Seminario MITECO

CENEAM -Valsaín,
25-27 Abril 2022

Teledetección multi-escala para el seguimiento de los ecosistemas de dehesa

M. Pilar Martín

Laboratorio de Espectro-radiometría y teledetección ambiental SpecLab

CSIC

Environmental Remote Sensing and Spectroscopy Laboratory (SpecLab)

SpecLab

TELEDETECT CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

Mediterranean Monitoring Biophysical Change Imagery Dehesa Grass Vegetation Modelling Europe Ecosystem Hyperspectral Fluxes Spectral Sentinel Synergies Exploring Tree ProximalSensing

MORE THAN a decade of research in multiescale proximal/remote sensing to monitor tree-grass ecosystems

2009 | 2013 | 2015 | 2016 | 2017 | 2018 | 2020

Biospec

FLUχPEC

SynerGE

I-LINK + SAVNET

DiverSpec-TGA

DEHESHyrE

EUFAR
European Facility for Airborne Research

TRUSTEE training
training on Remote Sensing for Ecosystem modelling

esa
European Space Agency

FLEXSense

esa
European Space Agency

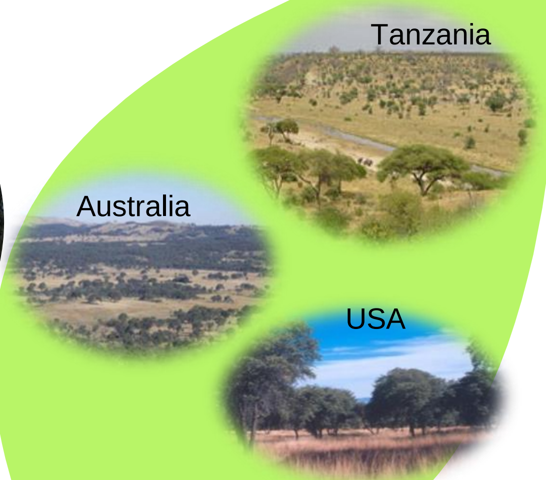
cost ES0903
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

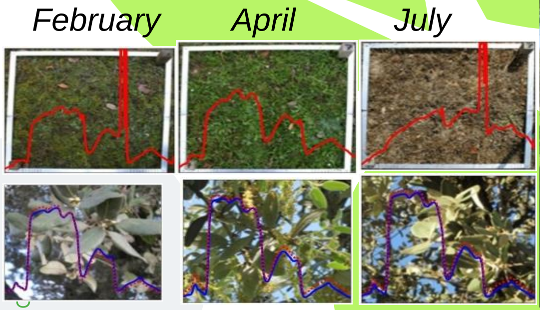
OPTIMISE

SENSECO

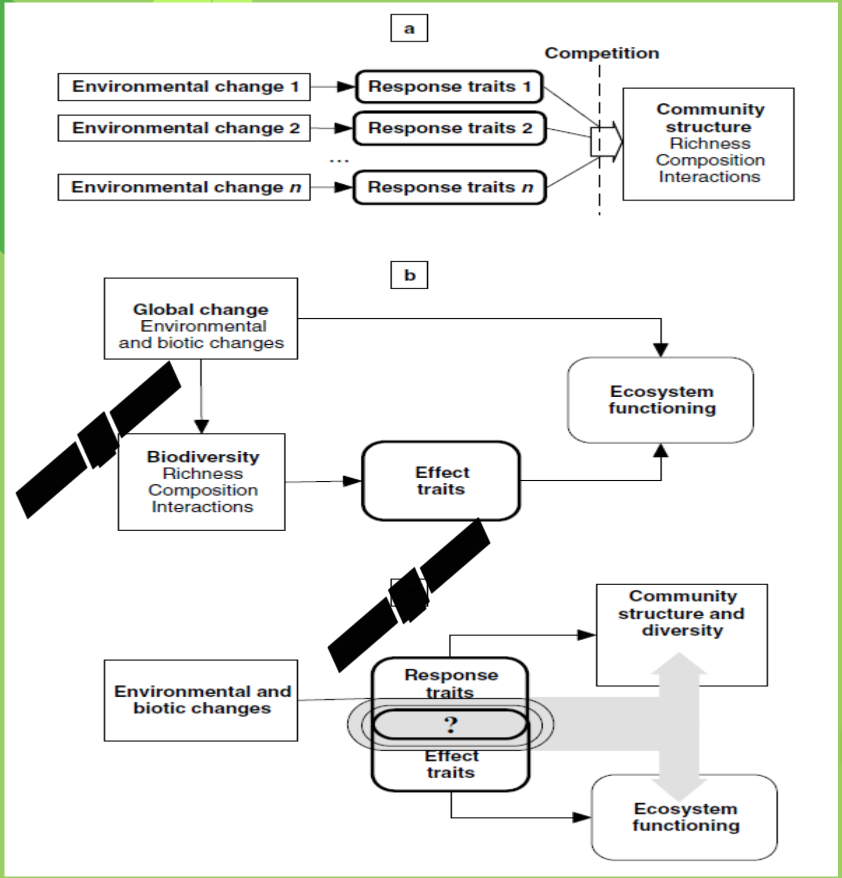
Tree-grass ecosystems

- >15% of Earth surface (Friedl et al., 2010)
- Continental Mediterranean climate
  - Semi-arid conditions
  - Highly seasonally dynamic
  - Vulnerable to drought events and global change
- Heterogenous land surface
  - ~20% tree
  - Unique spatial and temporal characteristics
- Remote sensing challenges:
  - Two vegetation layers with different dynamics / properties / function
  - Strong geometrical component
  - Optical properties badly represented by RTMs

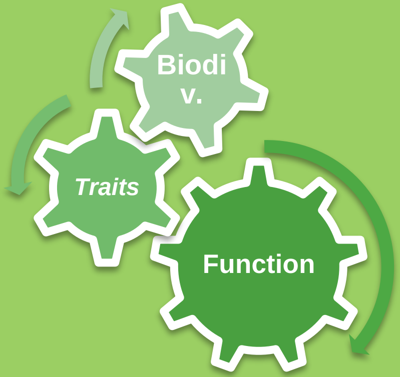


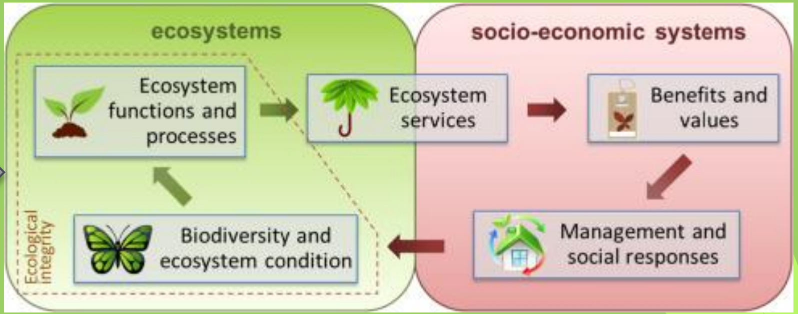


Monitoring plant traits



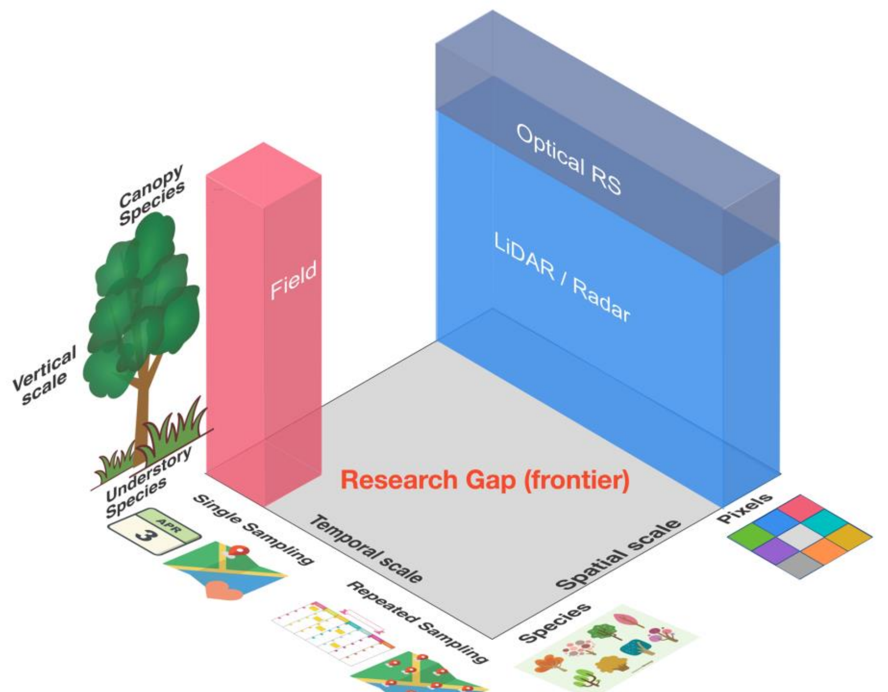
Lavorel and Garnier 2002. *Functional Ecology*





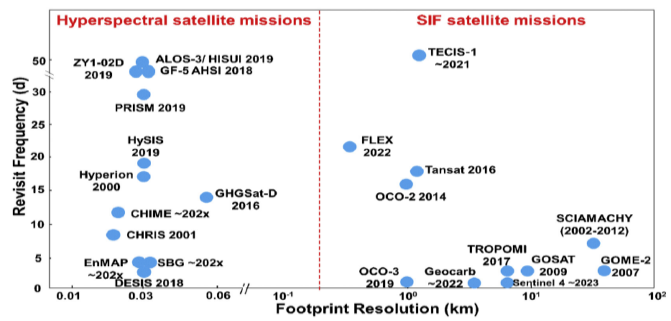
Liquete et al 2016. *Ecological Indicators*

New challenges and oportunities to monitor vegetation function and biodiversity from space



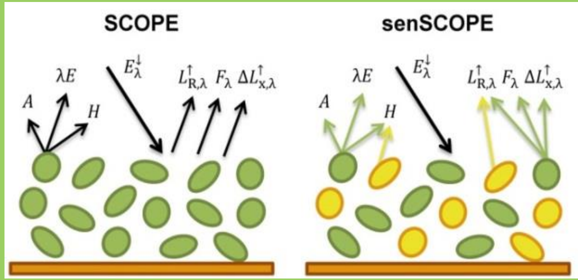
Ma et al., 2020 *Remote Sensing*

Next sensors´ generation: Hyper, SIF



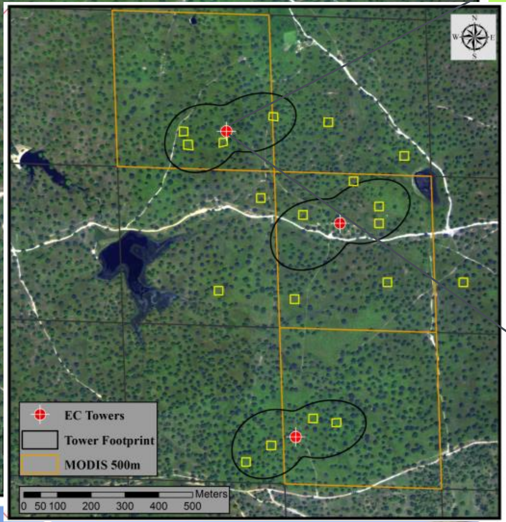
Zhang et al., 2021. *Remote Sensing of Environment*

New models

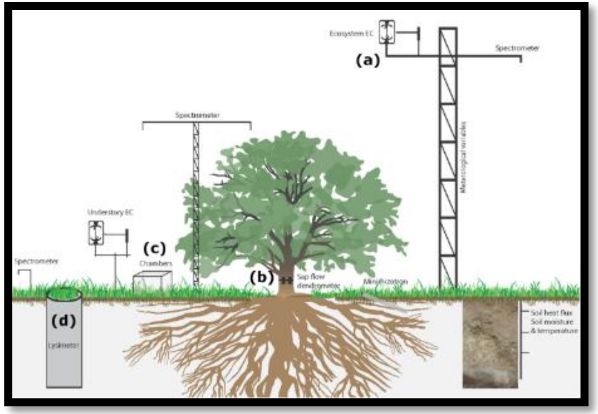


Pacheco-Labrador et al., 2021. *Remote Sensing of Environment*

Majadas de Tiétar research station



- ❑ Collaboration CSIC, INIA-CSIC CEAM, UEX and MPI-BGC
- ❑ Since 2009, *in-situ* spectral/bio sampling
- ❑ Since 2014, three EC towers in Majadas + full field equipment for ecosystem monitoring
- ❑ Fertilization experiment



CEAM FUNDACIÓN CENTRO DE ESTUDIOS AMBIENTALES DEL MEDITERRÁNEO

UEX UNIVERSIDAD DE EXTREMADURA

CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

INIA Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria

Max Planck Institut for Biogeochemistry

RS of tree-grass ecosystems: A two dimensional problem

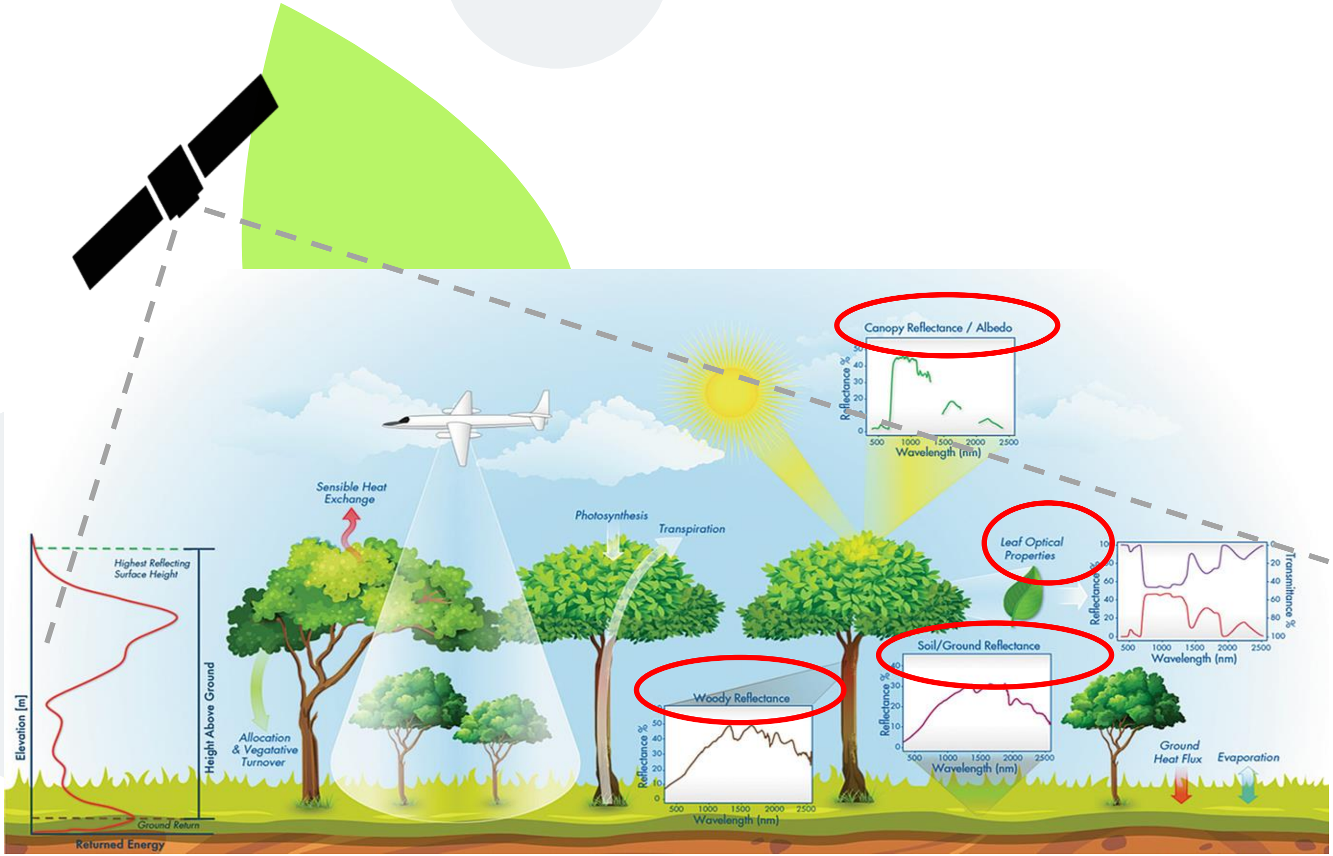
- **Temporal:** to capture main phenological periods in each stratum but also daily and intra-daily variations (CWC,LUE).
- **Spatial:** different spatial scales need to be considered: sub-plot - plot – pixel - footprint - ecosystem

leaf

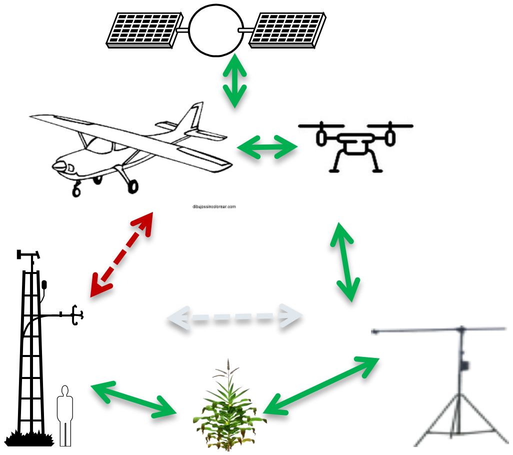
Sub-plot

plot

Multiescale, multisensor approach needed



Serbin and Townsend P.A. (2020) In: *Remote Sensing of Plant Biodiversity*

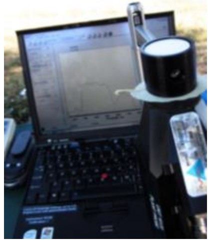


Integrating spatial and temporal domains

Biophysical, chemical and spectral dataset of tree and grass traits 2009-2022

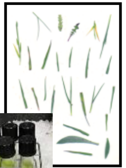
Tree data



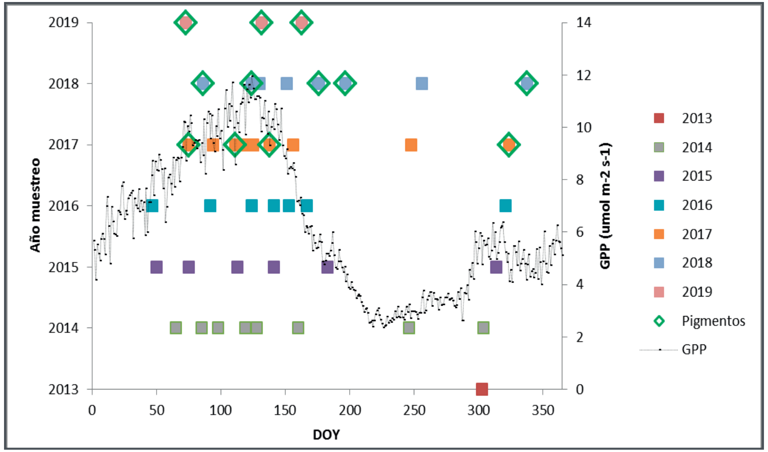



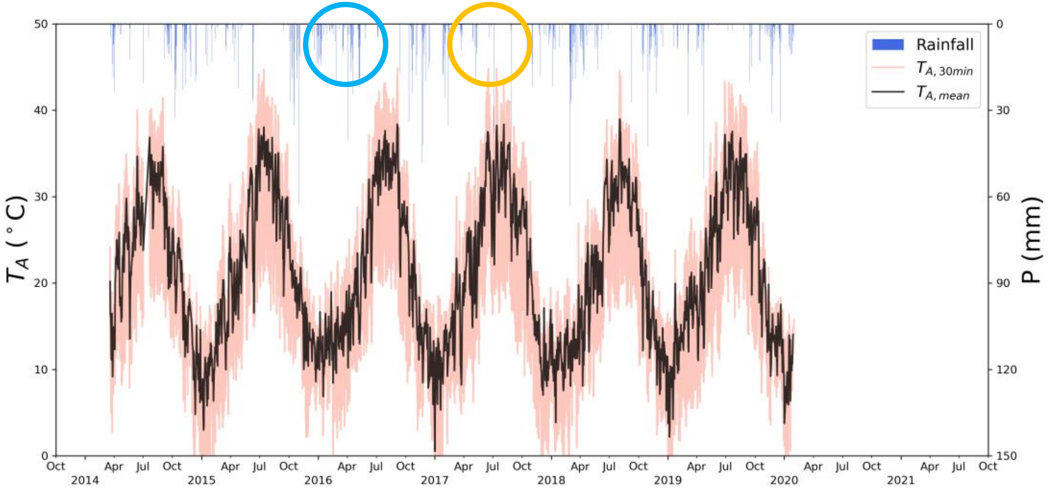
- Biophysical
  - Structural (LAI, SLA)
  - Water content (FMC, EWT, LWC)
  - Pigments and nutrients (Chl a+b, cartenoids, N, C)
- Spectral
  - ASD leaf level data (400-2500nm)
  - Leaves of current and previous sprouting years
  - North and South facing

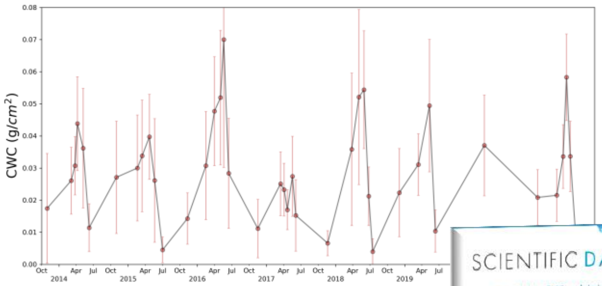
Grass data

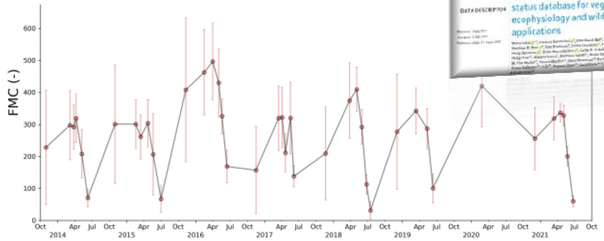



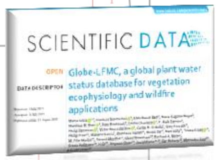

- Biophysical (Green and non-Green)
  - Structural (LAI, SLA, SLW, ABG)
  - Water content (FMC, EWT, LWC, CWC)
  - Pigments and nutrients (Chl a+b, cartenoids, N, C)
- Spectral
  - ASD data canopy level data (400-2500nm)
  - 1 m plots
  - 25 m transects

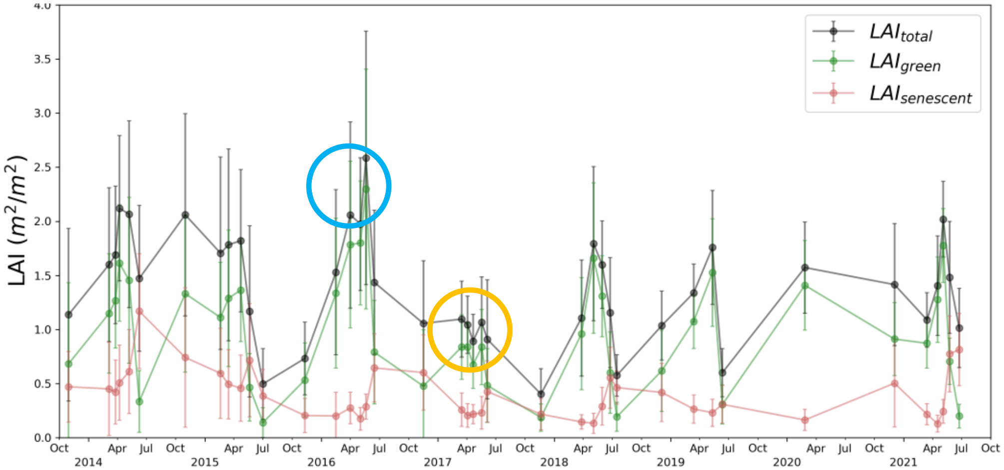

Año muestreo
DOY
GPP (umol m-2 s-1)
2013
2014
2015
2016
2017
2018
2019
Pigmentos
GPP


T_A (°C)
P (mm)
Rainfall
$T_{A,30min}$
$T_{A,mean}$
Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct
2014 2015 2016 2017 2018 2019 2020 2021

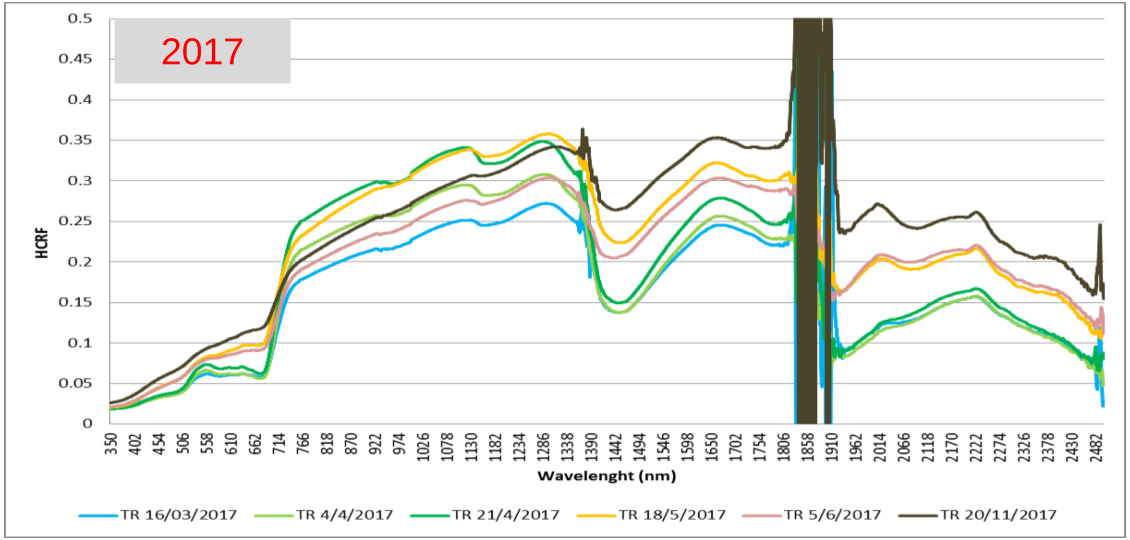

CWC (g/cm^2)

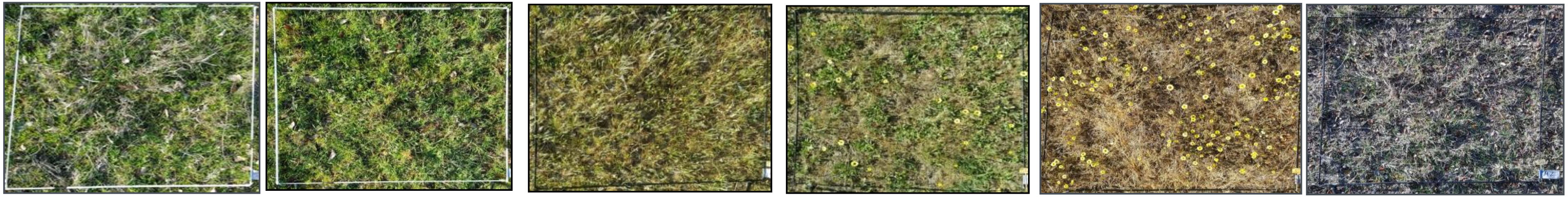

FMC (-)


SCIENTIFIC DATA
OPEN
DATA DESCRIPTOR
Globe-LFMC, a global plant water status database for vegetation ecophysiology and wildfire applications


LAI (m^2/m^2)
LAI_{total}
LAI_{green}
$LAI_{senescent}$
Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct Apr Jul Oct
2014 2015 2016 2017 2018 2019 2020 2021

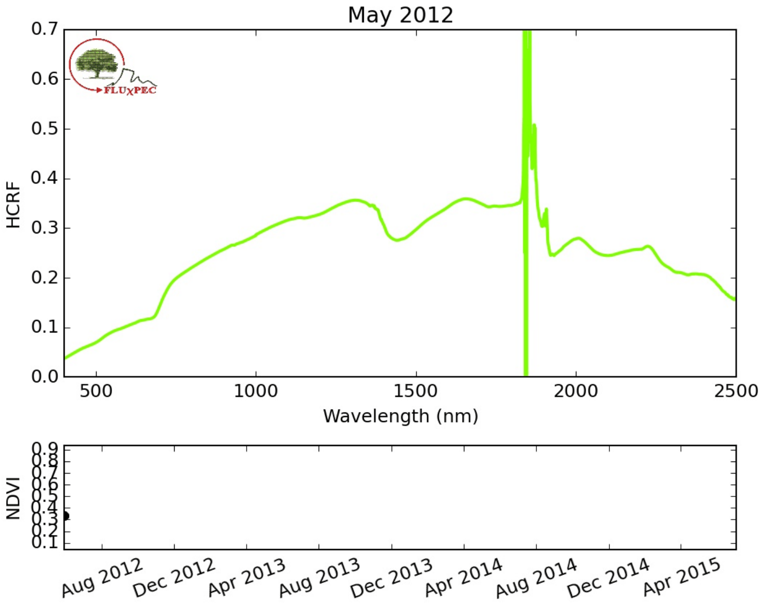
Field spectra temporal series: grass phenology

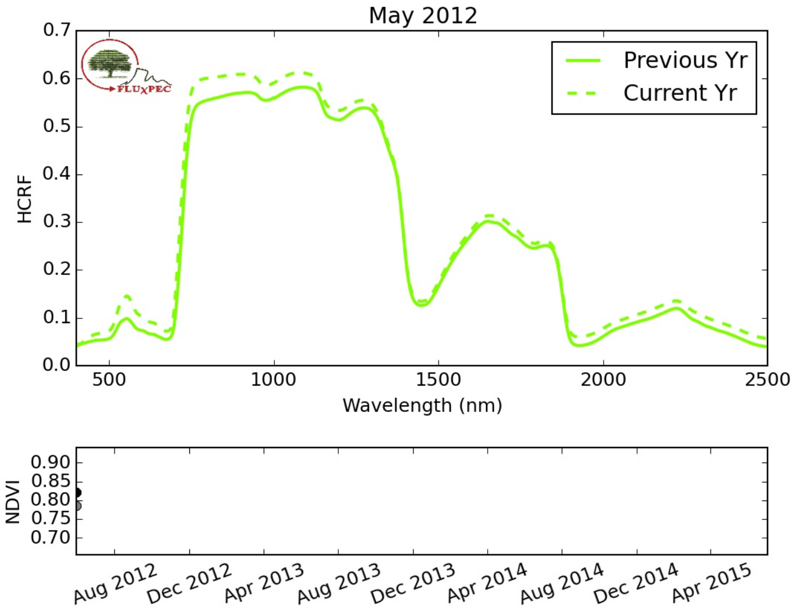


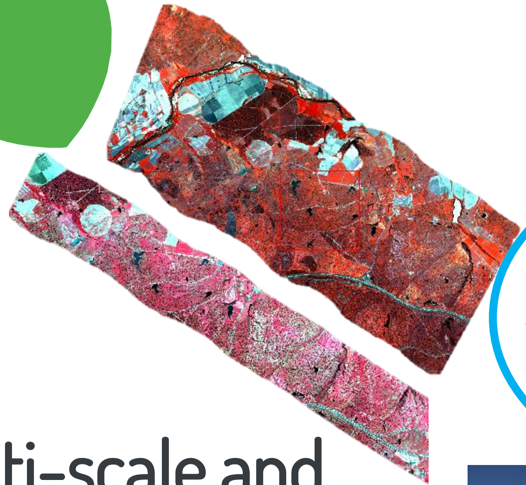


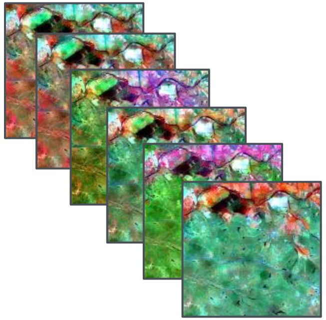
16/03 04/04 21/04 18/05 05/06 20/11

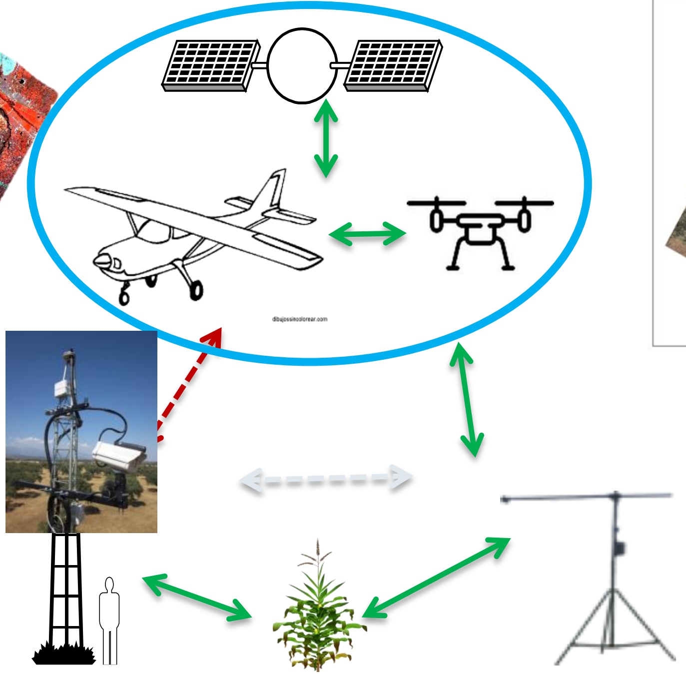
Field spectra temporal series: phenology and inter-anual changes of grass and trees







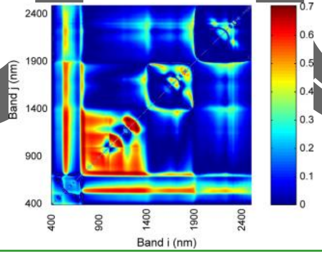




Multi-scale and multi-sensor remote sensing data

Scientific achivements in RS of tree-grass ecosystems (1/2)

Understanding spectral response of grass and trees at plot/leaf scale
Traits vs field spectra: empirical models to estimate traits



International Journal of Applied Earth Observation and Geoinformation 26 (2014) 105–118

Contents lists available at SciVerse ScienceDirect

International Journal of Applied Earth Observation and Geoinformation

journal homepage: www.elsevier.com/locate/jag

Understanding the optical responses of leaf nitrogen in Mediterranean Holm oak (*Quercus ilex*) using field spectroscopy

Javier Pacheco-Labrador[a,*], Rosario González-Cascón[b], M. Pilar Martín[a], David Riaño[a,c]

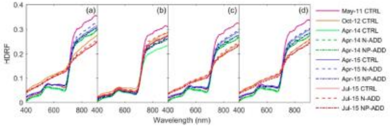


Figure 2. Mean spectra of different covers within a 1 km^2 square centered on the Eddy Covariance (EC) towers: (a) Grass; (b) Trees; (c) Vegetation (grass + trees); and (d) All covers.

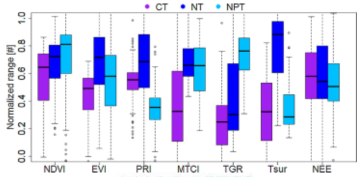
remote sensing MDPI

Article

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

Javier Pacheco-Labrador [1,*], Tarek S. El-Madany [1], M. Pilar Martín [2], Mirco Migliavacca [1], Micol Rossini [3], Arnaud Carrara [4] and Pablo J. Zarco-Tejada [5]

Relationship between traits, airborne hyperspectral data and fluxes: spatio-temporal issues



Agricultural and Forest Meteorology 262 (2018) 258–278

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

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

Tarek S. El-Madany[a,*], Markus Reichstein[a], Oscar Perez-Priego[a], Arnaud Carrara[b], Gerardo Moreno[c], M. Pilar Martín[d], Javier Pacheco-Labrador[a,d], Georg Wohlfahrt[e], Hector Nieto[f], Ulrich Weber[a], Olaf Kolle[a], Yun-Peng Luo[a], Nuno Carvalhais[a,g], Mirco Migliavacca[a]

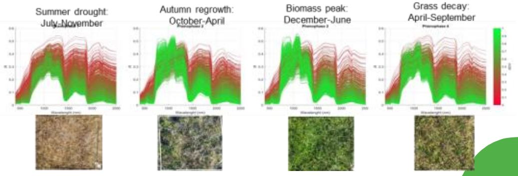
3-D Radiative Transfer Models to Simulate Optical Properties of the ecosystem

remote sensing MDPI

Article

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

José Ramón Melendo-Vega [1,*], M. Pilar Martín [1], Javier Pacheco-Labrador [2], Rosario González-Cascón [3], Gerardo Moreno [4], Fernando Pérez [5], Mirco Migliavacca [2], Mariano García [6], Peter North [7] and David Riaño [1,8]



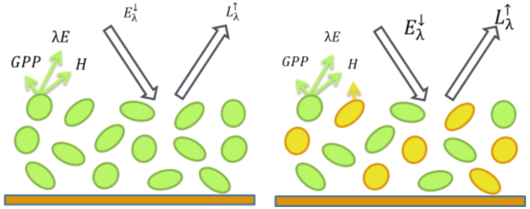
Scientific achivements in RS of tree-grass ecosystems (2/2)

Modeling mixed canopies combining green and brown senesced leaves


Remote Sensing of Environment 257 (2021) 112352
Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

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

Javier Pacheco-Labrador, Tarek S. El-Madany, Christiaan van der Tol, M. Pilar Martin, Rosario Gonzalez-Cascon, Oscar Perez-Priego, Jinhong Guan, Gerardo Moreno, Arnaud Carrara, Markus Reichstein, Mirco Migliavacca

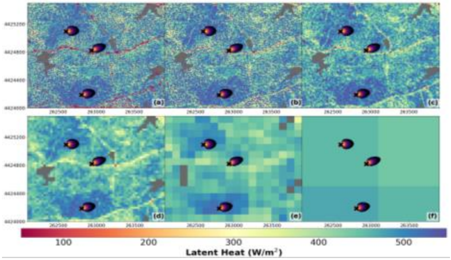



Remote Sensing of Environment 260 (2021) 112440
Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

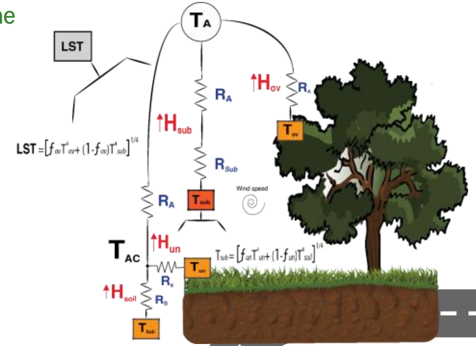
The effect of pixel heterogeneity for remote sensing based retrievals of evapotranspiration in a semi-arid tree-grass ecosystem

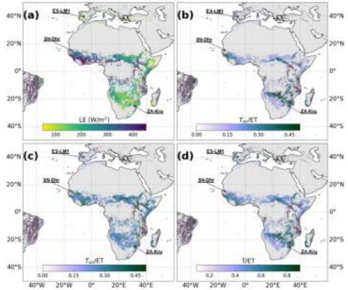
Vicente Burchard-Levine, Héctor Nieto, David Riaño, Mirco Migliavacca, Tarek S. El-Madany, Radoslaw Guzinski, Arnaud Carrara, M. Pilar Martín

Effect of pixel heterogeneity for remote sensing based retrievals of evapotranspiration



Seasonal Adaptation of the Thermal-Based Two-Source Energy Balance Model for Estimating Evapotranspiration



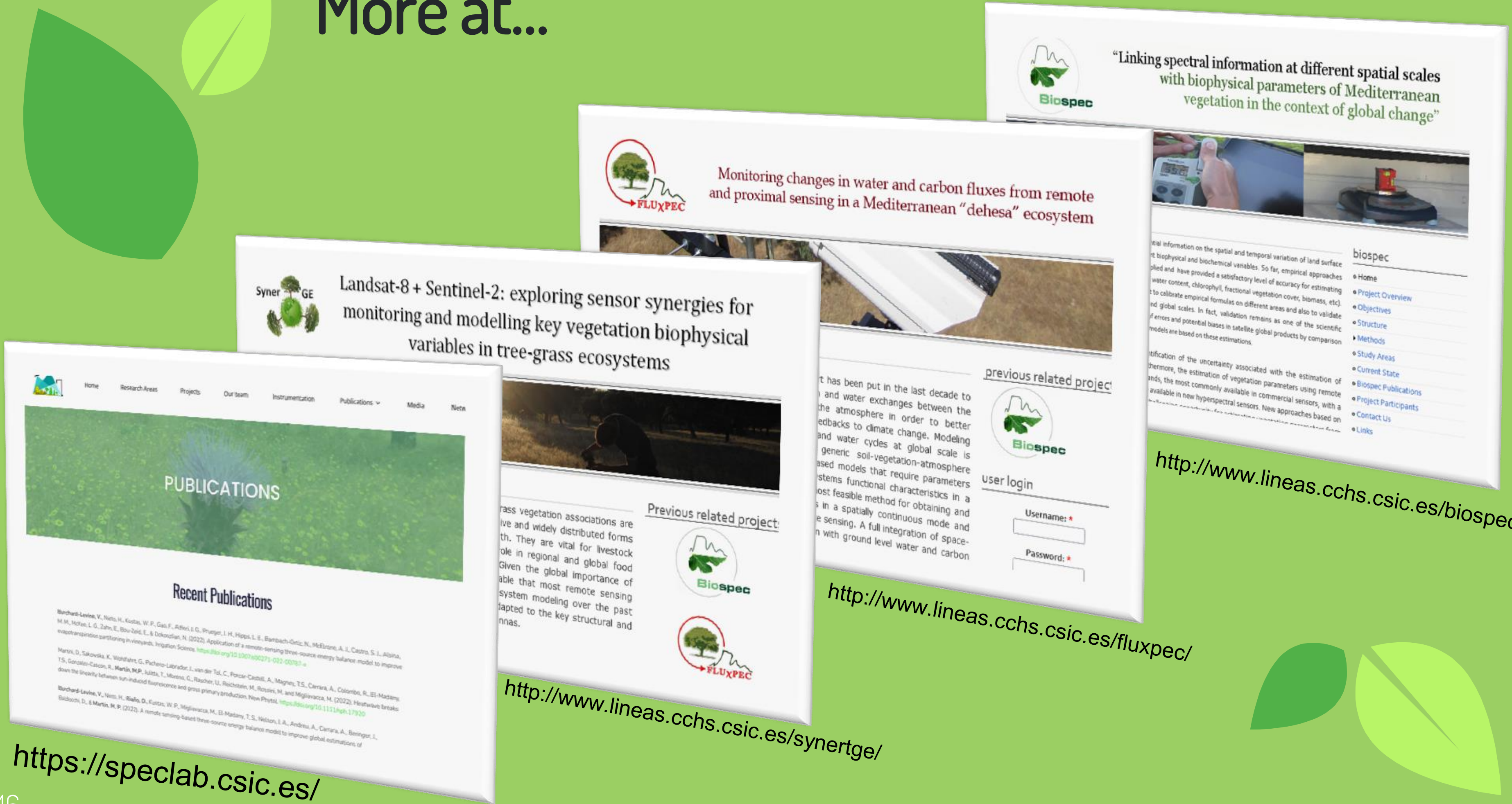


Global Change Biology WILEY

A remote sensing-based three-source energy balance model to improve global estimations of evapotranspiration in semi-arid tree-grass ecosystems

Vicente Burchard-Levine[1] | Héctor Nieto[2] | David Riaño[1,3] | Wiliam P. Kustas[4] | Mirco Migliavacca[5] | Tarek S. El-Madany[5] | Jacob A. Nelson[5] | Ana Andreu[6] | Arnaud Carrara[7] | Jason Beringer[8] | Dennis Baldocchi[9] | M. Pilar Martín[1]

More at...



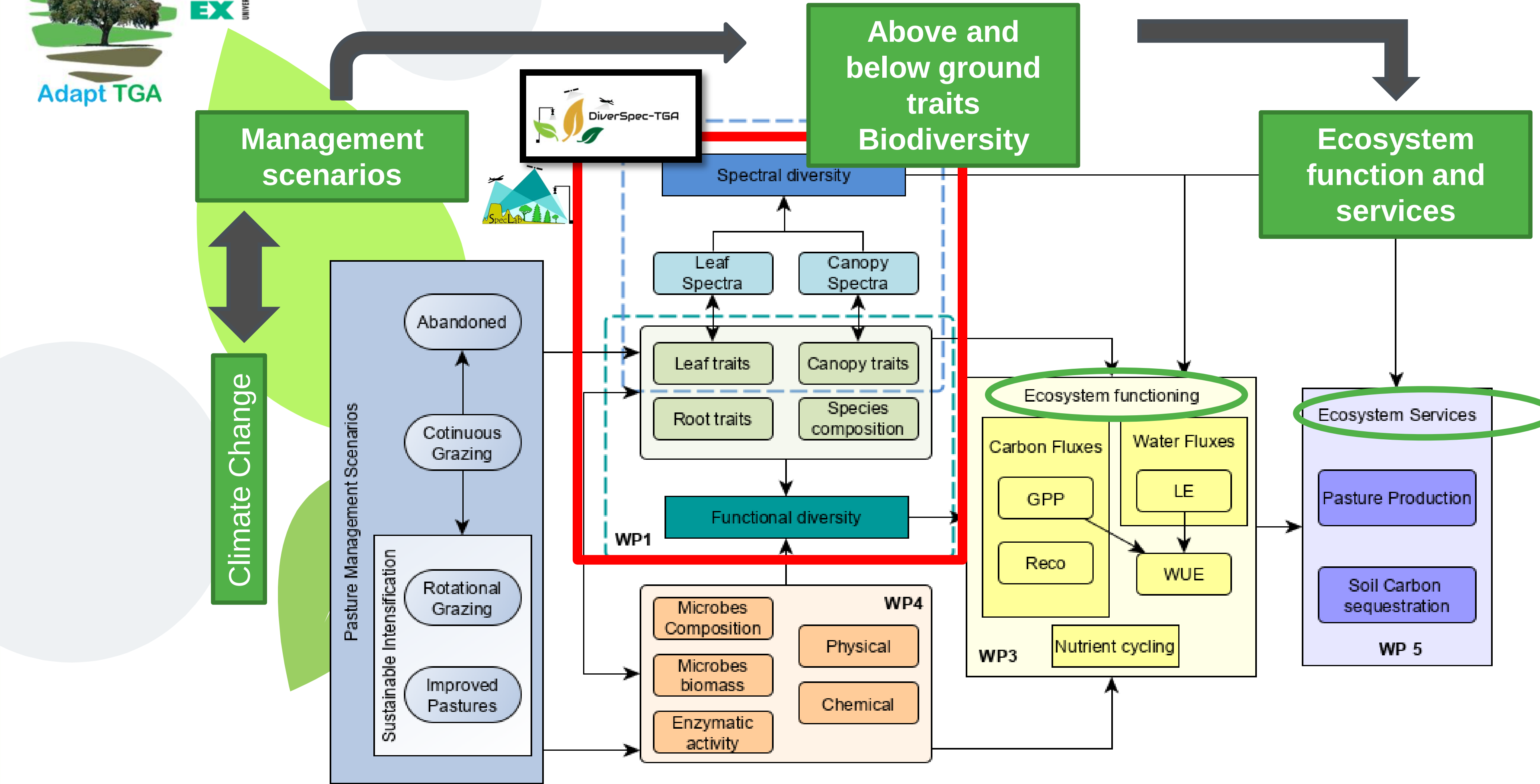
http://www.lineas.cchs.csic.es/biospec/

http://www.lineas.cchs.csic.es/fluxpec/

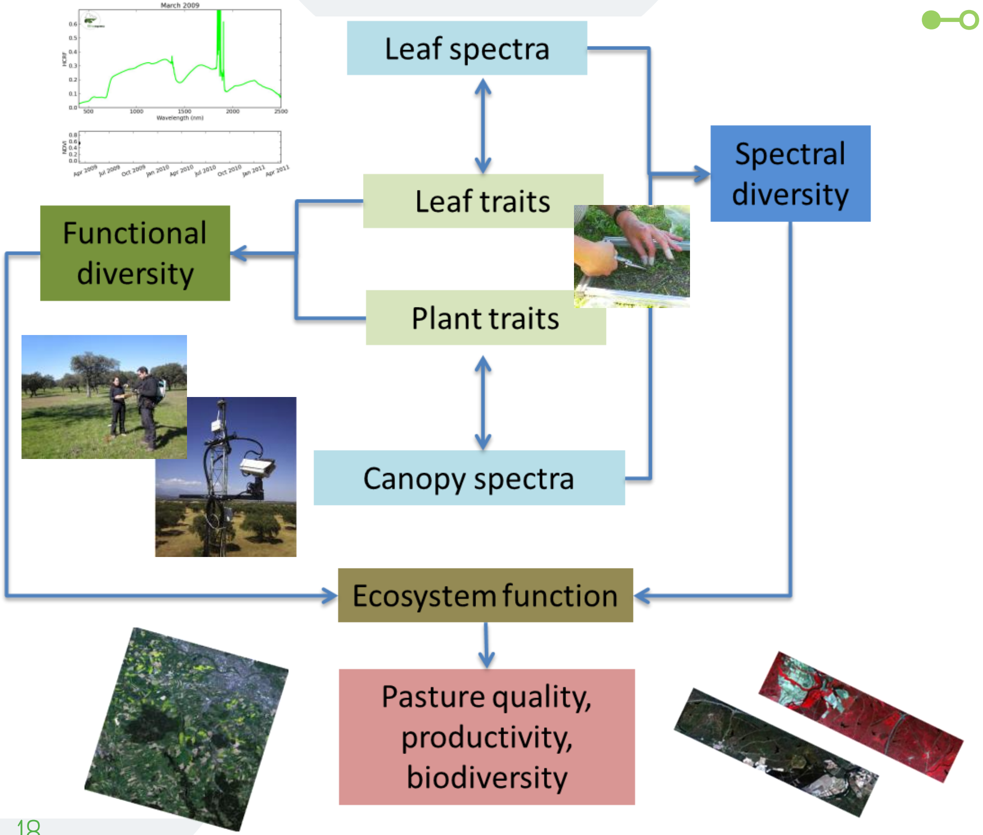
http://www.lineas.cchs.csic.es/synertge/

https://speclab.csic.es/

Current research



DiverSpec-TGA



Objectives

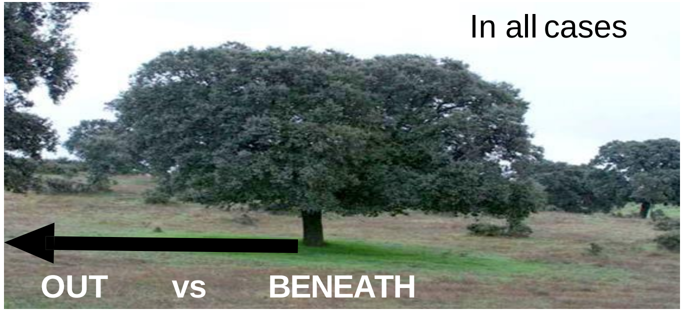
- Assess the capacity of optical data to detect intra- and inter-specific differences in foliar functional traits of pasture species and their plastic responses to water shortage
- Analyze the effect of structural parameters in the functional characterization of pasture communities at the canopy scale
- Calibrate and validate empirical and physically based models to map plant traits and functional diversity in **tree-grass agroecosystems** using airborne and satellite images

Monoculture experiment

- Leaf to canopy level analysis to characterize foliar functional traits (leaf scale) and structural effects (canopy scale) using proximal sensing
- Analysis based in chemical, morphological and optical data
- 45 (1.5x1.5 m) plots. Selected species dominant in Majadas
  - 8 species = 4 functional types (legumes, grass forbs, grasses C3 and grasses C4)
- Water manipulation experiment
- Optical instruments: two band sensors (NDVI /PRI), ASD, ROX, Specim IQ
- Destructive sampling and lab analysis of plant traits

Dehesa farms: management scenarios

CONTROL: Business as Usual



GRAZING ABANDOMENT
(> 10 years)

ECOLOGICAL INTENSIFICATION

ROTATIONAL GRAZING
(Long Resting Period)

LEGUME-ENRICHED
(By over-seeding)

New & Old (< 5 & > 10 y)

REPLICATED IN 9 SITES: 3 FARMS X 3 REGIONS (CLIMATE)

Sampling traits + spectra+ fluxes + Biodiversity + soil 2019-2021-2022

1 ASD Fieldspec 3 + SPECIM-IQ spectral measurements

2 Chambers

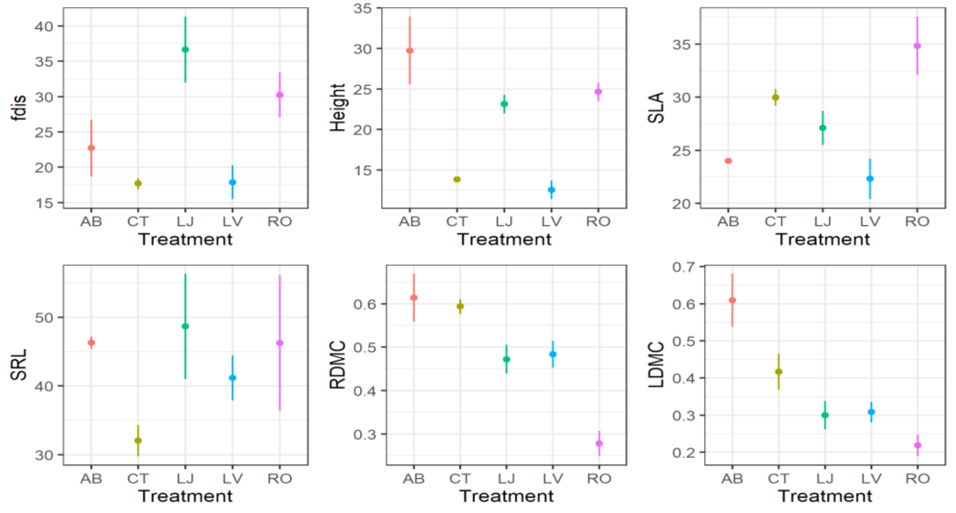
3 Destructive sampling and diversity analysis (25 x 25 cm)

4 Soil sampling

Variable Biofísica / Biodiversidad	Calibración	
	R^2	*rRMSE*
AGB	0.5	0.11
AGB_v	0.72	0.08
LAI	0.15	0.16
LAI_v	0.26	0.15
LAI_nv	0.15	0.37
SLA	0.69	0.07
SLA_v	0.69	0.07
SLA_nv	0.12	0.24
N%	0.75	0.07
N%_v	0.52	0.07
Índice de *Shannon*	0.01	0.23
Índice de *Evenness*	0.01	0.15
FDis	0.01	0.16

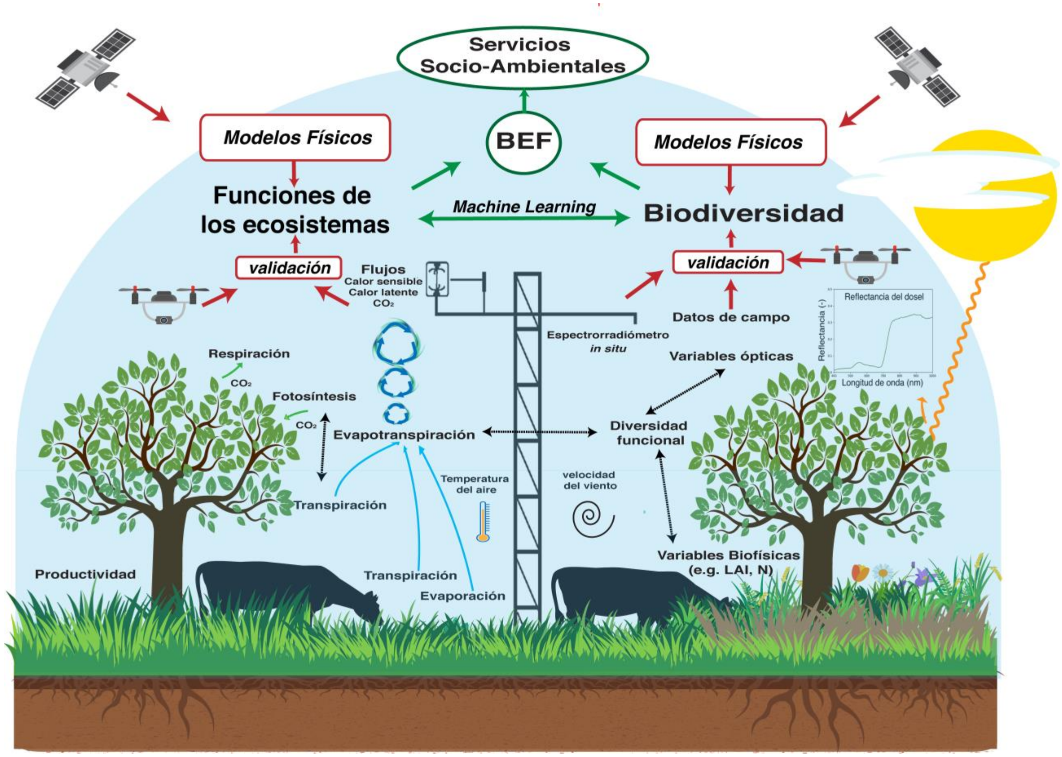
Empirical models relating traits and diversity *vs* field hyperspectral data

Partial Least Square Regression (PLSR)



Functional diversity in management scenarios

¿Can Earth observation satellites provide the information needed to understand the relationships between biodiversity and functioning of agroforestry ecosystems, thus allowing for more effective conservation and management?



Key aspects in RS monitoring of tree-grass ecosystems

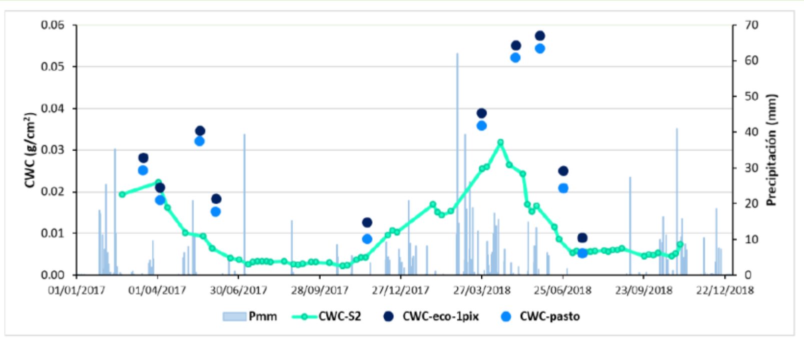
Recibido: 03/04/2020
Aceptado: 06/06/2020

REVISTA DE TELEDETECCIÓN
Asociación Española de Teledetección
(2020) 55, 31-48
ISSN 1133-0953
EISSN 1988-8740
https://doi.org/10.4995/raet.2020.13394

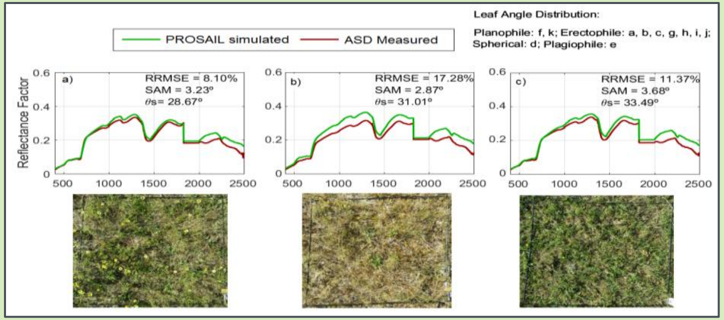
Estimación de variables esenciales de la vegetación en un ecosistema de dehesa utilizando factores de reflectividad simulados estacionalmente

Martín, M.P.[1*], Pacheco-Labrador, J.[2], González-Cascón, R.[3], Moreno, G.[4], Migliavacca, M.[2], García, M.[5], Yebra, M.[6], Riaño, D.[1,7]

- Low statistical relationship between multi-spectral data and plan traits
- Empirical models outperform RTMs
- Low statistical relationship between spectral data and biodiversity
- Large uncertainty in global remote sensing ET products over TGEs
- Poor performance of Copernicus products: Temporal trend well captured by S2 time series but bias observed in absolute values



- Phenologically adapted models: phenophases (Martin et al 2020, *Revista de Teledetección*)
- Hyperspectral information (SWIR data specially important)
- NPV and flowering to be included in RTMs
- Towards functional diversity via plant traits
- Three-source energy balance model (3SEB): improve ET estimation and allows to separate transpiration sources
- Sentinel-2 biophysical retrieval method may need to be adapted to better simulate for tree-grass ecosystem



Thanks!

ANY QUESTIONS?

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