BioSpace25 - Biodiversity insight from Space
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Towards mapping ecosystem resilience from space:
Canopy defensive properties in European temperate forest revealed with spaceborne imaging spectroscopy

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What are plant defensive traits?

Primary biochemicals

Growth, reproduction
(e.g., lignin, sugar, nitrogen, pigment, and protein)

Secondary biochemicals

Defense, mediation, pollination
(e.g., ***phenolics***, alkaloids, and terpenoids)
pollination

Physical defences

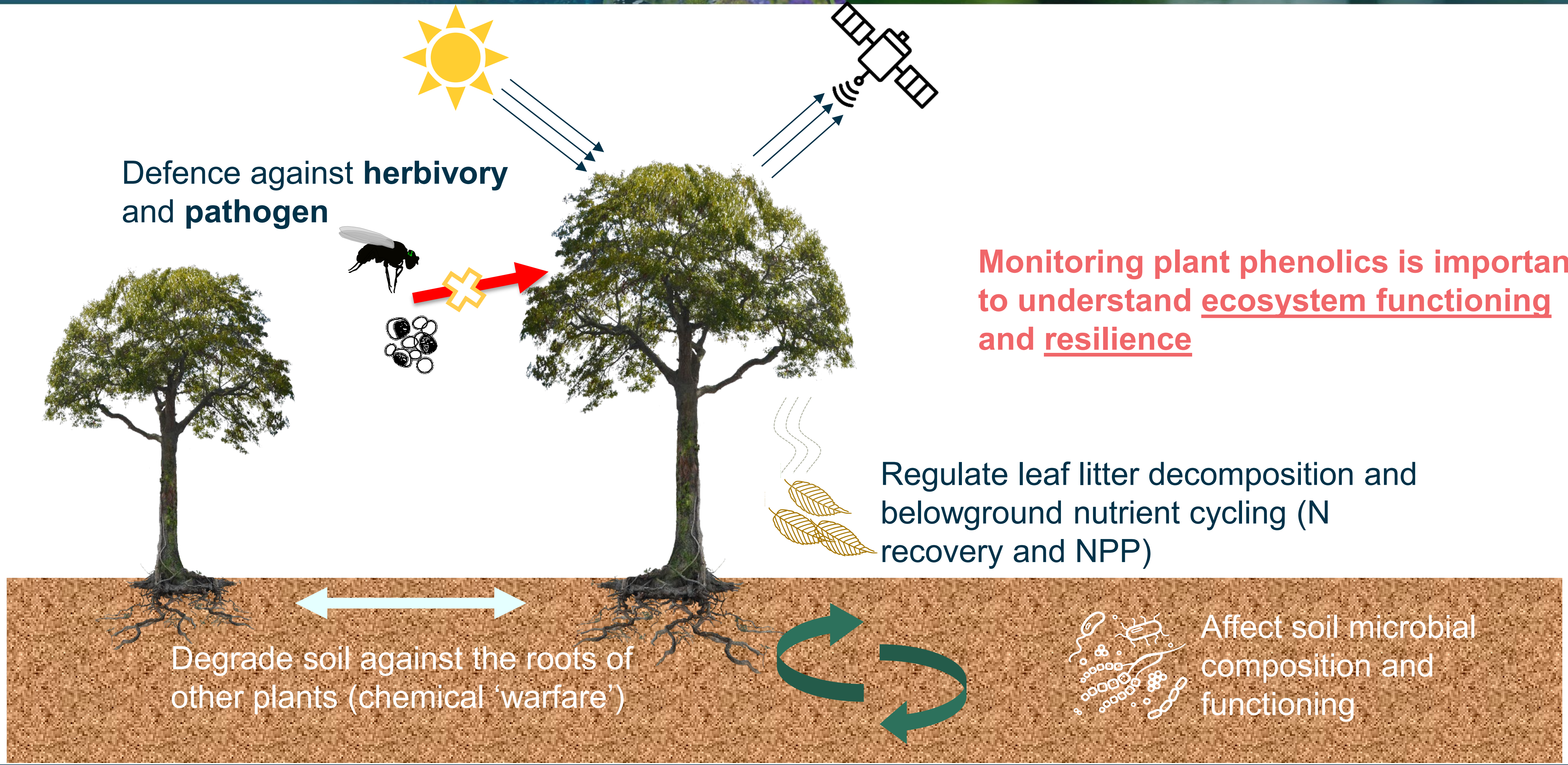
Chemical defences

Credit: University of Utah, Learn genetics

Plant phenolics are:

- the most important **non-structural carbon** constituents (**EBVs** candidate);
- widely studied for plant-defence mechanisms (known as plant "**chemical defensive traits**");
- **indicator of stresses** sourced from: heavy metal toxicity, air pollution, photodamage, etc.

Why plant phenolics?



Research objective

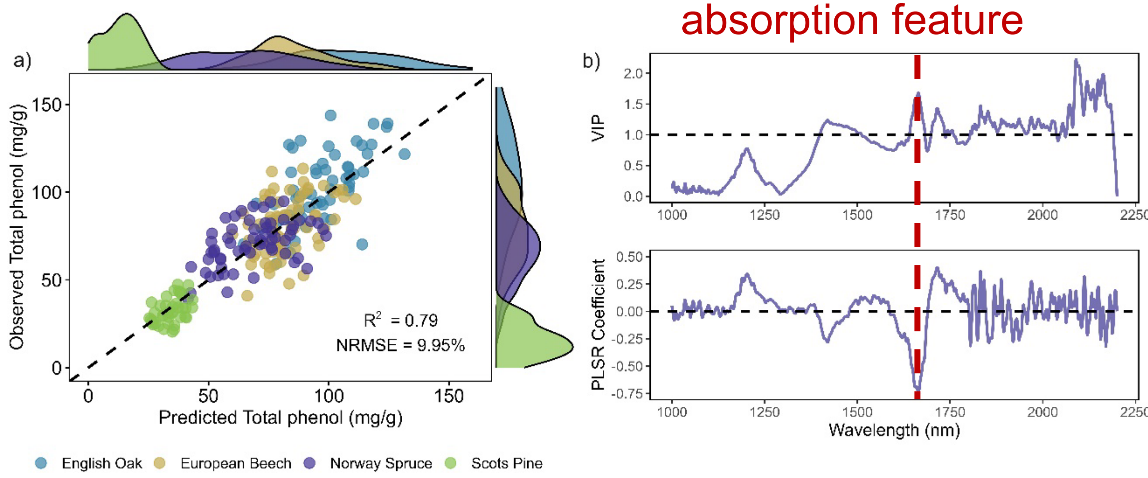
Leaf-level phenolic models successfully **established** for temperate fresh leaves (Xie et al., 2024);

? Spatially continuous information on plant phenolics are **missing**;

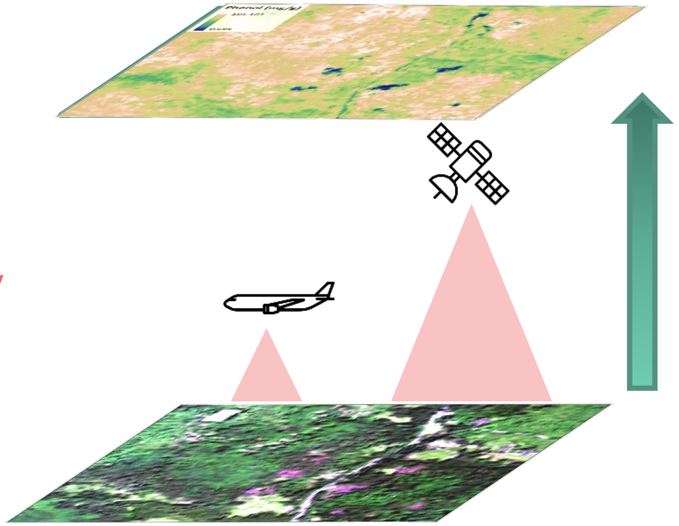
Imaging spectroscopy is a powerful tool to **characterize canopy properties across landscapes**

OBJECTIVE: to evaluate the potential of imaging spectroscopy for mapping canopy phenolic content in EU temperate forests

1.66 μm phenolic absorption feature



Xie et al., 2024

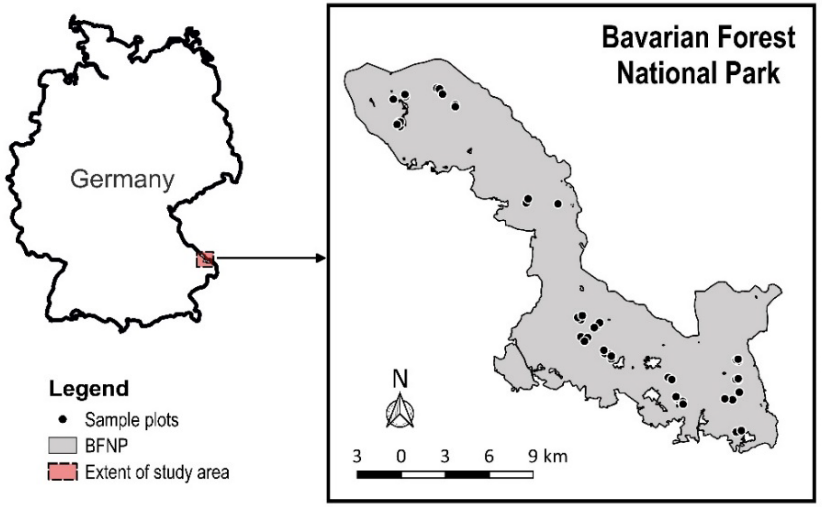


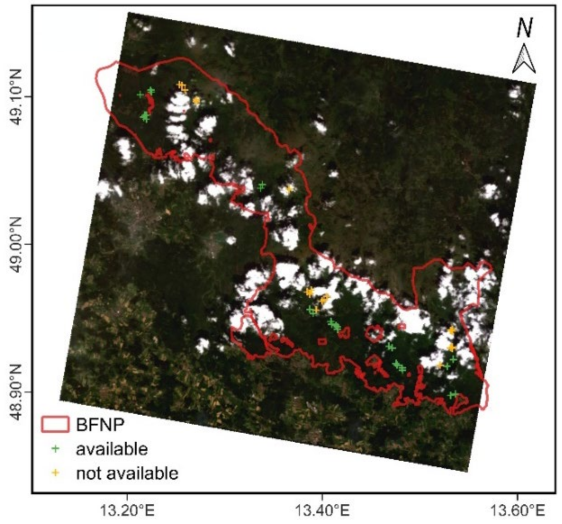
Data acquisition

- Study area: Bavarian Forest National Park
- Dominant species: **Norway spruce** (*Picea abies*, 67%) and **European beech** (*Fagus sylvatica*, 24.5%)

- Fieldwork in summer 2021
- Sunlit top-of-canopy, 46 plots (30 × 30 m)
- **Stratified sampling** based on dominant canopy species > 80%

- Imaging spectroscopy data: PRISMA (2021-06-15)
  - 400–2500 nm
  - 231 bands
  - 30 m spatial resolution

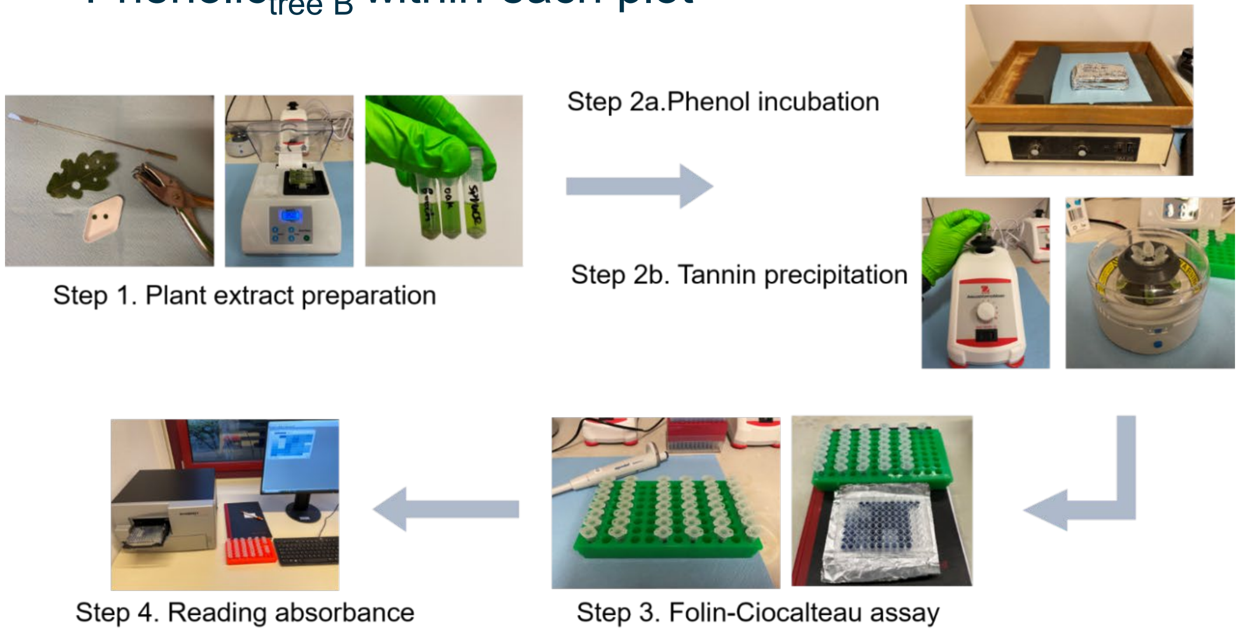




Method

Determination of total phenol and tannin content:

- Folin-Ciocalteau approach
- Protocol modified based on Ainsworth and Gillespie (2007) and Makkar (2007)
- Plot-level phenolics: averaging of $Phenolic_{treeA}$ and $Phenolic_{tree\ B}$ within each plot



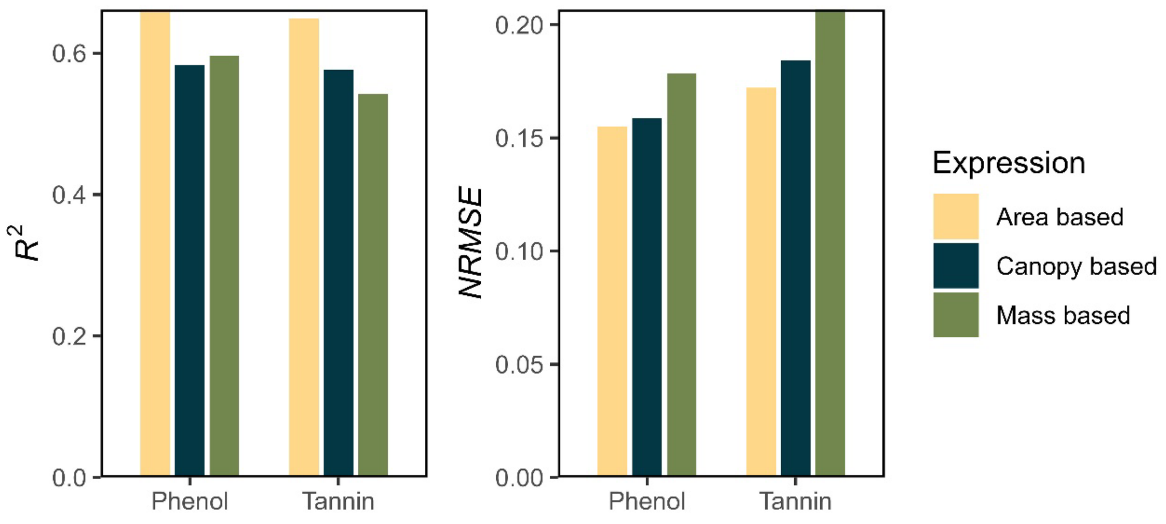
Modelling of plant phenolics:

- Partial least square regression (PLSR)
  - ✓ Cheap computational cost
  - ✓ Widely-used: allowing for comparison with other studies
- Band importance evaluation: PLS-VIP
- Expressions of phenolics:
  - ➢ foliar mass-based
    - ↓ × LMA
  - ➢ foliar area-based
    - ↓ × LAI
  - ➢ canopy-based

Model performance

Accuracy assessment:

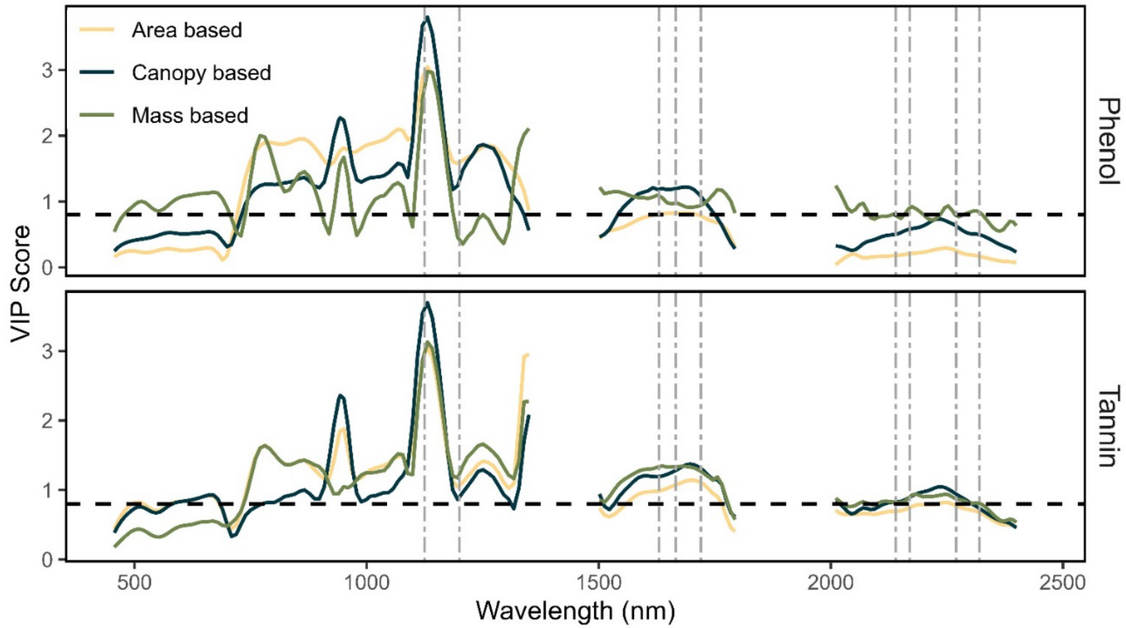
- Total phenol and tannin were both retrieved with reasonable accuracies;
- Foliar area based phenolics have stronger correlation with spectral reflectance



Xie et al. (2025, in prep.)

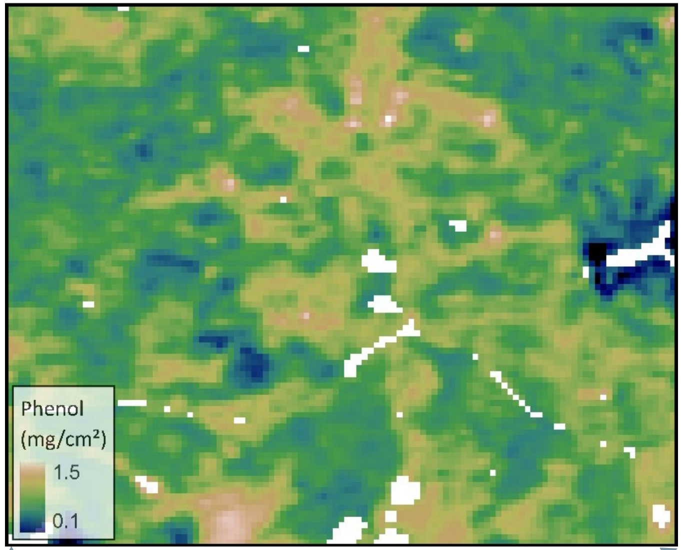
Band contribution:

- The informative wavelengths are overlapped with some known bands sensitive to phenolic compounds.
- Model leveraged correlation between phenolics and other plant biochemicals

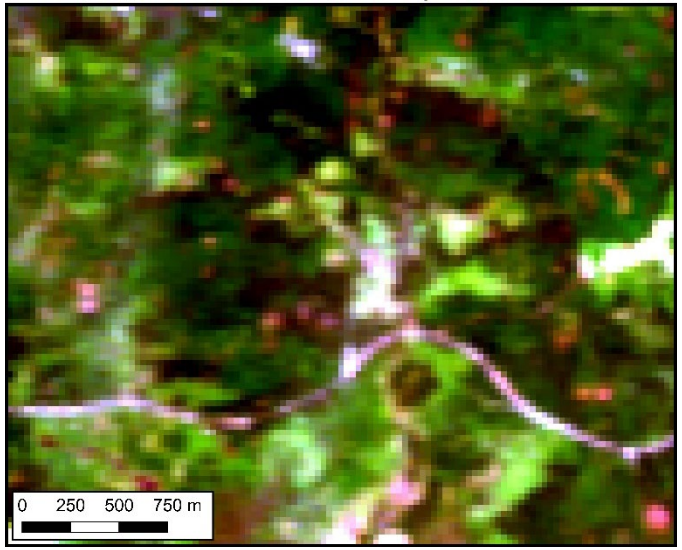


Mapping canopy phenolics

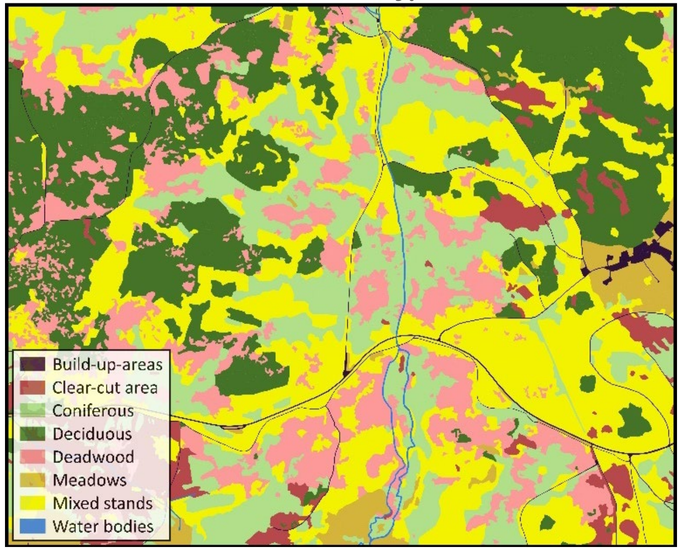
Phenol map (PRISMA)

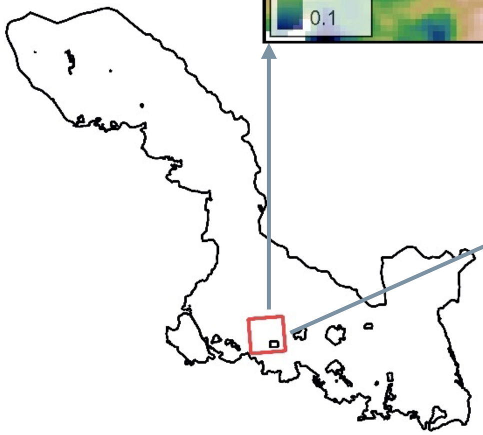


PRISMA RGB image



Landcover map

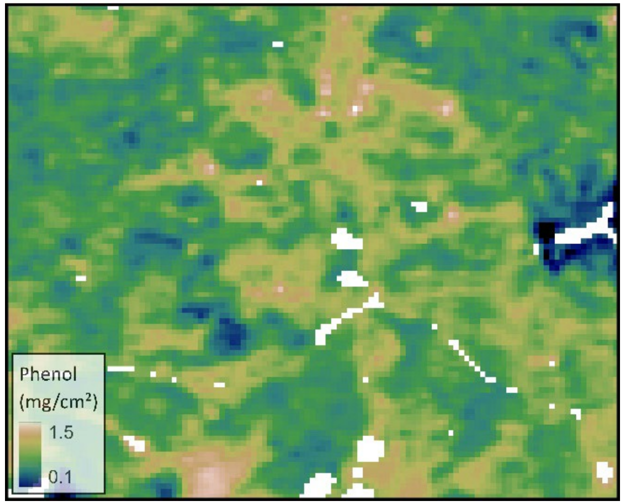




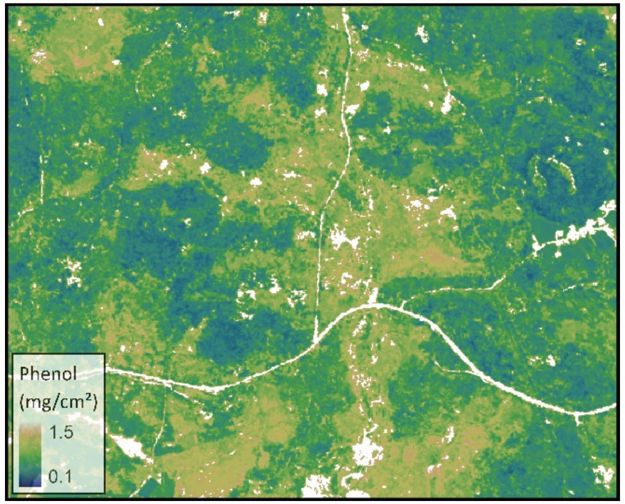
- Phenolic spatial patterns across landscape:
  - Higher phenol values in transitional zone (mixed stands) and conifers;
  - Difficult to capture variations for small forest patches.

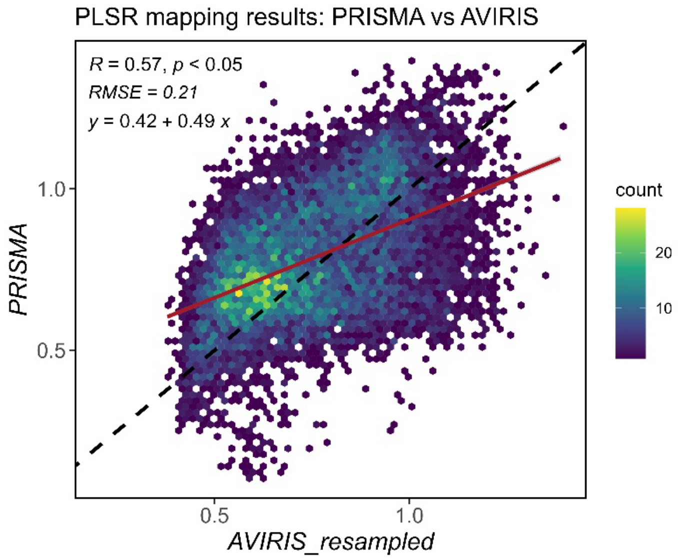
Spaceborne vs. Airborne

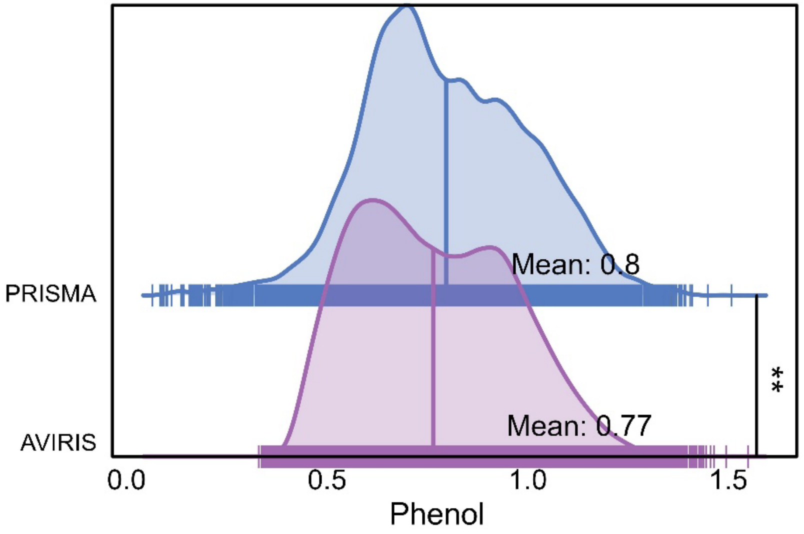
PRISMA – PLSR



AVIRIS – PLSR



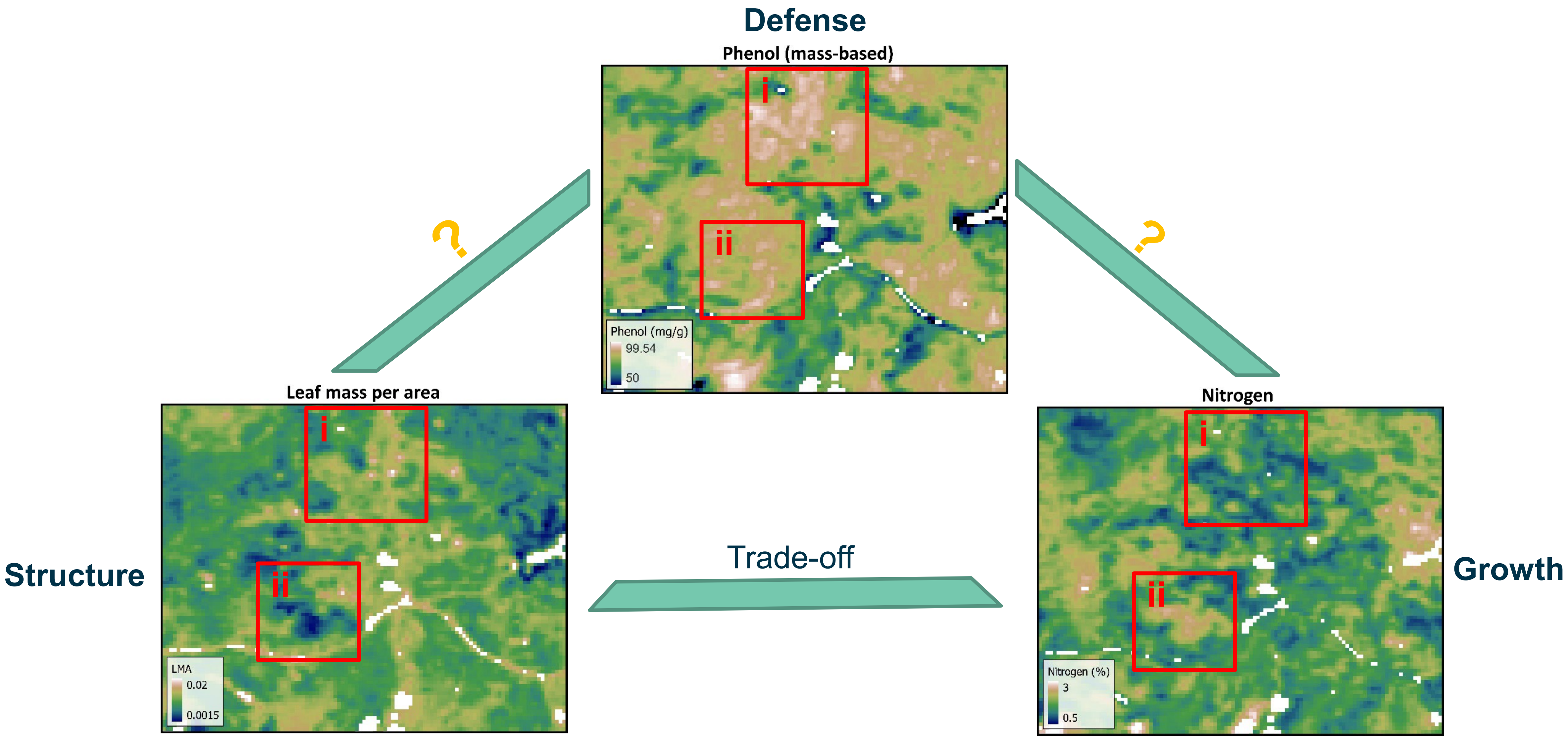




Xie et al. (2025, in prep.)

- **Spatial pattern** was **consistent** between **spaceborne** and **airborne** derived maps;
- Predicted values and data distributions are well-correlated;
- AVIRIS better captured **intra-species phenolic variations** compared to PRISMA;

Trait co-variation



Future works & key recommendations

Outlook for the future:

- Spanning **more biomes** to generalise our results (grassland, crop, shrub, boreal forest, etc.);
- Exploring the effectiveness of **other imaging spectroscopy data** (EnMAP, DESIS, SBG, CHIME)—work in synergy with other instrument.

Recommendations:

- Develop a **standardized protocol** for phenolic measurement to ensure **reliability**, **comparability**, **reproducibility**;
- Embed plant phenolics into existing **trait-based** ecological research;
- Understand the **response** of plant to stressors via modelling **dynamics** of defensive traits (and other functional traits);

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Thanks for your attention!

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