Using Photosynthetically Active Radiation as a Proxy to Estimate the Impact of NEON's Tower Infrastructure on Microclimate Measurements

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neon National Ecological Observatory Network

Background & Objective

To measure the plant microclimate vertically through the ecosystem structure, the National Ecological Observatory Network (NEON) constructs and utilizes towers equipped with ecological sensors. Constructing these sites is complex and the impact of its tower infrastructure on measuring environmental variables is unknown. A tower's presence can impact the microclimate, which may include air temperature and radiation profiles. One of NEON's goals is to **ensure that measurements are accurate and representative of the surrounding ecosystem.**

Figure 1. CASTNET tower

Objective:
To assess the environmental effects of NEON's tower infrastructure by using the **attenuation of photosynthetically active radiation (PAR)** measurements as a proxy for the radiation environment and other related environmental variables (e.g., short wave radiation and air temperature).

Data Collection

Field work was completed on May 30, 2015:

- PAR measurements were collected +/- 2 hours from solar noon
- Mostly sunny, partly cloudy conditions post solar noon

Figure 4. Transect system with a point sensor (PSQ1, Kipp & Zonen, Delft, Nederlands), line quantum sensor (LI-191SL, LI-COR Inc, Lincoln, NE) and a data logger (CR3000, Campbell Scientific, Logan, UT)

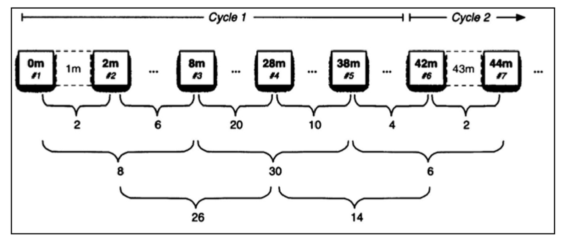

Figure 5. Spatial sampling method from Bond-Lamberty *et al.* (2006)

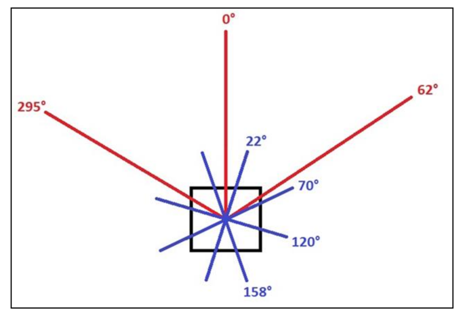

Figure 6. Transect layout; blue and red lines transects extended to 8 m and 126 m respectively

Systems

1. Tower top:
   - PQS1: point sensor
2. Transect / roving system
   - PQS1: point sensor
   - LI-191SL: line quantum sensor
   - Spatial sampling methods followed Bond-Lamberty *et al.* (2006) and Loescher *et al*. (2014)
   - 30 seconds of data collected at each transect point and tower top at 1 Hz

Site Description

CASTNET is located in Rocky Mountain National Park, CO (elevation: 2750 m)

- Semi-open ponderosa pine ecosystem
- Open understory

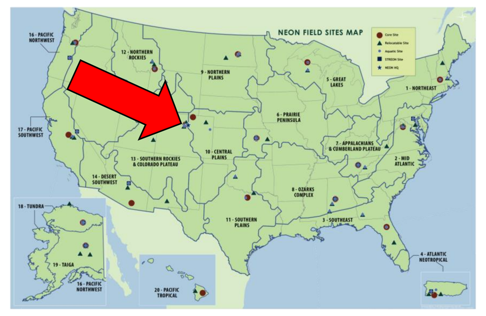

Figure 2. Map of NEON's 20 ecoclimatic domains

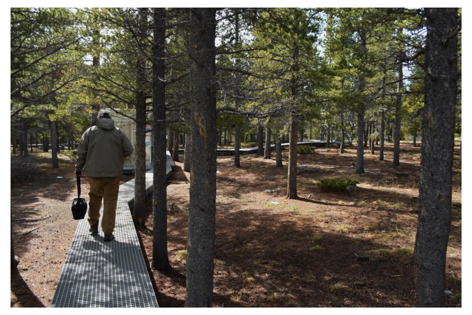

Figure 3. Understory of CASTNET site

Calibration

- Reference PAR sensors were calibrated on National Institute of Standards and Technology (NIST) **traceable light source**.
- Field PAR sensors were **compared to reference** PAR sensors for solar energy calibration at outdoor calibration laboratory.
- **Calibration coefficients were determined** by slope of linear fit between reference PAR measurements vs. sensor signals.

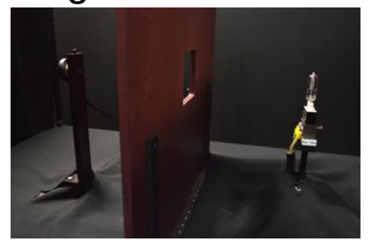

Figure 7. Transfer of standard from NIST lightbulb

Figure 8. PSQ1 sensors compared to standardized sensor

Figure 9. Line quantum sensors calibrated using six standardized point sensors

Data Processing & Uncertainty Quantification

Work Flow	Equations	Uncertainty Components
CALIBRATION	Linear Regressions	$u(CVAL)$
RAW FIELD MEASUREMENTS	I_i	$u(DAS)$
Calculate: Calibrated, individual PAR measurement	$PAR_i = I_i * C_1$	
Calculate: Mean PAR	$\overline{PAR} = \frac{1}{n}\sum_{i=1}^{n} PAR_i$	$u(\overline{PAR})$
Calculate: PAR attenuation ratio	$\overline{rAPAR} = \frac{\overline{PAR}_{TT} - \overline{PAR}_{TR}}{\overline{PAR}_{TT}}$	$u_c(\overline{rAPAR})$

TT = Tower top PAR
TR = Transect PAR

Uncertainty estimates of $\overline{rAPAR}$ averaged ±67% at 95% confidence*

Statistical Analyses & Results

1. Linear regressions and t-tests

- Determine if statistically significant difference exists

Between point and line PAR

- $R^2 = 0.87$
- Fail to reject null hypothesis

Between tower base and top

- $R^2 = 0.086$
- Reject null hypothesis

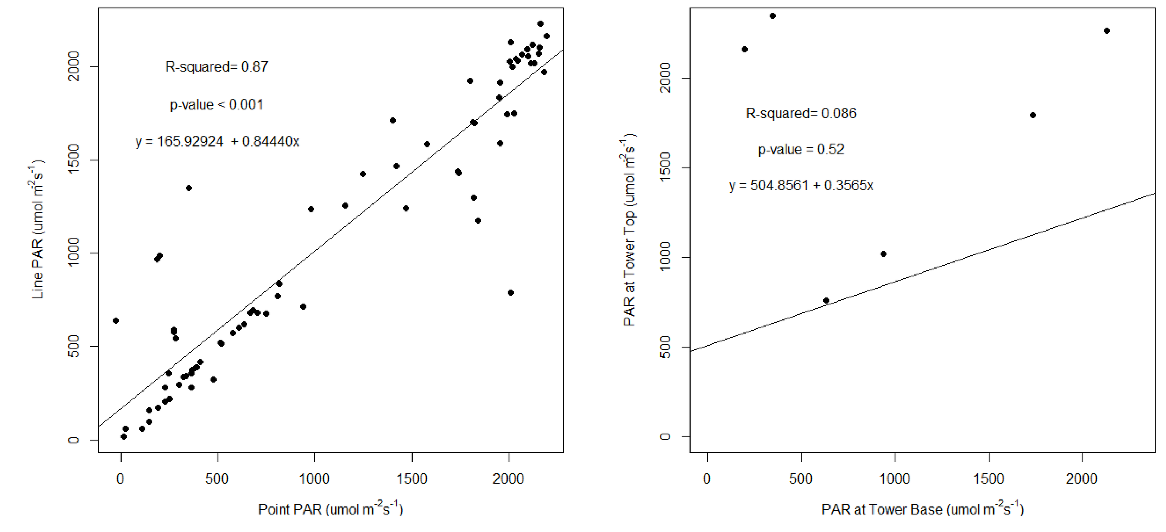

Figure 10. (Left) Relationship between point and line PAR measurements; (Right) Relationship between tower base and top measurements

2. Semivariance

- Range output on semivariogram gives distance of independence

Point PAR: ~ 20 m   Line PAR ~ 44 m

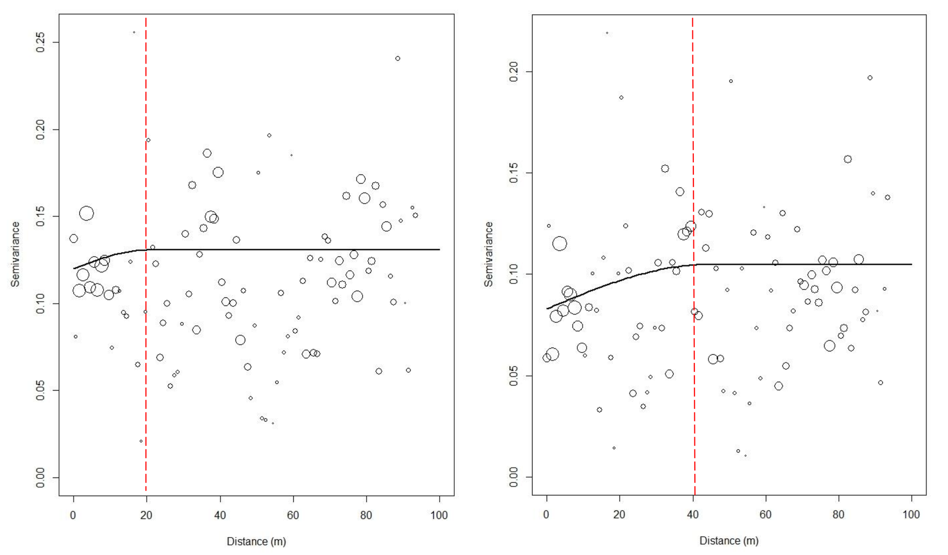

Figure 11. Semivariograms for PAR attenuation ratio of (left) point measurements, and (right) line measurements

3. Hypothesis Test

- Determine if statistically significant difference exists
  - Group 1: PAR < 20 m from the tower
  - Group 2: PAR ≥ 20 m from the tower
- Null Hypothesis: No difference between two groups
- P-value > 0.05
  - Fail to reject null hypothesis
- Group 1 mean: 932.87
- Group 2 mean: 1213.92

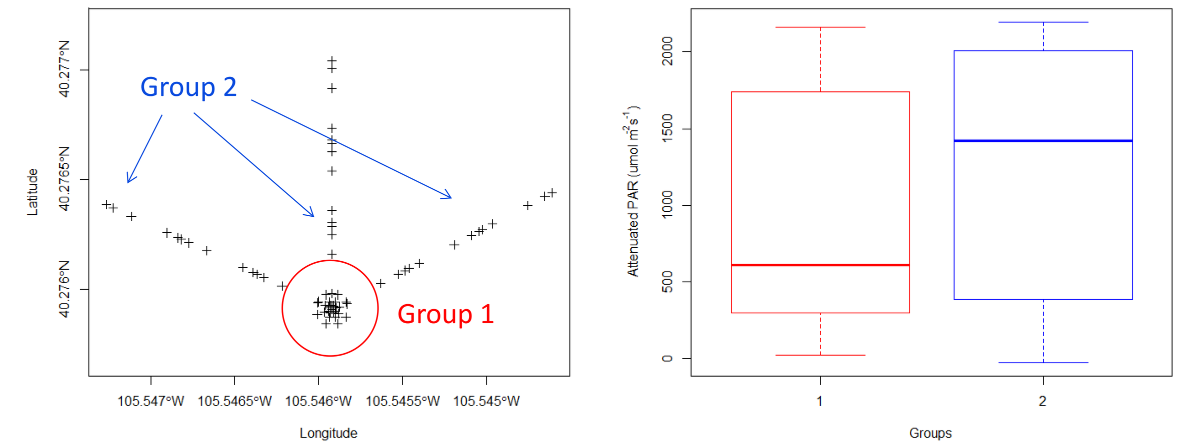

Figure 12. (Left) Spatial plot of transects; (Right) boxplots comparing Groups 1 and 2

Discussion

- **Ecological significance of 20 m range** corresponded to the distance from one projected tree shadow and open gap of sunlight.
- There was **no statistically discernable difference of PAR** at distances within 20 m of the tower when compared to PAR measurements at distances > 20 m from the tower.
- **No detectable impact from the tower** on radiation structure through canopy and could be that the tower structure mimicked the attenuation of light from the tree canopy.
- Differences in point and line PAR might be due to their structures in the amount of light they measure.
- **Other sources of uncertainty**
  - Sensor leveling
  - Differences in cloud cover (possibly contributing to the large magnitude $\overline{rAPAR}$ uncertainty)*
  - Semivariogram model fit

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Best Management Practices

Collaboration between NEON's instrumentation and construction teams is critical to mitigate environmental impact during design and construction processes for NEON sites.

- Infrastructure design facilitates construction within a limited working area.
- Traffic is restricted to 8-feet (8') wide on paths and to areas that extend only 2-feet (2') outside the foundation of structures.

Figure 13. Boardwalk at CASTNET within construction limits; photo taken by construction supervisor

Figure 14. Contractors building tower at CASTNET; photo taken by construction supervisor

Acknowledgements & References

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