"RS4Ag Development": from plot to landscape scales

Francelino Rodrigues

... and collaborators

Connecting NZ's Airborne Tech
Christchurch, April 2023

CIMMYT

LINCOLN AGRITECH LTD

MEASURE. MODEL. MANAGE.

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MEASURE. MODEL. MANAGE.

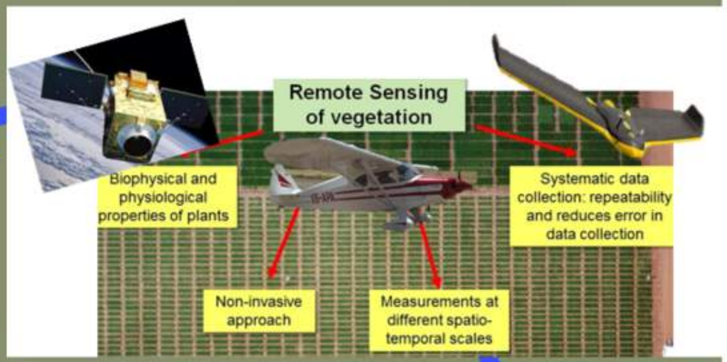
What is our interest at LAL?

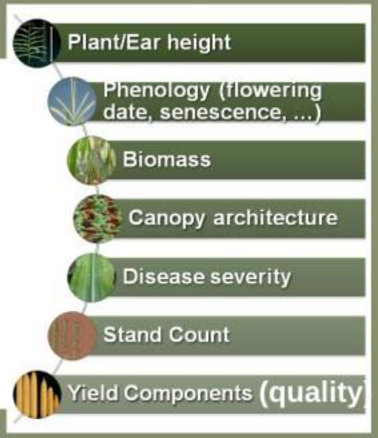
Plot scale - High throughput phenotyping

Work in partnership with plant breeding industries for developing sensing solutions to access plant traits

Next-generation phenotyping

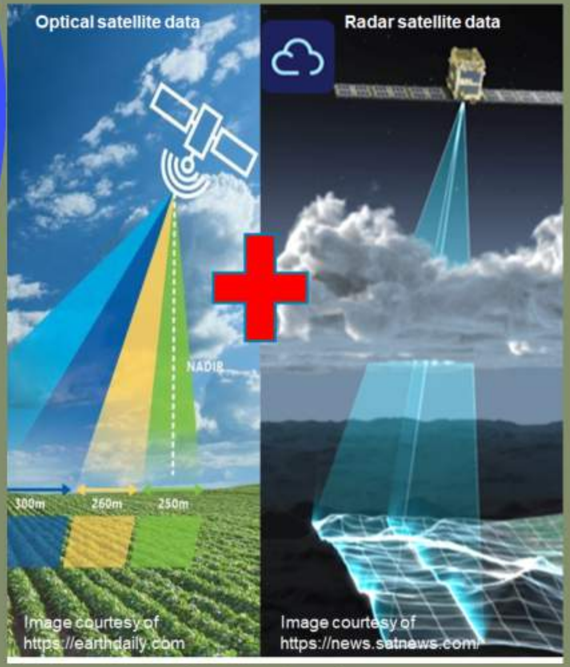
Reduce selection cost and contribute to faster genetic gain!





Farm / regional scales - Sensing tech for agronomic sustainable intensification

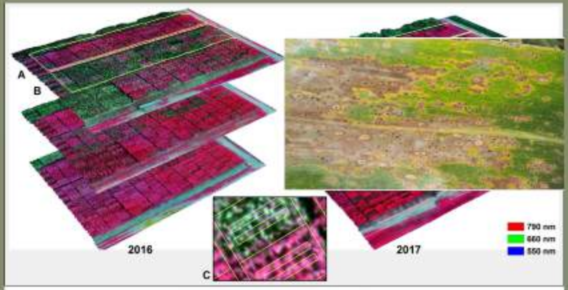
- Physically-based methods for plant traits retrieval
- Abiotic and biotic stresses assessment
- Yield and quality - Assessment from farmers fields up to landscape scales
- Landscape assessments:
  - Assessment of different metrics at landscape level through RS
  - Joint of different metrics into crop models
- Exploring different RS sensors/platforms - e.g. optical + SAR - and data fusion methods
- Ultimately - Farmer-centered design of DSS!

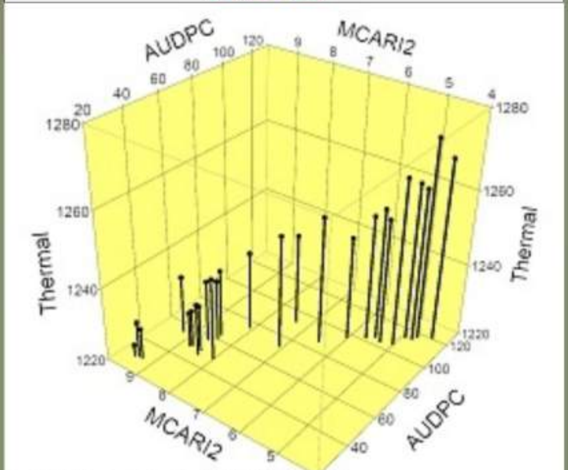


Data fusion

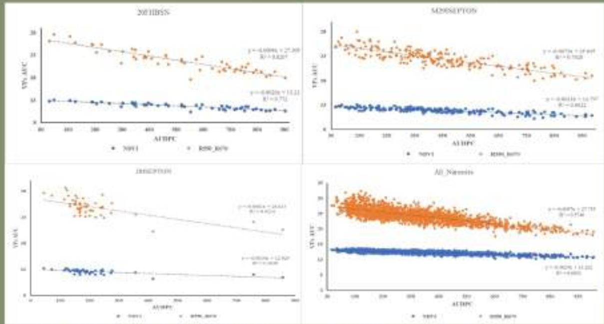
some studied cases:
High Throughput Field Phenotyping - Foliar Disease & Plant Height

Maize
Tar Spot Complex



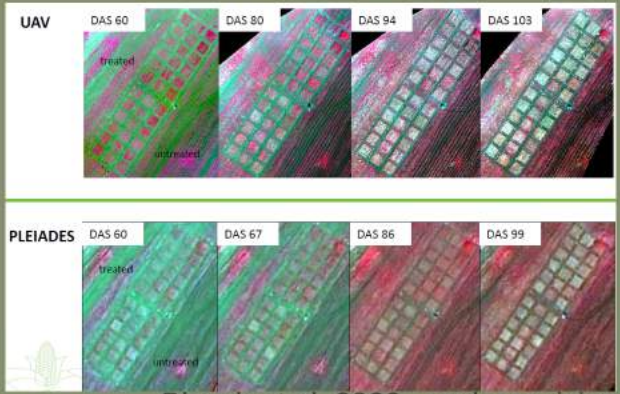


Loladze et al. 2019



CIMMYT et al. 2019 - in preparation

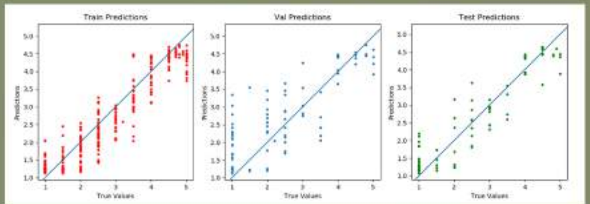
Wheat
Fusarium, spot blotch, septoria and rust
UAV vs Satellite vs visual



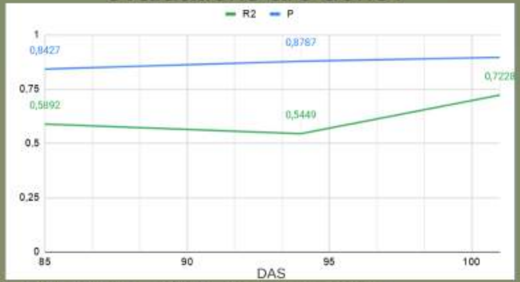
Blasch et al. 2023 - under revision

AI - towards automation of disease HTP

CNN for training and validation of severity scores

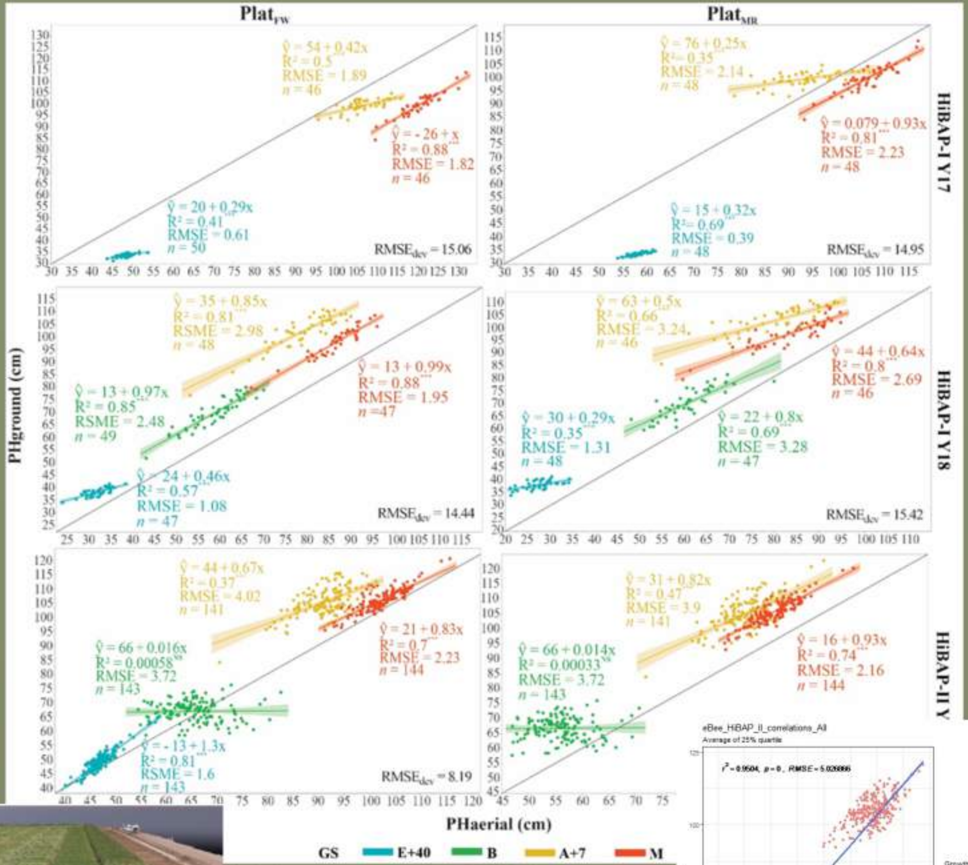


How is the model performance as evaluations are done?

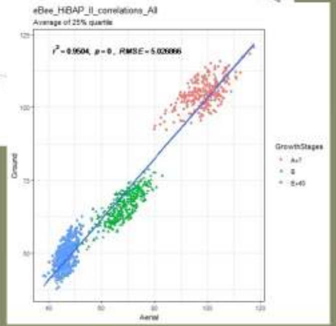


LAL & UTFPR, 2023 - in preparation

RS photogrametry - DSM - 3D point cloud



Volpato et al. 2021



- PPK can replace the use of GCPs
- Fixed-wing surpassed multi-rotor performance
- PH estimation through 3D-point cloud can deliver proper PH info in a breeding program

"RS4D" - towards landscapes - designing agricultural DSS

Case example:

COMPASS - Crop Observation, Management & Production Analysis Services System

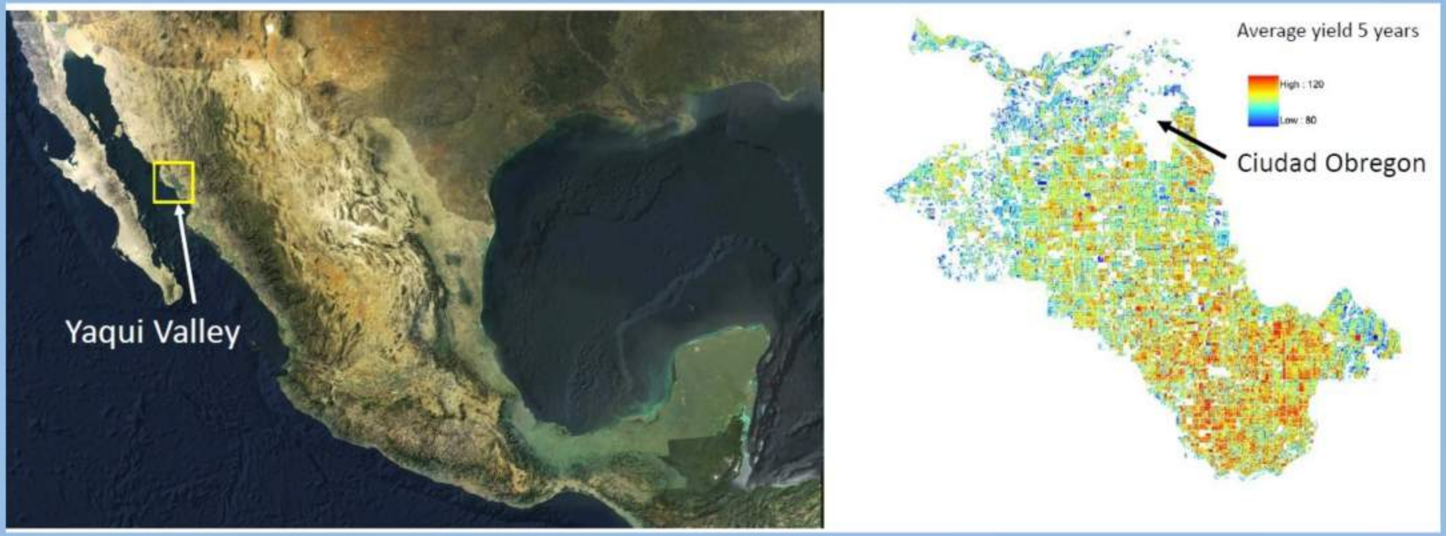
UK SPACE AGENCY

Rezatec

CIMMYT

Booker Tate

The University of Nottingham



Objectives - Wheat module

- Yaqui Valley: Mexico's most productive breadbasket - 225,000 ha
- Agro-ecologically represents 40% of the environments where wheat is produced in developing countries
- Sowing and irrigation timing - well known drivers of yield potential in this region
    - Even experienced farmers benefit from the adoption of a decision support tool to inform their decisions.

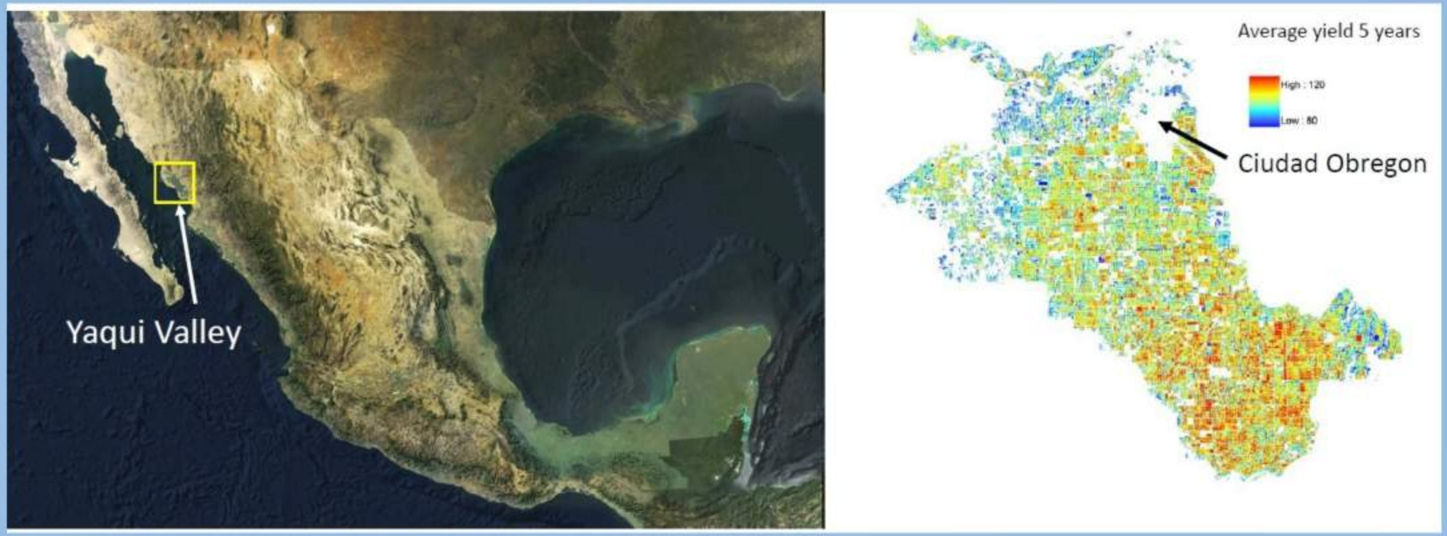
To produce a freely available mobile application providing:

- Irrigation scheduling feature which provides a probabilistic yield forecast for potential irrigation events over a 10-day window
- Optimum sowing date for a given location within Yaqui Valley.
    - Function of the number of post-planting irrigation (usually 3-4 irrigation).
- A tool where all crop management activities can be recorded and scheduled electronically
- Weekly time series of NDVI images of their fields during the cycle (Sentinel-2)

https://www.rezatec.com/resources/projects/mexican-compass/

Farmers' workshops and meetings

... from the beginning towards the end of the project



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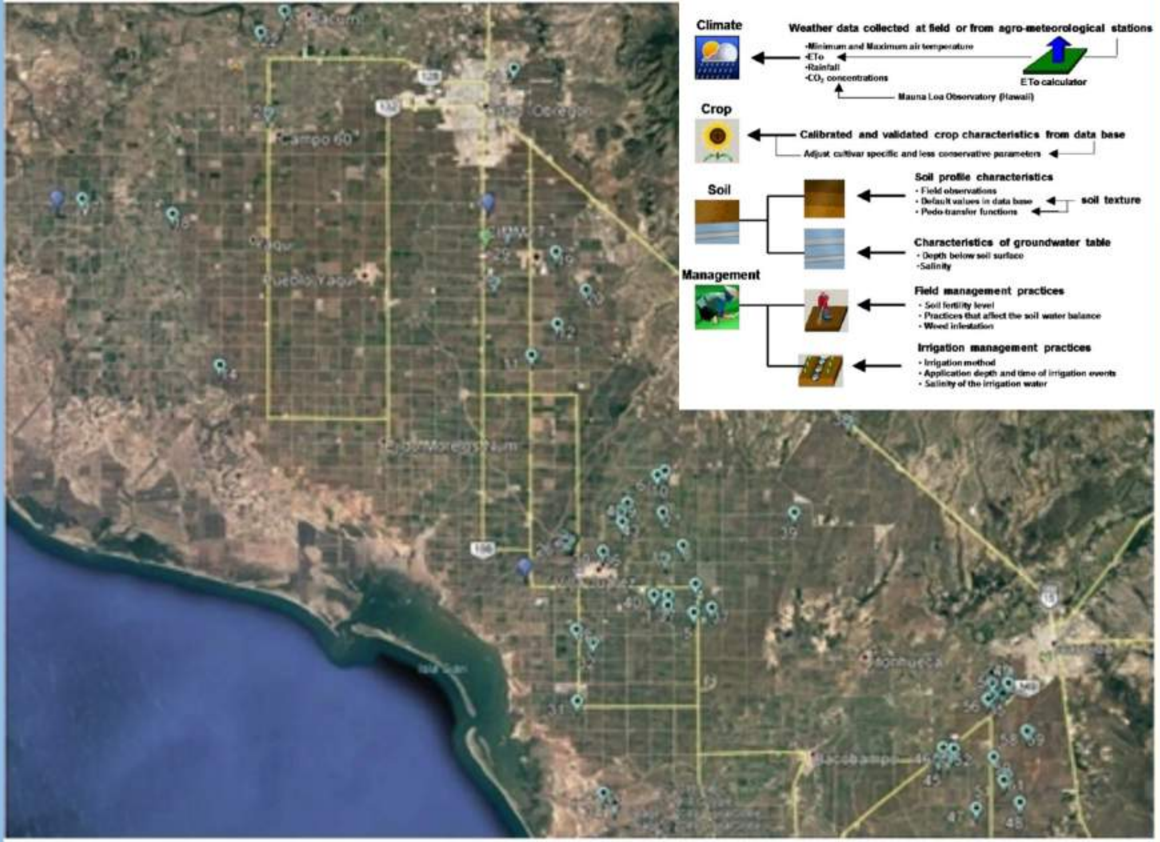
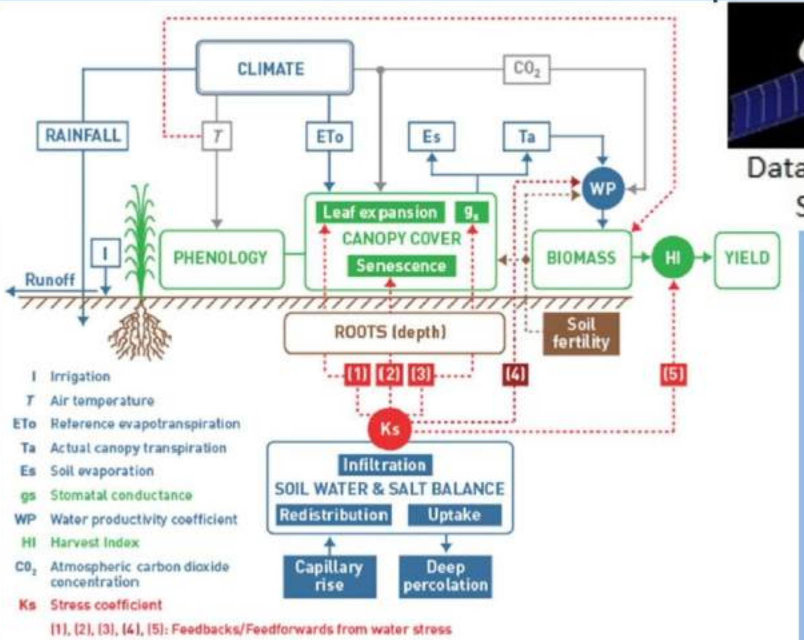
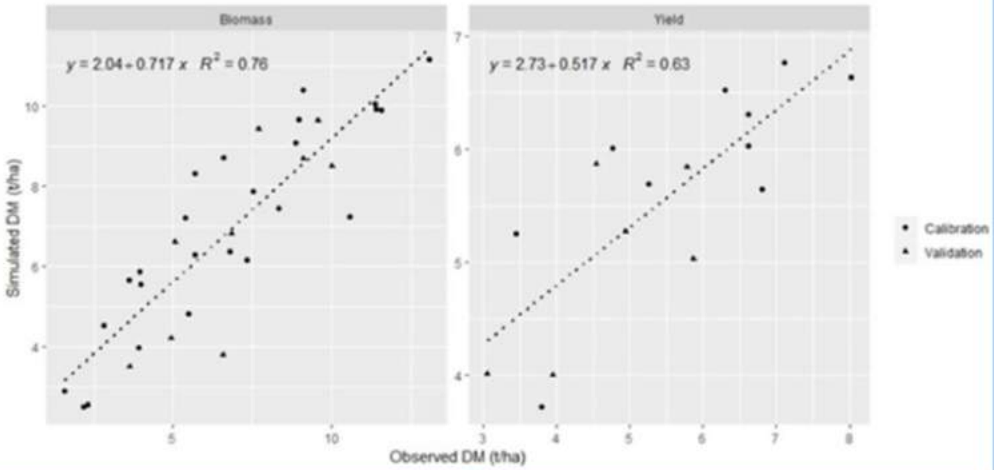


Cycle	Intensive farmers sites	Within Station experiments / validation sites	Farmer fields
2016-17	03	02	
2017-18	03	02	#16 farmer fields with soil, biomass/yield data
2018-19	03	02 / 01 Val	#62 farmer fields with soil, biomass/yield data
2019-20	-	01 Val	#5 farmer fields with side-by-side comparison between COMPASS vs farmer's irrigation dates

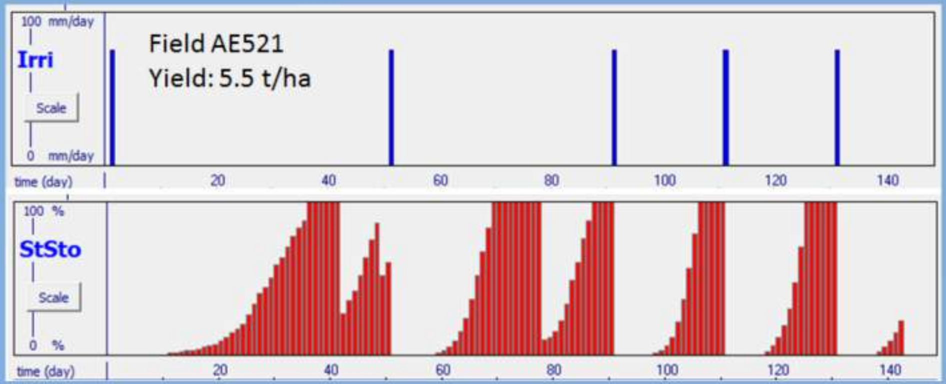


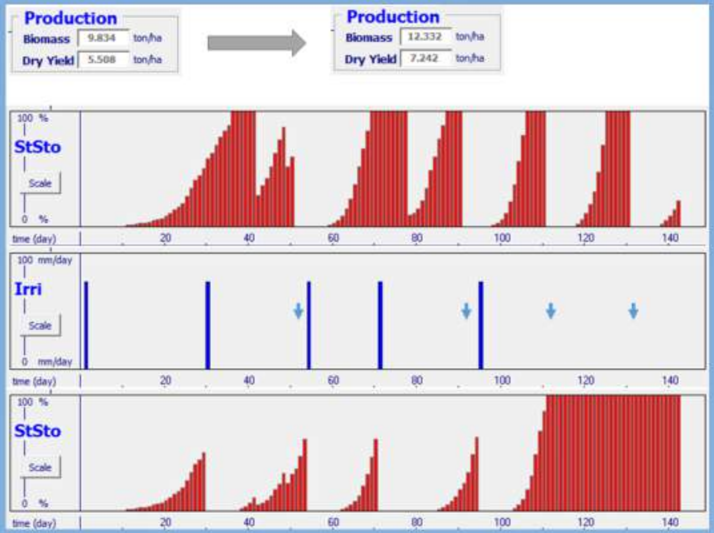
Data Assimilation Sentinel-2

- Developed out of FAO guidance for ag water management.
- Widely used – 1000s citations, many crops and environments
- 'Medium' complexity – relevant where water is limited.
- Well documented.
- Freely available in executable form



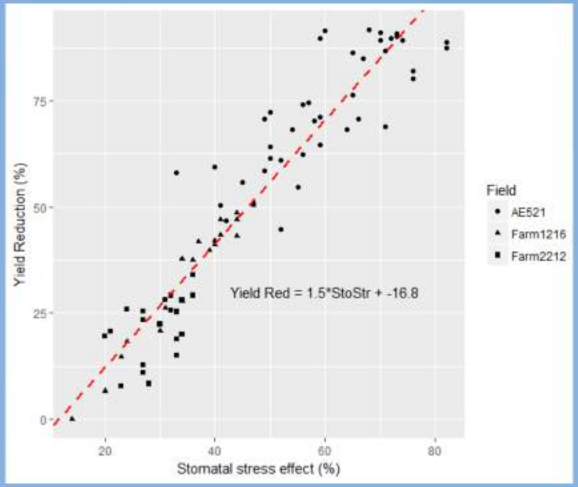
Results - towards irrigation scheduling





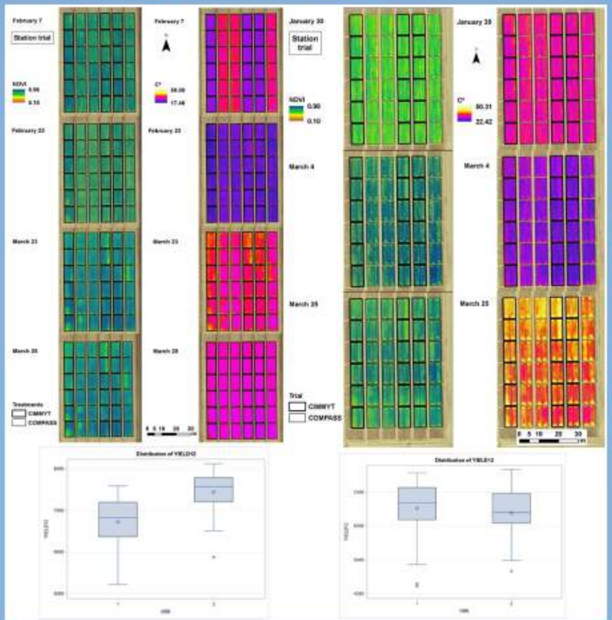
Stomata stress of 50% to trigger the irrigation

Same amount of water... just different timing



- Within station validation trial

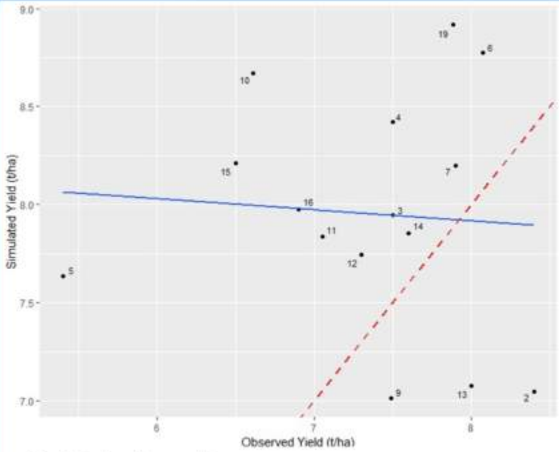
2018/19 2019/20



App view

EO Data assimilation exercise

Model Simulations for 15 wheat farms using calibrated model

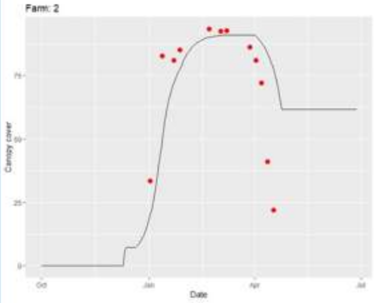


RMSE = 1.14 t/ha

NRMSE = 15.6 %

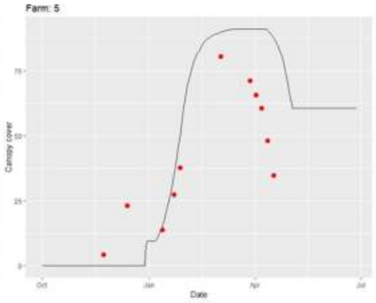
Simulated vs observed Canopy cover

Farm 2, highest yield (8.4 t/ha)

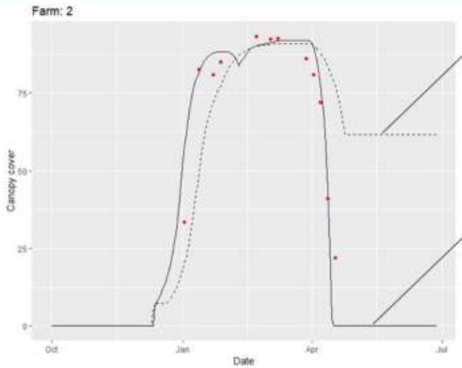


In both cases, the model over predicted the starting of crop senescence

Farm 5, lowest yield (5.4 t/ha)



Farm 5 has salinity issue whose effect on yield is not integrated into the model



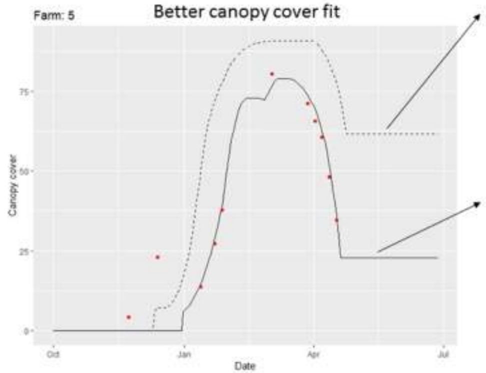
CC using base model

Assimilated CC

Simulated yield: 7.0 t/ha → Data Assimilation → Observed Yield: 8.4 t/ha

Simulated yield: 8.0 t/ha

Better canopy cover fit

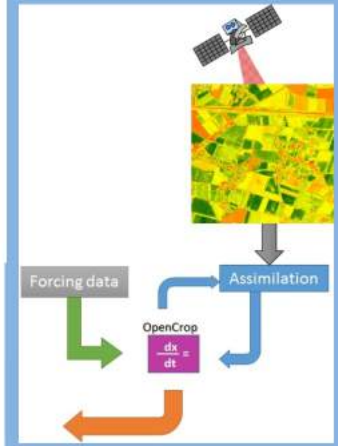


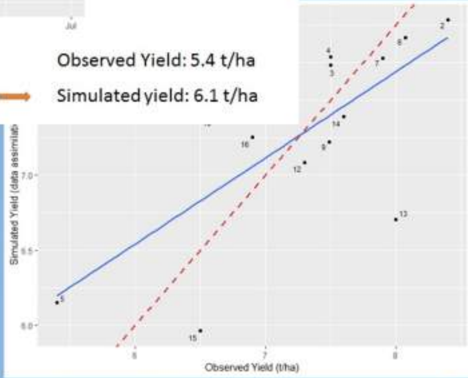
CC using base model

Assimilated CC

Simulated yield: 7.6 t/ha → Data Assimilation → Observed Yield: 5.4 t/ha

Simulated yield: 6.1 t/ha





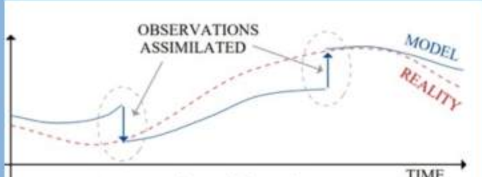
RMSE = 1.14 t/ha

NRMSE = 15.6 %

Data Assimilation

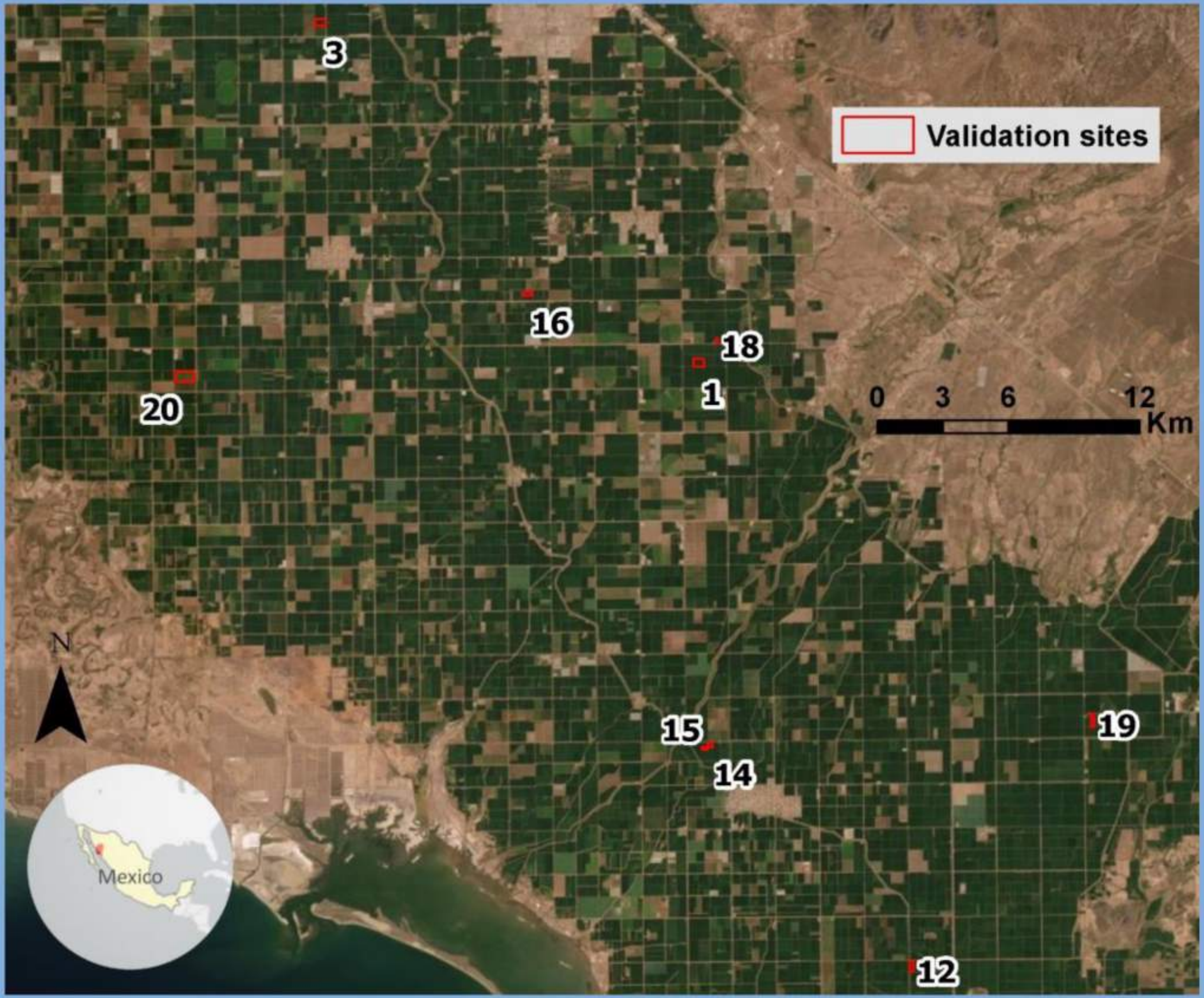
RMSE = 0.54 t/ha

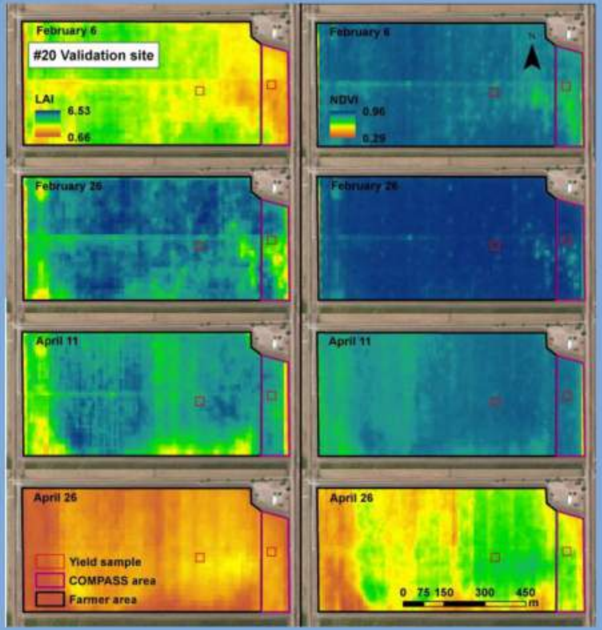
NRMSE = 7.3 %

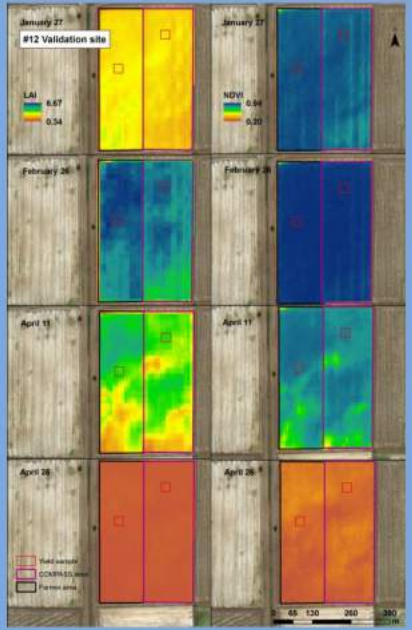


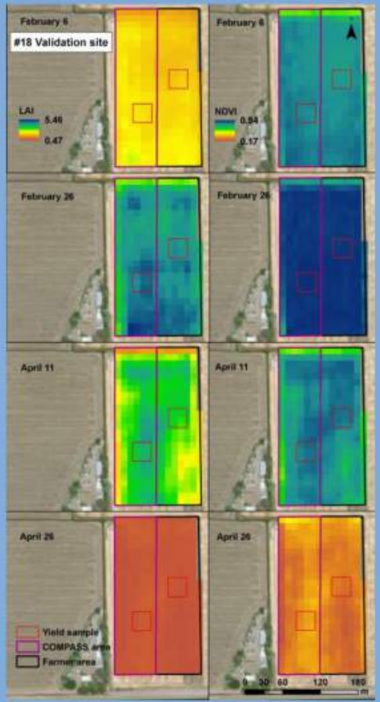
Improved model results

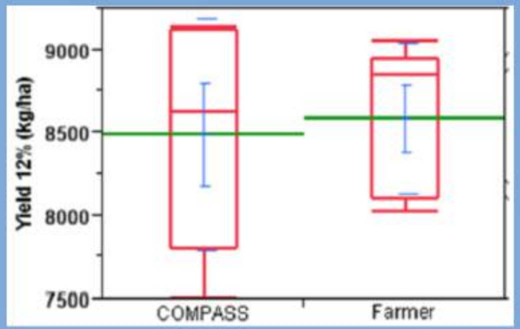
- Farmers validation - 2019/20 crop cycle

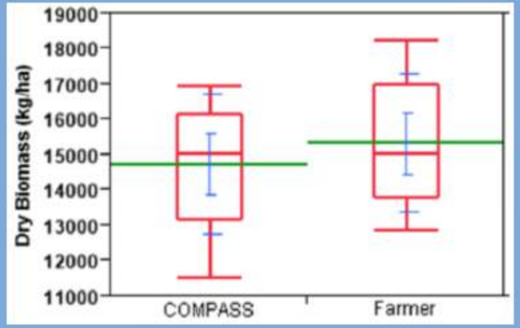












- Furrow irrigation*
- attention to the Dev component - avoid delays!

Modules and Interface (wheat)

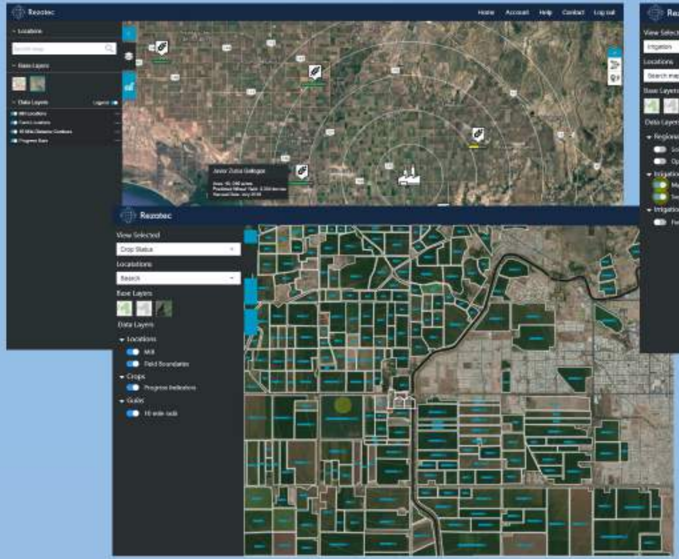
To farmers (freely available):

- Optimum sowing date
- Irrigation scheduling
- Crop monitoring (NDVI) - local/regional scales / and yield forecasting
- Field book for crop management practices

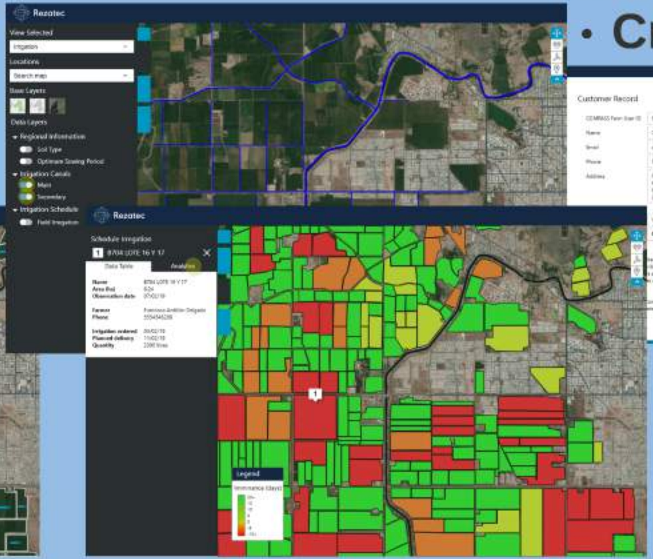
Co-designing with farmers

Dashboards - Commercial processors

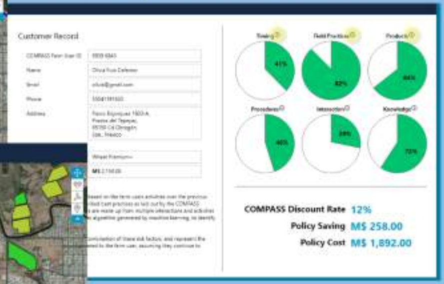
- Millers



- Irrigation management



- Crop Insurance



Win-win Business model!

UK SPACE AGENCY

Insights & key-messages

- RS - has become a game changer for agricultural research.

Easy measurements with reliable data (if well conducted!) - monitoring vegetative status at different spatial-temporal scales;

  - Plant breeding industry: Accelerate the breeding process - many more lines can be screened in a given time period.
    - **Constraints:** Initial investment needed for purchasing the system (cameras, platforms, software, hardware, laboring) -

However, hardware has become more affordable and freeware are getting more user-friendly. Satellite data may be an option (e.g. disease study from Ethiopia).

    - The need of dedicated staff for image acquisition and processing - potential delays in data processing;

  ***Next steps needed:**

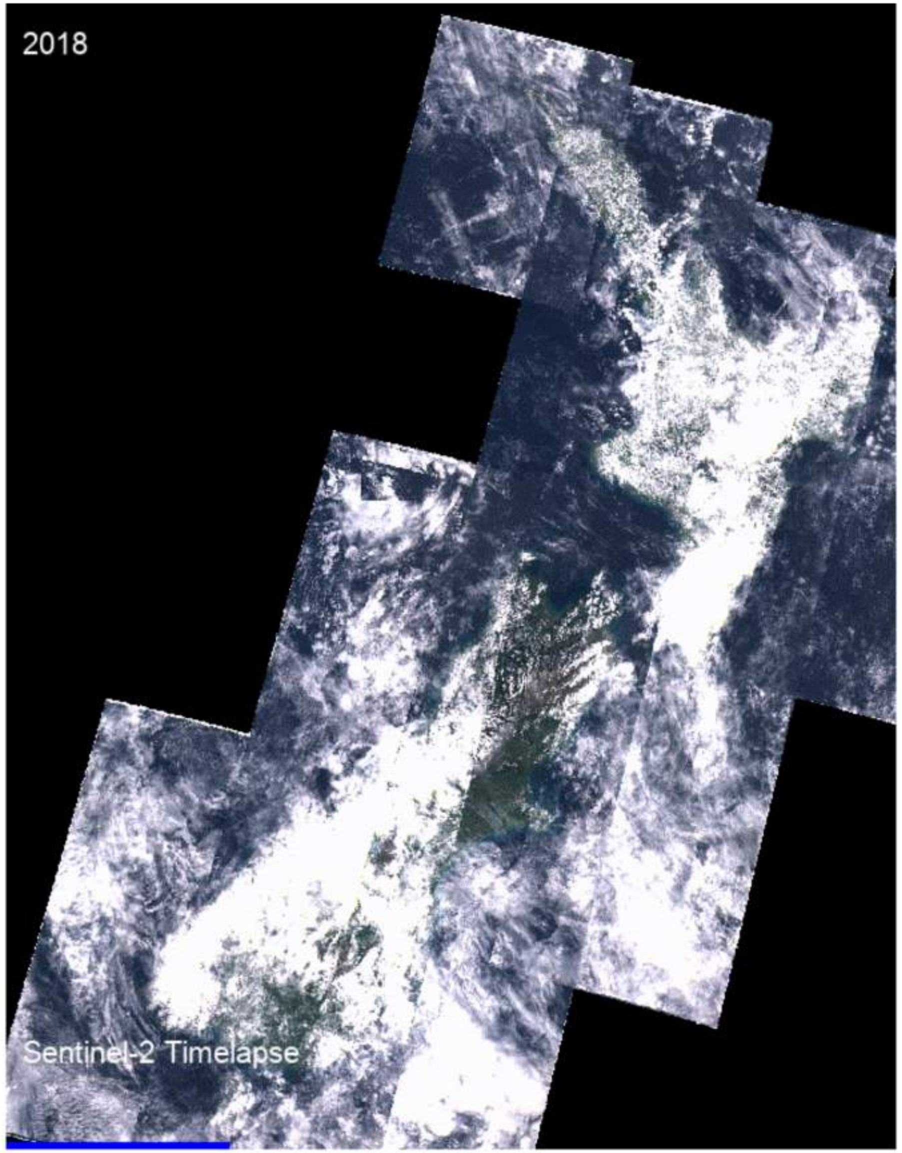
    - data workflow pipelines to automate data ingestion and delivery to facilitate decision making.
    - Physically-based approaches for biophysical & biochemical plant attributes retrieval - replacing proxies to actual estimated plant attributes!
    - Adoption!

- Satellite data are also getting cheaper (or free) and better (e.g. Sentinel family) and can be used within decision support tools (e.g. COMPASS App).
  - **Constraints and next steps:** 

- Crop modelling - farming systems modelling and its performance with EO data assimilation
- Scaling component - strategies for scaling and adoption
- Multidisciplinary - partnerships!
- Data management - attention must be paid!

- Cloud cover

The long white cloud country !



Physically based data fusion - Optical + SAR

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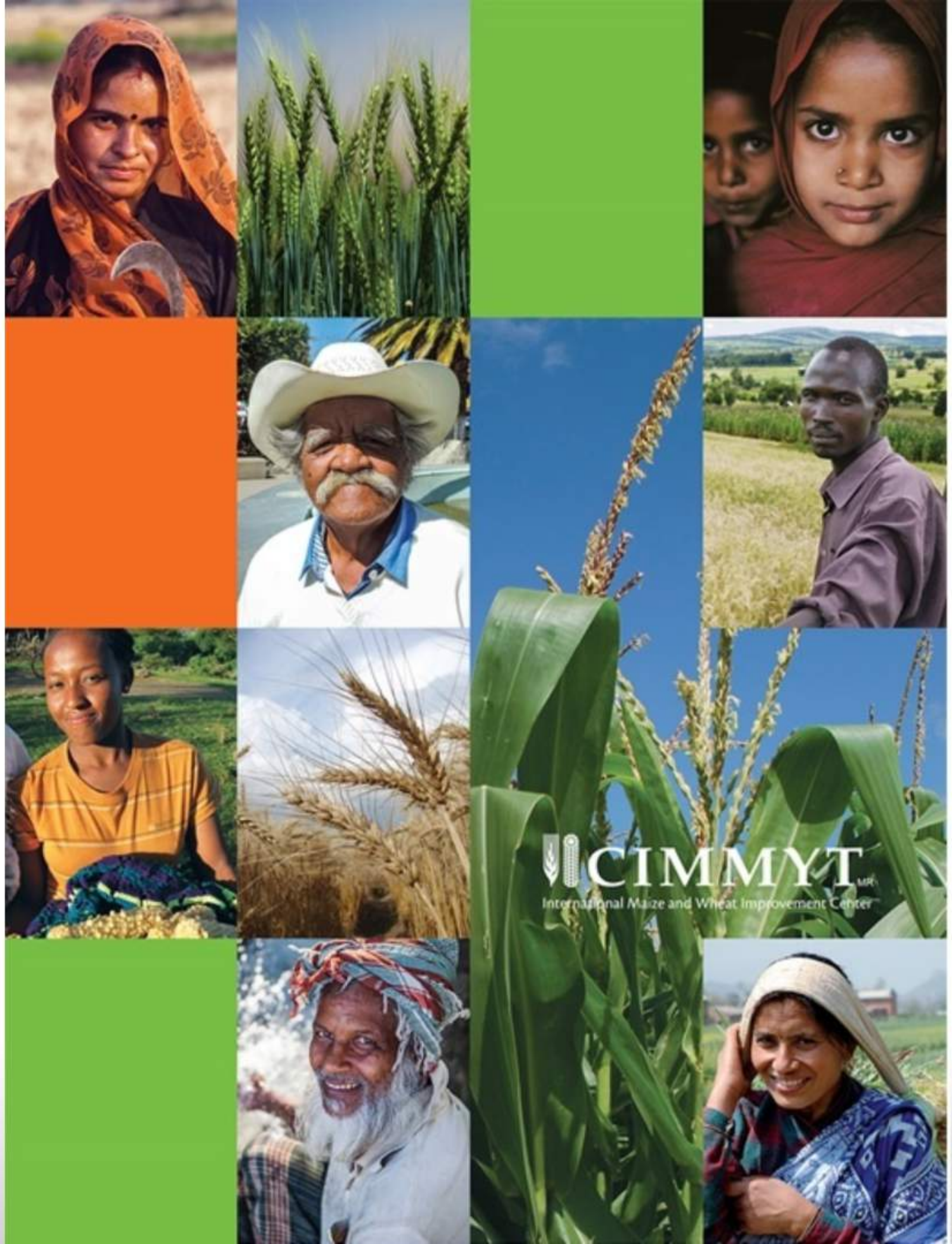

LINCOLN AGRITECH LTD

Thank you very much !
Muito obrigado !

Francelino Rodrigues
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farjunior@hotmail.com

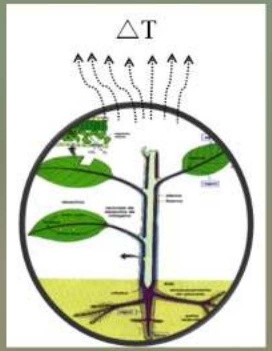
CGIAR RESEARCH PROGRAM ON Wheat

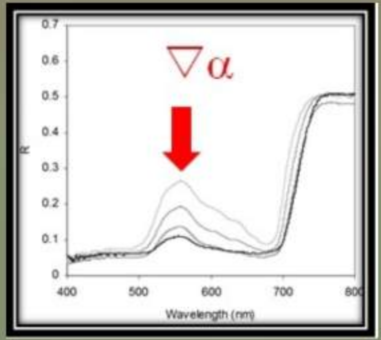
CGIAR RESEARCH PROGRAM Maize

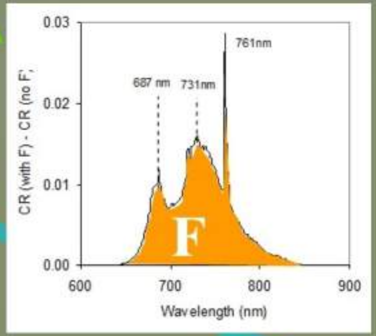
Vegetation stress indicators from RS

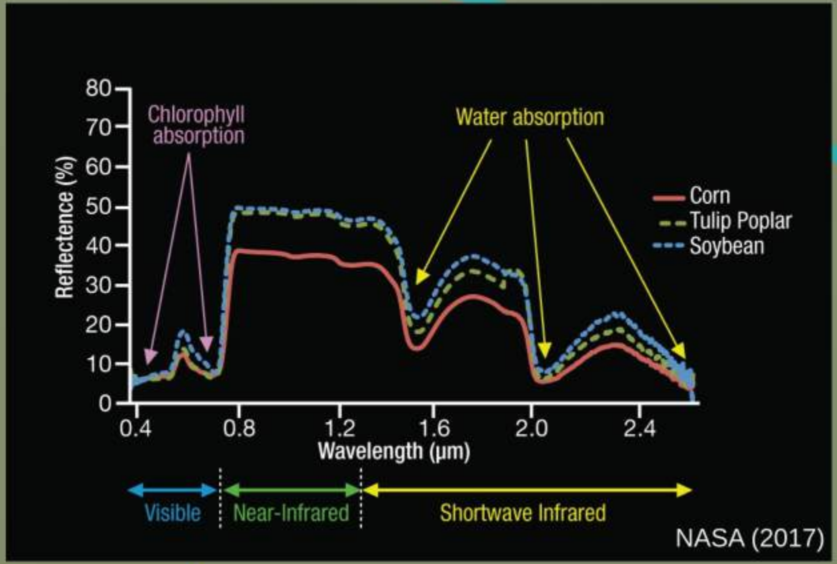
- Transpiration and CO_2 absorption reduction
- Photosynthesis reduction

- Temperature
- Photosynthetic pigments
- Chlorophyll Fluorescence
- Structure









Zarco-Tejada (2017)

How to establish vegetation stress indicators using RS as proxy?

- 1st: Empirical relationships - canopy reflectance | VIs vs Ground measurements
  * Simple and fast - depends on season, location, plant species and even varieties/genotypes!
  * Application of AI in a 'good library' is a way to go.

- 2nd: Physics between electromagnetic radiation and vegetation surface - radiative transfer theory
  - RTMs (e.g. PROSPECT + 4SAIL = PROSAIL) use biophysical variables as input to simulate reflectance
    - so its inversion produces biophysical variables! - e.g. LAI, Chl, Carotenoids
  * Complex, however it's transferable! E.g. BV-NET algorithm developed by INRA (Weiss et al) and embedded at SNAP-ESA and Sen2Agri-UCL tools.

PROSPECT

1. Leaf structure parameter N (unitless)
2. Leaf chlorophyll a + b concentration Cab (μg/cm2)
3. Equivalent water thickness Cw (g/cm2)
4. Dry matter content Cm (g/cm2)
5. Carotenoids (μg/cm2)
6. Brown Pigments (unitless)
7. Anthocyanin (μg/cm2)

4 5 D

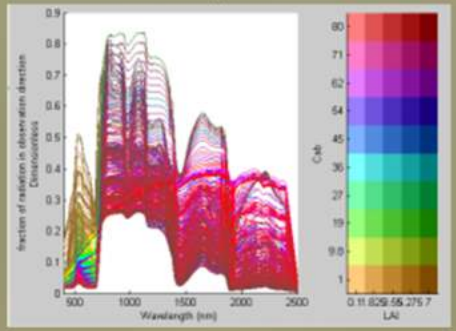
\+

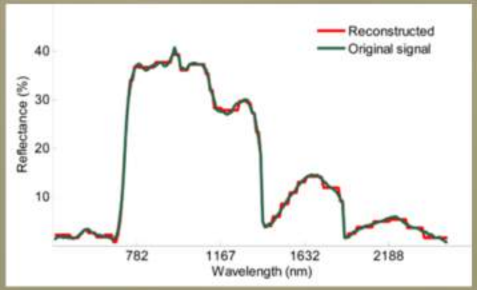
SAIL

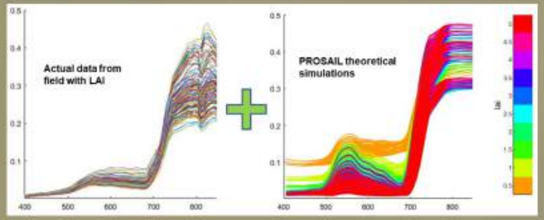
1. LAI (m2 m−2)
2. Average leaf angle ALA (deg)
3. Fraction of diffuse incoming solar radiation skyl (unitless),
4. Soil coefficient
5. Hot-spot size parameter (m/m−1).
6. Sun zenith angle (deg).
7. Sensor viewing angle (deg).
8. Relative azimuth angle phi (deg) between the sensor and sun.

=

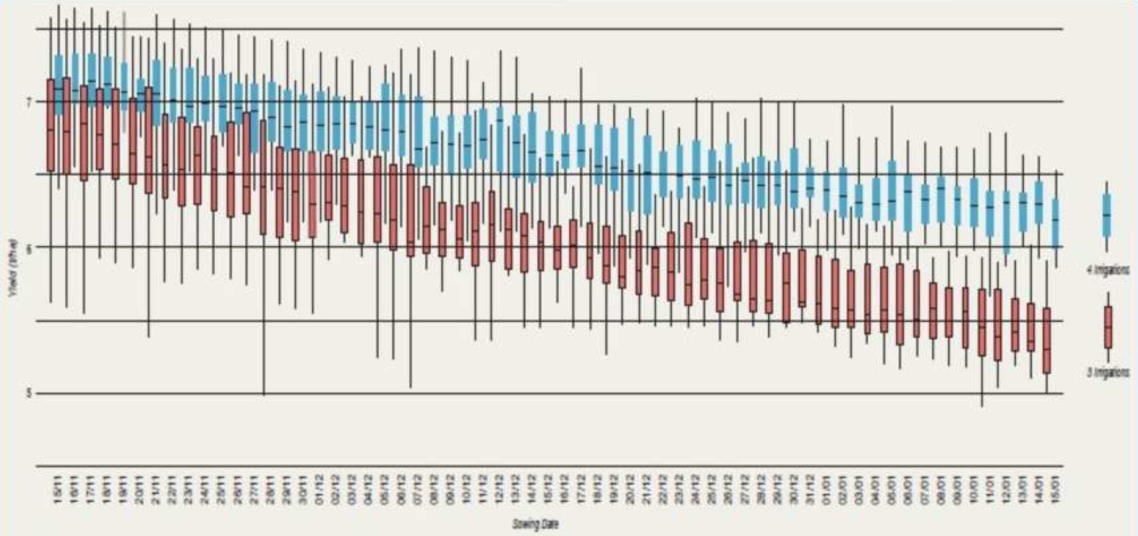
Look-up-table



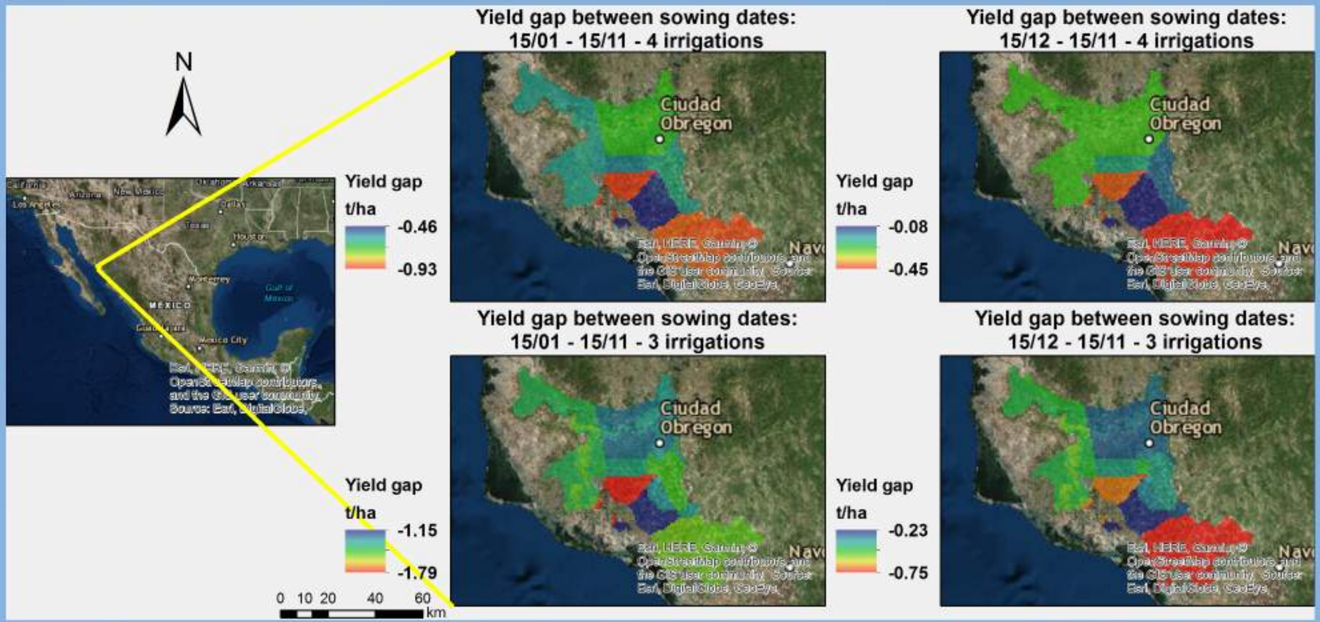




Results - towards optimum sowing date



- Power Project (https://power.larc.nasa.gov/) weather data over 20 years.
- Overview of the effect of the sowing date on grain yield.
- Provides farmers the opportunity to adjust their sowing dates to minimize yield loss.



App view

Rodrigues et al., 2019