

In-field disease detection on wheat using near infrared hyperspectral imaging coupled to chemometrics and deep learning

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In collaboration with:

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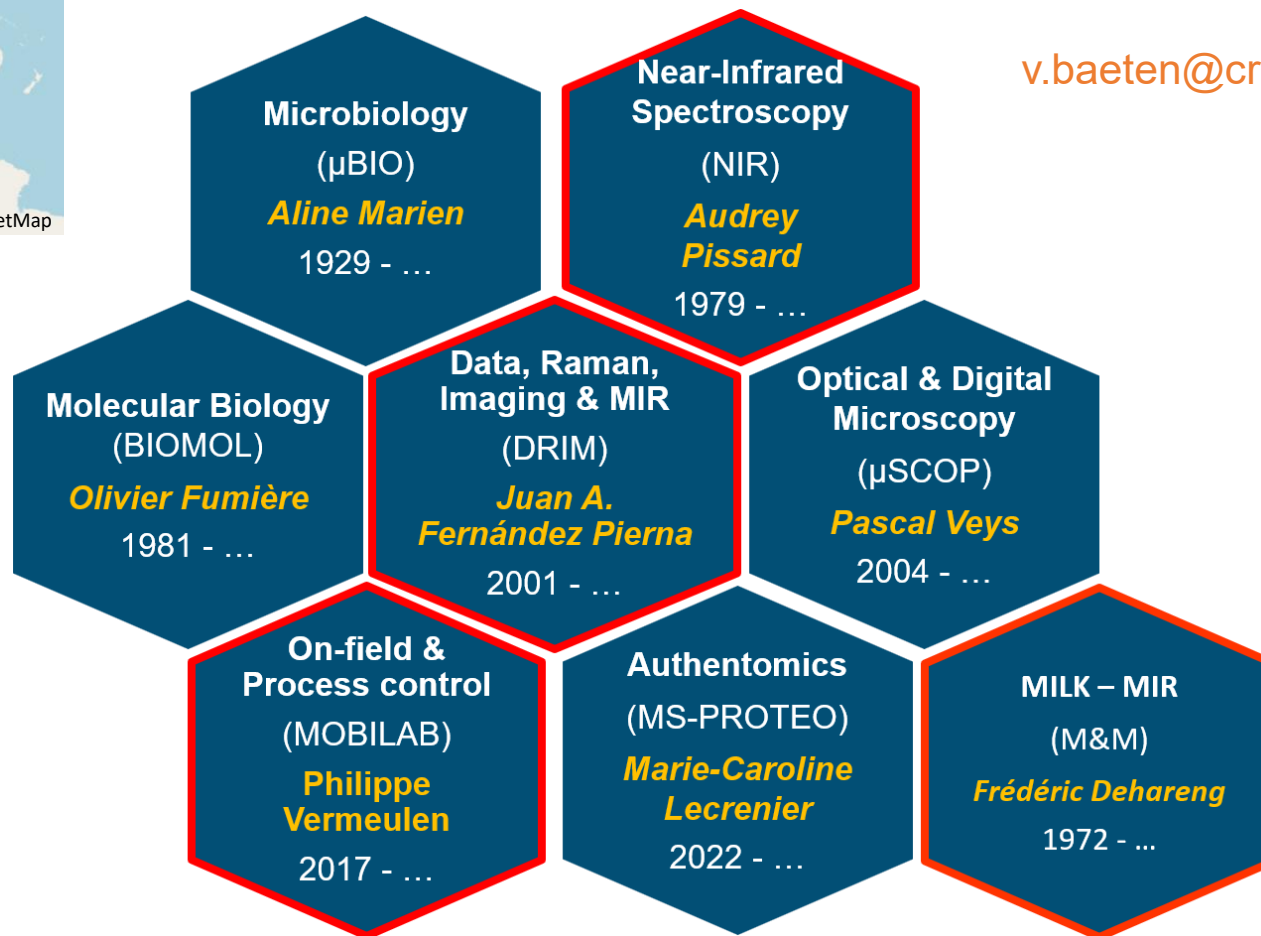


Quality and Authentication of Products Unit

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Scientific Director Unit QAP

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*To develop and validate,
analytical
methods & tools*

The Mobilab laboratory



Demonstrating the application of innovative sensors for agriculture and agrifood



Introduction

Fusarium Head Blight (FHB)

Wheat is the major grain cereal cultivated in Belgium (~ 14% of the agricultural area)

One of the major fungal diseases affecting wheat is Fusarium Head Blight

- ❑ Infects the ears at the flowering stage
- ❑ Damages the kernels
→ yield and quality decrease
- ❑ Can produce mycotoxins
→ risk for human and animal health
- ❑ ~3 billion € losses in Europe due to FHB mycotoxins over the last decade

→ Fungicide treatment is only preventive and not fully effective ...

→ Using resistant varieties is the main strategy to mitigate FHB and mycotoxins



Source: Birr T. et al. (2020)

Introduction

Fusarium Head Blight (FHB)

The assessment of varietal sensitivity



FHB field trial at CRA-W



Visual observation of FHB symptoms



Counting FHB infected wheat ears to assess the severity of infection

Field observations are time consuming and require trained personnel to avoid confusion with other stresses.

Objective

Develop a method using near infrared hyperspectral imaging (NIR-HSI) in the field to assess the severity of fusarium head blight

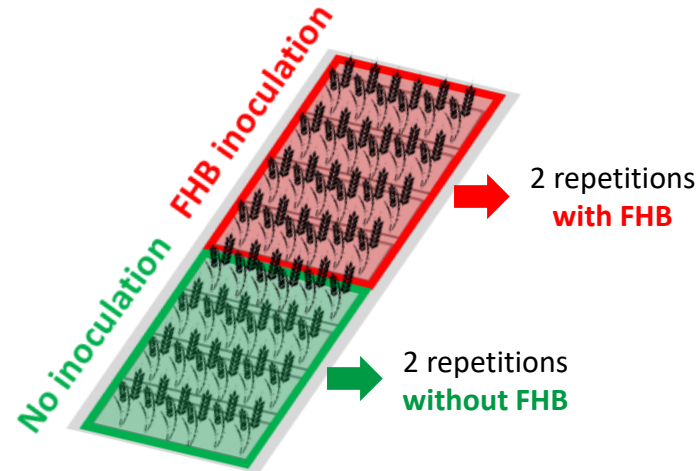


Material and methods

Design of experiment



Trial at CRA-W in cultivation bed



6 wheat varieties



Inoculation of FHB
(spray spores of *Fusarium graminearum*)

Material and methods

Design of experiment

Unexpected occurrence of another disease!

Take-all (*Gaeumannomyces graminis tritici*)

- Fungal disease infecting the root system
- Affects the whole plant
- Symptoms on the wheat ear look similar to FHB

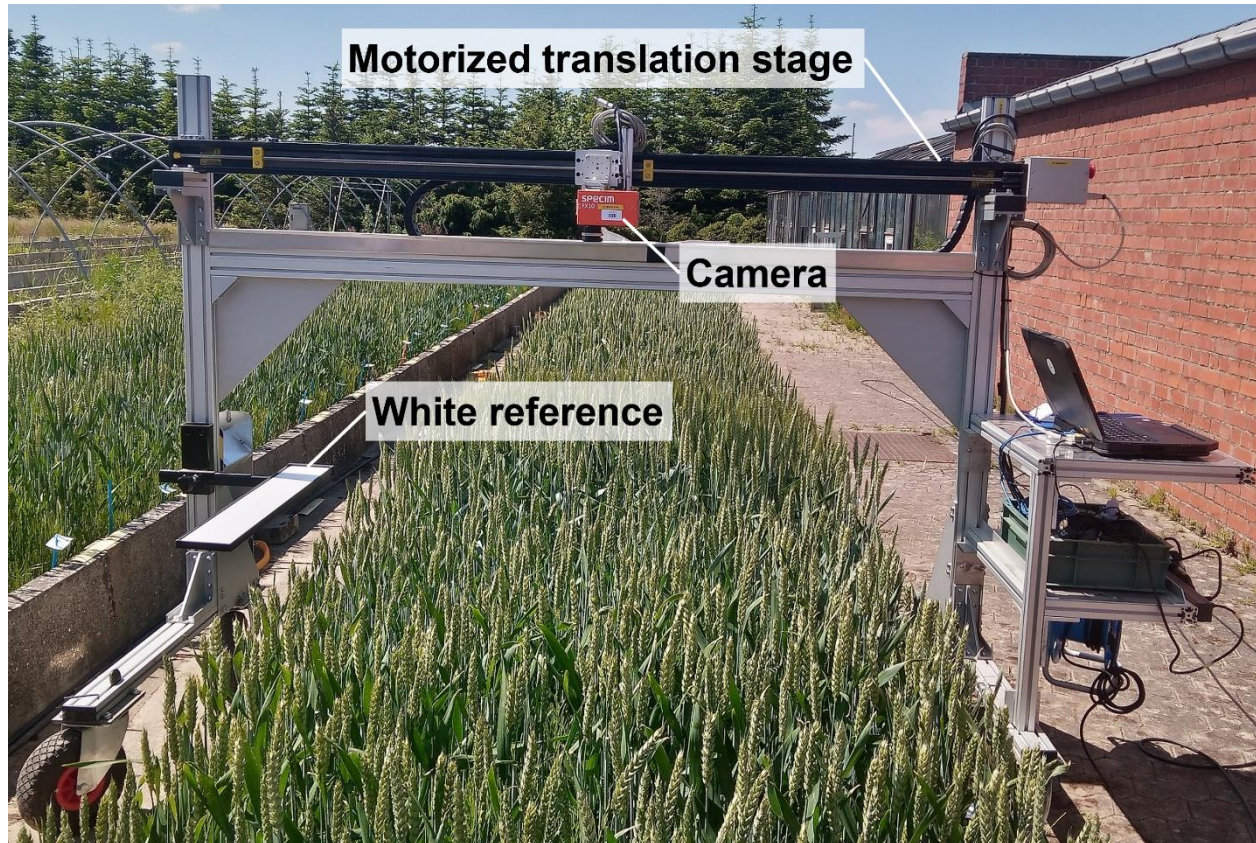


Very limited literature on NIR-HSI to discriminate multiple stresses directly in the field ...

Great opportunity for research!

Material and methods

Hyperspectral imaging system



Specim FX17
900 – 1700 nm

Image acquisition at 7 different dates in 2022
from June 28th to July 18th

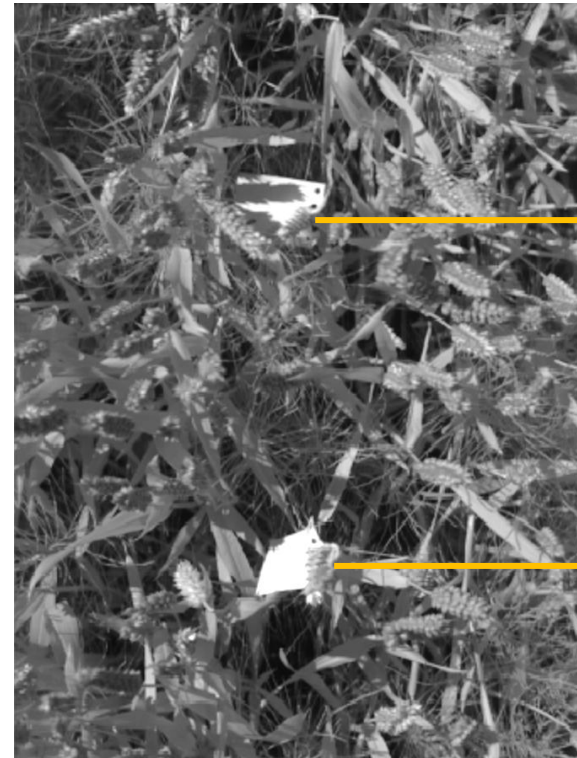
Material and methods

Image acquisition

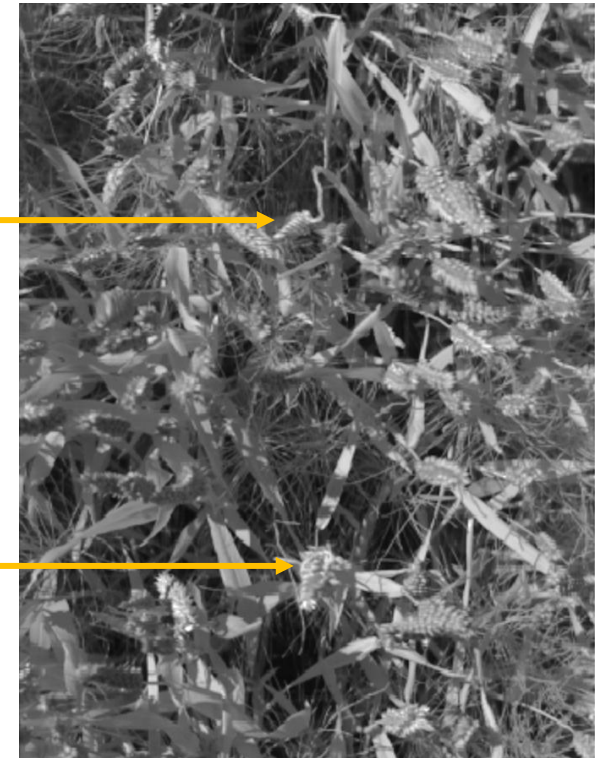
Identifying FHB in the HSI image to obtain reliable reference spectra



FHB-infected ears are tagged with a white label



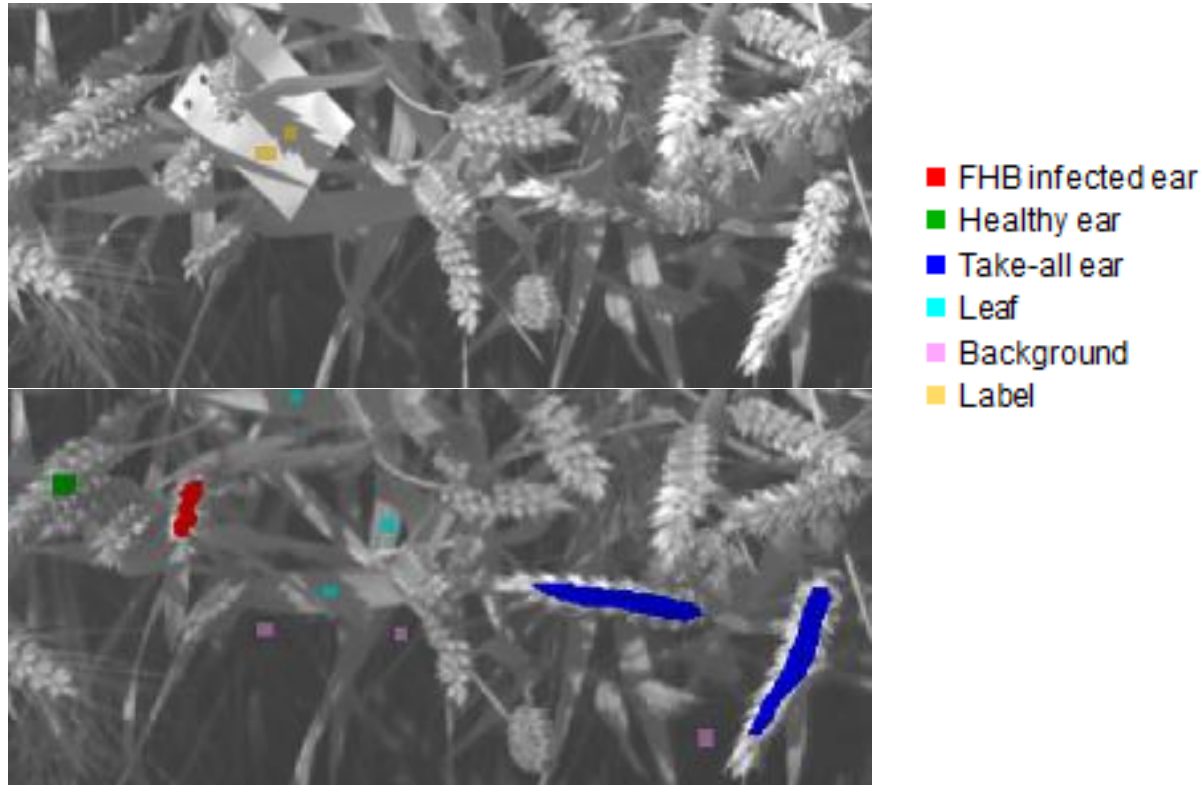
HSI image with label



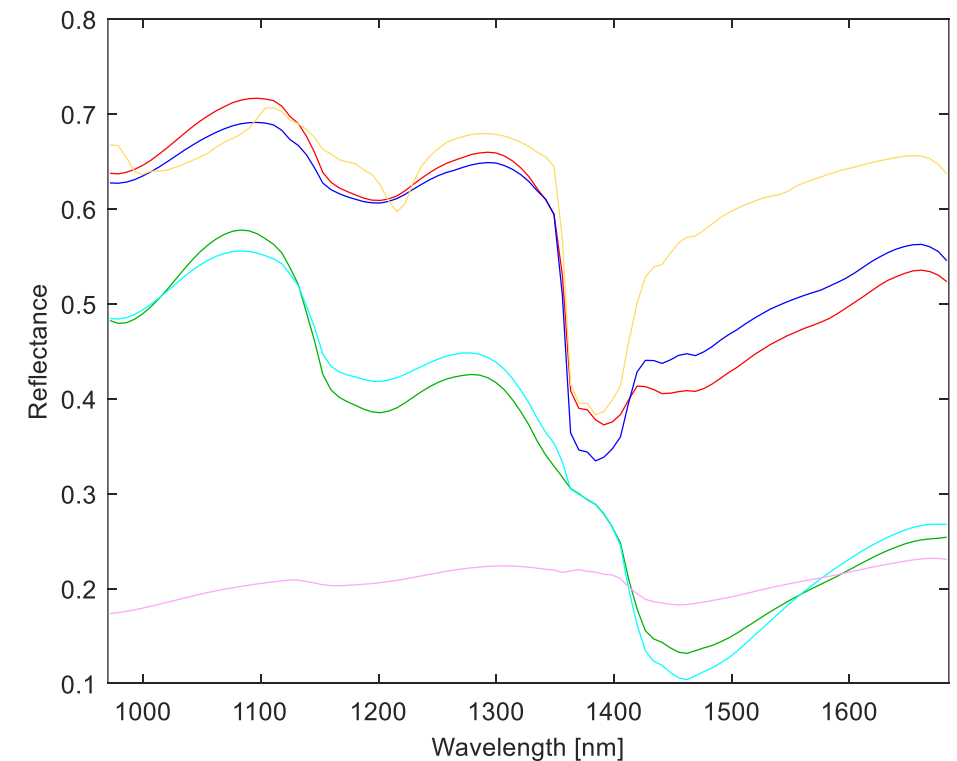
HSI image without label

Material and methods

Creation of spectral libraries



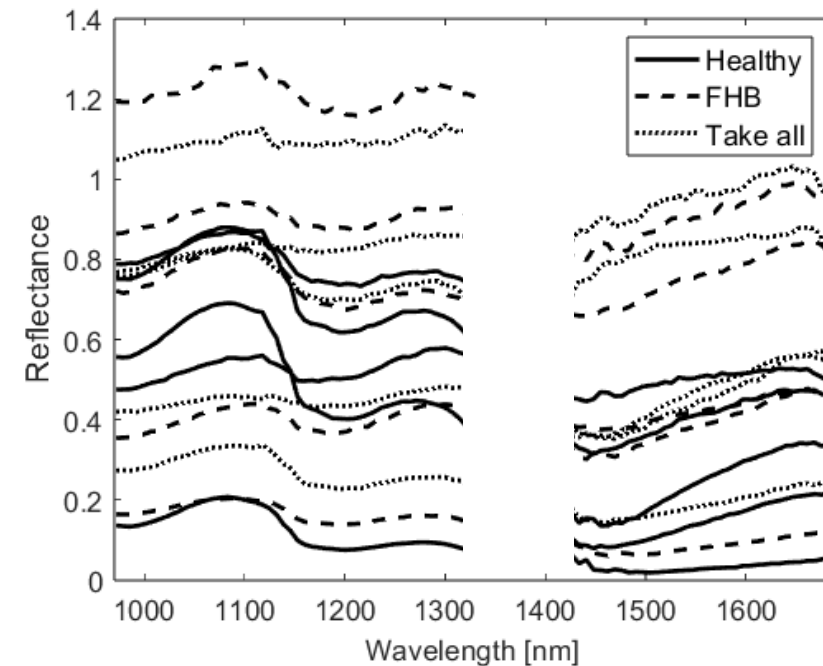
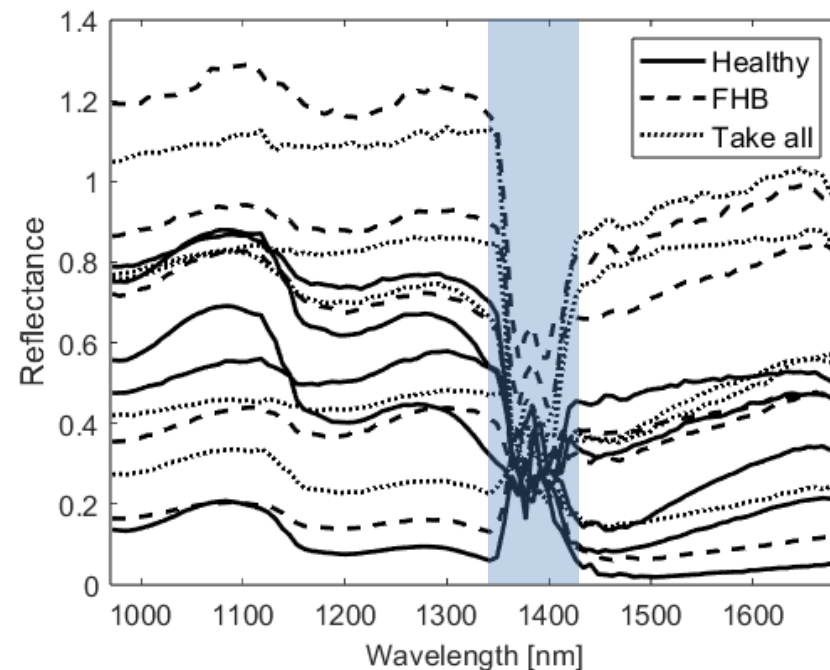
Annotation of 18 images from 3 dates (6 images/date)



Material and methods

Data treatment

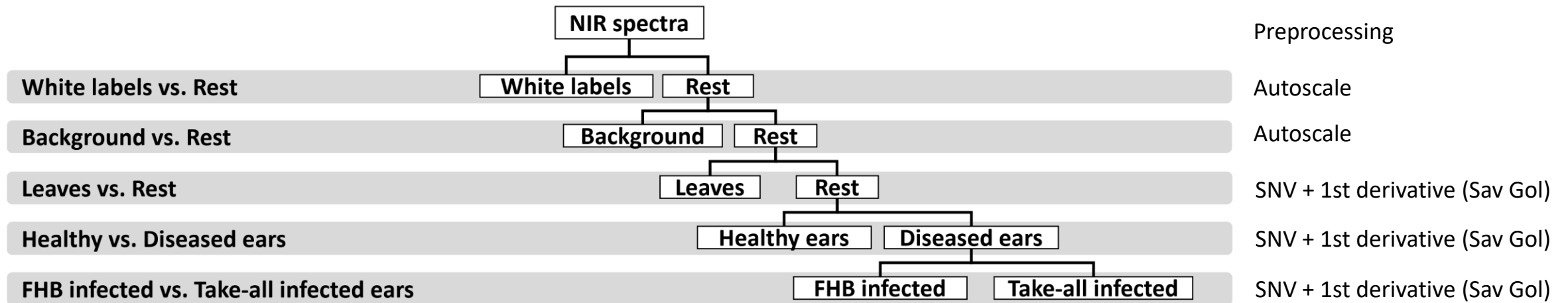
Remove noisy wavelengths related to atmospheric water vapor



Material and methods

Data treatment

Dichotomous classification with PLS-DA models



→ Models calibrated at 3 time points and validated on images from different time points.

Material and methods

Data treatment

Validation of the PLS-DA results at plot level

$$\text{Observed \% FHB} = \frac{\text{FHB infected heads}}{\text{number of heads}}$$

$$\text{Observed \% take - all} = \frac{\text{take - all infected heads}}{\text{number of heads}}$$

$$\text{Observed \% overall stress} = \frac{\text{FHB heads} + \text{take - all heads}}{\text{number of heads}}$$

$$\text{Predicted \% FHB} = \frac{\text{FHB pixels}}{\text{Ear pixels}}$$

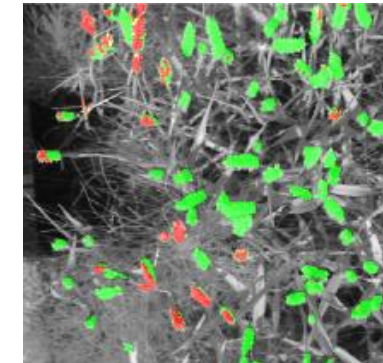
$$\text{Predicted \% take - all} = \frac{\text{take - all pixels}}{\text{Ear pixels}}$$

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Variety	Crossway	Gleam	KWS Keitum	LG Apollo	LG Skyscraper	Solange CS
Plot ID	1	2	3	4	5	6
Ear count	179	227	202	229	175	198
FHB ears	3	0	1	2	1	2
Take-all ears	0	5	0	0	0	1
FHB incidence [%]	1.7	0	0.5	0.9	0.6	1
Take-all incidence [%]	0	2.2	0	0	0	0.5
Overall stress [%]	1.7	2.2	0.5	0.9	0.6	1.5

Field observation



NIR-HSI predicted image

Material and methods

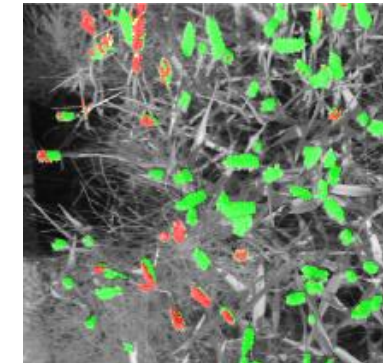
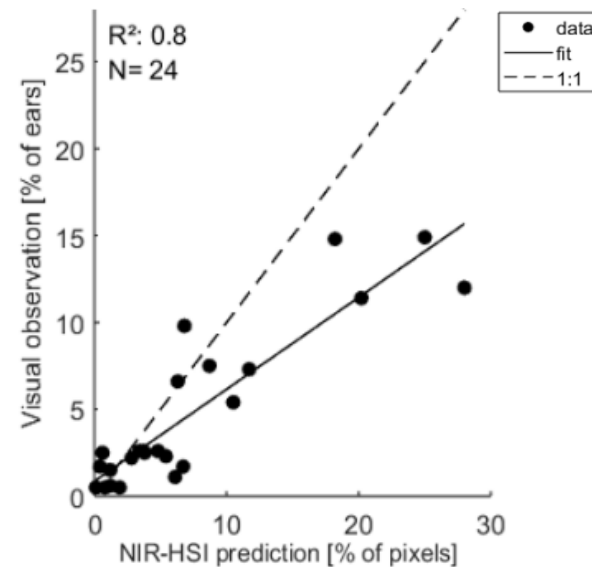
Data treatment

Validation of the PLS-DA results at plot level

Estimate the visual observation (% infected ears) using the NIR-HSI prediction (% pixels) ...



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Results

Validation of the PLS-DA results at plot level

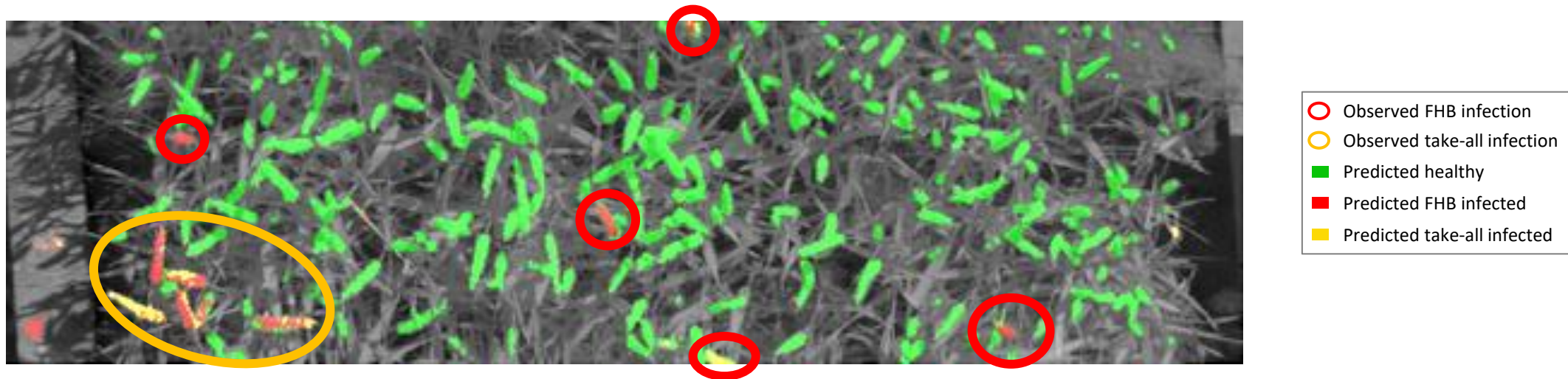
Estimate the visual observation (% infected ears) using the NIR-HSI prediction (% pixels) ...

Model date	Measure date	N	FHB		Take-all		Overall stress	
			RMSE	R ²	RMSE	R ²	RMSE	R ²
June 28 th	June 29 th	24	0.7	0.10	3.7	0.43	2.1	0.80
July 4 th	July 5 th	12	0.5	0.24	6.2	0.61	4.0	0.84
July 14 th	July 12 th	12	0.5	0.35	7.4	0.46	3.1	0.90
July 14 th	July 18 th	12	0.4	0.51	7.3	0.48	5.8	0.67

Results

Validation of the PLS-DA results at plot level

The method is not specific enough to differentiate take-all from FHB



Prospects

Testing Deep Learning algorithms

QUALISPECTRA project

Advanced algorithms of Machine Learning and Deep Learning for the analysis of Hyperspectral images applied to the quality control of agricultural product.

→ Exploit both spatial and spectral information in HSI images to have more accurate analyses

Two use cases:

- 1) Quantification of the homogeneity of mixtures of flour
- 2) Detection of FHB

Prospects

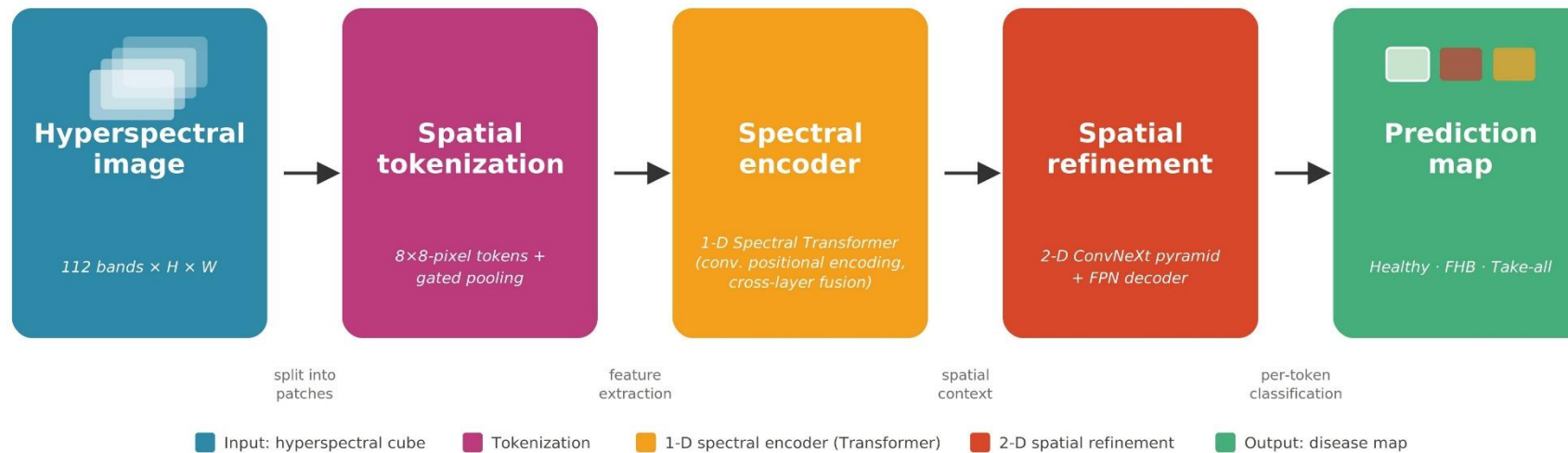
Testing Deep Learning algorithms



Arthur Lorin

SpectralTokenMapNet — Segmentation Pipeline

Wheat disease detection by hyperspectral imaging (112 bands)



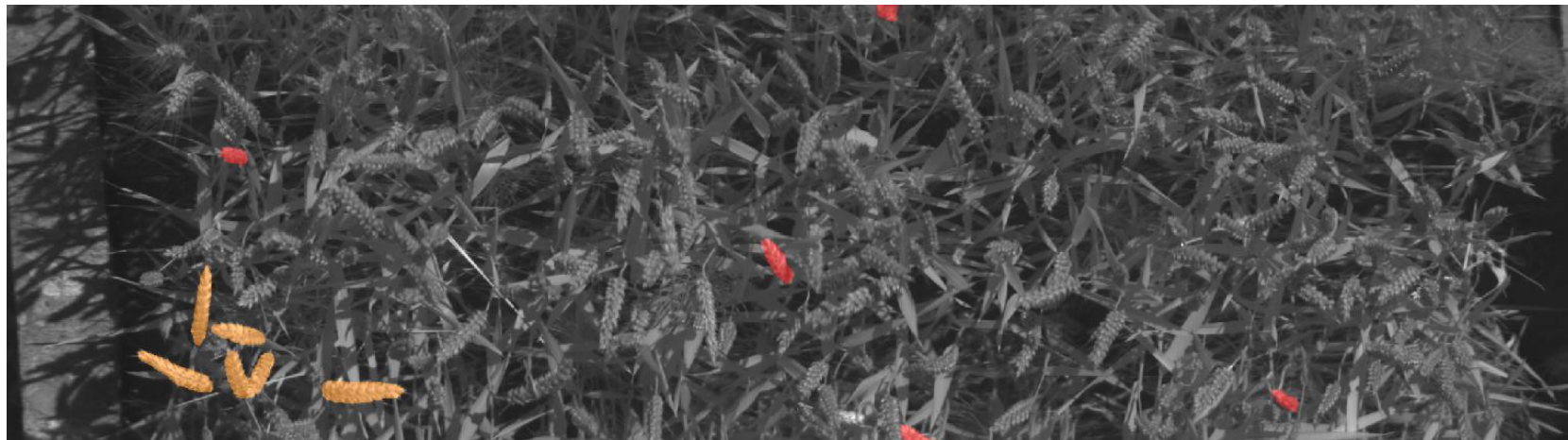
- Instead of analyzing each pixel independently, we analyze small regions by combining spectral information and spatial context.
- The model learns to distinguish genuine symptoms from simple noise.

Prospects

Testing Deep Learning algorithms

Image annotation

- Custom made platform from CETIC (SegLab)
- Annotate only diseased ears
- 122 images annotated from all dates

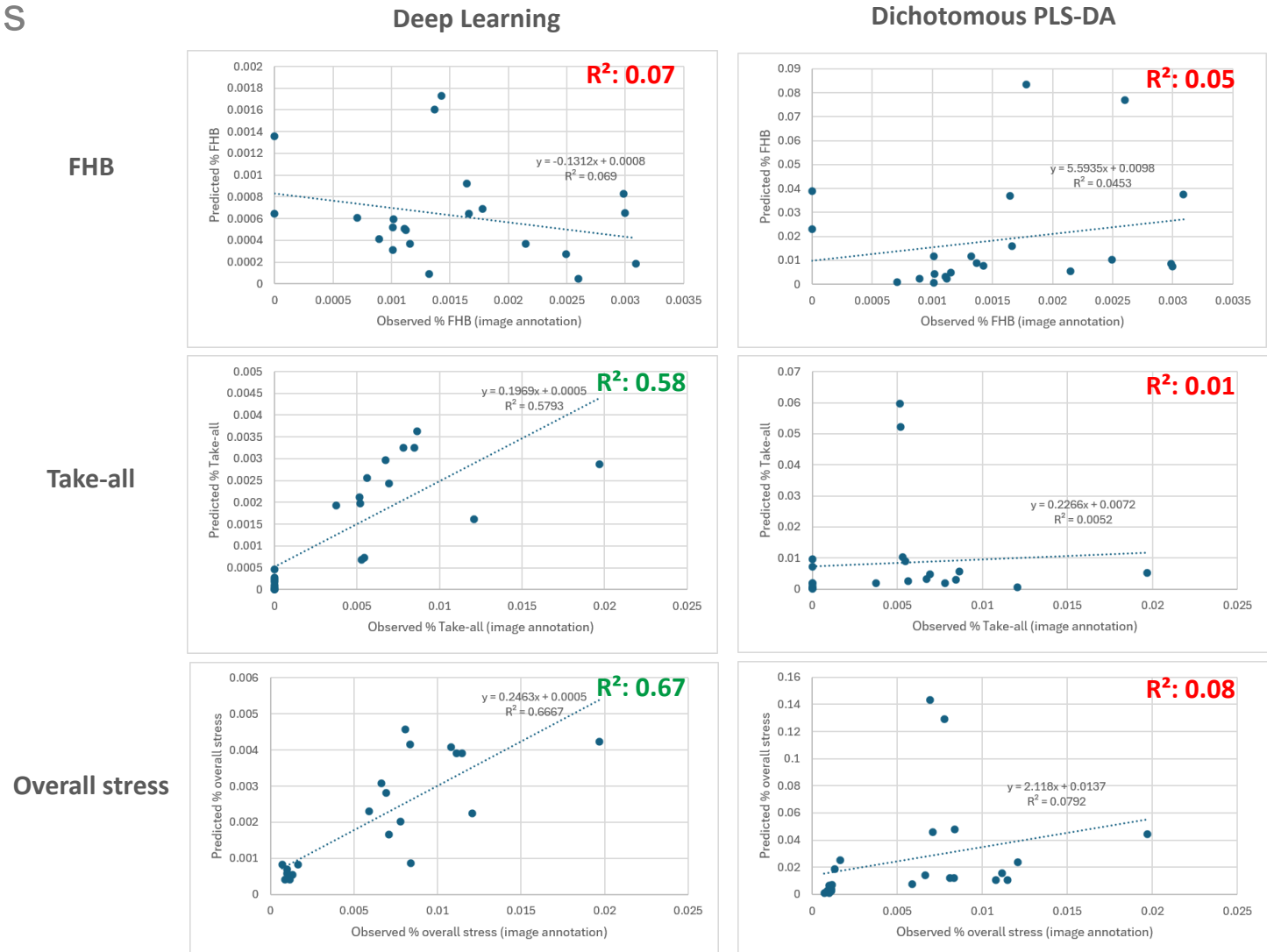


HSI image annotated with the Seglab platform from CETIC

Prospects

Testing Deep Learning algorithms

- Performance comparison using a set of 22 held-out images covering all acquisition dates
- Compare prediction and annotation

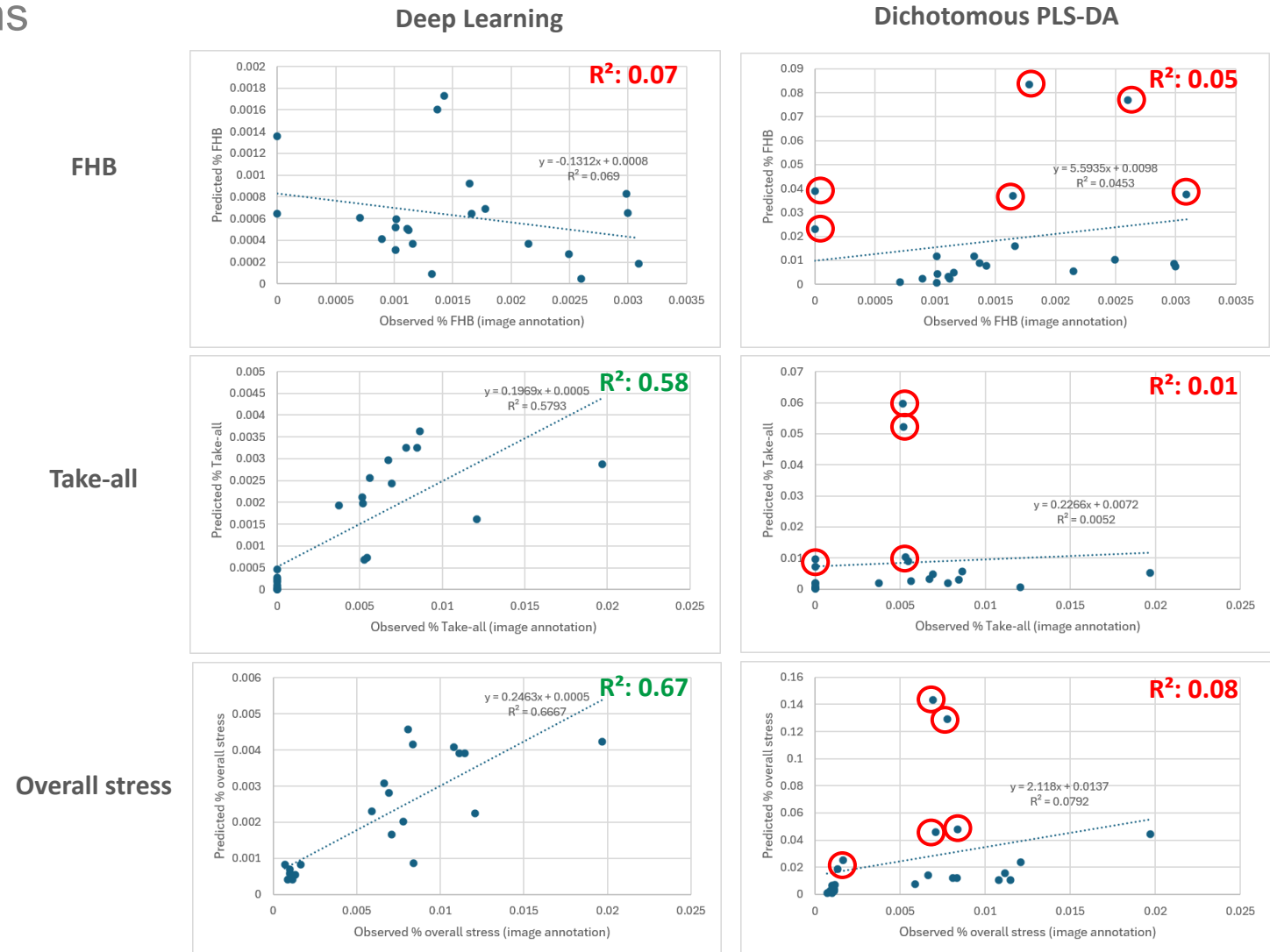


Training set of 100 images (Deep Learning) vs. training set of 18 images (PLS-DA)

Prospects

Testing Deep Learning algorithms

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Training set of 100 images (Deep Learning) vs. training set of 18 images (PLS-DA)

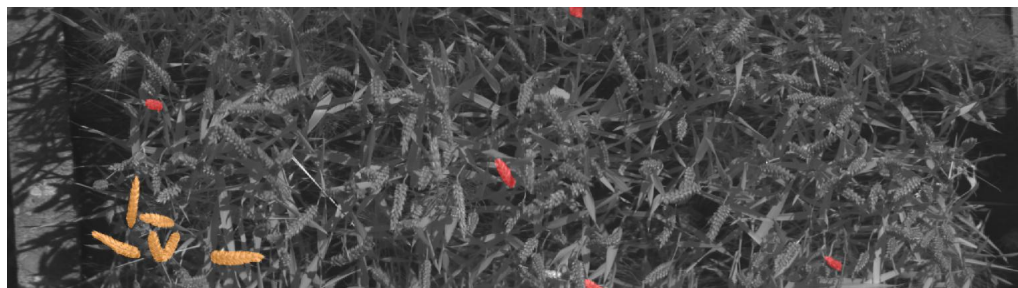
Prospects

Testing Deep Learning algorithms

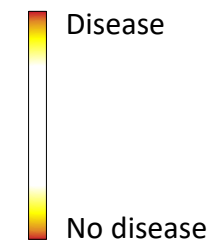
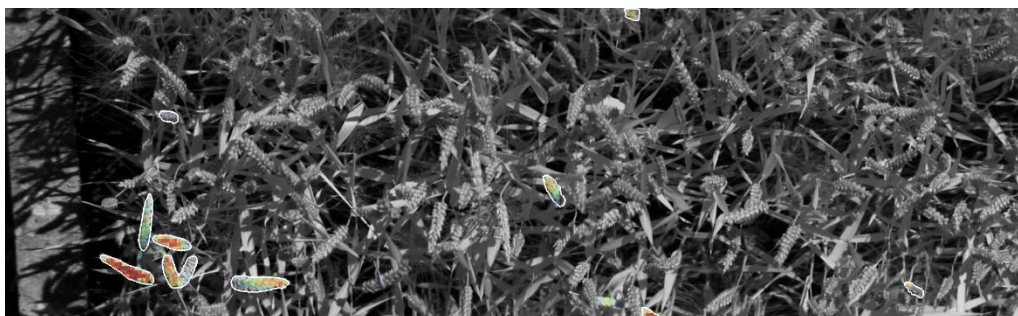
June 28th

July 18th

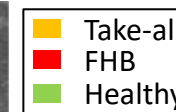
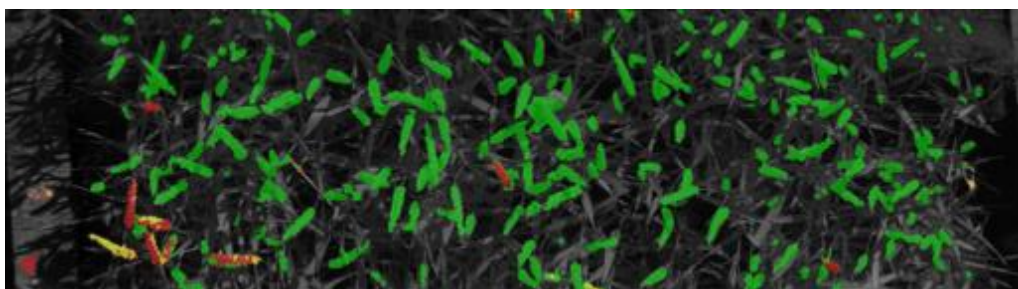
Annotated image



Deep Learning



Dichotomous PLS-DA



Conclusions

NIR-HSI in the field

- Variation of many parameters (light, wind, humidity)
- The developed NIR-HSI system is currently a research tool rather than an operational platform for routine analysis

Data treatment

- PLS-DA allows assessing the health status of the ear but is not specific enough to differentiate FHB from take-all
- Deep Learning approach is more accurate but needs large training sets (annotated images)
- Results from Deep Learning are preliminary and need further validation
- Image annotation platforms designed for HSI are needed (ex.: SegLab from CETIC)



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Understanding Faster***





Thank you for your attention!