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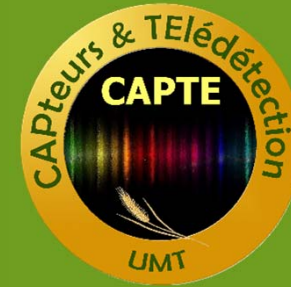
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Developing crop specific algorithms to derive accurate GAI and Chlorophyll Content from SENTINEL-2 data: 4D modeling & machine learning



Jingyi Jiang, Marie Weiss, Shouyang Liu
Frédéric Baret
EMMAH, UMT CAPTE

OBJECTIVES

- Decision tool for sustainable agriculture
 - Optimize nitrogen/water application in time and quantity at low cost
 - Satellite monitoring + Data assimilation in crop functioning models for decision support
 - Context = BELCAM project- BELgian collaborative Agriculture Monitoring at parcel level for sustainable cropping systems

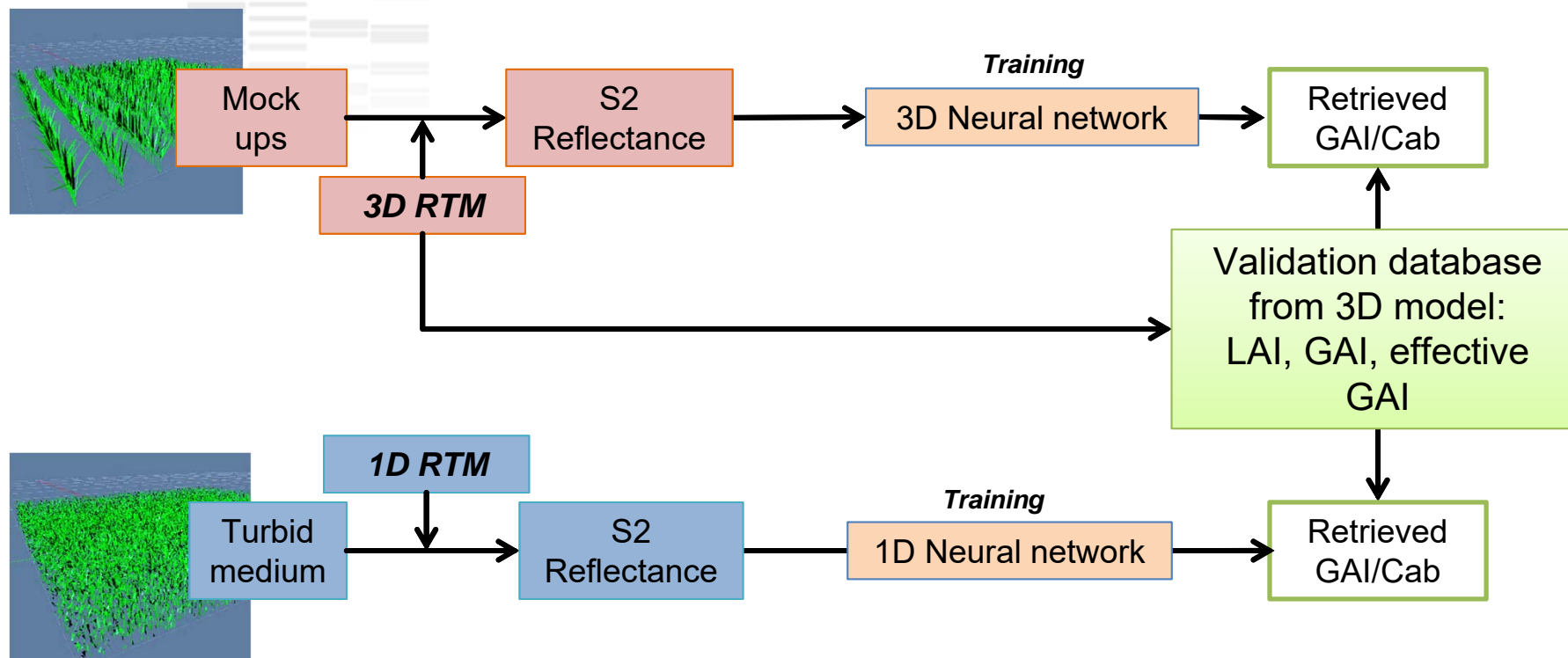
- Questions
 - Can generic algorithms (e.g SNAP toolbox) be applied for LAI and leaf Chlorophyll content estimation?
 - Which LAI do we estimate the best?

LAI definitions

Depend on the application/user needs

- Biomass allocation/allometric approach: LAI
half the total developed area of leaves per unit horizontal ground area (Chen and Black, 1992)
- Transpiration/Photosynthesis: GAI (Green area index):
all the green vegetation elements including leaves, stems or all other organs
- Radiation interception efficiency:
spatial arrangement between elements need to be taken into account (clumping):
effective GAI
- Rainfall interception efficiency: Plant Area Index (PAI) or effective PAI
all the vegetation elements including leaves, stems or all other organs, either
green or senescent

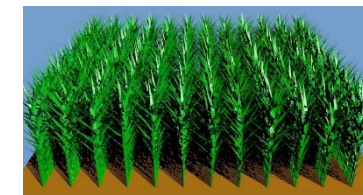
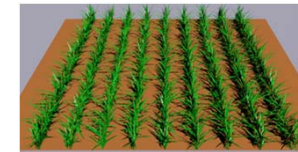
Compare Generic vs Specific: synthetic data set



The crop specific algorithm – 3DRTM simulations

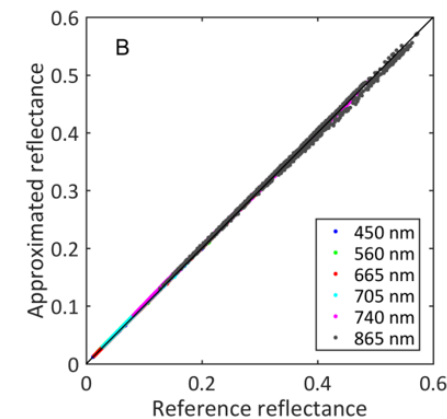
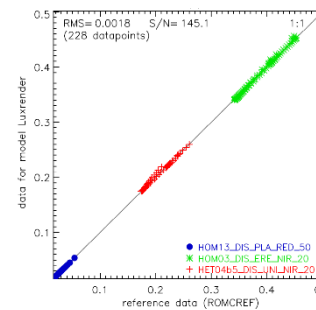
➤ 4D Mock-ups (3D architecture growth)

- ADEL-WHEAT
- Maize (Lopez-Lozano et al, 2007)

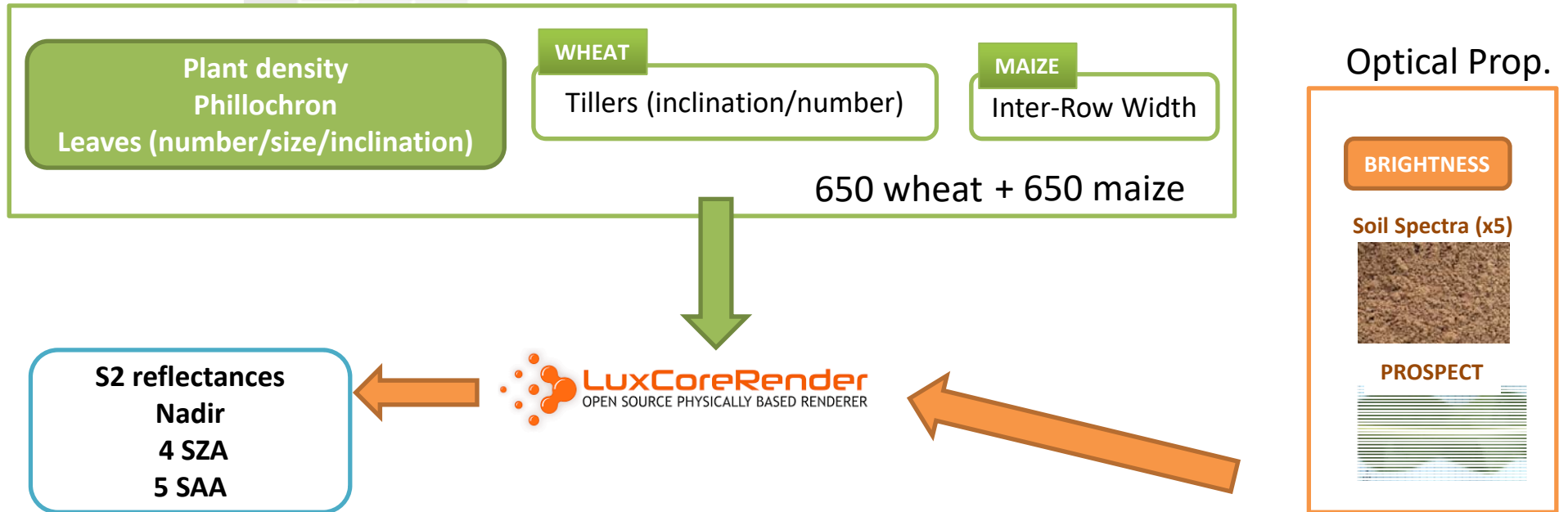


➤ RTM simulations

- PROSPECT: optical properties
- LuxCoreRender: ray tracing
- Validation with ROMC
- Fasten computation:
 - Decoupling soil/vegetation layers
 - Use the total absorption coefficient



The specific algorithm – 3DRTM simulations



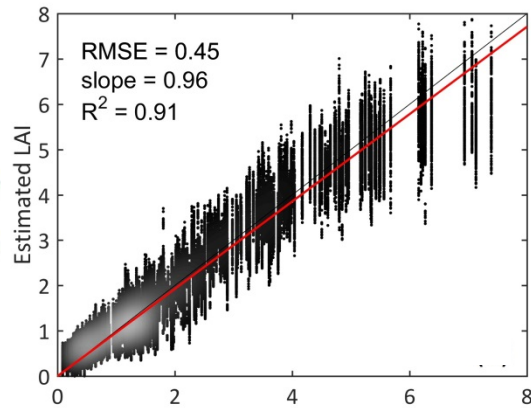
| | | | | | | | |
|-------------------------|------------------------------------------|-------|-------|-------|-------|---|---------|
| Leaf optical properties | Refractive Index n | 1.4 | | | | | |
| | Mesophyll, N | 1.5 | | | | | |
| | $C_{ab}(\mu\text{g}\cdot\text{cm}^{-2})$ | 20 | 90 | 45 | 30 | 5 | Gauss |
| | $C_{dm}(\text{g}\cdot\text{cm}^{-2})$ | 0.003 | 0.011 | 0.005 | 0.005 | 5 | Gauss |
| | C_{w_Rel} | 0.6 | 0.85 | 0.75 | 0.08 | 5 | Uniform |
| Soil background | C_{bp} | 0.0 | 2.0 | 0.0 | 0.3 | 3 | Gauss |
| | B_s | 0.5 | 3.5 | 1.2 | 2.0 | 5 | Gauss |

The generic algorithm (SNAP toolbox)

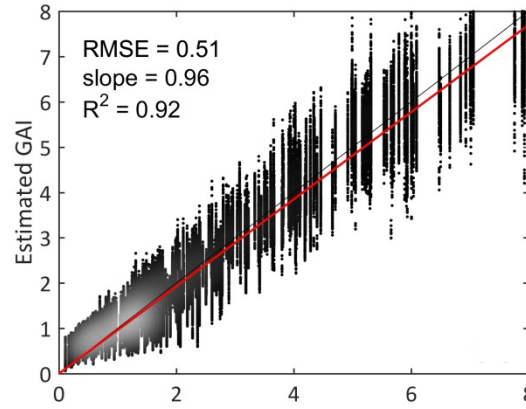
- Similar to the CYCLOPES product at 1km resolution
- Training data base = PROSAIL simulations, 1DRTM
- Distribution in agreement with 3D simulations

| | Input variable | Minimum | Maximum | Mean | Std | Class | Law |
|------------------|----------------|---------|---------|------|-----|-------|-------|
| Canopy structure | GAI | 0.0 | 8.0 | 2.0 | 3.0 | 6 | Gauss |
| | ALA (°) | 30 | 70 | 45 | 30 | 3 | Gauss |
| | hotspot | 0.1 | 0.5 | 0.2 | 0.5 | 1 | Gauss |

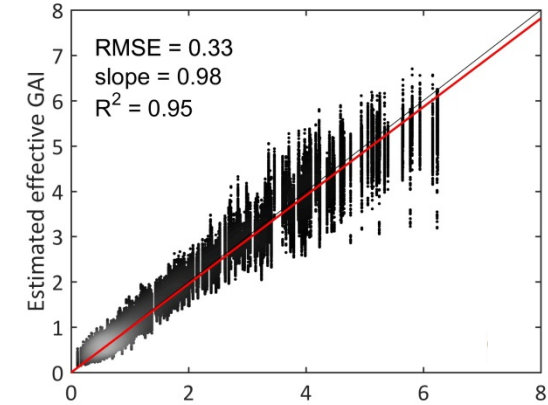
3D inversion - Specific – LAI definitions



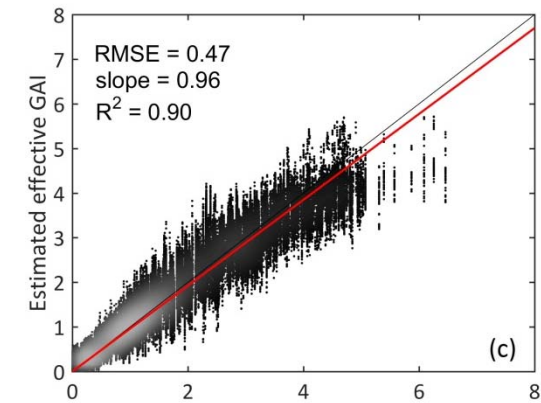
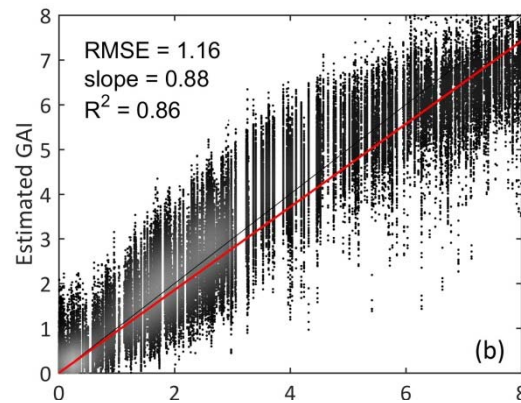
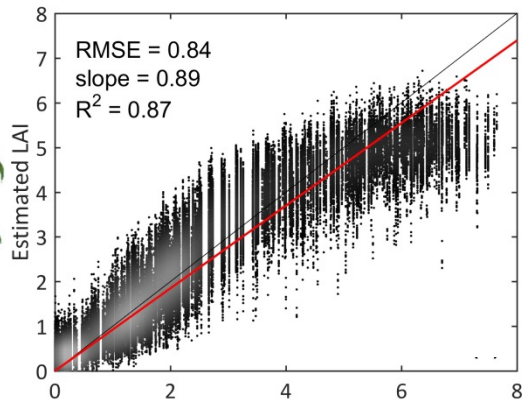
LAI



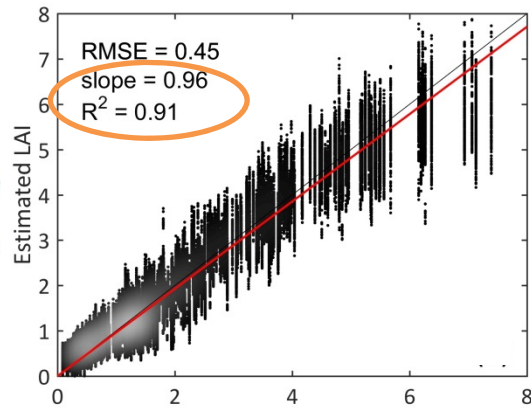
GAI



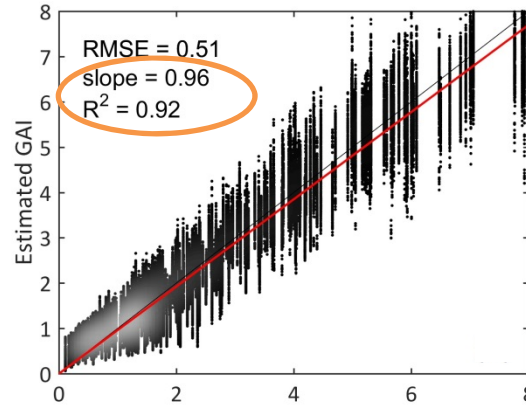
Effective GAI



3D inversion - Specific – LAI definitions

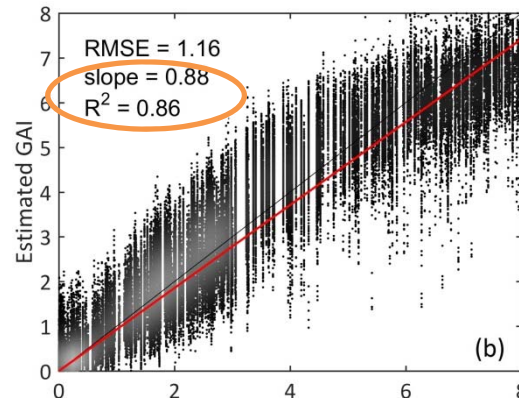
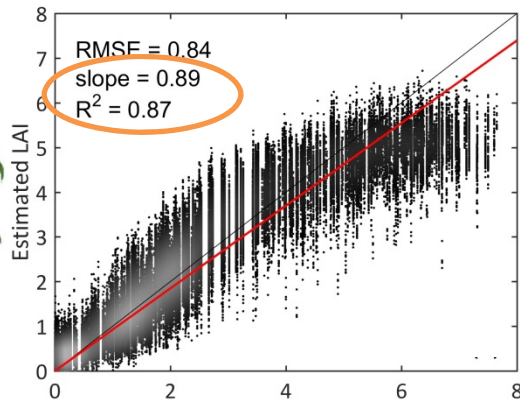


LAI



GAI

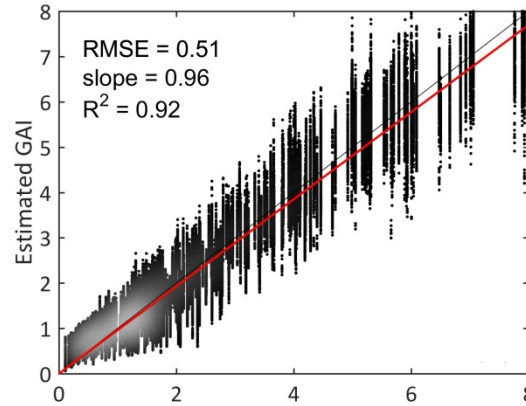
- Same R^2 and slope
- Higher RMSE, mainly due to the stems



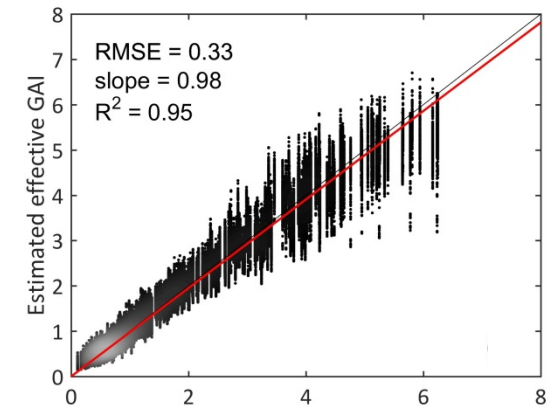
- Systematic underestimation high values = saturation

3D inversion - Specific – LAI definitions

- Effective GAI better estimated
- No bias



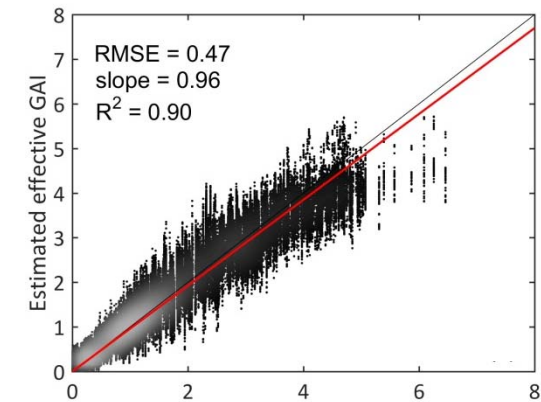
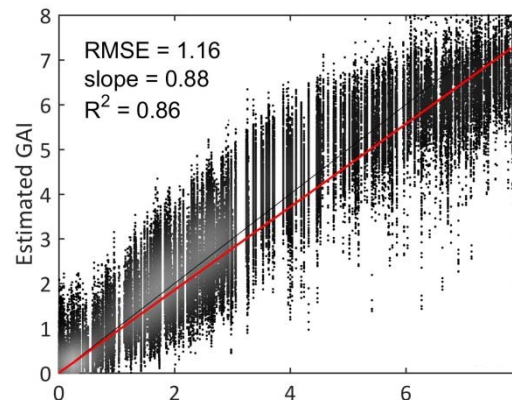
GAI



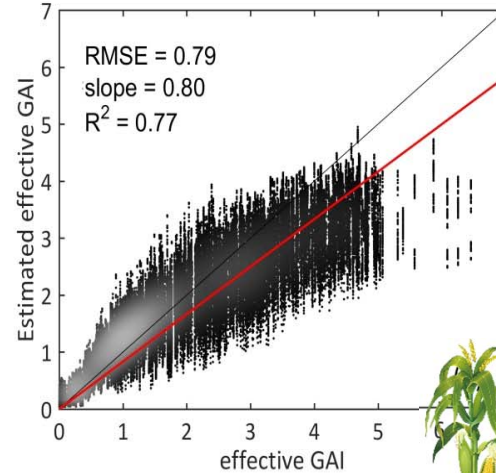
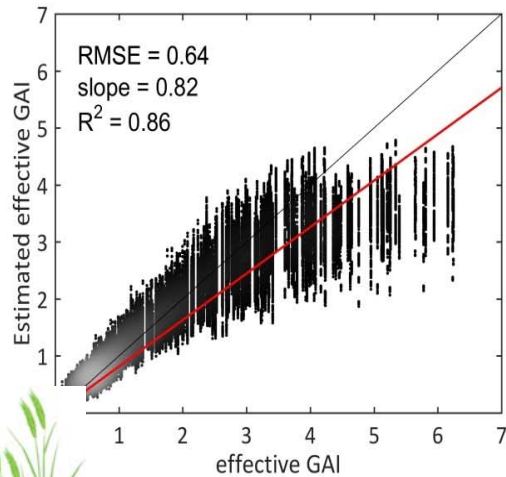
Effective GAI

- Saturation (improve training data base)

- Wheat better estimated than maize



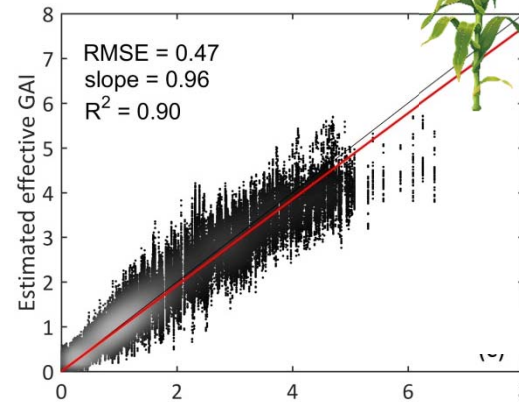
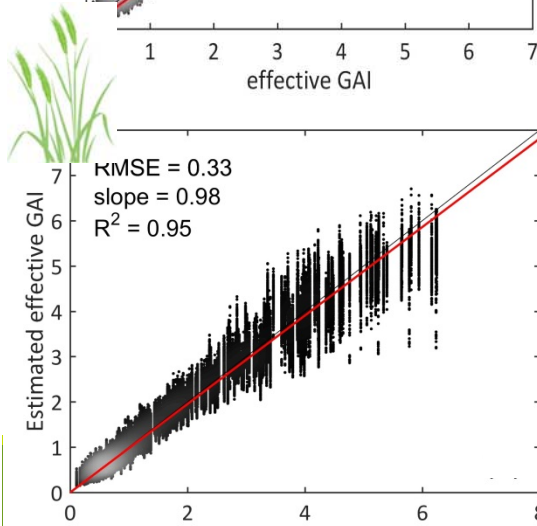
Crop Specific (3D NN) vs Generic (1DNN): effective GAI



1D
Inversion

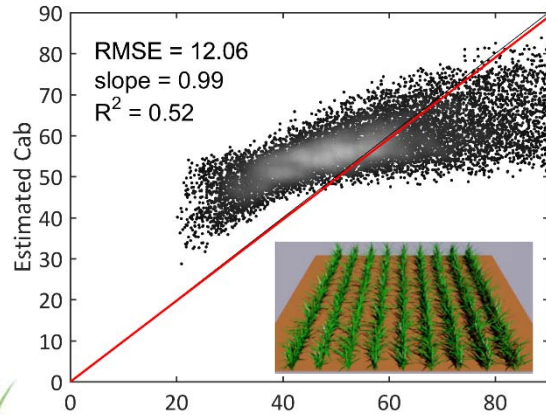
➤ 3D model provides better accuracy

➤ Less sensitive to sun position / row direction

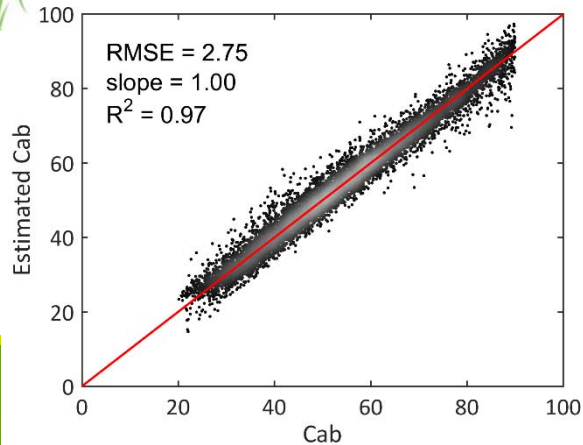
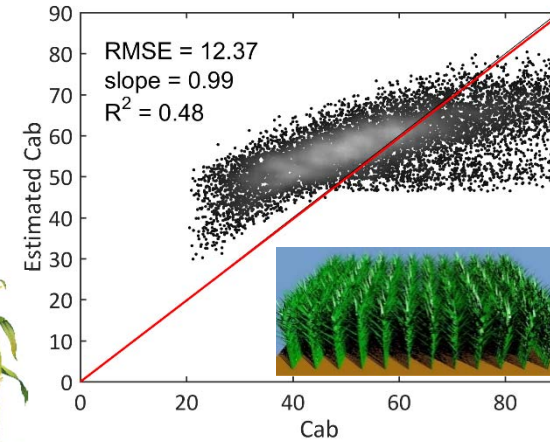


3D
Inversion

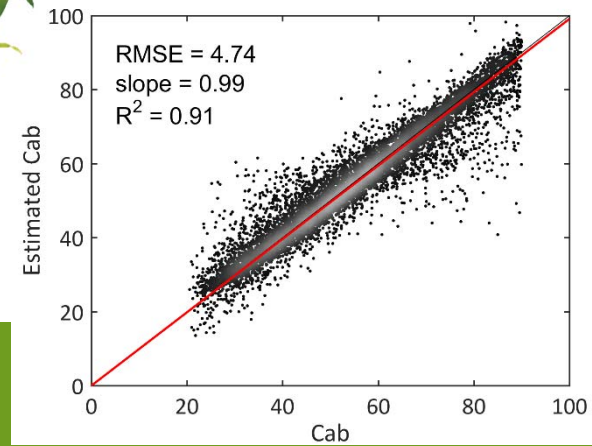
Generic vs Specific – Cab: comparison over simulations



1D
Inversion



3D
Inversion

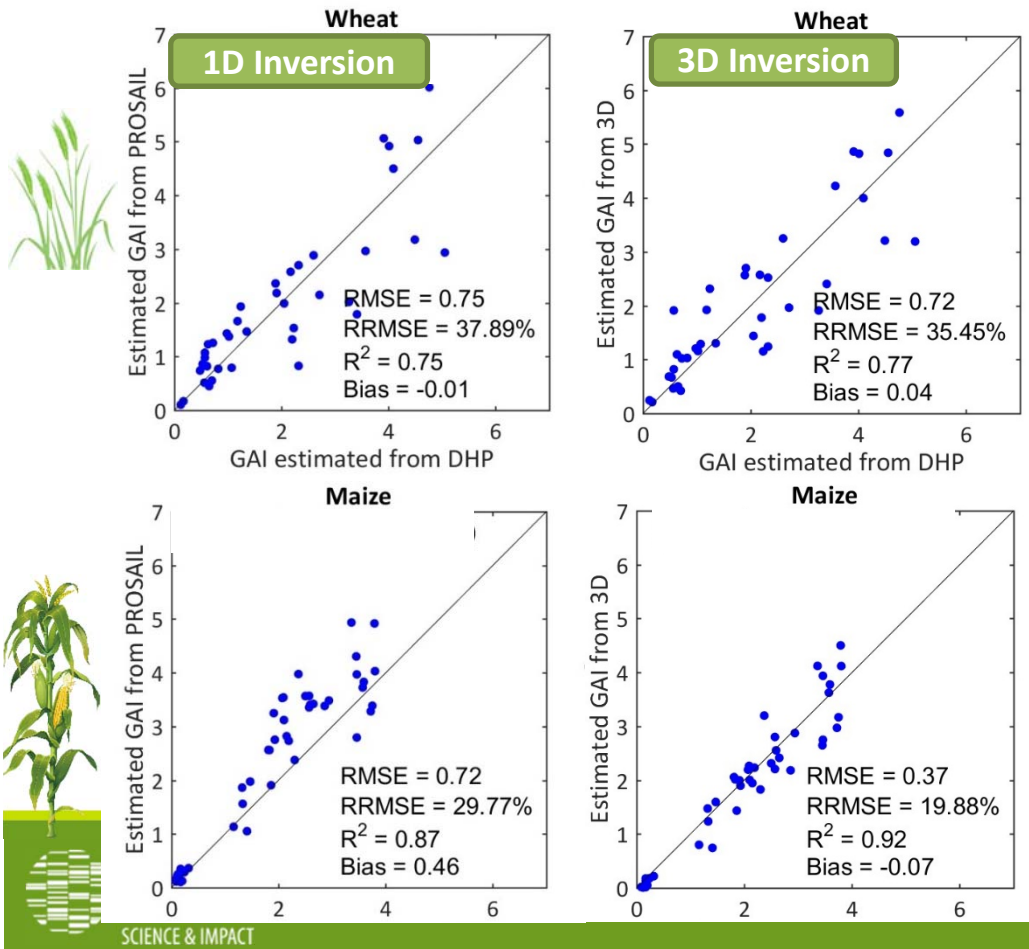




Validation against ground data

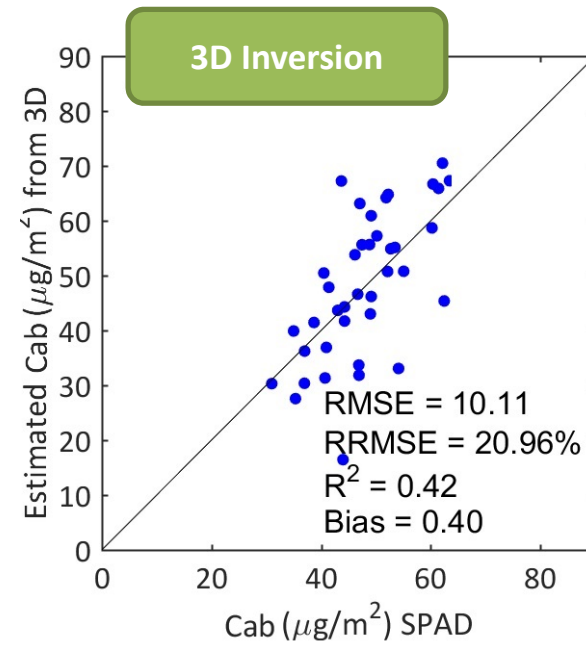
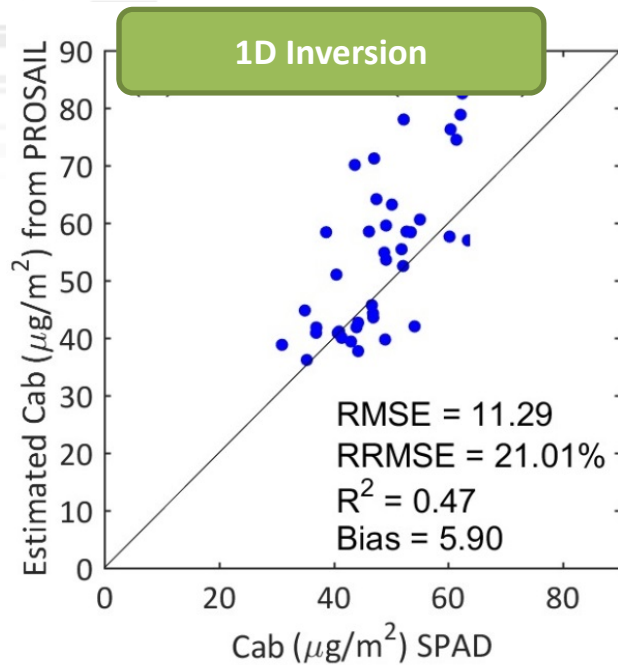
- P2S2 (see poster #222, Friday)
 - SENTINEL2
 - Digital Hemispherical Photographs, wheat (43) + maize (45)
 - SPAD

Generic vs Specific – effective GAI – P2S2 dataset



- Similar results on wheat
- Significant improvement on maize

Generic vs Specific – Leaf chlorophyll– P2S2 dataset



- Significant improvement for 3D simulations
- Need to be confirmed for maize

Conclusions

- 3D model inversion is more accurate
 - Especially for canopies far from the turbid medium assumption
 - 4D mock-ups
 - Growth limited to the period before earing/flowering
 - Other species?
- Effective GAI is better retrieved
 - PAI not investigated yet (not enough senescence)
 - To be accounted for in crop functioning models, process modeling
- Future work
 - Continue validation
 - Investigate data driven approach (machine learning)