Disentangling associations between vegetation greenness and dengue in a Latin American city: findings and challenges

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Introduction

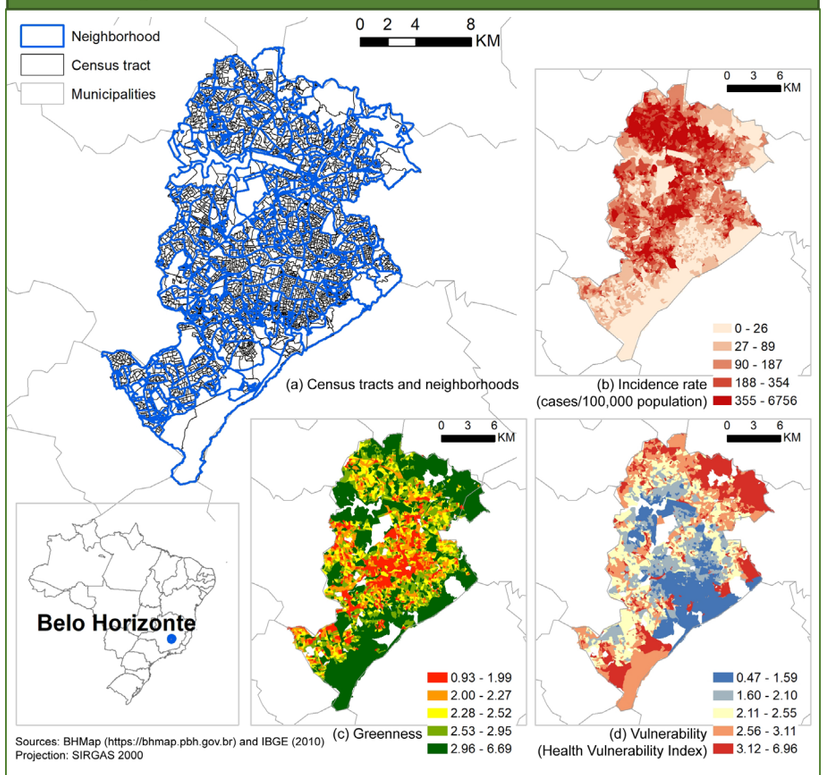
Background: Approximately 390 million dengue cases occur globally every year (Bhatt et al., 2013). Once under controlled in the Americas, dengue re-emerged at a faster pace and greater magnitutide since the 1970s. Cases are prevlant in tropical urban centers due to ineffecive mosquito control, high population density, substandard urbanization, and globalization.

High dengue incidence is associated with urban planning factors including:

- No piped water, household water storage
- Poor sanitation, accumulation of trash
- Overcrowding

Dengue and vegetation: Vegetation management is a feasible disease control approach in highly urbanized areas. Studies show mixed findings for the relationship between dengue and vegetation characteristics, likely due to Difference in spatial scales of analysis, measures of vegetation, and analytical approaches

Study Area



Belo Horizonte, Brazil, during its 2010 dengue epidemic, with 2,053 cases per 100,000 inhabitants. Study area covers 3828 census tracts (IQR of size: 2.61 – 7.87 hectares) nested in 474 neighborhoods.

Research Question

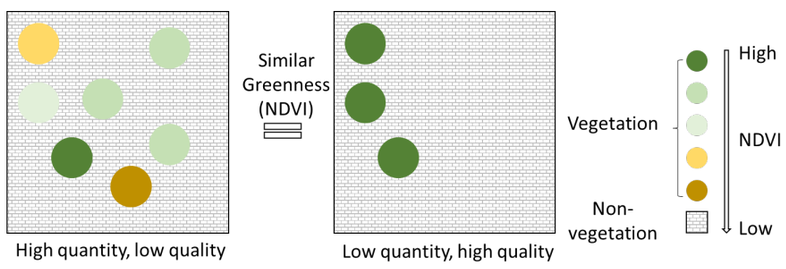
Q1: What is the relationship between vegetation greenness and dengue at fine spatial scales?
Q2: how does socioeconomic vulnerability modify the greenness-dengue relationship?

Data and Methods

Outcome: incidence = cases/100,000 people

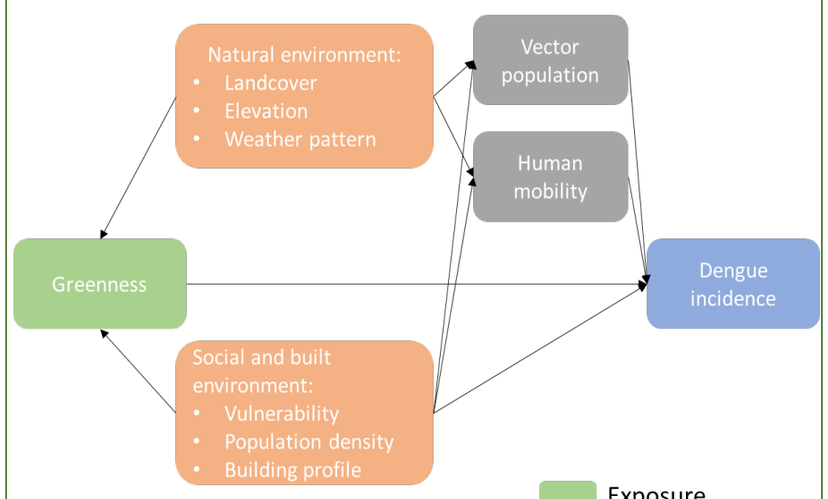
Exposure: Greenness from Normalized Difference Vegetation Index, NDVI, from Landsat

- Measures the combined effect of vegetation quantity and quality
- Quantity: coverage and biomass
- Quality: photosynthsis and vegetation health



- We controll for vegetation quantity to isolate the effect of quality

Covariates



Land cover composition:
- % built-up
- % vegetation
- % water

High Vulnerability:
- poor water supply,
- no sewage connection,
- irregular garbage collection

Directed acyclic graph for the outcome, exposure, and confounders

Model

$$\log(IRij) = \beta_0 + \beta_1 greenness_{ij} + \vartheta neighorhood_j + \varepsilon_{ij} \quad \text{(model 1)}$$

$$\log(IRij) = \beta_0 + \beta_1 greenness_{ij} + X\delta + \vartheta neighorhood_j + \varepsilon_{ij} \quad \text{(model 2)}$$

$$\log(IRij) = \beta_0 + \beta_1 greenness_{ij} + \beta_2 vulnerability_{ij} + \alpha greenness_{ij} \times vulnerability_{ij} + X\delta + \vartheta neighorhood_j + \varepsilon_{ij} \quad \text{(model 3)}$$

The models are specified as neighborhood fixed-effects Negative Binomial models with neighborhood clustered-robust standard error to control for autocorrelation;

We included alternative specifications as a robustness test.

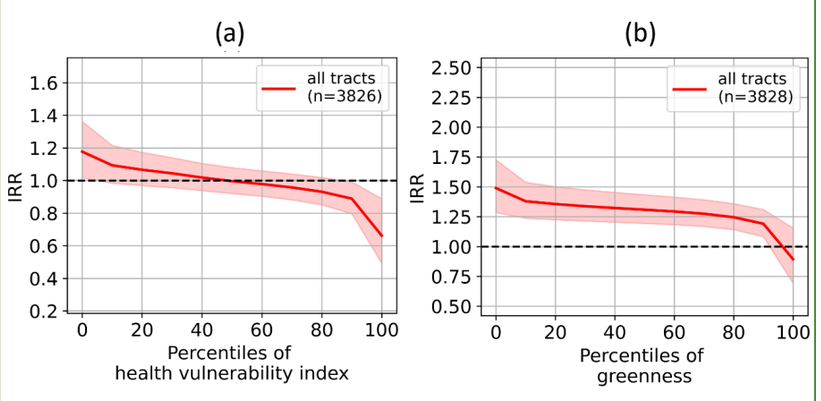
Results

Negative association between dengue incidence and greenness attenuated with additional controls.

	(1) IRR	(2) + additional controls, IRR	(3) + greenness-vulnerability interaction, IRR
Greenness (0-10)	0.86*** [0.81,0.91]	0.98 [0.90,1.06]	1.23** [1.03,1.46]
Vulnerability (HVI, 0-10)		1.25*** [1.14,1.37]	1.62*** [1.33,1.97]
Greenness × Vulnerability			0.92*** [0.86,0.97]
Population density (people/ha)		1.00*** [1.00,1.00]	1.00*** [1.00,1.00]
Pseudo R^2	0.18	0.20	0.20
Neighborhood fixed effects	Yes	Yes	Yes
Confidence interval	Neighborhood-clustered	Neighborhood-clustered	Neighborhood-clustered
# obs.	3828	3826	3826

Note: A coefficient, or incidence rate ratio (IRR), is the factor by which the dengue incidence rate (dengue cases per 100,000 residents) changes for a one-unit increase in the corresponding covariate, when holding other covariates constant. HVI stands for a Health Vulnerability Index that encompasses indicators of health-related infrastructures and resident socioeconomic status from the 2010 census. *, **, and *** indicate significant at p-value < 0.10, p-value < 0.05, and p-value <0.01. 95% confidence intervals are in square brackets.

Interaction between greenness and vulnerability



(a) dengue-greenness association modified by vulnerability
(b) positive dengue-vulnerability association attenuated by greenness

Discussion and conclusions

Insignificant overall association between dengue and greenness: Factors leading to high *Aedes aegypti* (the main disease vector) population and dengue incidence (e.g. household storage) captured by vulnerability rather than greenness.

Dengue-greeness association is negative and significant in more vulnrable census tracts: Many vulnerable census tracts are close to city border, which is abundant in natural vegetation that may not be suitable for *Aedes aegypti*. High greenness in these tracts is associated with reduced trash accumulation and improved habitat for predators or competing species.

Limitations in measuring greenness, landcover, and weather pattern: fine resolution datasets are necessary for tract-level study to improve data accuracy and capture fine-level variations.

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