Data Management
S5: Advanced data management (2)
Towards Data Science

Monday 11/12/2023 - 14:00-16:00 (CET)

Isabelle Alic, Farzaneh Kazemipour-Ricci - INRAE
Marie Weiss, Llorenç Cabrera Bosquet - INRAE

EMPHASIS

EUROPEAN INFRASTRUCTURE FOR PLANT PHENOTYPING

General objectives: Overview of data management for plant phenotyping - focus on FAIR data

Session 5

Advanced data management (2) - Towards Data Science

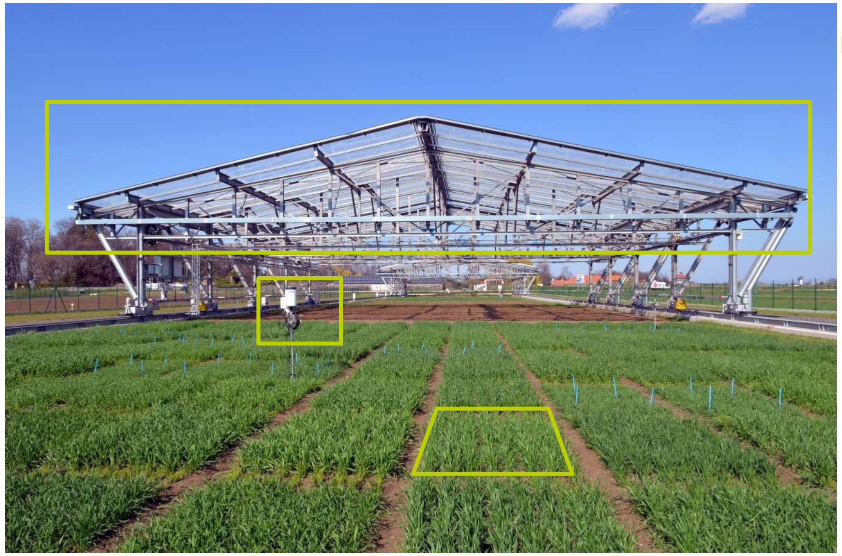
Overview

Towards Data Science

- Introduction & Review of last sessions
- Use case: from raw data to process analyses based on FAIR principles - 4P
- Data enrichment: Events, Annotation and Documents
- Use Case: Data analysis and integration
- Geospatial: Integration and a step towards decision support
- Conclusion & Perspectives

Introduction & Review of last sessions

Reminder - Data Management Best Practices



Step1 - Identification

URI of Experiment: <emphasis:study56>

URI of Facility: <emphasis:gantry2>

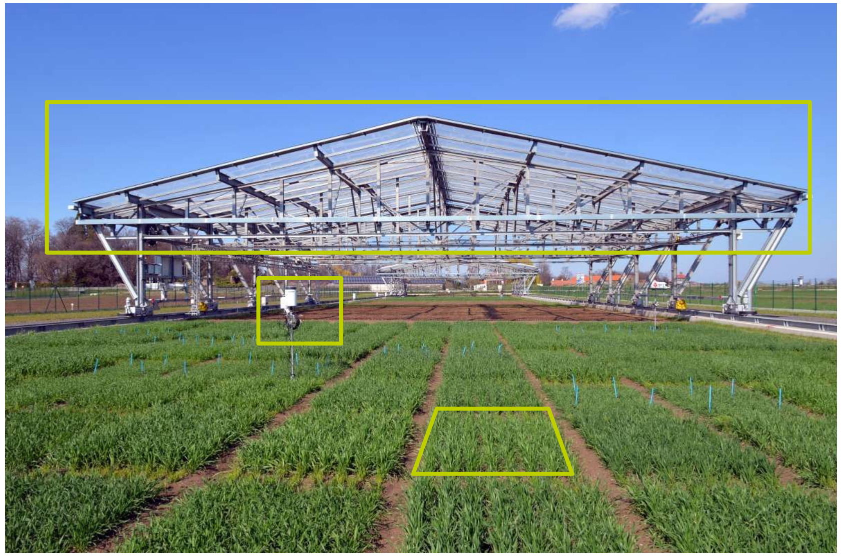
URI of Device: <emphasis:st14>

URI of microplot: <emphasis:plot15879>

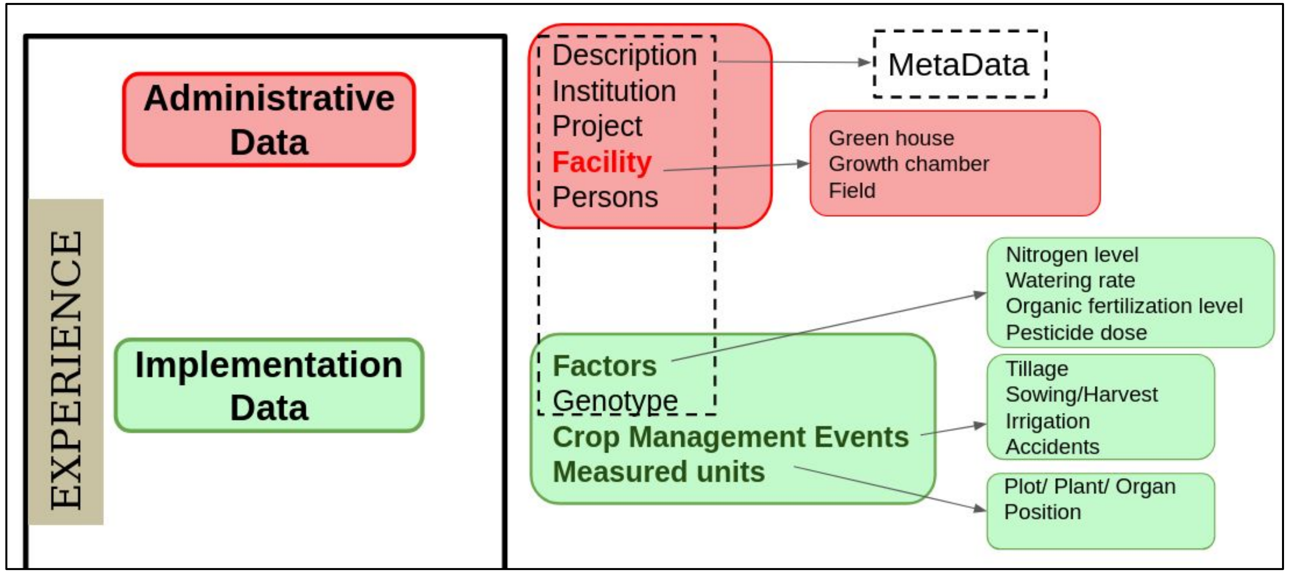
URI of germplasm:
<https://www.geves.fr/catalogue/variete/1002491-aubusson>

Introduction & Review of last sessions

Reminder - Data Management Best Practices



Step2 - Experiment Description

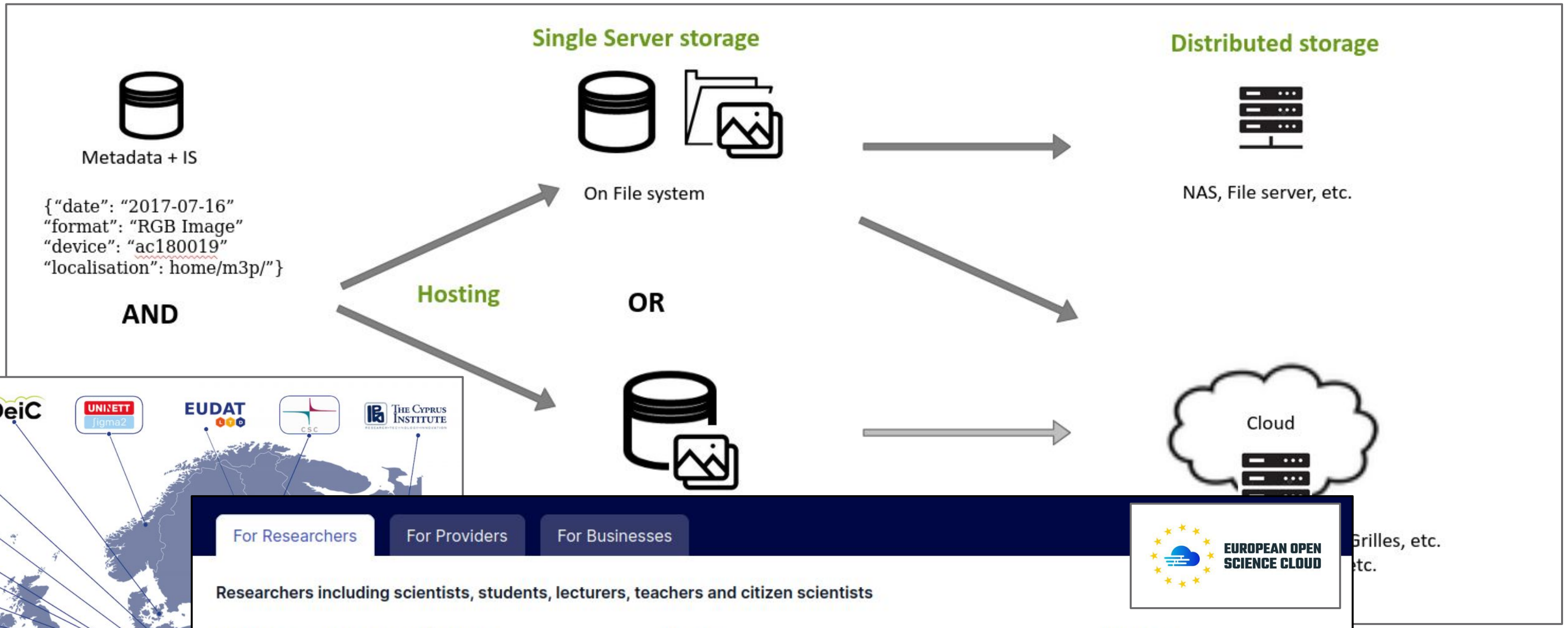


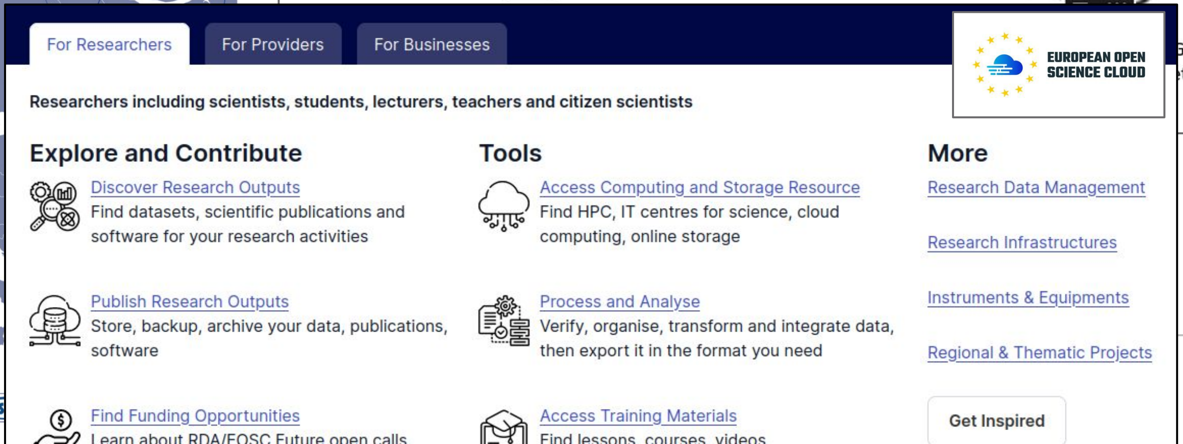
Introduction & Review of last sessions

Reminder - Data Management Best Practices

Step3 - Datafiles storage

Study the storage solution best suited to **your needs and uses!**



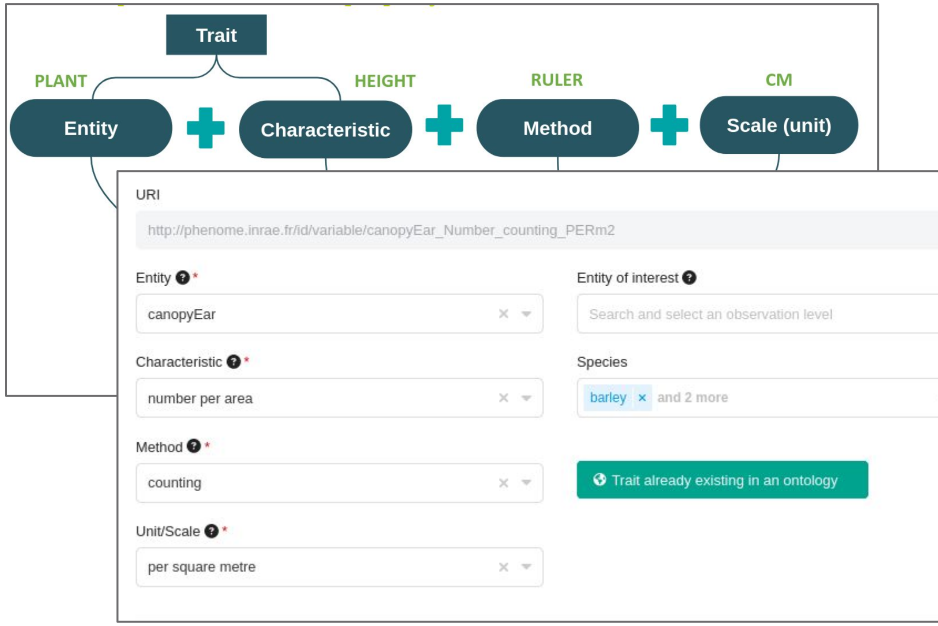


Introduction & Review of last sessions

Reminder - Data Management Best Practices

Step3 - Data Declaration

- Variable description
  - Using Model
  - With ID
- Provenance
  - Data Acquisition description
  - With ID



PROVENANCE

- Description
- Start / End Date
- Vector
- Sensor
- Operator
- …

Introduction & Review of last sessions

Reminder - Data Management Best Practices

Step3 - Data Declaration

Environmental Data

Provenance
Devices: emphasis:st14
Station: campbell-2018-dl53

Data
Variable: air_temperature_minimumDaily_degC
Date: 2023-07-01
Target: plot2023-BH53
Value: 12

Phenotypic Data

Provenance
Vector: fieldRobot1
Camera: campbell-2019-dl4
Software: 4P
ProvUsed: Datafile568

Data
Variable: Canopy_CoverFraction0deg_ImageSeg_Unitless
Date: 2023-07-01
Target: <emphasis:plot15879>
Value: 0.1

Introduction & Review of last sessions

Reminder - Data Management Best Practices

=> Having well-organized and well-described data will enable **data exploration and analysis**

e_minimumDaily_degC

_ImageSeg_Unitless

Use case: from raw data to process analyses based on FAIR principles

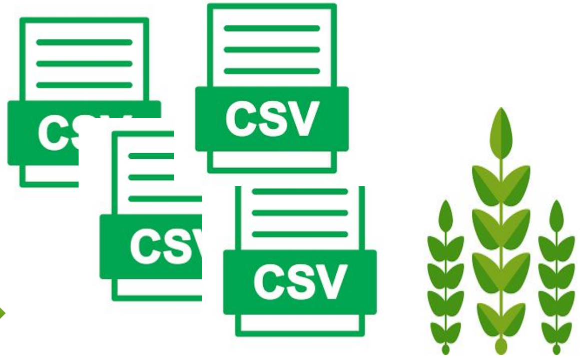
4P: Plant Phenotyping Processing Platform - **Marie Weiss**

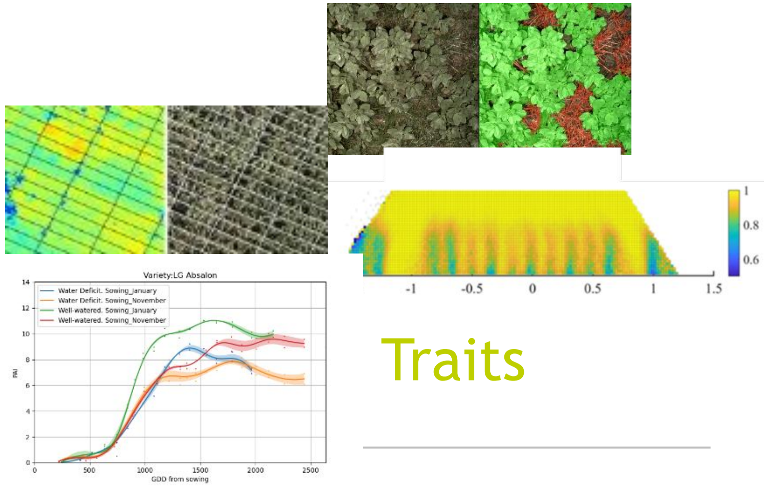
Field Acquisitions

PHIS

4P

Data Processing





Traits

Survey among phenotyping installations and users @ INRAE (2023)

Prioritization of needs

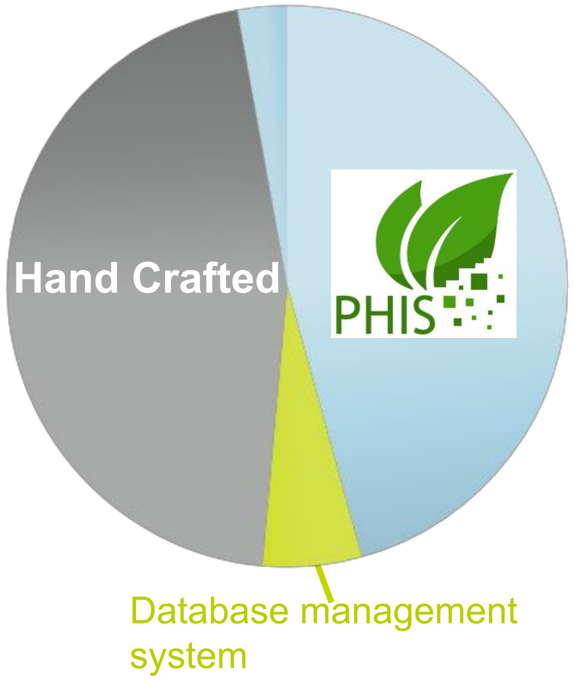
1. Data traceability – FAIR : 28% Data only 71% Data+ Algorithms
2. Ergonomy / Easy to use
3. Quick Processing & computing facilities
4. Data Storage
5. Processing traceability

Capacities for processing

1. 57%: No in-house high-speed processing capacity
2. 21%: Processing facilities within the installation/lab
3. 16%: subcontracting specialized companies
4. 6% : Not yet defined

Current Data Management

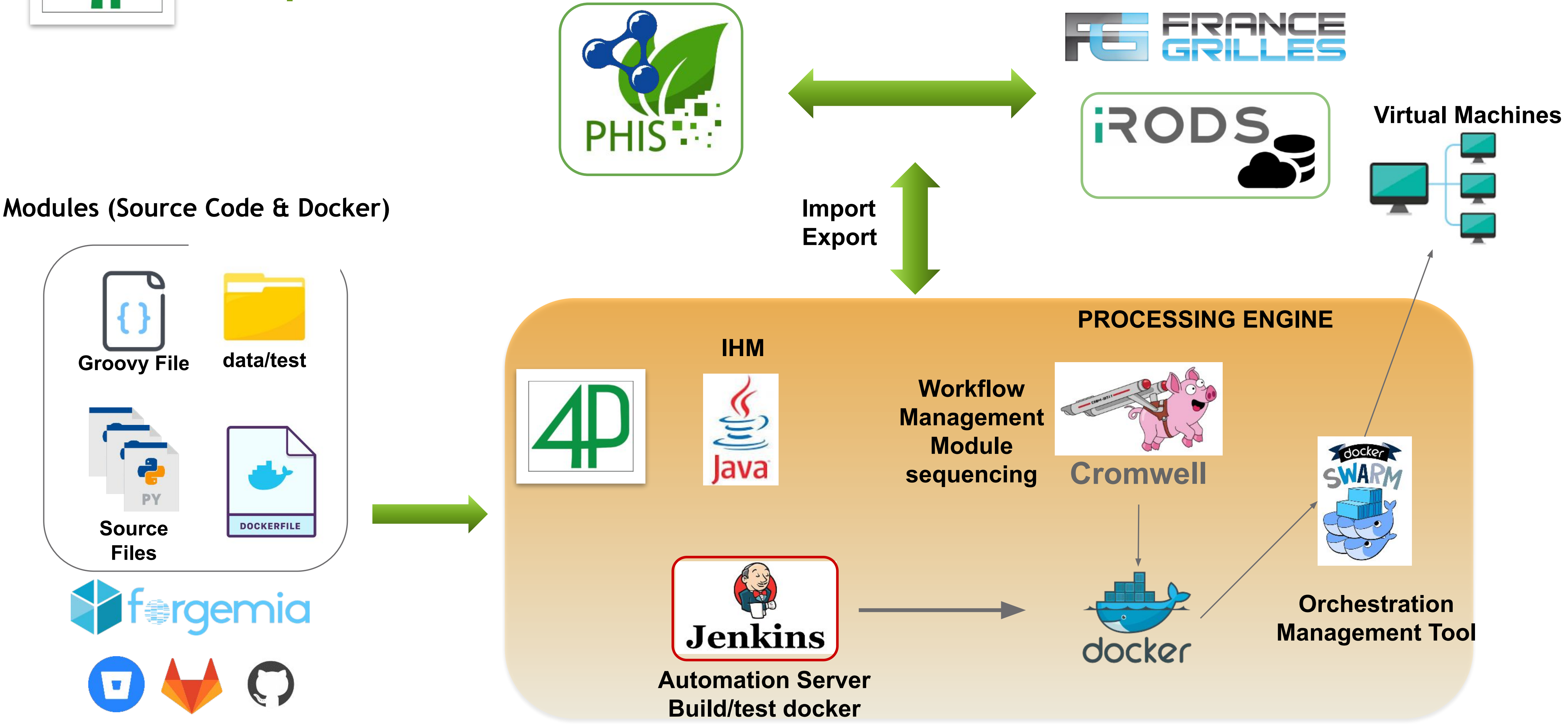
500 Go to 10 To / campaign



Requirements

- Usable by all phenotyping installations @ INRAE
  - Compatible with all vectors/sensors
  - Processing pipelines easily shareable with PHENOME partners
  - Ergonomic: users are not developers
- Traceable
  - Storage of information related to sensor/vectors/data
  - Management and versioning of data processing chains
- Flexibility
  - Genericity : able to integrate processing chains developed in different languages, use commercial softwares (e.g. metashape)
  - Management and versioning of data processing chains
  - Scalability: update with new sensors/vectors/algo/traits

Proposed Solution

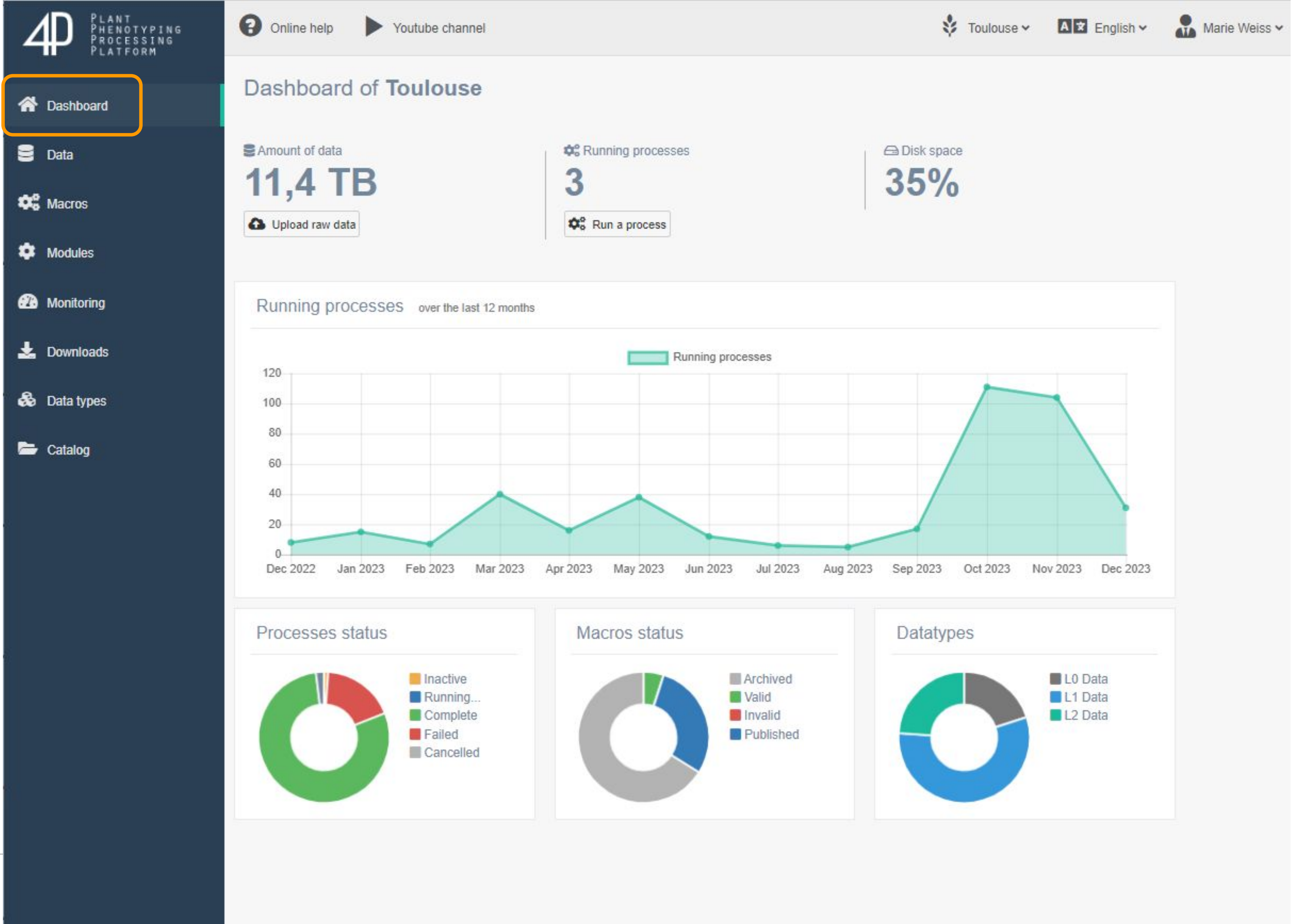


Home Page

Installation

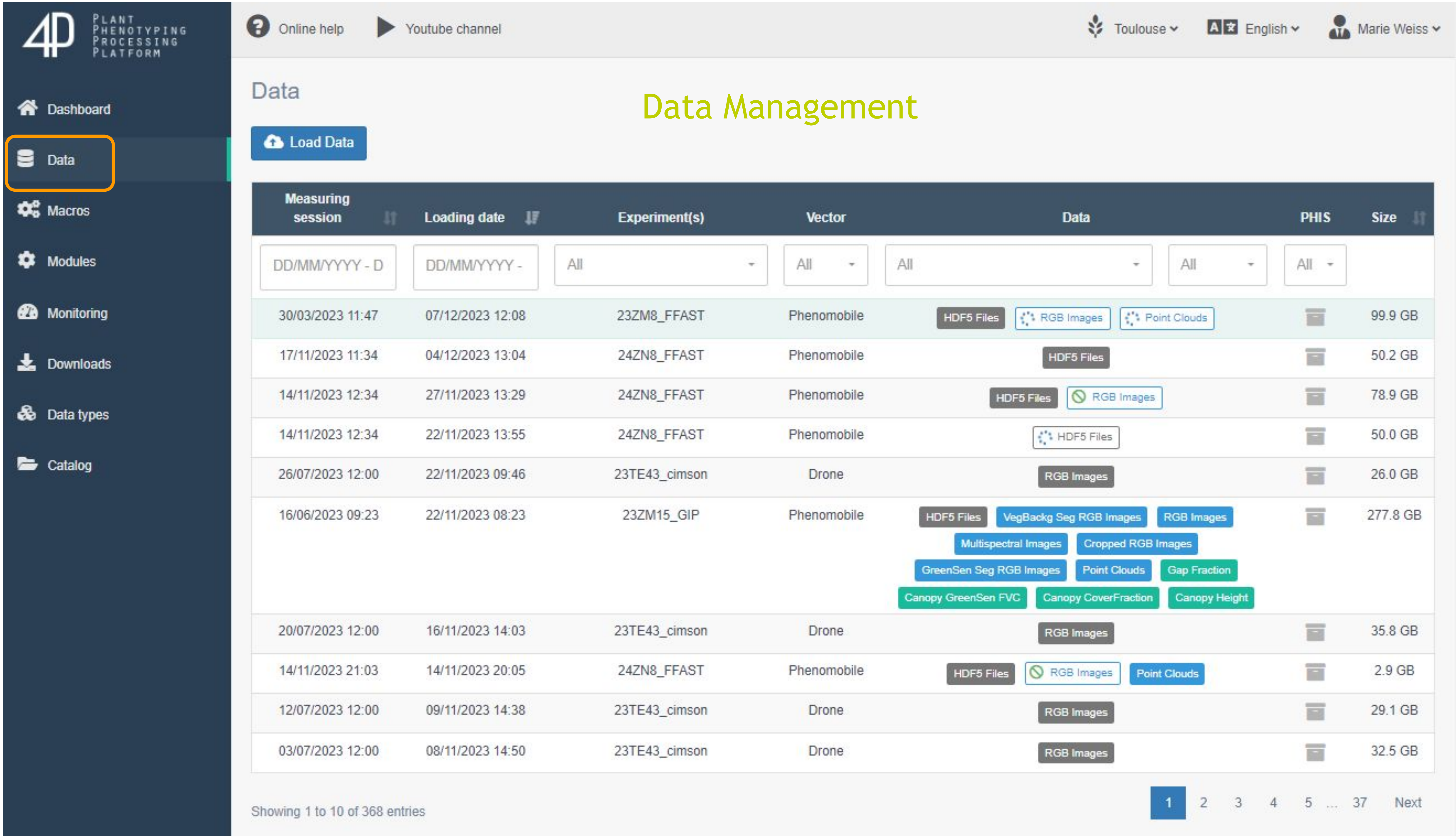
Data Processing

status



EMPHASIS

Data Management



Data Status

PLANT PHENOTYPING PROCESSING PLATFORM

Online help | Youtube channel | Toulouse | English | Marie Weiss

- Dashboard
- Data
- Macros
- Modules
- Monitoring
- Downloads
- Data types
- Catalog

Data / 23ZM15_GIP Phenomobile 16/06/2023 09:23 — « Previous group | Next group »

Upload to PHIS | Process dataset

Description (ID 2780)

Experiment(s): 23ZM15_GIP

Measuring session: 16/06/2023 09:23

Loading date: 22/11/2023 08:23

Size: 277.8 GB

iRODS path:

/FranceGrillesZone/home/4p/qualification/2780

Vector: Phenomobile

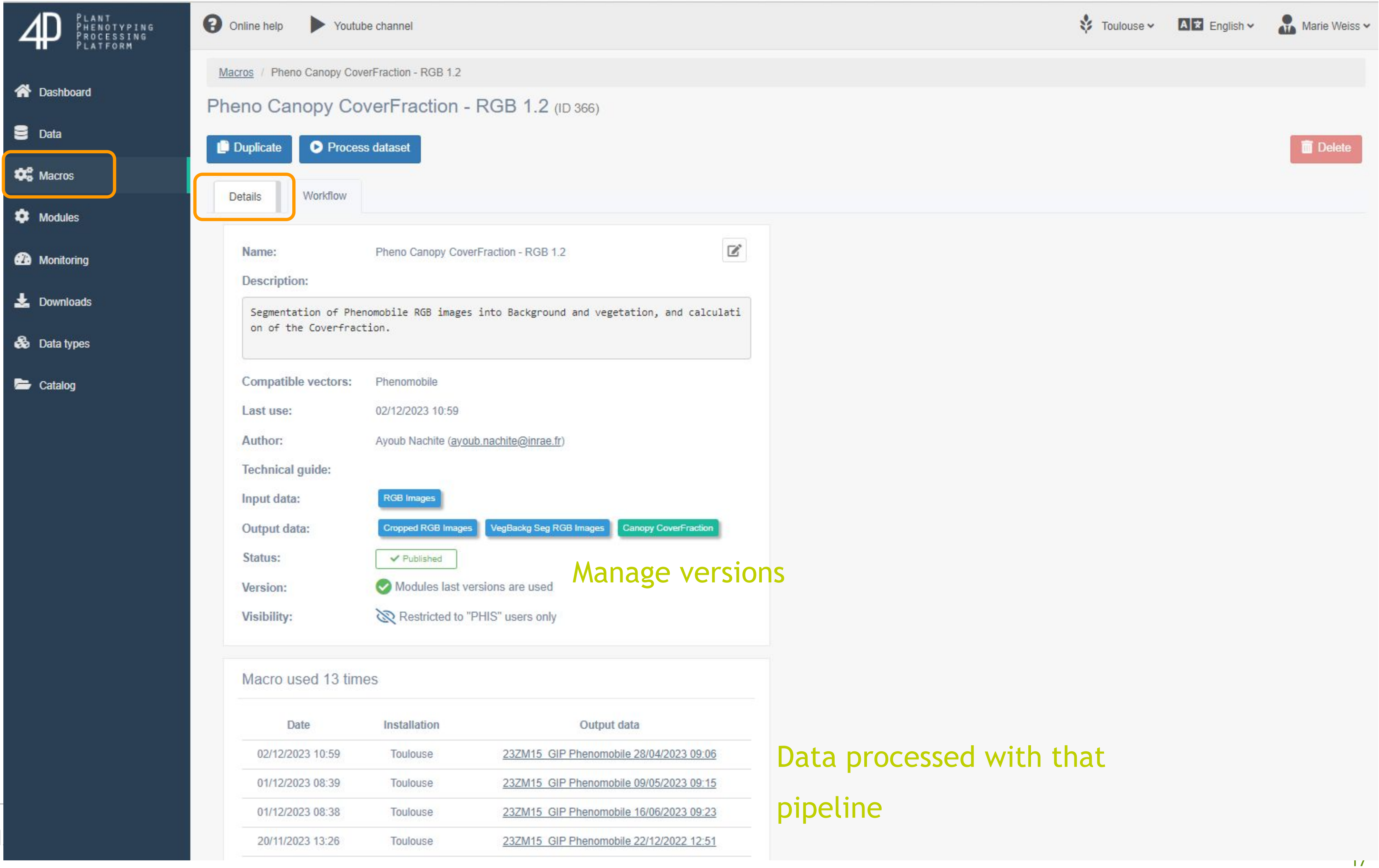
PHIS:

Data

Name	Version	State	PHIS	Size	Actions
HDF5 Files	v1	✓		63.4 GB	
RGB Images	v1	✓		40.5 GB	
Multispectral Images	v1	✓		15.9 GB	
Point Clouds	v1	✓		121.7 GB	
Cropped RGB Images	v1	✓		9.1 GB	
VegBackg Seg RGB Images	v1	✓		9.7 GB	
GreenSen Seg RGB Images	v1	✓		16.5 GB	
Gap Fraction	v1	✓		1.0 GB	
Canopy Height	v1	✓		194 KB	
Canopy CoverFraction	v1	✓		327 KB	
Canopy GreenSen FVC	v1	✓		419 KB	

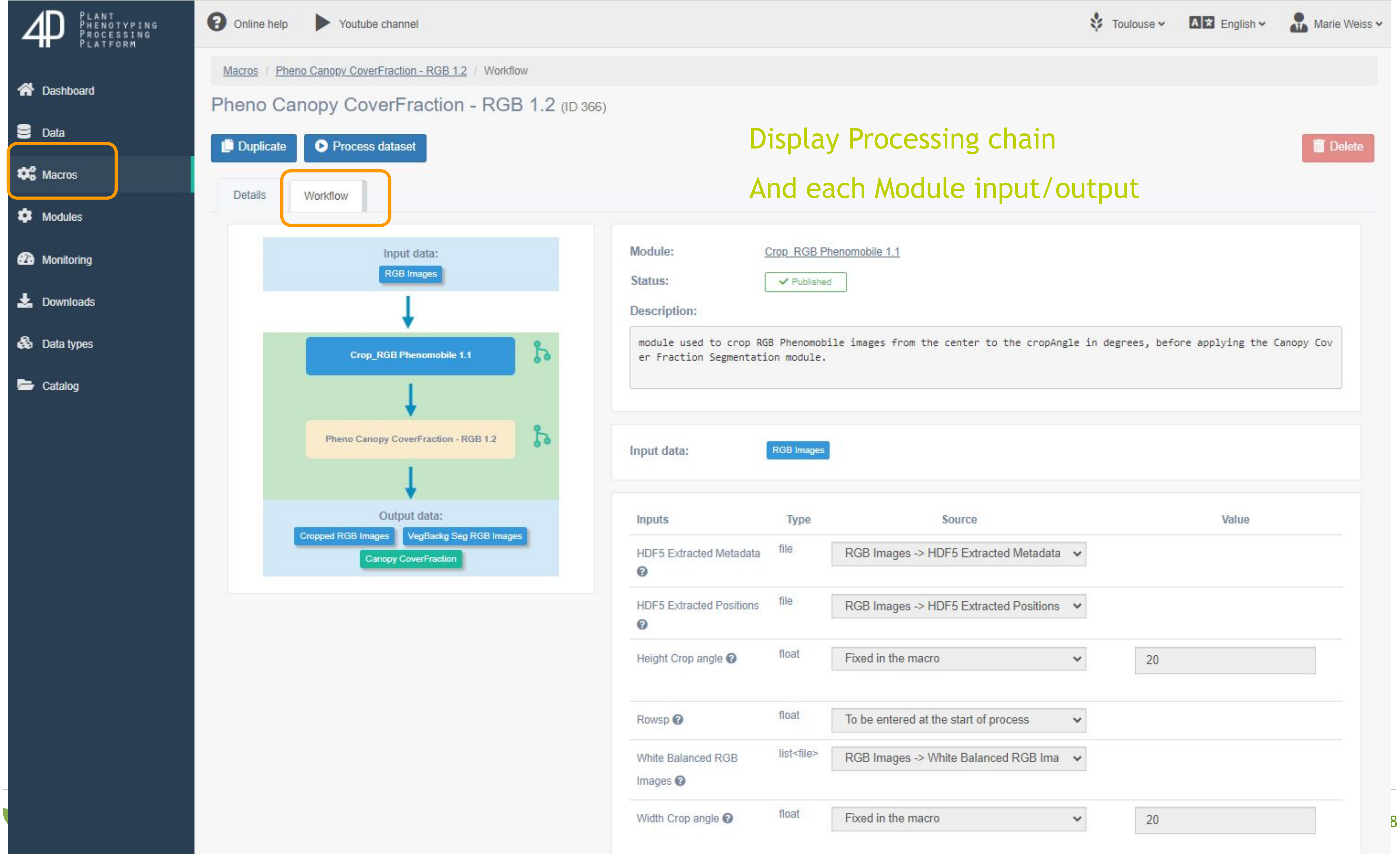
Task history

Label	Input data	Output data	Author	Start date	Duration	Status / Progress	Actions
Macro: Pheno GreenSenFvc - RGB SegVeg All v1.0	RGB Images v1, Cropped RGB Images v1, VegBackg Seg RGB Images v1	Canopy GreenSen FVC v1, GreenSen Seg RGB Images v1	Rémy Marandel	01/12/2023 14:36	02 h 33 min 43 s	Complete 3/3	
Macro: Pheno Canopy CoverFraction - RGB 1.2	RGB Images v1	Cropped RGB Images v1, VegBackg Seg RGB Images v1, Canopy CoverFraction v1	Rémy Marandel	01/12/2023 08:38	05 h 41 min 46 s	Complete 4/4	



Manage versions

Data processed with that pipeline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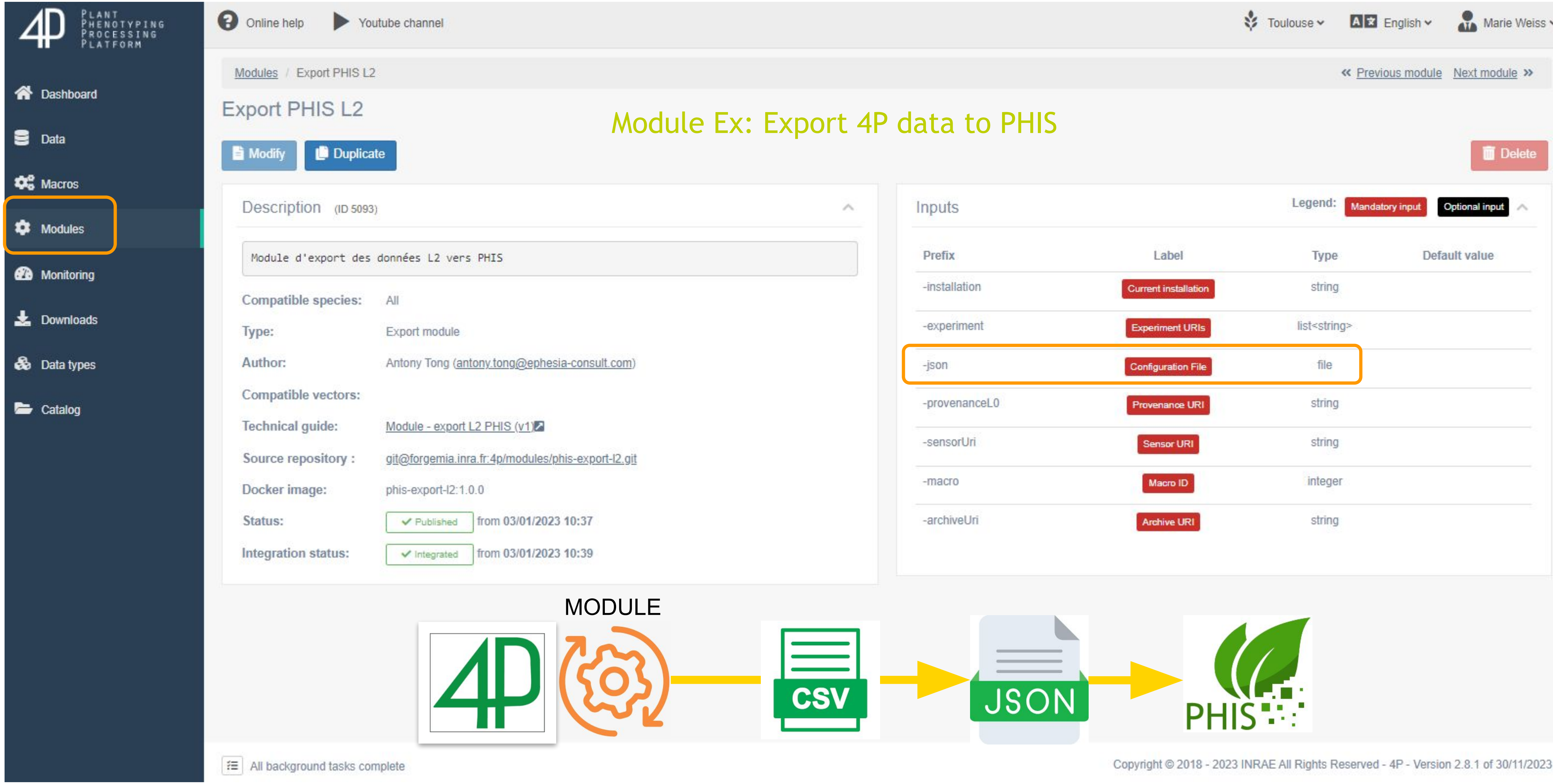
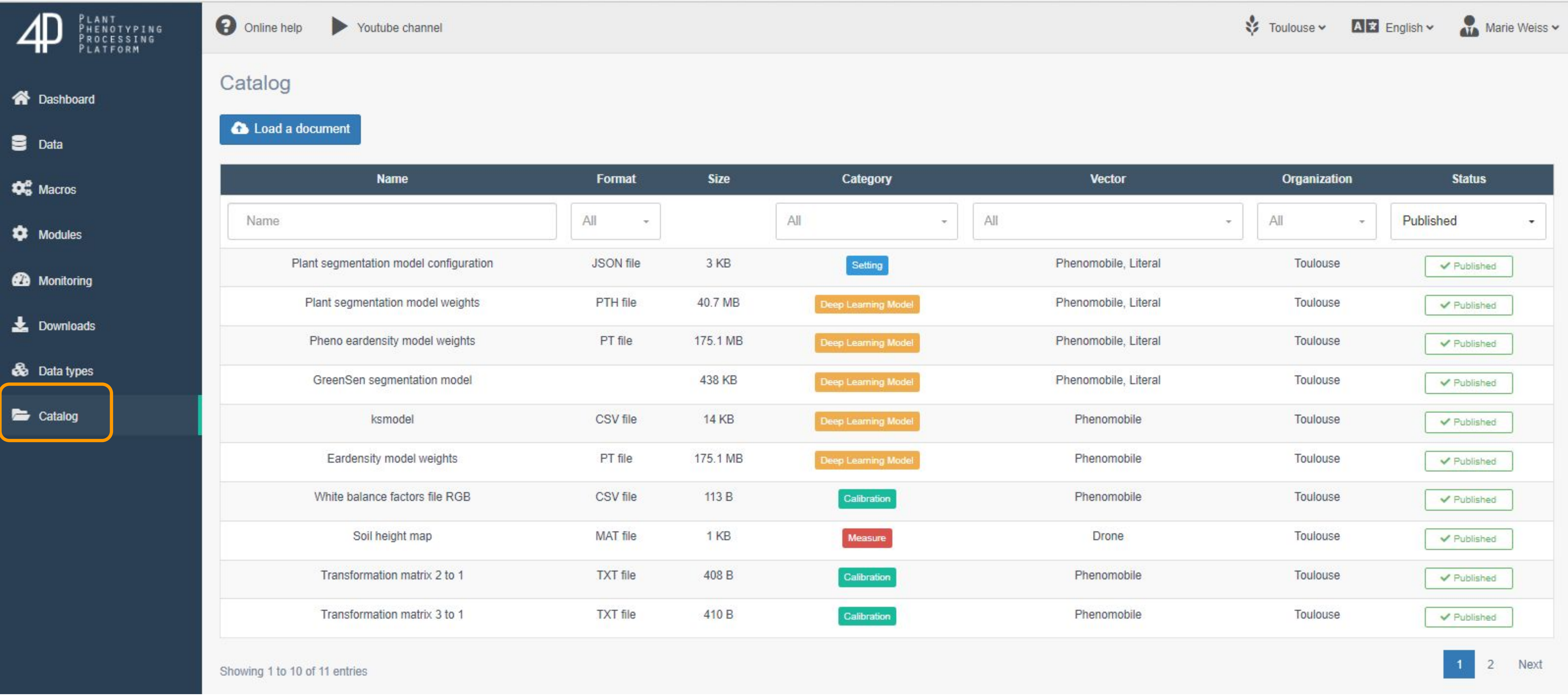
Macros / Pheno Canopy CoverFraction - RGB 1.2 / Workflow
Pheno Canopy CoverFraction - RGB 1.2 (ID 366)
Duplicate
Process dataset
Delete
Display Processing chain
And each Module input/output
Details
Workflow
Input data:
RGB Images
Crop_RGB Phenomobile 1.1
Pheno Canopy CoverFraction - RGB 1.2
Output data:
Cropped RGB Images
VegBackg Seg RGB Images
Canopy CoverFraction
Module: Crop_RGB Phenomobile 1.1
Status: Published
Description:
module used to crop RGB Phenomobile images from the center to the cropAngle in degrees, before applying the Canopy Cover Fraction Segmentation module.
Input data: RGB Images
Inputs | Type | Source | Value
HDF5 Extracted Metadata | file | RGB Images -> HDF5 Extracted Metadata
HDF5 Extracted Positions | file | RGB Images -> HDF5 Extracted Positions
Height Crop angle | float | Fixed in the macro | 20
Rowsp | float | To be entered at the start of process
White Balanced RGB Images | list<file> | RGB Images -> White Balanced RGB Ima
Width Crop angle | float | Fixed in the macro | 20

Module Ex: Export 4P data to PHIS





Name	Format	Size	Category	Vector	Organization	Status
Name	All		All	All	All	Published
Plant segmentation model configuration	JSON file	3 KB	Setting	Phenomobile, Literal	Toulouse	Published
Plant segmentation model weights	PTH file	40.7 MB	Deep Learning Model	Phenomobile, Literal	Toulouse	Published
Pheno eardensity model weights	PT file	175.1 MB	Deep Learning Model	Phenomobile, Literal	Toulouse	Published
GreenSen segmentation model		438 KB	Deep Learning Model	Phenomobile, Literal	Toulouse	Published
ksmodel	CSV file	14 KB	Deep Learning Model	Phenomobile	Toulouse	Published
Eardensity model weights	PT file	175.1 MB	Deep Learning Model	Phenomobile	Toulouse	Published
White balance factors file RGB	CSV file	113 B	Calibration	Phenomobile	Toulouse	Published
Soil height map	MAT file	1 KB	Measure	Drone	Toulouse	Published
Transformation matrix 2 to 1	TXT file	408 B	Calibration	Phenomobile	Toulouse	Published
Transformation matrix 3 to 1	TXT file	410 B	Calibration	Phenomobile	Toulouse	Published

List of available traits

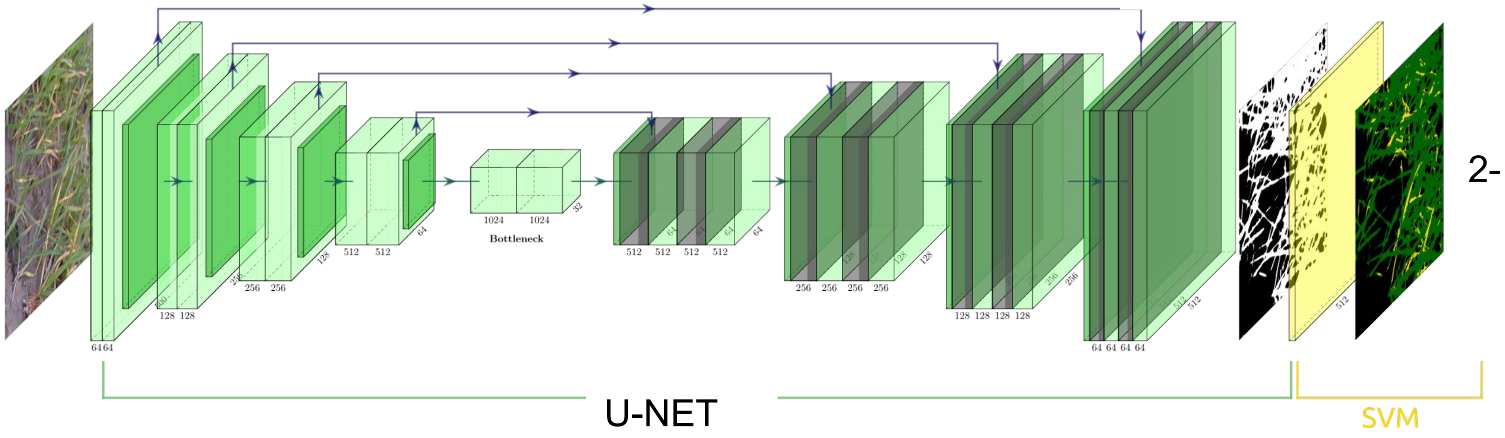
TRAIT	METHOD	SENSOR: RGB	SENSOR: Multispectral	SENSOR: LiDAR	VECTOR: UAV	VECTOR: Phenomobile	VECTOR: LITERAL	REFERENCE
Plant height	Structure from motion/stereo		■		■			Madec et al., 2017 Weiss et al, 2017 Jay et al, en prep.
	Height Distribution			■		■		Madec et al., 2017
Vegetation Fraction (VF)	DL 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 Lopez-Lozano et al, en prep
Plant Area Index (PAI)	1D Turbid	■		■		■		Lopez-Lozano et al, en prep

TRAIT	METHOD	SENSOR: RGB	SENSOR: Multispectral	SENSOR: LiDAR	VECTOR: UAV	VECTOR: Phenomobile	VECTOR: LITERAL	REFERENCE
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 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
3D Distribution of Leaf Area	1D Turbid			■		■		Liu et al., 2017 Lopez-Lozano et al, en prep
Plant density	DL	■			■	■	■	Jin et al., 2017 Velumani et al, 2021
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

Serouart et al, 2022
Madec et al, 2023

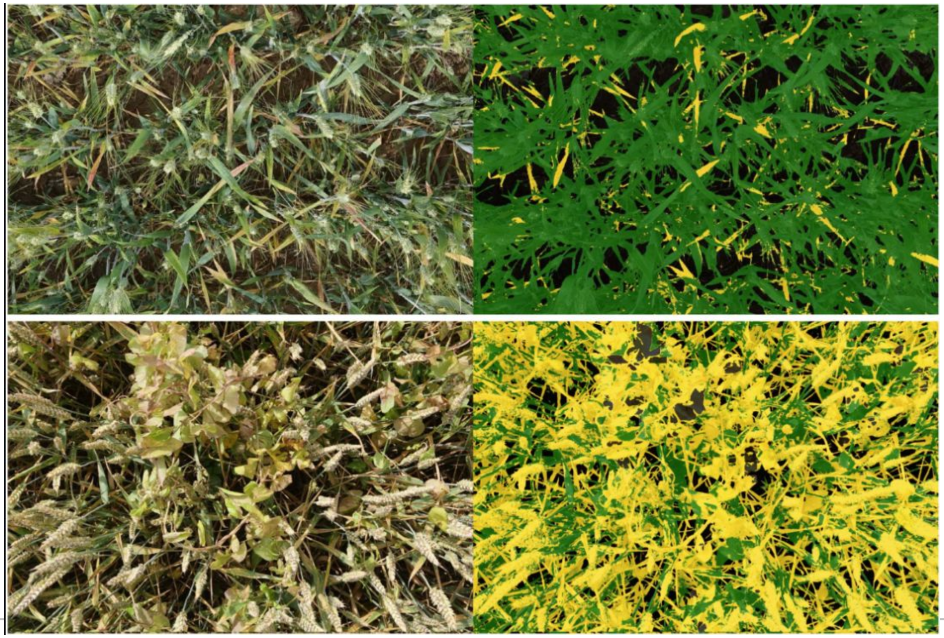
RGB Images/ Green Fraction

1 – Vegetation/Background Masks

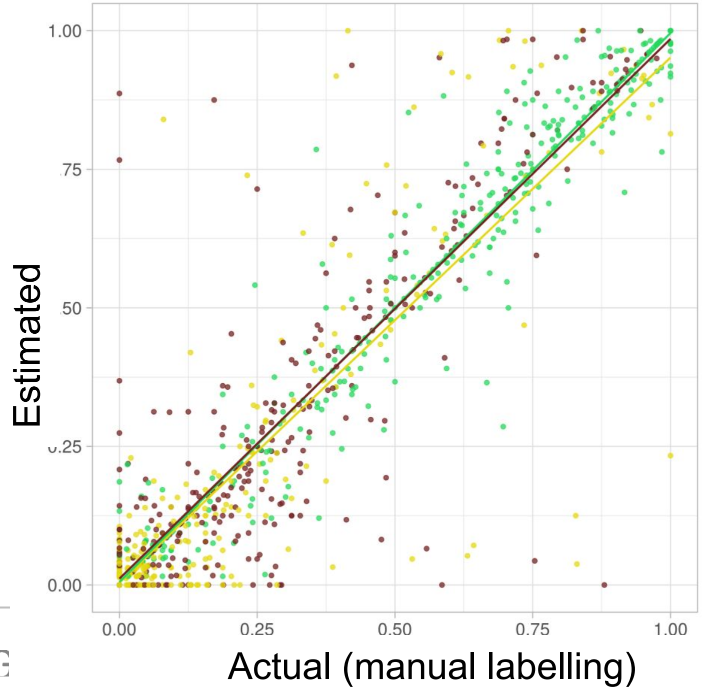


2- Green/Senescent vegetation

SVM

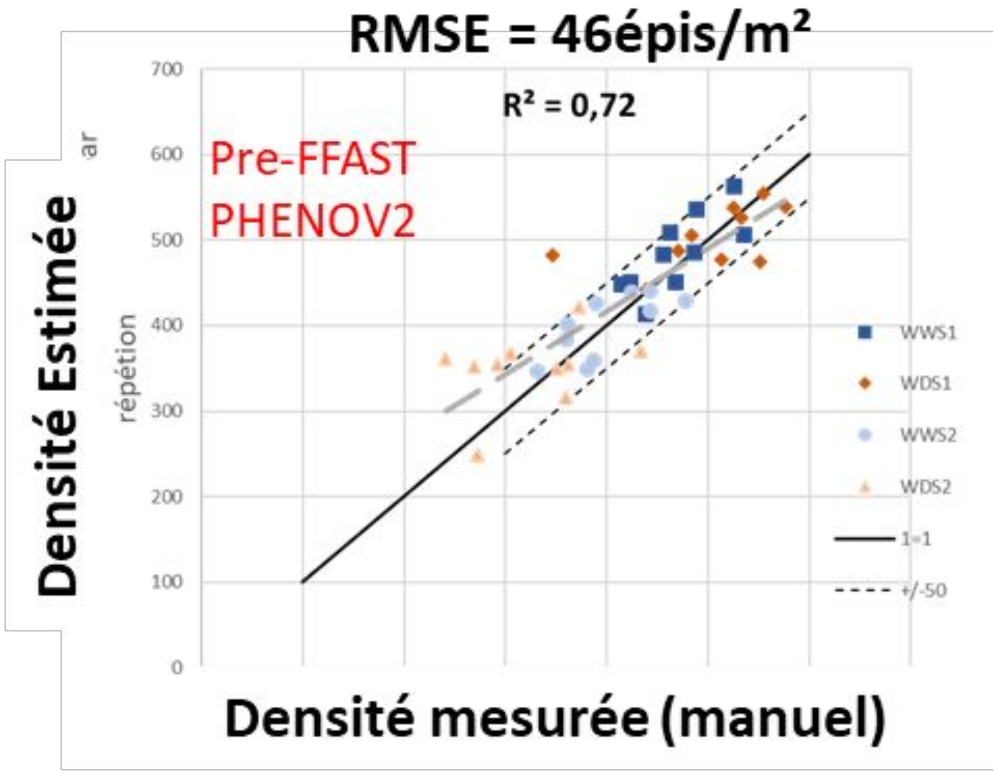


Background
Green Veg
Senscent Veg



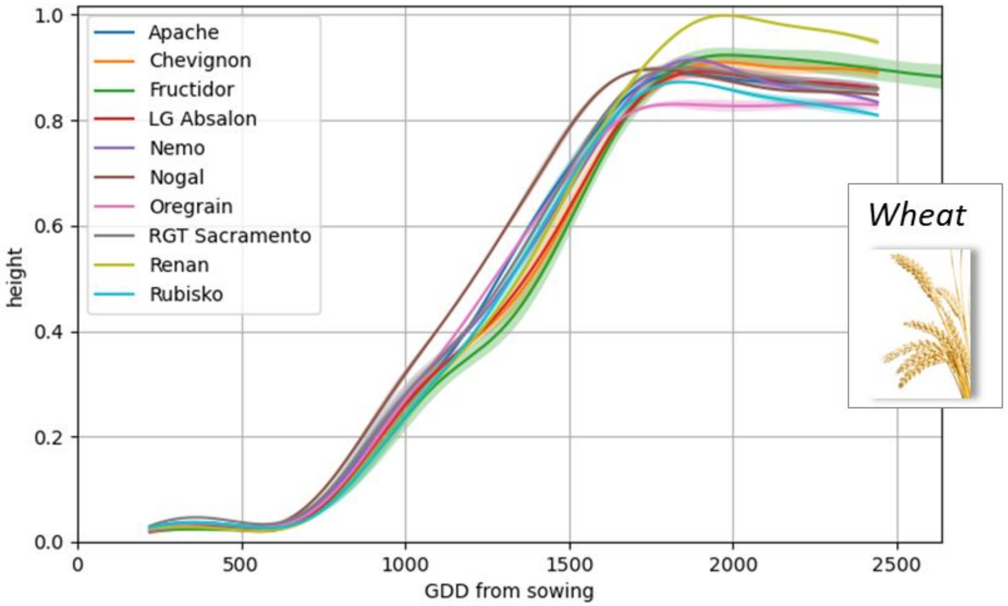
RGB Images+ LiDAR / Ear Density

DL model from the global wheat head data challenge : David et al, 2021, 2023
Footprint of the RGB camera derived from camera height estimated from LidAR

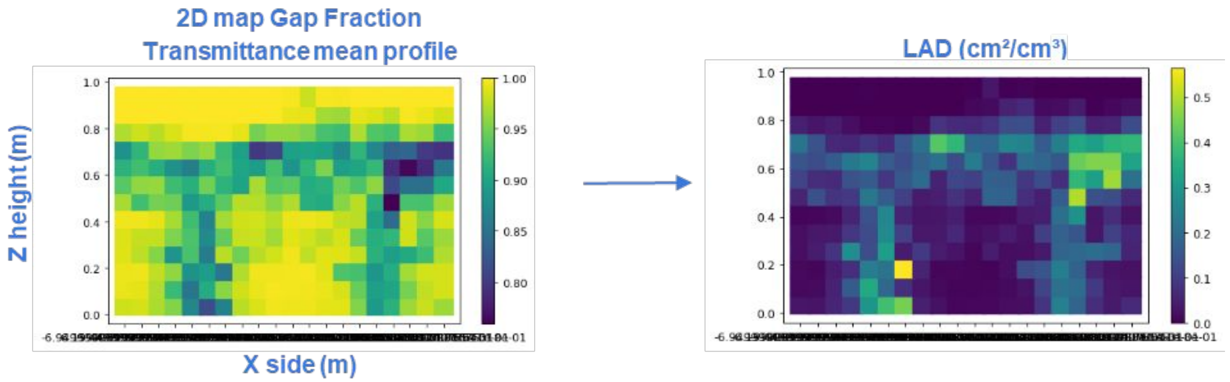


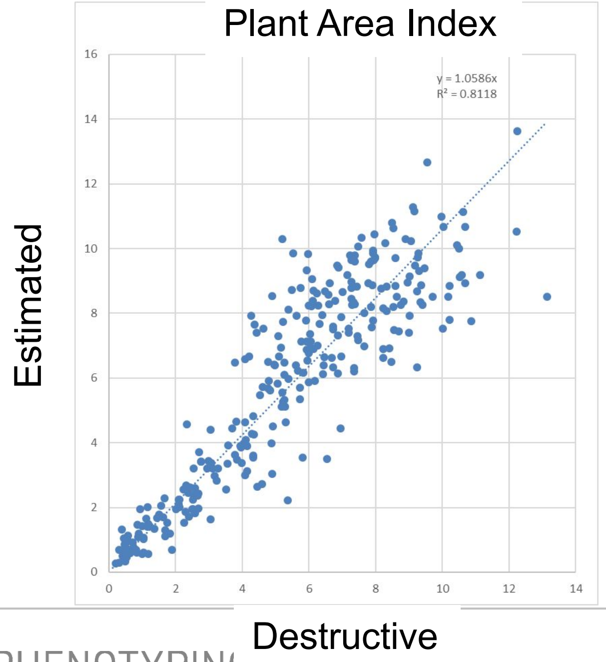
LiDAR / Height / Gap Fraction / Plant Area Density

Lopez-Lozano et al, in prep



Pre-FFAST project (2021) @ DiaScope.
10 G x well-watered x november sowing x 2 replicates





THE TEAM

INRAE

Platform Development Software and functional architecture

France Grille
Cloud computing and storage

UMR EMMAH

Platform Management
Algorithms
Processing pipelines

PHIS

UMR MISTEA

Information System

Experimental Units

UE GCA
UE PHACC
UE DIASCOPE

- Specifications
- Test
- Use

ARVALIS
Terres Inovia
l'agronomie en mouvement
hiphen

THANKS FOR YOUR ATTENTION

Data enrichment: Events, Annotation and Documents

Definitions

- **Events:** can be **processes, actions or facts** that occur in (or even precede) scientific experiments and have an influence on the experiment. Events are **identified and characterized**. Main categories are **controlled** (irrigation, fertilizer, maintenance, installation) or **uncontrolled** (hail, frost, pests, breakdown).

  => Treatment, Trouble, Pest attack, Move, etc.

- **Annotation:** A **short comment** added to an entity (data, object, experiment, device, etc.).

  => Motivations: Comment, Highlight, Classify, Moderate, Link, Tag, etc.

- **Documents:** A document refers to a **combination of a medium and information** (the content), the latter recorded in a persistent manner. It has explanatory, descriptive or evidential value.

  => Report, Publication, Technical document, Experimental protocol, Dataset, etc.

Data enrichment: Events, Annotation and Documents

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  => MIAPPE, Ontology of Experimental Events (OEEV) - https://agroportal.lirmm.fr/ontologies/OEEV

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  => Web Annotation Ontology (OA) - https://www.w3.org/ns/oa

  Word Wide Web Consortium

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  => Dublin Core - https://www.dublincore.org/specifications/dublin-core/dcmi-terms/

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  => W… …ww.w3.org/ns/oa

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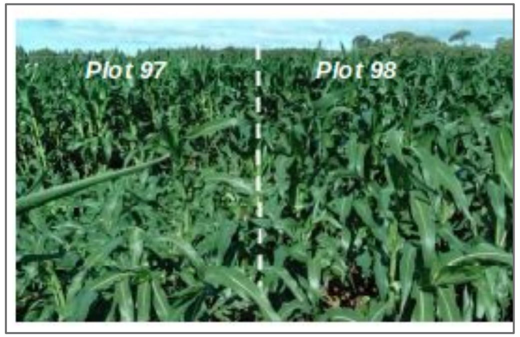
  => Dublin Core - https://www.dublincore.org/specifications/dublin-core/dcmi-terms/

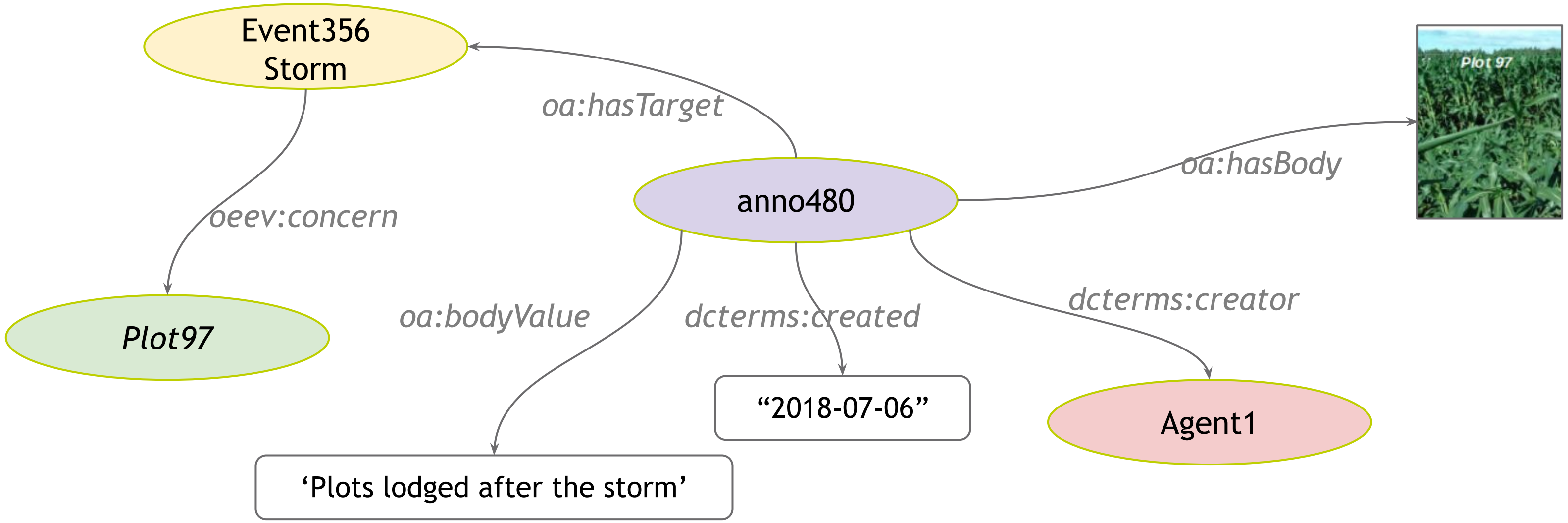
Add more value with semantic metadata!
Ontologies, thesaurus, etc.

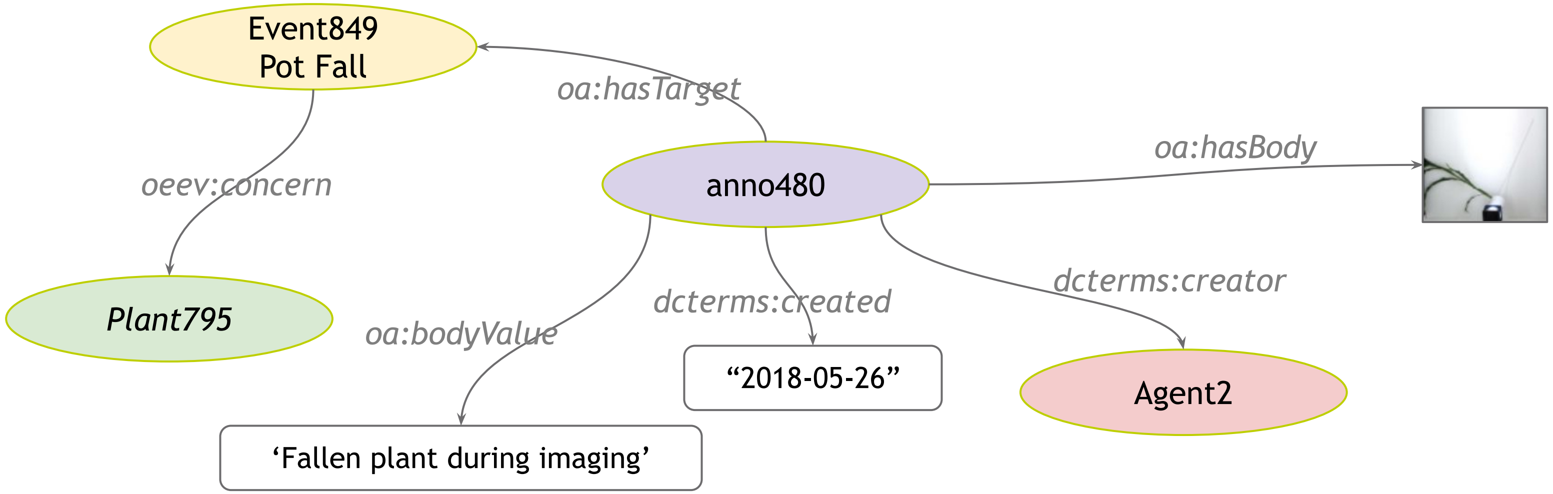
Word Wide Web Consortium

Data enrichment: Events, Annotation and Documents

Illustration

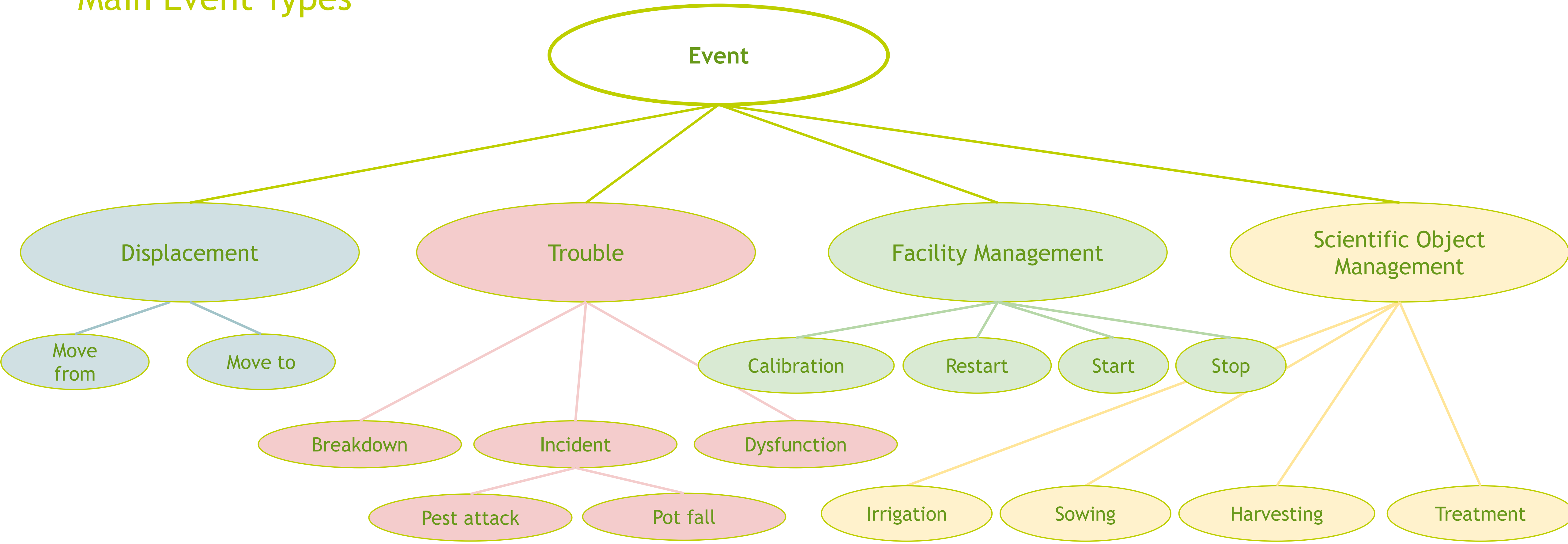






Events

Main Event Types



Events - MIAPPE important Section

Event

- Discrete, dated or time-stamped occurrence
- Natural (e.g. rain, pathogen attack)
- Cultural practice (e.g. sowing, irrigation)
- Applied to the whole study or by observation unit
- **This is not the factor,** but additional information.
- Event can be used to achieve a factor.

Event
Event type
Event accession number
Event description
Event date

Metadata : name, description and time/date

Example: POPLAR [2]

- the field establishment date, 2003
- the orchard was subjected to 15mm of rain on March 15, 2012 (fiction)

Study	Event		
	Name	**Description**	**Date**
Monclus *et al., 2012*	Rain	15mm of rain on the orchard	2012-03-15

Events

Event Types & Properties

- Event ID
- Event Type
- Event Description
- Event Date / Period
- Target

Events

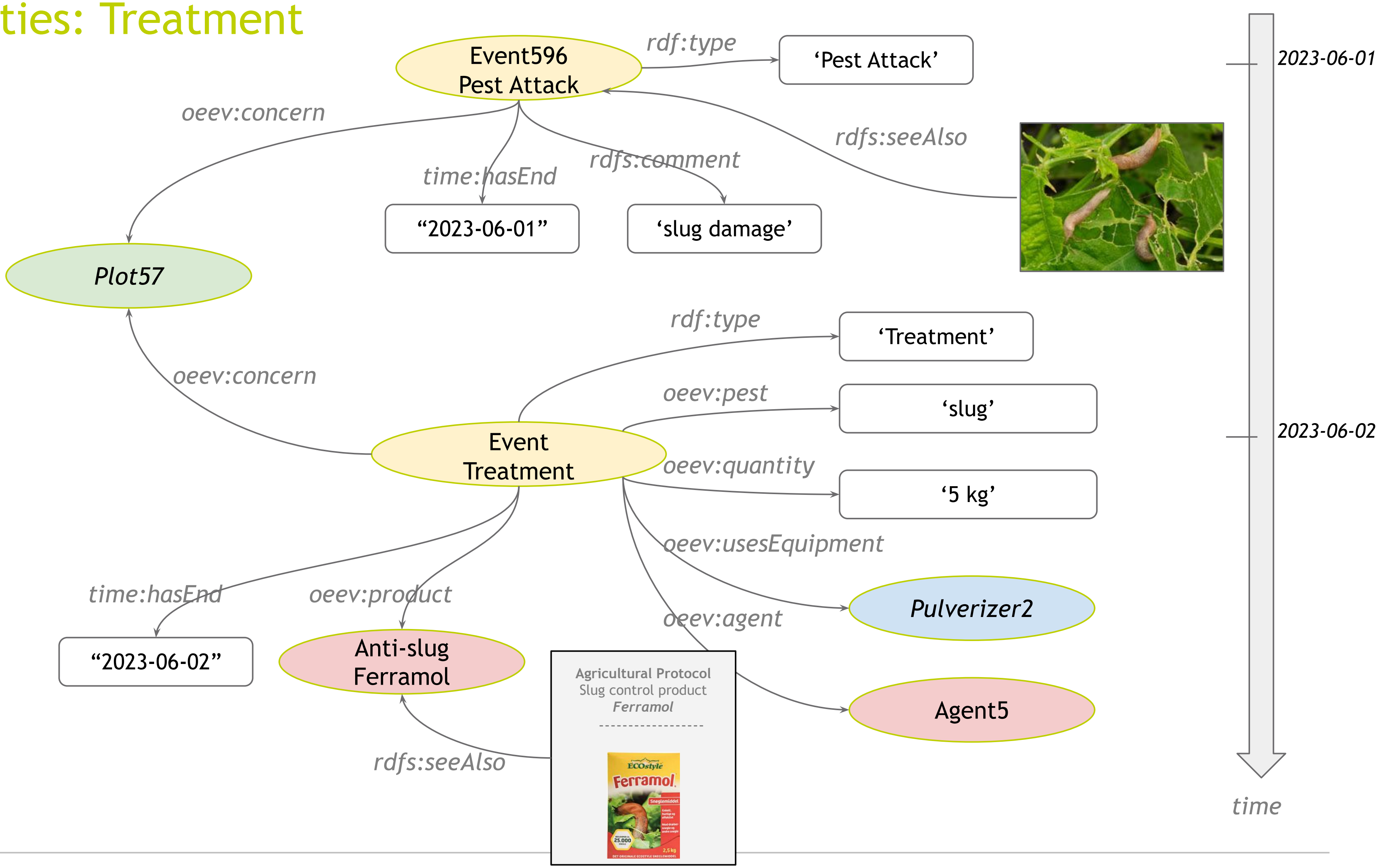
Event Types & Properties: Move

- Event ID
- Event Type
- Event Description
- Event Date / Period
- Target
- From
- To
- Coordinates
- X, Y, Z Position
- Textual position

Events

Event Types & Properties: Treatment

- Event ID
- Event Type
- Event Description
- Event Date / Period
- Target
- Product
- Quantity
- Pest
- Equipment used
- Agent



Events

Describe a scientific object life cycle

Pot *(MAC5)*

Greenhouse *(GH1)*

Definition and declaration of Pots 2017-01-12

Sowing 2017-02-10

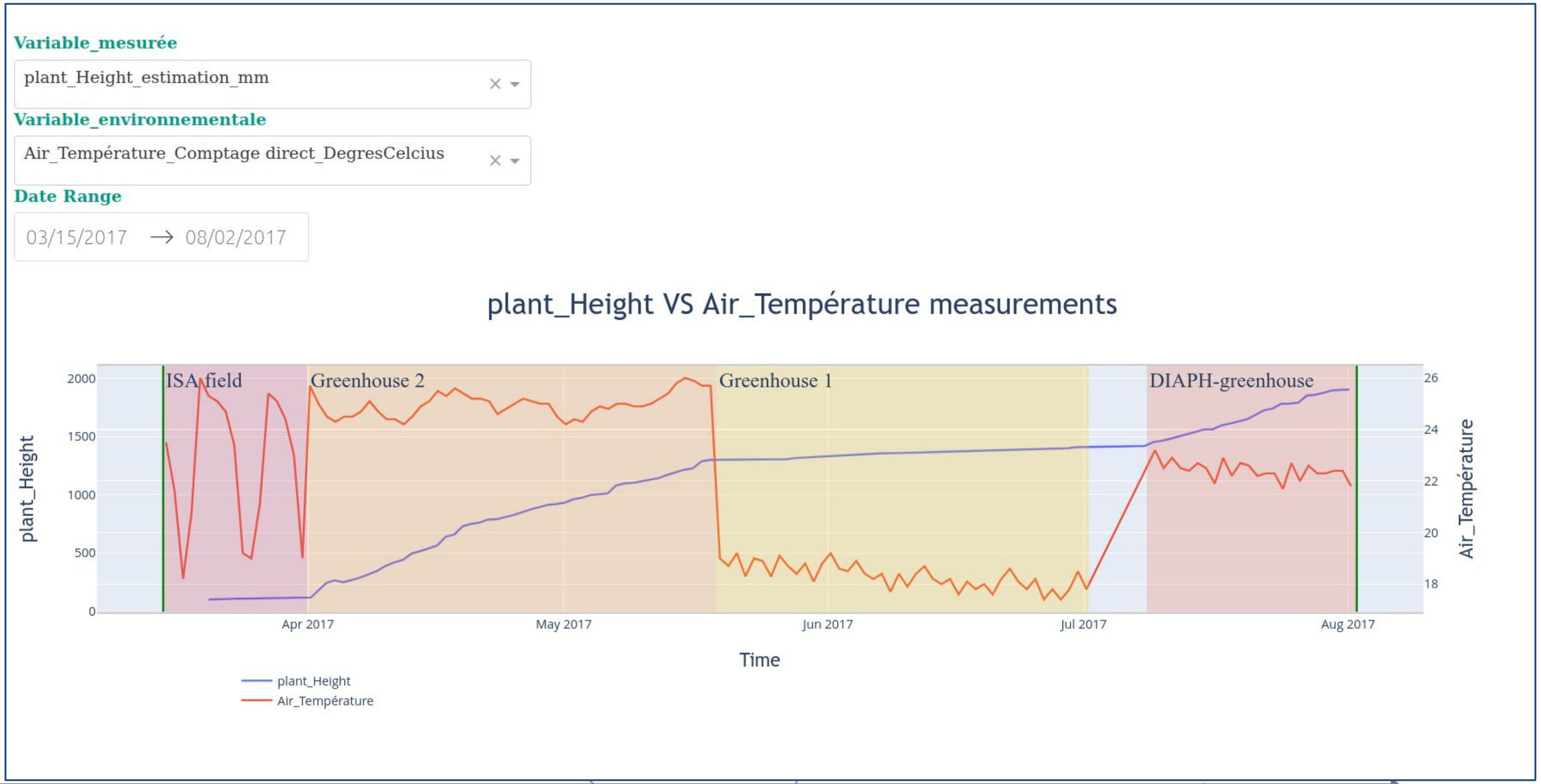
Definition and declaration of Plants 2017-04-12

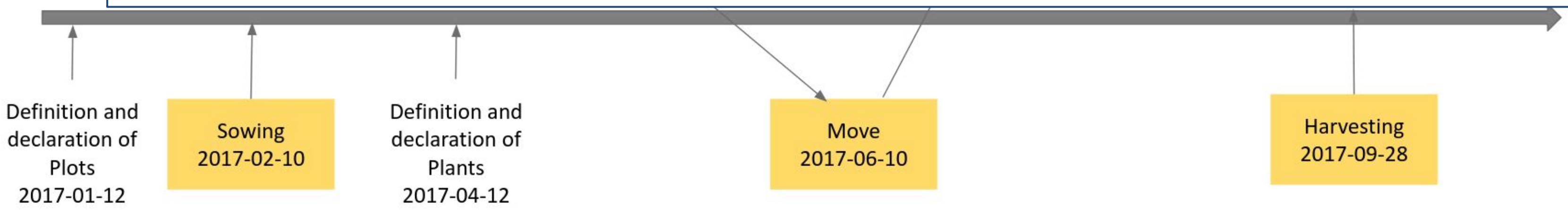
Move 2017-06-10

Harvesting 2017-09-28

Data Exploration: environmental and phenotypic data

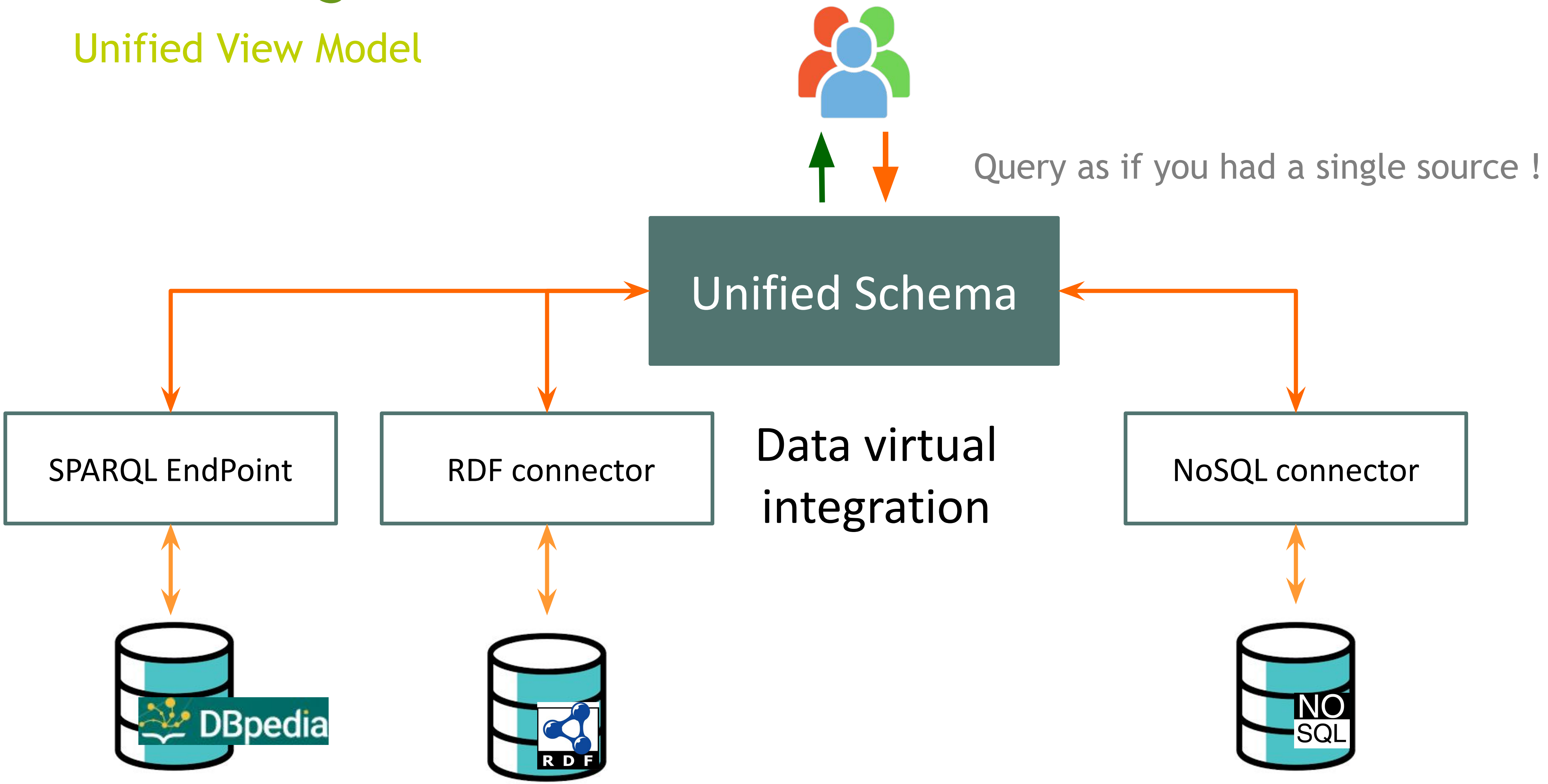
Visualising and linking environmental and phenotypic data





Data Integration Architecture

Unified View Model



Use Case: Data analysis and integration

How FAIR data may help in managing and analyzing data in HTPP experiments? - **Llorenç Cabrera Bosquet**

Data analysis and integration

How FAIR data may help in managing and analyzing data in HTPP experiments?

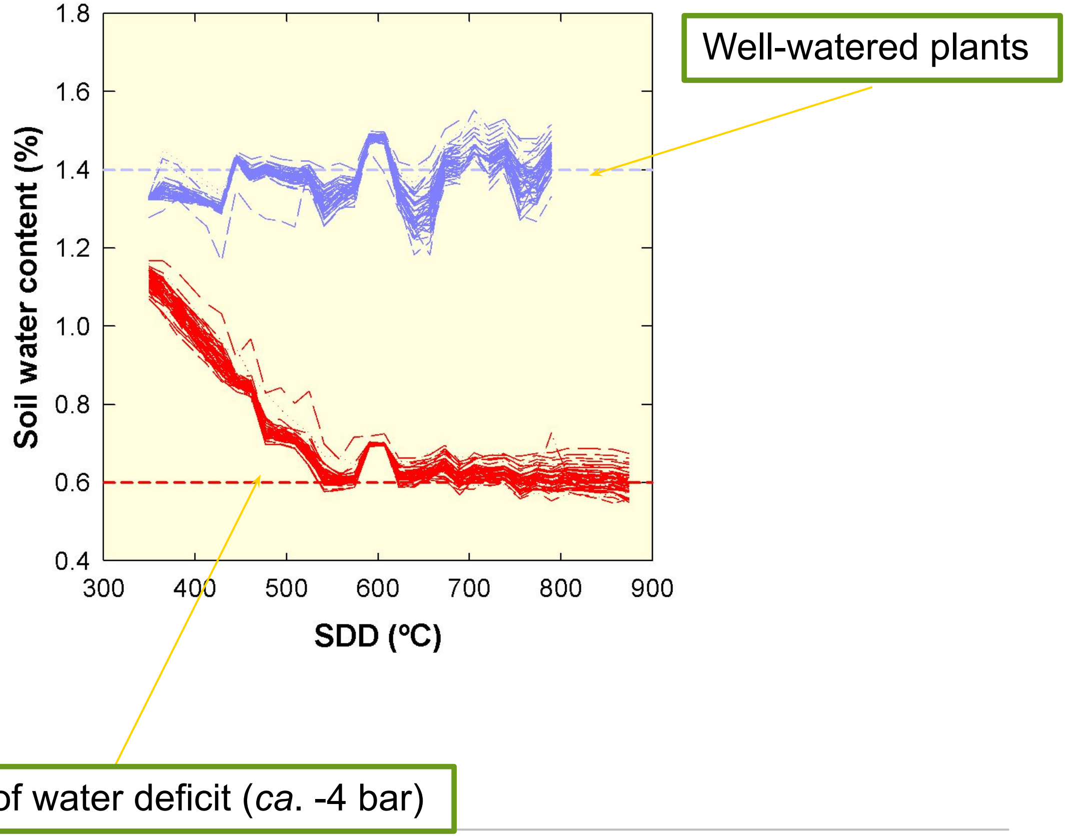
First ->Some prerequisites

- Data are organised and managed following FAIR principles
- All data includes phenotypic, environmental and metadata measurements
- Ideally, data is managed in ‘real time‘ (allows decision-taking)

Exemple 1: Piloting and monitoring water deficit in thousands of plants

We need to continuously and individually monitor and manage water scenarios in most experiments

PHENOARCH platform Montpellier, INRAE

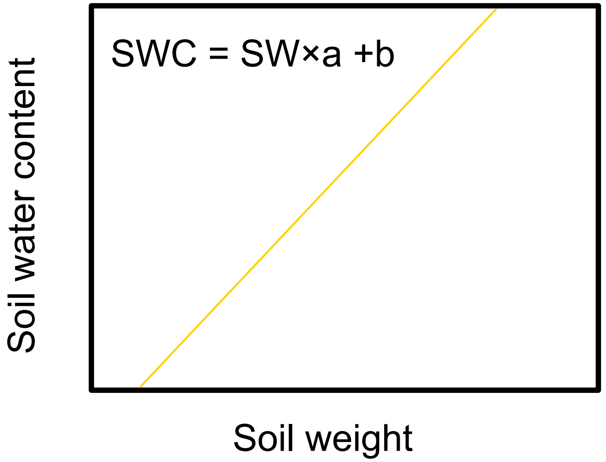


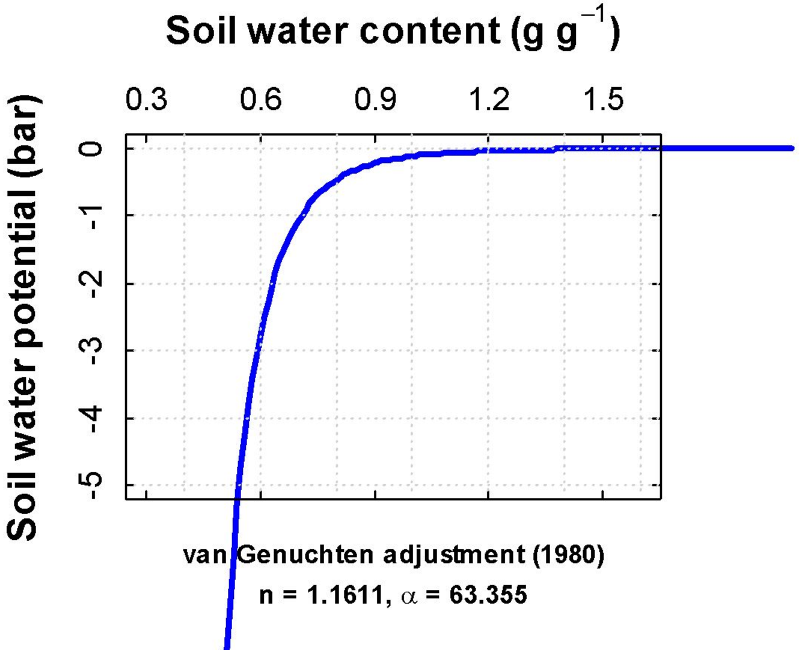
How soil water content (SWC) and SWP is measured?

1. Plant are weighed individually on a daily basis (or more)

2. Soil water content (g H_20 per g of dry soil) is deduced using a formula

3. Soil water potential (bar) is calculated using a soil retention curve (Ψ vs Φ)





This is not so easy…

1. Platform weighs the whole ‘system’, not only soil weight

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WE NEED

Proper identification of individual components

URI of plant
<m3p:arch/2017/c17000118>

URI of pot:
<m3p:arch/2013/pc13001542>

URI of cart:
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<m3p:arch/2013/ct1300123>

Weight of individual components + metadata

- Weight of pots, carts, soil, etc.
- Soil used and its characteristics
- Intitial soil water content at potting
- Events that may have affect the weight (e.g. fertilisation, adding of sticks, etc.)

This is not so easy…

2. Plants grow over time

This may have a HUGE impact on soil water content estimation if plant biomass is not taken into account

This is not so easy...

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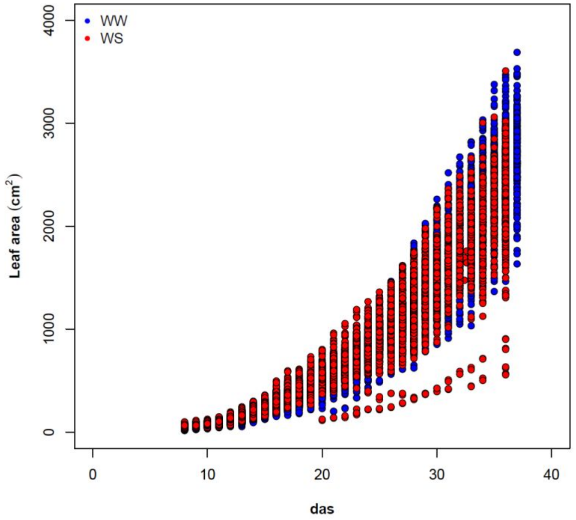
Plant biomass estimation over time

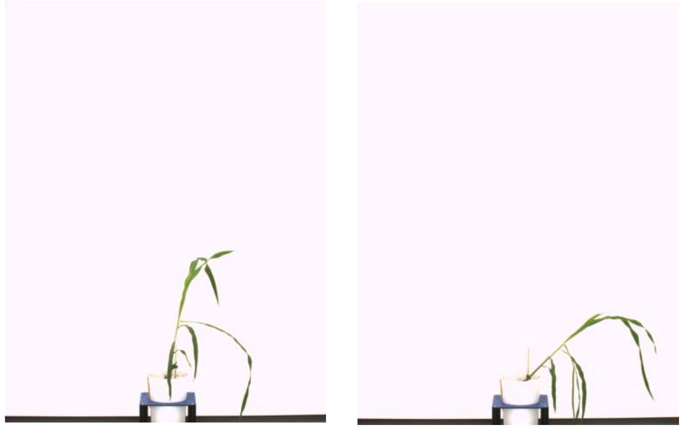


Requires real time monitoring and analysis of data

This is not so easy…

2. Plants grow over time

WE NEED



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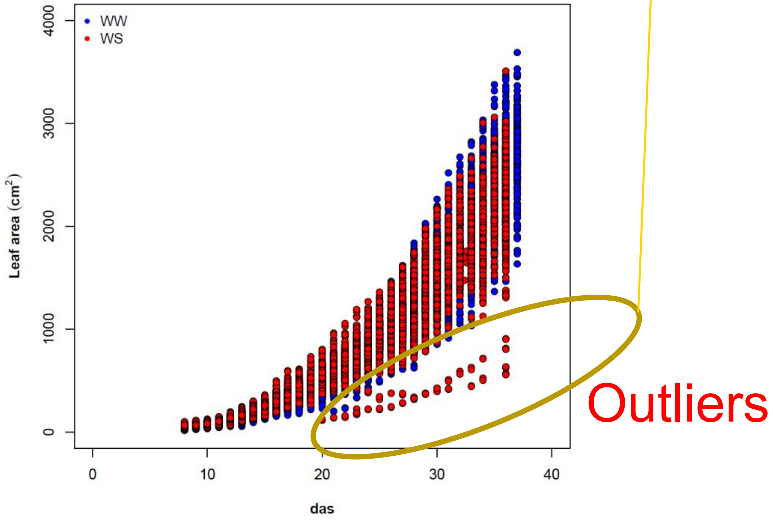
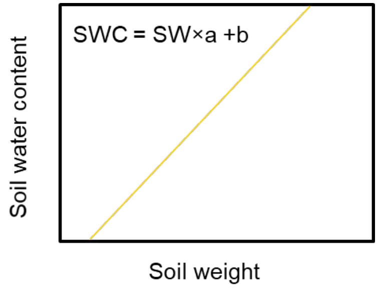
Plant biomass estimation over time



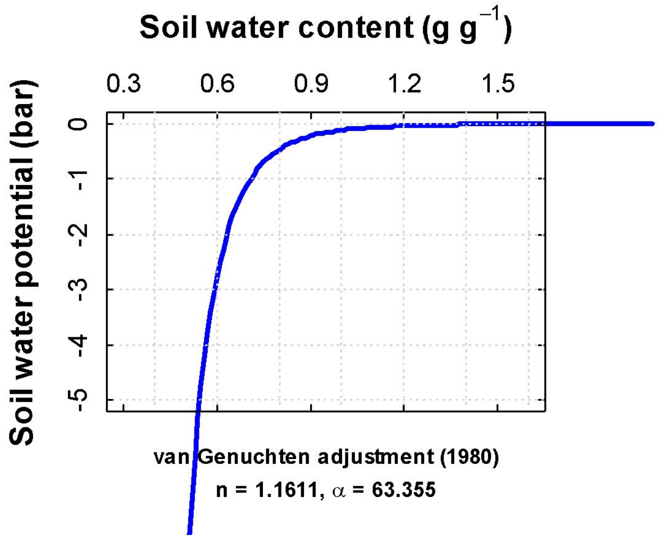
Requires real time monitoring and analysis of data

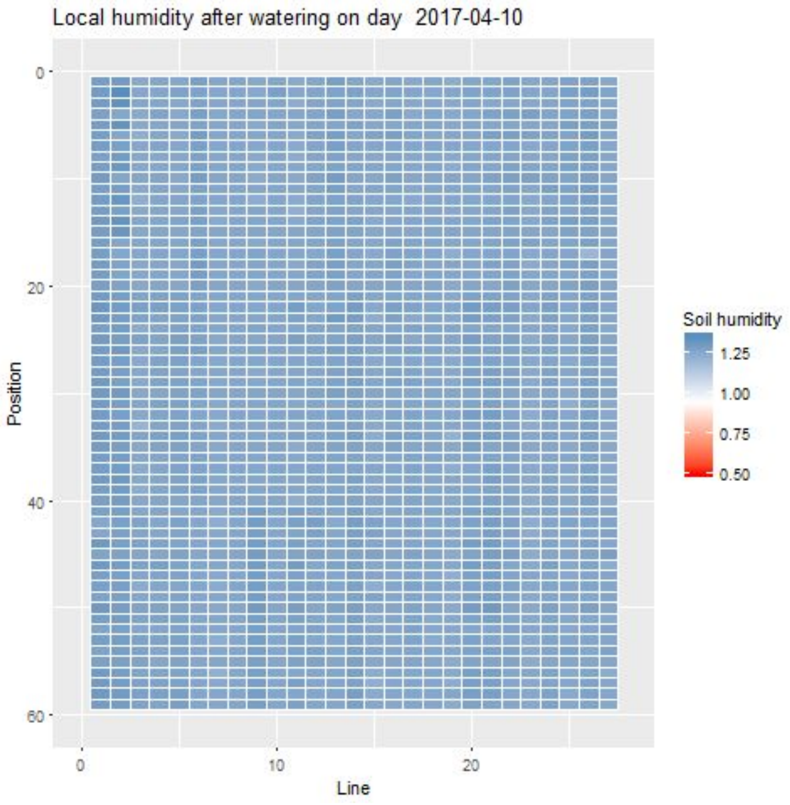
Finally SWC and SWP are calculated



SWC = Weight of 'whole system' - Plant biomass - Weight of Pot - Weight of Cart - b / a

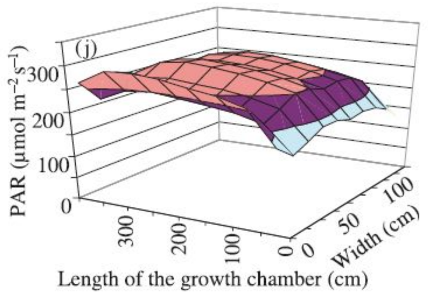
SWP = ((SWC/2)$^{(-n/(n-1))}$-1)$^{(1/n)}$/(-α)/10





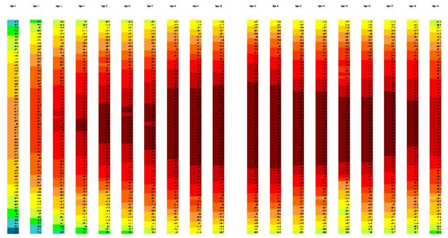
Envirotyping: Spatial and temporal variability and consequences for phenotyping

- Climate information is an essential **co-variate for monitoring growth** as drives most growth processes.
- Most platforms display a large temporal and spatial variability of environmental conditions

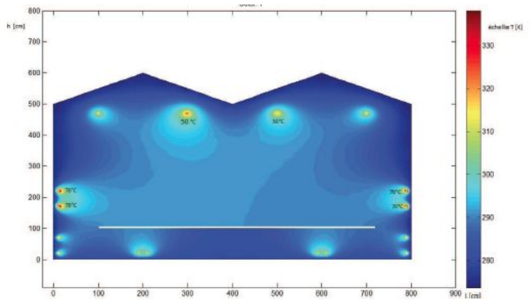


Granier et al 2006

PAR distribution (lights on)



4PMI Dijon
Julien Martinet,
Christophe Salon



RootPhair,
UCL
Xavier Draye

UCL Université catholique de Louvain

There are some consequences for phenotyping…

IGNORING IT => depreciates the value of phenotypic data.

MEASURING IT enables

=> The **combination of data** from different experiments, different platforms or from field and platforms.

=> Taking advantage of (undesired) climate variability to determine **environmental response curves** during an experiment.

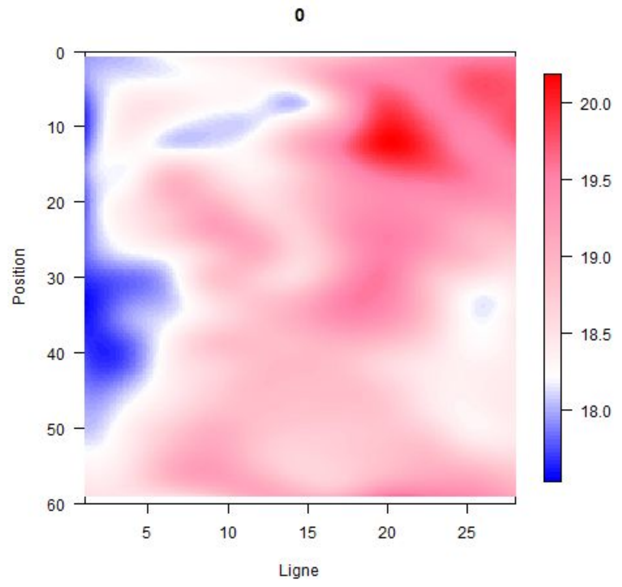
Exemple 2: Environmental quantification

AIM : Calculate thermal time from sowing for each plant in an experiment

$$ThermalTime = \sum_{i}^{n} T_{air} - T_b$$

Apparently easy but…

- Plants sown and harvested in batches at different dates
- Plants belonging to different crops
- Plants located in different positions of the greenhouse
- Sensors at different positions displaying significant variation in temperature



Exemple 2: Environmental quantification

AIM : Calculate thermal time from sowing for each plant in an experiment

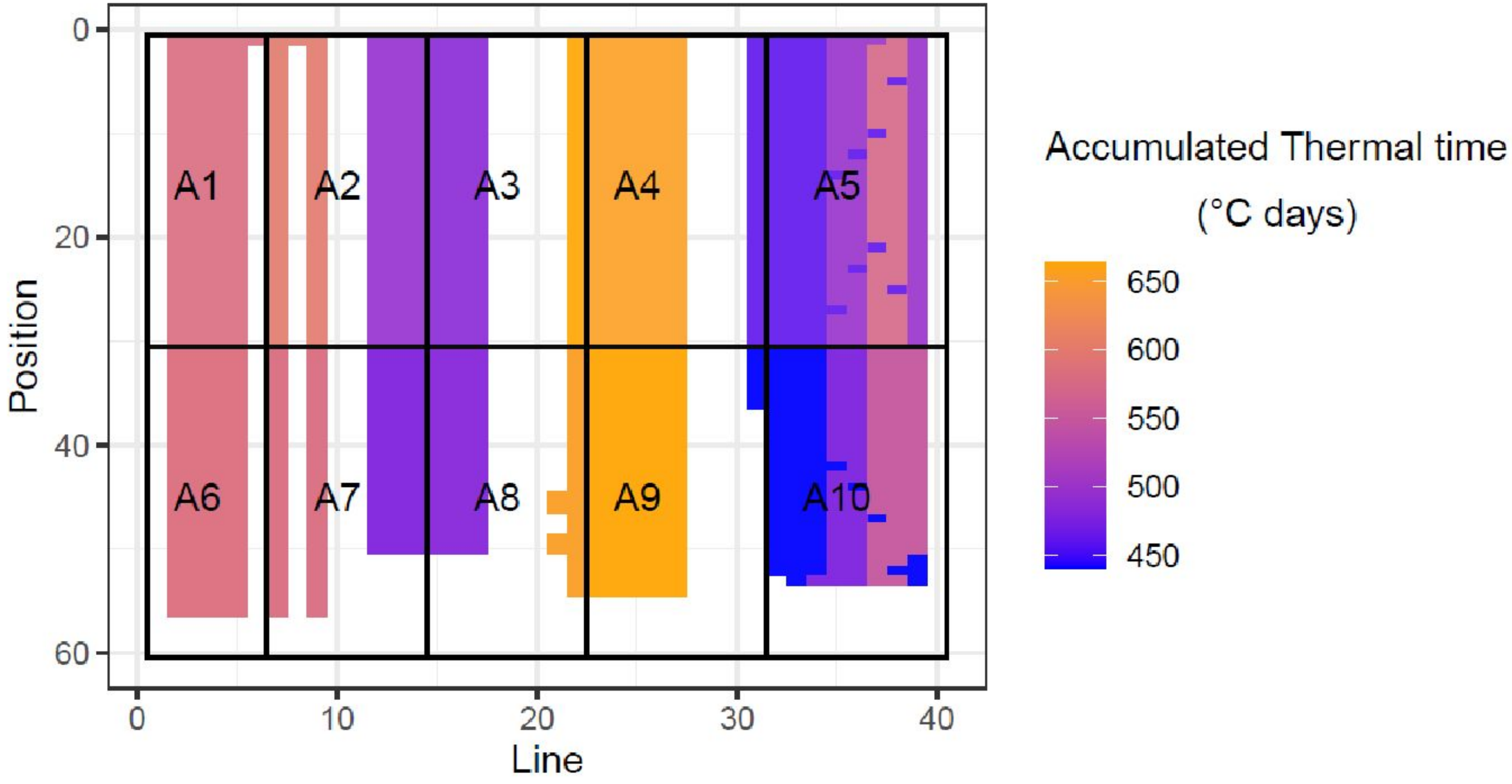
$$ThermalTime = \sum_{i}^{n} T_{air} - T_b$$

WE NEED

- Plants sown in batches at different dates => Sowing and harvest dates for each plant (events)
- Plants belonging to different crops => T_b specific for each crop (ex. 8°C for maize, 0°C for wheat)
- Plants located in different positions of the greenhouse => tracking of plants' position
- Sensors displaying significant variation in temperature => Sensor position, variable measured and units

Exemple 2: Environmental quantification

Taking into account all this annotated date allows to calculate thermal time for each plant in an experiment



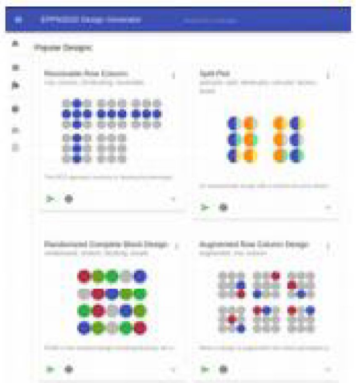
Statistical methods

Incorporation of statistical methods for platform management, data 'cleaning,' and analysis

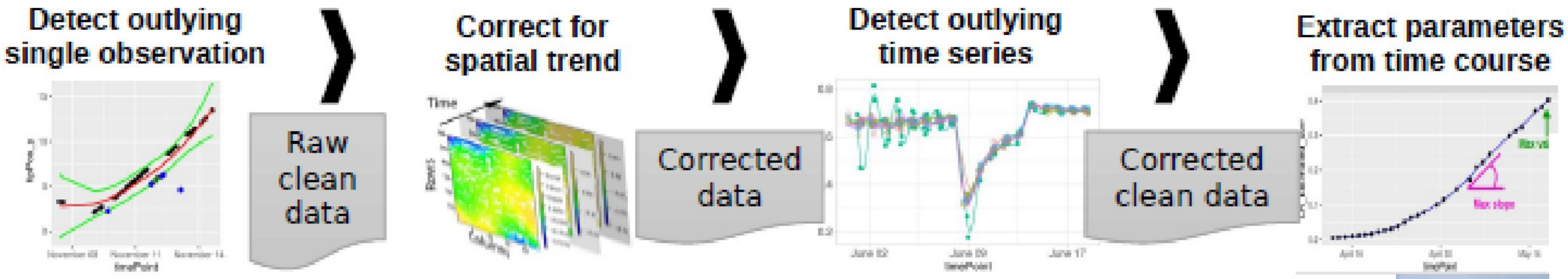
1. **Detection of outlier plants** (bad germinantion, disease, seed error)

Alvarez Prado *et al*. 2019

2. **Design Generator**: User friendly online service aimed at construction and generation of experimental designs https://eppn2020design.com/



3. **statgenHTP R package** (outlier detection, correction of spatial trends, patameter extraction from time series)



R pakage: statgenHTP

WAGENINGEN UNIVERSITY & RESEARCH
Emilie Millet
Bart-Jan van Rossum
Martin Boer
Fred van Eeuwijk

INRAE
Nadine Hilgert
Isabelle Sanchez

bcam
Diana Perez
Coté Rodriguez

https://cran.r-project.org/web/packages/statgenHTP/
https://biometris.github.io/statgenHTP/articles/vignettesSite/Intro_HTP.html

E. Millet

Spatio-temporal analysis of HTTP data

PHENOARCH - INRAE

FIP - ETH Zürich

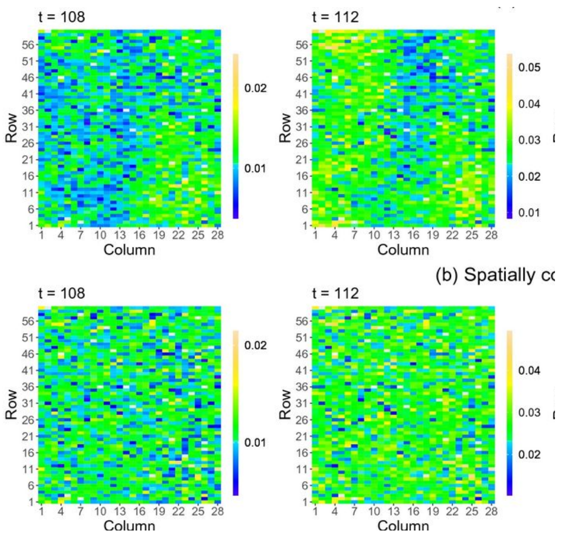
scientific reports

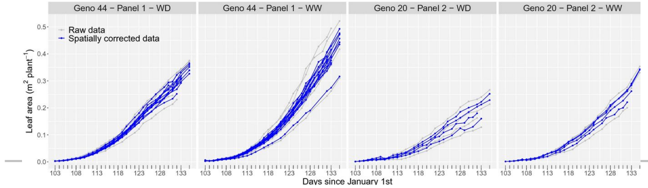
Article | Open Access | Published: 24 February 2022

A two-stage approach for the spatio-temporal analysis of high-throughput phenotyping data

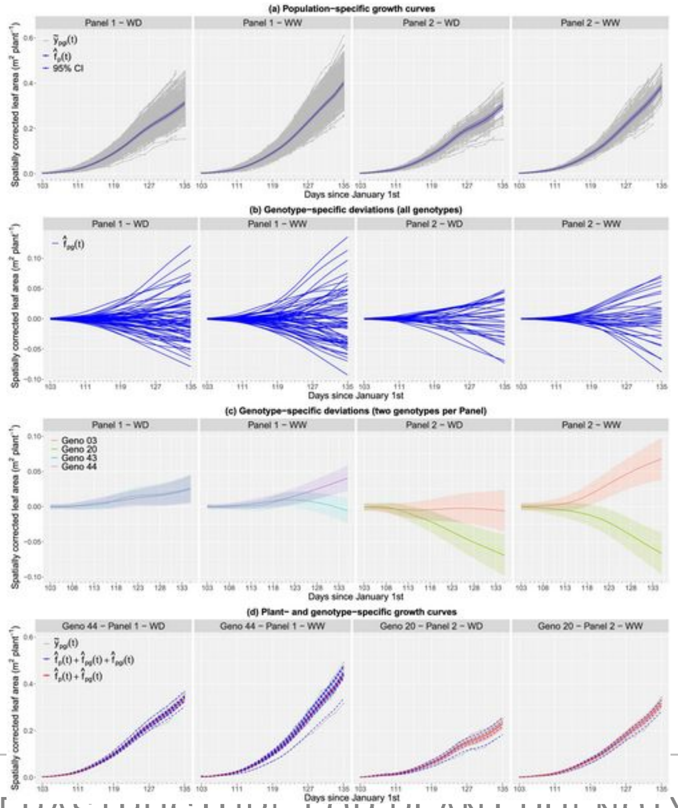
Diana M. Pérez-Valencia, María Xosé Rodríguez-Álvarez, Martin P. Boer, Lukas Kronenberg, Andreas Hund, Llorenç Cabrera-Bosquet, Emilie J. Millet & Fred A. van Eeuwijk

1. Design features and spatial trends correction per time point.

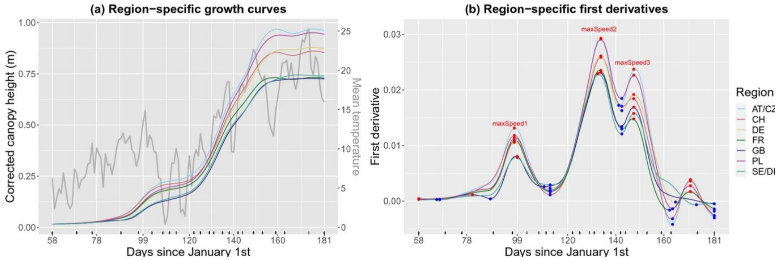




2. Longitudinal modelling of the spatially corrected data, thereby taking advantage of shared longitudinal features between genotypes and plants within genotypes



3. Extracting time-independent attributes to characterise genotypes



Code available

Geospatial Events

Event with an Area as a Target

- Event ID
- Event Type
- Event Description
- Event Date / Period
- Target = Area
    - Type
    - Name
    - Description
    - **Geometry**

Geospatial Events

Event with an Area as a Target

- Event ID
- Event Type
- Event Description
- Event Date / Period
- Target = Area
    - Type
    - Name
    - Description
    - **Geometry**

Events and also…

- Any observed object
- Any device
- Any facility
- Adresse (site, institution, …)
- …

IS *vs* GIS: How to deal with spatial data?

Vector
- Import
- Export
- Generation
- Update
- Attribute table

Raster
- Import
- Export
- Generation
- Processing

Georeferencing Projection sys
- Set up
- Up date
- Change
- Search & Geolocalisation

Maps
- Generation
- Symbology
- Atlas
- Layout

Analysis
- Filter
- Query
- Measurements
- Geostatistics

IS *vs* GIS: How to deal with spatial data?

Do we need a GIS to manage properly and FAIRly Geospatial phenotyping data?

What we need as minimum

- GIS: What are the limits?
  - File sizes, Transformation & Projection ⇒ access limits
  - DBMS : mostly relational
    - Limited performance and capacity in Big Data applications and MetaData management
    - Limited flexibility to handle complex data types and relationships

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Make a high-performance I.S. interoperable with a GIS

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⇒ **Make a high-performance I.S. interoperable with a GIS**

⇒
- Query & Analyse
- Exporting different formats (shapefiles, geojson, CSV,...)
- Spatial functions and indexation
- DB: PostGreSQL and extension PostGIS, Oracle Spatial, MongoDB, MySQL Spatial

What we need as minimum

Vector
- Import
- Export
- Generation
- Update
- Attribute table

Raster
- Import
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Analysis
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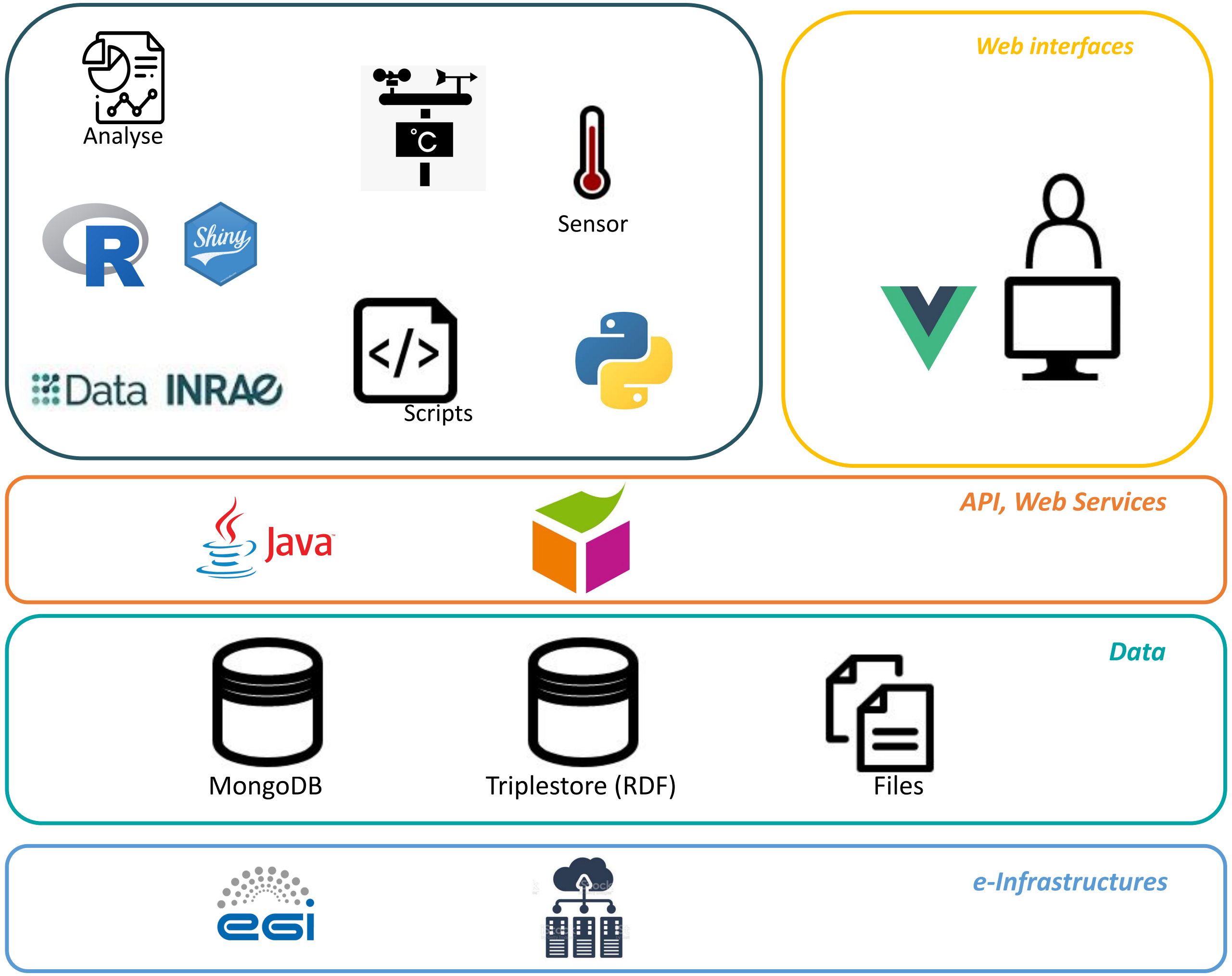
How to integrate spatial data (PHIS example)



How to integrate spatial data (PHIS example)

- **Implementation examples :**

Spatial data storage in ***MongoDB*** using ***SOSA*** ontology

MongoDB:

- Document oriented DBMS (Object = document, organized in collections) - NoSQL
- Data format : BSON (binary JSON)
- Spatial data format : GeoJson (WGS84)

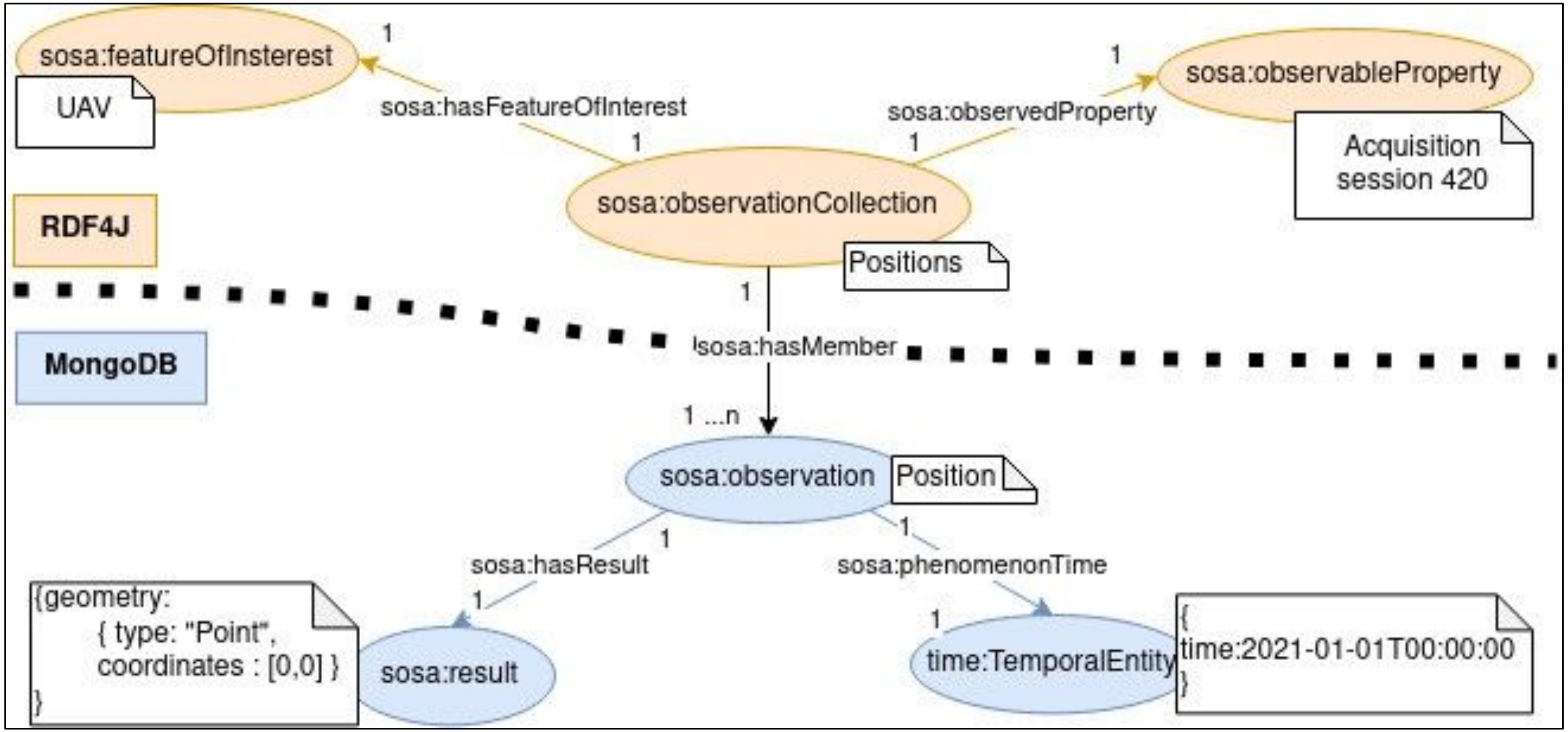
SOSA Ontology (Semantic Sensor Network Ontology) :

- Formal but lightweight general specification
- Modeling the interaction between entities
  - *S*ensor
  - *O*bservation
  - *S*ample
  - *A*ctuator
- Use the observation collection of SOSA :
  - 1 spatial data of 1 object = 1 observation
  - 1 liste of spatial data of 1 object = 1 observation collection

How to integrate spatial data (PHIS example)

GeoJSON document =
sosa: observation

“Location” collection=
sosa:observationCollection



How to integrate spatial data (PHIS example)

- Spatial Data format
  - Projection system: mostly WGS84 (World Geodetic System 1984 - EPSG:4326) : longitude/latitude
  - GeoJson, WKT, KML, ….
  - Visualization libraries: OpenLayers, MapBox, LeafLet


```
{
  "type": "Feature",
  "geometry": {
    "type": "Point",
    "coordinates": [125.6, 10.1]
  },
  "properties": {
    "name": "Dinagat Islands"
  }
}
```

GeoJSON

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2">
<Document>
<Placemark>
  <name>New York City</name>
  <description>New York City</description>
  <Point>
    <coordinates>-74.006393,40.714172,0</coordinates>
  </Point>
</Placemark>
</Document>
</kml>
```

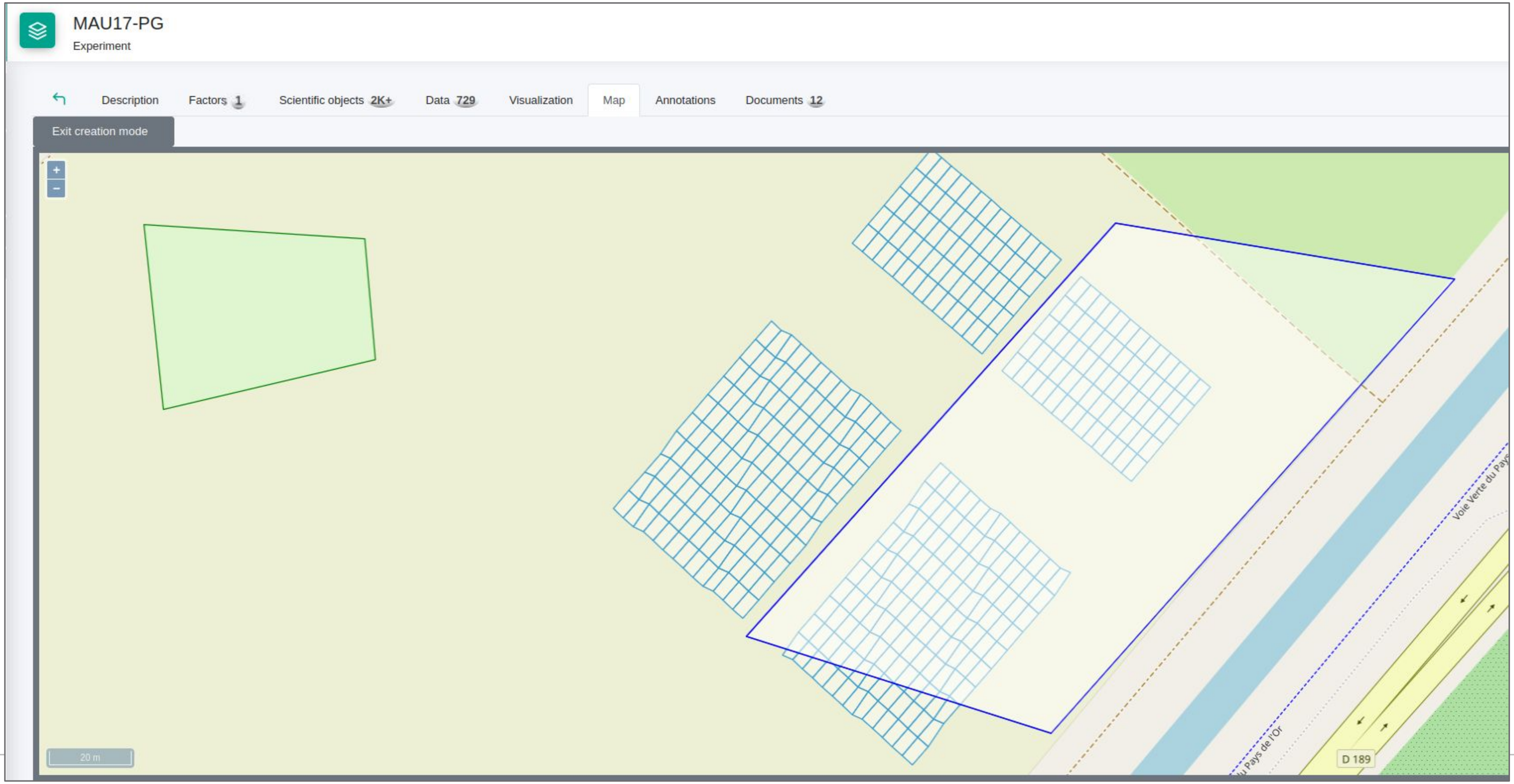
KML

```
POINT(6 10)
LINESTRING(3 4,10 50,20 25)
POLYGON((1 1,5 1,5 5,1 5,1 1))
```

WKT

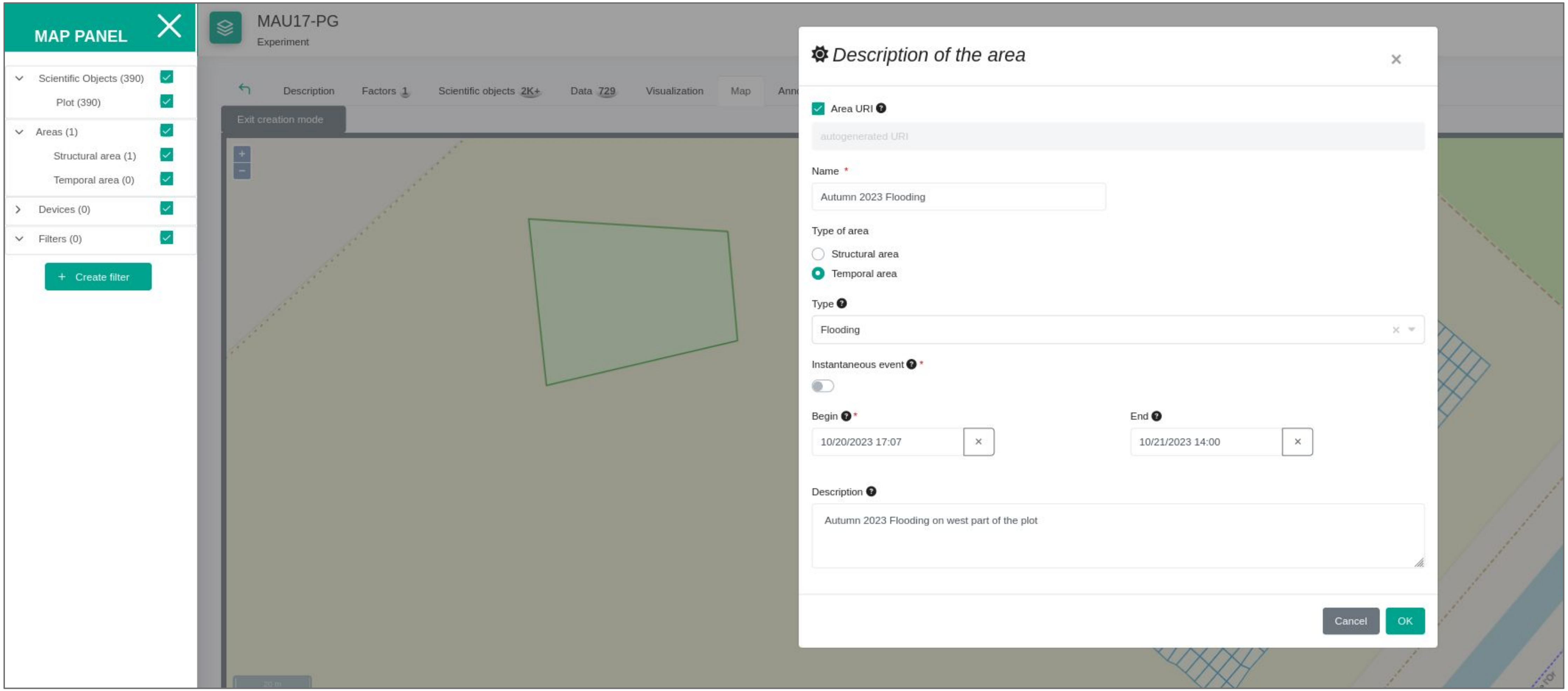
Geospatial targets (Events: PHIS)

Example: Irrigation location - Draw the area



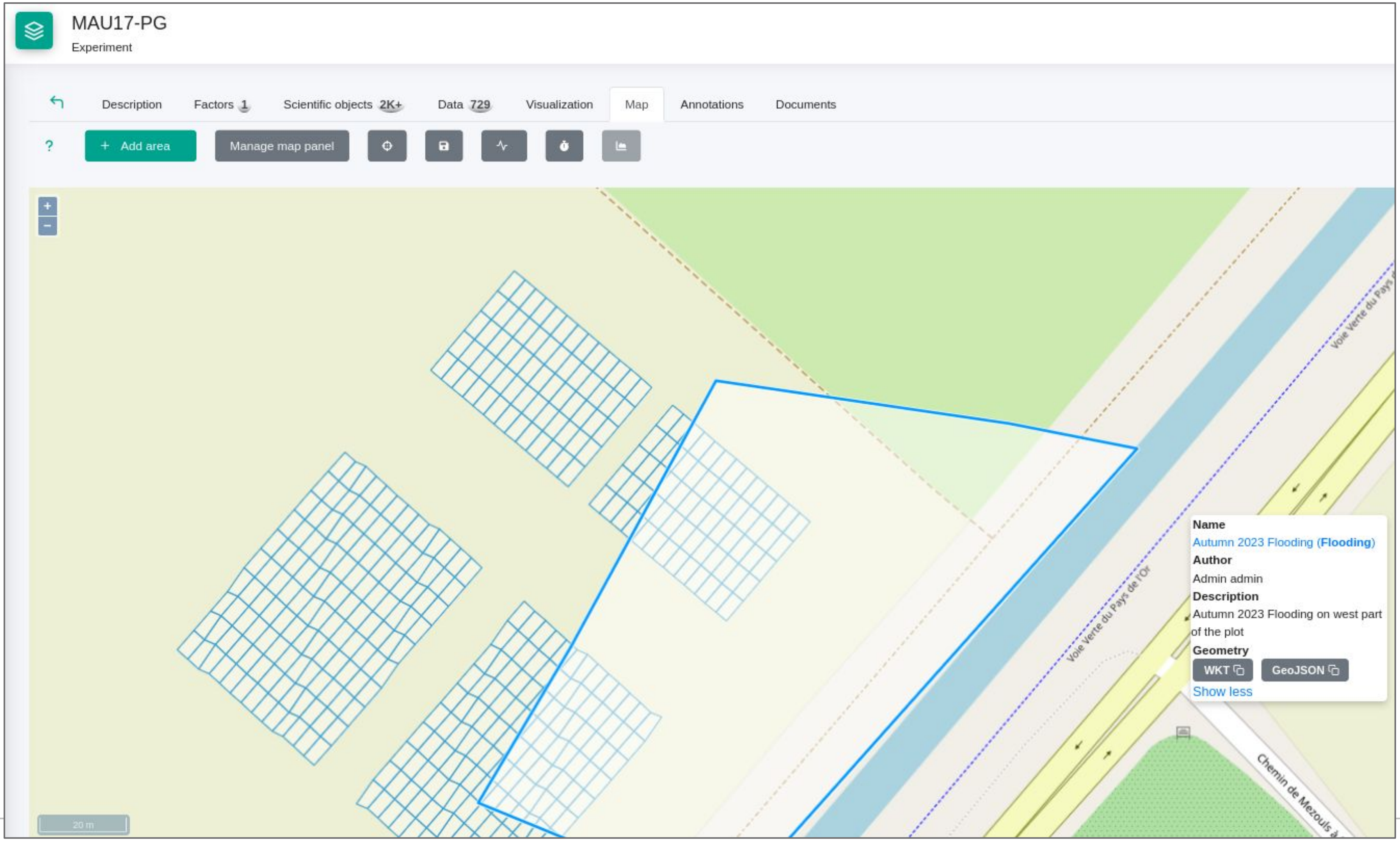
Geospatial targets (Events: PHIS)

Example: Irrigation location - Define the area

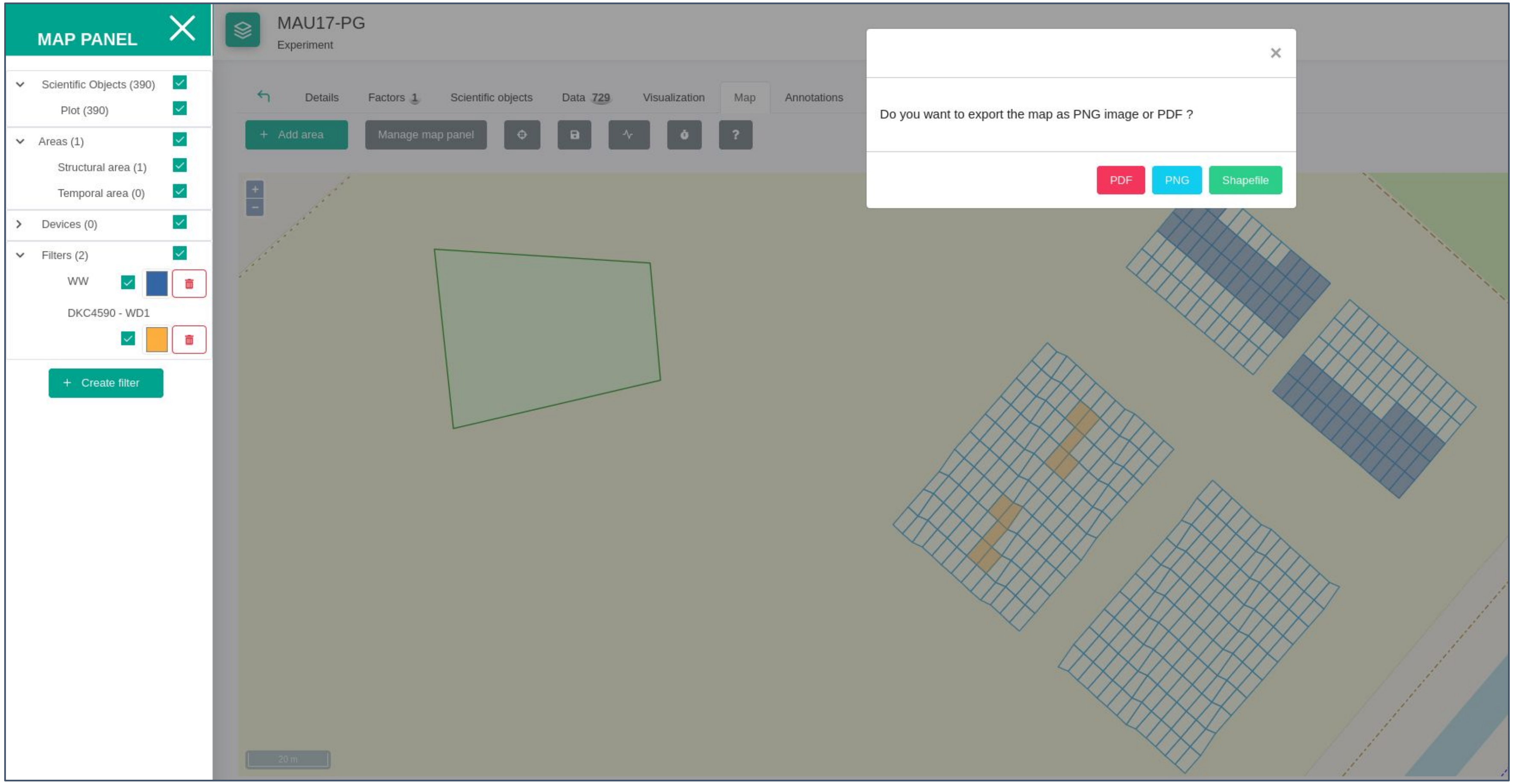


Geospatial targets (Events: PHIS)

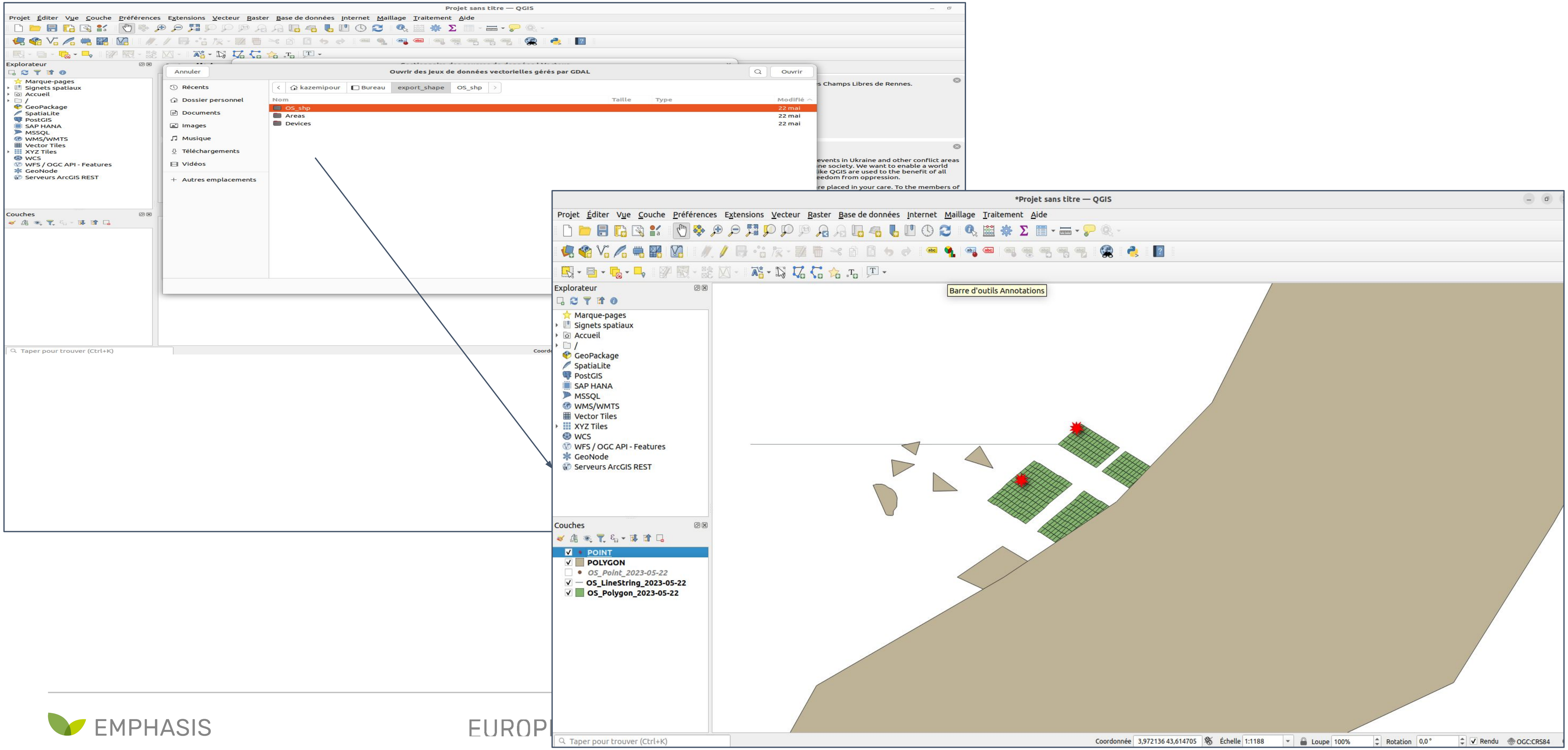
Example: Irrigation location - Visualize the area



Geospatial targets (Objects: PHIS)



PHIS to QGIS (objects, devices, events)



And then?

- I.S. managing all data including spatial data
    - Import and export
    - Query
    - Visualization
    - Interoperable with GIS

⇒ **Meta analysis & Geostatistic**

⇒ **Historical data as well as data for the current year**

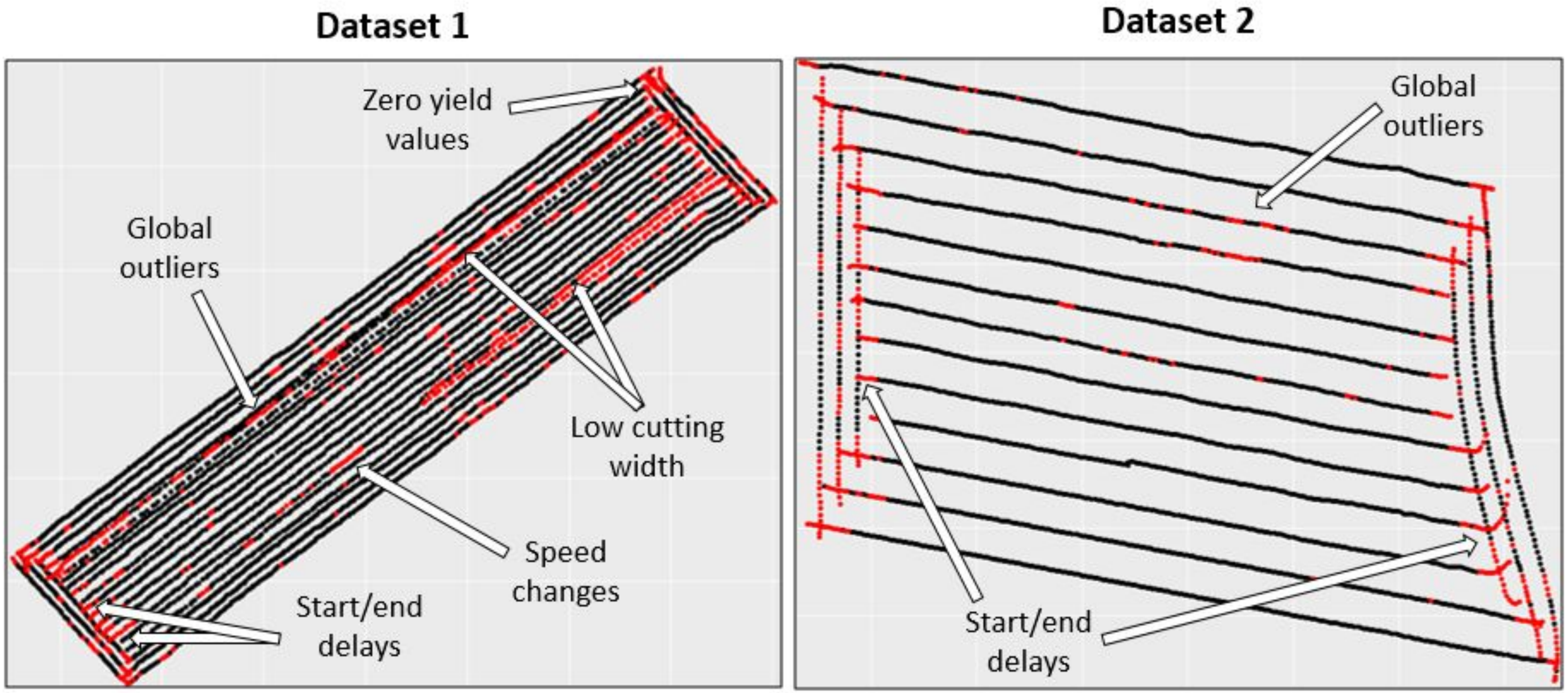
Geostatistics & Spatial tools: Zoning & beyond

Mostly used for yield data … and other spatial data!

- More and more agronomic variables
- Possibility of adaptive management based on intra-field variability
  - How and where implement an experiment?
  - How to filter and clean spatial data?
  - How to validate the relevance of the outlier detection and filtering?
  - How to integrate expertise (agricultures, advisors, …)?
  - How to simulate a spatial data set based on historical and current data?
  - How to generate recommendation maps (Decision-Support Tools)

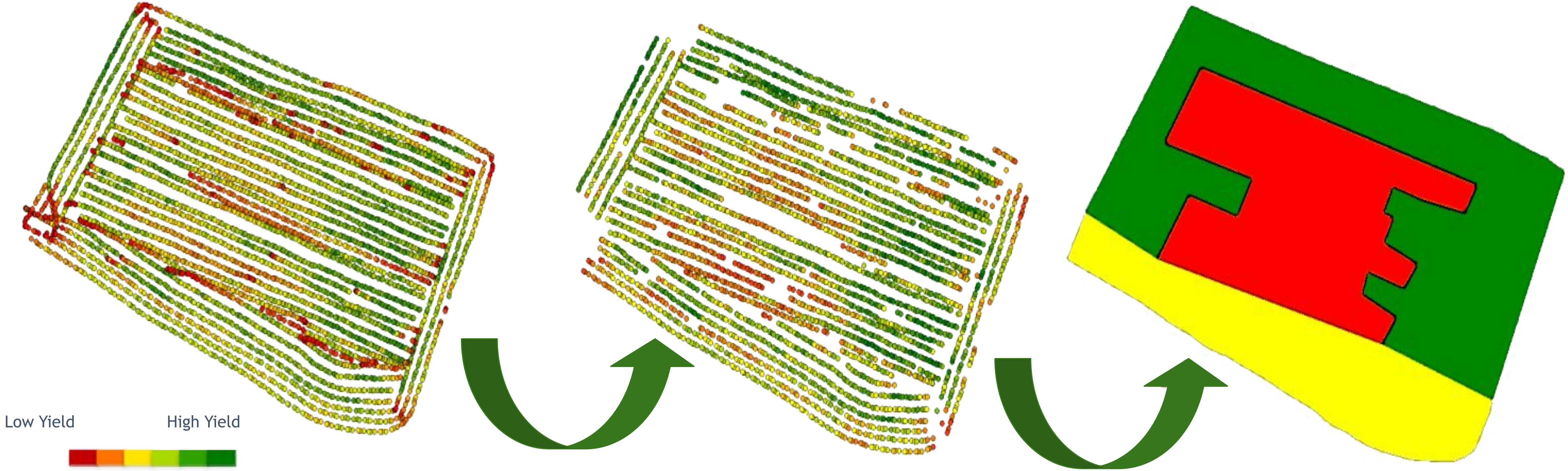
Geostatistics & Spatial tools: Outlier detection & filtering

Mostly used for yield data … and other spatial data! (C. Leroux & H. Jones)



Outlier detection, filtering & zoning (fertilization)

Mostly used for yield data … and other spatial data! (C. Leroux & H. Jones)

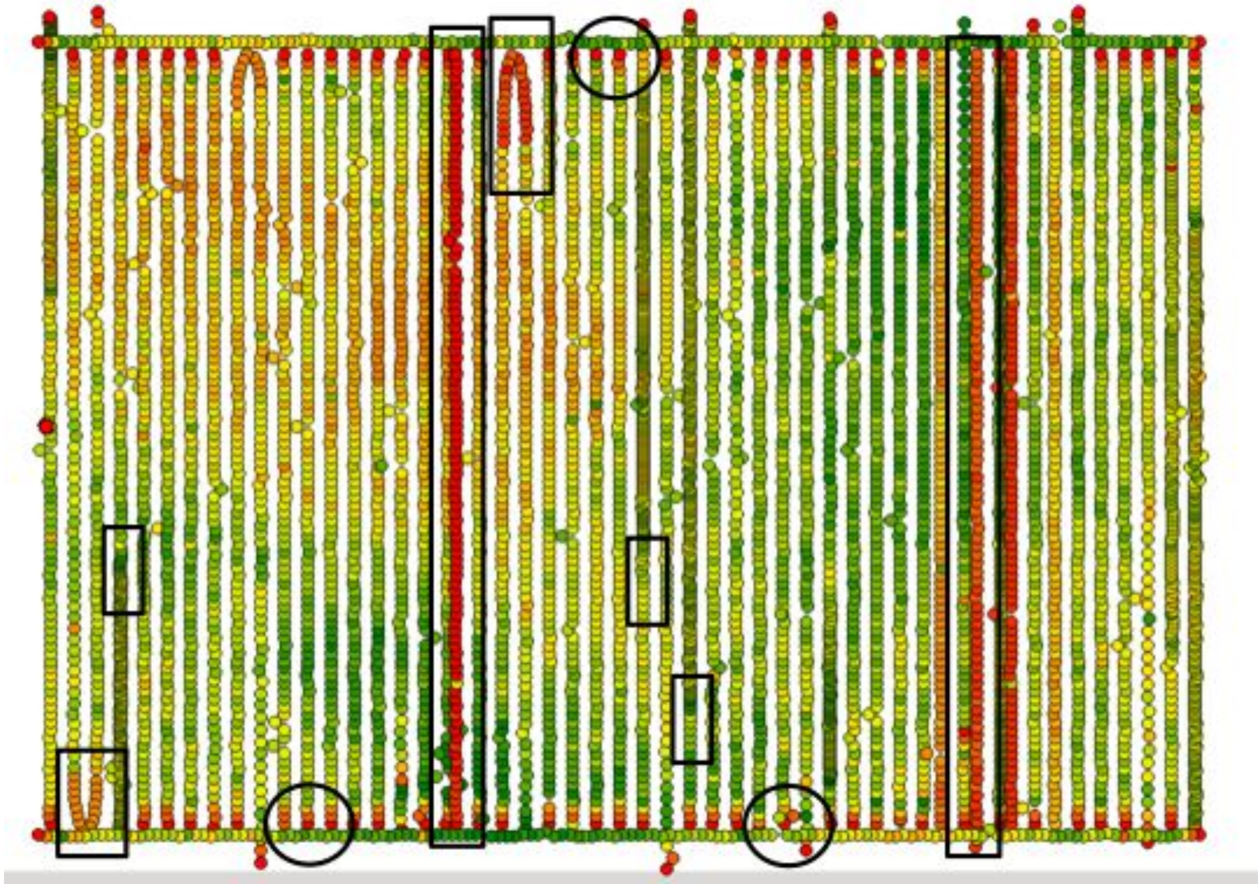


- Outlier deleting
- Reassessment of yield characteristics

- Operational zoning for yield data (clustering)
- Fertilization application

Geostatistics & Spatial tools: Yield map simulation

Mostly used for yield data … and other spatial data! (C. Leroux & H. Jones)



Geostatistics & Spatial tools

Zoning: Historical phenotyping data for experiment implementation

- Maximizing:
  - Inter zones heterogeneity
  - Intra zone homogeneity

- Shape constraints

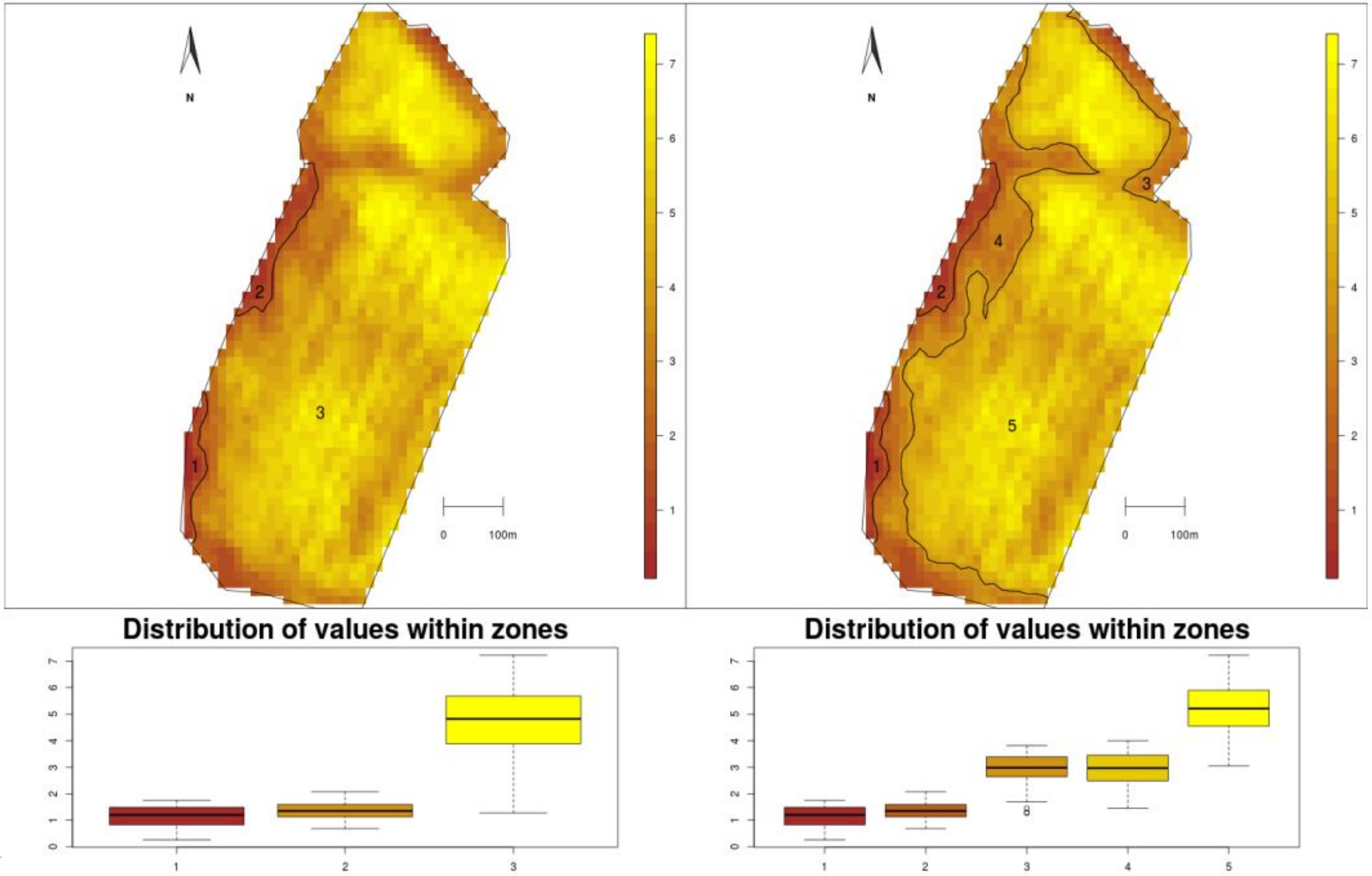
Variable: Yield, Soil parameters, Biomass, …

Geostatistics & Spatial tools: Zoning

Zoning: Historical phenotyping data for experiment implementation

Value: Yield (N-1)

(C. Leroux & H. Jones)



Geostatistics & Spatial tools: Zoning

Zoning: Historical phenotyping data for experiment implementation

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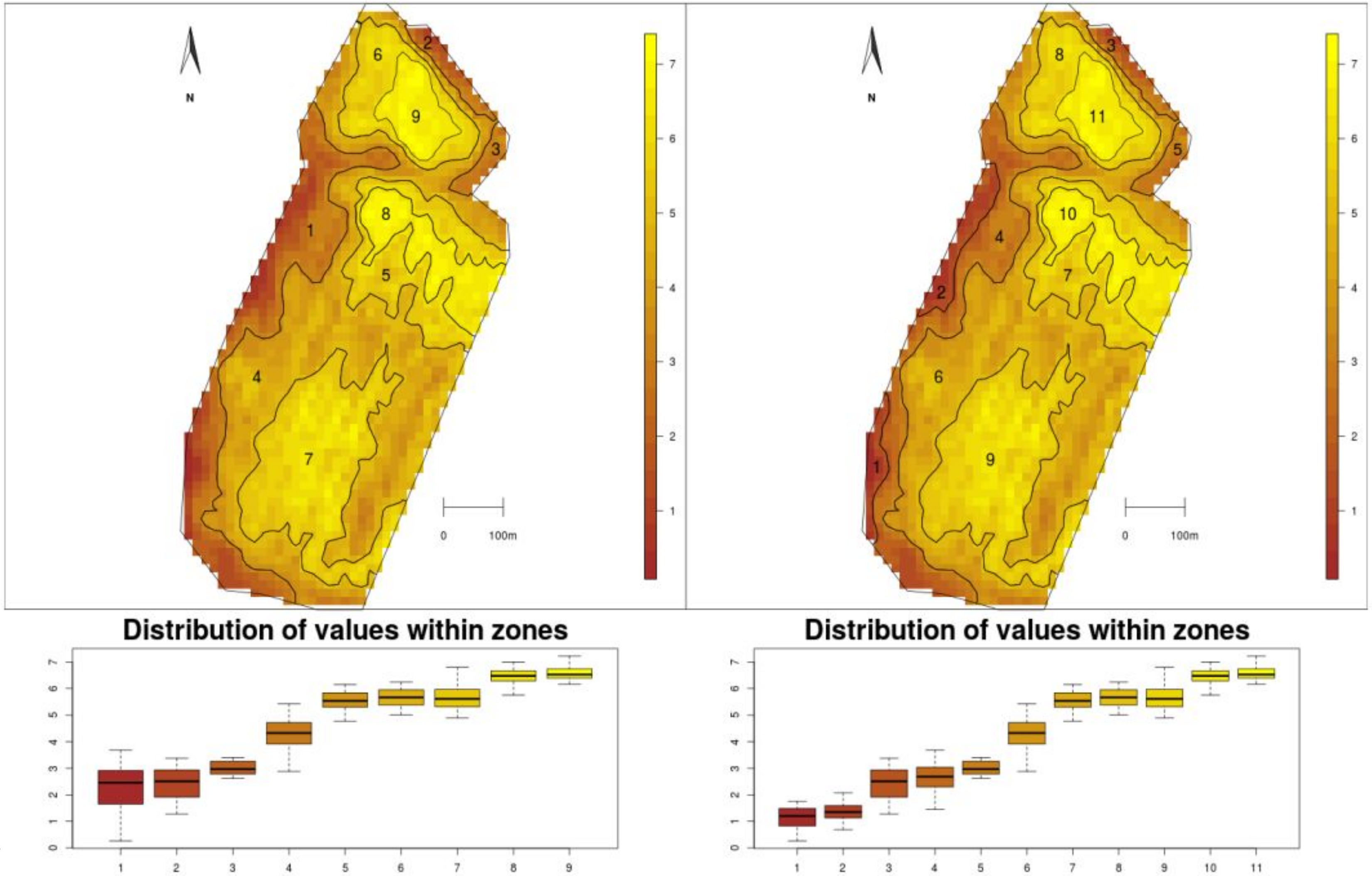
(C. Leroux & H. Jones)

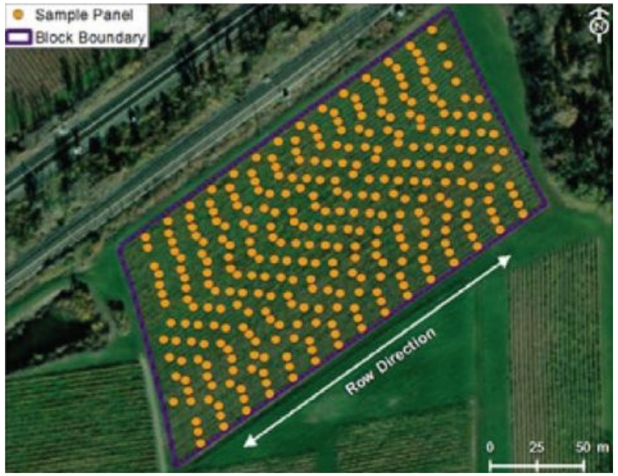


Geostatistics & Spatial tools

Vineyard yield forecasting based on machine learning methods (H. Jones et al.,)

Data (historical & spatio-temporel)

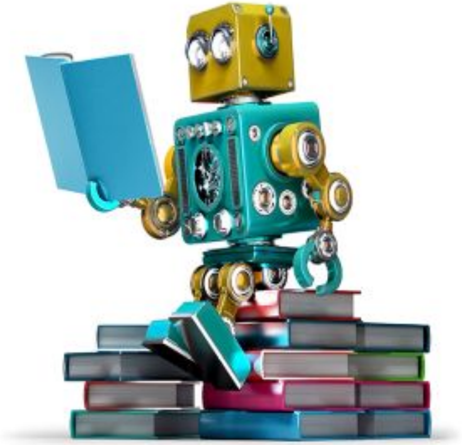
- Yield sensors
- Crop sensors (VIs)
- Soil sensors
- Pruning weight



Methode Random Forest

Machine learning algorithm

- Supervised learning (need for examples for inputs/output to learn)
- Possible to use on
  - Classification (predict a class)
  - Regression (predict a value)

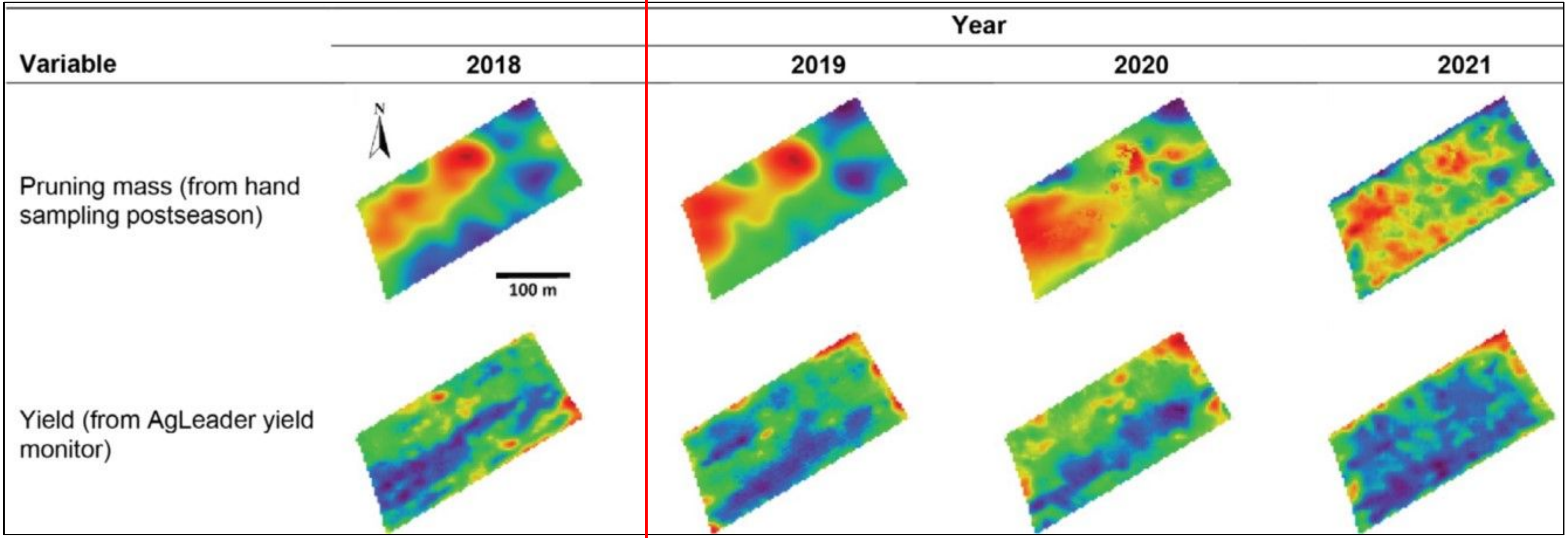


What & When are the best data for yield reporting?

Geostatistics & Spatial tools

Vineyard yield forecasting based on machine learning methods (H. Jones et al.,)

What is to be predicted?



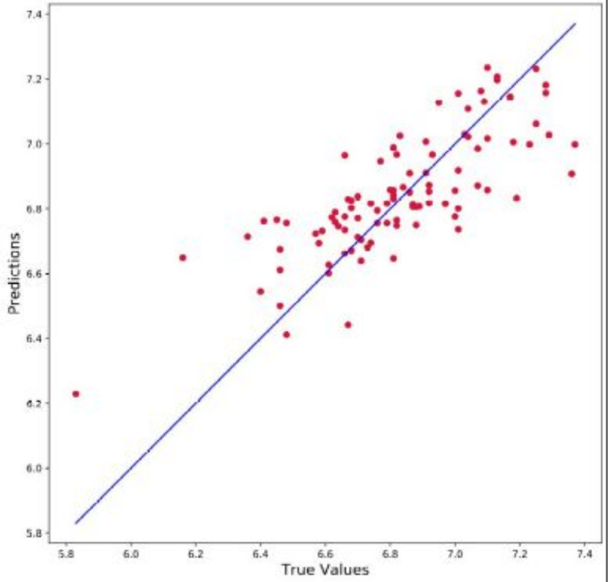
Geostatistics & Spatial tools

Vineyard yield forecasting based on machine learning methods (H. Jones et al.,)

Some results…

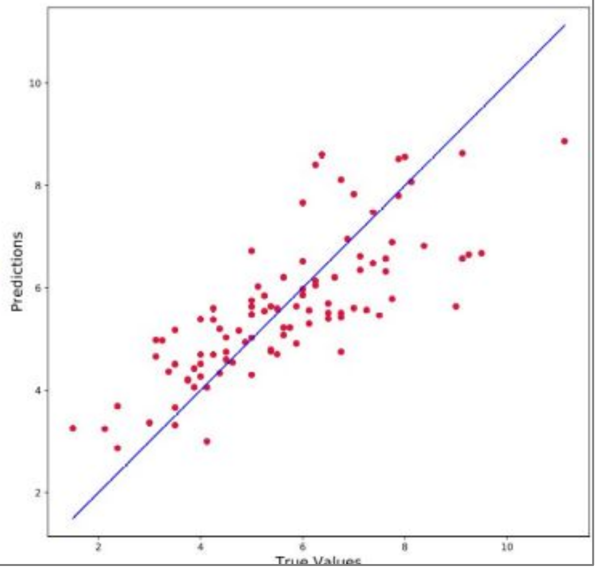
- Prediction on yield (2019)
  - Mean absolute error: 0.127
  - Mean absolute percentage error: 0.0187
  - explained_variance: 0.608
  - range y_test: [5.83 7.37]
  - **feature importance :**
  - SR_310519 0.079783
  - DifVI_170619 0.058389
  - MSR_170619 0.053485

Yield (2019)



- Prediction on Prune Weight (2020)
  - Mean absolute error: 0.887
  - Mean absolute percentage error: 0.174
  - explained_variance: 0.613
  - range y_test: [1.5 11.125]
  - **feature importance :**
  - PW_LbsperPanel_2019 0.281330
  - CropLoad2019_AgLeader 0.27707

Prune weight (2020)



Conclusion & Perspectives

- Think FAIR
- Structure Data
- Use Standards
- Think of MetaData
- Use Ontology
- Use semantic
- Use appropriate DBMS
- Use appropriate storage systems
- Make good DMP
- GDPR compliant

Conclusion & Perspectives

Think FAIR | Structure Data | Use Standards | Think of MetaData | Use Ontology | Use semantic

Use appropriate DBMS | Use appropriate storage systems | Make good DMP | GDPR compliant

Seems infeasible? Ask for help!

- Information systems
- Ontology
- Pipelines for data transmission & processing
- Mapping with standards
- DMP & GDPR setting
- Spatio-temporal data for advanced analysis (variables)

Conclusion & Perspectives

- Start changing habits and adopt appropriate methods & tools
- Trainings, workshops & Hackathons
  - PHENET-EMPHASIS Joint training event in 2024
    - ✉ Training materials and survey to set the dates and content
  - BrAPI Hackathon in 2024 - https://brapi.org/events/hackathon
  - BioHackathon in 2024 - https://biohackathon-europe.org/
  - PhenoHarmonIS - Montpellier May 2024

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THANK YOU

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EMPHASIS on Plant Phenomics

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