# Resilience in Urban Networks

Assessing Freetown's transportation system under meteorological hazards

Prof. Marta Gonzalez, DCRP & Andrew Nelson
University of California, Berkeley
Xavier Espinet, Fatima Arroyo-Arroyo, and Dunstan Matekenya

World Bank Group

# Objective

Planning from the **accessibility** perspective from **neighborhoods** to Education and Health facilities taking into account the **demand or limited capacity** into these facilities

Explore vulnerability of neighborhoods and services both

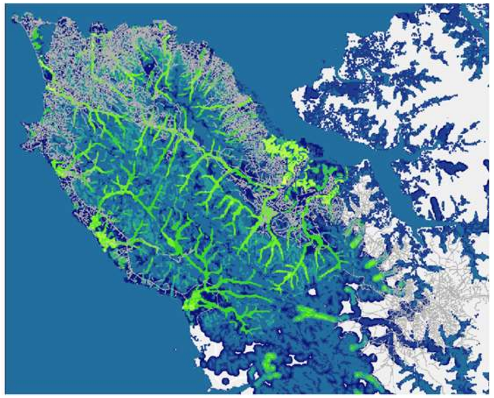
Major hazards

Seasonal disruptions

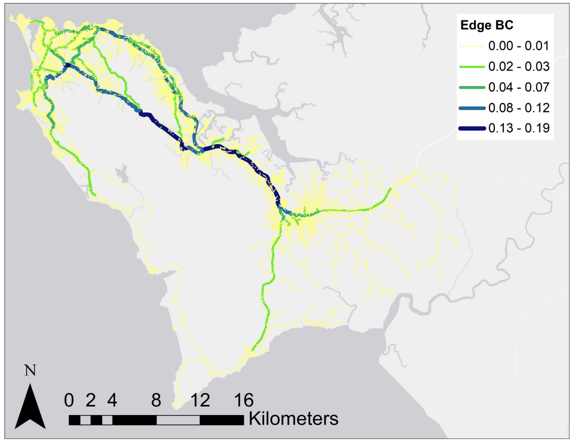
# “Resilience” has various meanings

How systems resist, absorb, adapt, transform, and recover after stress or disasters.

We view “resilience” as the flipside of “vulnerability” to hazards



Vulnerability




Resilience

Diminishing vulnerability increases resilience

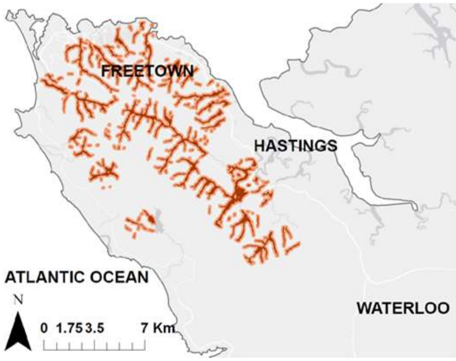
# Part I

- Identify vulnerable and critical roads
- Simulate hazard scenarios and test road intervention sites

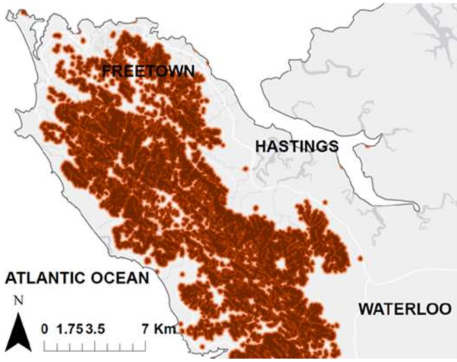
# Estimating Risks

## Geological Risk Factors

Mudslide

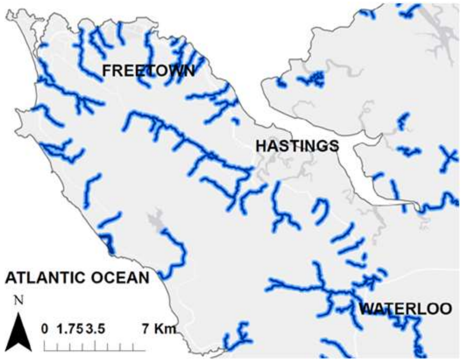



Landslide

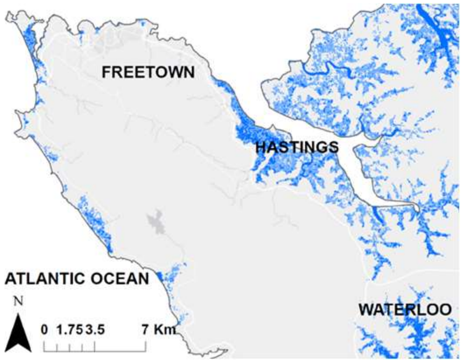



## Hydrological Risk Factors

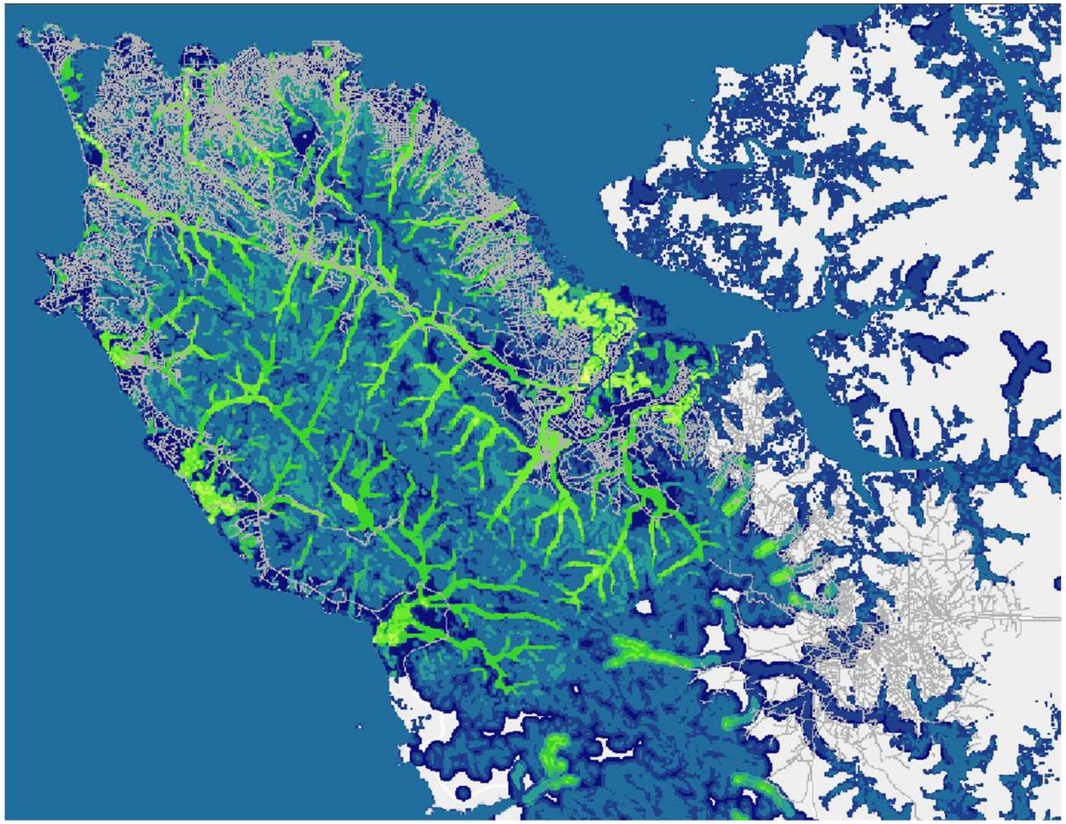
Riverine Flooding




Coastal Flooding




**Input**: Hydrological and Geological Risk Factors



**Output**: Hazard for river flooding, landslides, mudslides, sea level rise, and storm surge

Project Outline: PART I

# We developed a project with 3 key goals:

IDENTIFY KEY NODES

SIMULATE SCENARIOS

TEST IMPACT OF WORLD BANK PROJECTS

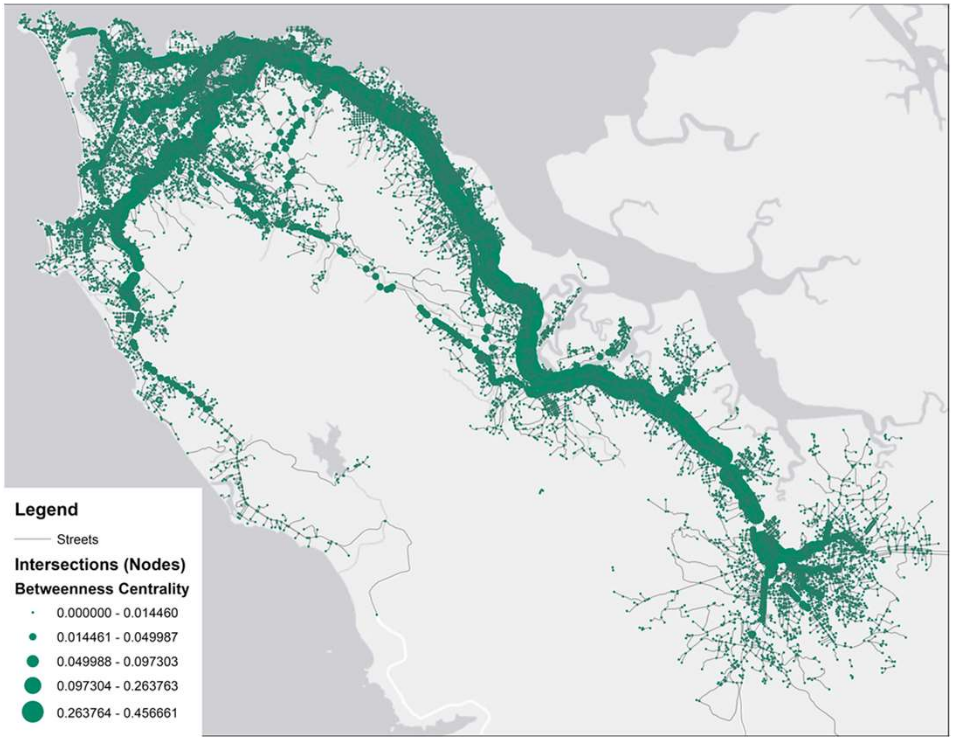


incl. how demand might change for projects if disaster happens and the network balance shifts.

# Network Science Analysis

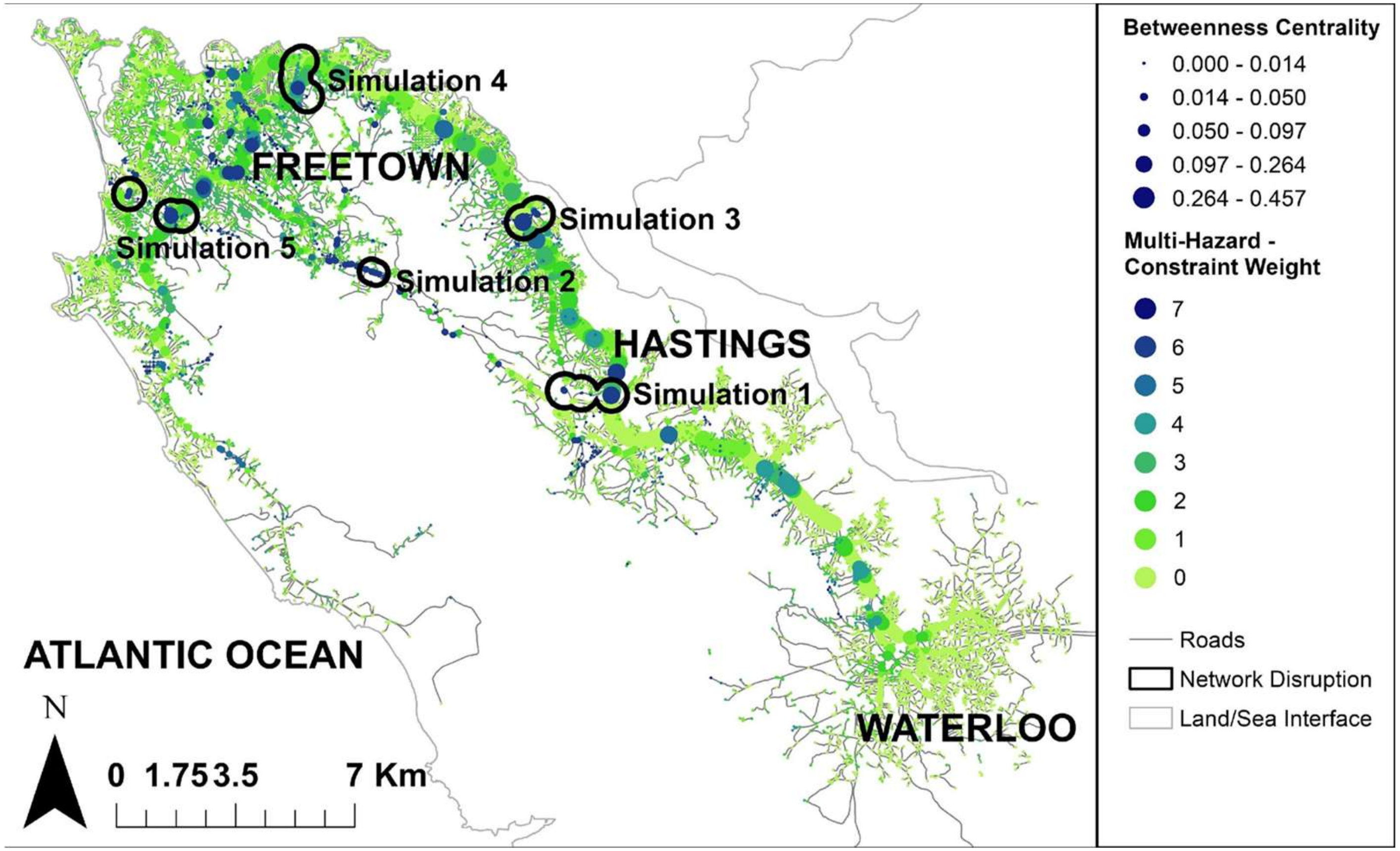
## KEY CONCEPT: BETWEENNESS CENTRALITY

Quantifies the number of times a node lies on any shortest paths in the graph, including every possible pair of origin and destination points. Its calculation is given by:

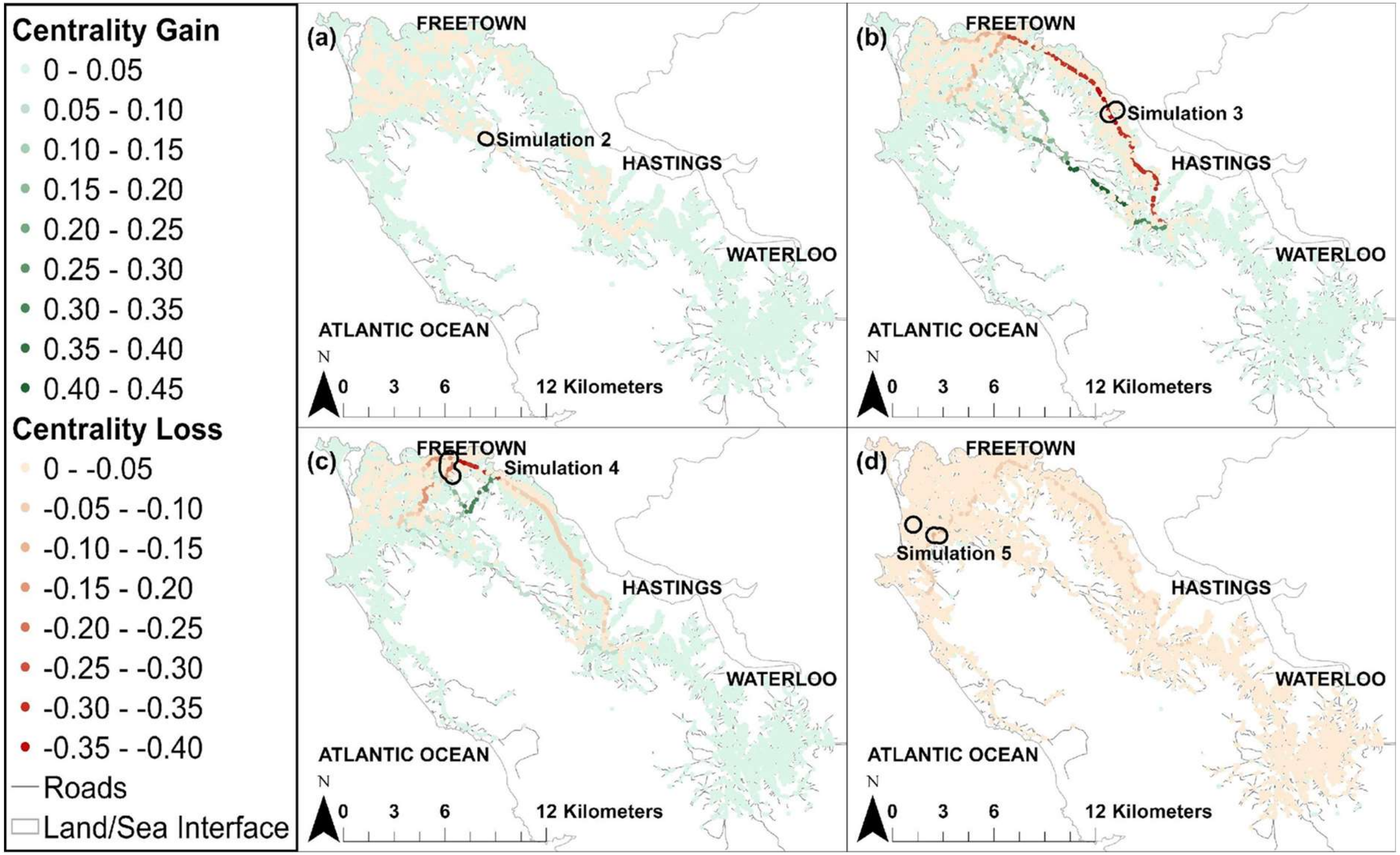



BC serves as a strong measure of how important each node is for all origin-destination node pairs within the transportation network

# Through matrix, we select scenarios

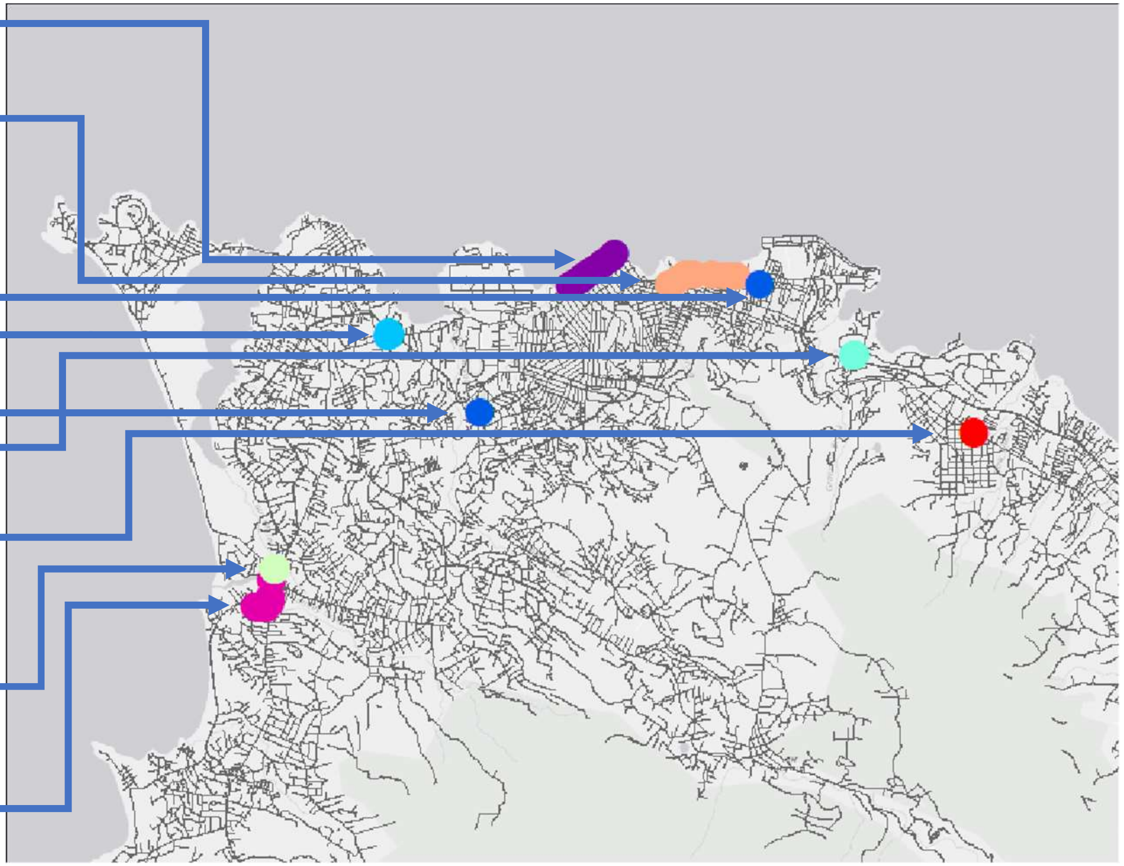


# Estimated Changes in the Road Network



# For current interventions

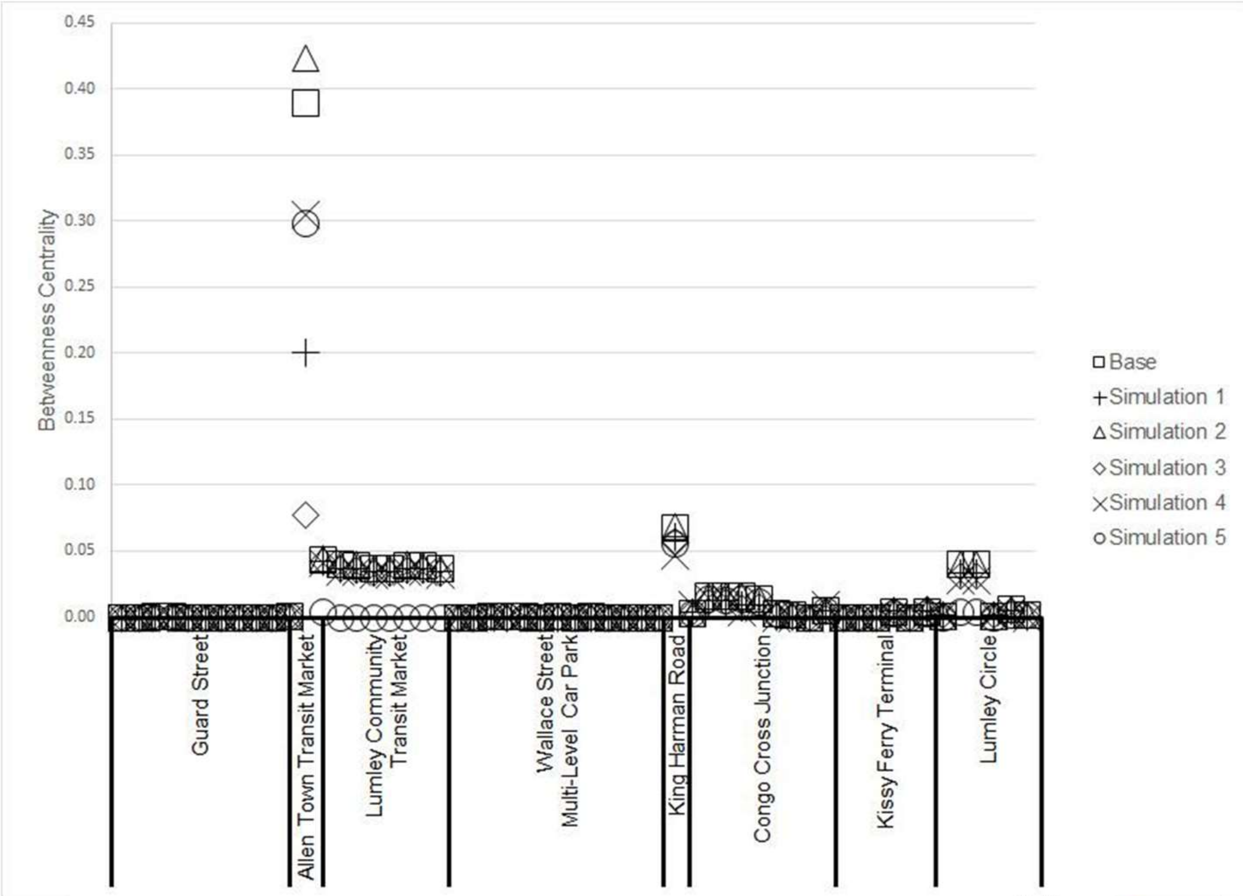
- Intervention: Wallace J. Street Multi-Level Car Park
- Guard Street
- Junction Improvement: King Harman Road
- Junction Intervention: Congo Cross
- Junction Intervention: Kissy Ferry Terminal
- Intervention: Allen Town Transit Market
- Junction Intervention: Lumley Circle Car Park
- Intervention: Lumley Community Transit Market



# Changes in Betweeness

The importance of certain projects changes significantly during hazard scenarios

- Allen Town Transit Market
- Lumley

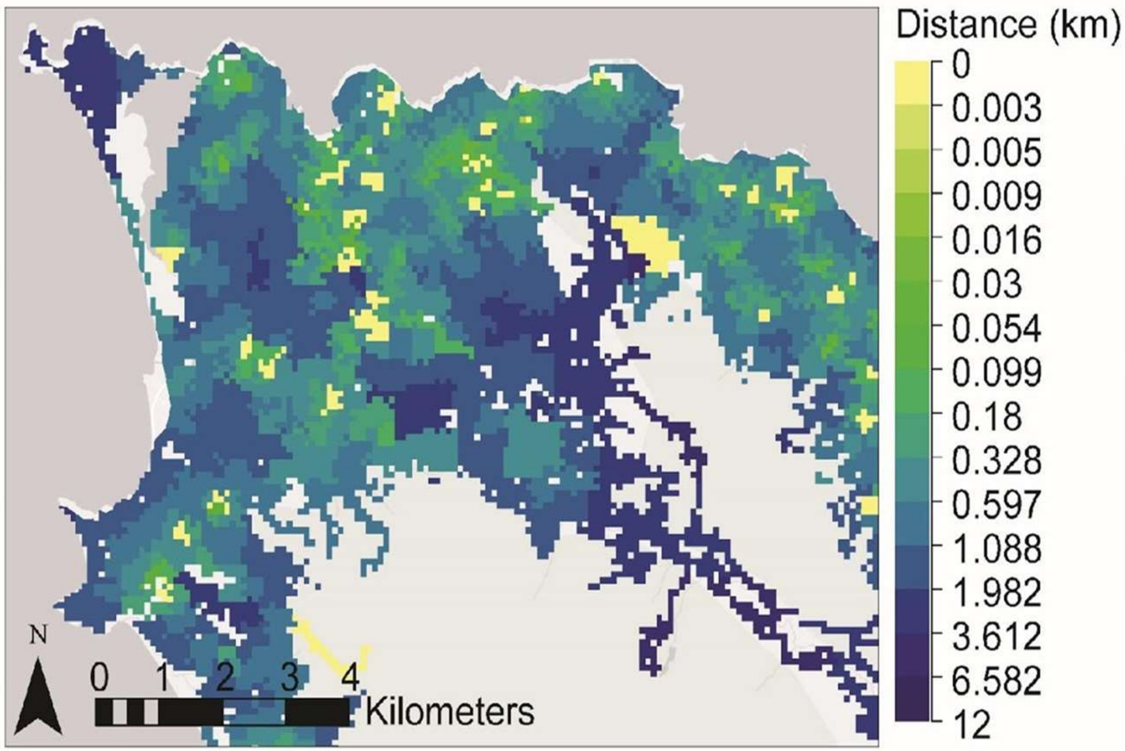


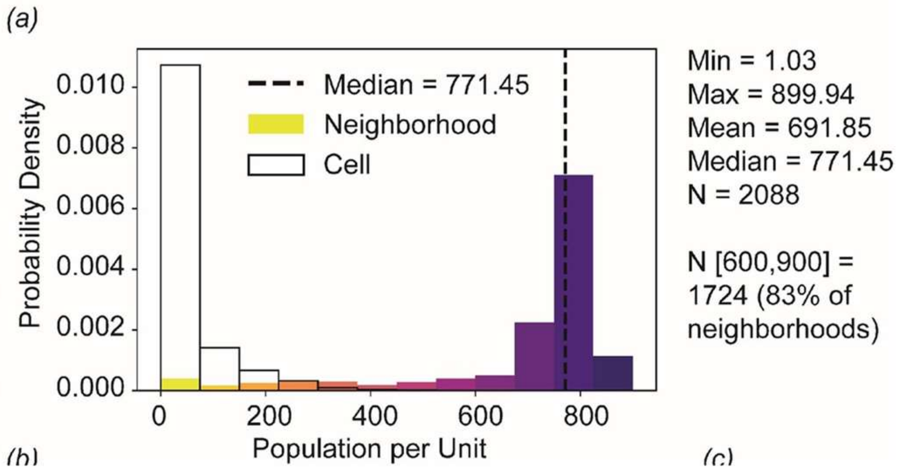
# Part II

- Quantify Vulnerability as the  Access to Key Facilities Service Area such as Schools and Health Centers

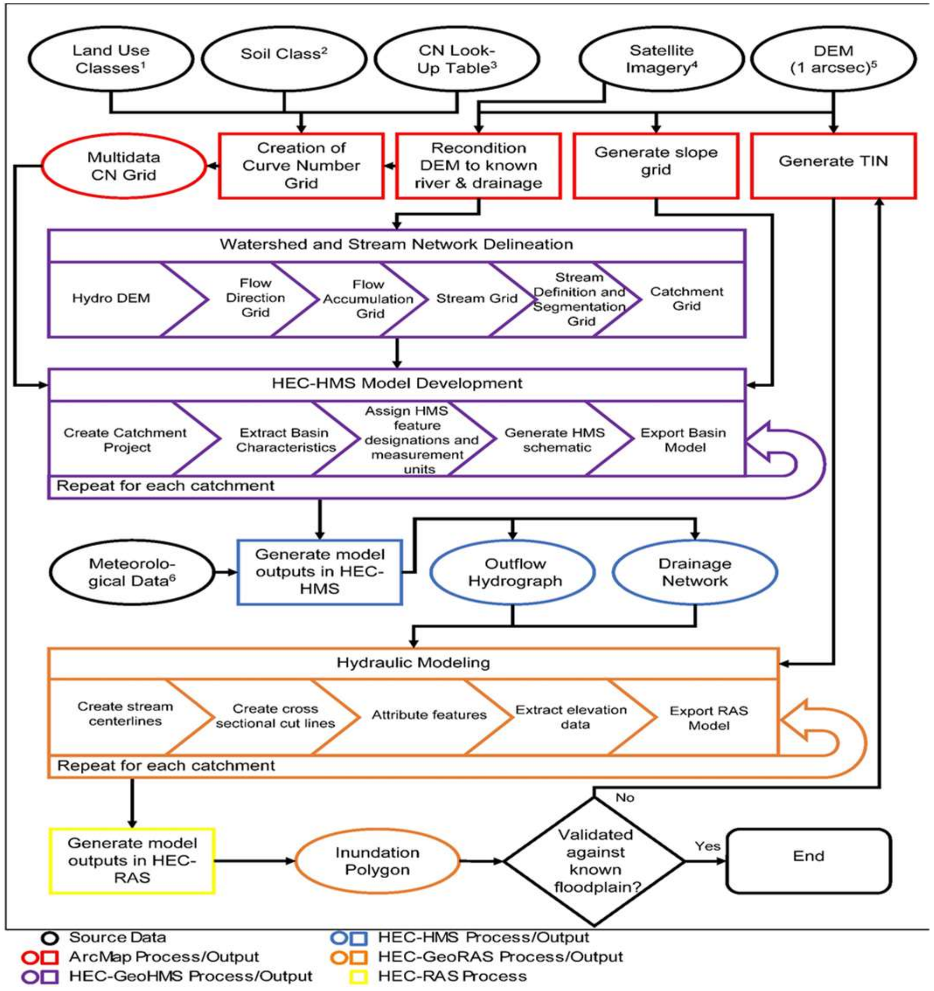
- Apply state of the art Climate Projection methods

# Accessibility via Road Network - Schools



# Flood Model Method from




US Army Corps of Engineers' free software: HEC-HMS, HEC-RAS, and their related plug-ins for use with ArcMap

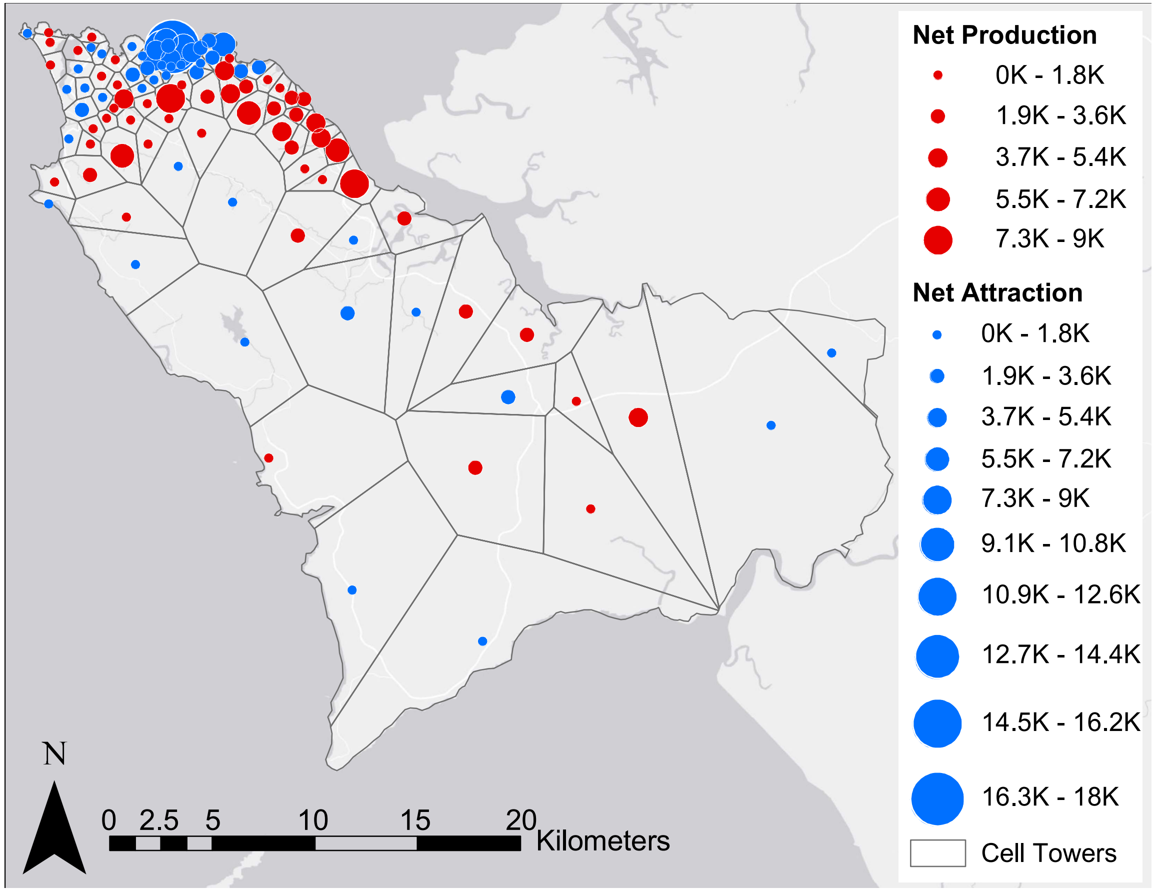
Integrates satellite images with ancillary information from GIS to do a hydraulic simulation model

# Part III

- Calculate trip demand informed by Call Detailed Records (CDRs)

- Focus vulnerability analysis on streets serving transit system

# Call detailed records: Trip Production and Attraction




Within each of these regions, blue and red dots indicate the

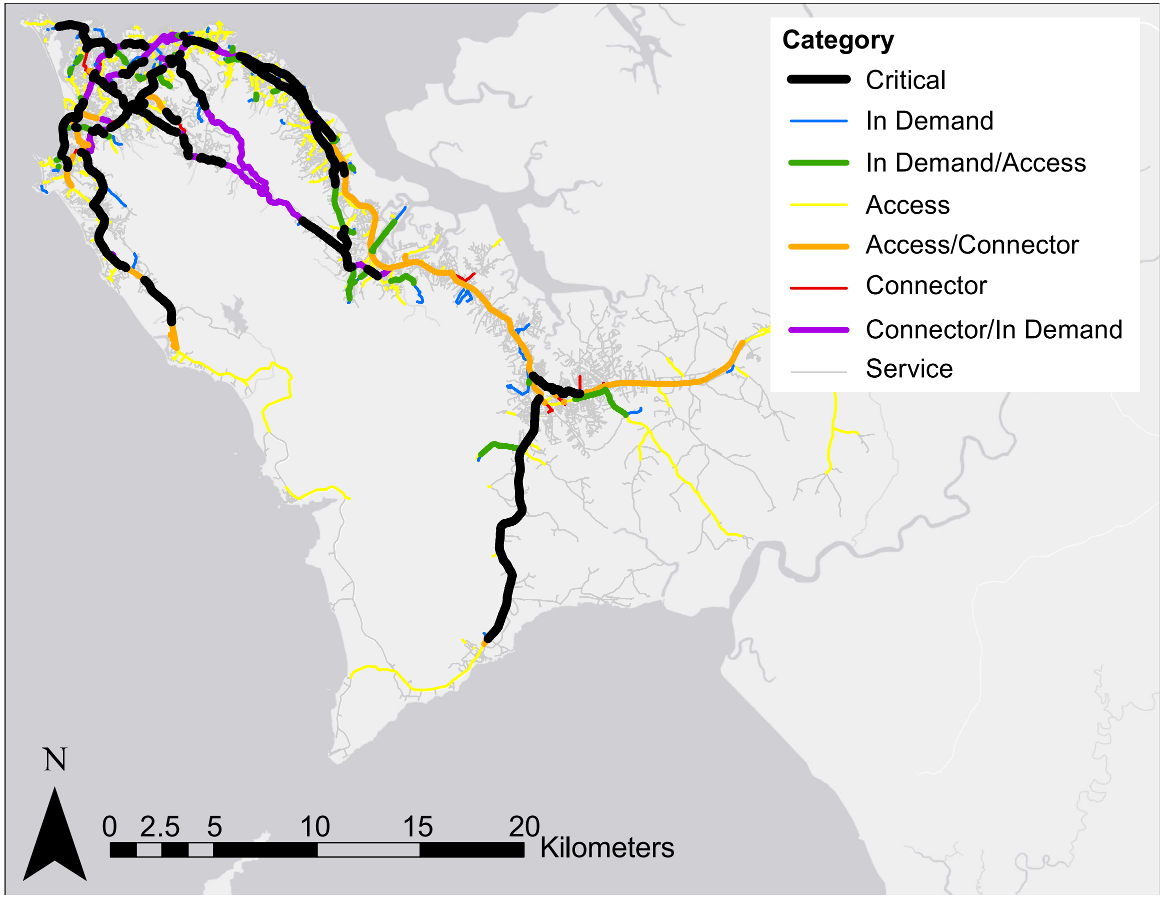
net attraction: (trips received - trips generated)

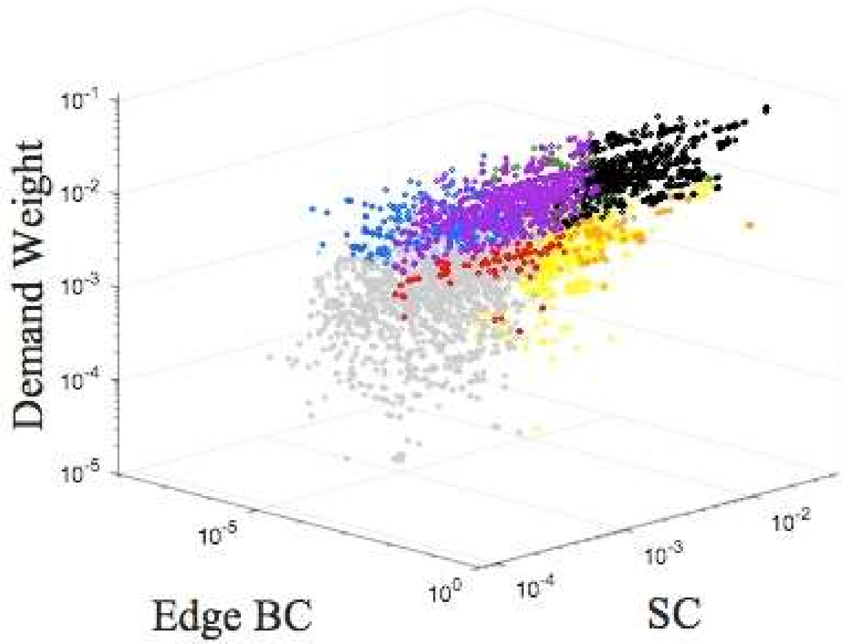
or

net production: (trips generated - trips received)

Using CDR-based OD matrix in the morning peak

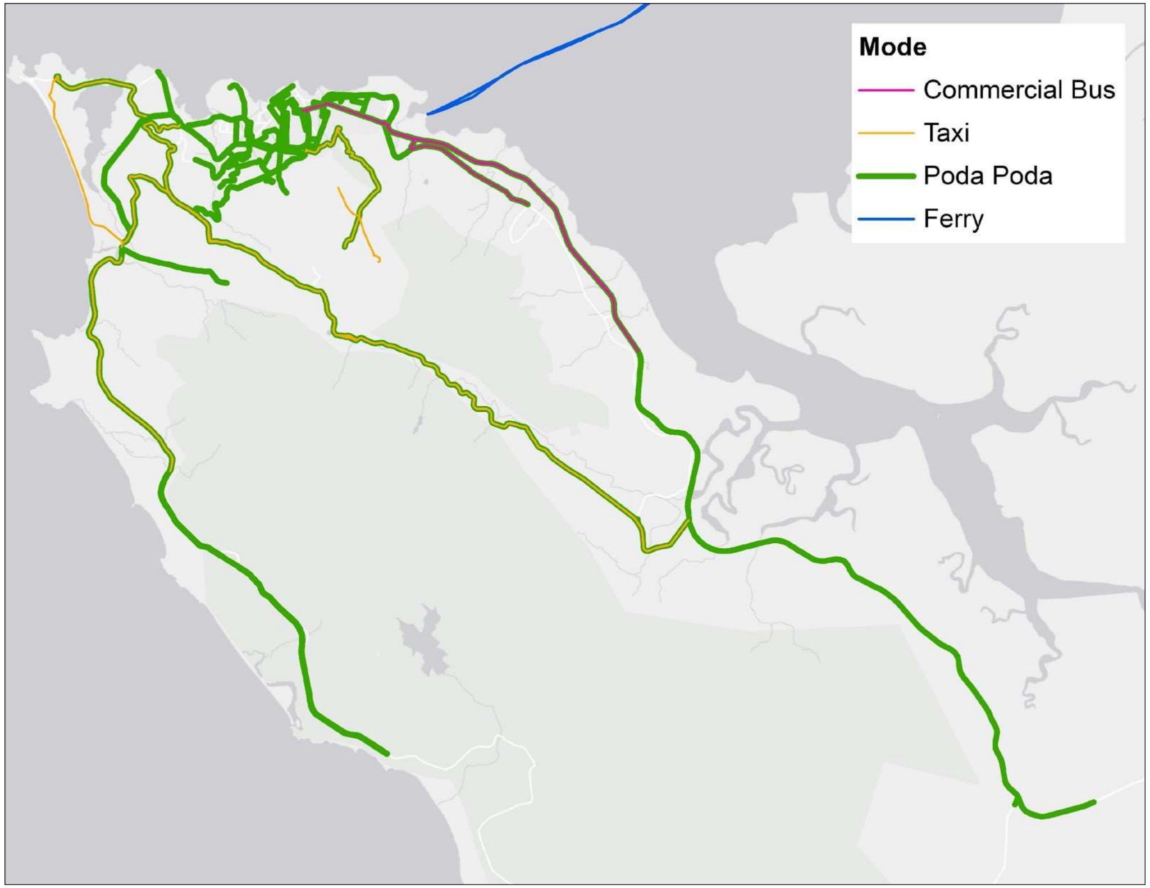
# Road Classification adding CDR weights



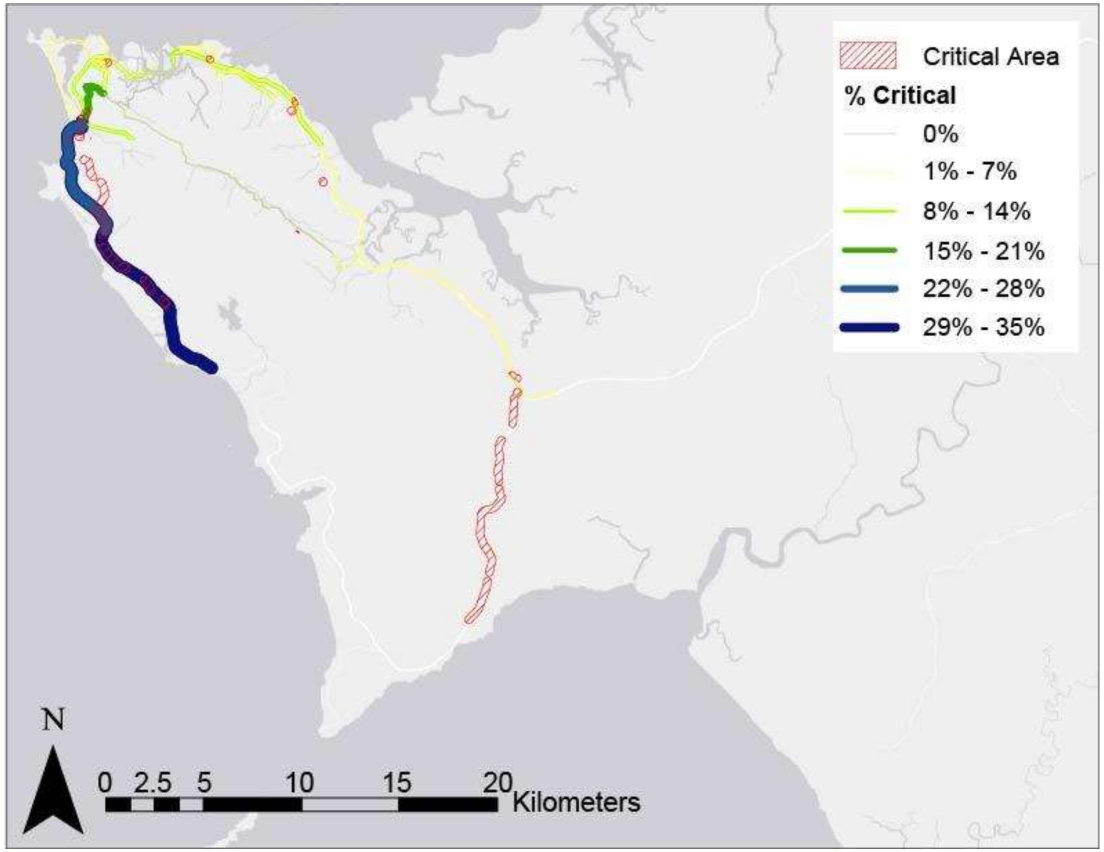




We identify the road facilities which represent the top 10% highest values in all metrics (Critical, black), and the varying combinations of these metrics which also result.

# Transit Routes



# Flooding Scenario on Transit Routes




*Transit corridor on Western Area* shown as most critical in terms on enhancing climate resilience of Freetown urban mobility

# Conclusions and Discussion

- This methods has:
  - Identify needs for climate resilience on urban mobility
  - Determine accessibility constraints to critical social services
  - Incorporate real transport demands with CDR
  - Define priority for transit corridor improvements from resilience angle

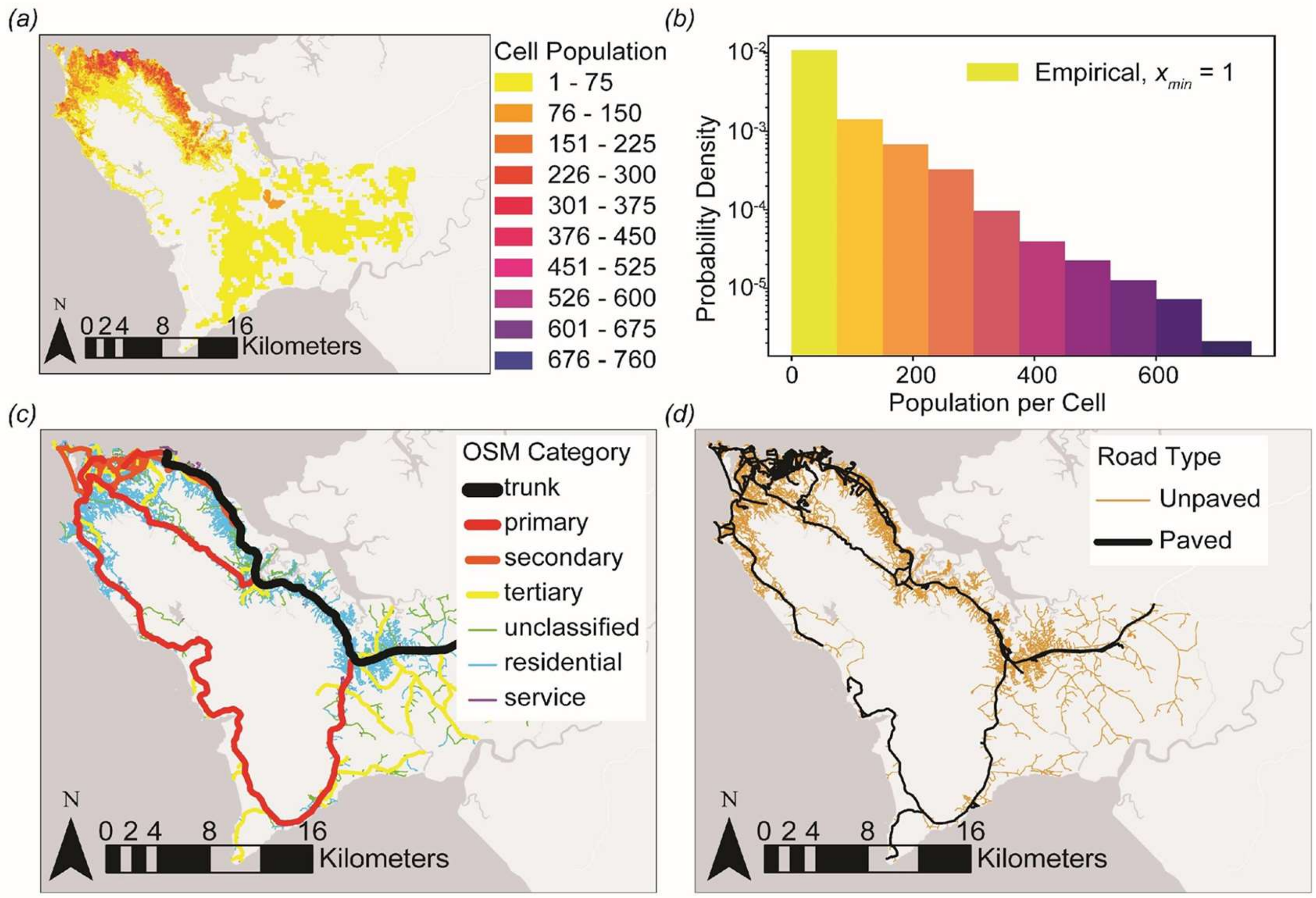
- Future: We will incorporate 2015 Census data to add an additional equity component – poverty

Thank you very much for your attention!

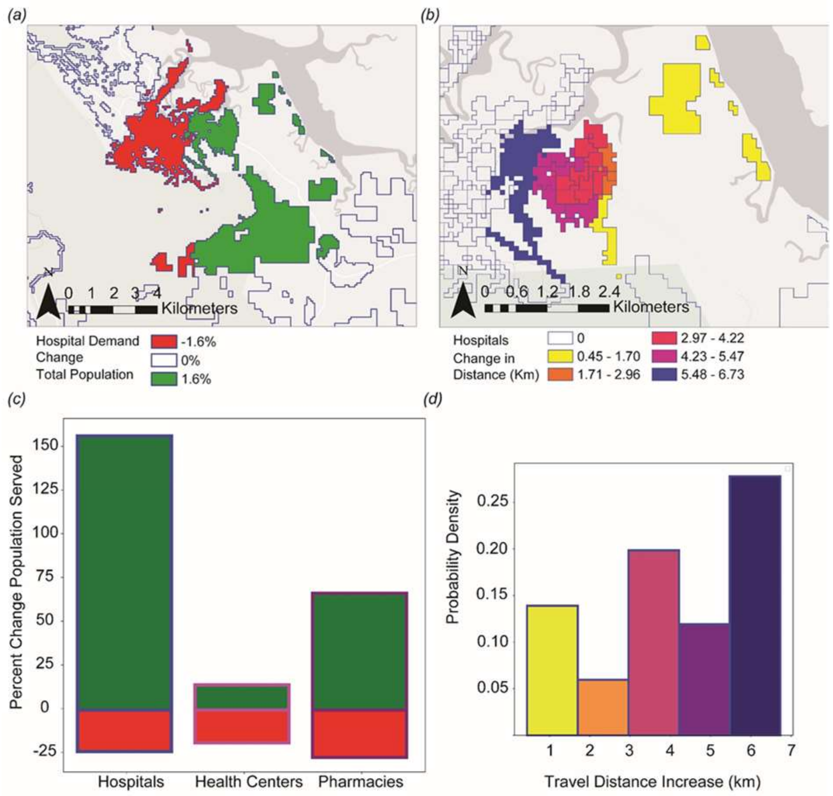
Questions or Comments?

# Appendix

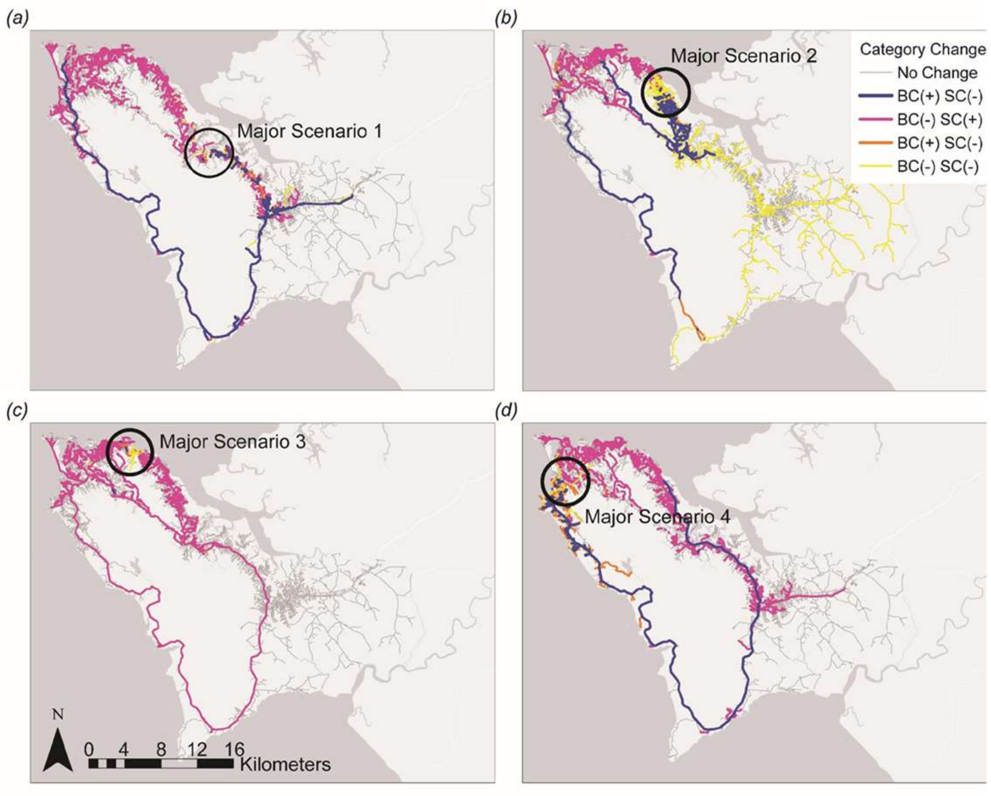
# Population and Road Network



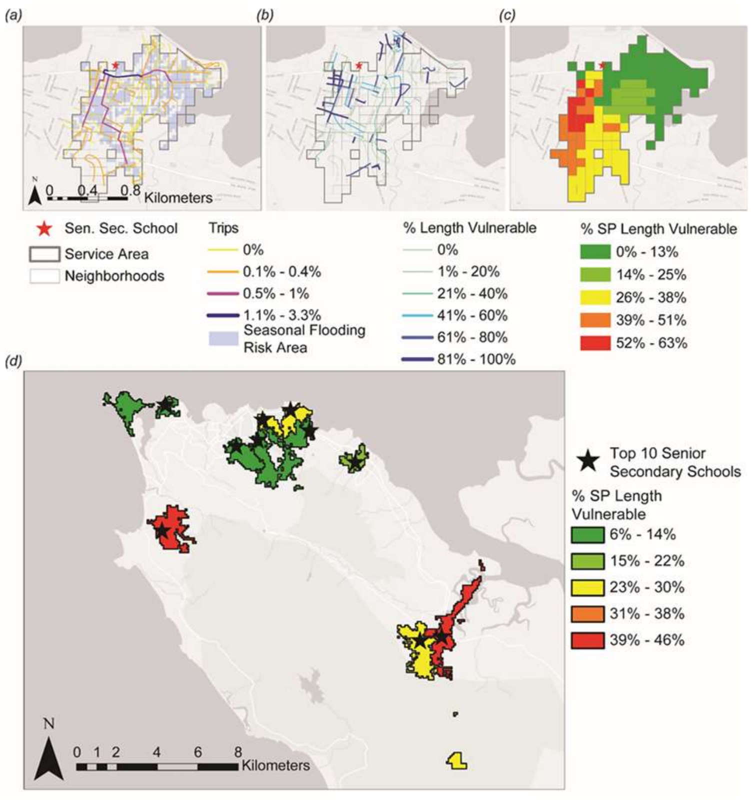
# Demand and Accessibility Shifts



# Vulnerability Metrics

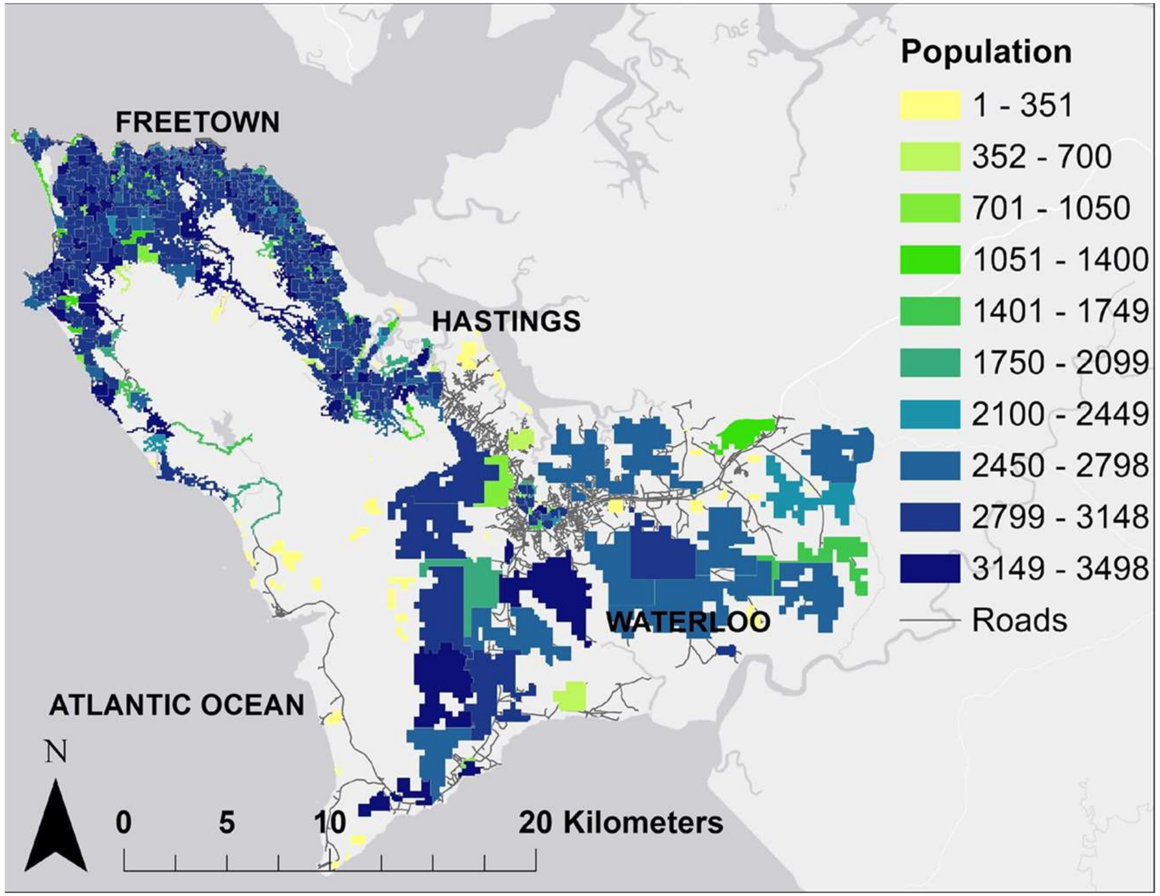


# Seasonal Risks



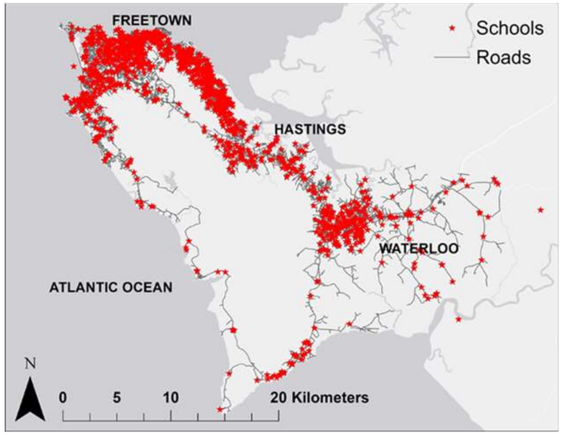
# Population Centers

- Population sources are defined by centers  of ~3000 people

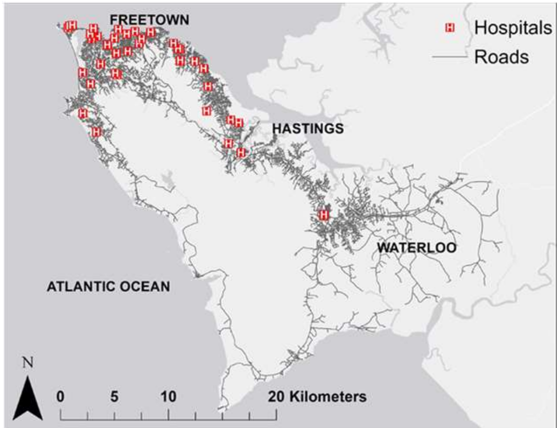


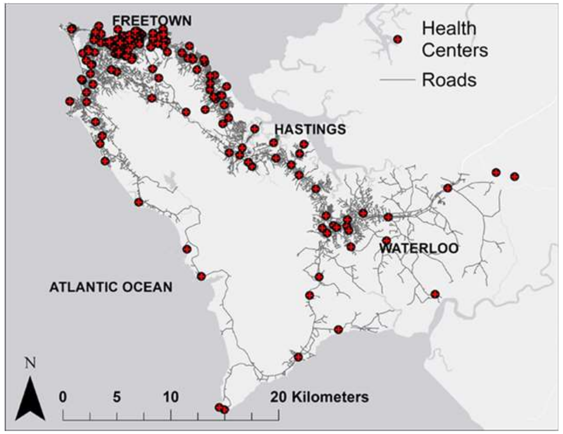
# Key Location Types

Schools

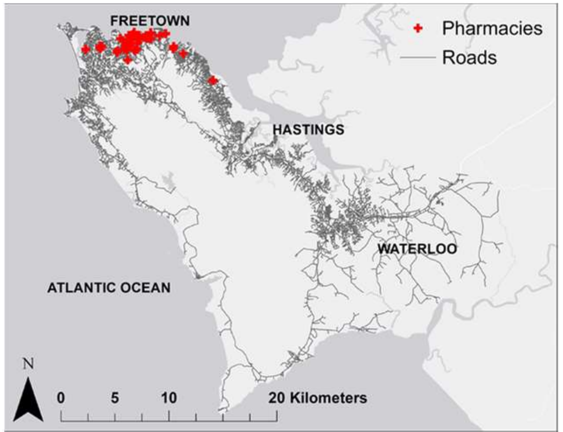



Hospitals



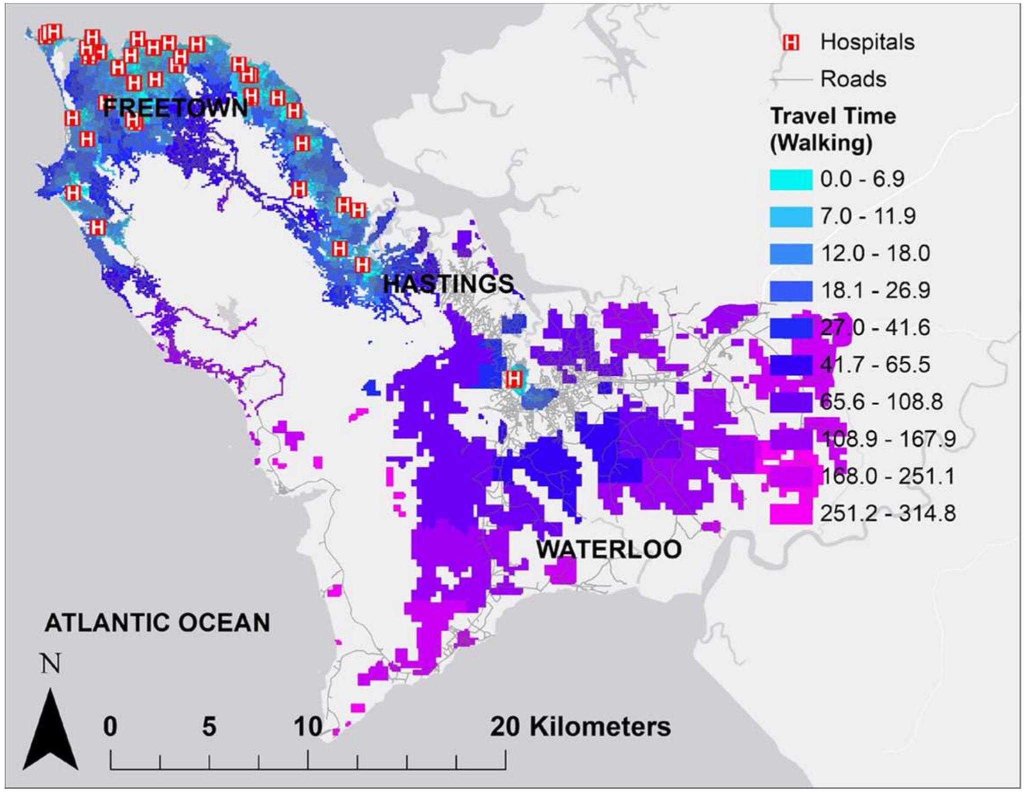



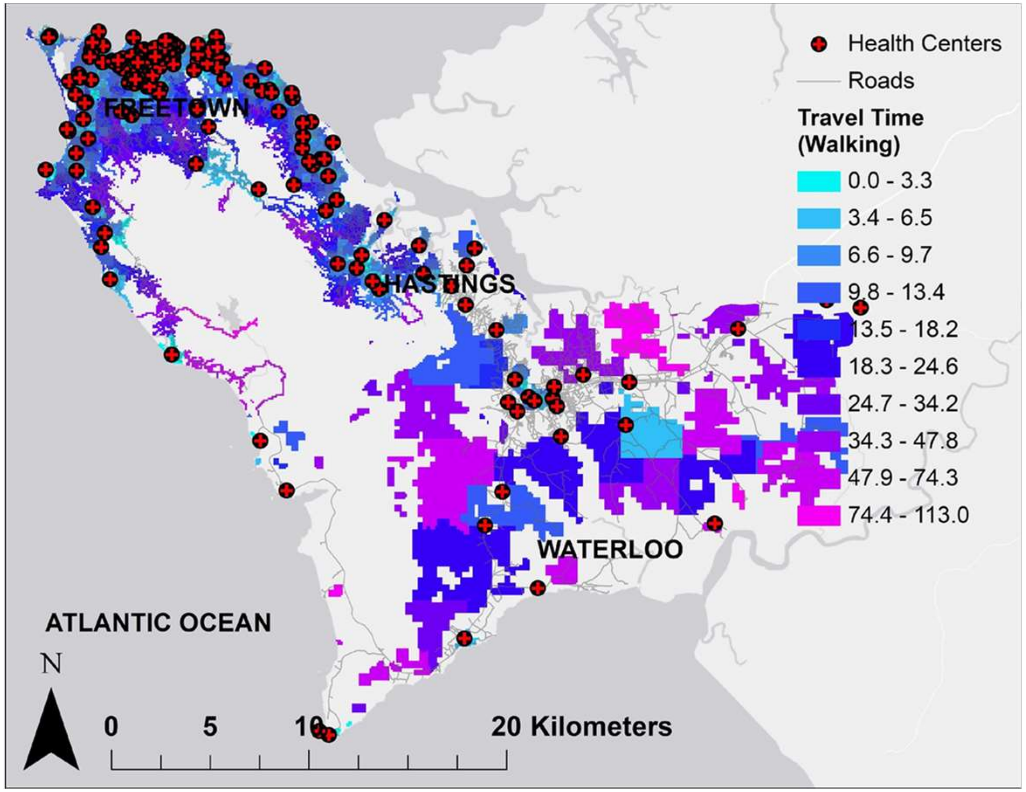

Health Centers



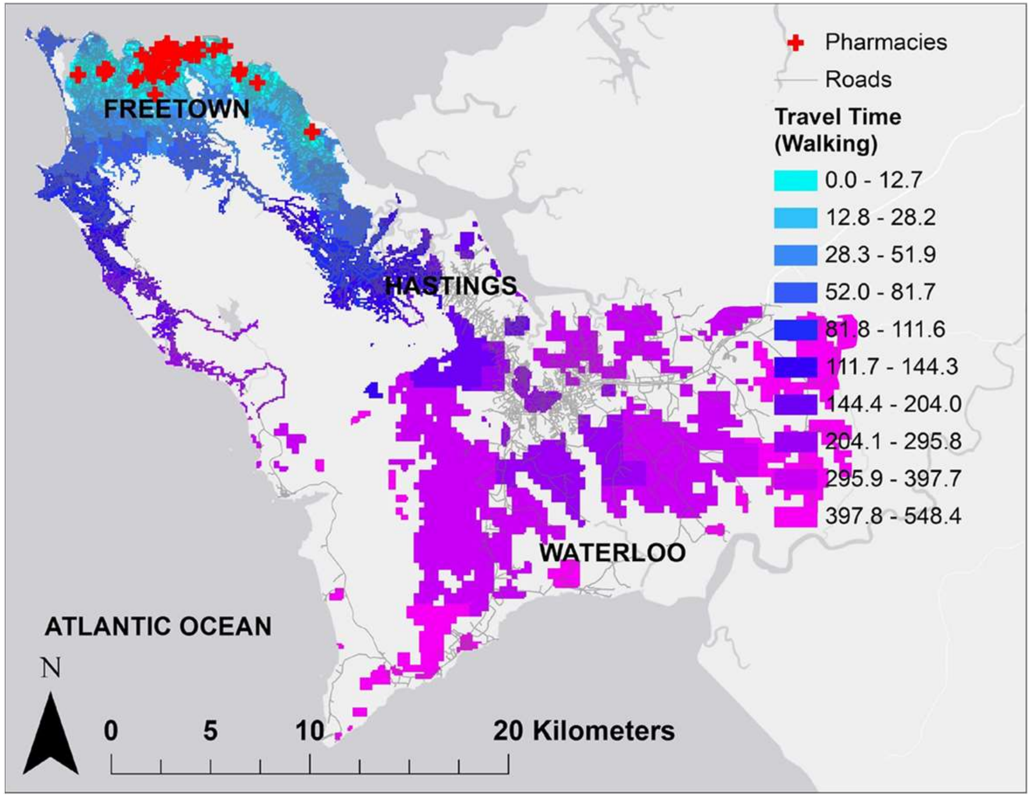

Pharmacies

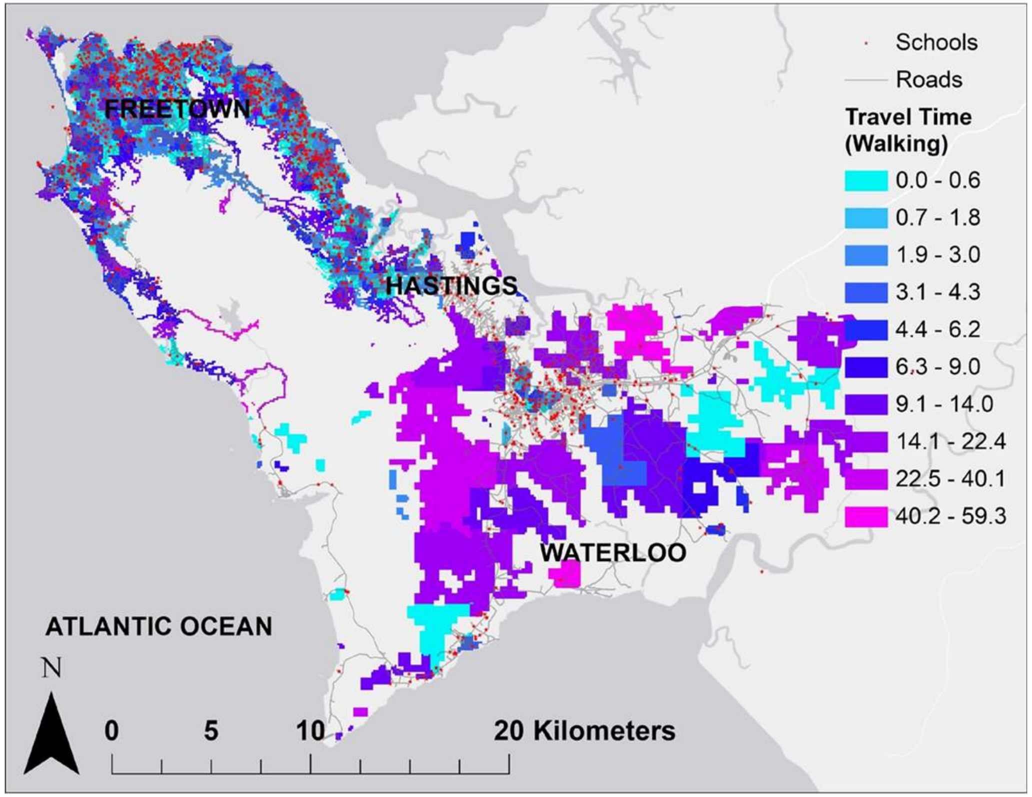
# Accessibility measures per center (H, HC)



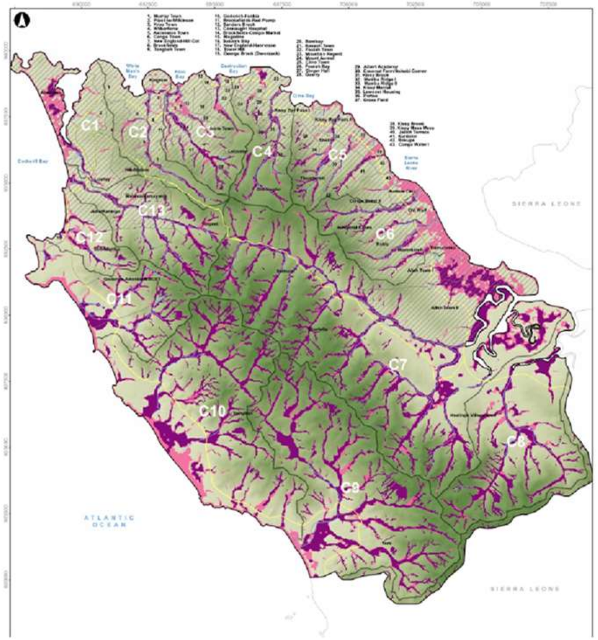
# Accessibility measures (P, Sch)



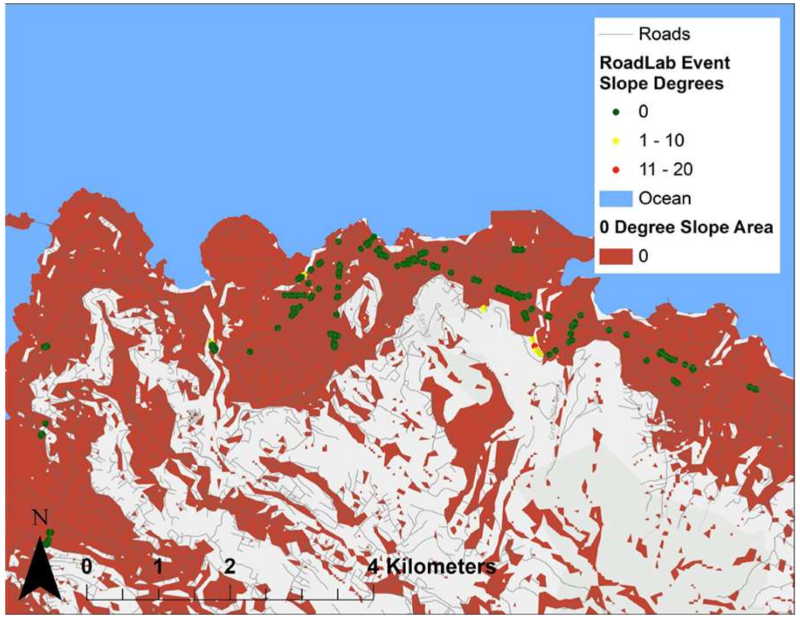



# New Data & New Opportunities

Data Source 1



Data Source 2



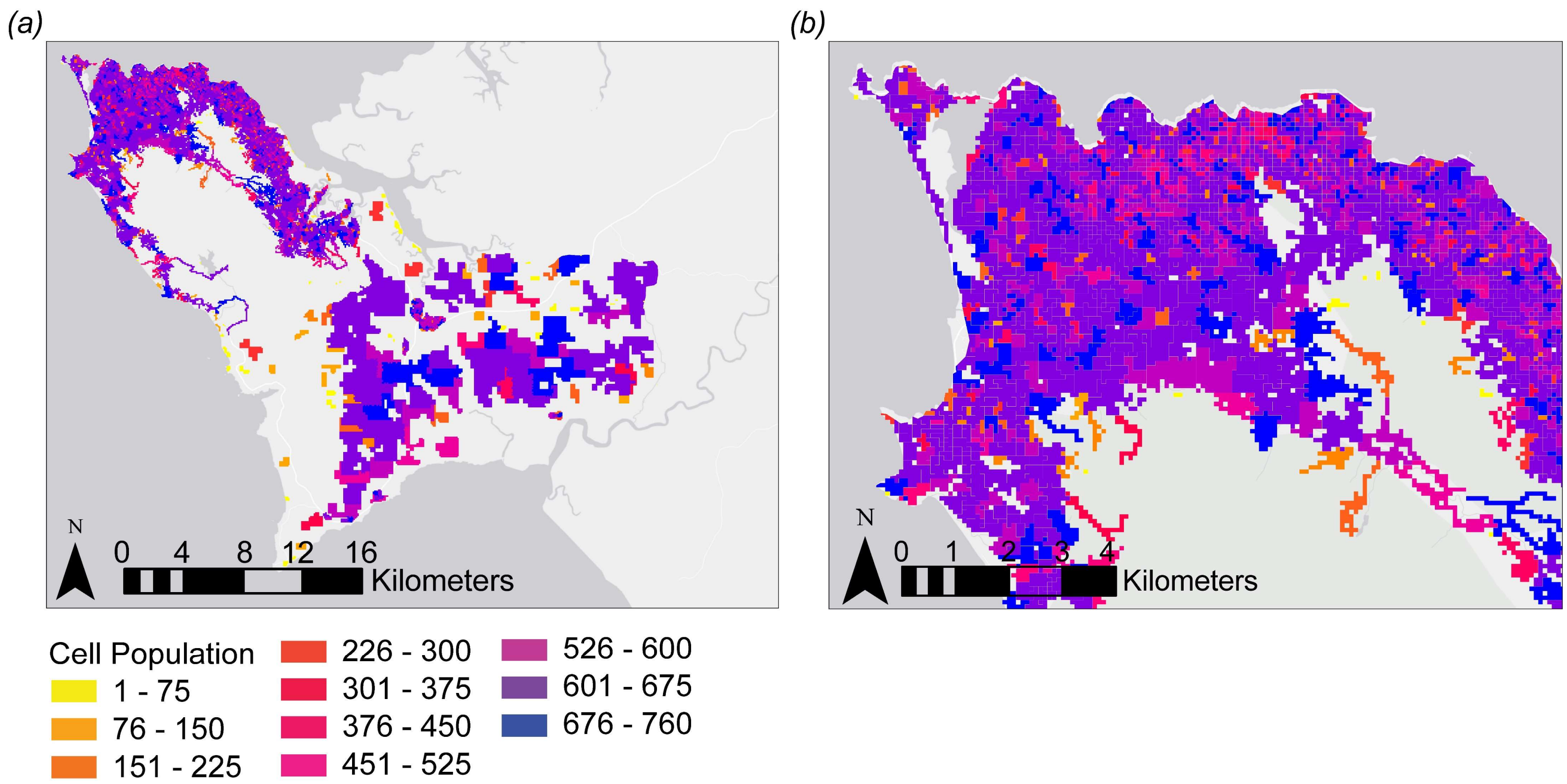

- Data Source 1:

Multi-hazard event maps plus modeling techniques identify major weather hazards (major floods and Landslides)

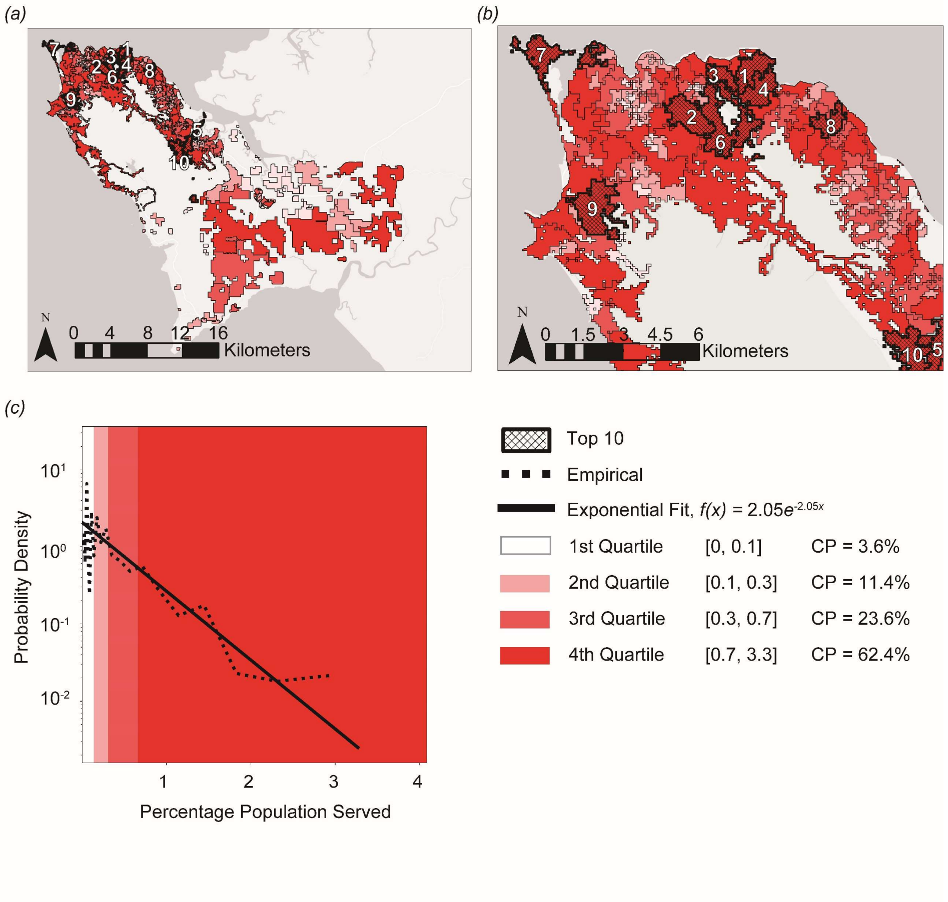
- Data Source 2:

Local university collaboration identifies minor weather hazards, temporary flooding and water accumulation on unpaved roads

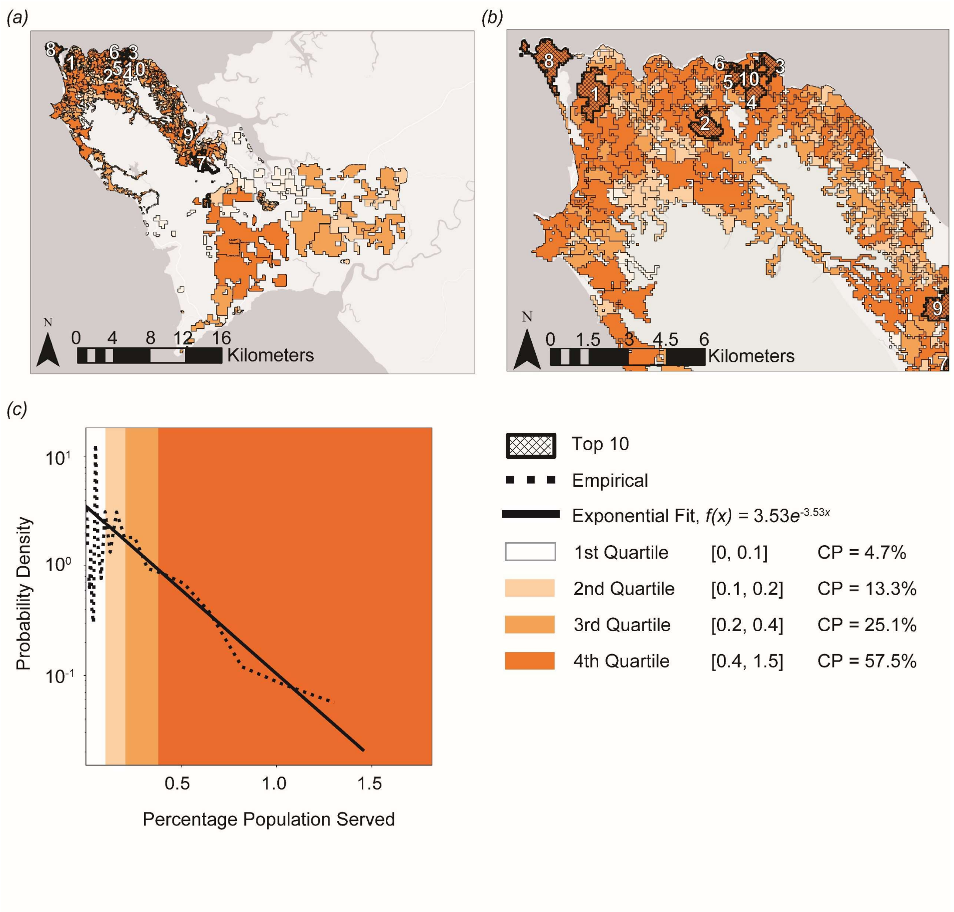
# S. Figure 1: Method: Neighborhood Generation, a) Neighborhood population size; b) Freetown CBD detail



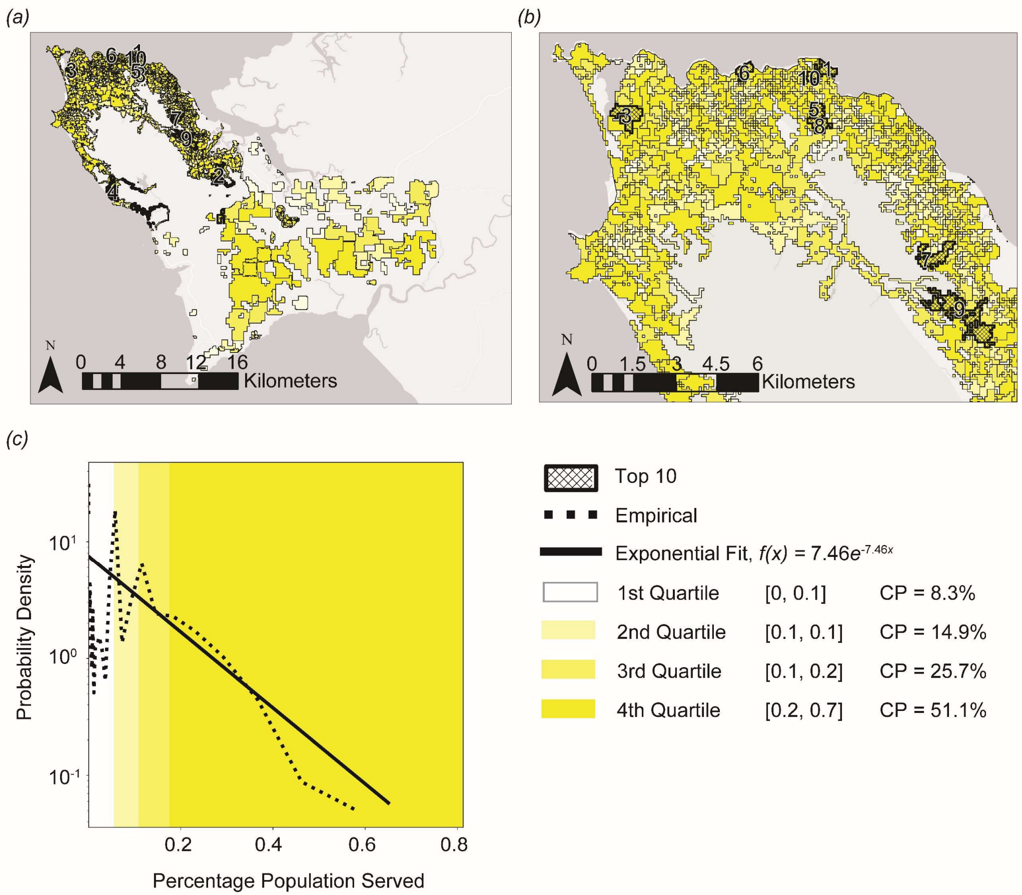
# S. Figure 2: Neighborhood Generation and Accessibility Calculation: Distribution of neighborhood distance to health facilities



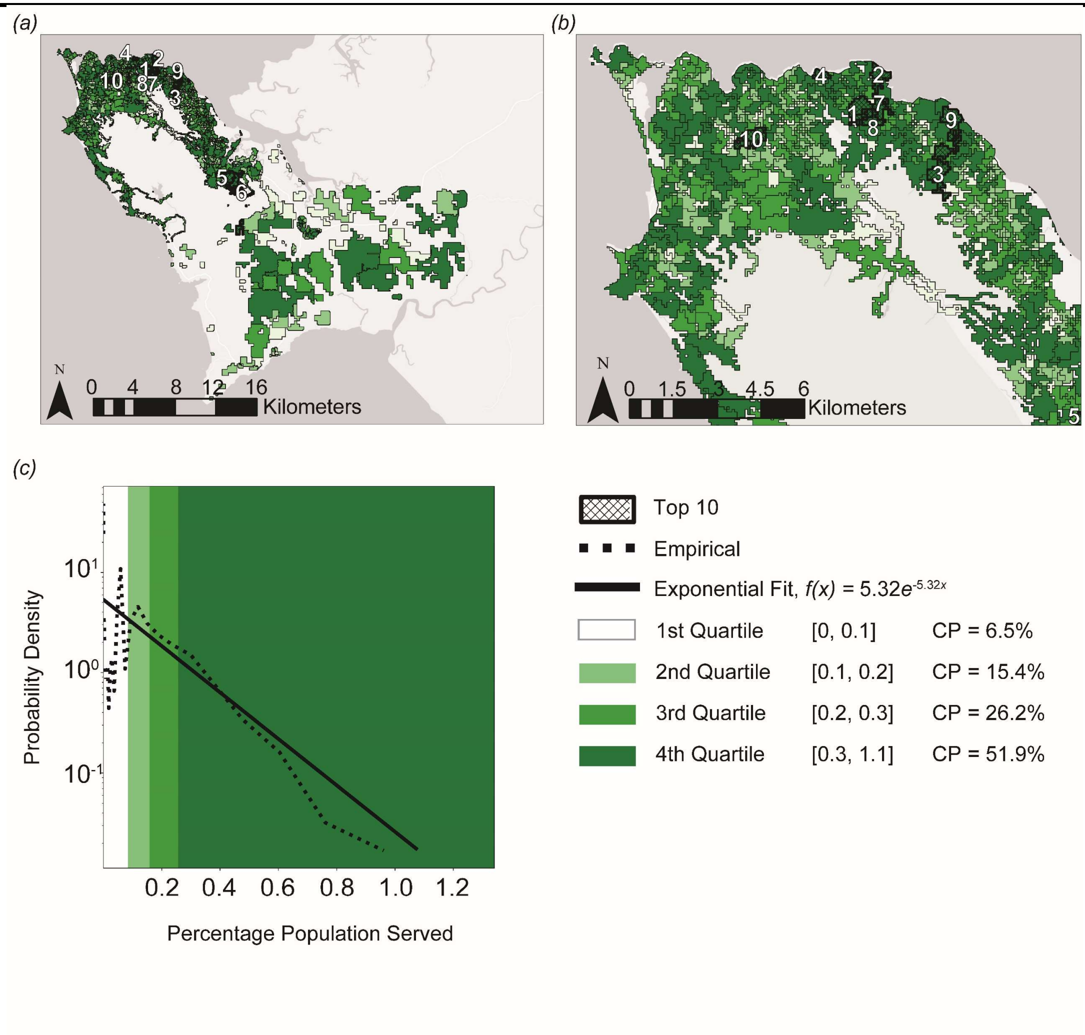
# S. Figure 3: Demand Distribution: a) Senior Secondary Schools (n = 208); b) Freetown Central Business District Detail; c) Distribution with fit



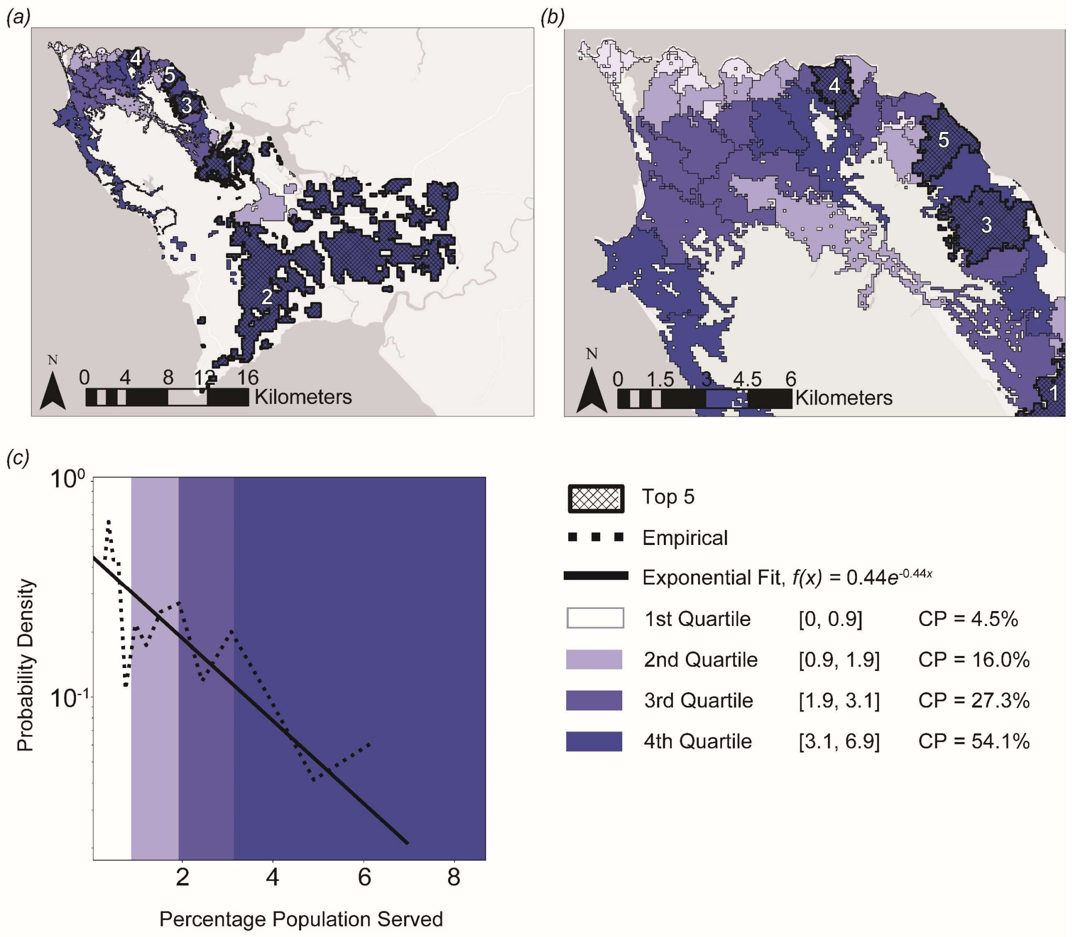
S. Figure 4: Demand Distribution: a) Junior Secondary Schools (n = 353); b) Freetown Central Business District Detail; c) Distribution with fit



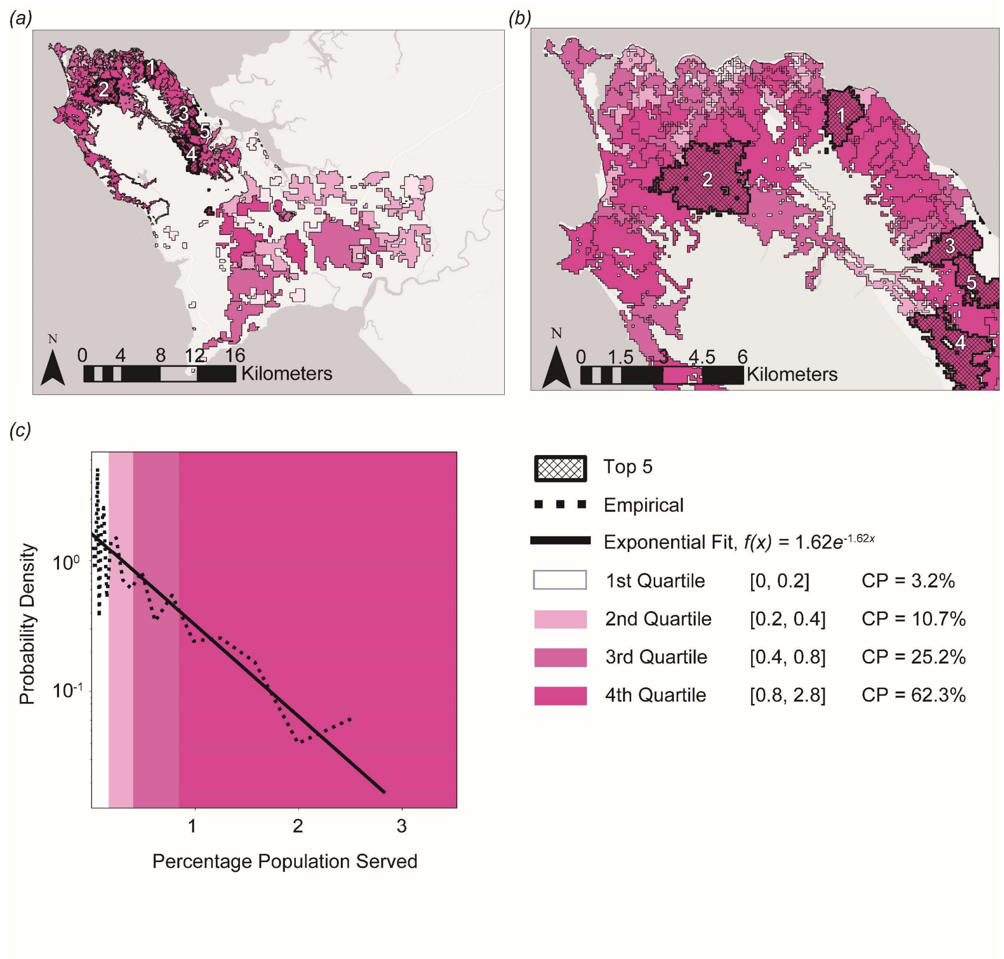
# S. Figure 5: Demand Distribution: a) Primary Schools (n = 746); b) Freetown Central Business District Detail; c) Distribution with fit



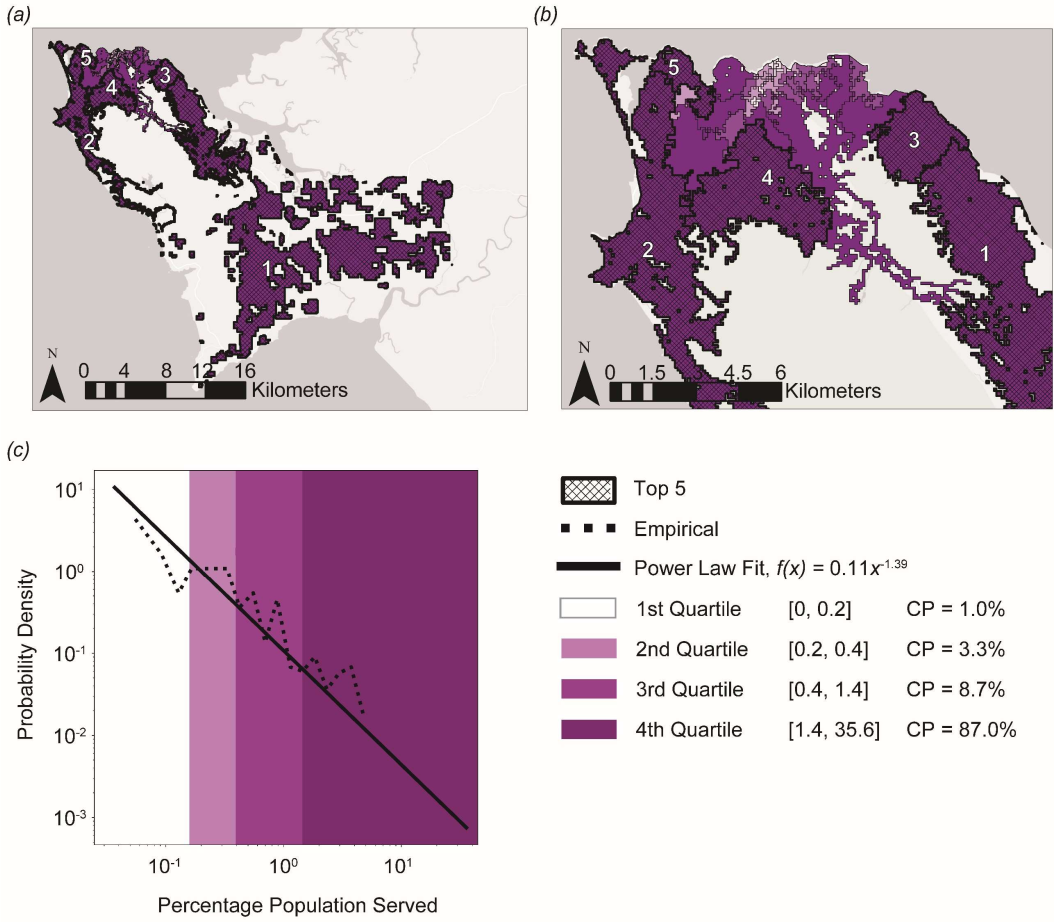
# S. Figure 6: Demand Distribution: a) Pre-Primary Schools (n = 532); b) Freetown Central Business District Detail; c) Distribution with fit



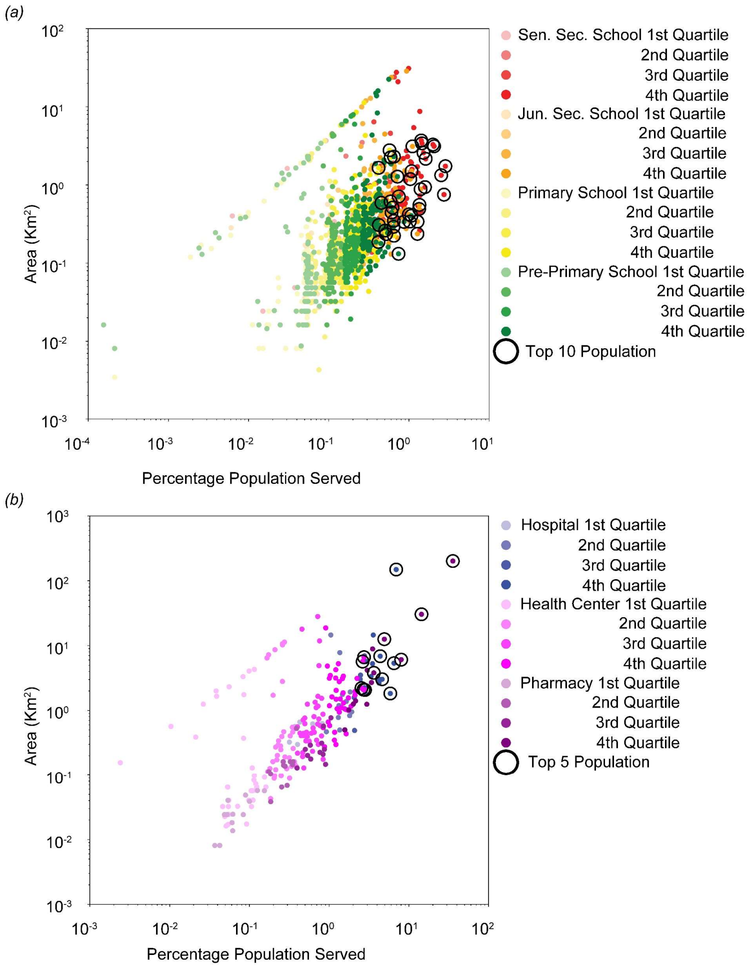
# S. Figure 7: Demand Distribution: a) Hospitals (n = 44); b) Freetown Central Business District Detail; c) Distribution with fit



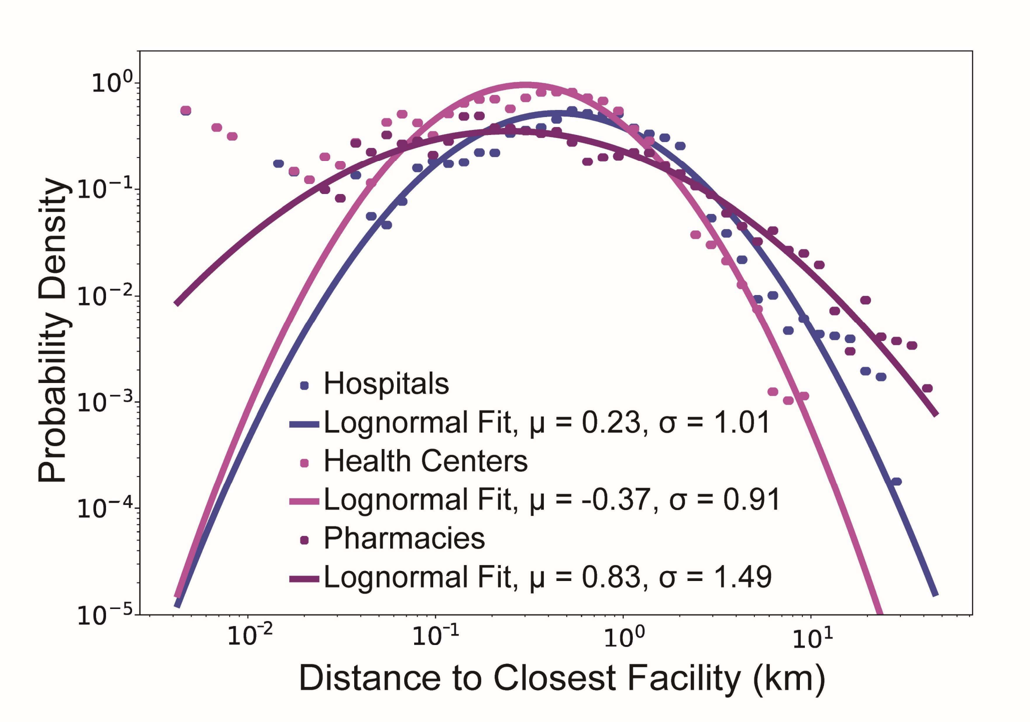
# S. Figure 8: Demand Distribution: a) Health Centers (n = 164); b) Freetown Central Business District Detail; c) Distribution with fit



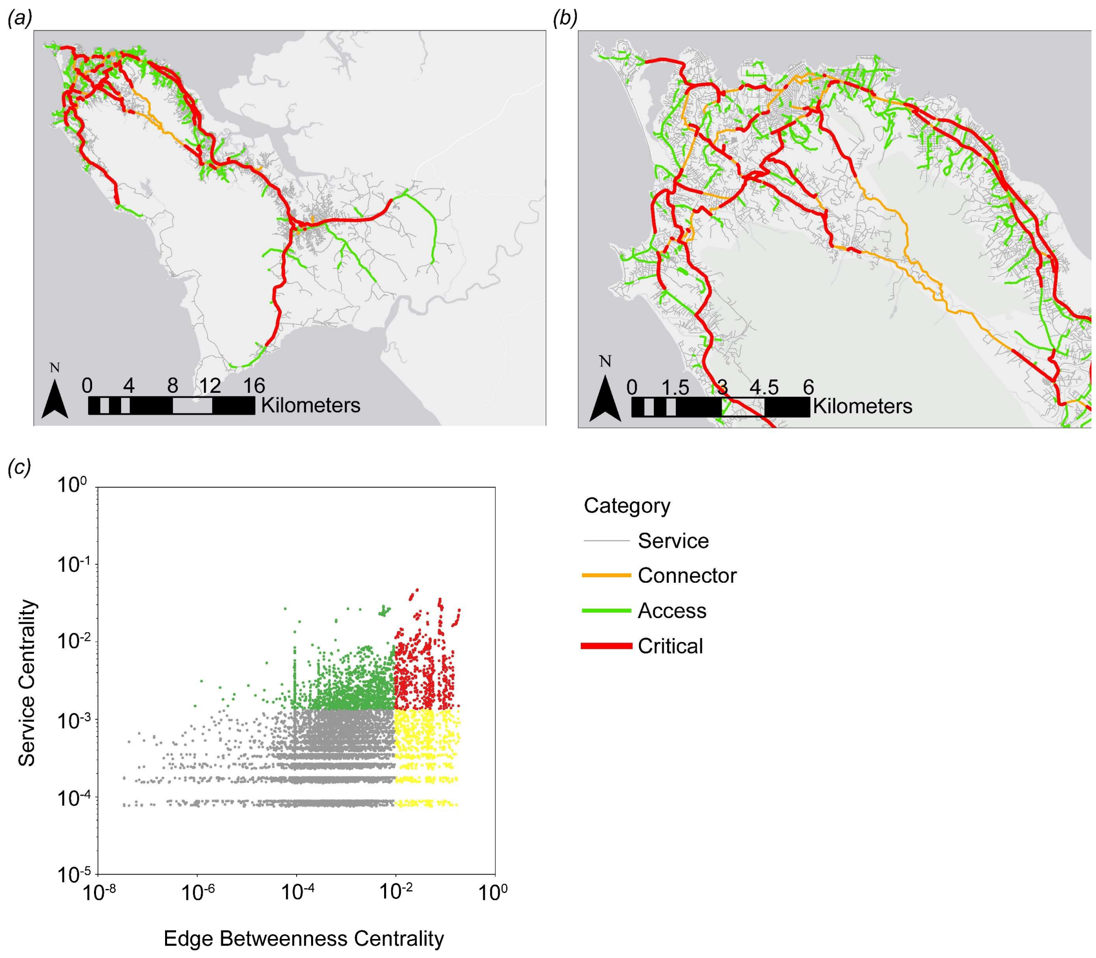
# S. Figure 9: Demand Distribution: a) Pharmacies (n = 50); b) Freetown Central Business District Detail; c) Distribution with fit



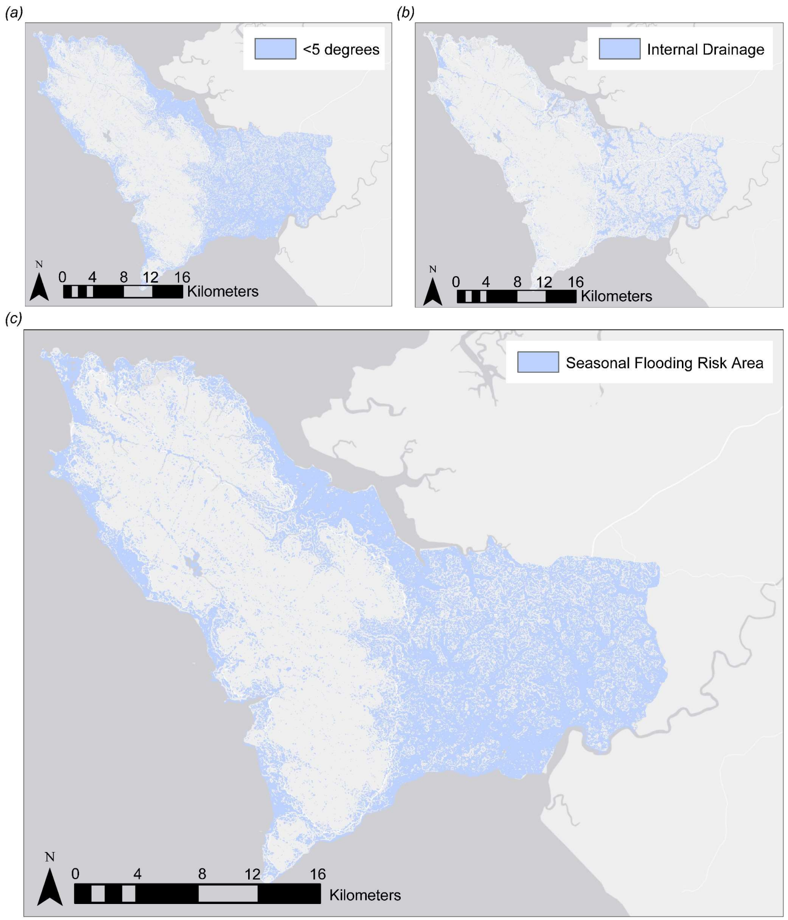
S. Figure 10: Demand, Size of service areas compared to population served: a) Education facilities; b) Health Facilities



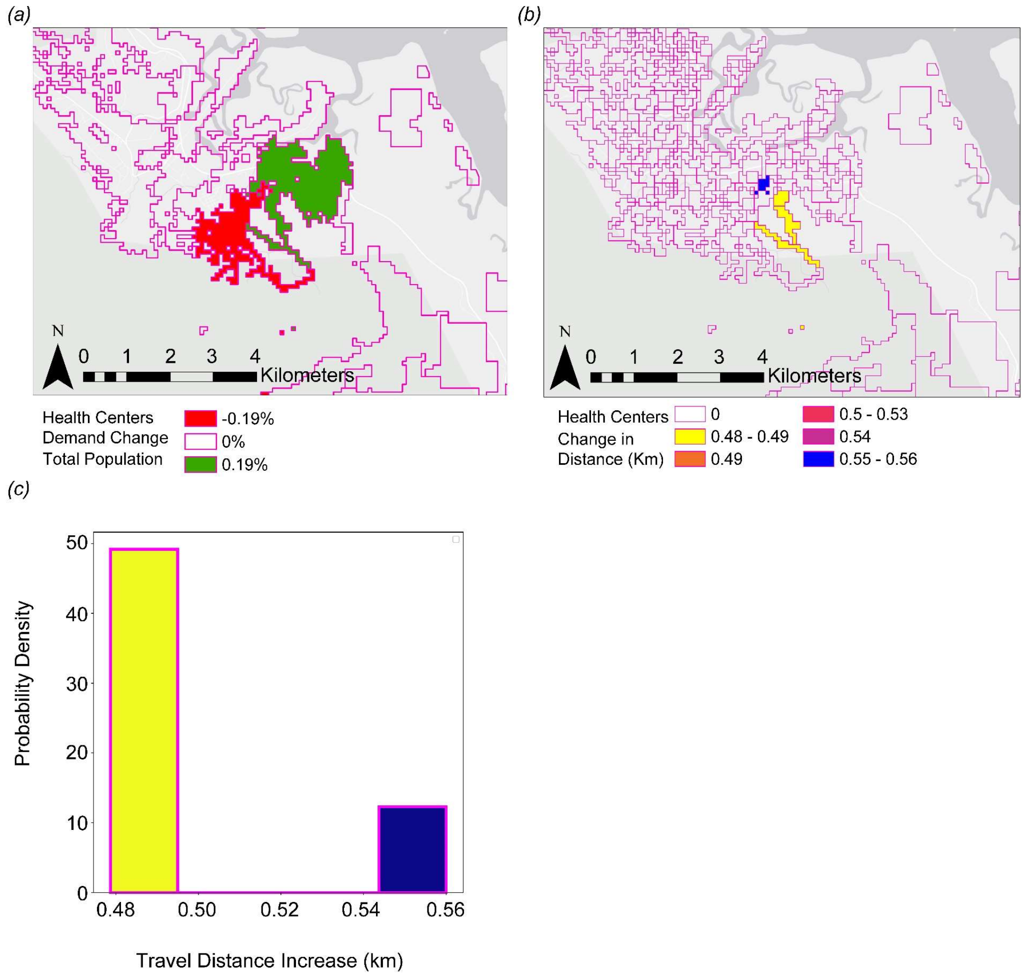
# S. Figure 11: Road Importance Process - Service Centrality for: a) health facilities, b) education facilities, and c) all facilities



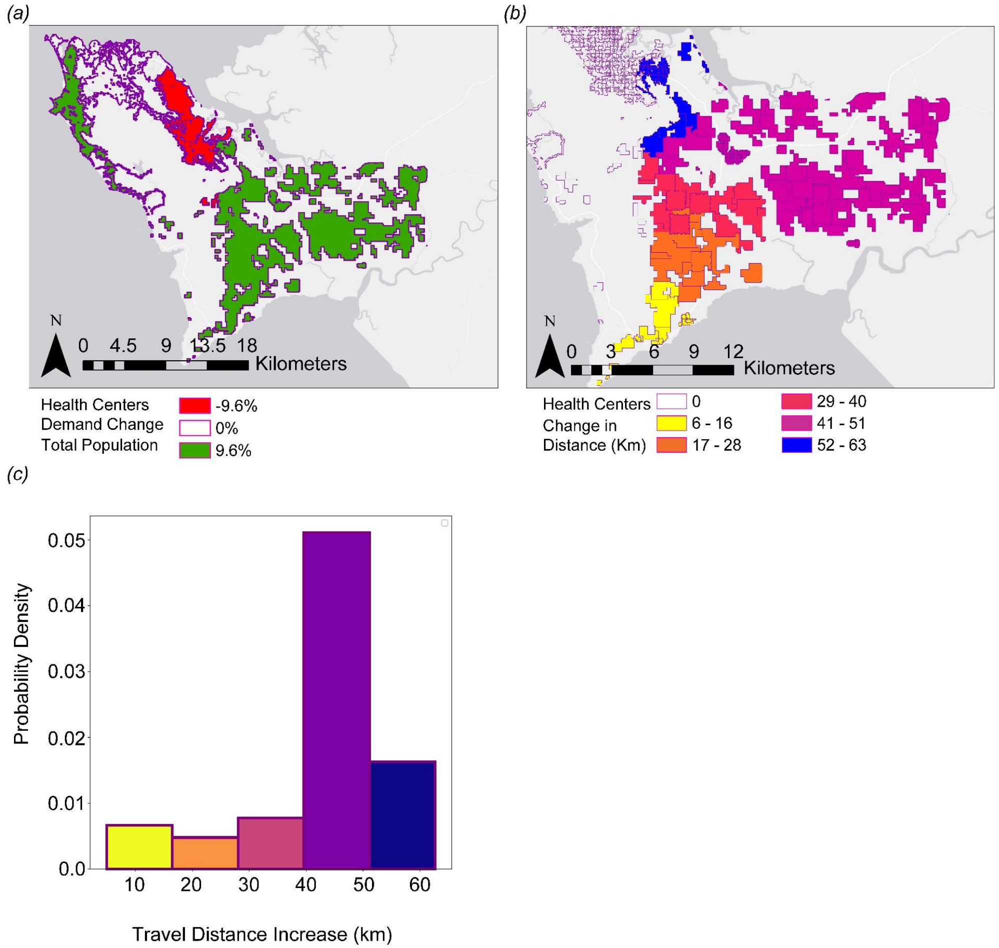
S. Figure 12: Combining Service Centrality and Global Connectivity in the road network allows road segments to be categorized by anticipated usage: a) road categories in Western Area Urban and Western Area Rural; b) Freetown CBD detail; c) scatterplot of service centrality and edge betweenness centrality of network edges



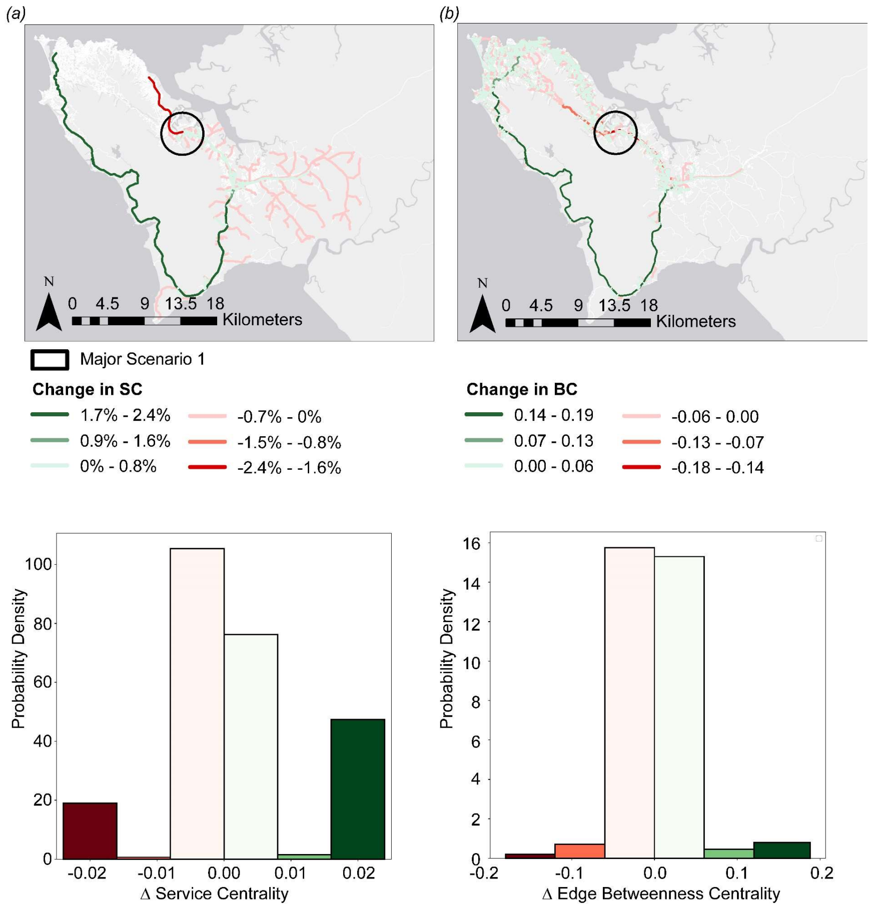
# S. Figure 13: Seasonal Flooding Hazard Extent, a) Areas with slope of less than five degrees; b) Sinks, or areas with no outlet for drainage, c) Union of 11a) and 11b), representing the extent of expected seasonal flooding risk



# S. Figure 14: Scenario 1 Results: a) Demand shifts for affected Health Centers; b) Health Center accessibility shifts for affected neighborhoods; c) Distribution of Health Centers accessibility shifts for affected neighborhoods



# S. Figure 15: Scenario 1 Results: a) Demand shifts for affected Pharmacies; b) Pharmacy accessibility shifts for affected neighborhoods; c) Distribution of Pharmacies accessibility shifts for affected neighborhoods



# S. Figure 16: Scenario 1 Results - Road Network (Major Flooding Hazard), a) Non-zero changes in service centrality and distribution; b) Non-zero changes in edge betweenness centrality and distribution