How are spectrally relevant plant traits distributed across plant functional gradients?

Teja Kattenborn & Sebastian Schmidlein
Rationale

- Global picture of plant functioning still remains incomplete, remote sensing as a high potential to close this gap.

- The most frequently assessed functional traits have no explicit relation to radiative transfer! → limited causality and transferability!

- ‘optical traits’ have not yet been systematically linked to functioning.
Methods

OPTICAL TRAITS

- Chlorophyll content ($\text{Cab_{area}}$)
- Carotenid content ($\text{Car_{area}}$)
- Anthocyanin content ($\text{Ant_{area}}$)
- Chlorophyll concentration ($\text{Cab_{mass}}$)
- Carotenid concentration ($\text{Car_{mass}}$)
- Anthocyanin concentration ($\text{Ant_{mass}}$)
- Leaf mass per area (LMA)
- Leaf water content (EWT)
- Leaf dry matter content (LDMC)
- Mesophyll thickness (N)
- Leaf angle distributio (ALA)
- Leaf Area Index (LAI)
- Fraction of absorbed PAR (fAPAR)
- Yearly accumulated PAR (APARcum)
- Foliage mass ($\text{LMA_{canopy}} = \text{LAI} \times \text{LMA}$)

TRAJECT MEASUREMENTS

- 42 Cultivated species (outdoor)
- grasses & herbs
- 30 * 30 cm pots, 4 repitions
- Median of weekly retrieved traits
Methods

OPTICAL TRAITS

- Chlorophyll content ($\text{Cab}_{\text{area}}$)
- Carotenid content ($\text{Car}_{\text{area}}$)
- Anthocyanin content ($\text{Ant}_{\text{area}}$)
- Chlorophyll concentration ($\text{Cab}_{\text{mass}}$)
- Carotenid concentration ($\text{Car}_{\text{mass}}$)
- Anthocyanin concentration ($\text{Ant}_{\text{mass}}$)
- Leaf mass per area (LMA)
- Leaf water content (EWT)
- Leaf dry matter content (LDMC)
- Mesophyll thickness (N)
- Average Leaf angle (ALA)
- Leaf Area Index (LAI)
- Fraction of absorbed PAR ($f_{\text{APAR}}$)
- Yearly accumulated PAR ($\text{APAR}_{\text{cum}}$)
- Foliage mass ($\text{LMA}_{\text{canopy}} = \text{LAI} \times \text{LMA}$)

FUNCTIONAL GRADIENTS

Leaf Economic Spectrum

- Slender leaves, fast growth, quick returns
- Robust leaves, slow growth, slow returns

CSR plant strategies

- Slender leaves
- Robust leaves
- Intermediates

OPTICAL TRAITS

- Leaf Economic Spectrum
- CSR plant strategies

Grime 1997

Wright et al. 2004

Teja Kattenborn - Mapping of invasive plant species with Sentinel-1 and -2 data calibrated with UAV-based training data

Institute for Geography and Geoecology (ifgg)
Results – Optical traits vs Leaf Economic Spectrum

Leaf Economic Spectrum (LES)
Significant correlation with LES
Non significant correlation with LES

Spurious correlation of LMA!
Results – Optical traits vs CSR plant strategies

- logLMA [g/cm²], R²adj 0.42
- LDMC [%], R²adj 0.43
- LAI [m²/m²], R²adj 0.36
- fAPAR [%], R²adj 0.4
- APAR_{cum} [kWh/m²], R²adj 0.57
- LMA_{canopy} [g/m²], R²adj 0.43

Energy per year

LMA * LAI
Conclusions & Outlook

- Pigments should be quantified as content [µg/cm²] and not as concentration [%]!

- Only leaf traits correspond to the Leaf Economic spectrum (LES). Canopy traits do not correspond to the LES but strongly to CSR plant strategies.

- Optical traits are a promising complement or complement to ‘traditional’ traits used in trait-based ecology!

- Causal links between optical traits and plant functioning implies that ‘Reflectance follows function’!
Thank you for your attention!

More information on this topic?

Teja Kattenborn
teja.kattenborn@kit.edu
Rationale – `optical traits´ (PROSAIL radiative transfer model)

Leaf traits

Canopy traits
Teja Kattenborn - Mapping of invasive plant species with Sentinel-1 and -2 data calibrated with UAV-based training data
Rationale

- Global picture of plant functioning still remains incomplete, Remote sensing as a high potential to close this gap.
- The most frequently assessed functional traits have no explicit relation to radiative transfer! → limited causality and transferability!
- ‘optical traits’ have not yet been systematically linked to functioning.

Why can we separate plant functional gradients?
How can we improve sensors and algorithms to differentiate plant functioning?
Can optical traits increase our understanding of plant functioning?
Results – Optical traits vs CSR plant strategies

- ALA [°], R²adj 0.27
- Cab\textsubscript{area}[µg/cm²], R²adj 0.29
- Cab\textsubscript{area}[µg/cm²], R²adj 0.52

Forbs only

Forbs only

Graminoids only