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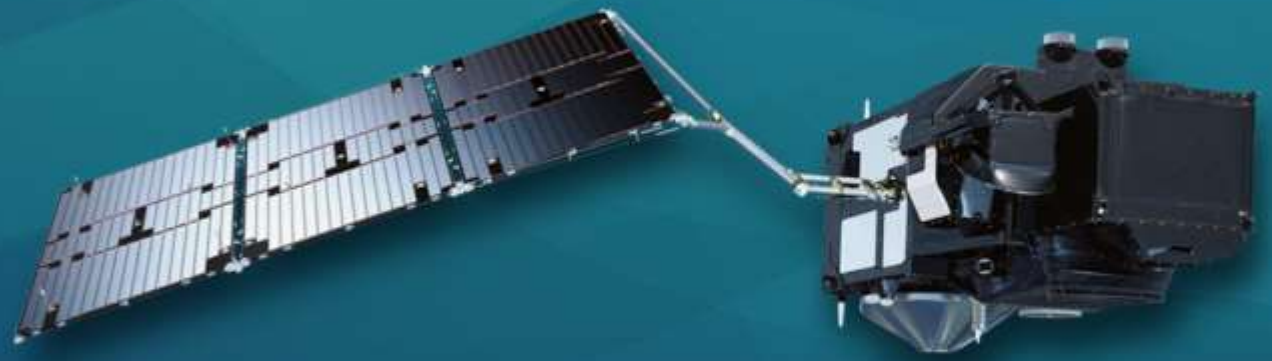


9th Sentinel-3 Validation Team meeting 2026

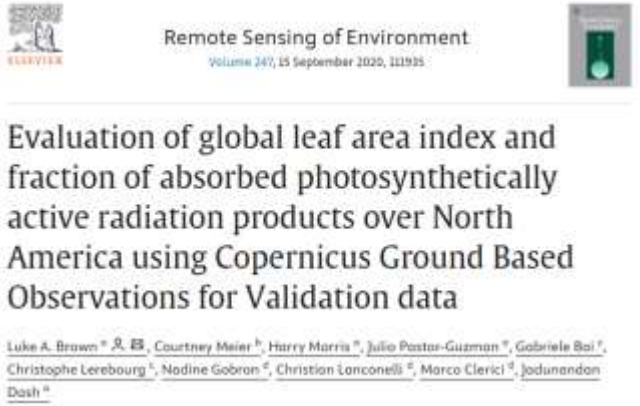
30 March–01 April 2026 | ESA–ESRIN | Frascati (Rome), Italy

Quantifying up-scaling uncertainty of GBOV biogeophysical land products using 3D radiative transfer virtual vegetation scenes

Christian Lanconelli[1], Nadine Gobron[2], Mirko Marioni[1], Fabrizio Cappucci[2] and Marco Clerici[2]
(1) Unisystems, (2) European Commission Joint Research Centre

Context

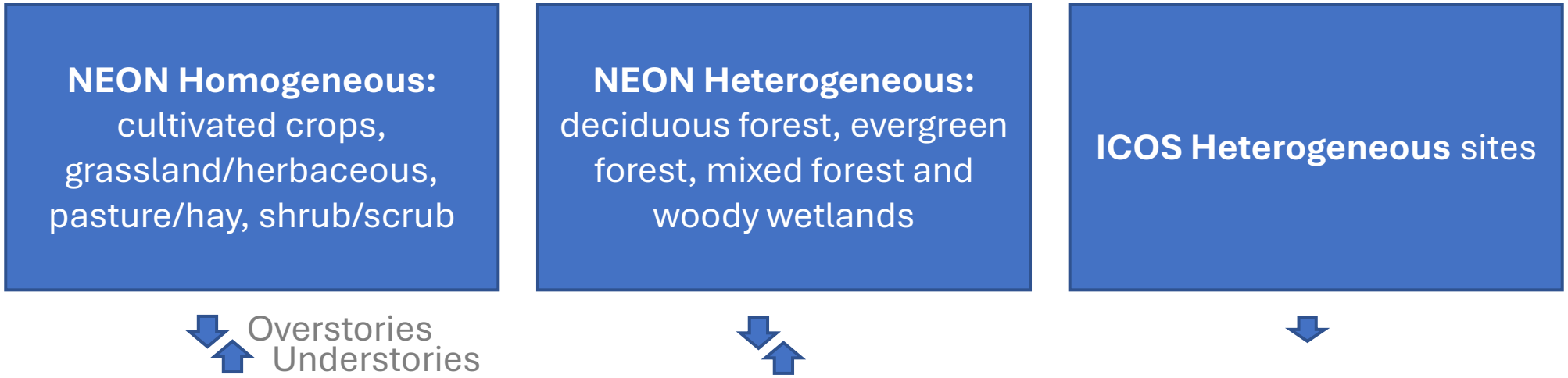
- GBOV as a connection between field activities and remote sensing CAL/VAL
  - harmonization, upscaling, uncertainty, …
- Vegetation products:
  - Reference measurements: RM4-6-7
  - → Upscaled Land Products **(ARD)** LP-3 (LAI), LP-4 (FAPAR) and LP-5 (FCOVER)
- Contributing Networks and (DHP) sampling approach
  - NEON
  - ICOS (San Rossore IT-SR2)
- S2-MSI (or OLI) Red and NIR bands (b4, b8a for MSI), θ_v
- Upscaling based on Transfer Functions
  - using SL2P (over sparse veg) or SAVI as predicting variables



Current approach

- From GBOV ATBD
  - *"Ideally, calibration function specific to vegetation type might provide a better upscaling function."*
  - *"However, as there were **few matchups** between RMs and SL2P's retrievals for some sites, it is not possible to process one calibration function per site"* …

→***Three transfer functions*** *based on SL2P's outputs (re-calibrated) over …*



But "SL2P cannot work on sparse veg as most pixels are classified as bare soil" …

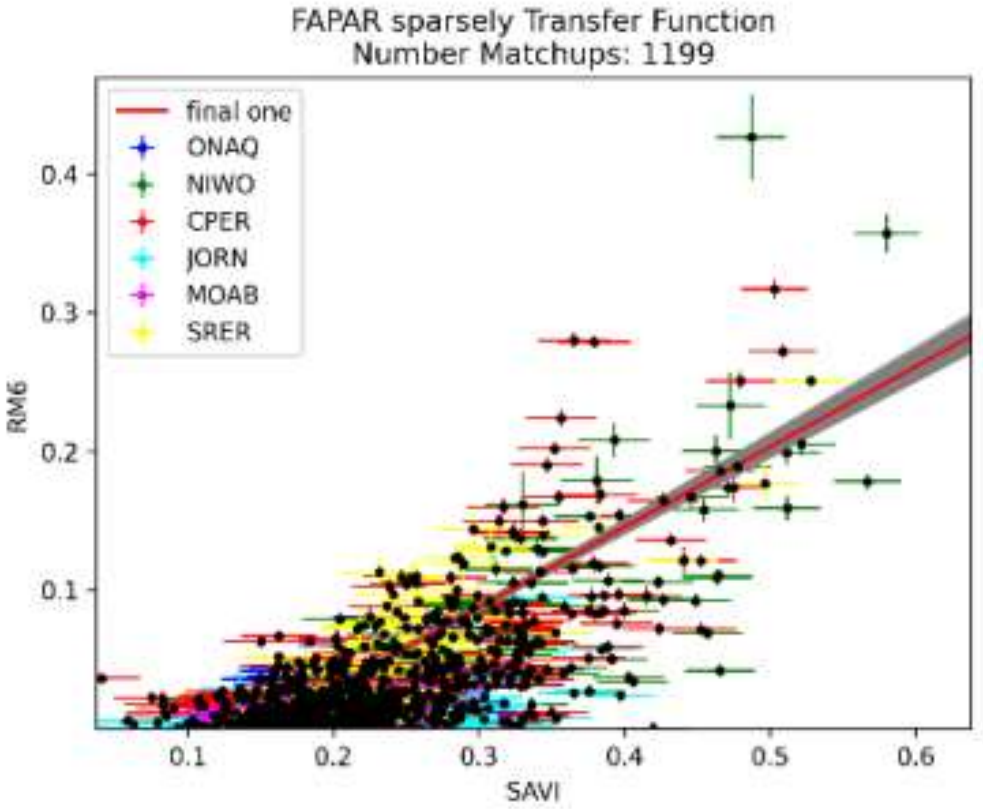
Transfer Functions based on SAVI (over sparse veg)

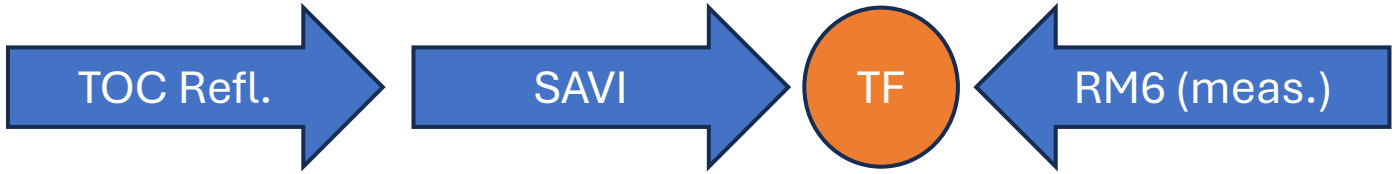
$f(SAVI) = a + b\,SAVI$ FAPAR, FCOVER

$f(SAVI) = a + e^{b\,SAVI}$ LAI

$SAVI = 1.5 \times$ (Nir-Red) / (Nir+Red+0.5)

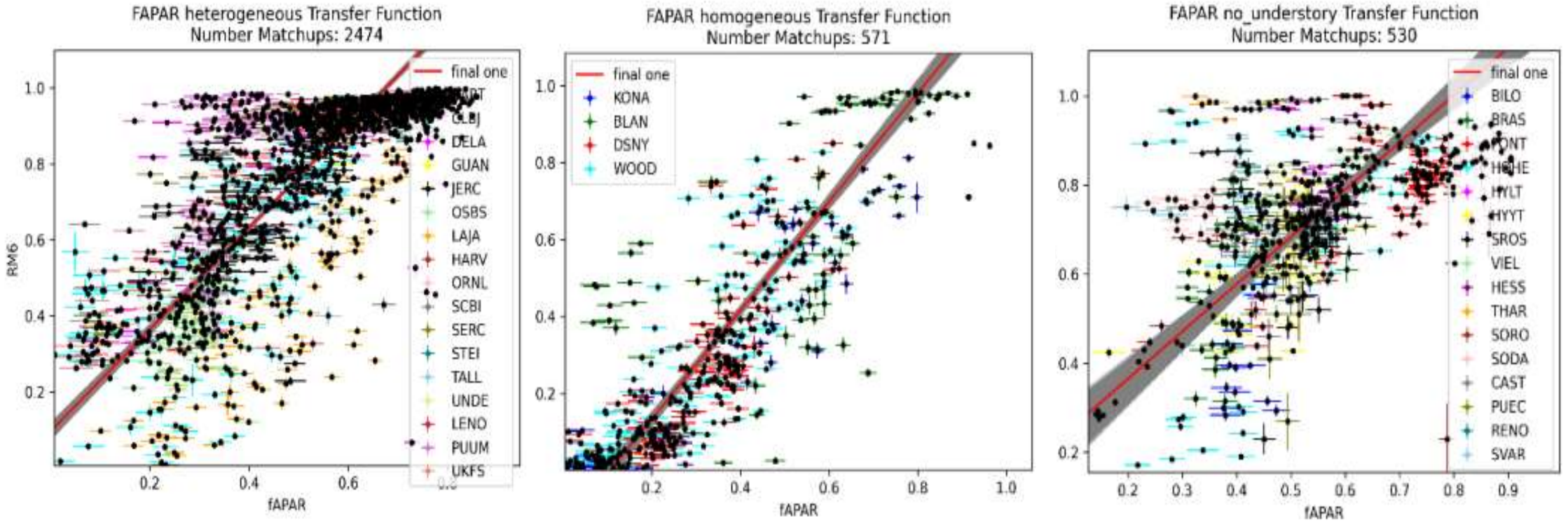
Soil Adjusted Vegetation index





Transfer function over dense canopies

Based on the Simplified Level 2 Prototype Processor (SL2P)



3D RTM framework approach

- **Using a 3D RTM framework allows us to**
  - Use realistic canopies (San Rossore TLS scene, RAMI, QA4ECV, JRC IESdblib)
    - against turbid medium used to caplibrate SL2P
  - **Work with known *FAPAR(t)*, LAI(t)**
    - expand the (virtual) measurement dataset to better «calibrate» the TF's
    - artificially acting on spectral properties and physical LAI, tree distribution, Leaf angle distribution (LAD), …
- **Simulations consist of**
  - Remote Sensing:
    - Simulate reflectances at deca/hecto-metric resolution (TOC, TOA, …)
    - Apply **SL2P** and/or SAVI on decametric resolution Reflectances → define TF against in-situ measurements
  - Ground Measurements:
    - Simulate DHP (sampling strategies: ICOS, NEON/TERN sampling at ESU level)
    - Apply **HemiPy** to assess FIPAR, PAI, fCover

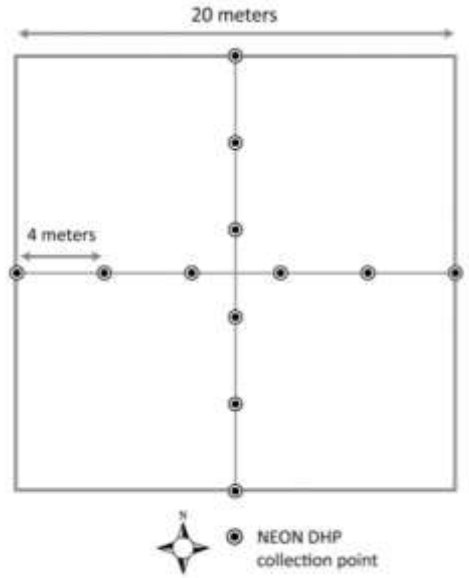


Fig. 3. Within each NEON plot, DHP images are acquired at twelve points arranged in a cross pattern.


Methods in Ecology and Evolution

APPLICATION Open Access

HemiPy: A Python module for automated estimation of forest biophysical variables and uncertainties from digital hemispherical photographs

Luke A. Brown, Harry Morris, Sylvain Leblanc, Gabriele Bai, Christian Lanconelli, Nadine Gobron, Courtney Meier, Jadunandan Dash

Actual scenarios examples

RESEARCH ARTICLE

The Fifth Phase of the Radiation Transfer Model Intercomparison Exercise (RAMI-V): Experiment Description and Results on Actual Canopy Scenarios

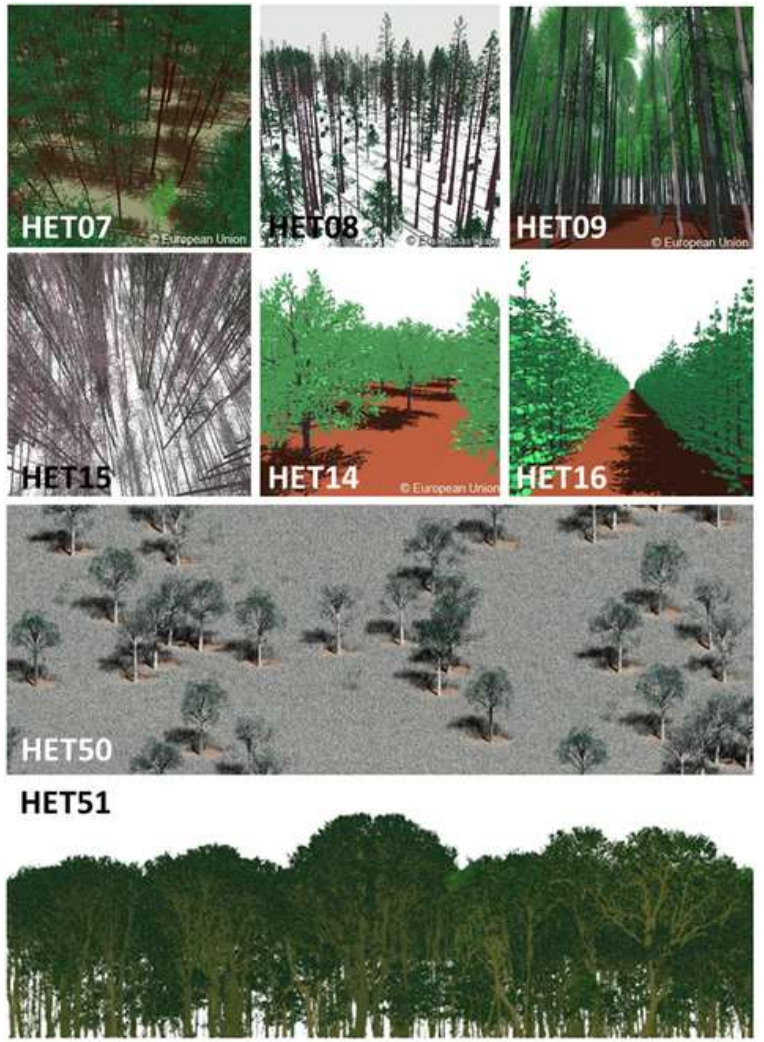
CHRISTIAN LANCONELLI, NADINE GOBRON, MONICA ROBUSTELLI, JENNIFER SUSAN ADAMS, KIM CALDERS, MATTHIAS DISNEY, JEAN-PHILIPPE GASTELLU-ETCHEGORRY, ADAM GOODENOUGH, YVES GOVAERTS, [...], AND FENG ZHAO +12 authors Authors Info & Affiliations

JOURNAL OF REMOTE SENSING · 29 Jul 2025 · Vol 5 · Article ID: 0663 · DOI: 10.34133/remotesensens.0663

Article 4 December 2024

Evaluation of In Situ FAPAR Measurement Protocols Using 3D Radiative Transfer Simulations

Christian Lanconelli[1], Fabrizio Cappucci[2], Jennifer Susan Adams[3] and Nadine Gobron[2,*]



Actual scenarios examples

Figure 1 Overview of the location of the IT-SR2 station (a). The blue area denotes the target area (TA) which has an extension of 37ha. (b) The IT-SR2 ecosystem tower and its surroundings give an idea of the vertical structure of the forest and the understory.

Flowchart from in-situ TLS collection to simulations

TLS point cloud georef

- Id object
- PDAL

Tree segmentation

QSM

- RayCloudTools
- TreeTools
- ~LeafGen

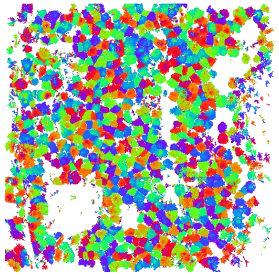
Simulations

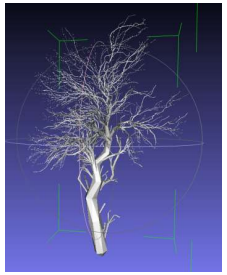
(**BRF**, **Flux**, **DHP**)

- Raytran/Rayshade
- Eradiate
- POV-Ray

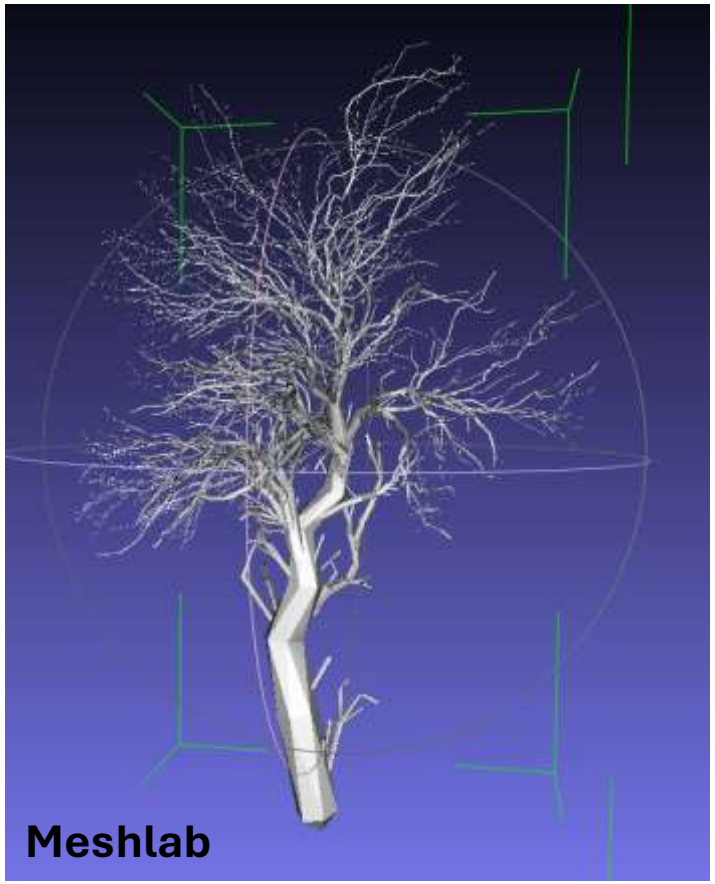
Calc LAI/FAPAR

- CanEye
- HemiPy

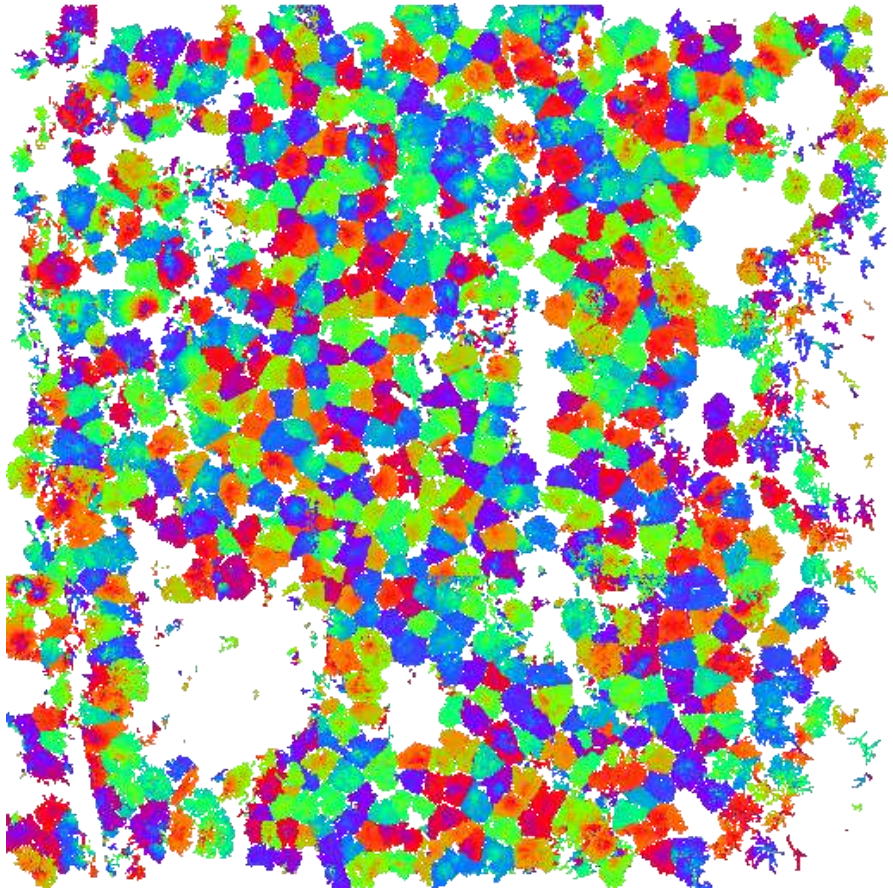




San Rossore ICOS SR-IT2
Tree 93, Mesh manipulation, Tree segmentation

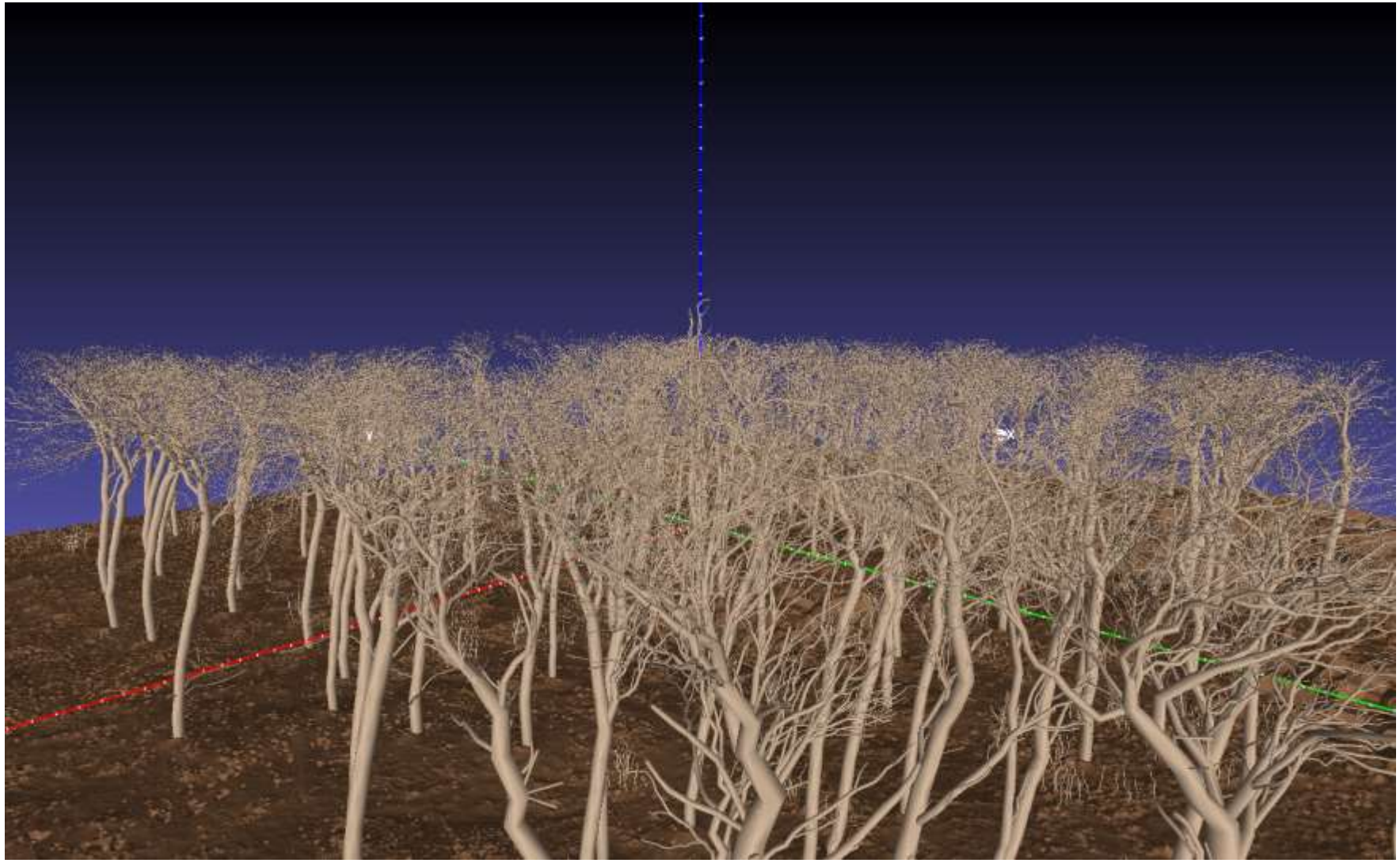


300m, 9 plots of 1ha (100x100m)

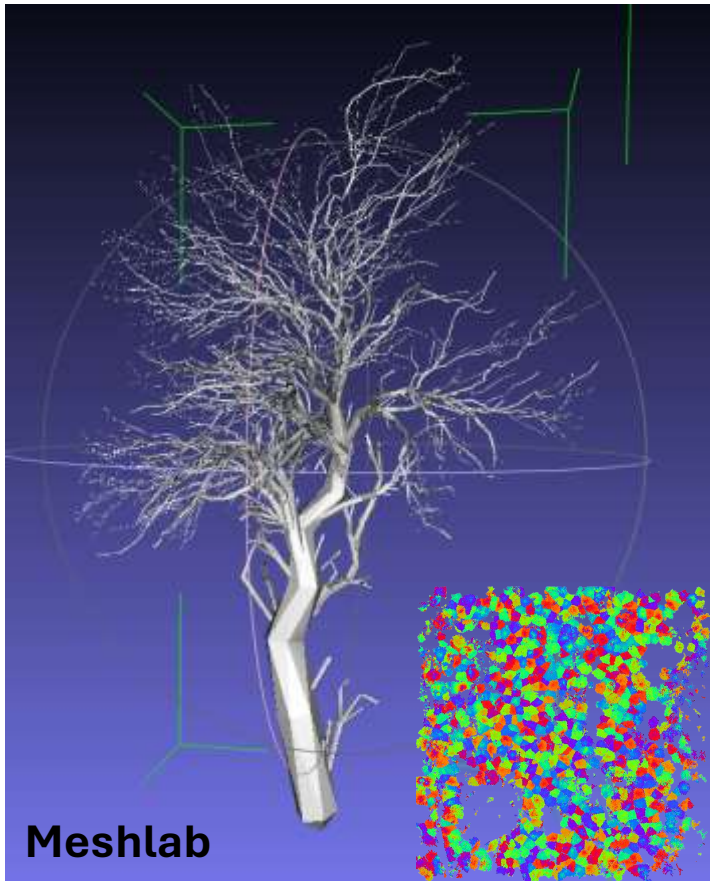


Raycloudtools, CloudCompare
PDAL

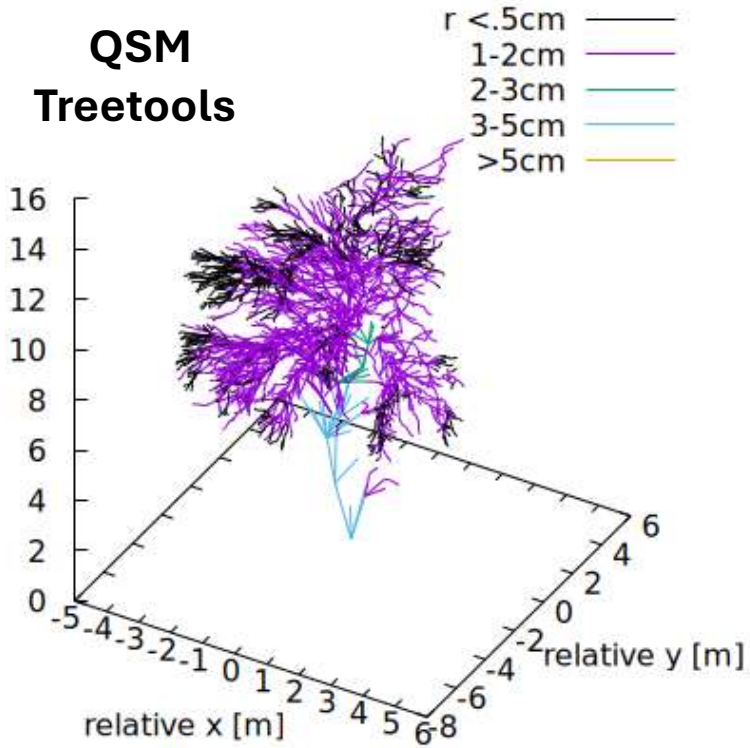
San Rossore ICOS SR-IT2
Tree 93, Mesh manipulation, Tree segmentation



Tree 93, Mesh manipulation, QSM, Shoots model

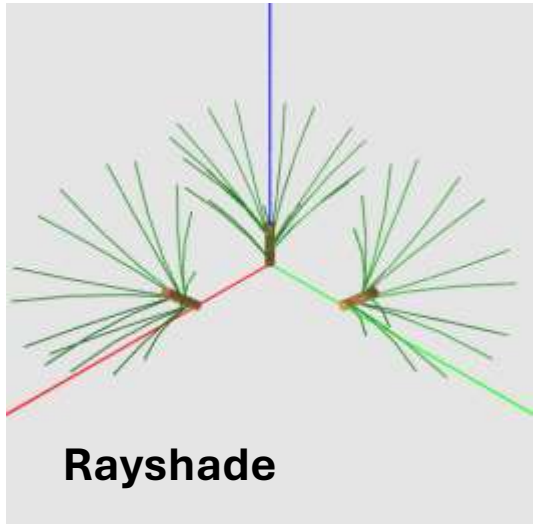


QSM
Treetools



Quantitative Structural Models (Volumes, Biomass, ...)

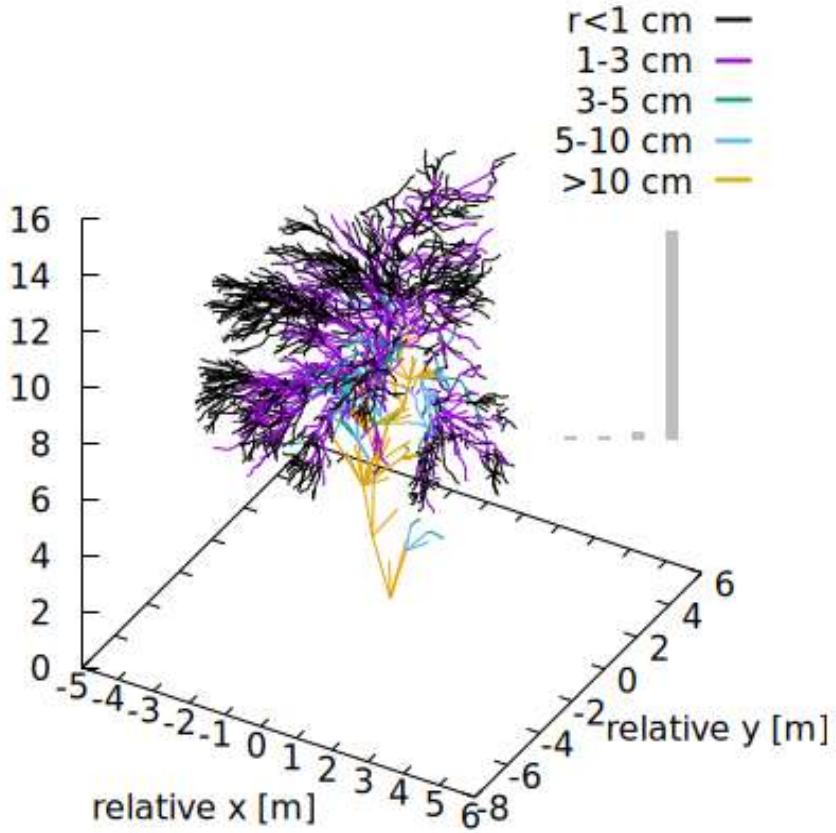
Pov-ray

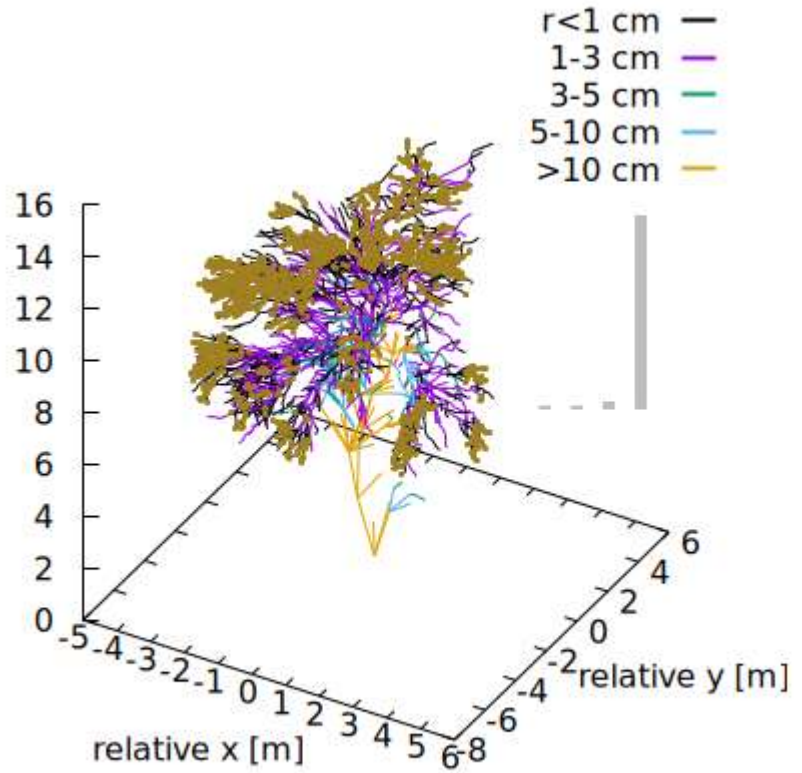


Rayshade

POV-Ray QSM based foliage deployent

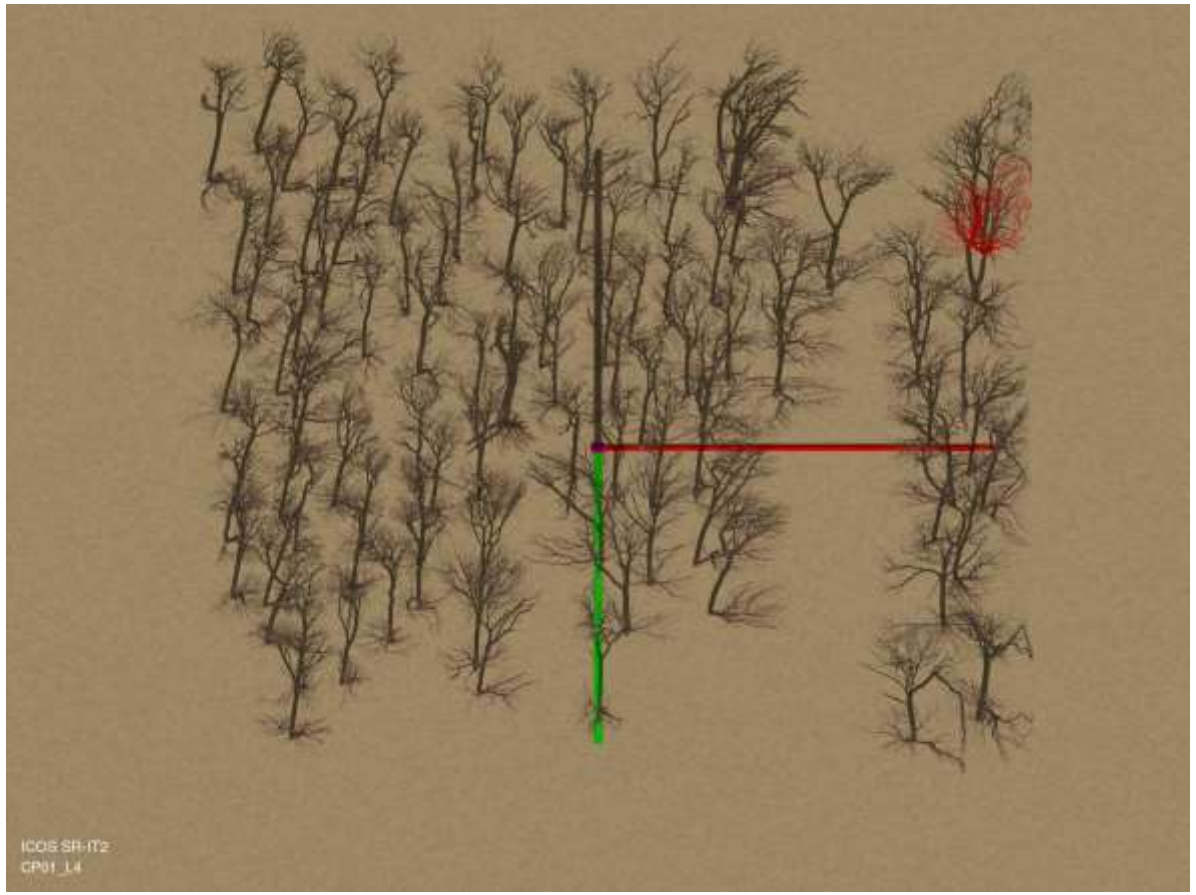
./treerender.sh -r 0.5 -d 0.1 -D 0.03 -f 2 -F



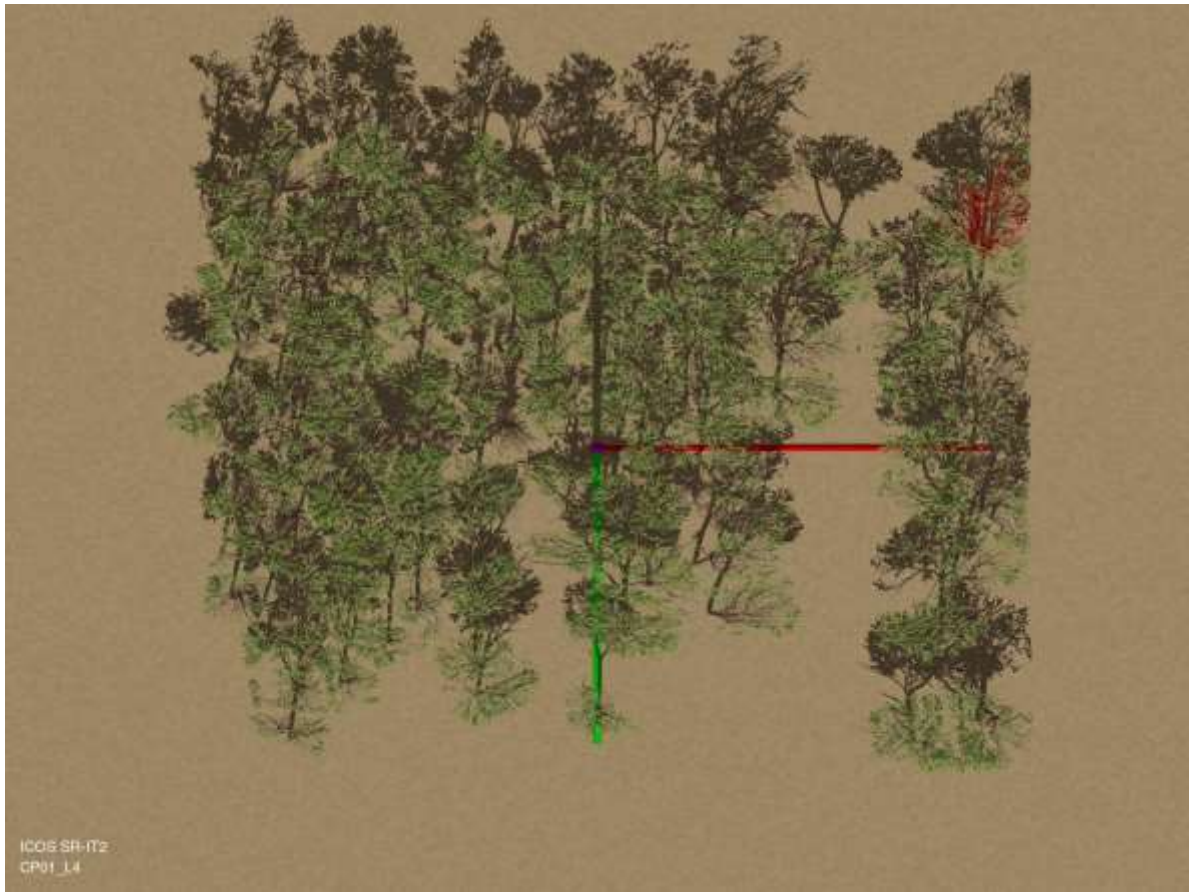


POV-Ray orthographic rendering IT-SR2 Central Plot

Leaf Off



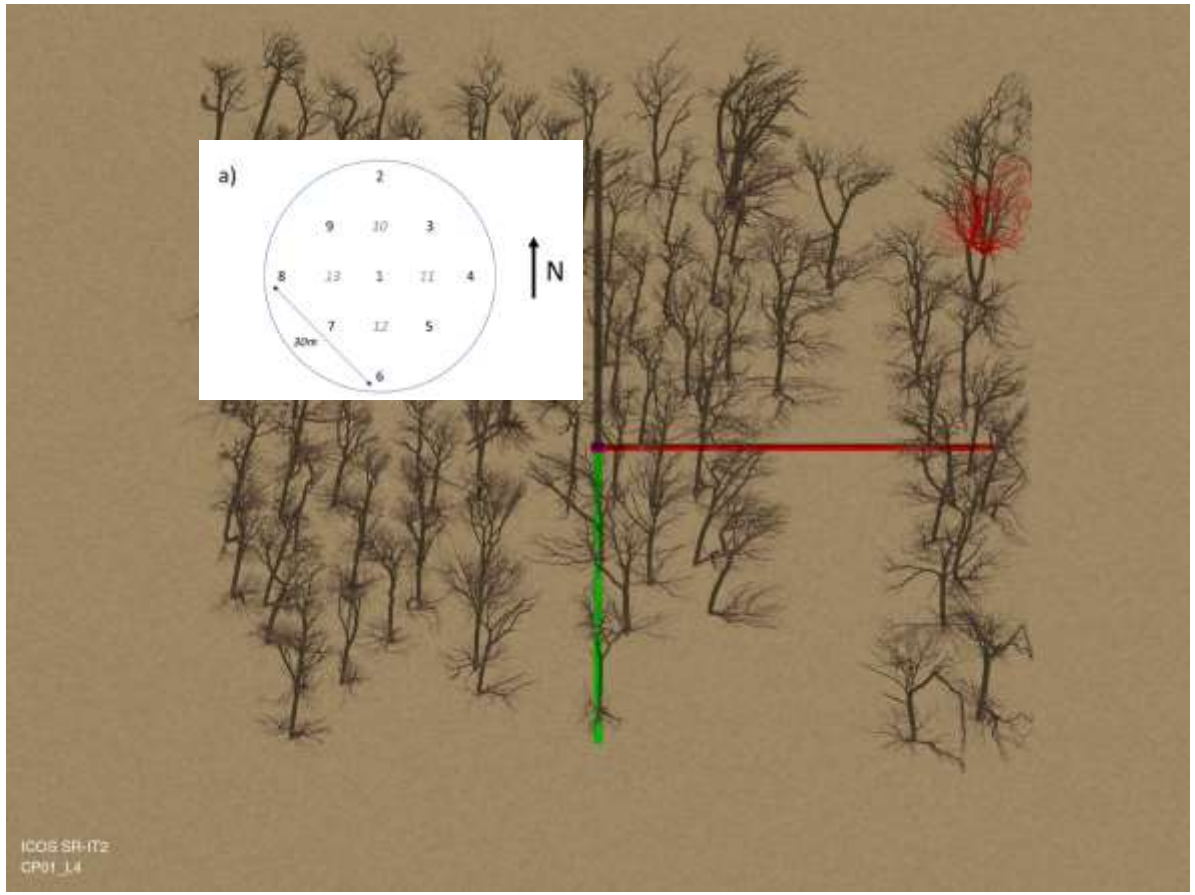
Leaf On



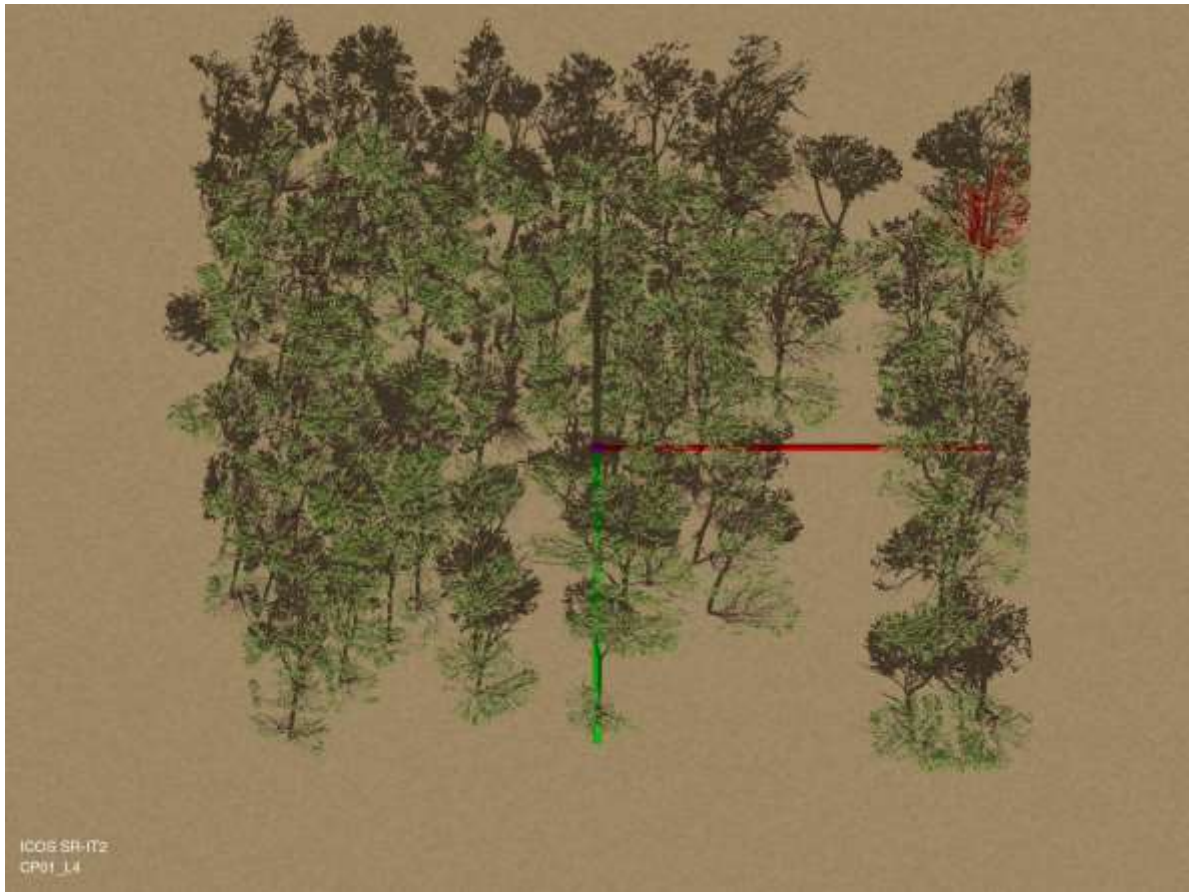
Note: render of the 100 largest trees only (of ~1500 trees)

POV-Ray orthographic rendering IT-SR2 Central Plot

Leaf Off



Leaf On

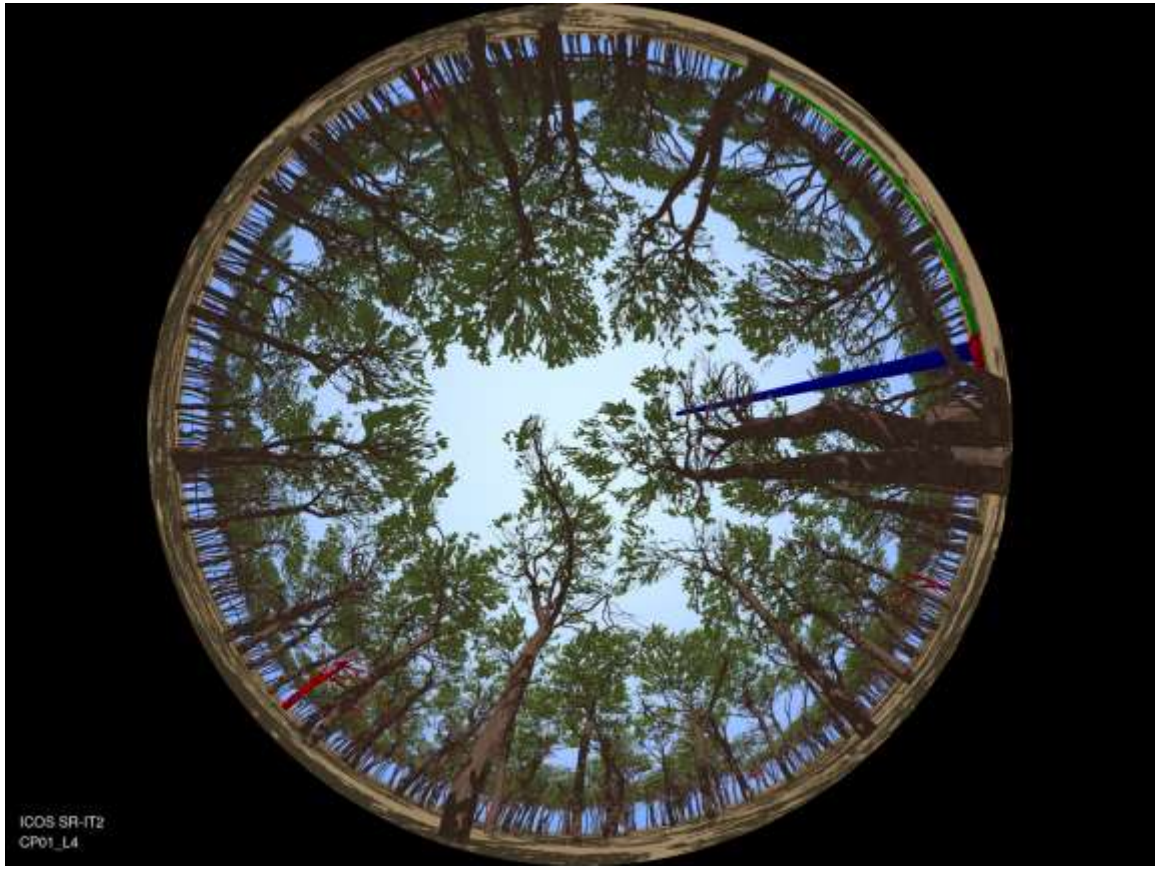


Note: render of the 100 largest trees only (of ~1500 trees)

POV-Ray fisheye rendering IT-SR2 Central Plot (1ha)

Leaf On (real)

Leaf On

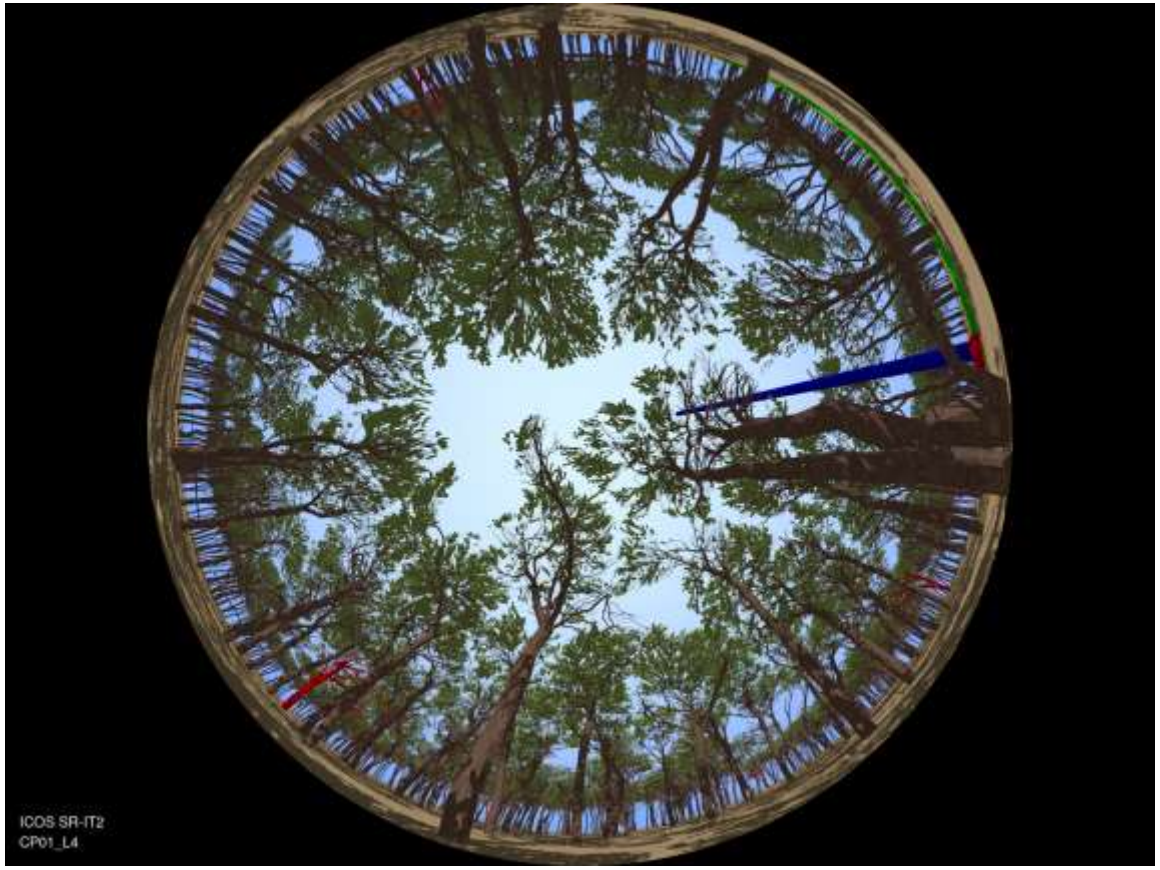


Note: render of the 100 largest trees only (of ~1500 trees)

POV-Ray fisheye rendering IT-SR2 Central Plot (1ha)

Leaf Off

Leaf On

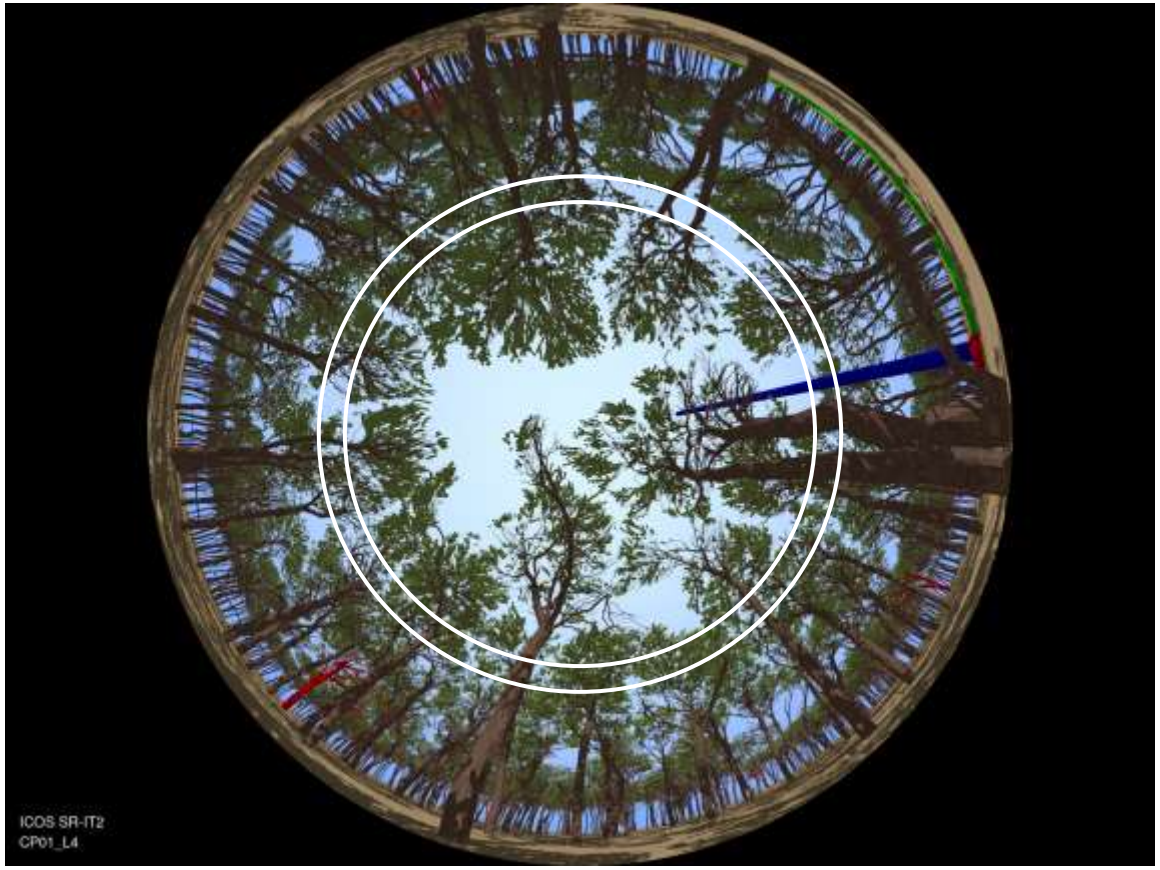


Note: render of the 100 largest trees only (of ~1500 trees)

POV-Ray fisheye rendering IT-SR2 Central Plot (1ha)

Leaf Off

Leaf On



Note: render of the 100 largest trees only (of ~1500 trees)

Generate DHP decimating foliage (CP_01)


APPLICATION

HemiPy: A Python module for automated estimation of forest biophysical variables and uncertainties from digital hemispherical photographs

With scene replication (and all the 9 DHP per plot)

LAI

LAI / 2

LAI / 4

LAI / 8

Leaf off

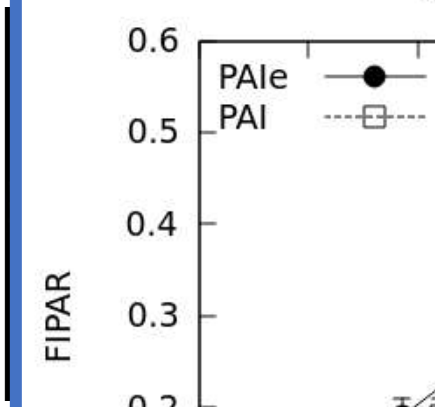
HemiPy results (L. Brown et al., 2023)

Date	Plot	Direction	**PAIe_Hinge**	**PAI_Hinge**	Clumping_Hinge	PAIe_Miller	PAI_Miller	Clumping_Miller	**FIPAR**	**FCOVER**
21/06/2024	leafon	up	**1.01+/-0.06**	**1.26+/-0.07**	0.80+/-0.07	1.009+/-0.035	1.26+/-0.04	0.80+/-0.04	**0.473+/-0.028**	**0.22+/-0.05**
21/06/2024	leafon_div2	up	**0.73+/-0.04**	**0.88+/-0.05**	0.83+/-0.07	0.704+/-0.024	0.840+/-0.030	0.84+/-0.04	**0.356+/-0.024**	**0.13+/-0.04**
21/06/2024	leafon_div4	up	**0.498+/-0.028**	**0.59+/-0.04**	0.84+/-0.08	0.471+/-0.017	0.558+/-0.025	0.84+/-0.05	**0.254+/-0.020**	**0.074+/-0.023**
21/06/2024	leafon_div8	up	**0.366+/-0.022**	**0.44+/-0.04**	0.83+/-0.08	0.346+/-0.014	0.419+/-0.023	0.83+/-0.06	**0.192+/-0.018**	**0.045+/-0.016**
21/06/2024	leafoff	up	**0.271+/-0.019**	**0.34+/-0.04**	0.80+/-0.10	0.251+/-0.013	0.318+/-0.022	0.79+/-0.07	**0.139+/-0.018**	**0.029+/-0.013**

Generate DHP decimating foliage (CP_01)

With scene replication (and all the 9 DHP per plot)

LAI



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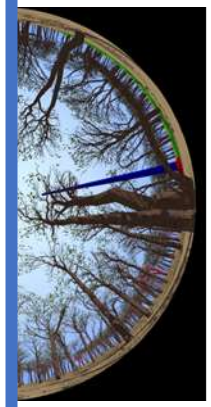
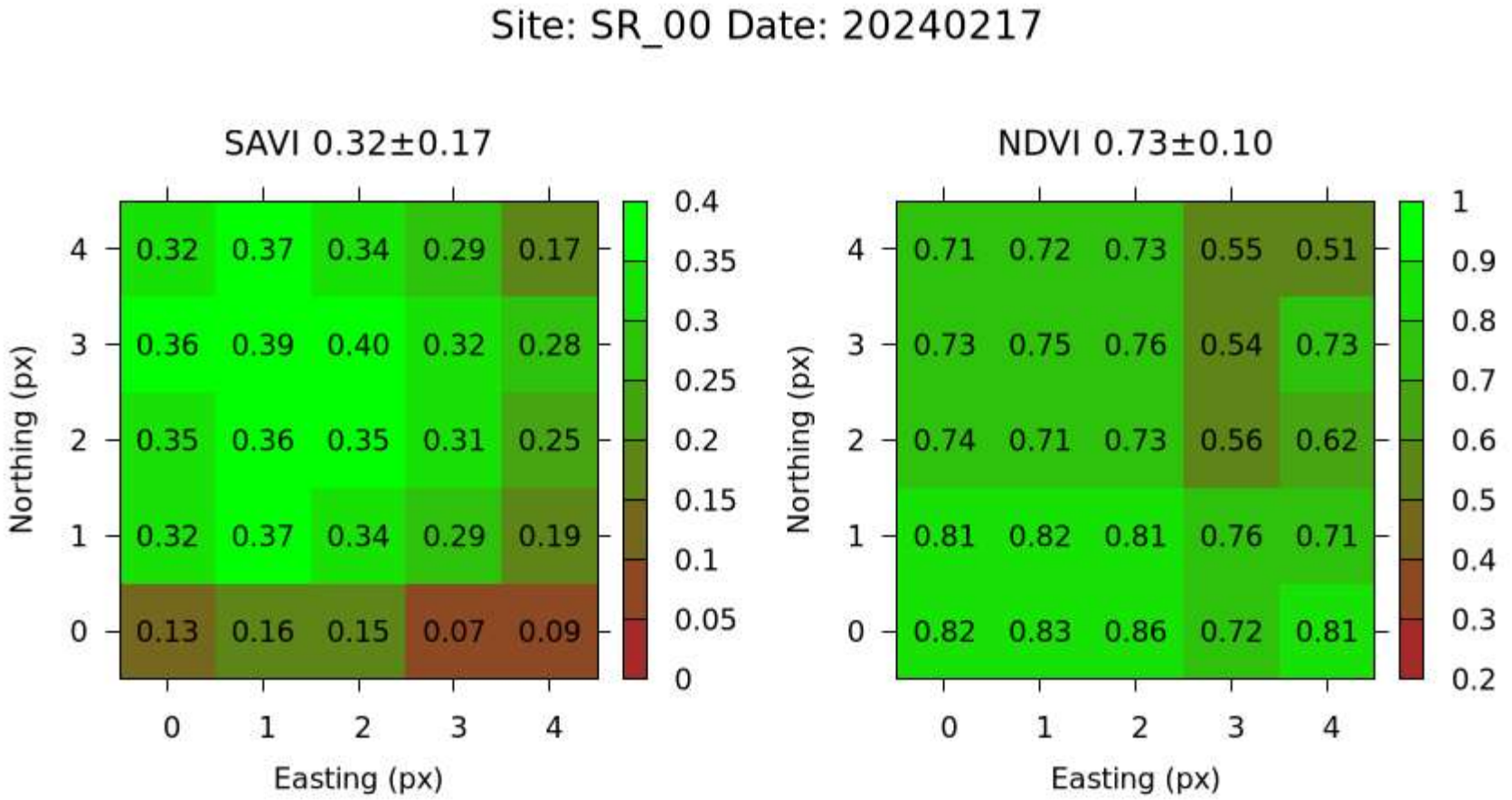


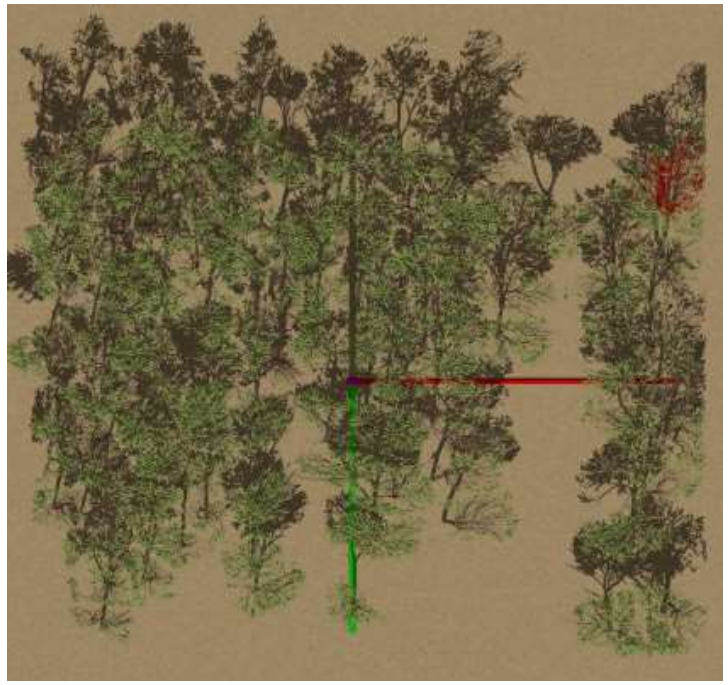
Leaf off

HemiPy result

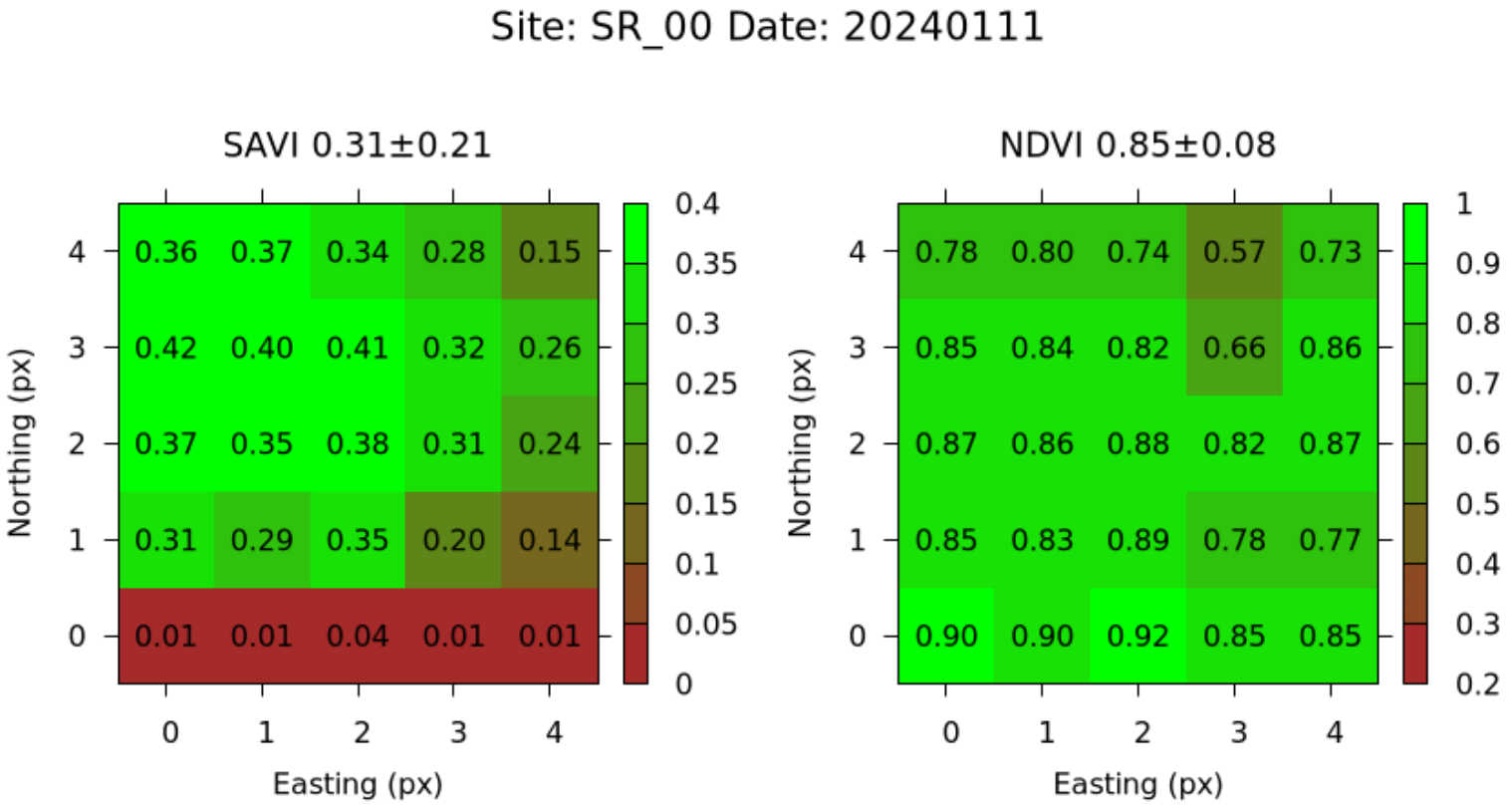
Date	Plot	Directi	ping_Miller	FIPAR	FCOVER
21/06/2024	leafon	up	/-0.04	**0.473+/-0.028**	**0.22+/-0.05**
21/06/2024	leafon_div2	up	/-0.04	**0.356+/-0.024**	**0.13+/-0.04**
21/06/2024	leafon_div4	up	/-0.05	**0.254+/-0.020**	**0.074+/-0.023**
21/06/2024	leafon_div8	up	/-0.06	**0.192+/-0.018**	**0.045+/-0.016**
21/06/2024	leafoff	up	/-0.07	**0.139+/-0.018**	**0.029+/-0.013**

Reflectances at 20m resolution combined to VI's

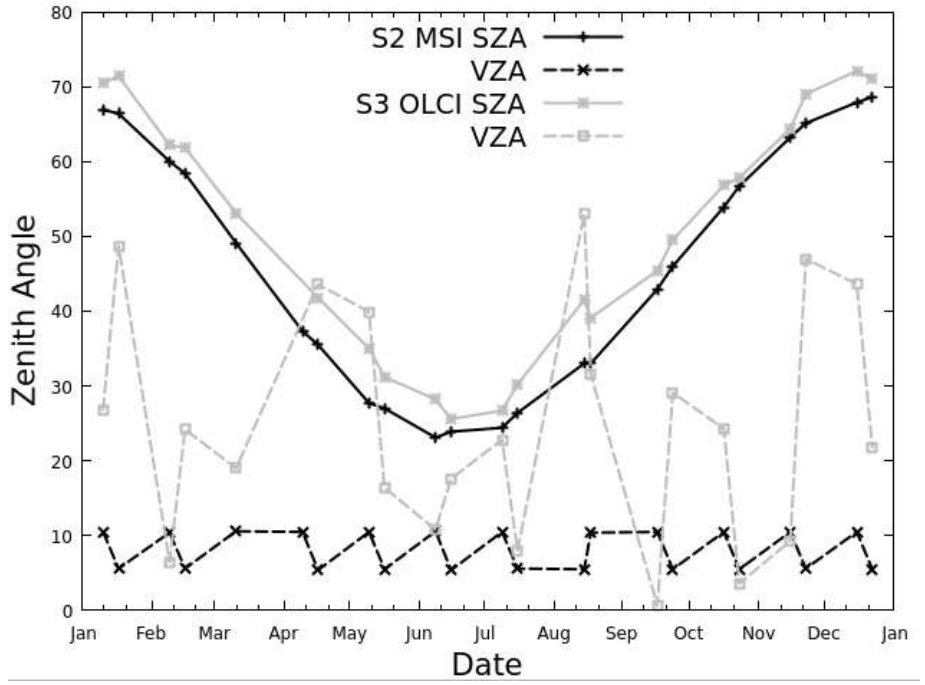




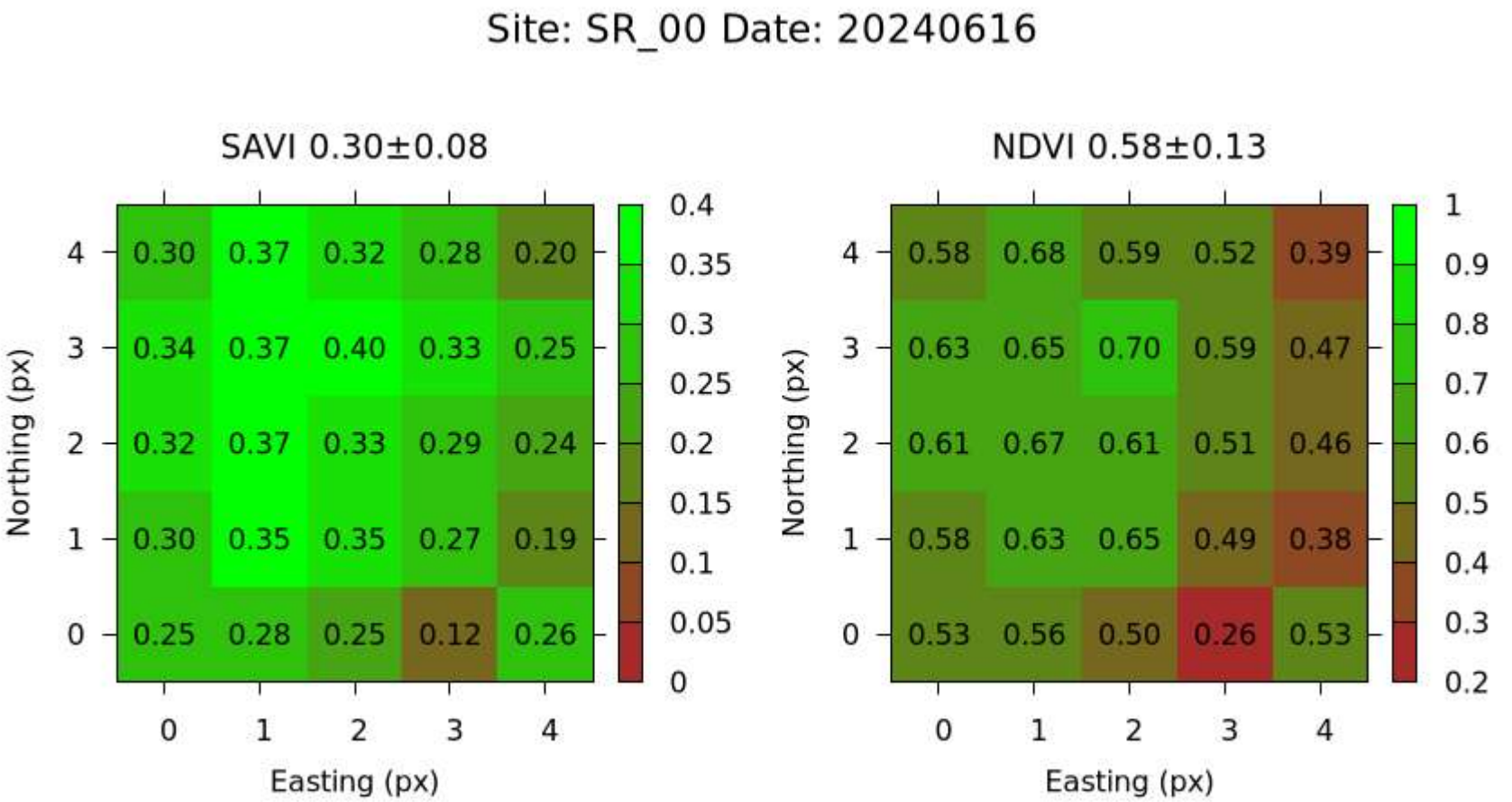
The predicting variables (SAVI, NDVI) Illumination Viewing geometries

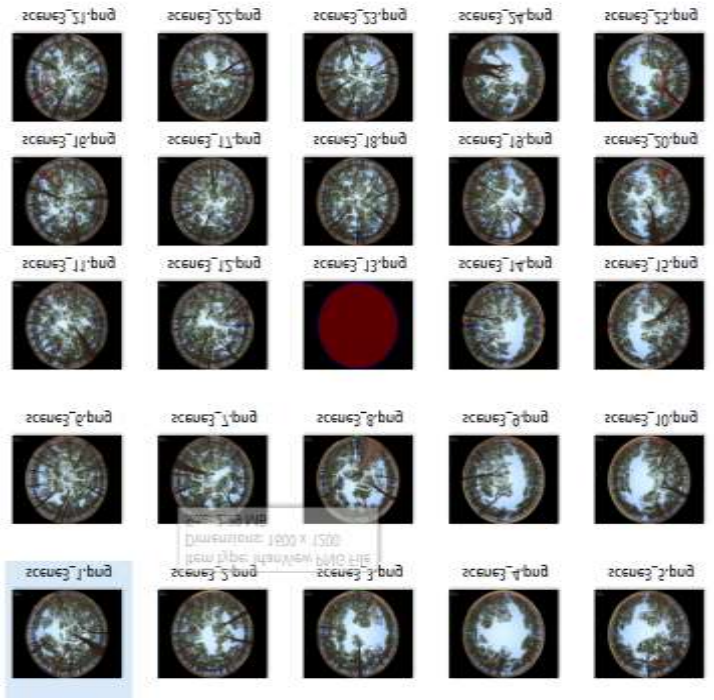


Selected geometries

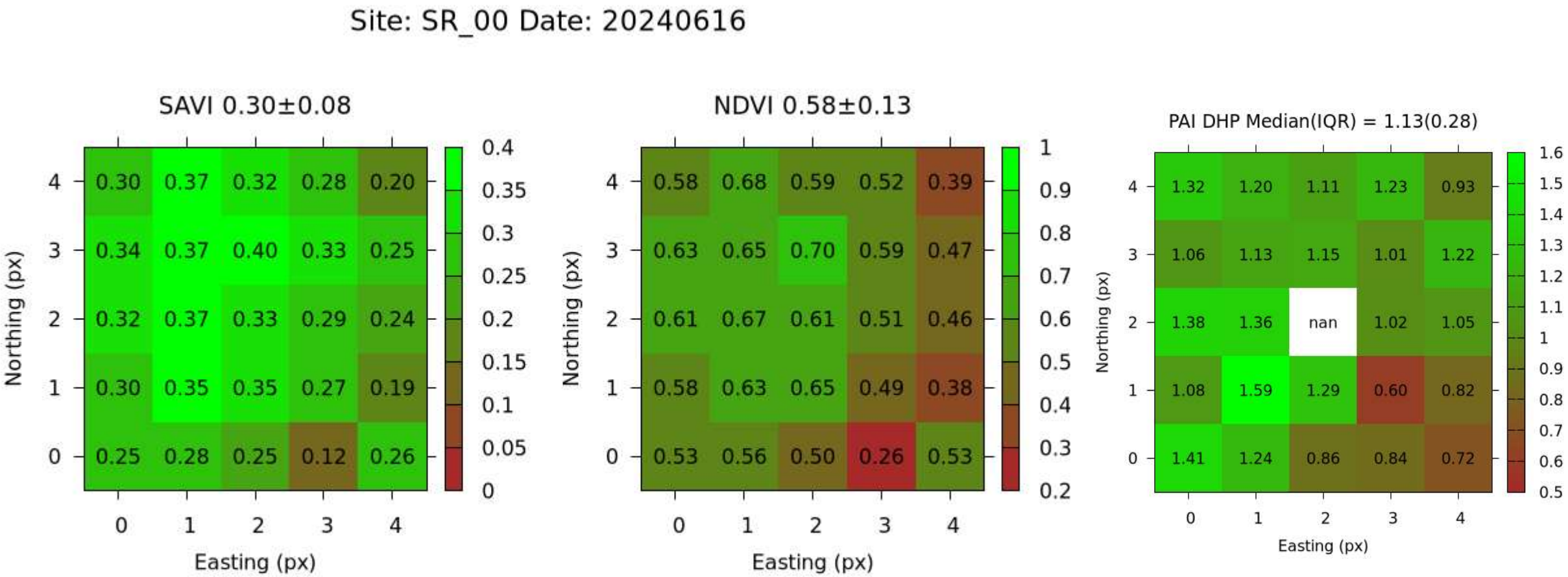


The predicting variables (SAVI, NDVI)

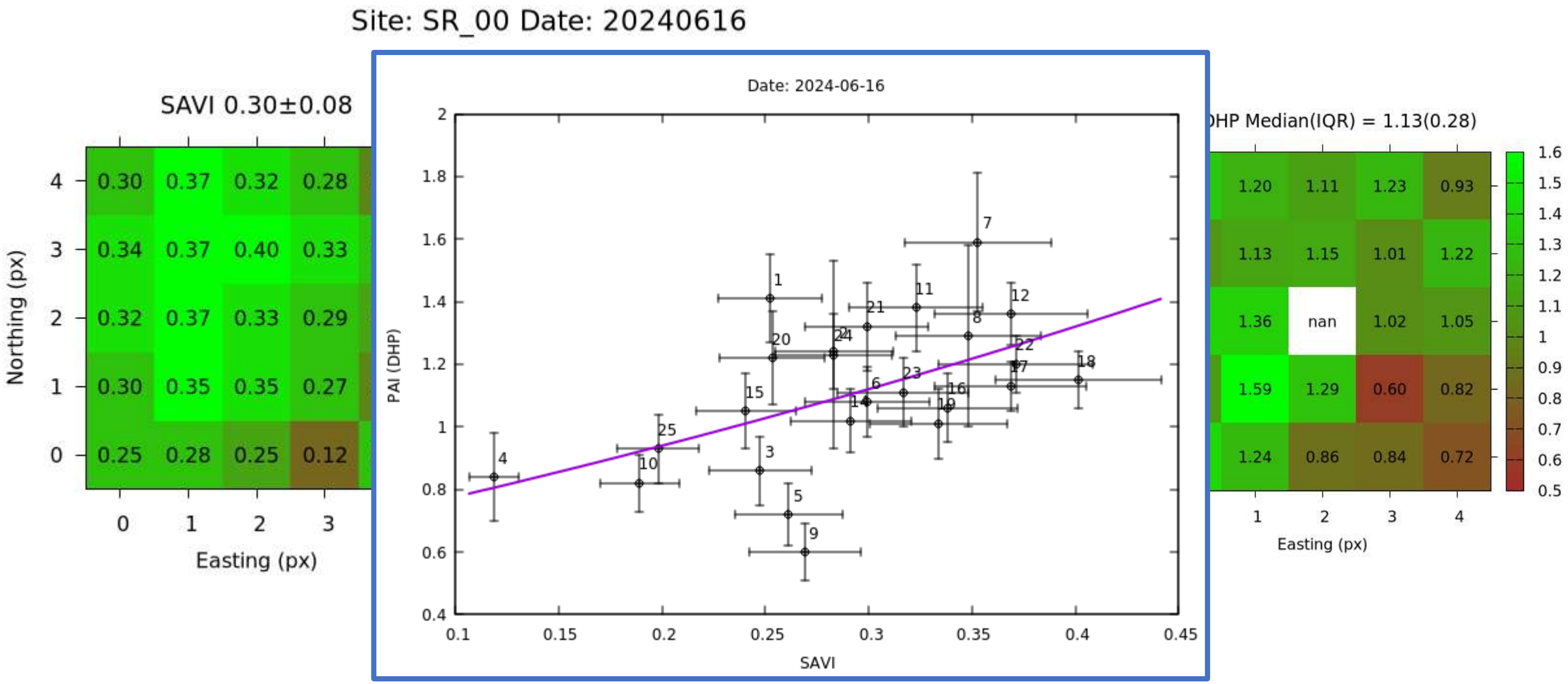




The predicting variables (SAVI, NDVI)



The predicting variables (SAVI, NDVI)



Summary

- 3D modelling can support CAL/VAL activities relying on controlled virtual laboratory conditions
  - structural and optical spectral parameters
- In-situ and remote sensing observations can be simulated
- Whole CAL/VAL process can be replicated with sensitivity and uncertainty assessment
- Trusted RTMs (Radiative Trasfer Model Intercomparison RAMI role)
- Having 3D replica of existing reference scene (ICOS) may be a value added
  - SL2P-like approach on Actual Canopies?
- Collaboration with DTE-S2GOS (Rayference) → support DestinE RT scheme over land