StatEO

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Deriving policy-relevant Essential Biodiversity Variables from EO multi-modal approach to assess forest condition across ecological gradients

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Motivation & Context

Climate stress on forests
Rising temperatures, droughts, fires and altered precipitation threaten forest health, regeneration and species composition

Functional diversity loss
Climate-driven disturbances erode functional diversity, the very trait buffer that makes forests resilient to future extremes

Operational monitoring gap
EBVs, linking empirical data to policy *(Pereira et al. 2013)*, are still missing at the spatial scale required by EU Biodiversity Strategy 2030 and Nature Restoration Law

The EO4Resilience project

→ Estimate **EO-based functional and structural EBVs** from hyperspectral and SAR data, simulating future CHIME and ROSE-L missions

→ Derive **functional diversity metrics** to gain understanding on the role of biodiversity in response to forest disturbances with a focus on drought

→ **Evaluate** and **interpret EBVs** and **diversity metrics** across three study sites with different ecological gradients and exposure to drought

Contribute to standardised EO-based biodiversity monitoring frameworks for policy reporting and operational forest condition assessment

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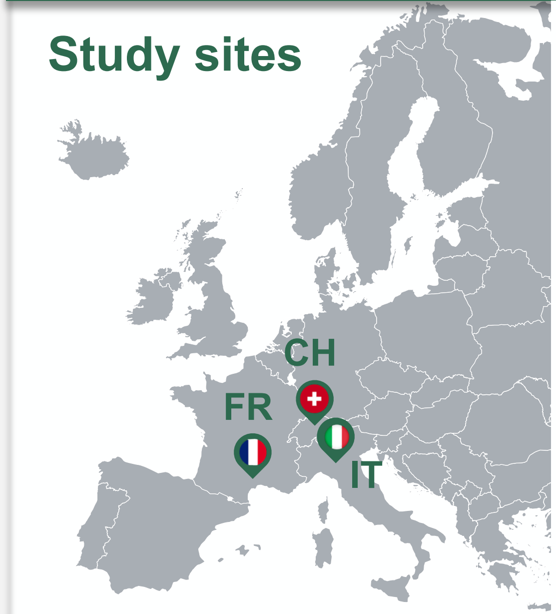
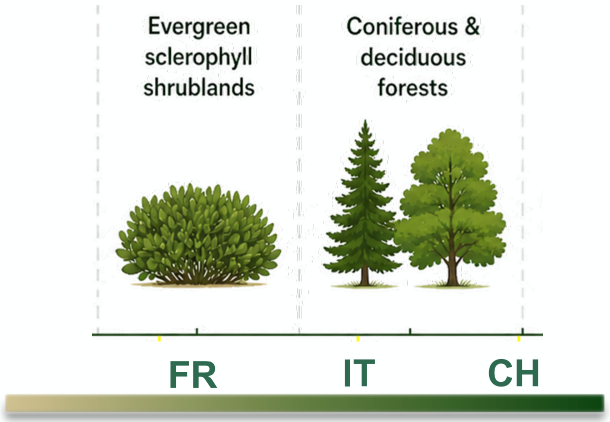
The EO4Resilience project

Study sites





Arid condition
open vegetation

Increasing moisture,
tree cover and complexity

Humid condition
closed forests

Puéchabon experimental forest (FR)

Ticino Regional Park (IT)

Lägeren experimental forest (CH)

Data availability

EO Dataset	Type	Availability
PRISMA/EnMAP (ASI/DLR)	Satellite hyperspectral	Mostly IT
AVIRIS-4 (NASA JPL/ARES)	Airborne hyperspectral	All sites
SAOCOM (CONAE)	Satellite SAR	All sites
F-SAR (DLR)	Airborne SAR	FR-CH
In-situ / Lab	Field functional and structural traits	FR-IT-CH

AVIRIS-4 → simulates CHIME
for functional traits estimates

SAOCOM → simulates ROSE-L
for structural traits estimates

Functional traits from simulated CHIME

esa

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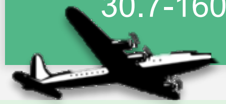
AVIRIS-4 data collection
CH-IT-FR
30.7-1608 km² surveyed



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Pre-processing
Rad: NASA JPL EMIT → Geo: PARGE → Refl: ATCOR-4
287 · 375–2500 nm · 1–3.5 m

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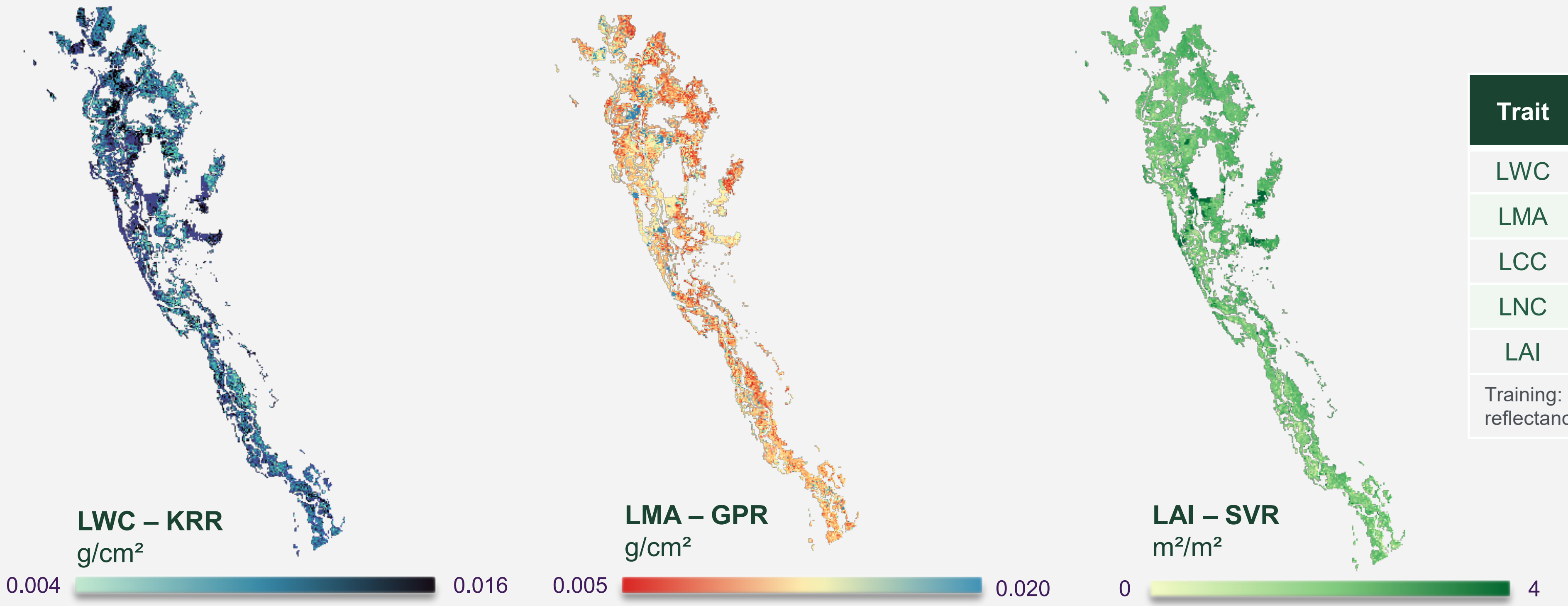
CHIME simulation
Spect: ATCOR (HS2MS) → Spat: gdalwarp (avg res.)
256 · 400–2500 nm · 30 m

Trait retrieval
ARTMO MLRA toolbox (GPR, RF, SVR, PLSR..) · Best model selected per trait

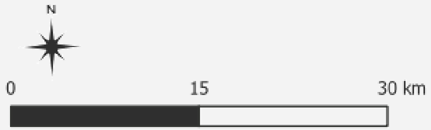
Validation vs. In-situ
5-fold cross-validation · R^2 and RMSE per trait

Target traits: Leaf Water Content (**LWC**) · Leaf Mass Area (**LMA**) · Leaf Chlorophyll Content (**LCC**) · Leaf Nitrogen Content (**LNC**) · Leaf Area Index (**LAI**)



Trait	Best MLRA	R^2	nRMSE [%]
LWC	**KRR**	0.96	6.53
LMA	**GPR**	0.86	10.81
LCC	**PLSR**	0.74	11.83
LNC	**RFR**	0.64	14.15
LAI	**SVR**	0.71	11.71

Training: in-situ measur. vs CHIME-simulated reflectance across **30 samples**



Structural traits from simulated ROSE-L

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SAOCOM data collection
CH-IT-FR
L-band · VV/VH · 10×5 m~100 scenes IT · 2022–2025

▶

sarmap
Processing
Multi-temporal speckle filtering → Dual-pol calibration (HH/HV, VV/VH)

▶

sarmap
ROSE-L simulation
SAOCOM Stripmap already matches ROSE-L nominal configuration

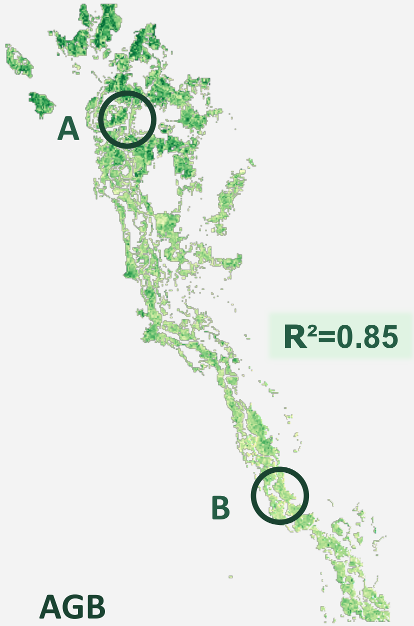
▶

sarmap
Trait retrieval
AGB: extended Water Cloud Model (WCM) + Meta Canopy Height · GF: spatial variance 7x7 + Perona-Malik filter

▶

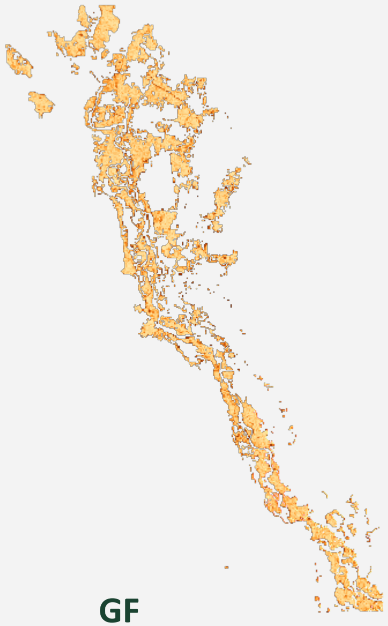
sarmap
Validation vs. In-situ
IT: calibration & validation · R² and RMSE per trait

Target traits: Above-ground biomass (**AGB**) · VH spatial covariance as proxy of gap fraction (**GF**)



AGB
Mg/ha
0

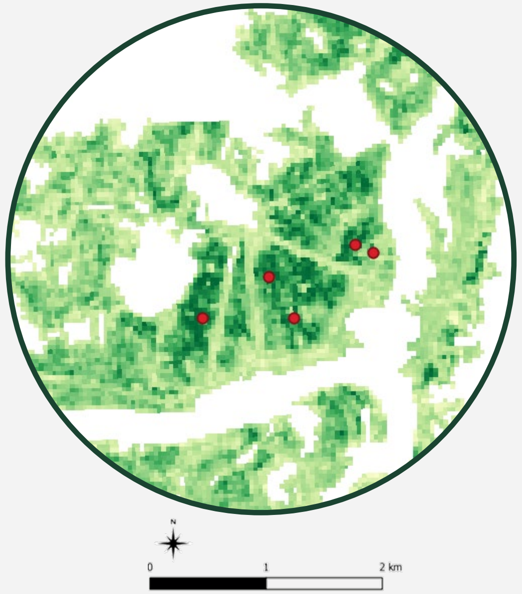
270



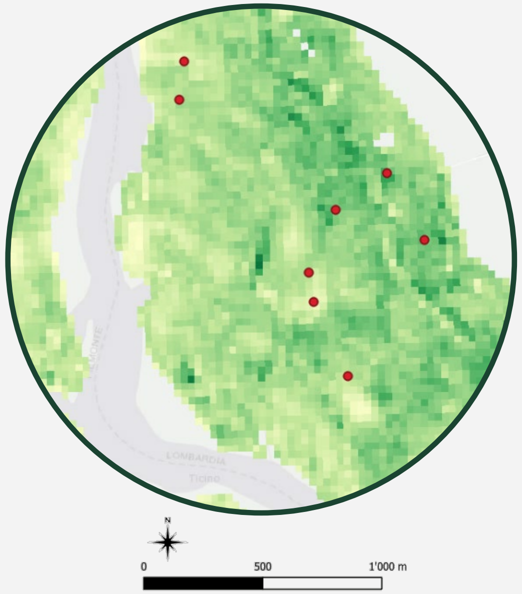
GF
spatial variance
0

0.8

A - Pitch pine stands (high AGB)



B - Xeric oak (low AGB)



Functional diversity Indicators – dual input

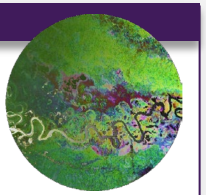
Input

Funct. traits
- LWC
- LMA
- LCC
- LNC

Struct. traits
- LAI
- AGB
- GF

HSI-derived | SAR-derived

biodivMapR approach
(Féret et al. 2019)

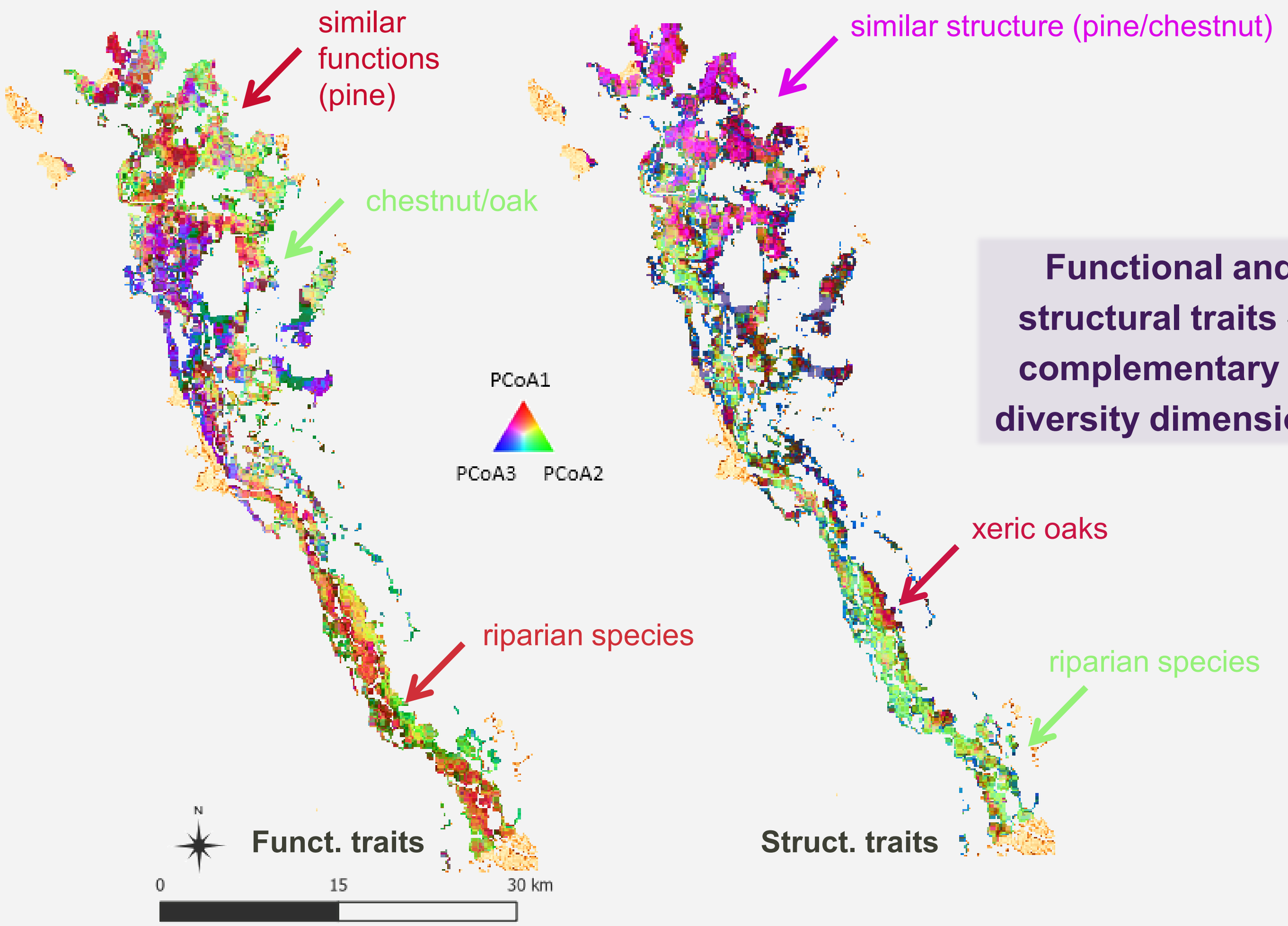


Main hypothesis: Plant species are spectrally separable, greater spectral variability reflects greater biodiversity

Processing steps:

- dimensionality reduction using principal component analysis (PCA)
- k-means clustering into 20 spectral species
- computation of β and functional diversity maps (FRic, FEve) using a mapping window of 150 m

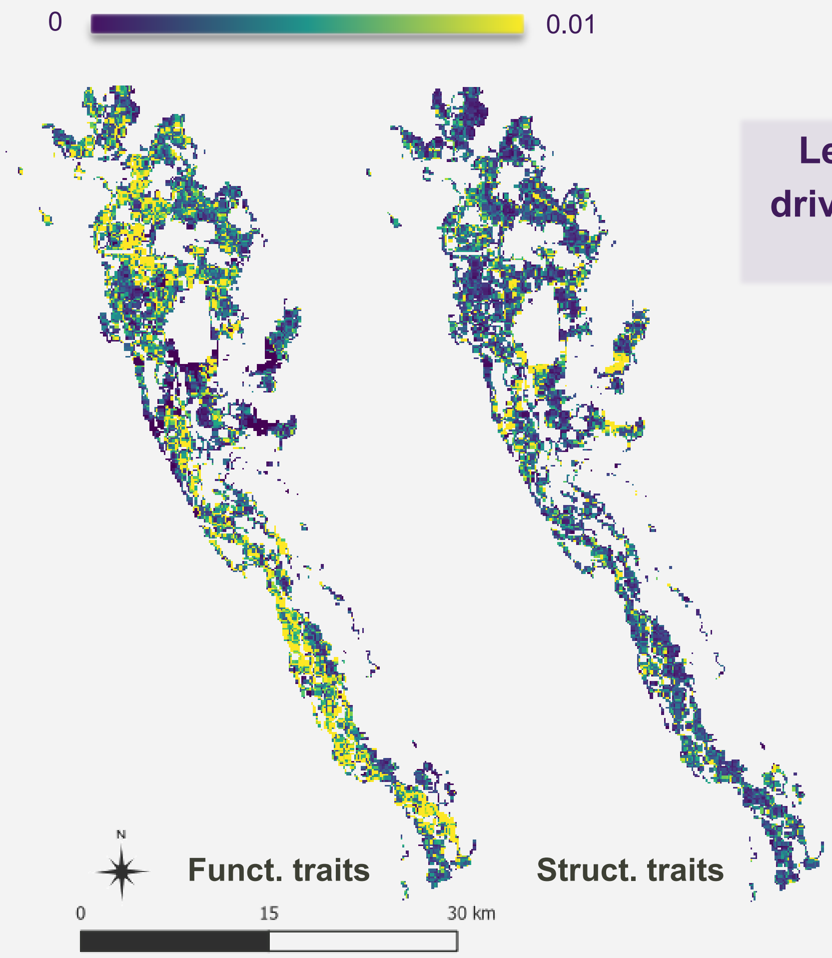
β-diversity
Bray–Curtis dissimilarity matrix



Functional and structural traits → complementary β-diversity dimensions

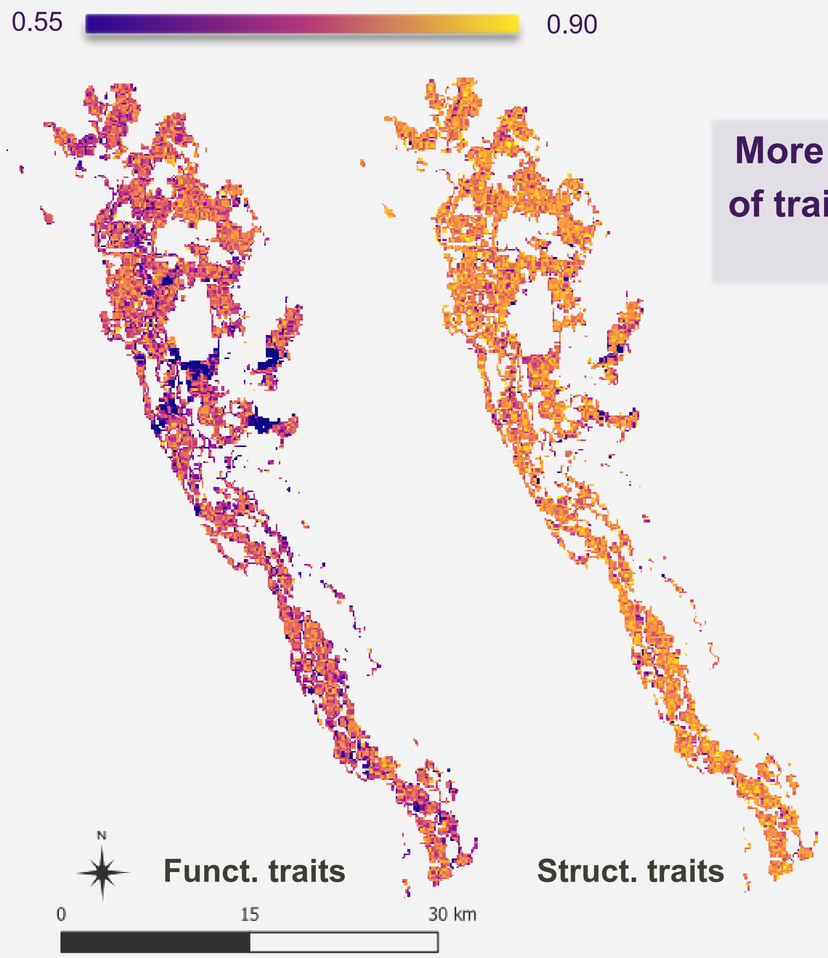
Functional diversity Indicators – dual input

Functional Richness (FRic)
volume of functional space



Leaf-level diversity drives FRic more than struct. traits

Functional Evenness (FEve)
regularity of functional distribution



More even exploitation of trait space for struct. traits

Conclusions, future work & key recommendations

Conclusions

- **CHIME and ROSE-L** enable **accurate mapping of EBVs** from space, combining hyperspectral and SAR information
- **Functional diversity** derived from plant traits **shows different patterns** compared to structural traits, often providing complementary ecological information
- CHIME and ROSE-L can **establish a baseline** of functional diversity, which is essential to monitor changes over time, especially in the context of climate change-driven biodiversity decline

Future work

- **Interpret diversity maps** along ecological gradients across the study sites, to better understand environmental drivers of variability
- **Analyze functional diversity patterns** in relation to forest **resilience to drought**, using time series (e.g. Sentinel-2) to identify resilient vs non-resilient areas based on post-disturbance recovery.

Three recommendations

01 Invest in complementary EO missions

Hyperspectral and SAR traits capture non-redundant biodiversity dimensions. CHIME and ROSE-L should be operated jointly as a coordinated observing system to enable comprehensive EBV mapping from space

02 Standardise cross-site validation protocols

Transferability across ecological gradients requires harmonised in-situ protocols and open EO benchmark datasets. Community-agreed standards are essential to move from site-specific results to operational, reproducible EBVs

03 Bridge EO products and policy reporting

EO-derived functional diversity indicators are scientifically increasingly used but not yet integrated into EU reporting frameworks. A structured dialogue between EO community and policy bodies is needed to operationalise EBVs

Thank you for the attention!

EO4Resilience
Share your perspective on EO-based biodiversity and resilience monitoring

FOR ANY FURTHER QUESTION

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