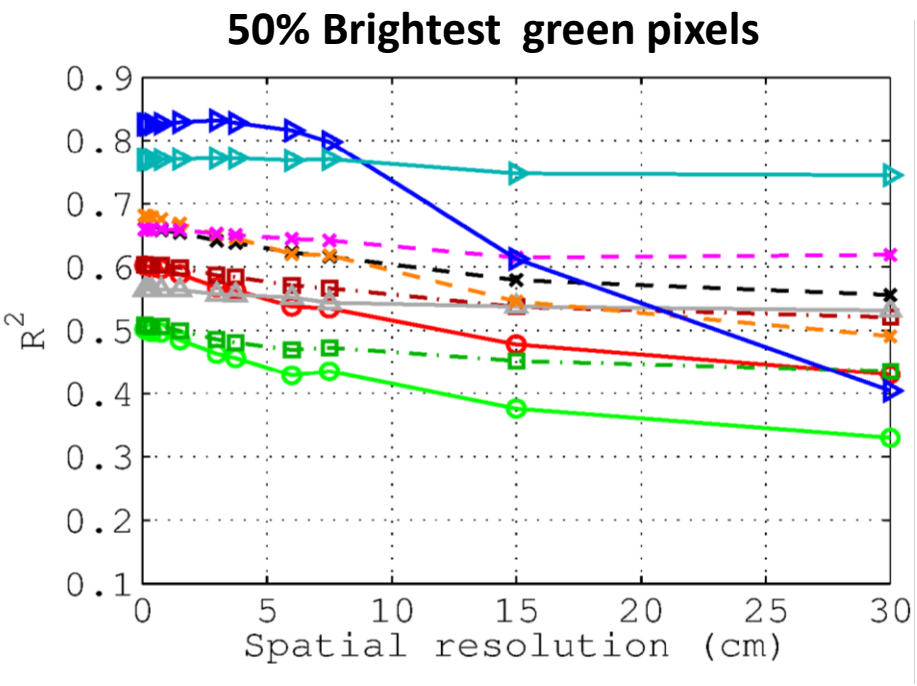
Canopy height is a very relevant trait:

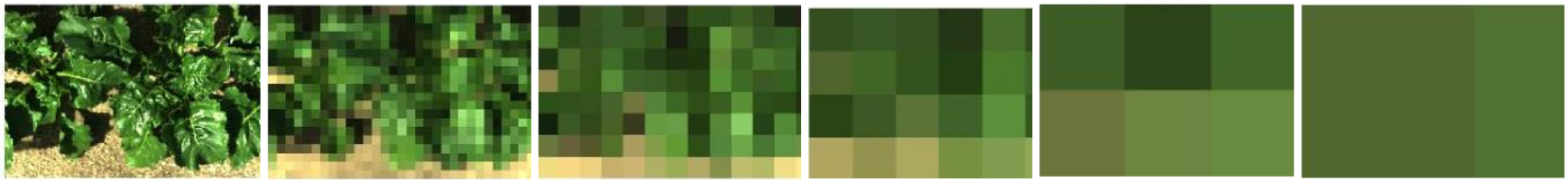
- **Highly heritable**
- **Dates the start of the stress**
- **Synchronism between stop of growth (height increase) and flowering**

From Madec et al. PM 2018

Canopy: Leaf Chlorophyll Content





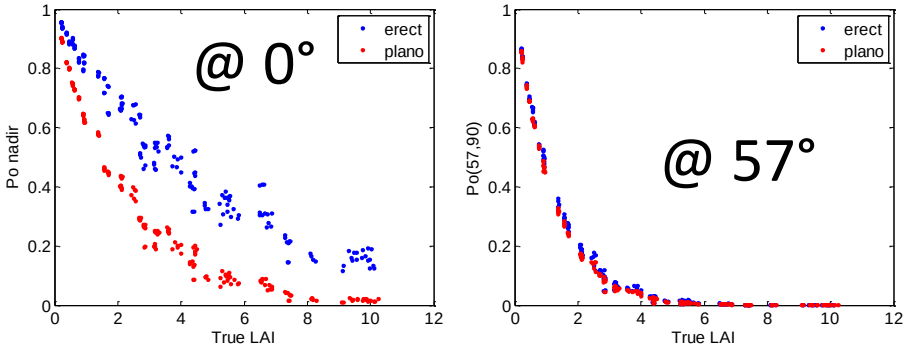


Improved retrieval performances when separating the background from the leaf problems

From Jay et al. , RSE 2017

Green fraction and second order functions

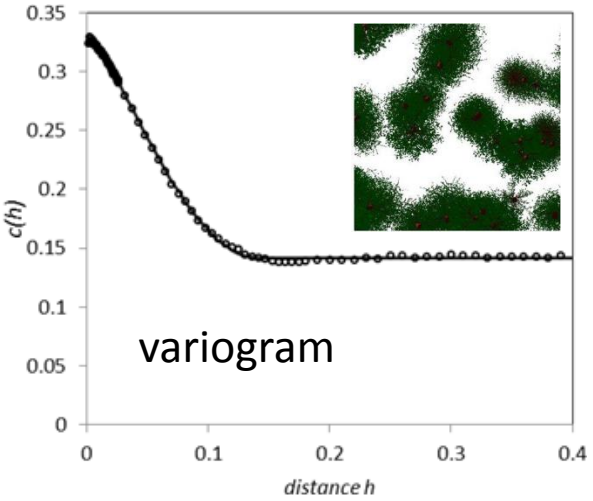
Green fraction (first order)

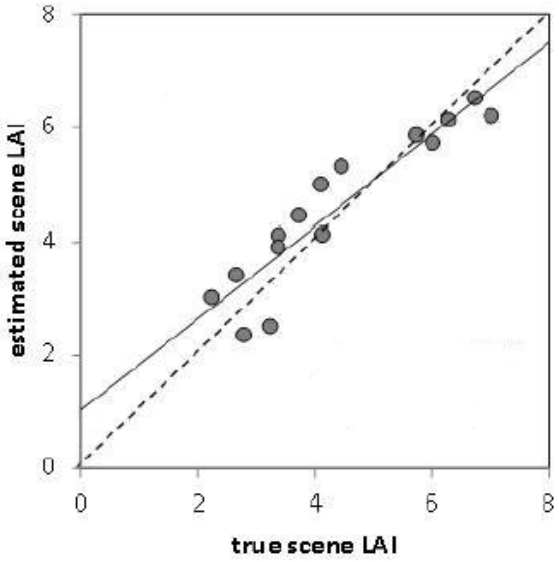


High spatial resolution imagery allows to account for leaf clumping through second order functions

From Baret et al., AFM 2010

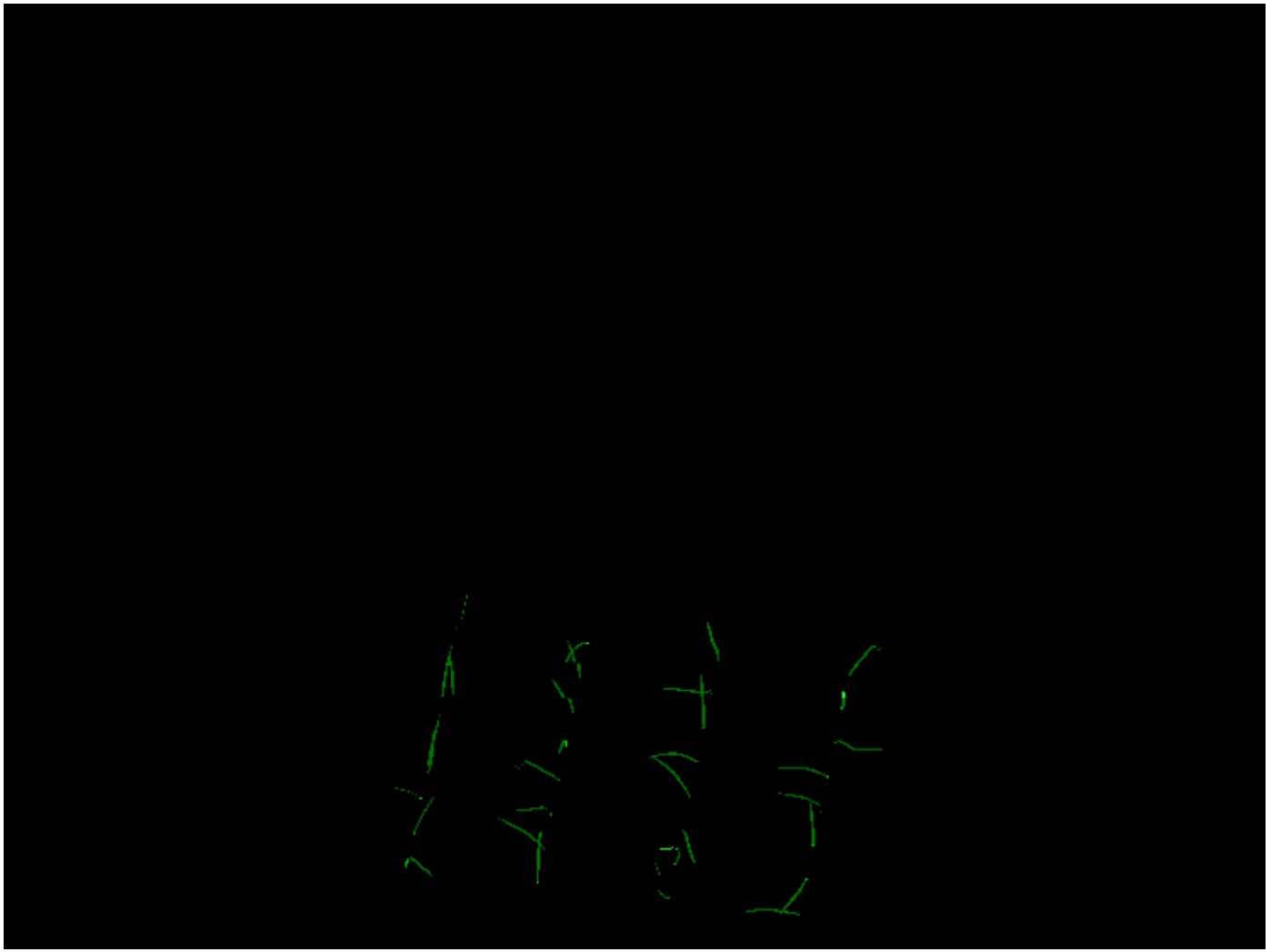
Second order functions





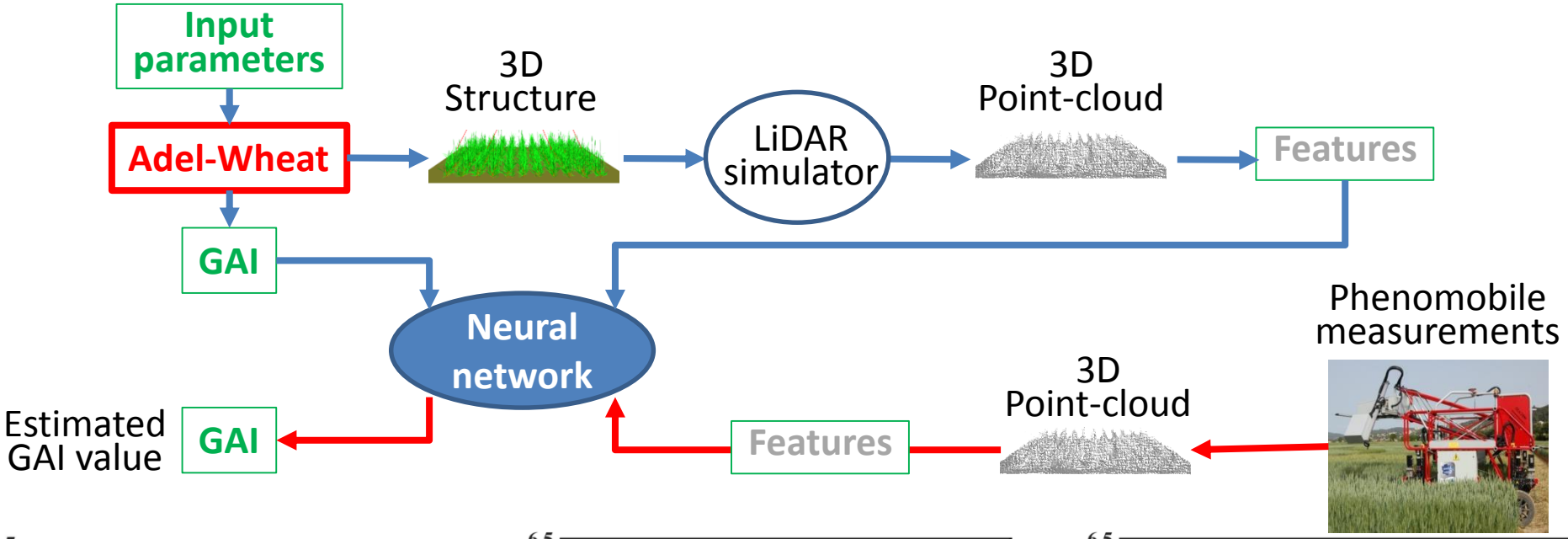
From Lopez-Lozano et al., AFM 2014

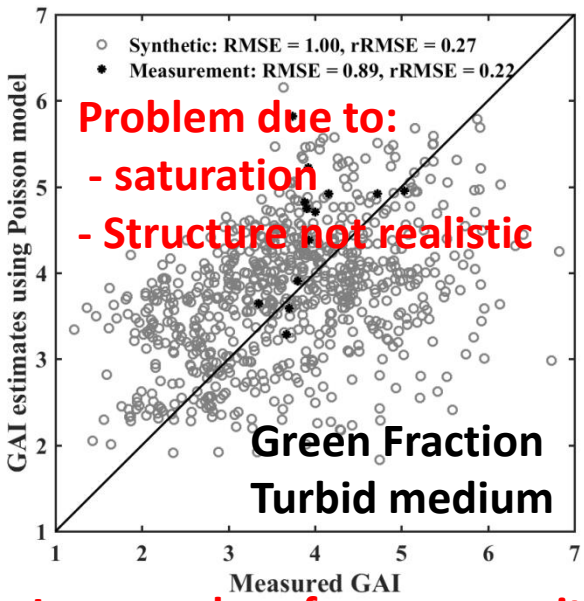
Combining observations with 3D models

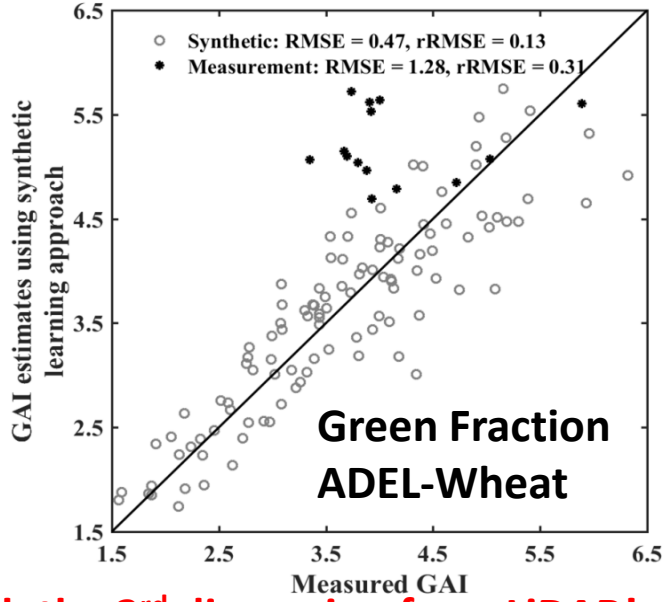


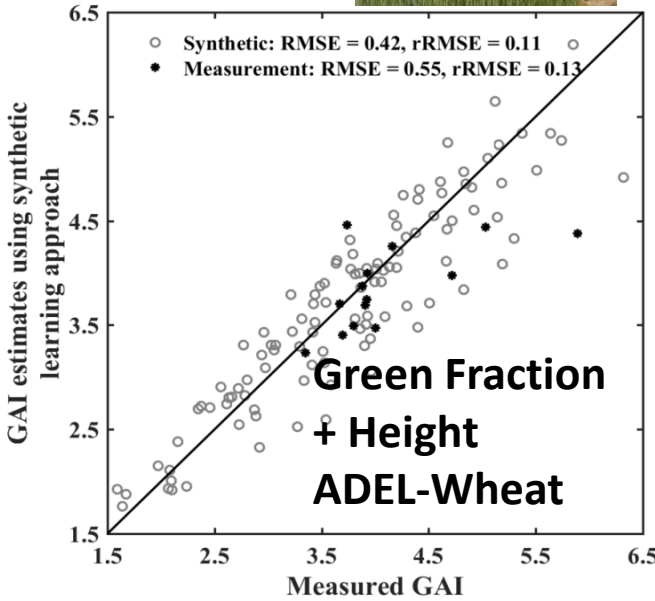
ADEL-Wheat model (20-30 parameters)

GAI estimates from LiDAR combined with ADEL-Wheat









Improved performances with the 3rd dimension from LiDAR!

Limited saturation effect as compared to that of the Green Fraction

From Liu et al. AFM, 2017

CONCLUSION

- **Much more pertinent information can be derived from extremely high resolution imagery**
  - ✓ Accessing new scales (organ, plant)
    - Characteristics of specific organ/plant
    - Average characteristics (most often)
  - ✓ Better description of the canopy
    - 3D structure (Structure from Motion)
    - Element grouping (clumping)
- **Different approaches as compared to the degraded resolution data**
  - ✓ From Radiative transfer model inversion to machine (deep) learning approaches
- **Using 3D models should improve accuracy of retrievals**
  - ✓ Limits of the realism of the 3D models
  - ✓ Develop hybrid learning mixing model and observations
- **Spatial extension methods to be developed to cover larger areas**
  - ✓ Combination with satellite observations


Thanks for your attention
Questions??