Hurricane Milton (October 2024): Social Vulnerability and Recovery Trajectories in Florida, U.S.

UNIVERSITY OF NOTRE DAME
Keough School of Global Affairs

Prepared by Janyl Ismailova
Master of Global Affairs, Governance & Policy

Abstract

This study examines Hurricane Milton's impact on Florida's power infrastructure using NASA's nighttime light (NTL) satellite data. It analyzes power loss and recovery trajectories, highlighting disparities in recovery rates among socioeconomically vulnerable regions. By integrating NTL data with the Social Vulnerability Index (SVI), the study underscores the need for targeted disaster responses, prioritizing vulnerable areas, and leveraging geospatial tools for efficient recovery. Further research is needed to enhance disaster resilience and equity.

Research Questions

1. What was the extent of power loss during Hurricane Milton, and how did the recovery process vary spatially and temporally across Florida counties?
2. How do social vulnerability factors influence the pace and effectiveness of power restoration efforts?
3. What patterns of inequality in recovery can be identified, and what are the implications for disaster risk management?

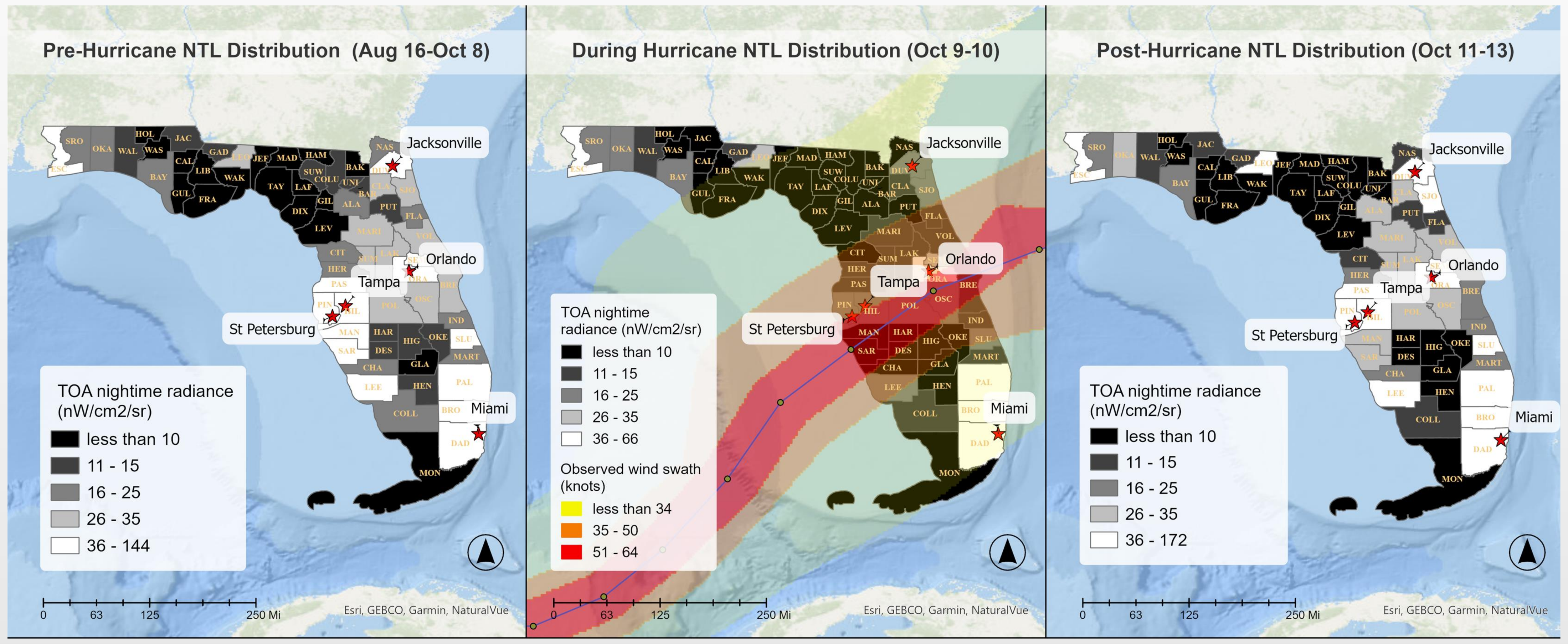

Figure 1. NTL Distribution Before, During, and After Hurricane Milton Across Florida

Introduction

Hurricane Milton, the strongest storm of the 2024 Atlantic hurricane season, landed near Siesta Key, Florida, on October 9, 2024, as a Category 3 hurricane (Guy Carpenter). Initially forming as a tropical disturbance in early October, Milton rapidly intensified due to favorable atmospheric conditions and warm sea surface temperatures, achieving Category 5 status with maximum sustained winds of 180 mph and a central pressure of 897 millibars before weakening before landfall (City of Cape Canaveral).

Milton's impacts were catastrophic and wide-ranging. It brought hurricane-force winds and tropical storm conditions to 51 Florida counties, with 34 declared disaster areas (Simpson). The storm caused over 3.5 million power outages statewide, a historic tornado outbreak with 126 warnings issued, and extreme rainfall, including a record 18 inches in St. Petersburg over 24 hours (Guy Carpenter). Flooding and storm surges compounded damages in both coastal and inland areas. Economically, Hurricane Milton inflicted preliminary agricultural losses estimated at $1.5 to $2.5 billion, severely affecting citrus, aquaculture, and livestock sectors (Simpson).

This study examines the effects of Hurricane Milton on Florida's power infrastructure and recovery using NASA's NTL satellite data. By overlaying recovery trajectories with the SVI, the analysis identifies disparities in recovery across socioeconomically vulnerable regions. The findings underscore the critical need for equitable resource allocation and resilience strategies in disaster response planning.

Methodology

Data Sources:

1. NTL Data: NASA's VNP46A1 dataset (August 16–October 15, 2024).
2. Hurricane Data: NOAA GIS data on wind speed and trajectory.
3. SVI Data: CDC's 2022 Social Vulnerability Index.

Analysis Steps

NTL data was analyzed to assess the impact and recovery following Hurricane Milton. Baseline radiance values were calculated by averaging pre-hurricane NTL data (August 16–October 8). Percent power loss was determined using the formula:

$$Percent\ Power\ Loss = \frac{(Baseline\ NTL - Post\ Hurricane\ NTL)}{Baseline\ NTL} \times 100$$

The recovery rate was calculated as:

$$Recovery\ Rate\ (\%) = 100\% - Power\ Loss\ (\%)$$

Methodology (cont'd)

Daily recovery rates were tracked post-hurricane to monitor power restoration progress. Recovery percentages (October 11–13) were compared with SVI themes to map delays in high-vulnerability areas. Spatial hotspot analysis using Getis-Ord Gi* identified regions with delayed recovery correlated with high SVI scores; no additional clustering methods were used.

Social Vulnerability Themes

1. Socioeconomic Status: Measures economic challenges such as poverty, unemployment, and lack of education or health insurance.
2. Household Characteristics: Focuses on age-related vulnerabilities, disabilities, single-parent households, and language barriers.
3. Racial and Ethnic Minority Status: Assesses areas with higher concentrations of minority populations and their associated vulnerabilities.
4. Housing Type & Transportation: Highlights housing instability, crowded living conditions, and lack of access to transportation.

Findings

NTL Analysis of Power Loss and Recovery (Fig.1)

Before the hurricane (August 16-October 8): High NTL radiance values were observed in urban areas such as Miami, Tampa, Orlando, and Jacksonville, indicating robust power infrastructure. Rural areas exhibited lower radiance, reflecting baseline vulnerabilities.

During the hurricane (October 9-10): Significant power loss occurred along the central and southwest path of the hurricane, especially in rural counties and coastal regions (e.g., Manatee, Sarasota, and Highland Counties). The wind swath (51-64 knots) correlated with the most affected areas.

Post-hurricane (October 11-13): Urban areas recovered power more rapidly, with counties like Miami-Dade and Orange showing higher radiance levels. However, recovery lagged in rural counties, particularly in central Florida.

Recovery Trajectory (Fig.2)

- On October 11, counties like Hardee, Highlands, and Glades showed less than 61% recovery. By October 13, recovery improved in urban centers, achieving over 95% restoration, while several rural areas around Miami struggled to surpass 70% recovery.

- Persistent disparities highlight systemic challenges in vulnerable counties. Rural areas in central Florida (e.g., DeSoto and Glades Counties) continued to experience prolonged power outages.

SVI and Recovery Correlation (Fig.3)

- Counties with high poverty levels and low incomes (e.g., Hardee, Glades, and Highlands) had the lowest recovery percentages, demonstrating the impact of limited resources on infrastructure restoration.

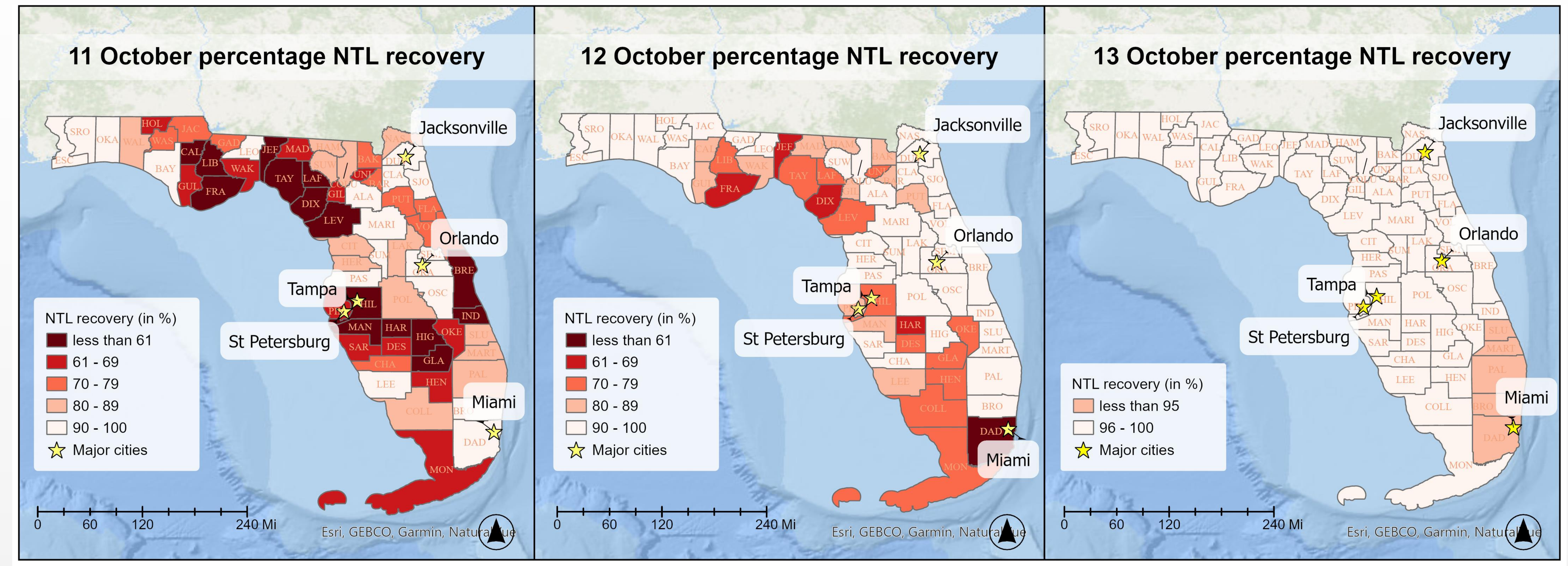

Figure 2. Recovery Trajectory: Percentage NTL Recovery Across Florida

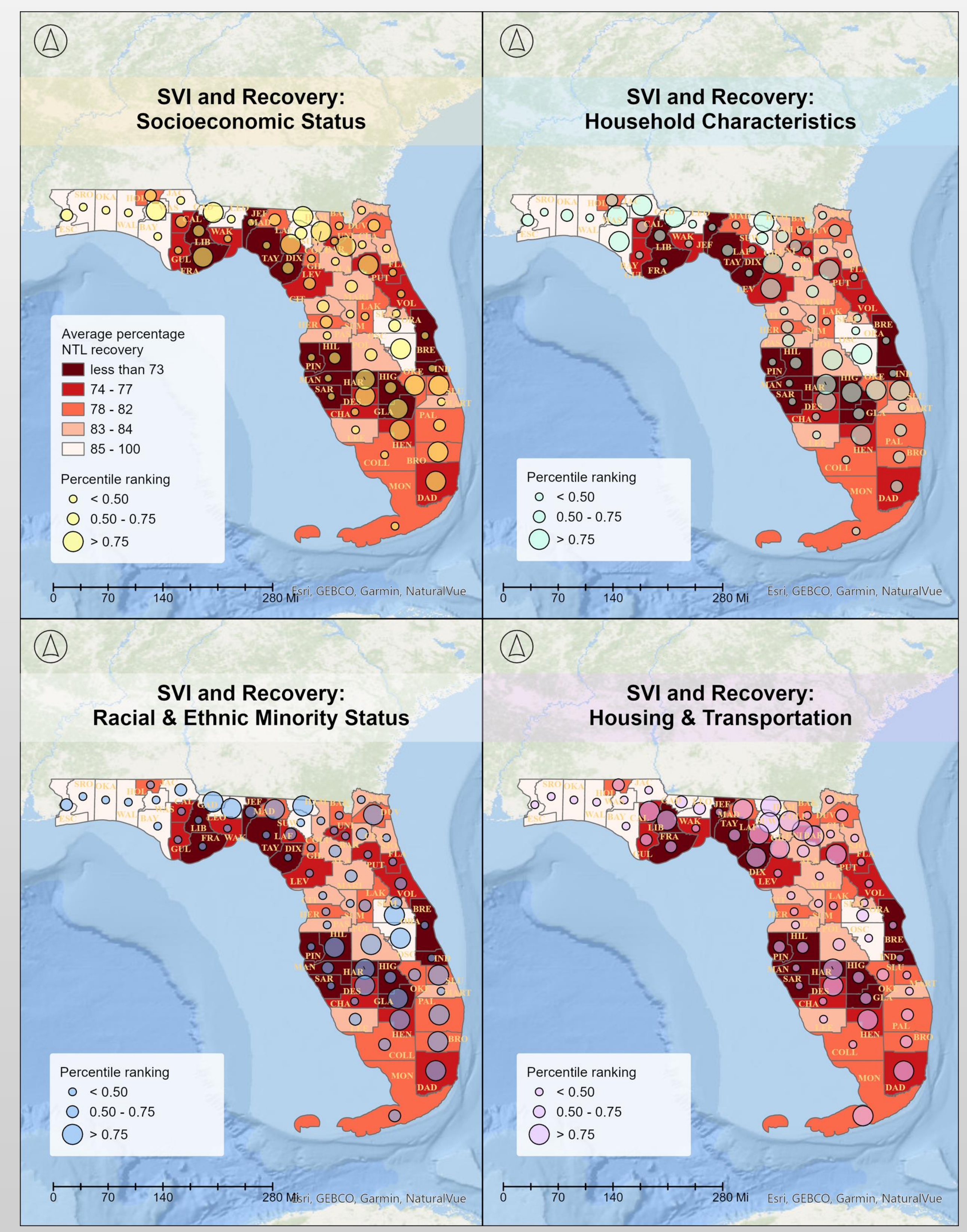

Figure 3. Social Vulnerability and Power Recovery Delays Across Florida

- Counties with a high percentage of elderly populations and people with disabilities (e.g., Taylor, Highland, and Levy) faced slower recovery due to mobility and accessibility challenges.

- Areas with significant minority populations, such as Miami-Dade and Hillsborough, exhibited slower recovery rates, indicating potential inequities in resource distribution.

- Counties with poor housing quality and limited transportation access, such as Hardee, Franklin, and Liberty, experienced the most prolonged delays in power restoration, highlighting structural infrastructure deficiencies.

- Clusters of Prolonged Recovery: Central Florida counties (e.g., Hardee, DeSoto, and Highlands) consistently emerged as hotspots of delayed recovery across all SVI themes. These areas also aligned closely with the hurricane's wind path. Urban areas with lower SVI scores, such as Pasco and Orange, recovered faster, emphasizing the role of existing infrastructure resilience.

The findings suggest a potential relationship between high social vulnerability and delayed recovery rates, particularly in rural and minority-dense counties.

Socioeconomic challenges, coupled with infrastructure and accessibility deficiencies, appear to contribute to disparities during recovery. Further research is needed to confirm and fully understand these patterns.

Limitations

- Cloud cover and satellite resolution challenges may have impacted NTL data accuracy, particularly in small-scale or densely populated areas.
- County-level SVI scores may mask intra-county disparities; more granular census tract-level data could provide deeper insights into recovery patterns.
- The study focused on immediate recovery patterns, limiting its ability to address long-term resilience and structural issues persisting after initial power restoration.
- The analysis lacks statistical correlation assessments to quantify the relationship between social vulnerability and recovery delays.
- Future research should incorporate statistical correlation analysis and utilize census-tract-level data to refine insights into the interplay between vulnerability and disaster recovery.

Recommendations

1. Prioritize repairing energy grids and transportation networks in the hardest-hit rural counties, ensuring equitable access to resources for areas with slower recovery rates.
2. Deploy emergency response teams to high-vulnerability areas, directly assisting minority and low-income households in recovery hotspots.
3. Set up temporary response hubs in areas with high SVI scores to coordinate aid, shelter, and immediate power restoration efforts.
4. Collaborate with local leaders and community representatives to address urgent needs and overcome immediate barriers to recovery, such as transportation or communication gaps.
5. Use NTL and SVI data to monitor daily recovery progress, identify critical delays, and adjust resource allocation as needed.

Conclusion

The study highlights the critical link between social vulnerability and delayed recovery after Hurricane Milton struck Florida in October 2024. Findings suggest that high-vulnerability counties experienced prolonged outages, likely influenced by socioeconomic and infrastructure challenges, while urban areas recovered faster, revealing potential systemic disparities. These patterns, though observed, require further investigation using more granular data and statistical analysis to confirm and fully understand their scope.

Acknowledgements

I sincerely thank Dr. Sisi Meng for her invaluable guidance, insightful advice on this research, and support in exploring this subject while utilizing geospatial analysis and methodologies.

References: CDC, "SVI Data & Documentation Download." 2024.
City of Cape Canaveral Emergency Operations Team, "Incident Report: Hurricane Milton - October 9, 2024 - October 11, 2024." 2024.
GuyCarpenter & Company, LLC. "Hurricane Milton Report #1 October 11, 2024." 2024.
Nasa.gov LAADS DAAC. "NASA Earth Data Search." 2024.
National Hurricane Center and Central Pacific Hurricane Center. "Tropical Cyclone Best Track." 2024.
Román, Miguel O., et al. "NASA's Black Marble Nighttime Lights Product Suite." 2018.
Simpson, Wilton. "Preliminary Estimates of Damage to Florida Agriculture from Hurricane Milton." 2024.
US Census Bureau. "TIGER/Line® Shapefiles." 2024.