

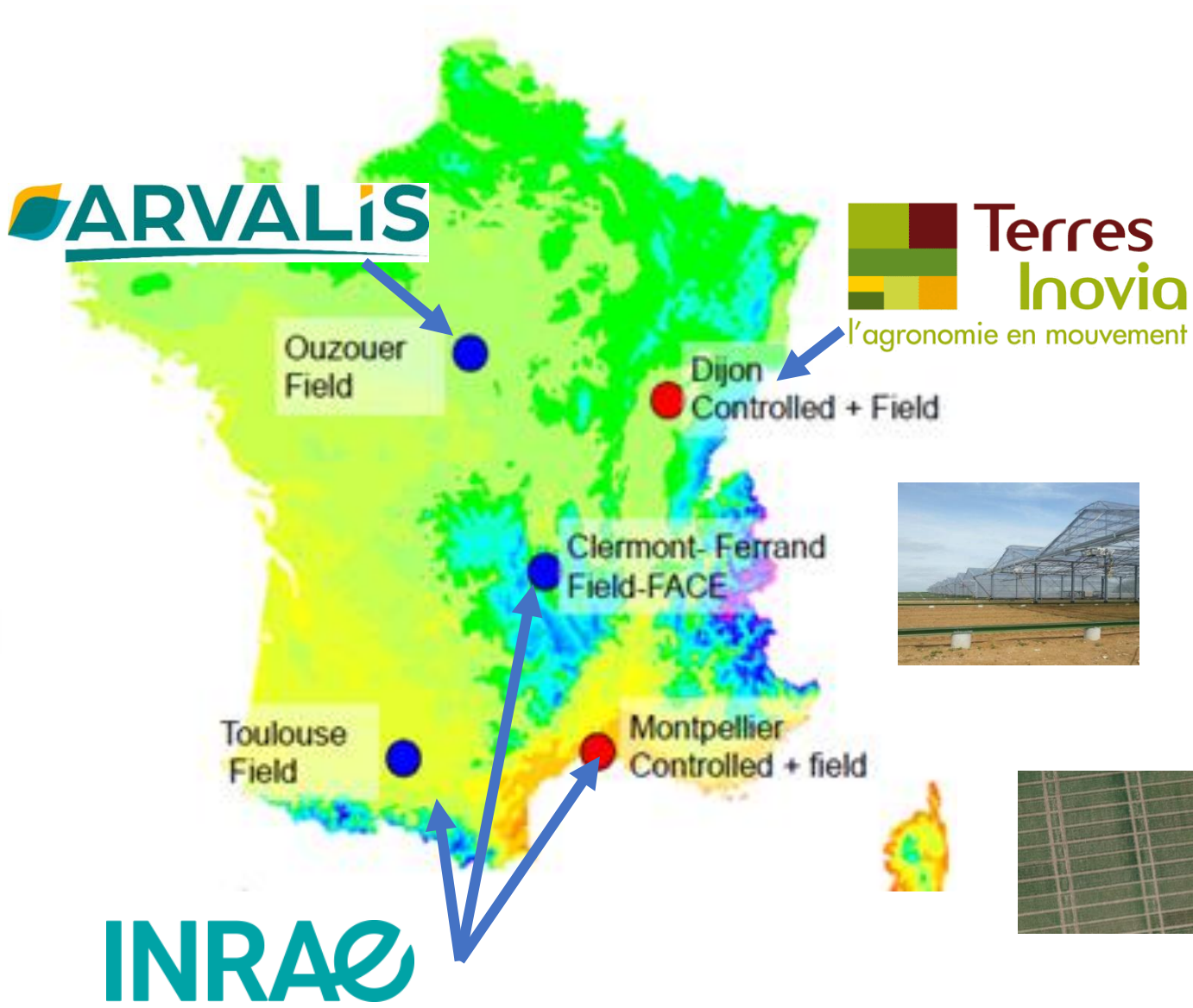
Systemes & chaines de traitement Phénotypage plein champ dans le réseau PHENOME

Marie Weiss, Raul Lopez-Lozano, Benoît De Solan

Au nom de l'UMT (LPA)  CAPTE



Infrastructure PHENOME : field experiments



Acquis Systems & Processing Pipelines

Systems & processing platforms

PHENOMOBILE V1/V2 PHENOFIELD

High/Low Crops
RGB/LiDAR/multispectral



DRONE

- Ground Meas.
- Photogrammetry
RGB/multispectral



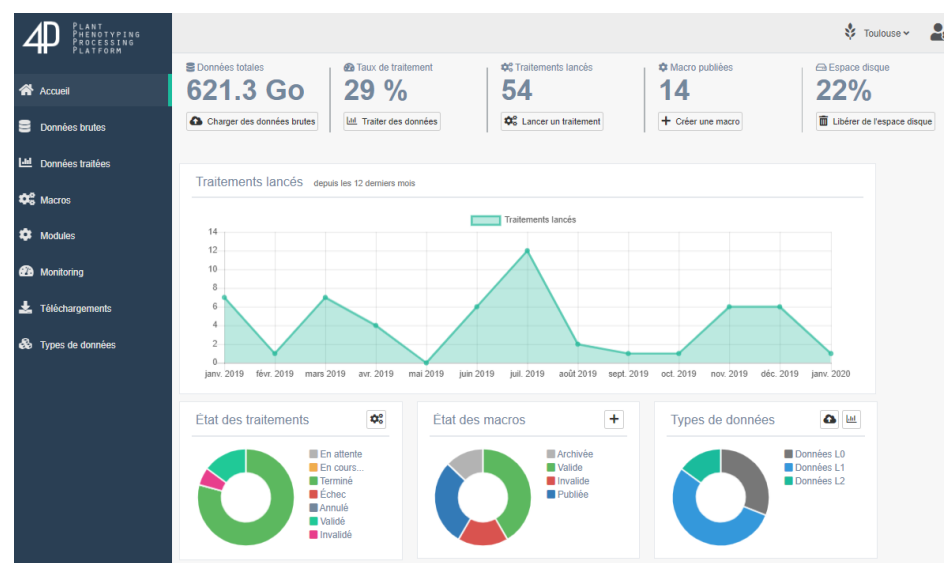
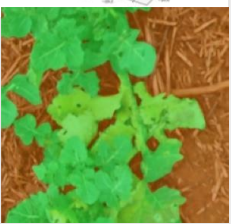
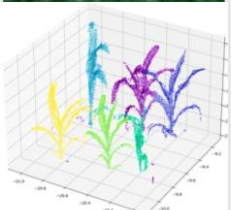
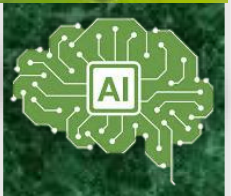
LITERAL

- Ground Meas.
- Stereovision
RGB(*multispectral*)



To Come
....

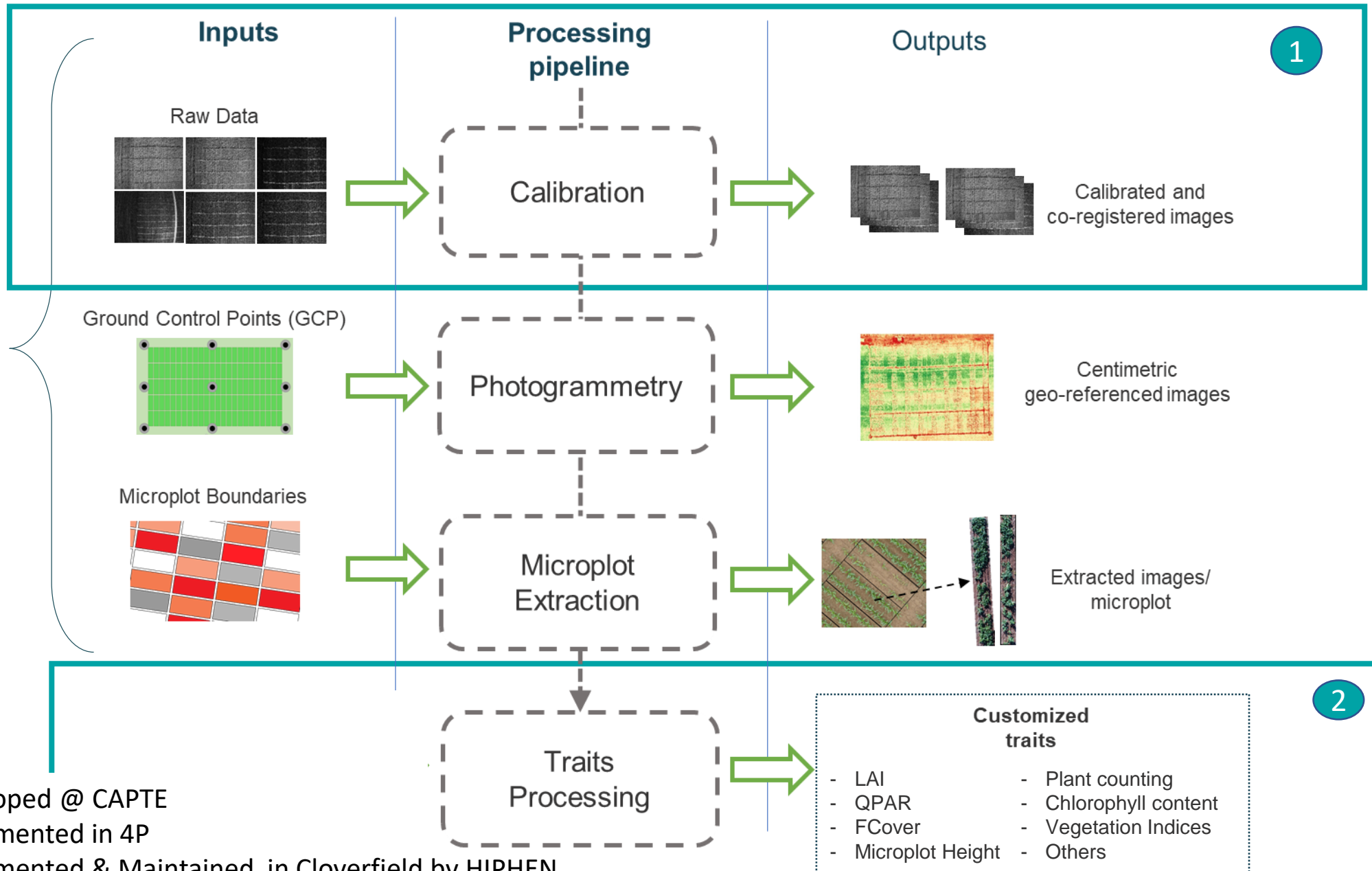
SENTINEL-2 PlanetScope Multispectral



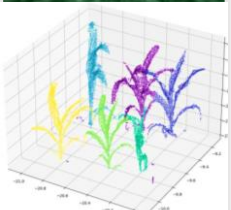
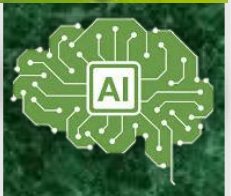
Plant Phenotyping
Processing Platform



Example of processing chain: PHENOSCRIPT



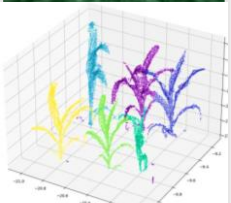
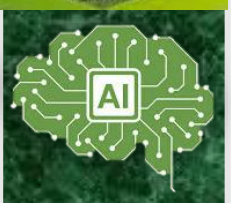
Developed @ CAPTE
 Implemented in 4P
 Implemented & Maintained in Cloverfield by HIPHEN



Traits and associated algorithms

TRAIT	METHOD	SENSOR			VECTOR			REFERENCE
		RGB	Multispectral	LiDAR	UAV	Phenomobile	LITERAL	
Plant height	Structure from motion/stereo		█					Madec et al., 2017 Weiss et al, 2017 Jay et al, en prep.
	Height Distribution			█				Madec et al., 2017
Vegetation Fraction (VF)	DL segmentation	█						Madec et al., 2022
	Height threshold			█				Lopez-Lozano et al., 2022
Green Fraction (GF)	VI Empirical		█					Jiang et al, 2018 Jay et al, 2019
	ML & DL segmentation	█						Serouart et al., 2022 Madec et al., 2022
	1D RTM inversion		█					Djamai et al, 2019 Camacho et al, 2021
Green Area Index (GAI)	VI Empirical		█					Jiang et al, 2018 Jay et al, 2019 Camacho, 2021
	1D RTM inversion		█					Djamai et al, 2019 Jay et al, 2019 Camacho et al, 2021
	3D RTM inversion			█				Liu et al., 2017 Jiang et al, 2019, 2020 Li et al, 2021 Soma et al, en prep
Plant Area Index (PAI)	1D Turbid			█				Lopez-Lozano et al., 2022

TRAIT	METHOD	SENSOR			VECTOR			REFERENCE
		RGB	Multispectral	LiDAR	UAV	Phenomobile	LITERAL	
Fraction of Intercepted Radiation (FIPAR) & fAPAR	VI Empirical		█					Camacho et al, 2021
	1D RTM inversion		█					Jiang et al, 2017 Liu et al., 2019 Li et al, 2021 Camacho et al, 2021
	3D RTM inversion			█				Jiang et al., 2017
Average Inclination Angle (AIA)	1D RTM inversion		█					Liu et al., 2022
	1D Turbid			█				Lopez-Lozano et al., en prep Liu et al., 2019
	3D RTM inversion			█				Jiang et al., 2019
Canopy Chlorophyll Content (CCC)	1D RTM inversion		█					Delloye et al, 2018
	VI Empirical		█					Jay et al., 2019
Canopy Water Content (CWC)	1D RTM inversion							Djamai et al, 2019
3D Distribution of Leaf Area	1D Turbid			█				Liu et al., 2017 Soma et al, en prep
Plant density	DL	█						Jin et al., 2017 Velumani et al, 2021
Stem density	DL @ harvest	█						Jin et al., 2019
Stem diameter	DL @ harvest	█						Jin et al., 2019
Ear density	DL @ reprod, stage	█						Madec et al., 2019
Leaf Chlorophyll Content	1D RTM inversion		█					Jiang et al, 2018
	VI ML, Empirical	█	█					Jay et al., 2017, 2019 Jay et al, en prep
Disease	ML Segmentation	█	█					Jay et al, 2020

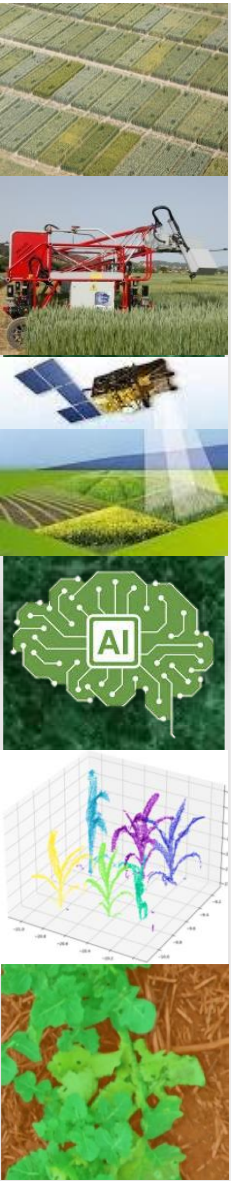


Traits and associated algorithms

TRAIT	METHOD	SENSOR			VECTOR			REFERENCE
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	Height Distribution			█				
Vegetation Fraction (VF)	DL segmentation	█						
	Height threshold			█				Lopez-Lozano et al., 2022
Green Fraction (GF)	VI Empirical		█					Jiang et al, 2018 Jay et al, 2019
	ML & DL segmentation	█						Serouart et al., 2022 Madec et al., 2022
	1D RTM inversion		█					Djamai et al, 2019 Camacho et al, 2021
Green Area Index (GAI)	VI Empirical		█					Jiang et al, 2018 Jay et al, 2019 Camacho, 2021
	1D RTM inversion		█					Djamai et al, 2019 Jay et al, 2019 Camacho et al, 2021
	3D RTM inversion			█				Liu et al., 2017 Jiang et al, 2019, 2020 Li et al, 2021 Soma et al, en prep
Plant Area Index (PAI)	1D Turbid			█				Lopez-Lozano et al., 2022

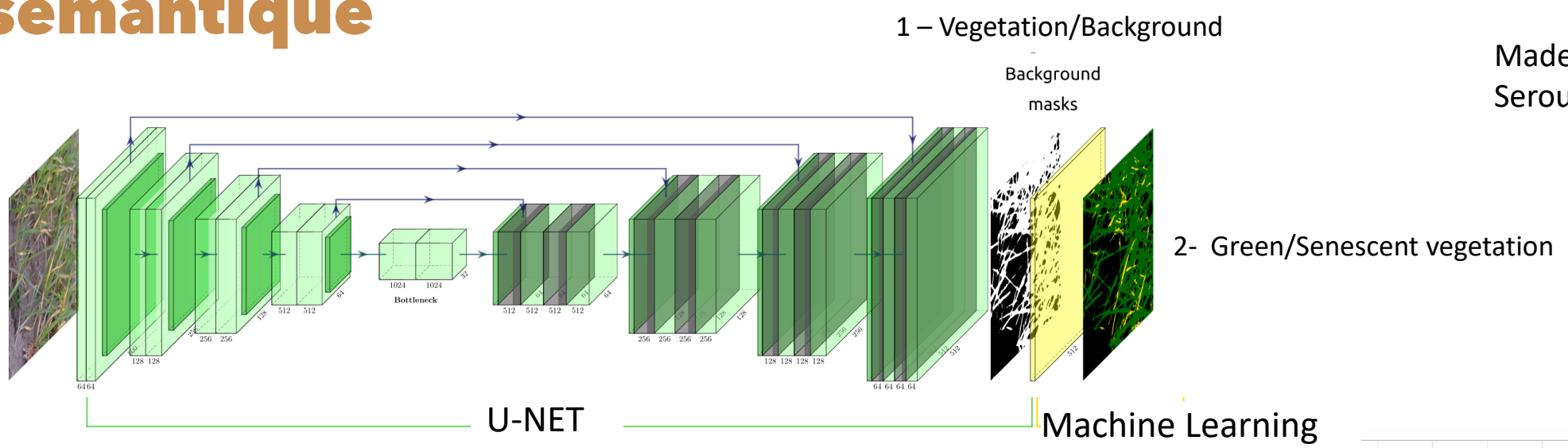
Deep learning for segmentation and object detection (RGB image, 3D point cloud)

TRAIT	METHOD	SENSOR			VECTOR			REFERENCE
		RGB	Multispectral	LiDAR	UAV	Phenomobile	LITERAL	
Fraction of Intercepted	VI Empirical		█					Camacho et al, 2021
	1D RTM inversion		█					Jiang et al, 2017 Liu et al., 2019 Li et al, 2021 Camacho et al, 2021 et al., 2017
Average Inclination Angle (AIA)	1D Turbid			█				Lopez-Lozano et al., en prep Liu et al., 2019
	3D RTM inversion						█	Jiang et al., 2019
Canopy Chlorophyll Content (CCC)	1D RTM inversion		█					Delloye et al, 2018
	VI Empirical		█					Jay et al., 2019
Canopy Water Content (CWC)	1D RTM inversion						█	Djamai et al, 2019
3D Distribution of Leaf Area	1D Turbid			█				Liu et al., 2017 Soma et al, en prep
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Stem density	DL @ harvest	█						Jin et al., 2019
Stem diameter	DL @ harvest	█						Jin et al., 2019
Ear density	DL @ reprod, stage	█						Madec et al., 2019
Leaf Chlorophyll Content	1D RTM inversion		█					Jiang et al, 2018
	VI ML, Empirical	█	█					Jay et al., 2017, 2019 Jay et al, en prep
Disease	ML Segmentation	█	█					Jay et al, 2020

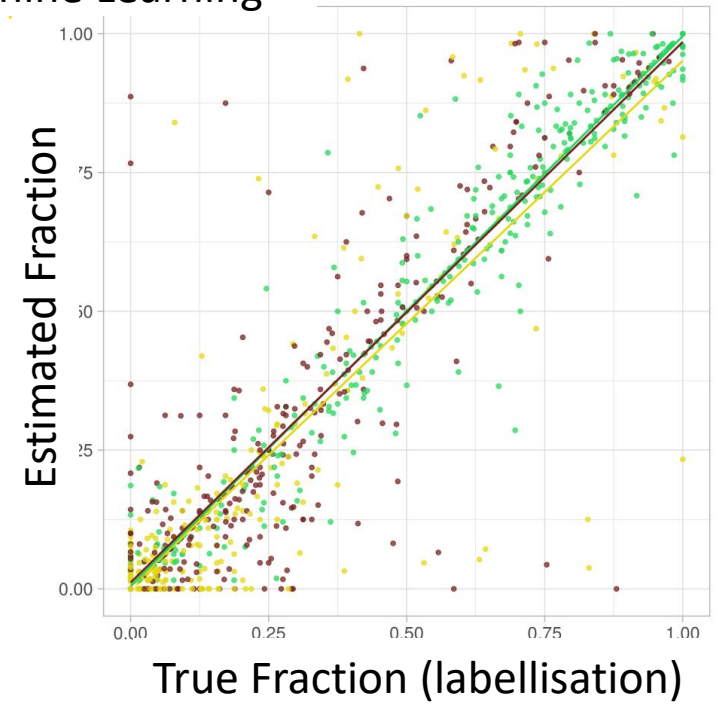


Deep & Machine Learning pour la segmentation sémantique

Madec et al, Accepted
Serouart et al, 2022



- Ground fraction (no veg)
- Green Fraction
- Senescent Fraction



Deep Learning for object detection

David et al, 2020
David et al, 2021



Ear Detection(densité)

Global Wheat Head dataset
16 partners
6000 images, 275000 ears

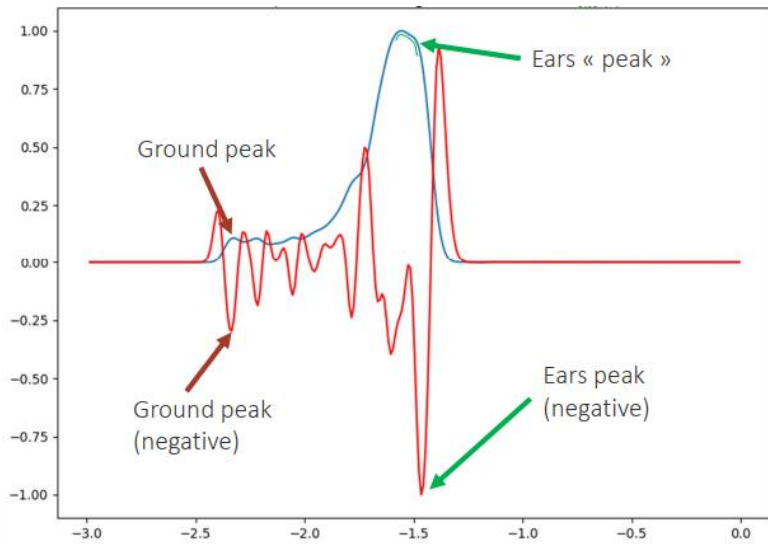
Global Wheat challenge (2020, 2021):

Solution name	WDA	
randomTeamName (1 st place)	0.700	Challenge Results
David_jeon (2 nd place)	0.695	
SMART (2 nd place)	0.695	
Reference (faster-RCNN)	0.492	Result before challenge

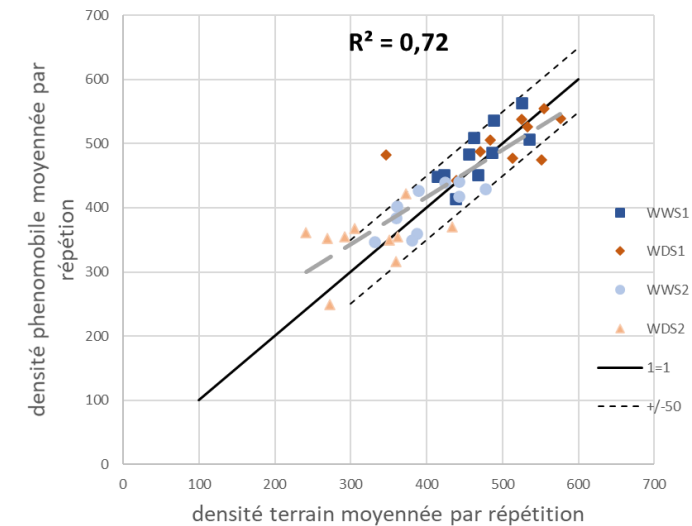
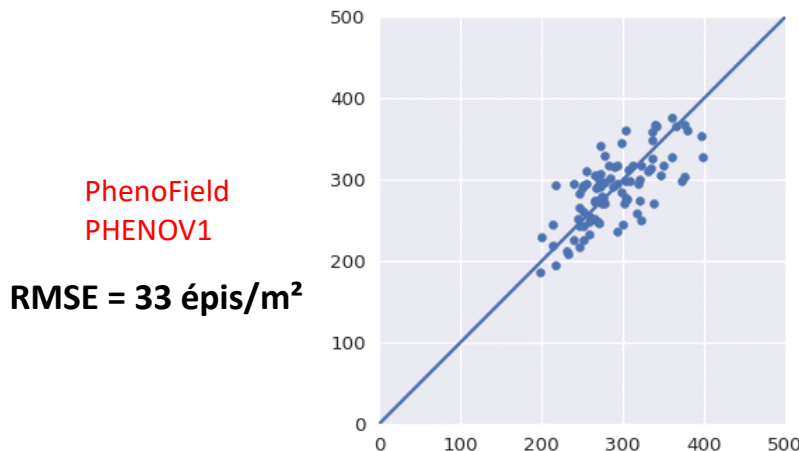
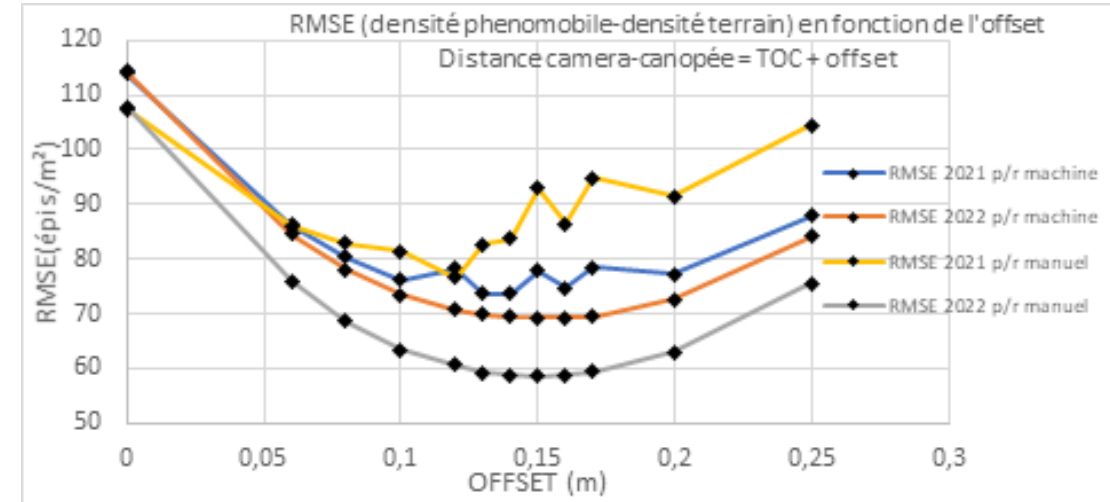


From Ear detection to Ear density: fusing RGB and LiDAR information

LiDAR height not stabilized
 Second derivative of intensity distribution
 Automatic Peak Detection



LiDAR height stabilized
 Estimate offset between LiDAR and RGB camera position

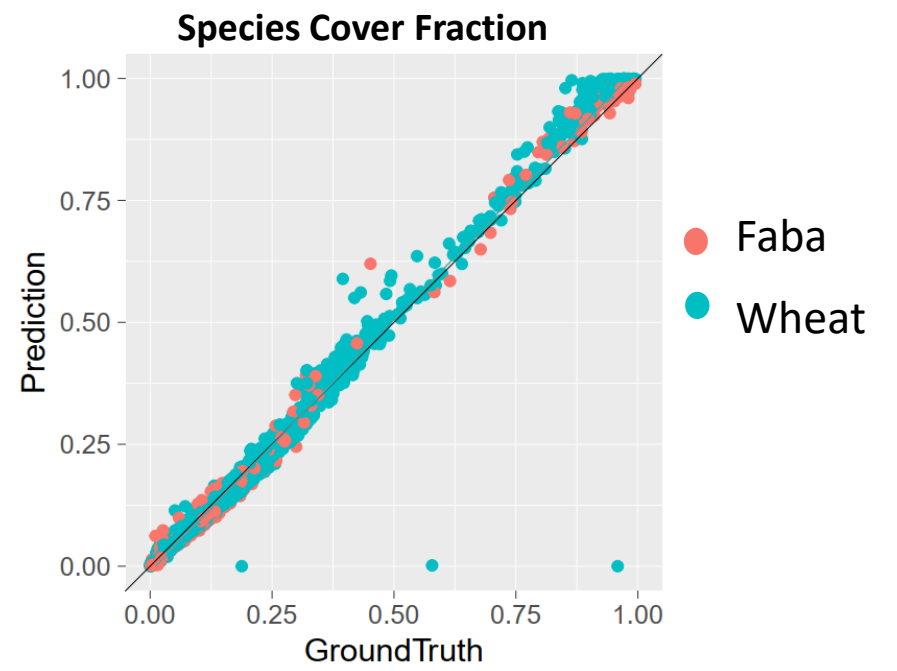
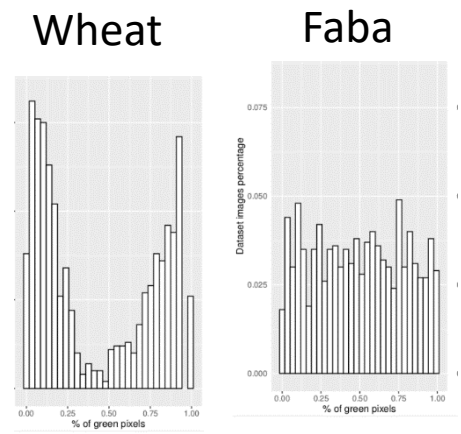
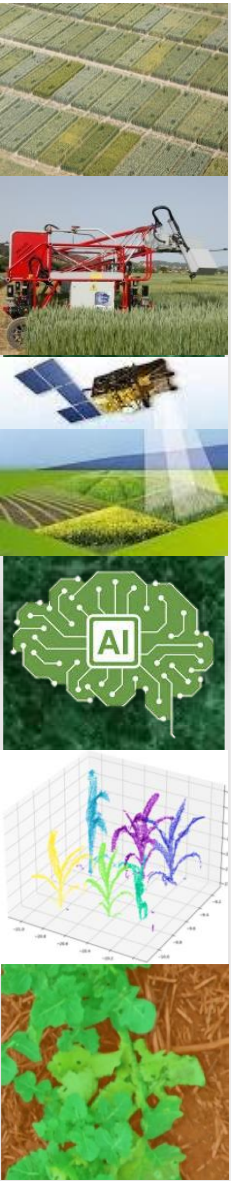


In Dev: mixed crops

T. Dubos, S. Jay, M. Weiss
L. Bernigaud, B. De Solan,

Limitating annotation workload by exploiting the SEGVEG results

Annotation
 1000 Pure Wheat (Segveg)
 1000 Vicia Faba (Segveg)
 +250 mixed (Segveg+manual)



Traits and associated algorithms

**Traits derived from multispectral acquisition
Data or radiative transfer model driven approaches**

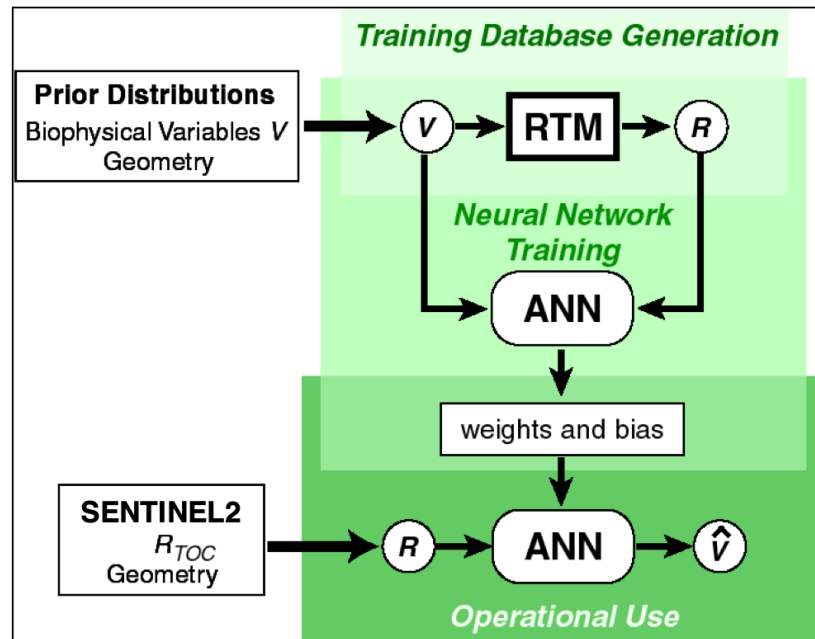
TRAIT	METHOD	SENSOR			VECTOR			REFERENCE
		RGB	Multispectral	LiDAR	UAV	Phenobile	LITERAL	
Vegetation Fraction (VF)	Height Distribution							Madec et al., 2017
	DL segmentation							Madec et al., 2022
	Height threshold							Lopez-Lozano et al., 2022
Green Fraction (GF)	VI Empirical							Jiang et al, 2018 Jay et al, 2019
	ML & DL segmentation							Serouart et al., 2022 Madec et al., 2022
	1D RTM inversion							Djamai et al, 2019 Camacho et al, 2021
Green Area Index (GAI)	VI Empirical							Jiang et al, 2018 Jay et al, 2019 Camacho, 2021
	1D RTM inversion							Djamai et al, 2019 Jay et al, 2019 Camacho et al, 2021
	3D RTM inversion							Liu et al., 2017 Jiang et al, 2019, 2020 Li et al, 2021 Soma et al, en prep
Plant Area Index (PAI)	1D Turbid						Lopez-Lozano et al., 2022	

TRAIT	METHOD	SENSOR			VECTOR			REFERENCE
		RGB	Multispectral	LiDAR	UAV	Phenobile	LITERAL	
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	3D RTM inversion							Jiang et al., 2017
Average Inclination Angle (AIA)	1D RTM inversion							Liu et al., 2022
	1D Turbid							Lopez-Lozano et al., en prep Liu et al., 2019
Canopy Chlorophyll Content (CCC)	1D RTM inversion							Jiang et al., 2019
	VI empirical							Delloye et al, 2018 Jay et al., 2019
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Stem density	DL @ harvest							Jin et al., 2019
Stem diameter	DL @ harvest							Jin et al., 2019
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Leaf Chlorophyll Content	1D RTM inversion							Jiang et al, 2018
	VI ML, empirical							Jay et al., 2017, 2019 Jay et al, en prep
Disease	ML Segmentation							Jay et al, 2020

Multispectral & Radiative Transfer Model Inversion

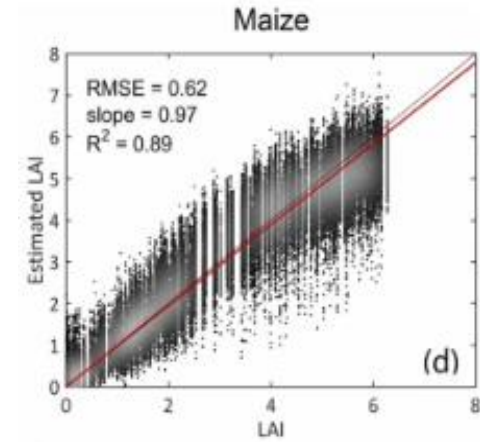
Green Area Index (GAI)
Leaf area Index (LAI)

Methods, based on radiative transfer models (RTM), were originally developed by remote sensing community

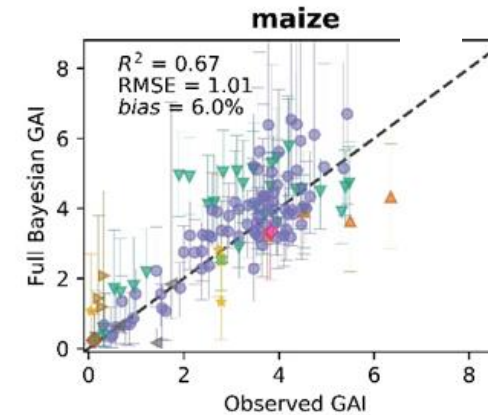


Weiss & Baret, 2016

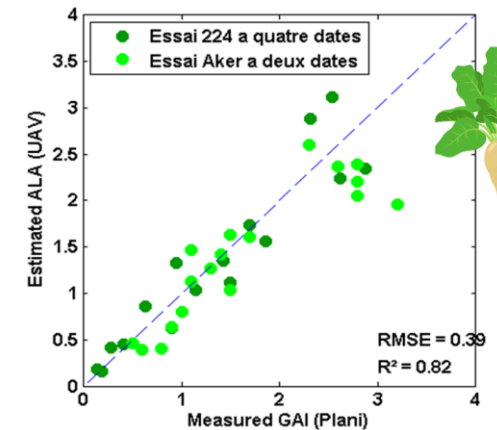
*Numerical experiment
3D mock-Up and RTM*
Jiang et al, 2022



*Actual experiment –
satellites Landsat8,
Sentinel 2*
Wang et al, 2022



*UAV multispectral
imagery*

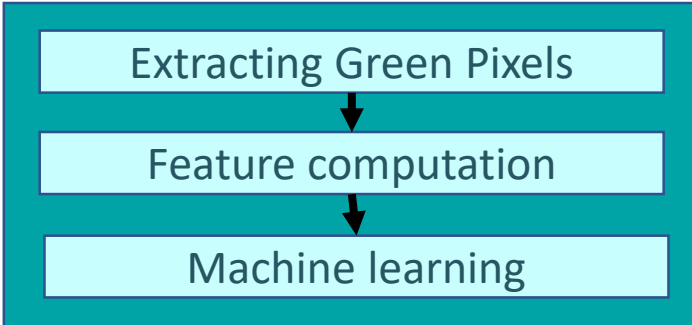


Multispectral, Data Driven (UAV)

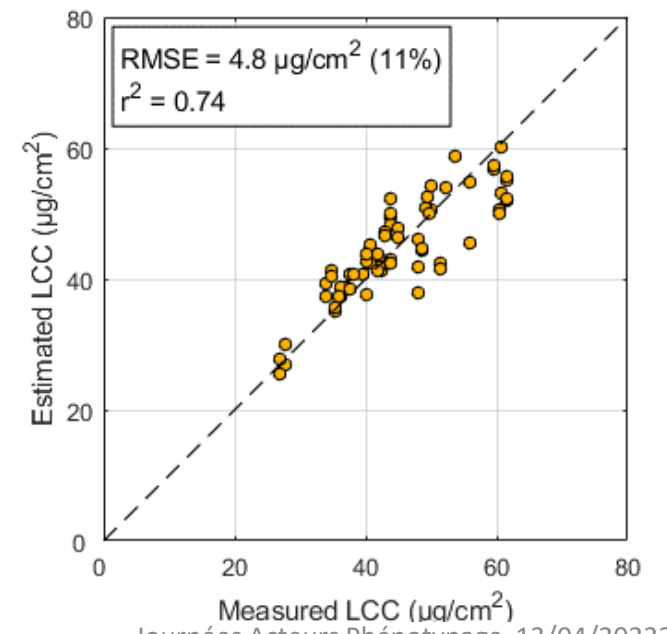
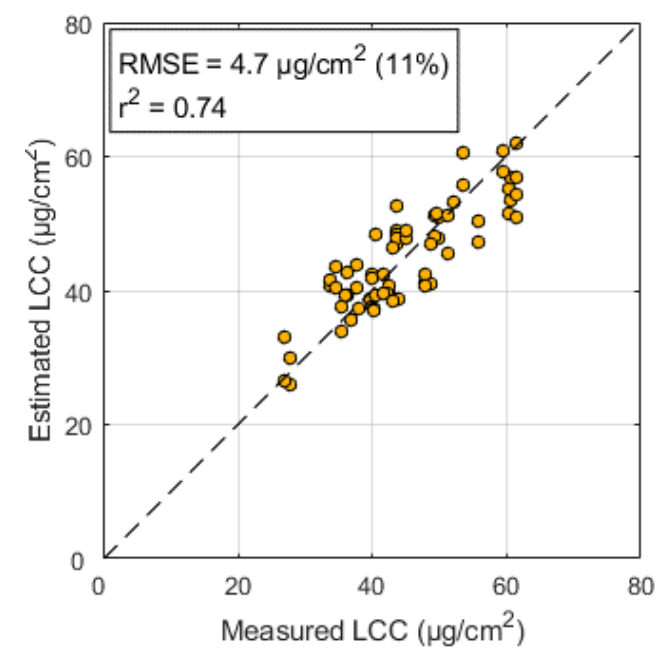
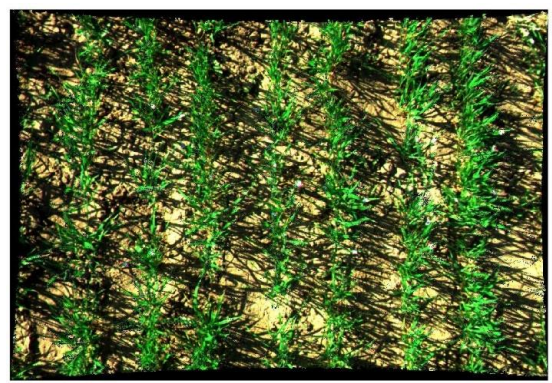
RGB



Jay et al, RSE, 2019 (sugar beet)

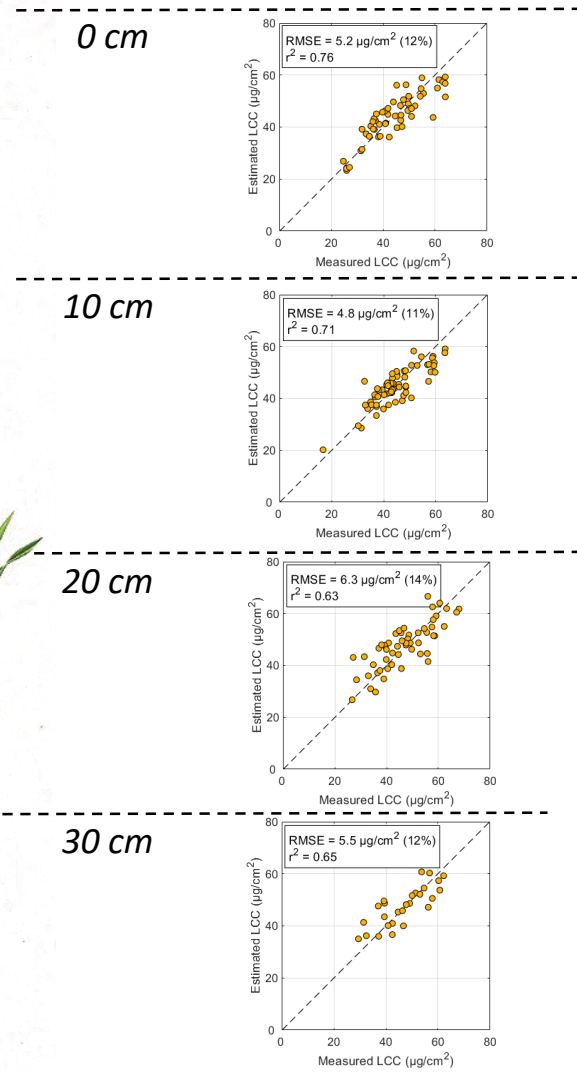
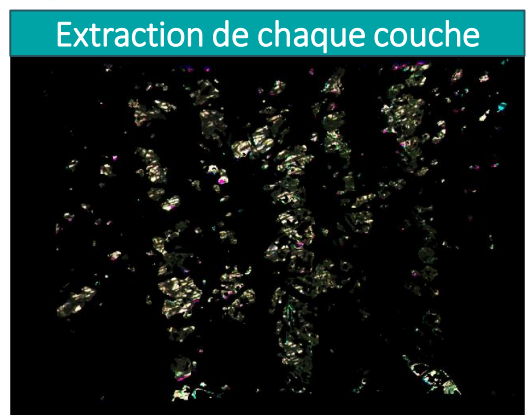
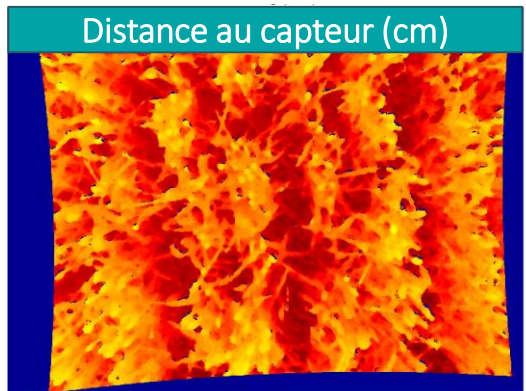
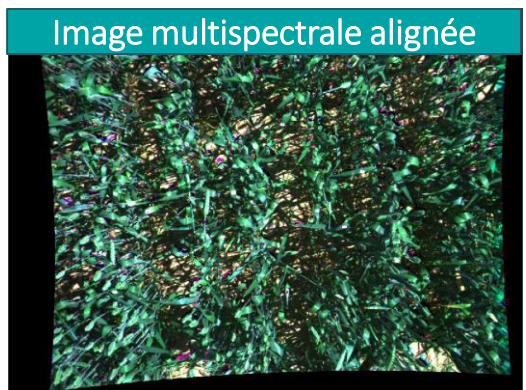


Multispectral



In dev: multispectral & Ground Level: Chlorophyll Vertical Profile

Jay et al, 2023, In preparation (wheat, RGB vs multispectral)



Distance to TOC

Traits and associated algorithms

Architecture & Point Clouds (LiDAR/Stéréovision)



TRAIT	METHOD	SENSOR						REFERENCE
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Plant height	Structure from motion/stereo							Madec et al., 2017 Weiss et al, 2017 Jay et al, en prep.
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	3D RTM inversion							Liu et al., 2017 Jiang et al, 2019, 2020 Li et al, 2021 Soma et al, en prep
Plant Area Index (PAI)	1D Turbid						Lopez-Lozano et al., 2022	

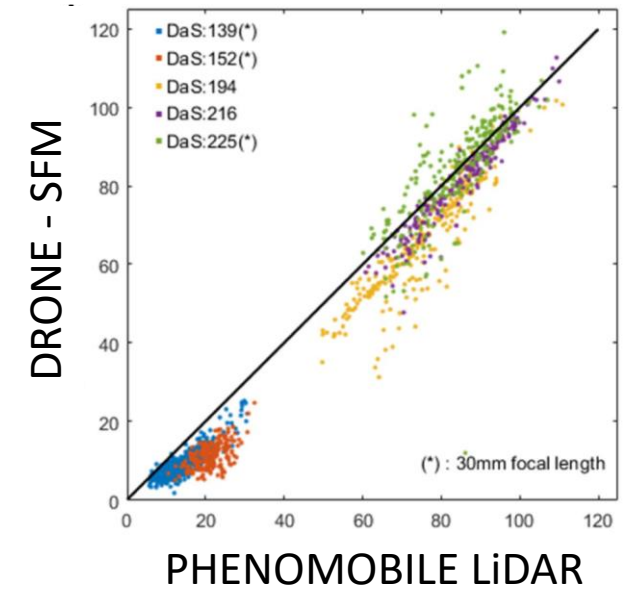
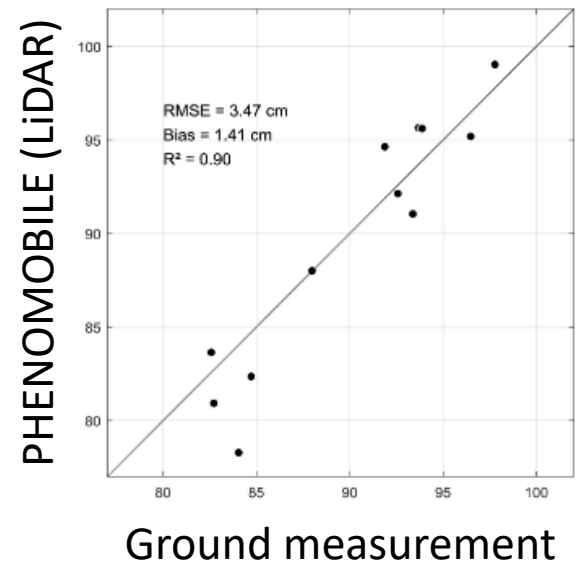
TRAIT	METHOD	SENSOR						REFERENCE
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	VI ML, Empirical							Jay et al., 2017, 2019 Jay et al, en prep
Disease	ML Segmentation							Jay et al, 2020

LiDAR, Photogrammetry & 3D Point Cloud: height



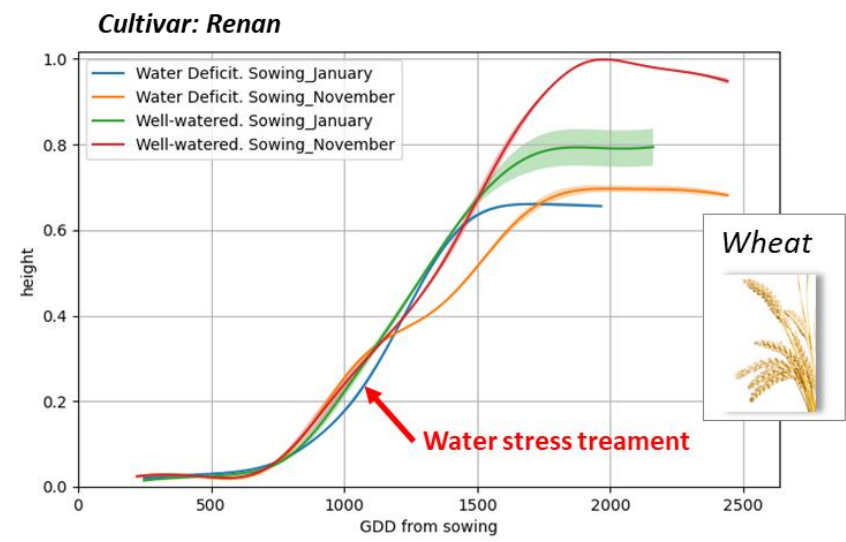
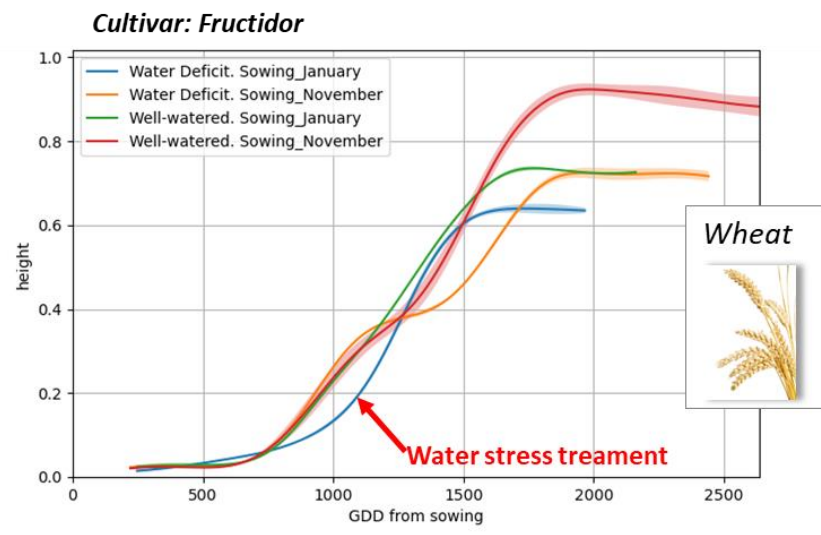
Canopy height

Validation with ground measurements, cross-comparison UAV (SfM), et LiDAR

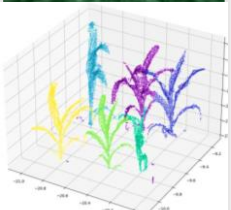
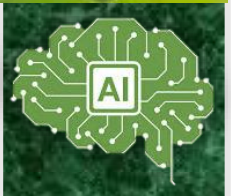


Madec et al, 2017

Operational: monitoring height dynamics of cultivars (Phenomobile-LiDAR)

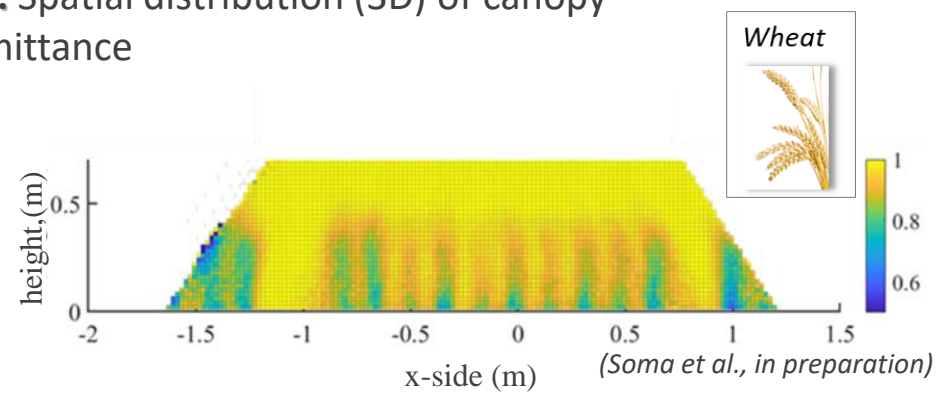


Projet ANR-FFAST @ DIASCOPE, R. Lopez-Lozano

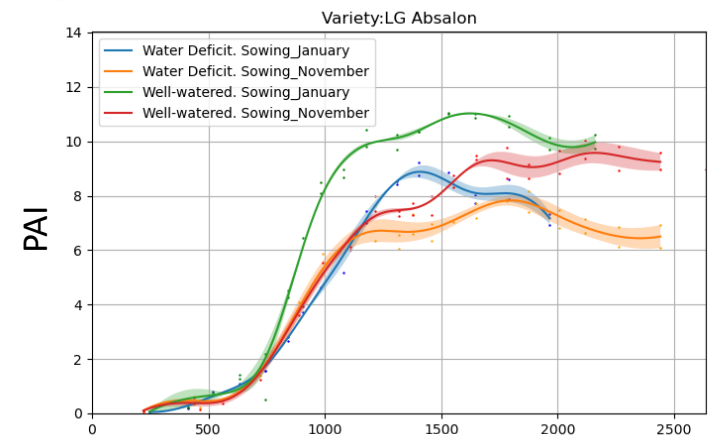


LiDAR, Photogrammetry & 3D Point Cloud: GAI

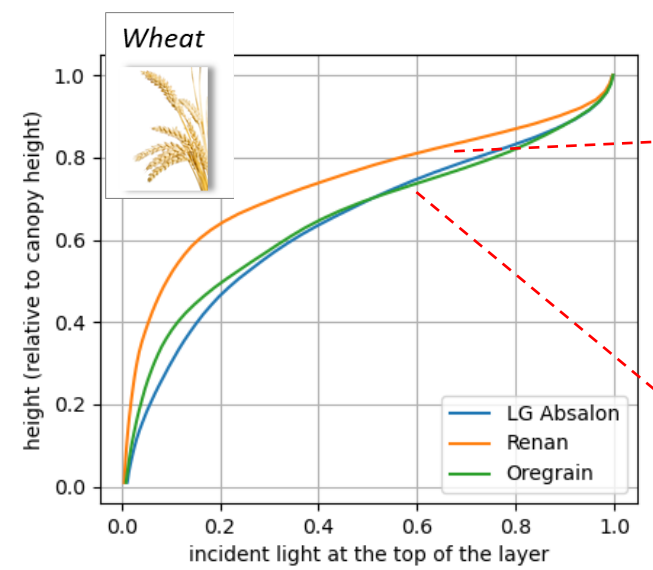
LiDAR: Spatial distribution (3D) of canopy transmittance



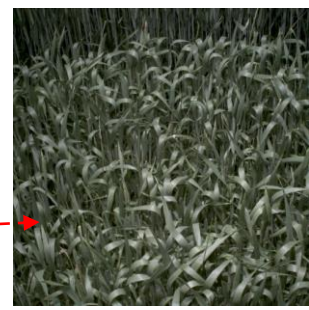
Plant area index (leaves + stems) – PAI / PAD



Vertical profile of light transmission



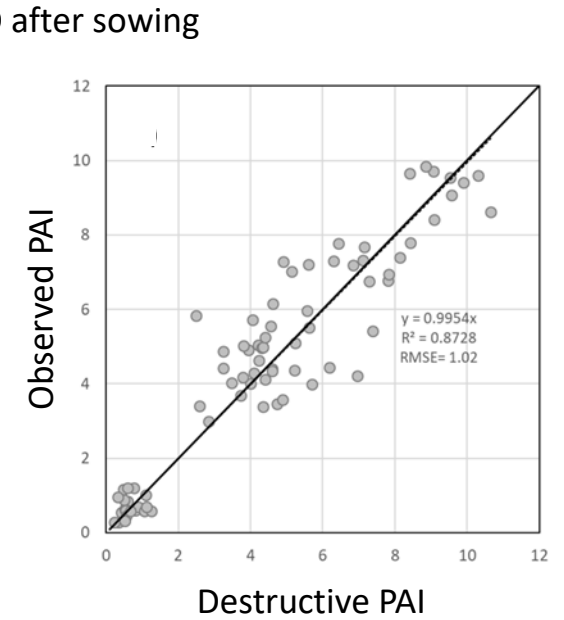
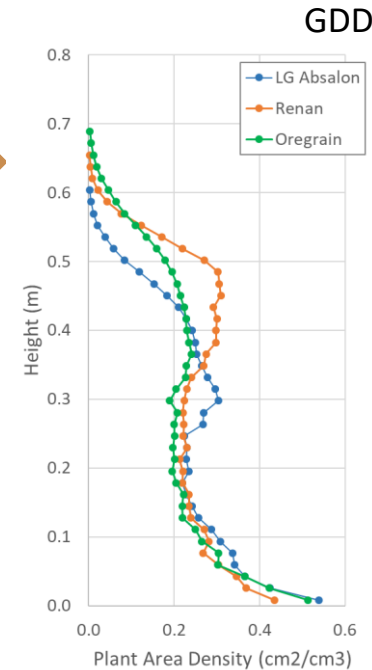
Renan



LG Absalon

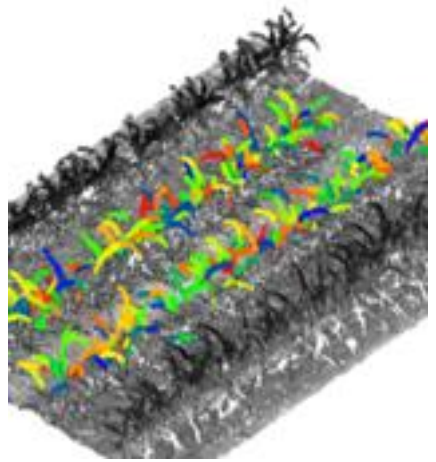


Physical Model

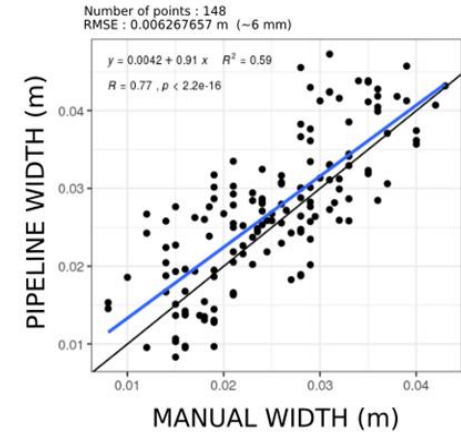
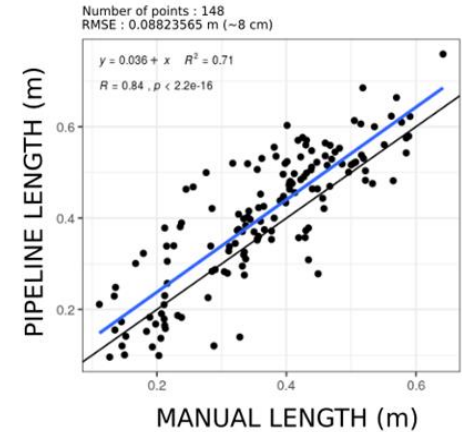


On study: Leaf Morphology from 3D point Cloud

M. Serouart, R. Lopez-Lozano, B. de Solan

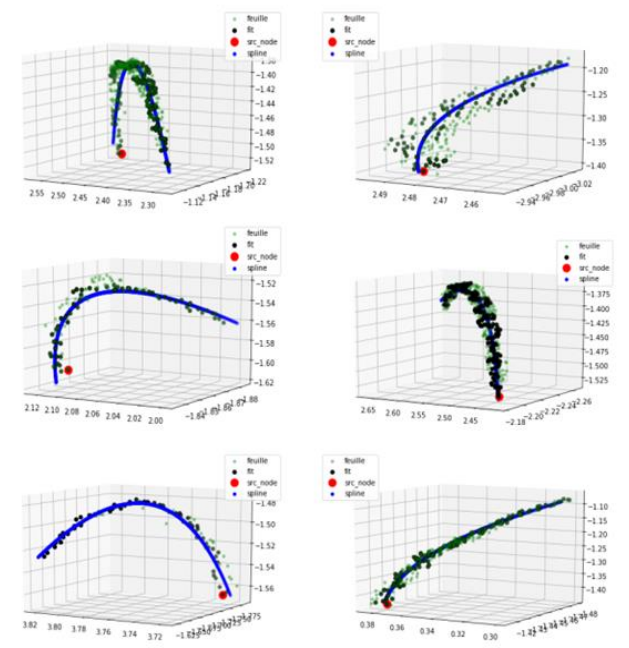


Width, Length



Curvature

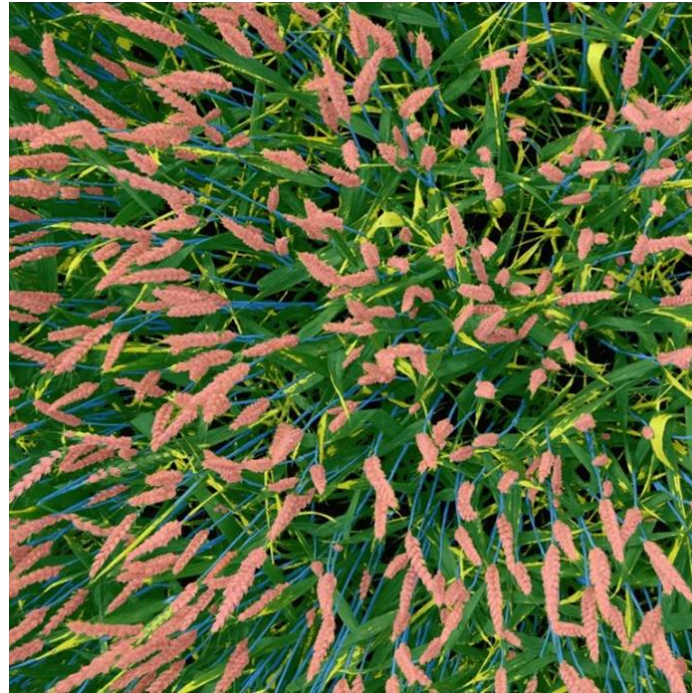
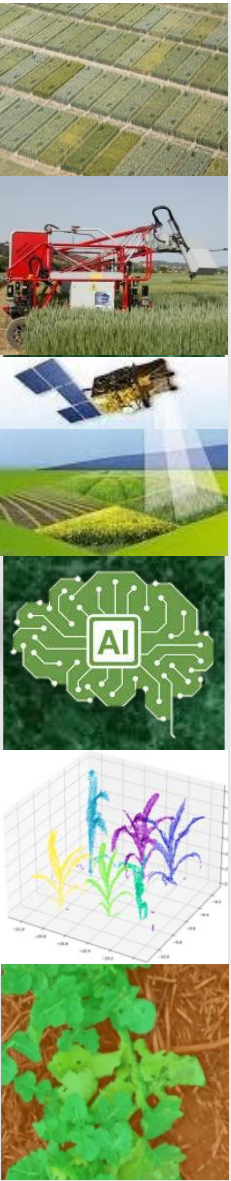
EXEMPLES FEUILLES EXTRAITES + SPLINE COURBE POUR LONGUEUR



Follow-up of GWHD

L. Bernigaud, B. de Solan,
M-P d'Argaignon,
R. Lopez-Lozano, M.Weiss

Global Wheat Segmentation Data set & challenge



Same methodology as



- Organ segmentation: leaf, stem, spikes
- First round
 - Build a reduced data set (image diversity)
 - Define a common annotation strategy
 - Annotate large validation/training dataset
 - Run the challenge

We are looking for sponsorship!
-annotation
- Challenge prizes

ETH zürich Lead: Andreas Hund