IDEAS-QA4EO

Cal/Val Workshop#5

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Developing a framework for automated and continuous measurements of FAPAR from distributed wireless sensor Network

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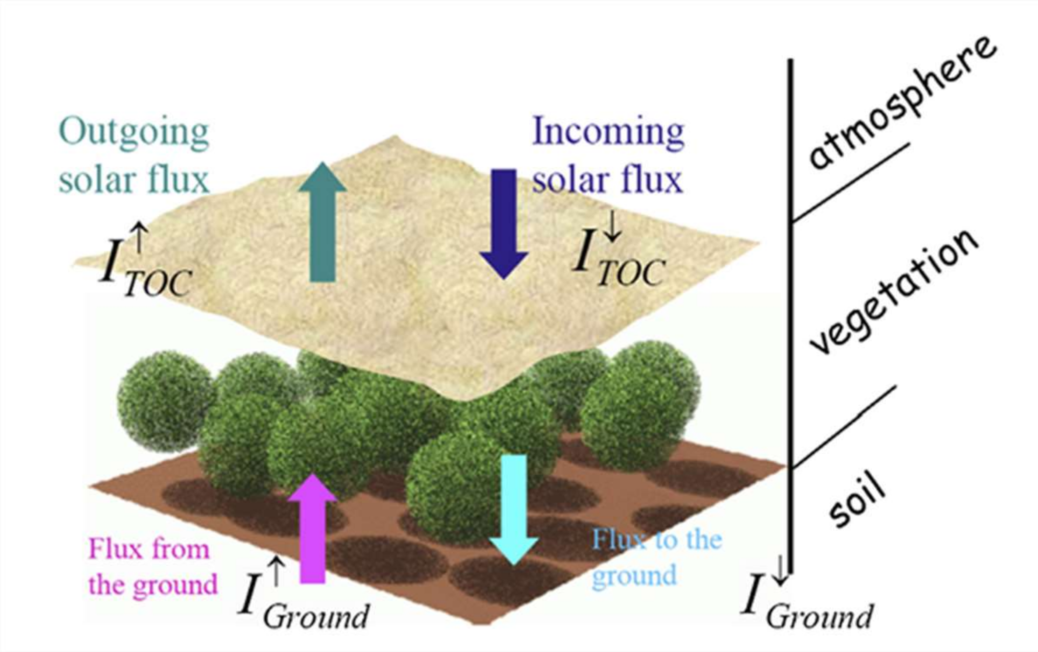
Introduction

Photosynthetically Active Radiation (PAR) is the portion of sunlight (400-700 nm) that plants use for photosynthesis.

Fraction of Absorbed-PAR (FAPAR) represents the proportion of incoming PAR that is absorbed by the vegetation canopy.

Importance: FAPAR is a critical parameter for estimating plant productivity, ecosystem health, and carbon sequestration.



Liang, S., & Wang, J. (2020). *Advanced Remote Sensing, 2nd ed.; Academic Press: Cambridge, MA, USA*, 447-476.

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Satellite FAPAR products

MOD15A2H v061
MODIS/Terra Leaf Area Index/FPAR 8-Day L4 Global 500 m SIN Grid

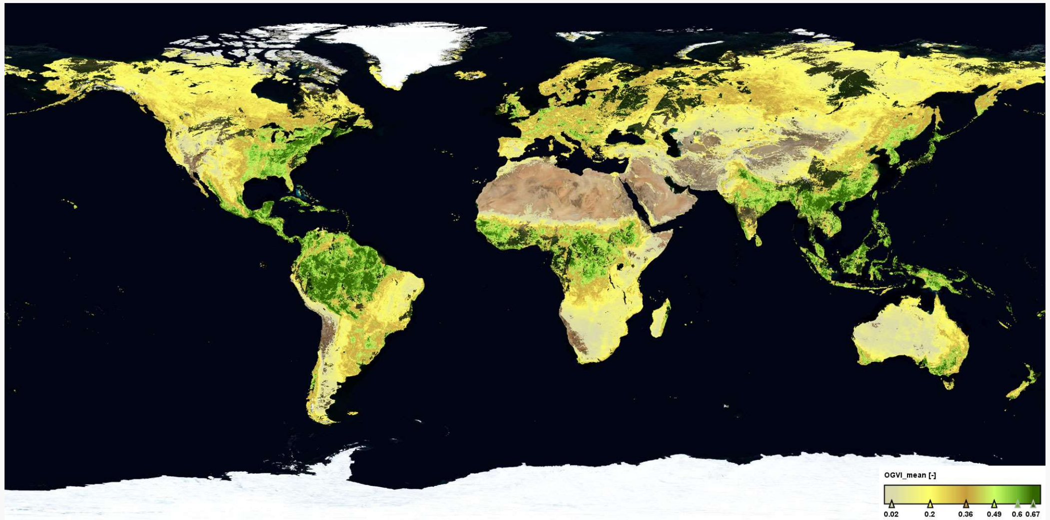
Copernicus co-funded with esa

SENTINEL 3A OLCI

Copernicus Land Monitoring Service

proba-v

Credit: ESA



Credit: Sentinel, ESA

Cal/Val is important to ensure the products meet user requirement.

FAPAR Estimation Techniques

- ❑Ground-based instruments like AccuPAR (LP-80) ceptometers or Plant Canopy Analyzers (LAI-2200), Digital hemispherical Photography (DHP).
- ❑Automatic PAR measurements from a wireless network

Hand-held instruments

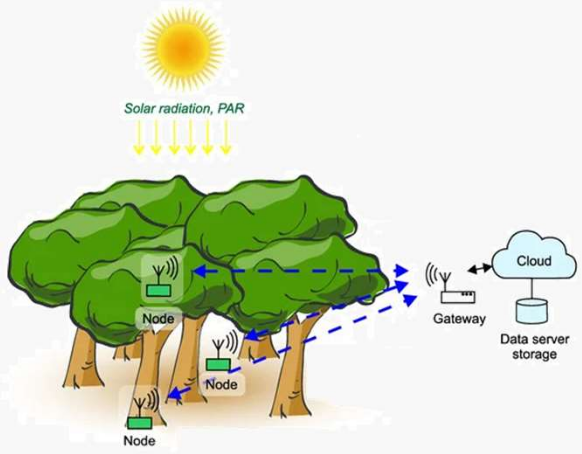
Wireless PAR network

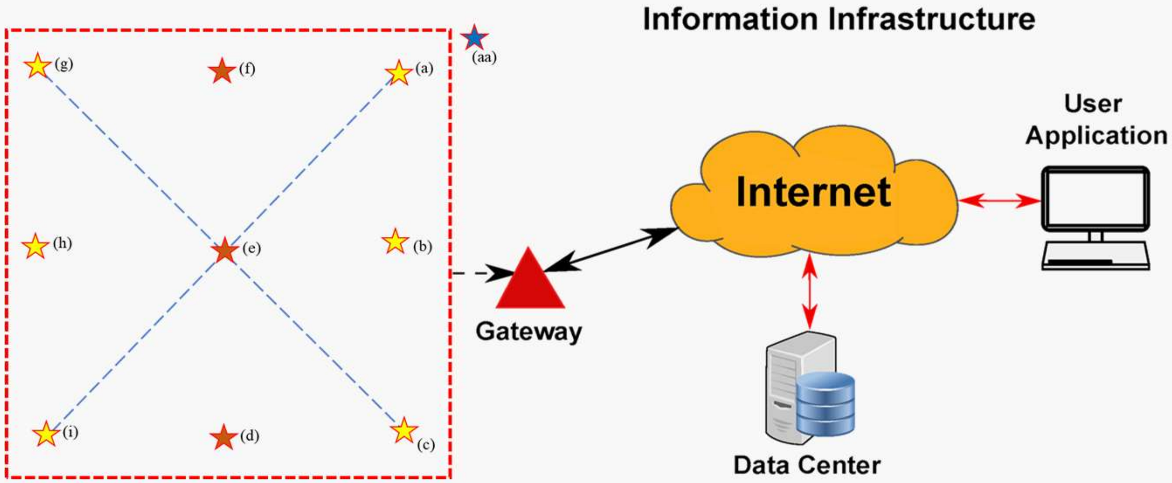
Challenges in ground instruments

- **Limited Spatial Coverage:** Laborious, time-consuming, difficult to cover inaccessible areas
- **Weather Dependence:** Precipitation can significantly impact measurements which may lead to data gaps.
- **Limited Real-Time Monitoring:** Difficult to get real-time dataset
- **High logistics:** Repeated field surveys need labour, travel cost

Advantages of Automatic Wireless PAR Network

- **Continuous Monitoring:** collect data at regular intervals with better error characterization
- **Improved Spatial Coverage:** can be installed where access is challenging
- **Reduced Labor Costs:** eliminates the frequent manual measurements, saving time and labour resources.
- **Real-Time Data Access:** it offers real-time access to PAR data, allowing for immediate monitoring.
- **Non-destructive:** reducing disturbance to the study site and its vegetation.

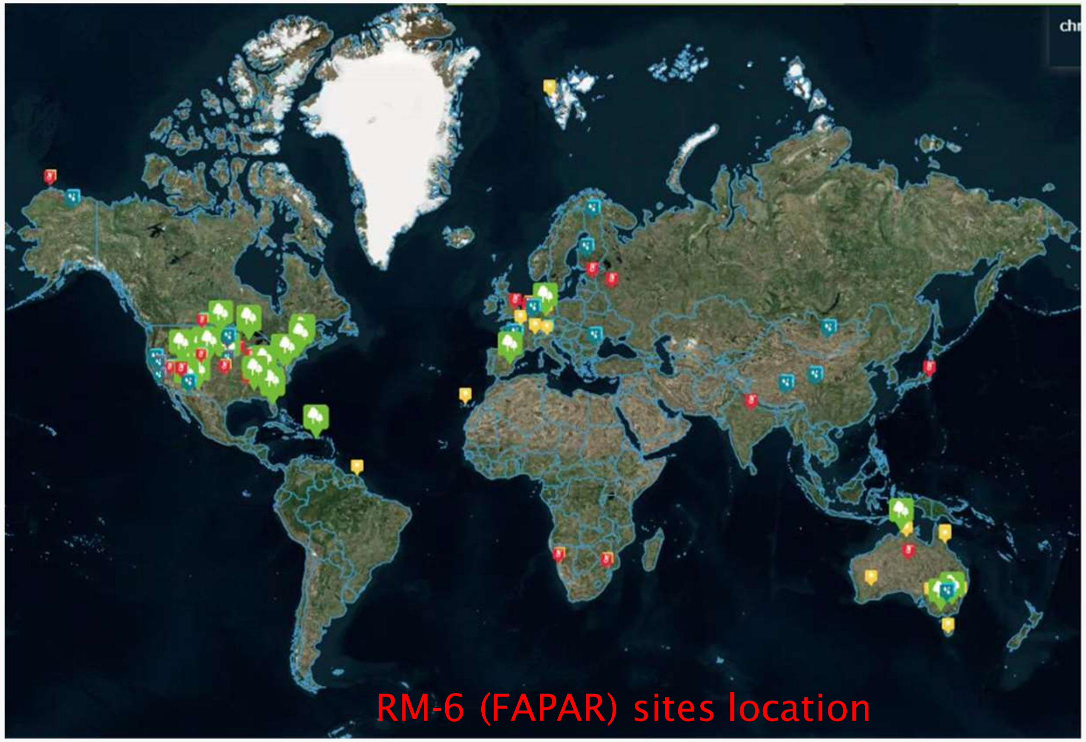




Research Gaps

Wireless sensor networks have been used for vegetation monitoring such as phenology, LAI, and environmental parameters (e.g., humidity, temperature, PAR, soil moisture); but

- ❑ Limited research (4) has been done using an automated PAR network system for FAPAR estimation
- ❑ There are no existing protocols for sensor installation and data processing
- ❑ Co-location with other measurements and assessments are not explored much
- ❑ Low-cost sensors are developed for PAR measurements but their potential and efficiency have not been checked for long-term monitoring and different vegetation ecosystems



The GBOV service provides multiple years of high-quality in-situ measurements (88 sites) to validate 7 core land products

Objectives

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Analysis and validation of PAR networks at the GBOV ***sites as a way to transfer to other sites***:

- This activity will collect all the available PAR measurements at the GBOV sites and process them to derive FAPAR measurements (i) FAPAR during the satellite overpass time and (ii) daily FAPAR.

- Validation/intercomparison with DHP-derived FAPAR.

Key Research questions

- ❑ What is the relation between **2-flux and 4-flux FAPAR**?
- ❑ What could be the **optimal number of nodes** and their arrangement for better agreement with ESU-level FAPAR?
- ❑ What could the impact between selecting **instantaneous (10 am) and whole day (sunrise to sunset)** PAR measurement?
- ❑ How FAPAR will vary based on the **canopy structure, row arrangement, and vegetation type**?
- ❑ How to estimate **uncertainty and error characterisation**?
- ❑ What would be the possible way to develop **quality flags** to remove the bad quality dataset?

Study area & sensor setup (Row crops)

❑Valencia Anchor site: western Mediterranean Sea, **grape vineyards**.

Study area & sensor setup (Natural vegetation)

C

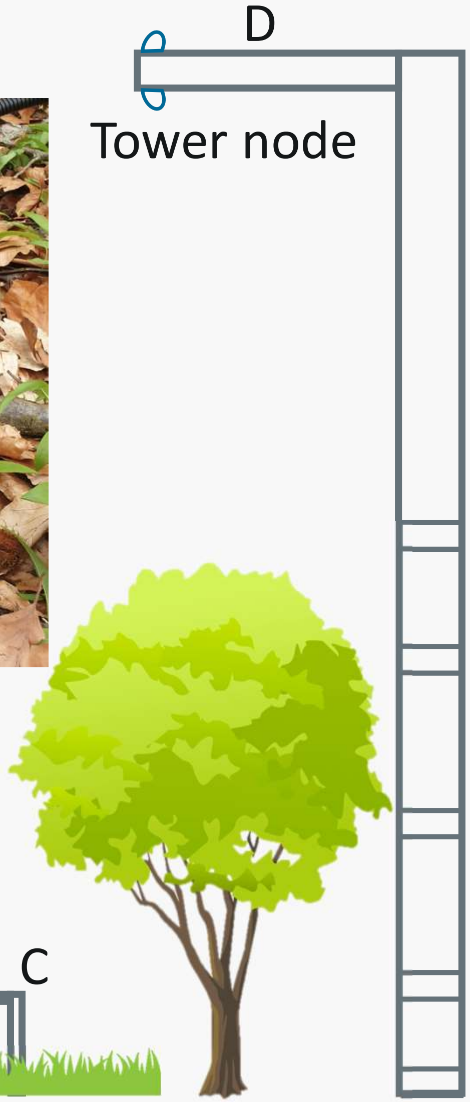
Lower canopy node

B

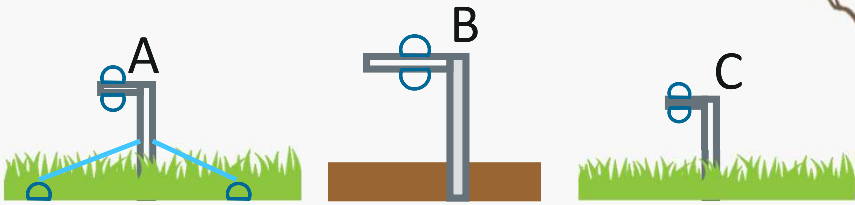
Bare soil node

A

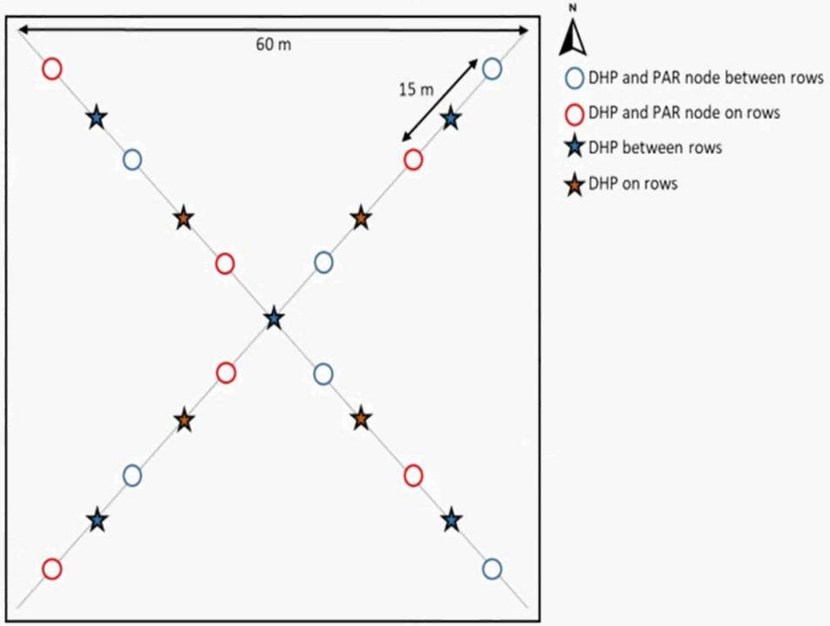
Soil node



- ❑ Hainich National Park: central Europe, temperate **forest ecosystem**.
- ❑ Litchfield: Australia, woody **savanna** ecosystem.

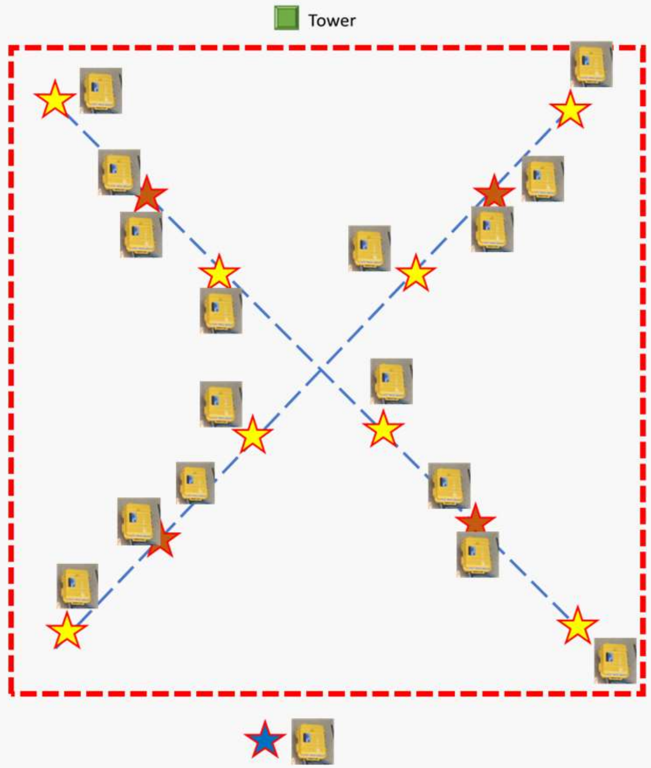


ESU Architecture



Sampling for row crops

Distribution of FAPAR nodes and DHP sampling locations across the ESU (60 m x 60 m)



Sampling for natural vegetation

- 8 nodes (up/down) with understory present
- 8 nodes (up/down) with understory present + up/up on ground
- 1 set (up/down or up/up) over cleared soil

Estimation of FAPAR

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$$FAPAR_{four-flux} = \frac{I_{TOC}^{\downarrow} - I_{ground}^{\downarrow} + I_{ground}^{\uparrow} - I_{TOC}^{\uparrow}}{I_{TOC}^{\downarrow}}$$

$$FAPAR_{two-flux} = \frac{I_{TOC}^{\downarrow} - I_{ground}^{\downarrow}}{I_{TOC}^{\downarrow}}$$

incoming solar flux (↓TOC)
flux to the ground (↓ground)
flux from the ground (↑ground)
outgoing solar flux (↑TOC)

2-flux FAPAR: The two-flux system measures only the incoming PAR and the radiation transmitted through the canopy. It ignores this reflected component.

4-flux FAPAR: The four-flux system accounts the reflected radiation from the soil. The two-flux system tends to overestimate FAPAR by ignoring this reflected component.

Uncertainty measurement

Individual Uncertainties: Each source of uncertainty is identified and quantified

- ❑Calibration uncertainty (C_u) = 0.05
- ❑Repeatability uncertainty (R_u) = 0.005
- ❑Long-term drift uncertainty (LD_u) = 0.02
- ❑Non-linearity uncertainty (LN_u) = 0.01
- ❑Temperature response uncertainty (TR_u) = 0.006
- ❑Levelling uncertainty (L_u) = 0.01

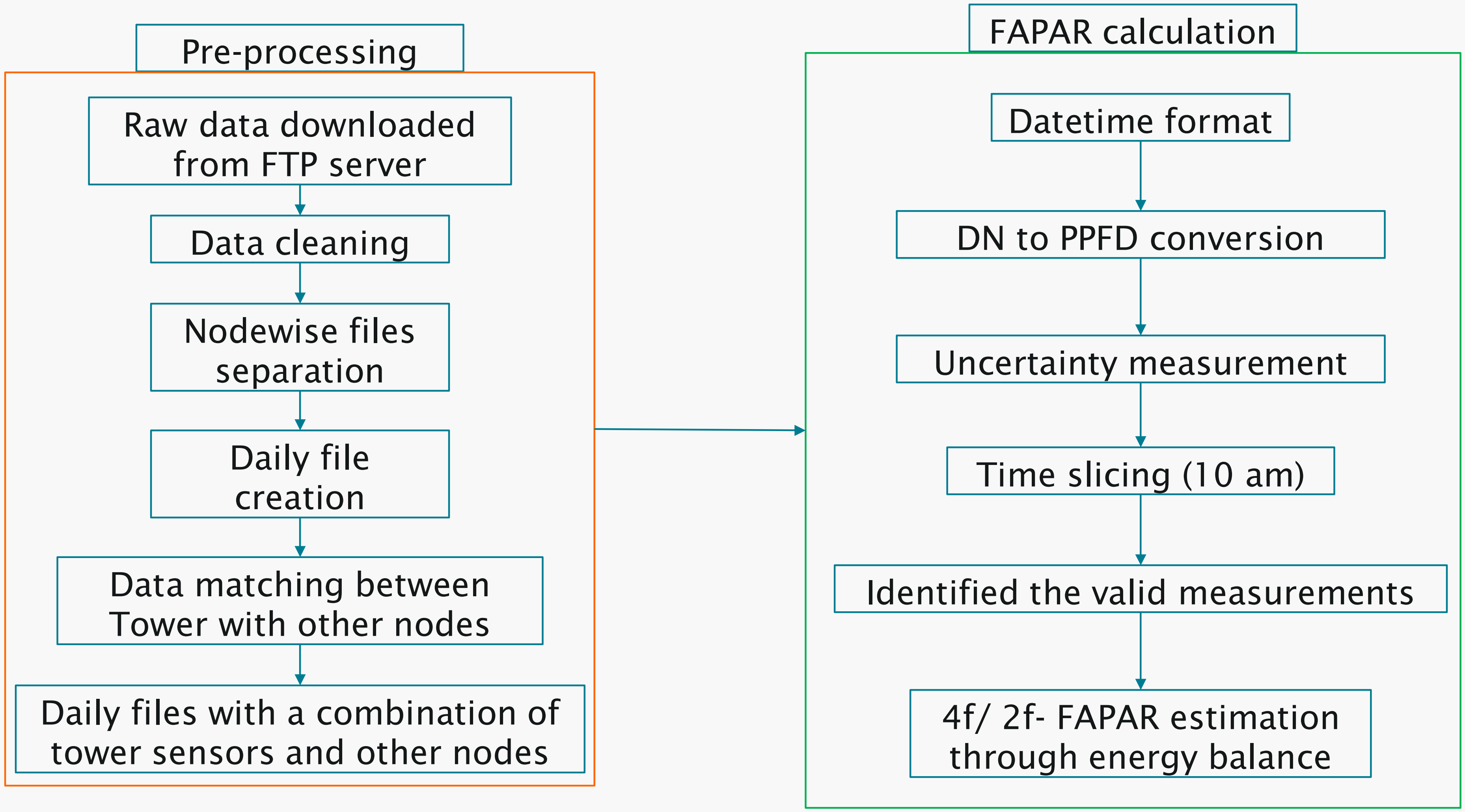
Combine Uncertainties using root sum of squares (**RSS)**: The combined uncertainty is calculated by taking the square root of the sum of the squares of each individual uncertainty. Mathematically, this can be expressed as:

$$PPFD_u = \sqrt{{C_u}^2 + {R_u}^2 + {LD_u}^2 + {LN_u}^2 + {TR_u}^2 + {L_u}^2}$$

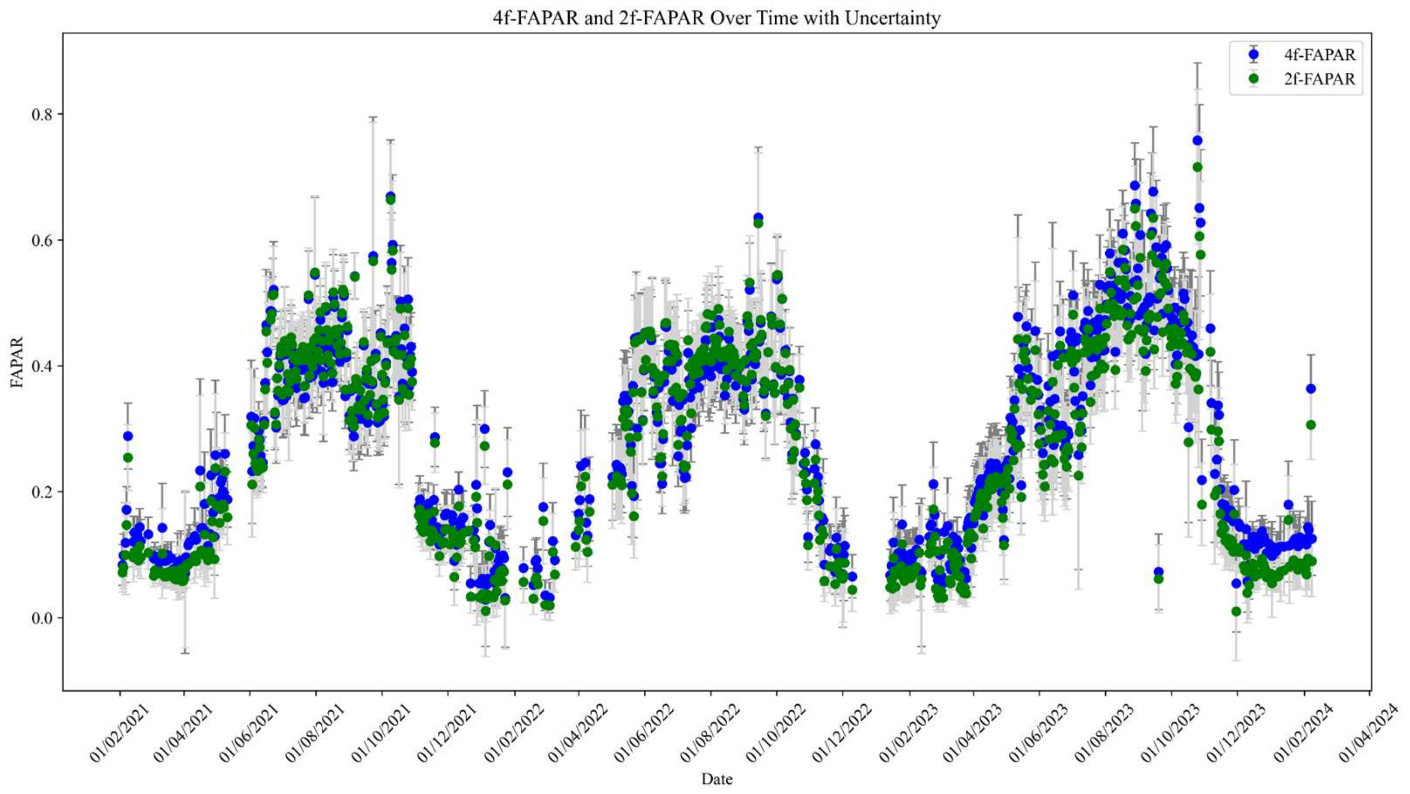
Calculate the Total Uncertainty: The resulting value from the RSS method (ppfd_ur) represents the combined relative uncertainty for the 'UP1' sensor.

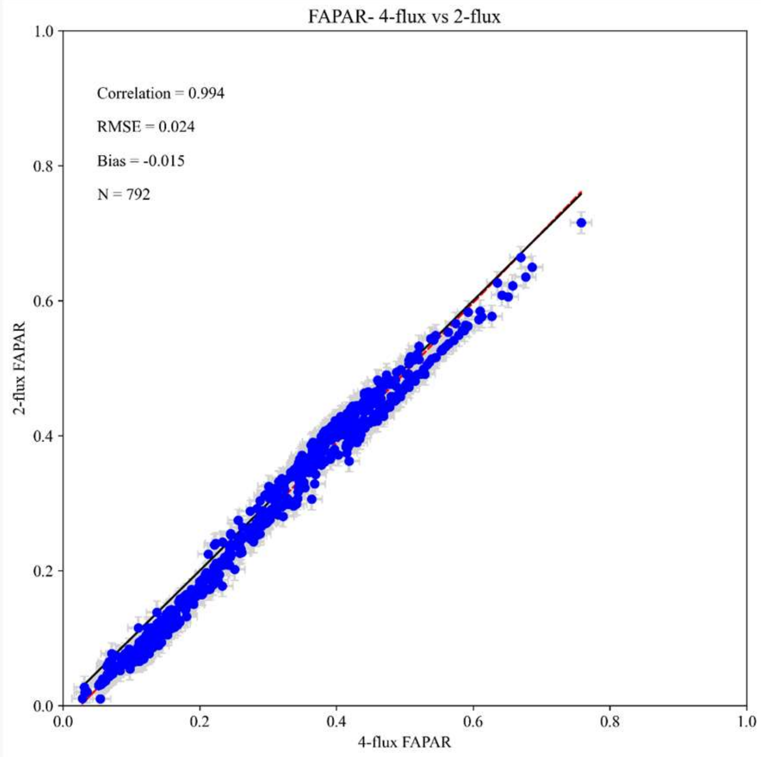
$$PAR_u = \textit{unumpy.uarray}\ (\text{PAR} \times PPFD_u)$$

FAPAR estimation steps



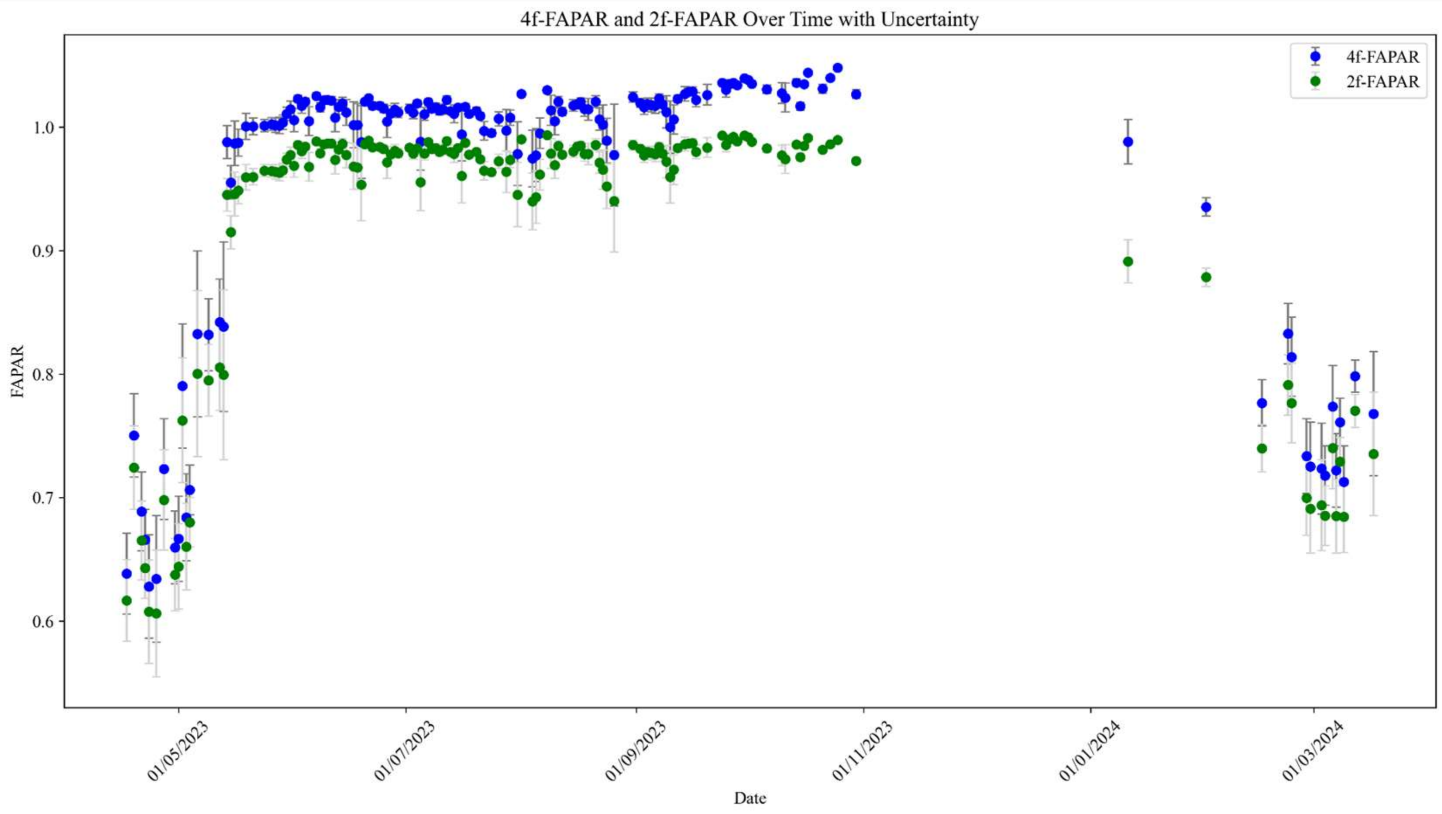
Case study: Valencia Anchor site

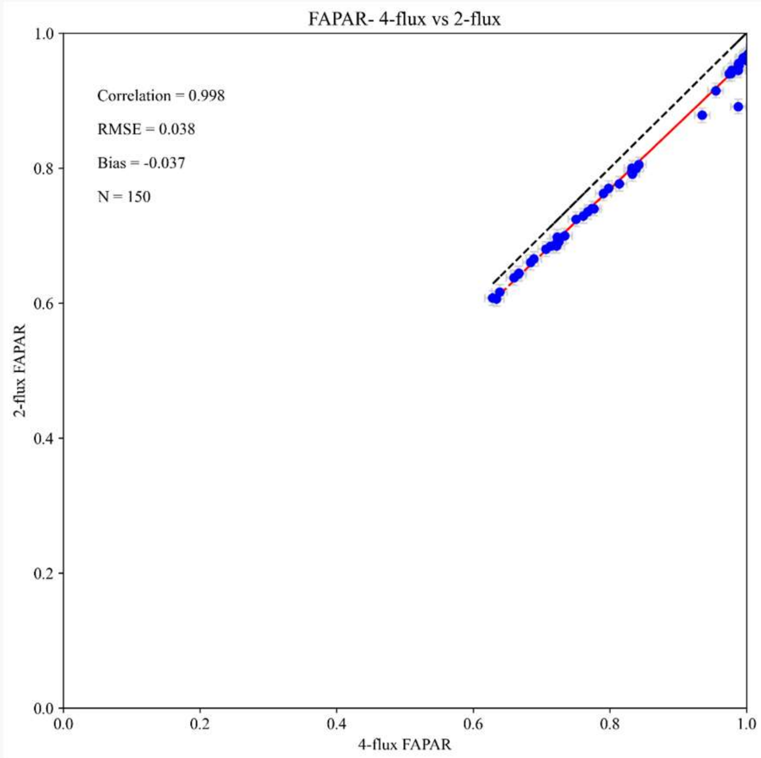




Comparison between 4flux and 2flux instantaneous FAPAR

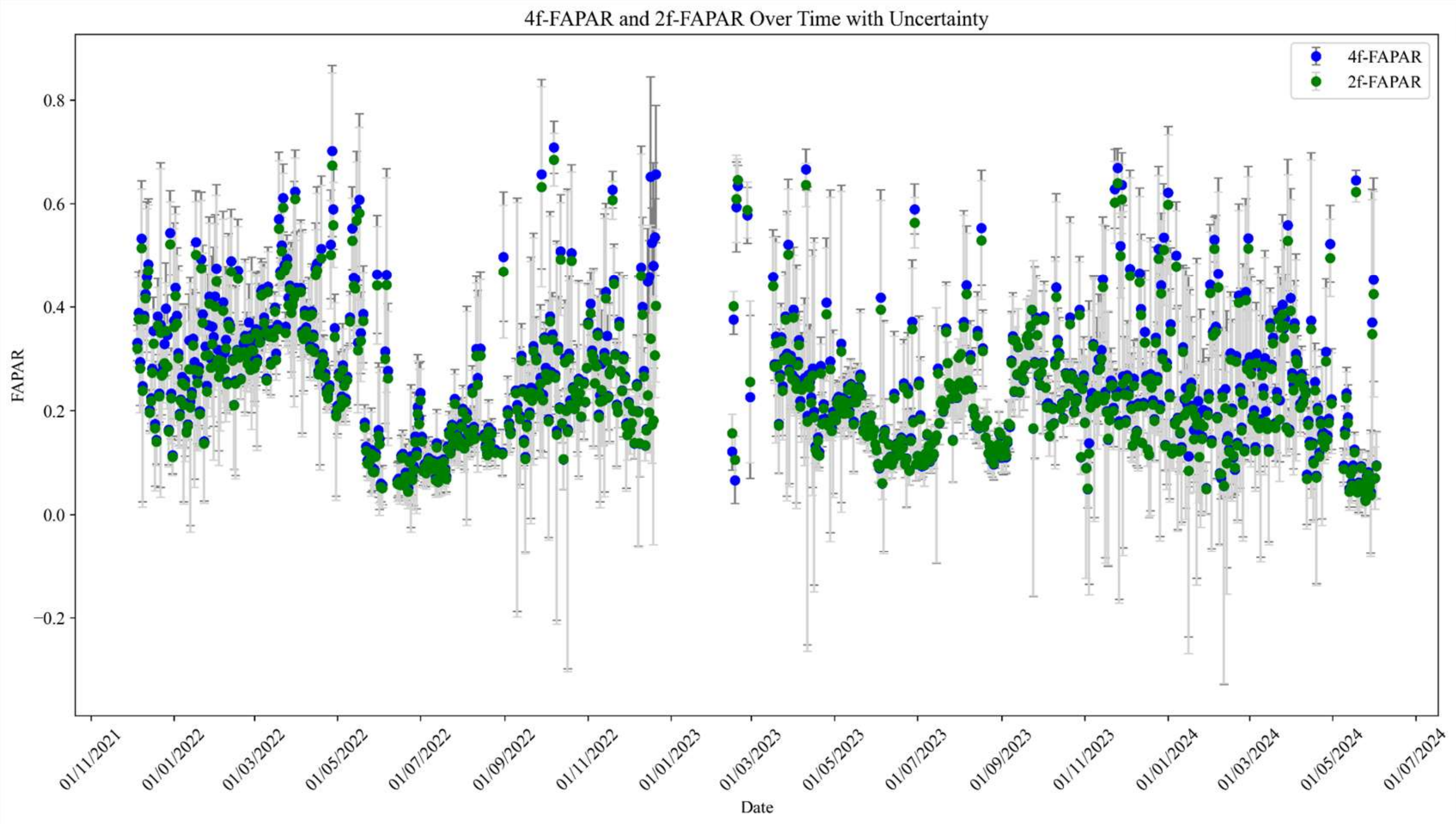
Case study: Hainich

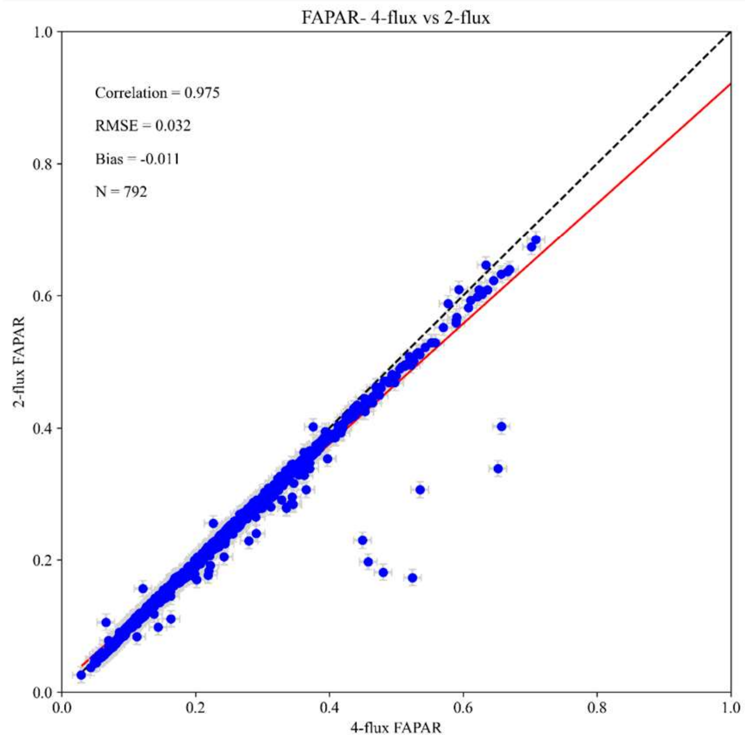




Comparison between 4flux and 2flux instantaneous FAPAR

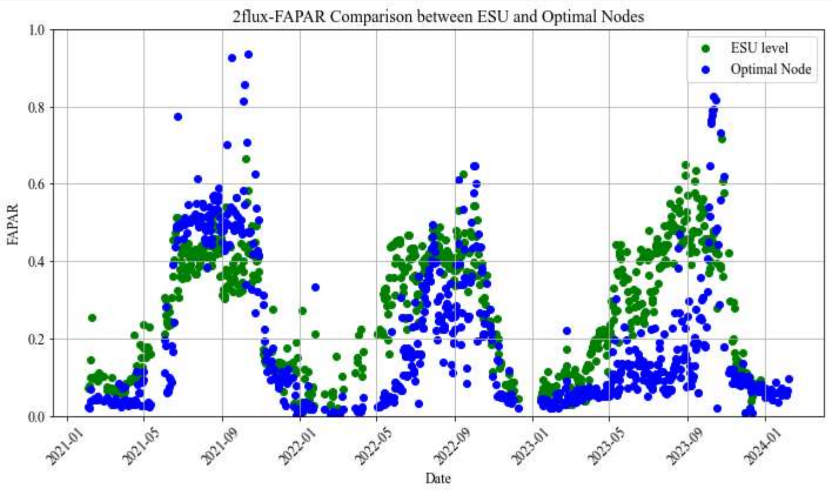
Case study: Litchfield

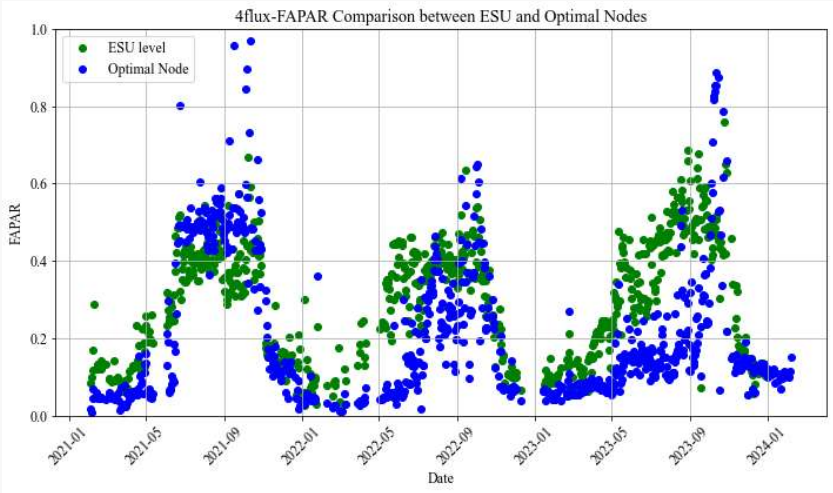




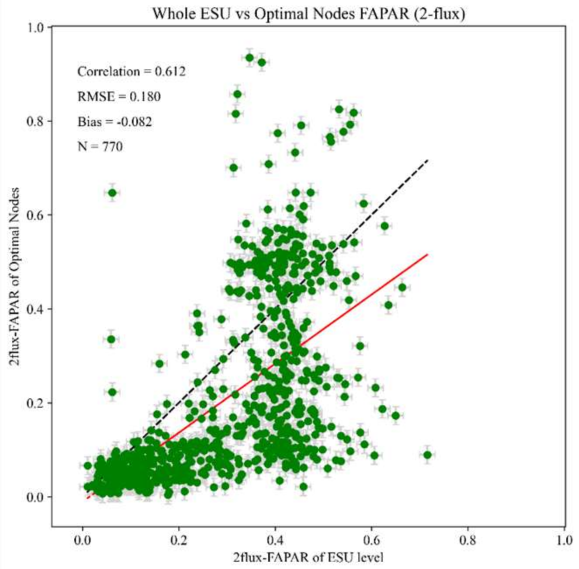
Comparison between 4flux and 2flux instantaneous FAPAR

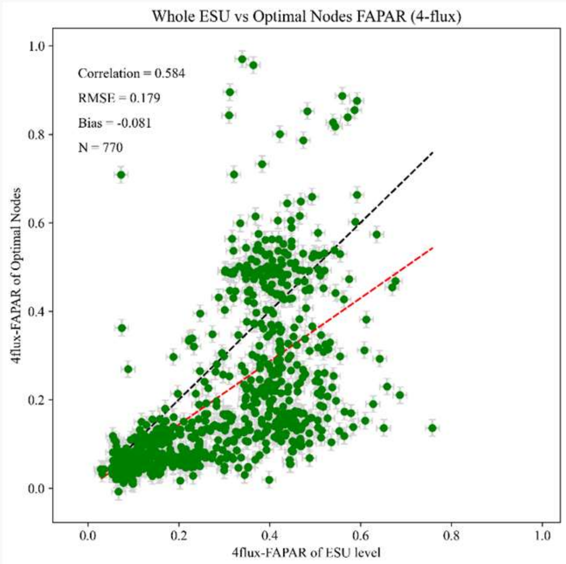
Optimal numbers of nodes (VAS)

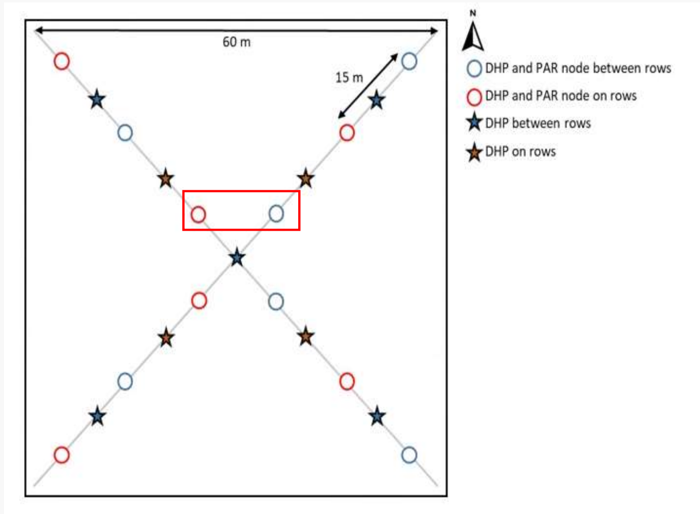




Total nodes:12
Optimal nodes: 2







Optimal numbers of nodes (Hainich)

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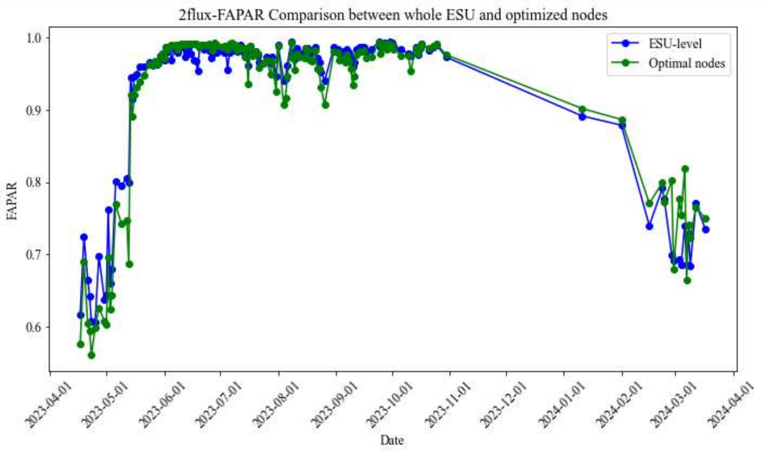
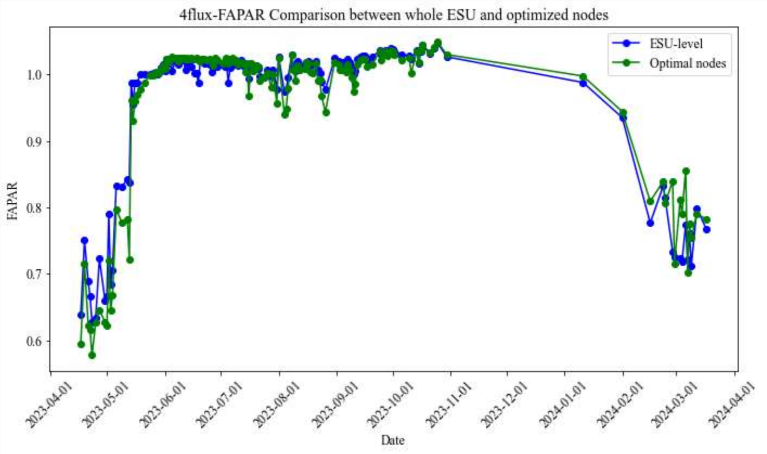
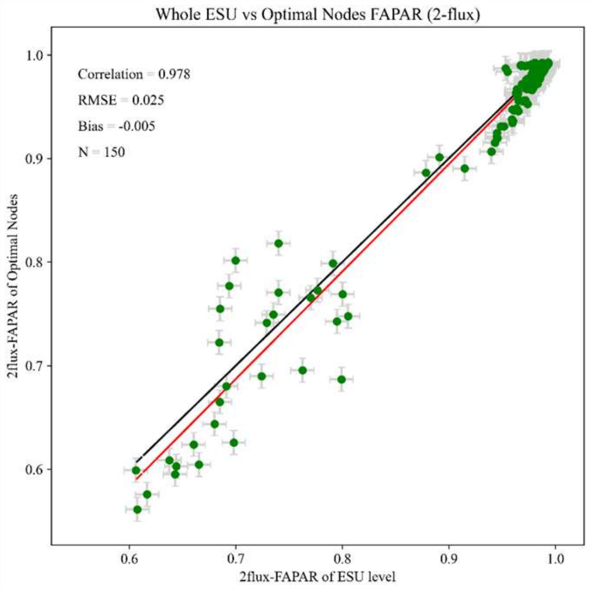
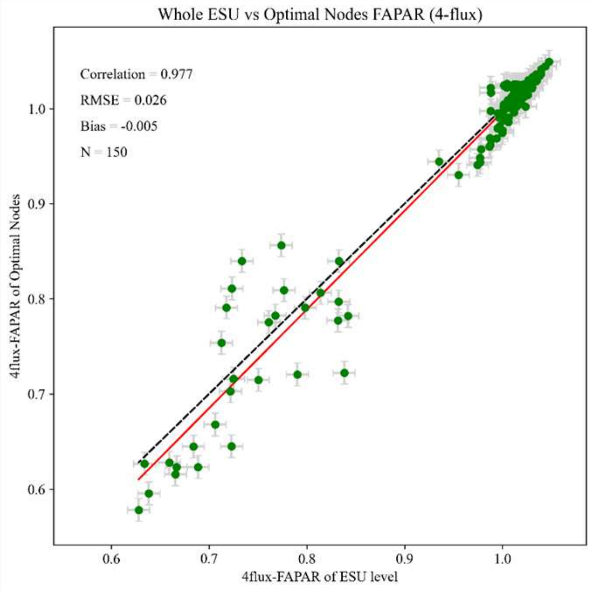
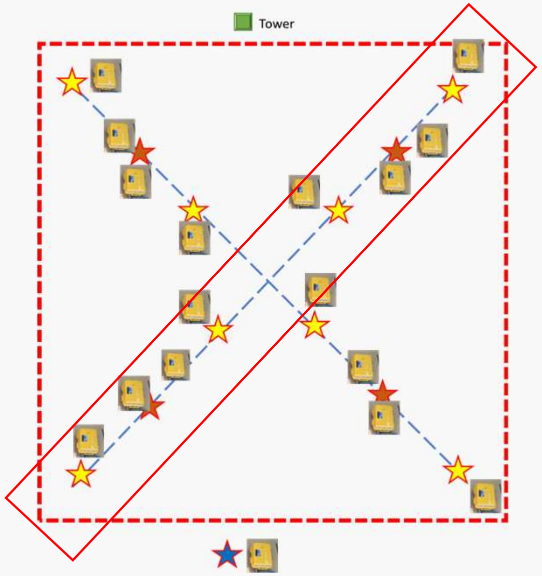




Total nodes:17
(8 for overstory)
Optimal nodes: 4







Optimal numbers of nodes (Litchfield)

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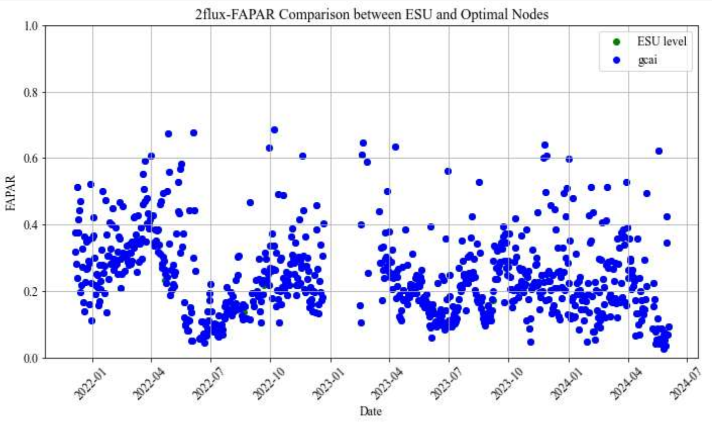
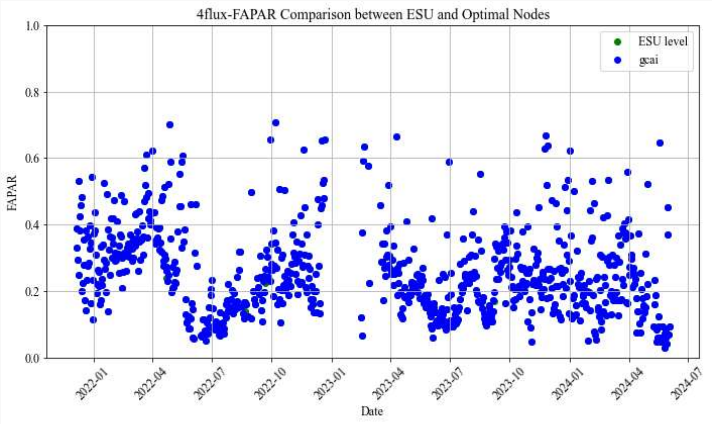
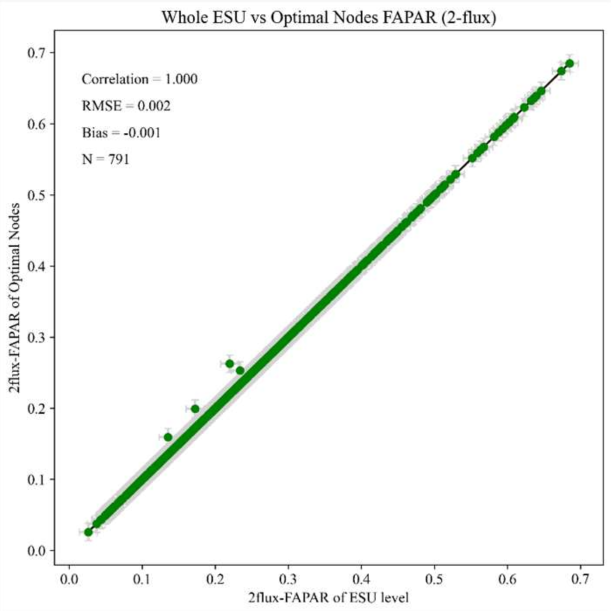
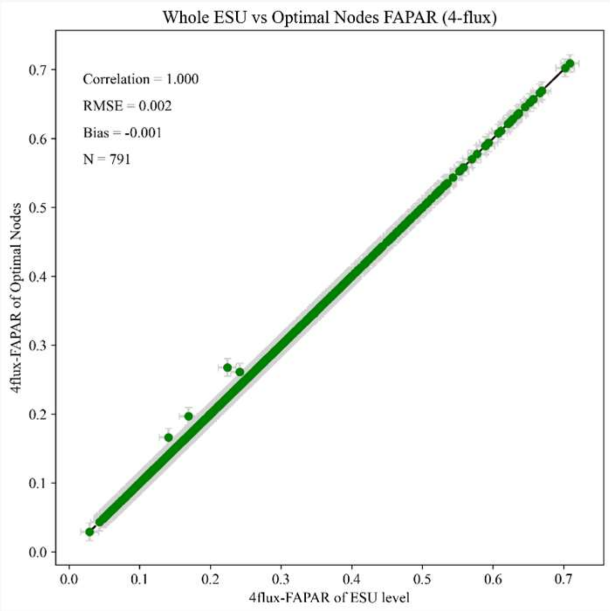


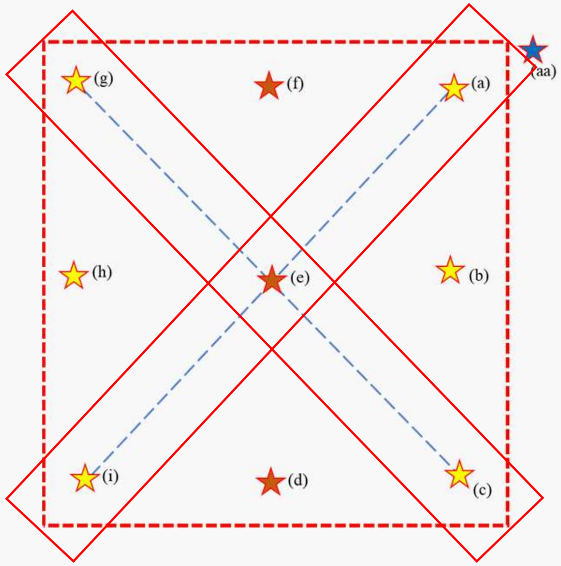


Total nodes:6

Optimal nodes: 4







Future work

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- ❑Comparison between PAR network extracted FAPAR and DHP extracted FAPAR
- ❑Intercomparison between instantaneous FAPAR and daily FAPAR
- ❑ This FAPAR estimation framework would be applied other potential sites.
- ❑ Validation with satellite data product (e.g., Proba-V, S3 OLCI)

Thank you