

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

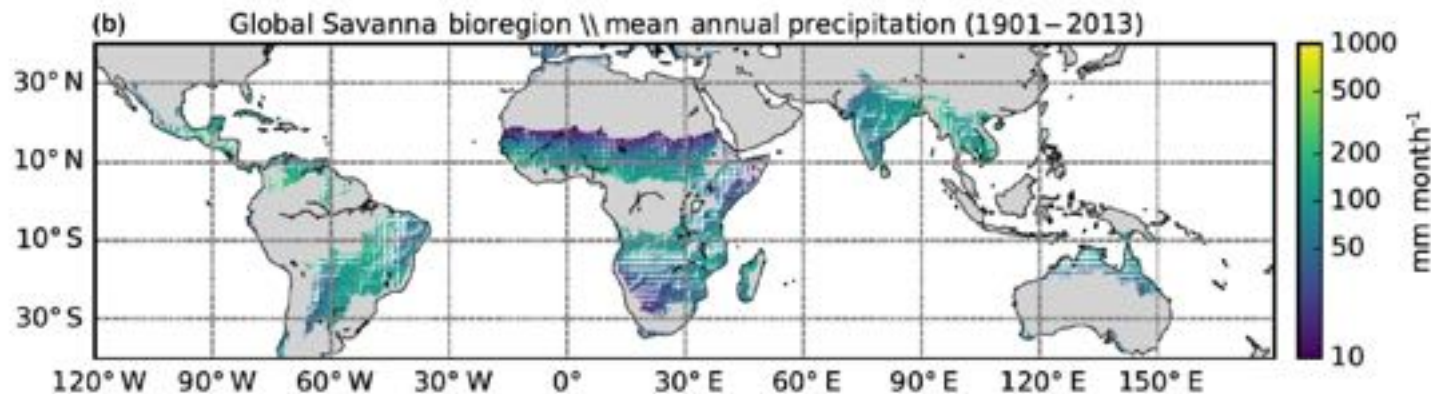
Vicente Burchard-Levine*, M. Pilar Martín, Héctor Nieto, Javier Pacheco-Labrador, Rosario González-Cascon, Gerardo Moreno, Victor Rolo, Mirco Migliavacca, Tarek El-Madany, Sung-Ching Lee and Arnaud Carrara

Tree-Grass Ecosystems (TGEs)

- ~16-35% of global land-surface
- High socio-economic and ecological value
 - Agro-pastoral 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

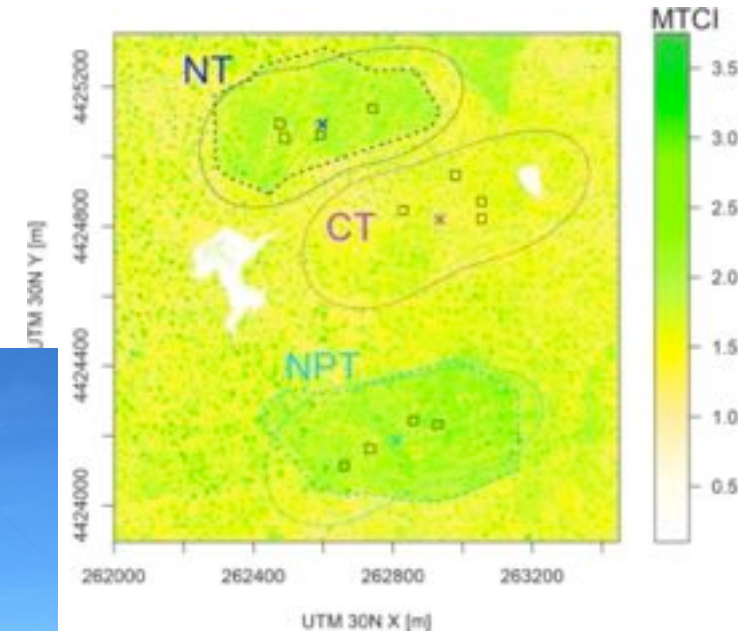
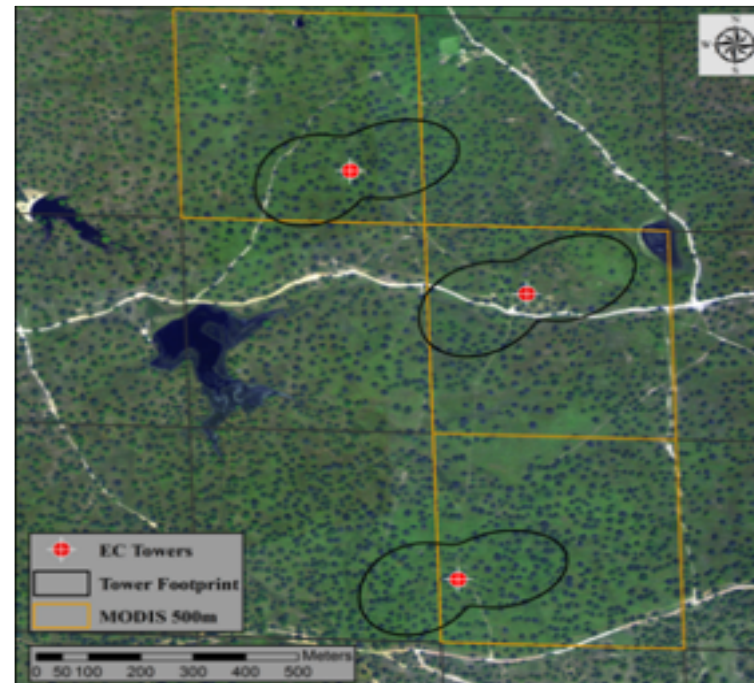


Source: Whitley et al. 2017



Majadas de Tiétar Research Station

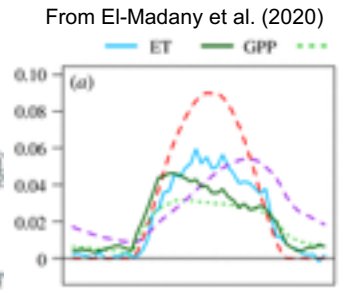
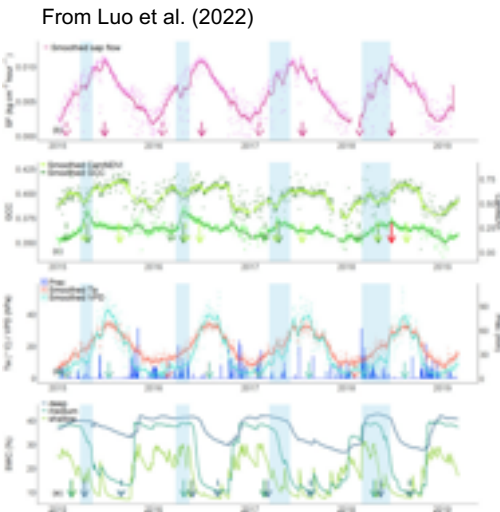
- Located in Extremadura, Spain
- EC flux tower set-up in 2003 (CEAM)
 - In 2014, +2 ecosystem towers + 3 sub-canopy (MPI-BGC)
 - MANIP: Large-scale nutrient manipulation experiment



Data and Research Areas

□ Unique dataset: **Multidisciplinary and complementary**

■ **Intensive and continuous sampling**



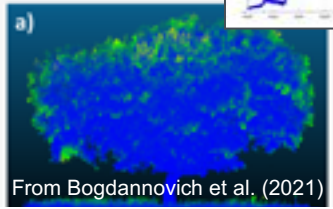
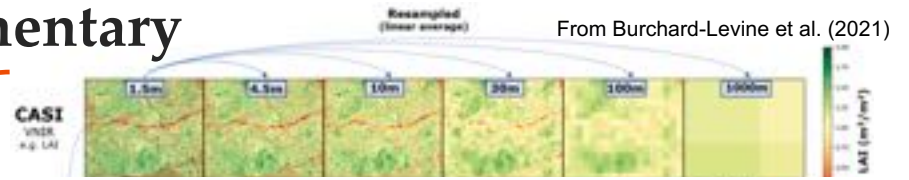
- ◆ Fluxes: EC systems
- ◆ Meteo+Radiometric
- ◆ Sap flow + lysimeters

Fluxes and biometeorological
Since 2003

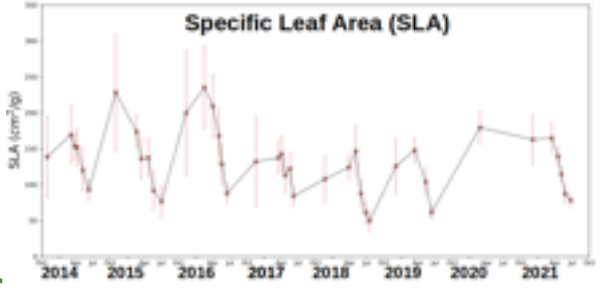
Multi-scale Remote Sensing
Since 2009

Biophysical and Ecological
Since 2009

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

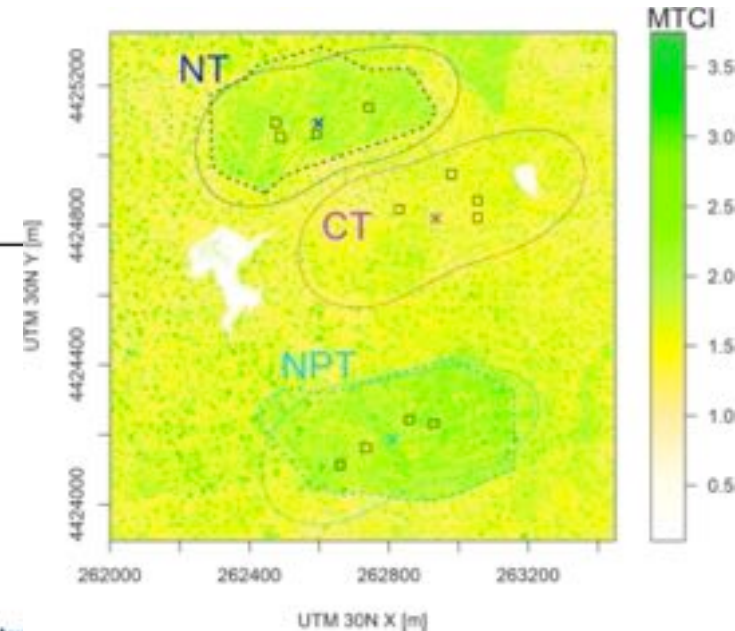


- ◆ Plant Traits (LAI, Cab, etc)
- ◆ Plant Diversity
- ◆ Soil sampling



In-Situ Flux Observations

- **Three Eddy-Covariance (EC)+ meteo systems**
 - Both **overstory** (15m, ecosystem) and **understory** (1.6m, grass-soil)
 - LE, H, G, CO₂, 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+dendrometers - 6 trees per tower
- **Three Lysimeters: Grass-soil ET**



IGR Biogeosciences

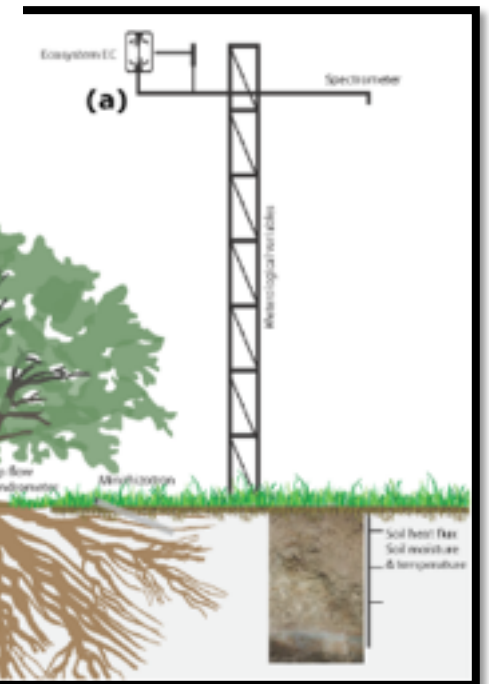
RESEARCH ARTICLE
15 JULY 2022

Key Points

- Measurements of P₂O₅ and related species improve ecosystem nitrogen management
- High nitrogen availability increases carbon uptake and changes the composition of a carbon-storing leaf litter
- Ecosystem-scale microbial communities are altered through nitrogen availability and related

How Nitrogen and Phosphorus Availability Change Water Use Efficiency in a Mediterranean Savanna Ecosystem

Tarek S. El-Madany^{1,2}, Markus Reichstein¹, Arnaud Carrara¹, M. Pilar Martin¹, Gerardo Moreno¹, Benigno Gonzalez-Causse¹, Josep Pedrola¹, David S. Ellsworth³, Vicente Sanchez-Lorenzo¹, Diana W. Hammer⁴, Hagen Kasper⁵, Olaf Kolle⁶, Yun-Peng Luo⁷, Javier Pacheco-Labrador¹, Jacob A. Nelson⁸, Oscar Perez-Prigo^{1,2}, Victor Roldan⁹, Thomas Wutzler¹, and Mirco Migliavacca¹



Drivers of spatio-temporal variability of carbon dioxide and energy fluxes in a Mediterranean savanna ecosystem

Tarek S. El-Madany^{1,2}, Markus Reichstein¹, Oscar Perez-Prigo^{1,2}, Arnaud Carrara¹, Gerardo Moreno¹, M. Pilar Martin¹, Javier Pacheco-Labrador¹, Georg Wohlfahrt¹, Hector Nieto¹, Ulrich Weber¹, Olaf Kolle⁶, Yun-Peng Luo⁷, Nuno Carvalhais¹⁰, Mirco Migliavacca¹

PI/Contact:

- Arnaud Carrara (CEAM)
- Sung-Ching Lee (MPI-BGC)
- Tarek El-Madany (MPI-BGC)

Automated Proximal Sensing



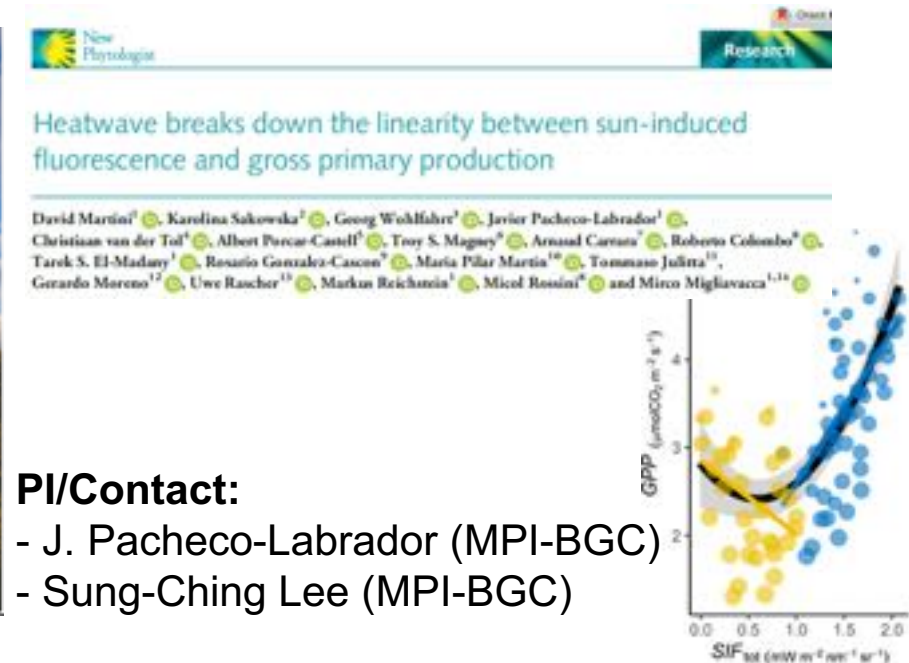
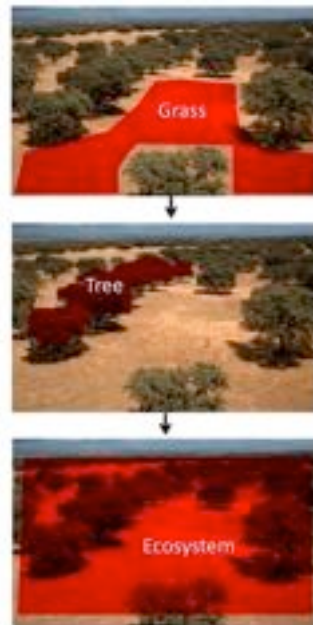
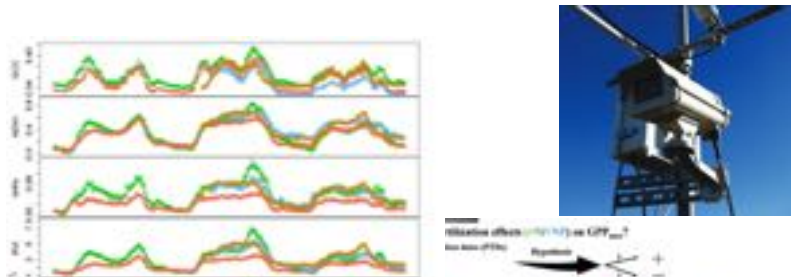
- **Phenocams** (each tower)
 - Blue, Green, Red, and NIR
- **NDVI/PRI** sensors (each tower)
- **Apogee TIR** sensors (each tower)
 - 0°, 35°, 55° view angle

- **FLuorescence bOX (FLOX)**

- High-res: SIF retrievals O₂ 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)



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PRIMARY RESEARCH ARTICLE

Nutrients and water availability constrain the seasonality of vegetation activity in a Mediterranean ecosystem

Yungang Luo¹ | Tarek El-Madany¹ | Xianlong Ma^{2,3} | Richard Nair¹ | Martin Jang¹ | Ulrich Weber¹ | Glaukka Filippa² | Solveig F. Bacher^{4,5} | Gerardo Moreno⁶ | Edoardo Cremonese⁷ | Arnaud Carrara⁷ | Rosario Gonzalez-Cascon⁸ | Yonatan Cáceres Escudero⁹ | Marta Galvagno³ | Javier Pacheco-Labrador¹ | M. Pilar Martín¹⁰ | Oscar Perez-Priego¹¹ | Markus Reichstein^{1,5} | Andrew D. Richardson^{12,13} | Annette Menzel¹⁴ | Christine Rosenmann^{2,4,5} | Mirco Migliavacca¹

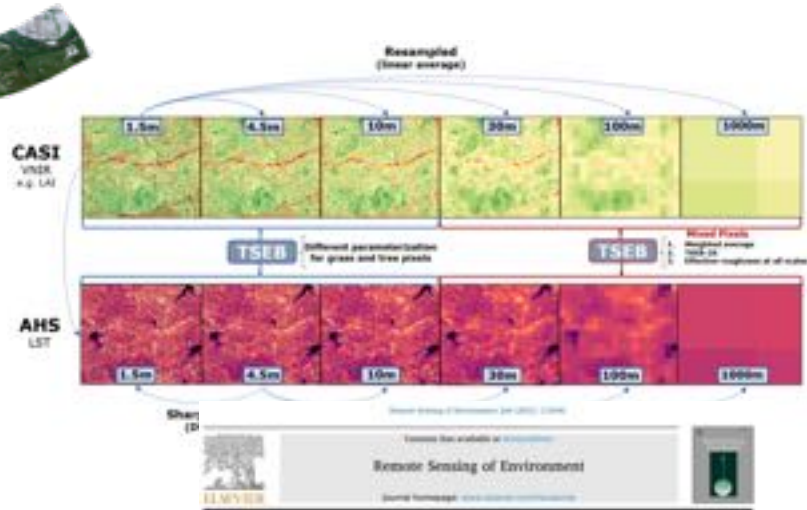
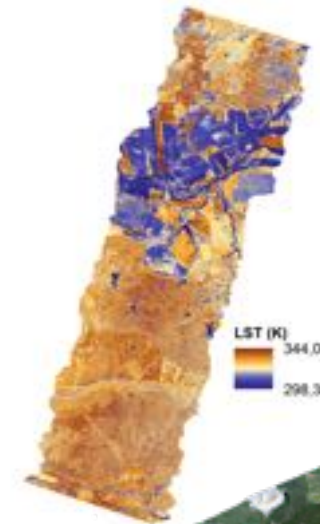
Airborne/UAV Acquisitions

- 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)

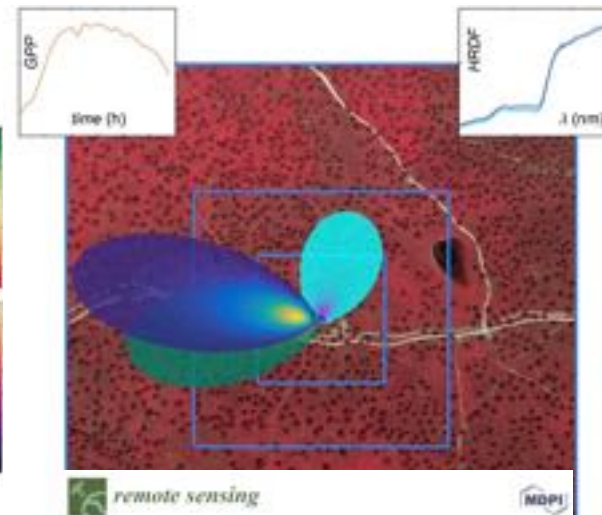
- UAV campaigns (2020-2021)

- DAAD/MONSOON/U. Augsburg:
 - May 2021: Micasense Altum (VNIR+TIR)
 - >30 overpasses between 5-20 May
- Diverspec/SpecLab-CSIC/UEX
 - May 2022: Sequoia (VNIR)



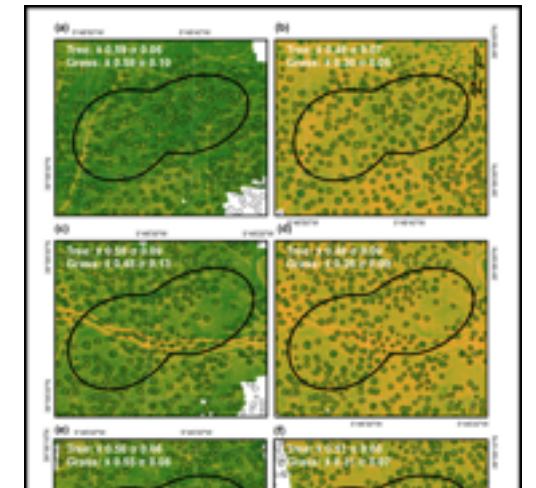
The effect of pixel heterogeneity for remote sensing based retrievals of evapotranspiration in a semi-arid tree-grass ecosystem

Vicente Bachard-Lavado^{1,2}, Hector Nieto¹, David Rizo^{1,3}, Mirco Migliavacca¹, Tarek S. El Madi^{1,4}, Radosław Gustowski¹, Anselm Canessa¹, M. Pilar Martín¹



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

Javier Pacheco-Labrador^{1,2}, Tarek S. El Madi¹, M. Pilar Martín¹, Mirco Migliavacca¹, Micol Bonini¹, Anselm Canessa¹ and Pablo J. Zarco-Tejada¹



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

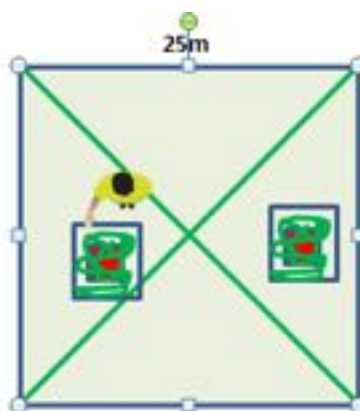
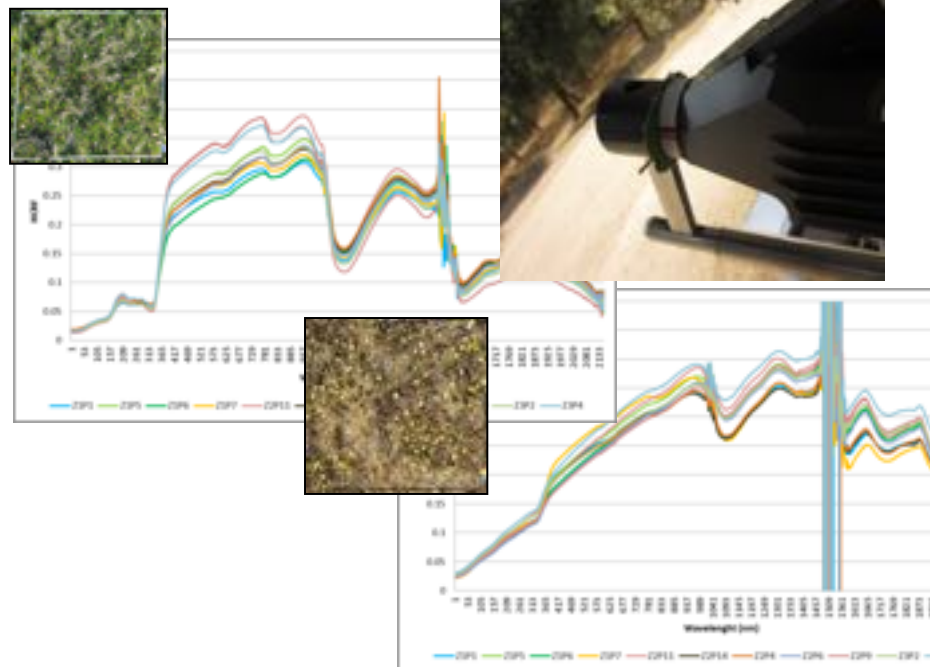
Jake E. Simpson¹, Steven H. Mullen¹, Hector Nieto¹, Tarek S. El Madi¹, Mirco Migliavacca¹, M. Pilar Martín¹, Vicente Bachard-Lavado¹, Anselm Canessa¹, Robert Bieker¹, Peter Fritsev¹, Jodi D. Kaplan¹

PI/Contact:
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 - Javier Pacheco (MPI-BGC)

In-Situ Spectroscopy

• ASD Spectral measurements since 2009

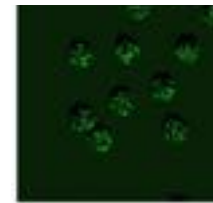
- Simultaneous to biophysical sampling in 25mx25m plots
- Ad hoc acquisition protocols
- Grass canopy: 5-6 times/y
 - 10-40 samples/campaign
- Tree leaf-level (plant-probe): 2-3 times/y
 - 5-15 trees/campaign



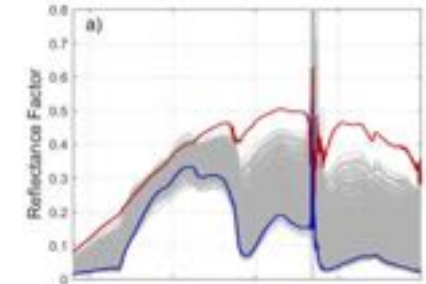
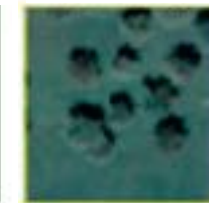
Improving the Performance of 3-D Radiative Transfer Model FLIGHT to Simulate Optical Properties of a Tree-Grass Ecosystem

José Esteban Melendo-Vega ^{1,*}, M. Pilar Martín ¹, Javier Pacheco-Labrador ¹, Rosario González-Cascón ¹, Gerardo Moreno ¹, Fernando Pérez ¹, Miroslav Migliavacca ¹, Mariano García ¹, Peter North ², David Riaño ^{1,3}

PROSAIL+FLIGHT



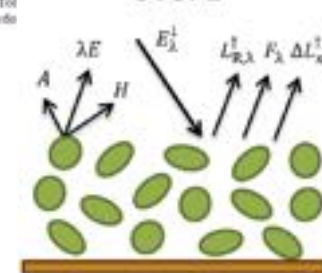
CASI image



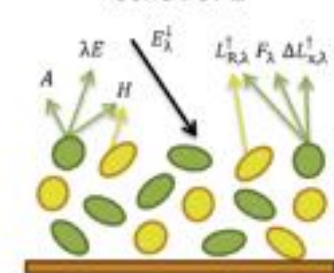
senSCOPE: Modeling mixed canopies combining green and brown senesced leaves. Evaluation in a Mediterranean Grassland

Javier Pacheco-Labrador ^{1,*}, Tarek S. El-Modayr ², Christian von der Tol Román González-Cascón ¹, Oscar Pérez-Priego ³, Jianhong Guo ⁴, Gerardo Antonio Casas ⁵, Markus Reichert ⁶, Miroslav Migliavacca ¹

SCOPE



senSCOPE



In-Situ Plant Traits

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

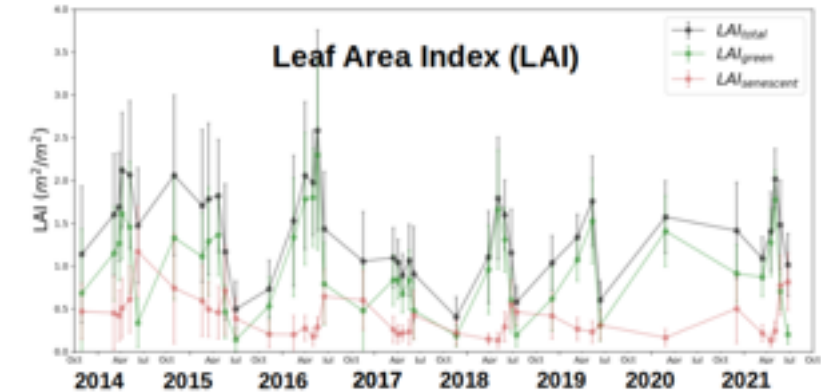
Tree leaf-level data

■ Biophysical

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

Tree canopy data

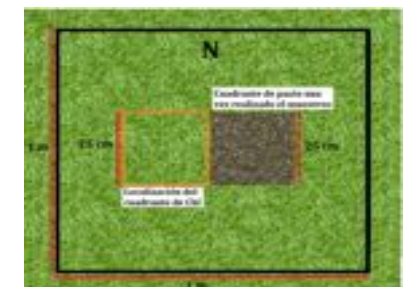
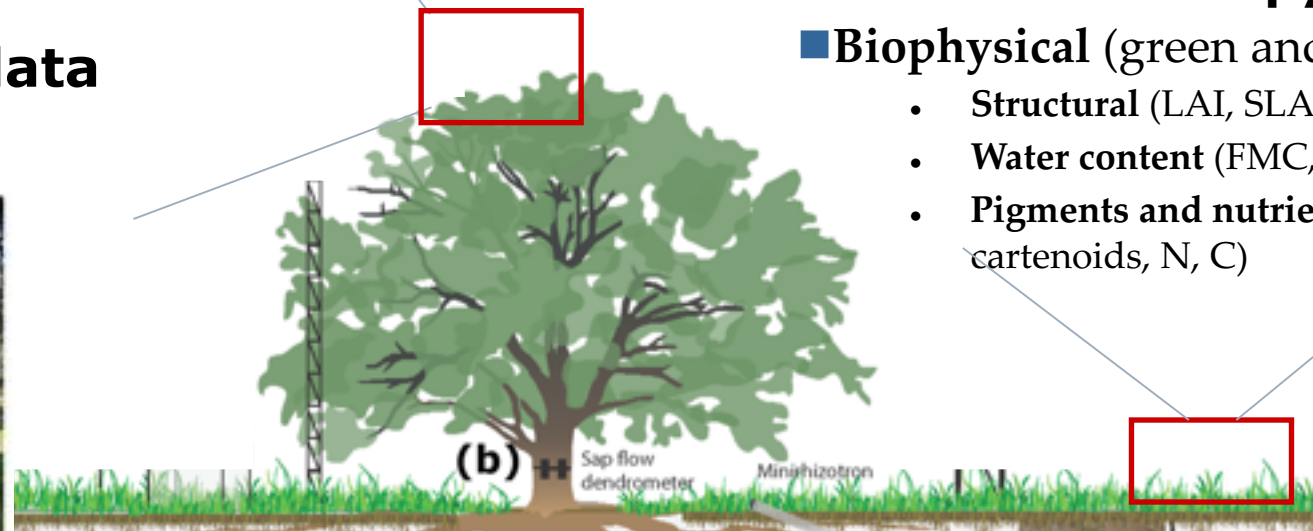
- LAI (using LAI-2200C)



Grass canopy data

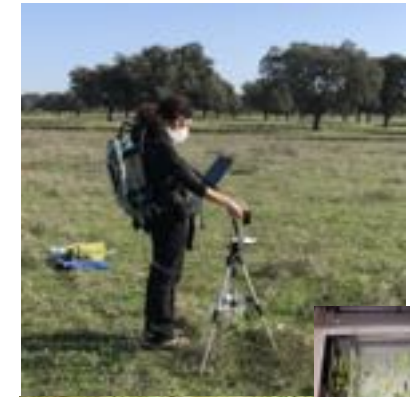
■ Biophysical (green and non-green)

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

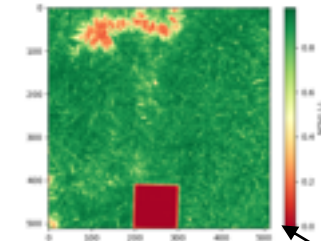


Plant Diversity and gas exchange

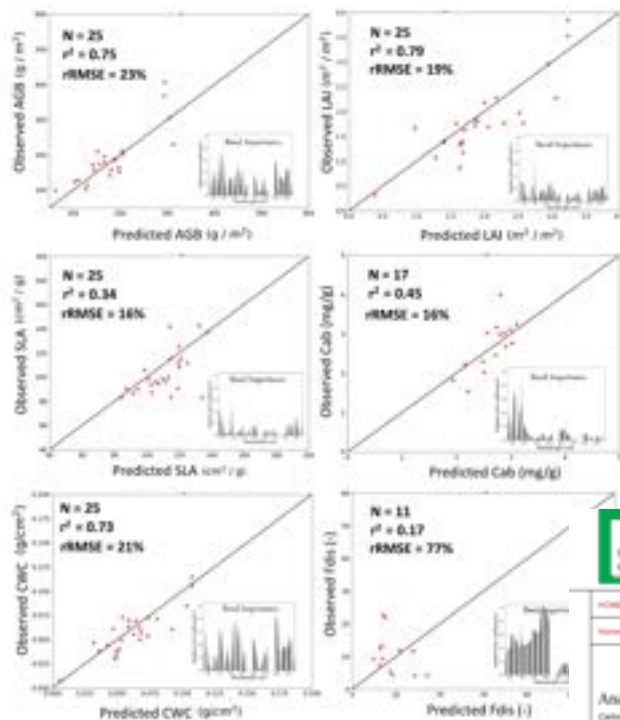
- Since 2019, joint **Speclab-UXE** campaigns to sample **functional diversity + gas exchange**
 - Relating grassland **spectral diversity/traits** with **functional diversity (Fdis, RaoQ)**
 - Portable hyperspectral camera (**Specim-IQ**) for within-plot spectral variability
 - Now processing data from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



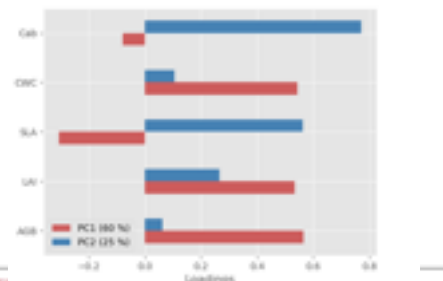
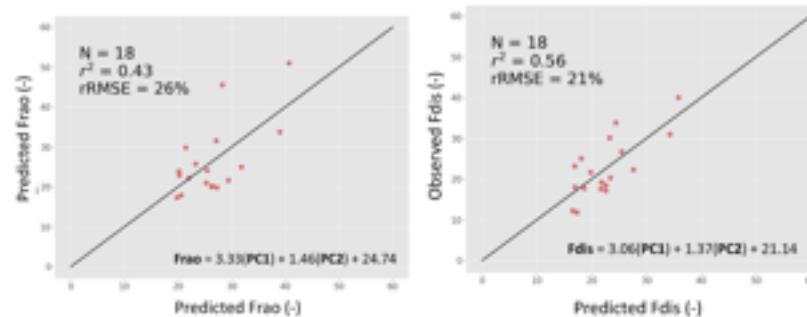
Specim-IQ



Hyperspectral Models using PLSR and ASD bands



Relation between PTs and FD



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CLAUDENOS
de
INVESTIGACIÓN GEOGRÁFICA
GEOGRAPHICAL RESEARCH LETTERS

Analysis of the functional diversity of the herbaceous stratum in a 'dehesa' ecosystem using in situ hyperspectral proximal sensing
Carla González, Víctor Rolo-López, Víctor Rolo, Ricardo González-Castro, Claudio Moreno, et al. Plant Methods

PI/Contact:

- M.Pilar Martín (Speclab-CSIC)
- Gerardo Moreno (UEX)
- Victor Rolo (UXE)

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 CALVAL 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 (Micrometeorology, eco-hydrology, ecology, etc)
- Datasets available for **scientific collaborations**



Thanks!

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Email: vburchard@ica.csic.es

Frascati, Italy
20-Oct-2022

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