Integrated Flood and Socio-Environmental Risk Analysis for Prioritizing ABC Activities

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FLORIDA INTERNATIONAL UNIVERSITY

ABC UTC
ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

COLLEGE OF ENGINEERING AND COMPUTING

Outlines

- Problem Statement
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  - ABC and Social Equity
  - ABC and Environmental Justice
  - Need to Multi-criteria Prioritization
- Objective
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- Methodology
  - Data Identification
  - Data Analysis
  - Data Integration: Multi Criteria Decision Analysis
  - Representative Scenarios
- Result
  - Vulnerability Risk Maps
  - Integrated Risk Map
- Conclusion
- Implementation

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Problem Statements- Accelerated Bridge Construction (ABC)

Benefits of ABC (FHWA):

Improvements in:

- Safety
- Quality
- Durability
- Social costs
- Environmental impacts

U.S. Department of Transportation
Federal Highway Administration

fhwa.dot.gov/bridge/abc/

Precast/Prestressed Concrete Institute (pci.org)

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Social Equity and Environmental Justice in the Context of Urban Infrastructure

- **Social equity:**
  - Providing equal resources and opportunities by infrastructure systems for all urban communities.
  - Incorporating social equity in infrastructure planning results in the elimination or reduction of disparate access to amenities and services among different community groups, including ethnic minorities, low-income groups, the elderly, etc.
- **Environmental justice:**
  - Fair treatment and involvement of all people regarding environmental policies
  - Requires the same degree of protection from environmental and health hazards for everyone

To address the existing inequalities built into urban communities and create better communities for all, social equity and environmental justice should be incorporated into civil infrastructure planning, including the decision making about suitability of ABC projects.

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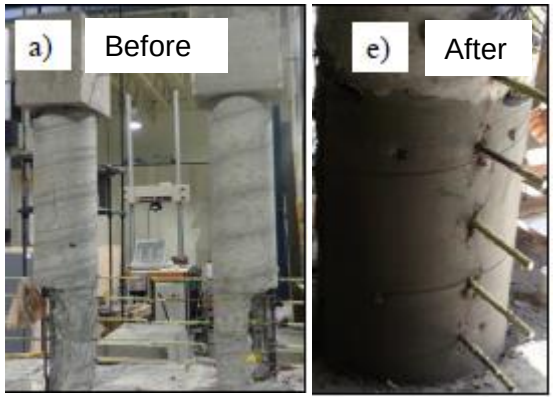
Problem Statements- Flood

Scour due to floods

- The most common natural disaster in the world (43% of all disasters between 1995-2015) (UN, 2015)
- 53% of bridge failures in the US between 1989-2000 because of scour due to floods (Wardhana and Hadipriono, 2003)
- Biggest cause of bridge failure in the US
- Major cause of increased construction and maintenance costs



Accelerated repair using UHPC (Azizinamini and Farzad, 2018)

- Accelerated upgrade solutions (retrofit prior to flood event)
- Accelerated repair solutions (retrofit after flood event)

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ABC in Flood-Prone Areas: Reducing Risk

- Flood can disrupt traffic flows by damaging bridges and roads.
- Bridges need to be operational as quickly as possible after a flood event.
- In some cases, repairs require additional resources and time to divert water flow.
- Flood can also damage construction equipment during repair, further delaying the project and causing additional costs.
- ABC can reduce the risk of damages to the bridge and construction equipment as well as injury to workers during repair.

Park Road Bridge in Iowa City, Iowa, 2017

Cedar River Bridge, Iowa, 2008

New Union Pacific Railroad Bridge over San Jacinto, Tx, 2019

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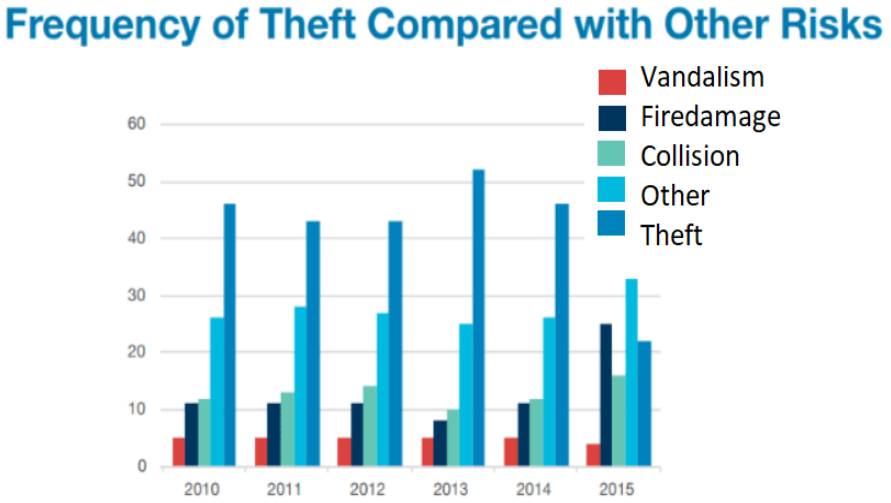
Improving Social Equity through ABC in Urban Communities

- Access to vital services: Minimizing the duration of road closures will lead to better accessibility to jobs, education, health services, and amenities (particularly important for vulnerable communities).
- Public acceptance: Traditional bridge construction methods can cause disruptions to traffic flow, businesses, and residents, which can lead to increased frustration and tension in the community.
- High crime rates areas: Chance of vandalism and theft of construction equipment and materials, which can further delay the construction process and increase insurance costs. Legal investigations can further delay the project.
- ABC:
  - Improved access to vital services for vulnerable communities, increased public acceptance,
  - Reduced project time results in reduced chance of vandalism/theft
  - In case of pauses due to legal investigations (for example, Oakland, CA , 2018), construction is less impacted because of offsite activities and prefabricated elements.



Top 10 States for Construction Equipment Theft 2016
1. California
2. Texas
3. Florida
4. Georgia
5. Arizona
6. Colorado
7. Illinois
8. Maryland
9. North Carolina
10. Pennsylvania

Top five states accounted for 31% of the total number of thefts in 2016

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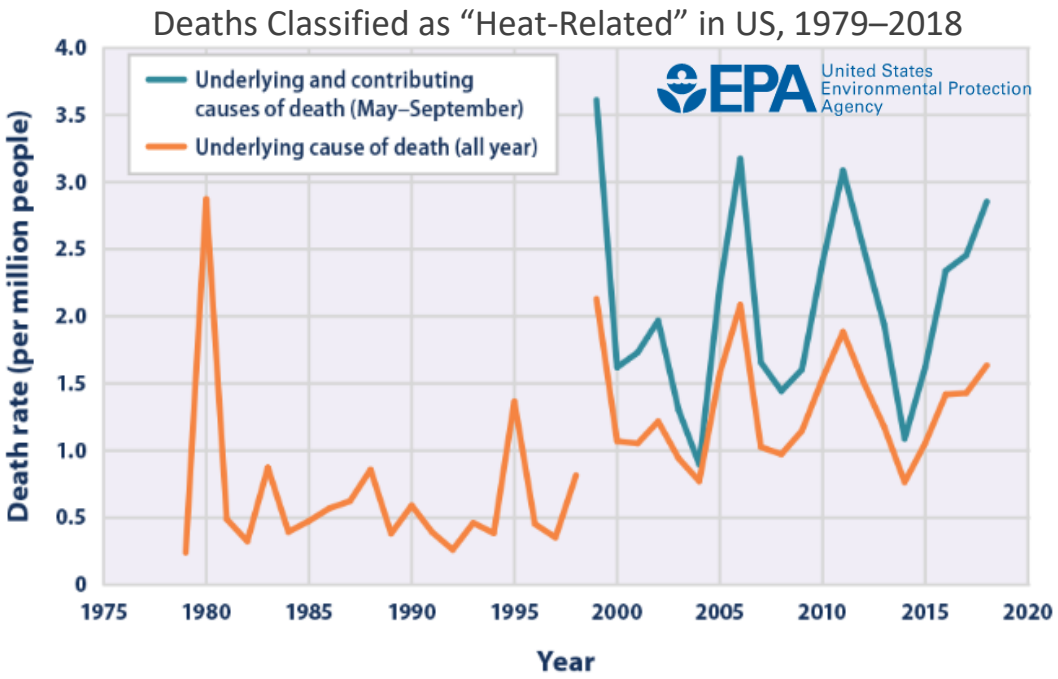
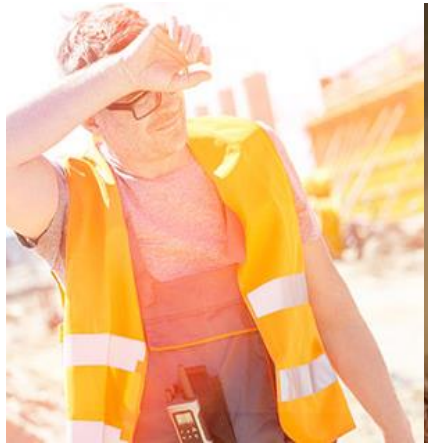
Improving Environmental Justice through ABC

- Effects of air quality on human health:
  - Threat to workers and urban communities adjacent to the project
- Effects of extreme heat on human health:
  - Threat to workers in the work zone
- Worker's health issues can further impact the construction speed and cost.
- ABC:
  - Reduced workforce exposure to environmental threats





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Problem Statement: Why Multi-Criteria Decision Support Tool?

- FHWA: ¼ of the bridges in the US require rehabilitation, repair, or total replacement.
- Limited budget
- Need to incorporate social equity in planning

- Need to a multi-criteria decision support tool for the prioritization of accelerated upgrade/repair projects
  - Structural and traffic condition of bridges
  - Flood
  - Social equity and environmental justice

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Objective

Developing a Risk-based, Spatial, Multi-criterion, Multi-stakeholder Decision Analysis Framework for the Prioritization of Accelerated Upgrade/Repair Projects based on:

- Structural and traffic condition of bridges
- Flood and socio-environmental vulnerability of bridge location

The decsision support tool should be:

✓Simple

✓Systematic (adjustable)

✓GIS based

✓Readily available data

✓Capable of group decision making

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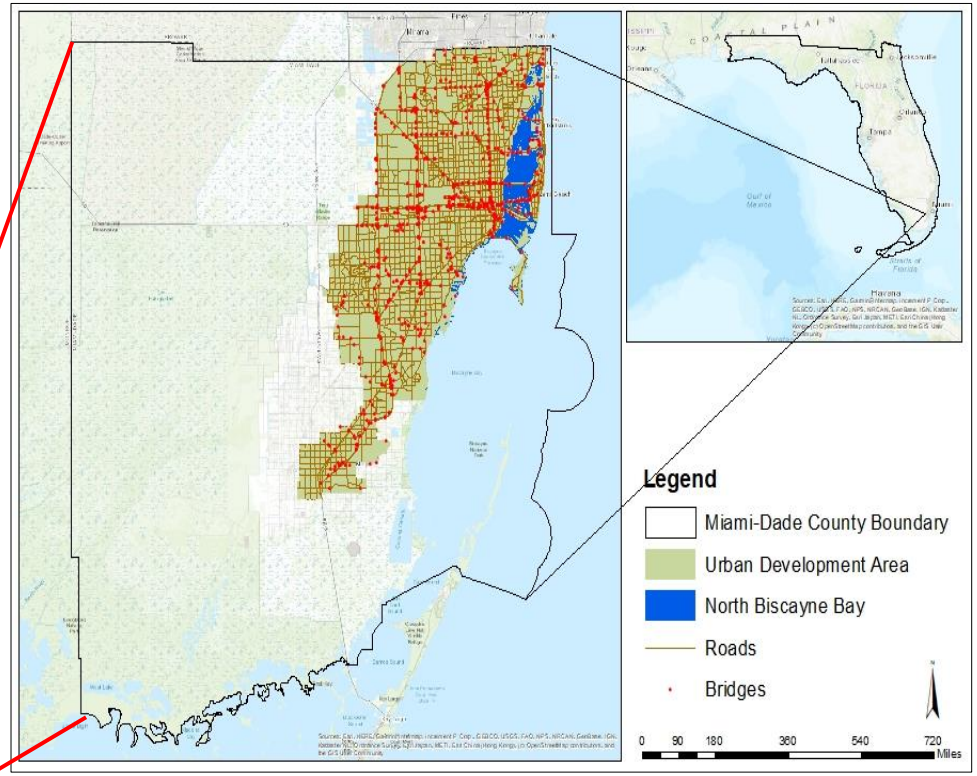
Study Area

Florida



Urban Areas of Miami-Dade County, FL

Miami-Dade County

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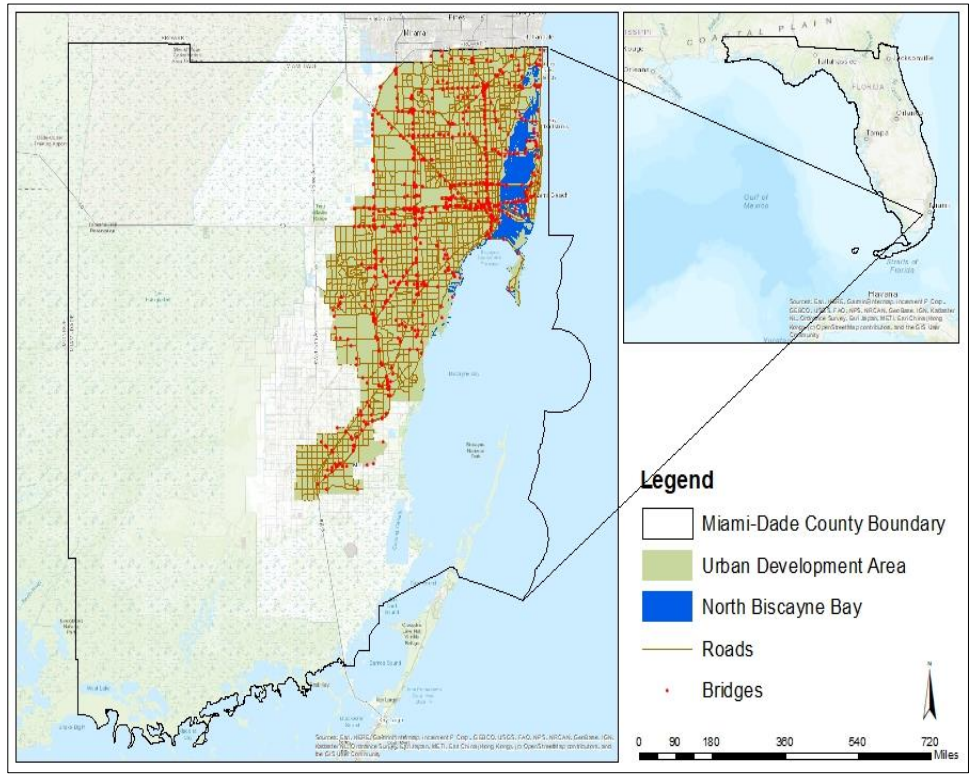
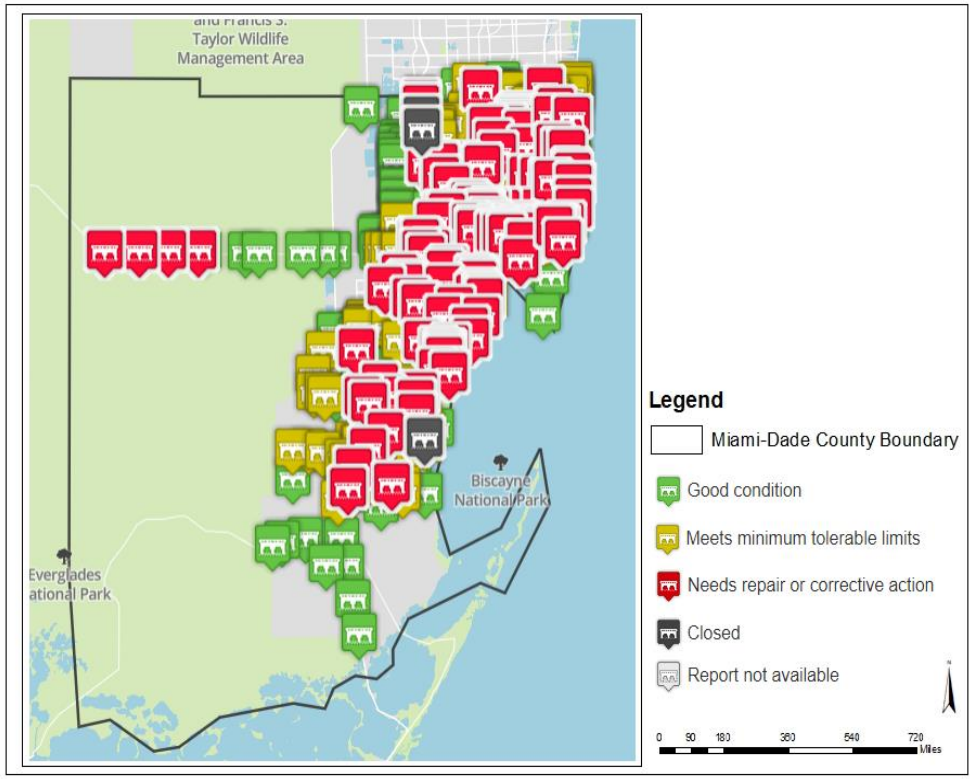
Study Area



Miami-Dade County, Florida
Total No. of bridges in urban development area= 986



Bridge inspections summary,
Miami-Dade County, FL
National Bridge Inventory, U.S. Federal Highway Administration, 2018 Inspections Summary

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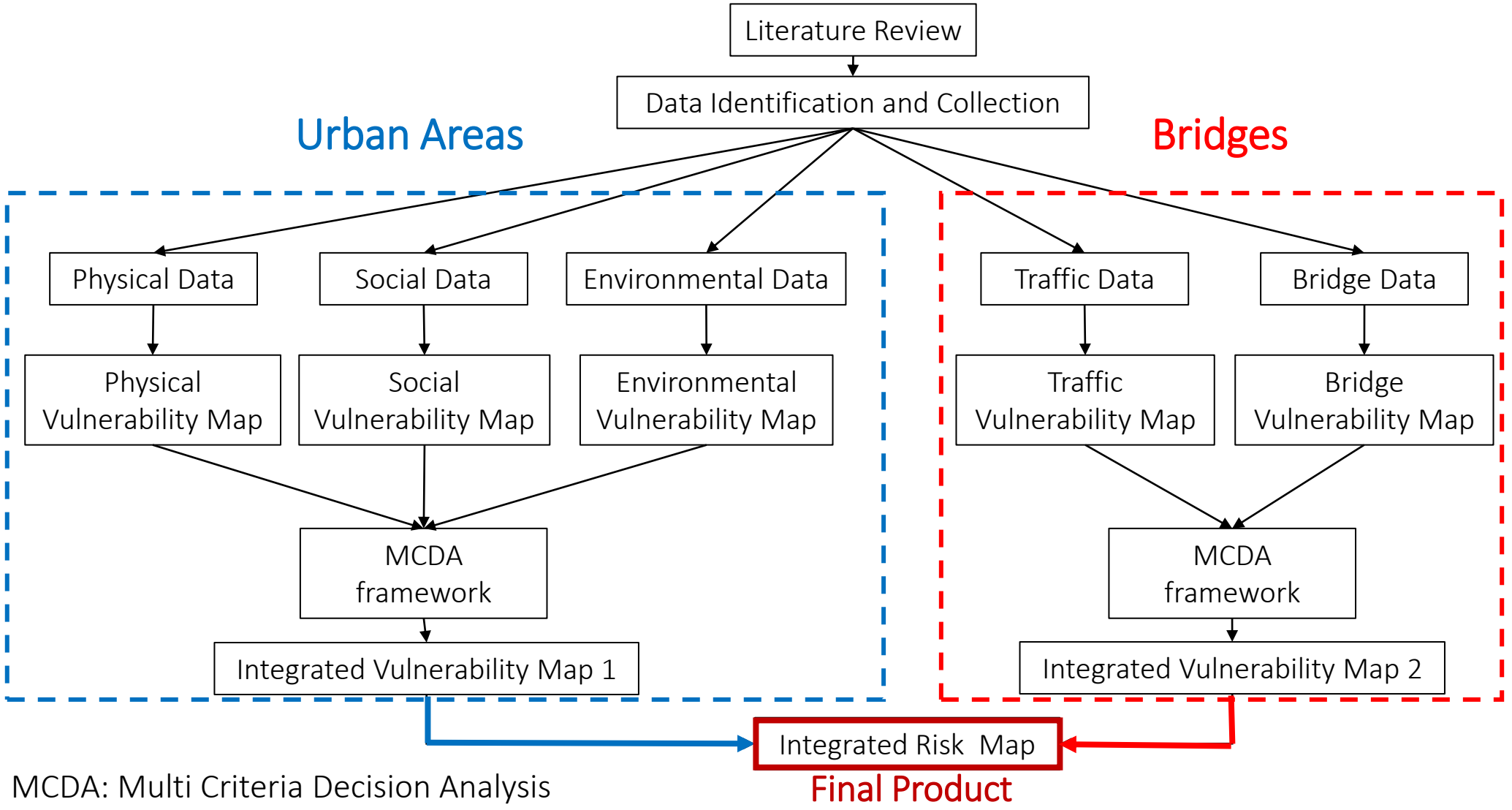
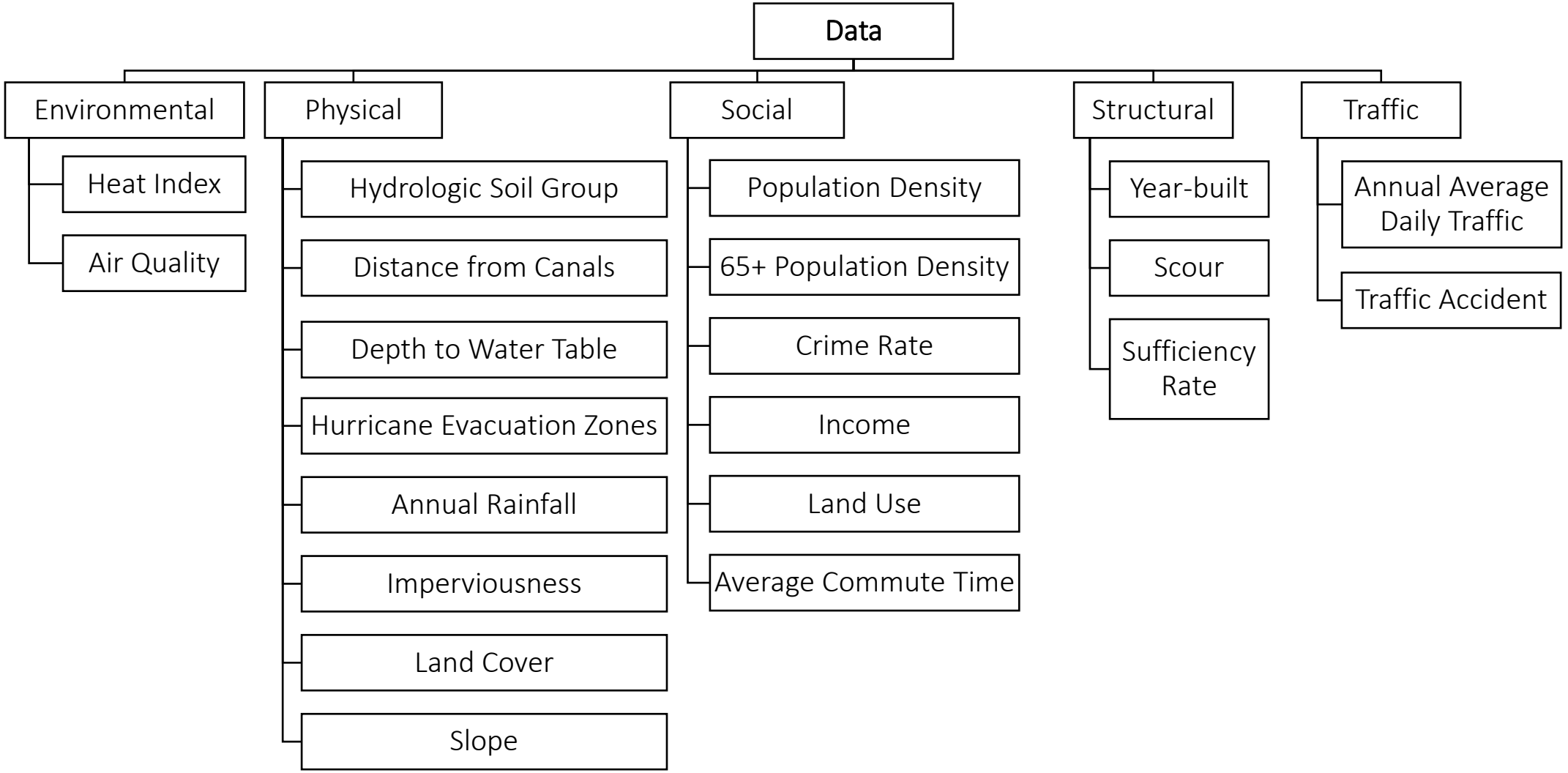
Methodology



MCDA: Multi Criteria Decision Analysis

Data Identification



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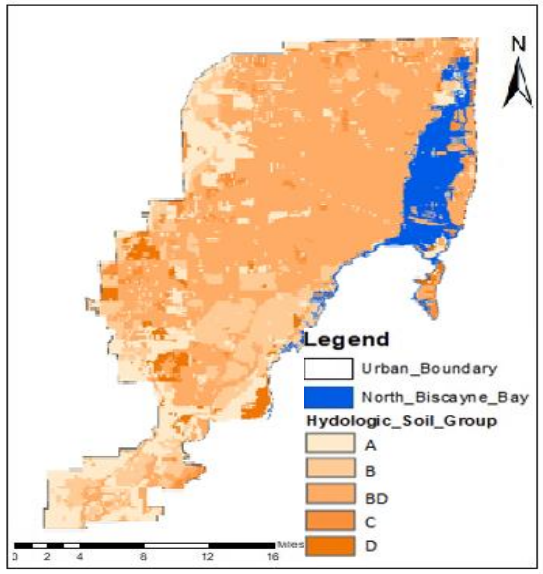
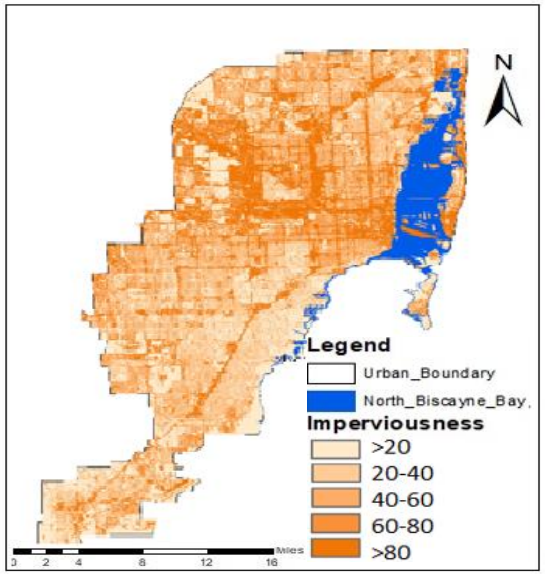
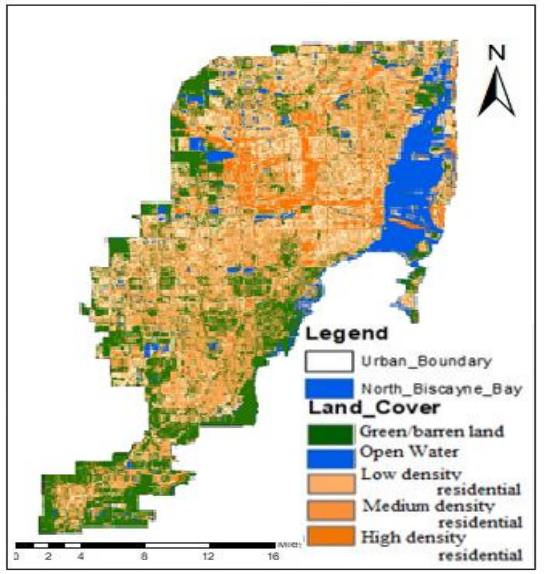
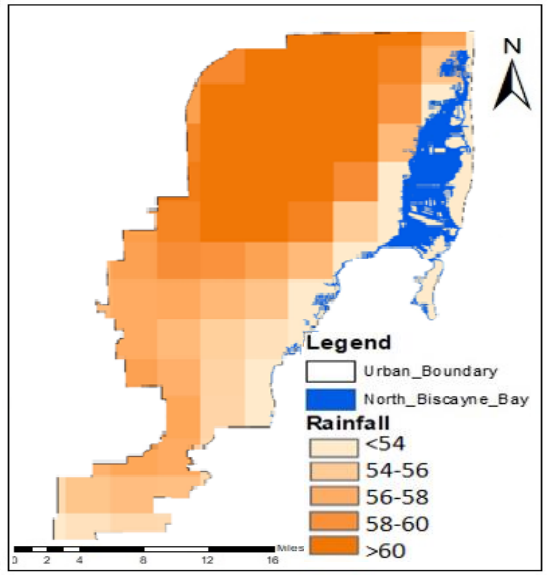
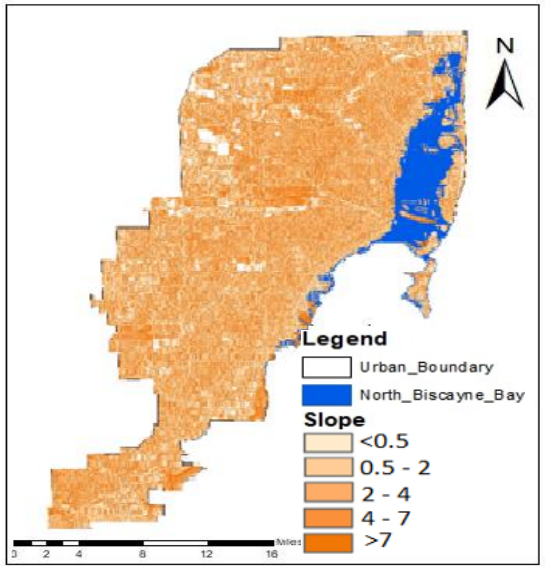
Physical (Flood-related) Data

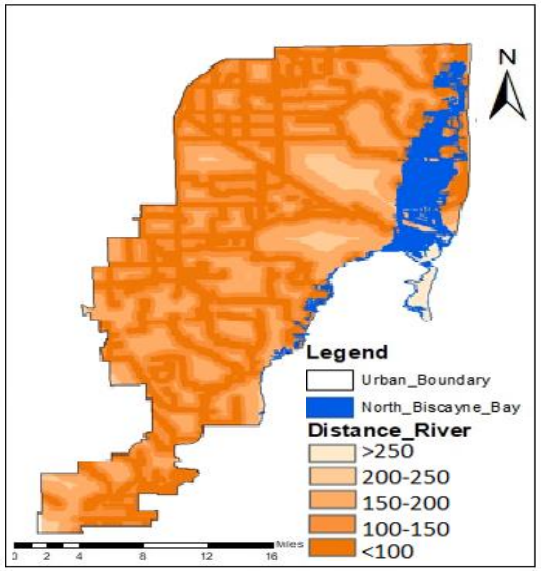


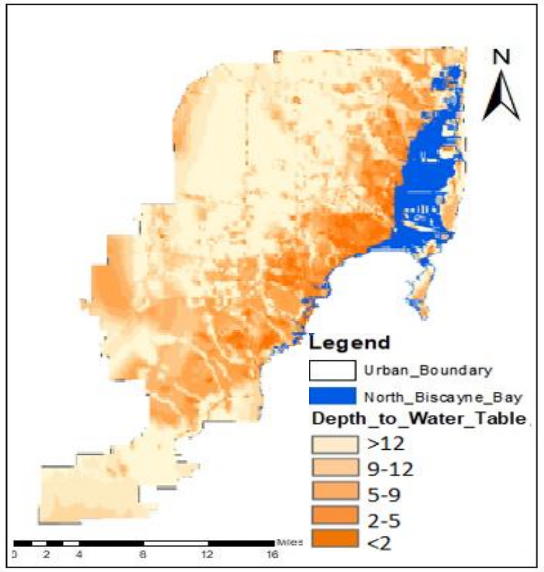


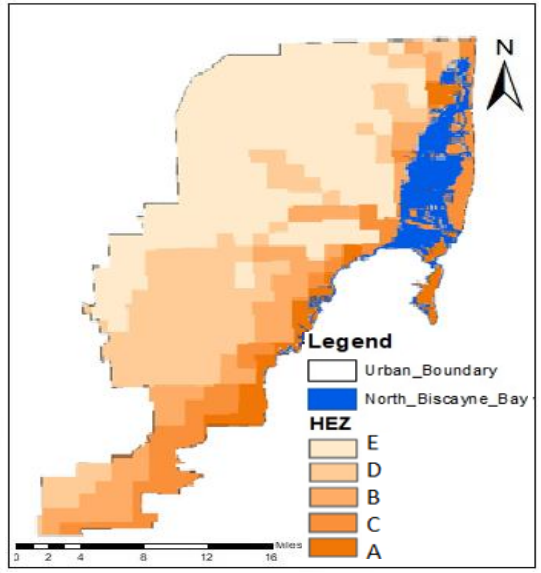












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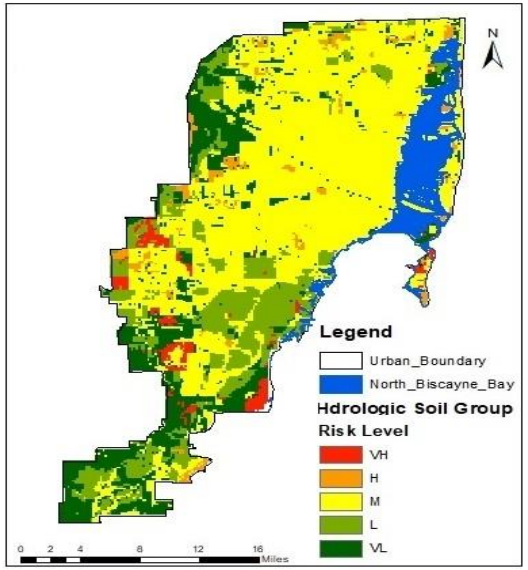
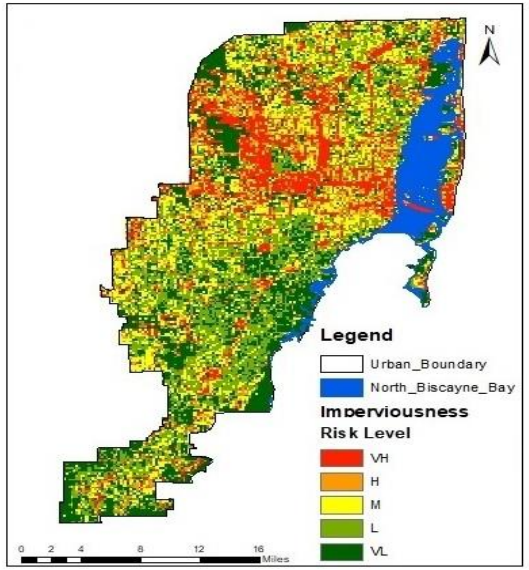
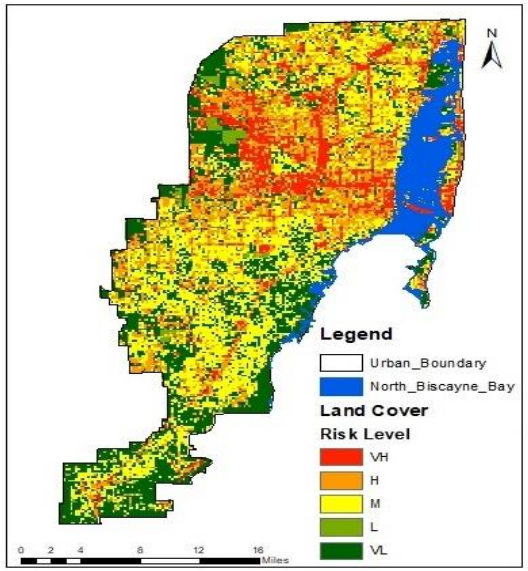
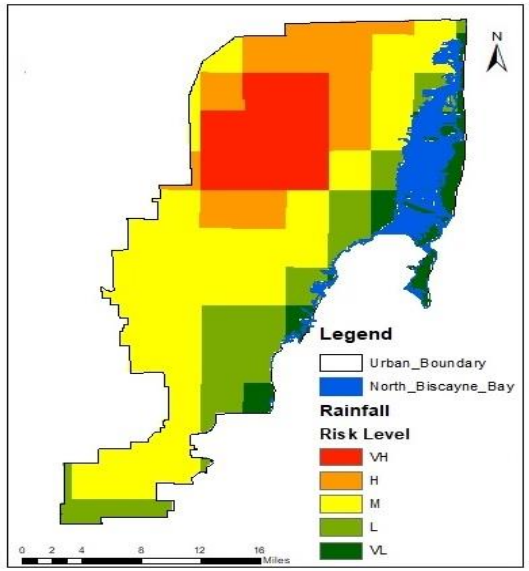
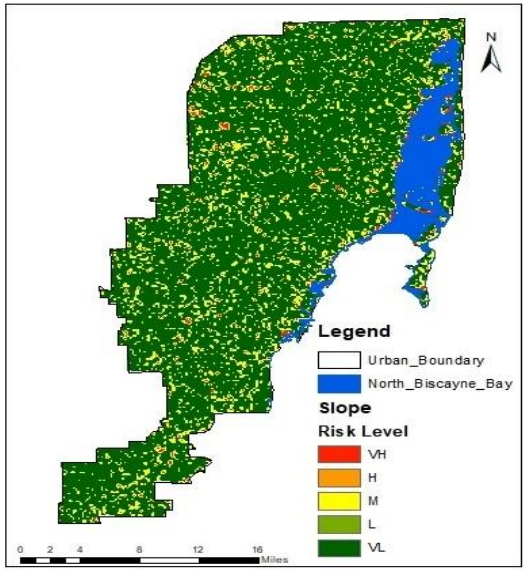
Flood Data Classification

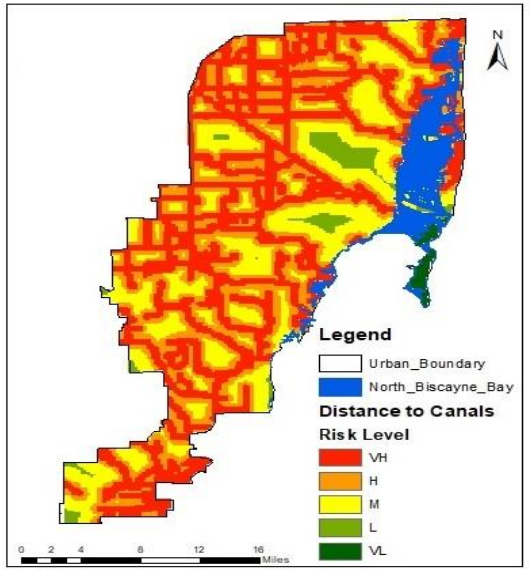


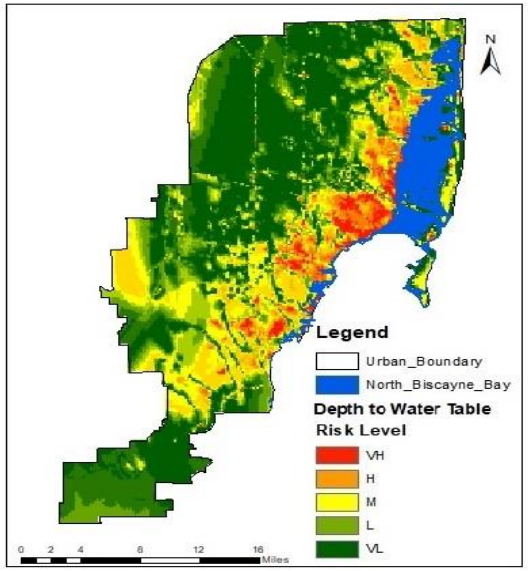


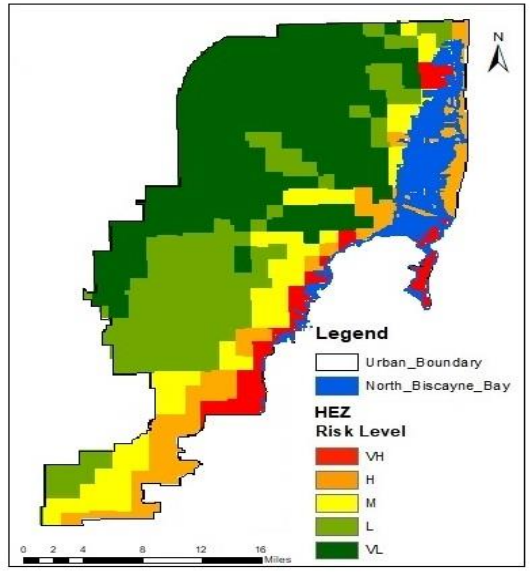












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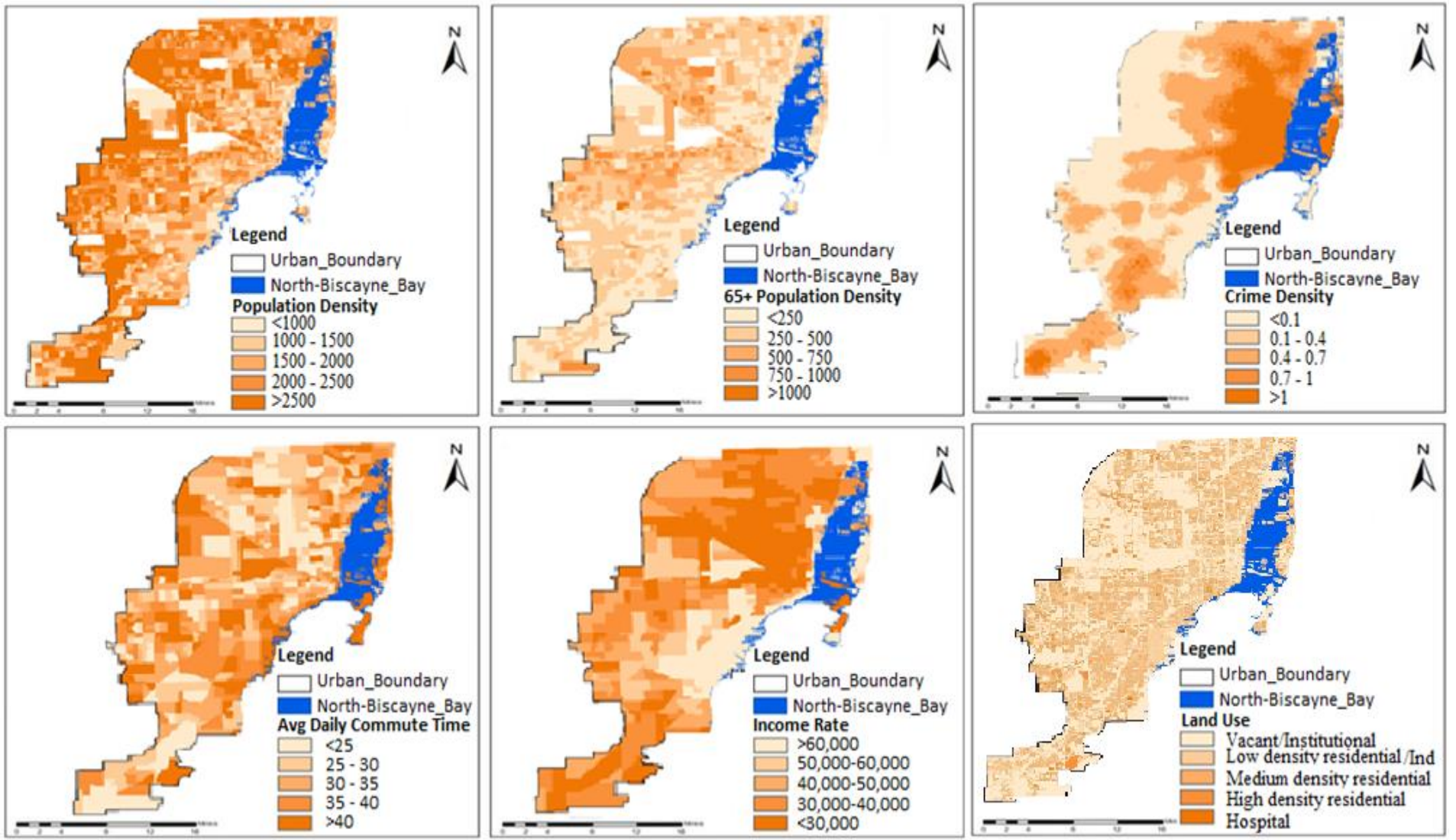
Social Data



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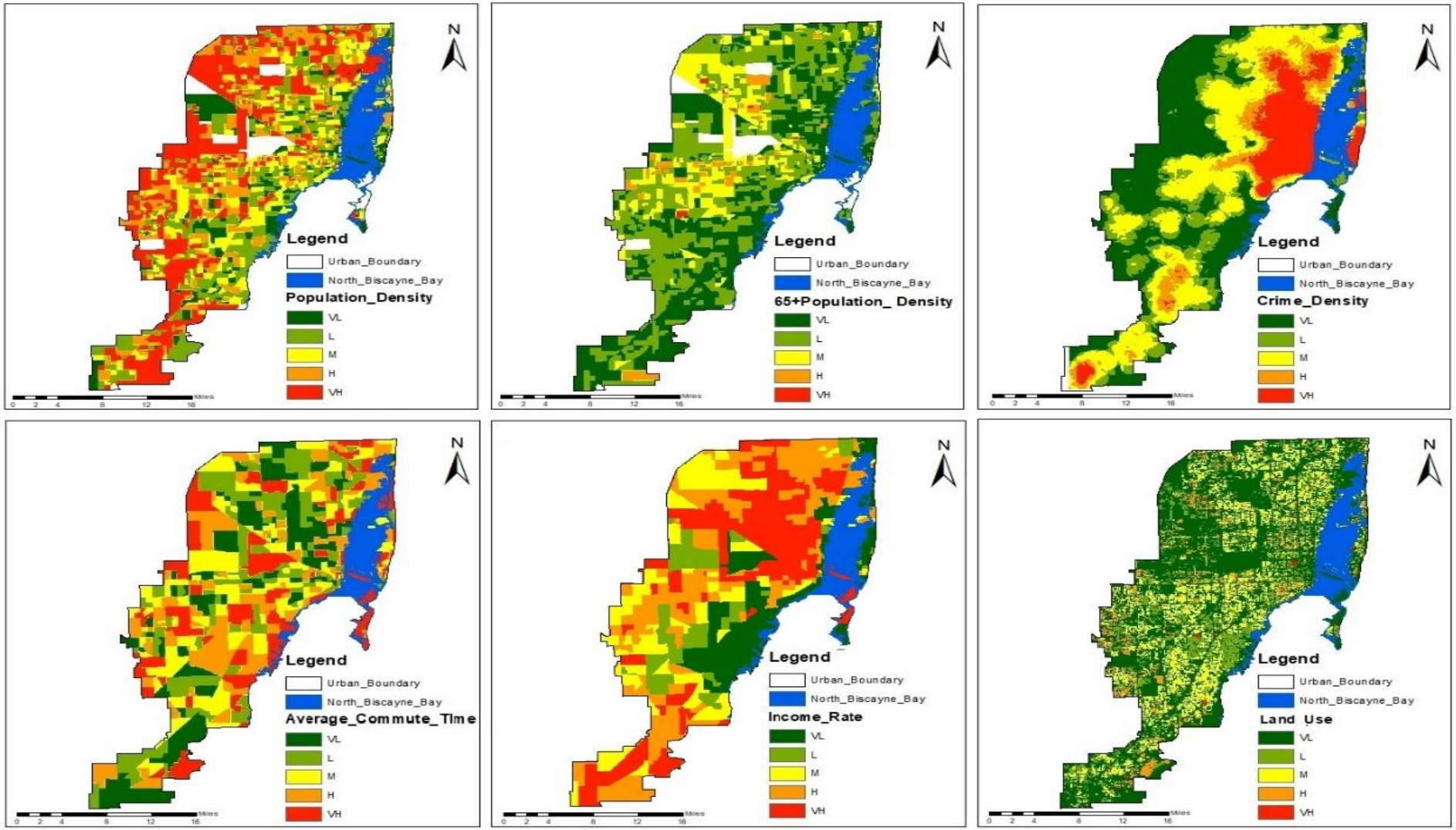
Social Data Classification



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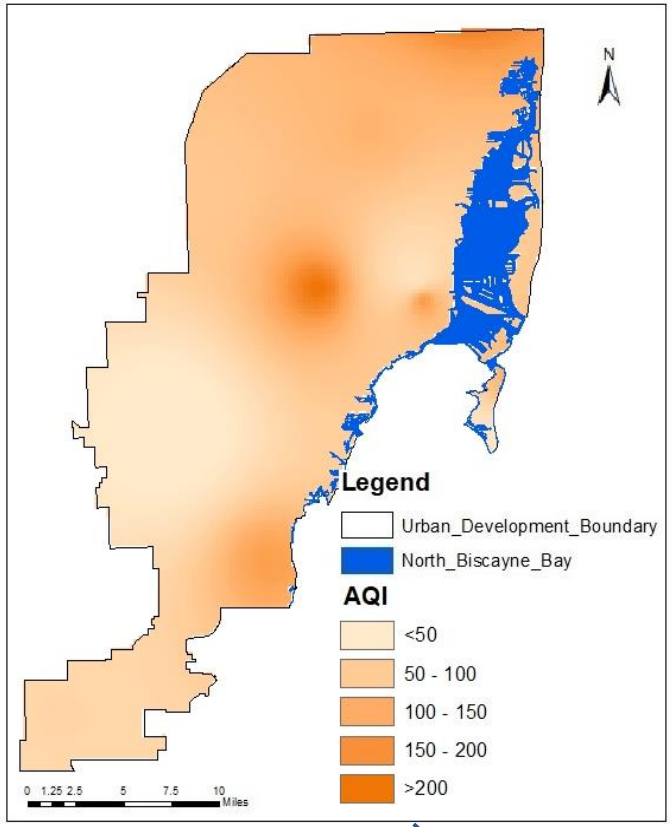
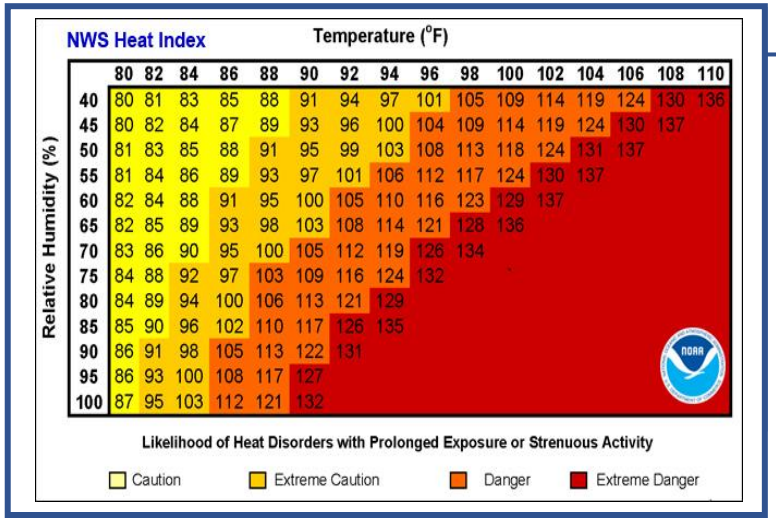
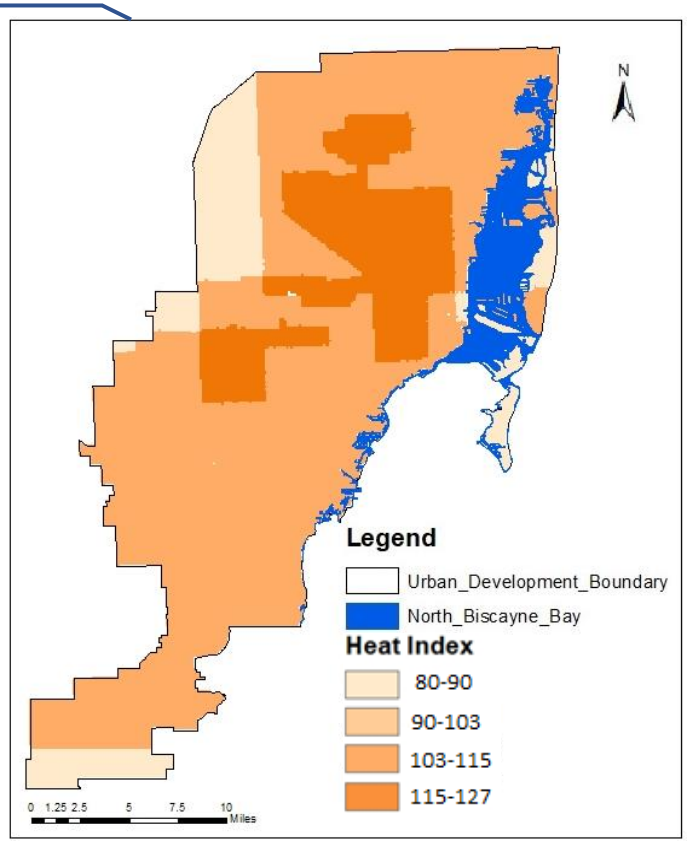
Environmental Data





AIR QUALITY INDEX - PARTICULATE MATTER	
301+	HAZARDOUS
201-300	VERY UNHEALTHY
151-200	UNHEALTHY
101-150	UNHEALTHY FOR SENSITIVE GROUPS
51-100	MODERATE
0-50	GOOD

EPA United States Environmental Protection Agency



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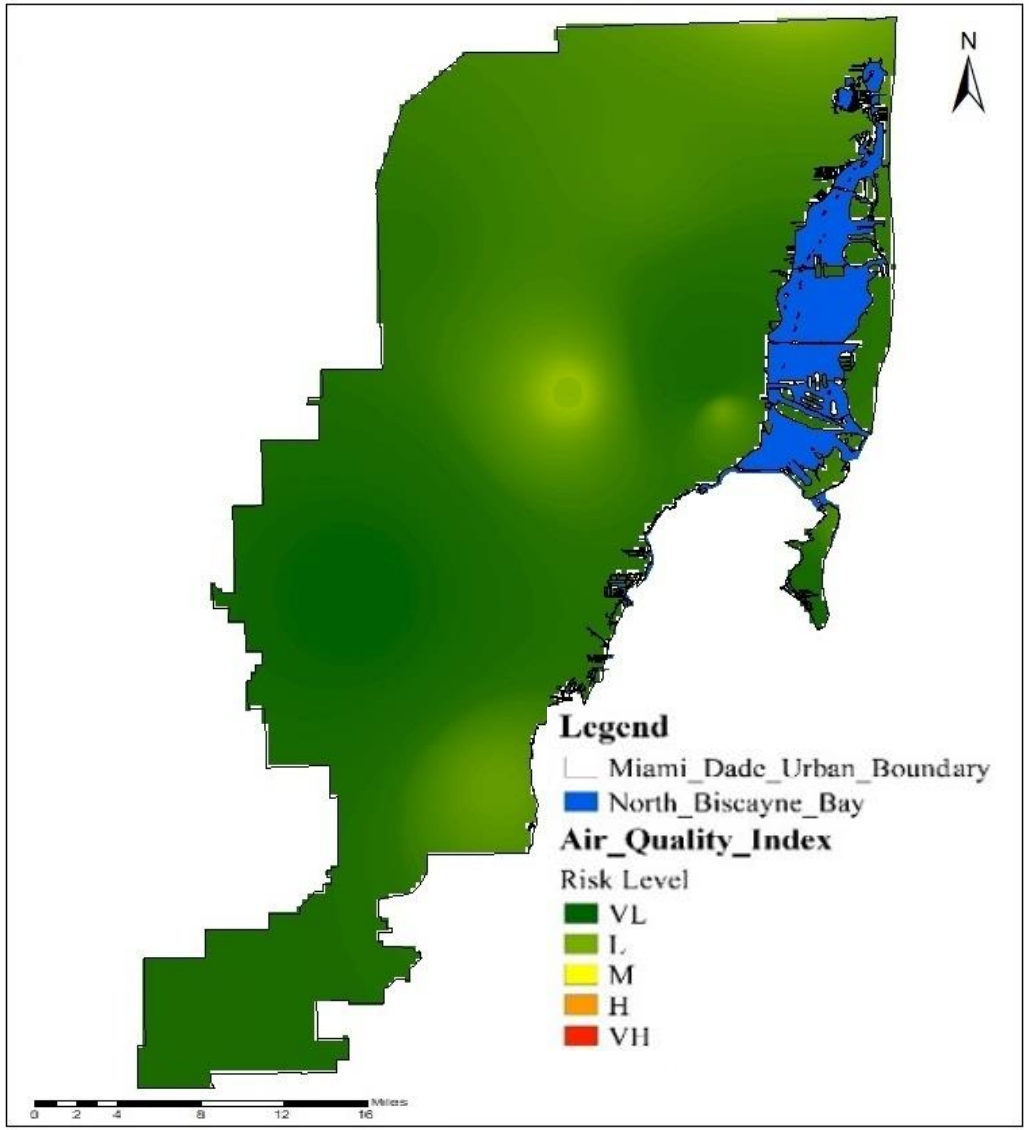

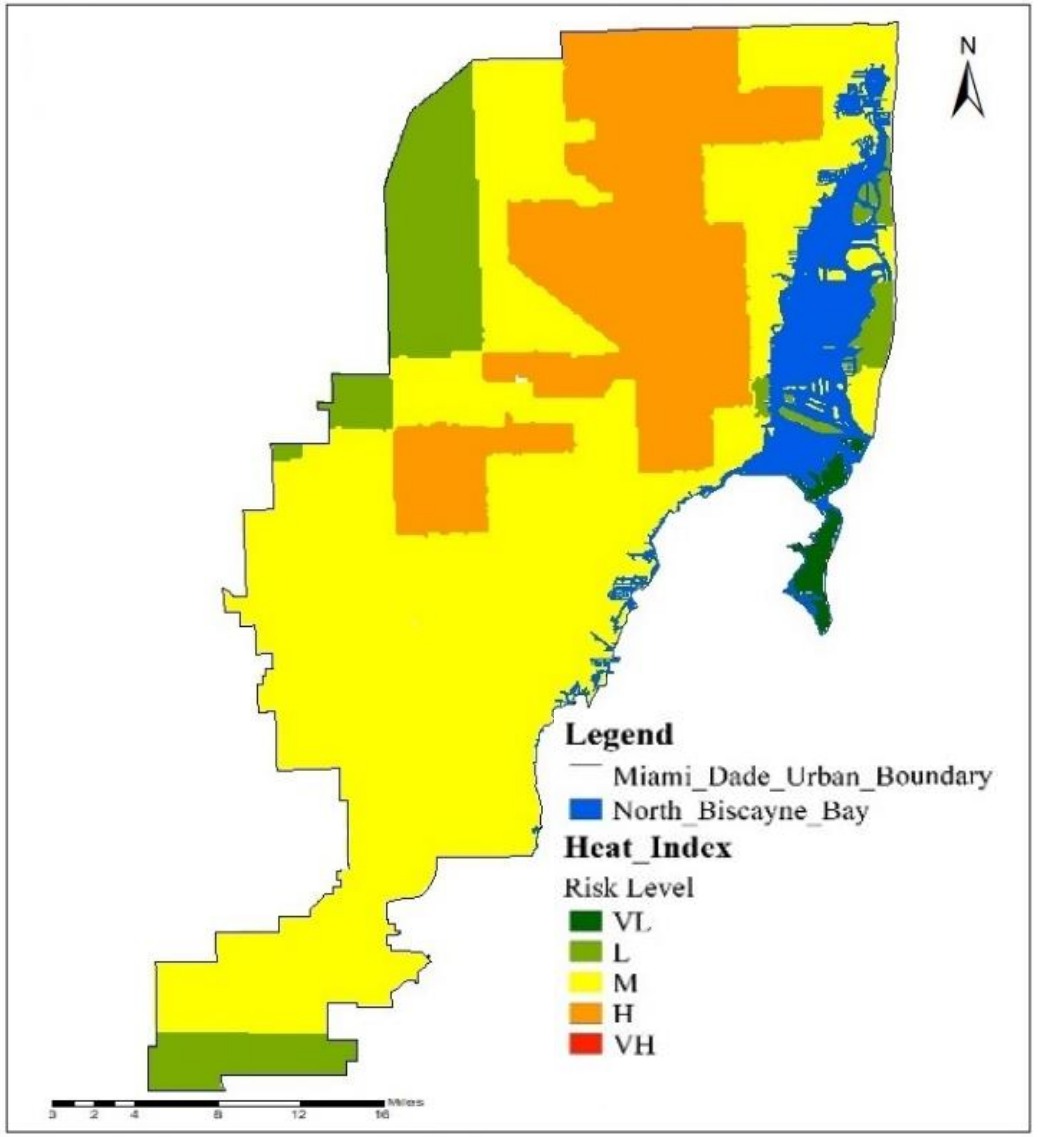

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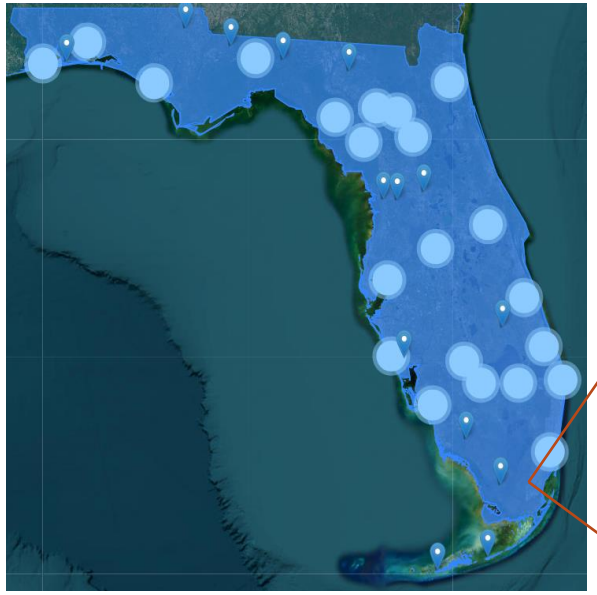
Flood Vulnerability Map Validation



IVM Institute for Environmental Studies

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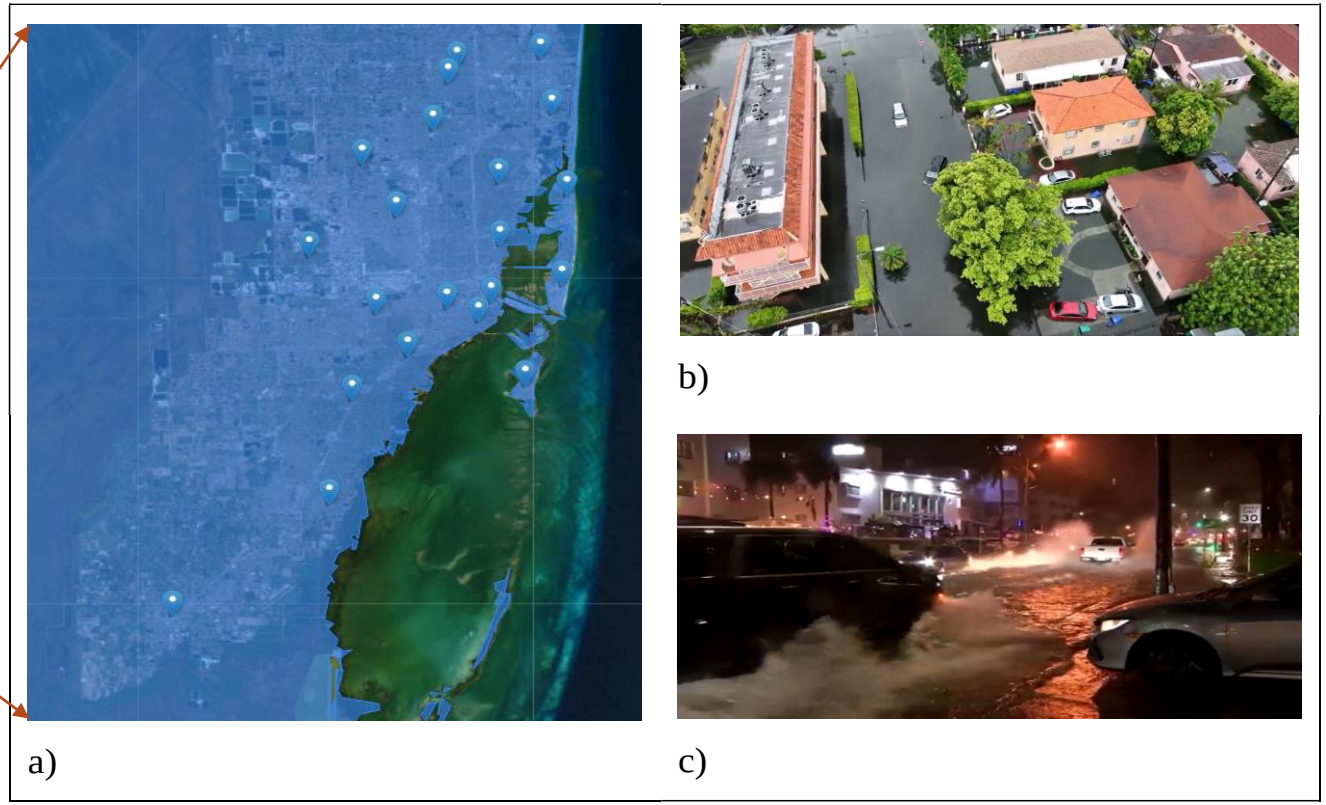
Global Flood Detection and Monitoring using Social Media

- Comparison with reported flood locations from social media (Global Flood Detection and Monitoring)



Validation flood risk map over the urban development area, Miami-Dade County, FL. a) flooded mapping, b) flooding in Little Havana, downtown Miami, and c) Miami Beach as cars buried deep into the floodwaters, Jun 4, 2022.

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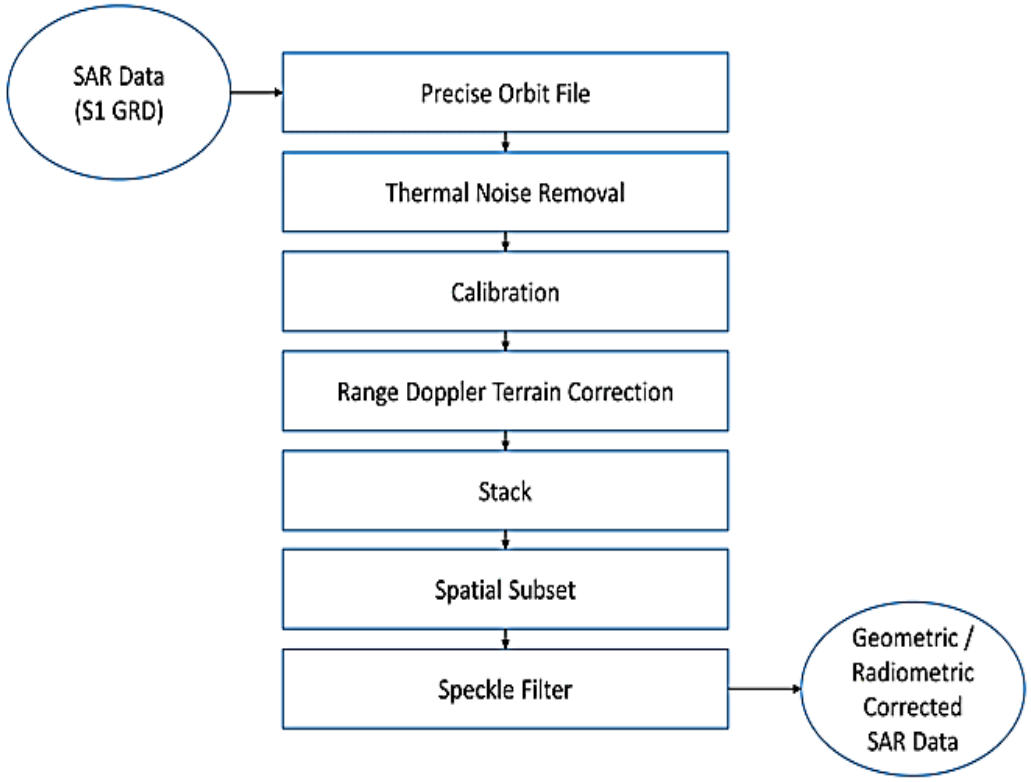
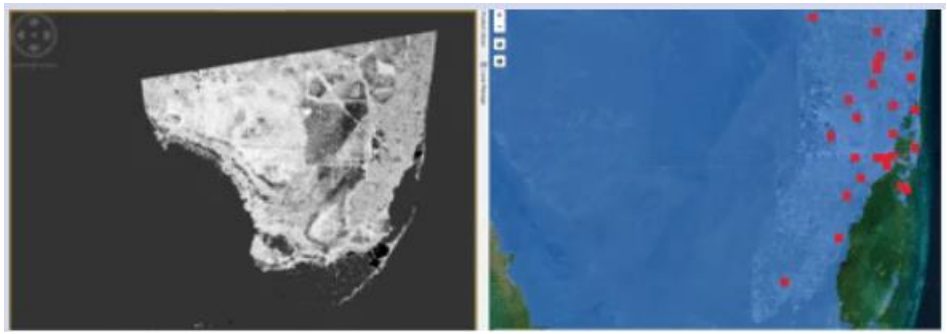
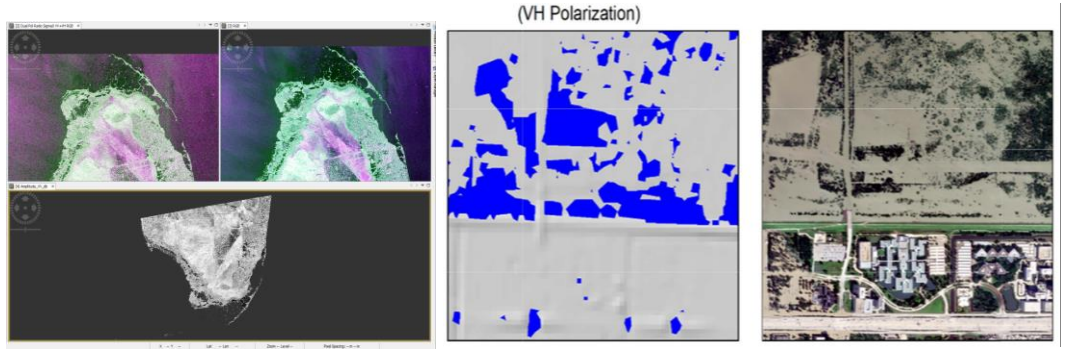
Flood Vulnerability Map Validation

- Flood detection using satellite image processing (Sentinel-1 GRD)
- Comparison with reported flood locations from social media (Global Flood Detection and Monitoring)





SNAP Satellite data pre-processing



Example of flood mapping (blue shows flooded areas) in in the study area: Flooding in Miami Beach, June 4, 2022, 10:14 AM UTC

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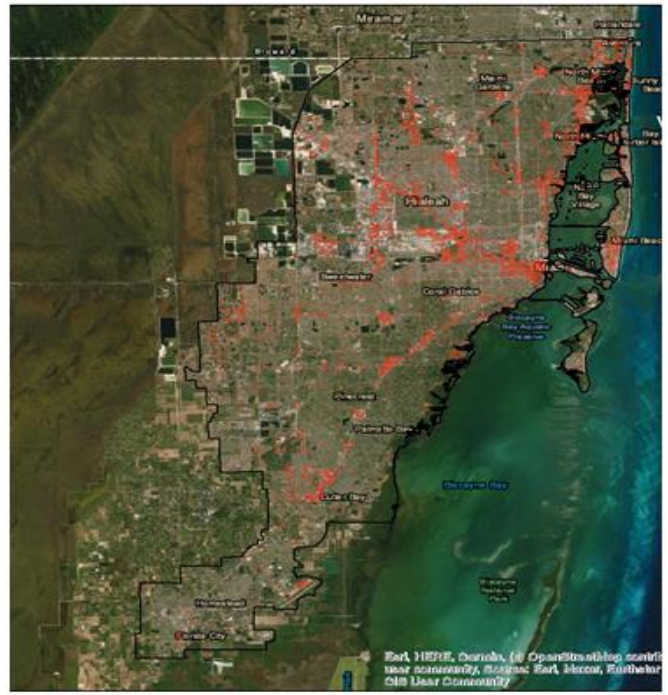
Flood Vulnerability Map Validation

Miami Beach

East Little Havana

Sweetwater

a)



b)

Legend

Miami_Dade_Urban_Boundary

North_Biscayne_Bay

Flood_Reports

Risk Level

VL

L

M

H

VH

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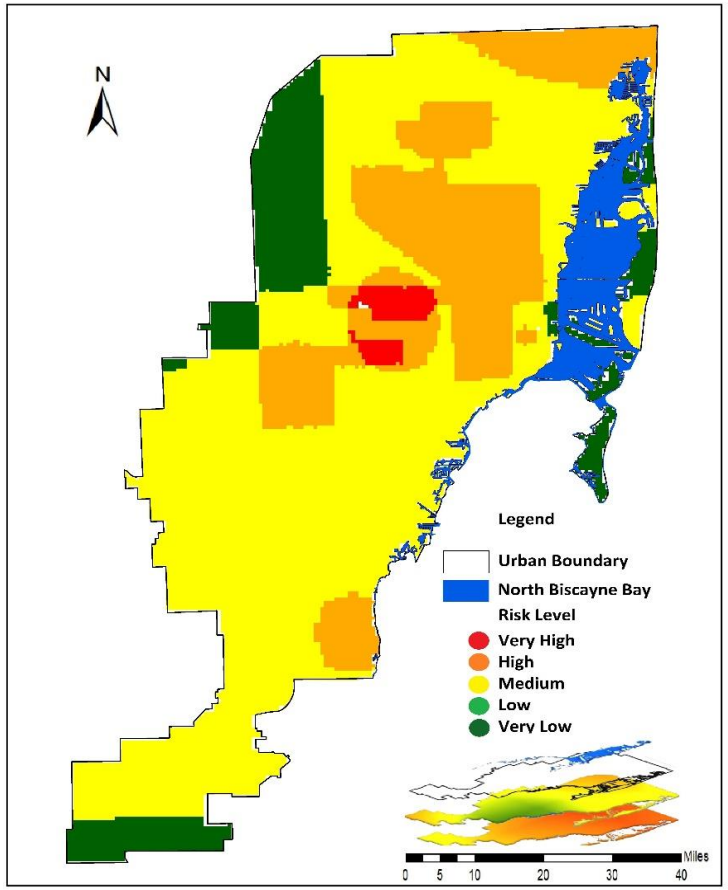
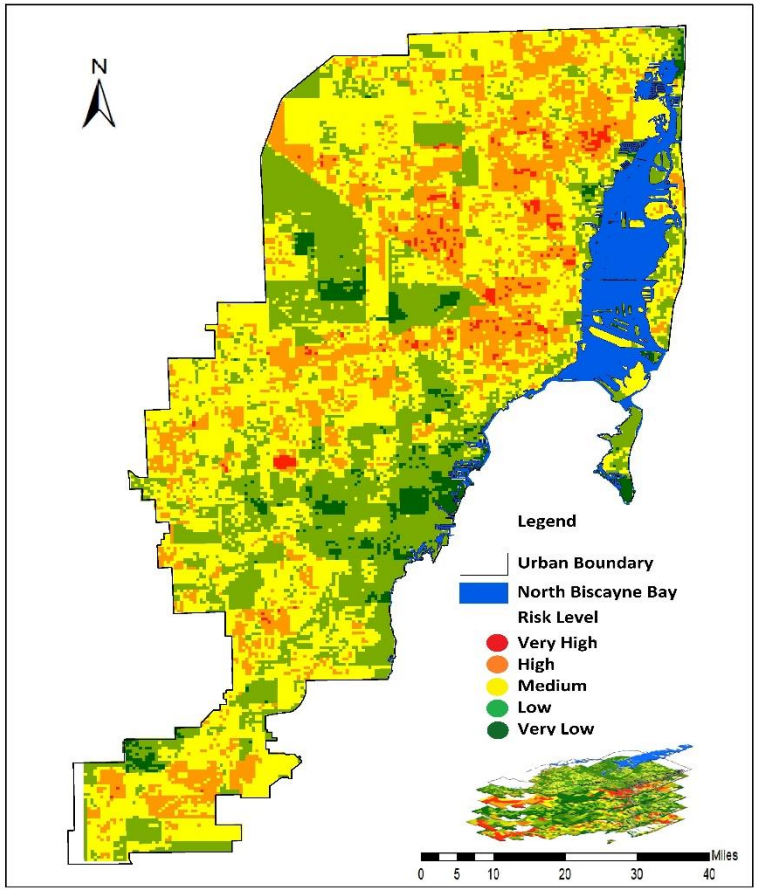
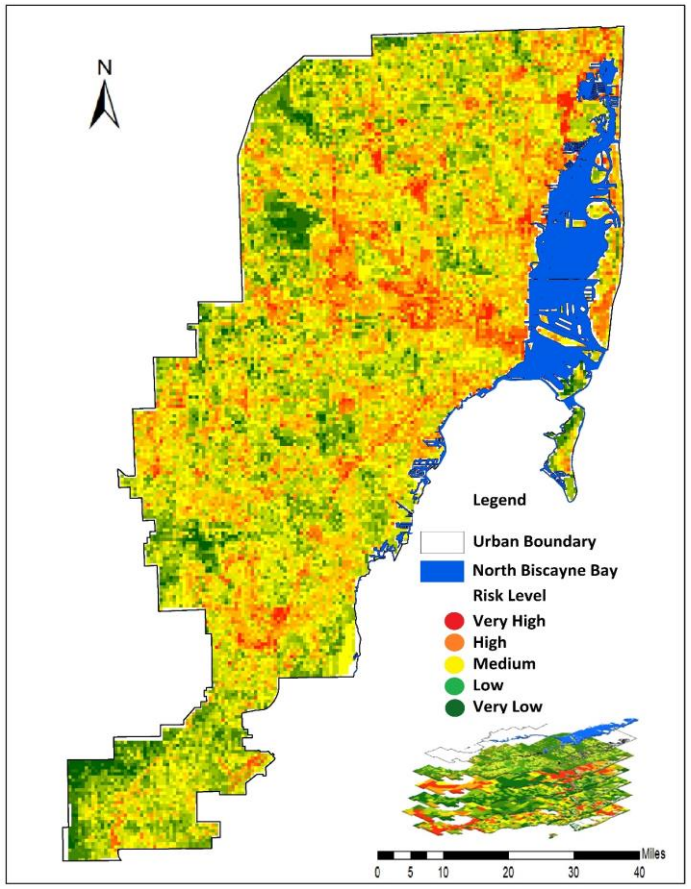
Integrated Maps



Environmental Vulnerability

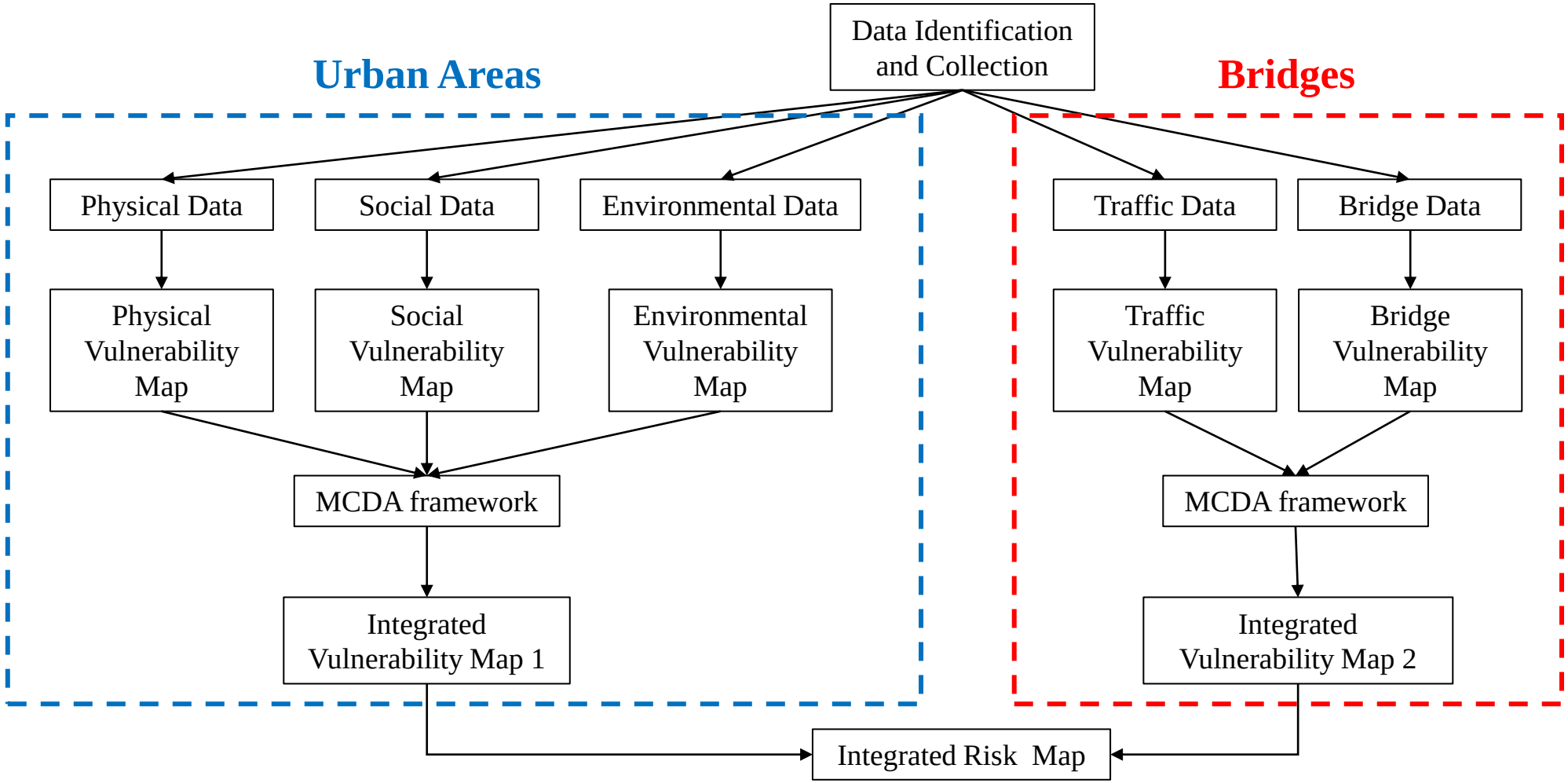


Social Vulnerability

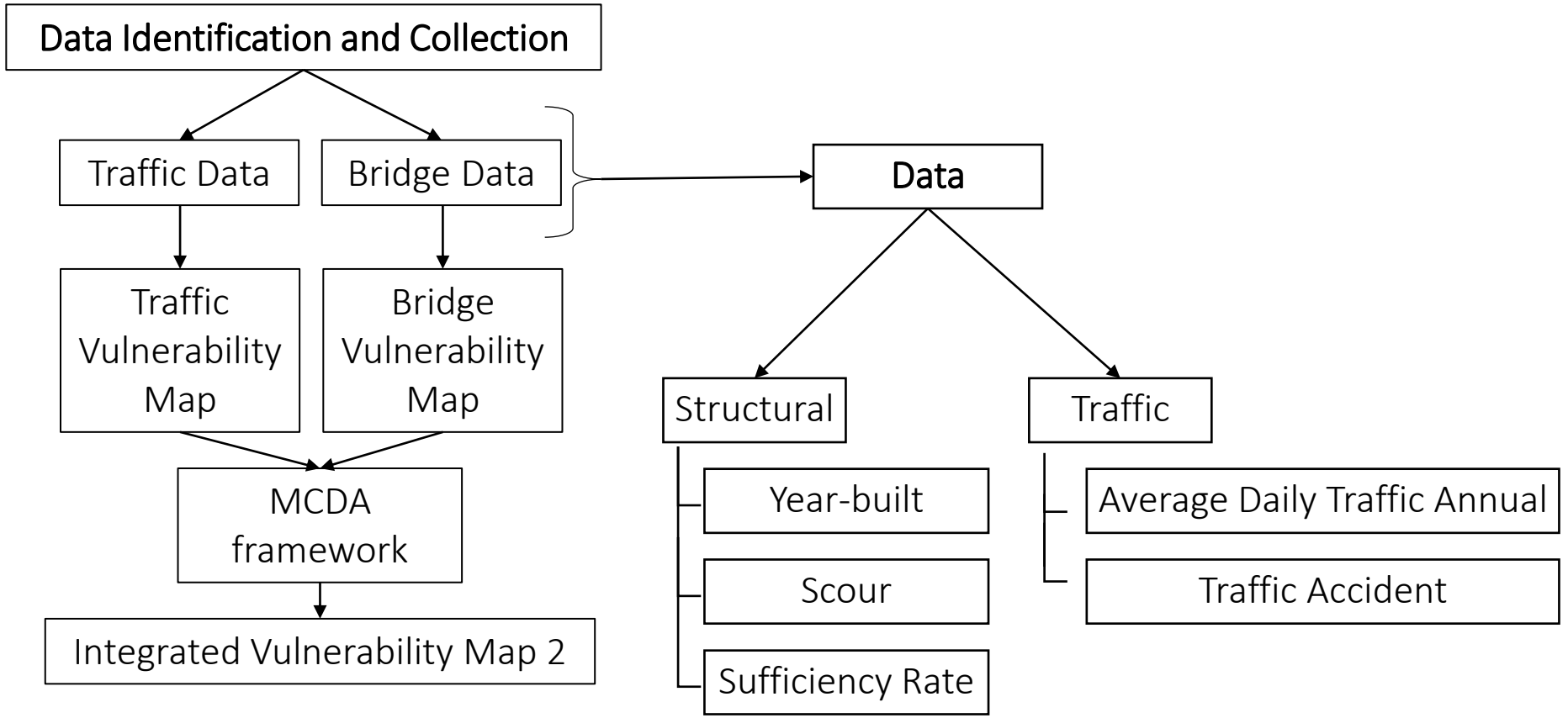


Flood Risk

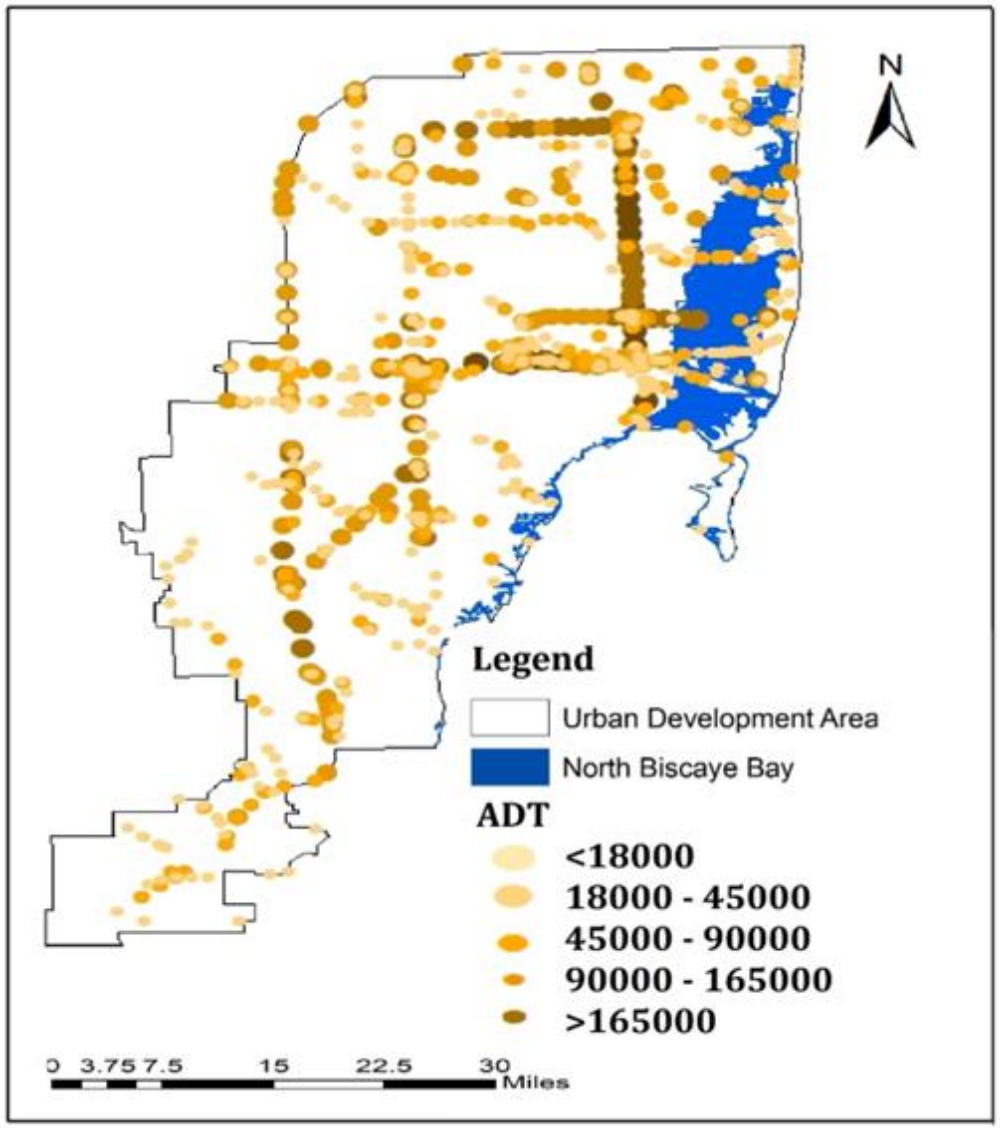
Methodology: Research Framework

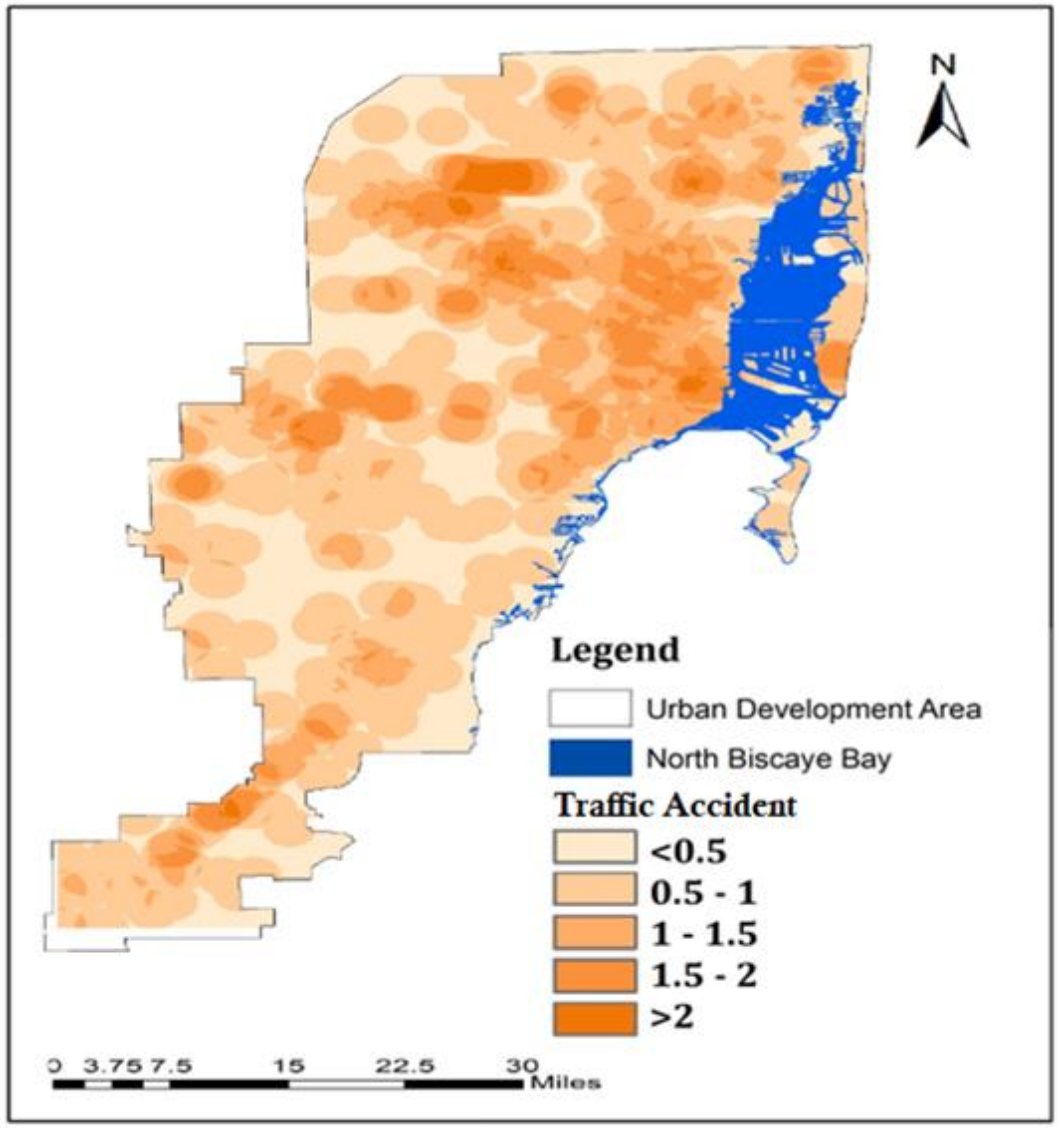


Traffic and Bridge Factors Identification

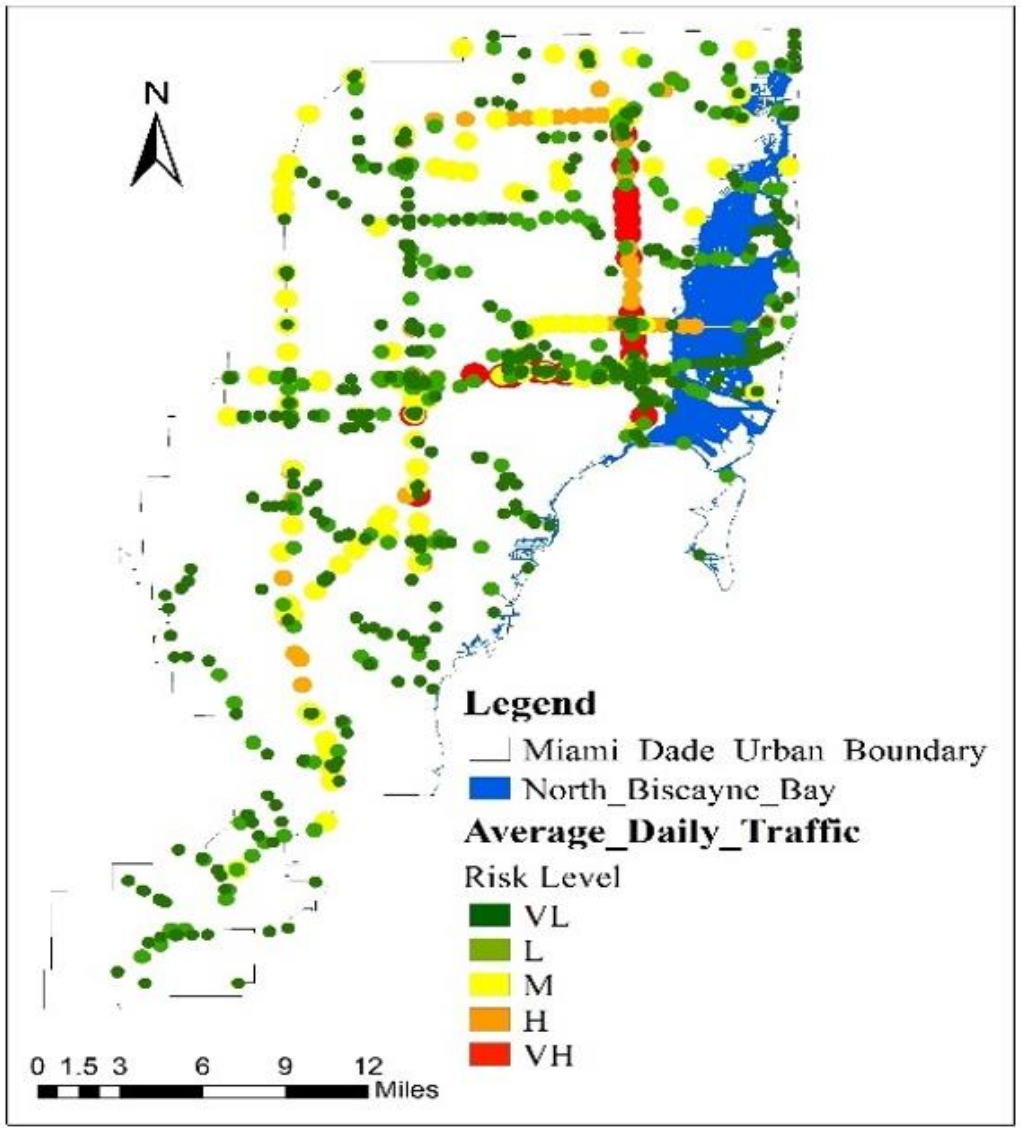


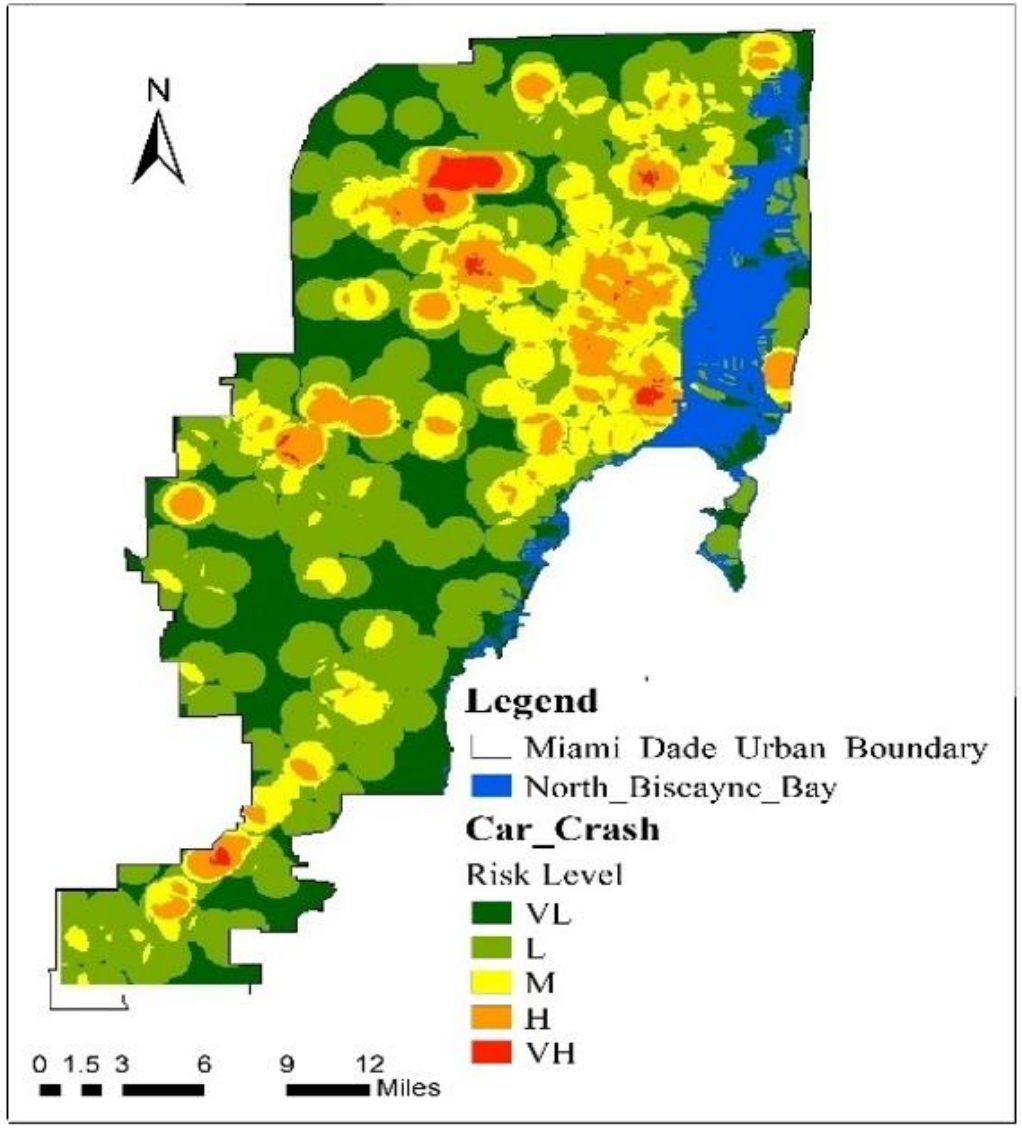
Traffic Data





Traffic Data Classification





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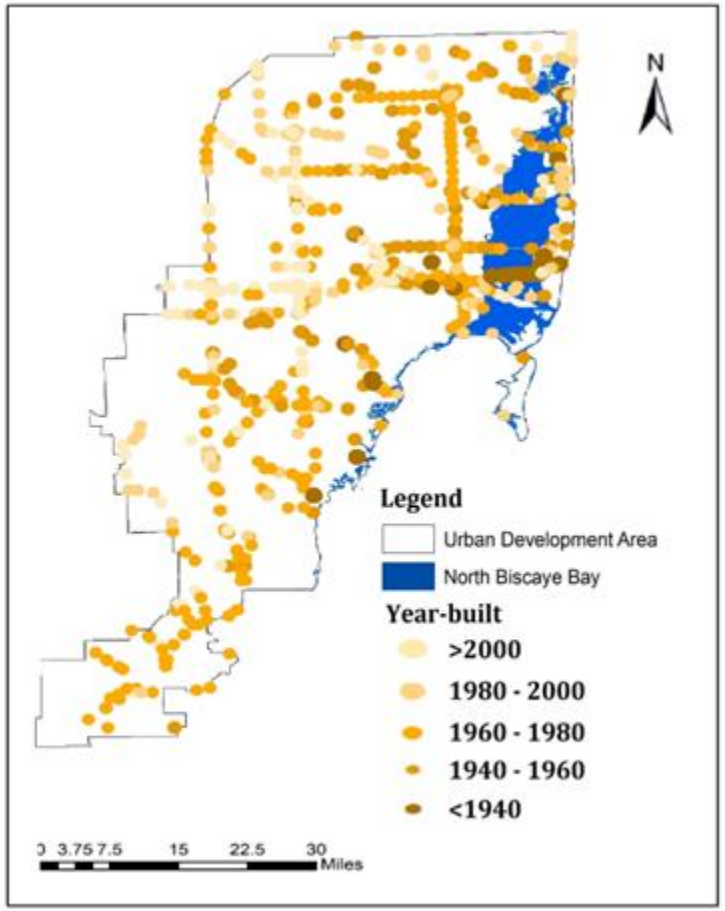
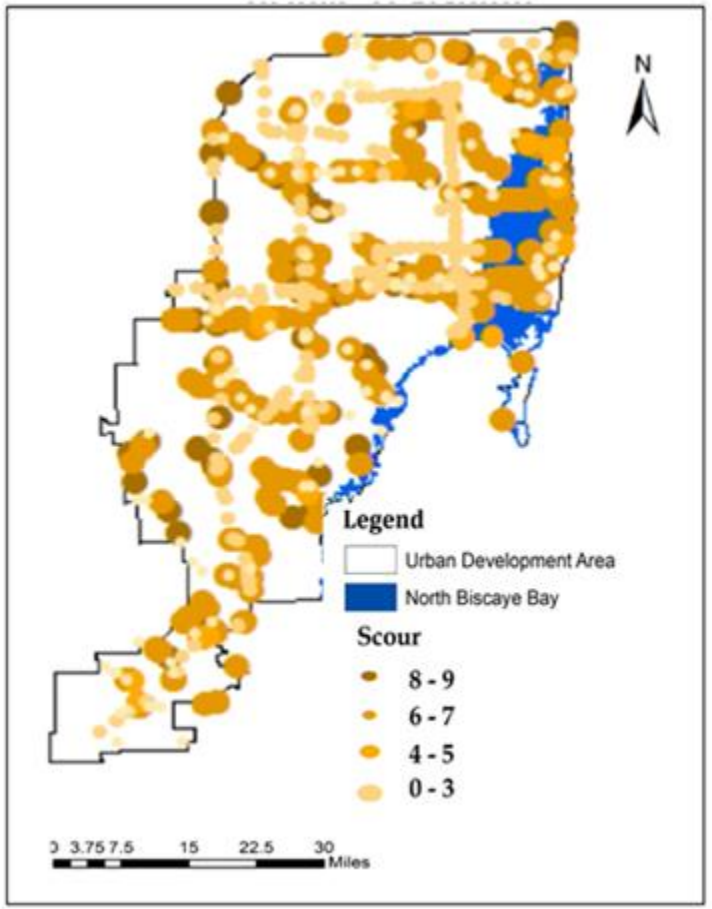
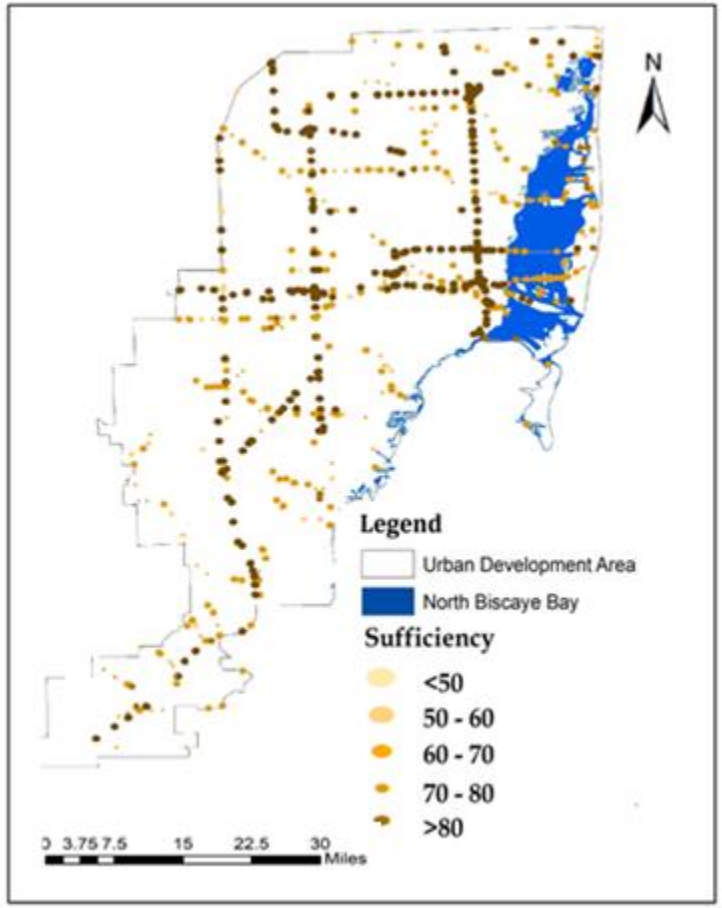
Structural Data







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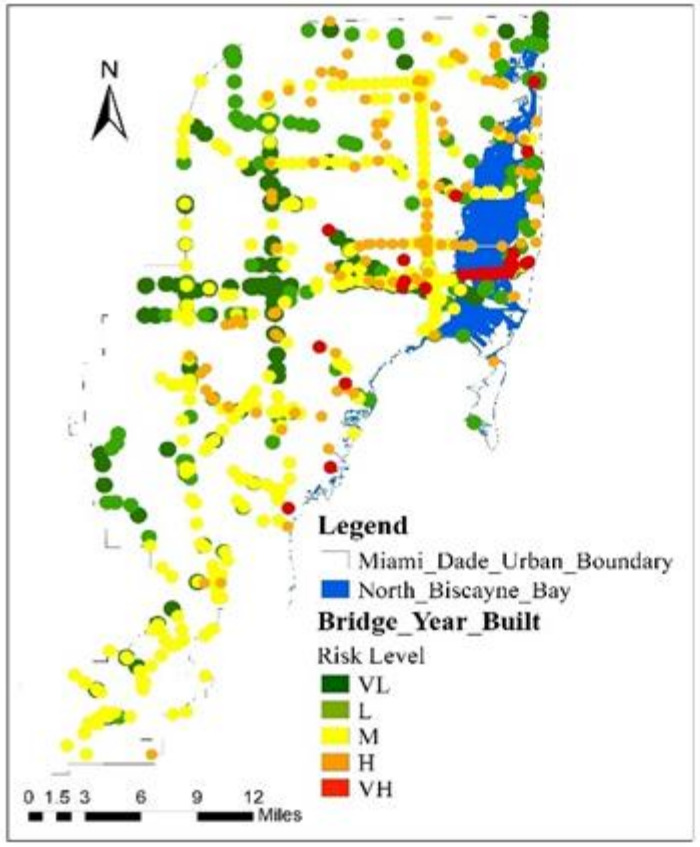
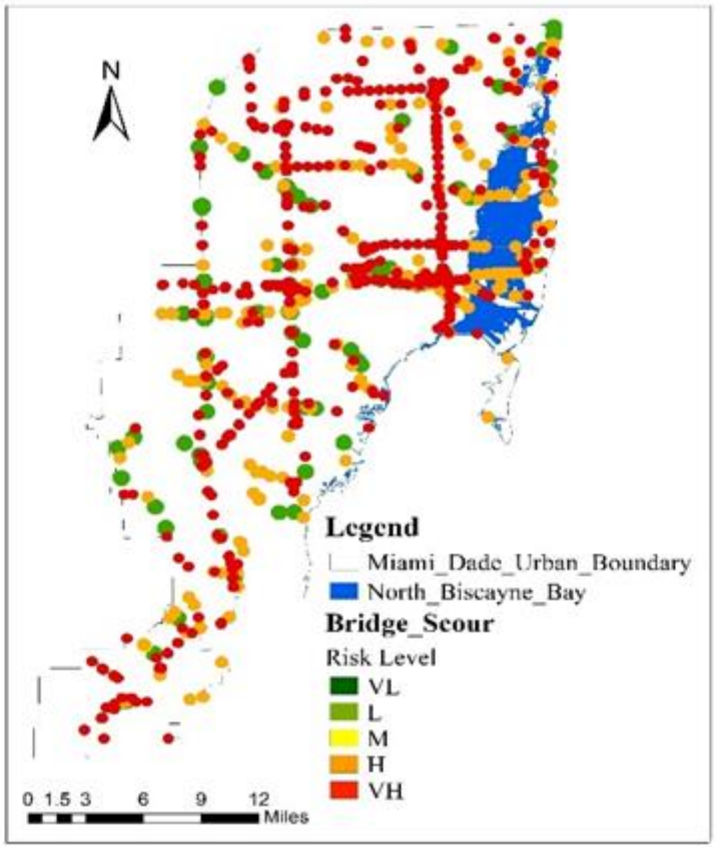
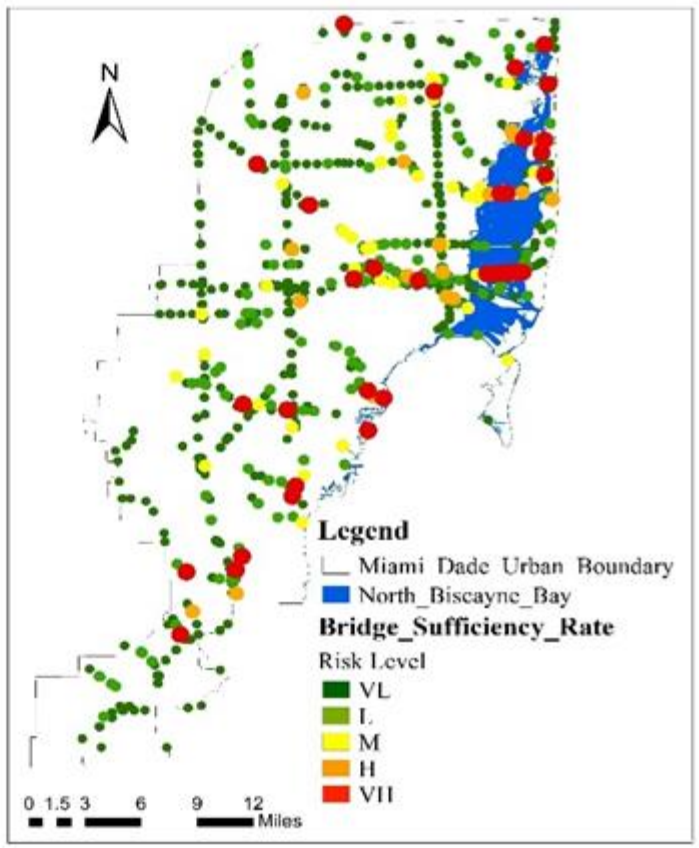
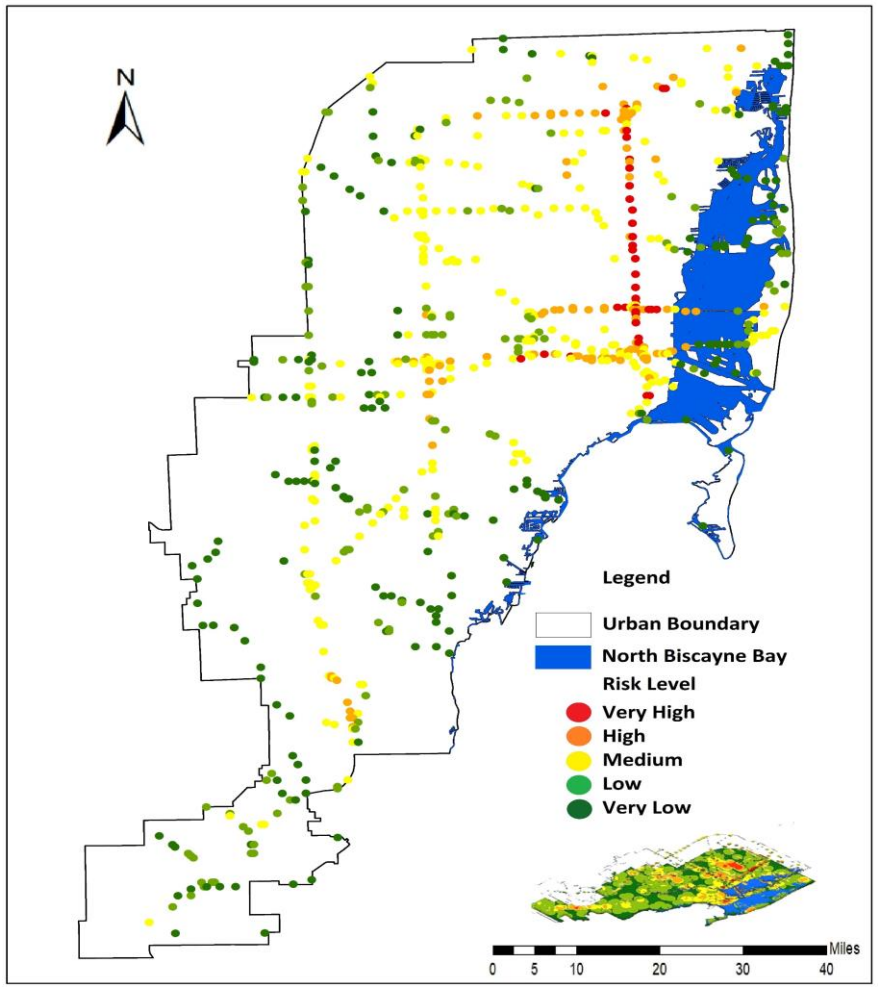
Structural Data Classification



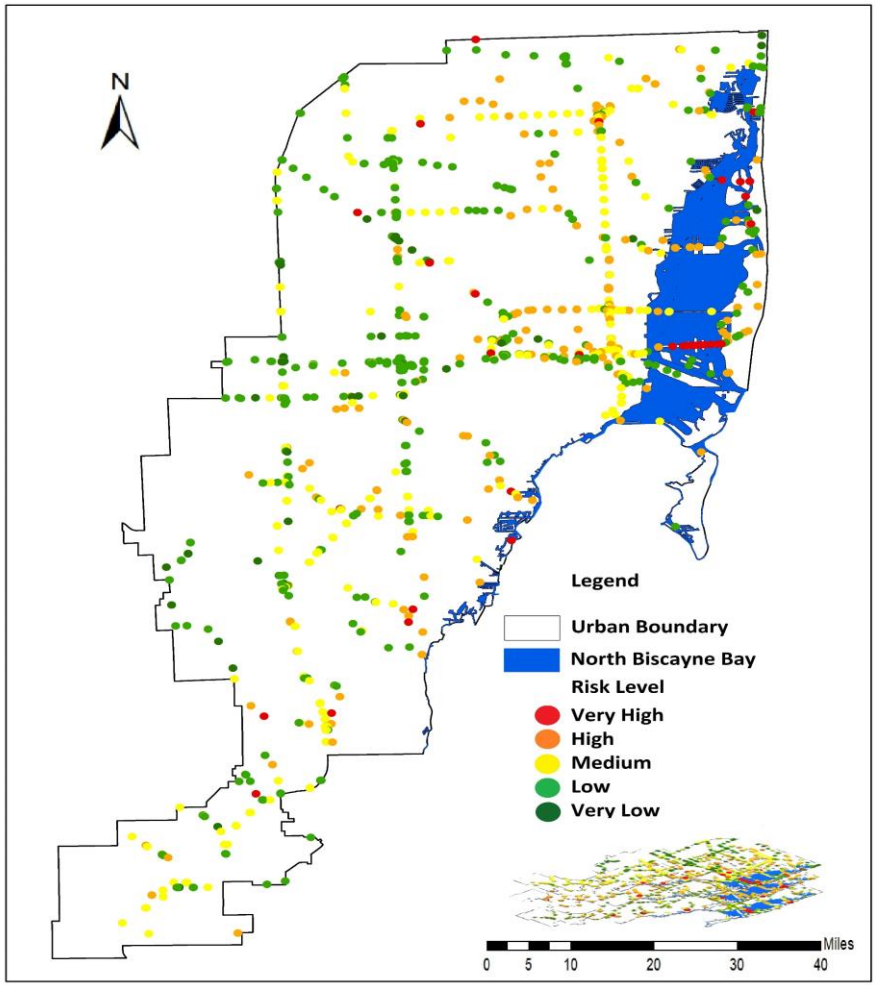




Integrated Structural and Traffic Maps



Traffic Risk



Structural Risk

Scenarios for Relative Weights of Criteria

Representative scenarios including various assumptions for the weights of criteria:

Scenario 1: Traditional Practice
Scenario 2: Traffic + Structural + Flood
Scenario 3: Most comprehensive scenario

Scenarios	Criteria				
	Traffic	Structural	Flood	Environmental Justice	Social Equity
Scenario-1	0.30	0.70	0.00	0.00	0.00
Scenario-2	0.35	0.35	0.30	0.00	0.00
Scenario-3	0.30	0.30	0.20	0.10	0.10

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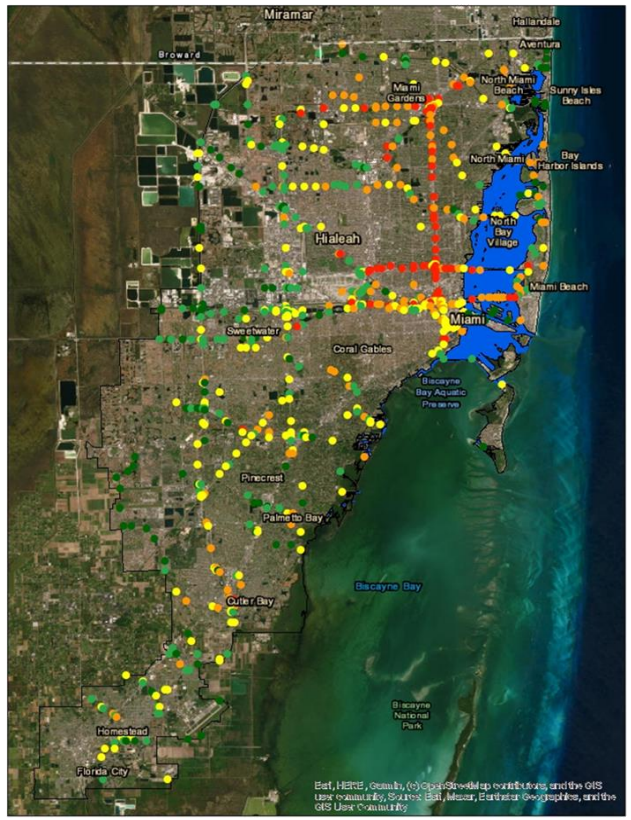
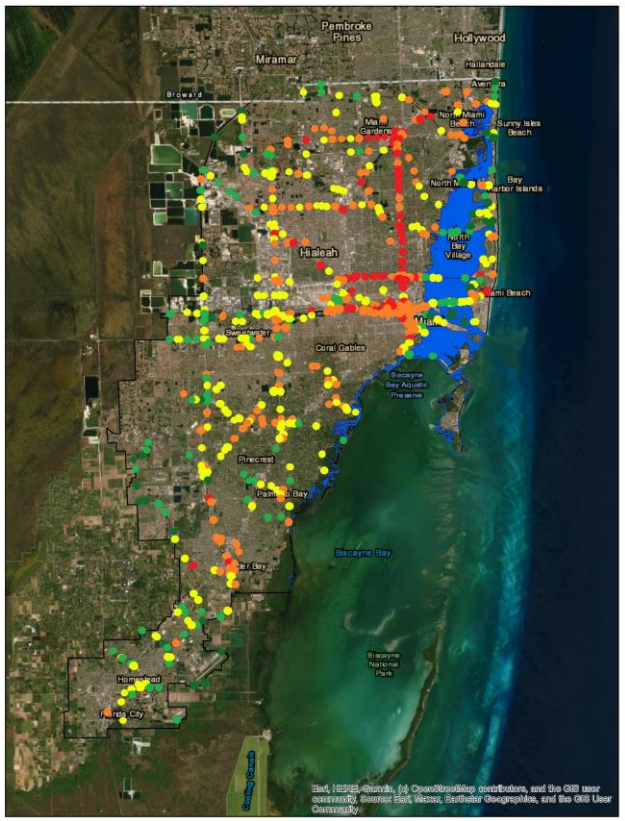
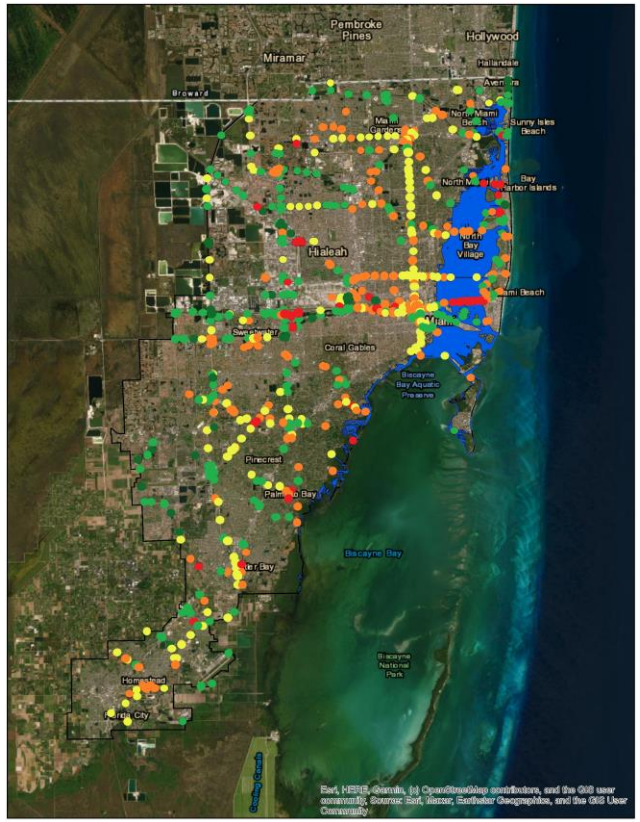
Risk Assessment Results



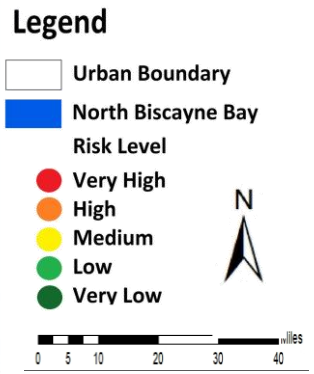
Scenario 1



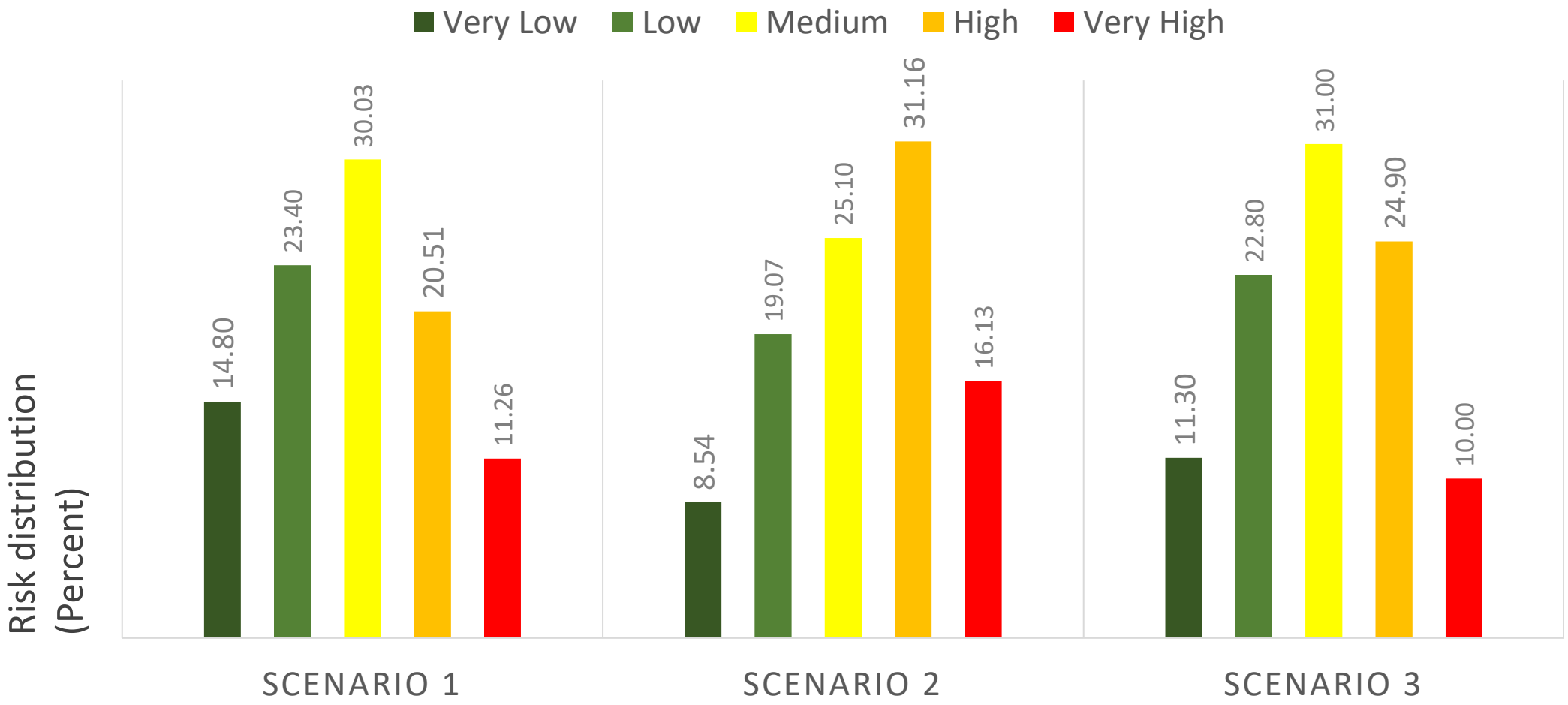
Scenario 2



Scenario 3

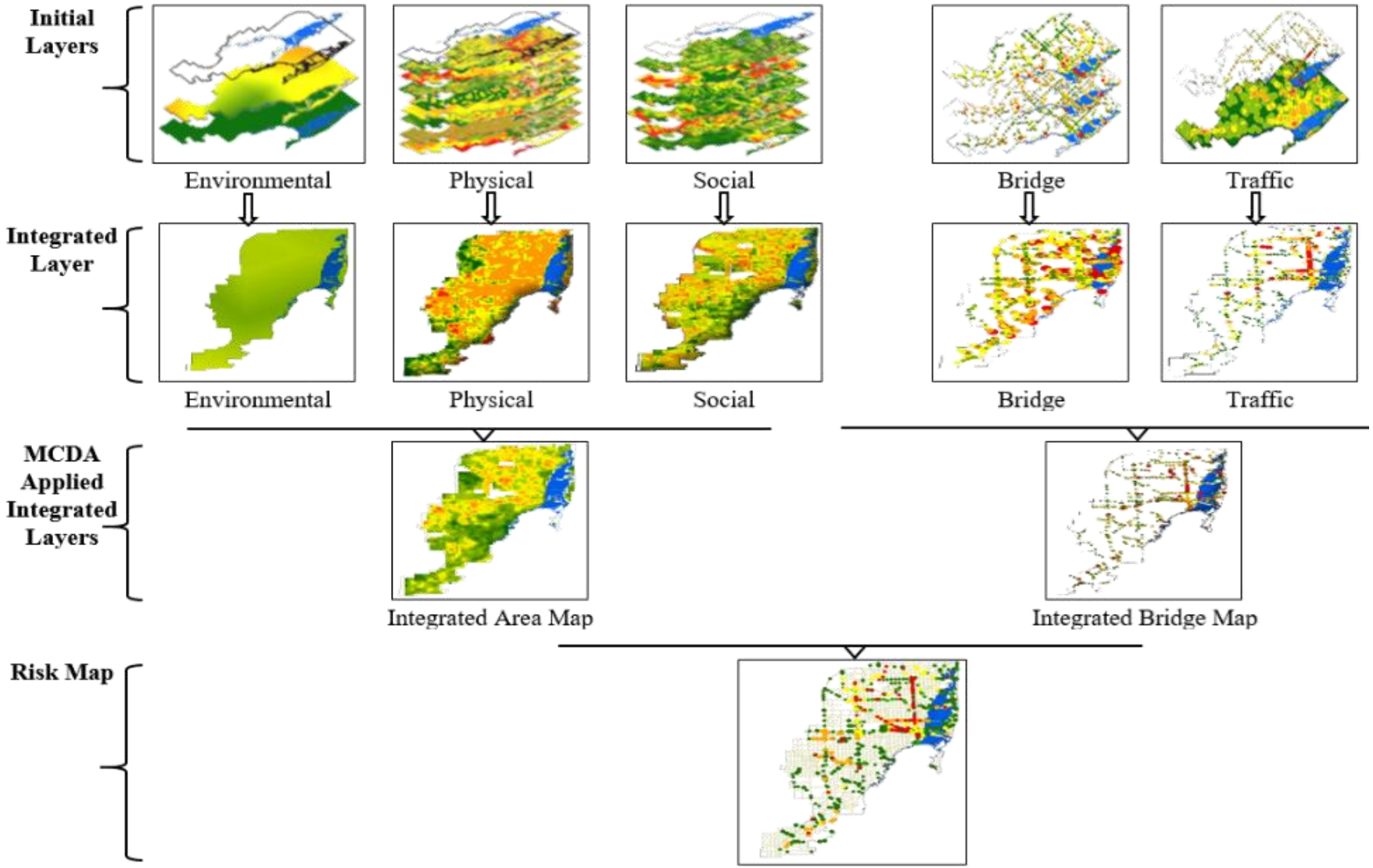


Risk Levels in each Scenario



Colored bars represent the percentage of risk distribution at each scenario

Summary



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Conclusions

- To address the existing inequalities built into urban communities and create better communities for all, social equity and environmental justice should be incorporated into civil infrastructure planning, including the decision making about suitability of ABC projects.
- Considering flood risk, social equity, and environmental justice in addition to structural and traffic condition of bridges can change the prioritization of rehabilitation projects.
- The developed decision support framework can practically support DOTs for equitable prioritization of accelerated bridge rehabilitation projects.

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Implementation

- The decision support framework uses readily available data.
  - Applicable to all states.
- The decision support framework is structured, flexible, and adjustable.
  - Decision makers can add or remove criteria.
  - Weights of criteria can be determined based on the decision makers preferences.
- Future Work: Use the framework to develop an online tool applicable for all state DOTs.

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Acknowledgements

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Thank you!

Questions and Comments?

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