Land product validation of MODIS derived FPAR products over a tropical dry-forest

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Introduction

The fraction of photosynthetically active radiation **(**Green FPAR**)** can currently be used as a proxy to track phenology in forest biomes:

- **Green FPAR** measures the photosynthetically active radiation (400 – 700nm) utilized by vegetation to quantify the amount of photosynthesis occurring within an ecosystem.
- **Green FPAR** is sensitive to changes in vegetation health and can be used to monitor and quantify the response of vegetation to inter-seasonal effects and climate change.

In this study two methods are employed to estimate Green FPAR**:**

1. A ground-based PAR budgeting (Gower et al., 1999) approach utilizing PAR sensors mounted to phenological, carbon flux towers, and Wireless Sensor Network nodes (**WSN**) distributed throughout the forest understory.
2. A satellite-based approach (using the **MODIS** 500m FPAR land product.) which utilizes the relationship between LAI and FPAR, as well as the relationship between vegetation's absorption of red light, and its reflection of near infrared radiation.

Hypothesis

- MODIS FPAR underestimates in-situ FPAR measurements.

Aims:

1. To create a temporally and spatially coherent data set between in-situ ground-based and MODIS derived FPAR products that can be used by the scientific community.
2. To identify biases of in-situ green FPAR, specifically in the context of a tropical dry-forest.
3. To investigate how biases of green FPAR may explain the discrepancies between in-situ and satellite based measurements.

Methods

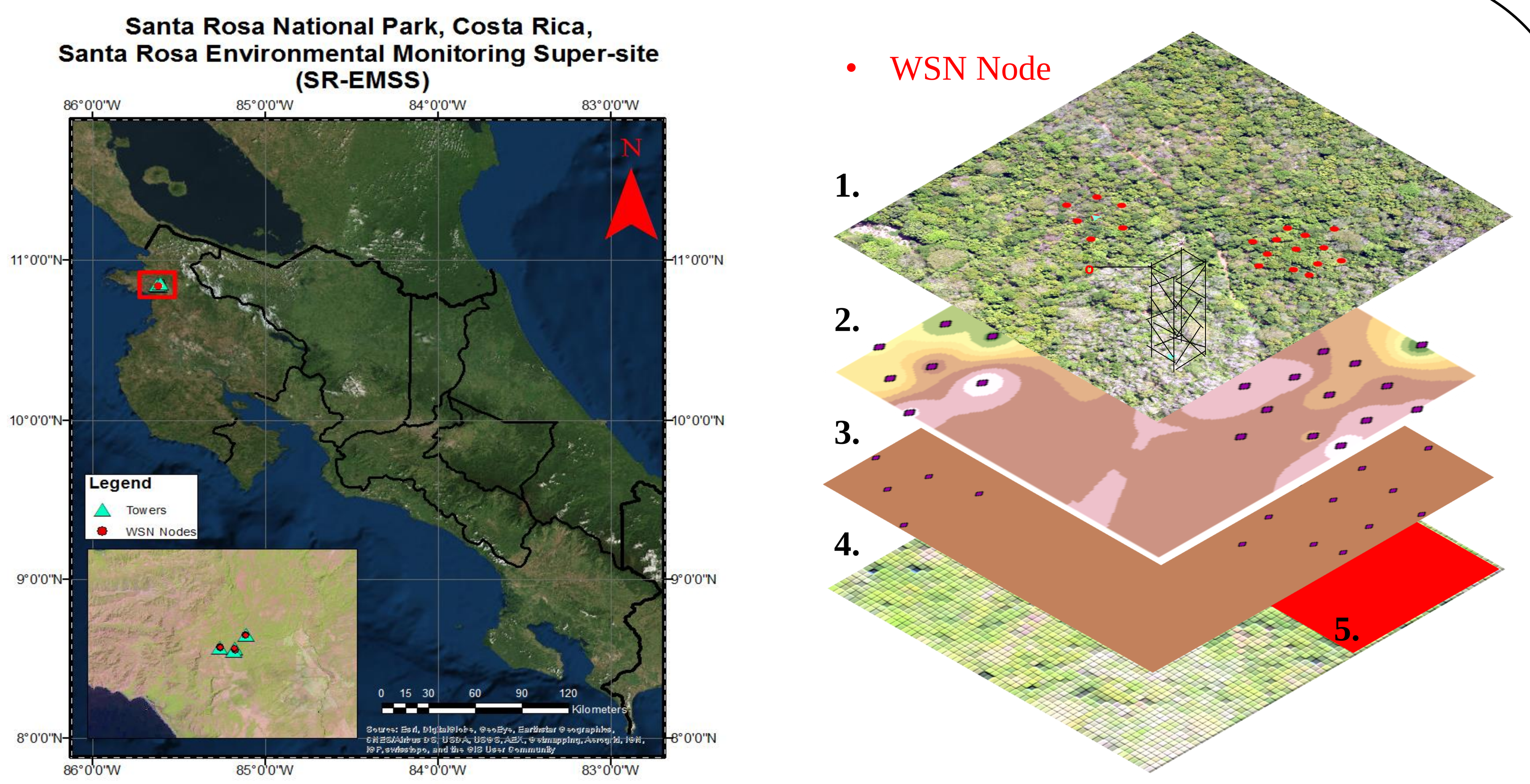

Figure 1: Location of the in-situ wireless sensor network (WSN) at the Santa Rosa National Park Environmental Monitoring Super-site (SR-NP EMSS) in Guanacaste, Costa Rica. 1) WSN and Phenology Tower Layout, 2) Spatial distribution of FPAR between WSN nodes within a MODIS pixel, 3) Average of WSN data under one MODIS pixel to upscale, 4) NASA LaRC Satellite overpass predictor to capture MODIS Terra and Aqua overpass times. 5) ORNL DAAC C6 MODIS Subset tool to capture MOD15A2H (Terra), MYD15A2H (Aqua) and MCD15A3H (4-Day MODIS) products over in-situ sites.

$$FPAR = \frac{iPAR - tPAR - rPAR}{iPAR}$$

*Figure 2: The wireless sensor network in the understorey and the associated tower measure incoming PAR, (**iPAR**) transmitted PAR (**tPAR**), and reflected PAR (**rPAR**) at a sampling frequency of 15 fifteen minutes. Combining the three measurements we are capable of producing an in-situ green FPAR product.*

Causes of Variance for in-situ FPAR

- Wind speeds >= 5 m/s cause an increase in the variance of in-situ FPAR measured, and a decrease in the overall FPAR values.
- PAR measurements made at a Solar Zenith Angle's <57° has increased variance and lower overall average.

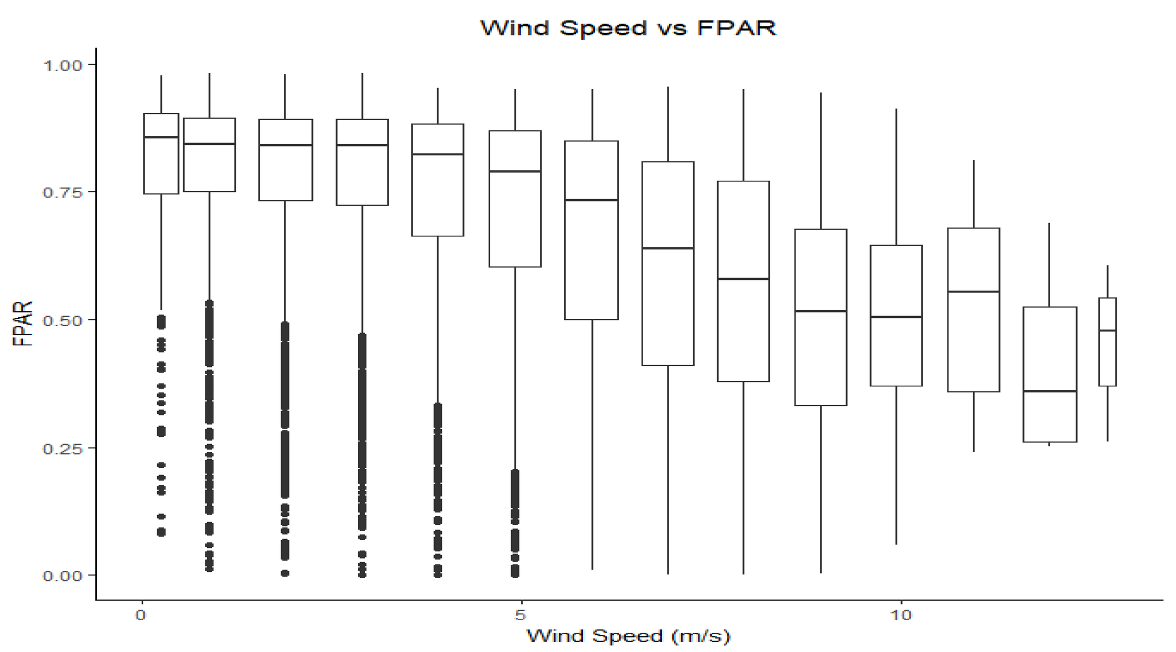

Figure 4: A box-plot analysis on the effect of wind speed on FPAR in the wet season. Each box represents a 1 m/s grouping.

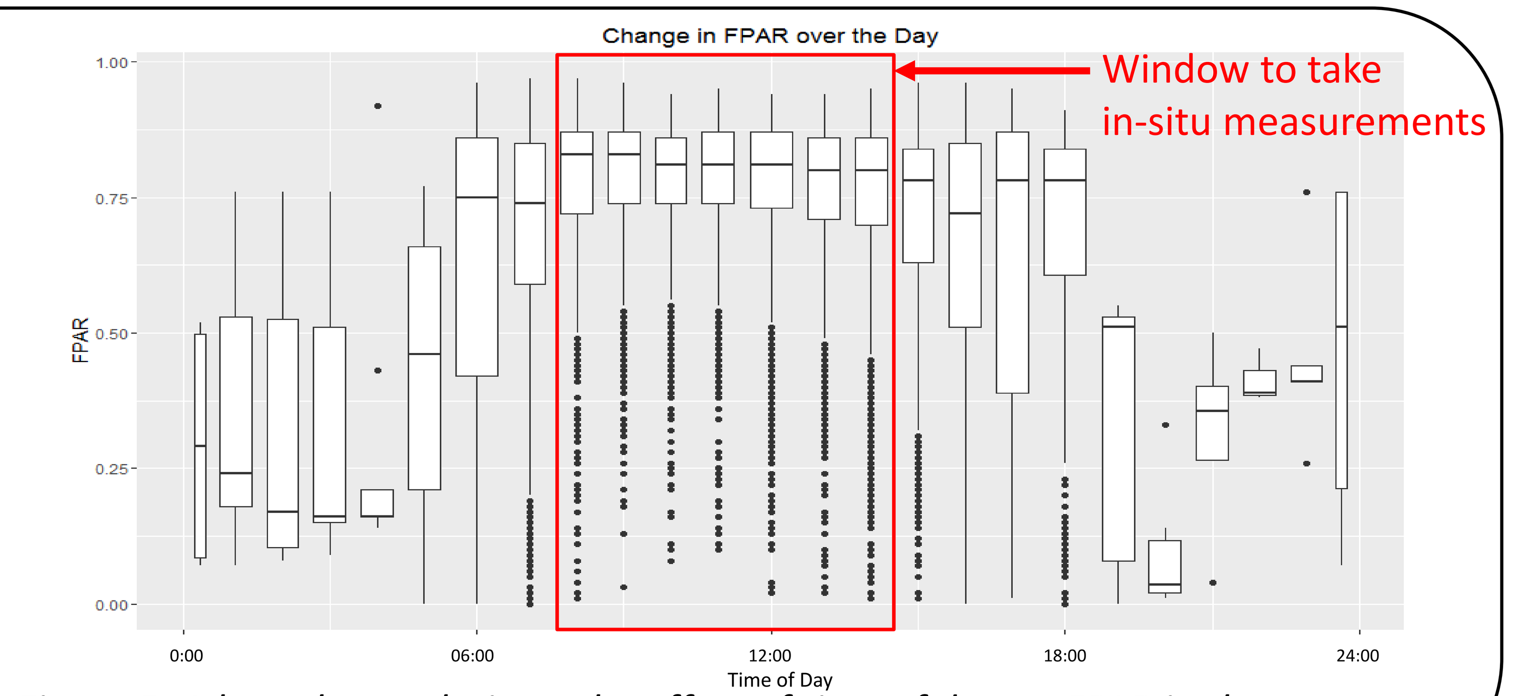

Figure 5: A box-plot analysis on the effect of time of day on FPAR in the wet season, and to ensure no effect of FPAR distribution during the time of overpass.

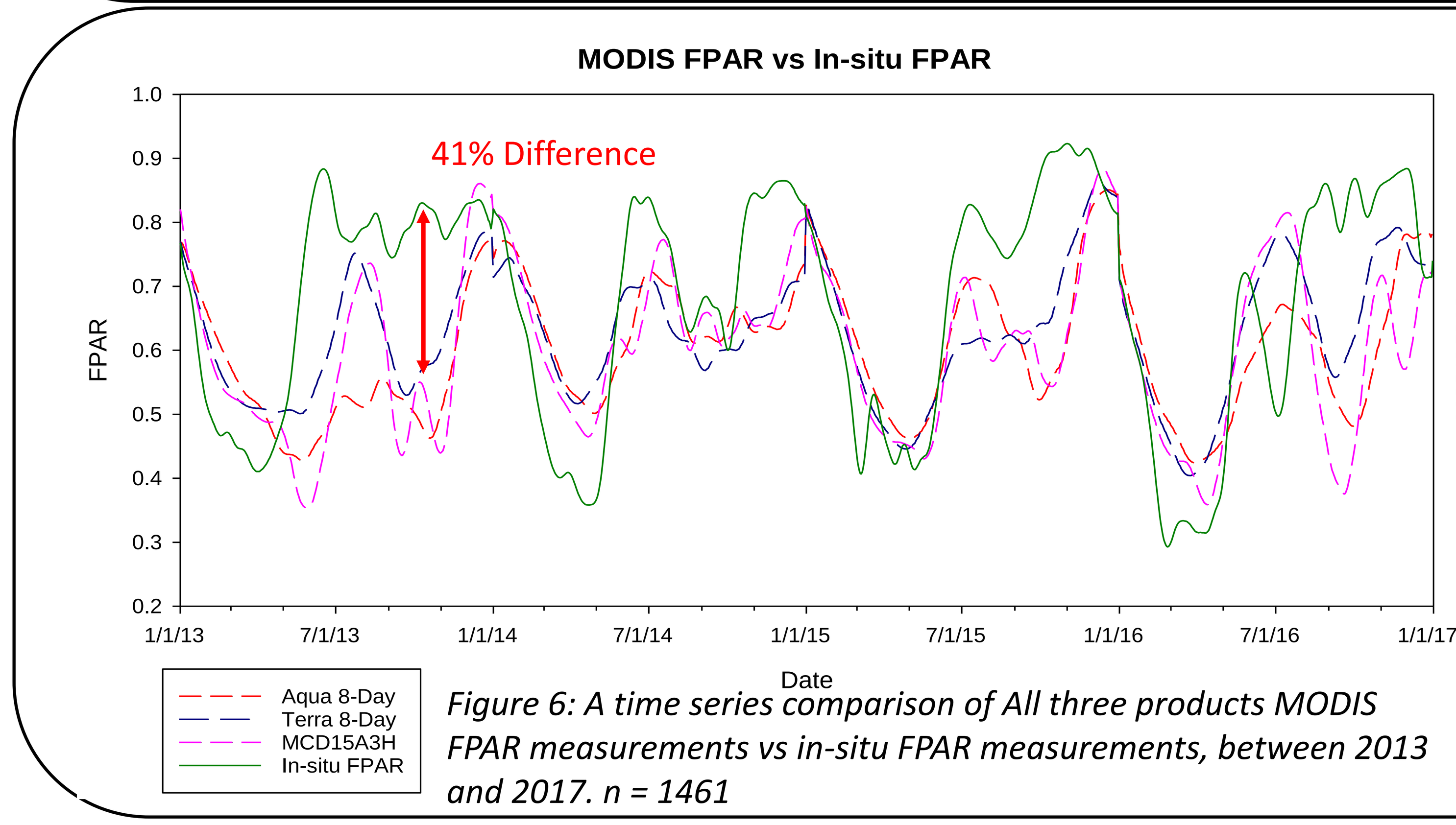

Figure 6: A time series comparison of All three products MODIS FPAR measurements vs in-situ FPAR measurements, between 2013 and 2017. n = 1461

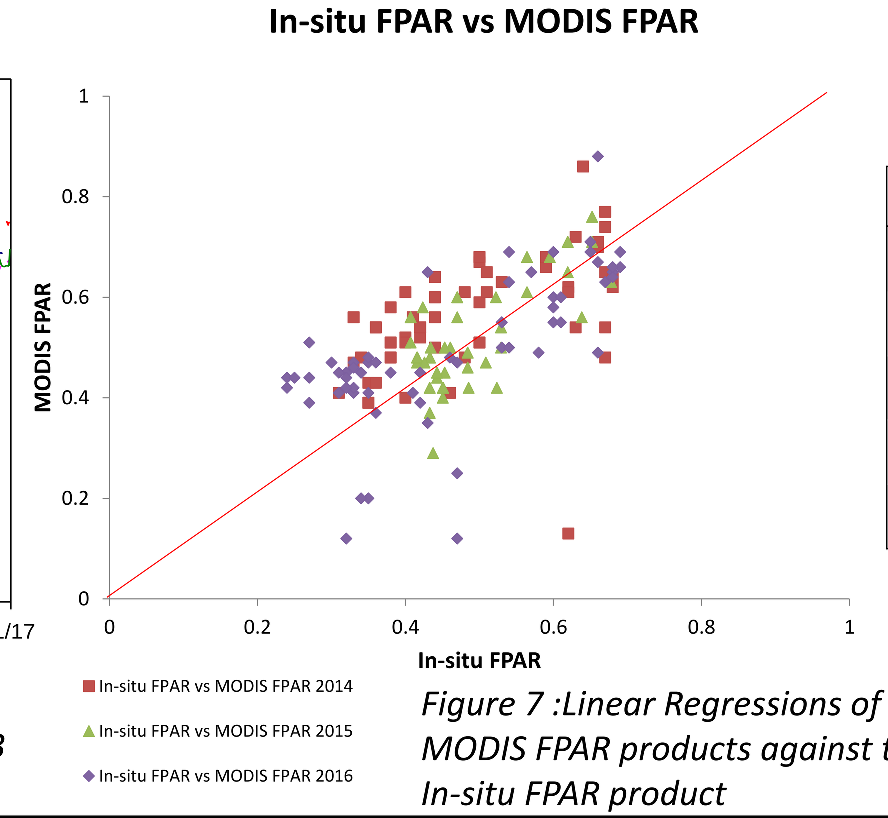

Figure 7 :Linear Regressions of all MODIS FPAR products against the In-situ FPAR product

Table 1 The start and end dates of the phenological growth and maturity seasons along with their lengths, and the difference in growing season length between MODIS Terra(C6), the MCD15A3H product, and in-situ FPAR products.

Year	In-situ			Terra 8-Day (C6)				Aqua 8-Day (C6)				MCD15A3H			
	Start	End	Length	Start	End	Length	Diff	Start	End	Length	Diff	Start	End	Length	Diff
2013	May 5	Feb 2, 2014	271	May 25	Feb 22, 2014	284	12	Nov 4	Feb 22, 2014	110	-171	Nov 15	Feb 12, 2014	89	-183
2014	May 18	Feb 5, 2015	264	Aug 8	Feb 3, 2015	214	-50	Oct 27	Feb 15, 2015	110	-104	Aug 8	Feb 20, 2015	182	-82
2015	June 6	Jan 19, 2016	223	June 15	Feb 2, 2016	241	19	Sep 19	Jan 15, 2016	122	-119	Oct 30	Jan 17, 2016	78	-145
2016	April 30	Jan 25, 2017	229	April 20	Feb 10, 2017	255	26	May 2	Jan 24, 2017	226	-3	April 24	October 10, 2016	192	-37

Table 2 Linear Regression results from comparison of MODIS FPAR products with in-situ FPAR results.

FPAR Product	R2	t-score	P
2014	0.285	10.242	<0.001
2015	0.574	26.785	<0.001
2016	0.457	19.879	<0.001

Conclusion

- All three of MODIS's FPAR products (MOD15A2) **underestimate** FPAR during phenological maturity, when compared with in-situ measurements (Figure 6).
- General phenological trends are captured accurately by the MODIS FPAR product during drought years (2014, 2015) but not during 'normal' wet seasons (2013, 2016) (Figure 6).
- The MODIS Aqua and MCD15A3H FPAR products consistently underestimate the growing season length, whereas the Terra product typically overestimates growing season length compared to the in-situ estimates of growing season length (Table 1).
- Wind speed has an affect on in-situ FPAR measurements (Figure 4), this is not a problem for long-term studies, but may for short-term studies if not taken into account. Short-term studies that have smaller sample sizes for collecting PAR data, may have an increased variance or a lower overall FPAR.