

# Demographic Differences in Fine Particulate Matter (PM<sub>2.5</sub>) Exposure Explained by Spatiotemporal Analysis within a Rural Biomass Burning Community

Ky Tanner, Howard Chang, Maggie Clark, Vincent Cleveland, Egide Kalisa, Kayleigh P Keller, Christian L'Orange, Richard Mori, Theoneste Ntakirutimana, Casey Quinn, Christian Sewor, Kellin Slater, Jessica Tryner, Rebecca Witinok-Huber, Bonnie Young, John Volckens  
*Colorado State University*

---

AAAR Annual Conference  
25 October 2024



MECHANICAL ENGINEERING  
COLORADO STATE UNIVERSITY

# Outline:

- Why is **PM<sub>2.5</sub> exposure bad?**
- What are we doing about it? **SHEAR study** and scope.
- Overall **PM<sub>2.5</sub> exposure results** and diurnal **trends.**
- **Spatiotemporal analysis,**
  - Geocoded boundary matrix with ML clustering.
- **Conclusions**



# Millions Die Every Year from Household Air Pollution Especially in Sub-Saharan Africa



Bonnie Young

**2021:**

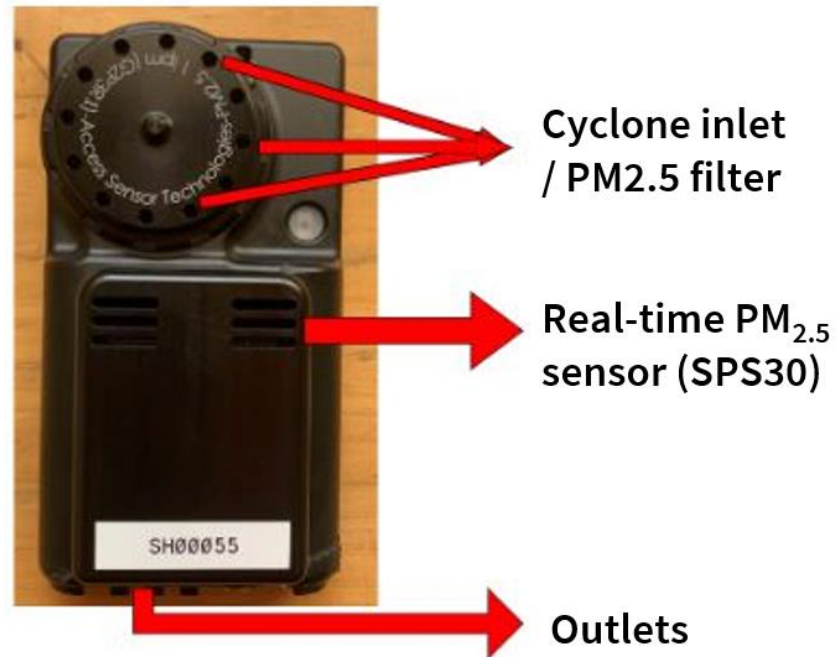
- Globally 3.1 million deaths from household air pollution.
- Sub-Saharan Africa had 23.7% of global deaths with only 18% of global population.
- Lim et al. (2022) identified 0 parent-child exposure studies in LMIC or LICs.



# Personal PM<sub>2.5</sub> Exposure Monitoring

## Historically Challenging, But Now Possible

UPAS V2 Plus (Ultrasonic Personal Aerosol Sampler)



- Gravimetric + Realtime PM<sub>2.5</sub> data
- GPS monitoring
- 48-hour runtimes
- 30-second resolution
- Active mass flow control
- Accelerometry





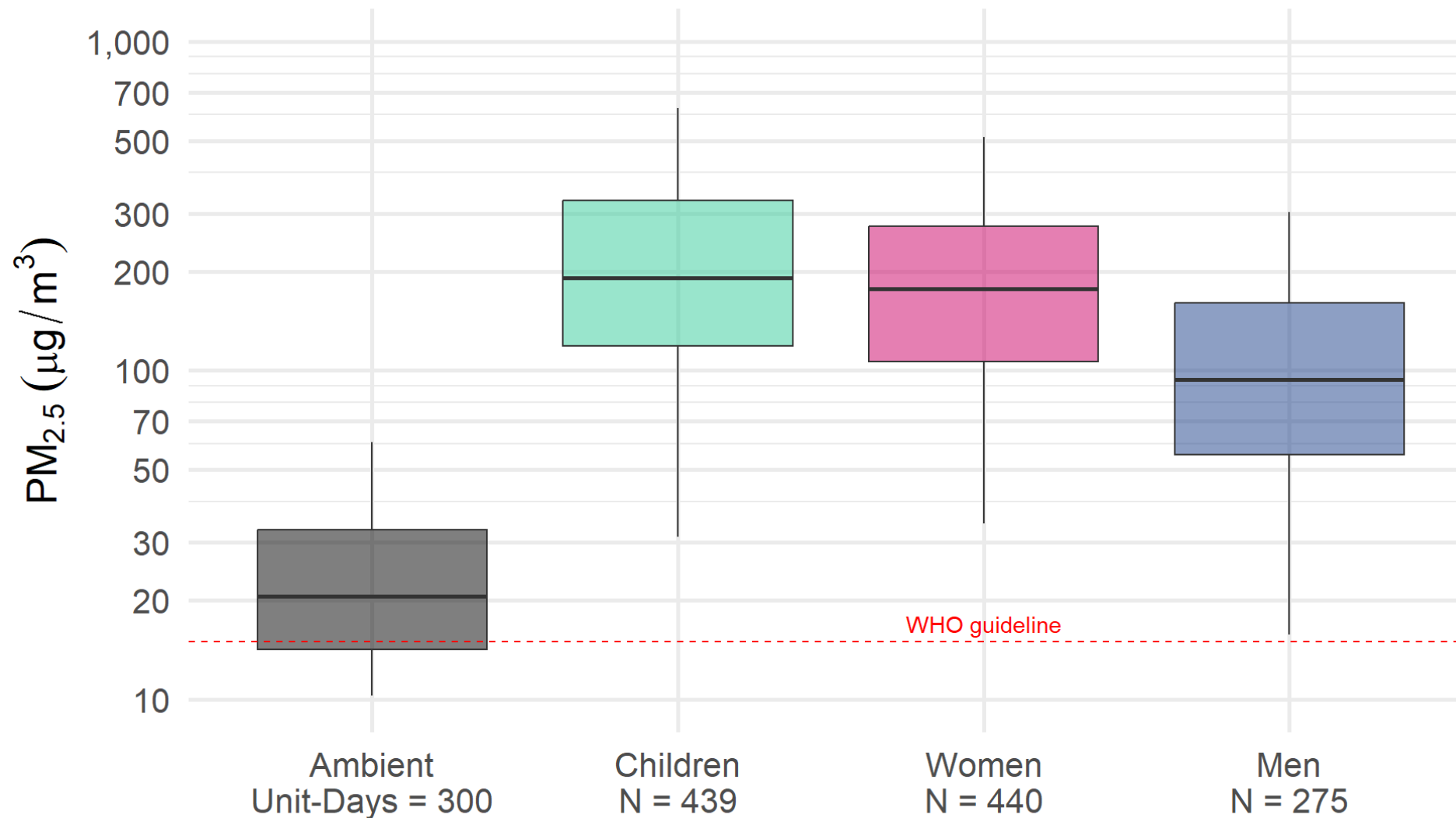
# SHEAR

## Rural Rwanda Biomass Burning Community

- 3-year randomized control trial (2022-2025)
- 48-hour sample.
  
- Pre-intervention (baseline) PM<sub>2.5</sub> exposure analysis
  
- 650 households
  
- 275 men
- 440 women
- 439 children



# Children Bear the Worst PM<sub>2.5</sub> Exposures Among a High-Exposure Community

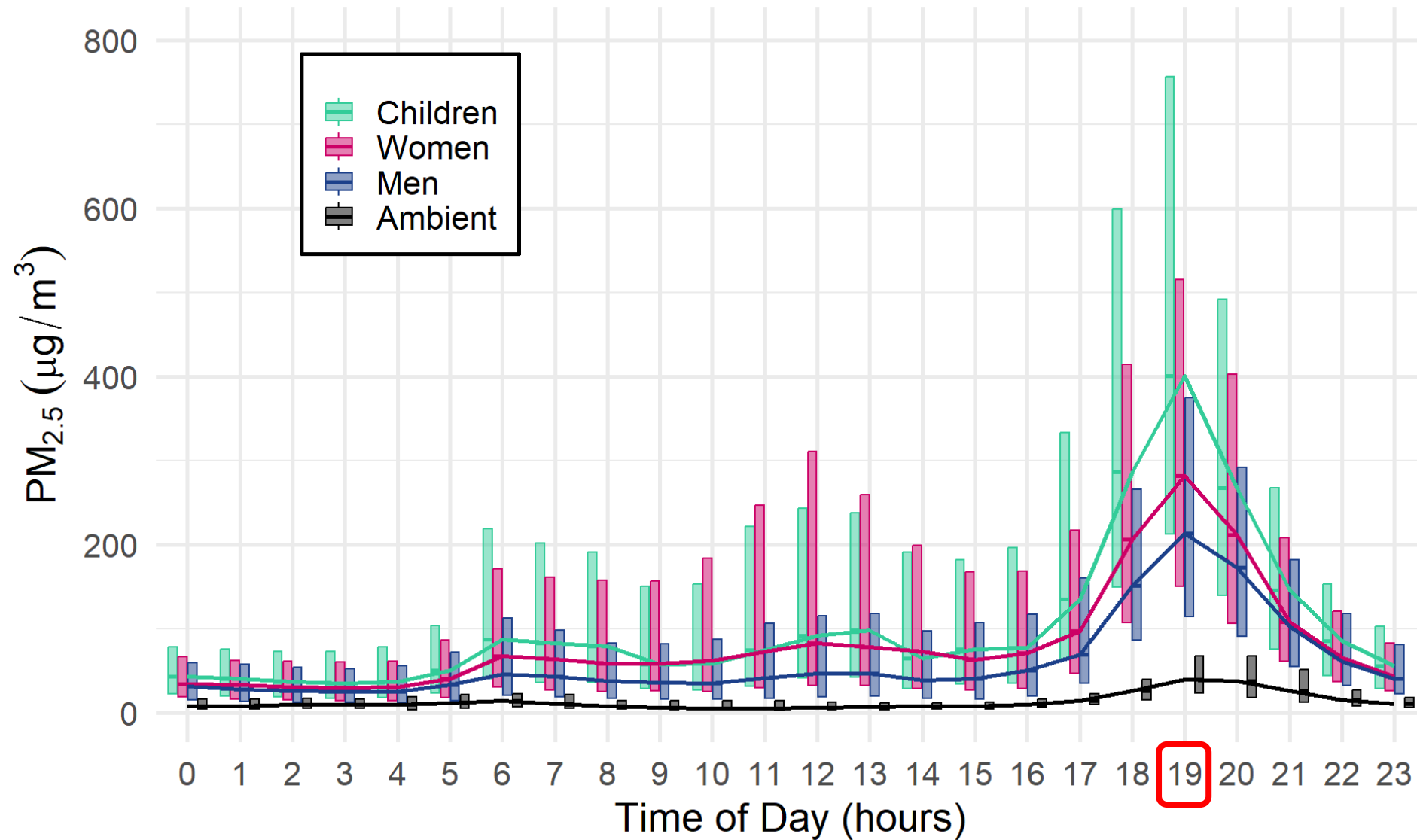


Red line is the WHO 24-hour average PM<sub>2.5</sub> target of 15 µg/m<sup>3</sup>.

Linear Mixed Effect Modeling:

- Children 5% (CI: 1, 8%) higher than mothers.
- Children 36% (CI: 31, 41%) higher than fathers.

# Hourly Average PM<sub>2.5</sub> Exposure Distributions



Everyone's PM<sub>2.5</sub> exposure peaks around dinner.

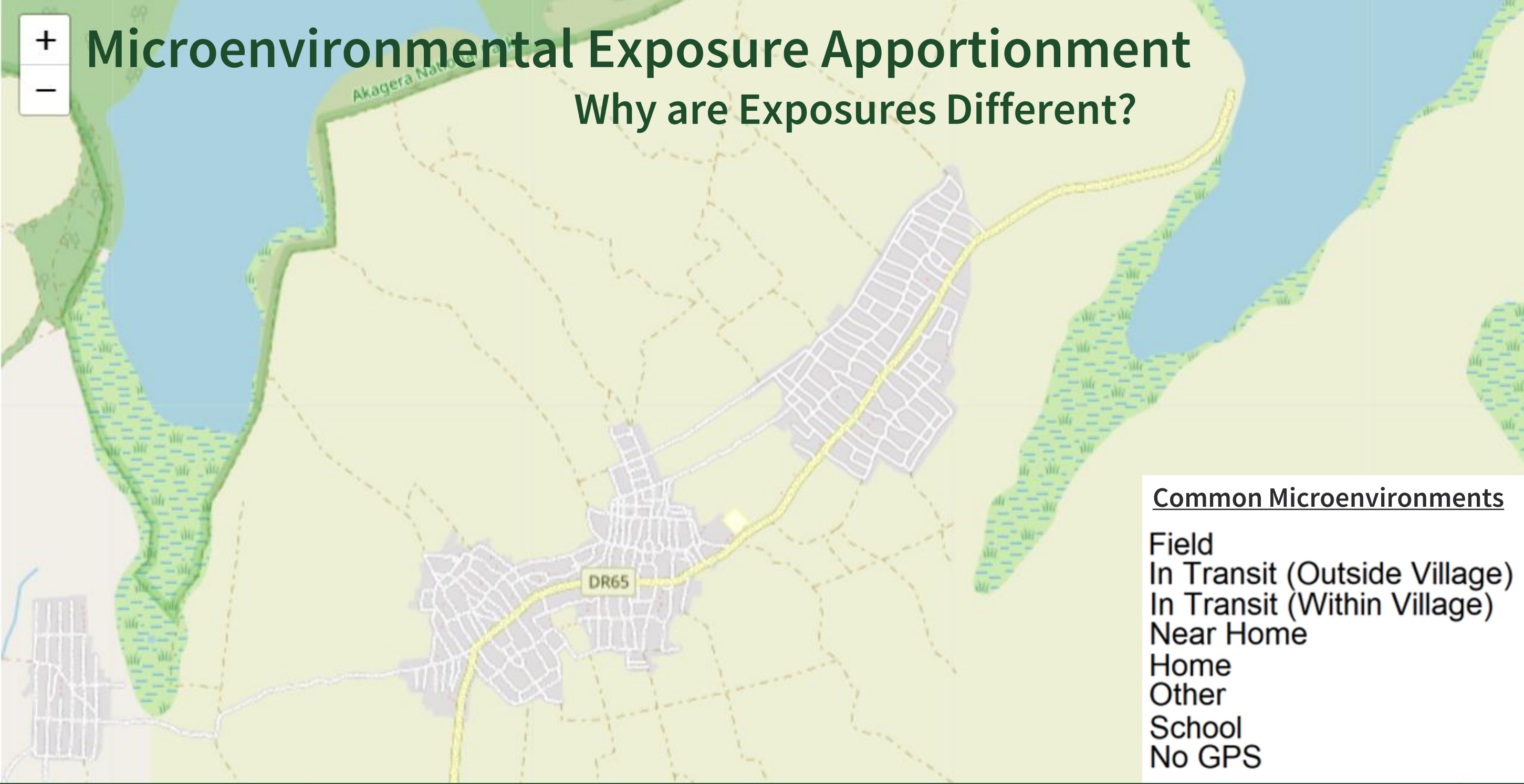
At 19:00:

- Children 18% (CI: 14, 22%) higher than mothers.
- Children 35% (CI: 29, 42%) higher than fathers.



# Microenvironmental Exposure Apportionment

## Why are Exposures Different?



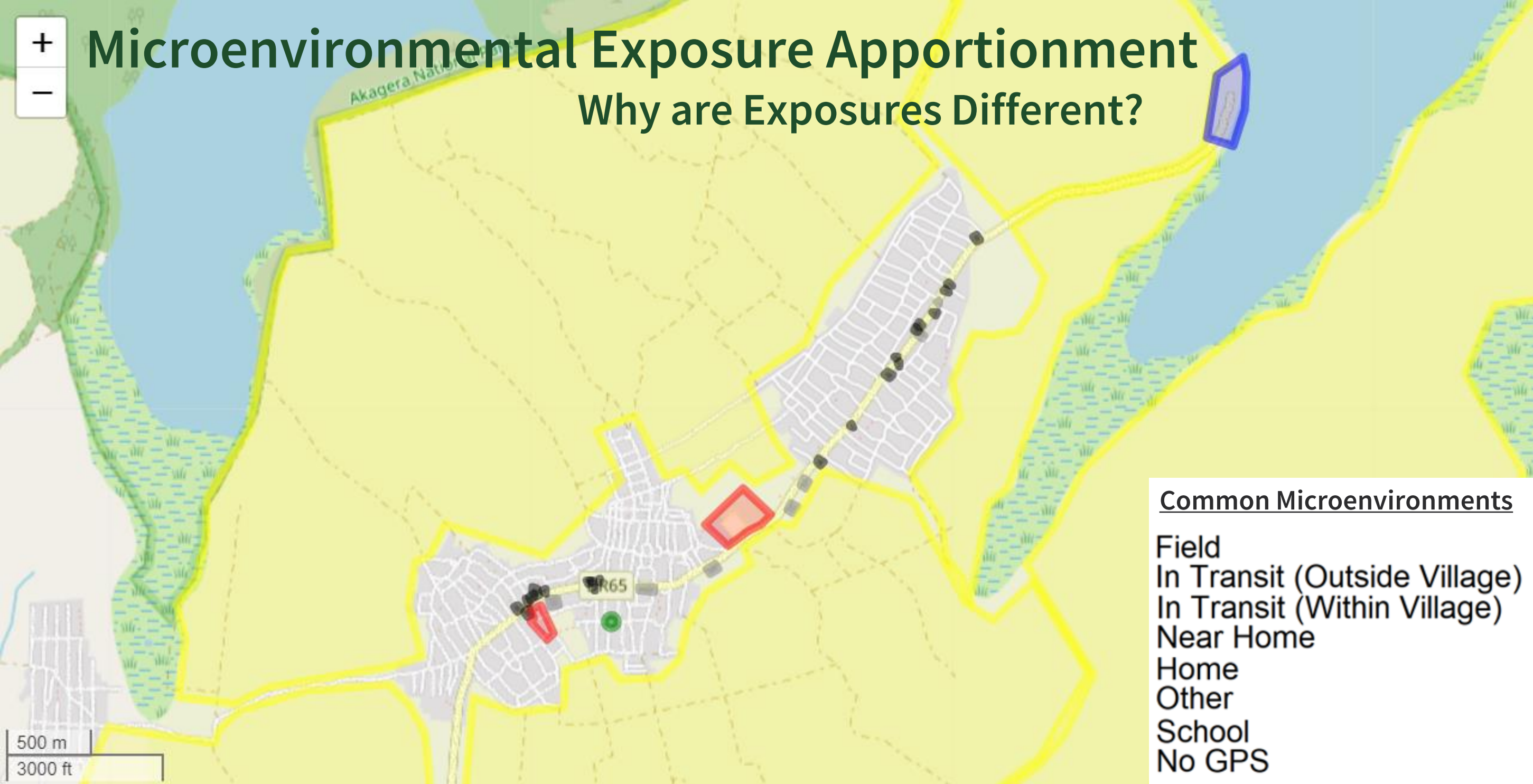
- Common Microenvironments
- Field
  - In Transit (Outside Village)
  - In Transit (Within Village)
  - Near Home
  - Home
  - Other
  - School
  - No GPS





# Microenvironmental Exposure Apportionment

## Why are Exposures Different?



- Common Microenvironments
- Field
  - In Transit (Outside Village)
  - In Transit (Within Village)
  - Near Home
  - Home
  - Other
  - School
  - No GPS



# Microenvironmental Exposure Apportionment

## Why are Exposures Different?

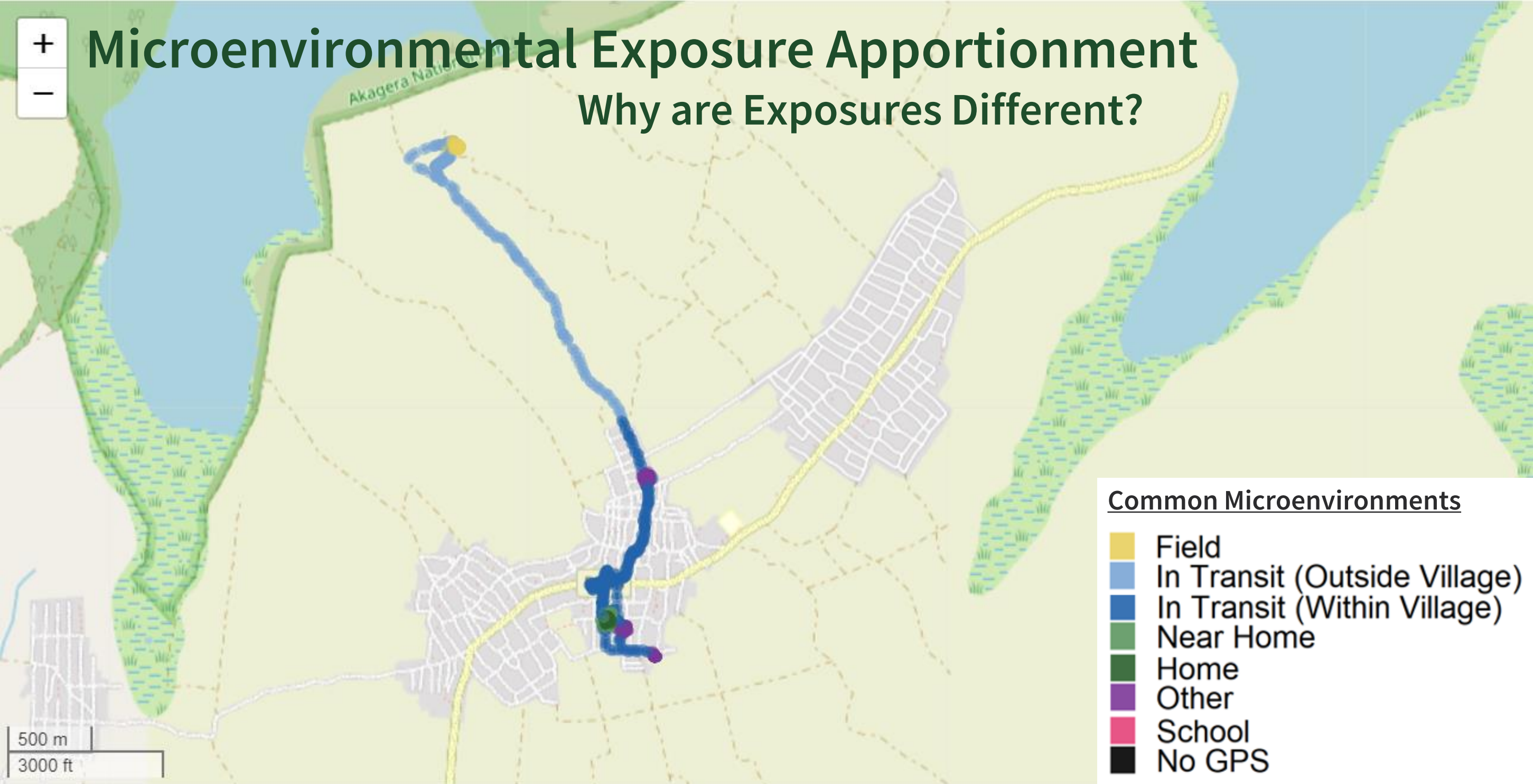


- Common Microenvironments
- Field
  - In Transit (Outside Village)
  - In Transit (Within Village)
  - Near Home
  - Home
  - Other
  - School
  - No GPS



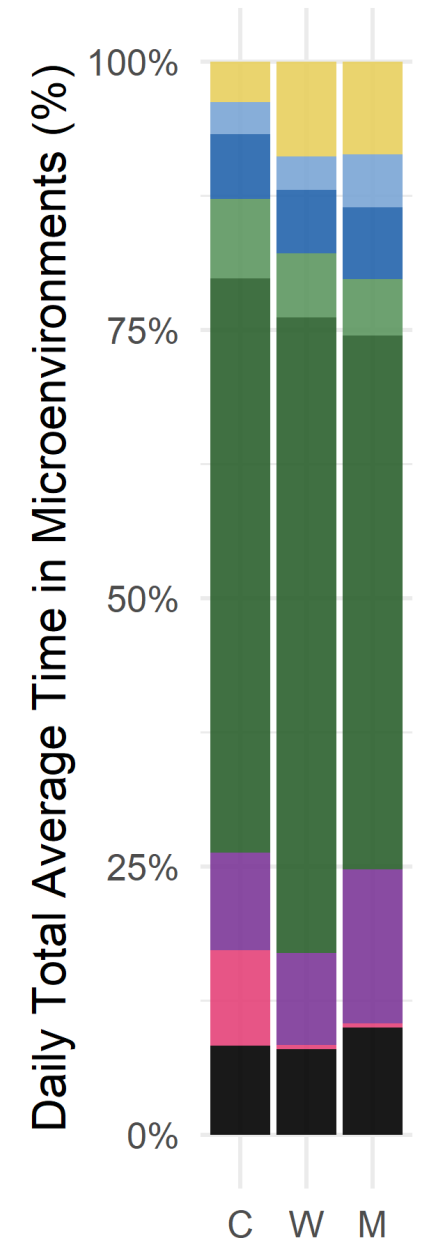
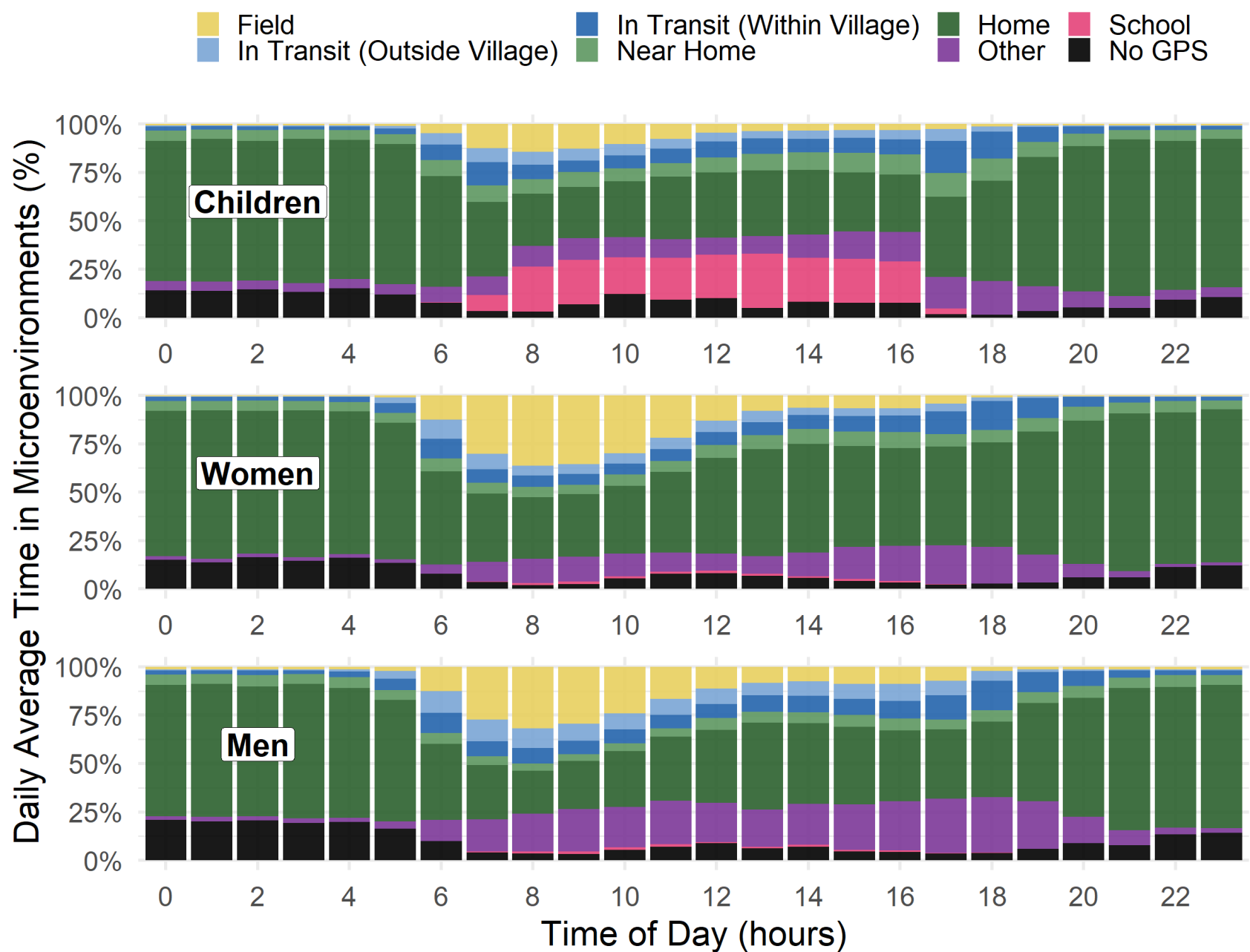
# Microenvironmental Exposure Apportionment

## Why are Exposures Different?



### Common Microenvironments

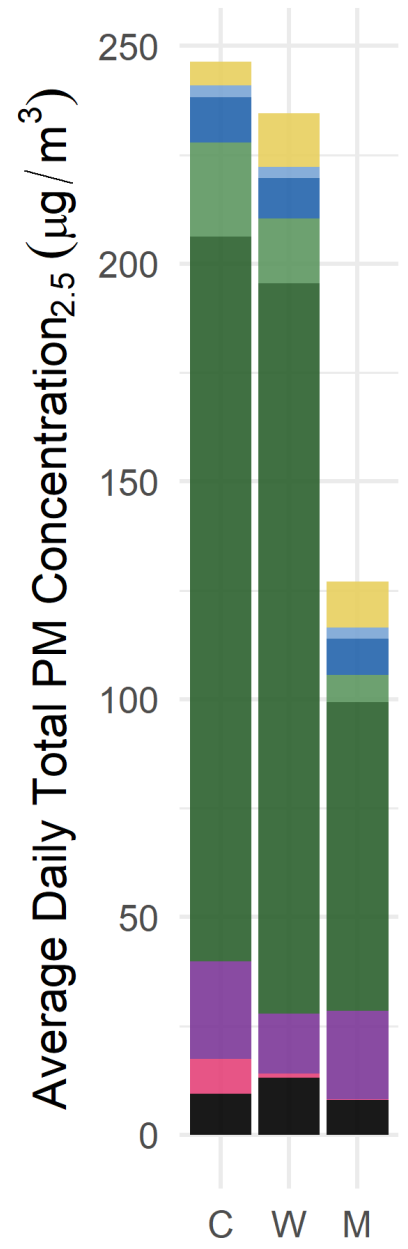
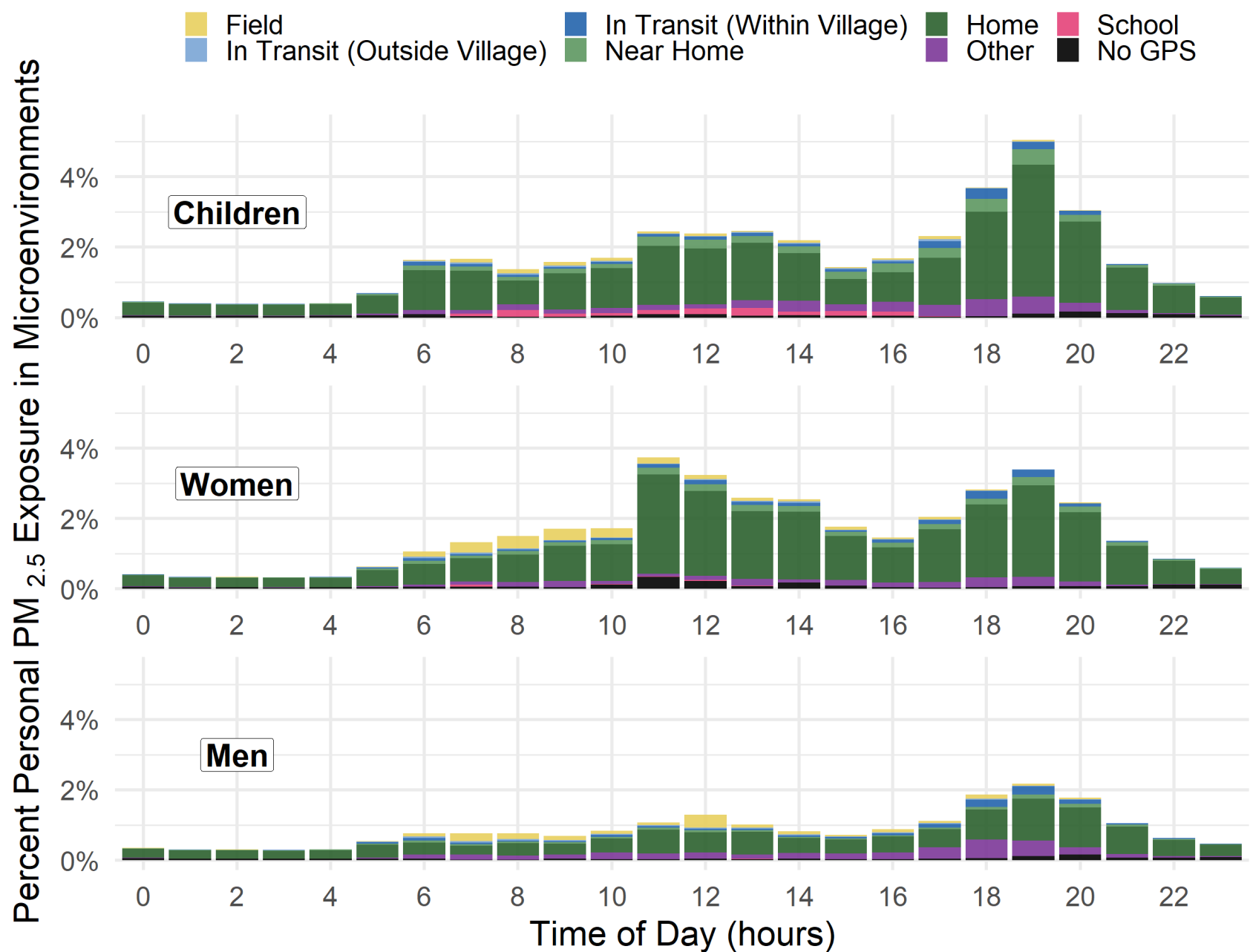
- Field
- In Transit (Outside Village)
- In Transit (Within Village)
- Near Home
- Home
- Other
- School
- No GPS



**Participants Home at 19:00:**

- Children 67%
- Women 64%
- Men 51%

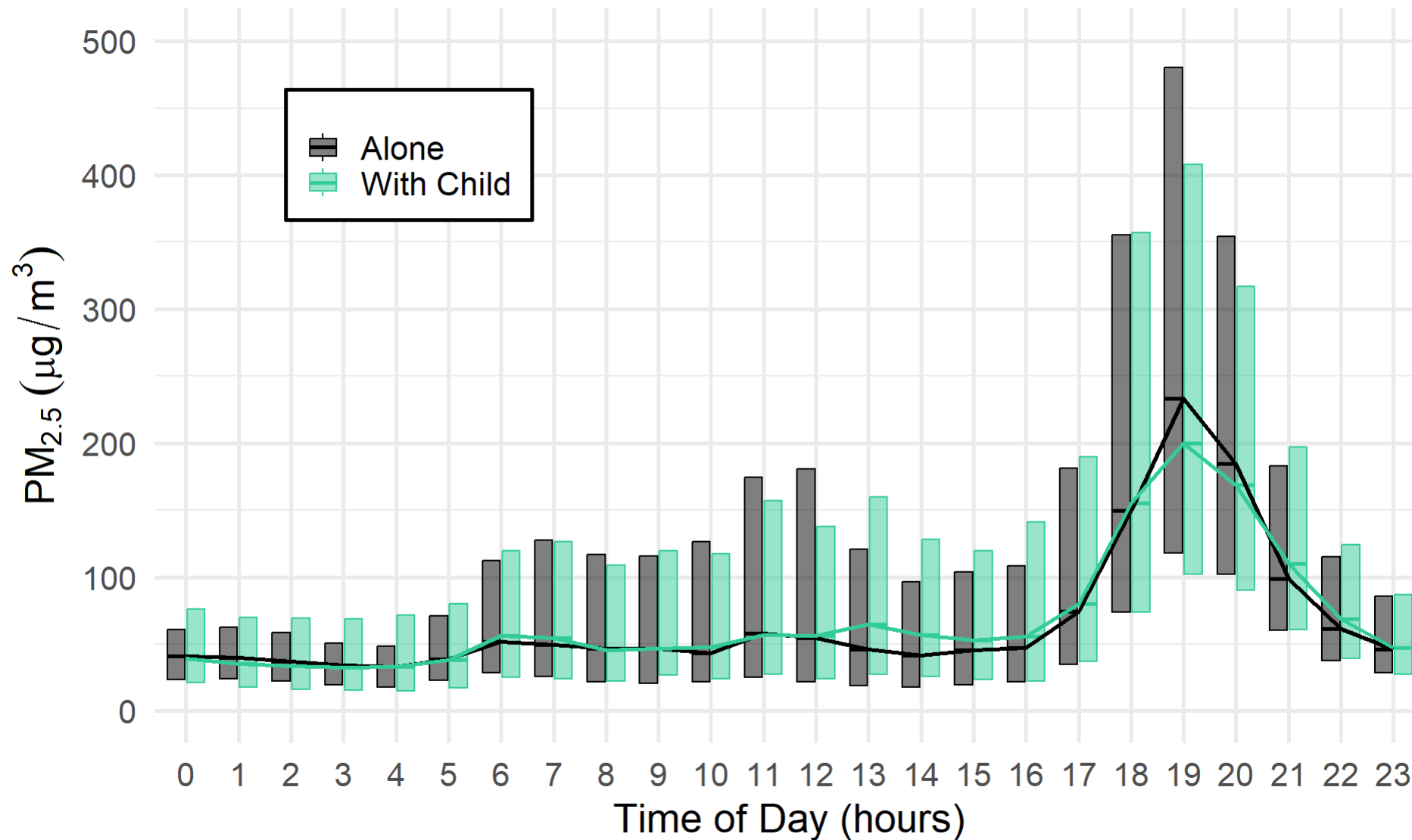
Maybe children help with cooking when at home?



- Majority of all PM from Home.
- Women have an 11:00 spike.
- Children have a large spike in the evening.
- Anecdotal evidence of children doing fire starting and maintenance tasks when home.

# Women's Hourly At-Home Exposure

## Comparing *Alone* Periods to When a Child Was Present (*With Child*)



- Mostly no effect mid-day.
- In the evenings, with child exposure was 2% (CI: 1 – 3%) lower than alone exposures.
- Supports anecdotal evidence from the field team.

# Conclusions:

- **Children > Women >> Men:** Children on average had 5% (CI: 1, 8%) higher PM<sub>2.5</sub> exposures than their mothers, and 36% (CI: 31, 41%) higher than fathers.
- Men (lowest exposure demographic) had **PM<sub>2.5</sub> exposures 6X above WHO guideline.**
- Everyone receives **most** of their **PM<sub>2.5</sub>** exposures at **home.**
- **Spatiotemporal** analysis highlighted that **children** likely do **fire maintenance** work when home, a behavioral pattern that explains their elevated exposures.
- **Ongoing SHEAR** trial will examine **exposures and health** outcomes following **whole-house energy intervention** (solar power and LPG).



# Acknowledgments

- Thank you to everyone involved with the SHEAR Study at CSU and in Rwanda, especially the local field team staff.
- Funding was provided by NIH (R01ES029995).





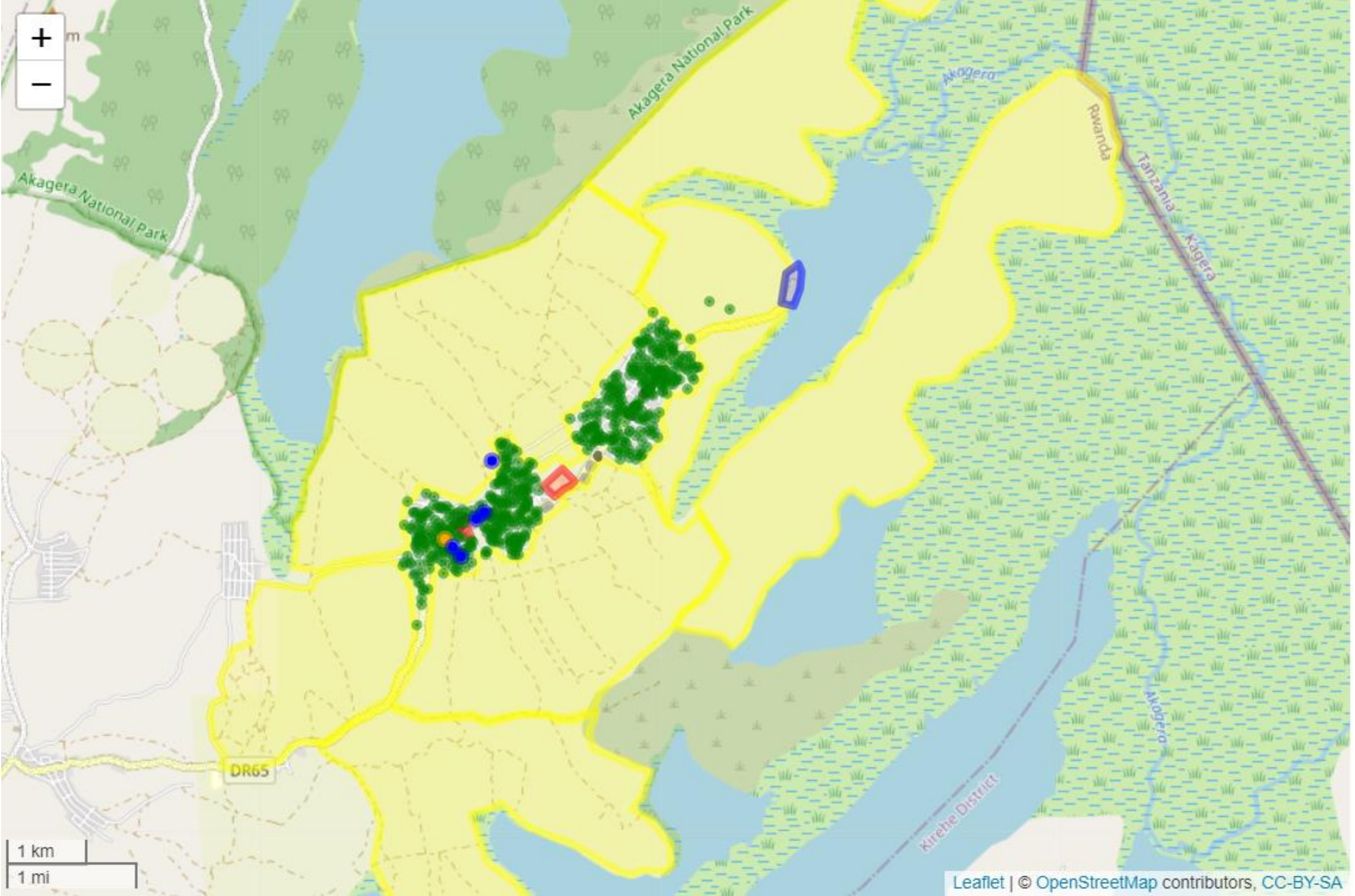
# Contact Information

[ky.tanner@colostate.edu](mailto:ky.tanner@colostate.edu)

[john.volckens@colostate.edu](mailto:john.volckens@colostate.edu)

# Thank you

---



1 km  
1 mi

# Still A Lot of Uncertainty in Estimations

## Unknown Demographic and Geographic Variations in Exposures

### Lim et al. (2022) Review of 140 PM<sub>2.5</sub> Personal Exposure Studies

Age Group	High Income	Upper Middle Income	Low and Lower Middle Income
Adult	75	72	26
Children and Infants	25	6	15
Elderly	28	13	2
Adult and Child	5	2	0
Elderly and Child	4	0	0



