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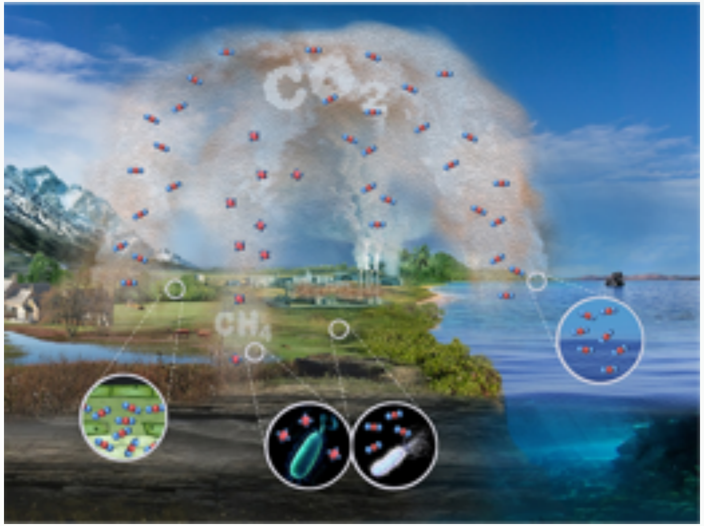
Introduction

- "Land and ocean ecosystems act as natural buffers that limit the increase of CO_2 in the atmosphere by absorbing and sequestering nearly half of emitted CO_2…" Kaushik et al., 2020
- "… space-based observations, field experiments, and models all contribute to our evolving understanding of the ways that Earth's systems absorb and release carbon…." Kaushik et al., 2020
- New hyperspectral data streams, in combination with advanced methods, enable to repetitively estimate functional vegetation traits, such as **non-photosynthetic vegetation biomass** and thus stored carbon content!



Earth's global carbon cycle includes major carbon sinks and sources. (Inset diagrams show key processes in the carbon cycle, such as plant and microbial respiration and ocean-atmosphere exchange.) Decades of global measurements can now help us understand how ecosystems respond to climate change and how this response will change the carbon budget in the future. Credit: The authors and David Hinkle, NASA/JPL-Caltech https://eos.org/features/the-future-of-the-carbon-cycle-in-a-changing-climate

Non-photosynthetic vegetation (NPV)

Amargosa wetlands, Photo: Rob Klinger/USGS

NPV refers to plant parts that **cannot perform photosynthesis**, such as dead vegetation, plant litter, or senescent foliage, branches and stem tissues.

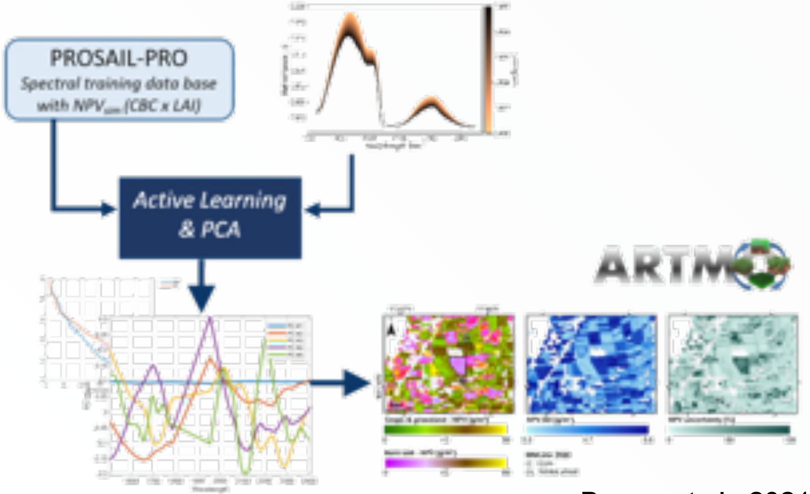
For agricultural applications:

- NPV biomass (e.g. in g/m^2), as standing vegetation, indicates environmental stress (drought), influences yield.
- Crop residue (CR) cover on the soil surface or a protective mulch, being **essential agricultural conservation practice:**
    - **significantly reduce wind and water erosion, and with this nutrient loss;**
    - **contribute to the maintenance of soil organic carbon (SOC) stores;**
    - **SOC loss can be buffered or offset by returning all crop residues to the soil (Stella et al., 2019).**

Objective

The objectives of this study were to:

- perform a **literature survey** about inference of NPV in agriculture using hyperspectral data;
- propose a **hybrid modelling workflow** for the quantification of NPV biomass over agricultural areas from hyperspectral data;
- test **mapping capabilities of the established prototype model** on recent spaceborne imaging spectroscopy scene.

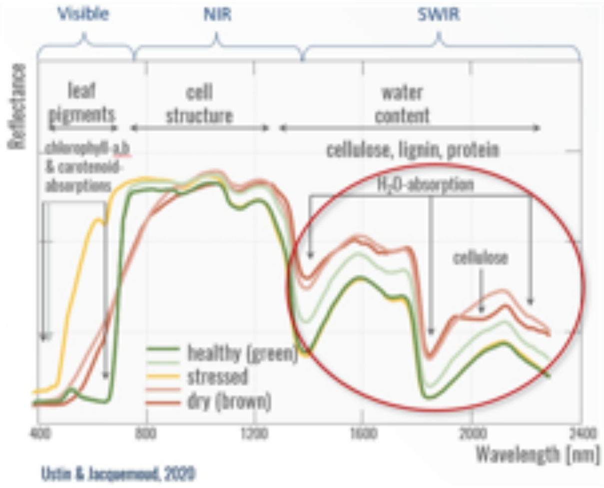


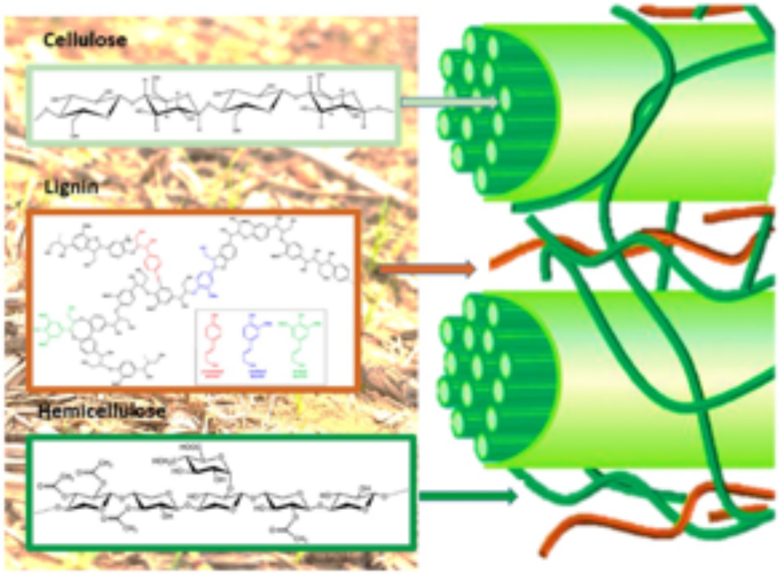
Berger et al., 2021

Physiology: Lignocellulosic biomass

- NPV and thus also LB are mainly composed of the polysaccharides **cellulose** and **hemicellulose**, the aromatic polymer **lignin** and starch, being the most ***abundant molecules produced by terrestrial photosynthesis.***

- LB is characterized by high **carbon to nitrogen (C/N)** ratios (more than 50!)





Structure of lignocellulosic biomass with cellulose, hemicellulose, and lignin.

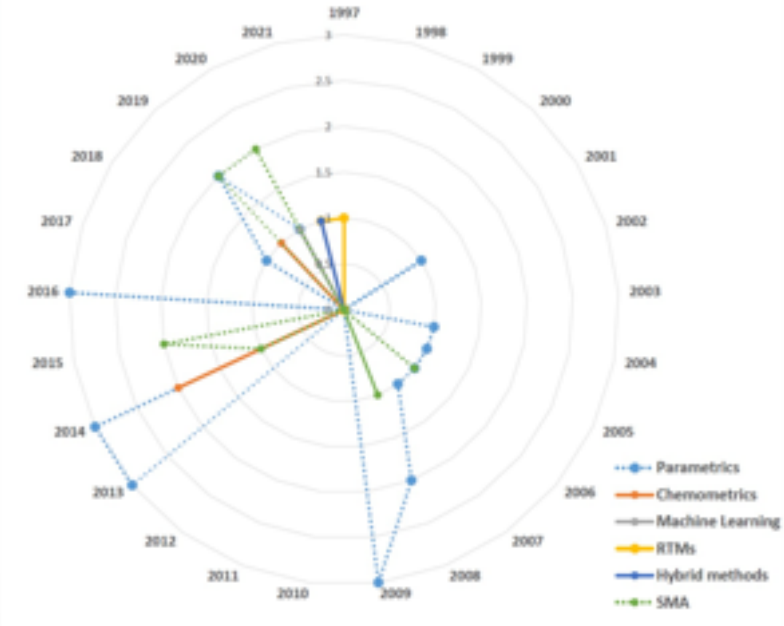
Source of cellulose and hemicellulose chemical structures from Hu (2020), lignin from Renault et al. (2017), inspired by Leahy (2016) (Fig. 1.3).

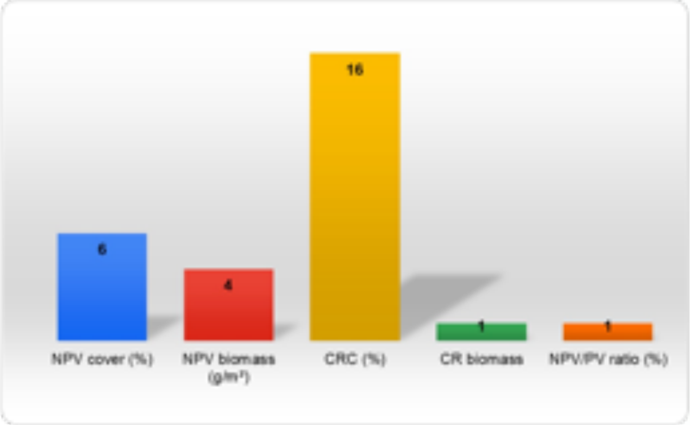
Outcome of the NPV survey

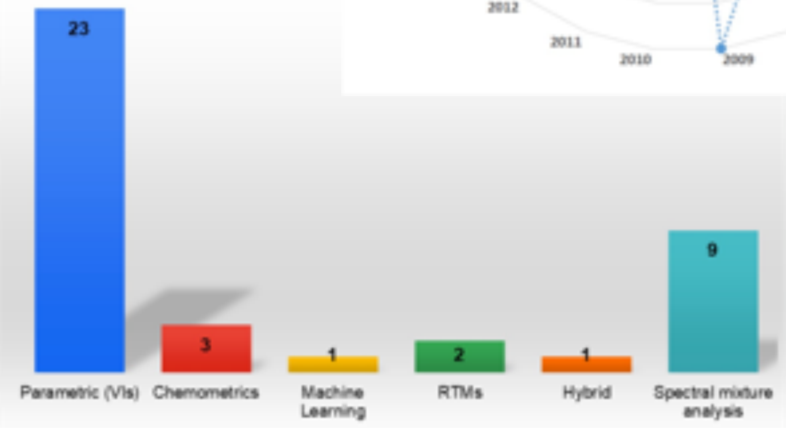
Search keywords: "Hyperspectral & NPV / CR & Agriculture"

- **31 peer-reviewed articles** could be considered as eligible, based on **systematic scanning process**

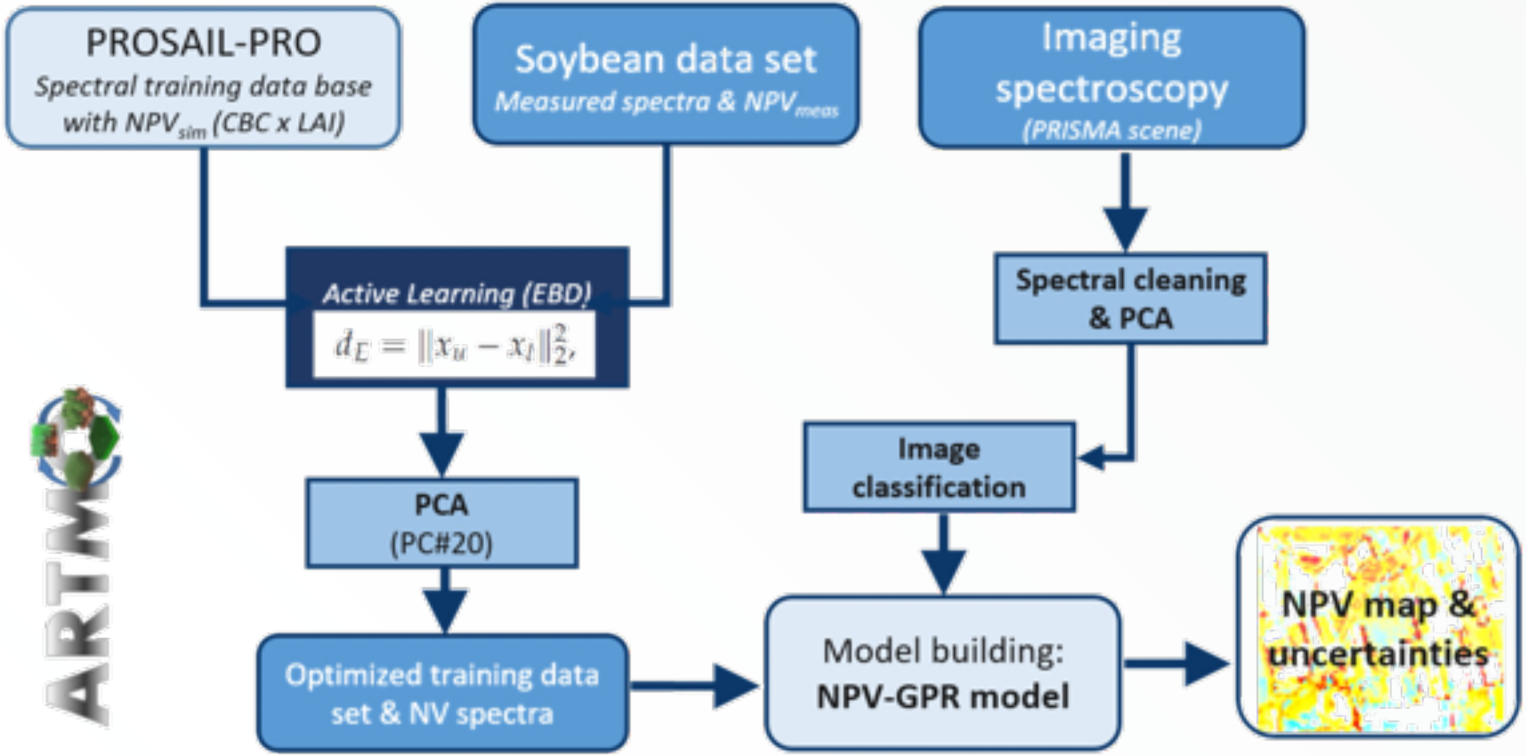
- **Main outcomes:** mostly focus on % (not biomass), mainly simple approaches, i.e. VIs and almost no use of RTMs or ML, also no visible trend in time…







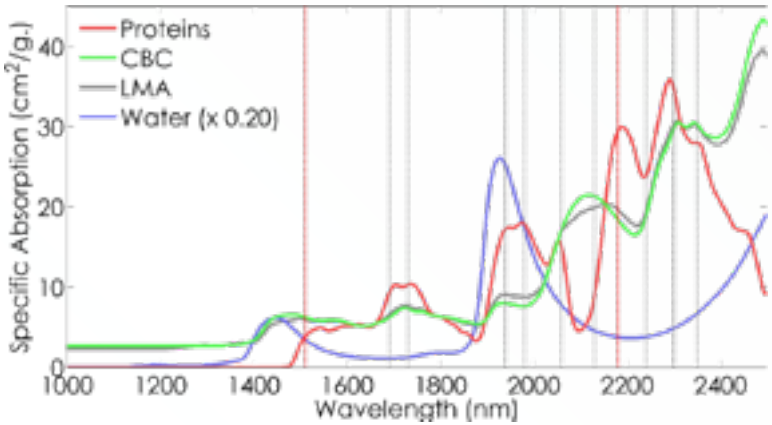
Hybrid modeling workflow for retrieval of NPV biomass



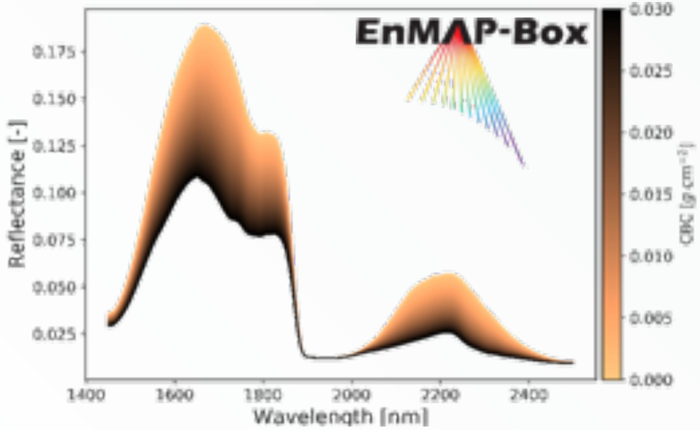
Training data set - PROSAIL-PRO

- **PROSPECT-PRO** (Féret et al., 2021): latest version of the leaf optical model PROSPECT, splitting leaf dry matter (LMA) into proteins and carbon-based constituents (CBC) in g/cm².
- Leaf-level **CBC** variable was up-scaled to the canopy-level by multiplying with LAI (4SAIL; i.e., PROSAIL-PRO model) resulting in simulated aboveground CBC or NPV_{sim} in g/m^2:

$$NPV_{sim} = LAI \cdot CBC \cdot 10,000$$



Specific absorption coefficients of leaf constituents in the shortwave infrared (SWIR) domain (Féret et al., 2021).



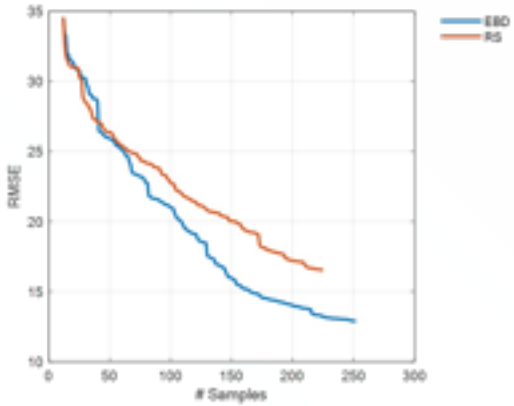
Local sensitivity analysis of carbon-based constituents in the SWIR, using the IVVRM tool of the EnMAP-Box Agri-Apps.

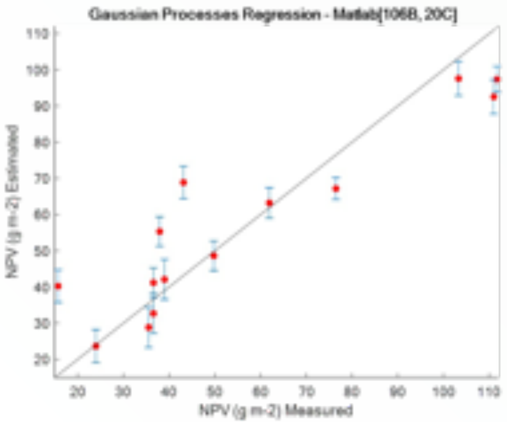
Non-photosynthetic cropland biomass mapping

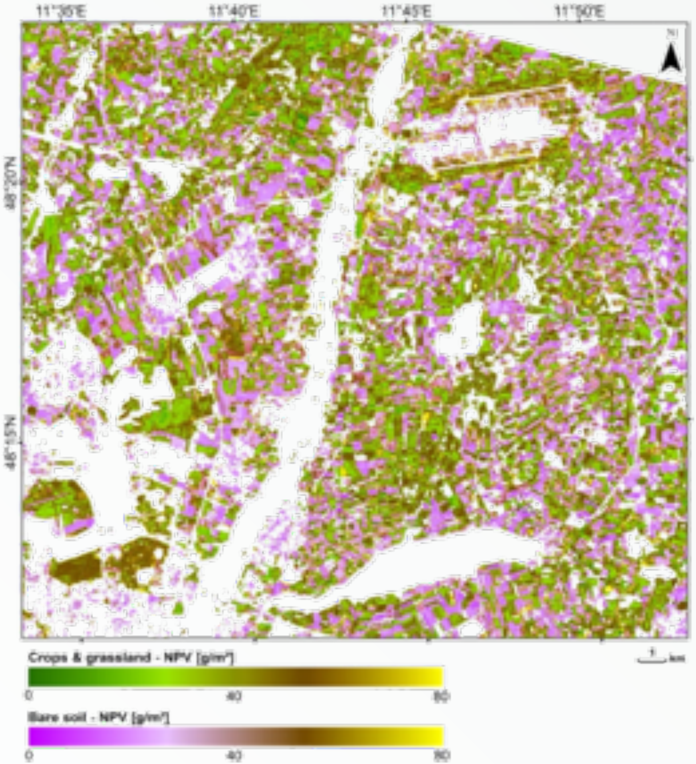
NPV model tuned with **AL-EBD** (see below) delivered **good validation** results ($R^2 = 0.85$, nRMSE = 13.4%) → model can be used for **mapping**!

PRISMA scene over North of Munich, Bavaria, acquired in *October 2020*. Subset includes LMU campaigns site **Munich-North-Isar** (EnMAP validation site).

Mapping of **non-photosynthetic cropland biomass** (right), based on the hybrid workflow using **GPR** trained over AL-optimized PROSAIL-PRO simulated data base.







ARTMO
https://artmotoolbox.com

Conclusions & Outlook

- Survey indicates limited number of studies estimating **NPV biomass - this may change with the new missions!**

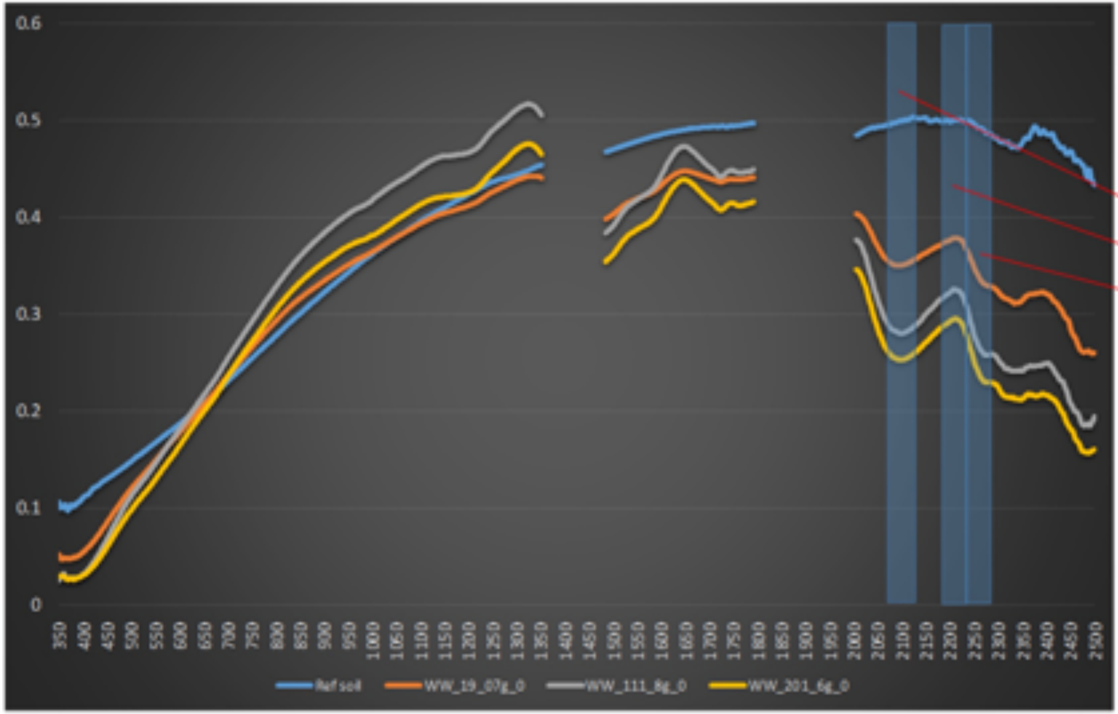
- Hybrid workflow presented for the retrieval of NPV biomass and successful mapping of (agricultural) areas with NPV (CR) using a PRISMA scene.

- NPV-GPR model provided *associated uncertainties* of the estimates, informing about transferability of the model in space and time.

- *Further refinements* needed to ensure the development of robust models by the time of the CHIME (and other) satellite launch (extensive validation required!)

- Workflow presents a **promising path towards operational mapping of global NPV biomass** by means of near-term imaging spectroscopy data streams
  - to understand where in the world are these **huge carbon storages**
  - to be assimilated in **process/ climate models**

NPV experimental measurements: Sentinel-2 NG



Measurements performed by Stefanie Steinhauser (Laboratory, LMU Munich)

Additional three proposed bands for Sentinel-2 Next Generation (thanks Marco 😊!)

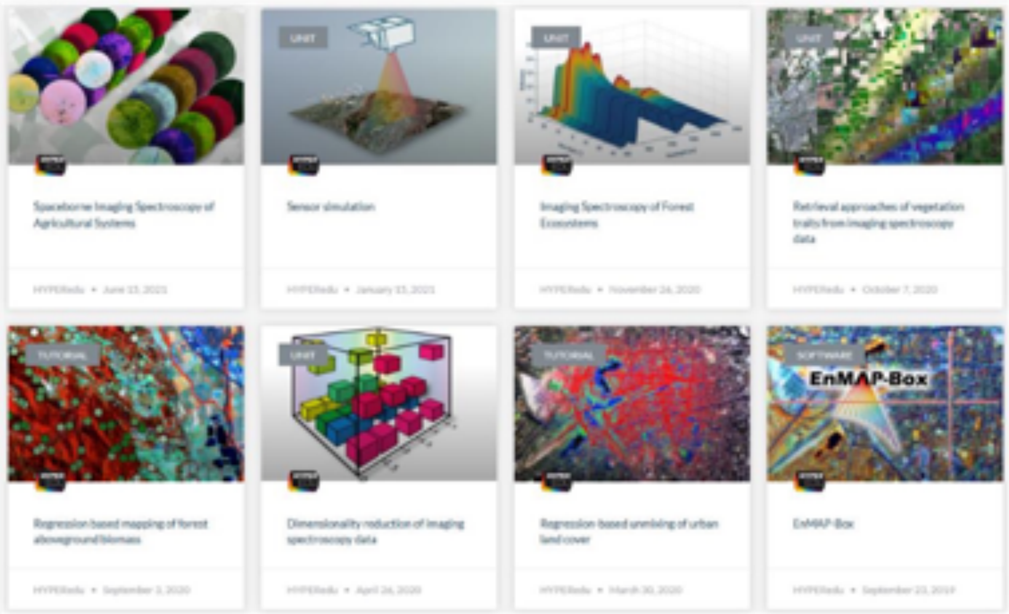
- 2100/2130
- 2210 and
- 2260 nm

(green/brown LAI, NPV, separation of soil vegetation, …)

All proposed bands are still **to be confirmed**!
Please contact
Marco Celesti (ESA) for feedback and more information on the bands

Thank you for following!

Any questions?



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Title and Layout Images from left to right: (1) ESA adapted - Great Barrier Reef, (2) ESA adapted - Mont Saint Michel, (3) KARI/ESA adapted - Namib Desert, (4) ESA adapted - Amsterdam, (5) ESA adapted - Uruguay River Wetlands, (6) EUSI/ESA adapted - Algerian Sands, (7) ESA adapted - Kenya, (8) ESA adapted - Namib Naukluft

Vector Graphic Elements: www.allppt.com, http://www.free-powerpoint-templates-design.com

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