
# Imaging Solutions for Seed Banks
## Characterization of Accessions During Regeneration

# THE JOURNEY OF A SEED IN A GENEBANK

**Genebanks** conserve and make available the crop diversity needed to adapt our agriculture to present and future challenges. To prevent invaluable diversity from being lost forever, genebanks follow well established standards and best practices.


## DATA MANAGEMENT

**DATA MANAGEMENT** refers to the activities related to the custodianship, documentation, protection and accessibility of the genebank's body of knowledge. This may include documents, databases, images, videos, websites, metadata, software, manuals, reports, policies, procedures and records. Accurate and updated genebank data ensures consistency and quality in management and provides evidence of compliance with standards. Most genebanks have a dedicated data management system.

## 1. COLLECTING

**COLLECTING** is one of the ways through which genebanks obtain new diversity for their collections. Genebanks periodically review the need for new, unique diversity and identify geographic regions and sites where they can obtain it. Collecting expeditions are planned to acquire new material for their collections.

## 2. POST-ENTRY QUARANTINE

**IN THIS STEP**, new material (either acquired via donation or collecting) is held in an isolated facility to assess its phytosanitary status, i.e., whether it is infected with a pest or disease.
It is observed, tested and, if necessary, treated before entering the genebank collection. This important process prevents the spread of pests and diseases, and ultimately, safeguards the health of the genebank's collection.

## 3. ACQUISITION

**AT THIS STAGE**, the material is cleaned, dried, packed and entered into the collection. Initial seed viability is tested to assess the quality of the seed. Healthy seeds harvested at optimum maturity and with high viability rates are indispensable for long-term conservation.


## 4. REGENERATION

**THIS IS A CRITICAL STEP** in genebank management in which seed accessions with low seed numbers or low viability rates (<85% for cultivated species) are sown in the field to produce fresh seeds, which are then stored in turn. Understanding the mating and pollination systems of each species is necessary to implement proper regenerations, ensuring that the genetic identity and integrity of the accessions are maintained.

## 5. CHARACTERIZATION

**THIS STEP** often occurs during regeneration. As newly sown seeds develop into plants, they display various characteristics that make accessions different from each other. Genebank staff record plant height, the shape of leaves, the color of the flowers and other plant characteristics following agreed descriptor lists. The importance of this step lies in the added value to the collections, e.g., in helping users decide which samples to request. These plant descriptions are also helpful in genebank management to detect possible hybridizations between samples or duplicates, as well as accidental mixing.

## 6. CONSERVATION

**GENEBANKS CONSERVE** seeds in two types of conditions: the most original samples are part of the base collection, which is maintained in long-term storage (LTS) at −18±3°C, 15±3% relative humidity. Samples in the active collection are maintained under medium-term storage (MTS) at 5-10°C, 15±3% relative humidity. These temperature and relative humidity regimes are achieved using specialized freezers, cabinets or tailored cold rooms. During this stage, genebank staff monitor seed quality and quantity at specific intervals to identify samples in need of regeneration.


## 7. DISTRIBUTION

**GENEBANKS RECEIVE** germplasm requests via mail, email, phone calls, in person and through their websites. Genebank staff fulfill requests by selecting samples, packing them in an envelope or box, and including the required documentation about the samples (country of origin, plant characteristics, conditions of use and distribution etc.). The consignment is sent to the recipient via the fastest way possible, usually by courier.

## 8. SAFETY DUPLICATION

**TO MITIGATE RISK**, genebanks safety duplicate their collections at two levels: one duplicate is placed in another actively managed genebank, preferably on a different continent (if possible), and another is deposited at the Svalbard Global Seed Vault in Norway.

## USERS

**GENEBANK USERS** include plant breeders, farmers, researchers and students.

CROP TRUST
german cooperation
KFW

**Seeds4Resilience**, a five-year, **EUR 20 million project** led by the **Crop Trust** and funded by the *German government, provides financial and technical support for the national genebanks of Nigeria, Zambia, Kenya, Ethiopia and Ghana* to reach international standards of operation, ensuring collections are safe – and available for use – over the long term.

Discover more on www.croptrust.org and donate today to help us secure our food, forever.

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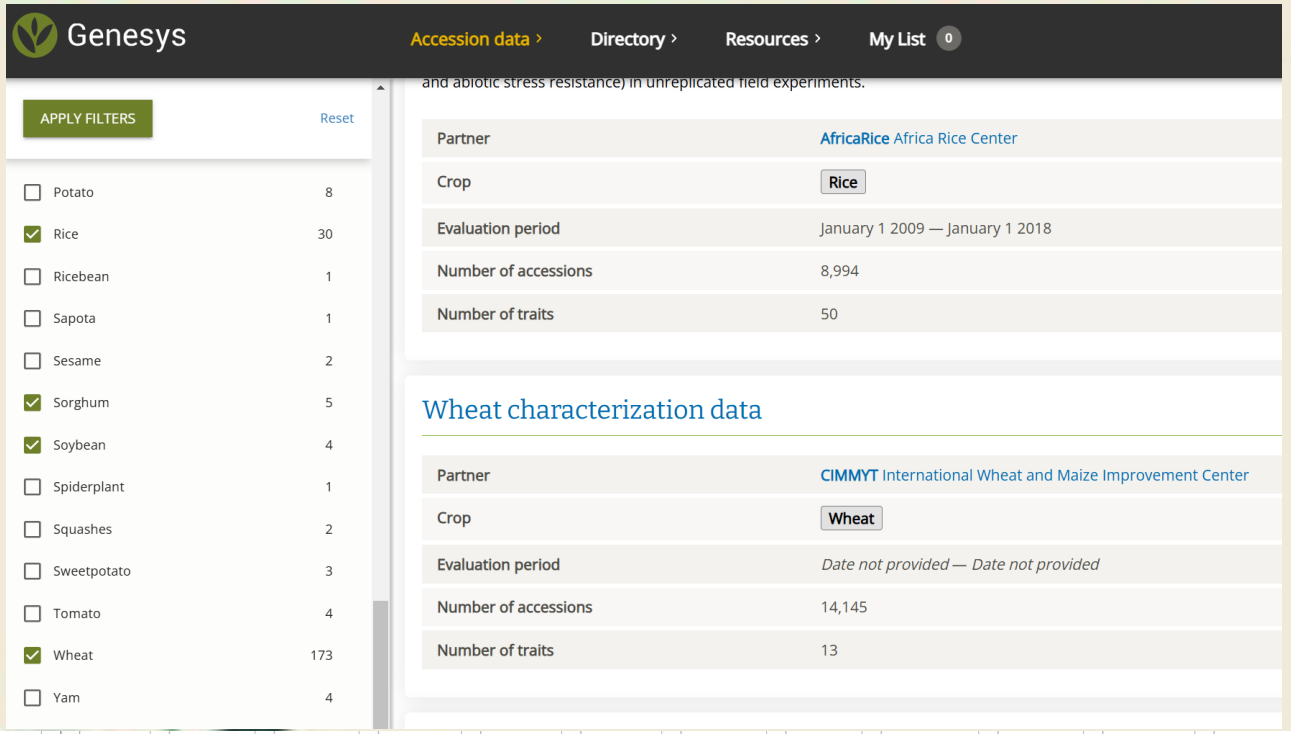
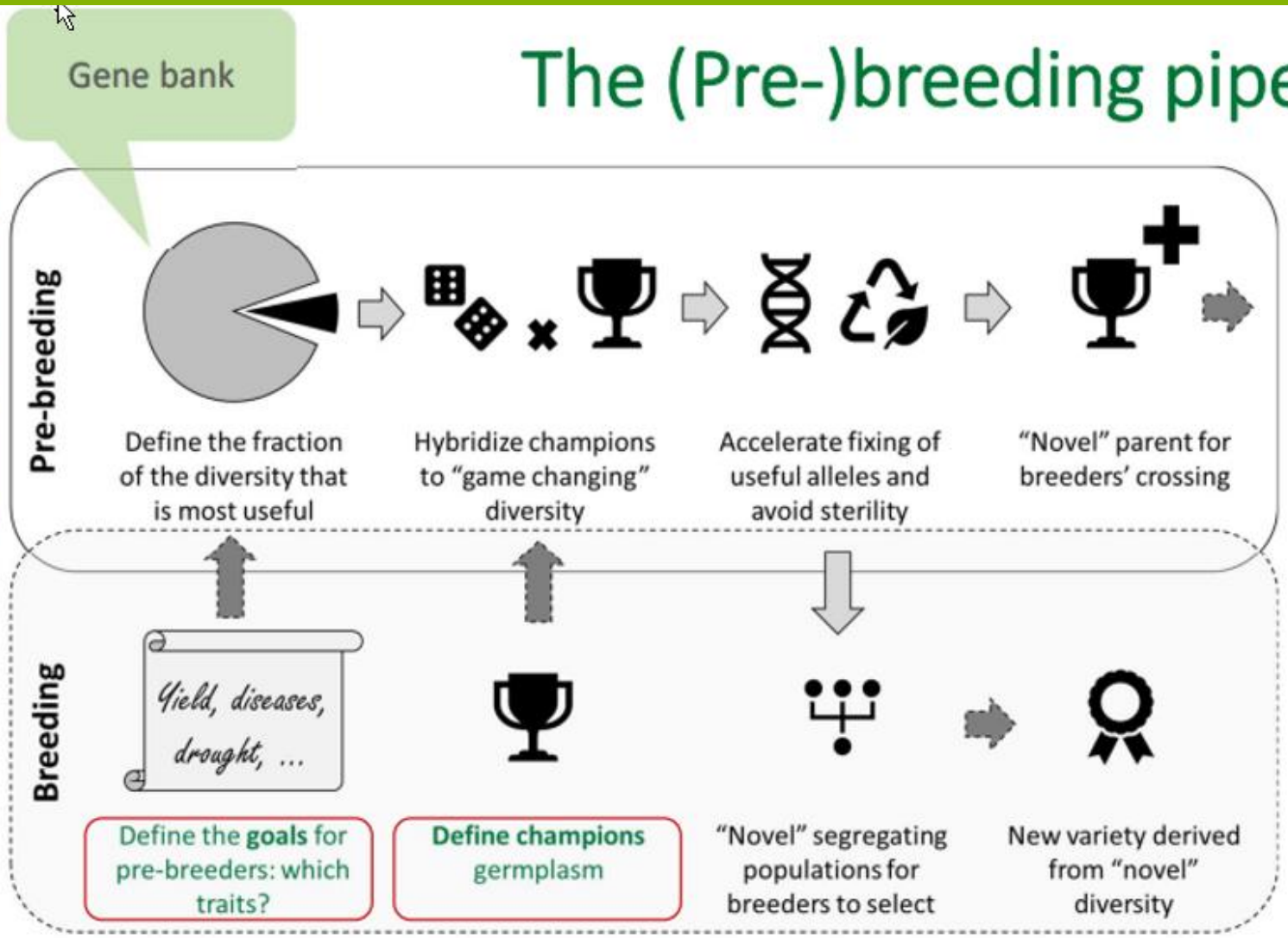
# 5. CHARACTERIZATION




| AcceNumb | LFSHP | PUBDEN | PUBCOL | PUBTYP | PLHTR1 | PLHTR8 | NOPBRN | LODGE | DAYSFLO | CORCOL | MATURE | NOPODS | SDNO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VI026010 | 5 | 7 | 9 | 3 | 1 | 31.4 | 48 | 3.2 | 1 | 41 | 7 | 5 | 22.4 | 2.4 |
| VI026011 | 5 | 7 | 5 | 3 | 2 | 32.8 | 35.4 | 3.8 | 1 | 37 | 3 | 5 | 34.3 | 2.4 |
| VI026013 | 3 | 7 | 3 | 1 | 2 | 37.4 | 46 | 3 | 1 | 37 | 7 | 3 | 27 | 2.4 |
| VI026014 | 3 | 7 | 3 | 1 | 3 | 15 | 15 | 1.7 | 1 | 37 | 7 | 3 | 18.9 | 2.3 |
| VI026016 | 3 | 7 | 3 | 3 | 2 | 17 | 13.6 | 2.3 | 1 | 41 | 7 | 5 | 10.8 | 2.3 |
| VI026017 | 3 | 7 | 5 | 3 | 1 | 22.4 | 23.4 | 1.8 | 1 | 37 | 3 | 5 | 25 | 2 |
| VI026018 | 3 | 7 | 3 | 3 | 3 | 19.6 | 18.6 | 2.4 | 1 | 34 | 7 | 5 | 13.4 | 2.3 |
| VI026019 | 3 | 7 | 7 | 3 | 1 | 24.6 | 27.4 | 1.5 | 1 | 36 | 7 | 5 | 25.3 | 2.5 |
| VI026020 | 3 | 7 | 7 | 1 | 2 | 22.4 | 26.6 | 2.2 | 1 | 37 | 7 | 3 | 27.5 | 2.7 |
| VI026021 | 3 | 7 | 7 | 1 | 3 | 37.6 | 33 | 2.1 | 1 | 34 | 7 | 7 | 21.1 | 2.1 |
| VI026022 | 5 | 7 | 3 | 3 | 3 | 26.4 | 22.2 | 2.5 | 1 | 36 | 3 | 7 | 26.6 | 2.1 |

# Breeders View – Seed Bank Customers

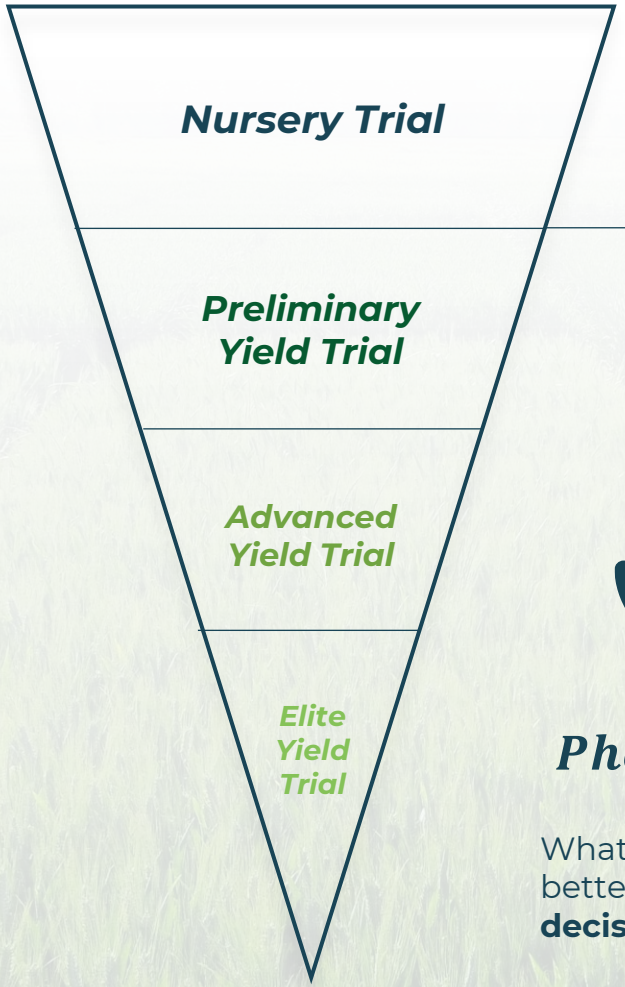



*Langdon set (NDSU, Fargo)*



*Shivali et al. submitted. Introducing beneficial alleles from plant genetic resources into the wheat germplasm*

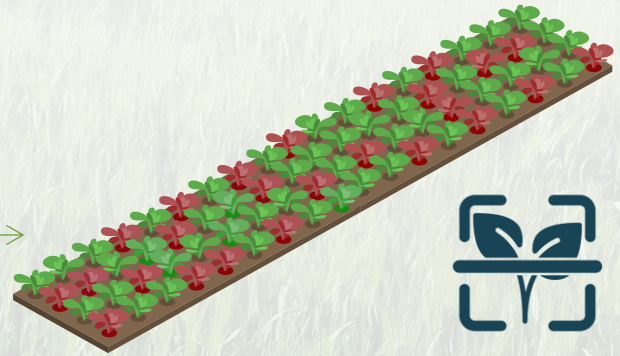
# Breeders View – Seed Bank Customers




There's no generic breeding cycles, it changes from one crop to another

$$Phenotype = Genotype\ X\ Environment$$

Whatever your crop or breeding stage, phenotyping helps better understand **G x E interactions to improve decision-making**

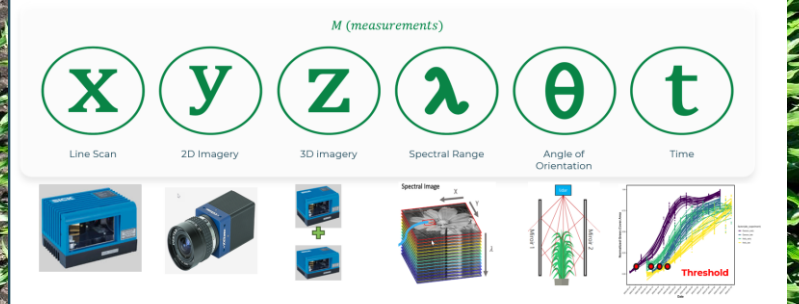


Evaluate the impact of environmental factors on the germination and development of each variety

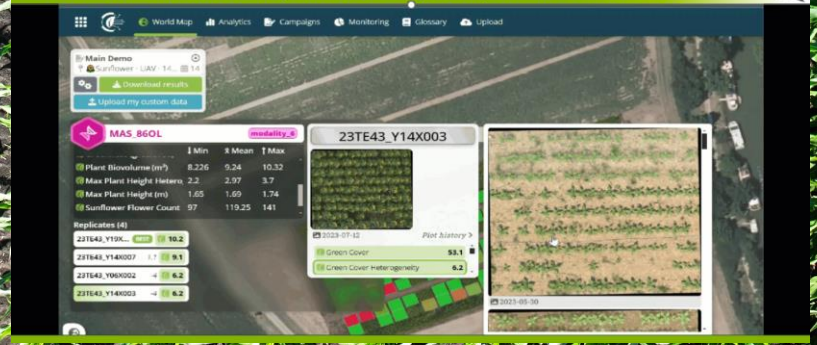
# In Practice – Phenotyping for Regeneration and In Situ Conservation

## Image Acquisition


## Trait Extraction




## Data Visualization, Image Query, and Analytics



# Characterization of Accessions – Image Acquisition Vectors

## Image Acquisition

**Drones**
1,000 to 50,000 plots

***Standard traits***
***High Throughput***

**Rovers (PhenoMobile)**
1,000 to 10,000 plots

***Intensive sampling***
***Moderate Throughput***

**Handheld (Literal)**
30 to 1,000 plots

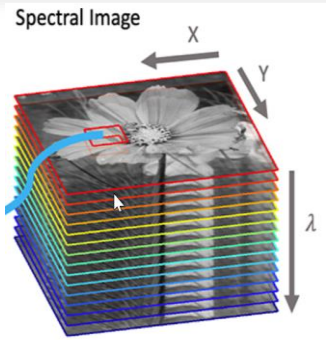
***High Resolution***
***Moderate Throughput***

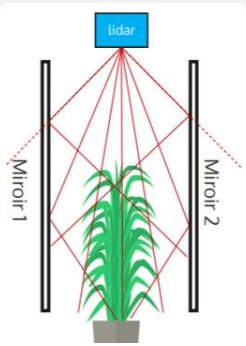
# Trait Extraction– 6 Dimensions of Phenotyping

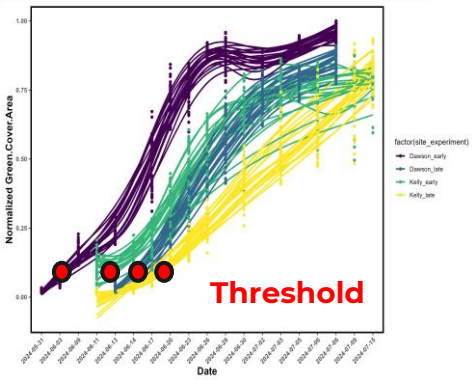
$M\ (measurements)$

| x | y | z | λ | θ | t |
|---|---|---|---|---|---|
| Line Scan | 2D Imagery | 3D imagery | Spectral Range | Angle of Orientation | Time |



# Image Acquisition Vectors

## Drones

**Frictionless High-throughput Phenotyping**

- Fast efficient image acquisition
- Automated processing
- Multi-sensor configuration
- Applicable for in situ conservation and regeneration

## Manual Ground Imaging Systems

**High-resolution Phenotyping**

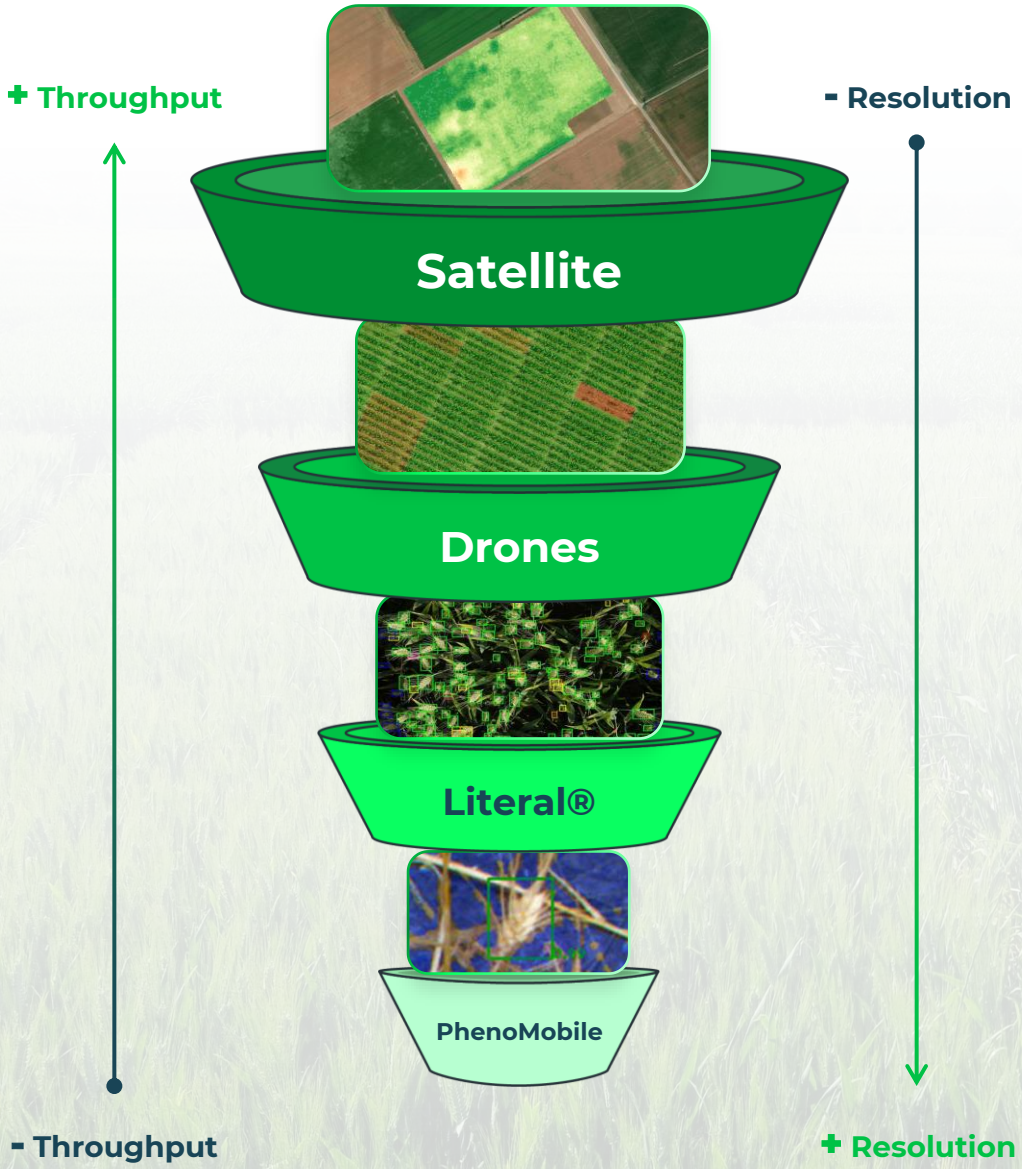
- Uncover new traits with high-resolution capabilities
- Automated processing
- Light & easy to operate
- Fixed sensors (RGB + NIR)

## Tractor Mounted Sensor Arrays

**High-intensity Sampling**

- Higher resolution imagery compared to drones
- On-site processing
- Multi-sensor configuration
- Tailored for stress-related plant research

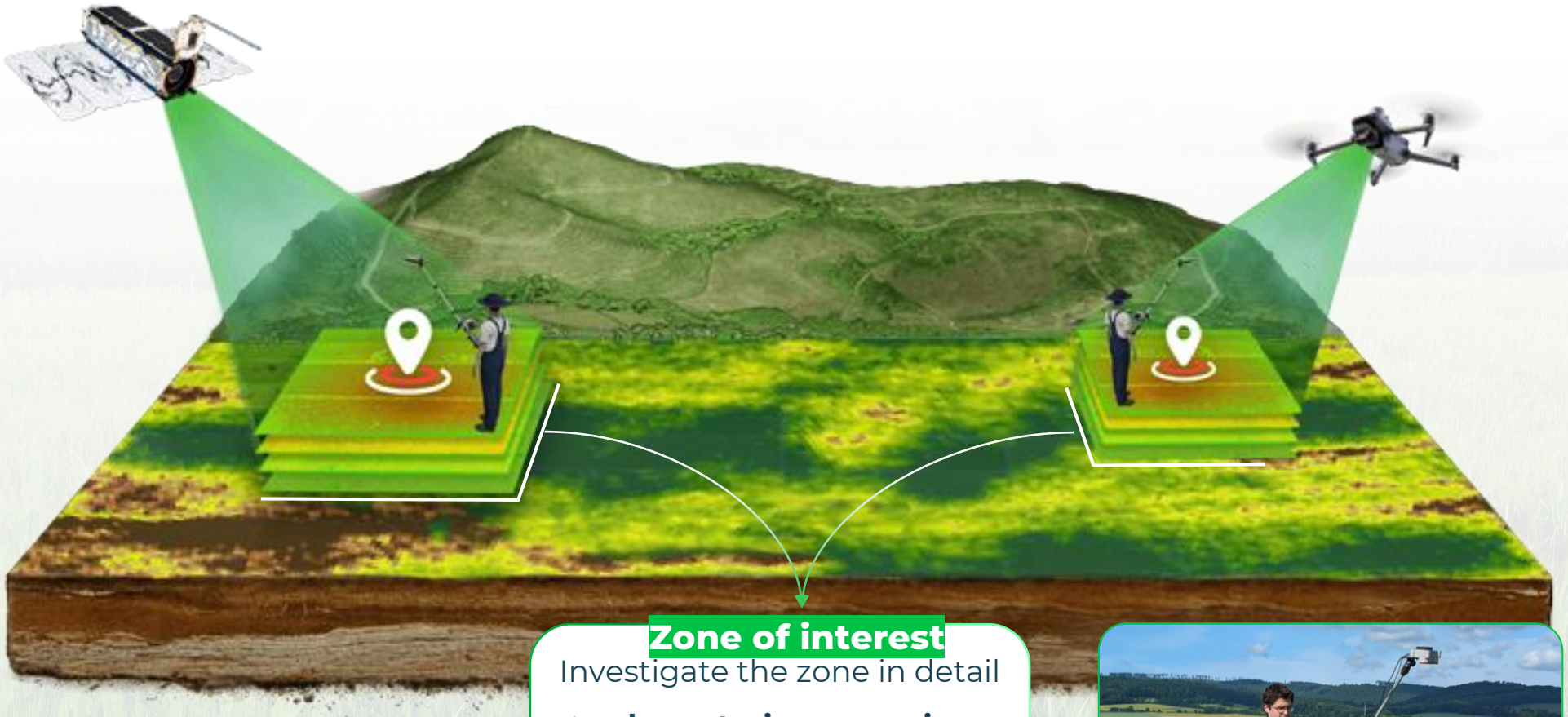
# Image Acquisition Vectors – Spatial, Spectral and Temporal Resolution




***Comparison matrix for wheat trial assessment:***

| | Satellite | Drone | Literal® | PhenoMobile |
|---|---|---|---|---|
| | | | | |
| **Throughput** *(plots/hour)* | **No limit** *(up to 25km² Every day)* | **10 000** *(up to)* | **150** *(up to)* | **400** *(up to)* |
| **Resolution** *(ground/pixel)* | **3 m** *(at 475 km high)* | **3,5 mm** *(at 13 m high)* | **0,36 mm** *(at 1,8 m high)* | **0,1 mm** *(at 1,5 m high)* |
| **Sensors** *(bands)* | **RGB + NIR** | **RGB + ALL MS BANDS** | **2 RGB + NIR** | **RGB, MS, LiDAR THERMAL,...** |
| **Traits Accessible** | ⊖ | ⊕ | ⊕ ⊕ ⊕ | 💎 |
| **Price** | $ | $ $ | $ $ | $ $ $ $ |

# Image Acquisition Vectors – Fusing Data From Multiple Vectors

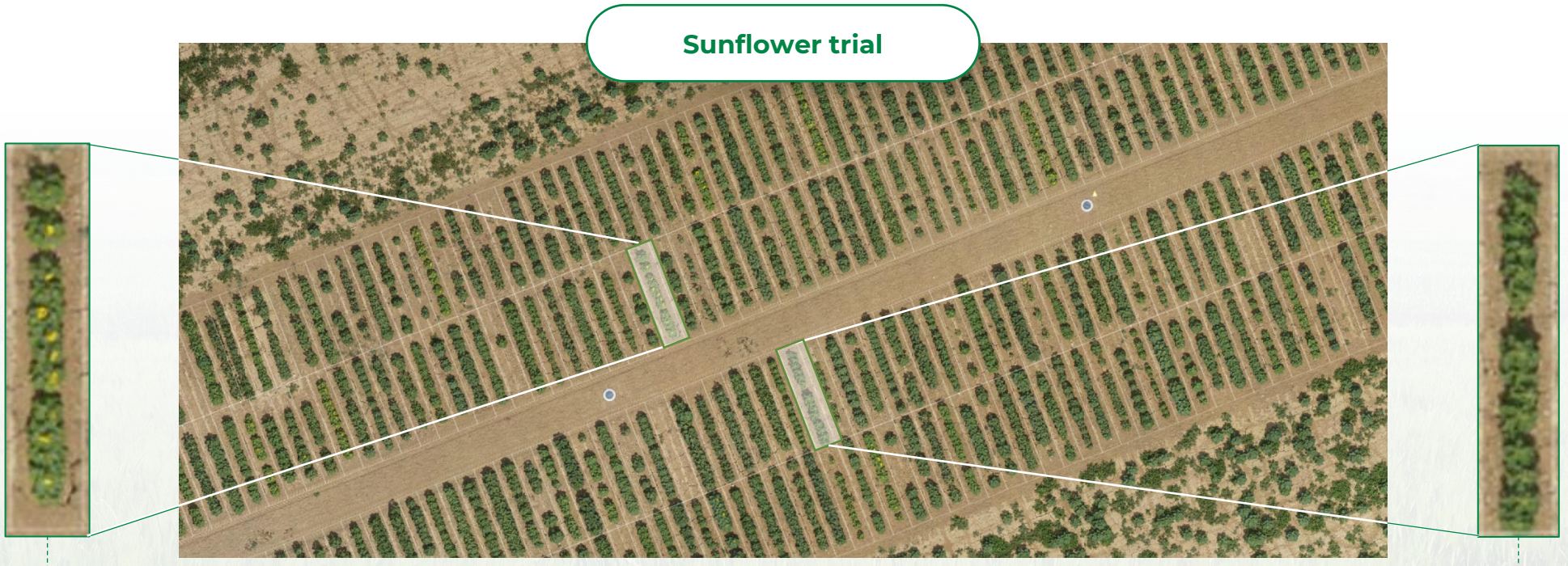


**Zone of interest**

Investigate the zone in detail to **characterize accessions at appropriate spatial, temporal and** ...

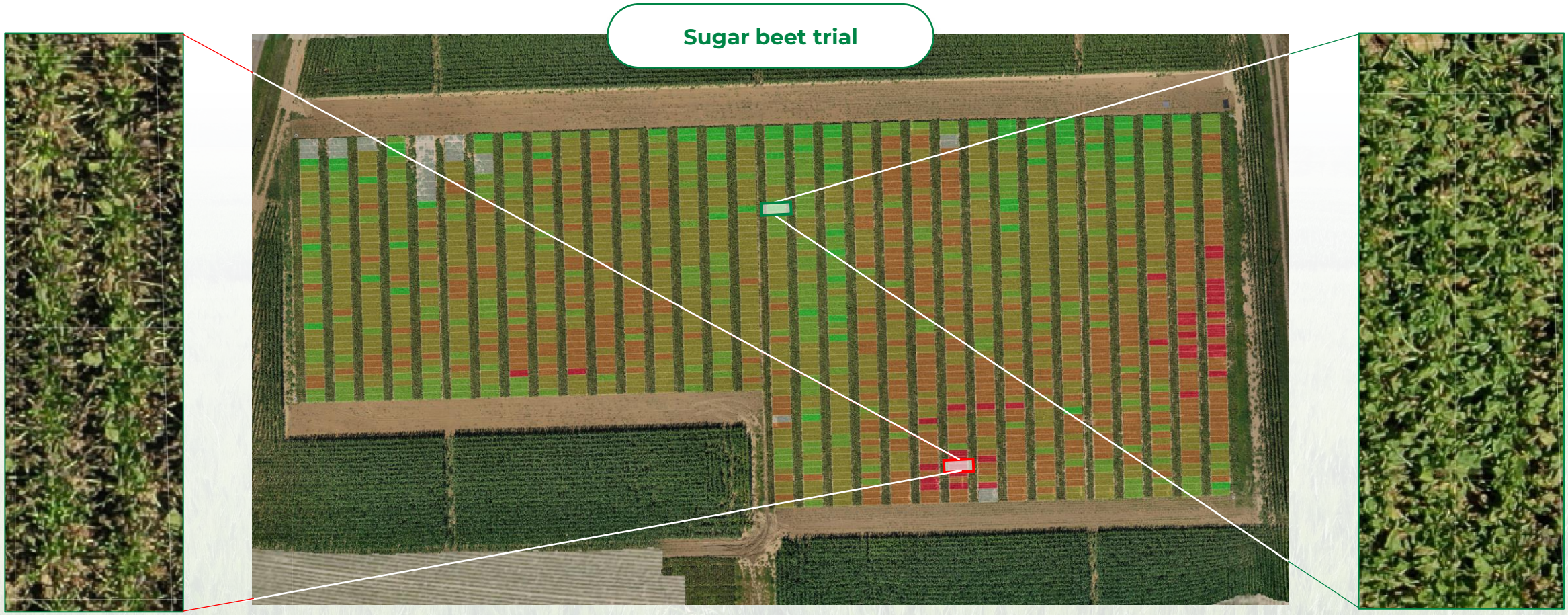
# Characterization of Accessions – Trait Extraction

# Trait Extraction– Phenological Stage Detection



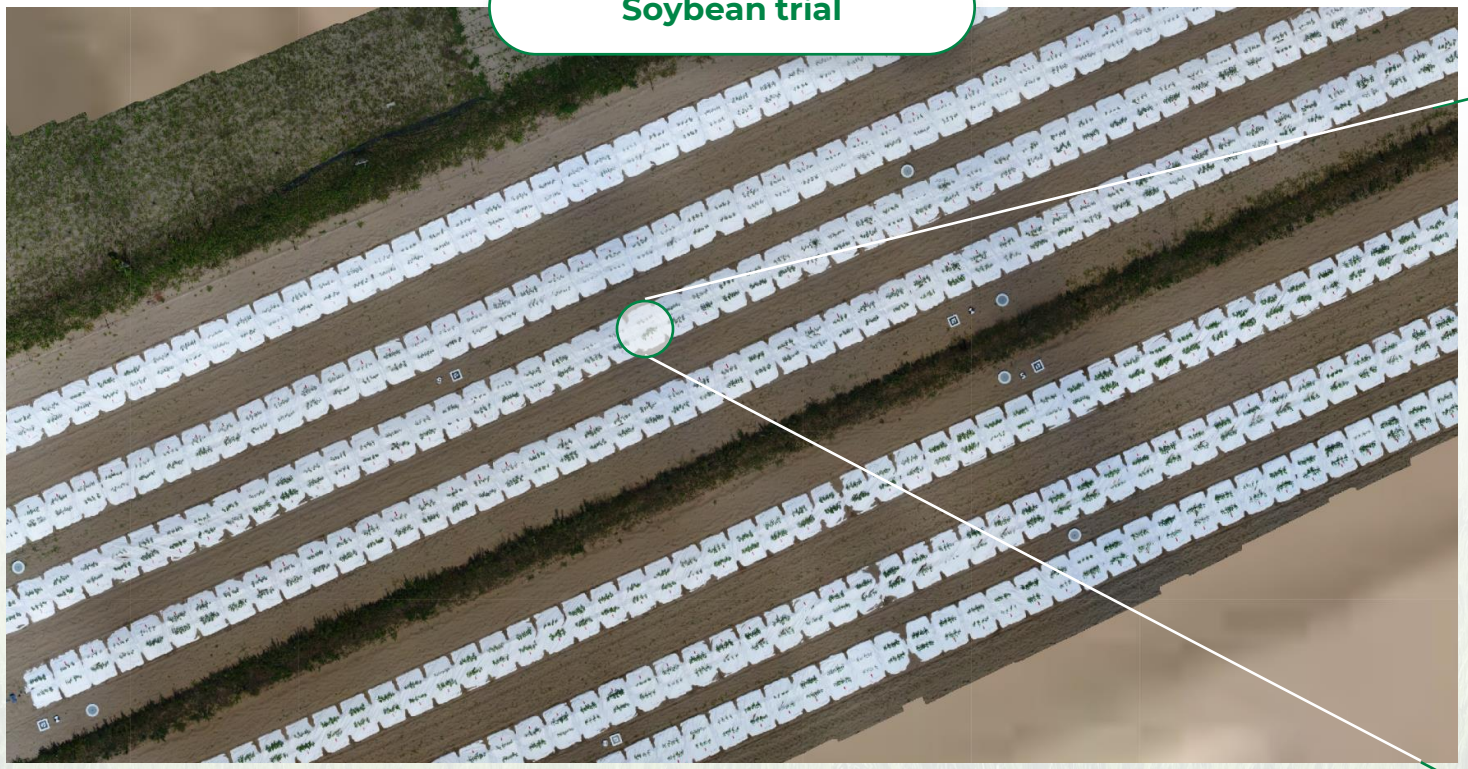

## Trait Phenotyping : Automated detection of phenological stage

# Trait Extraction– Disease Detection




# Trait Extraction– Early Vigor / Speed to Canopy Closure

**Soybean trial**

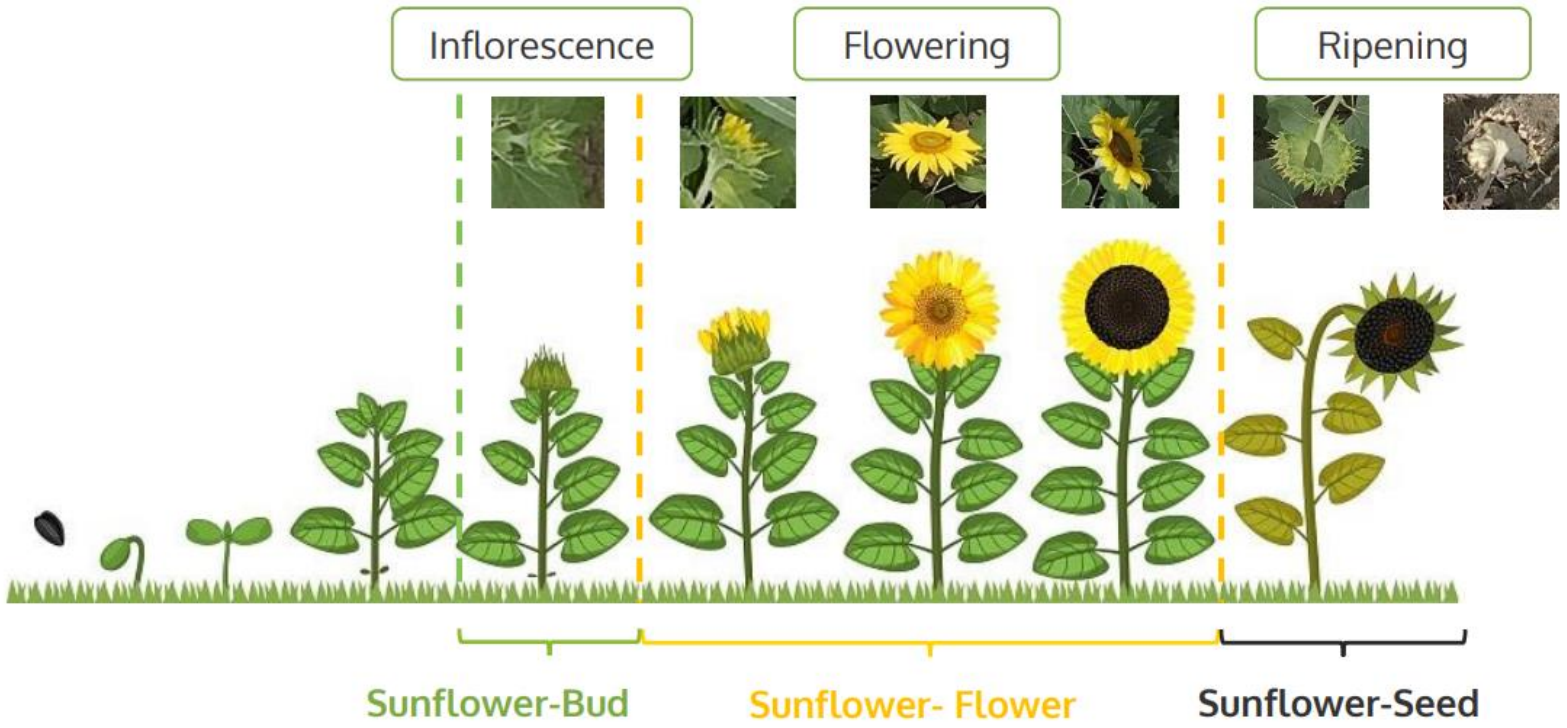


**Canopy Area:**
567 $cm^2$

**Canopy Area:**
2037 $cm^2$

# Trait Extraction– Flower Count and Dynamics

| Example with DJI Zenmuse P1 (focal length 35 eqv) | | |
|---|---|---|
| **Object size (mm)** | **GSD required (mm)** | **Altitude (m)** |
| 40 → 300 | 4,5 | 15-18 |




**Descriptions :**

3 classes of sunflower heads provided:

- **Sunflower-Bud:** corresponding to head bud emergence till petals appearance;
- **Sunflower- Flower:** corresponding to flowering stage till head turning;
- **Sunflower-Seed:** corresponding to ripening stage till senescence beginning.

# Drone Production Traits - Crop x Trait Matrix

hiphen
Agricultural Imaging Solutions

| | Traits | Maize | Wheat | OSR/Canola | Soy/Pulse | Sorghum | Sunflower | Rice | Veg * | Strawberry |
|---|---|---|---|---|---|---|---|---|---|---|
| Trial Quality | Plant Count | RGB | N/A | N/A | RGB | RGB | RGB | RGB | RGB | RGB |
| | Border & Gap | RGB | RGB | RGB | RGB | RGB | RGB | RGB | RGB | RGB |
| | Plant Lodging | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | N/A | RGB / MS |
| | Plot Heterogeneity | RGB | RGB | RGB | RGB | RGB | RGB | RGB | RGB | RGB |
| Canopy Development | Green Cover | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS |
| | Greenness | RGB | RGB | RGB | RGB | RGB | RGB | RGB | RGB | RGB |
| | Early Vigor | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS |
| | Maturity/Senescence | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS |
| | Flowering | RGB | RGB | RGB | RGB | N/A | RGB | N/A | RGB | RGB |
| Biomass Proxy (Requires Specific Flight Protocol) | Height & Biovolume | RGB | RGB | RGB | RGB | RGB | RGB | RGB | RGB | RGB |
| | Leaf Area Index | MS | MS | MS | MS | MS | MS | MS | MS | MS |
| | Chlorophyll Content | MS | MS | MS | MS | MS | MS | MS | MS | MS |
| | Vegetation Indices | MS | MS | MS | MS | MS | MS | MS | MS | MS |
| Harvest Index & Quality (Requires High Resolution) | Organs Count | RGB | RGB | N/A | N/A | RGB | RGB | N/A | N/A | RGB |
| | Organs Density | RGB | RGB | N/A | N/A | RGB | RGB | N/A | N/A | RGB |
| | Plot Area | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS | RGB / MS |

N/A NOT AVAILABLE *ASK OUR ENGINEERS

DATE

# Literal Production Traits - Crop x Trait Matrix

## Literal: High-resolution trait extraction

| | Trait x Crop | Wheat | Barley | OSR/Canola | Sugar Beet | Potato | New Crops Coming Soon ... |
|---|---|---|---|---|---|---|---|
| Trial Quality | Plant Count | ✓ | ✓ | ✓ | ✓ | ✓ | ... |
| | Disease Assessment | Fusarium Head Blight | Fusarium Head Blight | TBD | TBD | TBD | ... |
| Canopy Development | Green Cover | ✓ | ✓ | ✓ | Coming Soon... | Coming Soon... | ... |
| | Plant Cover | ✓ | ✓ | ✓ | Coming Soon... | Coming Soon... | ... |
| | Early Vigor | ✓ | ✓ | Coming Soon... | Coming Soon... | Coming Soon... | ... |
| | Flowering | TBD | TBD | ✓ | N/A | N/A | ... |
| Biomass Proxy | Plant Height | ✓ | ✓ | ✓ | Coming Soon... | Coming Soon... | ... |
| | Leaf Area Index | ✓ | ✓ | ✓ | Coming Soon... | Coming Soon... | ... |
| | NDVI | ✓ | ✓ | ✓ | ✓ | ✓ | ... |
| Harvest Index & Quality | Organ Count | Head Count | Head Count | Pod Count | N/A | N/A | ... |
| | Organ Density | Head Density | Head Density | Pod Density | N/A | N/A | ... |

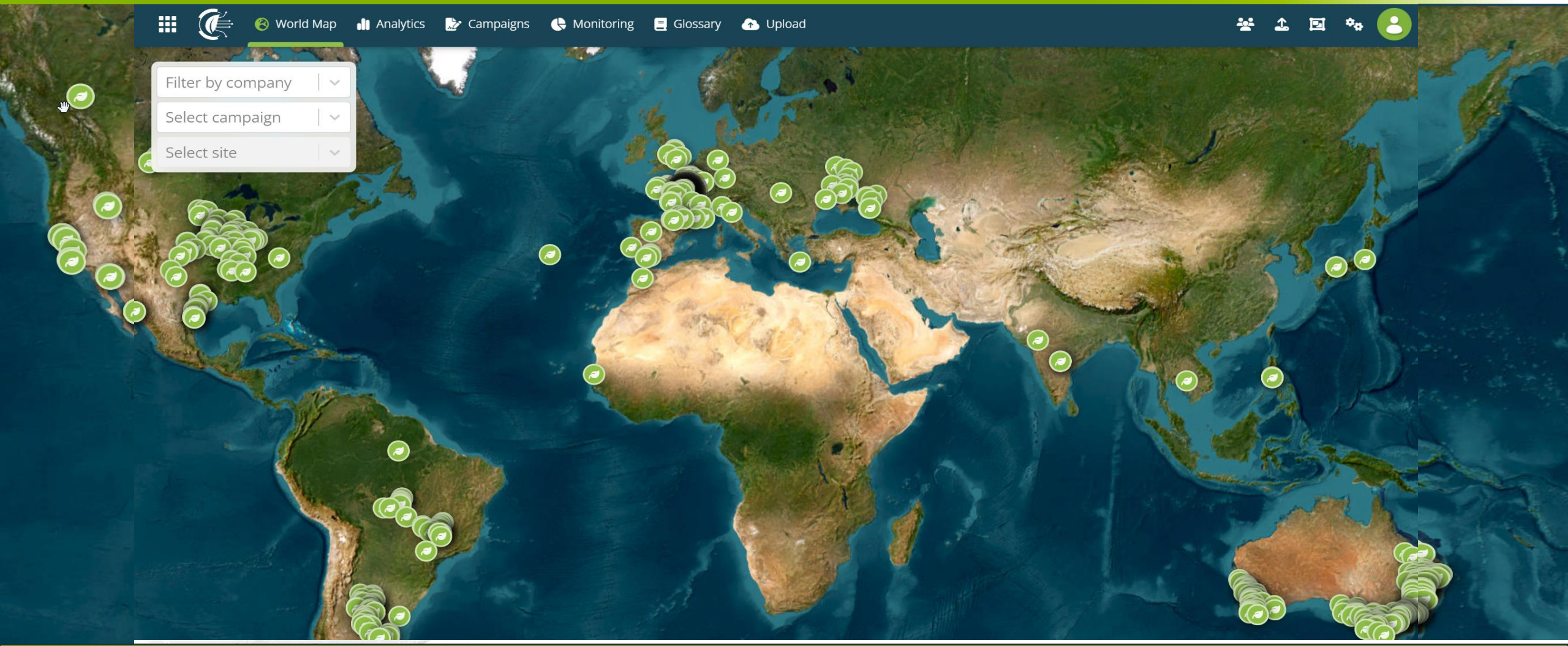
✓ Q1 2025

✓ Q3 2025

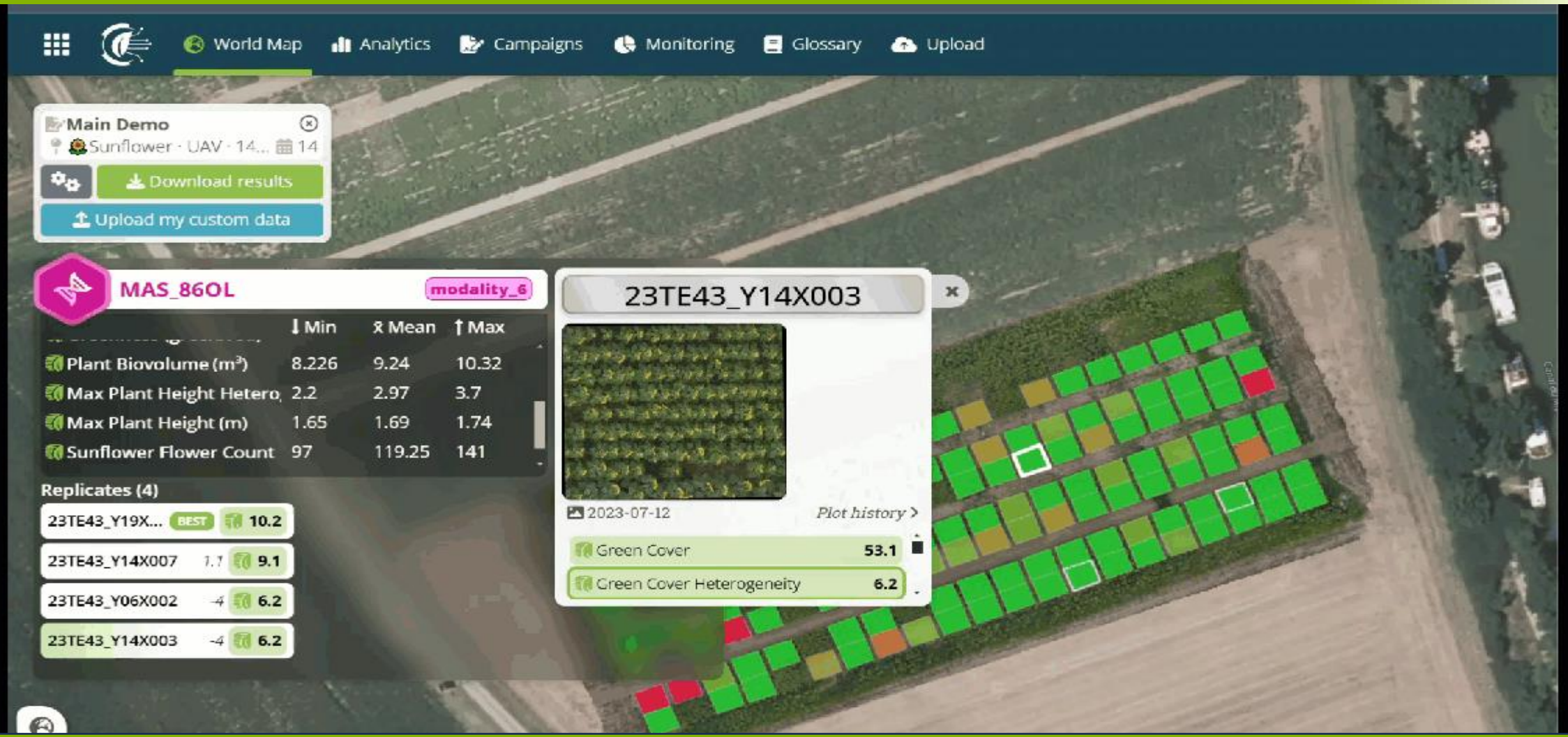
✓ Q3 2026

# Data Visualization, Image Query, and Analytics

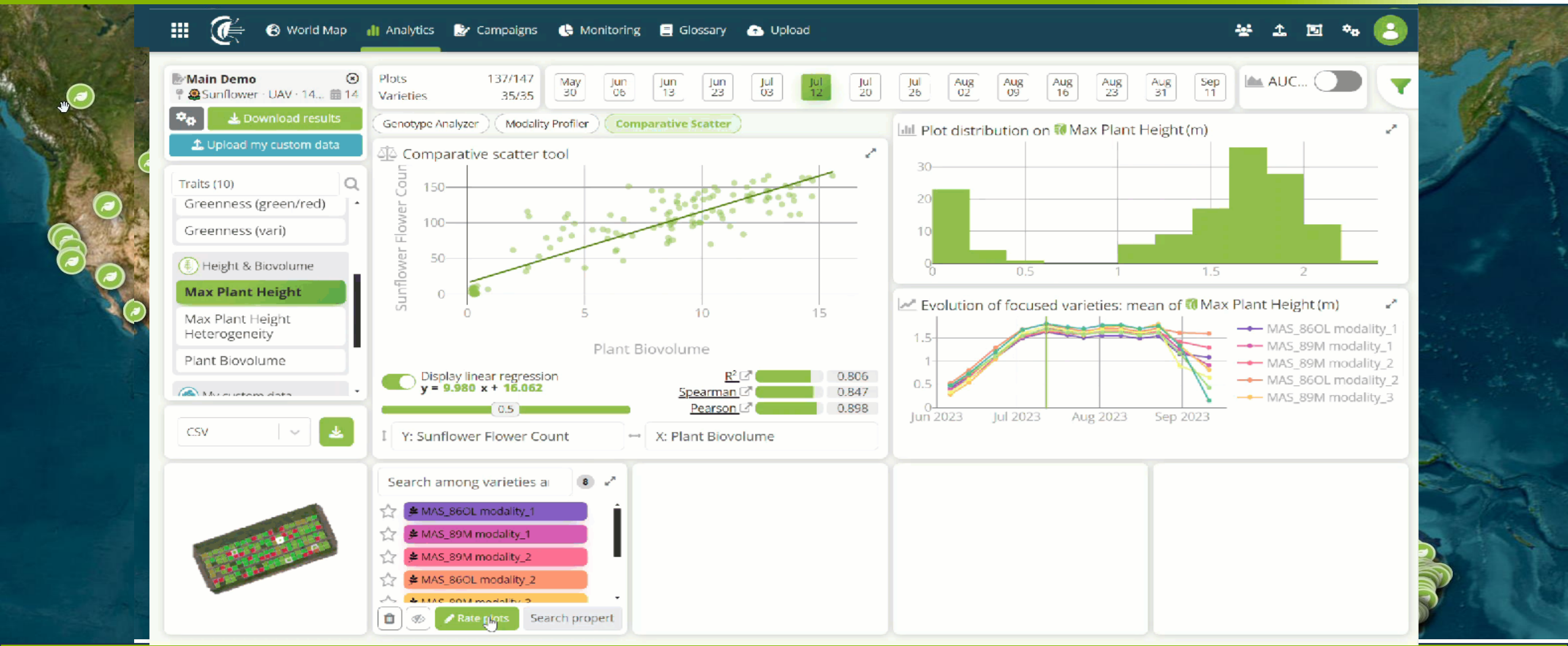
# Cloverfield Platform – Upload and View Images and Data



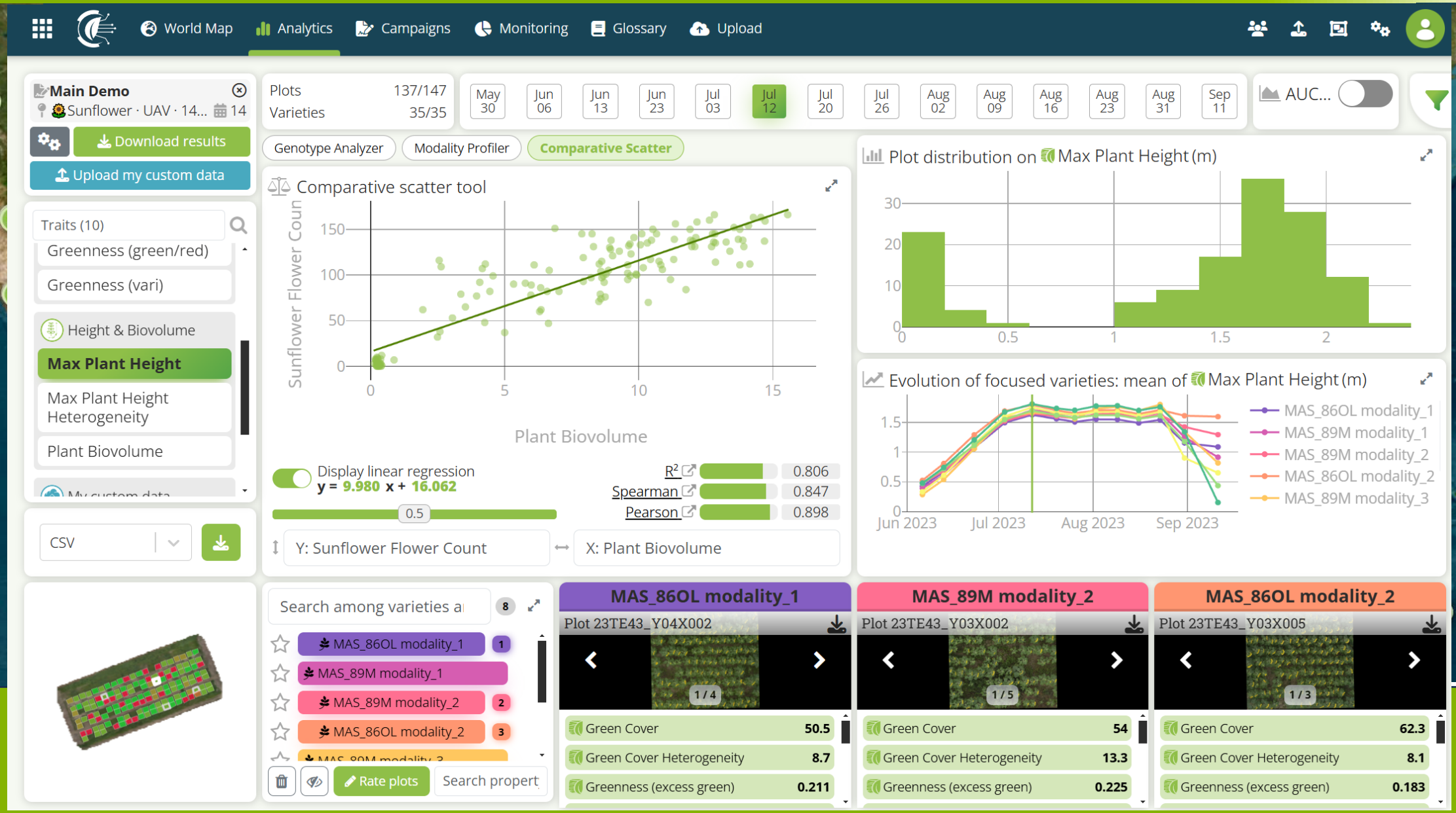
# Cloverfield Platform – Image Query – Plots Across Time



# Cloverfield Platform – Researcher Eye Rating Tool



# Cloverfield Platform – Analytics and Image Query



# New Frontiers in Image Analytics - Phenomic Prediction

# Phenomic Prediction – Predicting Seed Humidity

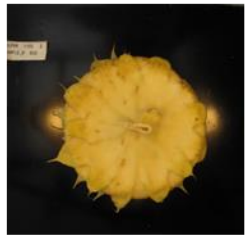
Phenomic Breeding values → Imaging domain → Encoding tech → Decoding fidelity → Spectral diversity → Similarity matrix → Prediction accuracy

HelEx

INRAE Toulouse

European project with 18 research partners to develop new **sunflower** varieties more resistant to high temperatures and drought



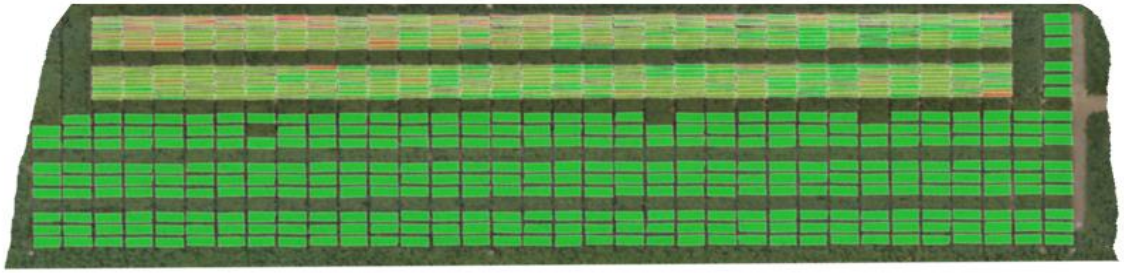



- DJI Matrice 300
- Zenmuse P1 50mm
- 7 flights
- GSD = 0.15cm/pixel

**Predicting Seed humidity %** from 2 capitulum per plot per flight

# Phenomic Prediction – Latent Space and Kinship/Similarity Matrices

Orthomosaic and plot boundaries generation

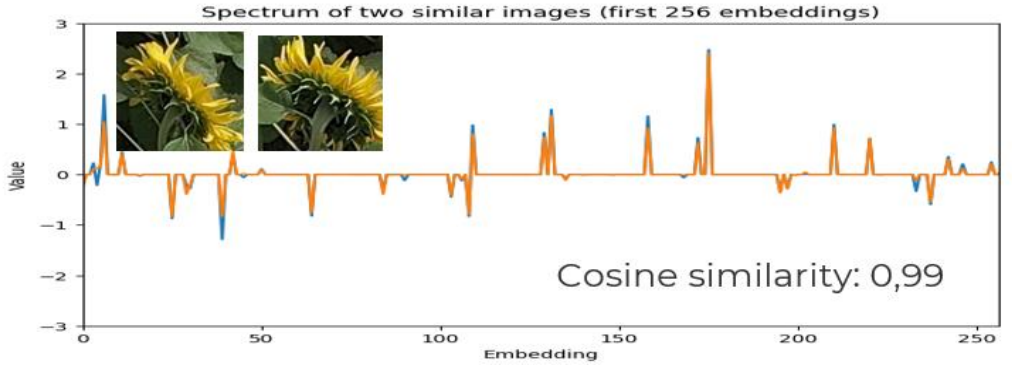


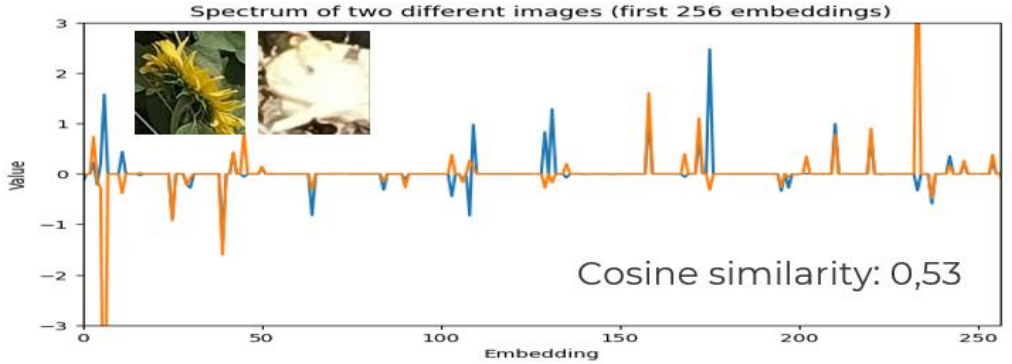
Plot image

Organ detection

Organ pre-processing

**Latent space**

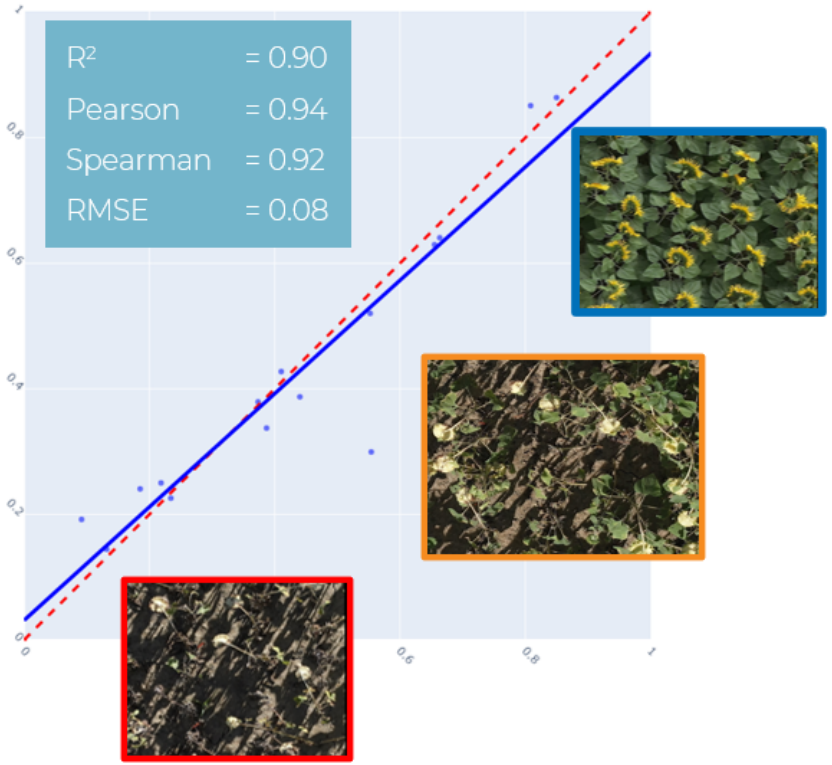


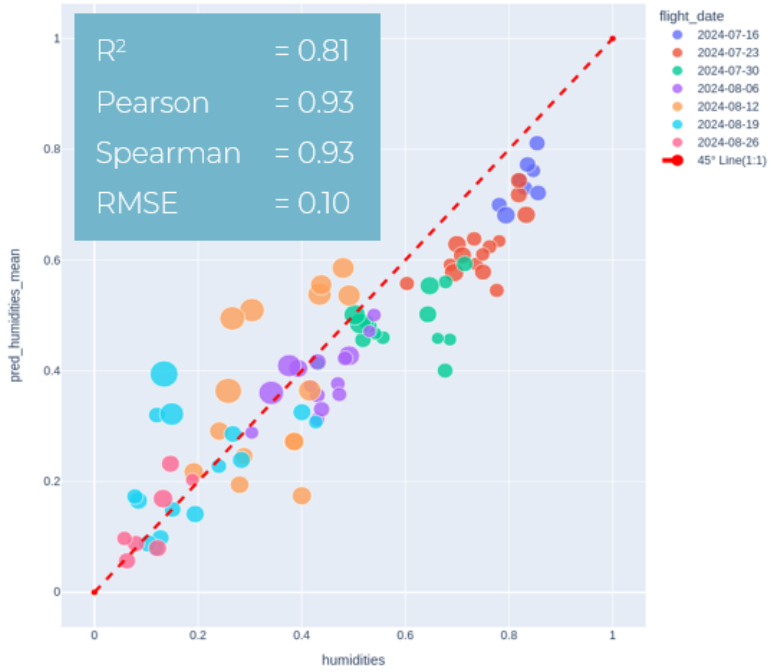
# Phenomic Prediction – Testing Predictions and Gaining Confidence

## Model trained in France 2023

### Prediction in France 2023




### Prediction in France 2024




### Prediction in Spain/Romania 2024

**Ongoing analysis**

**Every plant at every date has a seed humidity**

# Industry Partner Network

LongReach Plant Breeders

125 NPZ Jahre

RIJK ZWAAN

BAYER

ASUR plant breeding

CTC Centro de Tecnologia Canavieira

RAGT

Marionnet Label

syngenta

eurofins

PIVOT BIO

Oignon · Ail · Échalote Ferme des Arches

ADVANTA

ARVALIS

Florimond Desprez

Gautier semences

novozymes Rethink Tomorrow

Fondé en 1743 Moët & Chandon Champagne

Nutrien Feeding the Future™

And more...

# Research Partner Network

hiphen

Agricultural Image Analytics

# Imaging Solutions for Seed Banks

## Characterization of Accessions During Regeneration

CROP TRUST

Lwest@Hiphen-Plant.com