

Geospatial Analysis of Healthcare Accessibility in High Older-Adult Areas under Flood Scenarios: Implications for Disaster Management in an Aging Puerto Rican Population

Author: Mario O. Font-Martin

Advisor: Raúl Matos-Flores, Ph.D.

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Abstract

This study examines healthcare accessibility for older-adult populations (60+) in Puerto Rico under flooded road network scenarios. A geospatial transportation network-based analysis was conducted in ArcGIS Pro using a 1-kilometer distance threshold and FEMA 1% annual flood probability data to model transportation network interruptions. A ≤ 1 km threshold was applied from healthcare facilities under flooded network conditions. Accessibility was analyzed separately for hospitals and Centro 330 facilities and the combined to visualize overall service accessibility. Results show that flooding noticeably reduces short-distance healthcare access in several high older-adult census tracts, highlighting the vulnerability of local healthcare accessibility to transportation network interruptions and supporting evidence-based disaster planning for aging populations.

Introduction

- Puerto Rico is undergoing a rapid demographic transition, with spatial variation in the distribution of the older-adult population (60+).
- This demographic phenomenon creates challenges for equitable healthcare access [1], particularly in areas where healthcare facilities are spatially scattered.
- Flooding is a persistent hazard in Puerto Rico, exposing communities to risks when road networks become interrupted, reducing access to healthcare.
- Flooding can cause road interruptions which may isolate communities from hospitals and Centros 330, deepening pre-existing access barriers to healthcare facilities, especially for older adults.
- Healthcare accessibility considers interactions between population, infrastructure, and environmental risks. A GIS network analysis presents a spatial framework to reflect how flooding events disrupt access to healthcare.

Background

- Previous GIS network analyses have shown that short-distance healthcare accessibility is highly sensitive to transportation interruptions [2], particularly for older adults in areas exposed to hazards.

Problem

- In Puerto Rico, there is limited spatial evidence identifying where high older-adult (60+) communities lose functional access to healthcare when transportation networks are interrupted by flooding events, thus negatively impacting equitable and targeted disaster planning.

Methodology

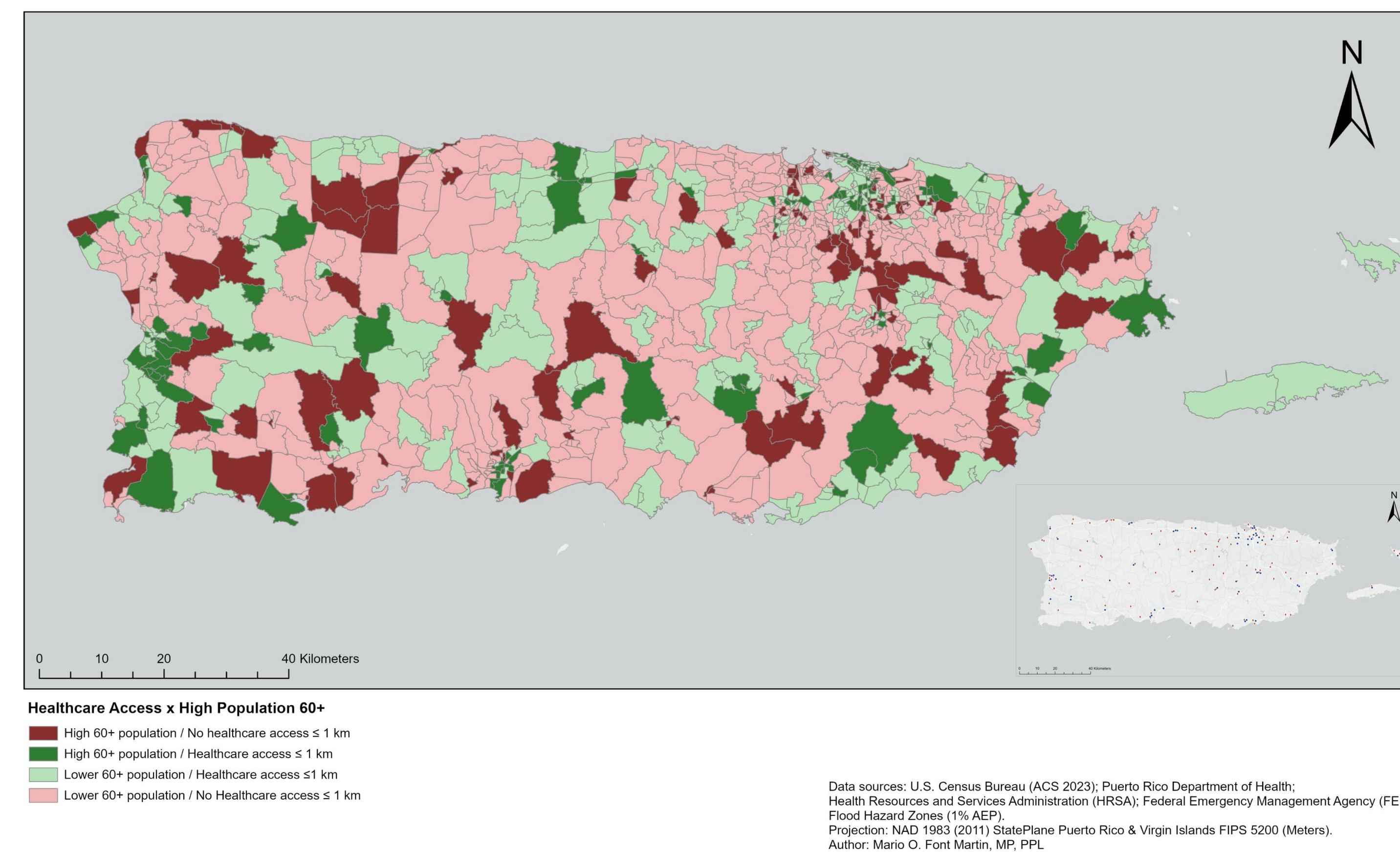
- 1. Study structure:** A network-based healthcare accessibility analysis [3], [4] was conducted in ArcGIS Pro using a flooded road network scenario under FEMA's 1% AEP.
- 2. Data sources:** ACS 2019 – 2023 population estimates for older adults (60+), hospitals and Centro 330 locations, road network datasets, and FEMA flood hazard layers.
- 3. Flooded network:** Roads intersecting FEMA 1% AEP zones were identified as disrupted to simulate reduced network connectivity under flood events.
- 4. Accessibility measure:** Tract-level accessibility was classified using ≤ 1 km threshold from healthcare facilities in flood conditions. Census tract centroids were used for spatial referencing.
- 5. Outputs:** Hospital and Centro 330 facilities locations and tract-level accessibility maps (hospital, Centro 330, combined) overlaid with high older-adult (60+) tracts ($\geq 75^{\text{th}}$ percentile).

Results and Discussion

Flooded road network conditions show local healthcare access disparities especially for older adults (60+), with several high older-adult census tracts losing functional access to healthcare facilities within short-distance thresholds.

Combined Healthcare Accessibility under Flooded Road Network Conditions and High Older Adult Population (60+)

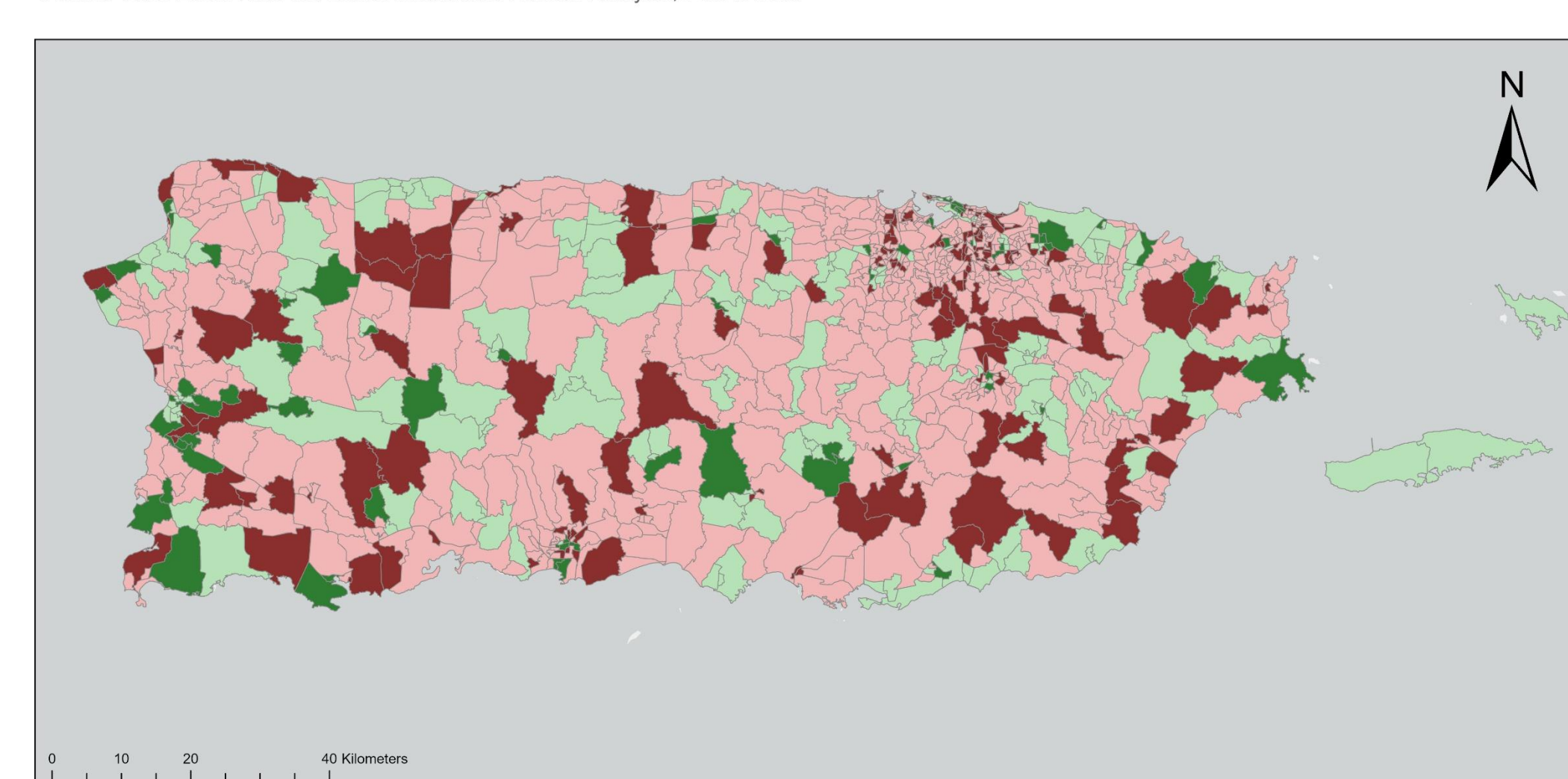
Census Tract-Level Network-Based Healthcare Access Analysis, Puerto Rico



Map 1

Combined Healthcare Accessibility under Flooded Network Conditions (High 60+ Areas)

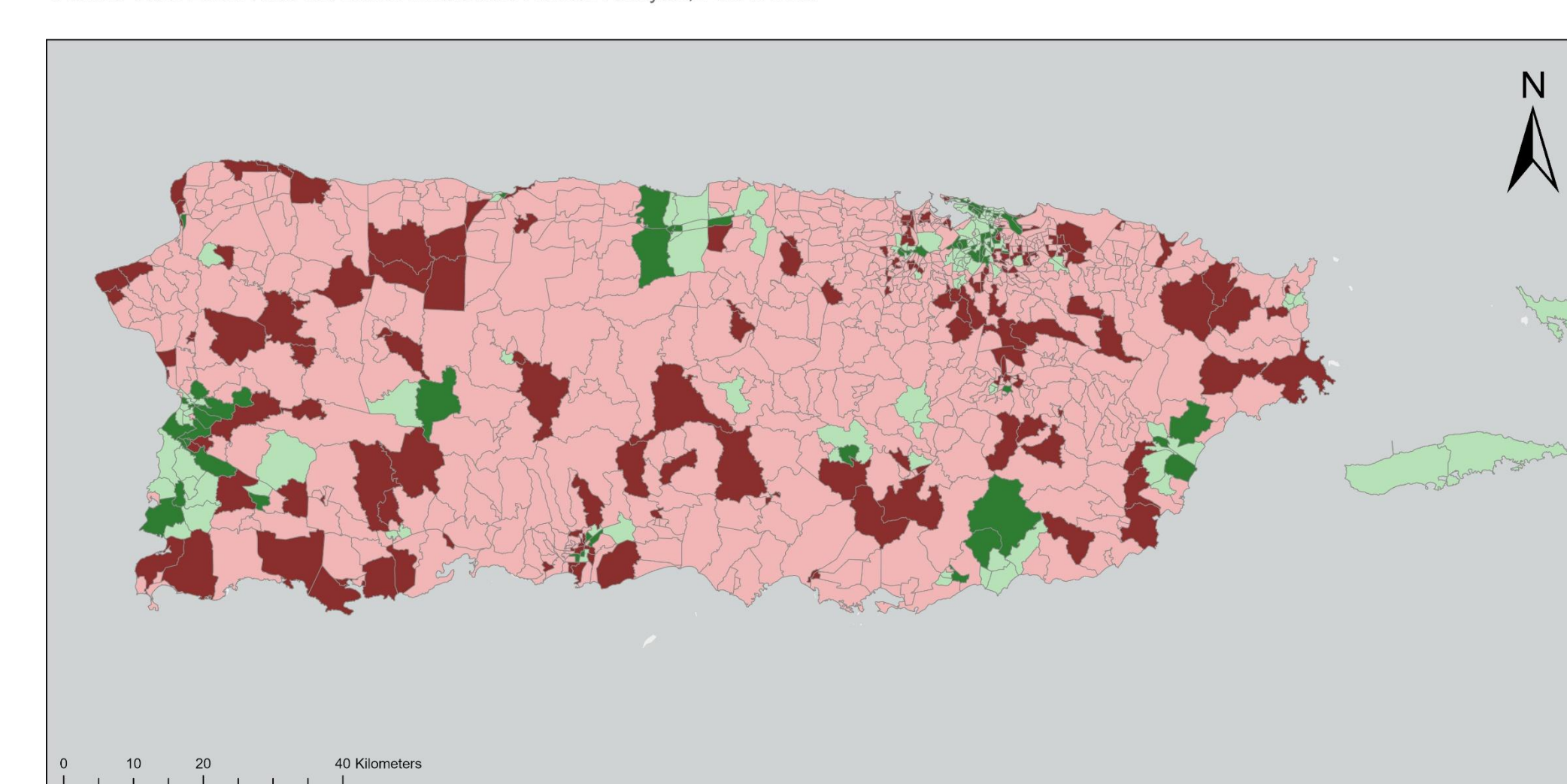
Centro 330 Accessibility under Flooded Road Network Conditions and High Older Adult Population (60+)



Map 2

Centro 330 Accessibility under Flooded Network (High 60+ Areas)

Hospital Accessibility under Flooded Road Network Conditions and High Older Adult Population (60+)



Map 3

Hospital Accessibility under Flooded Network (High 60+ Areas)

Table 1
Census Tract Classification by Older-Adult Concentration and Flooded-Network Accessibility

Category	Number of Census Tracts	%
High 60+ / No Access ≤ 1 km	118	12.51%
High 60+ / Access ≤ 1 km	112	11.90%
Lower 60+ / Access ≤ 1 km	271	28.74%
Lower 60+ / No Access ≤ 1 km	442	46.87%
Total	943	100.00%

*Percentages may not sum to 100% due to rounding.

Conclusions

- Flooded-network scenarios demonstrate intersecting vulnerabilities in high older-adult census tracts. These vulnerabilities are framed by demographic transition and transportation network interruptions, with notable impacts on local healthcare accessibility.
- At short-distance thresholds (≤ 1 km), accessibility patterns across facility types don't have substantial differences, indicating that proximity to healthcare matters more than service type for older adults during flooding. This phenomenon is more evident when considering the combined facilities analysis.
- Disaster management should prioritize transportation resilience and local healthcare connectivity in areas of high demographic vulnerability, particularly where there are high concentrations of older-adult populations (60+).

Future Work

- Continue the analysis at smaller spatial units (census blocks or groups) using population-weighted centroids to identify accessibility patterns among older-adult population.
- Include other transportation interruptions (bridge failures) and other multi-hazard scenarios.
- Incorporate future climate and flood scenarios into public-sector planning frameworks to support evidence-based decisions in healthcare and transportation policy for aging communities.

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References

- [1] World Health Organization, Ageing and Health, 2025.
- [2] N. Nurwatik et al., ISPRS Int. J. Geo-Inf., 11(4), 235, 2022.
- [3] W. Luo and S. Wang, Environ. Plan. B, 30(6), 865-884, 2003.
- [4] S. L. Handy and D. A. Niemeier, Environ. Plan. A, 29(7), 1175-1194, 1997.

Key Findings

- Flood-related road disruptions reduce short-distance healthcare access for older adults (60+).
- Hospital accessibility is more affected by flooding than Centro 330 accessibility.
- The combined model highlights areas where flooding may exacerbate pre-existing spatial inequities in healthcare access.