N.	Institution/Organization/Company
1	Centre International de Hautes Etudes Agronomiques Méditerranéennes of Bari, Italy **CIHEAM of Bari - Italy** *(Coordinator)*
2	Food and Environment Research Agency, United Kingdom **Fera Science Ltd. - UK** *(Coordinator)*
3	Department for Environment Food and Rural Affairs, United Kingdom **Defra - UK**
4	Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Centro di ricerca per la difesa e la certificazione, Italy **CREA-IT**
5	U.S. Department of Agriculture, Animal and Plant Health Inspection Service **USDA, APHIS**
6	**Terrasystem-IT**
7	Joint Research Centre - European Commission **JRC-EU**

The applications of Remote Sensing in Plant Health

PHeRS

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CIHEAM of Bari ITALY

Paul BROWN
FERA Science Ltd., UK

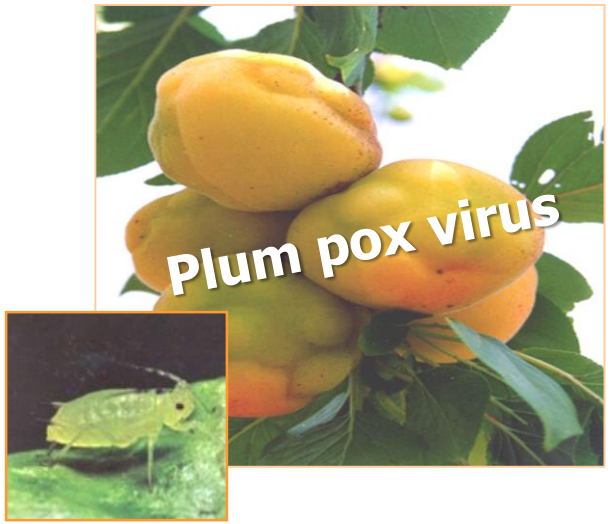
Introductions and establishments of new, economically or environmentally damaging plant pests constantly increase worldwide due to **global trade and climate change**.

These pests may become invasive when they rapidly colonize an area.

Once established, invasive pests are extremely difficult to eradicate and can destroy entire industry of specific crops or a forest system .

Prevention is economically and environmentally more efficient than eliminating pest outbreaks from which the infestation/infection can fast spread

It is the role of NPPOs to protect plants from regulated quarantine & no quarantine harmful pests



To early detect pests introductions and spread is important to have **efficient systematic surveillance systems** in order to apply immediate phytosanitary measures for their eradication/containment :

- Performing methodologies and tools
- Skills
- Adequate financial resources

EUPHRESCO STRATEGIC RESEARCH AGENDA

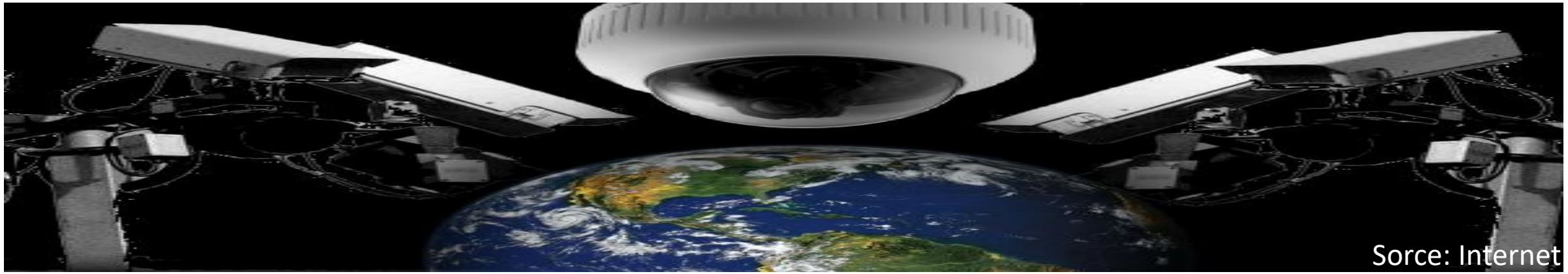
Euphresco Network for phytosanitary research coordination and funding

PHeRS

Priority 4

Objective 2017-R-4.2:
to explore the use of remote sensing technologies to support surveillance and detection activities

Early detection of pests is important
- ➢ to limit crop & environmental losses
- ➢ to prevent further expansion of outbreaks, thus facilitating containment or eradication campaigns.



Satellites, piloted aircraft and drones (UAV) can provide precise maps of the Earth's surface, reach locations that are difficult to survey and they can support sensors (e.g. multispectral/hyperspectral, thermal) for the early detection of biotic and abiotic stresses in plants, even before symptoms development

EARLY WARNING

EUPHRESCO STRATEGIC AGENDA

Objective 2017-R-4.2:
to explore the use of remote sensing technologies to support surveillance and detection activities

PHeRS objective

PHeRS aims to explore the current research being undertaken at each project partner and report on the benefits and limitations of remote sensing applications in plant health such as

- *Pest surveillance*
- *Plant host mapping*
- *Pest outbreak monitoring*
- *Pest spatial & temporal spread*

- ❑ evaluate the effectiveness of applied measures
- ❑ evaluate the environmental & economic impact and cost effectiveness
- ❑ consider further measures to strengthen containment and eradication actions

Euphresco Network for phytosanitary research coordination and funding

PHeRS

Project Phase 1

- Bring together RS experts from across Europe and the USA
- Map and review current work at each organisation
- Identify research gaps and/or areas for further development

Project Phase 2

- Report on current state of research at each partner organisation/Institution
- Specifically identifying work being undertaken to
  a) Identify host trees
  b) Identify pest infections

WP 1
Project management & coordination

WP 2
State of the art, research needs and gaps

WP 3
Advancements of research on identification of pest host species

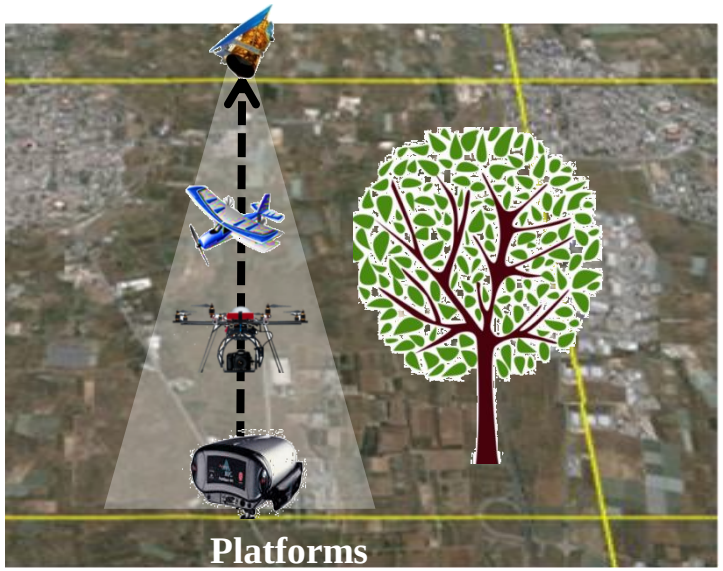
WP 4
Advancements of research to support pest identification

Conclusions

Euphresco Network for phytosanitary research coordination and funding

PHeRS

There are many platforms and sensors designed for the acquisition of remotely sensed data, ranging from satellite, airborne and UAS technology.
These platforms can mount various remote sensing sensors that can contribute in different ways to the monitoring of plant biotic and abiotic stresses.



Three main groups of sensors can be recognised:

- optical (RGB, multispectral/hyperspectral)
- thermal
- microwave

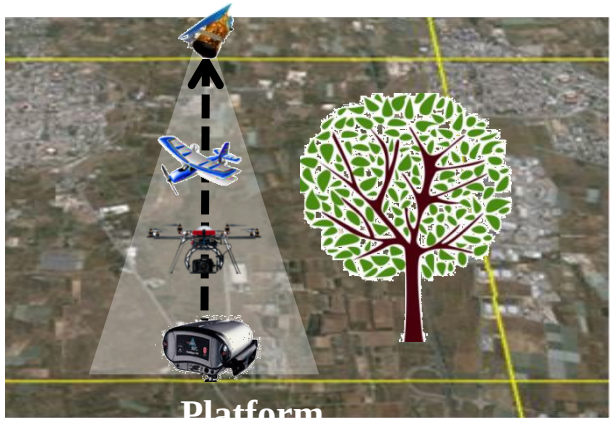
These sensors have various spatial, spectral and temporal resolutions and offer information valuable for certain plant/crop types and certain plant health status.

Most of these sensors can provide information on pest symptoms
not on presence/absence of a given pest.

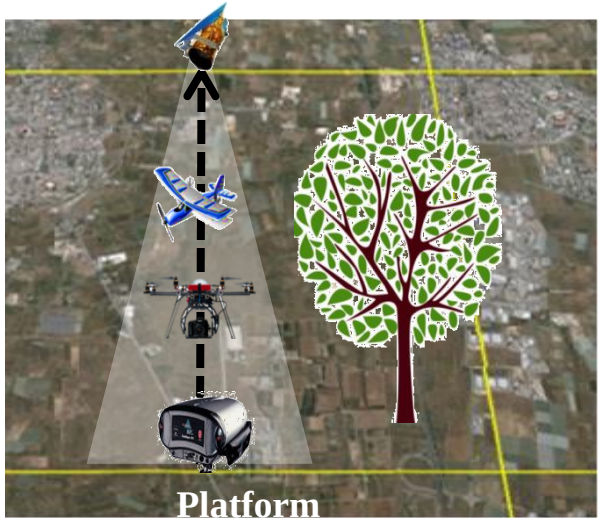
Conclusions

Major limitations in the application of remote sensing in plant health are:

- the low resolution of freely available satellite platforms (e.g. EU Copernicus programme)
- the high costs of airborne high resolution imagery
- few, expensive and high weight sensors available in the market
- no pest-specific sensors available
- lack of harmonized data quality
- and the lack of skills for data processing and interpretation with a competence in plant health.



Conclusions



What RS methodology is now applicable in pest monitoring programmes?

- Sentinel series of satellites (part of the EU Copernicus programme) are freely available for large area classification (vegetation classification mainly of pest-host plants of homogeneous cover) and higher temporal resolution.

- Other platforms provide higher resolution images (spatial and spectral) but are expensive.

- Application of semi-automatic and automatic plant counting (e.g. plant mapping; precise sampling procedures)

- Application of pest recognition procedures (e.g. predictions maps for *Citrus tristeza virus*, *Xylella fastidiosa*).

FUTURE & ONGOING RESEARCH

Identification of a ‘package of wavelengths‘ correlated to plant secondary metabolites pest-specific

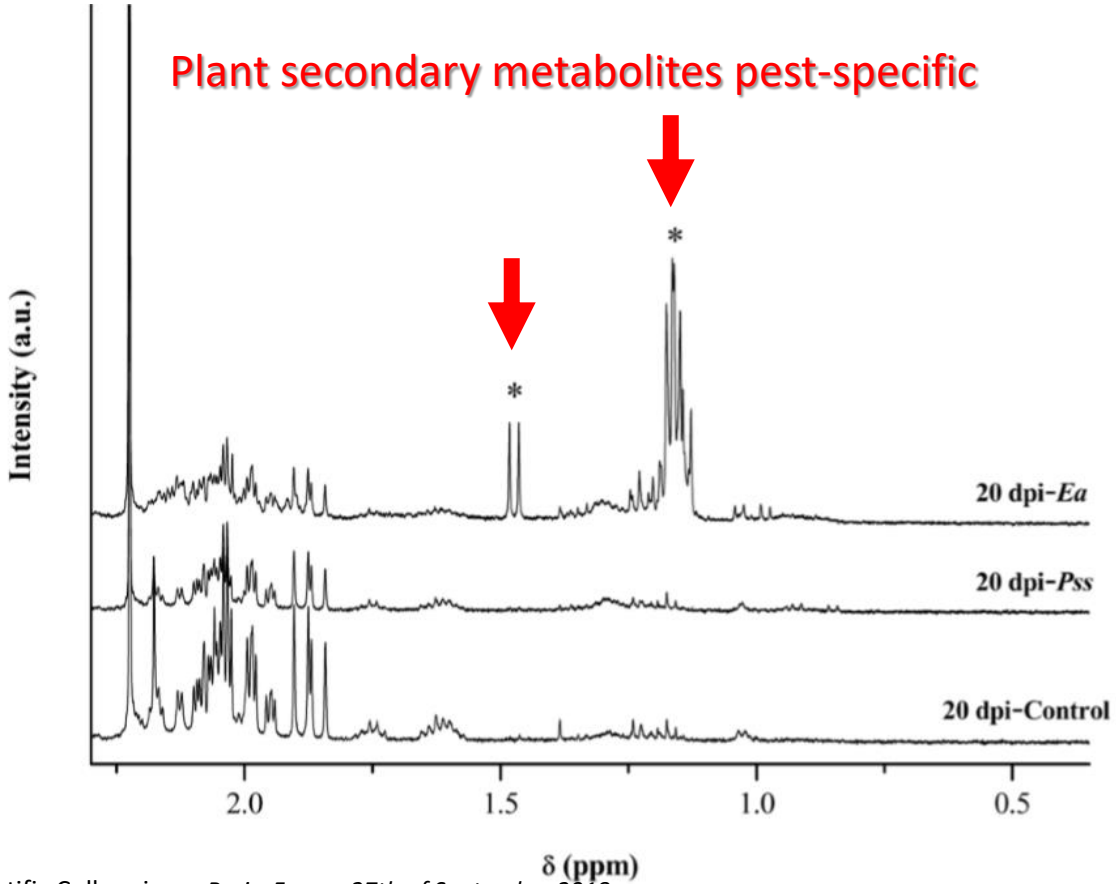
Phytopathologia Mediterranea (2018), 57, 2, 193–203
DOI: xxxxxxxxxxxxxxxx

RESEARCH PAPERS

Detection of Erwinia amylovora in pear leaves using a Combined Approach by Hyperspectral Reflectance and Nuclear Magnetic Resonance spectroscopy

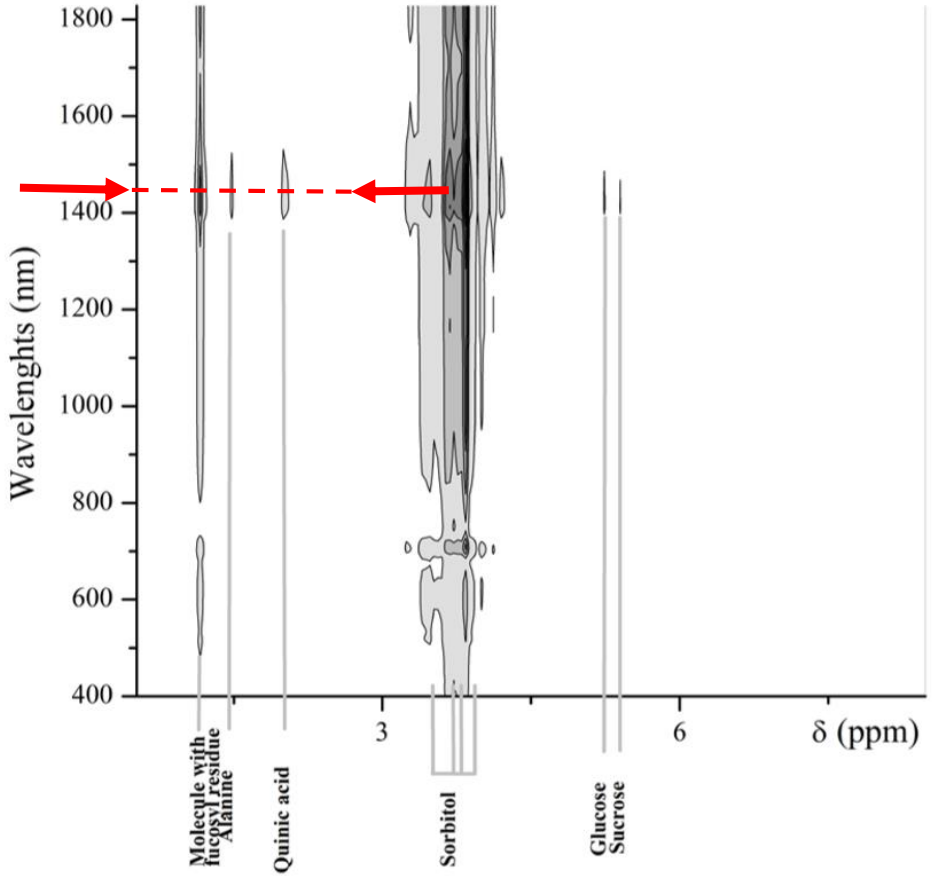
Antonino RIZZUTI[1,2], Luis Manuel AGUILERA-SÁEZ[1], Franco SANTORO[3], Franco VALENTINI[3], Stefania GUALANO[3], Anna Maria D'ONGHIA[3], Vito GALLO[1,2], Piero MASTRORILLI[1,2] and Mario LATRONICO[1,2]

Plant secondary metabolites pest-specific



Plant metabolites play a key role for the selection of pest-specific wavelengths

Wavelenghts correlated



FUTURE & ONGOING RESEARCH

Identification of a ‘package of wavelengths‘ correlated to plant secondary metabolites pest-specific

This approach is ongoing in WP3 of Xf-ACTORS H2020 project for the identification of specific spectral bands for *X. fastidiosa* in olive trees

FUTURE RESEARCH

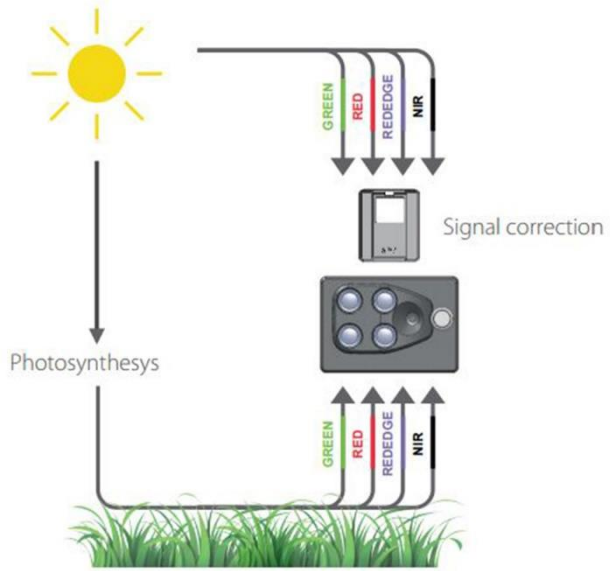
Development/customising a specific sensors for plant health

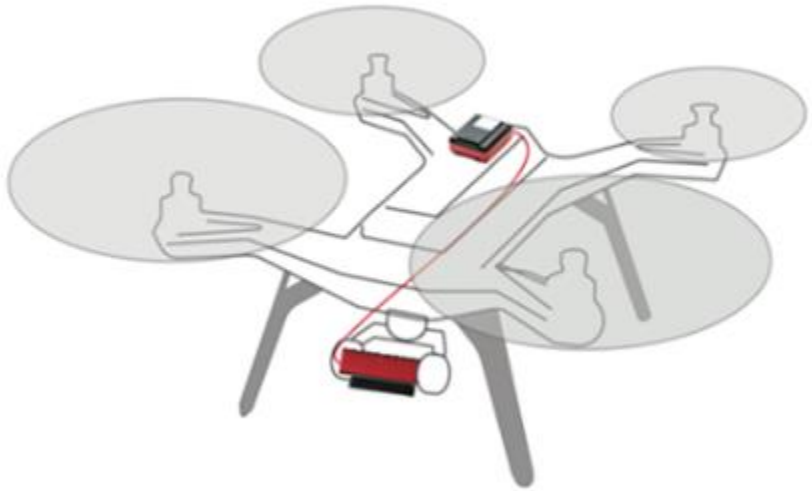
user's friendly (*low weight, small size etc*.)

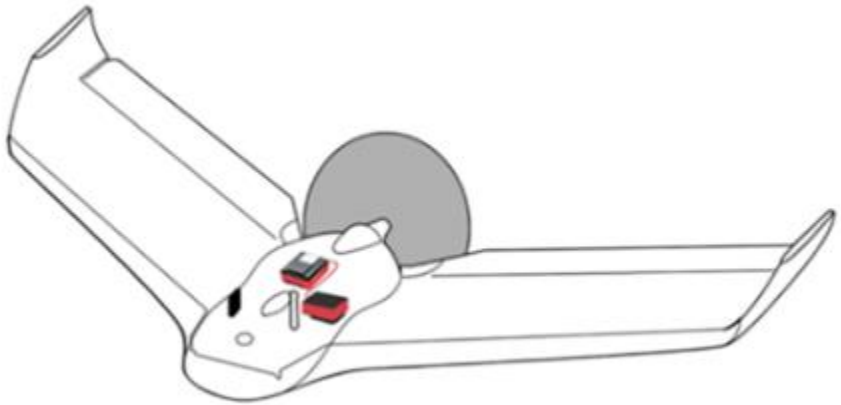
'package of wavelengths'

pest-specific for early identification of infections before symptoms development

- **host plant species-specific** for classification purposes





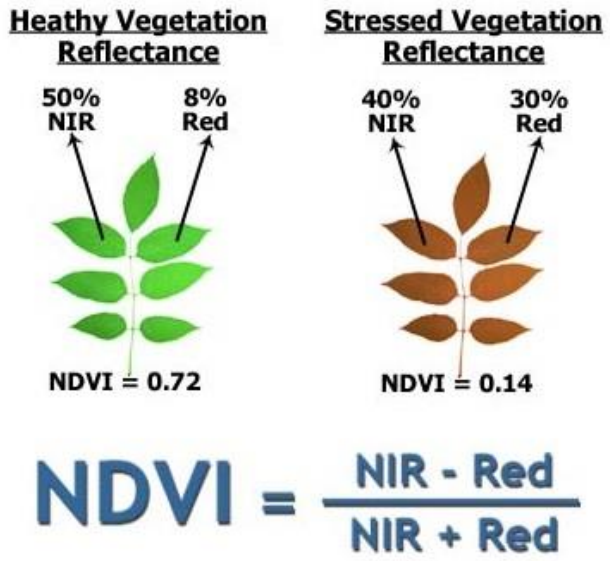


https://www.korecgroup.com/product/parrot-sequoia-sensor/

FUTURE RESEARCH

Development of most performing spectral Vegetation Indices (sVIs) for pest detection

Different studies in the last few years have focused on the ability of spectral Vegetation Indices (sVIs) to detect specific diseases. To this aim a 'package of wavelengths' (pest-specific) could also be used for the identification of new and most performing sVIs.



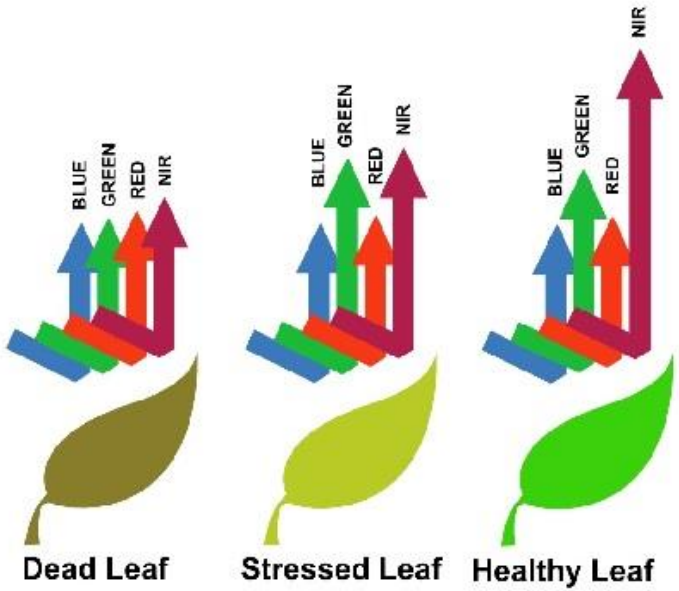
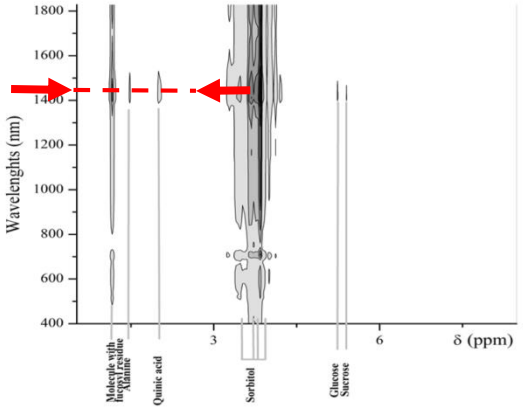


IMAGE PROCESSING

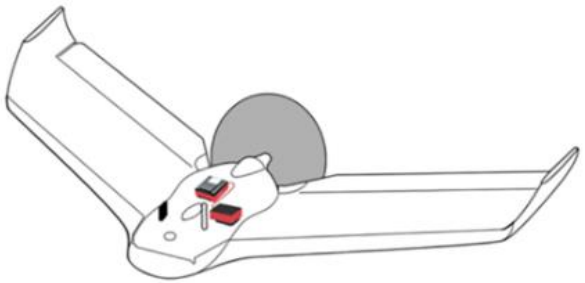
ONGOING & FUTURE RESEARCH

Image processing for early pest detection and/or host species classification



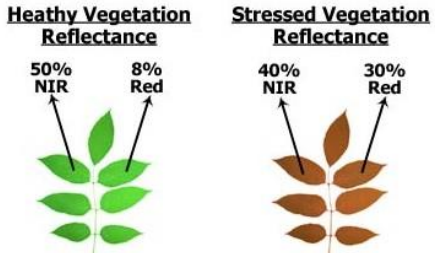
PACKAGE OF WAVELENGTHS

pest-specific



SENSOR

pest-specific



New sVIs

pest-specific

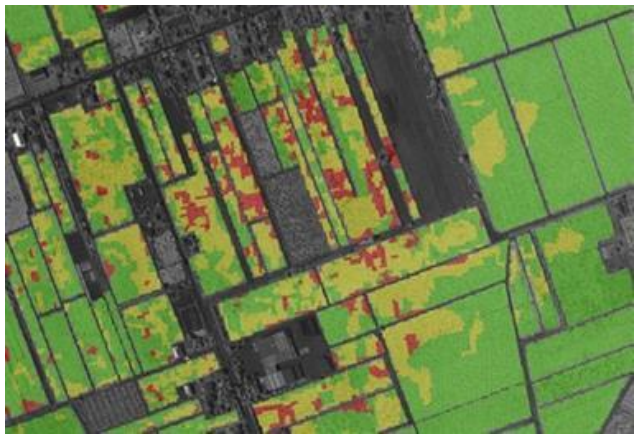


IMAGE PROCESSING

FUTURE RESEARCH

Development/customising a specific sensor for plant health

Sensor Technology and Readiness Levels

Technology Readiness Levels (TRL)

TRL9 **Operations**

TRL8 **Active Commissioning**

TRL7 **Inactive Commissioning**

TRL6 **Large Scale**

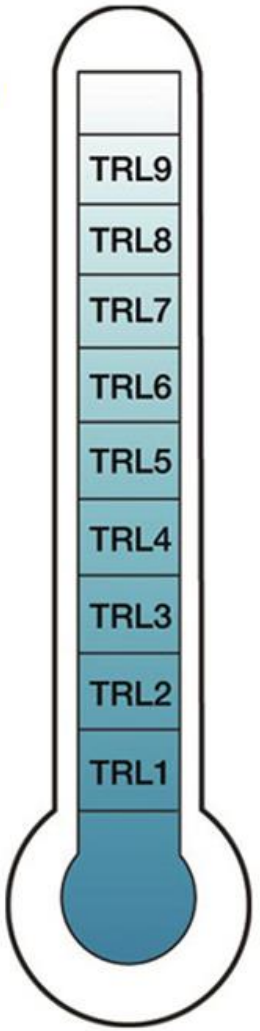
TRL5 **Pilot Scale**

TRL4 **Bench Scale Research**

TRL3 **Proof of Concept**

TRL2 **Invention and Research**

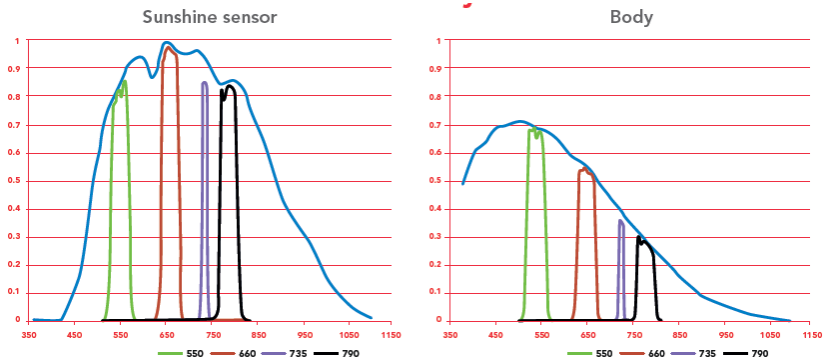
TRL1 **Basic principles**



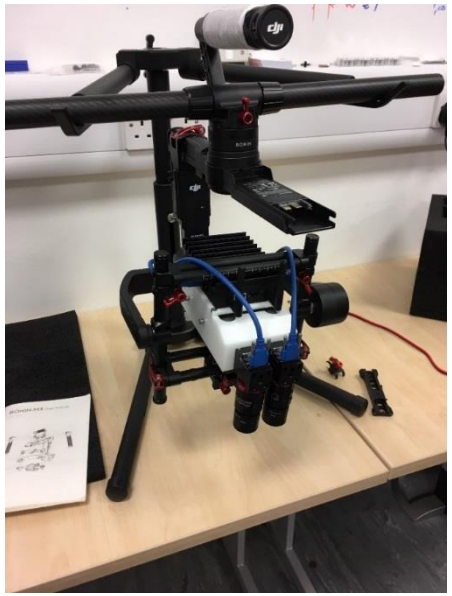
FUTURE RESEARCH

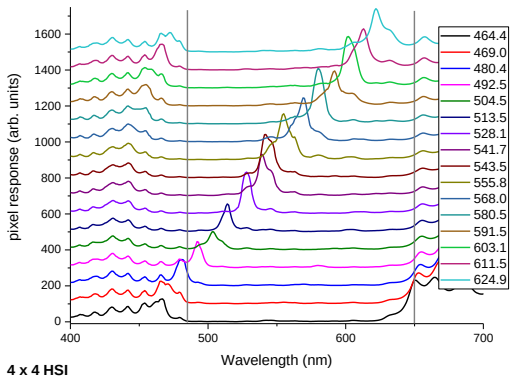
Development/customising a specific sensor for plant health

Current Operational Multispectral Sensor (TRL = 9)

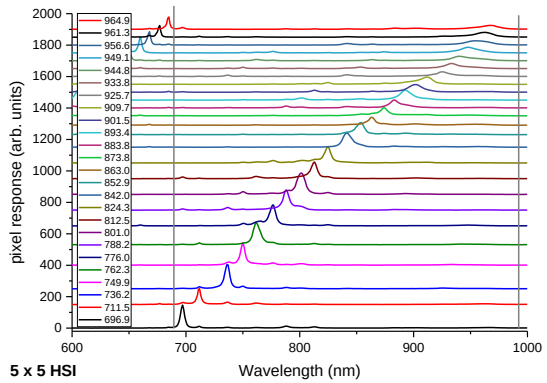


Current Research Hyperspectral Sensor (TRL = 2-3)





4 x 4 HSI



5 x 5 HSI

FUTURE RESEARCH

Development/customising a specific sensor for plant health

Future Sensor Development Focus:

- Continue progressing research sensor technology through the TRL Levels
- Identify areas of the electromagnetic spectrum, ‘packages of wavelengths’ for detecting specific biotic and abiotic stresses

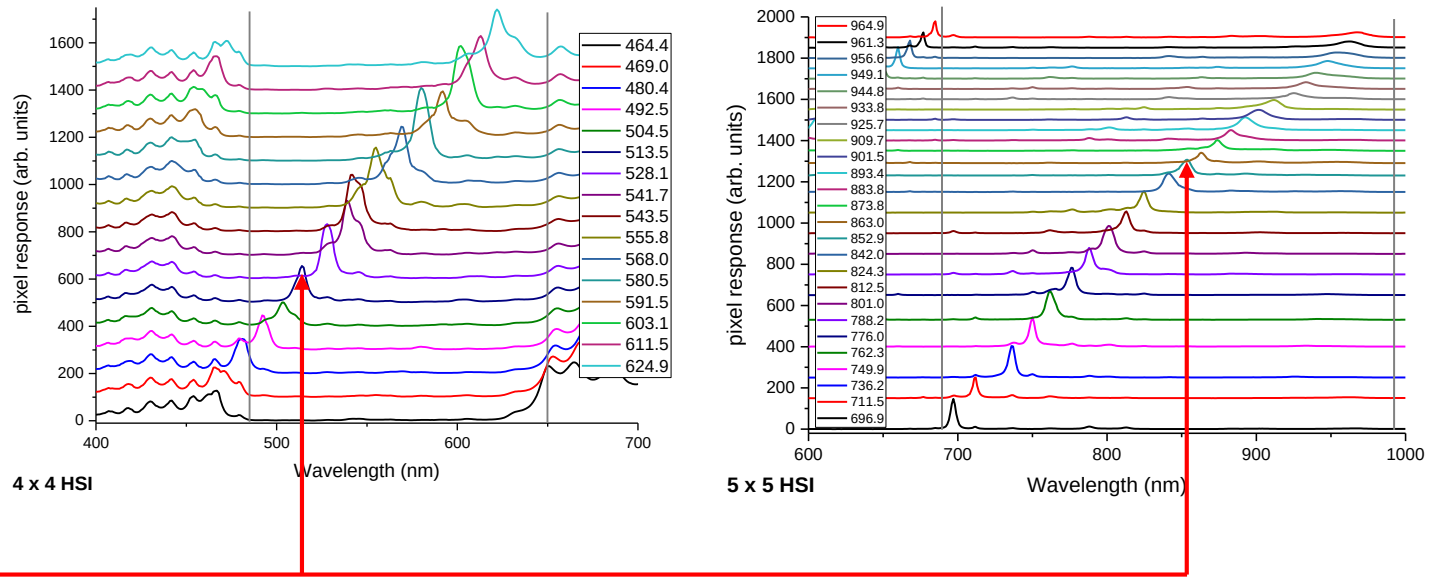
Allows for:

The development of cheaper sensors

a decrease data volume

a decrease processing time

a decrease analysis time



FUTURE RESEARCH

Development/customising a specific sensor for plant health

Platform Technology must be considered

2015

2018

FUTURE RESEARCH

Development/customising a specific sensor for plant health

- Development of drone platforms is progressing at pace, however:
  - Current legislation restricts the use of drones
  - Future drones for inspection purposes need to be:
    - Light
    - Cheap
    - More automation, pre-programable to area of interest
    - Automatic collision avoidance and geofencing improvements to satisfy legislation.

Not all about Drones!

FUTURE RESEARCH

Development/customising a specific sensor for plant health

Near Ground Sensors

- Deployable on:
  - Drones
  - Current machinery – tractors, mowers etc.
  - Hand held

- What about satellite platforms
  - Ground results used for upscaling to satellite data to cover larger areas of land if required
  - Highly accurate near ground instruments will enable more reliable ground results.

Thank you from PHeRS partners