Improvement of crop water use and crop productivity using PRISMA hyperspectral data

EOAfrica's Explorers initiative

Frascati, Italy
20-October-2022

H. Nieto, M.P. Martín, **V. Burchard-Levine*,** R. Gusinski, M. Munk, D. Ghent, M. Perry, N. Majozi, A. Ramoelo, A. Sawadogo, K. Dikgola

Project Objectives

EO-MAJI:

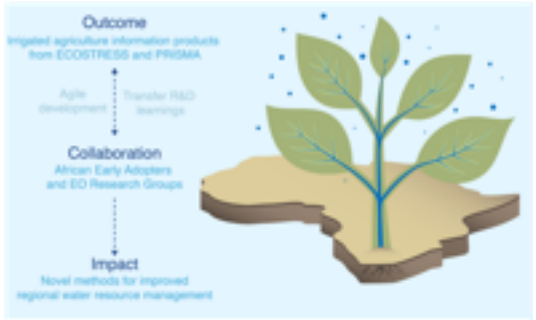
- **Earth Observation** system to **Manage Africa's** food systems by **Joint**-knowledge of crop production and **Irrigation** digitization

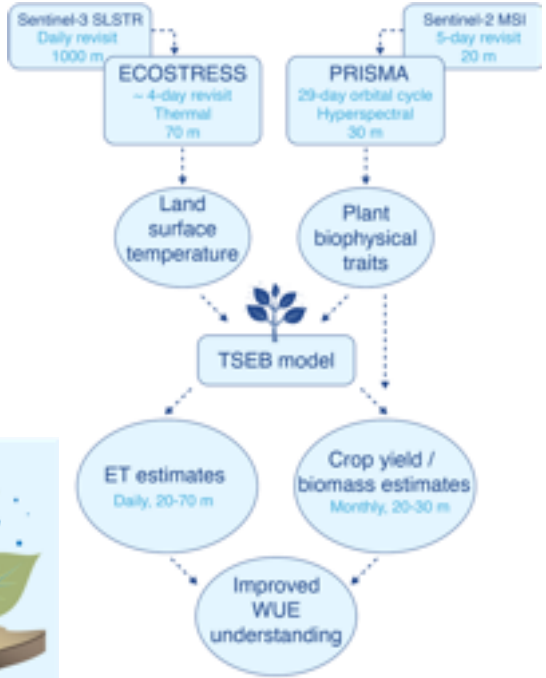
Main objectives:

- Develop inovative prototype to fully exploit **ECOSTRESS** and **PRISMA** (+Sentinel Constellation) to **monitor irrigation schemes**
- **Transfer** and **co-design** novel algorithms and processing chains with **African stakeholders**

Main Products:

- ET mapping
- Irrigation accounting
- Crop yield





Past Projects

ESA's Sentinels for Evapotranspiration (Sen-ET)

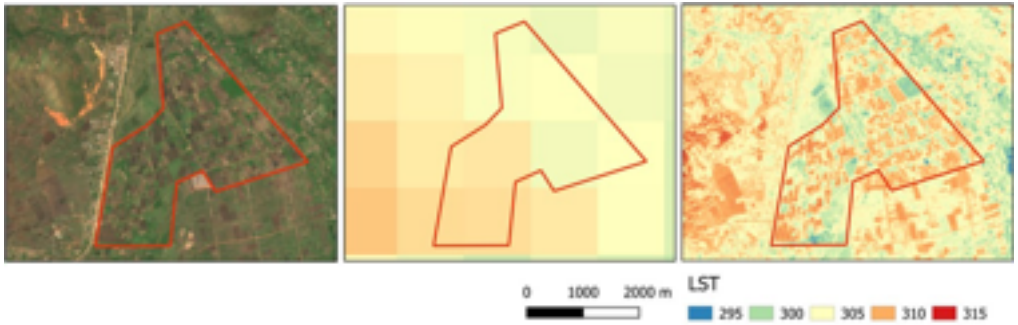
- **Operational ET** at high spatial resolution
- **Data fusion:** VSWIR: Sentinel-2 and TIR: Sentinel-3
- **ET model** review
- **Open-Source** software

sen-et
sentinels for evapotranspiration

Sentinel-2 Reflectance (20m)

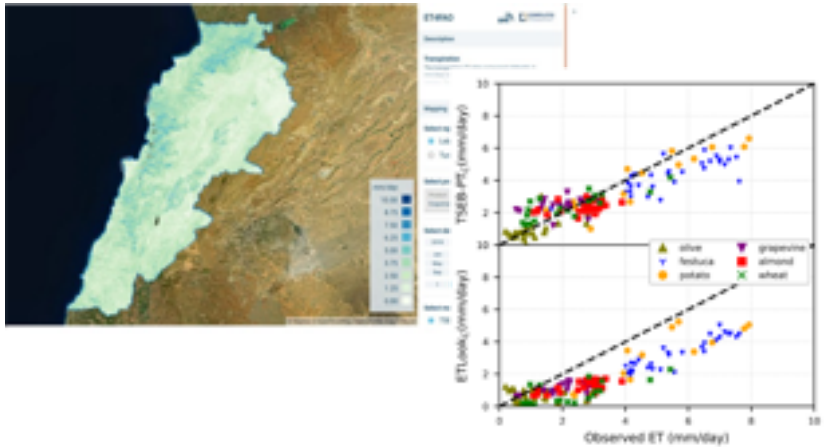
Sentinel-3 LST (1km)

Fused LST (20m)



ET4FAO

- Demonstrated use of **Copernicus data** for ET within **FAO's WaPOR** platform
- Dekadal ET at 30m, 100m and 250m at **national scale**



Prototyping for Copernicus Expansion

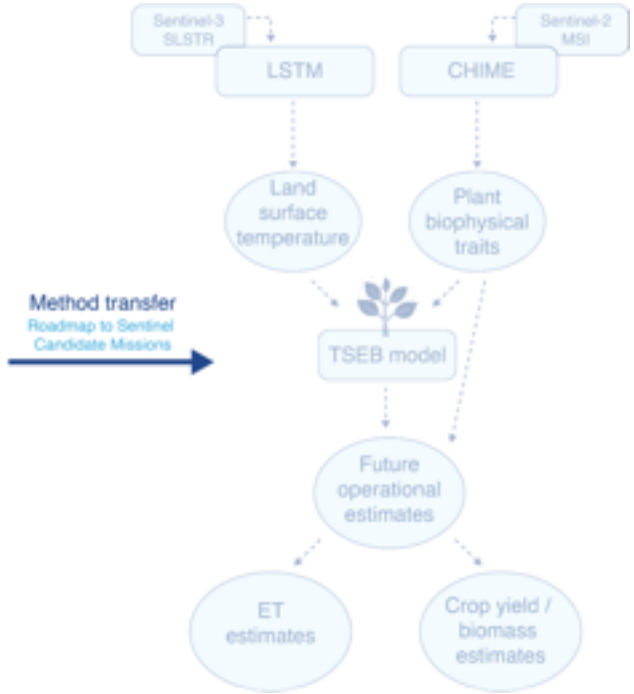
Current gap of high temporal and spatial resolution TIR

ECOSTRESS → LSTM:

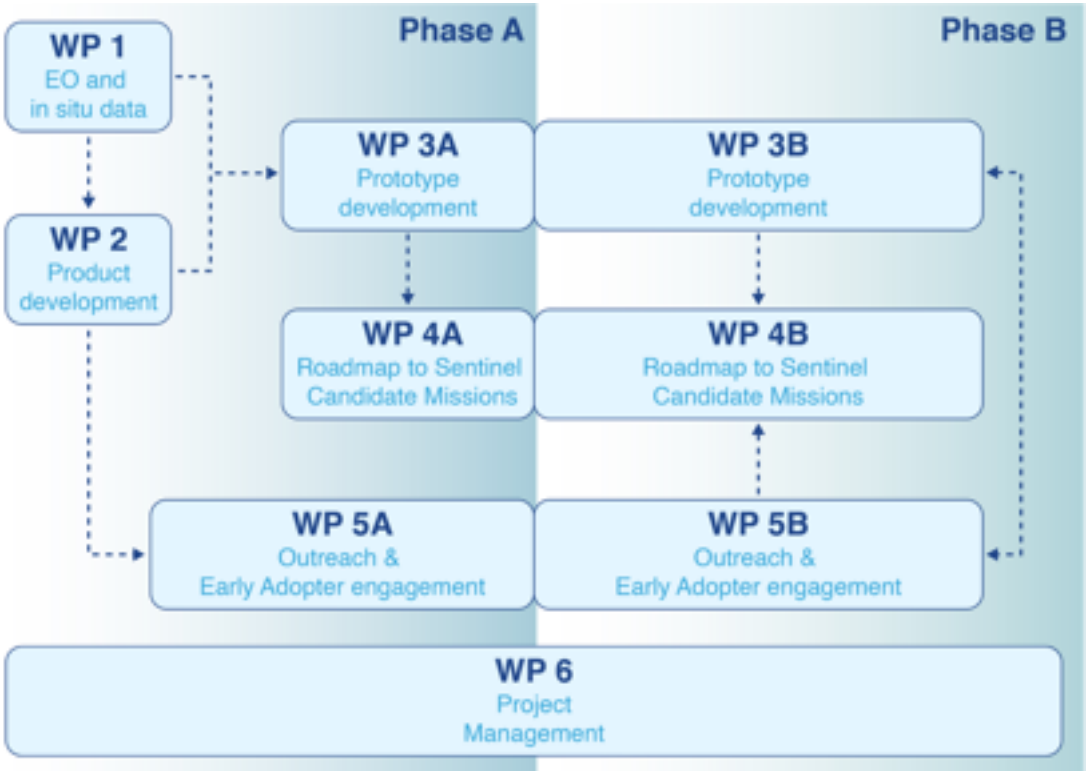
- Interpolation to daily ET at ~13:30 overpass
- Uncertainty propagation in TSEB (Jacobian)
- Crop-stress as covariate for crop-yield prediction

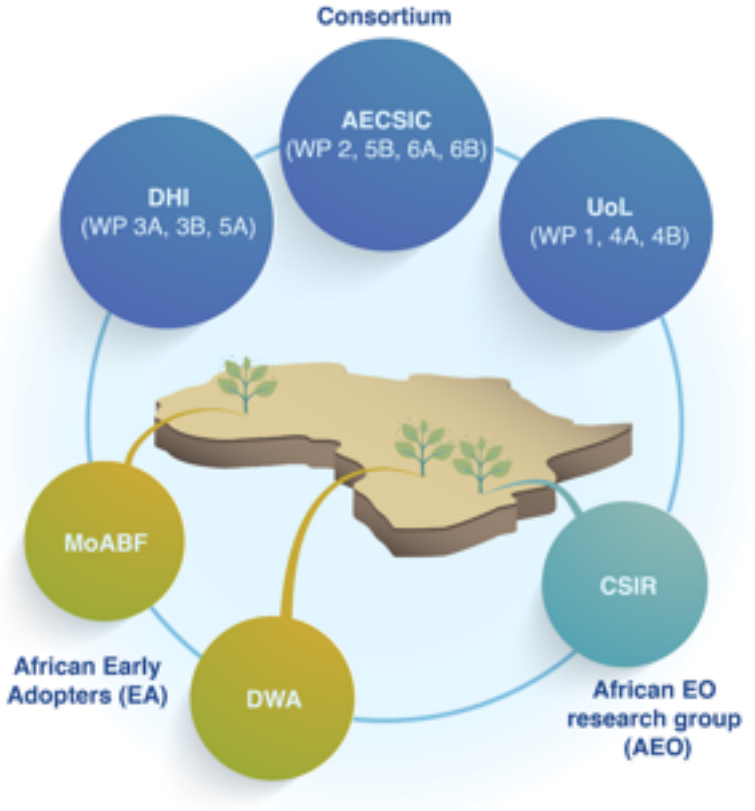
PRISMA → CHIME:

- Robust biophyical traits estimation
  - Non-photosynthetic vegetation
- Evaluation of retrieval models
  - Data-driven with in-situ measurements
  - Radiative transfer models (RTMs)



Project Structure

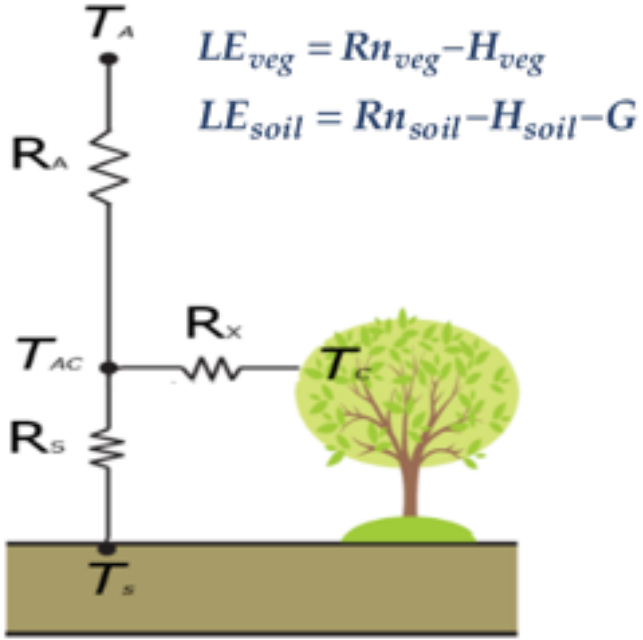




Two-Source Energy Balance Model (TSEB)

Partitions **transpiration** and **evaporation**
Requires detailed and accurate **biophysical traits:**

- **Plant Area Index** → radiation interception
- **Green LAI** → maximum transpiration/photosynthetic capacity
- **Leaf pigments/albedo** → radiation absorption
- Also canopy architecture



https://github.com/hectornieto/pytseb

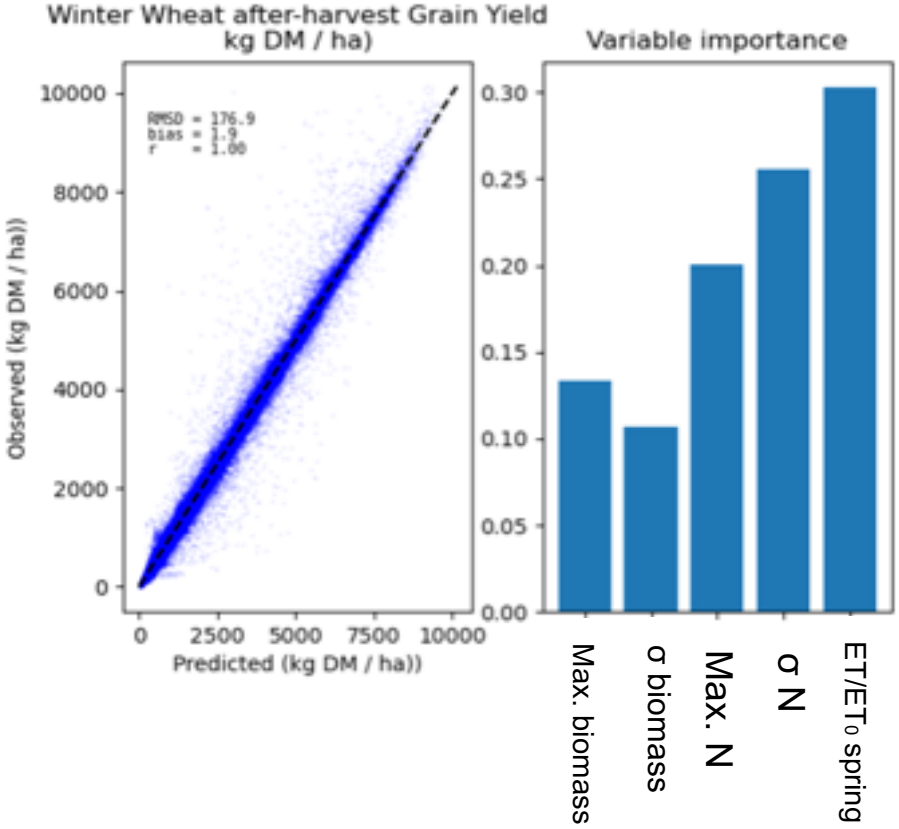
Crop Yield modeling from EO

Crop model simulations (Daisy) for exploring **EO explanatory variables**:

- LAI / leaf biomass (LAIxCm)
- Chorophyll / N concentration
- Crop stress (ET/ET_0)

D3: **State-of-art-review** of EO-based Crop Yield modeling

D6.1 Compare in-silico simulations using **crop models** vs **data-driven** from EO time series



Conclusions

- Spectroscopy from PRISMA (CHIME) would allow robust and accurate biophysical inputs for:
  - ET models
  - Crop Yield Assessment
- To be validated with:
  - in-situ measurements [e.g. Majadas/Barrax (ES), Kruger (ZA)]
  - Official yield statistics [e.g., Spanish Ministry, Burkina Faso Ministry of Agriculture]

Thanks!

European Space Agency

EO AFRICA

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2nd Workshop on International Cooperation in Spaceborne Imaging Spectroscopy
19-21 October 2022 | La Collinetta Eventi, Frascati IT

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Monitoring Key Ecosystem Properties with Hyperspectral Remote Sensing in a Complex Tree-Grass Ecosystem

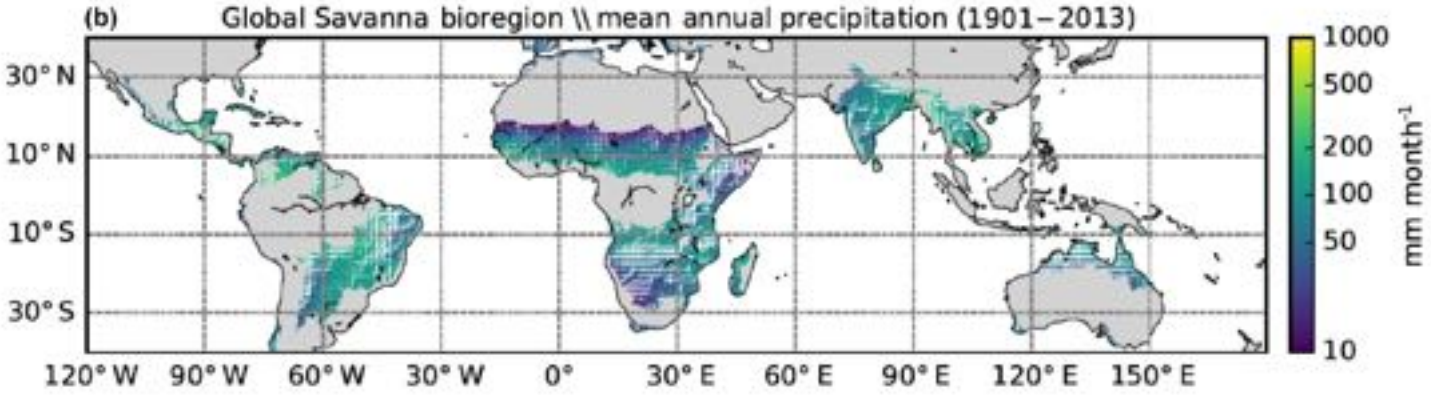
Vicente Burchard-Levine*, M. Pilar Martín, Héctor Nieto, Javier Pacheco-Labrador, Rosario González-Cascon, Gerardo Moreno, Victor Rolo, Mirco Migliavacca, Tarek El-Madany, Sung-Ching Lee and Arnaud Carrara

Frascati, Italy
20-Oct-2022

Tree-Grass Ecosystems (TGEs)

- **~16-35%** of global land-surface
- High **socio-economic** and **ecological** value
  - **Agro-pastural systems**
  - Dominant role in **global biogeochemical cycles**
- TGEs sensitive to **climate change**
- **EO** models **poorly constrained**
  - e.g. misclassified in global LULC maps, large bias in ET products
- **Heterogeneity** in space and time

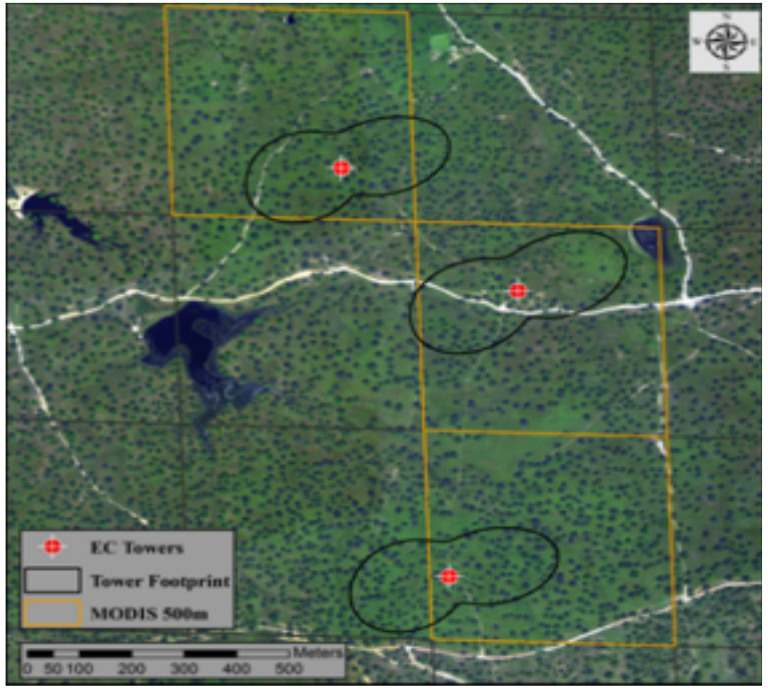
Pinty et al., 2001

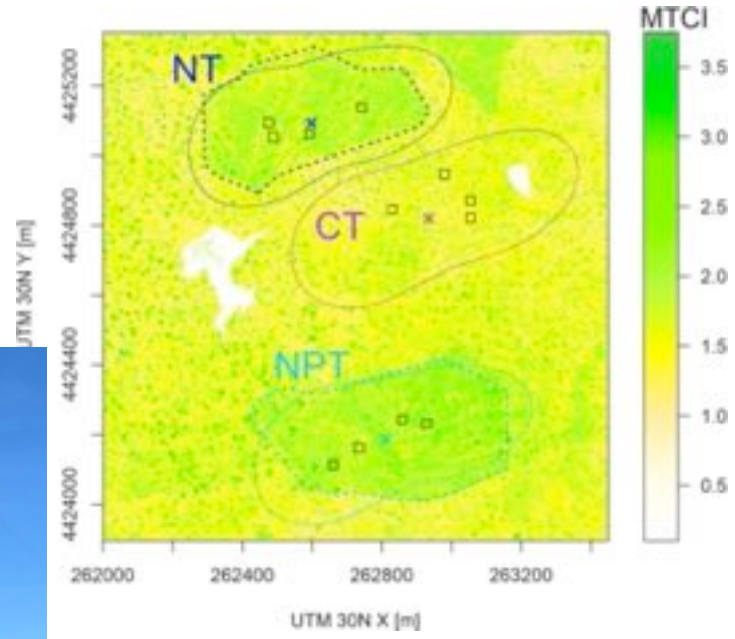


Source: Whitley et al. 2017

Majadas de Tiétar Research Station

- Located in **Extremadura, Spain**
- **EC flux tower** set-up in **2003** (CEAM)
  - In 2014, **+2 ecosytem towers + 3 sub-canopy** (MPI-BGC)
    - MANIP: Large-scale nutrient manipulation experiment

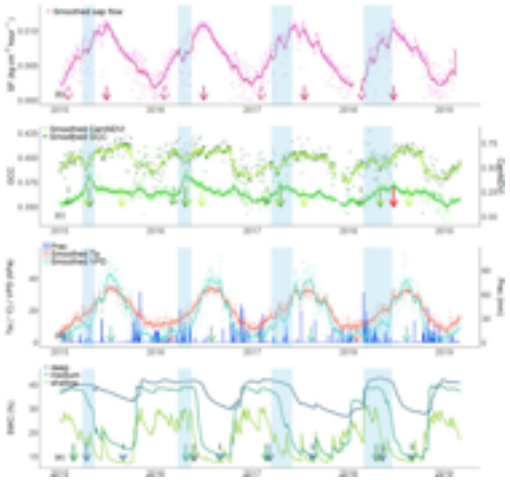




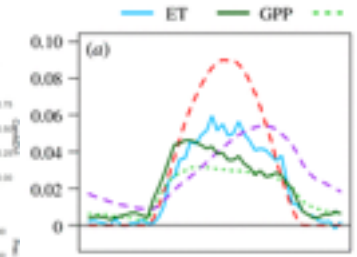
Data and Research Areas

- Unique dataset: **Multidisciplinary** and **complementary**
  - **Intensive** and **continuous** sampling

From Luo et al. (2022)



From El-Madany et al. (2020)



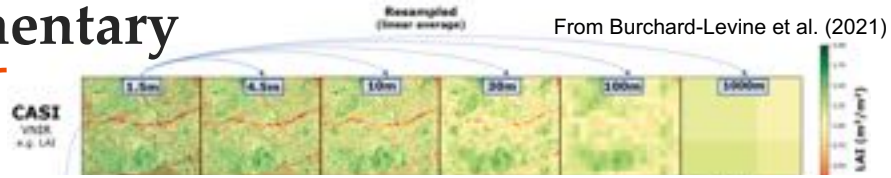
- Fluxes: EC systems
- Meteo+Radiometric
- Sap flow + lysimeters

Multi-scale Remote Sensing
Since 2009

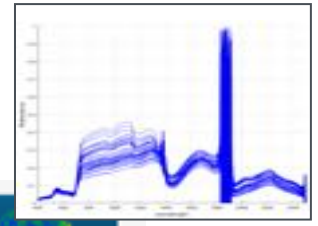
Fluxes and biometeorological
Since 2003

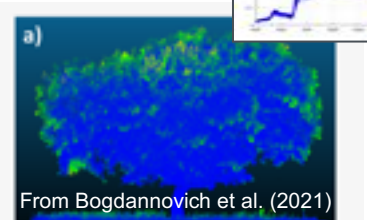
Biophysical and Ecological
Since 2009

From Burchard-Levine et al. (2021)



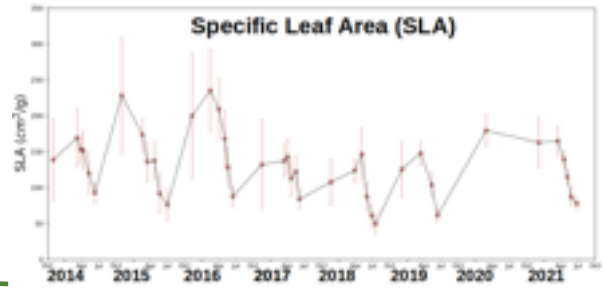
- Automated Proximal sensing
- Portable field spectroscopy
- Airborne/UAV campaigns
- Terrestrial LiDAR





From Bogdannovich et al. (2021)

- Plant Traits (LAI, Cab, etc)
- Plant Diversity
- Soil sampling

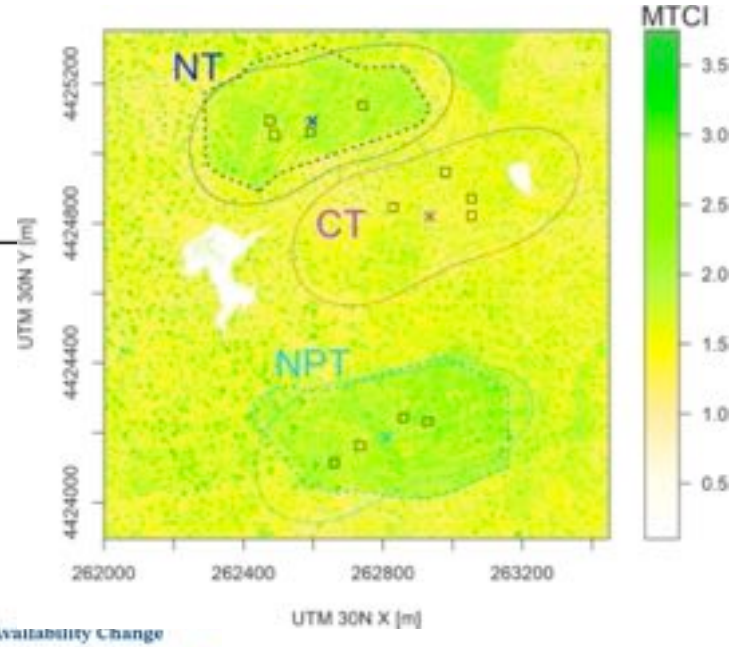


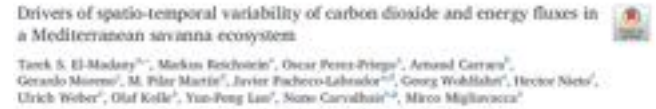
In-Situ Flux Observations

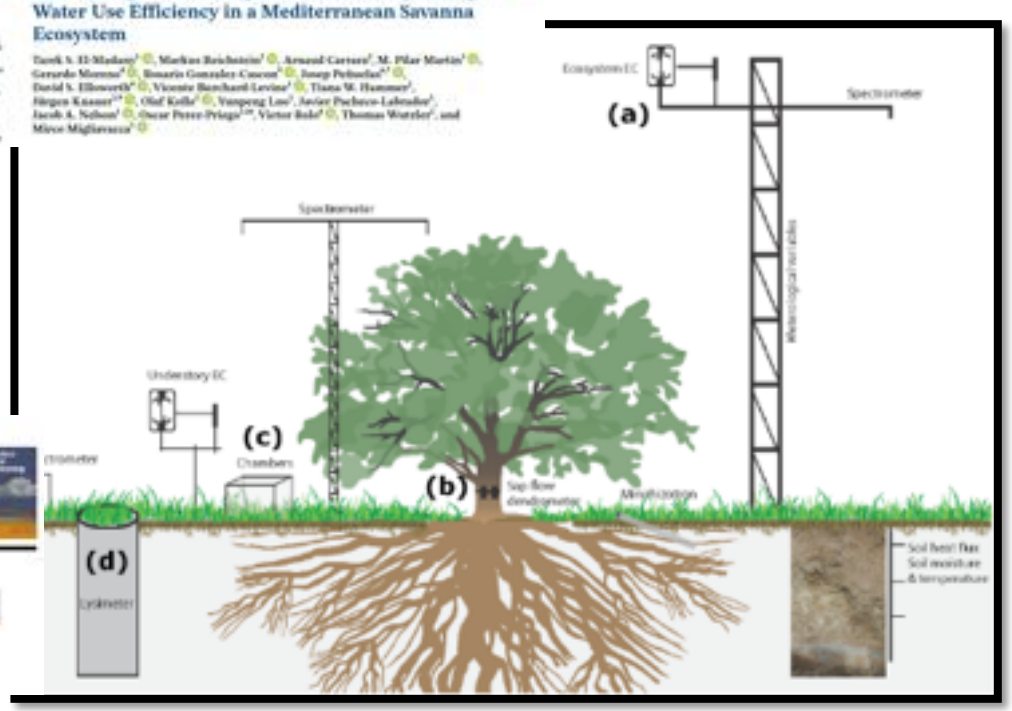
- **Three Eddy-Covariance (EC)**+ meteo systems
  - Both **overstory** (15m, ecosystem) and **understory** (1.6m, grass-soil)
    - LE, H, G, CO_2 , Vertical wind/temperature/humidity profile
  - **Radiation components** (SW/LW in/out)
    - Ecosystem, Tree canopy, grass-soil
  - **Soil**: moisture, temperature, hydraulic properties.

- **Tree transpiration**
  - Sap flow+dendometers - 6 trees per tower

- **Three Lysimeters**: Grass-soil ET







PI/Contact:
- Arnaud Carrara (CEAM)
- Sung-Ching Lee (MPI-BGC)
- Tarek El-Madany (MPI-BGC)

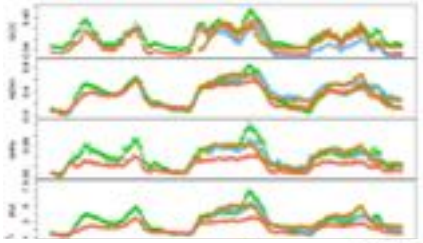
Automated Proximal Sensing

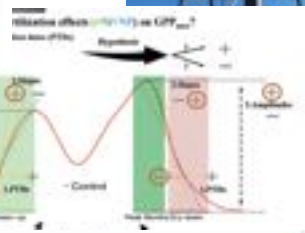
- **Phenocams** (each tower)
  - Blue, Green, Red, and NIR
- **NDVI/PRI** sensors (each tower)
- **Apogee TIR** sensors (each tower)
  - 0º, 35º, 55º view angle

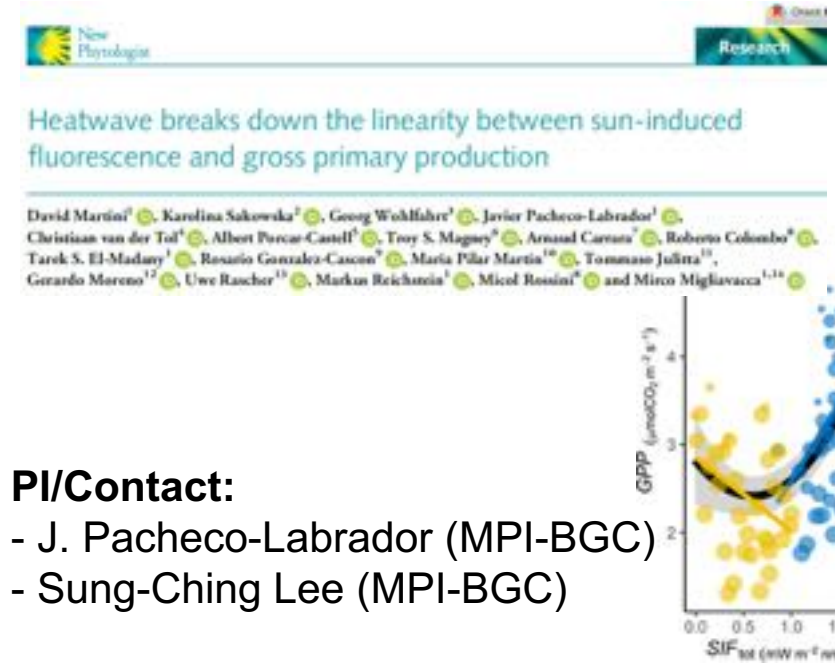
- **FLuorescene bOX (FLOX)**
  - High-res: SIF retrievals O_2 A and B bands
  - VNIR (400-950nm)
  - Sampling grass and tree crown alternatively (time step=5min)

AMSPEC-MED (2years, not operational now)

- Multi-angular hyperspectral sampling (Unispec DC)



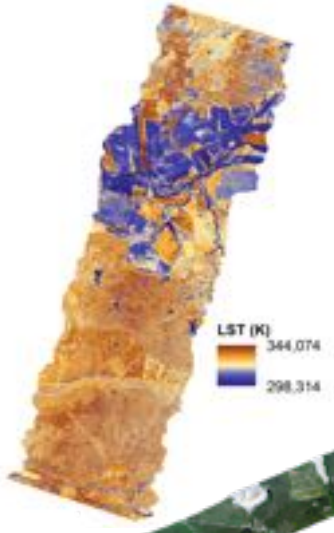


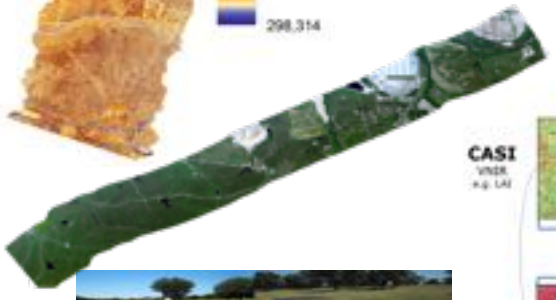


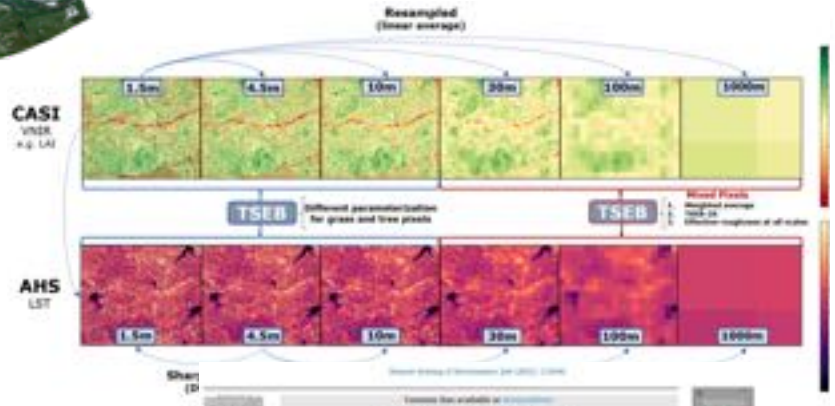
PI/Contact:
- J. Pacheco-Labrador (MPI-BGC)
- Sung-Ching Lee (MPI-BGC)

Airborne/UAV Acquisitions

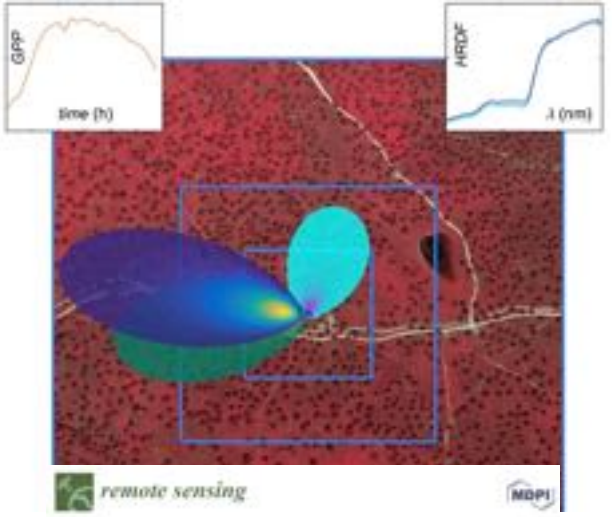
- **Airborne campaigns** (2010-2018)
  - **INTA**: 2010-2017 (8 campaigns)
    - **CASI** (VNIR, 1.5m) and **AHS** (SWIR-TIR, 4.5m)
  - **ESA-FLEXSENSE:** 2018 (2 campaigns)
    - June 2018: **HYPLANT** (VSWIR+SIF, 1.5 & 4.5m) **TASI** (TIR, 1.8 & 3.6 m)
    - July 2018 **APEX** (VSWIR, 2 & 3m)
- **UAV campaigns** (2020-2021)
  - **DAAD/MONSOON/U. Augsburg:**
    - May 2021: **Micasense Altum** (VNIR+TIR)
    - >30 overpasses between 5-20 May
  - **Diverspec/Speclab-CSIC/UEX**
    - May 2022: Sequoia (VNIR)



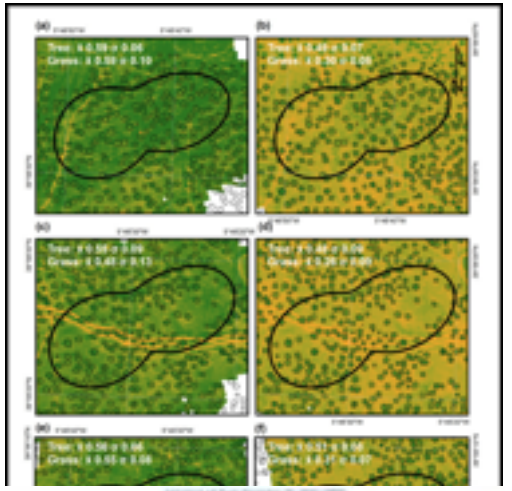




The effect of pixel heterogeneity for remote sensing based retrievals of evapotranspiration in a semi-arid tree-grass ecosystem



Spatio-Temporal Relationships between Optical Information and Carbon Fluxes in a Mediterranean Tree-Grass Ecosystem



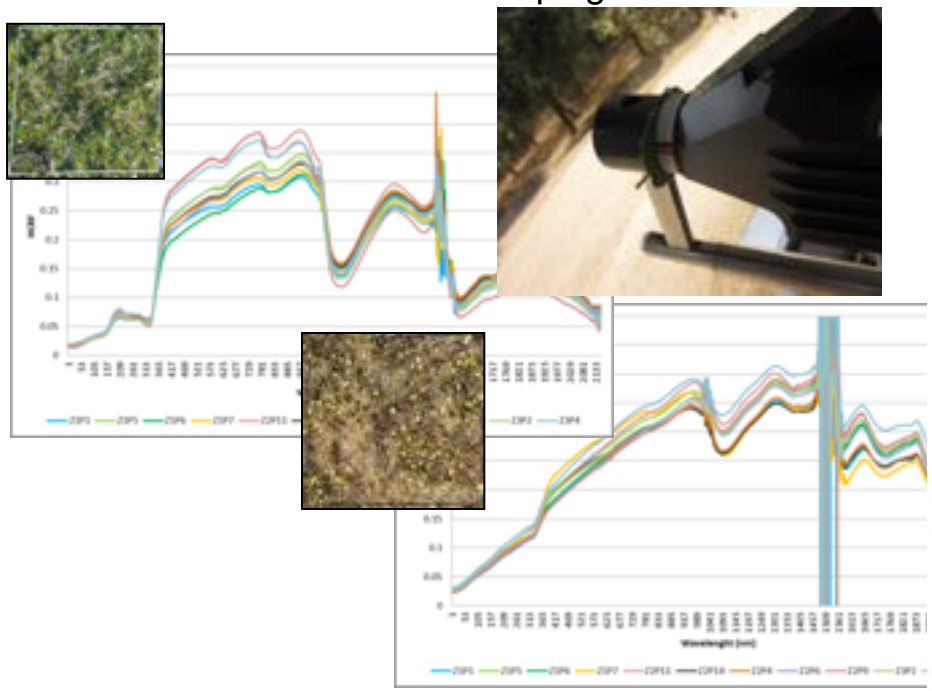
UAS-based high resolution mapping of evapotranspiration in a Mediterranean tree-grass ecosystem

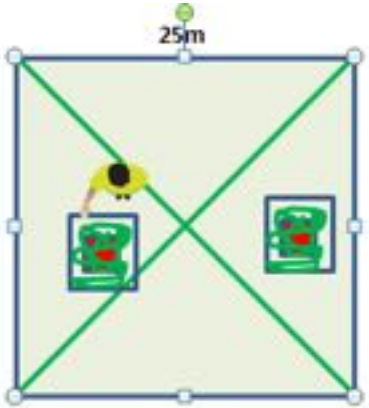
PI/Contact:
- M.Pilar Martín (Speclab-CSIC)
- Javier Pacheco (MPI-BGC)

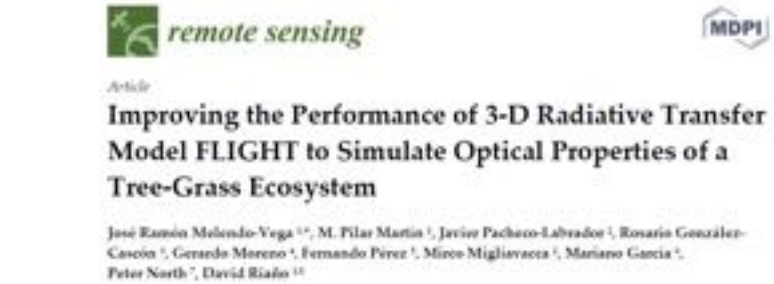
PI/Contact:
- M.Pilar Martín (Speclab-CSIC)

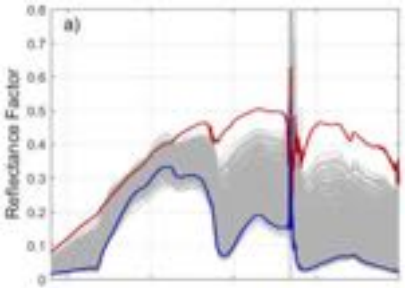
In-Situ Spectroscopy

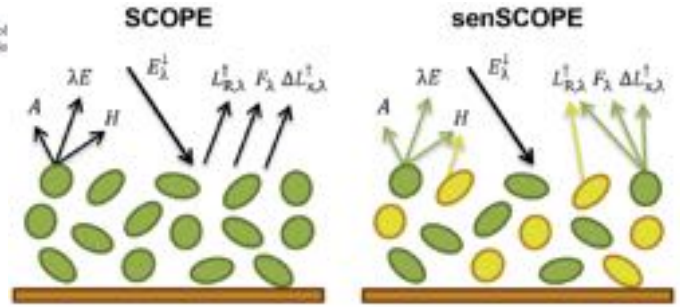
- **ASD Spectral measurements since 2009**
  - Simultaneous to biophysical sampling in 25mx25m plots
  - Ad hoc adquisition protocols
  - Grass canopy: 5-6 times/y
    - 10-40 samples/campaign
  - Tree leaf-level (plant-probe): 2-3 times/y
    - 5-15 trees/campaign







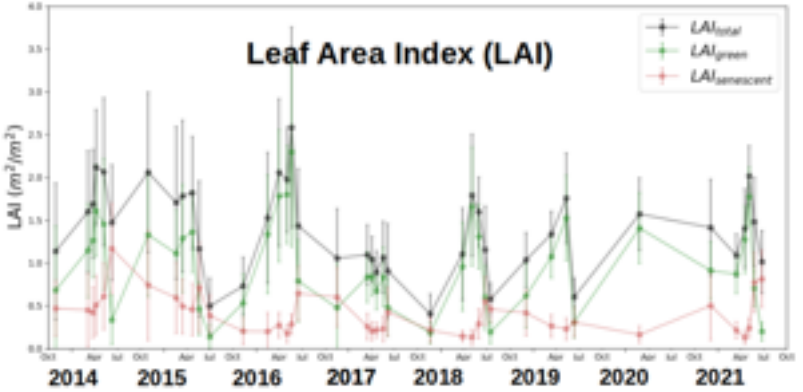




PI/Contact:
- M.Pilar Martín (Speclab-CSIC)

In-Situ Plant Traits

Long-term biophysical, chemical and spectral dataset of trees and grasses (2009-2022)

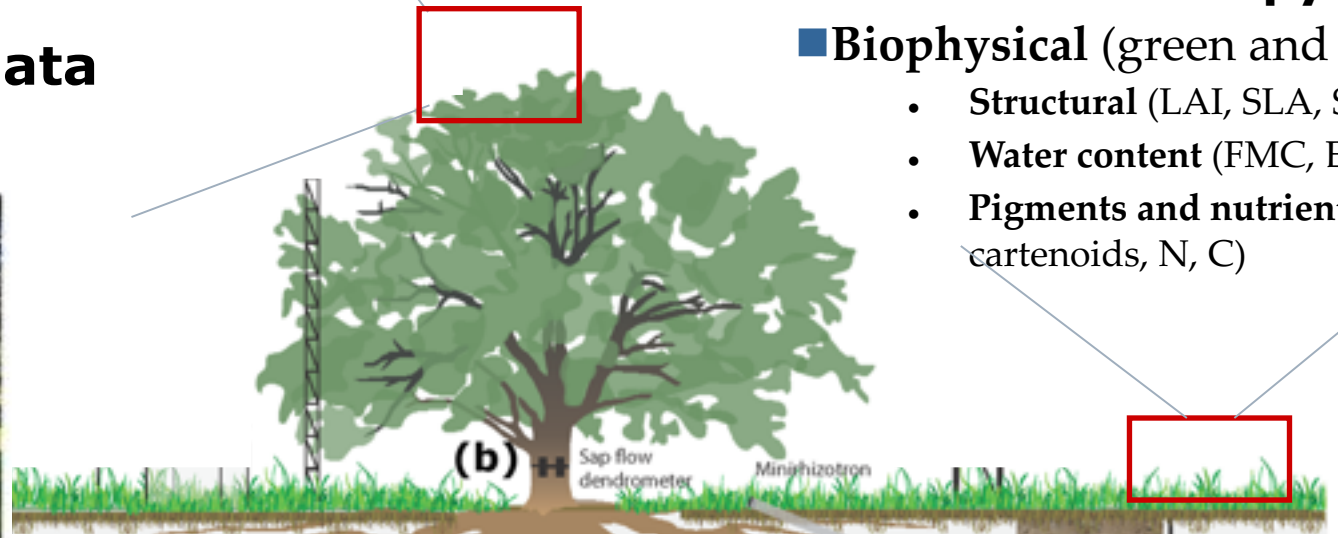


Tree leaf-level data

- **Biophysical**
  - **Structural** (LA, SLA)
  - **Water content** (FMC, EWT, LWC)
  - **Pigments and nutrients** (Chl a+b, cartenoids, N, C)

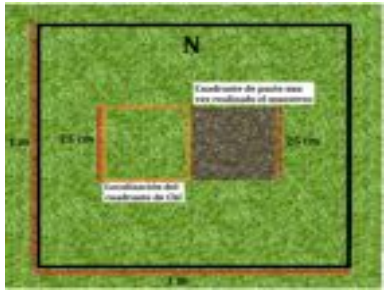
Tree canopy data

- LAI (using LAI-2200C)



Grass canopy data

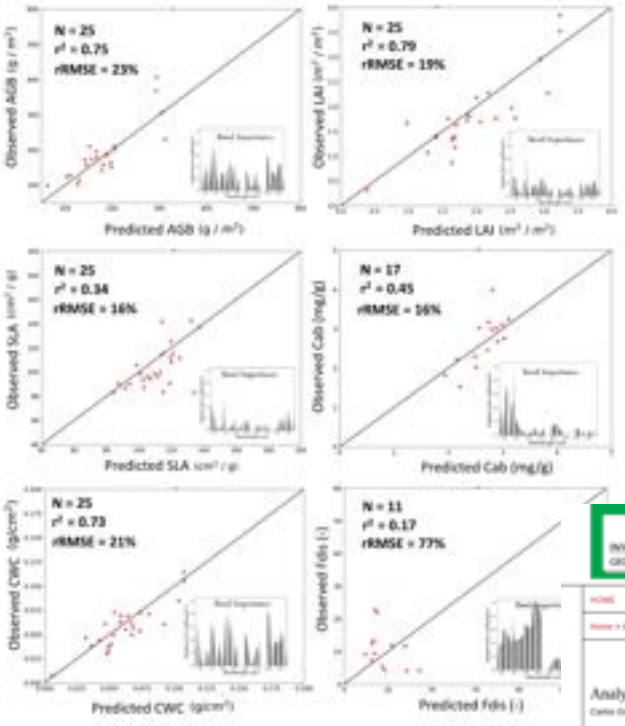
- **Biophysical** (green and non-green)
  - **Structural** (LAI, SLA, SLW, ABG)
  - **Water content** (FMC, EWT, LWC, CWC)
  - **Pigments and nutrients** (Chl a+b, cartenoids, N, C)



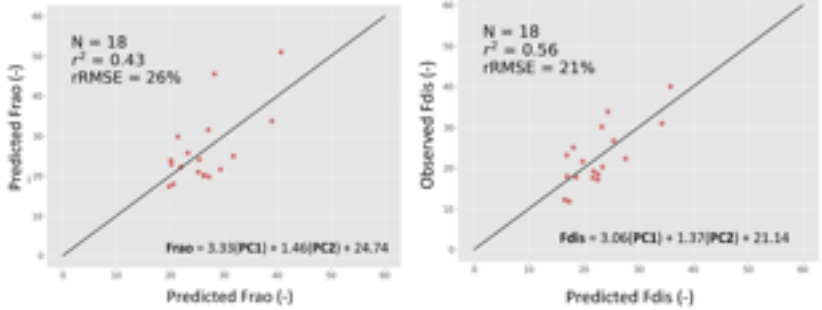
Plant Diversity and gas exchange

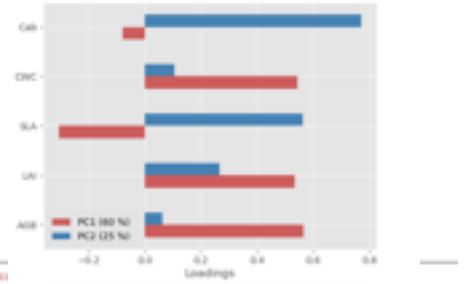
- Since 2019, joint **Speclab-UXE** campaigns to sample **functional diversity + gas exchange**
  - Relating grassland **spectral diversity/traits** with **functional diversity (Fdis, RaoQ)**
  - Portable hyperspectral camera (**Specim-IQ**) for within-plot spectral variability
  - Now processing data from 2022 campaign

Hyperspectral Models using PLSR and ASD bands

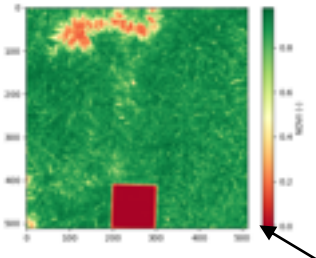


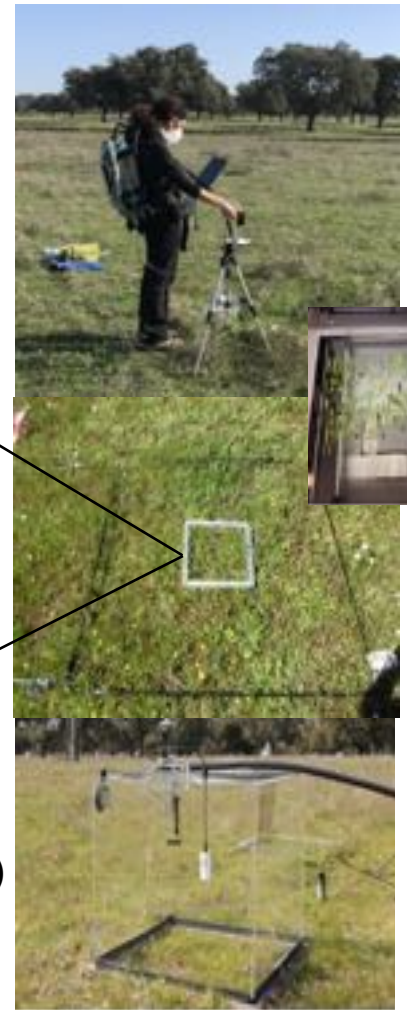
Relation between PTs and FD





Specim-IQ





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Key ongoing (hyperspectral) work

- Upscaling **functional diversity models** from proximal sensing to space-borne data
  - Acquisitions of **PRISMA** images (2020-2022) over Majadas
  - Daily acquisitions of Venμs sensor (4m, CNES) since March 2022 (PI: J. Pacheco-Labrador)

- Using hyperspectral data to quantify **non-photosynthetic vegetation**
  - Important in semi-arid grasslands
  - Affects **plant trait retrievals** (especially in mixed phenological periods). **Not well represented in RTMs**
  - Burchard-Levine et al. (2022) suggested important influence for heat and water fluxes

- Better characterize **'background' dry grass** in **3D RTM modeling** (using DART)

- Quantifying **spectral influence of tree cover** over mixed pixels and effect on **plant trait retrievals** from medium resolution sensors (Sentinel-2,3, PRISMA, DESIS, Venμs)

Conclusions

- Ideal CAL/VAL site as a **well-instrumented** and characterized **long-term monitored ecosystem**
  - Complex landscapes but globally very relevant
  - Scientific gap to better represent these heterogeneous systems
- **Long-term simultaneous datasets** over permanent plots (>13 years)
  - Multi-scale spectral data: leaf, canopy, UAV, Airborne, spaceborne
  - Both intensive periodic campaigns and continuous sampling
  - Coupled spectral and plant trait sampling strategy
- **Multidisciplinary research teams**
  - Important complimentary data and expertise (Micrometeoreology, eco-hydrology, ecology, etc)
- Datasets available for **scientific collaborations**

Thanks!

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20-Oct-2022

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