From Environmental Inequities to Health Disparities: A Remote Sensing and GIScience Study of the Effects of Socioeconomic Status and Greenspace on Infant Gut Microbial Community Composition in the WHEALS Cohort

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Introduction

- An ever-increasing literature implicates the human gastrointestinal (GI) microbial community composition (MCC) as a key player in governing human health. GI MCC in the first year of life is crucial to optimizing lifelong immunity.
- MCC to which humans are exposed has presumably changed due to urbanization, decreasing greenspace exposure (e.g., trees, parks,) to richer microbial environments.
- Reduced greenspace exposure and low socioeconomic status (SES) may work together to create a suboptimal environment for infant GI MCC development and contribute to observed health disparities in low SES, urban populations.

KEY QUESTIONS

- **Is greenspace exposure associated with more traditional measures of SES?**
- **Is SES, as measured by our *Environmental Deprivation Index*, associated with infant GI MCC measures?**
- **Is greenspace exposure proximal to participant residence (r=0.25 mi) associated with infant GI MCC measures in our socioeconomically and racially diverse cohort?**

Cohort Data

- Wayne County Health Environment & Allergy Longitudinal Study (WHEALS) is a birth cohort of 1200+ socioeconomically and racially diverse children throughout metro Detroit, MI.
- Our analysis utilized a sample of 293 infant stool samples, taken at ages 1 & 6 months from 2003-2007 with 16S rRNA sequencing data of infant gut MCC.

Methods

- Landsat 7 satellite imagery was used to estimate percentage of greenspace within each census tract in metro-Detroit, MI.
- An Environmental Deprivation Index (EDI) was constructed using Principal Components Analysis that includes 17 American Community Survey (2009 5-yr estimates) SES variables and the greenspace estimates.
- Landsat 7 satellite imagery was also used to estimate greenspace within a 0.25 mi radius of participant addresses.
- Geographic Information Systems (GIS) was used to understand geospatial patterns of EDI.
- Associations between EDI scores and MCC measures of evenness, diversity, and richness were estimated.

Constructing the Environmental Deprivation (EDI) Index

Data for 885 census tracts on 20 unique variables in Oakland and Wayne County, MI.

Percentage of Greenspace within each tract — Estimates derived from Landsat 7 satellite imagery

Socioeconomic Status Variables (n=19) — American Community Survey (2009 5-Yr Estimates)

→ Principal Component Analysis Data Reduction Method →

One EDI score for each census tract — Environmental Deprivation Index (EDI) Score — Range: 0 (lowest deprivation) to 100 (highest deprivation)

Index Variable			N = 885[1]
Factor 1	Factor 2	Factor 3	Median (IQR)
Percent vacant			0.10 (0.06, 0.20)
Percent of households with no kitchen available			0.03 (0.00, 0.08)
Percent below poverty level			0.11 (0.05, 0.27)
Percent Not Hispanic or Latino: Black or African American alone			0.10 (0.03, 0.82)
Percent of households with no vehicle available			4 (0, 14)
Percent Less than 12th grade, no diploma			0.010 (0.000, 0.010)
Percent of households with public assistance income			0.03 (0.01, 0.07)
Civilian labor force: Percent Unemployed			0.09 (0.06, 0.12)
Percent households with children headed by females			0.23 (0.11, 0.54)
Percent of households: Renter occupied			0.27 (0.12, 0.44)
	Median household value (dollars)		133,900 (85,200, 198,850)
	Median household income (dollars)		50,160 (31,402, 68,661)
	Percent females in management occupations		0.41 (0.26, 0.54)
	Percent males in management occupations		0.35 (0.18, 0.52)
	Percentage of land area greenspace		0.63 (0.39, 0.81)
		Percent Hispanic or Latino	0.02 (0.01, 0.04)
		Percent of households with greater than one person per room	0.010 (0.000, 0.030)

1 Principal Component Analysis Factor Loading for Environmental Deprivation Index. PCA resulted in a three-factor solution (KMO=.918) accounting for 70.08% of variability in the data. Rotation Method: Varimax with Kaiser Normalization.

Environmental Deprivation Scores
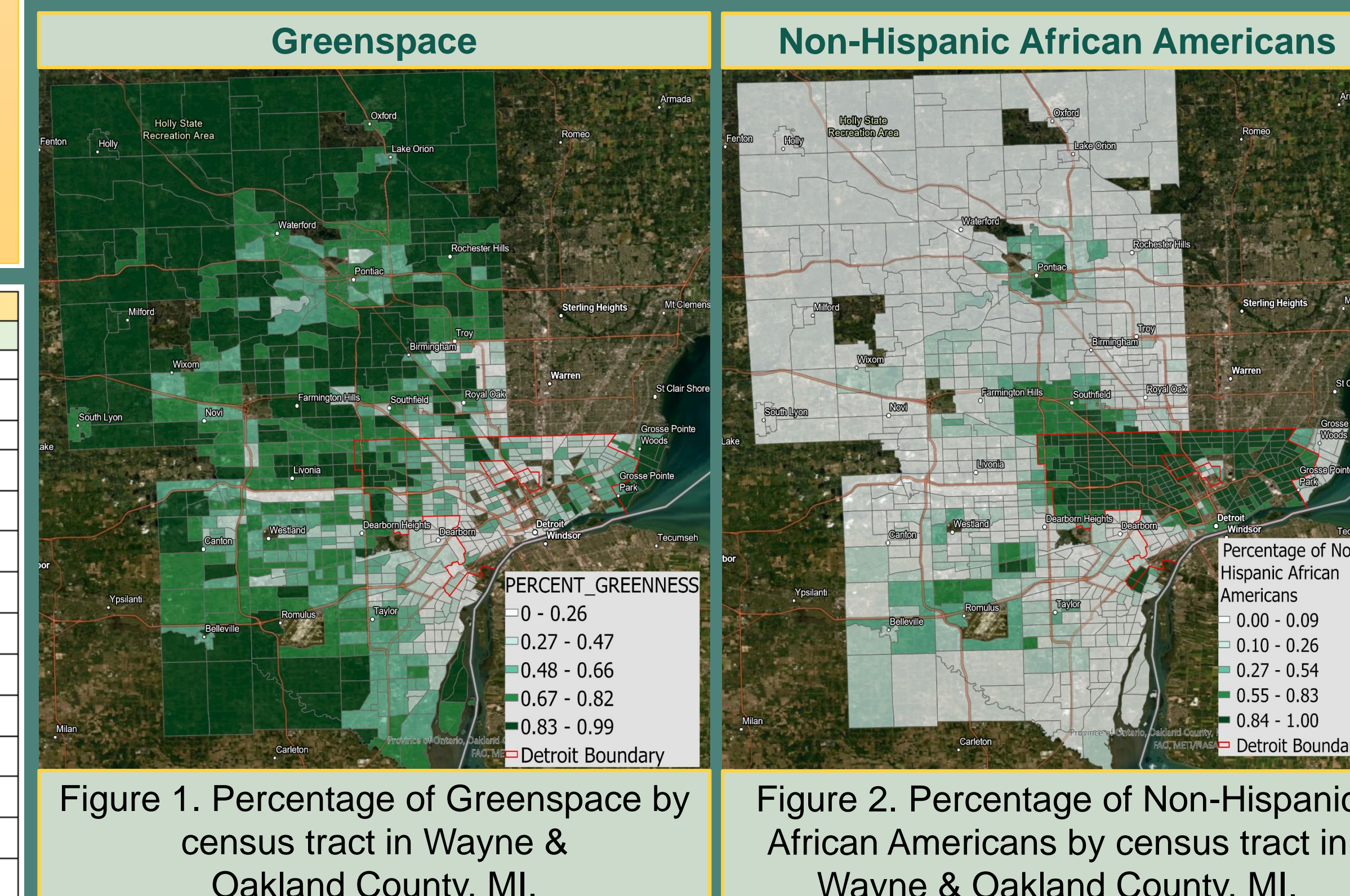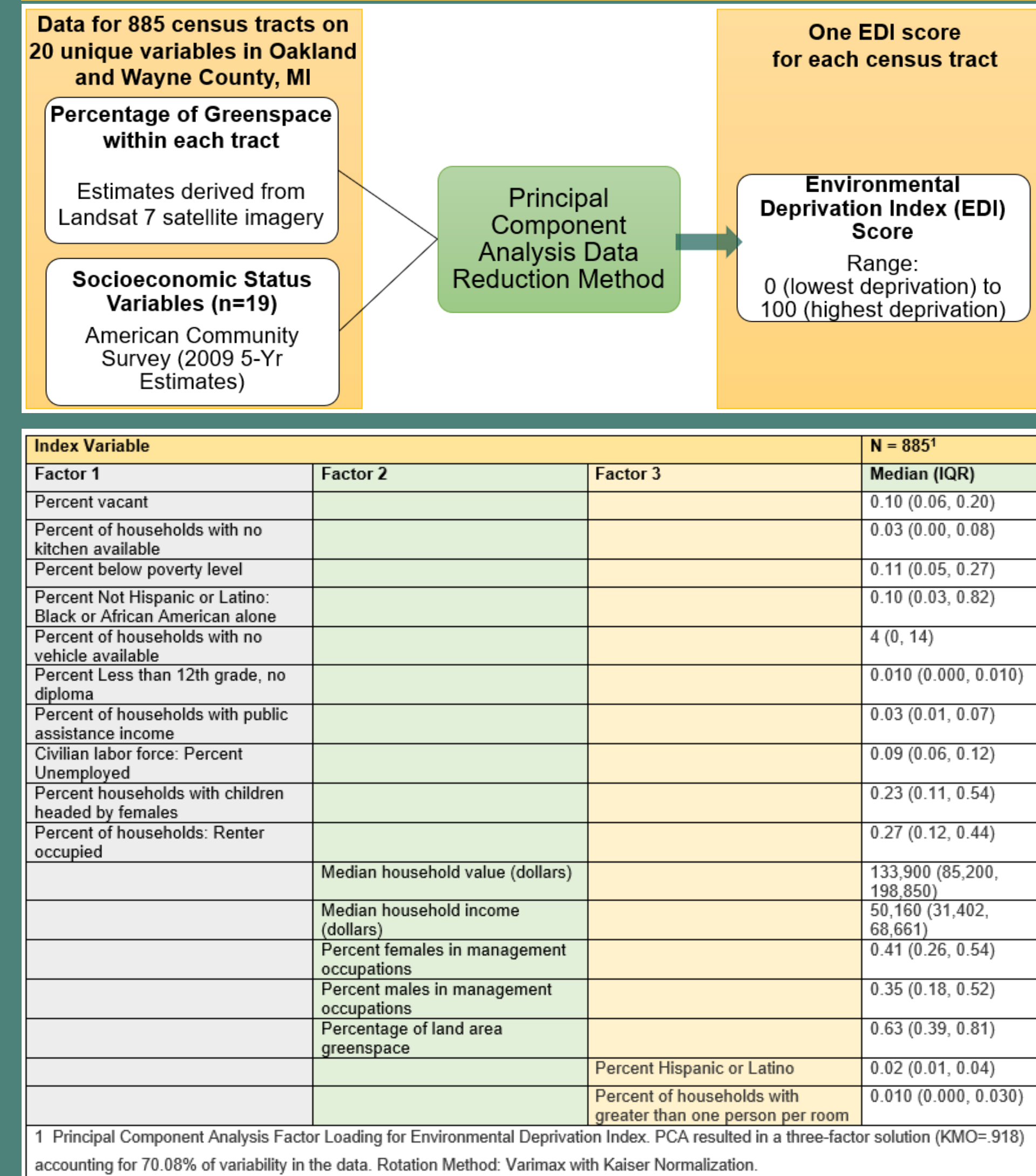

Greenspace

Non-Hispanic African Americans

Figure 1. Percentage of Greenspace by census tract in Wayne & Oakland County, MI.

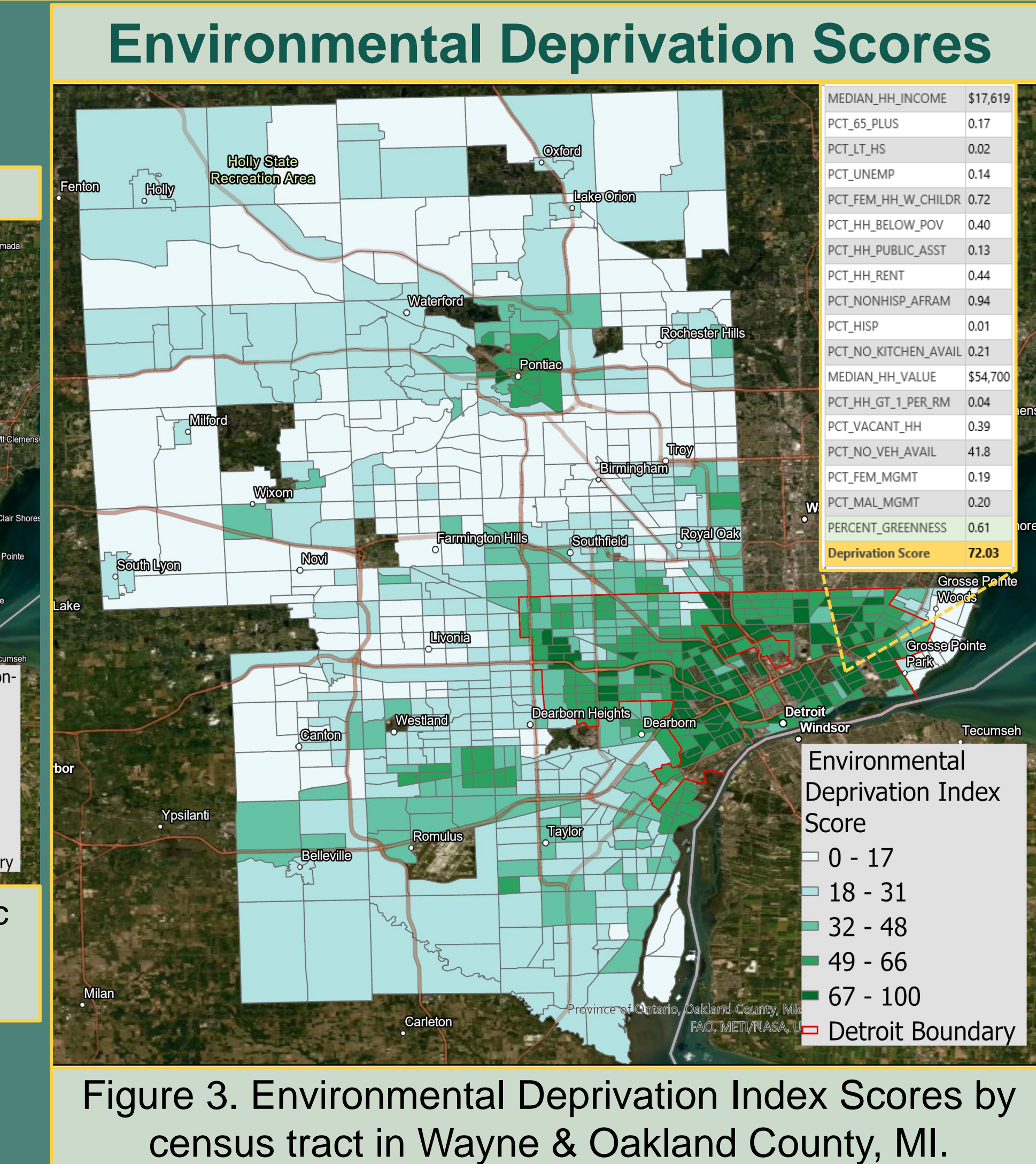Figure 2. Percentage of Non-Hispanic African Americans by census tract in Wayne & Oakland County, MI.

Figure 3. Environmental Deprivation Index Scores by census tract in Wayne & Oakland County, MI.

Microbial Community Composition

1 Month Samples

1 Month			EDI	Greenness in 0.25 Mile radius Buffer
Personal Greenness in 0.25 mile radius Buffer	Pearson Correlation		-.452**	
	Sig. (2-tailed)		<.001	
	N		208	
observed_species	Pearson Correlation		.061	-.095
	Sig. (2-tailed)		.385	.167
	N		208	214
simpson_reciprocal	Pearson Correlation		.066	-.101
	Sig. (2-tailed)		.344	.140
	N		208	214
pielou_evenness	Pearson Correlation		.150*	-.106
	Sig. (2-tailed)		.031	.122
	N		208	214
PD_whole_tree	Pearson Correlation		.074	-.098
	Sig. (2-tailed)		.291	.154
	N		208	214

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

6 Month Samples

6 Month			EDI	Greenness in 0.25 Mile radius Buffer
Personal Greenness in 0.25 mile radius Buffer	Pearson Correlation		-.609**	
	Sig. (2-tailed)		<.001	
	N		79	
observed_species	Pearson Correlation		.191	-.171
	Sig. (2-tailed)		.092	.129
	N		79	80
simpson_reciprocal	Pearson Correlation		.261*	-.209
	Sig. (2-tailed)		.020	.063
	N		79	80
pielou_evenness	Pearson Correlation		.187	-.260*
	Sig. (2-tailed)		.099	.020
	N		79	80
PD_whole_tree	Pearson Correlation		.174	-.146
	Sig. (2-tailed)		.125	.196
	N		79	80

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

- Infant GI MCC at 1 month: **EDI score was significantly associated with Pielou's evenness** (r=.15, p=.031), a measure that describes relative differences in the abundance of various species in the community
- At 6 months, **EDI score was significantly associated with Simpson's Reciprocal Diversity Index** (r=.261, p=.02), a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present.
- Percentage of **greenspace within a 0.25 mi buffer of participant address had a significant negative association with Pielou's evenness** (r=-.26, p=.02) at 6 months.

Implications

- Greenspace exposure is a potentially important overlooked variable in studying health disparities that shows geographic patterns similar to traditional SES measures.
- Current hypotheses propose greenspace impacts health indirectly through routes like stress reduction and behavior modification. We propose a potential direct mechanism through the GI MCC's impact on immune development.
- Proximal greenspace showed a negative association with MCC at 6 months, indicating that it may be related to the stabilization process of the GI MCC.
- The significant impact of EDI on MCC emerged earlier than personal greenness exposure in life and continued as the GI MCC assembled during infancy.

Future Directions

- Validate our findings with (> 500 rRNA) additional samples from WHEALS infants and the same children at 10 years of age.
- Utilize existing house dust MCC samples from infant residences to examine environmental MCC as a potential mediating pathway.
- Examine gender and race differences in the influence of EDI and greenness on infant GI MCC and include more environmental factors in the EDI, such as air pollution.
- Examine associations between the external environment, MCC, and health outcomes to explore greenspace exposure as a potential avenue for public health intervention.